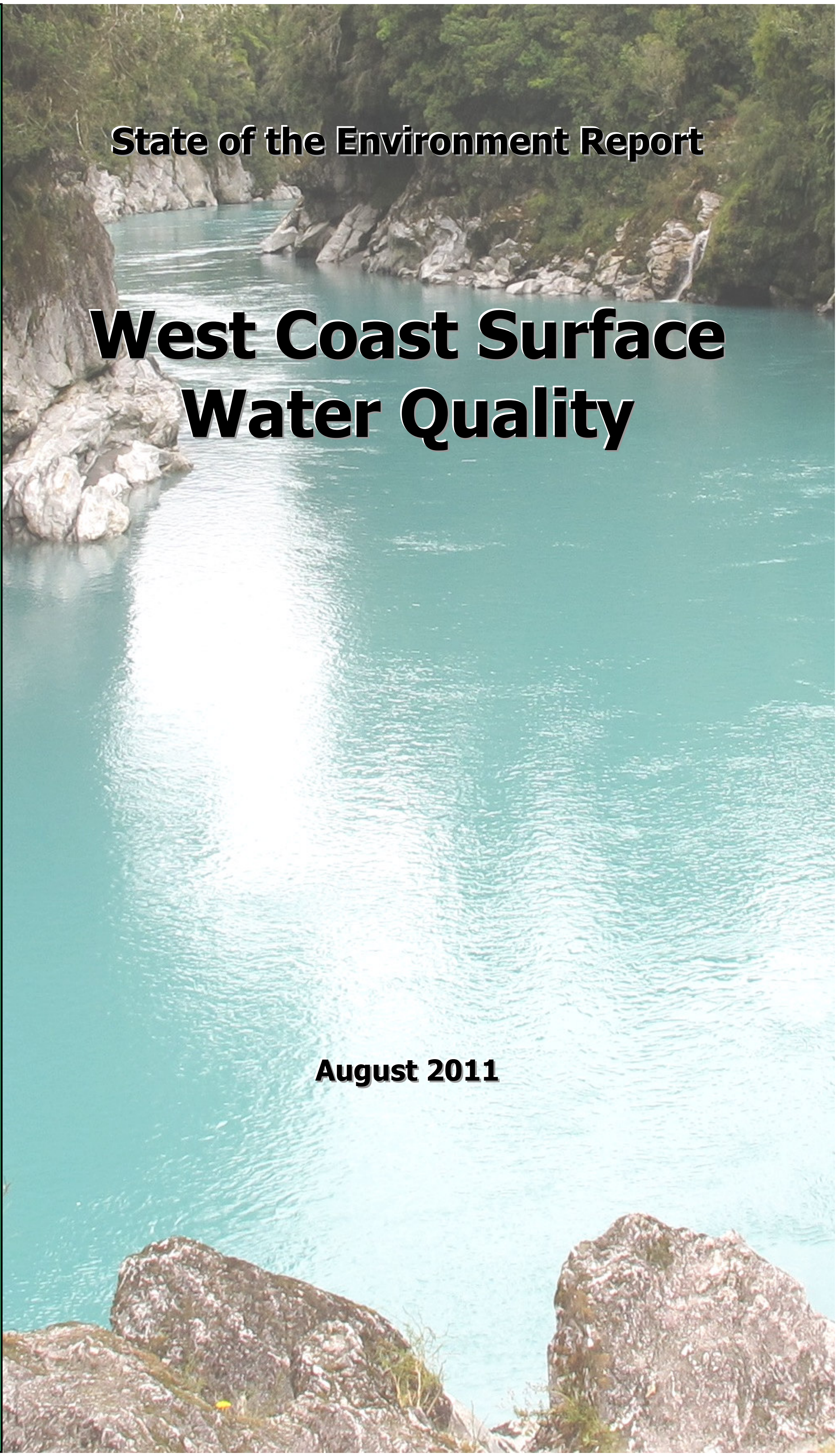
THE WEST COAST REGIONAL COUNCIL



State of the Environment Report

West Coast Surface Water Quality

August 2011

West Coast Surface Water Quality

State of the Environment Technical Report 11001

August 2011

A technical report presenting results of the West Coast Regional Council's Surface Water Quality Monitoring Programme from 1996 to 2011 and incorporating monitoring data collected by other organisations from 1989 to 2011.

Prepared by:

Jonny Horrox West Coast Regional Council

Emma Chaney West Coast Regional Council

Casey Beel West Coast Regional Council

Reviewed and approved for release by:

Michael Meehan

Manager, Planning and Environment
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 Programme, for data up until 2010-2011. This programme assesses surface water quality state and trends at selected sites where human impacts/pressures occur.

From 1996 to 2011, 41 sites were sampled for physical, chemical, and bacteriological water quality variables, as well as periphyton and macroinvertebrate communities. Sites were sampled four to six times per year. Eleven of these were reference sites, eight of which had a corresponding 'impact' sites downstream. An additional five sites were sampled as a part of NIWA's National River Water Quality Network. Other data included in this report came from the West Coast Regional Council Contact Recreation water quality programme. This consisted of 17 sites (in 2011). The Council also monitors the water quality in Lake Brunner, with monitoring efforts increasing over the last four years.

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 variables were compared with guidelines.

State of water quality in the West Coast Region

In the 2005 Surface Water Quality Report, many significant differences in physical, chemical, and biological water quality variables were observed between the River Environment Classification classes of flow source, geology, land cover, and stream size. Fundamental relationships observed for these variables amongst REC classes in 2005 remain current in 2011 (refer to Horrox 2005).

Previous analysis has shown that waterways in pasture dominated catchments had poorer water quality than those in indigenous forest, which was consistent with other parts of the country. Streams where acidity, metals, and metal precipitates occurred, resulting from acid mine drainage, had significantly reduced aquatic faunal health. Sediment alone from mining operations, if significant, could also reduce stream health. But when sediment was not combined with acid mine drainage, or was at a lower level, it had less of an impact. Most mining activities have individual consents that stipulate environmental monitoring, and three streams that Council monitors have substantial ongoing mining in their catchments.

Comparison of individual water quality variables to guidelines and benchmarks indicated a broad range of results among sites. Some sites rated poorly for many variables, 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. The West Coast's cool wet climate is also likely to be a limiting factor.

Lakes had the best water quality for contact recreation on the West Coast. In the past the West Coast's coastal beach monitoring sites have proven cleaner than their river counterparts. However over 2010-2011 34% of marine sites on the West Coast met with guidelines >95% of the time, compared with West Coast freshwaters (lagoons and estuaries, rivers, and lakes), where 91% of sites were guideline compliant >95% of the time.

Poorer water quality was observed in the downstream reaches of a number of streams that were impacted by human activities. However these comparisons indicate that upstream/downstream relationships for some water quality variables are not simple or caused solely by human impacts. Factors such as increasing dilution and changes in habitat and flow regimes can have opposing effects on water quality.

Trends in West Coast water quality

Variables important to aquatic ecosystems, such as turbidity, clarity, ammoniacal nitrogen, E. coli and faecal coliforms have again been seen to improve significantly at Regional Council monitoring program sites (table 3.2). Those parameters are typical of point source pollution (refer to Appendix 5.10 for graphs demonstrating trends for parameters measured).

Harris Ck and Duck Ck were the most improved, which both had improved ammoniacal nitrogen, faecal coliforms and clarity. Faecal coliforms and clarity improved at Murray Ck and Mawheraiti River. Clarity and ammoniacal nitrogen improved at Orowaiti River at the Excelsior Rd monitoring site. There is agricultural activity above all these monitoring sites and improved water quality may stem from changes to farm management practices within these catchments.

Sites on some of the much larger West Coast rivers, like the Grey and Buller, also showed improvements in clarity and ammoniacal nitrogen over a twenty year time frame. Improvements in clarity were no longer apparent at any NIWA sites for the last ten years with two sites showing significant declining trends in clarity. Dissolved reactive phosphorus and nitrate, along with total nitrogen, have increased at many NIWA sites. Being large rivers, their nutrient levels are a culmination of many sources hence they should be indicative of their many sub-catchments. Earlier West Coast Regional Council analysis in 2008 concluded that point source pollution has decreased, but diffuse source pollution has increased, and these patterns are similar to those evident in other parts of New Zealand. This most recent analysis continues to support this theory but suggests that improvements associated with better managed point source pollution may be slowing.

Lake Brunner

Assessment of water quality data collected in Lake Brunner from the 1990's until today indicated strongly that the water quality of Lake Brunner had deteriorated, although water quality in the lake is still relatively good.

Recent synthesis of data collected from the catchment supports the conclusion that phosphorus is the limiting nutrient in the lake. Comparison of phosphorus inputs from tributaries to those expected to be retained in the lake and measured in the discharge suggests that there is no significant release of phosphorus from lake sediments. This is good as recycling of lake bed phosphorus could lead to an unstoppable slide to further water quality degradation. Predictive modelling estimated that phosphorus inputs into the lake would need to increase by 70 % to shift the lake into mesotrophic status.

From 1992-2011, statistically significant negative trends were observed for most water quality variables. This indicates gradual enrichment of the lake and a reduction in water quality. These trends were not significant from 2001-2011, with the exception of total phosphorus and the Trophic Level Index (TLI), which continued to indicate a decline. Another interesting trend was observed for absorbance (g340 & g440), which indicated an increase in coloured dissolved organic matter (CDOM) – the dissolved brown substance in Lake Brunner and many other pristine waterways. Clarity is lower than would be expected from algal biomass concentrations alone because CDOM absorption reduces visibility and light penetration. A decreasing trend in clarity since the 1990s may, in part, be a result of changes in concentrations of CDOM. On top of this a significant inverse relationship between clarity and chlorophyll a concentration suggests that changes in water clarity mostly result from changes in algal biomass, on a seasonal basis.

Submerged plant surveys between 1982 and 2009 indicated that changes in water quality over this period were not sufficient to alter plant communities in any observable way. Cashmere Bay had the poorest water quality, compared with Iveagh Bay and the central lake, with localised conditions the probable cause of this.

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 Programme 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. Internal and external review of this report has been implemented.

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:

- Staff of the West Coast Regional Council.
- National Institute of Water and Atmospheric Research staff: Piet Verburg, Rob Davies-Colley, Paul Lambert, Pete Mason, Mike O'Driscoll, and John Porteous.
- John Stark for peer review.
- Bill Dyck and FRST for financial assistance.
- The Cawthron Institute and Hill Labs for laboratory analysis of water samples.
- The Ministry for the Environment for financial assistance and information.

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. These attributes, or resources, must be managed sustainably in support of their many uses that include recreation, industry, energy, and agriculture, not to mention maintaining the integrity of ecological and cultural values.

Under the Resource Management Act 1991 the West Coast Regional Council is responsible for the management of: water, air, and land (soil conservation, natural hazards, and hazardous substances); activities in the Coastal Marine Area; the discharge of contaminants; and the use of river and lakebeds. As a result of these responsibilities the 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 programme, and includes some information from territorial authorities, and other resource management agencies and institutes. 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 Programme (monitoring programme) 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 programme 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 programme 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 cumulative environmental effects from multiple discharges into surface waters.

- 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 programme 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 Programme, sites are sampled either twice-monthly or 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 programme 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 programme 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;

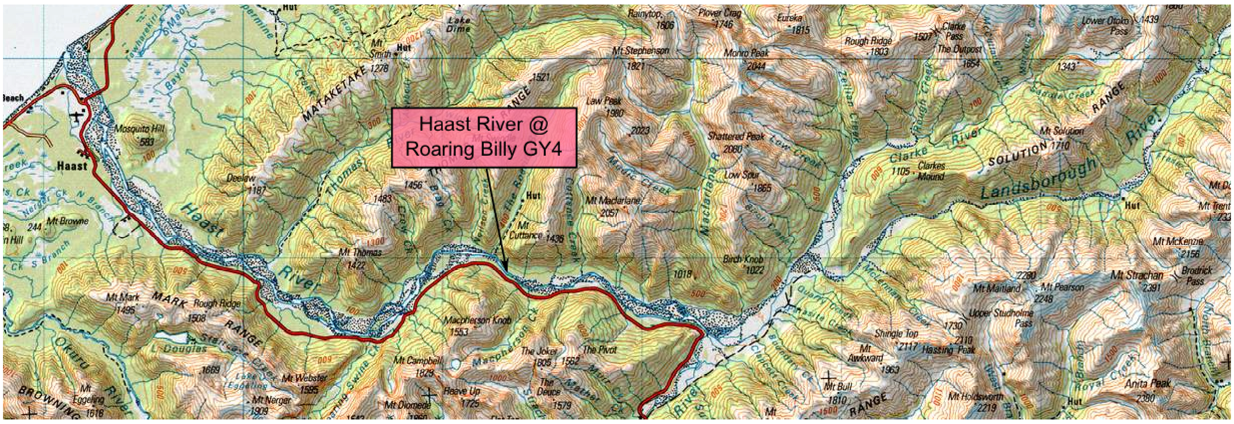
(d) In areas with high human use (such as for recreation or drinking) or significant ecological values.

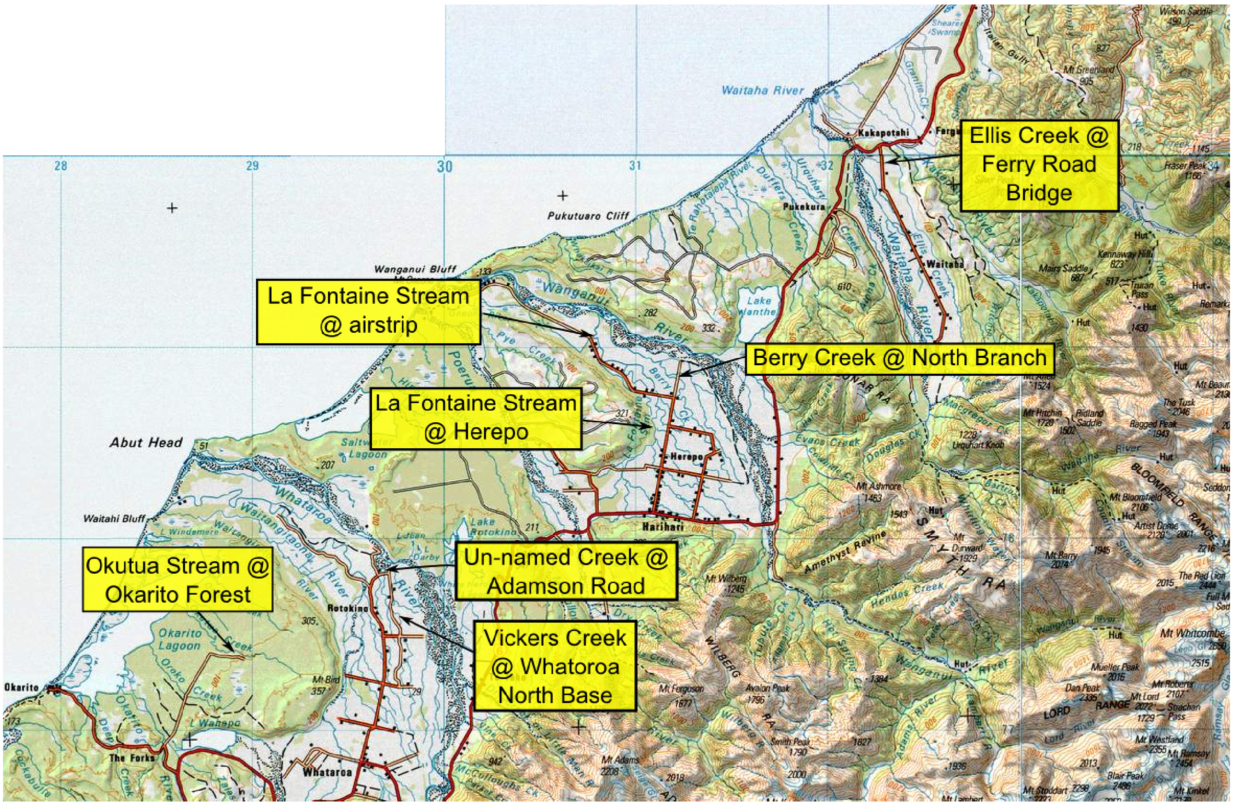
In order to address its aims while working within the constraints mentioned above, design of the monitoring program involved careful choice of indicators (measures) of water quality, sites, and methods. In addition to the intrinsic ecological values of waterways the issue of water quality is also related 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.

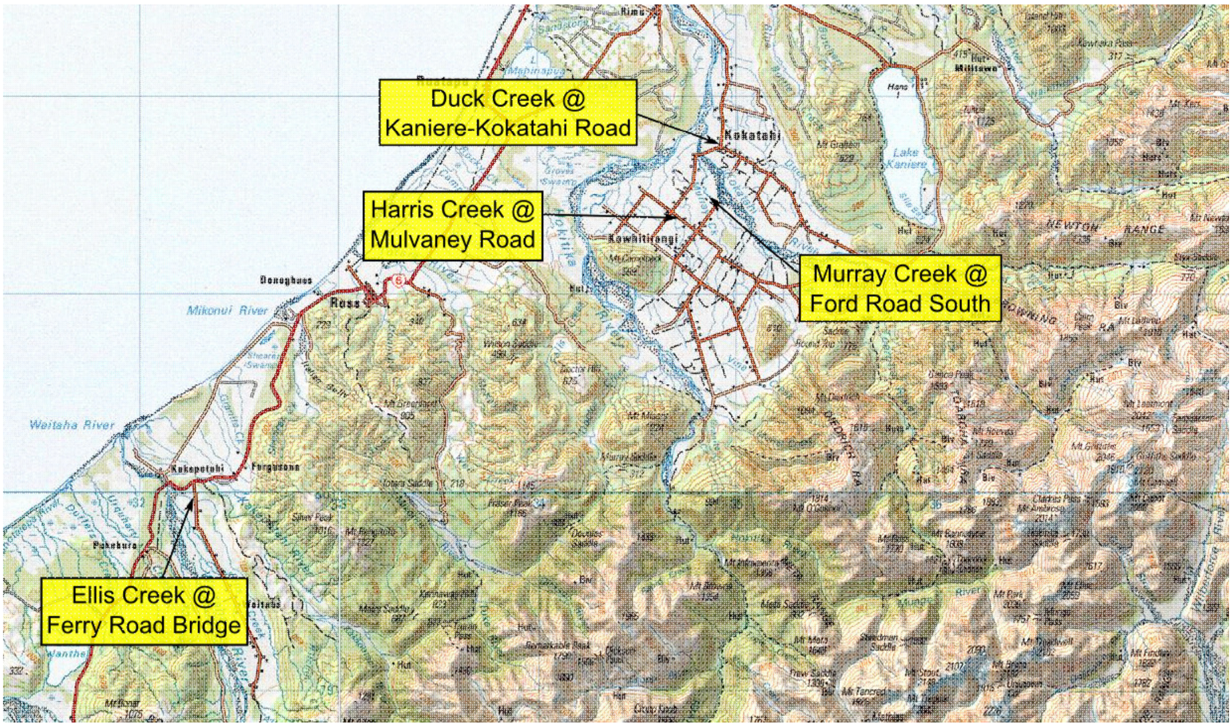
This report begins with an analysis of the state of West Coast surface water quality, followed by an assessment of surface water quality trends. A separate section covers state and trends of surface water quality in the Lake Brunner catchment. Supporting information can be found in the appendices including: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

1.3 Location of surface water quality monitoring sites

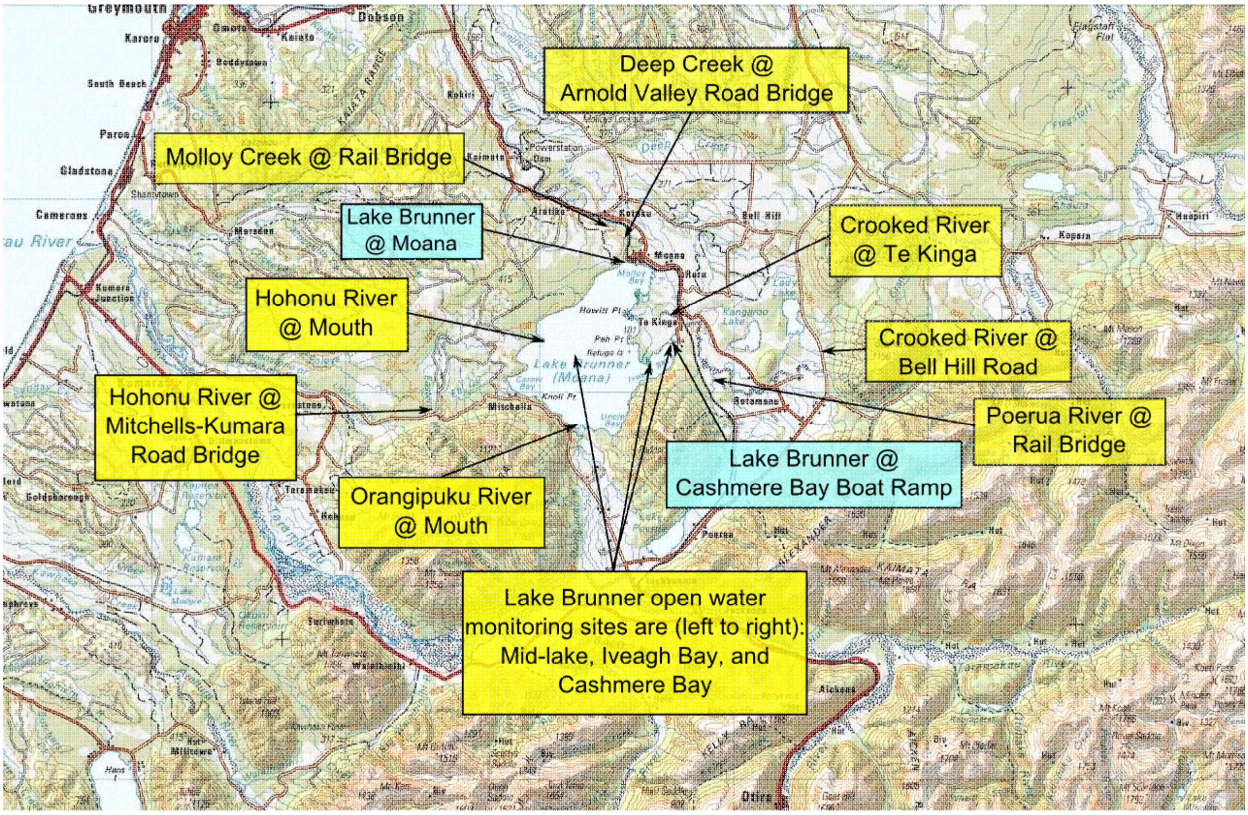
The following maps show the location of surface water quality monitoring sites in the West Coast Region. Yellow boxes indicate West Coast Regional Council surface water quality monitoring sites; blue boxes indicate West Coast Regional Council contact recreation water quality monitoring sites; and pink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

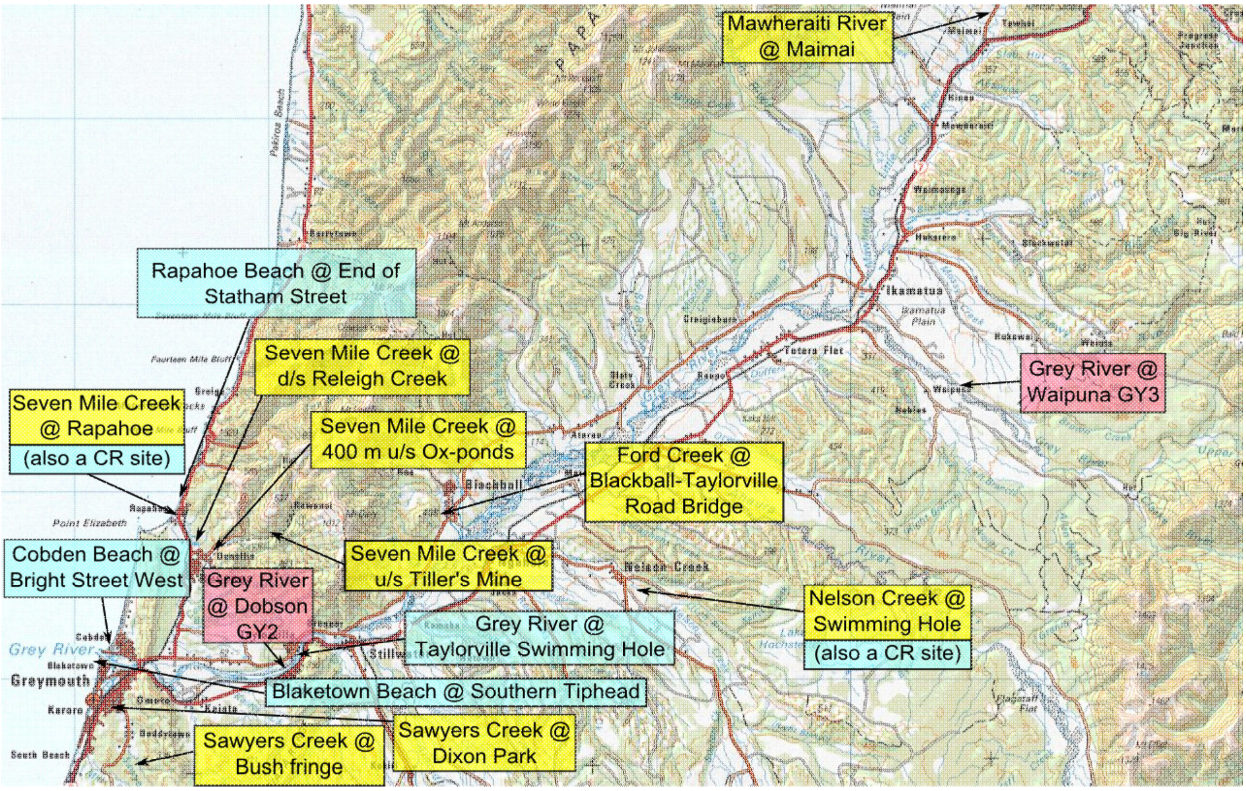



Ellis Creek @ Ferry Road Bridge
La Fontaine Stream @ airstrip
Berry Creek @ North Branch
La Fontaine Stream @ Herepo
Okutua Stream @ Okarito Forest
Un-named Creek @ Adamson Road
Vickers Creek @ Whatoroa North Base

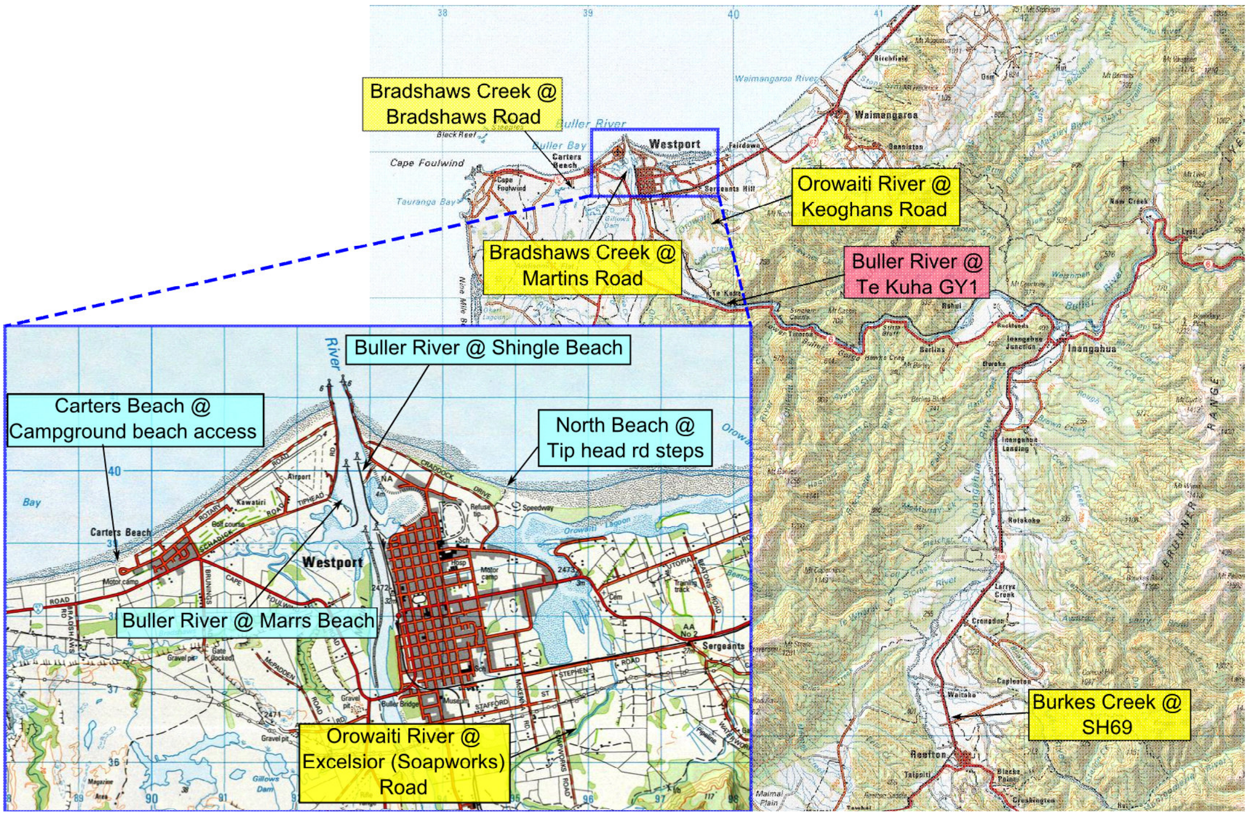

Duck Creek @ Kaniere-Kokatahi Road
Harris Creek @ Mulvaney Road
Murray Creek @ Ford Road South
Ellis Creek @ Ferry Road Bridge


Hokitika Beach @ Hokitika
Kaniere River @ Kokatahi-Kaniere Road
Lake Mahinapua @ Shanghai Bay

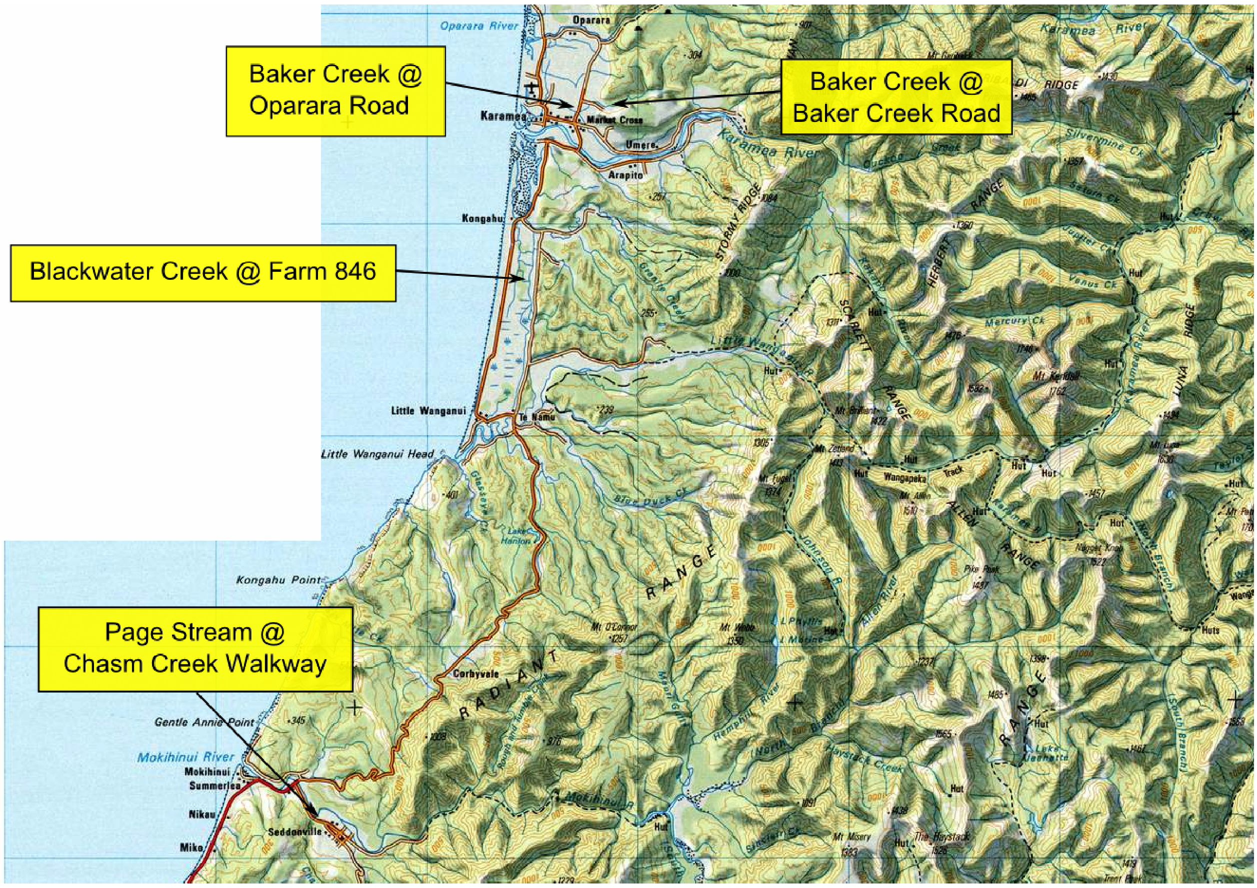

Deep Creek @ Arnold Valley Road Bridge
Molloy Creek @ Rail Bridge
Lake Brunner @ Moana
Crooked River @ Te Kinga
Hohonu River @ Mouth
Crooked River @ Bell Hill Road
Hohonu River @ Mitchells-Kumara Road Bridge
Poerua River @ Rail Bridge
Lake Brunner @ Cashmere Bay Boat Ramp
Orangipuku River @ Mouth
Lake Brunner open water monitoring sites are (left to right): Mid-lake, Iveagh Bay, and Cashmere Bay

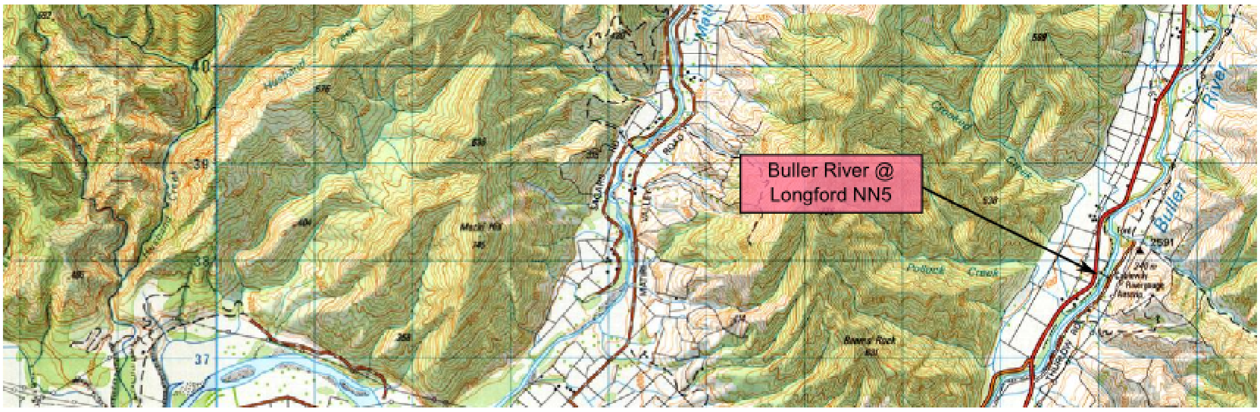


Mawheraiti River @ Maimai
Rapahoe Beach @ End of Statham Street
Seven Mile Creek @ d/s Releigh Creek
Seven Mile Creek @ Rapahoe (also a CR site)
Seven Mile Creek @ 400 m u/s Ox-ponds
Grey River @ Waipuna GY3
Ford Creek @ Blackball-Taylorville Road Bridge
Cobden Beach @ Bright Street West
Grey River @ Dobson GY2
Seven Mile Creek @ u/s Tiller's Mine
Nelson Creek @ Swimming Hole (also a CR site)
Grey River @ Taylorville Swimming Hole
Blaketown Beach @ Southern Tiphead
Sawyers Creek @ Bush fringe
Sawyers Creek @ Dixon Park
Greymouth



Bradshaws Creek @ Bradshaws Road
Orowaiti River @ Keoghans Road
Bradshaws Creek @ Martins Road
Buller River @ Te Kuha GY1
Buller River @ Shingle Beach
Carters Beach @ Campground beach access
North Beach @ Tip head rd steps
Buller River @ Marrs Beach
Orowaiti River @ Excelsior (Soapworks) Road
Burkes Creek @ SH69
Westport


Baker Creek @
Oparara Road
Baker Creek @
Baker Creek Road
Blackwater Creek @ Farm 846
Page Stream @
Chasm Creek Walkway


Buller River @
Longford NN5

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 compared with 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 a stream type with their own characteristics. 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 variables, waterways in pasture-dominated catchments had poorer water quality than those in indigenous forest, which agreed with previous analyses in 2005. Several water quality variables 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 evident. 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 affected waterways. It can be difficult to differentiate impacts between current and historic mining activities, although most acid mine drainage comes from historic coal mining.

It continues to be shown that in catchments impacted by human activities overall water quality is poorer at downstream sites compared to those upstream of them. This was evident when comparing paired impact/reference sites that are upstream and downstream of each other. However these comparisons indicate that upstream/downstream relationships for some water quality variables 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 an apparent improvement for a particular variable, or in some cases, an apparent deterioration depending on where in the catchment these factors are acting.

Comparison of data for water quality variables with their respective guidelines and benchmarks indicated a broad range of results among sites. Some sites rated poorly for many variables, 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.

For contact recreation suitability, lakes had the best water quality. In the past the West Coast's coastal beach monitoring sites have proven cleaner than their river counterparts. However over 2010-2011 34% of marine sites on the West Coast met with guidelines >95% of the time, compared with West Coast freshwaters (lagoons and estuaries, rivers, and lakes), where 91% of sites were guideline compliant >95% of the time. Further sampling over consecutive seasons will confirm whether marine sites continue to have more exceedances than freshwater areas ('freshwater sites' on the West Coast are defined as lagoons and estuaries, rivers, and lakes).

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 landuse. These particular analyses have not been repeated for this report. The general relationships for these aforementioned analyses are likely to remain consistent at the time this report has been compiled, and these relationships are summarised in Section 2.1.1 and 2.1.2.

2.1.1 REC analysis in 2005

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 5.5 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 variables were observed between the REC classes of source of flow, geology, land cover, and stream order. Patterns observed for these variables 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). Nationally, agriculture has the widest impact on water quality, covering 40% of New Zealand's land area in 2008.

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

Sites in the following figures are ordered according to their median value, for each particular variable. For all variables, 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 5.4. A model of one of these percentage bar graphs is provided in Section 5.6 to aid with interpretation. For more detailed information on data ranges for each water quality variable, per site, the reader is directed to box and whisker plots in Section 5.7.

Data from 2005-2010 have been used for the figures in Section 2.2. As our intention is to compare environmental state to thresholds (such as guidelines), the length of the data record used has been restricted to the most recent five years, should changes have occurred for a variable over a wider time frame. In most instances this provides at least 20 data points per site for evaluation. Please note that the box and whisker plots in Section 5.7 utilise 10 years of data and aim to give the reader a better idea of the spread and range of data.

No data for pH have been presented because this alone can be misleading. 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 2.1). Twenty degrees is only restrictive for the more temperature sensitive species e.g. trout, certain stoneflies etc. Sites where temperatures exceeded 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 be the cause of elevated river temperatures, which appeared to decrease downstream through dilution from cooler tributaries. Generally, a lack of riparian shading and/or small flows are conditions likely to lead to high temperatures in warm, sunny weather. Three sites have recorded temperatures as high as 24°C, with Burke Creek @ SH69 recording a temperature of 25°C (Figure 5.6.2). 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. Maximum values at many sites would be higher if continuous monitoring was utilised. An example of this is Hohonu River @ mouth where spot sampling has never achieved a result of over 20°C. Yet separate continuous temperature monitoring at this site (30 minute intervals) demonstrated that temperatures over summer are over 20°C for 20-25% of the time. To put that in context with Figure 2.1, that would be for 5% of time over a year. Temperatures can also vary depending on the time of day they are collected.

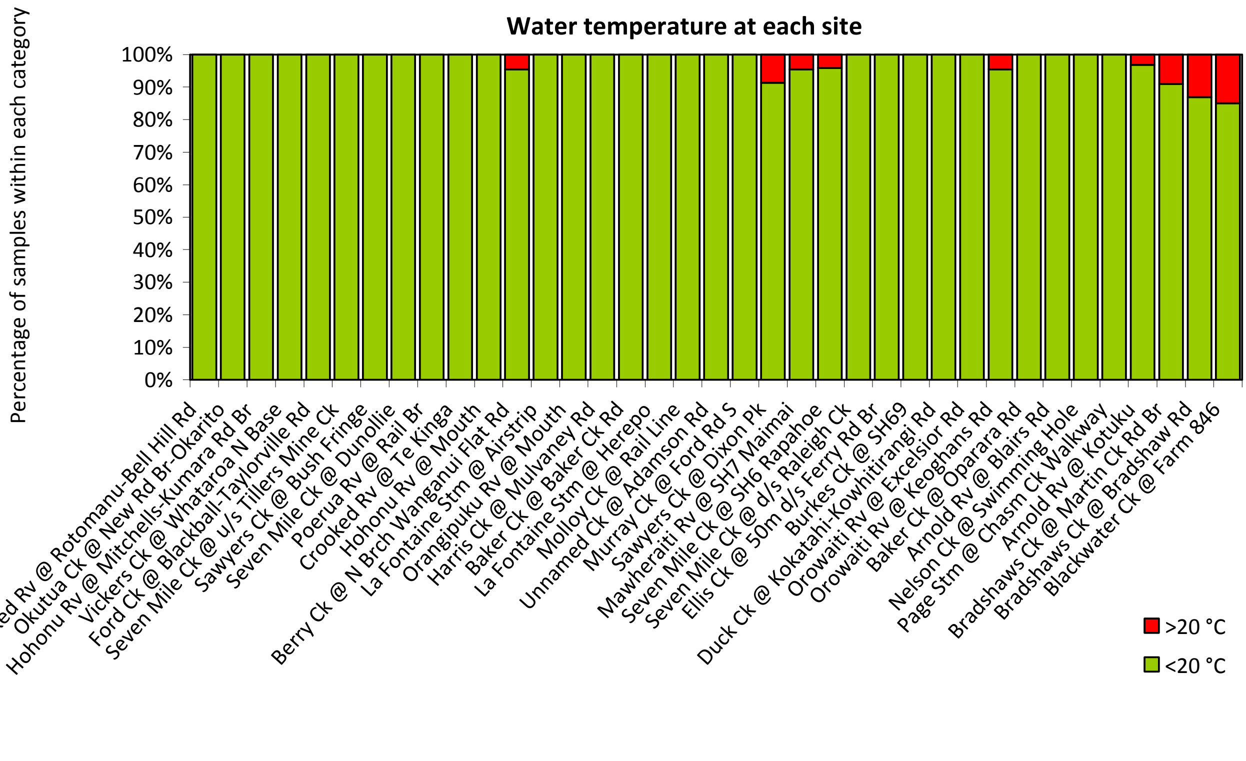
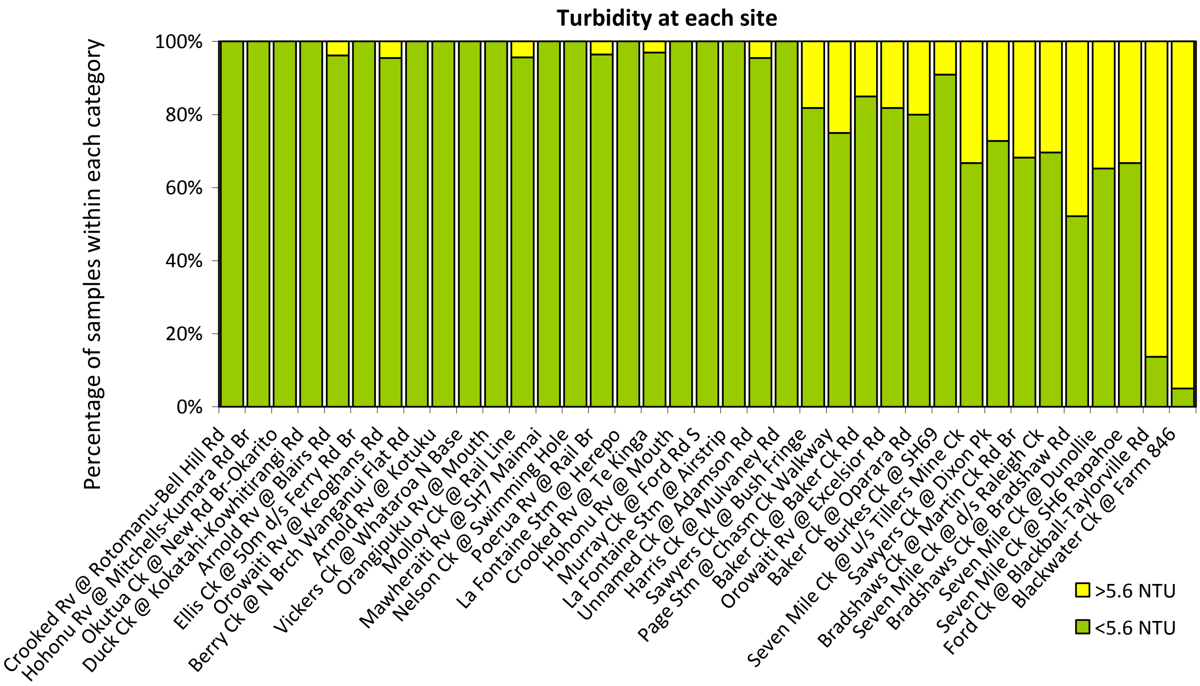


Figure 2.1 Percentage of samples in respective water temperature categories for individual Regional Council monitoring program sites.

2.2.2 Turbidity

Three sites had median turbidity over 5.6 NTU (Bradshaws Ck @ Martins Rd, Blackwater Ck and Ford Ck) (Figure 2.2). These sites have a range of compounding features contributing to higher turbidity. Erodible sedimentary geology is a common component, usually combined with varying degrees of anthropogenic influence. 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 land use a feature in Seven Mile and Sawyers Creeks. In general, agricultural land use within a catchment leads to increased turbidity downstream. Tidal activity at Bradshaws Ck @ Martins Rd, combined with agricultural land use combine to increase turbidity at this site. It is worth noting again the important influence of geology: For example, reference sites on Sawyers and Baker Creeks – both draining catchments with predominantly soft sedimentary geology – have higher median turbidity than the Orangipuku River. Much of the Orangipuku River drains intensive agricultural land, but inputs from tributaries with hard plutonic catchments and springs on the alluvial plains yield water of relatively low turbidity.

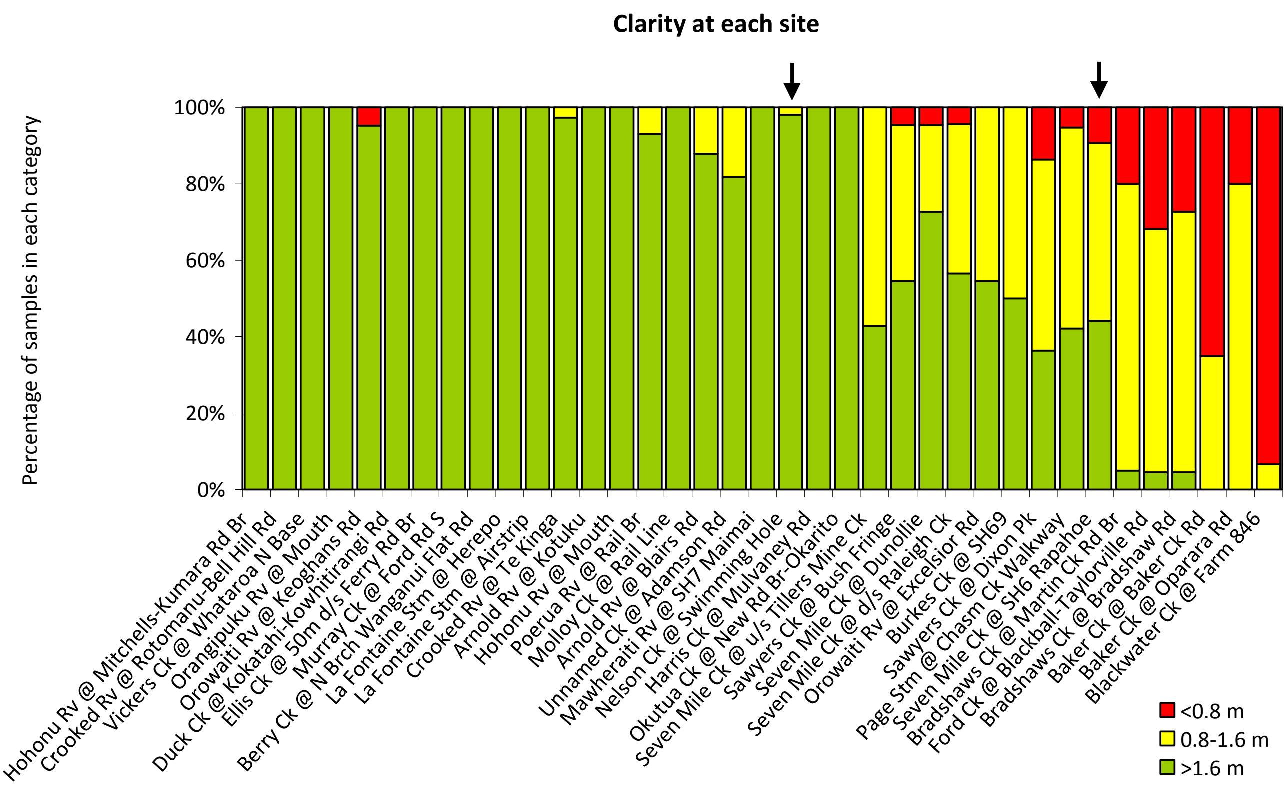


Figures 2.2 Percentage of samples in respective turbidity categories for individual Regional Council monitoring program sites.

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 2.2). Visible clarity, measured with a black disk, is a more sensitive measure of suspended material in clear waters compared with turbidity. However, brown 'tea' staining (correctly referred to as coloured dissolved organic matter or CDOM) is a natural feature of many West Coast waterways, particularly those draining lowland areas. It is a natural factor that can reduce water clarity in pristine waterways. This is the reason for the relatively low clarity observed in the Okutua Stream, which is a reference site in Okarito Forest. Median clarity for this site was in the middle of the field for monitoring program sites, yet the amount of mobile sediment was low, and median clarity at Okutua Stream has never failed the 1.6 m contact recreation guideline.

Under the Proposed Land and Water Plan (2010) all water bodies are to be managed for aquatic ecology, to which the 0.8 m clarity threshold applies. Ninety five 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. However, comparison to this guideline is only really relevant for sites managed for swimming – as stipulated in the Proposed Land and Water Plan - and these are indicated by arrows.

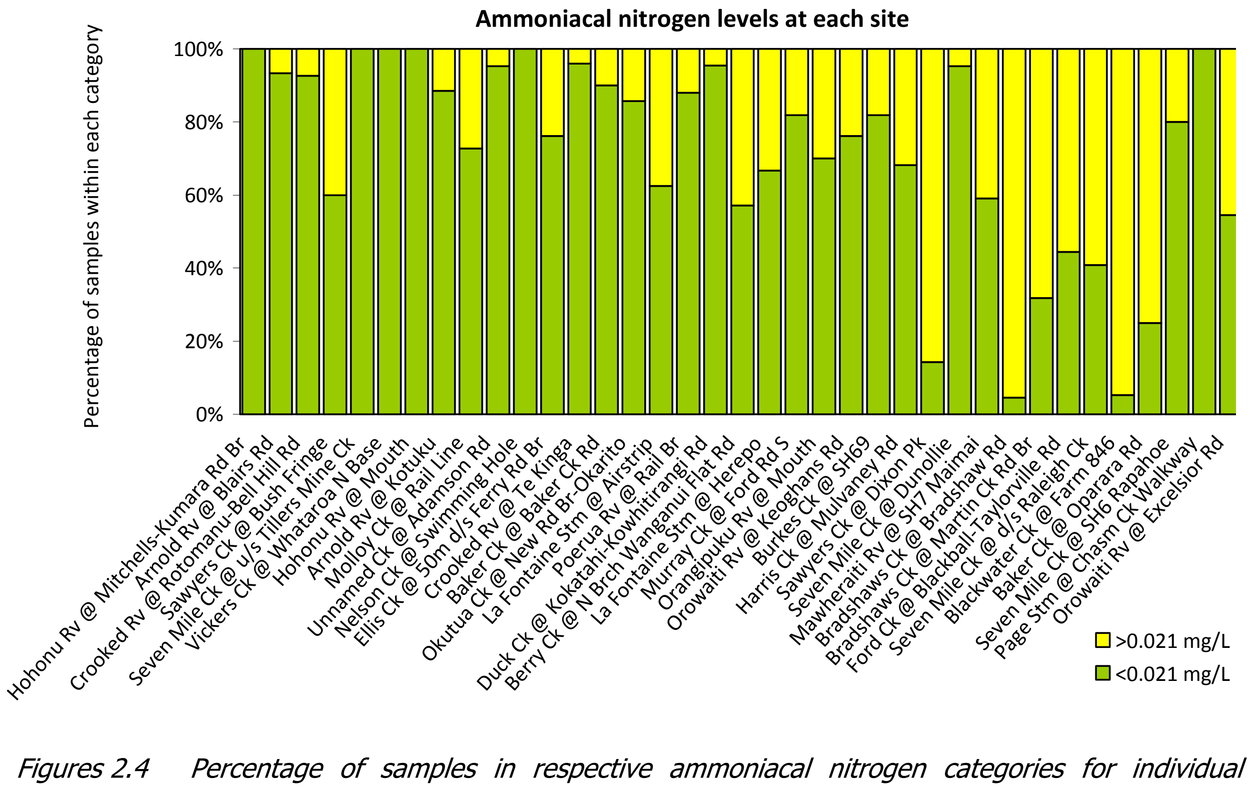


Figures 2.3 Percentage of samples in respective clarity categories for individual Regional Council monitoring program sites. Black arrows indicate sites also monitored for contact recreation suitability. Arrows indicate sites managed for contact recreation by the Regional Council.

2.2.4 Ammoniacal nitrogen

The threshold chosen in 2008 for evaluating ammoniacal nitrogen was based on a level delivering a 95% level of ecosystem protection against toxicity (0.9 mg/L at pH 8, ANZECC 2000). There were no sites with values greater than this so a smaller threshold of 0.021 mg/L was chosen. This is a trigger value from the Australian and New Zealand Environment Conservation Council (ANZECC) guidelines for lowland waterways (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. Refer to figure 5.3.7 for detailed explanation of ammonia toxicity.

No sites had values over 0.9 mg/L therefore no samples had ammoniacal nitrogen levels above a level likely to cause acute harm to aquatic life. Many sites had levels over 0.021 mg/L (Figure 2.4). More frequent exceedances and a higher median indicate effects of effluent discharges and farm run-off, where a catchment has a significant portion intensively farmed. Higher levels might also indicate the presence of point source ammoniacal nitrogen, particularly in catchments not dominated by agriculture. More detail on individual site medians can be found in Figure 5.6.



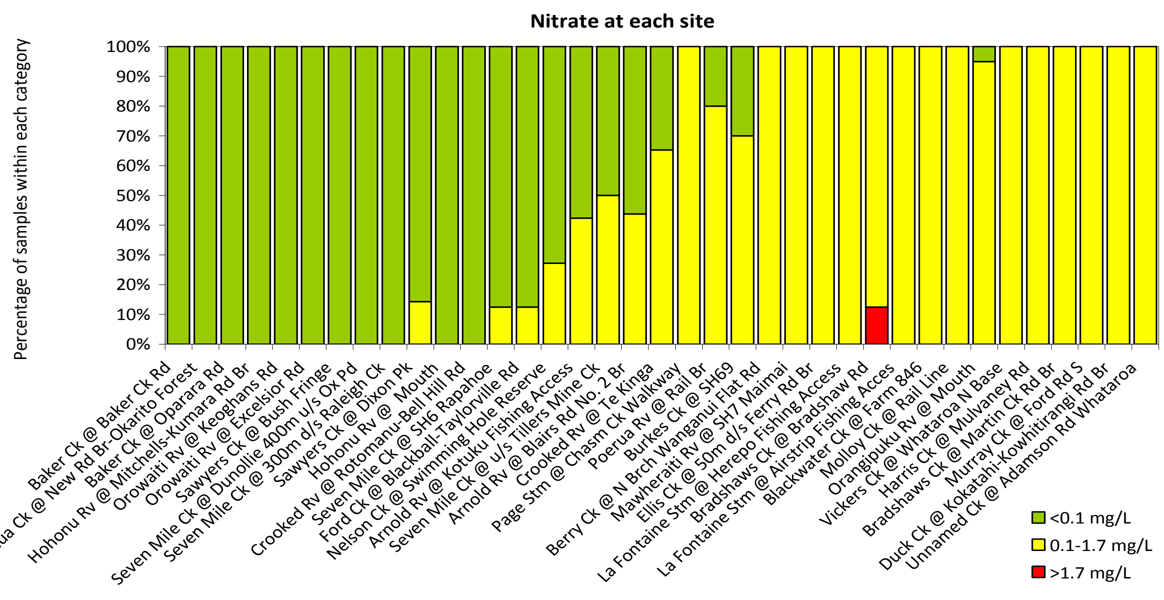
Figures 2.4 Percentage of samples in respective ammoniacal nitrogen categories for individual Regional Council monitoring program sites. No sites had values exceeding 0.9 mg/L which is the standard beyond which acute harm to aquatic life could be expected.

2.2.5 Nitrate-N

The term nitrate in this report refers to nitrate-N (NO_3-N). Two thresholds are used for nitrate (Figure 2.5). The first, at 0.1 mg/L is derived from the dissolved inorganic nitrogen (DIN) guideline for prevention of nuisance algal growths (0.04 - 0.1 mg/L). DIN is comprised of nitrate and ammonia, so using the upper bound solely for nitrate is erring towards generous. However, this is justified here by the fact that the majority component of DIN is nitrate, and that high rainfall and cool temperatures on the West Coast make nuisance algal growths less likely than other parts of New Zealand. The second threshold comes from Hickey and Martin's (2009) review for nitrate, which suggests a value of 1.7 mg/L to provide moderate protection for 95% of aquatic creatures.

Approximately half of the sites in the monitoring program consistently had nitrate levels over that designated high enough for potential nuisance algal growth. For nuisance algal growths to occur other factors such as warm temperatures and stable flows are also required, and these are often lacking despite adequate bioavailable forms of dissolved nitrogen such as nitrate. Another consideration is that phosphorus, not nitrogen, is normally the limiting nutrient in West Coast waterways (see Section 4 for more discussion on limiting nutrients). Therefore, large amounts of nitrate will not cause abundant algal growth if there is not enough phosphorus to match nitrogen at the right ratio.

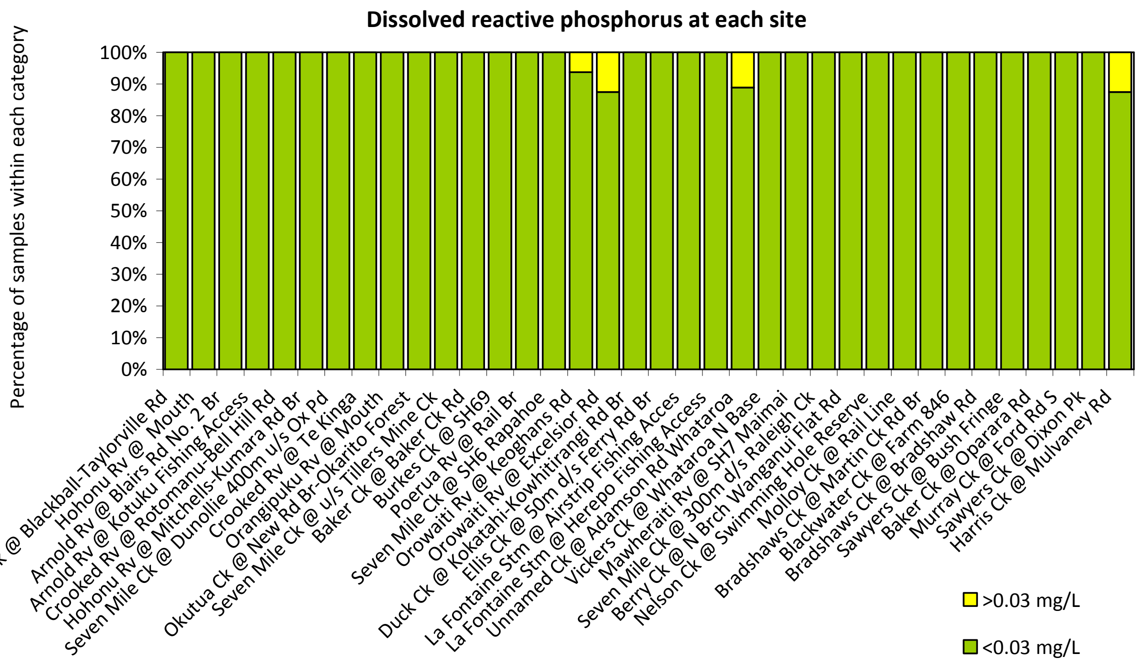
There were no sites with nitrates regularly over 1.7 mg/L. Streams with the highest nitrate occurred in intensively farmed catchments, and are predominantly spring fed during base flows (Figure 5.6.6). These stream catchments are predominantly agricultural, on free draining alluvial soils, and in high rainfall areas. Groundwater nitrate levels in these areas are not high by West Coast standards, given also that the land above is intensively farmed (refer Zemansky and Horrox, 2008), but stream nitrate concentrations are relatively similar to those of their neighbouring groundwaters. Cumulative diffuse agricultural sources are a more likely driver of elevated nitrates than point sources.



Figures 2.5 Percentage of samples in respective nitrate categories for individual Regional Council monitoring program sites.

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 2.4). 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. Nitrogen is already abundant, as is demonstrated by nitrate levels (Figure 2.5).

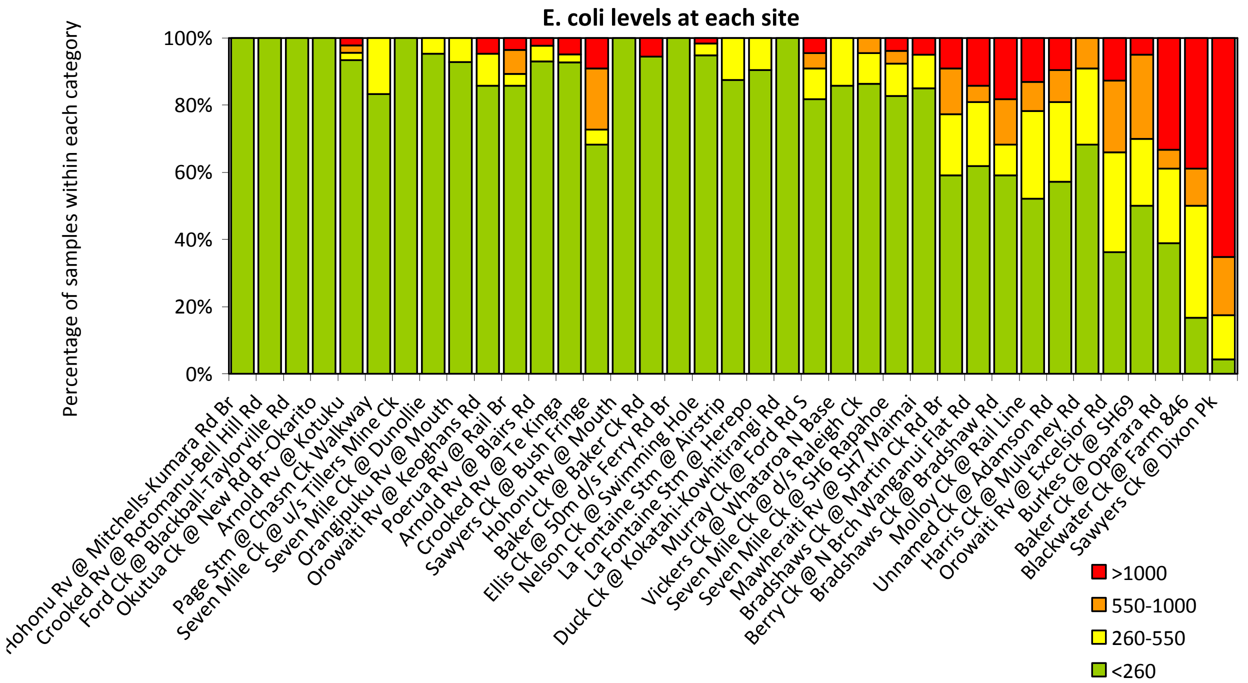


Figures 2.6 Percentage of samples in respective dissolved reactive phosphorus categories for individual Regional Council monitoring program sites.

2.2.7 E. coli

The faecal coliform *Escherichia coli* is an indicator of faecal contamination in water, which can lead to the presence of 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. The categories used here are based on contact recreation and stock drinking guidelines (refer to Figure 5.3.8). The top category of 1000 represents the ANZECC (1992) stock drinking water guideline for faecal coliforms. All lower categories are based on single sample guidelines for contact recreation suitability (refer Section 2.4). As mentioned previously, not all streams on the West Coast are managed and monitored for contact recreation, as stipulated in the West Coast Regional Council Water Plan, i.e. poor compliance with bathing water quality guidelines will not be a major issue if no one swims there.

Many sites have had *E. coli* levels above what is deemed appropriate for stock consumption. One site had *E. coli* levels over this threshold for more than 50% of the time. This would be a consideration for any sites where stream water is being used as a source for stock drinking water.



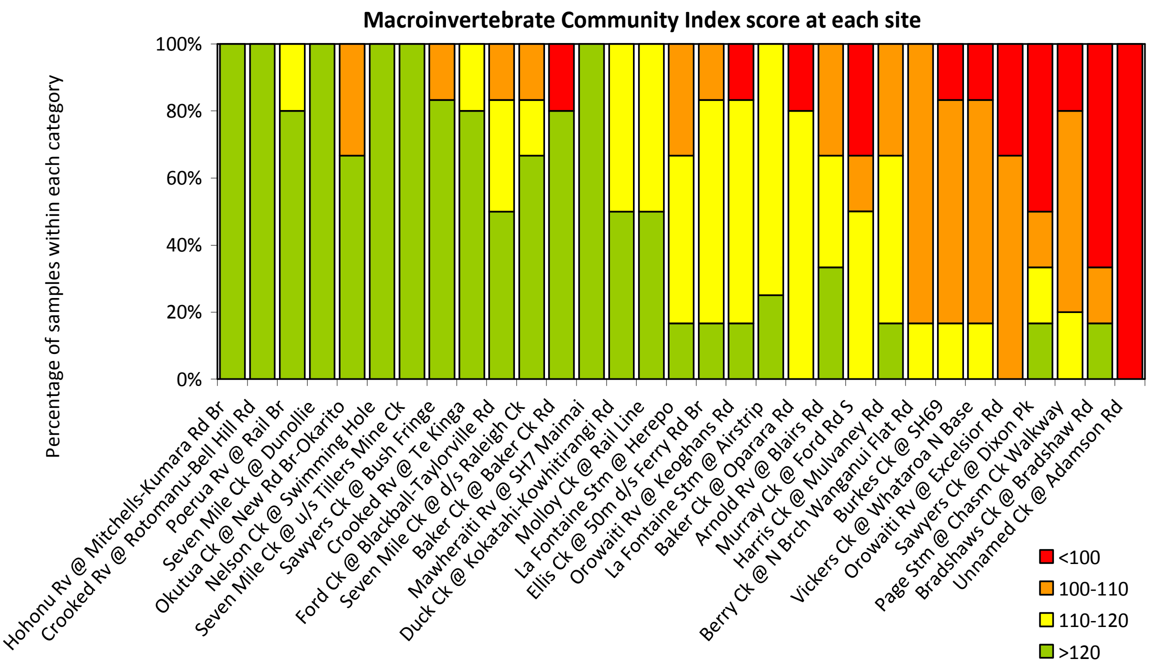
Figures 2.7 Percentage of samples in respective E. coli categories for individual Regional Council monitoring program sites. Blue arrows indicate sites also monitored for contact recreation suitability.

2.2.8 Macroinvertebrates

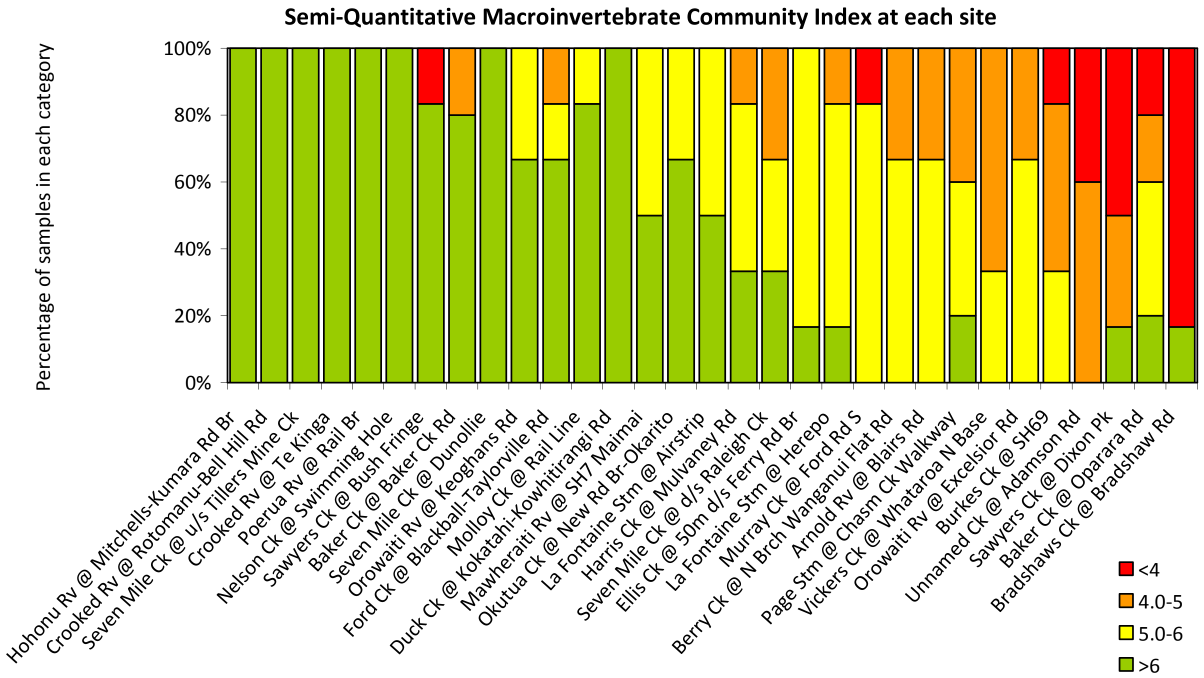
The Macroinvertebrate Community Index (MCI) and Semi-Quantitative Macroinvertebrate Community Index (SQMCI) evaluate water quality based on the types and tolerances of macroinvertebrates found at a site (Figures 2.8 and 2.9). The four categories relate to water quality classes going from poor (<80) to excellent (>120) (refer Section 5.4). The rank of sites based on medians for MCI and SQMCI differ. Some site ranks differ greatly e.g. Baker Creek @ Oparara Road. The SQMCI takes into account the abundance as well as the type of each macroinvertebrate collected. A lower SQMCI compared to MCI indicates that while there are pollution sensitive macroinvertebrate taxa present, they are not present in large numbers. The opposite – high SQMCI and lower MCI – might indicate that there are pollution tolerant species present, but the pollution sensitive types are numerically dominant. Baker Creek @ Oparara Road is a good example of the former: some pollution sensitive macroinvertebrates are often present at this site, but they are not as abundant as the pollution tolerant ones. Un-named Ck @ Adamson Rd is an example of the latter.

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 figure 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 stable flows and 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 slight to un-impacted water quality, with the bottom quarter consistently rating as having moderate to poor water quality.



Figures 2.8 Percentage of samples in respective MCI categories for individual Regional Council monitoring program sites.



Figures 2.9 Percentage of samples in respective SQMCI categories for individual Regional Council monitoring program sites.

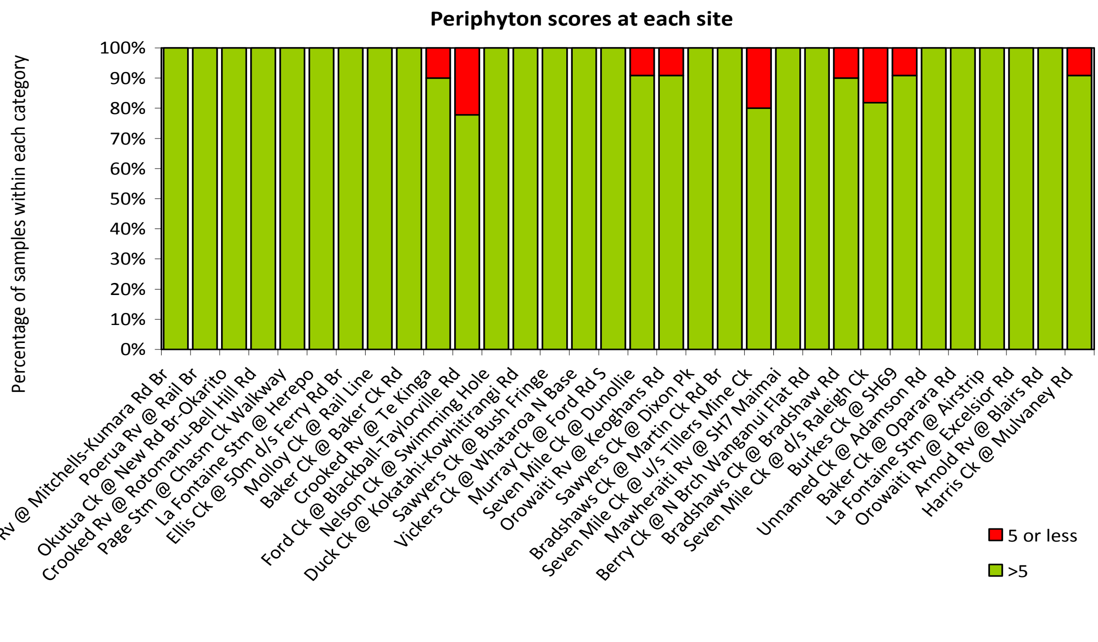
2.2.9 Periphyton

Figure 2.10 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 5.4.10 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.

Evaluation of seasonal periphyton cover at the NIWA monitoring sites indicated that highest periphyton cover was most likely in late summer-early autumn, but high cover can occur any time if climatic regimes are favourable (Figure 5.9.2b).

The introduced and invasive algae *Didymosphenia germinata* (Didymo) occurs upstream of all these NIWA sites, except Grey River @ Waipuna. Didymo was discovered in the Buller River (above Longford) in 2005 and data suggests that filamentous algal cover has increased noticeably around 2005 at the Buller River @ Longford site (Figure 5.9.1). More on trends in algal cover at NIWA sites is discussed in Section 3.1.2. The New Zealand Periphyton Guidelines (Biggs 2000) suggest a threshold of <30% cover to preserve aesthetic value. Over the 20 years of algal cover assessment at these NIWA sites, levels of cover over 30% were not common. The number of samples measuring over 30% cover ranged from 1-4% (Figure 5.9.1). Only Grey @ Dobson has had median dissolved inorganic nitrogen above the MfE (1992) nuisance algal growth threshold, and no site medians were above that for the DRP equivalent.

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.



Figures 2.10 Percentage of samples with periphyton scores equal or less than 5, for individual Regional Council monitoring program sites. Note that lower scores indicate more periphyton.

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 the value for a variable at the upstream site from that of the downstream site, from the same day (Figure 5.7.1a-c). No statistics were conducted to estimate the significance of the difference between sites. Negative differences occur when the upstream value is higher than the lower. This is favourable for some variables and not others. For example, 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). A negative clarity difference might indicate deterioration in downstream water quality. There may also be a trade off between continual additions of something, say nitrate, and additions of water that provide dilution. Therefore loadings will increase, but concentrations may not. Concentrations are primarily what are used in this Regional Council monitoring program report.

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 always have significantly less potential sources of pollution upstream of them compared with their downstream partners.

Faecal coliform bacteria increased downstream for all streams except Sawyers Creek. Medians were notably higher downstream for Baker Creek and Orowaiti River, but not at the other sites. Most streams had occasions where faecal coliforms were higher upstream, and this was common at Bradshaws Creek. Particle settling due to lower velocity, and tidal flushing, may have assisted with reducing faecal coliform levels at the lower Bradshaws site.

Conductivity increased downstream at all streams except Sawyers Creek. This is due to the presence of limestone in the headwaters of Sawyers Creek that increases both conductivity and pH. In-stream processes and further dilution reduce these variables downstream.

Ammoniacal nitrogen and dissolved reactive phosphorus increased downstream for all sites excluding Bradshaws Creek. While ammonia improved downstream at Bradshaws, median nitrate increased by 0.1 mg/L. 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 ammoniacal nitrogen.

Median turbidity and clarity deteriorated downstream except at Bradshaws Creek. Many sites showed no consistent trend of downstream deterioration. Upstream/downstream clarity and turbidity at Baker Creek, La Fontaine Stream and Seven Mile Creek did not differ greatly and were occasionally poorer upstream. This was accentuated at Baker Creek by high levels of natural dissolved organic carbon (CDOM) at the top, which reduces clarity (but not turbidity). Increasing downstream inflows that lack CDOM lead to an improvement in clarity at times, but this is often offset by increased levels of suspended particles.

Differences in dissolved oxygen between paired upstream and downstream sites were examined in 2008 but this analysis has been excluded from this report. Patterns in dissolved oxygen are difficult to interpret as many processes can be pushing dissolved oxygen in different directions simultaneously. Levels of pH, like dissolved oxygen, are influenced by many factors and vary significantly over the length of a day at some sites. In 2008 the often close pH relationship between paired upstream and downstream samples highlighted the role of climatic influence on pH levels.

Overall, periphyton increased downstream as indicated by median levels (a higher periphyton score indicates less periphyton). Higher upstream periphyton at Sawyers Creek was probably due to historic identification of moss as periphyton. Periphyton along the Arnold River is hard to compare. Being formed by the exit of Lake Brunner the Arnold has very stable flows. This means there is a lack of flushing and scouring – particularly upstream – thus algal and plant growth accumulates more easily upstream.

In most cases macroinvertebrate communities indicative of higher water quality occurred at upstream sites. Poorer habitat at the upstream sites on Bradshaws Creek and La Fontaine Stream, combined with negligible differences in water quality, may have lead to no real upstream/downstream pattern in macroinvertebrate communities there. In the Arnold River, differences in habitat and flow regimes (already explained for periphyton) will influence macroinvertebrate communities also. Taxonomic richness - a measure of species diversity - increased downstream at some sites but the additional species were likely to be those more tolerant of pollution.

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* are measured at sites that have fresh or brackish waters, while Enterrococci only are measured in marine environments.

There have been a number of changes to the contact recreation monitoring program over the last three years. In 2009 all three sites at Lake Kaniere were dropped due to consistently high water quality, with Blaketown Lagoon and Orowaiti River dropped due to lack of use for swimming. In 2010 Orowaiti Lagoon was dropped due to consistently poor water quality, with two new sites initiated in Westport – Carters Beach and North Beach, and one at Lake Mahinapua. Sites dropped for either very high or very low water quality will be re-instated into the sampling program - following a three year latency period – to re-assess their quality. Historically a number of sites - particularly those with brackish water - had both Enterrococci and faecal coliforms sampled. All sites currently have either Enterrococci *or* faecal coliforms and *E. coli* measured. Sampling frequency at many sites has been increased from 5 to 10 samples per season.

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); and 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 5.9.

Figure 2.11 summarises overall annual regional contact recreation quality. Numbers of sites and samples have varied between sampling seasons (Table 2.1), which may add bias and should be borne in mind when comparisons are made between years. Since 2000, 80% of samples have been in the low health risk category, excluding a dip to 67% in 2004. In the last five years the most recent season (2010-2011) showed a 5% increase in the frequency of high risk sample results. It is too early to conclude that this alone would indicate a significant overall deterioration in bathing suitability. Individual site data suggested that the overall regional increase in high risk sample results, observed in 2010-2011, was due to many individual sites having a single high risk sample in that season (Section 5.9). Other than these occasional high values, water quality at Regional Council monitoring sites appears to have remained consistent since previous SoE reporting in 2008.

Overall, lake sites had the best water quality. In the past the West Coast's coastal beach monitoring sites have proven cleaner than their river counterparts. It has been found nationally that coastal beaches have better water quality than inland waters (MfE 2010), due primarily to the increased dilution typically provided for by marine waters, and this trend held true for the West Coast in 2009-2010. During this season all marine sites met with guidelines >95% of the time (guideline defined as <280 Enterrococci/100 ml). Over the same 2009-2010 season, 73% of West Coast freshwater sites met with guidelines >95% of the time (guideline defined as <550 E. coli/100 ml). This still compares favourably with the national freshwater value for this period of 57% of sites with >95% guideline compliance.

But over 2010-2011 34% of marine sites on the West Coast met with guidelines >95% of the time, compared with West Coast freshwaters, where 91% of sites were guideline compliant >95% of the time. Sampling is avoided during or shortly after heavy rain. Even during drier periods, typically rough sea conditions can make it difficult to avoid samples free of suspended material, which increases the chance of a higher faecal coliform count. Further sampling over consecutive seasons will confirm whether marine sites continue to have more exceedances than water in freshwater areas.

It is worth reiterating that 'freshwater sites' on the West Coast are defined as lagoons and estuaries, rivers, and lakes. There are distinct trends in water quality between these specific types of environments. The Orowaiti Lagoon continued to have the poorest bacterial water quality of all. This site has been deemed unsuitable for swimming with signage onsite advising potential swimmers of the risk. Other than one exceedance early in 2010, Seven Mile Lagoon (Seven Mile Ck @ SH6 Rapahoe) has been low risk for the last two years. This represents a significant improvement on historic conditions.

Of the river sites those in the Buller, which are near the river mouth, were most likely to have exceedances although these remain much better following improvements associated with the Westport municipal sewerage upgrade. There are a number of potential sources of *E. coli* including stream and stormwater drain outlets, and various bird species occupying the intertidal zone. Overall, river water quality was good outside of wet periods where increased run-off from land, of material containing *E. coli.,* usually increases faecal bacteria substantially.

Lake water quality remains suitable for swimming. Sites at Lake Kaniere have been dropped temporarily from sampling for three years as they consistently had good water quality. A localised presence of water fowl often contributes to high *E. coli* at Regional Council lake monitoring sites.

Bathing water quality at the beaches has continues to be good, although many sites had single high risk sample results during the most recent sampling season. Some of these exceedances may result from run-off associated with recent rainfall, which is also the case for exceedances at river sites.

Table 2.1 Total site and sample numbers involved with contact recreation monitoring from 1995 (year ending in 1996) to 2011.

Season	Total number of sites	Total number of samples
1996	5	30
1997	7	14
1998	11	24
1999	10	49
2000	12	37
2001	16	51
2002	18	88
2003	18	100
2004	18	104
2005	20	127
2006	21	118
2007	21	121
2008	22	119
2009	22	148
2010	17	127
2011	17	137

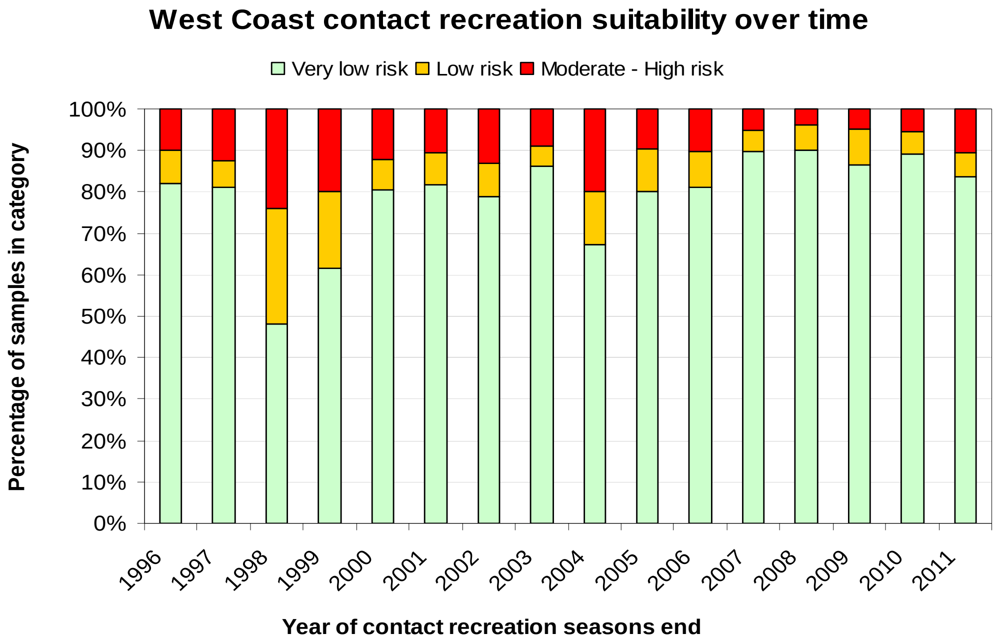


Figure 2.11 Proportional suitability for contact recreation at monitored contact recreation sites. All sites and samples collected within the contact recreation period (November – March) at contact recreation monitoring sites have been pooled for each season e.g. 1996 includes the summer of 1995-1996. The three categories are based on MfE (2003) E. coli single sample criteria for bathing suitability.

3 Trends

Summary of surface water quality trends on the West Coast

Variables important to aquatic ecosystems, such as turbidity, clarity, ammoniacal nitrogen, E. coli and faecal coliforms have again been seen to improve significantly at Regional Council monitoring program sites (Table 3.2). Those parameters are typical of point source pollution (see Appendix 5.10 for graph demonstrating trends for parameters measured). The largest West Coast rivers such as the Grey and Buller. A reduction in ammoniacal nitrogen was evident over the last 10 years at the NIWA sites as well as at many of the WCRC SWQMP sites. However, at the NIWA sites there was no improvement in clarity over the past 10 years, with two sites showing significant negative trends.

It is only in the last two years that nutrients like dissolved reactive phosphorus (DRP) and nitrate, which can increase in response to diffuse source pollution, have been sampled at all monitoring program sites with anthropogenic nutrient inputs. So it is still too early to evaluate trends for these nutrients at monitoring program sites. But DRP and nitrate, along with total nitrogen (TN), have increased at many NIWA sites. Being large rivers, their nutrient levels are a result of contributions from sub-catchments and tributaries upriver.

Earlier SoE analysis in 2008 concluded that point source pollution has decreased, but diffuse source pollution has increased, and these patterns are similar to elsewhere in New Zealand. This most recent analysis continues to support this conclusion but suggests that improvements associated with better managed point source pollution may be slowing.

Algal cover in the Buller River @ Longford (Tasman District) increased significantly in 2005 around the time that the invasive diatom Didymo was discovered in the catchment upstream. Macroinvertebrate community quality also decreased here from 1990-2010. Conversely, from 1990-2010, algal cover decreased in the Grey River @ Waipuna despite increasing nitrate and total nitrogen. Unusual patterns were also observed in the Haast River, which highlights the potential importance of longer-term climatic variability as an influence on certain variables at some sites (Scarsbrook et al. 2007).

3.1 Trends: NIWA sites

3.1.1 Water quality trends at NIWA sites

Trends were investigated for variables measured at NIWA's National River Water Quality Network sites. These 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 @ Roaring Billy is a single site for that catchment. The analysis determined either positive, negative, or no trends for all variables at each site. For a trend to be significant it required a p value of <0.05. We define a trend as 'meaningful' if it has statistical significance i.e. $p < 0.05$, *and* has an annual rate of change of more than 1%. Refer to Vant (2007) for a description of this rationale. However these meaningful trends are the main focus of following discussion. If a trend is discussed as increasing or decreasing, it can be taken as given that – unless stated otherwise - the trend is meaningful i.e. $p<0.05$ and annual change is >1% of the median. Trends were investigated over two time frames: one from 1990-2010 and the other from 2000-2010. All results for these analyses are presented in Table 3.1 and 3.2.

When the short and longer period trend evaluations are compared, most trends are the same. The exceptions are: that fewer trends are meaningful over the shorter time period; and that trends for clarity were quite different. Over the previous 20 years clarity has improved at the upper sites of both the Grey and Buller Rivers, but no meaningful change was observed at these sites for the last 10 years. Alternatively, deteriorating clarity was observed at the Haast @ Roaring Billy and Grey @ Dobson sites from 2000-2010. This wasn't apparent over the longer time frame.

All other trends were for nutrients, with fewer trends over the shorter ten year period. Ammoniacal nitrogen decreased at all sites from 1990-2010, but only at Buller @ Te Kuha and Haast @ Roaring Billy from 2000-2010. While ammonia levels improved, nitrate increased at both Grey River sites, and at Buller @ Te Kuha, over both the 10 and 20 year period. Of the trends for increasing total nitrogen (TN) in the Buller and Grey Rivers, and down trending TN in the Haast, from 1990-2010, only the Haast and Grey @ Dobson trends were apparent from 2000-2010. Dissolved reactive phosphorus increased over both time periods at Buller @ Longford (Tasman District) and Grey @ Dobson.

Water quality improvements in 2008 SoE reporting were observed for the Haast River @ Roaring Billy. Suggestions for possible contributing factors for this were: decreases in grazing e.g. the Landsborough Valley; an ongoing possum control programme in much of the catchment; and climatic variation (Horrox 2008). Strong trends continued for decreasing ammoniacal nitrogen and total nitrogen. Given that such a small proportion of the Haast River catchment above Roaring Billy Stream is affected by anthropogenic activity compared to the other four NIWA sites, it is somewhat of a mystery why ammoniacal nitrogen and total nitrogen are decreasing so markedly. Median nitrate for Haast River (34 ug/L) was higher than that for Grey @ Waipuna (26 ug/L) and Buller @ Longford (24 ug/L). Nitrate levels are often closely associated with anthropogenic nutrient sources so Haast @ Roaring Billy would have been expected to have the lowest nitrate levels.

Monthly sampling for E. coli commenced in 2005 with no significant trends detected at any of the monitoring sites. Seasonal Kendall testing was conducted on this data using the same methods as for the other sites, with no significant trends apparent.

3.1.2 Periphyton and macroinvertebrate trends at NIWA sites

Periphyton and macroinvertebrate data has been taken from 1990-2010. Increases in algal cover for Buller @ Longford (Tasman District) were statistically significant and visual assessment suggests that filamentous algal cover has increased noticeably around 2005 (Figure 5.9.1). Due to the number of zeros in the data, the median and trend slope were zero, but linear regression confirmed that the trend was an increasing one. The same statistical issue existed for a significant trend at Haast @ Roaring Billy, but regression indicated decreasing algal cover. Didymo has been in the Haast River above Roaring Billy since 2006, but if Didymo proliferations are occurring, they are not yet evident. The Grey

@ Dobson has always appeared to have substantial algal cover and no significant trend was observed (Seasonal-Kendall trend test: p=0.425). Conversely, cover at the Grey @ Waipuna *decreased* over time. The majority of the catchment upstream of Grey @ Waipuna is pristine and Didymo is not known to occur upstream of the sampling point. There is no obvious reason for declining periphyton cover at Grey @ Waipuna. This is despite increasing nitrate and climatic variation over time may be more important.

Macroinvertebrate communities have deteriorated at the Buller @ Longford site, as indicated by a decreasing MCI (p<0.01, annual slope 1% of median) and SQMCI (p<0.01, annual slope 1.8% of median) (Figure 5.9.3). This coincided with increasing periphyton cover, thus habitat changes brought about by more periphyton may be the cause. DRP and TN have increased, but median DRP and DIN are below their respective thresholds for nuisance periphyton growth. Reduced nutrients in the water column might in part be due to uptake by periphyton. Nutrient levels are less important to Didymo, which can proliferate in very clean rivers (Kilroy et al. 2009). Didymo proliferations may be decreasing the quality of macroinvertebrate communities, but further investigation of what periphyton species are dominant at this site would be required to confirm this.

Table 3.1 Seasonal Kendall test for NIWA water quality site data on the West Coast. Arrows indicate an increasing or decreasing trend. Blue indicates significant improvement, red indicates significant deterioration, and grey indicates a non-significant trend. FA=Flow adjusted. A meaningful trend is considered as one where the p-value is <0.05 and the annual rate of change (i.e. trend slope) is greater than 1% of the median. The trend slope represents the annual change for that variable, in the units given for that variable, in the table below. The data period is from January 1990 to December 2010 incorporating 240 samples (i.e. N = 240).

Variable	Site	Median (Non-FA)	p-value (FA)	Trend direction	Annual change (FA)
Dissolved oxygen (%)	Buller @ Longford	100.2	0.070	↘	-0.022
Dissolved oxygen (%)	Buller @ Te Kuha	99.1	0.180	↗	0.019
Dissolved oxygen (%)	Grey @ Waipuna	100.2	0.022	↗	0.062
Dissolved oxygen (%)	Grey @ Dobson	99.8	<0.010	↗	0.080
Dissolved oxygen (%)	Haast @ Roaring Billy	98.8	0.090	↗	0.018
Clarity (m)	Buller @ Longford	3.7	0.001	↗	0.100
Clarity (m)	Buller @ Te Kuha	1.9	0.780	↗	0.002
Clarity (m)	Grey @ Waipuna	3.2	<0.010	↗	0.031
Clarity (m)	Grey @ Dobson	1.6	0.110	↗	0.010
Clarity (m)	Haast @ Roaring Billy	2.03	0.640	↗	0.005
Conductivity (uScm)	Buller @ Longford	55.9	0.001	↗	0.140
Conductivity (uScm)	Buller @ Te Kuha	66.45	0.003	↗	0.135
Conductivity (uScm)	Grey @ Waipuna	52.4	0.001	↗	0.211
Conductivity (uScm)	Grey @ Dobson	56.25	0.002	↗	0.136
Conductivity (uScm)	Haast @ Roaring Billy	80.3	0.120	↘	-0.106
DRP (ug/L)	Buller @ Longford	1	0.010	↗	0.020
DRP (ug/L)	Buller @ Te Kuha	2	0.100	↘	-0.017
DRP (ug/L)	Grey @ Waipuna	2	0.194	↗	0.012
DRP (ug/L)	Grey @ Dobson	2.2	0.001	↗	0.030
DRP (ug/L)	Haast @ Roaring Billy	1.1	0.133	↗	0.011
NO_x – N (ug/L)	Buller @ Longford	24	0.114	↘	-0.204
NO_x – N (ug/L)	Buller @ Te Kuha	43.9	0.001	↗	1.604
NO_x – N (ug/L)	Grey @ Waipuna	26.6	0.001	↗	0.841
NO_x – N (ug/L)	Grey @ Dobson	83.05	0.001	↗	3.650
NO_x – N (ug/L)	Haast @ Roaring Billy	32	0.230	↘	-0.122
NH_x – N (ug/L)	Buller @ Longford	3	0.001	↘	-0.210
NH_x – N (ug/L)	Buller @ Te Kuha	4	0.001	↘	-0.210
NH_x – N (ug/L)	Grey @ Waipuna	4	0.001	↘	-0.190
NH_x – N (ug/L)	Grey @ Dobson	5.9	0.001	↘	-0.130
NH_x – N (ug/L)	Haast @ Roaring Billy	2.8	0.001	↘	-0.190
g340	Buller @ Longford	2.36	0.590	↗	0.006
g340	Buller @ Te Kuha	5.1	0.089	↗	0.036
g340	Grey @ Waipuna	6.16	0.850	↘	-0.006
g340	Grey @ Dobson	7.46	0.930	↘	-0.020
g340	Haast @ Roaring Billy	0.7	0.410	↗	0.004

Table 3.1 continued Seasonal Kendall test for NIWA water quality site data on the West Coast.

Variable	Site	Median (Non-FA)	p-value (FA)	Trend direction	Annual change (FA)
pH	Buller @ Longford	7.65	0.680	-	<0.001
pH	Buller @ Te Kuha	7.59	0.120	-	<0.001
pH	Grey @ Waipuna	7.48	0.530	-	<0.001
pH	Grey @ Dobson	7.35	0.100	-	<0.001
pH	Haast @ Roaring Billy	7.69	0.610	-	<0.001
Temperature ('C)	Buller @ Longford	10.6	0.940	↘	-0.002
Temperature ('C)	Buller @ Te Kuha	11.4	0.830	↗	0.005
Temperature ('C)	Grey @ Waipuna	10.6	0.002	↗	0.047
Temperature ('C)	Grey @ Dobson	11.9	0.790	↘	-0.005
Temperature ('C)	Haast @ Roaring Billy	8.3	0.150	↘	-0.025
TN (ug/L)	Buller @ Longford	81.8	<0.001	↗	0.989
TN (ug/L)	Buller @ Te Kuha	136.7	<0.001	↗	2.625
TN (ug/L)	Grey @ Waipuna	103	<0.001	↗	2.017
TN (ug/L)	Grey @ Dobson	198	<0.001	↗	5.710
TN (ug/L)	Haast @ Roaring Billy	60	0.002	↘	-0.678
TP(ug/L)*	Buller @ Longford	4.7	0.230	↗	0.039
TP(ug/L)*	Buller @ Te Kuha	8.3	0.555	↘	-0.021
TP(ug/L)*	Grey @ Waipuna	5	0.980	↗	0.001
TP(ug/L)*	Grey @ Dobson	9	0.228	↗	0.051
TP(ug/L)*	Haast @ Roaring Billy	4.2	0.346	↘	-0.039
Turbidity (NTU)	Buller @ Longford	0.8	0.343	↗	0.005
Turbidity (NTU)	Buller @ Te Kuha	1.6	0.175	↘	-0.015
Turbidity (NTU)	Grey @ Waipuna	0.84	0.530	↘	-0.004
Turbidity (NTU)	Grey @ Dobson	2.1	0.310	↘	-0.009
Turbidity (NTU)	Haast @ Roaring Billy	1.5	0.362	↗	0.014
Flow (cumecs)	Buller @ Longford	56.2	.	.	.
Flow (cumecs)	Buller @ Te Kuha	253.8	.	.	.
Flow (cumecs)	Grey @ Waipuna	33.1	.	.	.
Flow (cumecs)	Grey @ Dobson	227.5	.	.	.
Flow (cumecs)	Haast @ Roaring Billy	121.9	.	.	.

Table 3.1 Seasonal Kendall test for NIWA water quality site data on the West Coast. Arrows indicate an increasing or decreasing trend. Blue indicates significant improvement, red indicates significant deterioration, and grey indicates non-significant trend. FA=Flow adjusted. A meaningful trend is considered as one where the p-value is <0.05 and the annual rate of change is greater than 1% of the median. The trend slope represents the annual change for that variable, in the units given for that variable, in the table below. The data period is from January 2000 to December 2010, incorporating 120 samples (i.e. N = 120).

.

Variable	Site	Median (Non-FA)	p-value (FA)	Trend direction	Annual change (FA)
Dissolved oxygen (%)	Buller @ Longford	100.1	<0.01	↘	-0.063
Dissolved oxygen (%)	Buller @ Te Kuha	99	<0.01	↗	0.339
Dissolved oxygen (%)	Grey @ Waipuna	100.3	<0.01	↗	0.440
Dissolved oxygen (%)	Grey @ Dobson	99.8	<0.01	↗	0.377
Dissolved oxygen (%)	Haast @ Roaring Billy	98.9	0.415	↘	-0.024
Clarity (m)	Buller @ Longford	4.725	0.378	↗	0.046
Clarity (m)	Buller @ Te Kuha	2.2	0.039	↘	-0.040
Clarity (m)	Grey @ Waipuna	3.85	0.060	↗	0.070
Clarity (m)	Grey @ Dobson	1.99	0.026	↘	-0.051
Clarity (m)	Haast @ Roaring Billy	2.7	0.030	↘	-0.064
Conductivity (uScm)	Buller @ Longford	56.85	<0.01	↗	0.428
Conductivity (uScm)	Buller @ Te Kuha	68.3	<0.01	↗	0.334
Conductivity (uScm)	Grey @ Waipuna	53.55	0.076	↗	0.257
Conductivity (uScm)	Grey @ Dobson	58.1	0.157	↗	0.143
Conductivity (uScm)	Haast @ Roaring Billy	81.75	0.754	↘	-0.045
DRP (ug/L)	Buller @ Longford	1	<0.01	↗	0.050
DRP (ug/L)	Buller @ Te Kuha	1.7	0.329	↘	-0.024
DRP (ug/L)	Grey @ Waipuna	1.8	0.400	↗	0.022
DRP (ug/L)	Grey @ Dobson	2.3	0.035	↗	0.071
DRP (ug/L)	Haast @ Roaring Billy	1.2	0.054	↗	0.03
NO_x – N (ug/L)	Buller @ Longford	23	0.096	↗	0.476
NO_x – N (ug/L)	Buller @ Te Kuha	57.2	<0.01	↗	2.390
NO_x – N (ug/L)	Grey @ Waipuna	35.5	0.013	↗	1.290
NO_x – N (ug/L)	Grey @ Dobson	108.2	<0.01	↗	4.350
NO_x – N (ug/L)	Haast @ Roaring Billy	32.3	0.788	↗	0.788
NH_x – N (ug/L)	Buller @ Longford	1.6	0.570	↘	-0.029
NH_x – N (ug/L)	Buller @ Te Kuha	3	<0.01	↘	-0.148
NH_x – N (ug/L)	Grey @ Waipuna	3	0.570	↘	-0.038
NH_x – N (ug/L)	Grey @ Dobson	4.9	0.768	↘	-0.013
NH_x – N (ug/L)	Haast @ Roaring Billy	1.55	0.039	↘	-0.066
g340	Buller @ Longford	2.3	0.234	↗	0.029
g340	Buller @ Te Kuha	5.3	0.200	↗	0.079
g340	Grey @ Waipuna	6.08	0.700	↗	0.059
g340	Grey @ Dobson	7.39	0.144	↗	0.083
g340	Haast @ Roaring Billy	0.69	0.139	↗	0.014

Table 3.1 continuedSeasonal Kendall test for NIWA water quality site data on the West Coast. From 2000-2011.

Variable	Site	Median (Non-FA)	p-value (FA)	Trend direction	Annual change
pH	Buller @ Longford	7.66	0.982	-	0.000
pH	Buller @ Te Kuha	7.59	0.875	↗	0.001
pH	Grey @ Waipuna	7.49	0.605	↘	-0.002
pH	Grey @ Dobson	7.37	0.95	↘	-0.001
pH	Haast @ Roaring Billy	7.7	0.106	↗	0.004
Temperature ('C)	Buller @ Longford	10.95	0.669	↘	-0.021
Temperature ('C)	Buller @ Te Kuha	11.6	0.062	↘	-0.073
Temperature ('C)	Grey @ Waipuna	11	0.805	↗	0.007
Temperature ('C)	Grey @ Dobson	11.95	0.045	↘	-0.089
Temperature ('C)	Haast @ Roaring Billy	8.25	0.53	↘	-0.022
TN (ug/L)	Buller @ Longford	88.8	0.91	↘	-0.166
TN (ug/L)	Buller @ Te Kuha	151.7	0.946	↘	-0.107
TN (ug/L)	Grey @ Waipuna	113.4	0.946	↘	-0.088
TN (ug/L)	Grey @ Dobson	229.2	0.013	↗	3.33
TN (ug/L)	Haast @ Roaring Billy	55.8	0.013	↘	-1.292
TP(ug/L)*	Buller @ Longford	4.6	0.666	↘	-0.051
TP(ug/L)*	Buller @ Te Kuha	7.55	0.371	↘	-0.099
TP(ug/L)*	Grey @ Waipuna	5.5	0.089	↘	-0.151
TP(ug/L)*	Grey @ Dobson	9.3	0.781	↘	-0.026
TP(ug/L)*	Haast @ Roaring Billy	3.7	0.441	↘	-0.042
Turbidity (NTU)	Buller @ Longford	0.77	0.291	↗	0.016
Turbidity (NTU)	Buller @ Te Kuha	1.4	0.982	↗	0.002
Turbidity (NTU)	Grey @ Waipuna	0.71	0.012	↘	-0.02
Turbidity (NTU)	Grey @ Dobson	1.9	0.84	↗	0.005
Turbidity (NTU)	Haast @ Roaring Billy	1.2	0.209	↗	0.029
Flow (cumecs)	Buller @ Longford	55	.	.	
Flow (cumecs)	Buller @ Te Kuha	243.6	.	.	
Flow (cumecs)	Grey @ Waipuna	30.8	.	.	.
Flow (cumecs)	Grey @ Dobson	207.9	.	.	.
Flow (cumecs)	Haast @ Roaring Billy	111	.	.	.

3.2 Long-term trends: Regional Council sites

3.2.1 Trends in water quality variable medians

When data from all sites were combined, significant improving trends were apparent for turbidity, clarity, faecal coliforms, *E. coli*, ammoniacal nitrogen, and periphyton (Table 3.2). Yearly change for these variables is presented in Figures 5.10.1 to 5.10.13. This improvement for ammoniacal nitrogen and clarity are consistent with trends observed at many West Coast NIWA sites. Turbidity and clarity are usually closely correlated (Maasdam and Smith. 1994) and in general these have improved in many of the region's waterways. Despite the absence of suspended sediment monitoring, improved clarity and turbidity imply a reduction of suspended solids over time.

Table 3.2 Trends in regional medians over a 10-year period (Jan 2001- Dec 2010). Trends are expressed as Spearman rank correlation coefficients. Significant trends are highlighted, and the level of significance indicated by asterisks: **<0.05 *<0.01. All correlations have N=10.

Variable	Spearman rank order correlation
Temperature	-0.418
pH	0.048
Turbidity	-0.927**
Faecal coliforms	-0.769 *
E. coli	-0.769 *
Ammoniacal nitrogen	-0.927 **
Specific conductivity	0.066
Clarity	0.942 **
Taxa richness	-0.048
% EPT	0.115
EPT taxa	-0.170
MCI	0.218
SQMCI	0.357

3.2.2 Trends in water quality variables: individual sites

A common issue with investigating trends among Regional Council sites was that many sites did not have enough data for robust trend analysis. If a trend is not reported here it may be due to either a real lack of a trend or insufficient data to have confidence in the conclusion. A minimum of forty samples were required before a significant trend was considered robust and reported in this section – favouring sites with data records with at least 40 samples. Data has been presented in Appendix 5.10 for tests with fewer than 40 samples (Table 5.10).

Several meaningful trends were observed at monitoring program sites and most were improvements. As might be expected given the overall regional trend, several individual sites trended toward improved clarity (Table 5.11). All sites where turbidity improved also showed improved clarity, but there were twice as many sites with improved clarity. When waters are low in turbidity, clarity can be a more precise measure of suspended solids for the same site over time. Faecal coliforms and *E. coli* also decreased at many individual sites, consistent with the regional trend. Ammoniacal nitrogen decreased at 19% of sites. There were too few samples at most sites for trend analysis to be conducted for other nutrients.

Harris Ck and Duck Ck were the most improved, which both had improved ammoniacal nitrogen, faecal coliforms and clarity. Faecal coliforms and clarity improved at Murray Ck and Mawheraiti River. Clarity and ammoniacal nitrogen improved at Orowaiti River @ Excelsior Rd monitoring site. There is agricultural activitiy above all these monitoring sites and improved water quality may stem from changes to farm management practices within their catchments.

The only undesirable trend was for nitrate in the Crooked River @ Te Kinga, although DRP and total nitrogen decreased. Improvement in water quality in the Arnold Rv @ Kotuku Fishing Access probably reflect improvements in Moana's municipal sewage treatment system during the monitoring period.

3.2.3 Trends in water quality variables: differences between paired sites

Few meaningful trends were observed for differences between reference/impact sites. Insufficient data was a key reason for this. Total ammonia in the Orowaiti River showed improvement, as it did for the Crooked River, albeit not quite to a statistically significant level ($p<0.06$).

Table 3.3 Trends in differences between paired reference/impact sites (upstream minus downstream values). A meaningful trend is considered as one where the p-value is <0.05 and there are at least 40 samples in the analysis. If the annual rate of change is negative then the difference between sites is decreasing over time. A smaller difference between sites is seen as desirable. The data period is from January 2000 to December 2010.

		Arnold River	Baker Creek	Bradshaw Creek	Crooked River	LaFontaine Stream	Orowaiti River	Sawyers Creek	Seven Mile Creek
Faecal coliforms cfu/100 ml	Median	20	282.5	-15	40	10	202.5	1020	110
	p value	0.65	0.16	0.75	0.99	0.03	0.25	0.27	0.15
	Annual change	1.12	28.25	-2.087	0	-13.345	-9.957	117.37	-6.46
	N	56	38	31	46	23	50	26	47
Total ammonia ug/L	Median	-1.25	31	-40	5	-2.25	34.5	15.25	52
	p value	0.541	0.31	0.23	0.06	0.15	0.05	0.34	0.23
	Annual change	-0.247	-1.545	3.636	0.469	-0.724	-3.204	-1.541	1.964
	N	18	33	27	48	24	47	22	34
Clarity m	Median	-0.7	-0.03	0.08	-6.025	-0.065	-3.795	-0.27	-0.21
	p value	0.43	0.97	0.29	0.08	0.91	0.23	0.64	0.33
	Annual change	-0.059	0	0.03	-0.192	0.007	-0.15	0.04	-0.015
	N	40	39	25	48	22	42	24	36
Turbidity NTU	Median	0	1.15	-1	0.5	0.05	2.5	1.2	0.2
	p value	0.16	0.84	0.50	0.40	0.69	0.03	0.90	0.78
	Annual change	-0.063	0.012	-0.12	-0.1	-0.018	-0.249	-0.047	0.041
	N	27	28	27	36	22	37	26	33
Conductivity (specific) uScm	Median	6	2.5	3.5	6	4	2.5	-11.5	4
	p value	0.11	0.13	0.98	0.37	0.56	0.68	0.08	0.59
	Annual change	0.626	-0.43	0	0	0	0	-4.363	0.278
	N	32	28	24	37	25	40	26	33

4 Lake Brunner catchment

Summary of surface water quality in the Lake Brunner catchment

Water quality monitoring in Lake Brunner began in the early 1990s. From this data set, trends in some variables indicated that the water quality of Lake Brunner had deteriorated from 1994 to 2011, although water quality in the lake is still relatively good. In 2001, the West Coast Regional Council initiated further monitoring in the Brunner catchment, which has expanded to include monitoring of three sites in the lake, and sampling in the three main tributaries. Long term trends in lake water quality are based on data from 0-25 m depth composite water quality samples collected at the centre of the lake.

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. Recent synthesis of data collected from the catchment supports the conclusion that phosphorus is the limiting nutrient in the lake. Comparison of phosphorus inputs from tributaries to those expected to be retained in the lake and measured in the discharge, suggest that there is no significant release of phosphorus from lake sediments. This is good as recycling of lake bed phosphorus could lead to an unstoppable slide to further water quality degradation. Predictive modelling estimated that phosphorus inputs into the lake would need to increase by 70 % to shift the lake into mesotrophic status. Chlorophyll levels are estimated to be 3 ppb when this shift occurs (Verburg 2009).

Seasonal patterns were apparent for some variables, particularly clarity and nitrate. Clarity was poorest during summer and highest in late winter/early spring. Nitrate concentrations were lowest in summer increasing to a peak at the end of winter, then heading down again as the weather warmed. Dissolved reactive phosphorus and total nitrogen displayed a similar albeit less defined pattern. Trend analysis that accounted for seasonality was conducted on data collected at the central lake monitoring site.

From 1992-2011, statistically significant negative trends were observed for most water quality variables. This indicates gradual enrichment of the lake and a reduction in water quality. These trends were not significant from 2001-2011, with the exception of total phosphorus and the TLI, which continued to decline. Another interesting trend was observed for absorbance (g340 & g 440), which indicated an increase in coloured dissolved organic matter (CDOM).

Lake Brunner is a humic stained lake with a relatively high absorption by CDOM. As a result attenuation of light as it passes from the surface downwards is relatively high thus clarity is lower than would be expected from algal biomass concentrations alone because CDOM absorption reduces visibility in the vertical direction. A significant inverse relationship between Secchi depth and chlorophyll a concentration suggests that changes in water clarity mostly result from changes in algal biomass on a seasonal basis. However, a decreasing trend in Secchi depth since the 1990s may be in part a result of changes in concentrations of CDOM.

Submerged plant surveys between 1982 and 2009 indicated that changes in water quality over this period were not sufficient to alter plant communities in any significant, observable way. Cashmere Bay had the poorest water quality, compared with Iveagh Bay and the central lake, with localised conditions the probable cause.

Modelling has allowed for estimation of flow volumes and nutrient loads in the catchment and main tributaries of the lake. 18.9% of the catchment consists of high producing exotic grassland. Nutrient loadings per hectare were higher in agriculturally developed catchments. Estimated nutrient yields from high producing pasture in the Lake Brunner catchment were consistent for TN compared to the rest of the country, but over double for TP.

4.1 Seasonal patterns in Lake Brunner water quality variables

Lake Brunner undergoes seasonal cycles relating primarily to stratification and mixing. It is important to understand how these relate to measurement and interpretation of water quality data and a summary of Lake Brunner's limnology is provided in Section 5.13. Investigation of seasonal patterns for water quality variables were presented in the West Coast Regional Council 2008 SoE report (Horrox 2008), and the findings are summarized here. When data collected at the central lake site was grouped by month, seasonal patterns were apparent for many variables (refer to Horrox 2008 for figures). Clarity, as measured by secchi disk, was poorest during summer and highest in late winter/early spring. Strongly seasonal patterns were apparent in nitrate concentrations, which were lowest in summer increasing to a peak at the end of winter, then heading down as the weather warmed. While not as strong, total nitrogen (TN) displayed a similar pattern to nitrate, but dissolved organic nitrogen (DON) was lowest in winter. Levels of chlorophyll a were lowest in winter leading to higher water clarity. Chlorophyll a was negatively correlated with secchi disk clarity ($p<0.05$), hence higher phytoplankton biomass was largely responsible for poorer water clarity at this time of year. There was no obvious seasonal pattern in total phosphorus (TP), but dissolved reactive phosphorus (DRP) seemed to drop in late summer and peaked in winter.

Predictions for phosphorus and chlorophyll relationships with clarity

A lake eutrophication model was used to predict phosphorus concentrations in the lake under a range of nutrient loadings based on residence time and retention efficacy. The critical mean phosphorus concentration in the lake inflows beyond which the lake is expected to become mesotrophic is 22.5 ppb - about 1.7 times the present rate of phosphorus loading. Chlorophyll concentrations are predicted to exceed 3 ppb when the lake becomes mesotrophic and to exceed 7.5 ppb when the lake becomes eutrophic (Verburg 2009) (Figure 4.1).

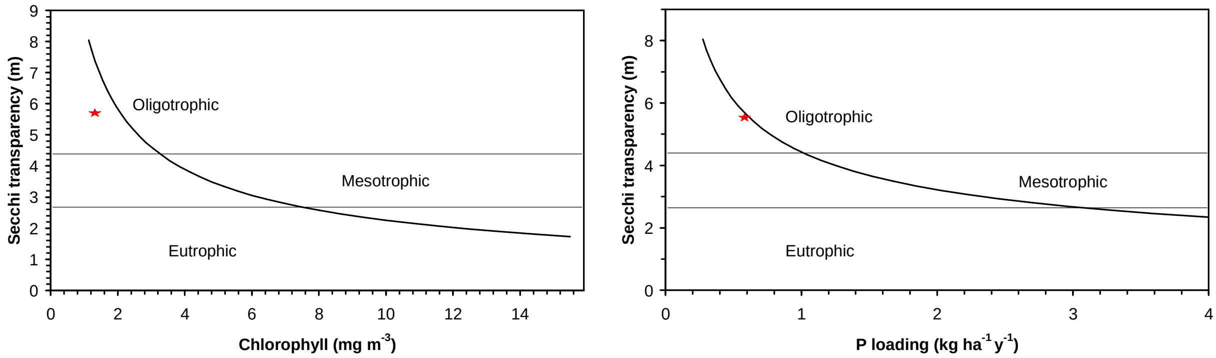


Figure 4.1Predicted clarity response of Lake Brunner to chlorophyll a and total phosphorus loadings from the catchment.

4.2 Trends in lake water quality

4.2.1 Aquatic plants

Surveys of submerged aquatic plant community structure have been conducted at sites around Lake Brunner since 1982. Information from these has been used to calculate LakeSPI (submerged plant indicator) scores, and comparison of these over the years is a useful tool for assessing potential change in water quality. Increased nutrients can increase the spread of certain species, and reduced clarity may reduce the distribution of deeper native plant species. Lake SPI analysis suggests that there has not been any change in aquatic plant community composition since 1982, hence water quality has not deteriorated sufficiently to alter them (Figure 4.2).

The invasive weed *Elodea canadensis* had a substantial impact in the mid-depth region but significant native character remained. There was a diverse array of shallow water plants observed in the latest survey that included six threatened and uncommon species.

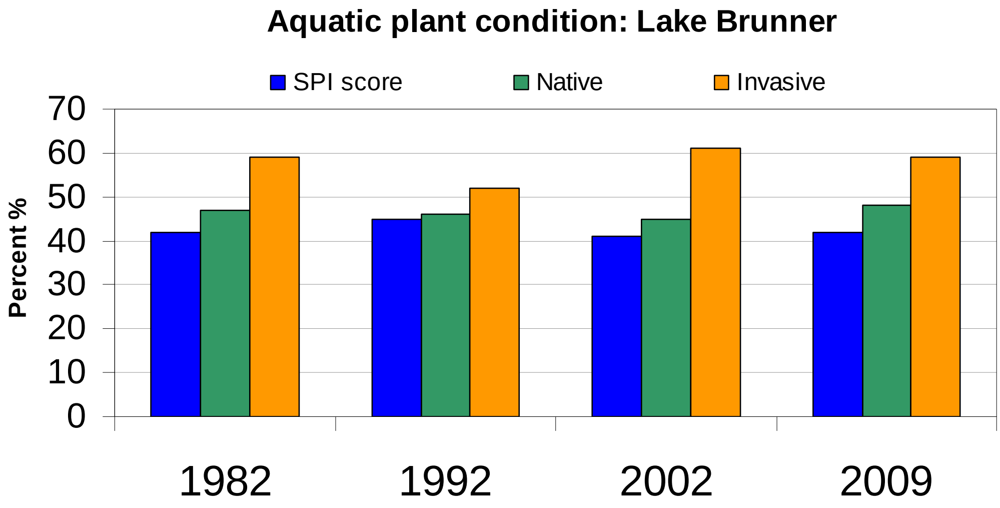


Figure 4.2 LakeSPI results for Lake Brunner showing overall LakeSPI, native and invasive scores.

4.2.2 Central lake sampling site

Analyses of all data from 1992 to March 2011 using the Seasonal Kendall test indicated that statistically significant trends have occurred for many water quality variables measured at the central lake monitoring station (Table 4.1). TN, TP, DRP and nitrate concentrations increased since monitoring began in 1992 (Figure 4.3a). Phytoplankton biomass (measured as chlorophyll a) has trended upwards, which was mirrored by a decrease in visual clarity as measured by the secchi disk depth (Figure 4.3). The trophic level index (TLI) combines TN, TP, clarity and chlorophyll a into one score that indicates the level of eutrification in the lake. This increased significantly from 1992 to 2011.

When the Seasonal Kendall analysis was conducted for the same variables, but for a shorter, more recent time period (2001-2011), there were fewer statistically significant trends. Of the individual nutrients sampled, only TP continued to show a significant increasing trend. Coloured dissolved organic carbon (CDOM), as inferred from surrogate g340 and g440 measures, has only been measured since 2001. CDOM is responsible for the brown colouration of the lake water. Levels of g340 and g440 increased significantly from 2001 to 2011.

It is not clear what factors influence CDOM levels in the catchment or whether anthropogenic changes in the catchment have affected CDOM levels. Absorption coefficients g340 and g440 did not correlate significantly with secchi disk depth ($p > 0.05$, $n = 24$) (Verburg 2011). Nevertheless, the absence of a correlation of absorption and estimated CDOM concentrations with secchi disk depth is not sufficient evidence that the decrease in secchi disk depth since the 1990s was entirely driven by an increase in algal biomass and not in CDOM. Absorbance data are only available since 2003 and do not span the same period as for which chlorophyll concentration and secchi disk depth data are available. While the decrease in secchi disk depth from the 1990s was significant, there was no trend in secchi disk depth since 2003 (Table 4.1) and the correlation of secchi disk depth with TP since 2003 was not significant ($p > 0.05$, $n = 27$) (Verburg 2011). However, the correlation between chlorophyll concentration and secchi disk depth was significant since 2003, ($p < 0.01$, $n = 28$, $r = 0.60$), suggesting that seasonal changes in water clarity were mostly driven by algal biomass (Verburg 2011).

Table 4.1 Seasonal Kendall trend testing for water quality data collected at Lake Brunner's central monitoring site. Up/down arrows indicate statistically significant increasing or decreasing trends. Red indicates an undesirable trend and blue indicates a good trend. Analysis is current to February 2011. The annual rate of change for all variables with significant trends was >1% of the median. A small p value means the trend is more likely to be real.

	Record	Trend	p value	Record	Trend	p value
Algae (chlorophyll)	**1992-2011**	↗	**0.001**	**2001-2011**	↗	**0.110**
Clarity	**1992-2011**	↘	**0.002**	**2001-2011**	↗	**0.510**
Dissolved reactive phosphorus	**1992-2011**	↗	**0.002**	**2001-2011**	↗	**1.000**
Nitrate	**1992-2011**	↗	**0.001**	**2001-2011**	↗	**0.570**
Total nitrogen	**1992-2011**	↗	**0.001**	**2001-2011**	↗	**0.117**
Total phosphorus	**1992-2011**	↗	**0.010**	**2001-2011**	↗	**0.040**
Suspended solids	**n/a**	**n/a**	**n/a**	**2001-2011**	↗	**0.330**
CDOM (g340)	**n/a**	**n/a**	**n/a**	**2001-2011**	↗	**0.001**
CDOM (g440)	**n/a**	**n/a**	**n/a**	**2001-2011**	↗	**0.010**
TLI	**1992-2011**	↗	**0.001**	**2001-2011**	↗	**0.004**

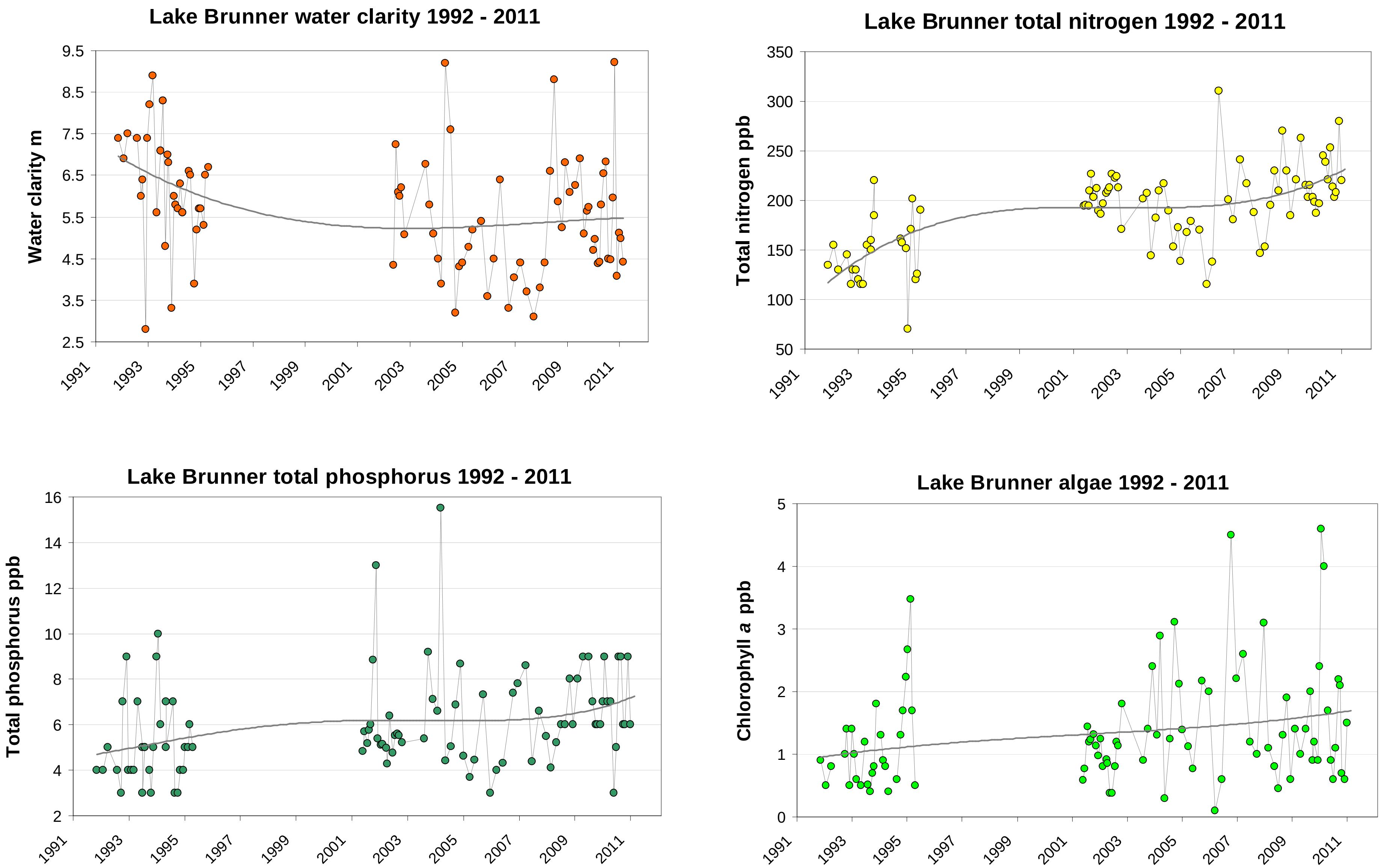
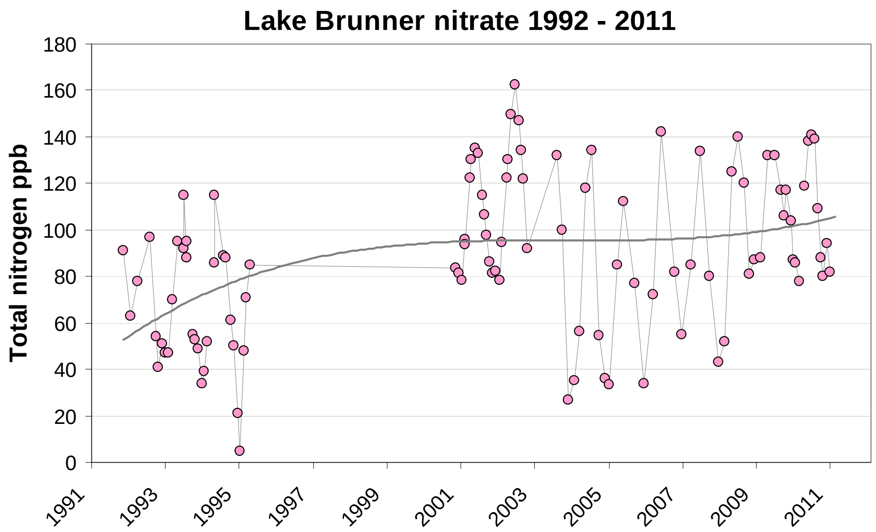
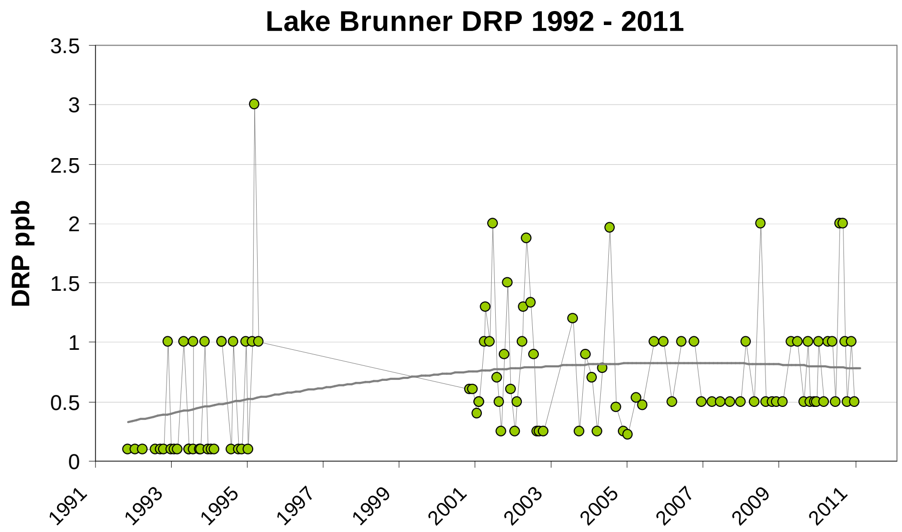


Figure 4.3a Full data record for water clarity, total nitrogen, total phosphorus, and phytoplankton algal abundance (as indicated by levels of chlorophyll a). Polynomial regression lines are overlaid in grey.





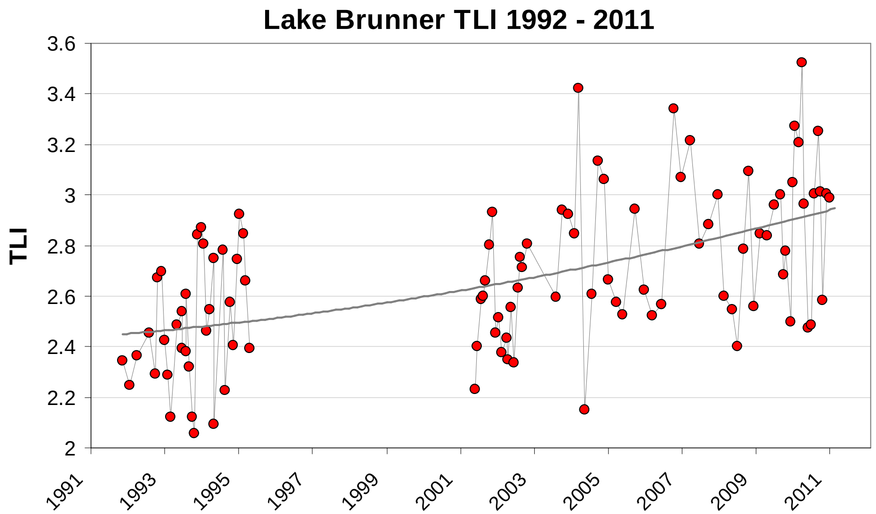


Figure 4.3b Full data record for nitrate, dissolved reactive phosphorus (DRP) and Trophic level index (TLI). Polynomial regression lines are overlaid in grey.

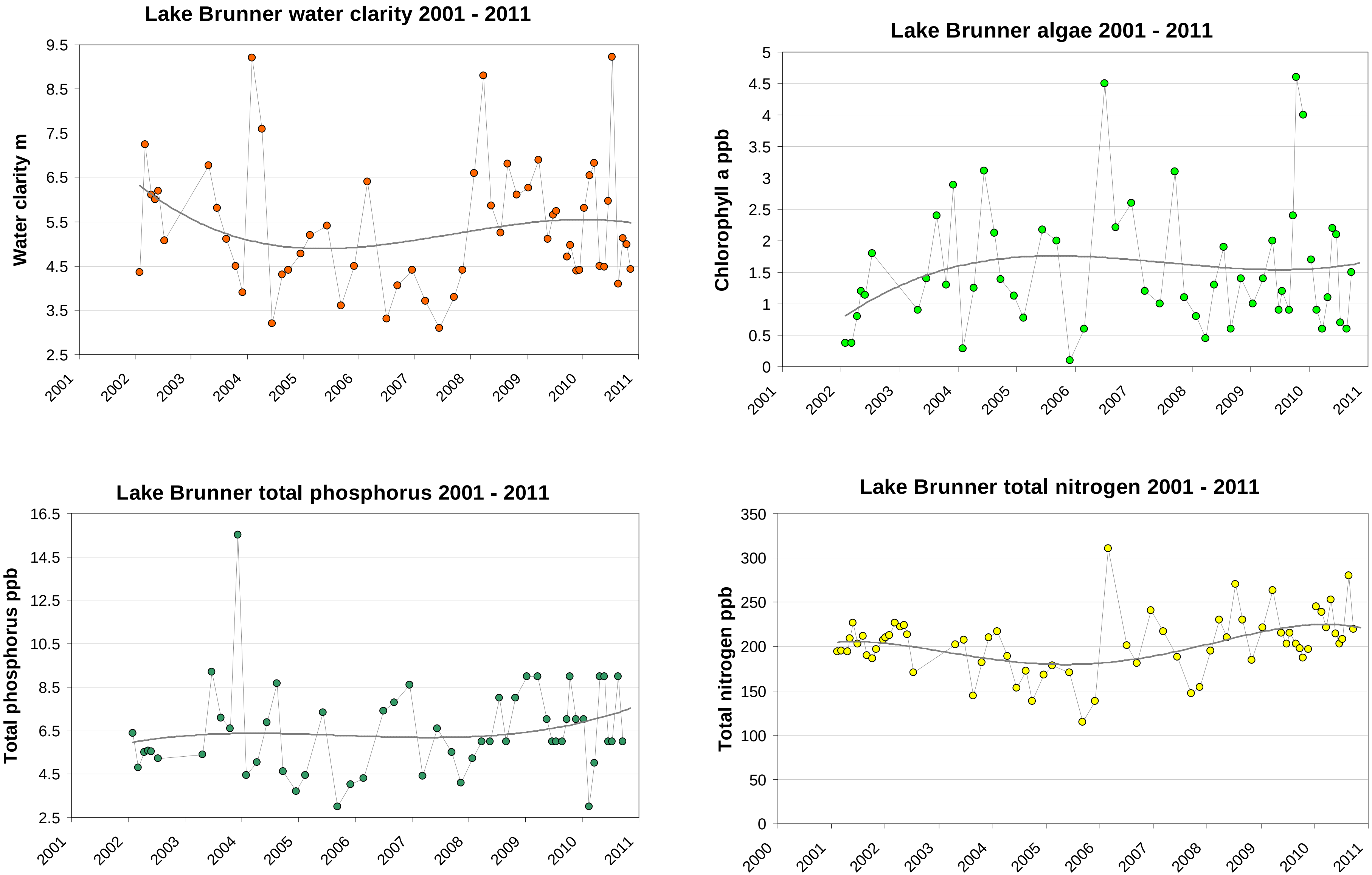


Figure 4.4a *Recent data record for water clarity, total nitrogen, total phosphorus, and phytoplanktonic algal abundance (as indicated by levels of chlorophyll a). Polynomial regression lines are overlaid in grey.*

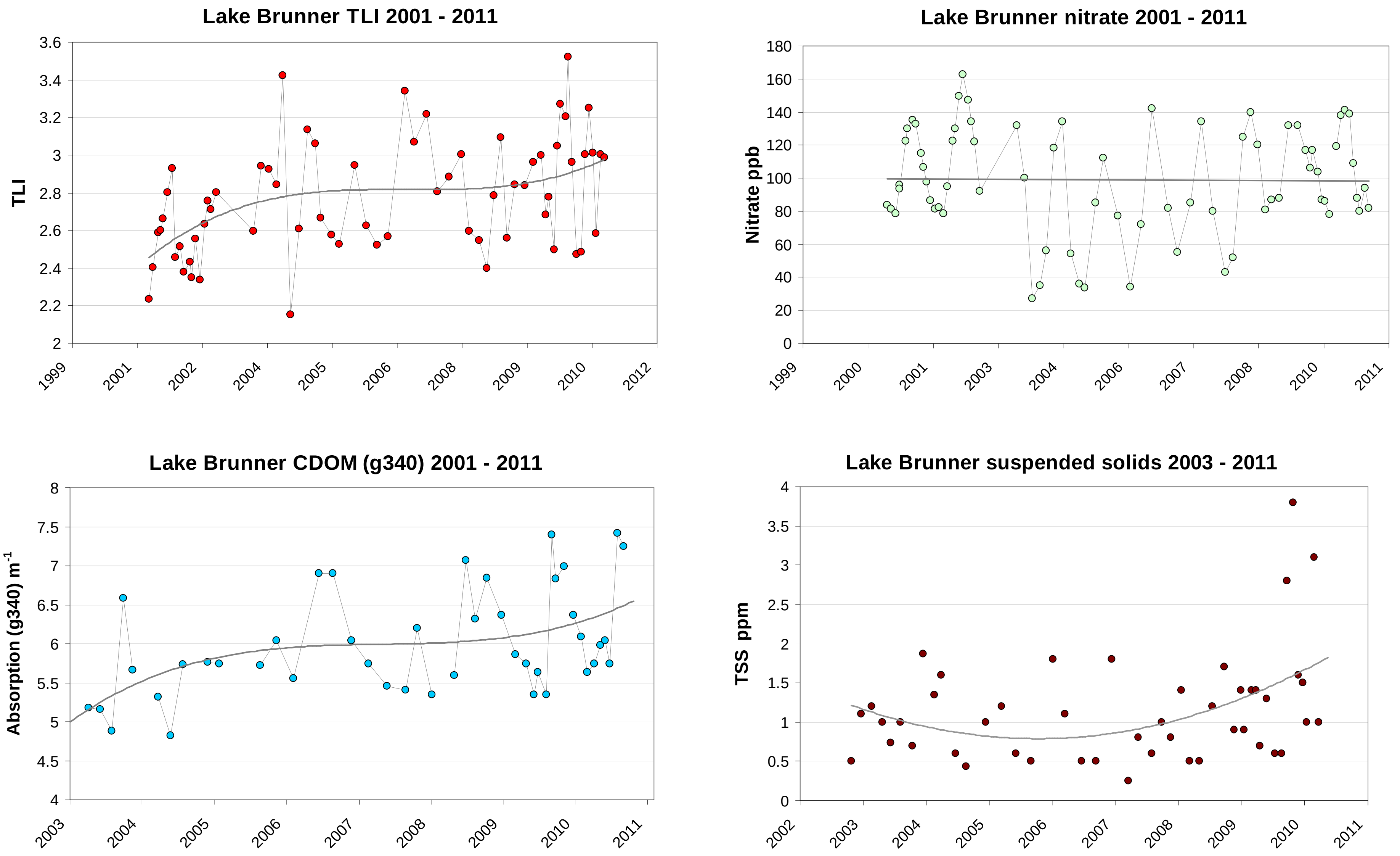


Figure 4.4b Recent data for trophic level index (TLI), nitrate, coloured dissolved organic matter (CDOM) and suspended solids. Polynomial regression lines are overlaid in grey.

4.2.3 Cashmere and Iveagh Bay stations

Nutrient concentration data consistently showed that water quality has been poorest in Cashmere Bay, in comparison to conditions at the mid-lake station and Iveagh Bay (Figures 5.12.1 & 5.12.2). Oxygen depletion has occurred near the lake bed in Cashmere Bay, which has lead to higher ammoniacal nitrogen levels compared to those for nitrate (Figure 5.12.1). TN and TP were higher near the lakebed compared with the surface. Chlorophyll a appeared to be increasing, but no distinct long-term trends were apparent for other variables. Localised conditions are likely to be contributing to poorer water quality in Cashmere Bay, and they are unlikely to be having any major influence on the rest of the lake given the small volume of water held by Cashmere Bay proportional to the rest of the lake.

At Iveagh Bay nutrient concentrations were similar at both surface and bottom depths. Unlike Cashmere, ammoniacal nitrogen levels were low near the bed of Iveagh Bay. TN and nitrate may have increased but chlorophyll a concentrations and clarity (secchi depth) seem to have varied inconclusively. Patterns in physical and chemical parameters at Iveagh Bay were similar to those observed at the central lake site.

4.3 Nutrient levels in lake tributaries

Rutherford *et al*. (2008) utilised existing Brunner tributary monitoring data to develop a model predicting flow and nutrient delivery to the lake. Information from this work was discussed in the 2008 SoE report. For further detail refer to Horrox (2008) and Rutherford *et al.* (2008). A summary of this information is provided here.

The three main tributaries – Crooked, Hohonu and Orangipuku – contribute 69% of the total lake inflow but do not contribute inflow in proportion to their catchment areas. For example, the Orangipuku River gains significant flow inputs from spring sources. Of the total catchment 18.9% is classified as high producing exotic pasture, with 74.6% of the catchment designated as undeveloped – forest, scrub, undeveloped grassland, rock or water. Low producing exotic grassland and tussock make up the remaining land cover. The Orangipuku is the most intensively developed catchment and this is reflected in it having the highest TN concentrations. Thirty-five percent of the Orangipuku catchment area is high producing exotic grassland while the Crooked/Poerua and Hohonu contain 18% and 10% of this land type, respectively.

In forested catchments (e.g., the Carew) TN is largely in the form of dissolved organic nitrogen (DON) (c. 100 mg N/m^3) with low dissolved inorganic nitrogen (DIN) concentrations (c. 10 mg/m^3). DON from forested areas generally has low bioavailability to plants. In the Crooked and Orangipuku catchments, which are most intensively farmed, DIN concentrations commonly exceed 100 mg N/m^3. TP comprises roughly equal proportions of DRP, dissolved organic phosphorus (DOP) and particulate phosphorus (PP). Phosphorus concentrations were low in forested catchments (e.g., the Carew) and high in the farmed catchments (e.g., the Orangipuku and Crooked) as expected. DIN and DRP are immediately bioavailable to plants in the lake.

TP concentrations increase with river flow in most of the tributaries, which is consistent in other catchments (Rutherford *et al*. 2008). TN concentrations in many tributaries were not well correlated with flow. TP and TN specific yields were highest in the Orangipuku (0.93 kg P/ha/yr and 21 kg N/ha/yr). This was consistent with it being the most intensively farmed catchment with 35% of the catchment being high producing exotic grassland.

The Crooked River was the only main tributary to show significant trends (Table 5.11), with adequate numbers of samples. TN decreased but nitrate increased (Figure 5.12.5). It might be assumed from this that particulate and/or organic forms have decreased in relation to dissolved inorganic forms. Unfortunately this can't be proven without particulate and dissolved organic nitrogen sampling. There has been no significant change in clarity indicating no major change in suspended particulate matter or dissolved matter. Also, CDOM has increased not decreased in the lake, and a large constituent of this is dissolved organic carbon. Since 2007 sampling at this site has been conducted consistently in the early morning instead of later in the day, which might explain a lower pH. Carbon dioxide levels could be higher in the morning following algal respiration (refer to Section 5.4.1 for an explanation of the relationship between carbon dioxide and pH).

5 Appendices

5.1 List of sites, variables, and sampling frequencies

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

Updated 13/11/2010

Area		Site	Grid Ref Easting	Grid Ref Northing	Continuous flow	Gauge per visit by WCRC	Freq.	Summer Peri	Summer Macro	Summer Extra	Autumn Peri	Autumn Macro	Autumn Extra	Winter Peri	Winter Macro	Winter Extra	Spring Peri	Spring Macro	Spring Extra
Grey Valley		Deep Ck@ Arnold Valley Rd Br	2383120	5849370	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	2383580	5849140	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	2388200	5865900	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	2379300	5868700	no	yes	1/4	-	-	SO4 (f/c & Nutrients) & other	4x5	Yes	SO4 (f/c & Nutrients) & other	-	-	SO4 (f/c & Nutrients) & other	4x5	Yes	SO4 (f/c & Nutrients) & other
Reefton		Burkes Ck @ SH69 Reefton	2414750	5901500	no	yes	1/4	-	-	SO4 (f/c & Nutrients) & other	4x5	Yes	SO4 (f/c & Nutrients) & other	-	-	SO4 (f/c & Nutrients) & other	4x5	Yes	SO4 (f/c & Nutrients) & other
Reefton		Mawheraiti Rv @ SH7 Maimai	2404200	5889000	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
Reefton		Garveys Ck @ SH7	2421490	5892570	no	no	1 yr			Yearly sonde deployment (1 month: pH, turbidity, EC, temp). Acid mine drainage site.								Yes	
Greymouth		Sawyers Ck @ Dixon Park	2362415	5859530	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	2363270	5855790	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 ponds	2366400	5867100	no	surrogate	1/4	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & other	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & other
Greymouth		Seven Mile Ck @ d/s Raleigh Ck	2366030	5867500	no	yes	1/4	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & other	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & other
Greymouth		Seven Mile Ck @ u/s Tillers	2368704	5867509	no	surrogate	1 yr	-	-	Solid Energy data	4x5	Yes	SO4 (f/c & Nutrients) & other	-	-	SENZ data	-	Yes	SENZ data
Greymouth		Seven Mile Ck @ SH6 Rapahoe	2365300	5868600	no	surrogate	1/4	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & other	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & other
Greymouth		Channel Ck @ Magazine Rd	2366480	5871530	no	no	1 yr			Yearly sonde deployment (1 month: pH, turbidity, EC, temp). Acid mine drainage site.								Yes	
Hokitika		Duck Ck @ Kokatahi-Kowhitirangi Rd	2349145	5817525	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	2347500	5815265	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	2349000	5814560	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	2388996	5937484	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 Ck Rd Br	2392150	5938120	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 @ Excelsior Rd	2395700	5936400	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	2398700	5936700	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	2322740	5799670	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)	2312100	5788400	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	2307720	5790620	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	2310380	5784650	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	2289610	5773870	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	2296900	5778180	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 Base)	2297220	5776320	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	2438400	5995500	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	2437070	5995260	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	2424800	5961700	no	surrogate	1/4	-	-	SO4	4x5	Yes	SO4	-	-	SO4	4x5	Yes	SO4
North Buller		Blackwater Ck @ Farm 846	2434380	5988440	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	NIWA	Grey Rv @ Dobson NIWA	2370100	5860200	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	2400500	5879200	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	2382070	5837750	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	2381800	5838700	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 Easting	Grid Ref Northing	Continuous flow	Gauge	Freq.	Feb Peri		Extra	April	June	August	October	December
												No macro	No macro	No macro	No macro
Brunner		Arnold Rv @ Blairs Rd	2376470	5857090	no	no	1/6	no		Nuts & F/C & other	As for Feb	As for Feb	As for Feb	As for Feb	As for Feb
Brunner		Arnold Rv @ Kotuku Fish Access	2383500	5848900	yes	no	1/6	no		Nuts & F/C & other	As for Feb	As for Feb	As for Feb	As for Feb	As for Feb
Brunner		Crooked Rv @ Rotomanu-Bell Hill Rd	2394900	5840950	no	no	1/6	4x5		Nuts & F/C & other	As for Feb	As for Feb	As for Feb	As for Feb	As for Feb
Brunner		Crooked Rv @ Te Kinga / mouth	2386700	5844015	no	yes	1/6	4x5		Nuts & F/C & other	As for Feb	As for Feb	As for Feb	As for Feb	As for Feb
Brunner		Hohonu Rv @ Mouth	2379580	5842970	no	yes	1/6	4x5		Nuts & F/C & other	As for Feb	As for Feb	As for Feb	As for Feb	As for Feb
Brunner		Hohonu Rv @ Mitchells - Kumara Rd Br	2374970	5838940	no	no	1/6	4x5		Nuts & F/C & other	As for Feb	As for Feb	As for Feb	As for Feb	As for Feb
Brunner		Orangipuku Rv @ Mouth	2382070	5837750	no	yes	1/6	4x5		Nuts & F/C & other	As for Feb	As for Feb	As for Feb	As for Feb	As for Feb
Brunner		Poerua River @ Rail Bridge	2381800	5838700	no	yes	1/6	4x5		Nuts & F/C & other	As for Feb	As for Feb	As for Feb	As for Feb	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

Site	Depth	pH	Conductivity	Temperature	DO	Turbidity	Flow gauging/data	Secchi disk	E coli and FC	Nutrients *[1]	Chlorophyll a	TSS	Turbidity (lab)	Colour *[2]
	Profiles measured using YSI Data sonde													
Lake														
Iveagh Bay (NIWA)	0 - 30 m							✓		Van Dorn 4 m & 25 m	✓			
Cashmere Bay (NIWA)	0 - 12 m							✓		Van Dorn 4 m & 10 m	✓			
Centre of Lake (NIWA)	0 - 100 m					0 - 100 m		✓		Van Dorn *[3]	✓			
Centre of Lake (NIWA)										Tube *[4]	✓	✓	✓	✓
Tributaries														
Crooked R @ Bell Hill Rd		✓	✓	✓	✓	✓			✓	✓				
Crooked R @ Mouth (NIWA)		✓	✓	✓	✓		✓		✓	✓		✓	✓	
Poerua R @ Rail Bridge		✓	✓	✓	✓	✓	✓		✓	✓				
Orangipuku R @ Mouth (NIWA)		✓	✓	✓	✓		✓		✓	✓		✓	✓	
Hohonu R @ Mitchells - Kumara Rd Br		✓	✓	✓	✓	✓			✓	✓				
Hohonu R @ Mouth (NIWA)		✓	✓	✓	✓		✓		✓	✓		✓	✓	
Arnold R @ Kotuku Fishing Access		✓	✓	✓	✓	✓			✓	✓				

*[1] All nutrients are = TN, TP, DRP, NO3, NH4, TDP, TDN

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

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

*[4] 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

Coordinates			
GYBS	2382509, 5839998		
GYBI	2386295, 5841869		
GYBC	2386834, 5842727		
Orangipuku mouth	2381700, 5838270		
Hohonu mouth	2379820, 5842730		
Crooked mouth	2384360, 5844180		

		Central site:	Full lake monitoring	van dorns 10, 20, 40, 70, 95
2010	Nov	yes		
2010	Dec	yes	yes	
2011	Jan	yes		
2011	Feb	yes	yes	
2011	Mar	yes		
2011	Apr	yes	yes	yes
2011	May	yes		
2011	Jun	yes	yes	
2011	Jul	yes		
2011	Aug	yes	yes	
2011	Sep	yes		
2011	Oct	yes	yes	yes
2011	Nov	yes		
2011	Dec	yes	yes	
2012	Jan	yes		
2012	Feb	yes	yes	
2012	Mar	yes		
2012	Apr	yes	yes	yes
2012	May	yes		
2012	Jun	yes	yes	
2012	Jul	yes		
2012	Aug	yes	yes	
2012	Sep	yes		
2012	Oct	yes	yes	yes
2012	Nov	yes		
2012	Dec	yes	yes	
	etc			

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 5.5 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 variables measured at Regional Council monitoring program sites compared to the respective guidelines for those variables. A guide to the interpretation of these figures is provided in Section 5.5 with more detail on these guidelines provided in Section 5.5.

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 a variable 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 5.7a-c.

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 variables for Regional Council sites was conducted using three techniques:

The first technique grouped data annually for all sites then variables were correlated against time. Annual grouping was done by firstly calculating a mean for all data - for the variable concerned - from each year. Then a median value from all the site means was calculated for each year (Table 3.2). These medians were correlated against year using Spearman rank correlation (Wessa 2011). Yearly medians for each variable are presented in Figure 5.10.

The second used Seasonal Kendall tests carried out on individual Regional Council sites for the 2000-2010 period (Table 5.11). 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 variables 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 and chemical variables

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 20^{th} and 80^{th} 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 effect 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 exceedences 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 variables 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 behaviour all described from New Zealand or elsewhere. Some of these effects are direct, with water temperature affecting behaviour, 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 BOD_5 (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 can not 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

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 µ*S*/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 ammoniacal nitrogen (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 ammoniacal nitrogen, 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 ammoniacal nitrogen is quoted, the pH and temperature are also relevant in determining toxicity (Figure 5.3.1).

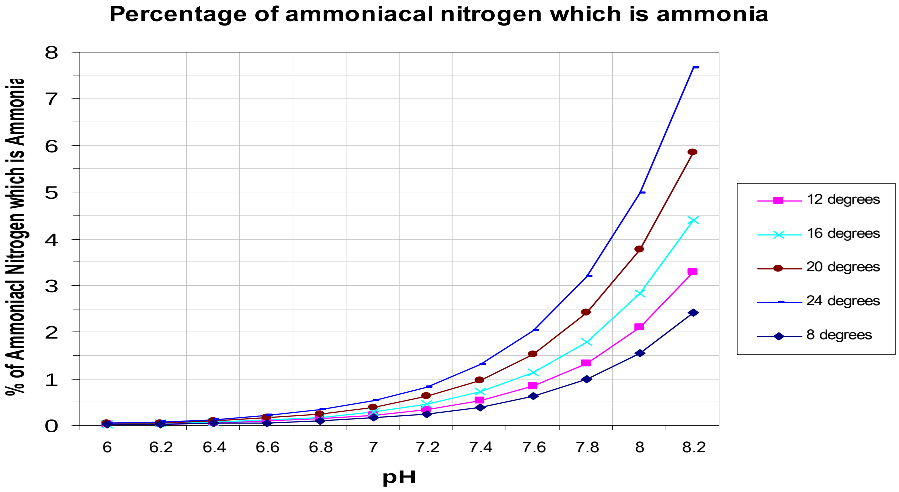


Figure 5.3.1 Percentage of ammoniacal nitrogen which is ammonia depending on the water pH and temperature.

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 ammoniacal nitrogen value of 0.9 mg/L (at pH 8, 20 ℃), has been suggested as a high reliability (95%) trigger value for freshwater (ANZECC 2000). This trigger value varies with pH and temperature (refer Table 5.4.1). 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 5.6.12). Based on an upper limit of pH 8.5, an ammoniacal nitrogen guideline of 0.4 mg/L has been selected as a benchmark for analysis in this report (Table 5.4.1).

Table 5.4.1 2000 ANZECC freshwater trigger values for ammoniacal nitrogen at different pH (temperature not taken into account).

pH	Freshwater trigger value (mg/L ammoniacal nitrogen-N)	pH	Freshwater trigger value (mg/L ammoniacal nitrogen-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 variables used for monitoring Regional Council sites are faecal coliforms/*Escherichia coli* and Enterococci. The later is used only at sites that have tidal influence or are located in marine waters*. E. coli* and Enterococci seasonal medians were plotted for all Regional Council contact recreation sites (Section 5.9). 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* 100ml) values in accordance with MfE (2003) contact recreation guidelines for individual values. For medians, the Department of Health (1992) guidelines for contact recreation waters recommend a season median of 126 E.coli/100 ml, with ANZECC (2000) stipulating a median of 150 faecal coliform cfu/100 ml and 35 Enterococci/100 ml as a safe limit.

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 use). 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 Sulphate

Sulphate is found in most natural waters as a result of the dissolution of sulphate-bearing minerals in soils and rocks. Mine wastewaters, tannery wastes and other industrial discharges often contain high concentrations of sulphate. Under anoxic conditions bacteria in water can reduce sulphate to sulfide, which results in the release of hydrogen sulfide, causing an unpleasant taste and odour and increasing the potential for corrosion of pipes and fittings.

Sulphate is used as an indicator by the Regional Council to monitor the effects of mining, current and historic, on water chemistry. The main environmental implications associated with sulphate are for consumption by stock and humans. Sulphate is an essential element for animal nutrition. It is not a highly toxic substance, but excessive concentrations of sulphate in water typically cause diarrhoea, especially if a change from low to high sulphate water occurs quickly. Animals generally avoid water containing high sulphate concentrations in favour of water containing lower concentrations. No adverse effects to stock are expected if the concentration of sulphate in drinking water does not exceed 1000 mg/L. Adverse effects may occur at sulphate concentrations between 1000 and 2000 mg/L, especially in young or lactating animals or in dry, hot weather when water intake is high. These effects may be temporary and may cease once stock become accustomed to the water. Levels of sulphate greater than 2000 mg/L may cause chronic or acute health problems in stock. The USEPA recommended maximum guideline for sulphate as a secondary contaminant in human drinking water is currently 250 mg/L, based on aesthetic effects (i.e., taste and odour).

5.3.10 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 variables 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.

5.3.11 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 5.4.2)

Table 5.4.2 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:

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

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 3.3).

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 3.2.1).

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

Table 5.4.3 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 5.5.1 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 5.5.1. Map distributions of source of flow, geology, and land cover are shown in Figure 5.4.2 to 5.4.3

Table 5.4 REC classes found in the West Coast region. Classes are hierarchical starting at the top in the order of: climate/source-of-flow/geology/land-cover/network position/valley landform. Those in bold are represented in the Regional Council SOE monitoring 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)

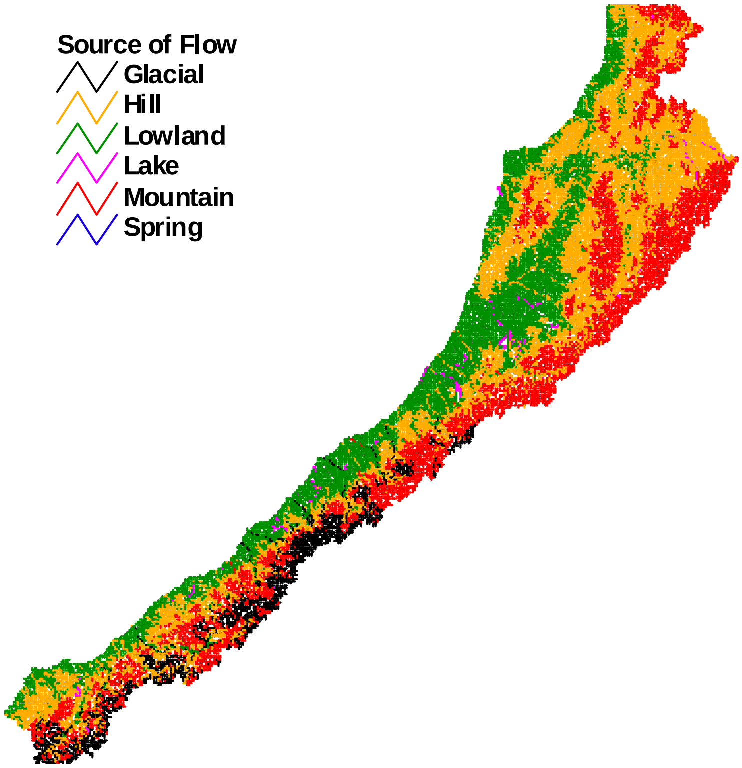


Figure 5.4.2. Map of the West Coast region showing source of flow according to REC.

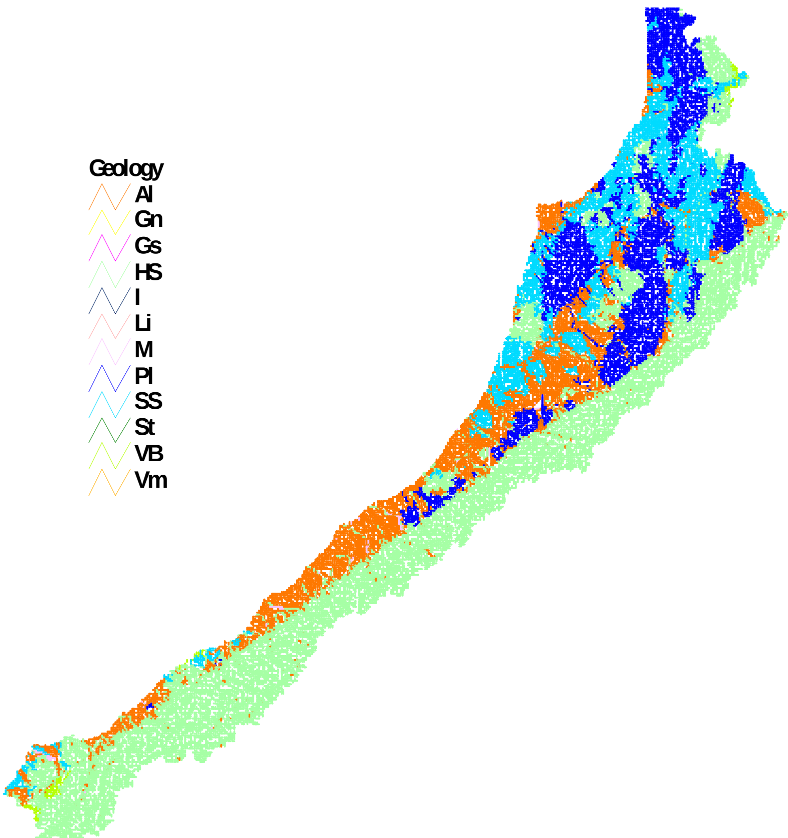
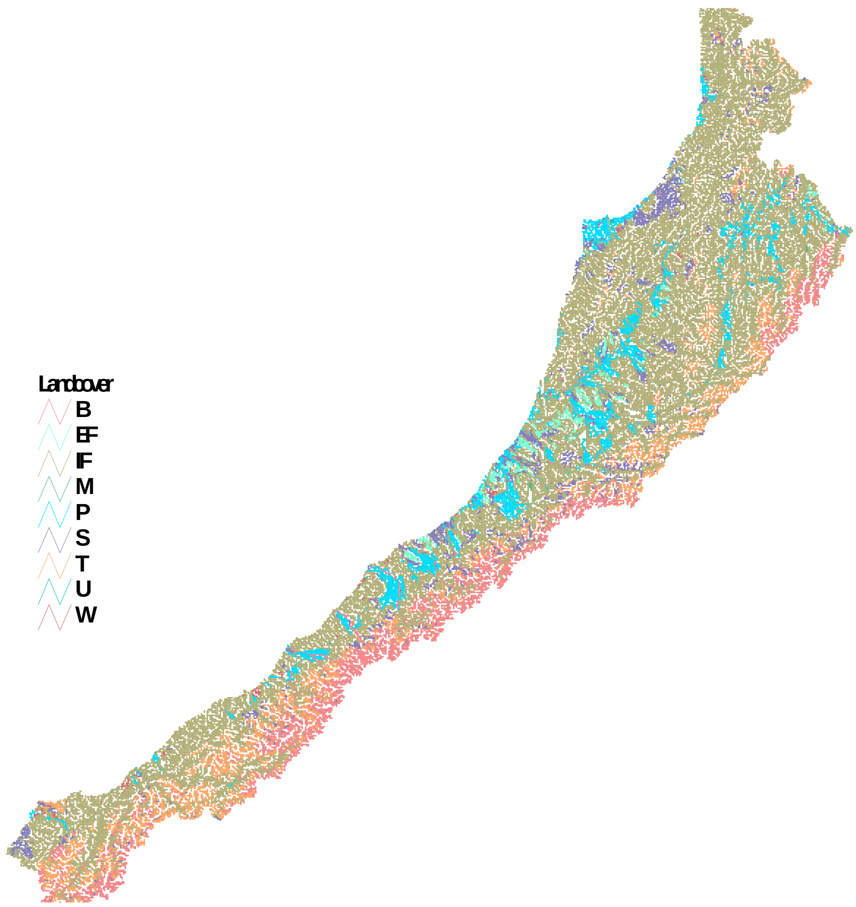


Figure 5.4.3 Map of the West Coast region showing geology class according to REC. From the key, only Al (alluvial), HS (hard sedimentary), M (metamorphic), Pl (plutonic), and SS (soft sedmentary), are present on the map.



Figures 5.4.4 Map of the West Coast region showing land cover type according to REC.

5.5 Percentage bar graphs: How they work

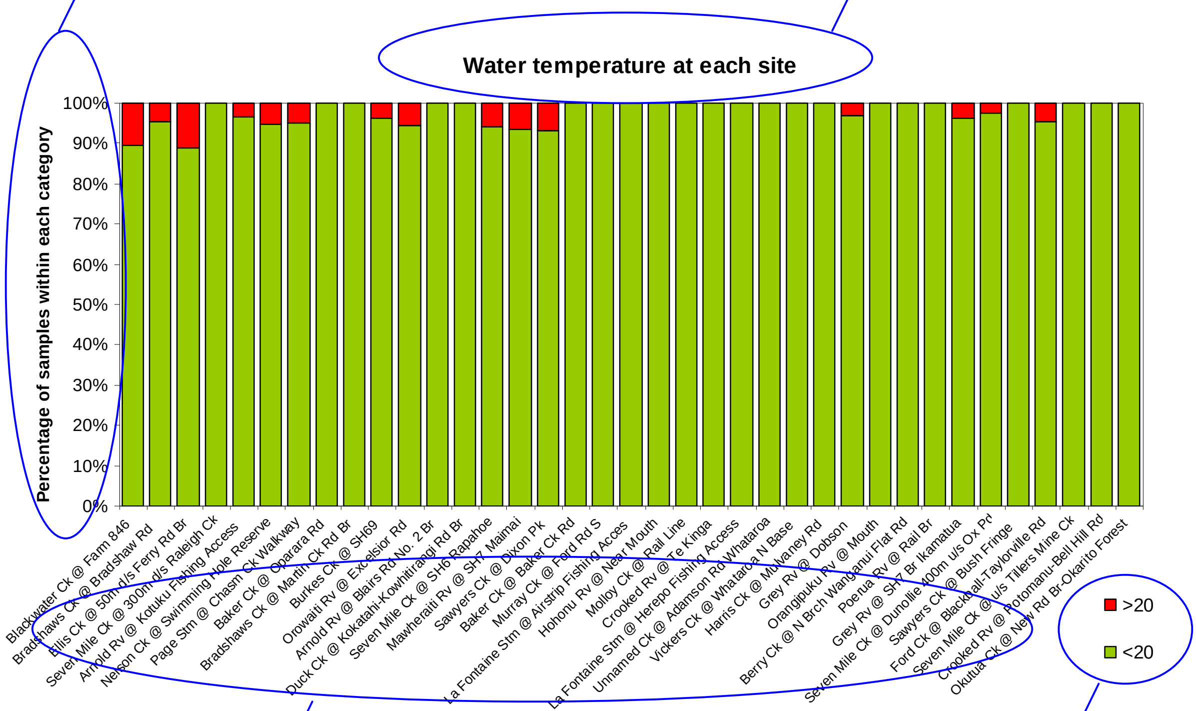
These are located in Section 2.4. Below is an example with some additional information to assist with their interpretation.

This indicates the percentage of samples that are within the categories indicated in the graph legend at the bottom right of each graph.

Note that the number of samples making up the 100% may differ between sites.

Lists the variable (in this case water temperature), and points out that a bar is presented for each site.

Note that all the available data for this site collected over time has been use for each site.

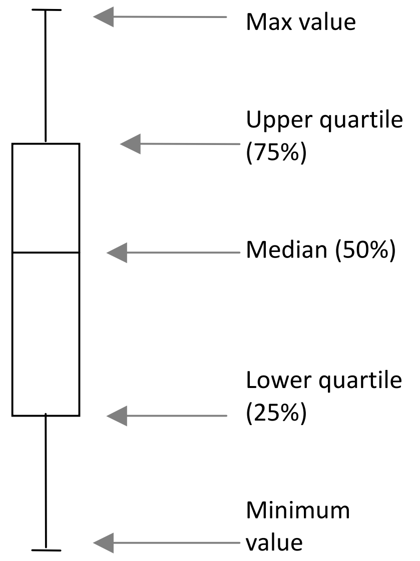


The bottom X axis lists what each bar represents. In this case it is each WCRC SWQMP site. All the data on record has been incorporated into each bar, and the amount of data might vary between sites. This is why a proportion has been used to standardise sites and make comparison easier. **Sites are ordered 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 neighbour 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



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% and the top and bottom). These values are represented by the ‘whiskers’, which terminate at the maximum and minimum value.

If only one data value has been collected then the value appears as a single line i.e. the median.

Sites listed in the following box and whisker graphs are listed in alphabetical order so easier comparison can be made between multiple sites on the same water body.

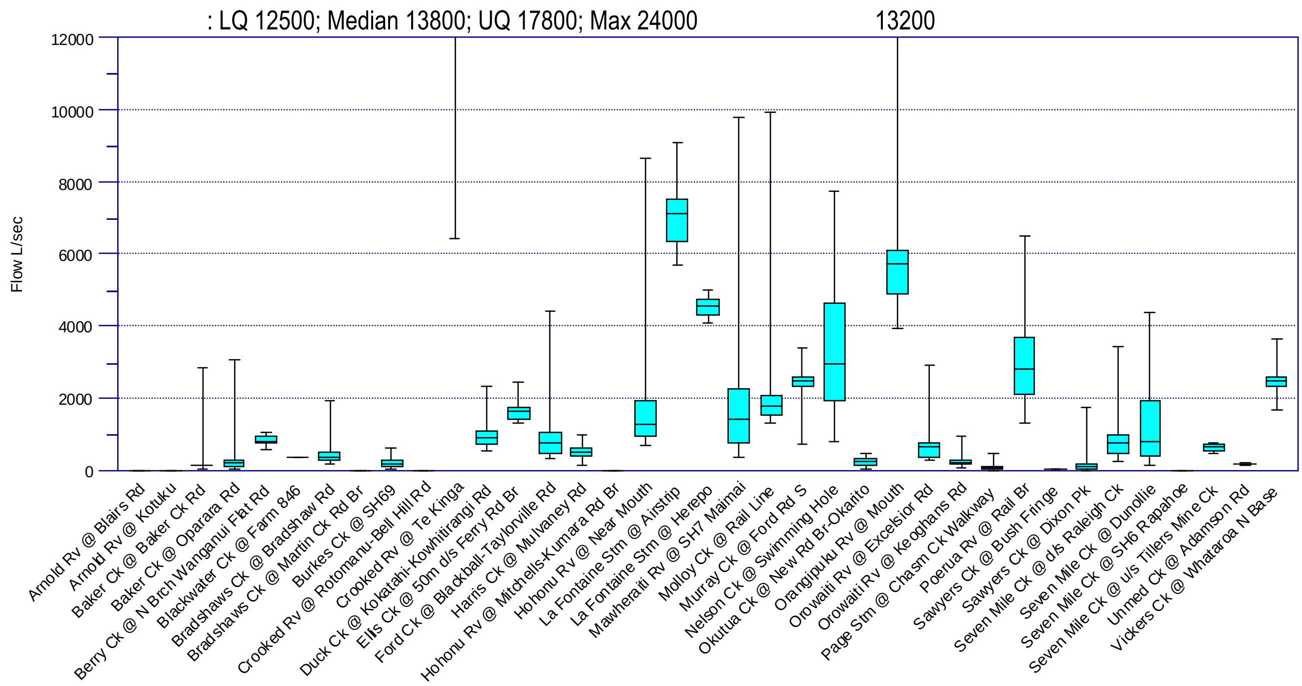


Figure 5.6.1 Box and whisker plot: Flow.

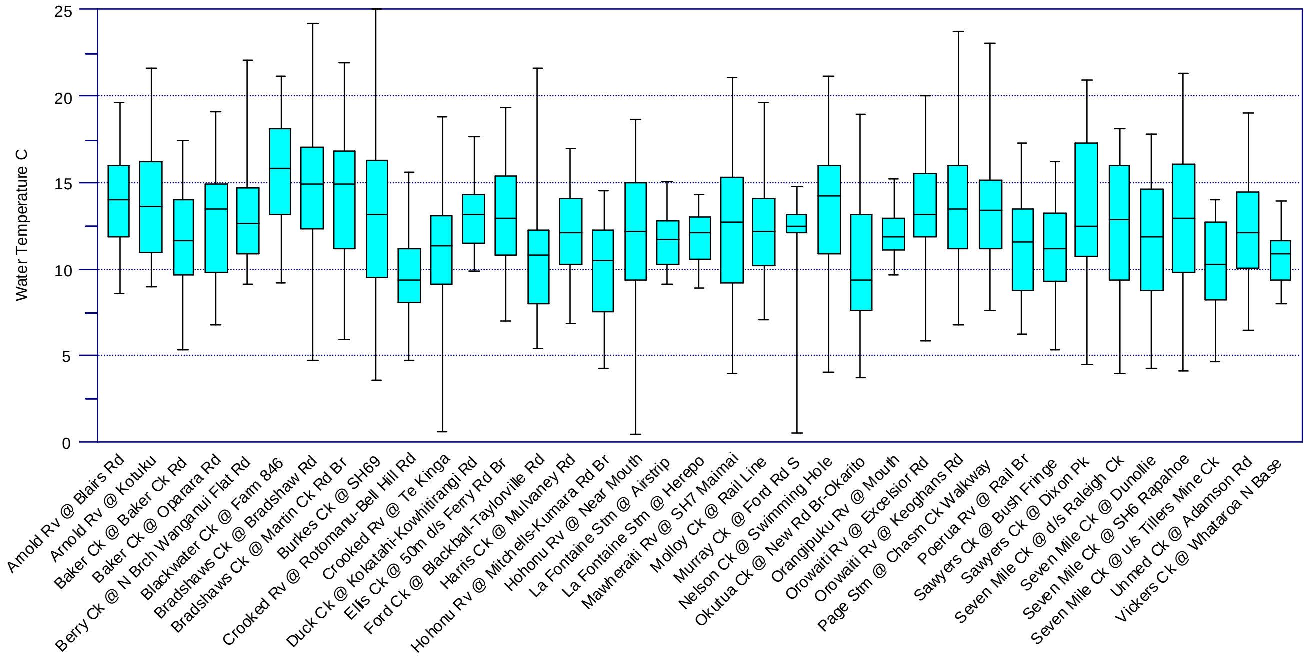


Figure 5.6.2 Box and whisker plot: Temperature.

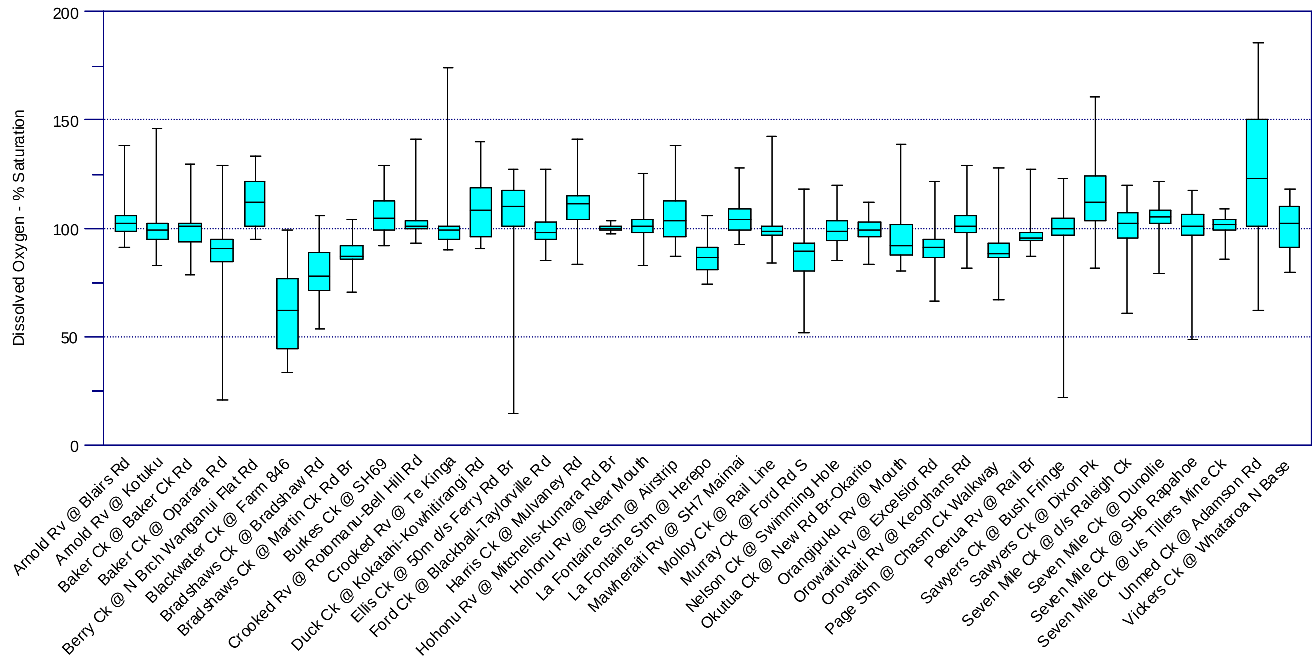


Figure 5.6.3 Box and whisker plot: Dissolved oxygen (% saturation).

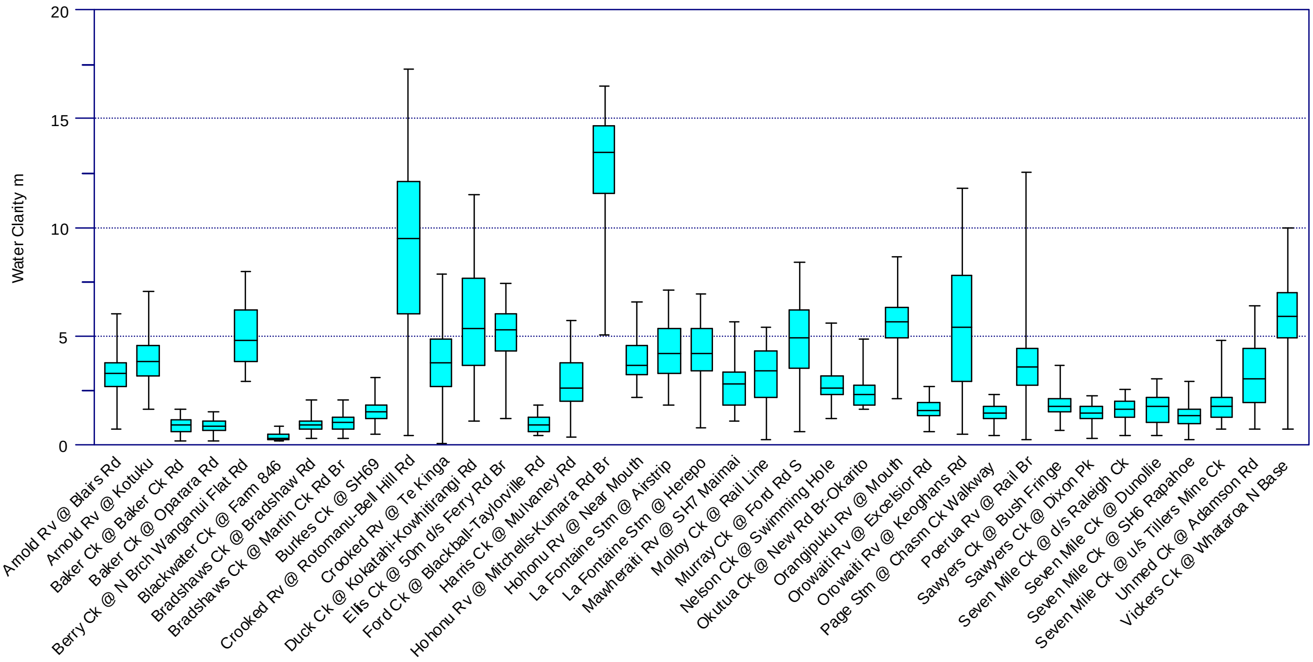


Figure 5.6.4 Box and whisker plot: Clarity.

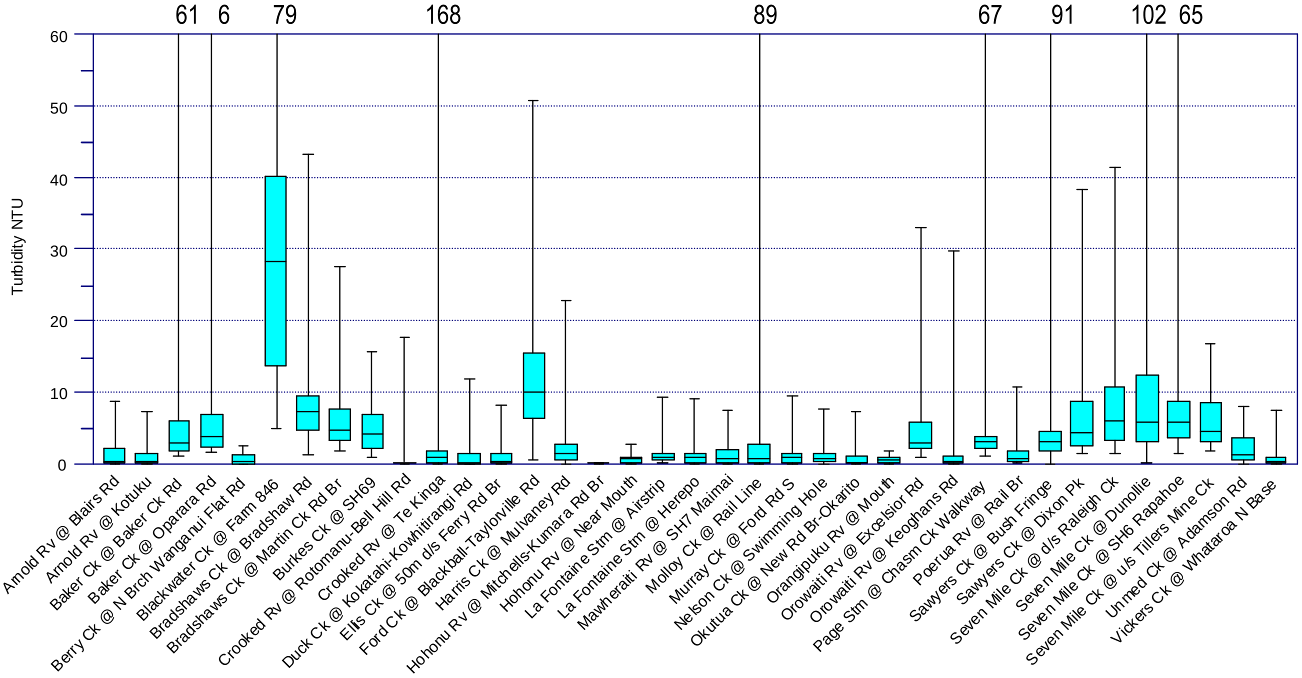


Figure 5.6.5 Box and whisker plot: Turbidity.

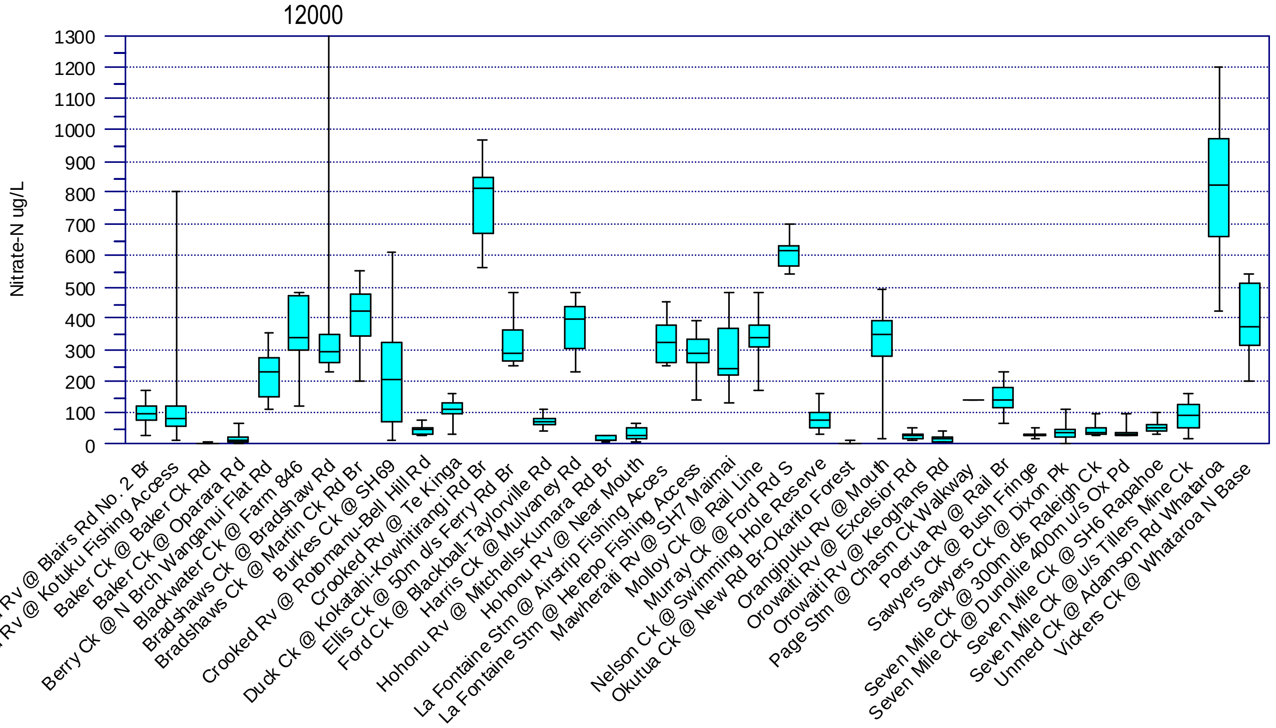


Figure 5.6.6 Box and whisker plot: Nitrate (NOx-N)

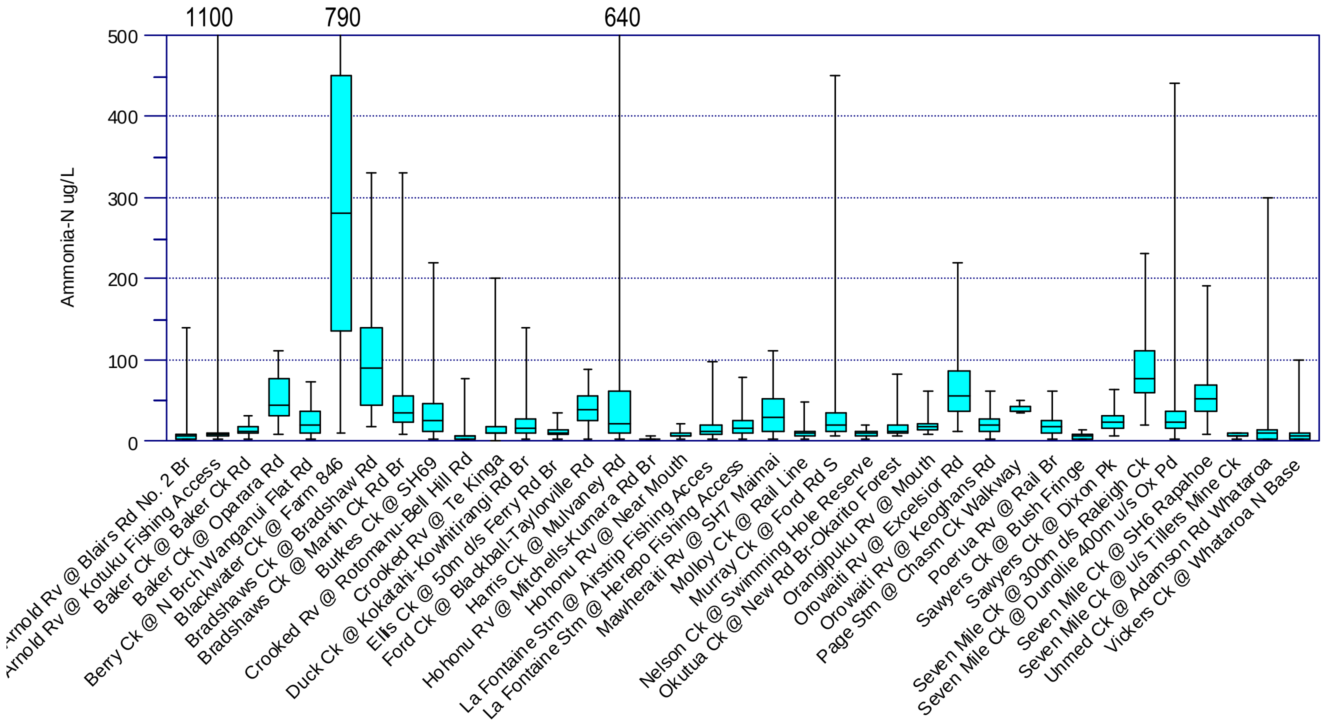


Figure 5.6.7 Box and whisker plot: Ammoniacal nitrogen (NH4-N)

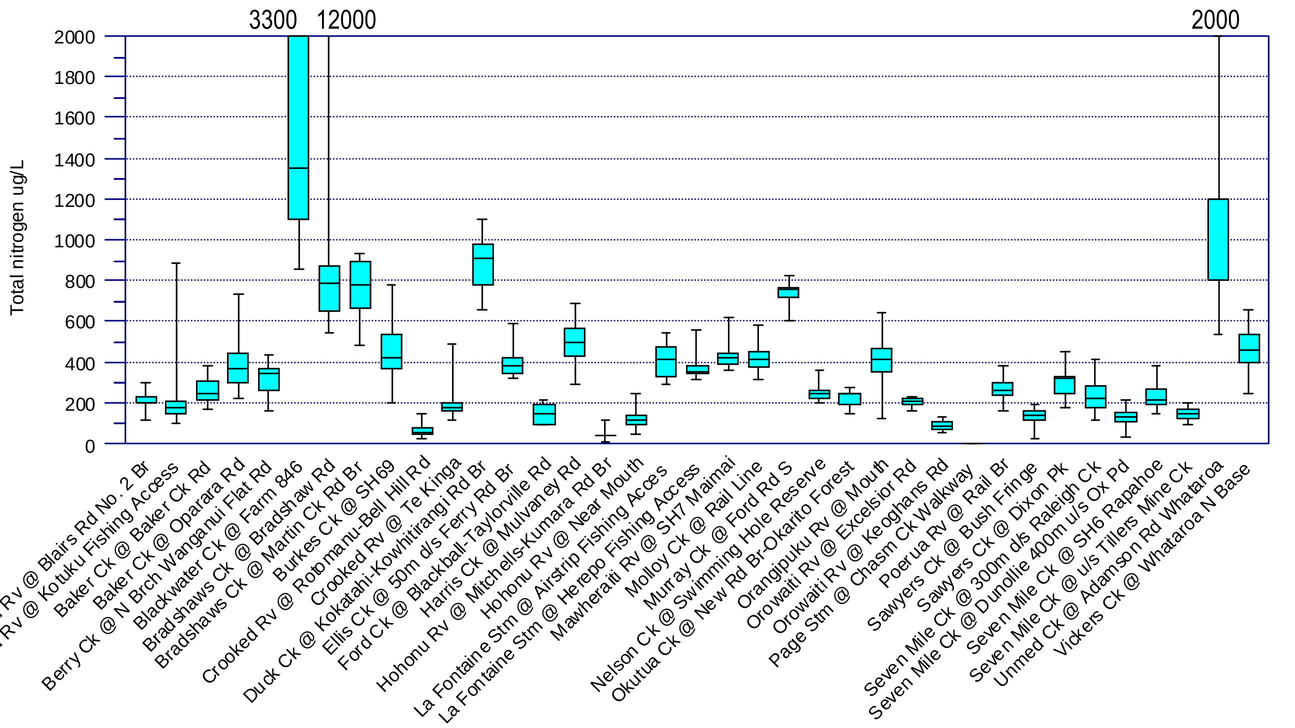


Figure 5.6.8 Box and whisker plot: Total nitrogen (TN).

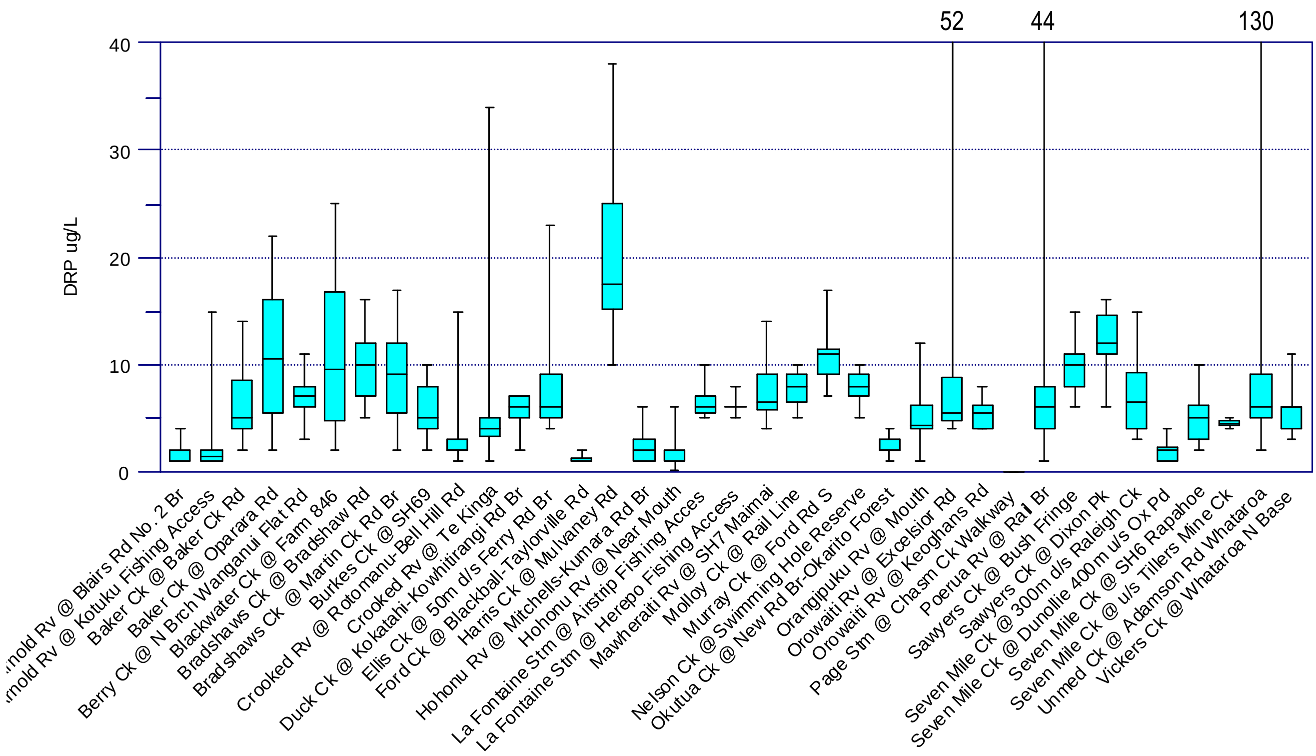


Figure 5.6.9 Box and whisker plot: Dissolved reactive phosphorous (DRP).

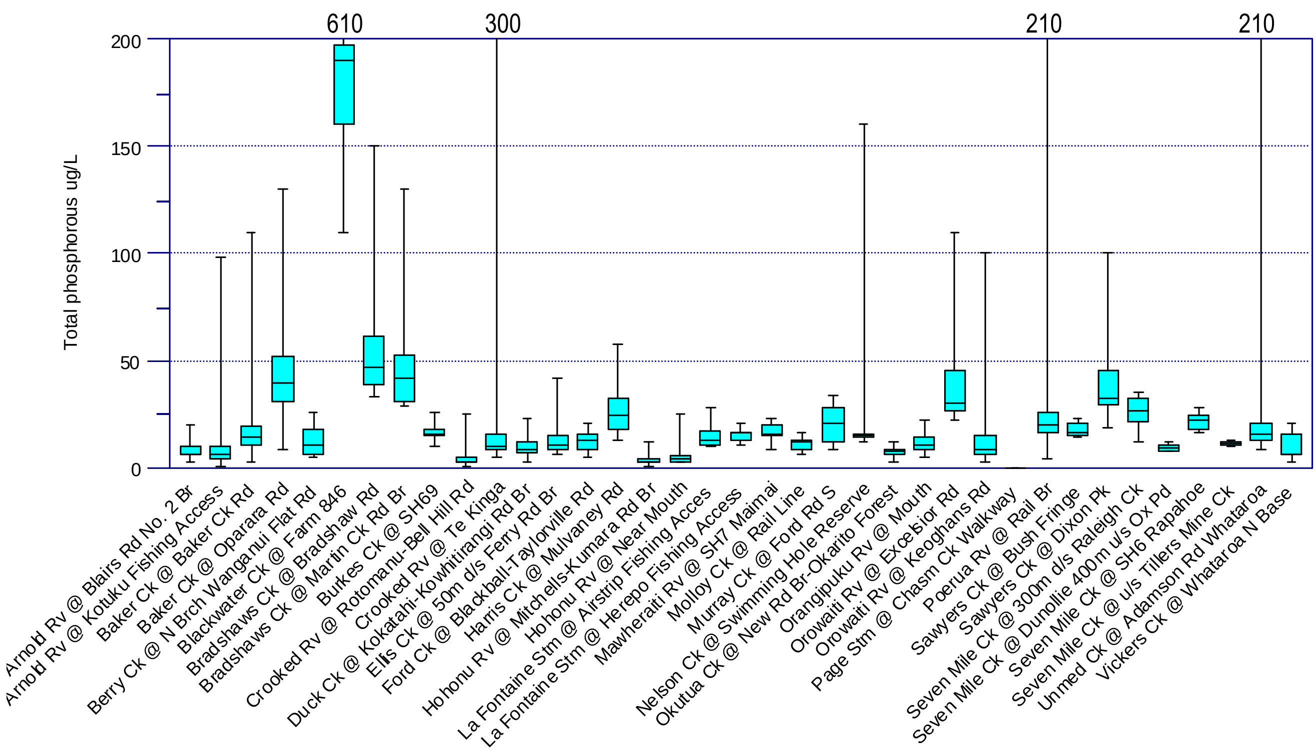


Figure 5.6.10 Box and whisker plot: Total phosphorous (TP).

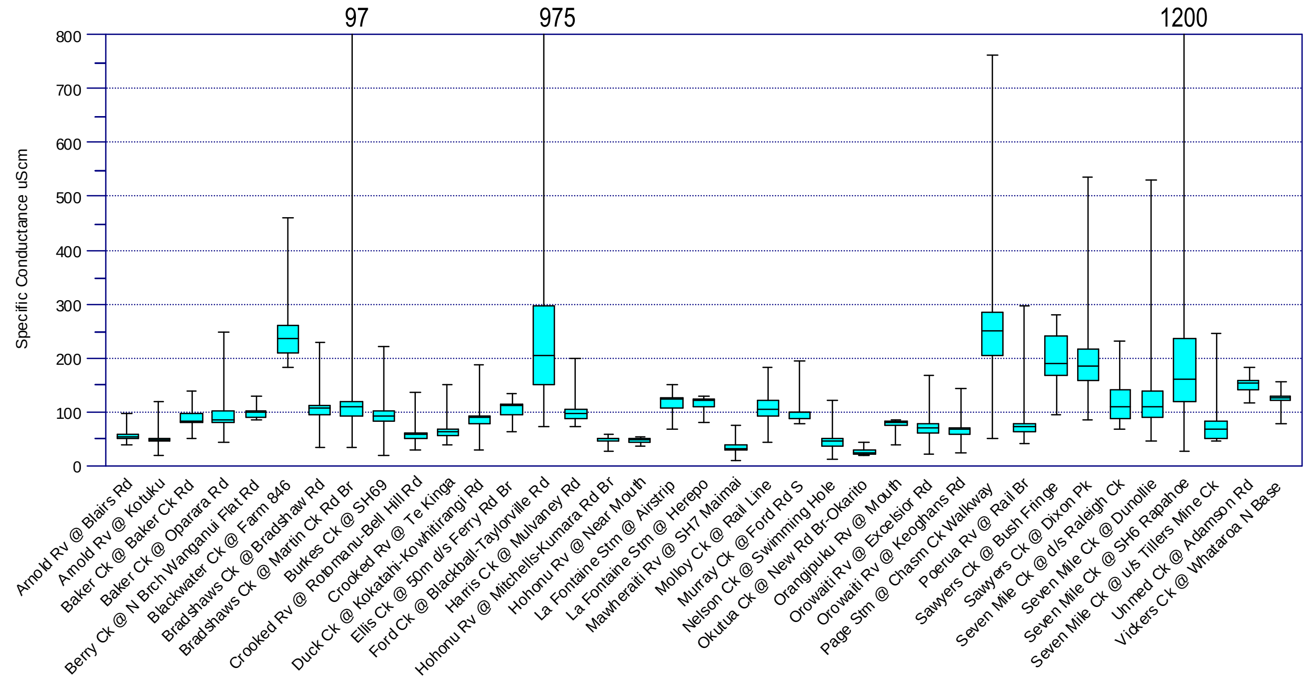


Figure 5.6.11 Box and whisker plot: Conductivity.

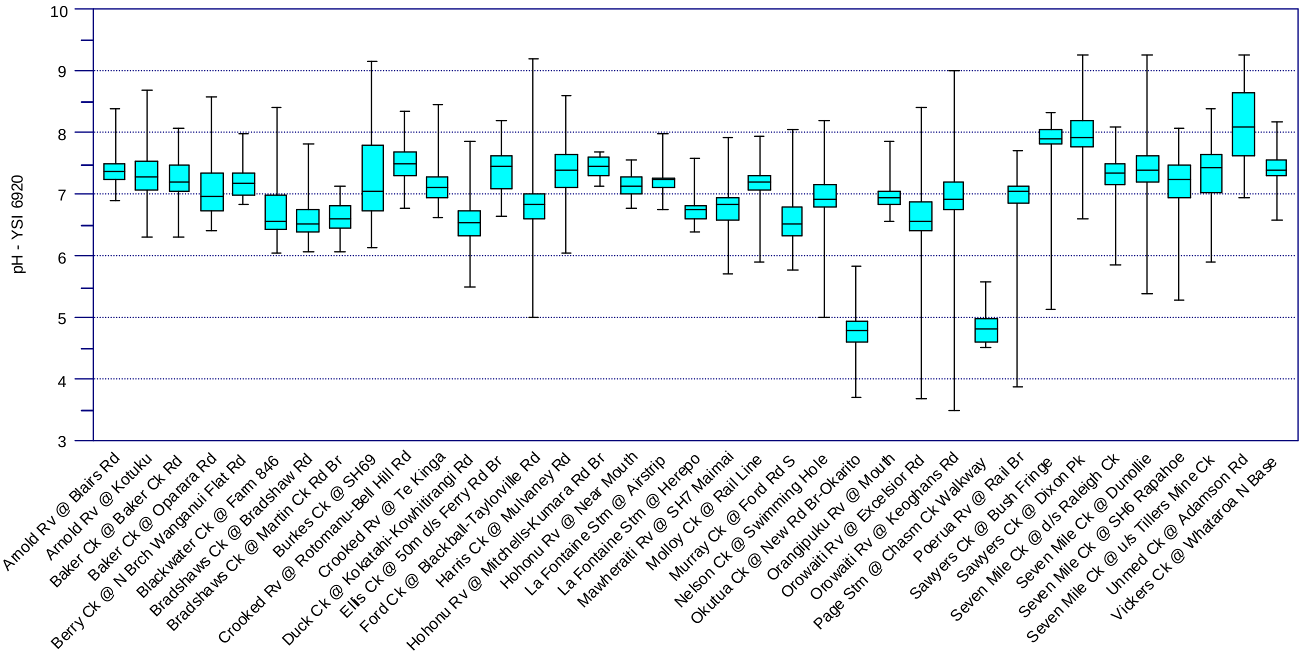


Figure 5.6.12 Box and whisker plot: pH.

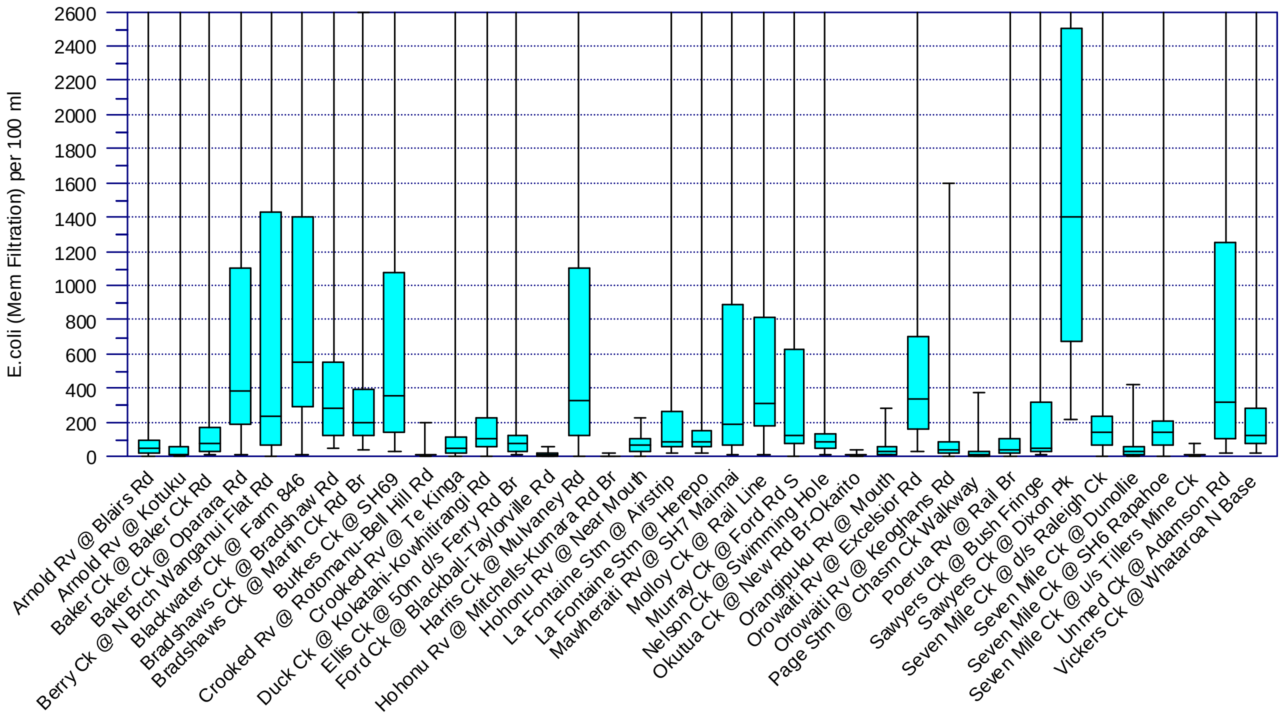


Figure 5.6.13 Box and whisker plot: E. coli - with maximum values shown - without maximum values shown.

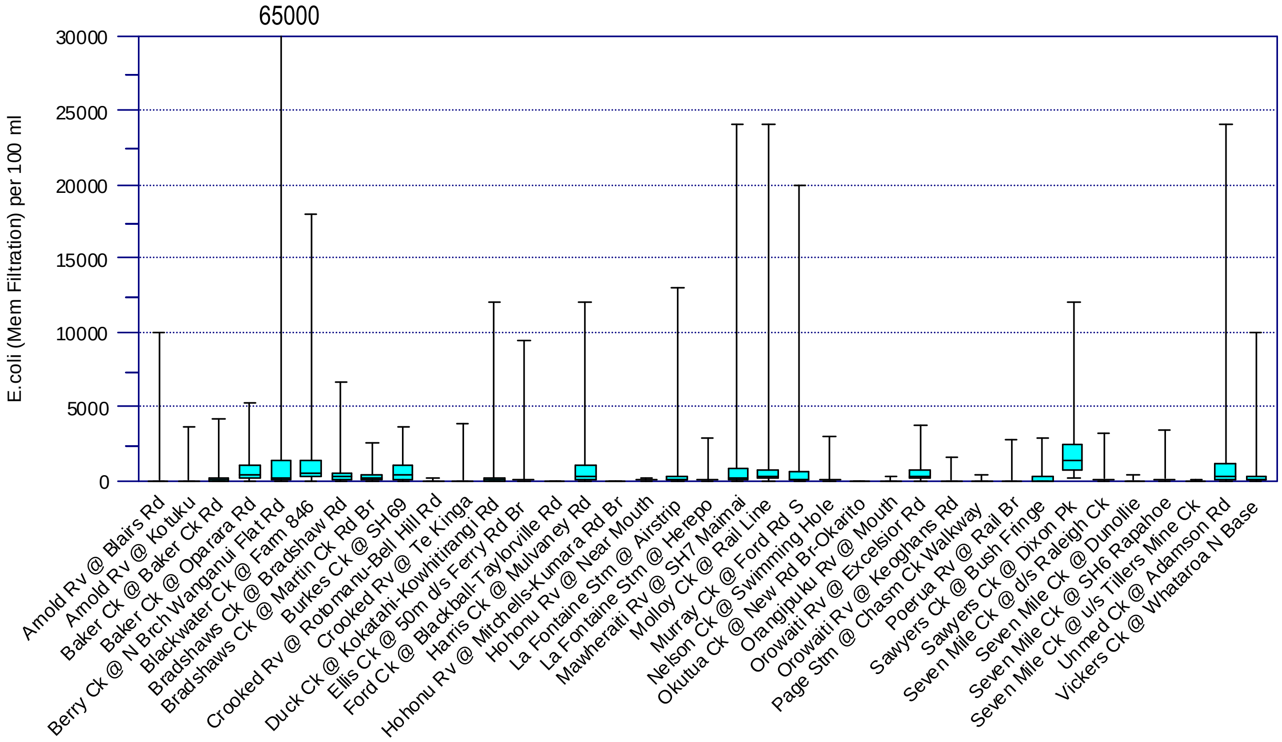


Figure 5.6.14 Box and whisker plot: E. coli – with maximum values shown.

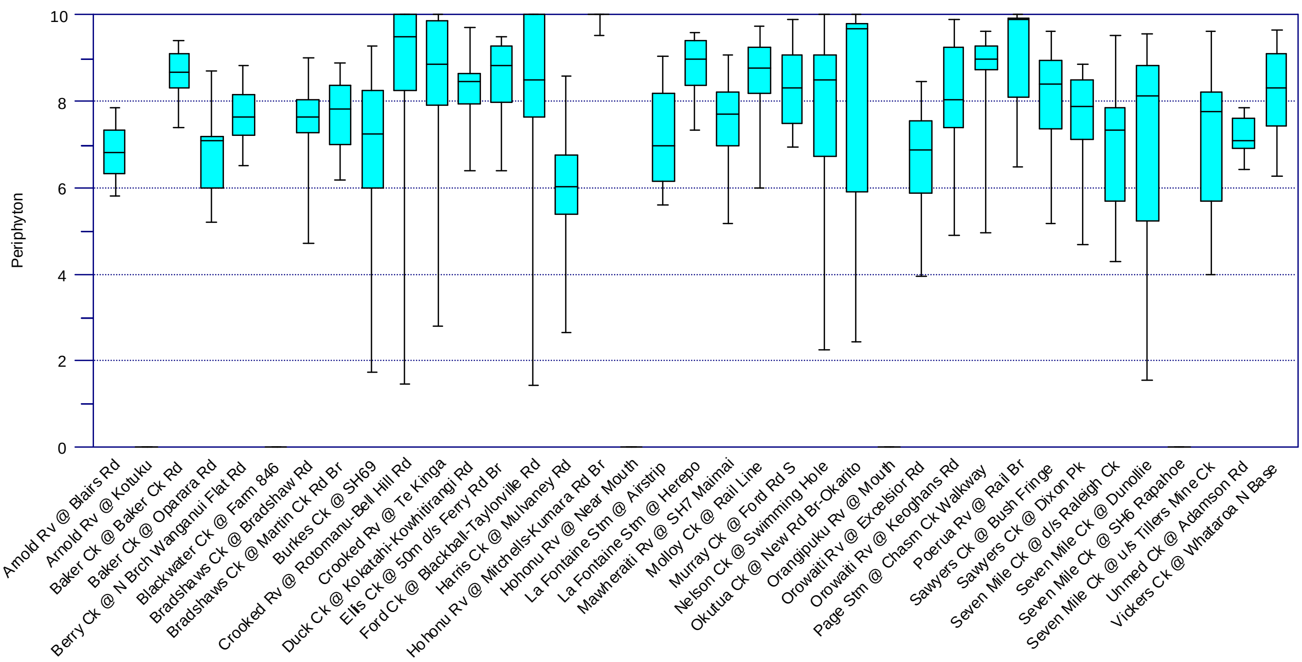


Figure 5.6.15 Box and whisker plot: Periphyton.

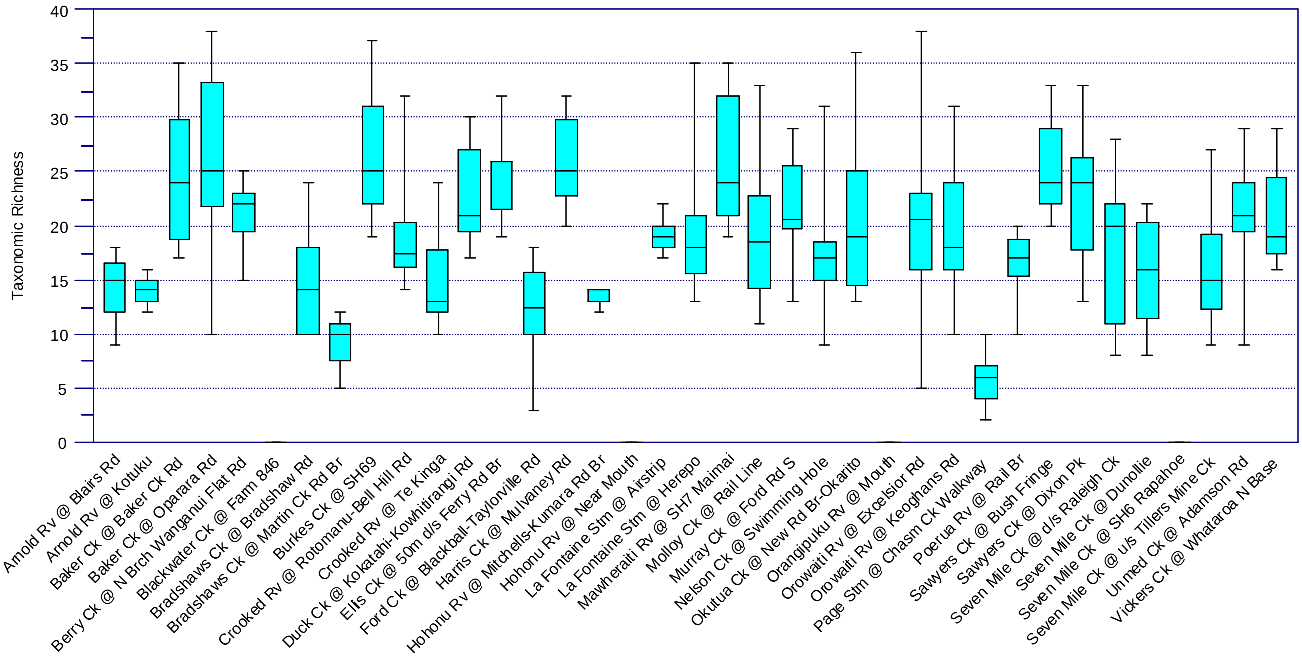


Figure 5.6.16 Box and whisker plot: Invertebrate taxonomic richness.

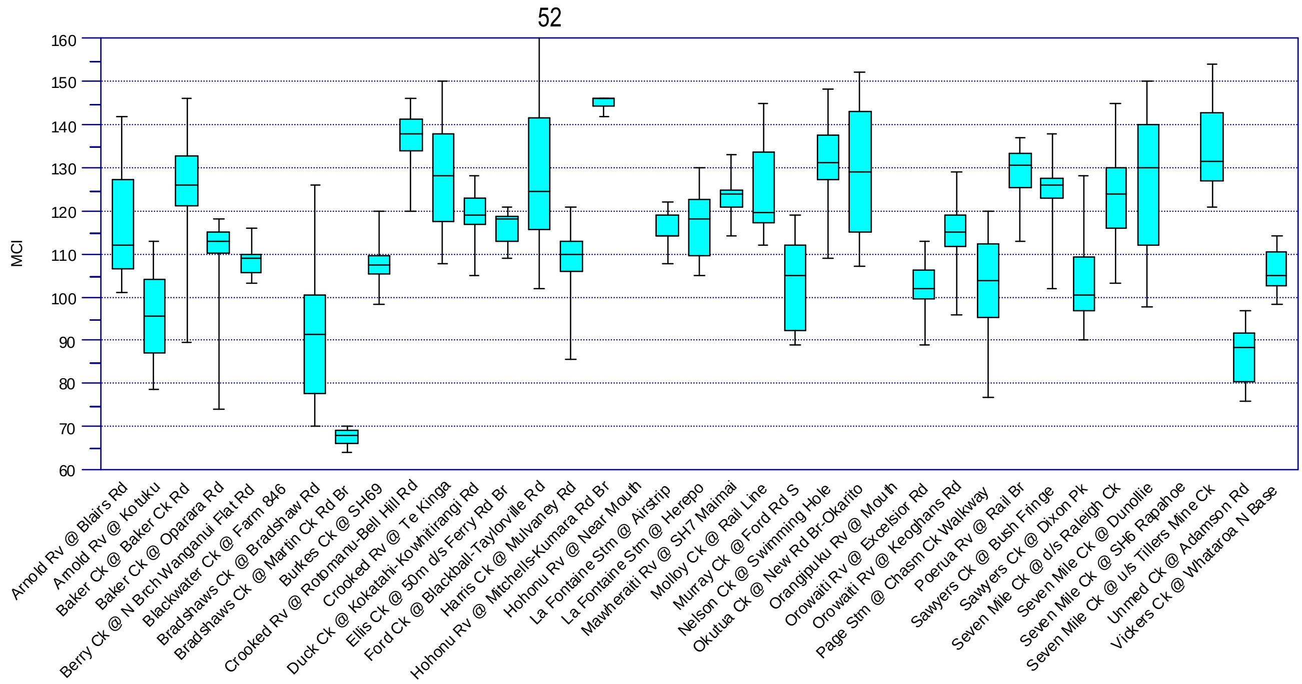


Figure 5.6.17 Box and whisker plot: Macroinvertebrate Community Index (MCI).

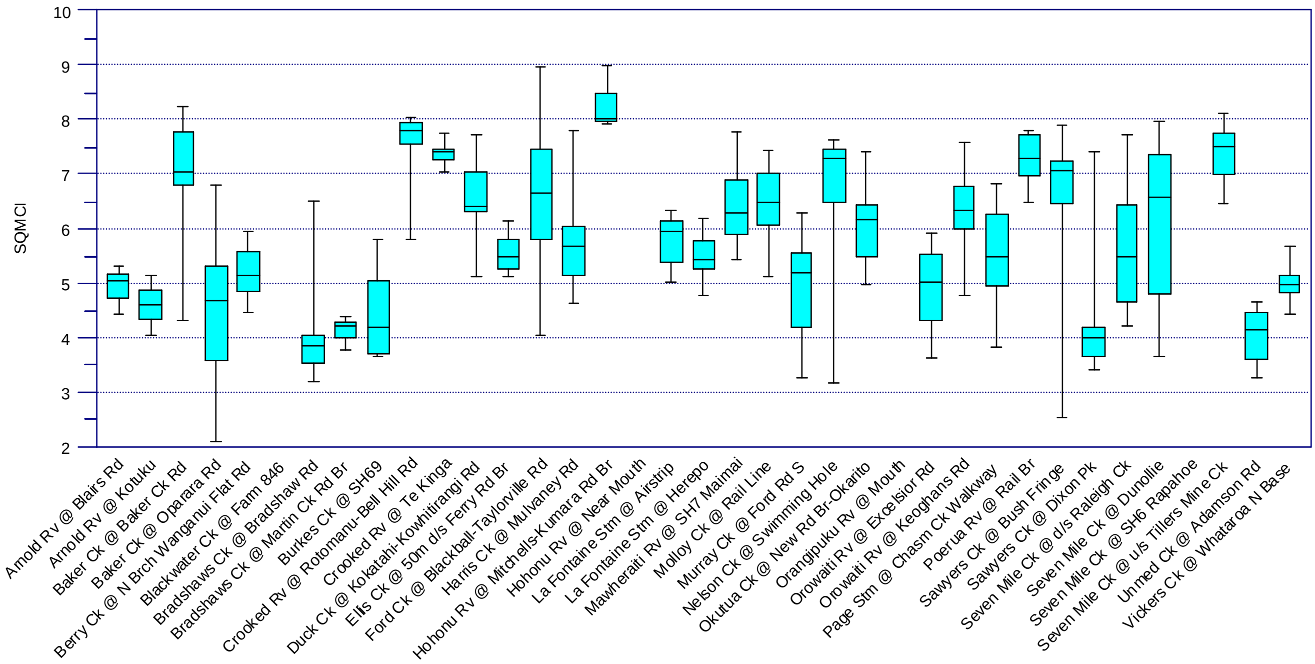


Figure 5.6.18 Box and whisker plot: Semi-Quantitative Macroinvertebrate Community Index (SQMCI).

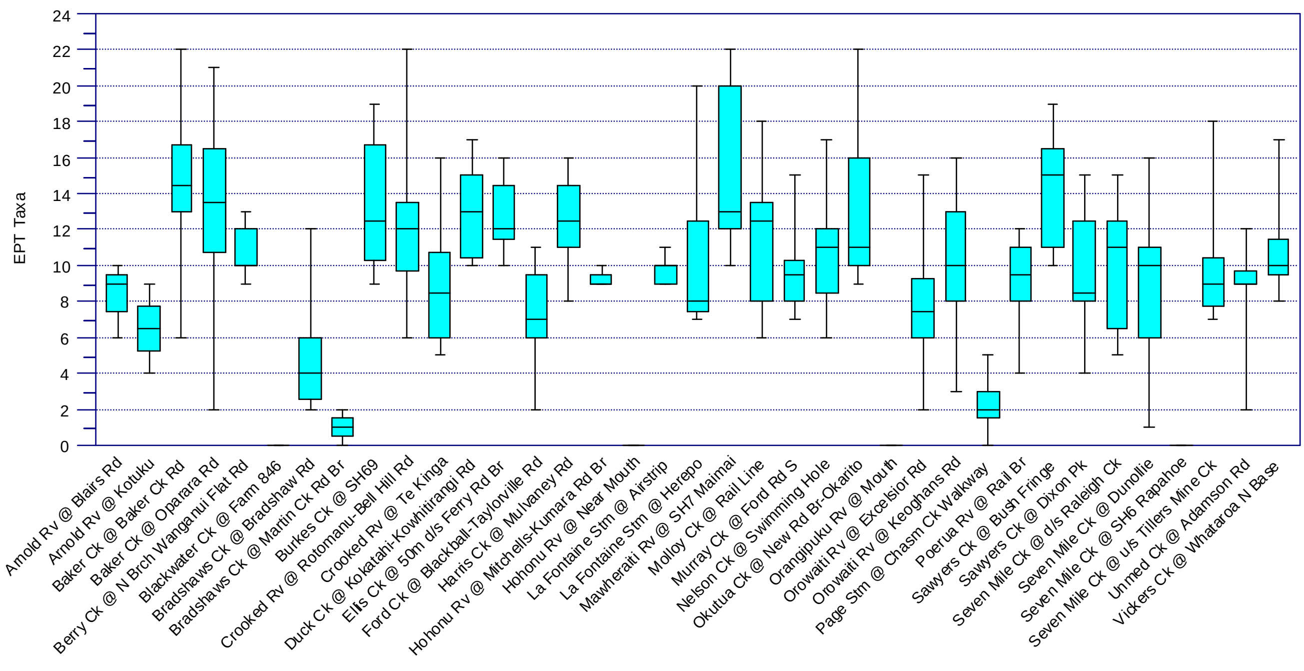


Figure 5.6.19 Box and whisker plot: EPT taxa.

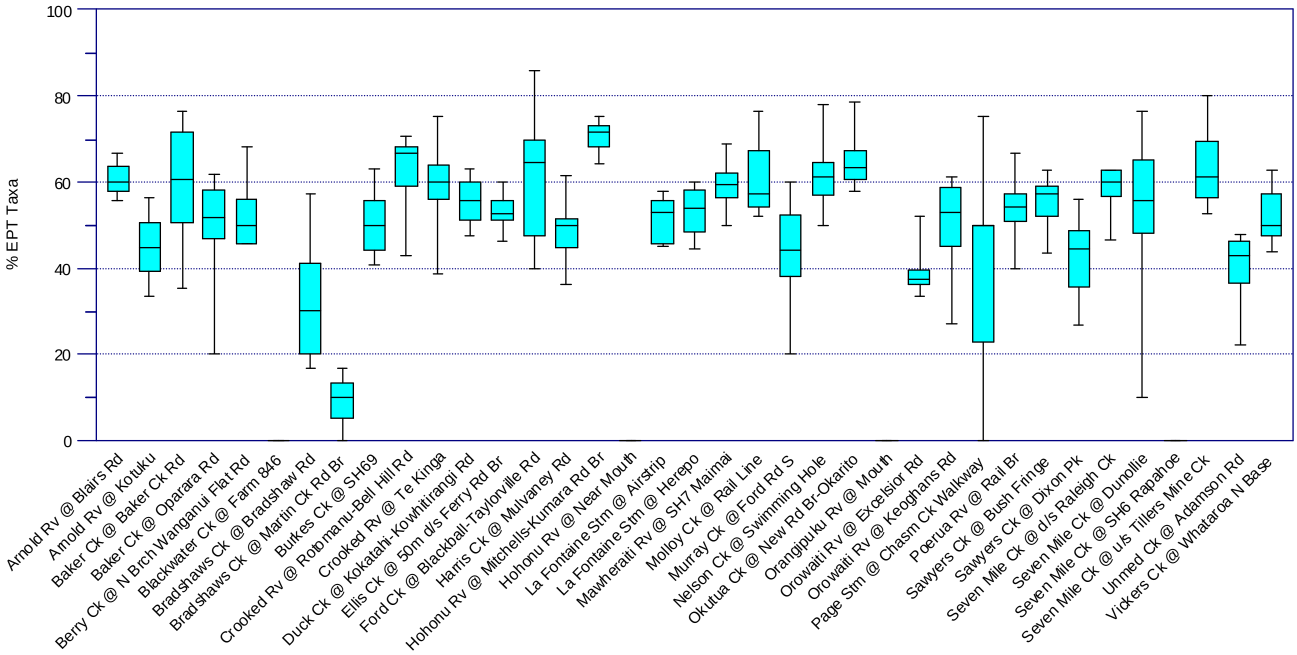


Figure 5.6.20 Box and whisker plot: % EPT.

5.7 Differences in water quality between paired upstream and downstream sites

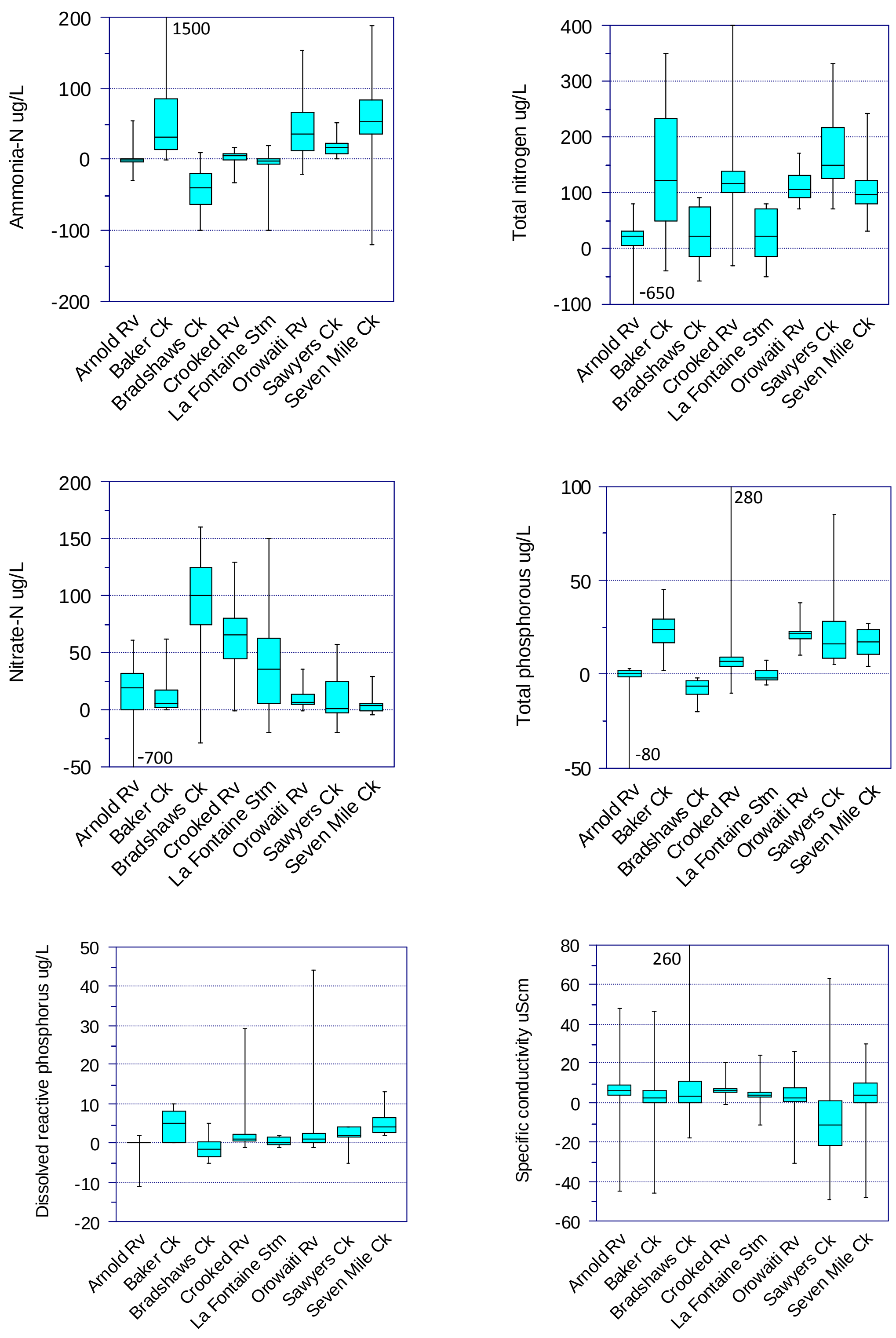


Figure 5.7.1a Differences between paired sites (upstream minus downstream values). Ammonia, total nitrogen, nitrate, total phosphorus, dissolved reactive phosphorus, specific conductivity (EC25).

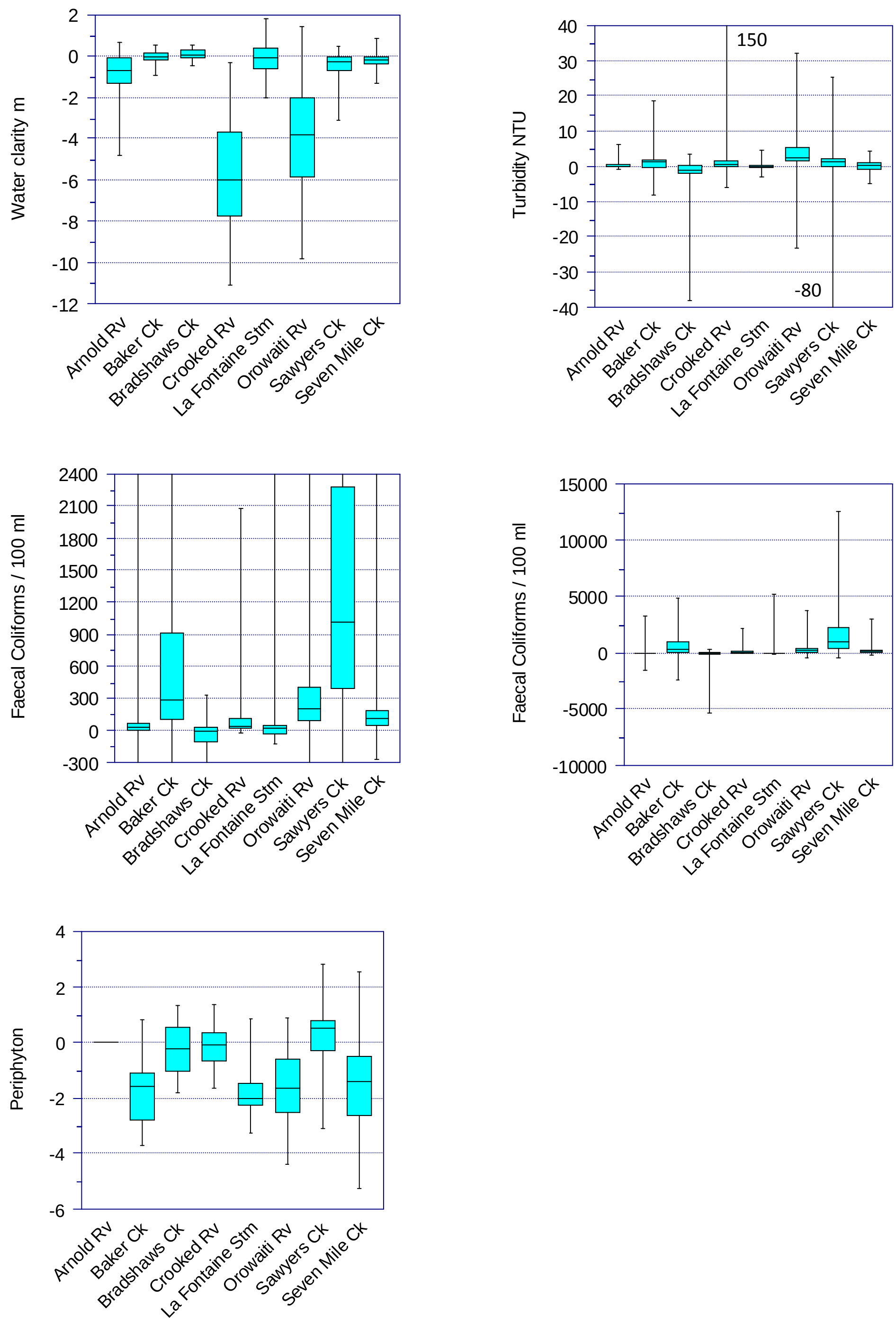


Figure 5.7.1b *Differences between paired sites (upstream minus downstream values). Clarity, turbidity, faecal coliforms, and periphyton.*

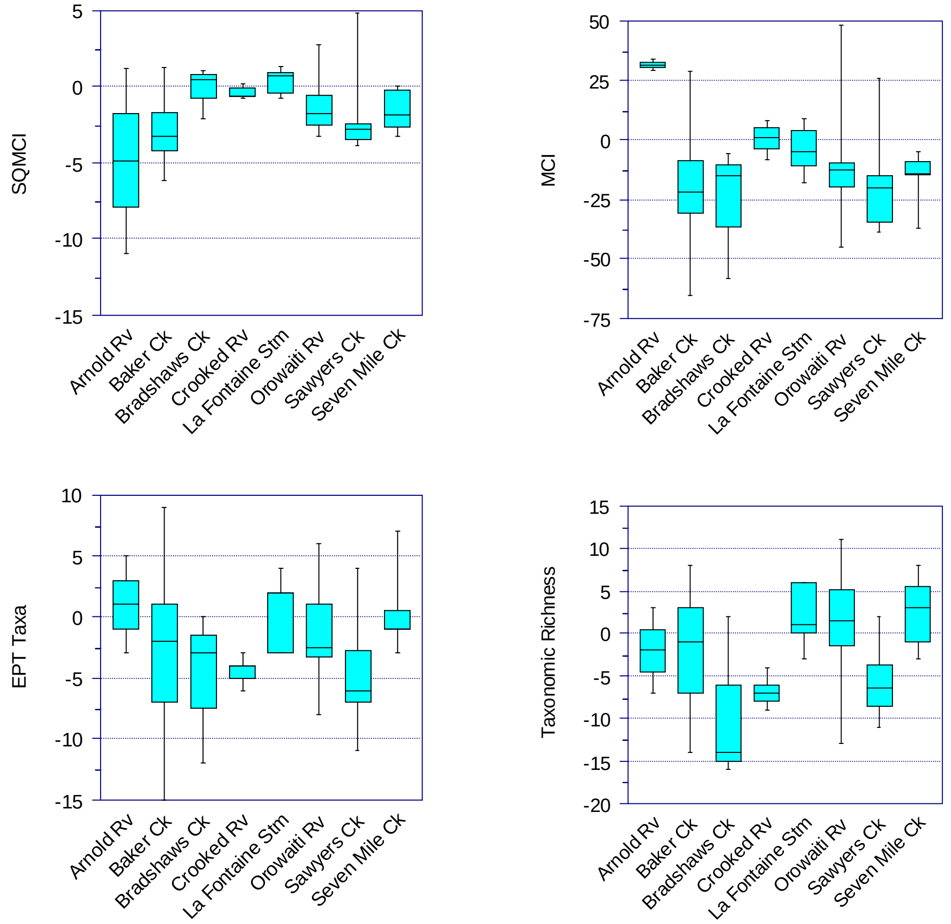


Figure 5.7.1c Differences between paired sites (upstream minus downstream values). MCI, SQMCI, EPT taxa and taxonomic richness.

5.8 Individual contact recreation sites

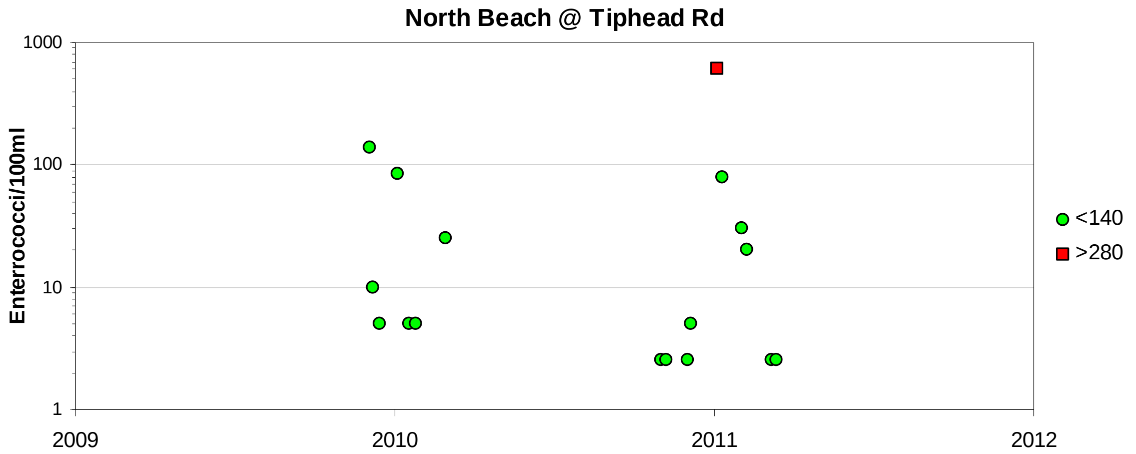


Figure 5.8.1 Single sample Enterrococci levels for Blaketown Beach @ Tiphead.

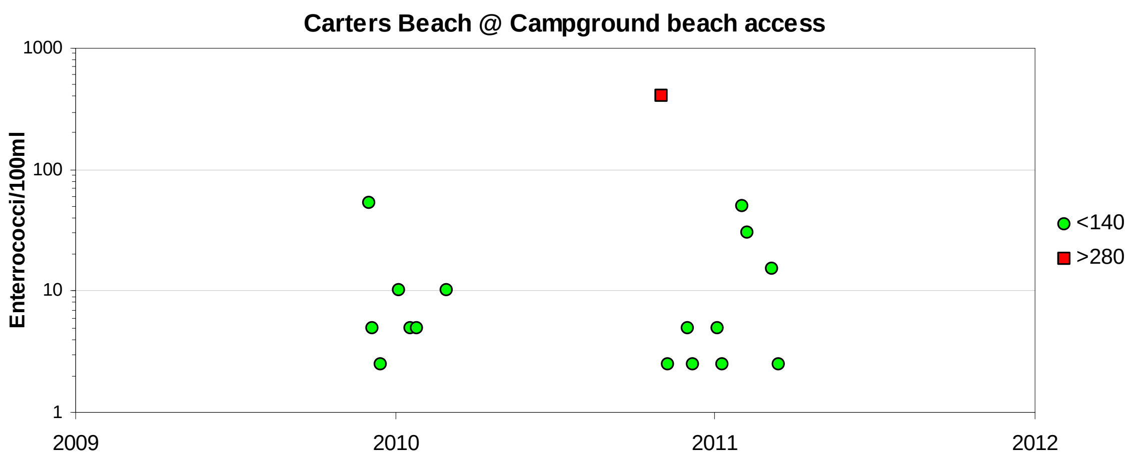


Figure 5.8.2 Single sample Enterrococci levels for Blaketown Beach @ Tiphead.

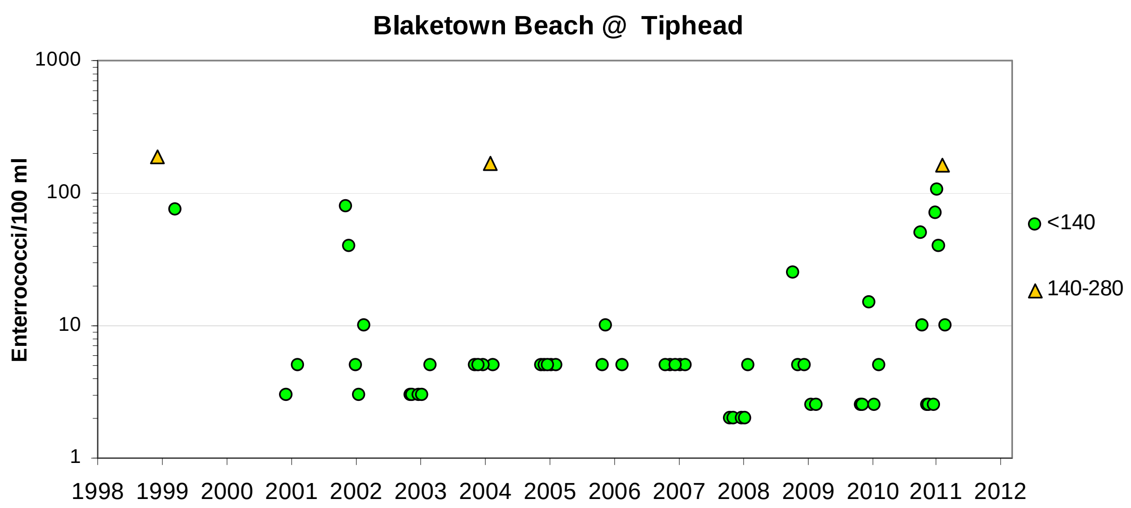


Figure 5.8.3 Single sample Enterrococci levels for Blaketown Beach @ Tiphead.

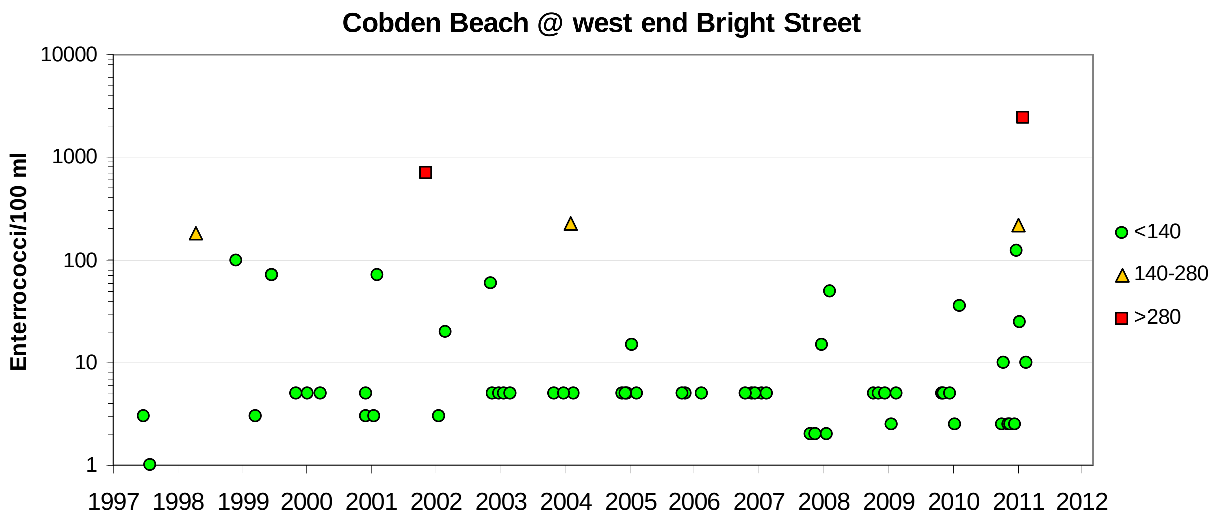


Figure 5.8.4 Single sample Enterrococci levels for Cobden Beach @ west end Bright Street.

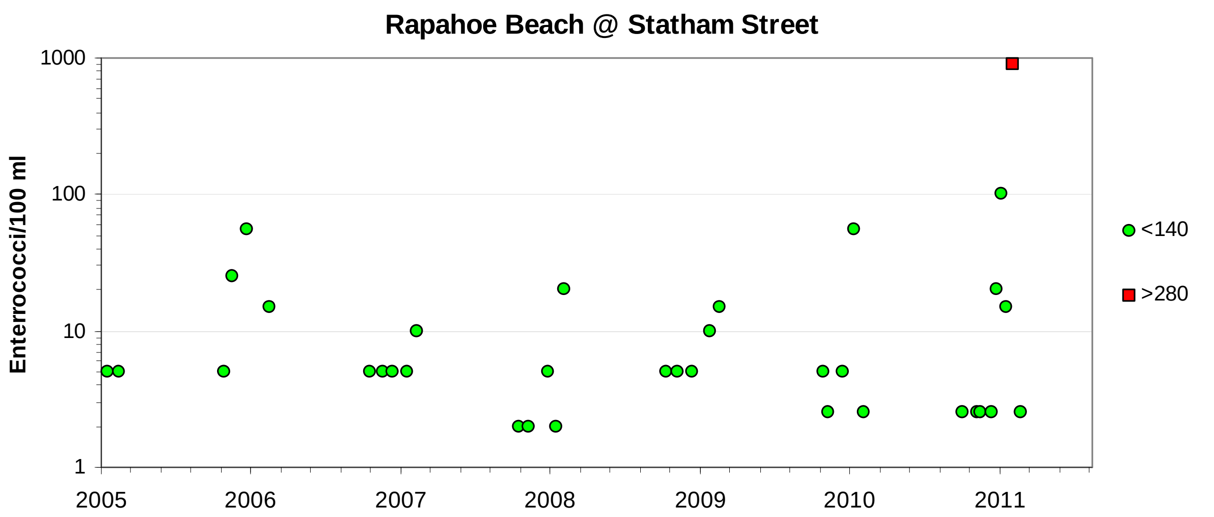


Figure 5.8.5 Single sample Enterrococci levels for Rapahoe Beach @ Statham Street.

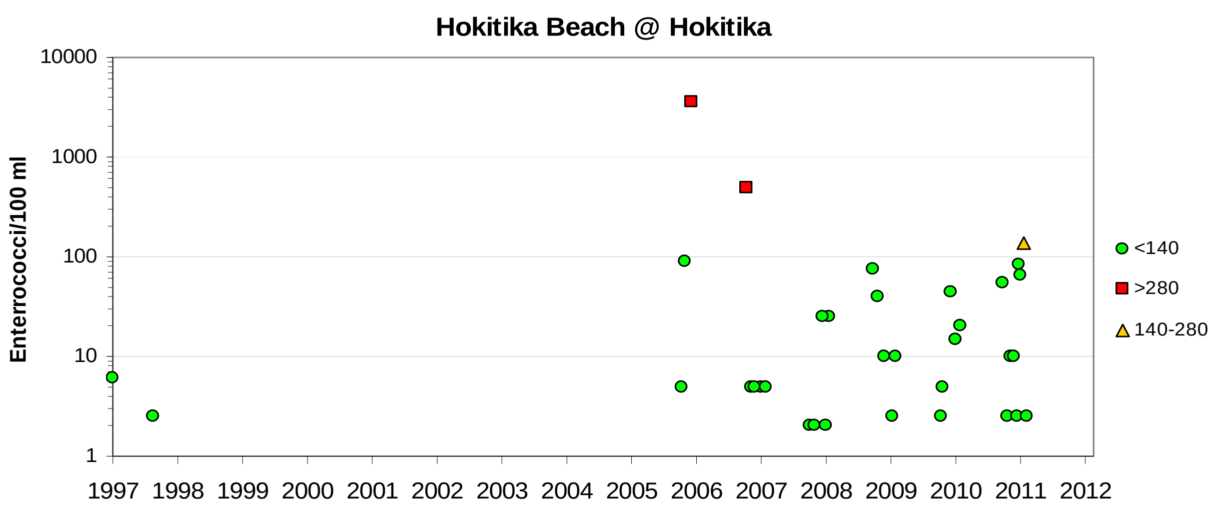


Figure 5.8.6 Single sample Enterrococci levels for Hokitika Beach @ Hokitika.

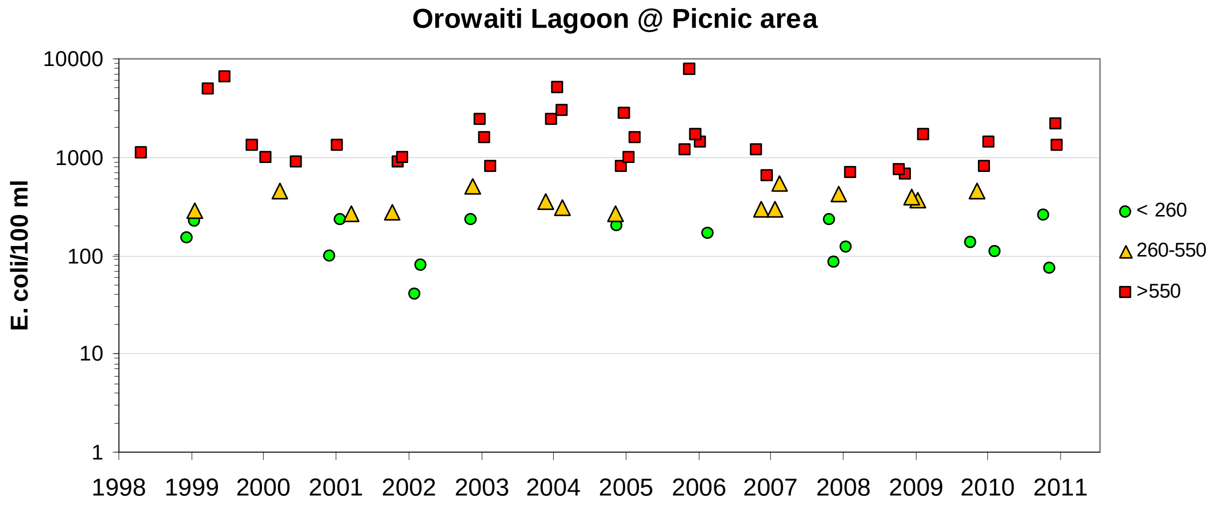


Figure 5.8.7 Single sample E. coli levels for Orowaiti Lagoon @ Picnic area.

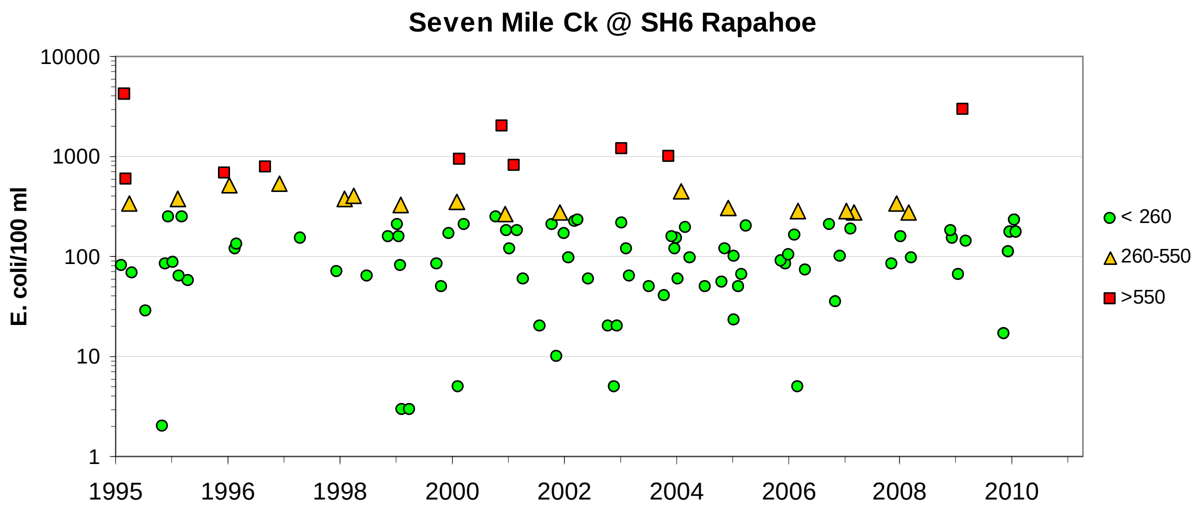


Figure 5.8.8 Single sample E. coli levels for Seven Mile Creek @ SH6 Rapahoe.

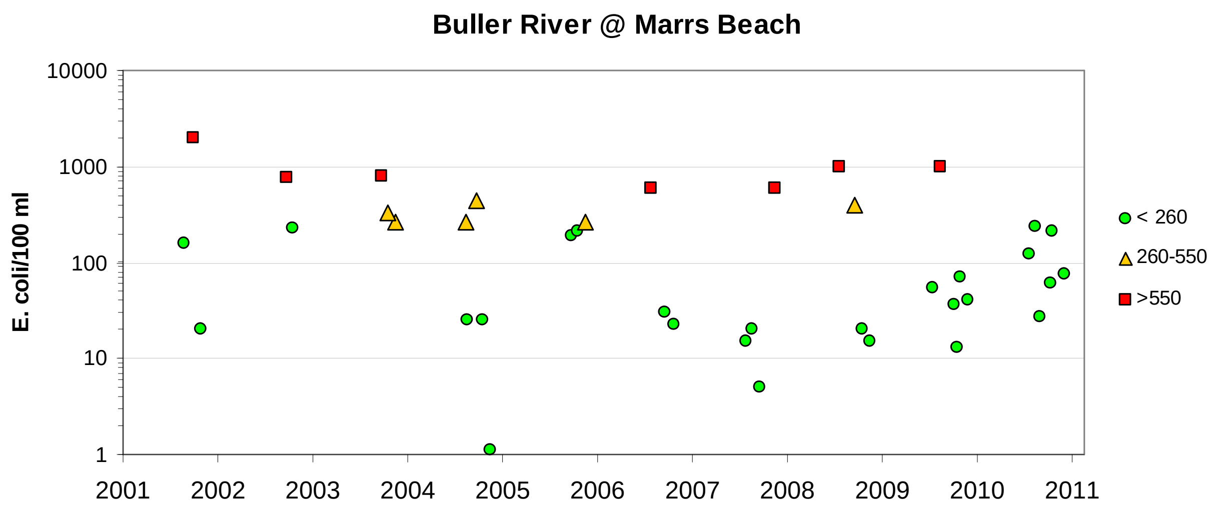


Figure 5.8.9 Single sample E. coli levels for Buller River @ Marrs Beach.

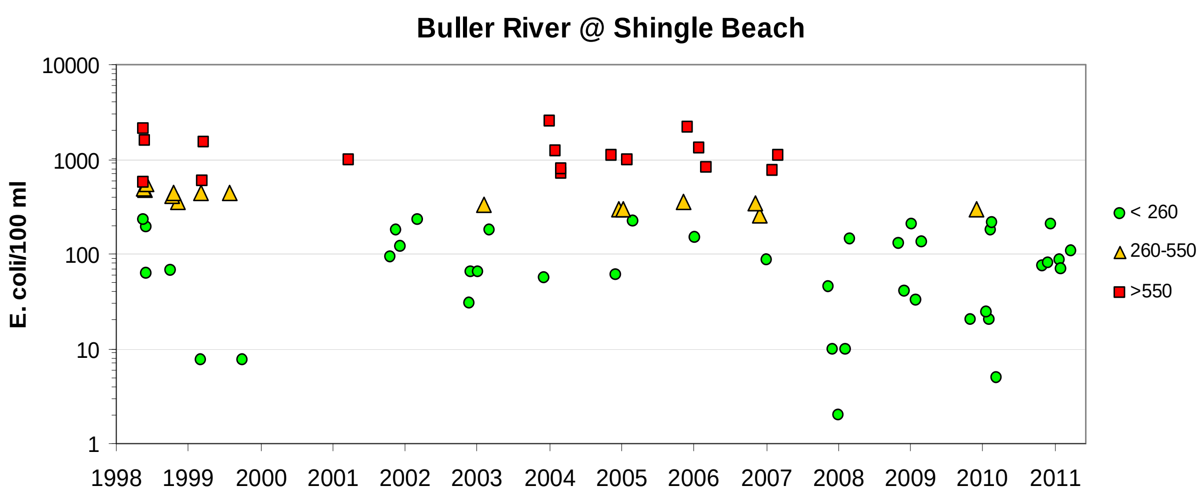


Figure 5.8.10 Single sample E. coli levels for Buller River @ Shingle Beach.

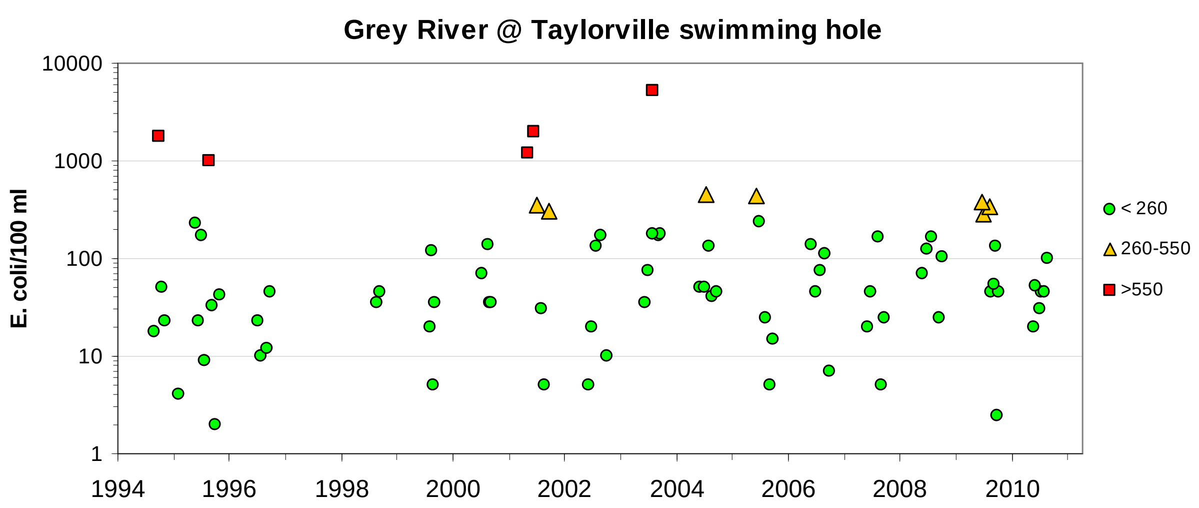


Figure 5.8.11 Single sample E. coli levels for Grey River @ Taylorville swimming hole.

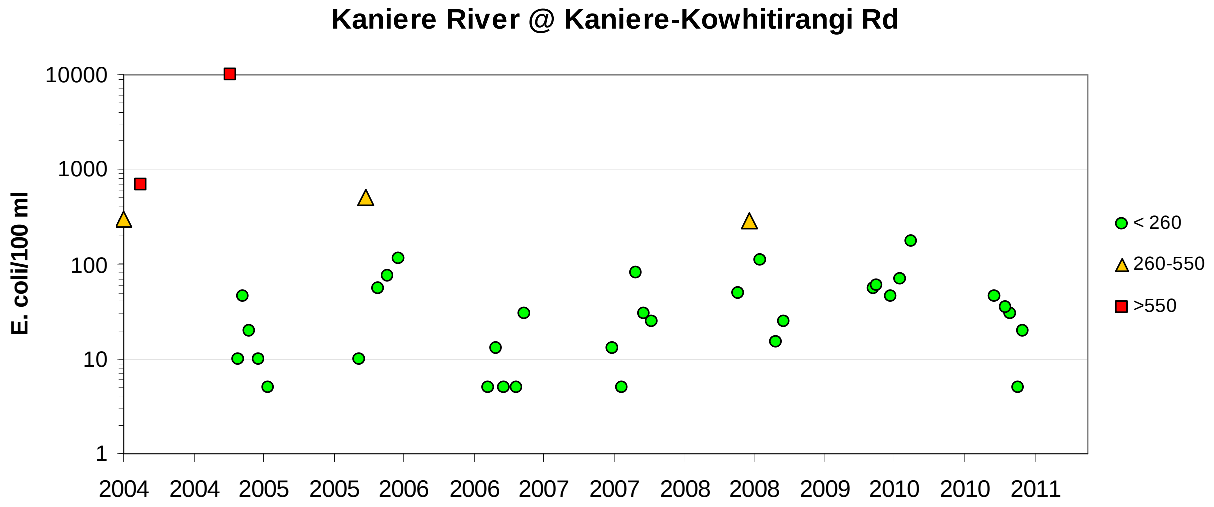


Figure 5.8.12 Single sample E. coli levels for Kaniere River @ Kaniere – Kowhitirangi Road.

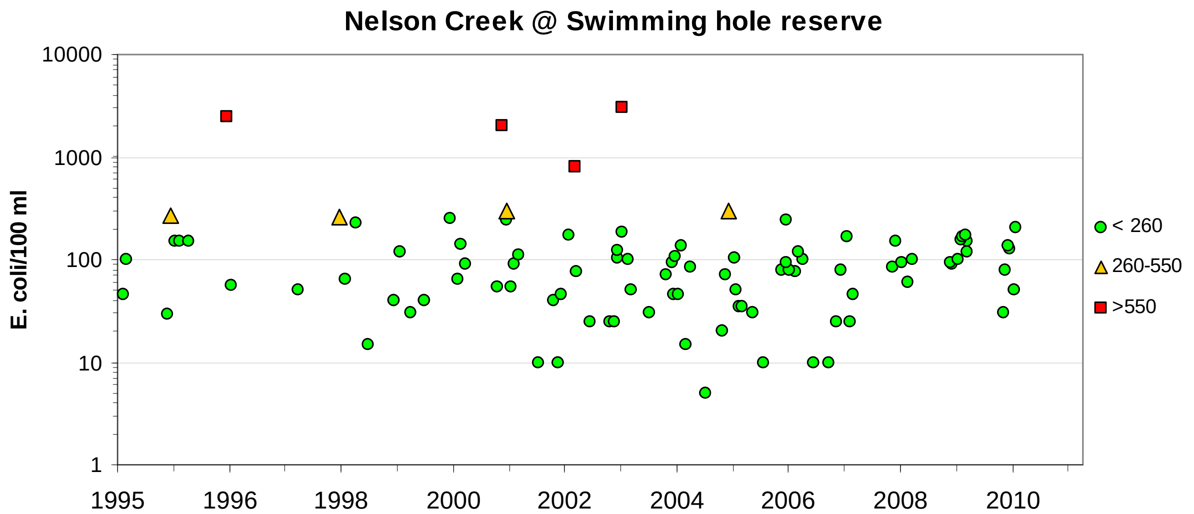


Figure 5.8.13 Single sample E. coli levels for Nelson Creek @ Swimming hole reserve.

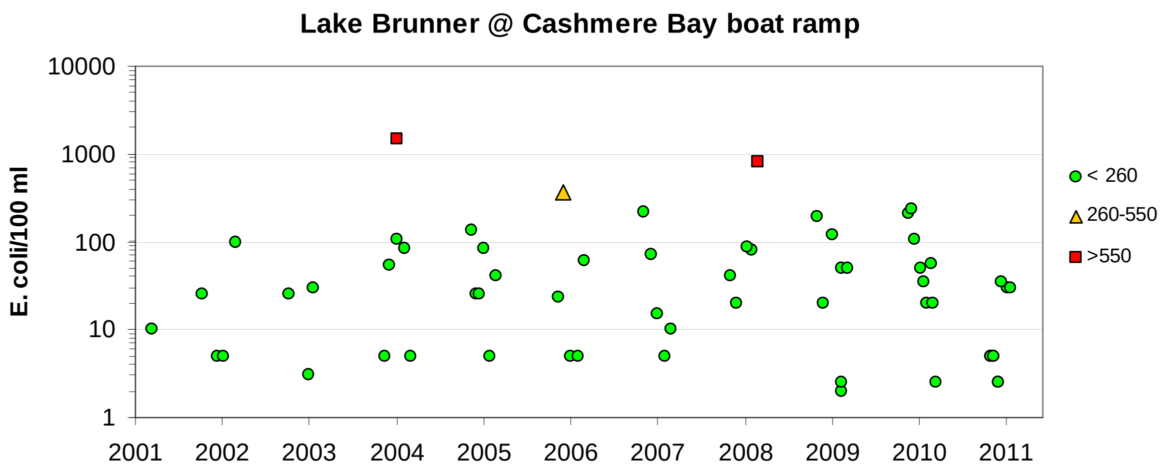


Figure 5.8.14 Single sample E. coli levels for Lake Brunner @ Cashmere Bay boat ramp.

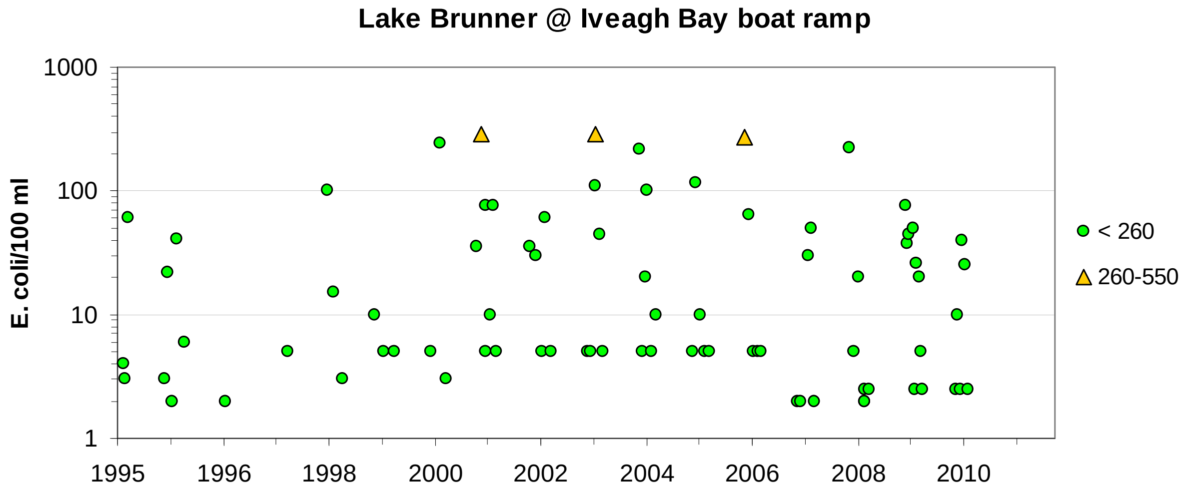


Figure 5.8.15 Single sample E. coli levels for Lake Brunner @ Iveagh Bay boat ramp.

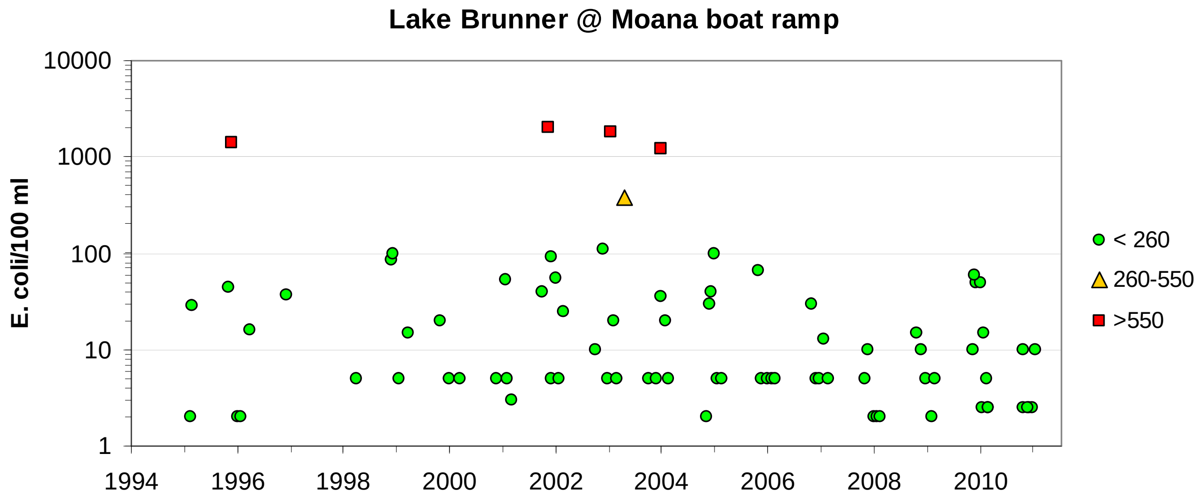


Figure 5.8.16Single sample E. coli levels for Lake Brunner @ Moana boat ramp.

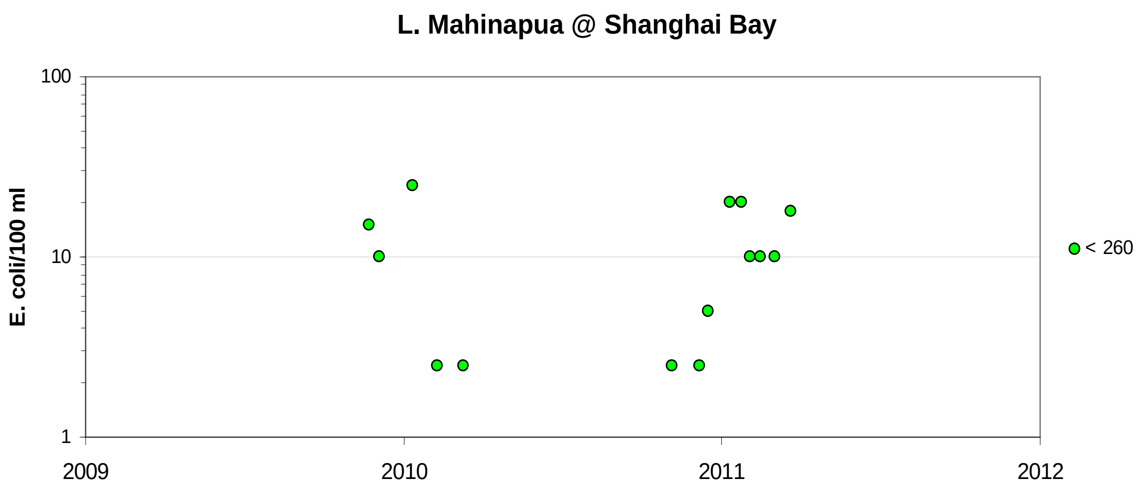


Figure 5.8.17 Single sample E. coli levels for Lake Brunner @ Moana boat ramp.

5.9 Algal cover and macroinvertebrate indices over time – NIWA sites

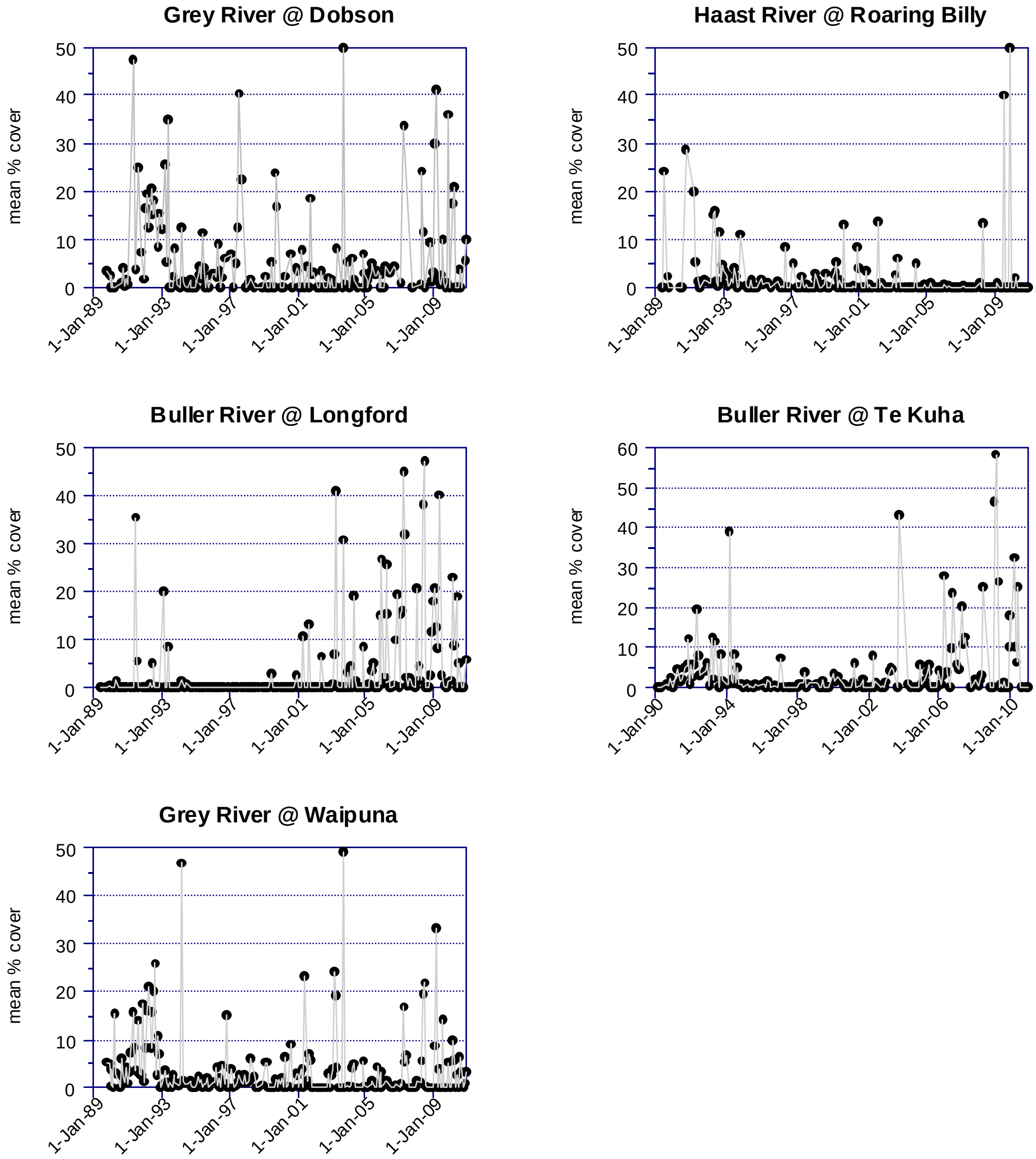


Figure 5.9.1 *Percentage periphyton cover has been assessed at these sites on a monthly basis. Sometimes assessment has not been possible due to high river levels and turbid water obscuring the streambed. An average figure has been calculated from individual estimates of the percentage cover of filamentous algae for ten 0.5 m quadrats, and algal mats for ten 0.5 m quadrats. This has been done for each site on each sampling occasion, which is represented by each point on the graphs. The number of samples exceeding 30% cover were: Grey River @ Dodson, 4%; Grey River @ Waipuna, 1%; Buller River @ Longford, 4%; Buller River @ Te Kuha, 3%; Haast River @ Roaring Billy, 1%. Seasonal Kendall trend testing was able to be conducted on the Buller River @ Te Kuha, Grey River @ Dobson, and Grey River @ Te Kuha. Of these the only significant and meaningful trend was for Grey River @ Waipuna: Seasonal-Kendall trend test: p=<0.01, median=1, annual sen slope=0.03, 12 seasons.*

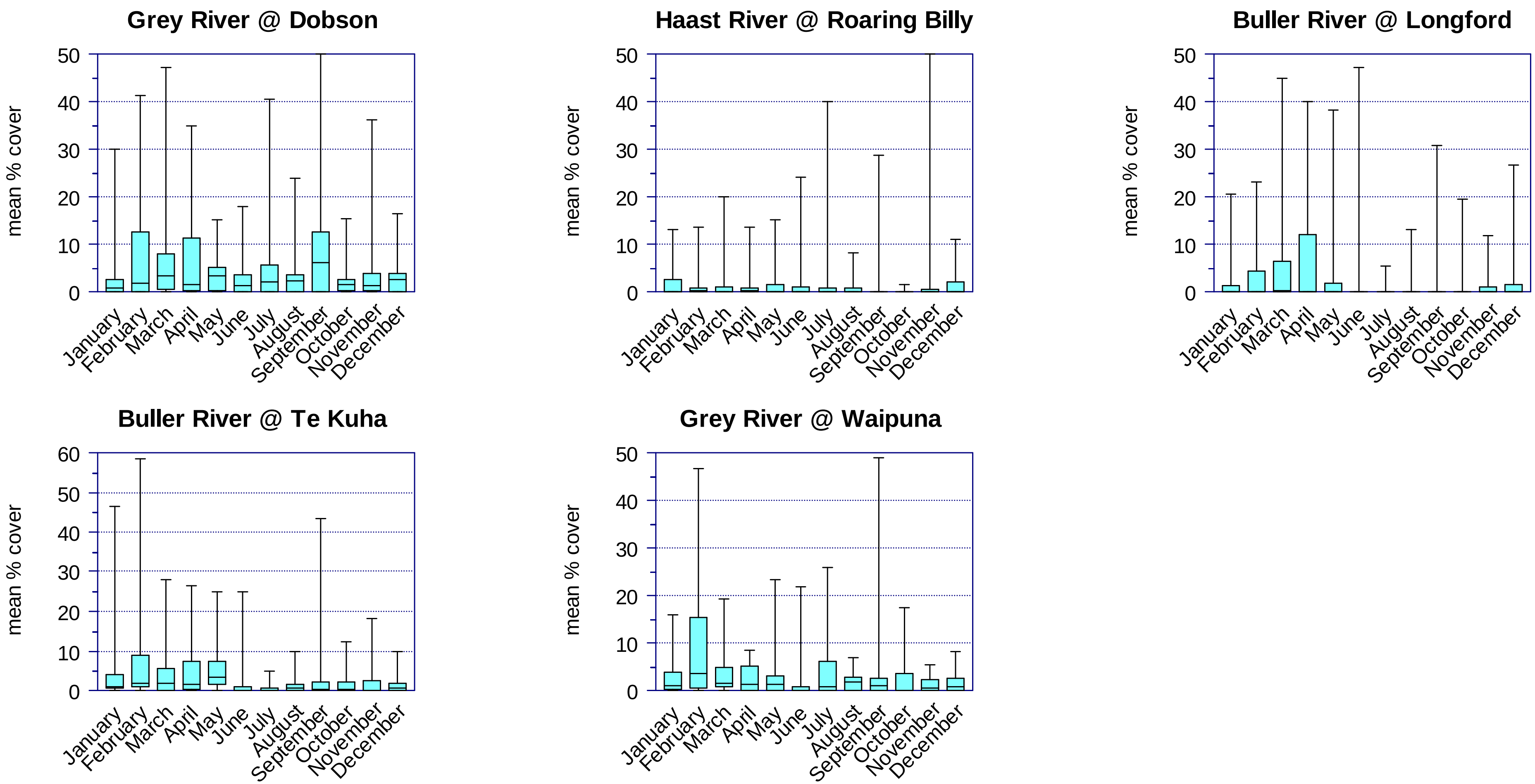


Figure 5.9.2 These plots show percentage periphyton streambed cover for each month, drawing on monthly data from 1989 to 2010. An average figure has been calculated from individual estimates of the percentage cover of filamentous algae for ten 0.5 m quadrats, and algal mats for ten 0.5 m quadrats. These averages have been combined for each month of the year and the quartiles are shown for each month in graphs above.

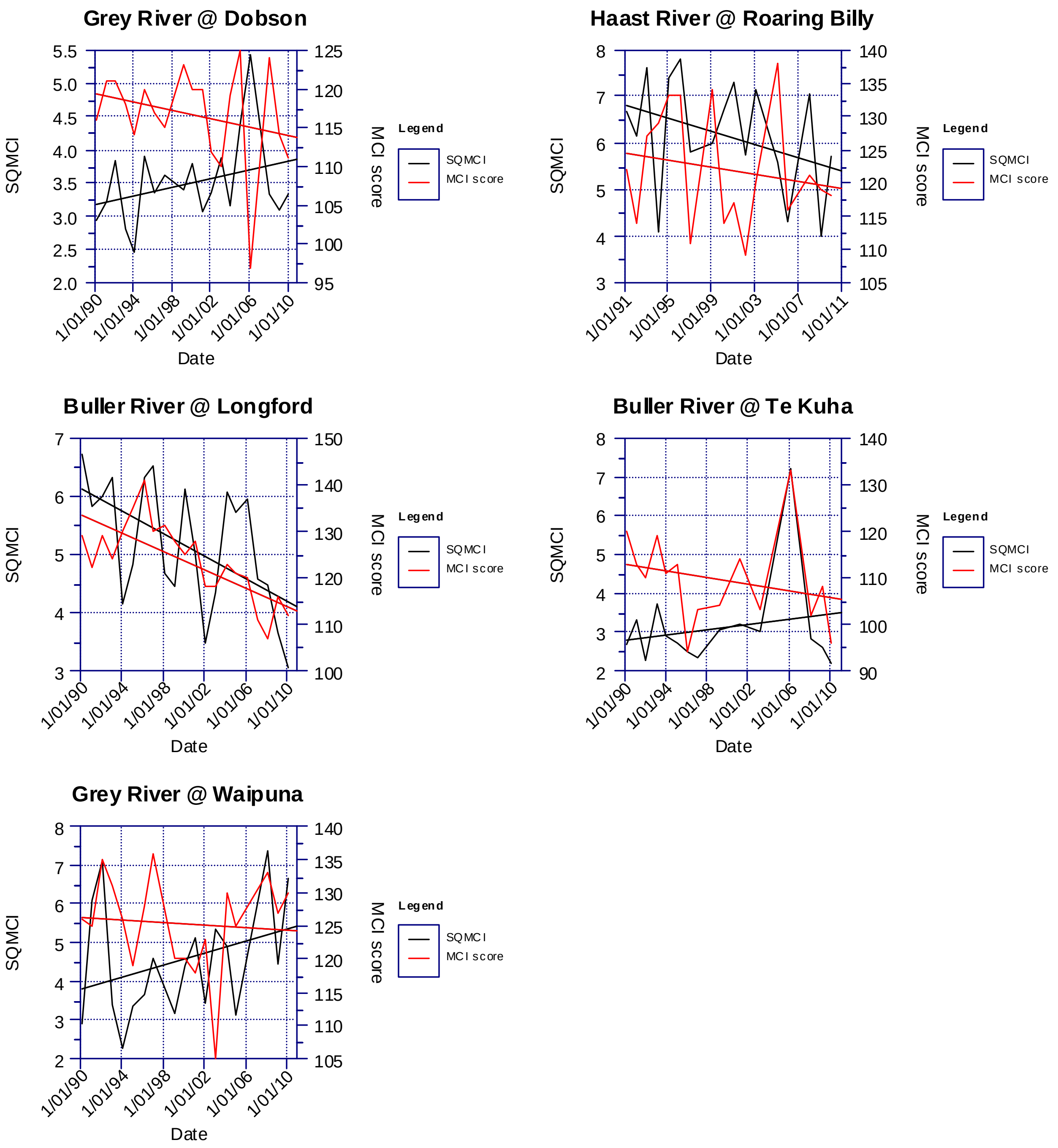


Figure 5.9.3 These plots show annual values for MCI (macroinvertebrate community index) and QMCI (quantitative macroinvertebrate community index) from 1990 to 2010. Linear regression lines are shown for both MCI and QMCI on each graph.

5.10 Regional-scale summary of water quality trends

The first step in producing summary figures was to compute annual median values at each site for all variables with sufficient length of record. Summary figures were then compiled with values from each site (i.e., annual median) used as the replicate data to calculate 25th, 50th (median) and 75th percentile values for the region in each year. This is similar to the approach taken by Scarsbrook (2006) in national SoE reporting.

Values of N for each year are given at the top of the graph.

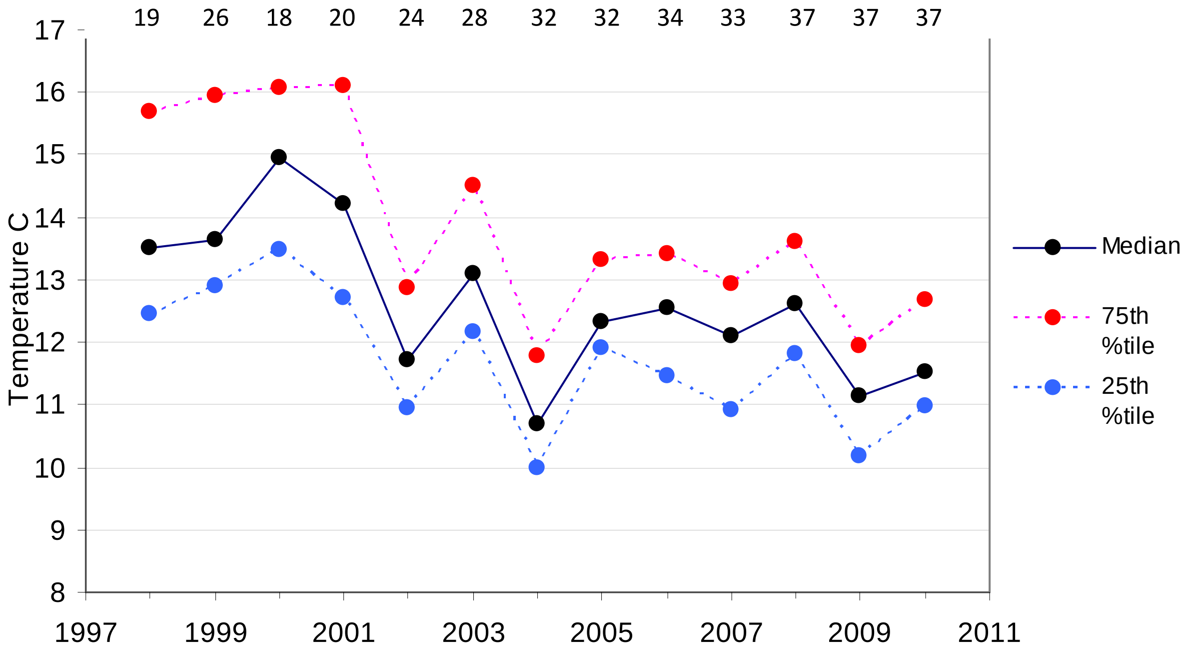


Figure 5.10.1 Seasonal annual median: Temperature.

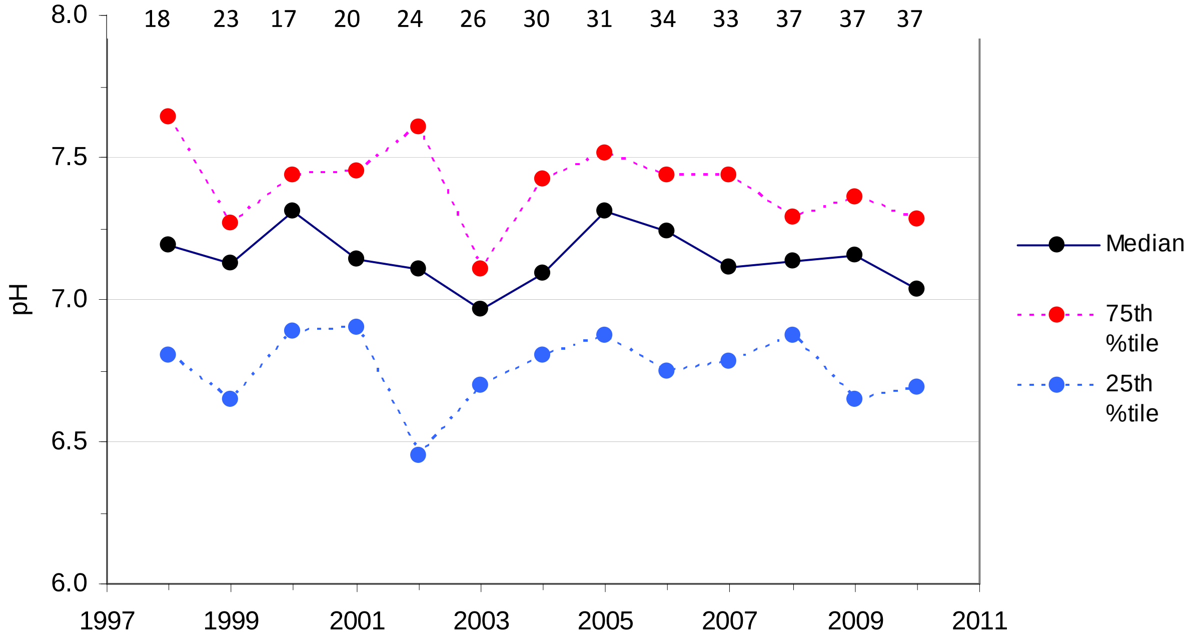


Figure 5.10.2 Seasonal annual median: pH.

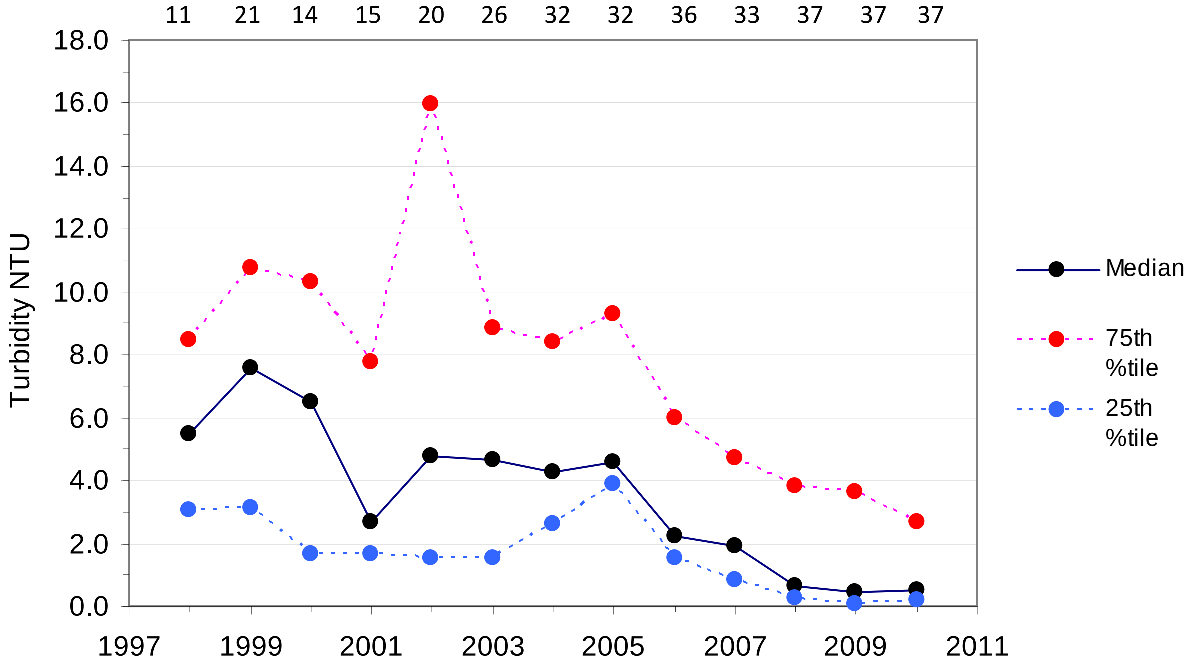


Figure 5.10.3 Seasonal annual median: Turbidity.

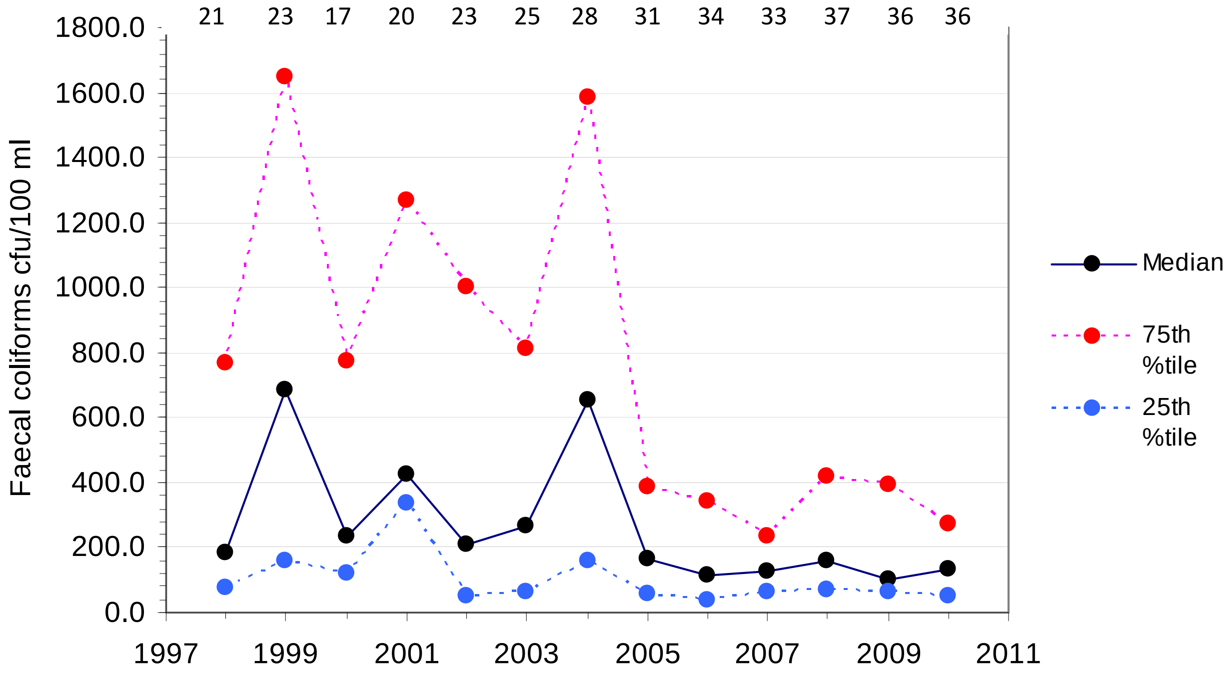


Figure 5.10.4 Seasonal annual median: Faecal coliforms.

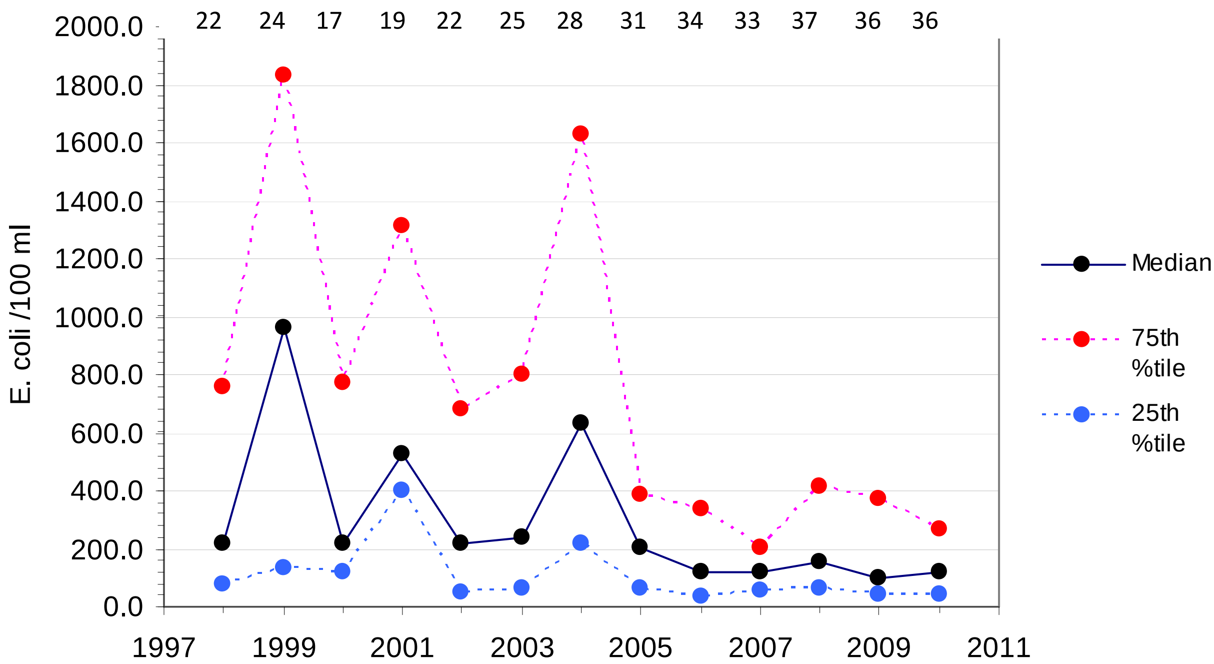


Figure 5.10.5 Seasonal annual median: E. coli.

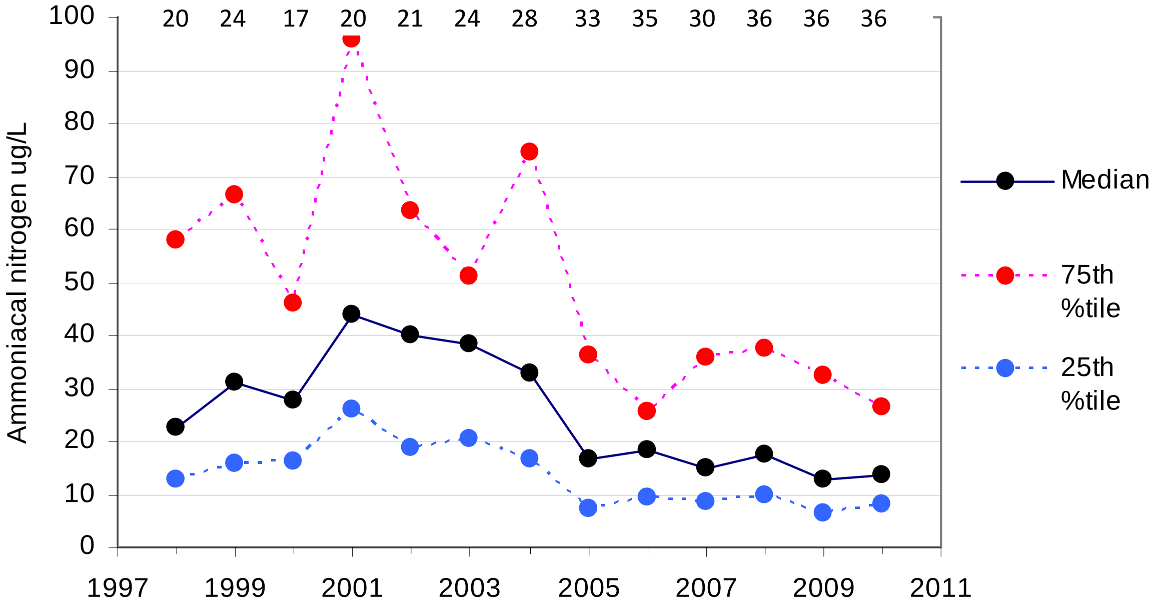


Figure 5.10.6 Seasonal annual median: Ammoniacal nitrogen.

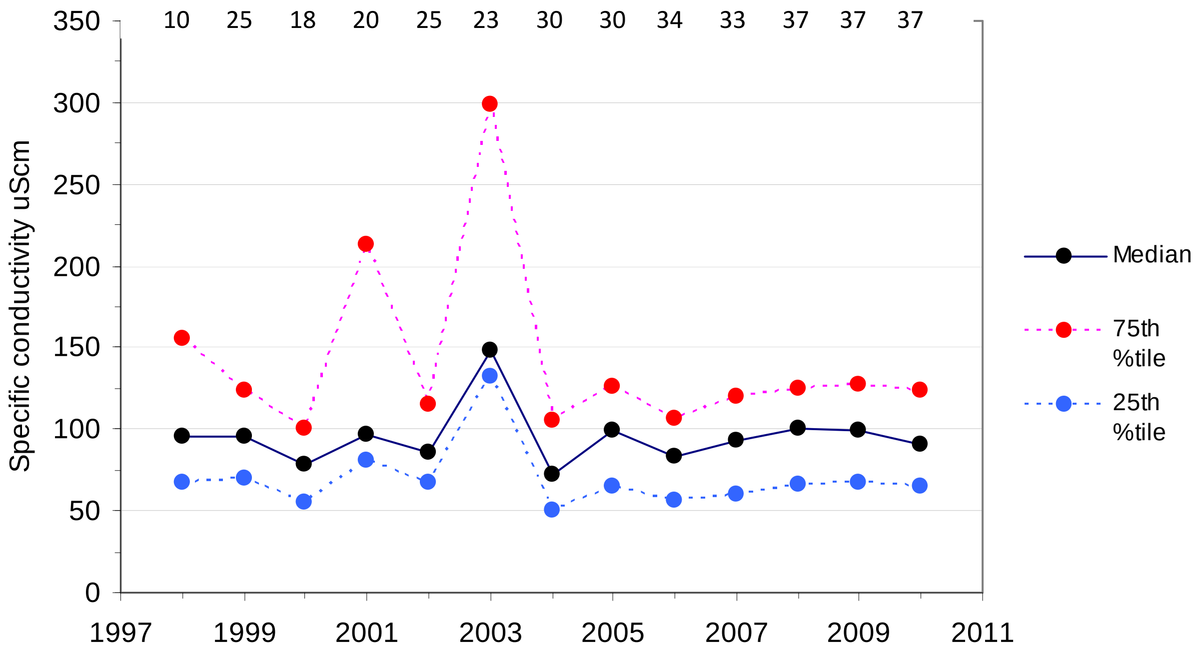


Figure 5.10.7 Seasonal annual median: Conductivity.

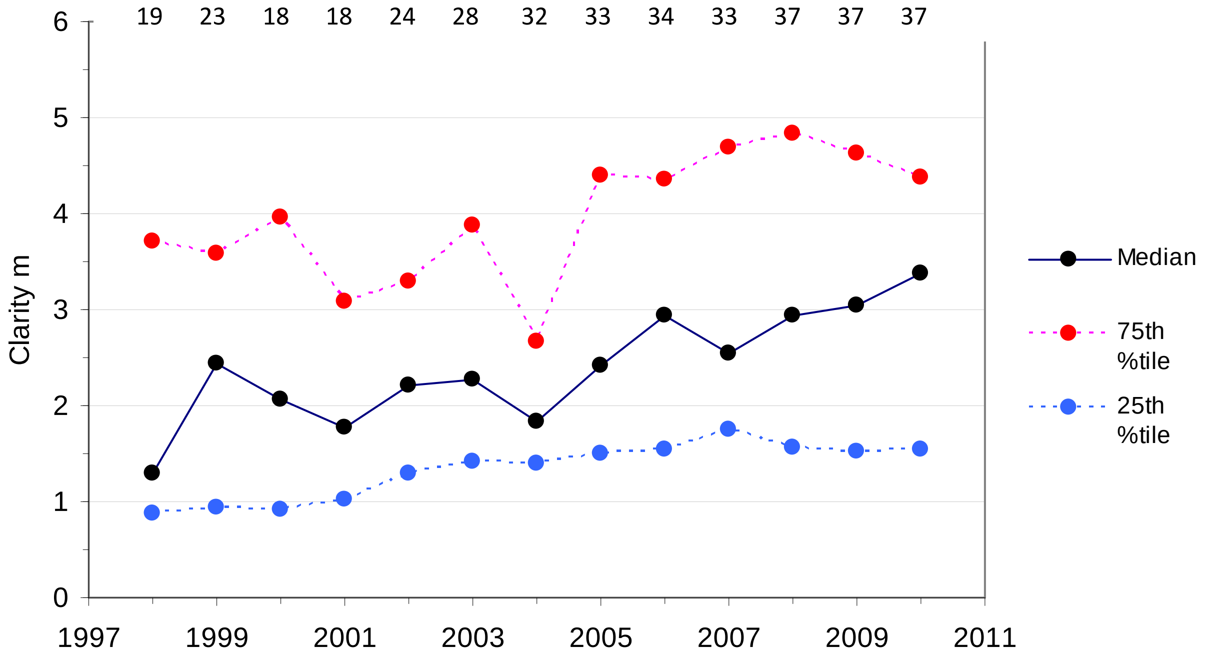


Figure 5.10.8 Seasonal annual median: Clarity.

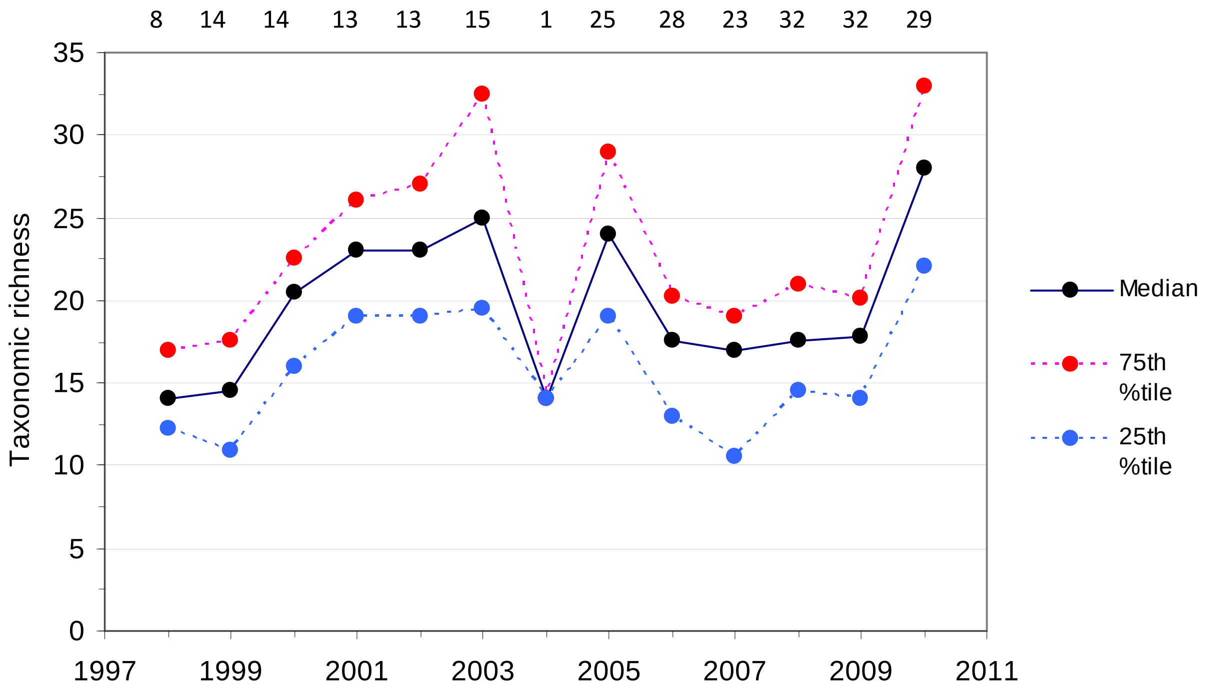


Figure 5.10.9 Seasonal annual median: Taxon richness.

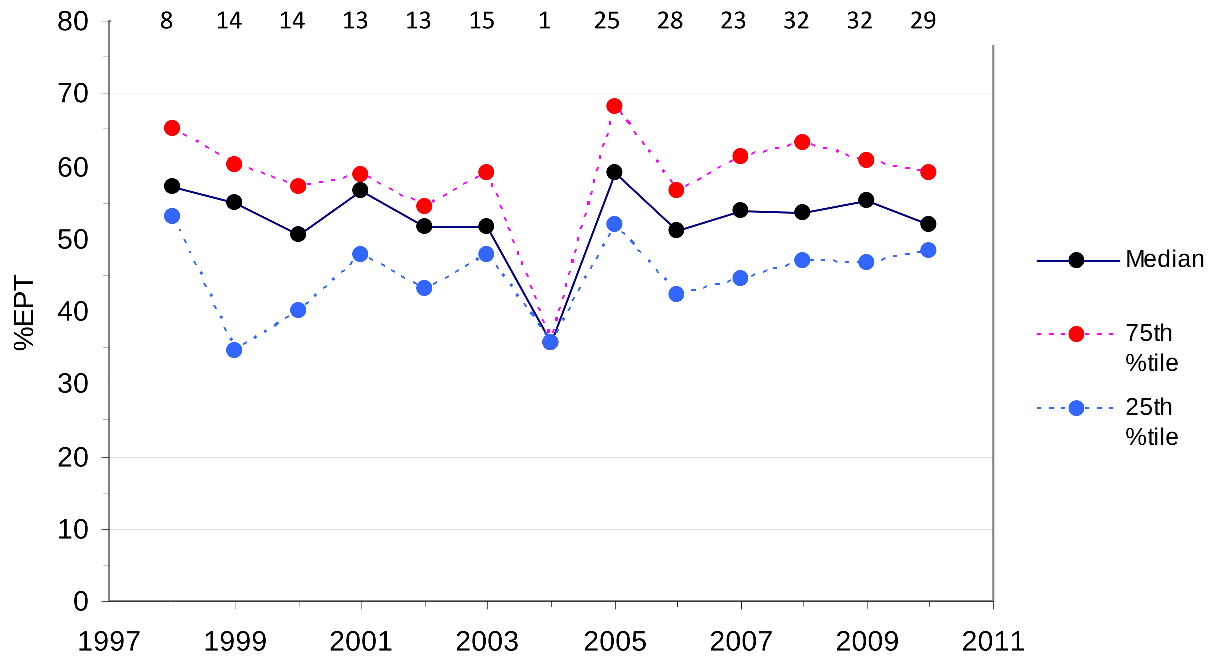


Figure 5.10.10 Seasonal annual median: Percentage EPT.

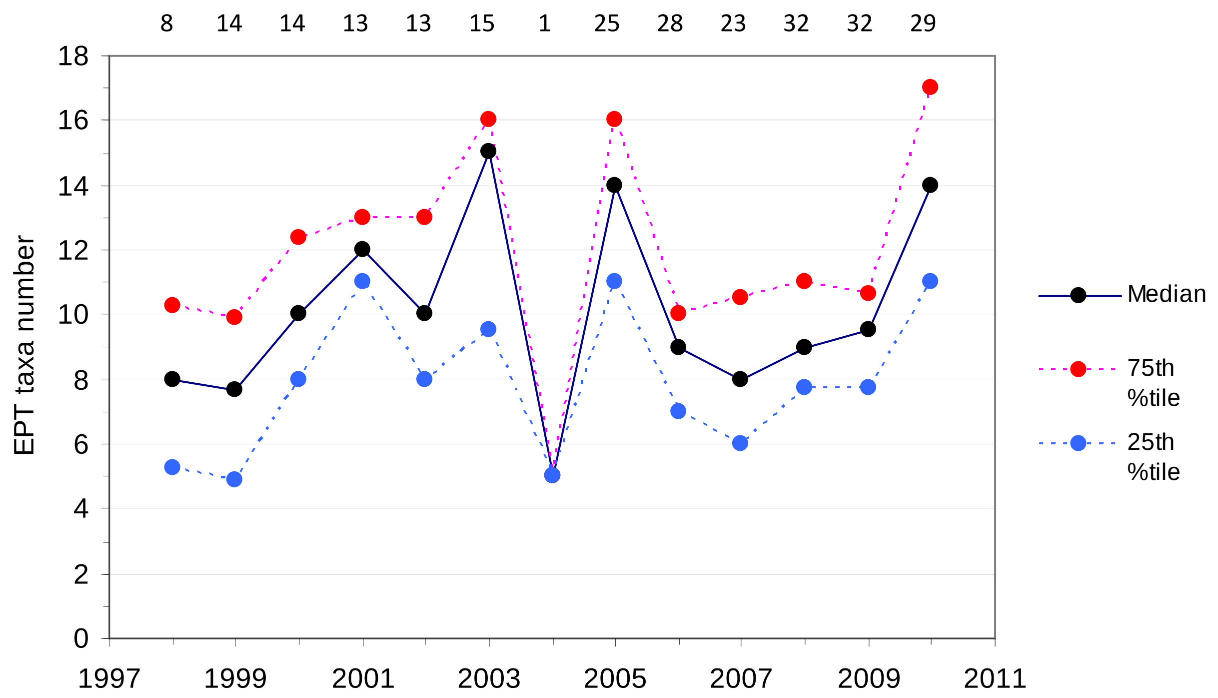


Figure 5.10.11 Seasonal annual median: EPT taxa.

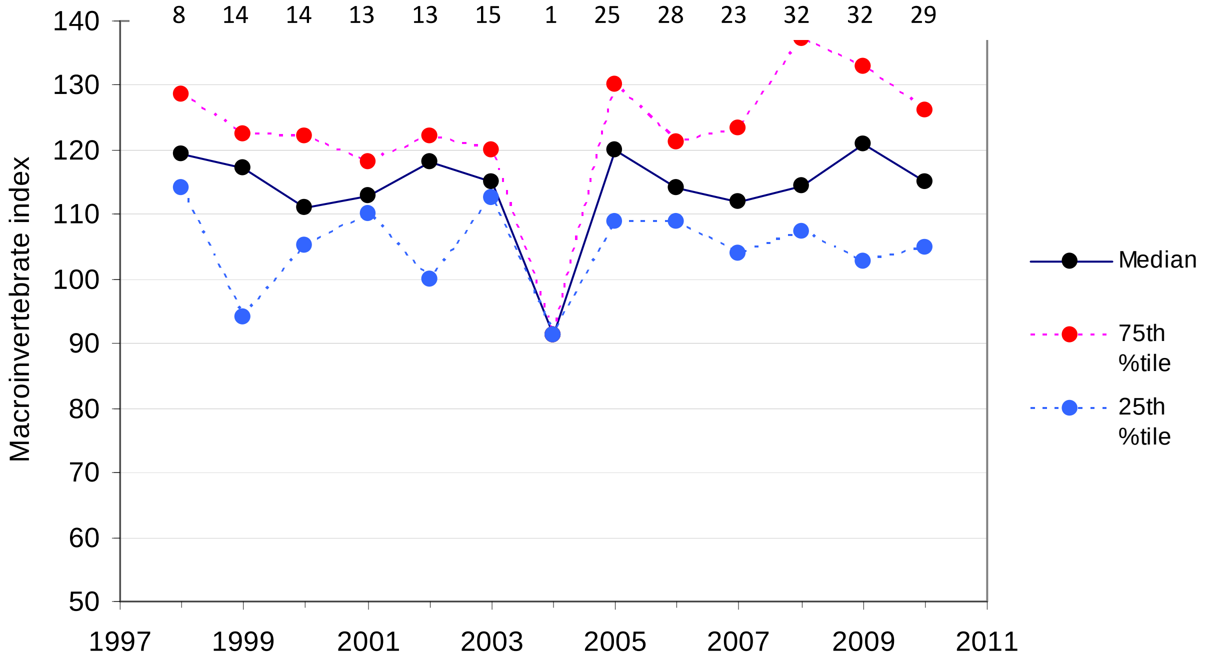


Figure 5.10.12 Seasonal annual median: Macroinvertebrate Community Index (MCI).

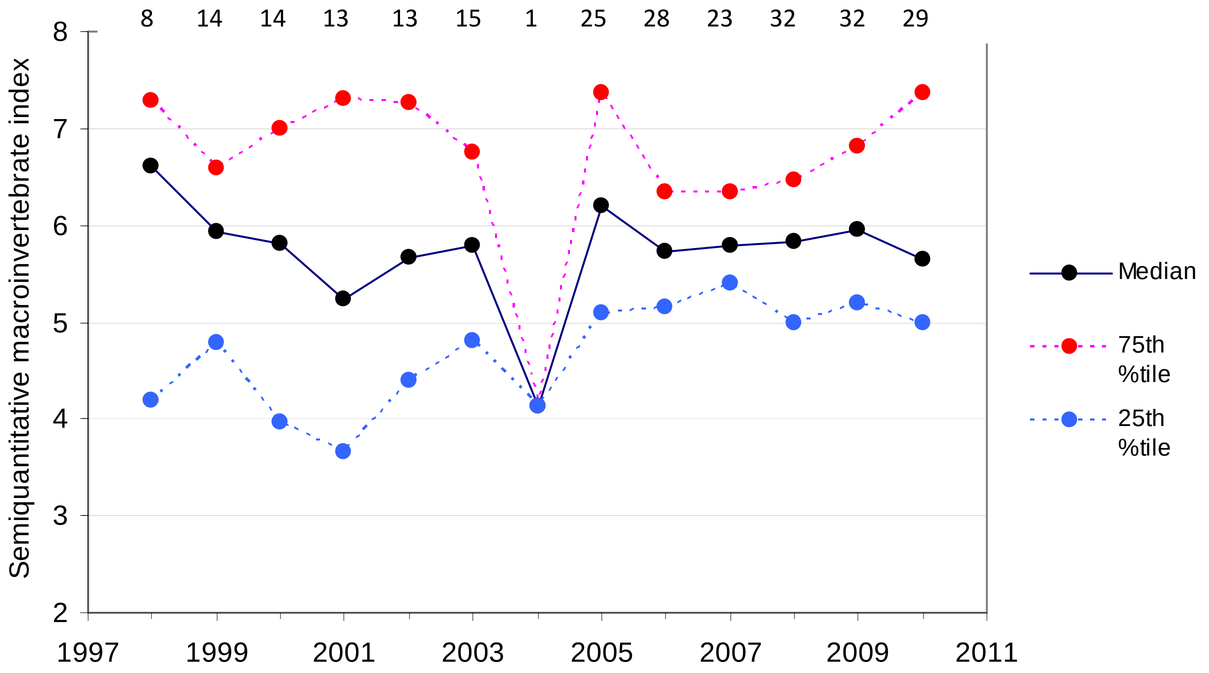


Figure 5.10.13 Seasonal annual median: Semi-Quantitive Macroinvertebrate Community Index (SQMCI).

Table 5.10 Seasonal Kendall trend test results for individual Regional Council monitoring program sites. A meaningful trend is considered as one where the p-value is <0.05 <u>and</u> the annual rate of change is greater than 1% of the median. The trend slope represents the annual change for that variable, in the units given for that variable. It is also preferable that there are at least 40 data points utilised in each test.

	Turbidity					Clarity					Nitrate				
	Median NTU	P value	Annual change NTU	N	Trend?	Median m	P value	Annual change m	N	Trend?	Median ug/L	P value	Annual change ug/L	N	Trend?
Arnold Rv @ Blairs Rd	0.3	0.008	-0.329	31	-	3.3	0.23	0.114	44	-	95	0.023	9.763	21	-
Arnold Rv @ Kotuku	0.4	0.004	-0.085	39	-	3.75	0.021	0.095	67	Yes	79	0.414	2.007	31	-
Baker Ck @ Baker Ck Rd	3.3	0	-0.484	32	-	0.845	0.2	0.016	40	-	1	1	0	8	-
Baker Ck @ Oparara Rd	4.05	0.104	-0.229	32	-	0.8	0.029	0.031	43	Yes	7.5	1	0	8	-
Berry Ck @ N Brch Wanganui Flat Rd	0.35	0.003	-0.269	24	-	4.5	0.185	0.1	39	-	210	0.311	-3.844	23	-
Blackwater Ck @ Farm 846	28.95	0.068	-2.718	30	-	0.3	0.938	-0.001	27	-	335	1	0	8	-
Bradshaws Ck @ Bradshaw Rd	6.9	0.028	-0.522	34	-	0.88	0.022	0.045	31	-	295	1	0	8	-
Bradshaws Ck @ Martin Ck Rd Br	4.8	0	-1.098	28	-	1.035	0.005	0.106	26	-	420	1	0	8	-
Burkes Ck @ SH69	4.2	0.006	-0.562	35	-	1.525	0.068	0.058	40	-	205	0.326	20.587	10	-
Crooked Rv @ Rotomanu-Bell Hill Rd	0.1	0.01	-0.032	33	-	9.5	0.205	0.179	58	-	44	0.308	0.519	39	-
Crooked Rv @ Te Kinga	0.859	0.216	-0.069	66	-	3.9	0.826	-0.012	77	-	110	0.026	3.838	43	Yes
Duck Ck @ Kokatahi-Kowhitirangi Rd	0.2	0.005	-0.121	32	-	5.1	0	0.519	54	Yes	810	0.439	142.753	9	-
Ellis Ck @ 50m d/s Ferry Rd Br	0.3	0	-0.248	28	-	5.05	0.081	0.194	31	-	285	0.221	68.534	10	-
Ford Ck @ Blackball-Taylorville Rd	9.8	0.799	-0.141	35	-	0.925	0.463	0.018	32	-	71	1	-47.947	9	-
Harris Ck @ Mulvaney Rd	1.75	0	-0.246	46	Yes	2.46	0	0.183	56	Yes	390	0.439	28.222	9	-
Hohonu Rv @ Mitchells-Kumara Rd Br	0.1	0.019	0	19	-	13.4	1	0	19	-	10.5	0.215	-1.989	18	-
Hohonu Rv @ Near Mouth	0.6	0	-0.125	32	-	3.63	0.038	0.226	26	-	21	0.358	1.379	32	-
La Fontaine Stm @ Airstrip	0.95	0.001	-0.275	24	-	4.18	0.64	-0.09	23	-	325	0.335	37.959	8	-
La Fontaine Stm @ Herepo	0.8	0.002	-0.202	29	-	4.21	0.355	0.071	29	-	285	0.126	82.736	10	-
Mawheraiti Rv @ SH7 Maimai	0.7	0.001	-0.345	30	-	2.74	0	0.189	52	Yes	240	0.743	23.18	10	-
Molloy Ck @ Rail Line	0.6	0	-0.565	31	-	3.4	0.028	0.205	37	-	335	0.029	50.616	12	-
Murray Ck @ Ford Rd S	0.95	0	-0.249	40	Yes	4.9	0.038	0.148	55	Yes	615	1	0	8	-
Nelson Ck @ Swimming Hole	0.7	0.004	-0.128	39	-	2.67	0.209	-0.027	85	-	73	1	0.67	11	-
Okutua Ck @ New Rd Br-Okarito	0.1	0.004	-0.148	29	-	2.3	1	0	25	-	1	0.371	-1.497	10	-
Orangipuku Rv @ Mouth	0.5	0.001	-0.124	32	-	5.65	0.158	0.23	26	-	344	0.074	11.553	31	-
Orowaiti Rv @ Excelsior Rd	3.5	0.034	-0.255	43	Yes	1.525	0.019	0.041	46	Yes	23.5	1	0	8	-
Orowaiti Rv @ Keoghans Rd	0.329	0.001	-0.066	39	-	5.33	0.028	0.275	44	Yes	13	1	0	8	-
Page Stm @ Chasm Ck Walkway	3.095	1	-0.001	22	-	1.43	0.012	0.079	28	-	140	1	0	1	-
Poerua Rv @ Rail Br	0.7	0.008	-0.275	33	-	3.55	0.177	0.152	40	-	140	0.095	10.203	28	-
Sawyers Ck @ Bush Fringe	3	0.114	-0.356	27	-	1.73	1	0.005	25	-	25.5	1	0	8	-
Sawyers Ck @ Dixon Pk	4.6	0.256	-0.252	38	-	1.45	0.763	0.008	45	-	37	1	0	7	-
Seven Mile Ck @ d/s Raleigh Ck	6	0.001	-0.926	34	-	1.62	0.886	-0.01	37	-	36.5	1	0	8	-
Seven Mile Ck @ Dunollie	6.95	0.001	-0.533	56	Yes	1.71	0.017	0.07	60	Yes	31	1	0	8	-
Seven Mile Ck @ SH6 Rapahoe	7.5	0	-0.445	57	Yes	1.35	0.319	0.016	76	-	52.5	1	0	8	-
Seven Mile Ck @ u/s Tillers Mine Ck	4.5	1	1	17	-	1.745	0.756	-0.041	20	-	87	1	0	2	-
Unnamed Ck @ Adamson Rd	1.7	0	0	31	-	2.94	0.088	0.313	29	-	820	0.52	72.242	10	-
Vickers Ck @ Whataroa N Base	0.4	0	-0.143	31	-	5.675	1	-0.011	30	-	375	1	76	10	-

Table 5.10 Seasonal Kendall trend test results for individual Regional Council monitoring program sites continued.

	Total ammonia					Total nitrogen					Dissolved reactive phosphorus				
	Median ug/L	P value	Annual change ug/L	N	Trend?	Median ug/L	P value	Annual change ug/L	N	Trend?	Median ug/L	P value	Annual change ug/L	N	Trend?
Arnold Rv @ Blairs Rd	5	0.904	0	20	-	200	0.364	-5.119	21	-	1	1	0	21	-
Arnold Rv @ Kotuku	7.5	0.623	0	50	-	175	0.46	3.314	30	-	1.5	0.706	0	30	-
Baker Ck @ Baker Ck Rd	12.5	0.001	-0.996	42	Yes	245	1	0	8	-	5	1	0	8	-
Baker Ck @ Oparara Rd	48	0.101	-3.91	37	-	370	1	0	8	-	10.5	1	0	8	-
Berry Ck @ N Brch Wanganui Flat Rd	16	0.175	-0.586	38	-	340	1	28.76	9	-	8	0.032	-0.389	22	-
Blackwater Ck @ Farm 846	280	0.123	8.767	39	-	1350	0.488	48.777	10	-	11	0.439	-2.828	9	-
Bradshaws Ck @ Bradshaw Rd	90	0.005	-14.048	35	-	785	1	0	8	-	10	1	0	8	-
Bradshaws Ck @ Martin Ck Rd Br	34.5	0.003	-8.005	28	-	780	1	0	8	-	9	1	0	8	-
Burkes Ck @ SH69	24	0	-5.266	41	Yes	420	1	0	8	-	5	0.643	-0.332	9	-
Crooked Rv @ Rotomanu-Bell Hill Rd	5	0.001	-0.295	53	Yes	60	0.003	-4.623	39	-	2	0.716	0	38	-
Crooked Rv @ Te Kinga	11	0.155	-0.327	72	-	180	0.014	-5.156	41	Yes	4	0.042	-0.247	41	Yes
Duck Ck @ Kokatahi-Kowhitirangi Rd	18	0	-1.299	63	Yes	825	0.012	38.251	12	-	6	0.411	0.166	11	-
Ellis Ck @ 50m d/s Ferry Rd Br	9.5	0.501	-0.163	30	-	380	0.439	124.463	9	-	6	1	6.702	9	-
Ford Ck @ Blackball-Taylorville Rd	39.5	0.053	6.208	20	-	145	1	0	8	-	1	1	0	8	-
Harris Ck @ Mulvaney Rd	22	0.001	-2.224	65	Yes	500	0.597	-3.565	11	-	20	0.113	-0.713	11	-
Hohonu Rv @ Mitchells-Kumara Rd Br	2.5	0.722	0	18	-	40	0.755	0	18	-	2	0.885	0	18	-
Hohonu Rv @ Near Mouth	5.8	0.163	-0.742	32	-	110	1	0	31	-	1	0.707	0	28	-
La Fontaine Stm @ Airstrip	12	0.94	0	27	-	410	0.355	100.659	7	-	6	1	0.959	7	-
La Fontaine Stm @ Herepo	16	0.638	0.426	30	-	350	0.439	115.039	9	-	6	1	0.959	9	-
Mawheraiti Rv @ SH7 Maimai	29	0.49	-0.76	53	-	415	1	0	8	-	6.5	1	0	8	-
Molloy Ck @ Rail Line	8	0.025	-0.979	35	-	410	0.248	27.394	11	-	8	0.366	0.516	11	-
Murray Ck @ Ford Rd S	21	0.019	-1.479	59	Yes	725	0.046	16.476	12	-	11	0.393	-0.663	11	-
Nelson Ck @ Swimming Hole	10	0.241	-0.463	41	-	240	1	58.596	9	-	8	1	0.488	9	-
Okutua Ck @ New Rd Br-Okarito	17	0.262	-0.545	31	-	240	1	9.574	9	-	2	0.439	-0.957	9	-
Orangipuku Rv @ Mouth	17	0.654	-0.523	31	-	408.5	0.311	14.162	30	-	4.3	0.65	-0.024	31	-
Orowaiti Rv @ Excelsior Rd	56	0.002	-2.808	59	Yes	205	1	0	8	-	5.5	1	0	8	-
Orowaiti Rv @ Keoghans Rd	19.5	0.344	0.333	50	-	85	1	0	8	-	5.5	1	0	8	-
Page Stm @ Chasm Ck Walkway	53.5	0.584	-1.243	10	-	ND	ND	ND	ND	-	-	-	-	-	-
Poerua Rv @ Rail Br	17	0.006	-1.417	35	-	260	1	0	31	-	6	0.55	-0.166	31	-
Sawyers Ck @ Bush Fringe	5	0.145	-0.502	23	-	135	1	0	8	-	10	1	0	8	-
Sawyers Ck @ Dixon Pk	22.5	1	0	42	-	320	1	0	7	-	12	1	0	7	-
Seven Mile Ck @ d/s Raleigh Ck	76	0.167	1.638	36	-	220	1	0	8	-	6.5	1	0	8	-
Seven Mile Ck @ Dunollie	23	0.493	0.284	55	-	140	1	0.753	10	-	3	0.014	-0.332	13	-
Seven Mile Ck @ SH6 Rapahoe	48.5	0.3	0.773	50	-	230	0.743	-4.64	10	-	6.5	0.336	-0.278	14	-
Seven Mile Ck @ u/s Tillers Mine Ck	6	0.624	-0.259	9	-	145	1	0	2	-	4.5	1	0	2	-
Unnamed Ck @ Adamson Rd	11	0.042	-0.868	30	-	1200	0.602	-382.962	9	-	6	0.439	-59.359	9	-
Vickers Ck @ Whataroa N Base	7	0.481	-0.499	31	-	460	0.439	81.379	9	-	6	0.674	-2.394	9	-

Table 5.10 Seasonal Kendall trend test results for individual Regional Council monitoring program sites continued.

	Total phosphorus					Specific conductivity					pH				
	Median ug/L	P value	Annual change ug/L	N	Trend?	Median uScm	P value	Annual change uScm	N	Trend?	Median	P value	Annual change	N	Trend?
Arnold Rv @ Blairs Rd	7	0.514	-0.204	21	-	55	0.222	1.194	36	-	7.36	0.07	-0.048	35	-
Arnold Rv @ Kotuku	6	0.787	0	30	-	48	0.165	-0.982	45	-	7.27	0.92	0.001	49	-
Baker Ck @ Baker Ck Rd	14	1	0	8	-	82	0.417	0.752	31	-	7.21	0.88	-0.009	36	-
Baker Ck @ Oparara Rd	39.5	1	0	8	-	88	0.44	0.948	33	-	6.97	0.78	0.006	38	-
Berry Ck @ N Brch Wanganui Flat Rd	14	0.065	-0.722	22	-	99.5	0.933	-0.165	26	-	7.17	0.10	-0.079	26	-
Blackwater Ck @ Farm 846	190	0.439	4.158	9	-	235	0.083	4.151	30	-	6.56	0.06	-0.037	34	-
Bradshaws Ck @ Bradshaw Rd	47	1	0	8	-	105.5	0.162	1.497	32	-	6.58	0.07	-0.049	35	-
Bradshaws Ck @ Martin Ck Rd Br	41.5	1	0	8	-	109	0.056	8.732	26	-	6.595	0.66	0.02	28	-
Burkes Ck @ SH69	16	1	0	9	-	94	0.856	0.563	39	-	7.045	0.65	0.009	42	-
Crooked Rv @ Rotomanu-Bell Hill Rd	3	0.262	-0.123	38	-	60	0.463	-0.361	47	-	7.5	0.26	-0.021	50	-
Crooked Rv @ Te Kinga	10	0.097	-0.515	41	-	63	0.619	-0.286	53	-	7.105	0.03	-0.028	58	Yes
Duck Ck @ Kokatahi-Kowhitirangi Rd	9	1	0	11	-	90	0.216	0.846	45	-	6.52	0.10	-0.021	47	-
Ellis Ck @ 50m d/s Ferry Rd Br	11	1	12.446	9	-	110.5	0.841	0.331	30	-	7.44	0.09	-0.054	32	-
Ford Ck @ Blackball-Taylorville Rd	13	1	0	8	-	199	0.916	-1.372	35	-	6.835	0.17	0.024	36	-
Harris Ck @ Mulvaney Rd	24.5	1	0	11	-	97.5	0.715	-0.29	46	-	7.34	0.21	0.018	51	-
Hohonu Rv @ Mitchells-Kumara Rd Br	2.5	0.009	0.766	18	-	49	0.275	1.108	19	-	7.45	0.34	0.055	19	-
Hohonu Rv @ Near Mouth	4	0.738	-0.252	31	-	47	0.206	2.12	15	-	7.125	0.72	0.117	14	-
La Fontaine Stm @ Airstrip	13	1	3.835	7	-	126.5	0.942	-0.361	28	-	7.25	0.76	-0.008	27	-
La Fontaine Stm @ Herepo	17	1	1.917	9	-	122	1	0	31	-	6.745	0.03	-0.034	30	-
Mawheraiti Rv @ SH7 Maimai	16	1	0	8	-	32	0.364	0.333	42	-	6.83	0.50	0.02	36	-
Molloy Ck @ Rail Line	12	1	0.516	11	-	105	0.007	4.259	33	-	7.19	0.41	-0.016	34	-
Murray Ck @ Ford Rd S	21	1	0	11	-	99	0.218	0.504	47	-	6.48	0.01	-0.036	46	Yes
Nelson Ck @ Swimming Hole	15	1	1.953	9	-	46	0.399	-0.578	47	-	6.935	0.05	-0.03	52	Yes
Okutua Ck @ New Rd Br-Okarito	8	1	-0.479	9	-	26	1	0	30	-	4.81	0.01	-0.08	28	-
Orangipuku Rv @ Mouth	11	0.946	-0.039	31	-	79	0.575	1.001	15	-	6.95	0.41	0.102	13	-
Orowaiti Rv @ Excelsior Rd	30	1	0	8	-	70	0.609	0.397	43	-	6.555	0.15	-0.024	46	-
Orowaiti Rv @ Keoghans Rd	9	1	0	8	-	67	0.123	1	41	-	6.93	0.73	-0.013	41	-
Page Stm @ Chasm Ck Walkway	ND	ND	ND	ND	-	251	0.64	-2.991	30	-	4.735	0.50	0.01	34	-
Poerua Rv @ Rail Br	20	0.315	-0.994	31	-	72	0.065	1.997	34	-	7.04	0.78	-0.005	37	-
Sawyers Ck @ Bush Fringe	17	1	0	8	-	191	0.306	7.269	27	-	7.9	0.14	-0.043	27	-
Sawyers Ck @ Dixon Pk	32	1	0	7	-	185	0.335	0.308	39	-	7.92	0.07	0.062	37	-
Seven Mile Ck @ d/s Raleigh Ck	27	1	0	8	-	109.5	0.628	1.688	34	-	7.34	0.30	-0.029	35	-
Seven Mile Ck @ Dunollie	11	1	0	13	-	108.5	0.973	-0.306	46	-	7.39	0.41	-0.014	47	-
Seven Mile Ck @ SH6 Rapahoe	27	0.026	-2.476	14	-	155.5	0.07	7.08	42	-	7.25	0.26	-0.009	59	-
Seven Mile Ck @ u/s Tillers Mine Ck	11.5	1	0	2	-	70	0.203	-2.983	18	-	7.48	0.75	0.023	19	-
Unnamed Ck @ Adamson Rd	16	0.439	0	9	-	153	0.201	1.4	29	-	8	1.00	0.002	31	-
Vickers Ck @ Whataroa N Base	7	1	-1.915	9	-	127	0.945	0	30	-	7.38	0.28	-0.036	32	-

Table 5.10 Seasonal Kendall trend test results for individual Regional Council monitoring program sites continued.

	Faecal coliforms					E. coli				
	Median cfu/100 ml	P value	Annual change cfu/100 ml	N	Trend?	Median E. coli/100 ml	P value	Annual change E. coli/100 ml	N	Important?
Arnold Rv @ Blairs Rd	43	0.411	-2.292	68	-	40	0.53	-1.752	67	-
Arnold Rv @ Kotuku	10	0	-2.891	83	Yes	10	0.00	-4.277	83	Yes
Baker Ck @ Baker Ck Rd	100	0.035	-9.442	41	Yes	75	0.08	-6.707	39	-
Baker Ck @ Oparara Rd	410	0.818	-5.788	43	-	380	1.00	1.103	41	-
Berry Ck @ N Brch Wanganui Flat Rd	135	0.092	-21.058	25	-	234.5	0.00	-70.521	38	-
Blackwater Ck @ Farm 846	500	0.051	60.642	36	-	550	0.10	46.181	37	-
Bradshaws Ck @ Bradshaw Rd	275	0.361	-6.951	35	-	275	0.36	-10.245	35	-
Bradshaws Ck @ Martin Ck Rd Br	245	0.624	-4.985	32	-	197.5	0.39	-8.574	32	-
Burkes Ck @ SH69	380	0.008	-57.905	42	Yes	356.5	0.00	-83.891	36	-
Crooked Rv @ Rotomanu-Bell Hill Rd	5	0.797	0	61	-	5	0.64	0	55	-
Crooked Rv @ Te Kinga	45	0.414	-1.25	94	-	45	0.28	-2.042	92	-
Duck Ck @ Kokatahi-Kowhitirangi Rd	105	0.041	-8.507	65	Yes	104	0.01	-9.919	59	Yes
Ellis Ck @ 50m d/s Ferry Rd Br	80	0.445	1.645	31	-	80	0.66	0.818	31	-
Ford Ck @ Blackball-Taylorville Rd	5	1	0	20	-	5	1.00	0	19	-
Harris Ck @ Mulvaney Rd	445	0.003	-39.909	67	Yes	326.5	0.00	-47.551	60	Yes
Hohonu Rv @ Mitchells-Kumara Rd Br	2.5	0.766	0	19	-	2.5	0.77	0	19	-
Hohonu Rv @ Near Mouth	57.5	0.84	6.723	14	-	57.5	0.84	6.723	14	-
La Fontaine Stm @ Airstrip	100	0.049	-4.723	27	-	87.5	0.21	-3.346	26	-
La Fontaine Stm @ Herepo	95	0.093	5.381	29	-	87.5	0.11	5.761	28	-
Mawheraiti Rv @ SH7 Maimai	180	0.012	-25.359	59	Yes	182	0.01	-19.885	56	Yes
Molloy Ck @ Rail Line	311.5	0.722	-3.936	40	-	305	0.55	-6.414	39	-
Murray Ck @ Ford Rd S	152.5	0.004	-10.587	66	Yes	120	0.00	-12.052	58	Yes
Nelson Ck @ Swimming Hole	90	0.98	0	11	-	86.5	0.76	0.57	104	-
Okutua Ck @ New Rd Br-Okarito	5	0.257	0	30	-	5	0.42	0	29	-
Orangipuku Rv @ Mouth	32.5	1	0	14	-	27.5	0.58	-3.019	14	-
Orowaiti Rv @ Excelsior Rd	317.5	0.901	0.84	94	-	337.5	0.87	1.245	88	-
Orowaiti Rv @ Keoghans Rd	35	0.372	-1.235	51	-	35	0.55	-0.271	48	-
Page Stm @ Chasm Ck Walkway	10	1	0	10	-	10	1.00	0	10	-
Poerua Rv @ Rail Br	32.5	1	0	40	-	35	0.93	0	39	-
Sawyers Ck @ Bush Fringe	45	0.876	0.705	27	-	45	0.70	1.757	27	-
Sawyers Ck @ Dixon Pk	1350	0.884	0	46	-	1400	0.67	28.919	47	-
Seven Mile Ck @ d/s Raleigh Ck	140	0.629	-3.022	49	-	140	0.67	-2.565	49	-
Seven Mile Ck @ Dunollie	32.5	0.165	-1.367	68	-	25	0.26	-0.914	61	-
Seven Mile Ck @ SH6 Rapahoe	150	0.67	-1.297	12	-	140	0.96	0	105	-
Seven Mile Ck @ u/s Tillers Mine Ck	10	0.506	-3.984	11	-	12.5	0.50	-3.984	10	-
Unnamed Ck @ Adamson Rd	293.5	0.019	-100.028	32	-	320	0.00	-115.952	31	-
Vickers Ck @ Whataroa N Base	127.5	0.014	-15.539	32	-	122.5	0.01	-18.858	32	-

5.11 Impact/reference sites: Longitudinal patterns over time

A number of rivers in the region are sampled at two or more locations. There is usually an upstream 'reference site' and downstream site impacted by one or more anthropogenic pressures. There are two types of figures in this section.

The first show the downstream minus upstream difference between paired sites, over time. The line on each of these figures is the sen slope trend, calculated by the Mann-Kendall trend test. These figures are for supporting the Mann-Kendall trend analysis presented in section 3.2.3. Only variables with enough data have been analysed at paired sites. These variables were: faecal coliforms, ammoniacal nitrogen (ammonia), clarity, turbidity, EC25. Differences for SQMCI, MCI, and periphyton have been combined for all sites and presented collectively.

The second figures – box whisker plots – show the range of differences for each variable.

Table 5.11 Number of samples (n) available for upstream/downstream differences at paired sites, by variable.

	Arnold Rv	Baker Ck	Bradshaws Ck	Crooked Rv	La Fontaine St	Orowaiti Rv	Sawyers Ck	Seven Mile Ck
Dissolved reactive phosphorus	19	8	8	33	7	8	7	8
Ammonia-N	18	33	27	48	24	47	22	34
Total nitrogen	19	8	7	34	7	8	7	8
Total phosphorous	19	8	8	33	7	8	7	8
Nitrate-N	20	8	7	35	8	8	7	8
Water clarity	40	39	25	48	22	42	24	36
Periphyton	no data	10	2	9	8	15	9	11
Dissolved oxygen %saturation	30	20	22	29	19	34	24	25
Turbidity	27	28	27	36	22	37	26	33
Faecal Coliforms	56	38	31	46	23	50	26	47
E.coli	53	37	31	42	22	47	27	43
Specific conductivity	32	28	24	37	25	40	26	33
pH	32	32	26	39	24	38	26	33
Water temperature	33	34	27	36	22	44	26	31
SQMCI	2	13	3	5	5	16	6	7
MCI	2	13	3	5	5	16	6	7
EPT Taxa	2	13	3	5	5	16	6	7
% EPT Taxa	2	13	3	5	5	16	6	7
Taxonomic Richness	2	13	3	5	5	16	6	7

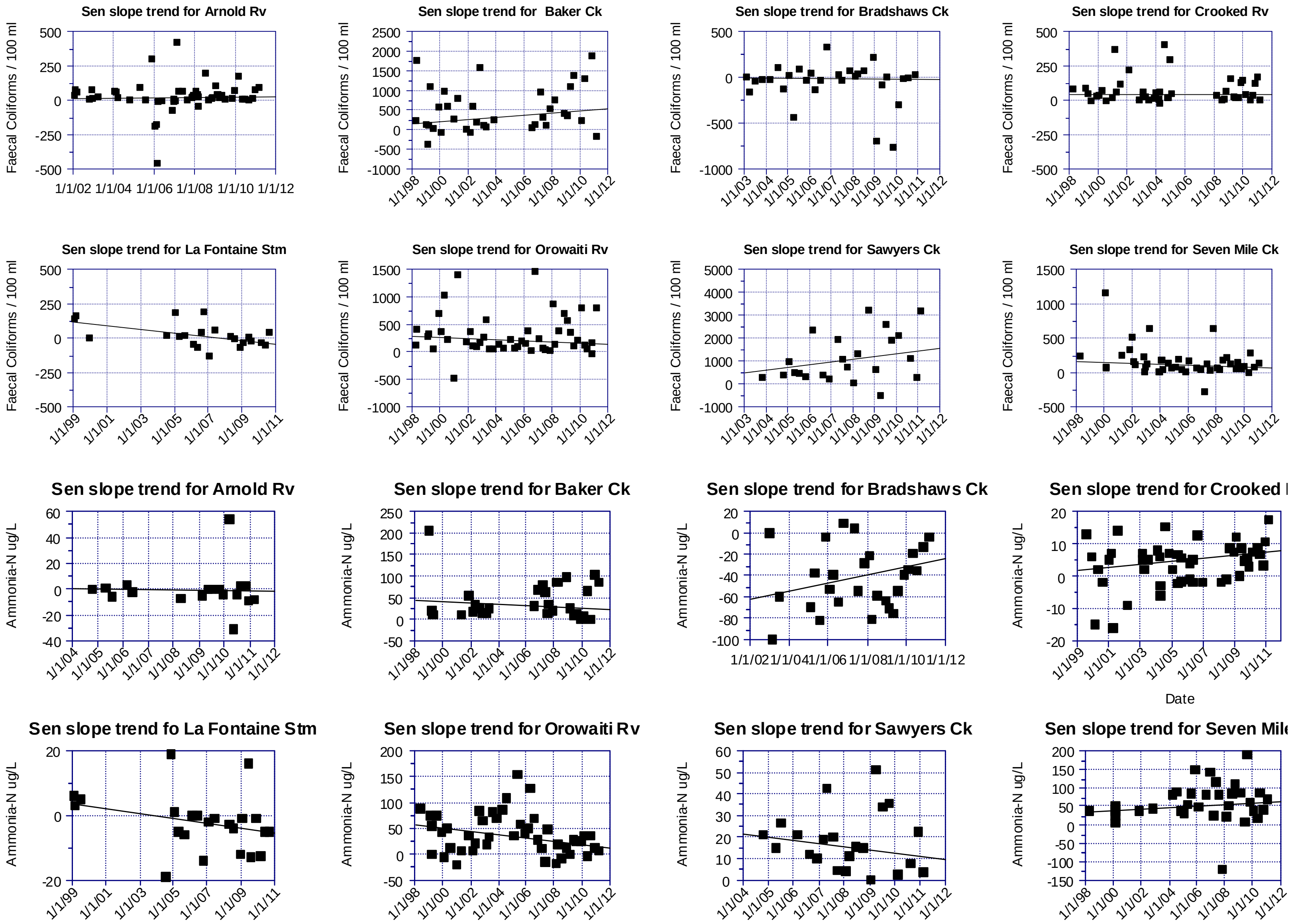


Figure 5.11.1a Individual difference values between paired sites (downstream minus upstream values) over time. Ammoniacal nitrogen and faecal coliforms.

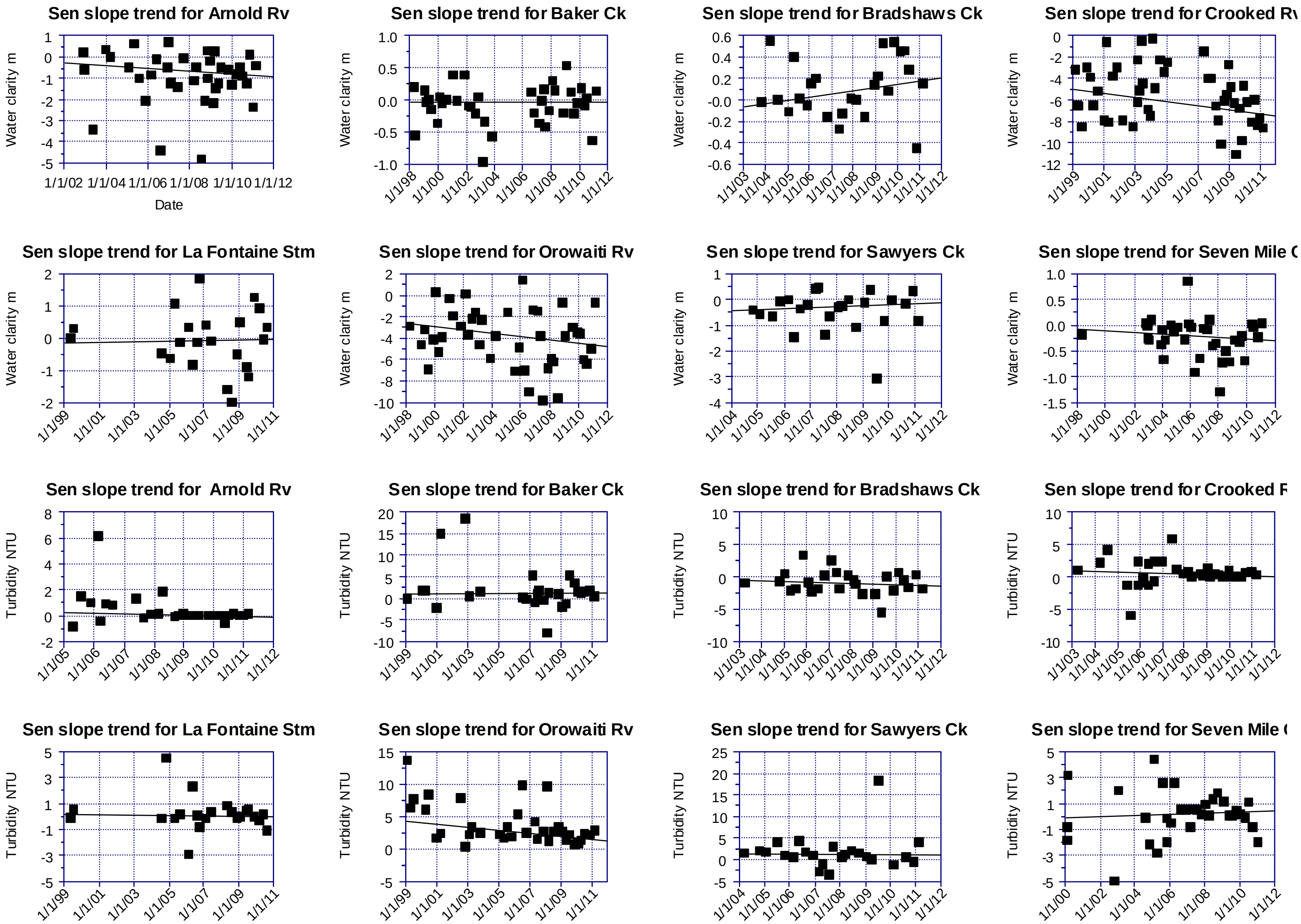


Figure 5.11.1b Individual difference values between paired sites (downstream minus upstream values) over time. Clarity and turbidity.

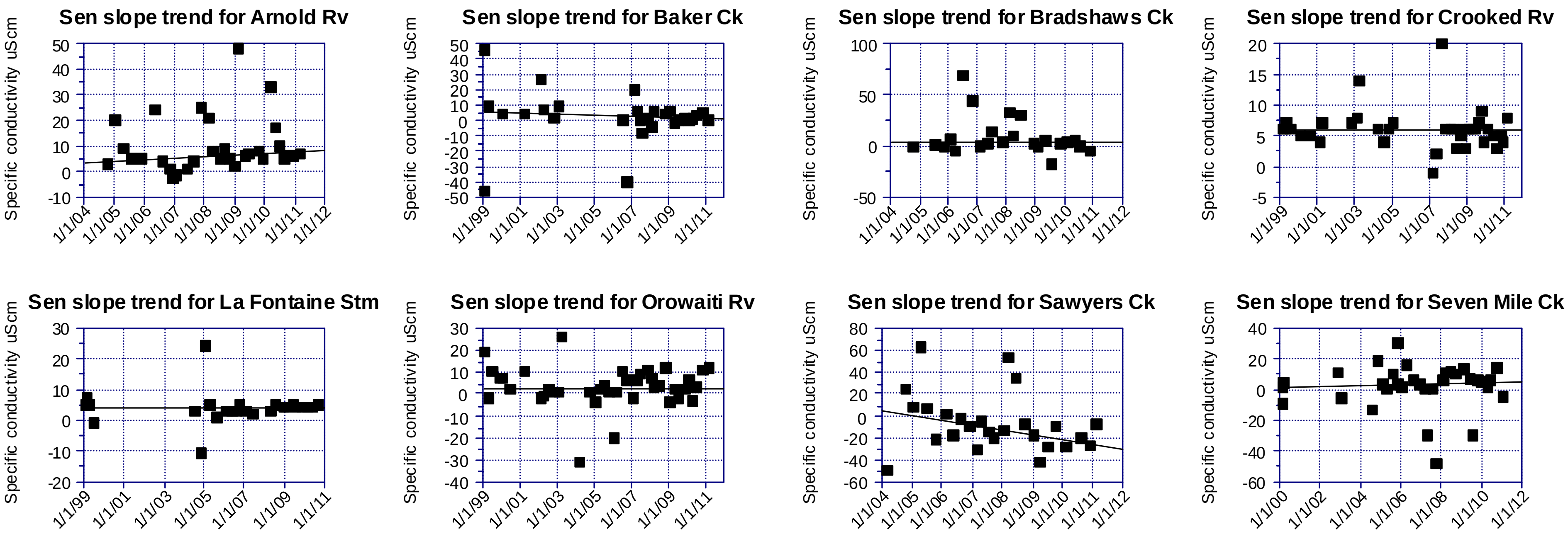


Figure 5.11.1c Individual difference values between paired sites (downstream minus upstream values) over time. Specific conductance (conductivity).

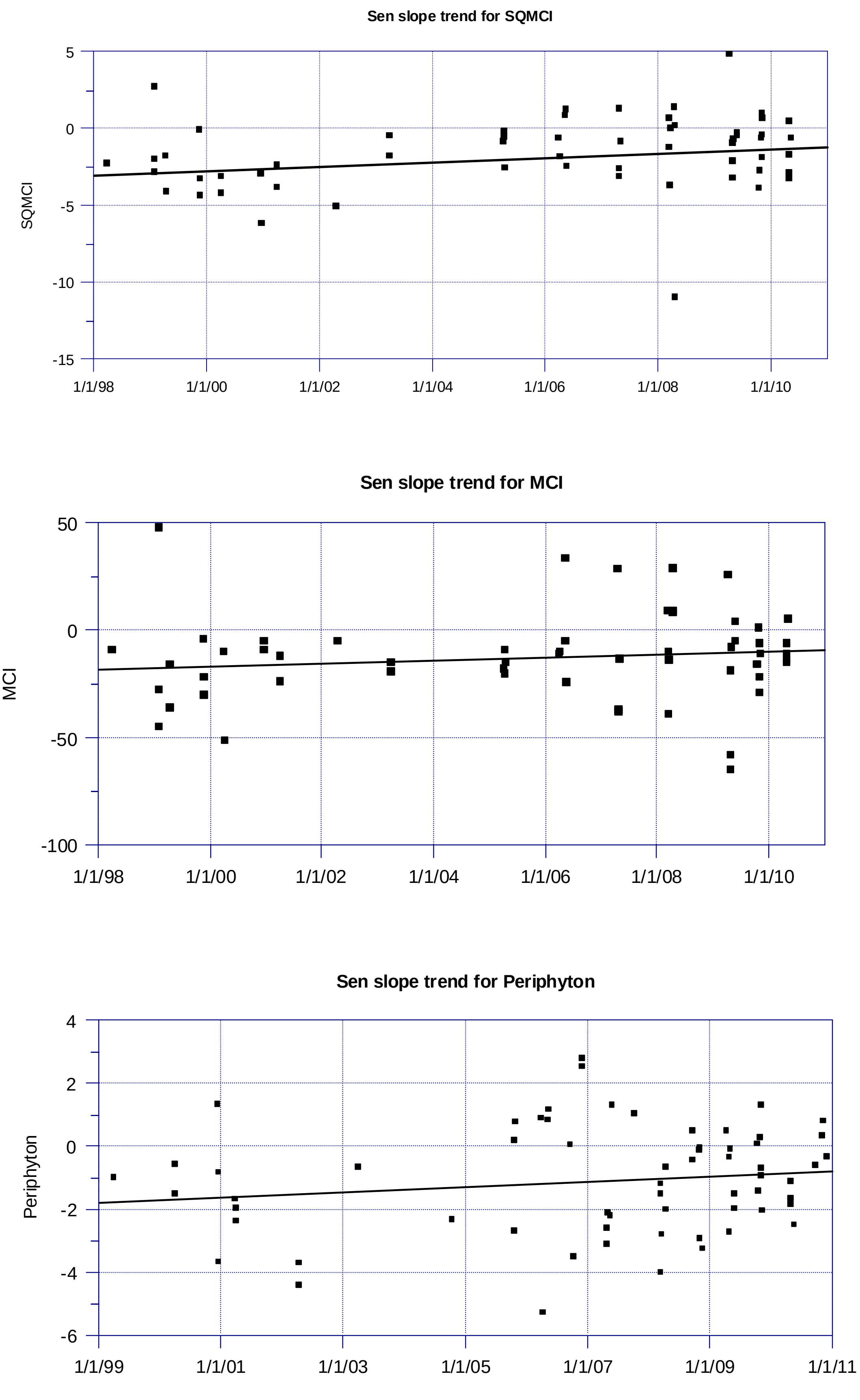


Figure 5.11.1d Individual difference values between paired sites (downstream minus upstream values) over time. Data for all eight pairs are shown on the one graph. Semi-quantitative macroinvertebrate community index (SQMCI), macroinvertebrate community index (MCI), and periphyton enrichment score.

5.12 Lake Brunner catchment: water quality

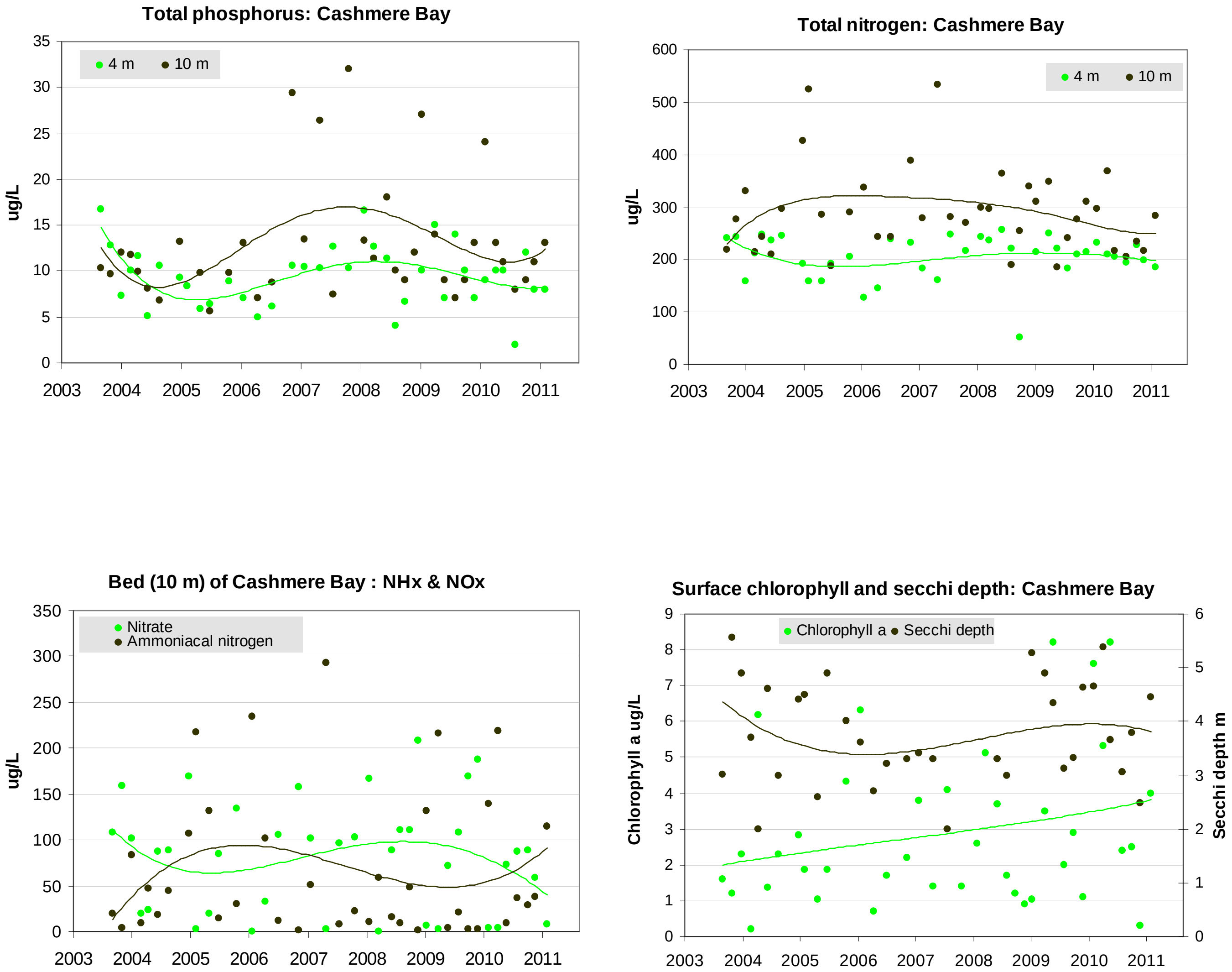


Figure 5.12.1 Total nitrogen, total phosphorus, nitrate, ammoniacal nitrogen, secchi depth and chlorophyll a, over time recorded at Cashmere Bay. Polynomial curves have been added to indicate trends.

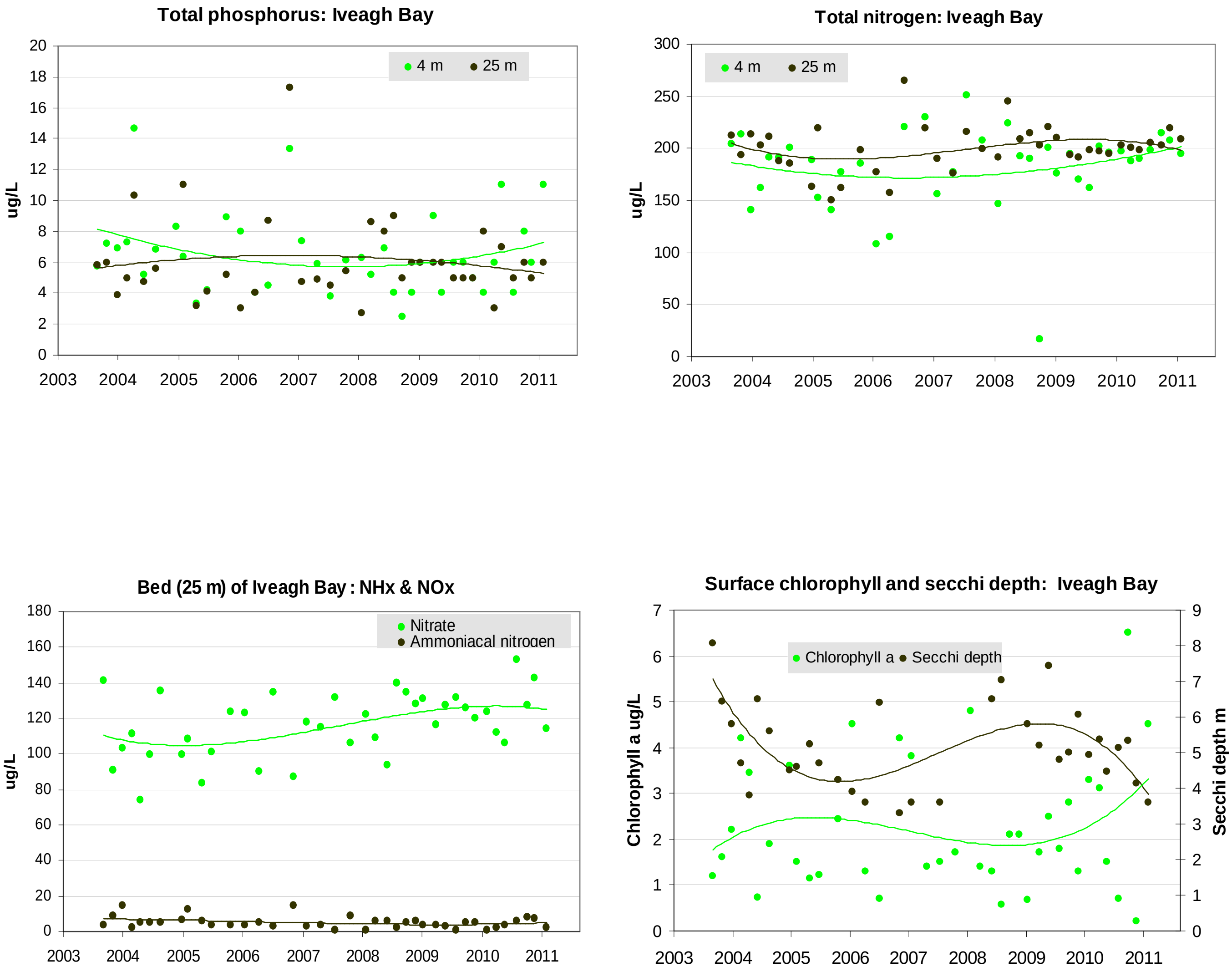
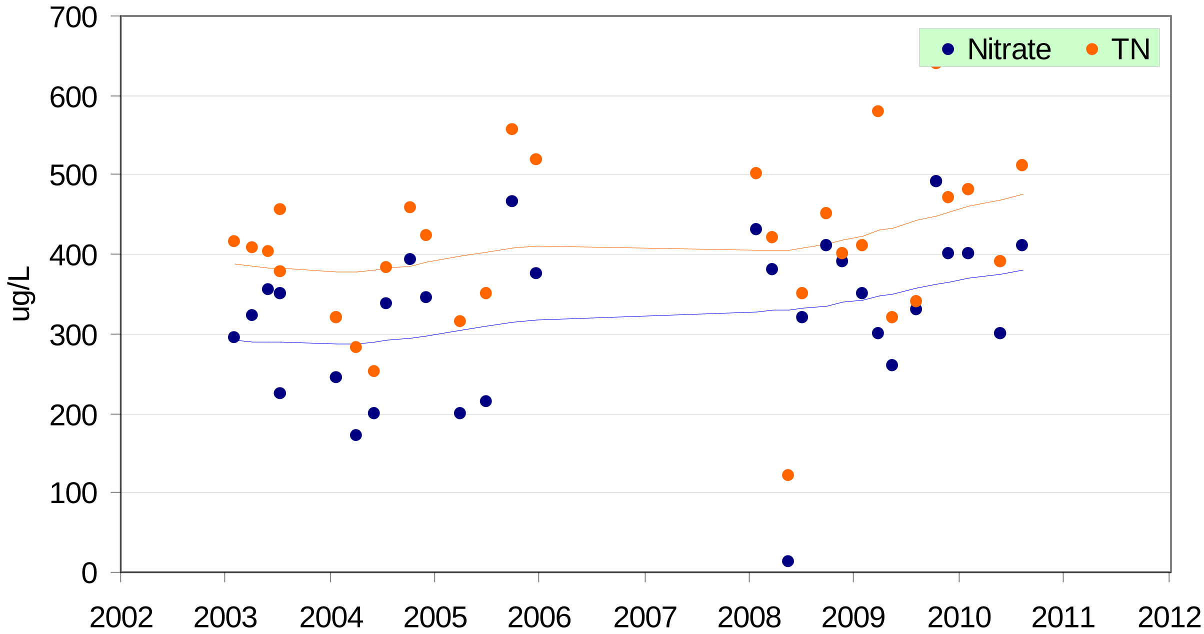


Figure 5.12.2 Total nitrogen, total phosphorus, nitrate, ammoniacal nitrogen, secchi depth and chlorophyll a, over time recorded at Iveagh Bay. Polynomial curves have been added to indicate trends.



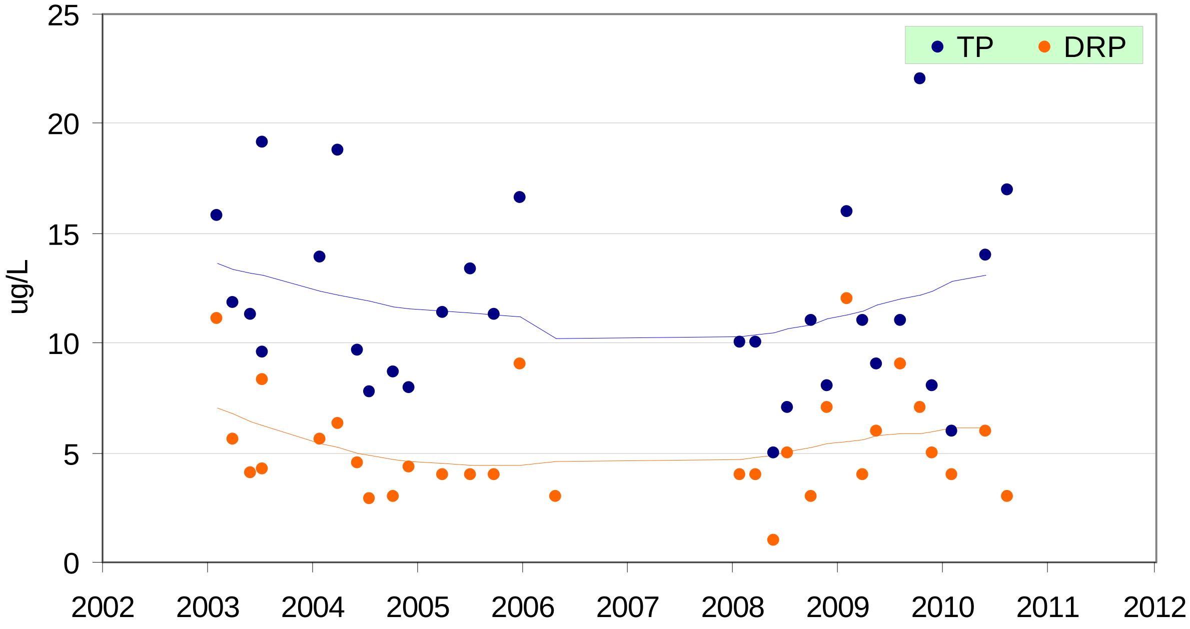
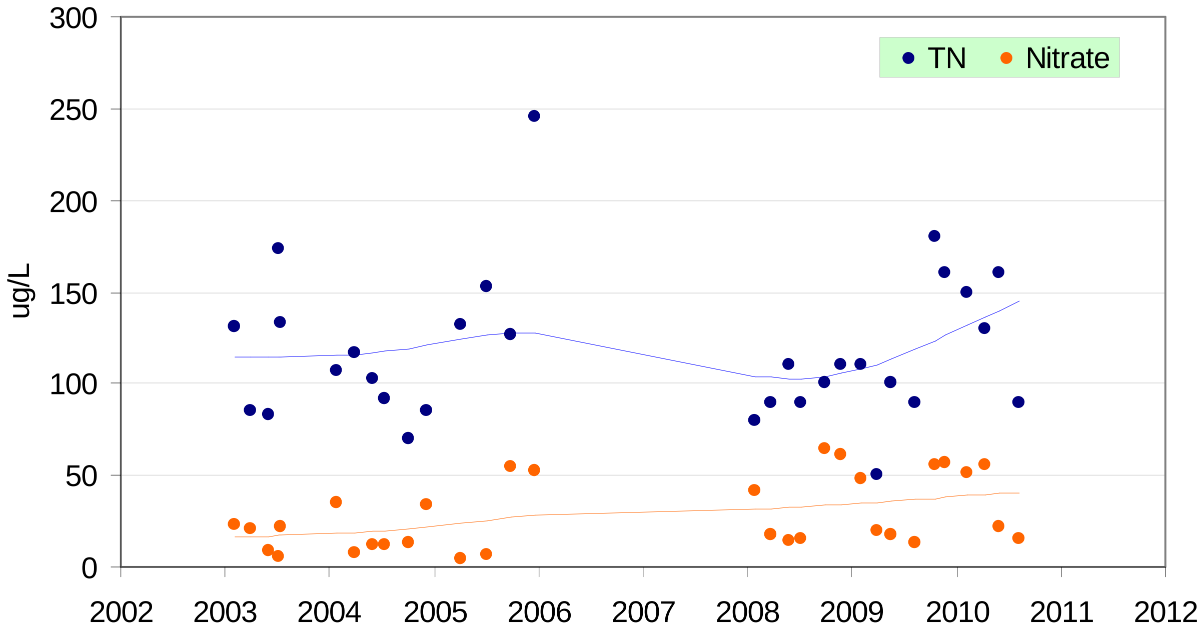


Figure 5.12.3 Phosphorus and nitrogen levels in the Orangipuku River measured near the river mouth, before it enters the lake. Trend lines have been calculated using LOESS smoothing.



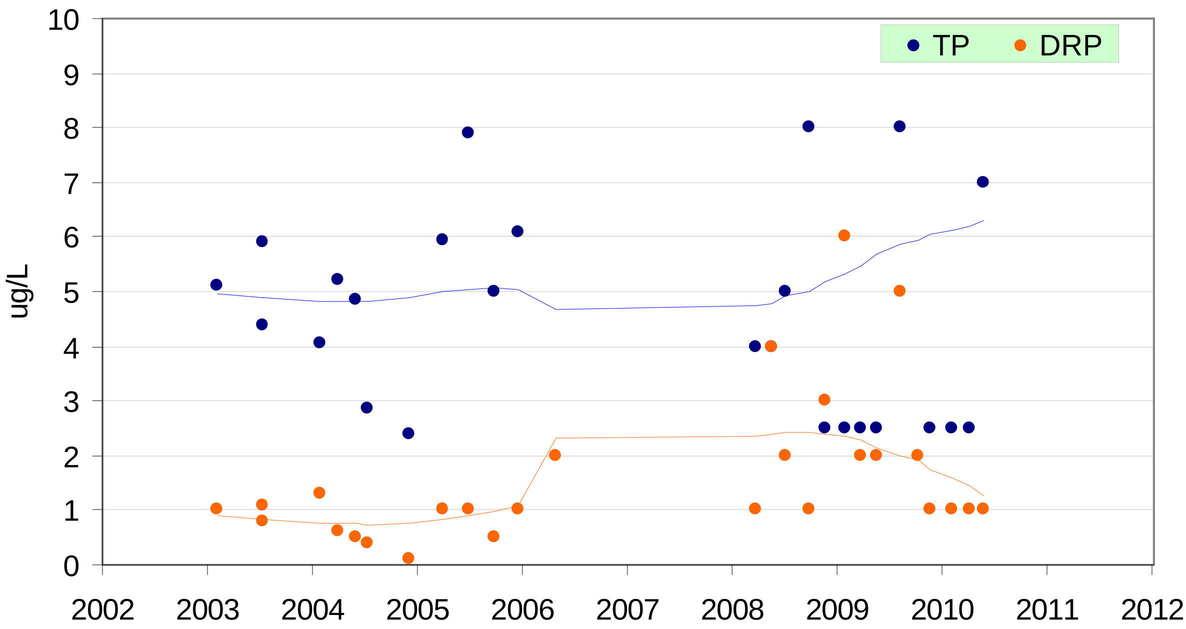
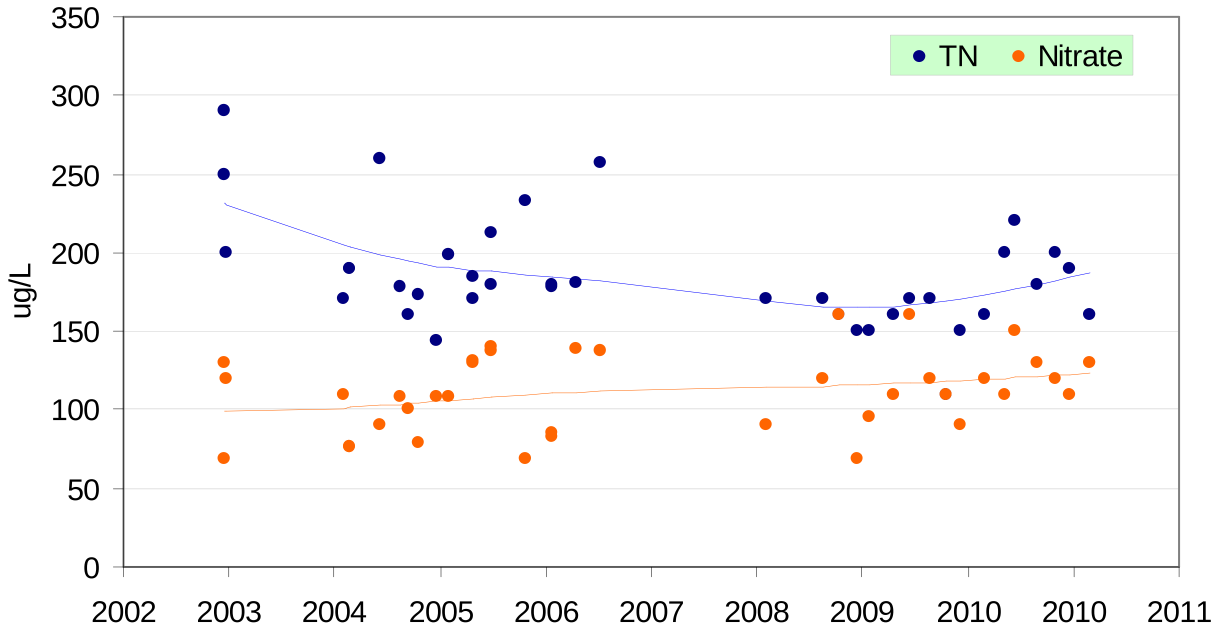


Figure 5.12.4 Phosphorus and nitrogen levels in the Hohonu River measured near the river mouth, before it enters the lake. Trend lines have been calculated using LOESS smoothing.



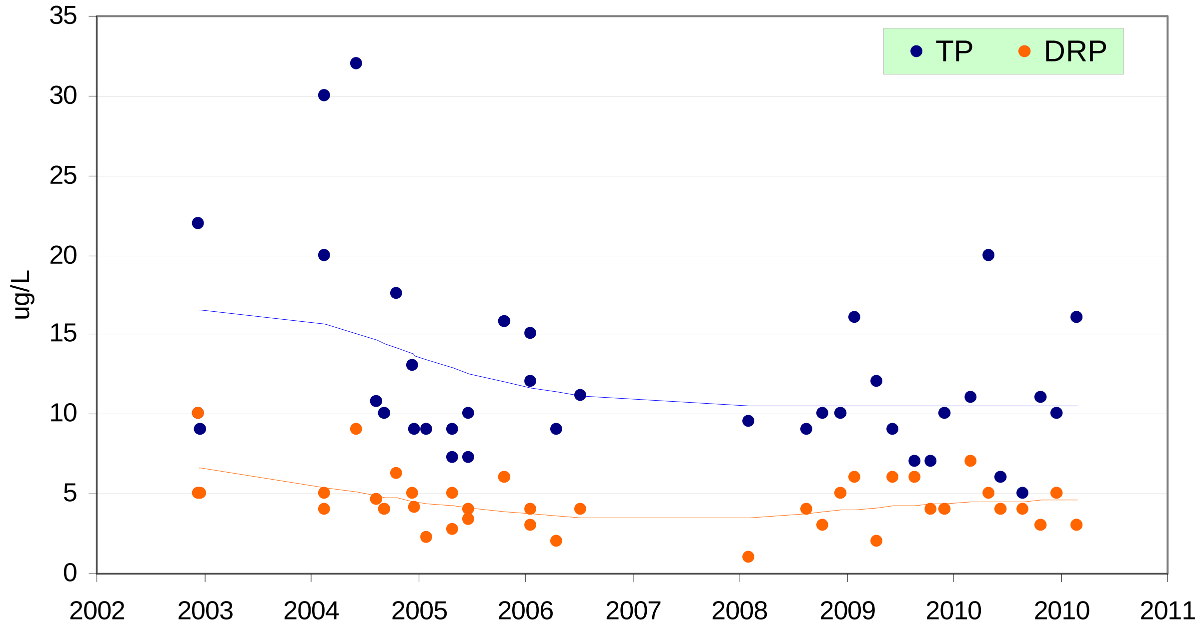


*Figure 5.12.5 Phosphorus and nitrogen levels in the **Crooked River** **measured at Te Kinga, near the river mouth,** before it enters the lake. Two very high TP readings (280 mg/m³ @ 2/5/03 and 300 mg/m³ @ 9/1/04) have been omitted to ease the interpretation of remaining data. Trend lines have been calculated using LOESS smoothing.*

5.13 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 5.13.1). 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 5.13.2). 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.

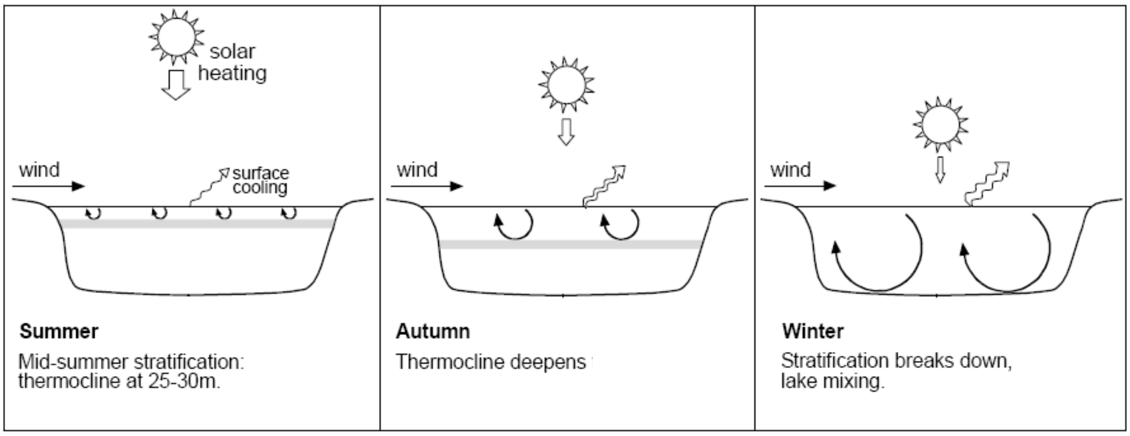


Figure 5.13.1 Lake stratification and mixing is dependent on the interactions of the sun's energy and wind energy and on the net effect of heating and cooling. The sun tends to heat the lake and increase stratification, the wind tends to mix the lake and break down stratification (courtesy of Kelly and Howard-Williams, 2003).

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.

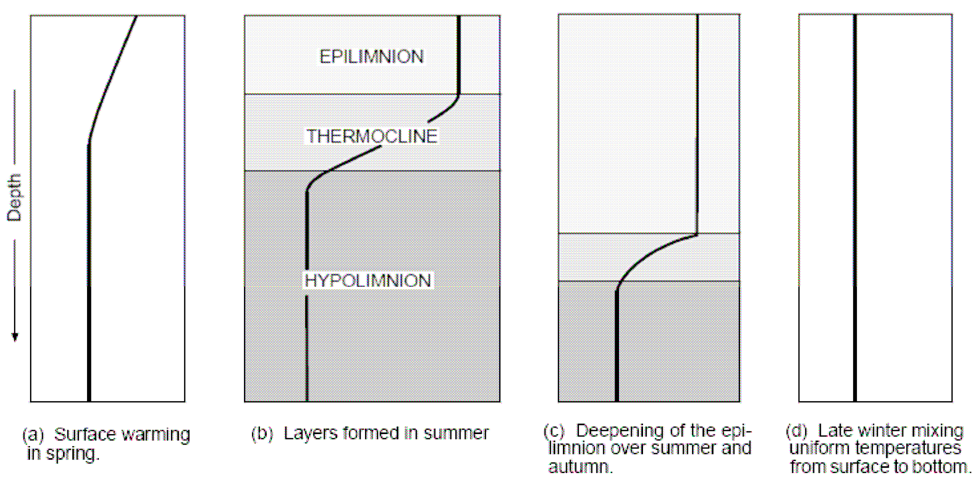


Figure 5.13.2 The mixing cycle of the water of Lake Brunner. Each panel represents water temperature with depth in the lake for a particular season: (a) spring, (b) summer, (c) late summer/autumn, (d) late winter. Water temperature is represented by the thick black line in each panel with temperature 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 affects on lake water quality, nutrients entering the lake from tributaries are the major concern.

6 References

American Public Health Association (APHA) 1992. Standard methods for the examination of wastes and wastewater. 18th Ed. American Public Health Association, Washington D.C.

Australian and New Zealand Environment and Conservation Council (ANZECC), 2000. Australian and New Zealand guidelines for fresh and marine water quality. Volume 2, Aquatic Ecosystems.

Ballantine, D.J., Davies-Colley, R. 2009. Water quality trends at National River Water Quality Network sites for 1989–2007. Prepared for Ministry for the Environment, Wellington, June 2000.

Biggs, B.J.F. 2000. New Zealand periphyton guideline: Detecting, monitoring and managing enrichment of streams. Prepared for Ministry for the Environment, Wellington, March 2009.

Biggs, B.J.F., Kilroy, C. 2000. Stream periphyton monitoring manual. Prepared for Ministry for the Environment, Wellington.

Boothroyd, I. and Stark, J. 2000. Use of invertebrates in monitoring. In Collier, K.J. and Winterbourn, M.J. ed. New Zealand stream invertebrate ecology and implications for management. New Zealand Limnological Society, Christchurch. pp 344-373.

CCREM (Canadian Council of Resource and Environment Ministers). 1987. Canadian Water Quality Guidelines. Prepared by the Task Force on Water Quality Guidelines. NIWA Client Report: CHC2008-077, June 2008. WCR08501

Collier, K.J.,Ball, O.J., Graesse, A.K., Main, M.R., Winterbourn, M.J. 1990. Do organic and anthropogenic acidity have similar effects on aquatic fauna? Oikos. 59:33-38.

Cox, T. and Rutherford, J.C. 2000. Thermal tolerances of two stream invertebrates exposed to diurnally varying temperature. New Zealand Journal of Marine and Freshwater Research. 34: 203-208.

Department of Health. 1992. Provisional microbiological water quality guidelines for recreational and shellfish-gathering waters in New Zealand. New Zealand Department of Health.

Francoeur, S.N., Biggs, B.J.F., Smith, R.A., and Lowe, R.L. 1999. Nutrient limitation of algal biomass accrual in streams: seasonal patterns and a comparison of methods. Journal of the North American Benthological Society. 18:242-260.

Hickey, C.W. and Martin, M.L. 2009. A review of nitrate toxicity to freshwater aquatic species. NIWA technical report HAM 2009-099.

Horrox, J. 2005. State of the Environment Report: West Coast Surface Water Quality, August 2005. The West Coast Regional Council. Technical report # 05001, August 2005.

Horrox, J. 2008. State of the Environment Report: West Coast Surface Water Quality, June 2008. The West Coast Regional Council. Technical report # 08002, June 2005.

Kelly, D. and Howard-Williams, C. 2003. Notes on changes in water quality of Lake Brunner: 1992-2002. Report prepared for the West Coast Regional Council by NIWA, June 2003.

Kilroy, C., Larned, S. T. and Biggs, B. J. F. 2009. The non-indigenous diatom Didymosphenia geminata alters benthic communities in New Zealand rivers. Freshwater Biology. 54(9): 1990-2002.

Larned, S., Scarsbrook, M., Snelder, T., Norton, N. 2005. National and regional state and trends in river water quality 1996-2002. Ministry for the Environment.

Lenat, D.R. 1988. Water quality assessment of streams using a qualitative collection method for benthic invertebrates. Journal of the North American Benthological Society. 5: 267-289.

Maasdam, R. and Smith, D.J. 1994. New Zealand's National River water Quality Network 2. Relationships between physico-chemical data and environmental factors. New Zealand Journal of Marine and Freshwater Research. 28: 37-54.

McNeill, A. R. 1985. Microbiological Water Quality Criteria: A Review for Australia. Technical Paper 85. Australian Water Resources Council.

Ministry for the Environment (MfE). 1992. Water Quality Guidelines No. 1: Guidelines for the control of undesirable biological growths in water. Ministry for the Environment, Wellington, New Zealand.

Ministry for the Environment (MfE). 1994. Water quality guidelines No. 2: Guidelines for the management of water colour and clarity. Ministry for the Environment, Wellington, New Zealand, June 1994.

Ministry for the Environment (MfE). 2003. Microbiological Water Quality Guidelines for Marine and Freshwater Areas. Ministry for the Environment, Wellington, New Zealand.

Ministry for the Environment (MfE). 2008a http://www.mfe.govt.nz/issues/land/land-cover-dbase/index.html.

Ministry for the Environment (MfE). 2008b. Environment New Zealand. Ministry for the Environment, Wellington, New Zealand, 31 January 2008.

Ministry for the Environment (MfE). 2010. http://www.mfe.govt.nz/environmental-reporting/freshwater/recreational/snapshot/coastal.html#current

Quinn, J.M. and Hickey, C.W. 1990. Characterisation and classification of benthic invertebrate communities in 88 New Zealand rivers in relation to environmental factors. New Zealand Journal of Marine and Freshwater Research Vol. 24: 387-409.

Richardson, J., Boubee, A.J., West, D.W. 1994. Thermal tolerance and preference of some native New Zealand freshwater fish. New Zealand Journal of Marine and Freshwater Research. 28:399-407.

RMA. 1991. New Zealand Resource Management Act.

Rowe, D. 1991. Native fish habitat and distribution. Freshwater Catch. 46:4-6.

Rutherford, K., Chague-Goff, C., McKerchar, A. 2008. Nutrient load estimates for Lake Brunner. Report prepared for the West Coast Regional Council: HAM2008 - 060, May 2008.

Scarsbrook, M. 2006. State and Trends in the National River Water Quality Network (1989–2005). Ministry for the Environment, Wellington, New Zealand, November 2006.

Scarsbrook, M. 2008. An assessment of river water quality state and trends for the West Coast Regional Council. NIWA Client Report: May 2008. NIWA Project: ELF082XX.

Scarsbrook, M.R., McBride, C.G., McBride, G.B. and Bryers, G.G. 2007. EFFECTS OF CLIMATE VARIABILITY ON RIVERS: CONSEQUENCES FOR LONG TERM WATER QUALITY ANALYSIS. Journal of the American Water Resources Association. 39 (6), 1435–1447.

Smith, D. G., Cragg, A. M., & Croker, G. F. 1991. Water clarity criteria of bathing waters based on user perception. Journal of Environmental Management. Vol. 36: 225-235.

Snelder, T., Biggs, B., Weatherhead, M. 2003. New Zealand River Environment Classification: a guide to concepts and use. Ministry for the Environment.

Spigel, R. 2008. Lake Brunner study: modelling thermal stratification. NIWA Client Report prepared for the West Coast Regional Council: CHC2008—080, June 2008.

Stark, J.D. 1985. A macroinvertebrate community index of water quality for stony streams. Water and Soil Miscellaneous Publication, 87: 53.

Stark, J.D. 1993. Performance of Macroinvertebrate Community Index: effects of sampling method, sample replication, water depth, current velocity, and substratum on index values. New Zealand Journal of Marine and Freshwater Research, 21: 463-478.

Stark, J.D. 1998. SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. New Zealand Journal of Marine and Freshwater Research. 23:55-66.

Vant, W. 2007. Trends in River Water Quality in the Waikato Region, 1987-2007. Environment Waikato Technical Report 2008/33. July 2008.

Viner, A.B. (Ed.). 1987. Inland Waters of New Zealand. DSIR Science Information Publishing Centre. pp 494.

Wessa, P. (2011), Free Statistics Software, Office for Research Development and Education,version 1.1.23-r6, URL http://www.wessa.net/

West Coast Regional Council. 2007. Proposed Water Management Plan. The West Coast Regional Council, Greymouth, New Zealand. June 2007.

Zemansky, G. and Horrox, J. 2008. Groundwater assessment: Kowhitirangi and Kokatahi Plains, Hokitika – 2007. West Coast Regional Council Technical report 08002. http://www.wcrc.govt.nz/Resources/Documents/Publications/Environmental%20Management/Council%20Monitoring%20Reports/Kowhitirangi%20and%20Kokatahi%20plains%20groundwater%202007.pdf

Figures and tables

List of figures

Page

List of tables