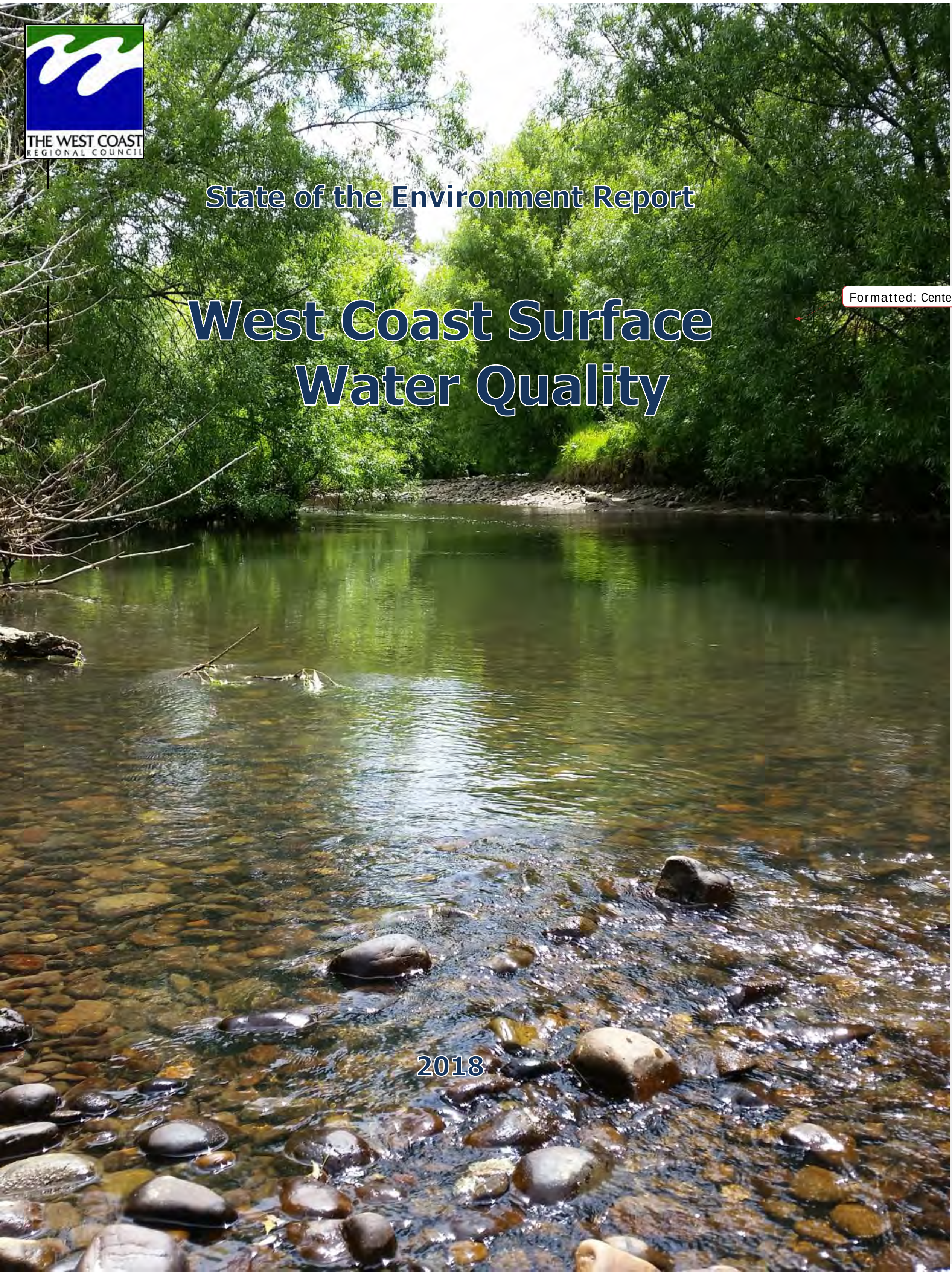

THE WEST COAST
REGIONAL COUNCIL

State of the Environment Report

West Coast Surface Water Quality

2018

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West Coast Surface Water Quality

State of the Environment Technical Report 18001

2018

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Executive Summary

This report summarises results from the West Coast Regional Council Surface Water Quality Monitoring Program, for data up until 2018. This program assesses water quality state and trends at sites that are predominantly subject to human impacts/pressures. River quality and contact recreation suitability are covered – lake quality is presented in separate publications.

Thirty-nine sites from the West Coast Regional Council's river water quality monitoring program were assessed for a range of physical, chemical, and biological attributes. Data from an additional five sites that were part of NIWA's National River Water Quality Network were included in the analysis. Sites were sampled four to twelve times per year. Data from the West Coast Regional Council Contact Recreation water quality program has also been included, consisting of 18 sites.

State of water quality in the West Coast Region

Previous analysis has shown that waterways in indigenous forest dominated catchments have better water quality compared to those in pasture catchments, which is consistent with other parts of the country. Streams affected by acid mine drainage, with elevated acidity and metals, had reduced stream health. Sediment from mining operations, if significant, can reduce stream health but impact is less when not combined with acid mine drainage.

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

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Invertebrate indices suggested that approximately three-quarters~~half~~ of the sites had slight to un-impacted water quality, with the bottom quarter consistently having moderate to poor water quality. Nuisance periphyton growths were 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 likely to be a factor limiting nuisance algal growth.

Sites most suitable for swimming are typically located at West Coast lakes. Coastal beach sites were often good, with periodic exceptions while river sites exceeded bathing water quality guidelines the most. Rivers are affected by run-off, generated by rain events, which transport pathogen indicator bacteria from land to water. Pathogen risk for swimmers was normally higher at all sites during and after rain events.

Trends in West Coast water quality

Ammonia improved at 38% of WCRC sites and 40% of NIWA sites, mirroring the trend observed around New Zealand, and suggesting an overall improvement in the management of point source discharges. Improving levels in phosphorus at many sites may also be due to better discharge and nutrient management. Elevated nitrate nitrogen is associated with agriculture, and an increase in nitrate at 20% of sites (and 60% of NIWA sites) likely reflects increasing agricultural intensification, as does an increase in total nitrogen at a third of all sites. Nitrate levels are not toxic in West Coast rivers, but they are high enough to support nuisance algal growth if conditions are suitable. Few sites displayed actual trends in algal abundance.

To a point, dissolved natural substances can reduce clarity of West Coast waterways. Suspended material such as sediment will reduce clarity and make water turbid. There were twice as many sites deteriorating as were improving for these qualities, with no trend for the remaining ~75% of sites. 60% and 40% of NIWA sites had declining trends for clarity and turbidity respectively. Fewer sites displayed trends in *E. coli* concentrations; a decline was apparent at four WCRC sites (11%), with one site improving. Overall, there were no relationships between water quality state and water quality trends, although a small number of sites that had the most rapid decline for an attribute, relative to other sites, also had the poorest water quality states.

Statement of data verification and liability

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

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

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

Acknowledgements

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

- Staff of the West Coast Regional Council.
- National Institute of Water and Atmospheric Research (NIWA): Rob Davies-Colley, Paul Lambert, Pete Mason, Mike O'Driscoll, and John Porteous.
- Bill Dyck and Envirolink.
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1 Introduction

1.1 Rationale

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

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

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

1.2 The monitoring program

The Surface Water Quality Monitoring Program (monitoring program) has involved the collection of data on water quality, periphyton (algae on the stream bottom) and stream invertebrates from selected rivers and streams since the mid-nineties. Additional information has also been collected during the Council's contact recreation surveys and as part of scientific studies carried out in the West Coast region. Detailed specifications of the Regional Council sampling program are provided in Section ~~4.1 and~~ 5.4. The National Institute of Water and Atmospheric Research's (NIWA)'s National River Water Quality Network has five sites within the West Coast region that have been sampled monthly since 1989, and data from this program is incorporated into analysis presented in this report. Lake Brunner is a particular area of focus where monitoring is conducted at a range of sites in the lake and its tributaries as part of the monitoring program.

Field Code Changed

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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 5.5 & 5.6. Maps showing the location of monitoring program sites are provided in Section 5.1~~Section 4.1.~~

Aims of the West Coast monitoring program are:

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

- To identify environmental effects and compare to relevant guidelines and standards. .
- To understand the nature of surface water quality problems/issues in order to provide information that enables defensible management responses to be enacted. Such responses include seeking reviews to Regional Council resource management plans, regulations, and resource consent conditions.
- To identify new issues and monitoring requirements.
- To identify factors that cause change in surface water quality (i.e. impact monitoring).

The monitoring program was designed to achieve these aims. However, the program must work within a number of constraints. Given the resources available, quarterly sampling was ~~is~~ undertaken until autumn 2016. Since then sampling frequency has incrementally increased to monthly at most sites. Due to the increased frequency of sampling the sampling protocols have also changed. Previously, sampling only occurred at base flow so very little was~~is~~ known about water quality after rain or flood flow conditions. Sampling now occurs on a recurring schedule meaning that sites are sampled at the same time each month irrespective of prior rainfall. Due to the larger amount of data now being collected, we are better able to deal with spikes that we get in our dataset after heavy rainfall. Monthly sampling gives a better representation of overall water quality at sites. For the Contact Recreation Water Quality Monitoring Program, sites are sampled twice-monthly from November-March, during base flow and non-rainfall periods. From summer 2018 five sites, identified as being susceptible to more catchment pressures, have been sampled weekly. While information from the monitoring program will give clues as to the cause of poor water quality, it is often only after intensive sampling within a catchment that clear conclusions of cause and effect relating to specific land-use activities can be drawn. Such follow-up investigations are undertaken on a prioritised basis.

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

(a) Geographical spread throughout the West Coast region;

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

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

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

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

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

2 State of surface water quality on the West Coast

Summary of surface water quality state on the West Coast

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

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

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

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

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The National Policy Statement for Freshwater Management (NPS-FM) was introduced in 2014. This contained the National Objectives Framework (NOF), which has been applied to a range of lake and river water quality attributes. 2019 draft NOF guidelines for DIN and DRP have also been applied as these were not previously included in the 2014 NOF.~~.~~In general, lake and river attributes covered by the NOF scored well (e.g. A), and were well above national bottom lines (e.g. D), with the exception of *E. coli* for which a number of sites are below the bottom line.~~.~~

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Comparison of data for water quality attributes with their respective guidelines and benchmarks indicated a broad range of results among sites. Some sites rated poorly for many attributes, while other sites only rated poorly for some. The particular natural characteristics of a water body can mitigate or exacerbate anthropogenic effects, and are an important consideration when comparing water quality among sites. Invertebrate indices suggested that approximately three-quarters~~half~~ of the sites had MCI and SQMCI scores indicative of slight to un-impacted water quality, with the bottom quarter consistently rating as having moderate to poor water quality. Nuisance periphyton growths have been infrequent at most sites. Often substantial nitrogen is not combined with sufficient phosphorus levels for nuisance periphyton growth to occur. The West Coast's cool wet climate is also likely to be a limiting factor.

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

2.1 Conclusions from previous state of the environment analyses

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

2.1.1 REC analysis

The 2005 Regional Council SoE report covered Regional Council data records up until 2004–2005, conducting analysis under the framework of the River Environment Classification (REC). The REC was used to group sites by climate, source of flow, geology, land cover, and stream order. Refer to Section 5.6 for a detailed description of the REC. Relationships between these REC classes and water quality were investigated.

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

- Streams with a hill source of flow; hard sedimentary or plutonic geology; often incorporating larger rivers; with higher, less variable water quality; brown trout more abundant.
- Lowland streams (low elevation source of flow); higher turbidity, nutrients, and temperature (which may not solely have been a response of human activity); smaller, more variable and susceptible to impact; potentially higher fish and invertebrate diversity.
- Streams draining predominantly agricultural catchments (sub-set of lowland streams); comparatively poorer water quality with fewer sensitive macroinvertebrate taxa.

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

2.1.2 Effect of land use on water quality

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

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

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

Sites in the following percentage bar graphs are ordered according to their median value, for each particular water quality attribute. Five years' worth of data was used for the analyses ~~Data was drawn~~ from 2013~~04~~ to early 2018~~14~~. For all attributes, sites go from a desirable condition to an undesirable one, from left to right, respectively. So medians go either from low to high or vice versa depending on whether a high value is good or bad. For example, higher clarity is good but higher turbidity isn't. Further information on the origin, meaning and rationale behind criteria used for categories is presented in Section ~~4.3~~4. A model of one of these percentage bar graphs is provided in Section ~~4.5~~6 to aid with interpretation. For more detailed information on data ranges for each water quality attribute, per site, the reader is directed to box and whisker plots in Section ~~4.6~~7.

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Some attributes are not described by percentage bar graphs. These are instead covered by tables that have scores derived through the National Objectives Framework (NOF) methodology. The NOF framework is part of the National Policy Statement for Freshwater Management (NPS-FM 2014). There are four scores in the NOF framework: A, B, C, and D (E. coli includes a fifth 'E' category)~~.~~ The NPS-FM states that values below C are considered to be below the national bottom line. River attributes where the NOF system has been applied include: nitrate, total ammonia,~~ and~~ *E. coli*, and dissolved oxygen~~.~~ NOF scores are calculated from a five year block of data. Up to five years of NOF scores have been provided for comparison, but trends are better evaluated with the techniques used in Section 3. Some attributes (clarity and periphyton) have been assessed using a NOF-like system derived from other guidelines, refer to individual attributes detailed information in section 2.2. Dissolved reactive phosphorus and dissolved inorganic nitrogen have been assessed using 2018 draft NOF scores.

~~No data for pH has been presented in this section. There are a variety of drivers that influence pH on the West Coast, and a low or high pH could be either good or bad depending on what is driving it. For example, there are several sites that have pH levels around pH 4, for example Page Stream and Okutua Stream. Low pH at the former site is caused by historic mining, and in combination with dissolved metal~~

toxicity and precipitates that smother the bed, aquatic biodiversity is low. In contrast Okutua Stream is pristine and the dissolved organic acids reducing the pH do not have a significant effect on stream biota.

2.2.1 Temperature

Few sites had high temperature i.e. above 20°C, when sampled (Figure 1). Twenty degrees is restrictive for temperature sensitive species e.g. trout, certain stoneflies, and some native fish. Sites that had temperatures exceeding 20°C varied regarding their catchment type and physical characteristics. The Arnold River @ Kotuku Fishing Access has high water quality and is close to the outlet of Lake Brunner. Warm summer surface layers in the lake are likely to elevate river temperatures, which decrease downstream with additions from cooler tributaries. Generally, sites with a lack of riparian shading and/or small flows had high temperatures in warm, sunny weather. Thirteen~~en~~ sites recorded temperatures over 20°C, with Baker Ck ~~radshaws Ck~~ @ Oparara~~Bradshaws~~ Rd recording a temperature of 24.91~~2~~°C (Figure 30). It should be noted that temperatures used in this analysis are collected over the entire year, and are based on single spot samples. Summer medians will be higher. Also, maximum values at these sites will be higher than what is reported here. ~~This would be apparent if~~ C~~c~~ontinuous temperature monitoring has been carried out at some sites – many have permanent continuous temperature loggers however a few sites have only had short deployments in summer months (for example Sawyers Ck @ Bush Fringe). Figure 2 shows this data, separated into geographical areas.~~was utilised~~. Northern sites generally had some of the warmer temperatures – Blackwater Ck in Karamea had the highest median temperature. Stream size, shading and source are all factors that affect temperature. Spring fed creeks such as Duck Ck, Harris Ck and Murray Ck in the Hokitika Valley, generally retain lower water temperatures than other sites due to continual recharge from groundwater. Most sites monitored in the Grey Valley reached maximum temperatures over 25°C. Burkes Ck, a small relatively unshaded creek in the upper Grey Valley, reached a maximum temperature of 29.84°C. Well shaded creeks such as those draining bush covered land, for example Okutua Ck at Okarito Forest and Orangipuku Rv @ Kumara-Inchbonnie Rd, generally had cooler temperatures and a smaller temperature range.

There is currently no NPSFM NOF for temperature, a method developed by Davies-Colley et al. 2013 has been used to determine state from continuous data. This method uses a CRI mean, calculated on the 5 hottest days in summer, to assign a state from A to D.

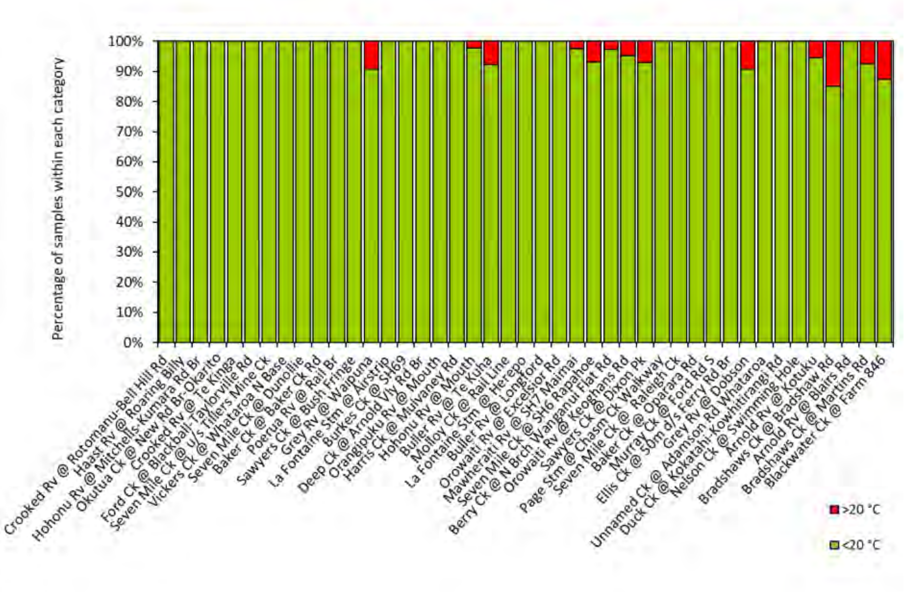
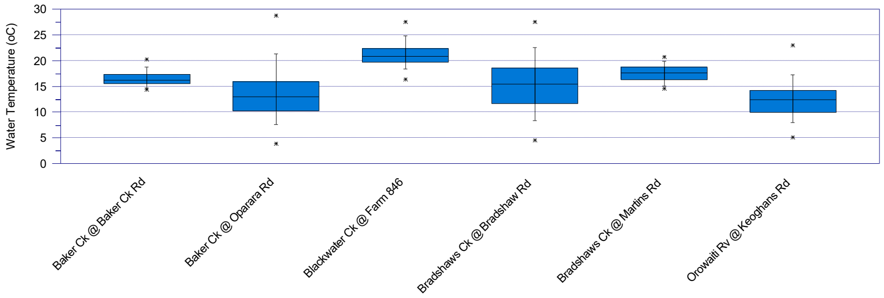
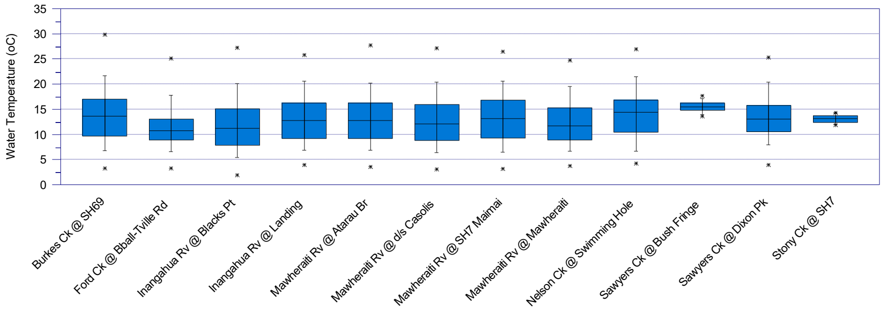


Figure 1 Percentage of samples in respective water temperature categories for individual Regional Council monitoring program sites 2013 – 2017.





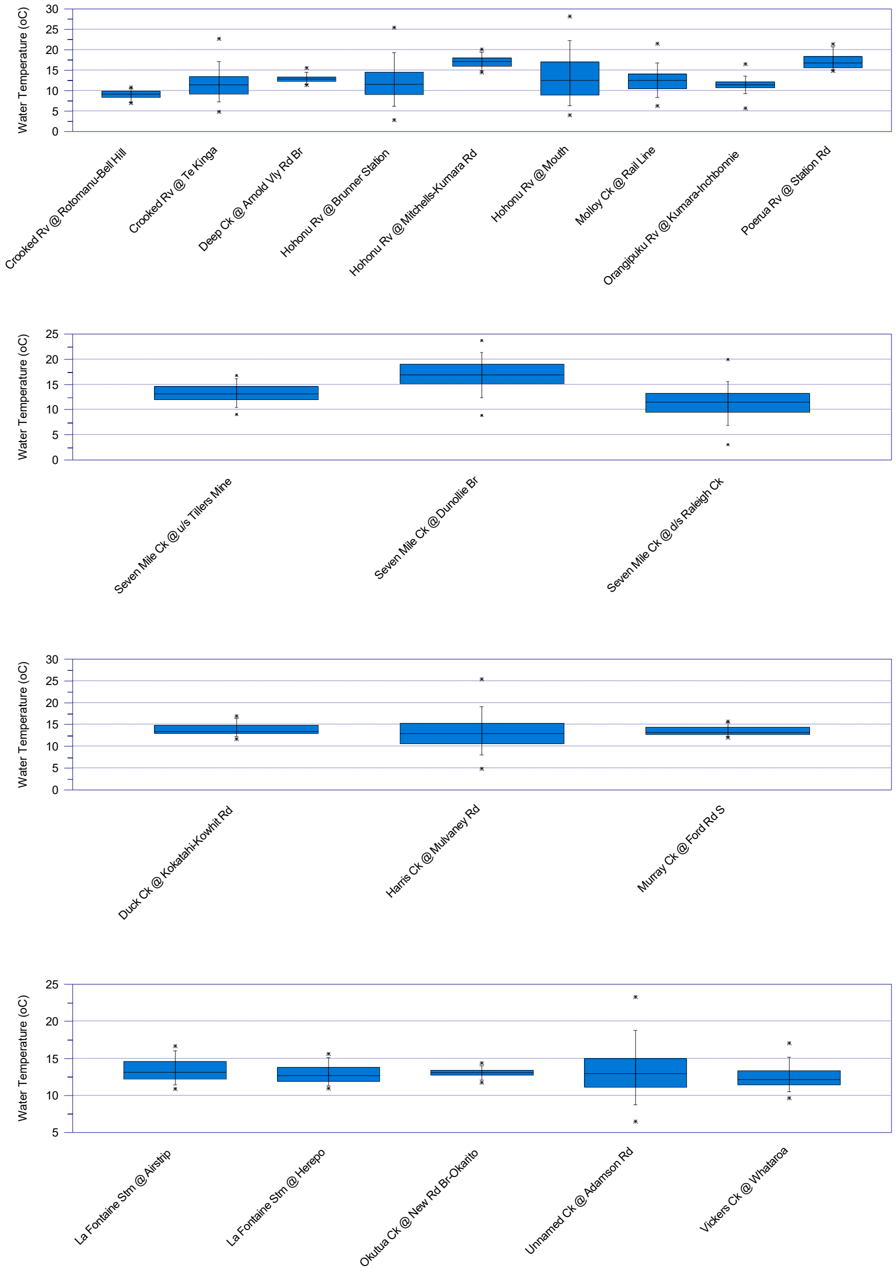


Figure 2 Box and whisker graphs showing the spread of water temperature data for individual Regional Council monitoring program sites 2013 – 2017 where there is continuous data available. Graphs group sites into geographical areas.

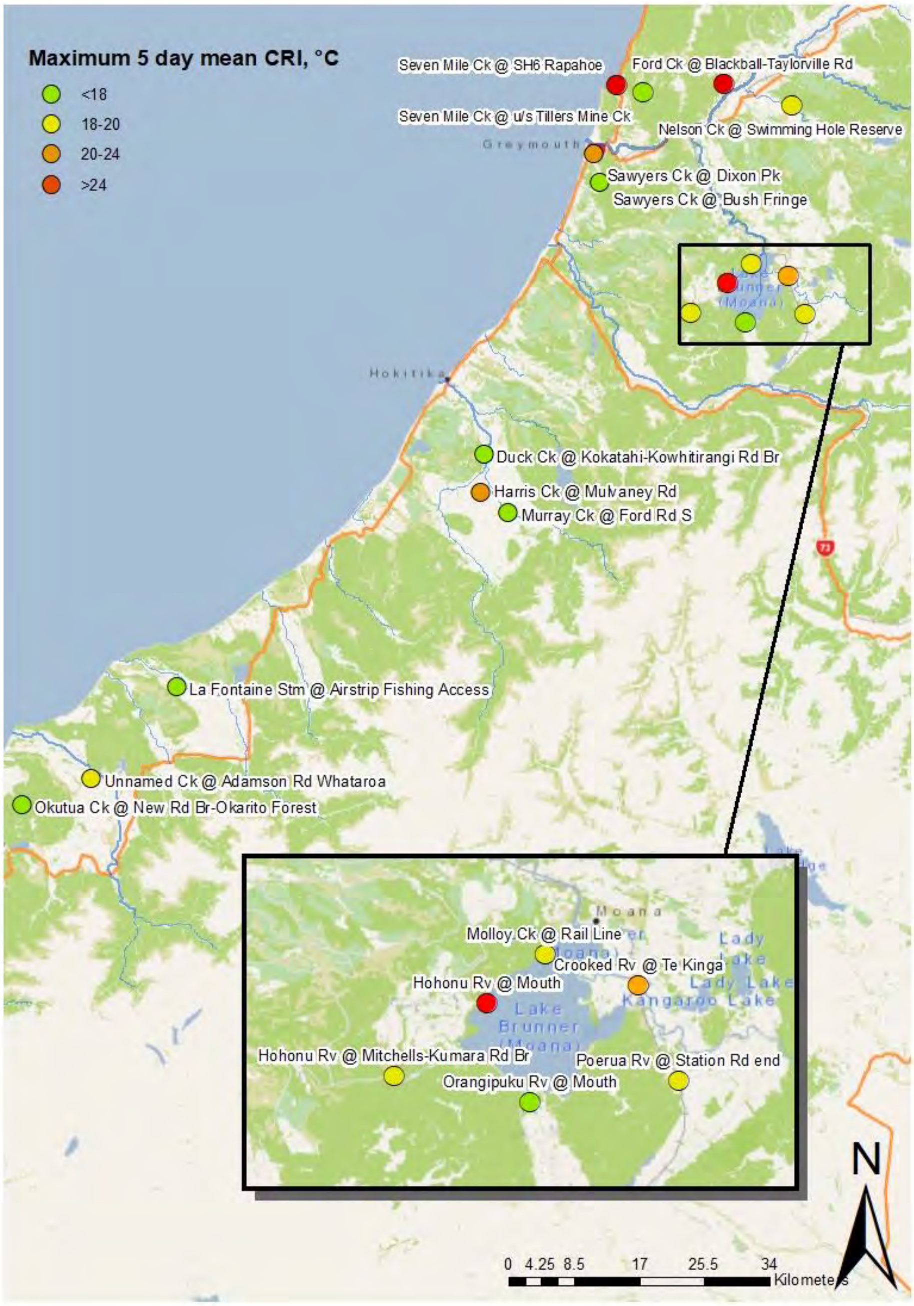


Figure 3 Map showing state of temperature at monitored waterways in the Grey and Westland districts of the West Coast based on a CRI mean, calculated on the 5 hottest days in summer. Green = A state, yellow = B, orange = C and red = D.

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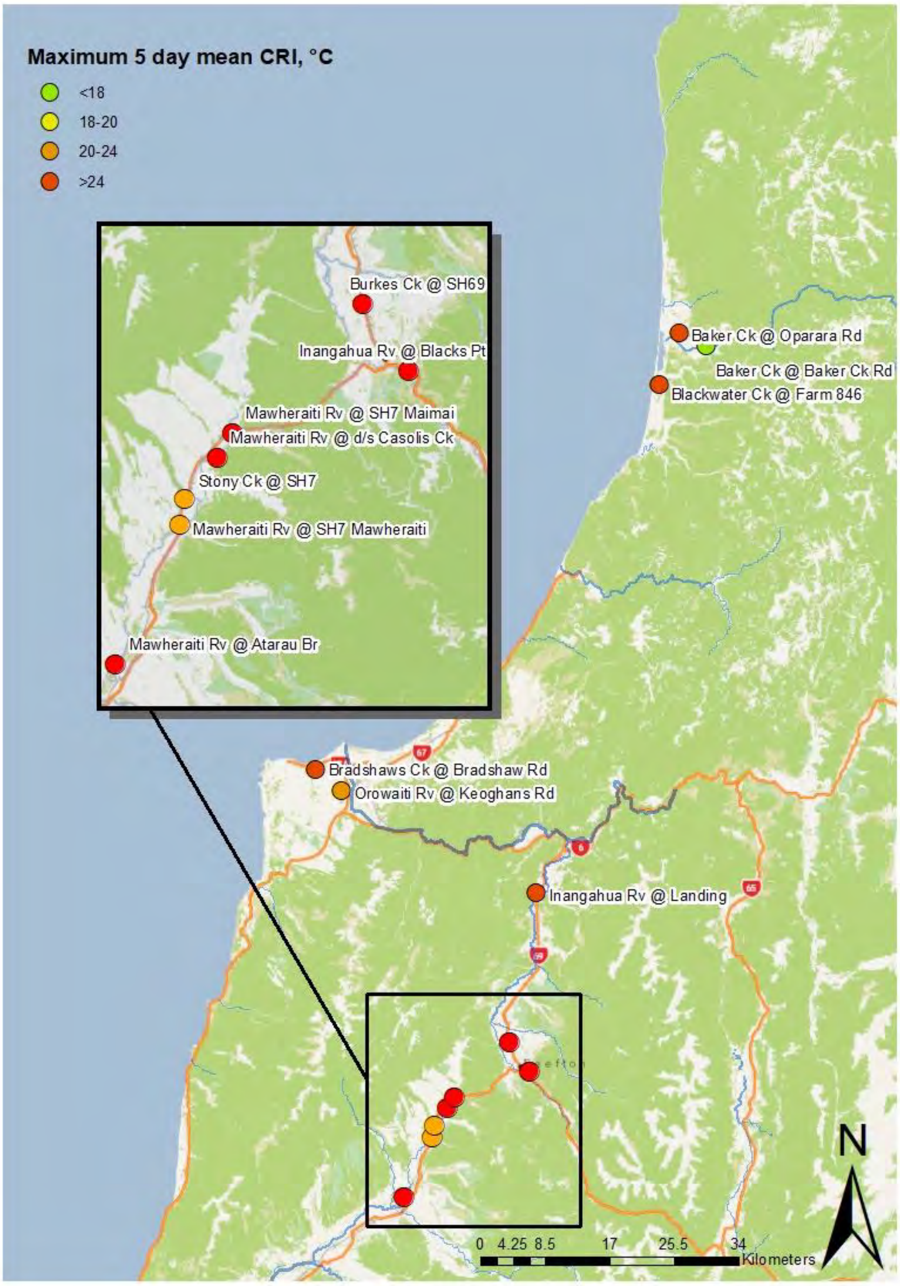

Figure 4 Map showing state of temperature at monitored waterways in the Buller district and upper Grey district of the West Coast based on a CRI mean, calculated on the 5 hottest days in summer. Green = A state, yellow = B, orange = C and red = D.

2.2.2 Turbidity

Three~~wo~~ sites had median turbidity over 5.4~~6~~ NTU (Blackwater Ck, ~~and~~ Ford Ck and Burkes Ck) (Figure 5). These sites have different reasons for higher turbidity. Erodible sedimentary geology is a common reason, usually combined with varying degrees of human disturbance. Sediment contributions from current and historic mining related activities are a feature in the Ford Creek, ~~and~~ Seven Mile Creek, ~~and~~ Page Stream and Burkes Creek catchments, with urban activity a feature in Seven Mile and Sawyers Creeks. In general, agricultural land use within a catchment leads to increased downstream turbidity. It is worth noting the influence of geology: For example, reference sites on Sawyers and Baker Creeks – both draining catchments with predominantly soft sedimentary geology – have higher median turbidity compared with the Orangipuku River. Much of the Orangipuku River drains intensive agricultural land, but it is spring-fed, with hard plutonic geology, thus yields water with relatively low turbidity. Duck CK?. Figure 4 shows continuous turbidity data for sites where this is available. This data is from short term sonde deployments, with the exception of Mawheraiti River @ Atarau Rd Br which has a continuous turbidity sensor installed. Of these sites, Un-named Creek @ Adamsons Rd has the highest median turbidity. This catchment is high in agricultural land use and has soft sedimentary geology. Nearby Vickers Creek has lower median turbidity over the same period of continuous data collection. Vickers Creek is a larger waterway, spring fed and for a larger part of its stretch has more riparian cover, which may help reduce surface run-off???

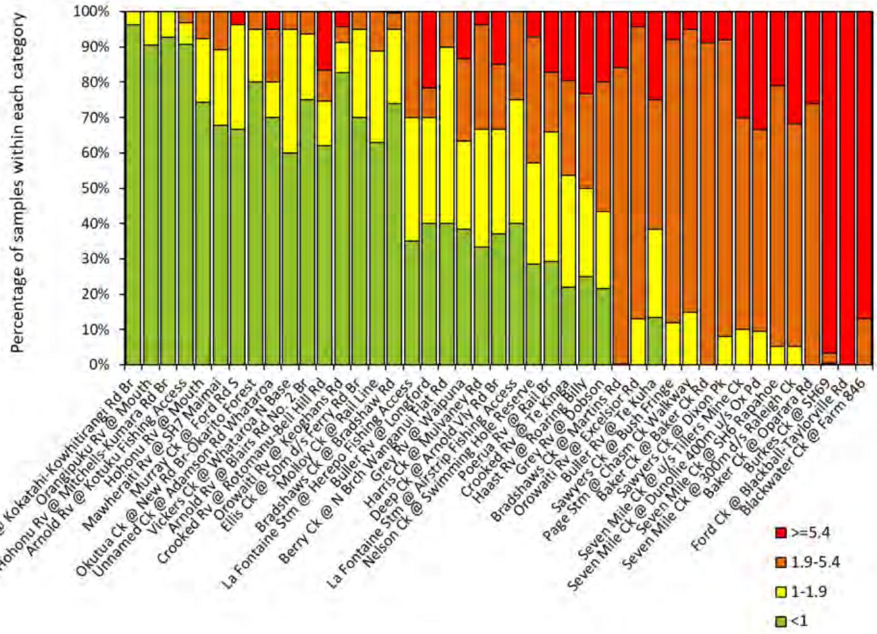

Figure 5 Percentage of samples in respective turbidity categories for individual Regional Council monitoring program sites 2013 – 2017

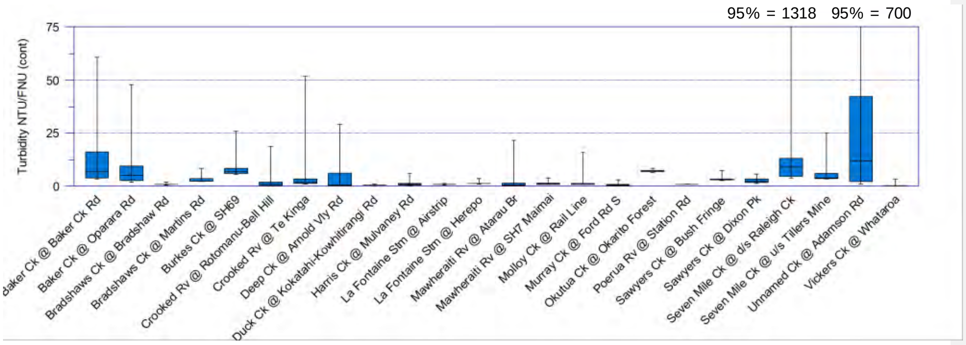

Figure 6 Box and whisker graphs showing the spread of turbidity data for individual Regional Council monitoring program sites 2013 – 2017 where there is continuous data available (maximums excluded).

2.2.3 Dissolved oxygen

Dissolved oxygen is an important factor affecting fish and macroinvertebrate health. 71% of sites have dissolved oxygen levels indicative of no, or minor, stress for sensitive species based on NOF scores of 1-day minimum and/or 7-day mean minimum dissolved oxygen over summer (Figure 8). Significant stress and reduced ecological health was measured for 8% of sites. Factors such as temperature and macrophyte and algal abundance affect the range of dissolved oxygen measured at a site. Un-named Creek @ Adamsons Rd shows the greatest range of dissolved oxygen (Figure 7). This site has high macrophyte and filamentous algae cover, especially over summer, which drives diurnal changes in dissolved oxygen - resulting in low morning dissolved oxygen (due to respiration) and supersaturation in the afternoons (driven by photosynthesis). Nutrients and discharges from wastewater can also affect levels of dissolved oxygen. Sawyers Creek @ Dixon Park has median dissolved oxygen lower than most sites. It is in an urban catchment with stormwater and septic tank discharges, some agricultural land use, is tidal and has warm temperatures over summer. Warmer water with higher salinity can hold less oxygen. Duck Ck @ Kokatahi-Kowhitirangi Rd Br also has lower median dissolved oxygen compared to other sites. Spring fed = lower oxygen from groundwater contribution?

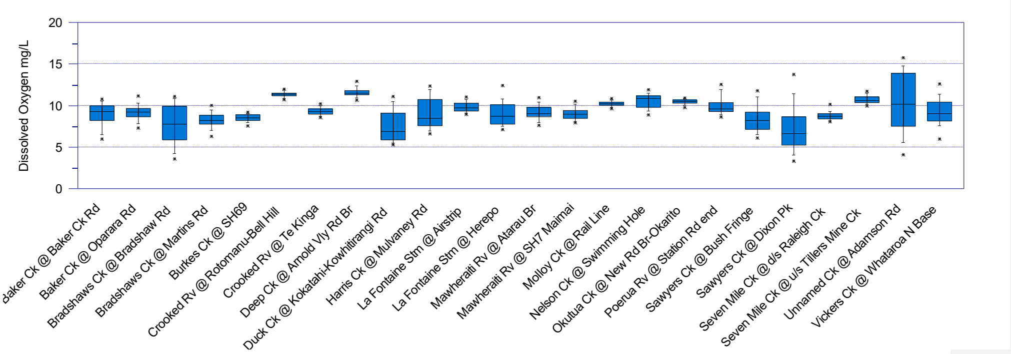

Figure 7 Box and whisker graphs showing the spread of dissolved oxygen (mg/L) data for individual Regional Council monitoring program sites 2013 – 2017 where there is continuous data available.

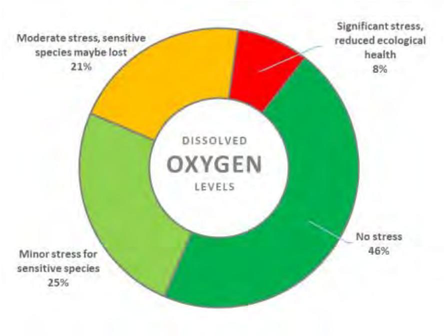

Figure 8 Doughnut graph showing NOF categories for dissolved oxygen (mg/L) for Regional Council monitoring program sites 2013 – 2017?

2.2.4 pH

pH has not been included in previous SOE reports as only spot data was available and due to the diurnal variability of pH (due to temperature and oxygen changes) this was not considered sufficient to provide an accurate representation of state. Continuous pH data has now been collected at a number of sites during short term sonde deployments (Figure 7). pH can be influenced by a range of factors including catchment geology, land cover, anthropogenic activities, macrophyte and algal cover. Un-named Creek @ Adamsons Rd has higher pH due to respiration and photosynthetic processes from high macrophyte and filamentous algae cover. Harris Creek has similar factors affecting pH. Some anthropogenic activities can reduce the pH of waterways though exposure of acid forming rock to water however low ph can also occur naturally. Okutua Stream @ Okarito Forest has naturally low pH due to dissolved organic acids leaching from the bush covered catchment.

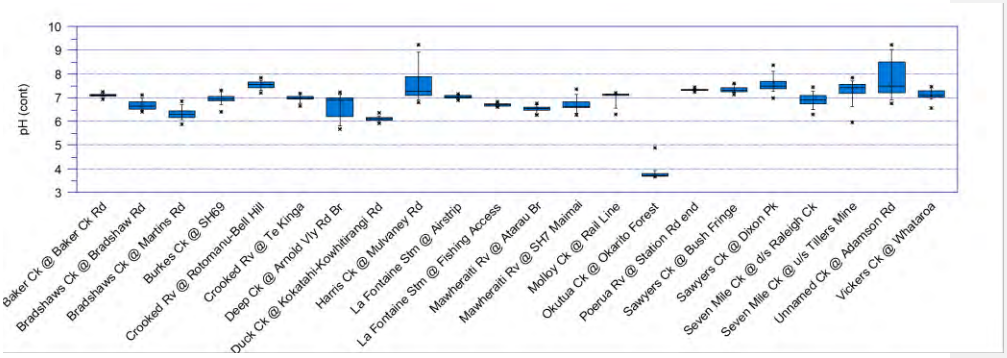

Figure 9 Box and whisker graph showing the spread of pH data for individual Regional Council monitoring program sites 2013 – 2017 where there is continuous data available.

~~2.2.4~~2.2.5Clarity

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 – geology, land use etc (Figure 10). Horizontal clarity, measured with a black disk, is a more sensitive measure of suspended material than turbidity in clear waters that have low coloured dissolved organic matter (CDOM). CDOM is the brown 'tea' staining colour found in many West Coast streams. It is a natural feature that can significantly reduce water clarity. This is the reason for the relatively low clarity observed in the Okutua Stream, which is a pristine site in Okarito Forest. Median clarity for this site was in the middle of the field compared to other sites, yet the quantity of sediment deposits, and suspended sediment (as indicated by turbidity) was low. Median clarity at Okutua Stream has never failed the 1.6 m contact recreation guideline.

The NPSFM does not currently include a NOF category for clarity. WCRC has determined categories deemed appropriate based on other guidelines available. Under the Land and Water Plan (2014) all water bodies are to be managed for aquatic ecology, to which the 0.8 m clarity threshold applies. The minimum clarity for swimmability is 1.6 m and median clarity of waterways (as determined by Stats NZ) is 2.62 m. The grades of A to D are derived from these guidelines. Ninety eight~~seven~~ percent of sites had a median clarity above 0.8 m. The 1.6 m level has been used as a visibility threshold for swimming suitability. Comparison to this guideline is most relevant for sites that are managed for swimming, as stipulated in the Proposed Land and Water Plan.

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Using these categories, five-yearly medians show that Blackwater Creek in Karamea consistently has the lowest water quality and is the only site to be in the 'D' category. Blackwater Creek is a tidal creek that flows through reclaimed swamp land used predominately for agriculture. The surrounding catchment has soft sedimentary geology and the creek generally has low flows.

Sites consistently in the 'C' category are affected by similar factors – geology, CDOM and land use.

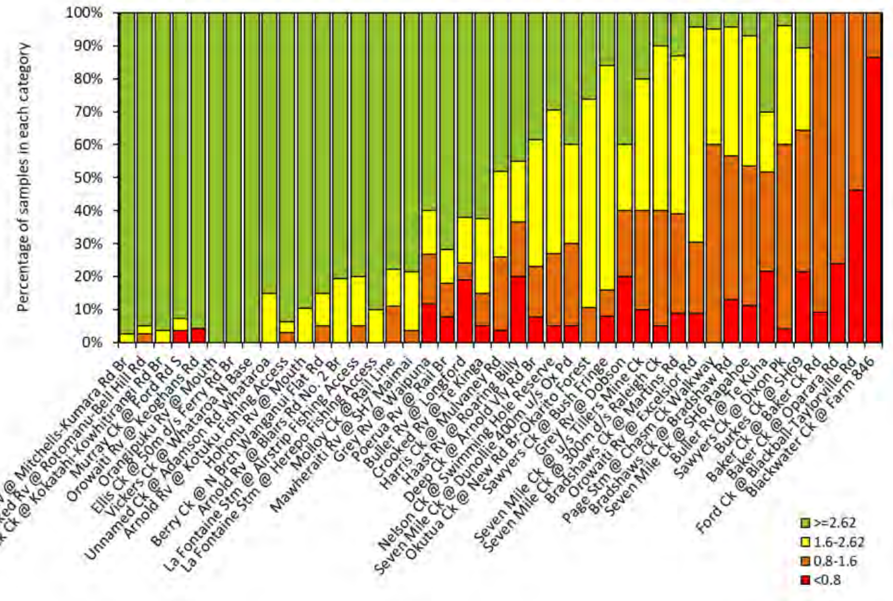

Figure 10 Percentage of samples in respective clarity categories for individual Regional Council monitoring program sites 2013 - 2017.

Table 1 Water clarity (Black disk) for Regional Council monitoring program sites. Calculated as 5 yearly medians (displayed as year ending of 5 year block of data).

	2013	**2014**	**2015**	**2016**	**2017**
Arnold Rv @ Blairs Rd No. 2 Br	A	A	A	A	A
Arnold Rv @ Kotuku Fishing Access	A	A	A	A	A
Baker Ck @ Baker Ck Rd	C	C	C	C	C
Baker Ck @ Oparara Rd	C	C	C	C	C
Berry Ck @ N Brch Wanganui Flat Rd	A	A	A	A	A
Blackwater Ck @ Farm 846	D	D	D	D	D
Bradshaws Ck @ Bradshaw Rd	C	C	C	C	C
Bradshaws Ck @ Martins Rd	C	B	B	B	B
Buller Rv @ Longford	A	A	A	A	A
Buller Rv @ Te Kuha	B	C	C	B	C
Burkes Ck @ SH69	C	C	C	C	C
Crooked Rv @ Rotomanu-Bell Hill Rd	A	A	A	A	A
Crooked Rv @ Te Kinga	A	A	A	A	A
Deep Ck @ Arnold Vly Rd Br	A	A	B	B	B
Duck Ck @ Kokatahi-Kowhitirangi Rd Br	A	A	A	A	A
Ellis Ck @ 50m d/s Ferry Rd Br	A	A	A	A	A
Ford Ck @ Blackball-Taylorville Rd	C	C	C	C	C
Grey Rv @ Dobson	B	B	B	B	B
Grey Rv @ Waipuna	A	A	A	A	A
Haast Rv @ Roaring Billy	A	A	B	B	B
Harris Ck @ Mulvaney Rd	A	A	A	A	B
Hohonu Rv @ Mitchells-Kumara Rd Br	A	A	A	A	A
Hohonu Rv @ Mouth	A	A	A	A	A
La Fontaine Stm @ Airstrip Fishing Access	A	A	A	A	A
La Fontaine Stm @ Herepo Fishing Access	A	A	A	A	A
Mawheraiti Rv @ SH7 Maimai	A	A	A	A	A
Molloy Ck @ Rail Line	A	A	A	A	A
Murray Ck @ Ford Rd S	A	A	A	A	A
Nelson Ck @ Swimming Hole Reserve	B	B	B	B	B
Okutua Ck @ New Rd Br-Okarito Forest	B	B	B	B	B
Orangipuku Rv @ Mouth	A	A	A	A	A
Orowaiti Rv @ Excelsior Rd	B	B	B	B	B
Orowaiti Rv @ Keoghans Rd	A	A	A	A	A
Page Stm @ Chasm Ck Walkway	B	B	B	B	C
Poerua Rv @ Rail Br	A	A	A	A	A
Sawyers Ck @ Bush Fringe	B	B	B	B	B
Sawyers Ck @ Dixon Pk	B	B	B	B	C
Seven Mile Ck @ 300m d/s Raleigh Ck	B	B	B	B	B
Seven Mile Ck @ Dunollie 400m u/s Ox Pd	B	B	B	B	B
Seven Mile Ck @ SH6 Rapahoe	B	B	B	B	C
Seven Mile Ck @ u/s Tillers Mine Ck	B	B	B	B	B
Unnamed Ck @ Adamson Rd Whataroa	A	A	A	A	A
Vickers Ck @ Whataroa N Base	A	A	A	A	A

~~2.2.5~~2.2.6Ammonia

The term ammonia in this report refers to total ammonia-N (NH_3 + NH_4^-). The NOF has attribute states for ammonia based on two numeric methods – a median and maximum. Ammonia toxicity varies with pH so ammonia states incorporate pH correction (Section 5.4.2). This means that high total ammonia may not be as toxic if the pH is low (Section 5.5.1). The overall NOF score is ~~has been allocated based on~~ the worst out of the median and maximum.

Ammonia toxicity risk is determined by the 2017~~3~~ state (calculated from 2013~~09~~ to 2017~~13~~ data). There were 84~~2~~% of sites in the A state (Table 2), where there should be no observable effect on species. Ammonia levels in the B state are considered to be suitable for 95% of species, with occasional impact on the 5% most sensitive species. Six~~even~~ sites (14~~6~~%) scored a B. One site, Harris Creek @ Mulvaney Rd~~Un- named southern trib @ Lake Haupiri~~, scored a C. This state is supposed to signify levels where there are regular impacts and reduced survival for the 20% most sensitive species. The C was derived from a high maximum ammonia result, but it should be noted that median ammonia at this site was not high (0.009~~27~~ mg/L, ~~un~~corrected).

Blackwater Ck @ Farm 846 and Seven Mile Ck @ 300m d/s Raleigh Ck had medians below A, indicating that ammonia toxicity was consistently higher than other B sites (Table 2). The remainder of B and C sites achieved their overall score due to spikes rather than consistently high ammonia.

Blackwater Ck @ Farm 846 had much higher ammonia levels than other streams (Figure 35) but toxicity was contained to a B state due to slightly acidic pH's. Nitrate is commonly associated with agricultural run-off yet Blackwater Ck nitrate was similar to other streams (Figure 34). Therefore unique stream and catchment characteristics are the most likely driver of high ammonia. Blackwater Ck is a slow flowing, soft bottomed stream with low dissolved oxygen (Figure 31). The catchment is low lying with wet, peaty soils. Abundant ammonia can be generated in these conditions, and oxidation of ammonia to nitrate inhibited. Total nitrogen was high (Figure 36), which will associate with high particulate loads (Figure 33, Figure 32), rather than an abundance of dissolved nitrogen.

Baker Creek, Deep Creek and Un-named Creek are also sites in agricultural catchments which will have similar factors driving high ammonia.

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

Table 2 Ammonical nitrogen NOF grades for Regional Council monitoring program sites. Calculated as 5 yearly medians and maximums (displayed as year ending of 5 year block of data).

	2013	2013	2014	2014	2015	2015	2016	2016	2017	2017
	Median	Max	Median	Max	Median	Max	Median	Max	Median	Max
Arnold Rv @ Blairs Rd No. 2 Br	A	B	A	B	A	A	A	A	A	A
Arnold Rv @ Kotuku Fishing Access	A	B	A	B	A	A	A	A	A	A
Baker Ck @ Baker Ck Rd	A	A	A	A	A	A	A	A	A	A
Baker Ck @ Oparara Rd	A	B	A	B	A	B	A	B	A	B
Berry Ck @ N Brch Wanganui Flat Rd	A	A	A	A	A	A	A	A	A	A
Blackwater Ck @ Farm 846	B	B	B	B	B	B	B	B	B	B
Bradshaws Ck @ Bradshaw Rd	A	A	A	A	A	A	A	A	A	A
Bradshaws Ck @ Martins Rd	A	A	A	A	A	A	A	A	A	A
Buller Rv @ Longford	A	A	A	A	A	A	A	A	A	A
Buller Rv @ Te Kuha	A	A	A	A	A	A	A	A	A	A
Burkes Ck @ SH69	A	A	A	A	A	A	A	A	A	A
Crooked Rv @ Rotomanu-Bell Hill Rd	A	A	A	A	A	A	A	A	A	A
Crooked Rv @ Te Kinga	A	A	A	A	A	A	A	A	A	A
Deep Ck @ Arnold Vly Rd Br	A	B	A	B	A	B	A	B	A	B
Duck Ck @ Kokatahi-Kowhitirangi Rd Br	A	A	A	A	A	A	A	A	A	A
Ellis Ck @ 50m d/s Ferry Rd Br	A	A	A	A	A	A	A	A	A	A
Ford Ck @ Blackball-Taylorville Rd	A	A	A	A	A	A	A	A	A	A
Grey Rv @ Dobson	A	A	A	A	A	A	A	A	A	A
Grey Rv @ Waipuna	A	A	A	A	A	A	A	A	A	A
Haast Rv @ Roaring Billy	A	A	A	A	A	A	A	A	A	A
Harris Ck @ Mulvaney Rd	A	A	A	A	A	A	A	A	A	C
Hohonu Rv @ Mitchells-Kumara Rd Br	A	A	A	A	A	A	A	A	A	A
Hohonu Rv @ Mouth	A	A	A	A	A	A	A	A	A	A
La Fontaine Stm @ Airstrip Fishing Access	A	A	A	A	A	A	A	A	A	A
La Fontaine Stm @ Herepo Fishing Access	A	A	A	A	A	A	A	A	A	A
Mawheraiti Rv @ SH7 Maimai	A	A	A	A	A	A	A	A	A	A
Molloy Ck @ Rail Line	A	A	A	A	A	A	A	A	A	A
Murray Ck @ Ford Rd S	A	A	A	A	A	A	A	A	A	A
Nelson Ck @ Swimming Hole Reserve	A	A	A	A	A	A	A	A	A	A
Okutua Ck @ New Rd Br-Okarito Forest	A	A	A	A	A	A	A	A	A	A
Orangipuku Rv @ Mouth	A	A	A	A	A	A	A	A	A	A
Orowaiti Rv @ Excelsior Rd	A	A	A	A	A	A	A	A	A	A
Orowaiti Rv @ Keoghans Rd	A	A	A	A	A	A	A	A	A	A
Page Stm @ Chasm Ck Walkway	A	A	A	A	A	A	A	A	A	A
Poerua Rv @ Rail Br	A	A	A	A	A	A	A	A	A	A
Poerua Rv @ Station Rd end	ND	ND	ND	ND	A	A	A	A	A	A
Sawyers Ck @ Bush Fringe	A	A	A	A	A	A	A	A	A	A
Sawyers Ck @ Dixon Pk	A	A	A	A	A	A	A	A	A	A
Seven Mile Ck @ 300m d/s Raleigh Ck	B	B	B	B	B	B	B	B	B	B
Seven Mile Ck @ Dunollie 400m u/s Ox Pd	A	B	A	B	A	B	A	B	A	A
Seven Mile Ck @ SH6 Rapahoe	A	B	A	B	A	B	A	B	A	B
Seven Mile Ck @ u/s Tillers Mine Ck	A	A	A	A	A	A	A	A	A	A
Unnamed Ck @ Adamson Rd Whataroa	A	B	A	B	A	B	A	B	A	B
Vickers Ck @ Whataroa N Base	A	A	A	A	A	A	A	A	A	A

~~2.2.6~~2.2.7 Nitrate-N

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

Nitrate toxicity risk is determined by the 2017~~3~~ state (calculated from 2013~~09~~ to 2017~~3~~ data). Most sites (98~~95~~%) were in the A state (Table 3), where it is unlikely there will be effects even on sensitive species. Nitrate levels in the B state are considered to have some growth effect on 5% of species. One~~Two~~ site~~s~~ (2~~5~~%) scored a B. This was due to high median and 95th percentiles.

Table 3 Nitrate NOF grades for individual Regional Council monitoring program sites, calculated as a 5 yearly median and 95th percentile (displayed as year ending of 5 year block of data).

	2013	**2014**	**2015**	**2016**	**2017**	**2013**	**2014**	**2015**	**2016**	**2017**
	Median	Median	Median	Median	Median	95%ile	95%ile	95%ile	95%ile	95%ile
Arnold Rv @ Blairs Rd No. 2 Br	A	A	A	A	A	A	A	A	A	A
Arnold Rv @ Kotuku Fishing Access	A	A	A	A	A	A	A	A	A	A
Baker Ck @ Baker Ck Rd	A	A	A	A	A	A	A	A	A	A
Baker Ck @ Oparara Rd	A	A	A	A	A	A	A	A	A	A
Berry Ck @ N Brch Wanganui Flat Rd	A	A	A	A	A	A	A	A	A	A
Blackwater Ck @ Farm 846	A	A	A	A	A	A	A	A	A	A
Bradshaws Ck @ Bradshaw Rd	A	A	A	A	A	B	A	A	A	A
Bradshaws Ck @ Martins Rd	A	A	A	A	A	A	A	A	A	A
Buller Rv @ Longford	A	A	A	A	A	A	A	A	A	A
Buller Rv @ Te Kuha	A	A	A	A	A	A	A	A	A	A
Burkes Ck @ SH69	A	A	A	A	A	A	A	A	A	A
Crooked Rv @ Rotomanu-Bell Hill Rd	A	A	A	A	A	A	A	A	A	A
Crooked Rv @ Te Kinga	A	A	A	A	A	A	A	A	A	A
Deep Ck @ Arnold Vly Rd Br	A	A	A	A	A	A	A	A	A	A
Duck Ck @ Kokatahi-Kowhitirangi Rd Br	A	A	A	A	A	A	A	A	A	A
Ellis Ck @ 50m d/s Ferry Rd Br	A	A	A	A	A	A	A	A	A	A
Ford Ck @ Blackball-Taylorville Rd	A	A	A	A	A	A	A	A	A	A
Grey Rv @ Dobson	A	A	A	A	A	A	A	A	A	A
Grey Rv @ Waipuna	A	A	A	A	A	A	A	A	A	A
Haast Rv @ Roaring Billy	A	A	A	A	A	A	A	A	A	A
Harris Ck @ Mulvaney Rd	A	A	A	A	A	A	A	A	A	A
Hohonu Rv @ Mitchells-Kumara Rd Br	A	A	A	A	A	A	A	A	A	A
Hohonu Rv @ Mouth	A	A	A	A	A	A	A	A	A	A
La Fontaine Stm @ Airstrip Fishing Access	A	A	A	A	A	A	A	A	A	A
La Fontaine Stm @ Herepo Fishing Access	A	A	A	A	A	A	A	A	A	A
Mawheraiti Rv @ SH7 Maimai	A	A	A	A	A	A	A	A	A	A
Molloy Ck @ Rail Line	A	A	A	A	A	A	A	A	A	A
Murray Ck @ Ford Rd S	A	A	A	A	A	A	A	A	A	A
Nelson Ck @ Swimming Hole Reserve	A	A	A	A	A	A	A	A	A	A
Okutua Ck @ New Rd Br-Okarito Forest	A	A	A	A	A	A	A	A	A	A
Orangipuku Rv @ Mouth	A	A	A	A	A	A	A	A	A	A
Orowaiti Rv @ Excelsior Rd	A	A	A	A	A	A	A	A	A	A
Orowaiti Rv @ Keoghans Rd	A	A	A	A	A	A	A	A	A	A
Page Stm @ Chasm Ck Walkway	A	A	A	A	A	A	A	A	A	A
Poerua Rv @ Rail Br	A	A	A	A	A	A	A	A	A	A
Poerua Rv @ Station Rd end	A	A	A	A	A	A	A	A	A	A
Sawyers Ck @ Bush Fringe	A	A	A	A	A	A	A	A	A	A
Sawyers Ck @ Dixon Pk	A	A	A	A	A	A	A	A	A	A
Seven Mile Ck @ 300m d/s Raleigh Ck	A	A	A	A	A	A	A	A	A	A
Seven Mile Ck @ Dunollie 400m u/s Ox Pd	A	A	A	A	A	A	A	A	A	A
Seven Mile Ck @ SH6 Rapahoe	A	A	A	A	A	A	A	A	A	A
Seven Mile Ck @ u/s Tillers Mine Ck	A	A	A	A	A	A	A	A	A	A
Unnamed Ck @ Adamson Rd Whataroa	A	A	B	B	B	B	B	B	B	B
Vickers Ck @ Whataroa N Base	A	A	A	A	A	A	A	A	A	A

~~1.1.1~~2.2.8Dissolved inorganic nitrogen

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Dissolved inorganic nitrogen (DIN) refers to ammonia (NH_3 + NH_4^-) plus nitrate (NO_3-N). The NOF attribute states for DIN are based on two numeric methods – a median and 95th percentile.

About half of ~~Most~~ sites (55~~98~~%) were in the A state (Table 3), where it is unlikely there will be effects even on sensitive species. DIN~~Nitrate~~ levels in the B state have a slight impact on ecological communities.~~are considered to have some growth effect on 5% of species~~. 11 ~~One~~ sites (29~~2~~%) scored a B, 5 sites were in the C category (13%) and 1 site, Un-named Ck, was in the D category which is below the national bottom line and a level at which sensitive macroinvertebrate and fish species may be lost. These levels of DIN also contribute to proliferation of aquatic plants and alage.~~. This was due to high both median and 95th percentiles.~~

Table 4 Dissolved inorganic nitrogen NOF grades for individual Regional Council monitoring program sites, calculated as a 5 yearly median and 95th percentile (displayed as year ending of 5 year block of data, 2018 is April 2013 – Mar 2018).

	2013	2013	2014	2014	2015	2015	2016	2016	2017	2017	2018	2018
	Median	95 %ile	Median	95 %ile	Median	95 %ile	Median	95 %ile	Median	95 %ile	Median	95 %ile
Arnold Rv @ Blairs Rd No. 2 Br	A	A	A	A	A	A	A	A	A	A	A	A
Arnold Rv @ Kotuku Fishing Access	A	A	A	A	A	A	A	A	A	A	A	A
Baker Ck @ Baker Ck Rd	A	A	A	A	A	A	A	A	A	A	A	A
Baker Ck @ Oparara Rd	A	A	A	A	A	A	A	A	A	A	A	A
Berry Ck @ N Brch Wanganui Flat Rd	A	A	A	A	B	A	B	A	B	A	B	A
Blackwater Ck @ Farm 846	C	C	C	C	C	C	C	C	C	C	C	C
Bradshaws Ck @ Bradshaw Rd	B	D	B	C	B	B	B	B	B	B	B	B
Bradshaws Ck @ Martins Rd	B	B	B	B	B	B	B	B	B	B	B	B
Burkes Ck @ SH69	B	B	B	B	B	B	B	B	A	B	A	B
Crooked Rv @ Rotomanu-Bell Hill Rd	A	A	A	A	A	A	A	A	A	A	A	A
Crooked Rv @ Te Kinga	A	A	A	A	A	A	A	A	A	A	A	A
Deep Ck @ Arnold Vly Rd Br	C	B	C	C	C	C	C	C	C	C	C	C
Duck Ck @ Kokatahi-Kowhitirangi Rd Br	C	C	C	C	C	C	C	C	C	B	C	B
Ellis Ck @ 50m d/s Ferry Rd Br	B	A	B	B	B	B	B	B	B	B	B	B
Ford Ck @ Blackball-Taylorville Rd	A	A	A	A	A	A	A	A	A	A	A	A
Harris Ck @ Mulvaney Rd	B	B	B	B	B	B	B	B	B	B	B	B
Hohonu Rv @ Mitchells-Kumara Rd Br	A	A	A	A	A	A	A	A	A	A	A	A
Hohonu Rv @ Mouth	A	A	A	A	A	A	A	A	A	A	A	A
La Fontaine Stm @ Airstrip Fishing Access	B	A	B	B	B	B	B	B	B	B	B	B
La Fontaine Stm @ Herepo Fishing Access	B	A	B	A	B	A	B	A	B	A	B	A
Mawheraiti Rv @ SH7 Maimai	B	B	B	B	B	B	B	B	B	B	B	B
Molloy Ck @ Rail Line	B	B	B	B	B	B	C	B	C	B	C	B
Murray Ck @ Ford Rd S	C	B	C	B	C	B	C	B	C	B	C	B
Nelson Ck @ Swimming Hole Reserve	A	A	A	A	A	A	A	A	A	A	A	A
Okutua Ck @ New Rd Br-Okarito Forest	A	A	A	A	A	A	A	A	A	A	A	A
Orangipuku Rv @ Mouth	B	B	B	B	B	B	B	B	B	B	B	B
Orowaiti Rv @ Excelsior Rd	A	A	A	A	A	A	A	A	A	A	A	A
Orowaiti Rv @ Keoghans Rd	A	A	A	A	A	A	A	A	A	A	A	A
Page Stm @ Chasm Ck Walkway	A	A	A	A	A	A	A	A	A	A	A	A
Poerua Rv @ Rail Br	A	A	A	A	A	A	A	A	A	A	A	A
Sawyers Ck @ Bush Fringe	A	A	A	A	A	A	A	A	A	A	A	A
Sawyers Ck @ Dixon Pk	A	A	A	A	A	A	A	A	A	A	A	A
Seven Mile Ck @ 300m d/s Raleigh Ck	A	A	A	A	A	A	A	A	A	A	A	A
Seven Mile Ck @ SH6 Rapahoe	A	A	A	A	A	A	A	A	A	A	A	A
Seven Mile Ck @ Dunollie 400m u/s Ox Pd	A	A	A	A	A	A	A	A	A	A	A	A
Seven Mile Ck @ u/s Tillers Mine Ck	A	A	A	A	A	A	A	A	A	A	A	A
Unnamed Ck @ Adamson Rd Whataroa	C	C	C	C	D	C	D	C	D	C	D	C
Vickers Ck @ Whataroa N Base	B	B	B	B	B	B	B	B	B	B	B	B

~~1.1.2~~2.2.9Dissolved reactive phosphorus

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~~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.~~ Elevated levels of dissolved reactive phosphorus can be a driver for ~~For nuisance~~ algal and plant proliferation and loss of sensitive macroinvertebrate and fish species. However, for this ~~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 (Table 5). 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. DRP toxicity risk is determined by the 2018 state (calculated from April 2013 to April 2018 data). Most sites (71%) were in an A state according to the NOF. Two sites were in the D state for both median and 95 % ile (Table 5) – Harris Ck @ Mulvaney Rd and Blackwater Ck @ Farm 846, these sites are below the national bottom line for DRP. Proliferation of plants / algae and loss of sensitive macroinvertebrate and fish species may occur. ~~Harris Ck @ Mulvaney Rd and Blackwater Ck @ Farm 846 had the highest DRP (), both exceeding 0.03 mg/L for 20 % of the time.~~

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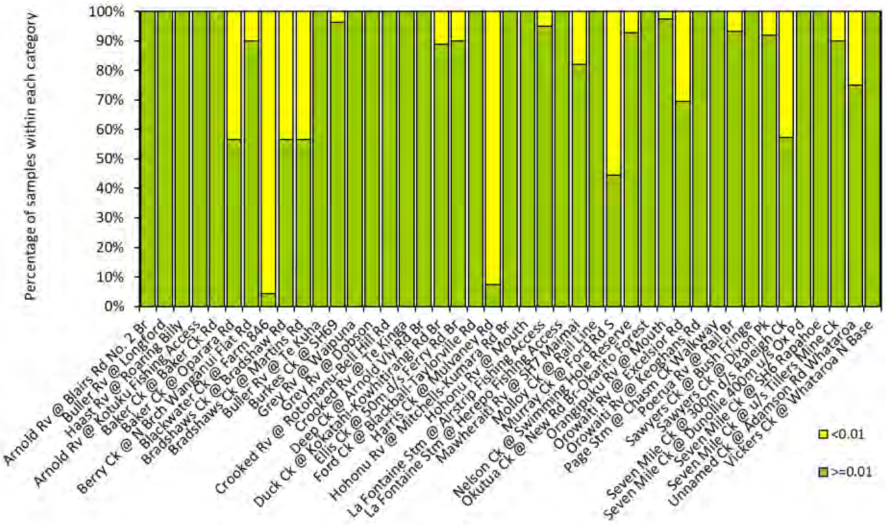

~~Figure 9 Percentage of samples in respective dissolved reactive phosphorus categories for individual Regional Council monitoring program sites 2013 – 2017.~~

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Table 5 Dissolved reactive phosphorus NOF grades (proposed) for individual Regional Council monitoring program sites, calculated as a 5 yearly median and 95th percentile (displayed as year ending of 5 year block of data, 2018 is April 2013 – Mar 2018).

	2013	**2013**	**2014**	**2014**	**2015**	**2015**	**2016**	**2016**	**2017**	**2017**	**2018**	**2018**
	Median	95 %ile	Median	95 %ile	Median	95 %ile	Median	95 %ile	Median	95 %ile	Median	95 %ile
Arnold Rv @ Blairs Rd	A	A	A	A	A	A	A	A	A	A	A	A
Arnold Rv @ Kotuku	A	A	A	A	A	A	A	A	A	A	A	A
Baker Ck @ Baker Ck Rd	A	A	A	A	A	A	A	A	A	A	A	A
Baker Ck @ Oparara Rd	C	B	C	B	C	B	C	C	B	C	B	C
Berry Ck @ Wanganui Flat Rd	A	A	A	A	A	A	A	A	A	A	A	A
Blackwater Ck @ Farm 846	C	C	D	C	D	C	D	D	D	D	D	D
Bradshaws Ck @ Bradshaw Rd	B	A	B	A	B	A	B	A	B	A	B	A
Bradshaws Ck @ Martins Rd	B	A	B	A	B	A	B	A	B	A	B	A
Burkes Ck @ SH69	A	B	A	A	A	A	A	A	A	A	A	A
Crooked Rv @ Roto-Bell Hill	A	A	A	A	A	A	A	A	A	A	A	A
Crooked Rv @ Te Kinga	A	A	A	A	A	A	A	A	A	A	A	A
Deep Ck @ Arnold Vly Rd	A	A	B	A	A	A	A	A	A	A	A	A
Duck Ck @ Koka-Kowhit Rd	A	A	A	A	A	A	A	A	A	A	A	A
Ellis Ck @ d/s Ferry Rd Br	A	A	B	A	B	A	B	A	B	A	B	A
Ford Ck @ Bball-Taylorville Rd	A	A	A	A	A	A	A	A	A	A	A	A
Harris Ck @ Mulvaney Rd	C	C	D	D	D	D	D	D	D	D	D	D
Hohonu Rv @ Mitchells-Kumara	A	A	A	A	A	A	A	A	A	A	A	A
Hohonu Rv @ Mouth	A	A	A	A	A	A	A	A	A	A	A	A
La Fontaine Stm @ Airstrip	A	A	B	A	B	A	A	A	A	A	A	A
La Fontaine Stm @ Herepo	A	A	A	A	A	A	A	A	A	A	A	A
Mawheraiti Rv @ Maimai	A	A	A	A	A	A	A	A	A	A	A	A
Molloy Ck @ Rail Line	B	A	A	A	A	A	A	A	A	A	A	A
Murray Ck @ Ford Rd S	C	A	C	A	C	A	C	A	B	A	C	C
Nelson Ck @ Swimming Hole	B	A	B	A	A	A	A	A	A	A	A	A
Okutua Ck @ Okarito Forest	A	A	A	A	A	A	A	A	A	A	A	A
Orangipuku Rv @ Mouth	A	A	A	A	A	A	A	A	A	A	A	A
Orowaiti Rv @ Excelsior Rd	A	B	A	A	A	A	A	A	B	A	B	A
Orowaiti Rv @ Keoghans Rd	A	A	A	A	A	A	B	A	A	A	A	A
Page Stm @ Chasm Ck Walkway	A	A	A	A	A	A	A	A	A	A	A	A
Poerua Rv @ Rail Br	A	A	B	A	B	A	A	A	A	A	A	A
Sawyers Ck @ Bush Fringe	B	A	B	A	B	A	B	A	B	A	B	A
Sawyers Ck @ Dixon Pk	B	A	B	A	B	A	B	A	B	A	B	A
Seven Mile Ck @ d/s Raleigh Ck	B	A	B	A	B	A	B	A	B	B	B	A
Seven Mile Ck @ SH6 Rapahoe	A	A	A	A	A	A	A	A	A	A	A	A
Seven Mile Ck @ u/s Ox Pd	A	A	A	A	A	A	A	A	A	A	A	A
Seven Mile Ck @ u/s Tillers Mine	A	A	A	A	A	A	A	A	A	A	A	A
Unnamed Ck @ Adamson Rd	A	A	A	A	A	A	A	A	A	A	A	A
Vickers Ck @ Whataroa	A	A	A	A	A	A	A	A	A	A	A	A

~~1.1.3~~2.2.10*E. coli*

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

E. coli risk is determined by the 2017~~3~~ state (calculated from 2013~~09~~ to 2017~~3~~ data). The NOF attribute states for *E. coli* are based on four~~two~~ numeric methods – % greater than 260 cfu / 100 ml, % greater than 540 cfu / 100 ml, median and 95th percentile. The median relates to pathogen risks to people engaging in activities that involve occasional immersion such as wading and boating. The 95th percentile relates to pathogen risks to people engaging in activities that involve complete immersion e.g. swimming. Only the median risk threshold states for occasional immersion have been applied as only two sites in Table 6~~Table 3~~ are managed for swimming in the Water Plan. Assessment of swimming suitability on the West Coast is covered in section 2.3.

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48~~89~~% of sites scored an A (Table 6~~Table 3~~). An A represents a very low risk of infection (about 1%) (less than 0.1% risk) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating). The B state represents a low risk of infection (~~also less than~~ 2~~1~~% risk). Six~~Three~~ sites (14~~6~~%) scored a B.

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

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

A number of sites scored in the E category. People are exposed to a high risk of infecton (greater than 7% risk) from contact with water at these sites for primary contact recreation (eg. Swimming).These sites are below the national bottom line and require improvement.

Table 6 *E. coli* 5 yearly NOF grades for individual Regional Council and NIWA monitoring program sites 2013 – 2017 (displayed as year ending of 5 year block of data). Should this just be median data?

	2013	2014	2015	2016	2017
Arnold Rv @ Blairs Rd No. 2 Br	A	A	A	A	A
Arnold Rv @ Kotuku Fishing Access	A	A	A	A	A
Baker Ck @ Baker Ck Rd	C	C	C	C	B
Baker Ck @ Oparara Rd	E	E	E	E	E
Berry Ck @ N Brch Wanganui Flat Rd	D	D	D	D	D
Blackwater Ck @ Farm 846	E	E	E	E	E
Bradshaws Ck @ Bradshaw Rd	E	E	E	E	E
Bradshaws Ck @ Martins Rd	E	E	E	E	E
Buller Rv @ Longford	A	A	B	B	A
Buller Rv @ Te Kuha	A	B	B	B	B
Burkes Ck @ SH69	D	D	D	D	E
Crooked Rv @ Rotomanu-Bell Hill Rd	A	A	A	A	A
Crooked Rv @ Te Kinga	A	A	A	B	A
Deep Ck @ Arnold Vly Rd Br	D	D	D	D	E
Duck Ck @ Kokatahi-Kowhitirangi Rd Br	A	A	A	A	A
Ellis Ck @ 50m d/s Ferry Rd Br	A	A	A	A	A
Ford Ck @ Blackball-Taylorville Rd	A	A	A	A	A
Grey Rv @ Dobson	C	C	C	C	C
Grey Rv @ Waipuna	A	A	A	A	A
Haast Rv @ Roaring Billy	A	A	A	A	A
Harris Ck @ Mulvaney Rd	D	D	D	D	E
Hohonu Rv @ Mitchells-Kumara Rd Br	A	A	A	A	A
Hohonu Rv @ Mouth	A	B	B	B	A
La Fontaine Stm @ Airstrip Fishing Access	B	D	D	D	D
La Fontaine Stm @ Herepo Fishing Access	B	B	B	B	D
Mawheraiti Rv @ SH7 Maimai	B	B	A	B	B
Molloy Ck @ Rail Line	D	D	D	D	D
Murray Ck @ Ford Rd S	B	B	A	B	B
Nelson Ck @ Swimming Hole Reserve	A	A	A	A	A
Okutua Ck @ New Rd Br-Okarito Forest	A	A	A	A	A
Orangipuku Rv @ Mouth	A	A	A	B	B
Orowaiti Rv @ Excelsior Rd	E	E	E	E	E
Orowaiti Rv @ Keoghans Rd	B	E	E	B	A
Page Stm @ Chasm Ck Walkway	A	A	A	A	A
Poerua Rv @ Rail Br	A	A	A	A	A
Poerua Rv @ Station Rd end	ND	ND	A	B	C
Sawyers Ck @ Bush Fringe	E	E	A	B	A
Sawyers Ck @ Dixon Pk	E	E	E	E	E
Seven Mile Ck @ 300m d/s Raleigh Ck	A	A	A	C	B
Seven Mile Ck @ Dunollie 400m u/s Ox Pd	A	A	A	A	A
Seven Mile Ck @ SH6 Rapahoe	B	B	D	E	E
Seven Mile Ck @ u/s Tillers Mine Ck	A	A	A	A	A
Unnamed Ck @ Adamson Rd Whataroa	D	D	D	D	D
Vickers Ck @ Whataroa N Base	A	A	A	A	A

~~1.1.4~~2.2.11Macroinvertebrates

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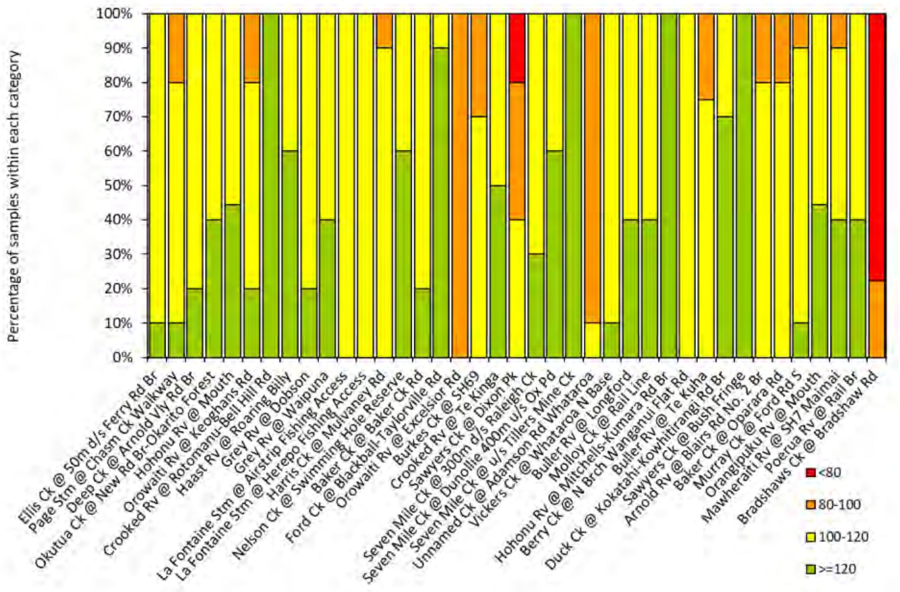

The Macroinvertebrate Community Index (MCI) and Semi-Quantitative Macroinvertebrate Community Index (SQMCI) evaluate water quality based on the types and tolerances of macroinvertebrates found at a site (Figure 11 and Figure 12). The four categories relate to water quality classes going from poor (<80) to excellent (>120) (refer Section 5.5.10). The rank of sites based on medians for MCI and SQMCI differ. The SQMCI takes into account the relative abundance of each type of macroinvertebrate collected, whereas the MCI works only on presence/absence. There was a close relationship between MCI and SQMCI (R=0.98) (I get an R2 of 0.59…) when tested with linear regression, so sites with good MCI scores also had comparative SQMCI ranking.

A range of environmental factors influence macroinvertebrate community composition. Chemical and physical properties of water are the most obvious. Habitat type is also very important. Some habitat degradation can result from anthropogenic activity e.g. poorly managed land development can lead to excessive sediment suspended in the water, and deposited on the stream bed (refer Appendix 5.5.4 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 @ Martins Rd Bridge is an example of this; where tides influence flow and sediment movements to the detriment of sensitive macroinvertebrate species. The Arnold River @ Kotuku is an example where water quality is high but stable flows, resulting from close proximity to a lake outlet, give rise to abundant algal growth, which suits pollution tolerant species. For these reasons both these sites have been omitted from MCI and SQMCI analysis.

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

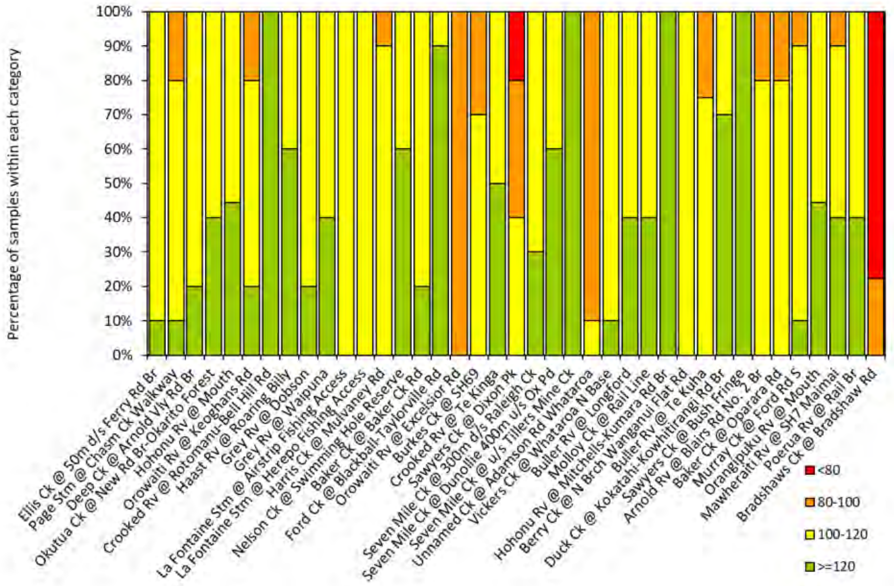

Figure 11 Percentage of samples in respective MCI categories for individual Regional Council monitoring program sites 2013 – 2017.

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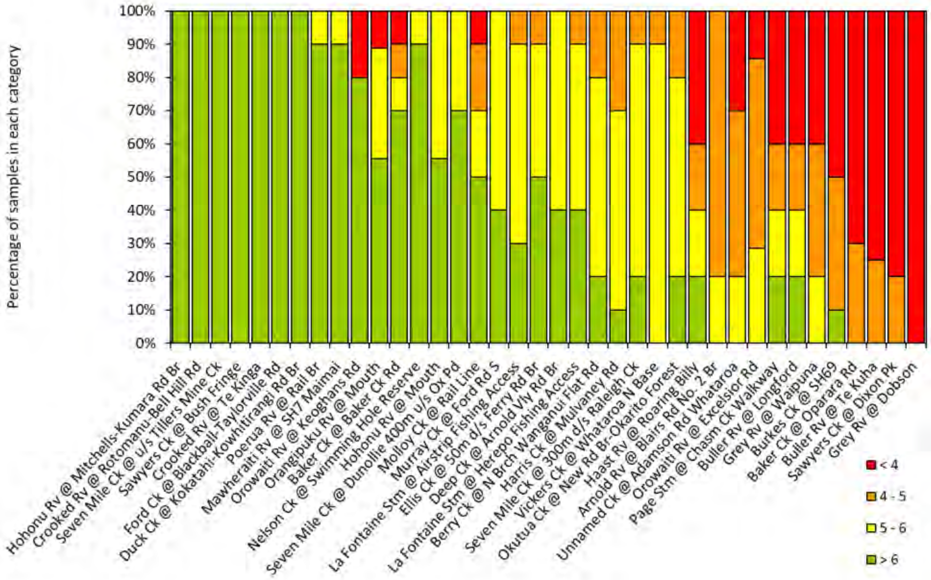

Figure 12 Percentage of samples in respective SQMCI categories for individual Regional Council monitoring program sites 2013 – 2017.

~~1.1.5~~2.2.12Periphyton

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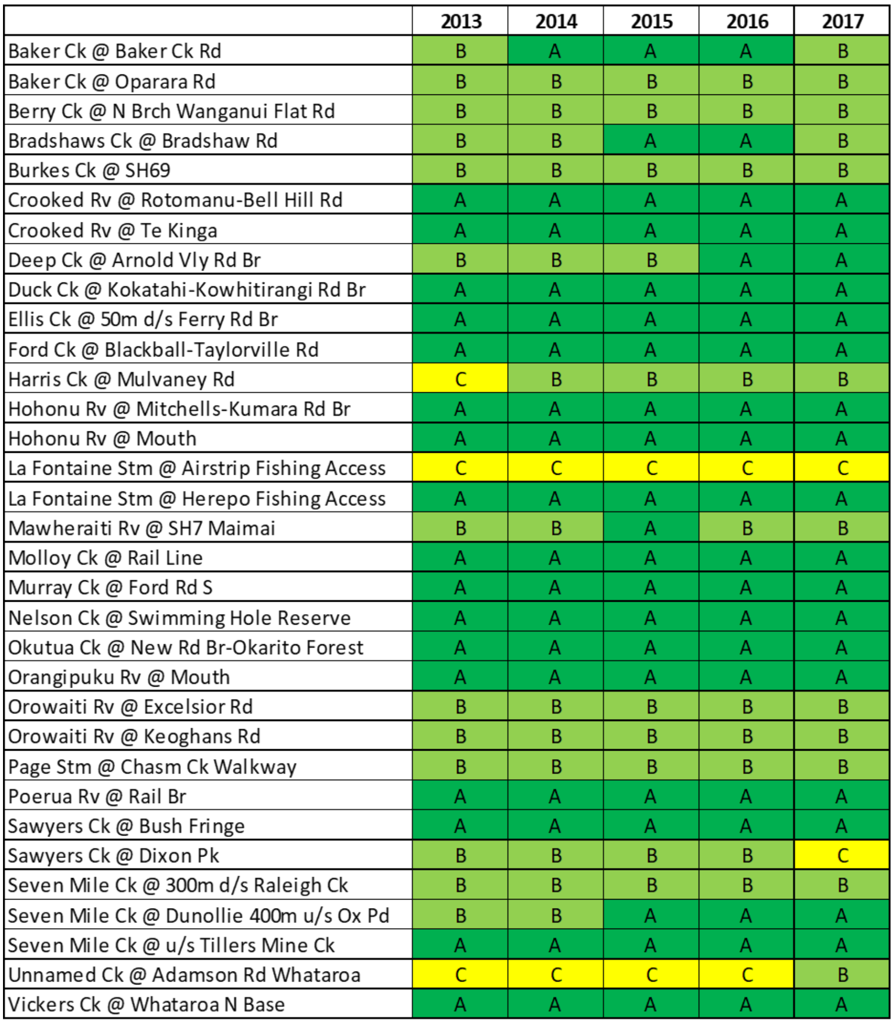
Table 7 shows the state of periphyton at Regional Council monitoring sites. The scores were generated using RAM 2 visual assessment scores as a surrogate for chlorophyll-a and applying the data to state categories in the NOF. 57% of sites were in the A state for 2017. 36% were a B and 6% were a C. ~~indicates 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 4.3.9 for an explanation of how this was derived).~~ As well as nutrient levels, other environmental conditions can be required for large algal proliferations. These include: adequate light, warmth, and stable conditions. Such conditions can occur simultaneously during summer low flows, and high algal biomass during these periods may relate more with climatic regimes than nutrient concentrations. High nutrient levels will not cause nuisance periphyton growth if, for example, flow stability and light are not adequate for major growth to occur and build up.

Levels of anthropogenic impact varied among sites that had nuisance biological growths suggesting the role of climatic regime was often more important than nutrient concentrations. Nuisance biological growths occurred in intensively farmed catchments and those with major upstream nutrient sources e.g. sewerage treatment ponds. But they also occurred in streams where major anthropogenic sources of nutrient were unlikely. Suitable climatic regimes can promote occasional periphyton blooms in West Coast streams irrespective of land use, and did not relate to median periphyton enrichments scores (Table 7 Periphyton NOF grades for individual Regional Council monitoring program sites.



	2013	2014	2015	2016	2017
Baker Ck @ Baker Ck Rd	B	A	A	A	B
Baker Ck @ Oparara Rd	B	B	B	B	B
Berry Ck @ N Brch Wanganui Flat Rd	B	B	B	B	B
Bradshaws Ck @ Bradshaw Rd	B	B	A	A	B
Burkes Ck @ SH69	B	B	B	B	B
Crooked Rv @ Rotomanu-Bell Hill Rd	A	A	A	A	A
Crooked Rv @ Te Kinga	A	A	A	A	A
Deep Ck @ Arnold Vly Rd Br	B	B	B	A	A
Duck Ck @ Kokatahi-Kowhitirangi Rd Br	A	A	A	A	A
Ellis Ck @ 50m d/s Ferry Rd Br	A	A	A	A	A
Ford Ck @ Blackball-Taylorville Rd	A	A	A	A	A
Harris Ck @ Mulvaney Rd	C	B	B	B	B
Hohonu Rv @ Mitchells-Kumara Rd Br	A	A	A	A	A
Hohonu Rv @ Mouth	A	A	A	A	A
La Fontaine Stm @ Airstrip Fishing Access	C	C	C	C	C
La Fontaine Stm @ Herepo Fishing Access	A	A	A	A	A
Mawheraiti Rv @ SH7 Maimai	B	B	A	B	B
Molloy Ck @ Rail Line	A	A	A	A	A
Murray Ck @ Ford Rd S	A	A	A	A	A
Nelson Ck @ Swimming Hole Reserve	A	A	A	A	A
Okutua Ck @ New Rd Br-Okarito Forest	A	A	A	A	A
Orangipuku Rv @ Mouth	A	A	A	A	A
Orowaiti Rv @ Excelsior Rd	B	B	B	B	B
Orowaiti Rv @ Keoghans Rd	B	B	B	B	B
Page Stm @ Chasm Ck Walkway	B	B	B	B	B
Poerua Rv @ Rail Br	A	A	A	A	A
Sawyers Ck @ Bush Fringe	A	A	A	A	A
Sawyers Ck @ Dixon Pk	B	B	B	B	C
Seven Mile Ck @ 300m d/s Raleigh Ck	B	B	B	B	B
Seven Mile Ck @ Dunollie 400m u/s Ox Pd	B	B	A	A	A
Seven Mile Ck @ u/s Tillers Mine Ck	A	A	A	A	A
Unnamed Ck @ Adamson Rd Whataroa	C	C	C	C	B
Vickers Ck @ Whataroa N Base	A	A	A	A	A

Table 7 Periphyton NOF grades for individual Regional Council monitoring program sites.

	2013	2014	2015	2016	2017
Baker Ck @ Baker Ck Rd	B	A	A	A	B
Baker Ck @ Oparara Rd	B	B	B	B	B
Berry Ck @ N Brch Wanganui Flat Rd	B	B	B	B	B
Bradshaws Ck @ Bradshaw Rd	B	B	A	A	B
Burkes Ck @ SH69	B	B	B	B	B
Crooked Rv @ Rotomanu-Bell Hill Rd	A	A	A	A	A
Crooked Rv @ Te Kinga	A	A	A	A	A
Deep Ck @ Arnold Vly Rd Br	B	B	B	A	A
Duck Ck @ Kokatahi-Kowhitirangi Rd Br	A	A	A	A	A
Ellis Ck @ 50m d/s Ferry Rd Br	A	A	A	A	A
Ford Ck @ Blackball-Taylorville Rd	A	A	A	A	A
Harris Ck @ Mulvaney Rd	C	B	B	B	B
Hohonu Rv @ Mitchells-Kumara Rd Br	A	A	A	A	A
Hohonu Rv @ Mouth	A	A	A	A	A
La Fontaine Stm @ Airstrip Fishing Access	C	C	C	C	C
La Fontaine Stm @ Herepo Fishing Access	A	A	A	A	A
Mawheraiti Rv @ SH7 Maimai	B	B	A	B	B
Molloy Ck @ Rail Line	A	A	A	A	A
Murray Ck @ Ford Rd S	A	A	A	A	A
Nelson Ck @ Swimming Hole Reserve	A	A	A	A	A
Okutua Ck @ New Rd Br-Okarito Forest	A	A	A	A	A
Orangipuku Rv @ Mouth	A	A	A	A	A
Orowaiti Rv @ Excelsior Rd	B	B	B	B	B
Orowaiti Rv @ Keoghans Rd	B	B	B	B	B
Page Stm @ Chasm Ck Walkway	B	B	B	B	B
Poerua Rv @ Rail Br	A	A	A	A	A
Sawyers Ck @ Bush Fringe	A	A	A	A	A
Sawyers Ck @ Dixon Pk	B	B	B	B	C
Seven Mile Ck @ 300m d/s Raleigh Ck	B	B	B	B	B
Seven Mile Ck @ Dunollie 400m u/s Ox Pd	B	B	A	A	A
Seven Mile Ck @ u/s Tillers Mine Ck	A	A	A	A	A
Unnamed Ck @ Adamson Rd Whataroa	C	C	C	C	B
Vickers Ck @ Whataroa N Base	A	A	A	A	A

~~1.2~~2.3 Suitability for contact recreation

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

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

Taylorville Swimming Hole, Lake Brunner @ Moana, Buller Rv @ Marrs Bch, Buller Rv @ Shingle Bch and Nelson Ck @ Swimming Hole Reserve) have been sampled weekly over summer since November 2017.

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

- Very low ~~Low~~ Health Risk (<260 *E. coli*/100ml or <140 Enterococci/100ml);
- Low - Moderate Risk, increased health risk but still within an acceptable range (260-550 *E. coli*/100ml or 140-280 Enterococci/100ml);
- Moderate - 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.

In the past coastal beach monitoring sites have proven cleaner than river counterparts. It has been found nationally that coastal beaches have better water quality than inland waters (MfE 2010), due to the increased dilution typically occurring in marine waters. During the 2013~~1~~ - 2018~~4~~ period 2~~5~~ out of 7 coastal sites had results under 280 Enterococci/100 ml all of the time. Four sites had 1 exceedance of 280 Enterococci/100 ml. One notable exception was Hokitika Beach with 9 exceedances of the moderate – high risk threshold since 2013.~~two exceedances in 2012 – 2013, and five in 2013 – 2014~~ (Figure 52).

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Lakes had the best water quality for swimming. Both Lake Mahinapua and Lake Brunner have had good swimming water quality. From 2013~~1~~ – 2018~~4~~ Lake Mahinapua was in the very low risk category (<260 cfu/100 ml) for 97% of the time (Figure 62). Since 2013~~1~~, sites at Lake Brunner, including Iveagh Bay (Figure 60), Cashmere Bay (Figure 59), and Moana (Figure 61), have had results within the very low risk category (<260 cfu/100 ml) for 96~~3~~%, 91~~100~~%, and 96~~7~~% of the time, respectively.

From 2013~~1~~ to 2018~~4~~, 1~~2~~ out of 7~~6~~ river sites (~~Kaniere Rv @ Kaniere – Kokatahi Rd and~~ Nelson Ck @ Swimming Hole Reserve) had results less than 550 cfu/ *E. coli* for all sampling occasions. The Buller River (Figure 54 & Figure 55) and Seven Mile Ck (Figure 53) had several exceedances - these sites are below municipal sewerage systems discharges. The Grey River at Taylorville, Kaniere River and Arahura River have also had exceedances There are other potential sources of *E. coli* including stormwater outlets, agricultural run-off, and aquatic birds. Although many sites had single high risk sample results in recent sampling seasons, the majority of these exceedances may result from run-off associated with recent rainfall. With increased sampling frequency there is a greater likelihood of rainfall affected results being present in datasets.

~~2~~3 Trends in West Coast river water quality: 2008 - 2018

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~~2.1~~3.1 Summary of trends in river water quality

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Patterns in West Coast river water quality from 2008-2018 were investigated using flow corrected trend analysis, and utilized a rigorous process to determine whether trends were robust. There were a wide range of landcover types and activities among the sites assessed with agriculture being the most widespread and dominant human influence. Agricultural land use intensified in many West Coast catchments and was likely to be driving some of the deteriorating trends observed in water quality. Multiple activities and land uses were often present in each catchment. Water quality improvement or deterioration for each site will have been strongly influenced by individual management practices within each catchment.

Ammonia improved at 38% of sites, mirroring the trend observed around New Zealand, and suggesting an overall improvement in the management of point source discharges. Improving levels in phosphorus at many sites may also be due to better discharge and nutrient management. Elevated nitrate nitrogen is associated with agriculture, and an increase in nitrate at 20% of sites likely reflects increasing agricultural intensification, as does an increase in total nitrogen at a third of all sites. Nitrate levels are not toxic in West Coast rivers, but they are high enough to support nuisance algal growth if conditions are suitable. Few sites displayed actual trends in algal abundance.

To a point, dissolved natural substances can reduce clarity of West Coast waterways. Suspended material such as sediment will reduce clarity and make water turbid. There were twice as many sites deteriorating as were improving for these qualities, with no trend for the remaining ~75% of sites. Fewer sites displayed trends in *E. coli* concentrations; a decline was apparent at four sites (11%), with one site improving. Overall, there were no relationships between water quality state and water quality trends, although a small number of sites that had the most rapid decline for an attribute, relative to other sites, also had the poorest water quality states.

3.2 Methods used for assessing trends in West Coast river water quality

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Trend analysis investigates whether water quality has changed over time. Changes in water quality often take several years to be seen due to variation that can occur for a measured water quality attribute. Physical and chemical measures of water quality can be influenced by flow as well as patterns associated with season and climatic cycles.

A rivers flow rate when a water quality measurement is made can affect the value because many water quality variables are subject to either dilution (decreasing concentration with increasing flow) or wash-off (increasing concentration with increasing flow) (Smith et al. 1996). Different mechanisms may dominate at different sites so that the same water quality variable (e.g., *E. coli*) can exhibit positive or negative relationships with flow (Snelder et al. 2016). Adjusting a measurement to account for the effect of flow increases the likelihood of detecting a trend with certainty if the measurement is related to flow. Flow adjusted analyses were given priority for site/measurement combinations that had a statistically significant relationship to flow.

Trends that had statistically significant seasonal patterns were evaluated using the Seasonal Kendall trend test. If significant seasonality was not observed then the Mann-Kendall trend test was used. Sampling frequency has increased at many sites over the period analysed, going from quarterly sampling (4 per year), to once a month (12 per year). Where this occurred, four seasons were used in the analysis, with all data values in the season used.

Where a substantial trend was detected, the raw data was visually assessed to ensure that the data looked natural. Other factors were considered when evaluating the validity of a trend including trends in flow over time, the strength of the relationship between flow and water quality attribute, and flow corrected vs. non-flow corrected results.

For assessing the significance of trends we used the criteria stipulated in Time Trends (Jowett 2017). This utilised a system adapted from that used by the Intergovernmental Panel on Climate Change (Stocker et al. 2014), that has nine levels of confidence. We required trends to be 'extremely likely' or 'virtually certain' as one of the criteria for considering whether trends were significant. Whether a trend was 'extremely likely' or 'virtually certain' is stipulated in Table 1. Another important consideration is the rate of change, which we have assessed as the annual percentage of change relative to the median. While a significant trend may exist, the rate of change may be so small that it is not meaningful. How important a rate of change is will vary depending on a range of factors like the current state of a water quality attribute, and how close it is to a threshold that is considered unsatisfactory (Larnard et al. 2015). For example, a 10% per year nitrate increase would represent a lot more nitrate in a stream with levels around 5 mg/L, compared to a stream with levels around 0.05 mg/L. Other important factors are the streams current state, and the values it is being managed for. We have used a 1% of the median annual rate of change as a minimum to indicate a meaningful change rate, as per traditional methods (eg Ballantine et al. 2010). Only trends that meet all the stated criteria are been reported here and can be considered significant. Median values and the annual rate of change are provided to assist interpretation, as well as an indication of state, for each significant trend presented in Tables 1 and 2.

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We have explored river water quality trends for ten water quality attributes: electrical conductivity, water clarity (black disc), turbidity, *E. coli*, total nitrogen, ammoniacal nitrogen, nitrate, dissolved reactive phosphorus, total phosphorus, and periphyton enrichment. These attributes had relevant and suitable time series datasets for trend analysis. Trends in macroinvertebrate community indices were not evaluated due to changes in macroinvertebrate data detection limits.

~~2.2~~3.2.1 Trends in West Coast river water quality

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A number of statistically significant trends were rejected following further evaluation of the raw data. There were a range of reasons why this was done with most involving detection limits. Raising all values to create a consistent baseline is common practice to deal with this, but often when this was implemented it led to too many censored results of the same value. At this point data resolution was considered insufficient to have full confidence in our ability to detect real trends. The ramifications of these trends were also likely to be less important given that water quality state was normally high for any attribute that was difficult to detect. As previously mentioned, trends with a very small rate of change were also not accepted. There were on occasions other time series anomalies in lab data for a site/attribute combination that could not be explained and led to the omission of a trend.

~~2.2.1~~3.2.2 Effect of landcover and activities within a catchment

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The majority of sites had a portion of indigenous landcover within their catchment, often in their headwaters. Pastoral agriculture was the most consistently encountered and dominant form of anthropogenic activity occurring across sites that displayed significant trends (Table 2). Most sites had a degree of agricultural activity within their catchment, as well as some indigenous vegetation in their headwaters. Those sites with no indigenous vegetation were typically streams on alluvial river plains with a significant spring fed flow component. Influences from mining and urban activity were more of a point source nature. Impacts from mining and forestry were likely to have been of a periodic nature, and involving sediment (turbidity and clarity), rather than nutrients and *E. coli*.

It is difficult to make consistent conclusions about trends based on changes in landcover when there are so many combinations of landcover and activities among sites, and with the proportion of each type varying widely among them. Agricultural intensification has been underway in parts of New Zealand since the late 1970s, as indicated by increased stocking rates and yields; increased fertiliser, pesticides, and food stock inputs; and conversion to more intensive forms of agriculture, such as dairying (MacLeod & Moller 2006). Exotic grassland increased on the West Coast by 10,000 hectares from 1996 to 2012, matched by a similar sized reduction in scrubland over the same time. As dairy products have become more profitable over recent decades, many farmers have moved away from sheep farming to more intensive dairy farming (DairyNZ, 2013). In 2015 the number of dairy cattle on the West Coast was 182,298 representing an increase of 130% since 1994.

~~2.2.2~~3.2.3 Nutrients

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~~2.2.3~~3.2.4 Periphyton cover

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Certain types and/or an over abundance of periphyton (algae) and plants can smother riverbed habitats, reduce recreational values, lower oxygen in the water, impede river flows, and block water supply intakes. The periphyton enrichment score (PEC), scale 1-10, indicates how much algae covers the stream bed. A high number indicates little algal cover, while low numbers are generated when there is consistently thick algal coverage across the stream bed that consists of species that respond to nutrient enrichment. Three sites showed a significant reduction in algal cover, while one displayed an increasing trend (Table 1). Only one of these sites had a significant trend in nutrient concentrations – phosphorus (TP and DRP) increased in Harris Creek yet periphyton growth decreased over the same period. Most West Coast monitoring sites (92%) have high enough nitrogen levels for prolific algal growth to occur (dissolved inorganic nitrogen >0.04 - 0.1 mg/L), but the response of stream periphyton to nutrients is complex and influenced by many factors such as light, flow history (eg floods), and species composition (Larned 2010).

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Nutrient concentration thresholds to achieve periphyton objectives are therefore always uncertain and must be considered alongside other factors.

~~2.2.4~~3.2.5 Clarity and turbidity

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Water clarity is a measure of underwater visibility. Fine particles like silt and dissolved substances can reduce water clarity. Some West Coast water bodies have naturally reduced water clarity, despite a lack of suspended particulate material, due to dissolved organic carbon (brown colouration). Beyond this natural colouration suspended material, e.g. fine sediment, is the typical cause of reduced clarity and elevated turbidity. Turbidity differs from clarity in that it is only affected by suspended material. Significant changes in both are likely to be caused by suspended material derived from land disturbance. Rivers that arise from lakes may additionally have suspended phytoplankton. Turbidity improved at three sites (two on the same waterway), and clarity improved at two sites, representing 5% - 7% of monitoring sites. In contrast, clarity and turbidity deteriorated at 12% - 21% of sites, respectively (Figure 1).

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~~2.2.5~~3.2.6 E. coli

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E.coli in rivers or lakes comes from animal or human faeces. Higher levels of *E.coli* are indicative of higher risks of infection from pathogens like Campylobacter while swimming, wading, or boating. Pathogens can also affect people and stock if the water is consumed. Four sites (11%) had declining trends for *E. coli* and one (3%) was improving (Figure 1). Point source pollution and sources that are more diffuse can contribute faecal contamination to waterways. Improvements in point source management can be offset by an increase in more diffuse sources associated with agricultural intensification, with trends in each catchment probably reflecting that balance.

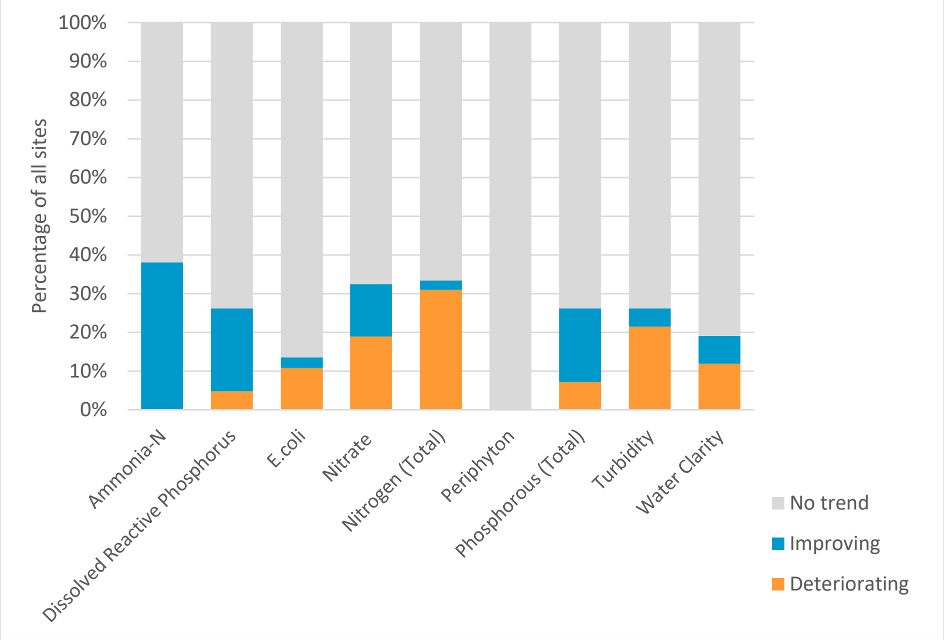

Figure 13 Proportion of West Coast river sites that have significant trends for selected water quality attributes, from 2008 to 2018.

Table 8 Summary of Seasonal Kendall trend test and **percentage change** for 10 years of data collected at West Coast Regional Council water quality sites. The data period analysed is from autumn 2008 to summers end in February 2018. Only trend confidences (**TC**) that are 'extremely likely' (one dot), or 'virtually certain' (two dots), have been reported in the table below. The percent annual change (**PAC**) reflects the percentage change of the median per year. A minimum PAC of 1% per year was required for a trend to be reported in the table below. The PAC scale goes out to +/- 20%, with a yellow bar indicating deterioration, and a blue bar indicating improvement. The water quality **state** is also included to provide an additional reference, with 'A' representing high quality, down to 'E' for lowest quality. Attributes in solid color have compulsory criteria taken from the National Policy Statement for Freshwater Management's (NPSFM) National Objectives Framework (NOF). Hatched colour indicates adapted criteria not contained in the NOF. Periphyton state is adapted from the NOF chlorophyll a criteria. Criteria for clarity, turbidity, and DRP states have been derived by the WCRC and are not contained in the NOF. Criteria for dissolved reactive phosphorus (DRP) and nitrate have been applied to total nitrogen (TN) and total phosphorus (TP), because there are no TN or TP criteria for rivers. TN and TP are often higher than nitrate and DRP, respectively; therefore applying the criteria in this way is potentially overly stringent.

Attribute	Site	TC	% change of median per year		Median	Units	State
E. coli	Bradshaws Ck @ Bradshaw Rd	• •	-9.9	-9.9	185	E. coli/100ml	C
E. coli	La Fontaine Stm @ Herepo Fishing Access	•	8.8	8.8	120	E. coli/100ml	B
E. coli	Ford Ck @ Blackball-Taylorville Rd	•	10.1	10.1	12	E. coli/100ml	A
E. coli	Harris Ck @ Mulvaney Rd	•	11.9	11.9	200	E. coli/100ml	E
E. coli	La Fontaine Stm @ Airstrip Fishing Access	• •	13.3	13.3	130	E. coli/100ml	E
Ammonia	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	• •	-17.4	-17.4	0.014	mg/L	A
Ammonia	Bradshaws Ck @ Bradshaw Rd	• •	-14.8	-14.8	0.030	mg/L	A
Ammonia	Sawyers Ck @ Dixon Pk	•	-12.2	-12.2	0.010	mg/L	A
Ammonia	Murray Ck @ Ford Rd S	• •	-11.6	-11.6	0.011	mg/L	A
Ammonia	Poerua Rv @ Rail Br	• •	-10.8	-10.8	0.007	mg/L	A
Ammonia	Bradshaws Ck @ Martins Rd	•	-10.3	-10.3	0.010	mg/L	A
Ammonia	Crooked Rv @ Te Kinga	•	-8.6	-8.6	0.006	mg/L	A
Ammonia	Duck Ck @ Kokatahi-Kowhitirangi Rd Br	• •	-8.2	-8.2	0.005	mg/L	A
Ammonia	Ellis Ck @ 50m d/s Ferry Rd Br	•	-8	-8	0.008	mg/L	A
Ammonia	Nelson Ck @ Swimming Hole Reserve	• •	-7.8	-7.8	0.005	mg/L	A
Ammonia	La Fontaine Stm @ Airstrip Fishing Access	•	-7.2	-7.2	0.007	mg/L	A
Ammonia	La Fontaine Stm @ Herepo Fishing Access	•	-7.0	-7.0	0.011	mg/L	A
Ammonia	Orowaiti Rv @ Excelsior Rd	•	-7.0	-7.0	0.032	mg/L	A
Ammonia	Orangipuku Rv @ Mouth	• •	-6.2	-6.2	0.013	mg/L	A
Ammonia	Seven Mile Ck @ 300m d/s Raleigh Ck	•	-5.0	-5.0	0.088	mg/L	A
Ammonia	Grey Rv @ Waipuna	• •	-4.6	-4.6	0.003	mg/L	A
Nitrate	Seven Mile Ck @ SH6 Rapahoe	• •	-11	-11	0.05	mg/L	A
Nitrate	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	• •	-9	-9	0.03	mg/L	A
Nitrate	Seven Mile Ck @ 300m d/s Raleigh Ck	• •	-7.3	-7.3	0.04	mg/L	A
Nitrate	Mawheraiti Rv @ SH7 Maimai	•	-3.6	-3.6	0.26	mg/L	A
Nitrate	Crooked Rv @ Rotomanu-Bell Hill Rd	•	-2.6	-2.6	0.04	mg/L	A
Nitrate	Arnold Rv @ Blairs Rd No. 2 Br	• •	3.2	3.2	0.14	mg/L	A
Nitrate	La Fontaine Stm @ Herepo Fishing Access	• •	3.8	3.8	0.34	mg/L	A
Nitrate	Ellis Ck @ 50m d/s Ferry Rd Br	• •	4.8	4.8	0.41	mg/L	A
Nitrate	Nelson Ck @ Swimming Hole Reserve	•	5.2	5.2	0.09	mg/L	A
Nitrate	Blackwater Ck @ Farm 846	•	5.5	5.5	0.48	mg/L	A
Nitrate	Deep Ck @ Arnold Vly Rd Br	•	5.9	5.9	0.75	mg/L	A
Nitrate	Molloy Ck @ Rail Line	• •	6.9	6.9	0.49	mg/L	A
DRP	Burkes Ck @ SH69	• •	-16.8	-16.8	0.003	mg/L	A
DRP	Molloy Ck @ Rail Line	• •	-13.0	-13.0	0.005	mg/L	A
DRP	Deep Ck @ Arnold Vly Rd Br	• •	-9.8	-9.8	0.005	mg/L	A
DRP	Mawheraiti Rv @ SH7 Maimai	•	-6.6	-6.6	0.006	mg/L	A
DRP	Nelson Ck @ Swimming Hole Reserve	•	-6.4	-6.4	0.006	mg/L	A
DRP	Orangipuku Rv @ Mouth	• •	-6.1	-6.1	0.004	mg/L	A
DRP	Murray Ck @ Ford Rd S	•	-5.4	-5.4	0.011	mg/L	B
DRP	Haast Rv @ Roaring Billy	• •	-4.2	-4.2	0.001	mg/L	A
DRP	Grey Rv @ Dobson	• •	-2.3	-2.3	0.003	mg/L	A
DRP	Harris Ck @ Mulvaney Rd	• •	8.4	8.4	0.021	mg/L	B
DRP	Blackwater Ck @ Farm 846	• •	9.1	9.1	0.027	mg/L	B

Field Code Changed

Table 9 Summary of Seasonal Kendall trend test and percentage change continued.

Field Code Changed

Attribute	Site	TC	% change of median per year		Median	Units	State
Total nitrogen	Murray Ck @ Ford Rd S	• •	-1.5	-1.5	0.70	mg/L	A
Total nitrogen	Arnold Rv @ Kotuku Fishing Access	• •	2.7	2.7	0.20	mg/L	A
Total nitrogen	Orangipuku Rv @ Mouth	• •	2.8	2.8	0.47	mg/L	A
Total nitrogen	Nelson Ck @ Swimming Hole Reserve	•	3	3	0.26	mg/L	A
Total nitrogen	Crooked Rv @ Te Kinga	• •	3.7	3.7	0.20	mg/L	A
Total nitrogen	La Fontaine Stm @ Airstrip Fishing Access	• •	3.8	3.8	0.46	mg/L	A
Total nitrogen	Baker Ck @ Baker Ck Rd	• •	4.2	4.2	0.26	mg/L	A
Total nitrogen	Hohonu Rv @ Mouth	• •	4.5	4.5	0.13	mg/L	A
Total nitrogen	Arnold Rv @ Blairs Rd No. 2 Br	• •	4.7	4.7	0.24	mg/L	A
Total nitrogen	La Fontaine Stm @ Herepo Fishing Access	• •	5	5	0.43	mg/L	A
Total nitrogen	Ellis Ck @ 50m d/s Ferry Rd Br	• •	5.1	5.1	0.49	mg/L	A
Total nitrogen	Ford Ck @ Blackball-Taylorville Rd	• •	5.3	5.3	0.19	mg/L	A
Total nitrogen	Molloy Ck @ Rail Line	• •	6.1	6.1	0.65	mg/L	A
Total phosphorus	Molloy Ck @ Rail Line	•	-8.3	-8.3	0.008	mg/L	A
Total phosphorus	La Fontaine Stm @ Herepo Fishing Access	• •	-7.3	-7.3	0.013	mg/L	B
Total phosphorus	Murray Ck @ Ford Rd S	•	-7.3	-7.3	0.015	mg/L	B
Total phosphorus	Burkes Ck @ SH69	•	-6.8	-6.8	0.015	mg/L	B
Total phosphorus	Orangipuku Rv @ Mouth	• •	-6.0	-6.0	0.009	mg/L	A
Total phosphorus	Unnamed Ck @ Adamson Rd Whataroa	•	-6.0	-6.0	0.016	mg/L	B
Total phosphorus	La Fontaine Stm @ Airstrip Fishing Access	• •	-5.2	-5.2	0.012	mg/L	B
Total phosphorus	Haast Rv @ Roaring Billy	• •	-5.0	-5.0	0.003	mg/L	A
Total phosphorus	Crooked Rv @ Te Kinga	•	-4.9	-4.9	0.010	mg/L	A
Total phosphorus	Buller Rv @ Longford	•	2.9	2.9	0.005	mg/L	A
Total phosphorus	Harris Ck @ Mulvaney Rd	• •	9.1	9.1	0.029	mg/L	C
Turbidity	Bradshaws Ck @ Bradshaw Rd	• •	-9.2	-9.2	3.3	FNU	C
Turbidity	Bradshaws Ck @ Martins Rd	• •	-5.9	-5.9	2.7	FNU	C
Turbidity	Buller Rv @ Te Kuha	• •	5.3	5.3	2.0	FNU	C
Turbidity	Ford Ck @ Blackball-Taylorville Rd	•	5.4	5.4	10.6	FNU	D
Turbidity	Grey Rv @ Waipuna	• •	5.605	5.605	1.0	FNU	A
Turbidity	Buller Rv @ Longford	•	6.047	6.047	1.1	FNU	B
Turbidity	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	•	6.7	6.7	3.5	FNU	C
Turbidity	Poerua Rv @ Rail Br	• •	10.7	10.7	1.0	FNU	A
Turbidity	La Fontaine Stm @ Herepo Fishing Access	• •	12.3	12.3	0.8	FNU	A
Turbidity	La Fontaine Stm @ Airstrip Fishing Access	• •	15.1	15.1	0.8	FNU	A
Turbidity	Harris Ck @ Mulvaney Rd	• •	19.4	19.4	0.8	FNU	A
Clarity	Bradshaws Ck @ Martins Rd	•	4.5	4.5	1.60	m	B
Clarity	Bradshaws Ck @ Bradshaw Rd	• •	4.4	4.4	1.44	m	C
Clarity	Murray Ck @ Ford Rd S	• •	4.3	4.3	5.50	m	A
Clarity	La Fontaine Stm @ Herepo Fishing Access	•	-2.7	-2.7	3.90	m	A
Clarity	Nelson Ck @ Swimming Hole Reserve	• •	-2.8	-2.8	2.37	m	B
Clarity	Crooked Rv @ Te Kinga	• •	-3.2	-3.2	3.45	m	A
Clarity	Poerua Rv @ Rail Br	•	-3.2	-3.2	3.50	m	A
Clarity	Harris Ck @ Mulvaney Rd	• •	-7.0	-7.0	3.16	m	A
Periphyton	Orowaiti Rv @ Excelsior Rd	• •	3.0	3.0	8	PES	B
Periphyton	Berry Ck @ N Brch Wanganui Flat Rd	• •	2.5	2.5	8.3	PES	A
Periphyton	Harris Ck @ Mulvaney Rd	•	1.9	1.9	7.8	PES	B
Periphyton	Sawyers Ck @ Dixon Pk	•	-2.0	-2.0	8.2	PES	A
EC25	Burkes Ck @ SH69	• •	9.7	9.7	113.5	uScm	N/A

Table 10 Summary of Seasonal Kendall trend tests and **actual** change for 10 years of data collected at West Coast Regional Council water quality sites. The data period analysed is from autumn 2008 to summers end in February 2018. Significant **landcover types** and activities are included: Indigenous (I), Forestry (F), Pastural agriculture (P), Mining (M), and Urban (U) for municipal sewerage/stormwater. The **actual change per year** (AC) has a yellow bar for deterioration, and a blue bar for improvement. The AC scale is different for each attribute and determined by the maximum value in each attribute group. The water quality **state** is included to provide an additional reference, with 'A' representing high quality, down to 'E' for lowest quality. Attributes in solid color have compulsory criteria taken from the National Policy Statement for Freshwater Management's (NPSFM) National Objectives Framework (NOF). Hatched colour indicates adapted criteria not contained in the NOF. Periphyton state is adapted from the NOF chlorophyll a criteria. Criteria for clarity, turbidity, and DRP states have been derived by the WCRC and are not contained in the NOF. Criteria for dissolved reactive phosphorus (DRP) and nitrate have been applied to total nitrogen (TN) and total phosphorus (TP), because there are no TN or TP criteria for rivers. TN and TP are often higher than nitrate and DRP, respectively; therefore applying the criteria in this way is potentially overly stringent. Only trend confidences that are either 'extremely likely', or 'virtually certain', have been reported in the table below. A minimum percent annual change of 1% per year was required for a trend to be reported in the table below. PEC = periphyton enrichment score. EC 25 = electrical conductivity.

Attribute	Site	I	F	P	M	U	Actual change per year		Units	State
E. coli	Bradshaws Ck @ Bradshaw Rd			🟩			-18	-18	E. coli/100ml	C
E. coli	Ford Ck @ Blackball-Taylorville Rd	🟩			🟫	▨	1	1	E. coli/100ml	A
E. coli	La Fontaine Stm @ Herepo Fishing Access	🟩		🟩			11	11	E. coli/100ml	B
E. coli	La Fontaine Stm @ Airstrip Fishing Access	🟩		🟩			17	17	E. coli/100ml	E
E. coli	Harris Ck @ Mulvaney Rd			🟩			24	24	E. coli/100ml	E
Ammonia	Bradshaws Ck @ Bradshaw Rd			🟩			-0.0044	-0.0044	mg/L	A
Ammonia	Seven Mile Ck @ 300m d/s Raleigh Ck	🟩			🟫	▨	-0.0044	-0.0044	mg/L	A
Ammonia	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	🟩			🟫	▨	-0.0024	-0.0024	mg/L	A
Ammonia	Orowaiti Rv @ Excelsior Rd	🟩		🟩			-0.0022	-0.0022	mg/L	A
Ammonia	Murray Ck @ Ford Rd S	🟩		🟩			-0.0013	-0.0013	mg/L	A
Ammonia	Sawyers Ck @ Dixon Pk	🟩	🟩	🟩		▨	-0.0012	-0.0012	mg/L	A
Ammonia	Bradshaws Ck @ Martins Rd			🟩			-0.0010	-0.0010	mg/L	A
Ammonia	Orangipuku Rv @ Mouth	🟩		🟩			-0.0008	-0.0008	mg/L	A
Ammonia	La Fontaine Stm @ Herepo Fishing Access	🟩		🟩			-0.0008	-0.0008	mg/L	A
Ammonia	Poerua Rv @ Rail Br	🟩		🟩			-0.0008	-0.0008	mg/L	A
Ammonia	Ellis Ck @ 50m d/s Ferry Rd Br	🟩		🟩			-0.0006	-0.0006	mg/L	A
Ammonia	Crooked Rv @ Te Kinga	🟩		🟩		▨	-0.0005	-0.0005	mg/L	A
Ammonia	La Fontaine Stm @ Airstrip Fishing Access	🟩		🟩			-0.0005	-0.0005	mg/L	A
Ammonia	Duck Ck @ Kokatahi-Kowhitirangi Rd Br	🟩		🟩			-0.0004	-0.0004	mg/L	A
Ammonia	Nelson Ck @ Swimming Hole Reserve	🟩	🟩	🟩	🟫		-0.0004	-0.0004	mg/L	A
Ammonia	Grey Rv @ Waipuna	🟩		🟩			-0.0001	-0.0001	mg/L	A
Nitrate	Mawheraiti Rv @ SH7 Maimai	🟩	🟩	🟩			-0.009	-0.009	mg/L	A
Nitrate	Seven Mile Ck @ SH6 Rapahoe	🟩			🟫	▨	-0.005	-0.005	mg/L	A
Nitrate	Seven Mile Ck @ Dunollie 400m u/s Ox Pd	🟩			🟫		-0.003	-0.003	mg/L	A
Nitrate	Seven Mile Ck @ 300m d/s Raleigh Ck	🟩			🟫	▨	-0.003	-0.003	mg/L	A
Nitrate	Crooked Rv @ Rotomanu-Bell Hill Rd	🟩		🟩			-0.001	-0.001	mg/L	A
Nitrate	Arnold Rv @ Blairs Rd No. 2 Br	🟩	🟩	🟩		▨	0.004	0.004	mg/L	A
Nitrate	Nelson Ck @ Swimming Hole Reserve	🟩	🟩	🟩	🟫		0.005	0.005	mg/L	A
Nitrate	La Fontaine Stm @ Herepo Fishing Access	🟩		🟩			0.013	0.013	mg/L	A
Nitrate	Ellis Ck @ 50m d/s Ferry Rd Br	🟩		🟩			0.020	0.020	mg/L	A
Nitrate	Blackwater Ck @ Farm 846	🟩		🟩			0.026	0.026	mg/L	A
Nitrate	Molloy Ck @ Rail Line	🟩	🟩	🟩			0.034	0.034	mg/L	A
Nitrate	Deep Ck @ Arnold Vly Rd Br	🟩	🟩	🟩	🟫		0.044	0.044	mg/L	A
DRP	Molloy Ck @ Rail Line	🟩	🟩	🟩			-0.0007	-0.0007	mg/L	A
DRP	Murray Ck @ Ford Rd S			🟩			-0.0006	-0.0006	mg/L	B
DRP	Burkes Ck @ SH69	🟩		🟩	🟫		-0.0005	-0.0005	mg/L	A
DRP	Deep Ck @ Arnold Vly Rd Br	🟩	🟩	🟩	🟫		-0.0005	-0.0005	mg/L	A
DRP	Mawheraiti Rv @ SH7 Maimai	🟩	🟩	🟩			-0.0004	-0.0004	mg/L	A
DRP	Nelson Ck @ Swimming Hole Reserve	🟩	🟩	🟩	🟫		-0.0004	-0.0004	mg/L	A
DRP	Orangipuku Rv @ Mouth	🟩		🟩			-0.0002	-0.0002	mg/L	A
DRP	Grey Rv @ Dobson	🟩	🟩	🟩	🟫	▨	-0.0001	-0.0001	mg/L	A
DRP	Haast Rv @ Roaring Billy	🟩		🟩			0.0000	0.0000	mg/L	A
DRP	Harris Ck @ Mulvaney Rd			🟩			0.0018	0.0018	mg/L	B
DRP	Blackwater Ck @ Farm 846	🟩		🟩			0.0025	0.0025	mg/L	B

Field Code Changed

Table 11 Summary of Seasonal Kendall trend tests and actual change continued.

Attribute	Site	I	F	P	M	U	Actual change per year		Units	State
TN	Murray Ck @ Ford Rd S			🟩			-0.011	🟦 -0.011	mg/L	A
TN	Arnold Rv @ Kotuku Fishing Access	🟩		🟩		▨	0.005 🟨	0.005	mg/L	A
TN	Hohonu Rv @ Mouth	🟩	🟩	🟩			0.006 🟨	0.006	mg/L	A
TN	Crooked Rv @ Te Kinga	🟩		🟩		▨	0.007 🟨	0.007	mg/L	A
TN	Nelson Ck @ Swimming Hole Reserve	🟩	🟩	🟩	🟧		0.008 🟨	0.008	mg/L	A
TN	Ford Ck @ Blackball-Taylorville Rd	🟩			🟧	▨	0.010 🟨	0.010	mg/L	A
TN	Baker Ck @ Baker Ck Rd	🟩		🟩			0.011 🟨	0.011	mg/L	A
TN	Arnold Rv @ Blairs Rd No. 2 Br	🟩	🟩	🟩		▨	0.011 🟨	0.011	mg/L	A
TN	Orangipuku Rv @ Mouth	🟩		🟩			0.013 🟨	0.013	mg/L	A
TN	La Fontaine Stm @ Airstrip Fishing Access	🟩		🟩			0.017 🟨	0.017	mg/L	A
TN	La Fontaine Stm @ Herepo Fishing Access	🟩		🟩			0.022 🟨	0.022	mg/L	A
TN	Ellis Ck @ 50m d/s Ferry Rd Br	🟩		🟩			0.025 🟨	0.025	mg/L	A
TN	Molloy Ck @ Rail Line	🟩	🟩	🟩			0.040 🟨	0.040	mg/L	A
TP	Murray Ck @ Ford Rd S			🟩			-0.0011	🟦 -0.0011	mg/L	B
TP	Burkes Ck @ SH69	🟩		🟩	🟧		-0.0010	🟦 -0.0010	mg/L	B
TP	Unnamed Ck @ Adamson Rd Whataroa			🟩			-0.0010	🟦 -0.0010	mg/L	B
TP	La Fontaine Stm @ Herepo Fishing Access	🟩		🟩			-0.0009	🟦 -0.0009	mg/L	B
TP	Molloy Ck @ Rail Line	🟩	🟩	🟩			-0.0007	🟦 -0.0007	mg/L	A
TP	La Fontaine Stm @ Airstrip Fishing Access	🟩		🟩			-0.0006	🟦 -0.0006	mg/L	B
TP	Orangipuku Rv @ Mouth	🟩		🟩			-0.0005	🟦 -0.0005	mg/L	A
TP	Crooked Rv @ Te Kinga	🟩		🟩		▨	-0.0005	🟦 -0.0005	mg/L	A
TP	Haast Rv @ Roaring Billy	🟩		🟩			-0.0002	🟦 -0.0002	mg/L	A
TP	Buller Rv @ Longford	🟩	🟩	🟩	🟧	▨	0.0001 🟨	0.0001	mg/L	A
TP	Harris Ck @ Mulvaney Rd			🟩			0.0026 🟨	0.0026	mg/L	C
Turbidity	Bradshaws Ck @ Bradshaw Rd			🟩			-0.30	🟦 -0.30	FNU	C
Turbidity	Bradshaws Ck @ Martins Rd			🟩			-0.16	🟦 -0.16	FNU	C
Turbidity	Grey Rv @ Waipuna	🟩		🟩			0.06 🟨	0.06	FNU	A
Turbidity	Buller Rv @ Longford	🟩	🟩	🟩		▨	0.07 🟨	0.07	FNU	B
Turbidity	La Fontaine Stm @ Herepo Fishing Access	🟩		🟩			0.09 🟨	0.09	FNU	A
Turbidity	Poerua Rv @ Rail Br	🟩		🟩			0.10 🟨	0.10	FNU	A
Turbidity	Buller Rv @ Te Kuha	🟩	🟩	🟩	🟧	▨	0.11 🟨	0.11	FNU	C
Turbidity	La Fontaine Stm @ Airstrip Fishing Access	🟩		🟩			0.12 🟨	0.12	FNU	A
Turbidity	Harris Ck @ Mulvaney Rd			🟩			0.16 🟨	0.16	FNU	A
Turbidity	Seven Mile Ck @ Dunollie 400m u/s Ox Pd				🟧		0.23 🟨	0.23	FNU	C
Turbidity	Ford Ck @ Blackball-Taylorville Rd	🟩			🟧	▨	0.57 🟨	0.57	FNU	D
Clarity	Murray Ck @ Ford Rd S			🟩			0.24	🟦 0.24	m	A
Clarity	Bradshaws Ck @ Martins Rd			🟩			0.07	🟦 0.07	m	B
Clarity	Bradshaws Ck @ Bradshaw Rd			🟩			0.06	🟦 0.06	m	C
Clarity	Nelson Ck @ Swimming Hole Reserve	🟩	🟩	🟩	🟧		-0.07 🟨	-0.07	m	B
Clarity	La Fontaine Stm @ Herepo Fishing Access	🟩		🟩			-0.11 🟨	-0.11	m	A
Clarity	Crooked Rv @ Te Kinga	🟩		🟩		▨	-0.11 🟨	-0.11	m	A
Clarity	Poerua Rv @ Rail Br	🟩		🟩			-0.11 🟨	-0.11	m	A
Clarity	Harris Ck @ Mulvaney Rd			🟩			-0.22 🟨	-0.22	m	A
Periphyton	Orowaiti Rv @ Excelsior Rd	🟩		🟩			0.24	🟦 0.24	PES	B
Periphyton	Berry Ck @ N Brch Wanganui Flat Rd			🟩			0.21	🟦 0.21	PES	A
Periphyton	Harris Ck @ Mulvaney Rd			🟩			0.15	🟦 0.15	PES	B
Periphyton	Sawyers Ck @ Dixon Pk	🟩	🟩	🟩		▨	-0.16 🟨	-0.16	PES	A
EC	Burkes Ck @ SH69	🟩		🟩	🟧		11 🟨	11	uScm	N/A

4 Lake Brunner water quality

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Lake Brunner water quality summary

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Lake Brunner is a large (41 km^2), deep lake (max. depth 109 m), inland from Greymouth on the West Coast. It has high water quality and is a popular recreational destination for people within and beyond the region. It is likely that intensive agriculture in the catchment has contributed to nutrient increases, which have been observed following the initiation of monitoring in the early 1990's.

Central lake monitoring supports a long and comprehensive data record. Data collected at Cashmere Bay and the tributaries has also been analysed.

The National Policy Statement for Freshwater Management 2014 (NPS-FM) contains a National Objective Framework (NOF) with a set of national bottom lines to achieve ecosystem health and human health for recreation. The NOF attribute states range from A to D. Category (or state) D is the worst and below the national bottom line. For Lake Brunner, we can apply the NOF to total nitrogen, total phosphorus, ammonia, and chlorophyll *a* data. We can also apply it to *E. coli* bacteria data. A five year block of data is used to determine these.

Lake processes

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

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

Additional information on the processes occurring in Lake Brunner can be found in previous West Coast Surface Water Quality reports, which can be found on the Council website www.wcrc.govt.nz.

Water quality trends

Central lake

Data collected at the central lake monitoring site represents the overall health of Lake Brunner. Council monitor's vertical oxygen and temperature profiles monthly throughout the year. Currently, oxygen at the bottom of the lake remains high enough to avoid undesirable cycles of phosphorus release from the lake bed. When phosphorus inputs are contrasted against anticipated outputs, no obvious phosphorus recycling is apparent. This is also supported through an absence of surface phosphorus increases in winter, when deep water that has been trapped at the bottom of the lake over summer by a warm surface layer is able to be mixed once the surface cools. When this warm surface layer forms a barrier to mixing the lake is said to be stratified. Oxygen levels at the bottom of the lake are usually lowest in June, which is consistent for most years. Temperature stratification was gone by June/ July 2018 and oxygenated water from the surface replenished deeper waters July/August 2018.

The bottom section of the lake during stratification is called the hypolimnion and oxygen can't reach the hypolimnion from the epilimnion (surface layer) when the lake is stratified. In the last nine years dissolved oxygen in the hypolimnion has reached lower levels compared with levels pre-2001 (Figure 1). However, oxygen levels are currently above what would result in nutrient release from the sediments.

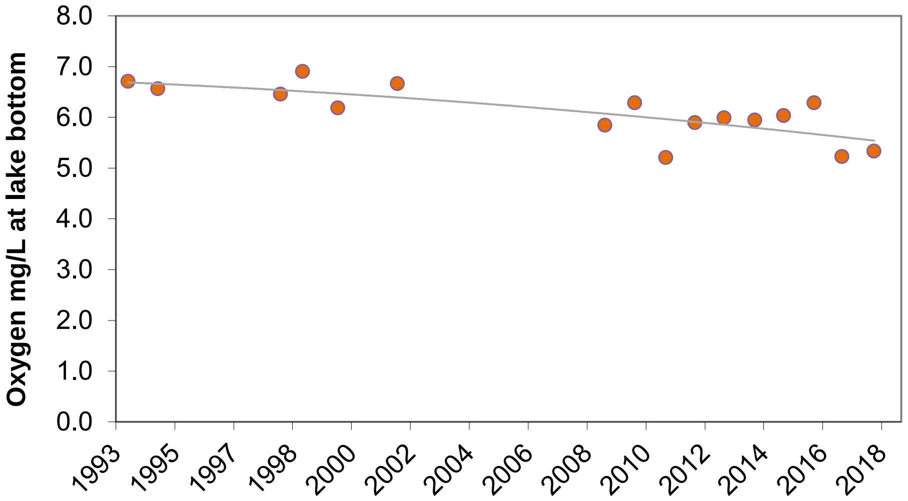

Figure 1 *Minimum dissolved oxygen levels measured in autumn/winter prior to mixing. All measurements are from the lake bottom at ~ 100 m depth, central Lake Brunner.*

Hypolimnetic oxygen depletion rates have varied between years. Increased eutrophication will lead to higher depletion rates. The rate at which oxygen is depleted is strongest nearest the lake bottom as this is where aerobic decomposition of organic matter is occurring (Figure 2). The overall rate of hypolimnetic oxygen consumption appeared to be slower (improved) in more recent times, although this decrease was not significant statistically. This was apparent with both 1998-2018, and 2008-2018 comparisons, at all depths (100, 90, 80, 70 m).

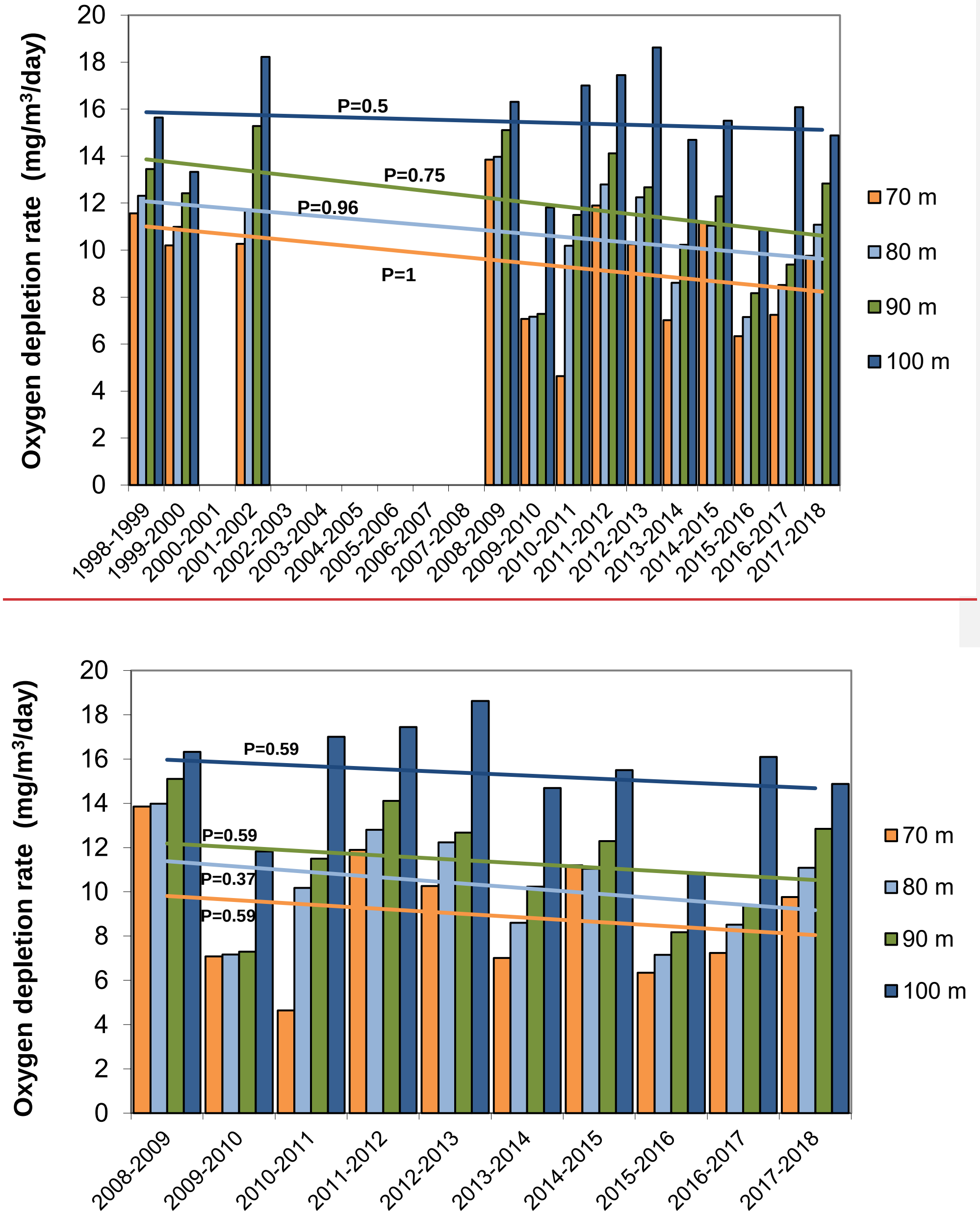

Figure 2 Hypolimnetic oxygen depletion rates in Lake Brunner 1998 to 2018, and 2008 to 2018. The P values represent the level of significance of the trend in depletion rates over time, as determined by the Mann-Kendall trend test. The '100 m' depth measurements are those measured from the very bottom of the lake,

so the actual distance from the surface will typically vary +/- 1 m, and occasionally by +/- 2 m. Other readings are consistently measured from the top.

Trends have been evaluated using the “Seasonal Kendall trend test” and “Seasonal Kendall slope estimator” (SKSE) in Time Trends v6.33. The SKSE measures the magnitude of the trend and can be used to determine the rate of change. The seasonal Kendall trend test determines whether the trend is statistically significant.

Central lake trends 1992-2018

Analyses incorporating the entire data record from (1992-2018) indicated that there were important deteriorating trends for total nitrogen (TN), nitrate, and DRP (Table 1). A slight decline was apparent for the Trophic Level Index (TLI). The TLI incorporates TN, total phosphorus (TP), clarity (vertical Secchi), and chlorophyll *a* levels, to form one score indicative of a lakes overall nutrient status (Burns et al. 2000).

Increasing TLI was driven primarily by the nutrient increases, primarily nitrogen. This suggests that agricultural intensification has led to an increase in nutrients over this period. However, there was no significant trend in phytoplankton abundance, as indicated by chlorophyll *a* concentrations, with an observed improvement in water clarity. Levels of chlorophyll *a* have been trending down; however they did spike abruptly in 2017 (Figure 3b).

Central lake trends 2001-2018

Over this shorter time period (2001-2018), the increasing trend in total nitrogen and nitrate remained apparent, but was less significant (Table 1). DRP showed no significant change (Table 1). Clarity and chlorophyll levels improved from 2001-2018, which was not observed over the longer 1992-2018.

Forms of nitrogen

Of the forms of dissolved nitrogen, 4% was ammonia, and 53% was nitrate, thus 57% was DIN (ammonia plus nitrate). Dissolved organic nitrogen (DON) accounted for 36% of all dissolved nitrogen. DON is the dominant form of dissolved nitrogen coming from forested catchments whereas nitrate is the dominant form leaving Lake Brunner’s pasture catchments (Rutherford et al. 2008; Verburg 2009). Intensification of farming will have contributed to this increase in nitrate. Nitrate is easily leached, particularly in wet places such as the Lake Brunner catchment.

Seasonality drives annual variation for many of the parameters measured in the lake. This is why we use statistical tests that accommodate for seasonal patterns within the data.

National objectives framework (NOF) categories

The NOF attribute states for the central lake site were “A’’ for TP, ammonia, and chlorophyll *a*. An “A” indicates ‘ecological communities that are healthy and resilient, similar to natural reference conditions’ (Table 2). Total nitrogen was a “B”, which indicates that ‘ecological communities are slightly impacted by additional algal and plant growth arising from nutrient levels that are elevated above natural reference conditions’ (MfE 2014). A wet climate will promote leaching of dissolved nitrogen. Higher nitrogen in Brunner (primarily in dissolved forms), relative to phosphorus and chlorophyll *a* levels, could be due to the surrounding cool, wet climate.

Tributary trends

Trends in water quality for the main tributaries were investigated. Like the lake, nitrogen increased in several tributaries. Ammonia improved in three tributaries. This may indicate an improvement in the management of point source discharges in the catchment, but is unlikely to have any effect on lake eutrophication given the small proportion of overall nitrogen ammonia represents. On a positive note, phosphorus levels improved in the lower Crooked and Orangipuku Rivers. The Crooked River, at this point, is a complicated catchment, that includes three lakes and a variety of catchment types.

Table 1 Seasonal Kendall trend analysis for water quality data collected at central Lake Brunner. Trends in red are undesirable and trends in blue are good. Statistically significant trends where the rate of change is larger than ± 1% per year, and the P value is <0.05, are described as being "important" (blue and red). Those trends where the rate of change is smaller than this, but the P value is still <0.05, are described as being "slight" (pink). Change tables

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Variable	Samples	Sampling period	Median	P	PAC
Nitrate	183	10/1/92-2	102	0	1.796
Dissolved reactive phosphorus	183	10/1/92-2	0.5	0	3.331
Chlorophyll *a*	172	10/1/92-2	1	0.773	0
Total suspended solids	124	29/9/03-2	0.9	0.319	-2.223
CDOM (Absorbance g340)	122	29/9/03-2	5.863	0.128	0.518
CDOM (Absorbance g440)	122	29/9/03-2	1.206	0.689	0.156
Clarity (vertical)	177	10/1/92-2	6	0.727	0.098
Total nitrogen	168	10/1/92-2	205	0	1.396
Total phosphorus	176	10/1/92-2	6	0.152	0
Dissolved inorganic nitrogen	144	19/7/01-2	119.375	0	1.18
Trophic level index (TLI)	177	10/1/92-2	2.731	0.001	0.378
Dissolved Organic Nitrogen	110	29/9/03-21/9/17	76	0.053	1.314
Variable	**Samples**	**Sampling p**	**Median**	**P**	**PAC**
Nitrate	150	5/1/01-2	111.615	0	0.986
Dissolved reactive phosphorus	150	5/1/01-2	0.515	0.008	0
Chlorophyll a	144	19/7/01-2	1.05	0.075	-1.8
Total suspended solids	124	29/9/03-2	0.9	0.319	-2.223
CDOM (Absorbance g340)	122	29/9/03-2	5.863	0.128	0.518
CDOM (Absorbance g440)	122	29/9/03-2	1.206	0.689	0.156
Clarity (vertical)	143	19/7/01-2	5.92	0.011	1.199
Total nitrogen	144	19/7/01-2	209.545	0	0.759

Total phosphorus	144	19/7/01-2	6	0.33	0
Dissolved inorganic nitrogen	144	19/7/01-2	119.375	0	1.18
Trophic level index (TLI)	143	19/7/01-21/9/17	2.786	0.595	-0.14
Dissolved Organic Nitrogen	110	29/9/03-21/9/17	76	0.053	1.314

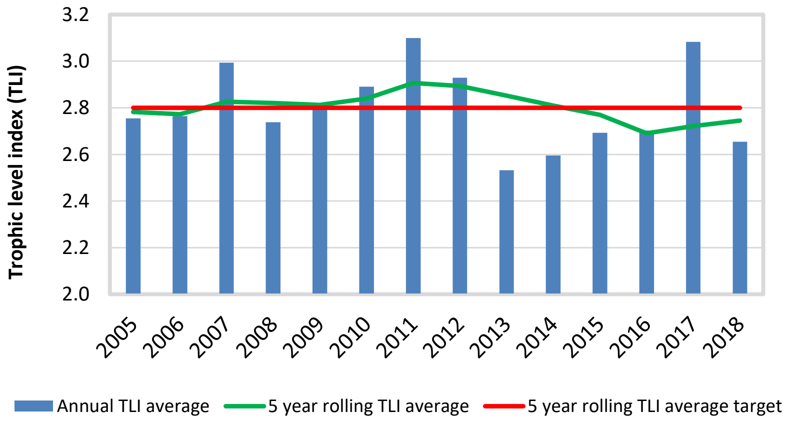
Table 2 NPS-FM NOF attribute states for Lake Brunner at the middle lake site, composite 1-25 m depth sample. States are calculated for both maximum and medians for ammonia and chlorophyll a. A five year block of data is used to calculate states – the final year is the year stated.

Mid Lake - 0-25 m tube	**2013**		**2014**		**2015**		**2016**		**2017**	
	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max
Ammonia	A	A	A	A	A	A	A	A	A	A
Chlorophyll a	A	A	A	A	A	A	A	A	A	A
Total nitrogen	B		B		B		B		B	
Total phosphorus	A		A		A		A		A	

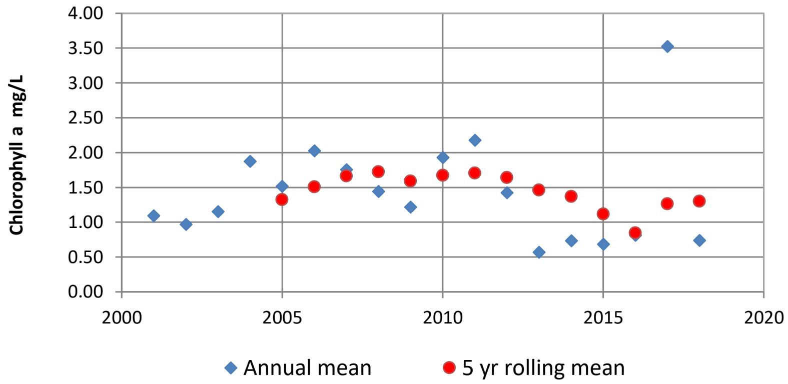
Table 3 Summary of Seasonal Kendall trend test and percentage change for 10 years of data collected at Lake Brunner tributary water quality sites. The data period analysed is from autumn 2008 to summers end in February 2018. Only trend confidences (TC) that are 'extremely likely' (one dot), or 'virtually certain' (two dots), have been reported in the table below. The percent annual change (PAC) reflects the percentage change of the median per year. A minimum PAC of 1% per year was required for a trend to be reported in the table below. The PAC scale goes out to +/- 20%, with a yellow bar indicating deterioration, and a blue bar indicating improvement.

Water quality attribute	Site	TC	PAC	Median	Units
Ammonia	Poerua Rv @ Rail Br	• •	-10.8	0.007	mg/L
Ammonia	Crooked Rv @ Te Kinga	•	-8.6	0.006	mg/L
Ammonia	Orangipuku Rv @ Mouth	• •	-6.2	0.013	mg/L
Nitrate	Crooked Rv @ Rotomanu-Bell Hill Rd	•	-2.6	0.042	mg/L
DRP	Orangipuku Rv @ Mouth	• •	-6.1	0.004	mg/L
Total nitrogen	Orangipuku Rv @ Mouth	• •	2.8	0.470	mg/L
Total nitrogen	Crooked Rv @ Te Kinga	• •	3.7	0.200	mg/L
Total nitrogen	Hohonu Rv @ Mouth	• •	4.5	0.130	mg/L
Total phosphorus	Orangipuku Rv @ Mouth	• •	-6	0.009	mg/L
Total phosphorus	Crooked Rv @ Te Kinga	•	-4.9	0.010	mg/L
Turbidity	Poerua Rv @ Rail Br	• •	10.7	1.0	FNU
Clarity	Crooked Rv @ Te Kinga	• •	-3.2	3.45	m
Clarity	Poerua Rv @ Rail Br	•	-3.2	3.50	m

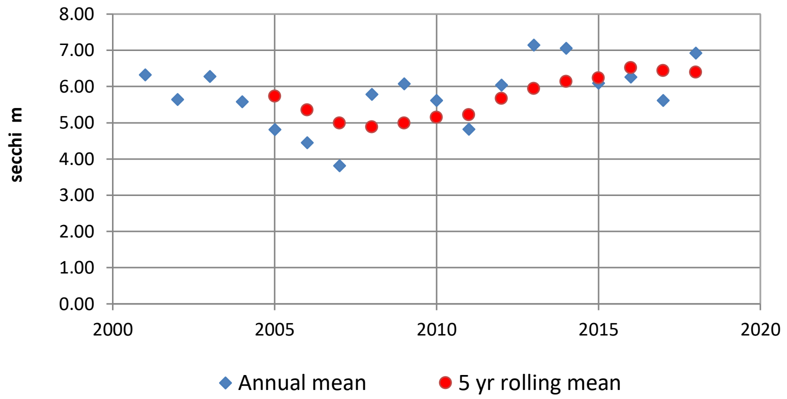
a)


Trophic level index (TLI)
3.2
3.0
2.8
2.6
2.4
2.2
2.0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Annual TLI average
5 year rolling TLI average
5 year rolling TLI average target

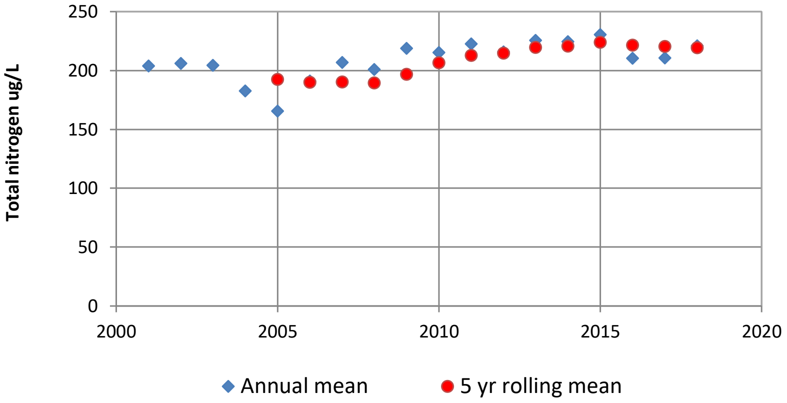
b)


Chlorophyll a mg/L
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2000
2005
2010
2015
2020
Annual mean
5 yr rolling mean

c)


secchi m
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2000
2005
2010
2015
2020
Annual mean
5 yr rolling mean

d)



e)

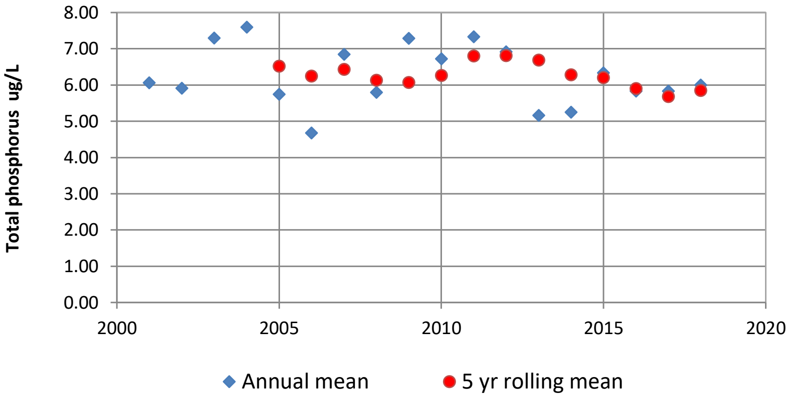


Figure 3a to 3e Annual means, and five yearly rolling means, for TLI, chlorophyll a, clarity (secchi), TN, and TP, measured at the central lake site (GYBS).

Cashmere Bay

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

Cashmere Bay is not deep, but its depth is sufficient for annual thermal stratification. Vertical mixing of water ceases once stratification has occurred. During stratification, oxygen is progressively used up at the bottom until it's gone. At this point, different biological and chemical processes occur.

The duration of seasonal low oxygen at the bottom of Cashmere Bay increased from 2009 to 2018 (Table 3, Figure 4), suggesting that oxygen depletion has increased. We might expect that this has led to the observed increase in phosphorus and ammonia near the bottom (Table 3). Dissolved phosphorus was higher on the bottom, compared to the surface, suggesting some recycling of phosphorus from sediments. On average, bottom ammonia was three times higher than at the surface, and during peak stratification ammonia can be 30-40 times higher. Higher DIN (ammonia + nitrate), at the bottom, also suggested some release of ammonia from bottom sediments during anoxic periods.

Ammonia and dissolved phosphorus have increased at the bottom of Cashmere Bay since 2003. As discussed, lower oxygen levels at the bottom are a likely driver of these increases – oxygen levels near the bed have decreased significantly since 2003. In contrast phosphorus decreased near the surface. A reduction in water quality near the bottom has not affected water quality at the surface. No changes in phytoplankton were observed (as indicated chlorophyll *a*), and clarity improved, probably as a result of less sediment inputs (Table 3).

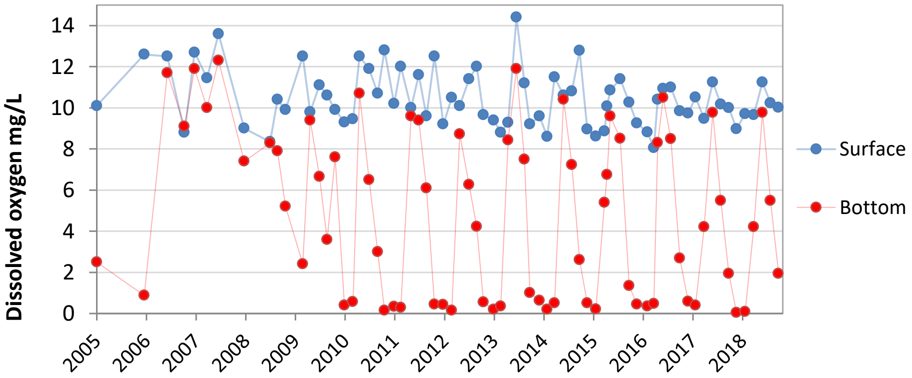


Figure 4 Dissolved oxygen levels at the surface and the bottom of Cashmere Bay, Lake Brunner.

In Cashmere Bay the NOF attribute states for surface water, based on median concentrations, were "A'' for ammonia and total phosphorus. An ammonia spike in 2016 pushed the 'max' criteria up to "B" making the overall ammonia category for 2016 a "B". Seasonal ammonia spikes during stratification meant bottom waters were in "C" category. Total nitrogen was consistently "B" at all depths. Chlorophyll *a* levels were "A" at both the top and bottom of the bay in 2017.

Table 3 Seasonal Kendall trend analysis for water quality data collected at Cashmere Bay, Lake Brunner. Important trends are in red (undesirable) and blue (good). DRP is dissolved reactive phosphorus; TDN is total dissolved nitrogen; TDP is total dissolved phosphorus; DON is dissolved organic nitrogen; DIN is dissolved inorganic nitrogen; DOP is dissolved organic phosphorus; DO is dissolved oxygen. Black disk clarity is measured horizontally and secchi disk clarity is measured vertically.

Depth	**Variable**	**Units**	**Samples**	**Sampling period**	**Median**	**P**	**PAC**
4	Ammonia *	mg/L	88	29/9/03-21/11/18	0.011	0.19	-2.195
4	Nitrate	mg/L	88	29/9/03-21/11/18	0.069	0.782	0.133
4	DRP	mg/L	88	29/9/03-21/11/18	0.001	0	-0.937
4	TDN	mg/L	74	29/9/03-21/11/18	0.158	0.58	-0.158
4	TDP	mg/L	74	29/9/03-21/11/18	0.004	0.127	-0.098
4	DON	mg/L	74	29/9/03-21/11/18	0.084	0.002	-2.866
4	DOP	mg/L	73	29/9/03-21/11/18	0.003	0.145	-1.336
4	Chlorophyll a	mg/L	88	29/9/03-21/11/18	0.002	0.525	-0.607
4	Clarity (secchi)	m	121	29/9/03-21/11/18	0.005	0	3.574
4	Total nitrogen	mg/L	89	29/9/03-21/11/18	0.209	0.057	-1.118
4	Total phosphorus	mg/L	89	29/9/03-21/11/18	0.008	0.004	-4.164
4	DIN	mg/L	88	29/9/03-21/11/18	0.083	0.968	0
Surface	DO @ 1 m	mg/L	72	2/3/05-21/11/18	10.200	0.791	0.07
Bottom	DO @ bottom	mg/L	72	2/3/05-21/11/18	4.710	0.003	-3.699
10	Ammonia	mg/L	89	29/9/03-21/11/18	0.033	0.015	4.508
10	Nitrate	mg/L	89	29/9/03-21/11/18	0.089	0.46	0.554
10	DRP	mg/L	89	29/9/03-21/11/18	0.001	0.002	4.652
10	TDN	mg/L	75	29/9/03-21/11/18	0.248	0.371	0.333
10	TDP	mg/L	75	29/9/03-21/11/18	0.006	0.004	4.164
10	DON	mg/L	75	29/9/03-21/11/18	0.097	0.283	-0.714
10	DOP	mg/L	75	29/9/03-21/11/18	0.004	0.039	2.527
10	Chlorophyll a	mg/L	87	29/9/03-21/11/18	0.001	0.526	-1.039
10	Total nitrogen	mg/L	89	29/9/03-21/11/18	0.283	0.969	0
10	Total phosphorus	mg/L	89	29/9/03-21/11/18	0.012	0.238	0.983
10	DIN	mg/L	88	29/9/03-21/11/18	0.154	0.009	1.207

** Ammonia represents 'total ammonia', hence the sum of ammonia and ammonium.*

Table 4 NPS-FM NOF attribute states for Lake Brunner at Cashmere Bay, for 4 m and 10 m depths. States are calculated for both maximum and medians for ammonia and chlorophyll a. Data from an entire year are used, hence no data has been used from 2018 as this years dataset was not complete at the time of analysis.

Cashmere Bay	**2013**		**2014**		**2015**		**2016**		**2017**	
	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max
Ammonia @ 4 m	A	A	A	A	A	A	A	B	A	B
Ammonia @ 10 m	A	C	A	B	A	C	B	C	B	C
Chlorophyll a @ 4 m	B	A	A	A	A	A	A	A	A	A
Chlorophyll a @ 10 m	A	A	A	A	A	A	A	B	A	A
Total nitrogen @ 4 m	B		B		B		B		B	
Total nitrogen @ 10 m	B		B		B		B		B	
Total phosphorus @ 4 m	A		A		A		A		A	
Total phosphorus @ 10 m	A		B		A		B		B	

Suitability for swimming in the lake

Faecal pathogen indicator bacteria, *E. coli*, are monitored annually between November and March at Iveagh Bay, Cashmere Bay, and the Moana boat ramp. Occasional spikes in these indicators have occurred over time (Figure 5). This can be caused by water fowl (based on records of water fowl numbers concurrent with each *E. coli* sample), or significant rainfall events that wash off bacteria from the surrounding land. The NPS-FM has a NOF scoring system for primary contact recreation, that ranges from A (best) to E (worst) – all swimming sites were in the A category.

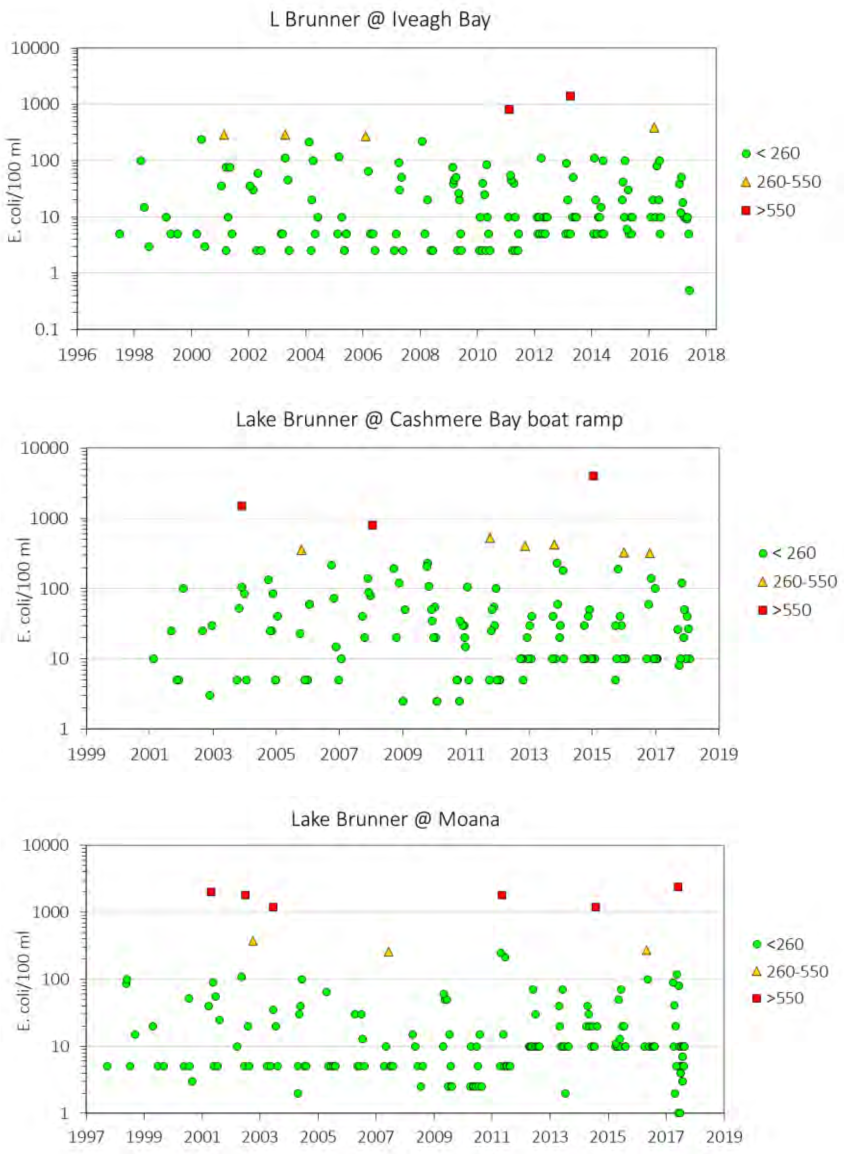


Figure 7 Individual sample results for Lake Brunner contact recreation monitoring sites. Single sample criteria are used; circles indicate acceptable pathogen levels for swimming, triangles indicate low risk, and squares indicate a moderate to high risk for bathing. Sampling is current up until the summer of 2017/2018.

Summary

Lake Brunner currently remains in an oligotrophic (low nutrient) state, safe for swimming and other recreational activities. Over the 2001 to 2018 time period clarity and chlorophyll a levels improved, but nitrogen, particularly its inorganic forms, have increased. Inorganic nitrogen (primarily nitrate), has also increased in some of Lake Brunner's main tributaries.

Increasing nitrate is most likely a result of agricultural activity. Dissolved nitrogen is easily leached and nitrogen from all sources are likely to leach in abundance given the catchment's wet climate. Lake Brunner is phosphorus limited. An increase in nitrate is unlikely to affect lake biology without an accompanying increase in phosphorus, although ecological dynamics of the lake are complicated and not easily predicted.

While nitrate has increased, there was a trend for improving phosphorus in the lower Crooked and Orangipuku Rivers.

Cashmere Bay water quality is poorer than that found in the main lake due to Cashmere's inherently different suite of physical characteristics. Dissolved forms of nitrogen and phosphorus have increased near the bottom of Cashmere Bay since 2003. This might be due in part to some nutrient recycling from sediment during periods when oxygen is absent. However, the quality reduction in Cashmere Bay's deeper waters has not affected its surface waters.

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~~3~~5 Appendices

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5.1 Location of surface water quality monitoring sites

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

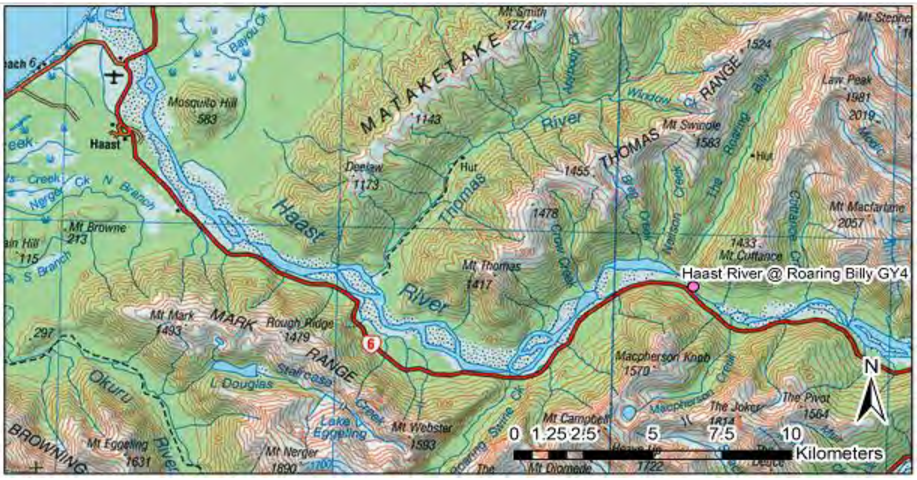


Figure 14 Site location map for Haast area.

Figure 15 Site location map for Whataroa and Hari Hari areas

Figure 16 Site location map for Hokitika area.

Figure 17 Site location map for Lake Brunner area.

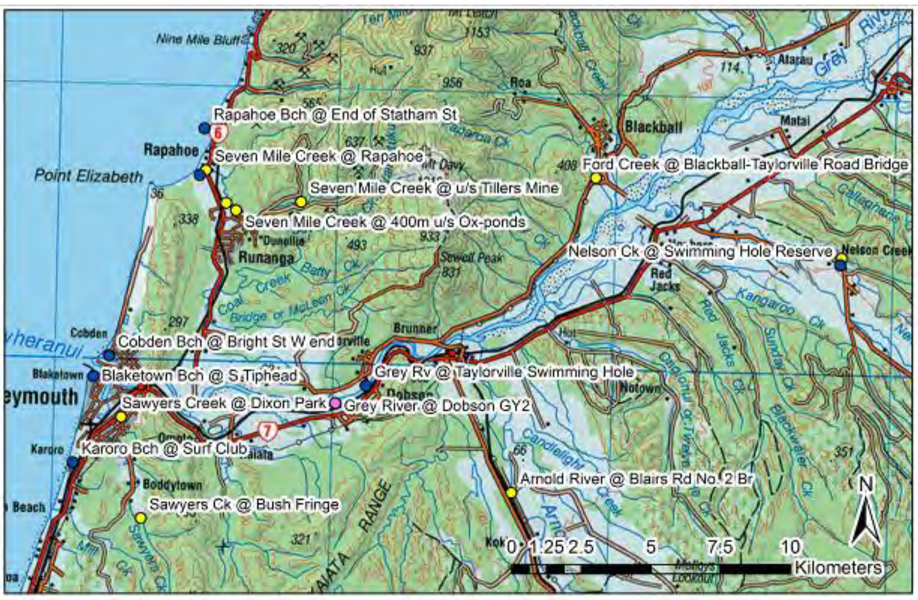


Figure 18 Site location map for Greymouth area.

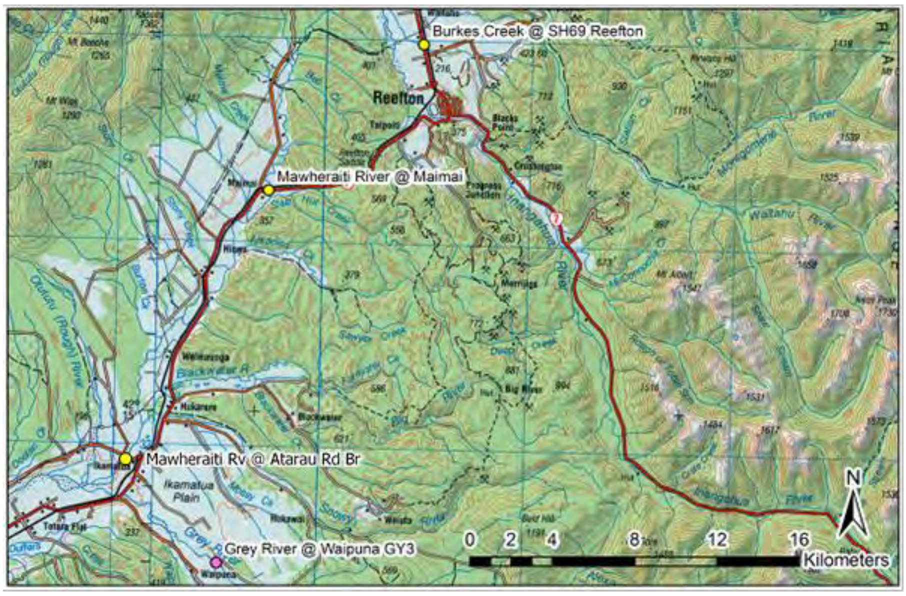


Figure 19 Site location map for Reefton area.

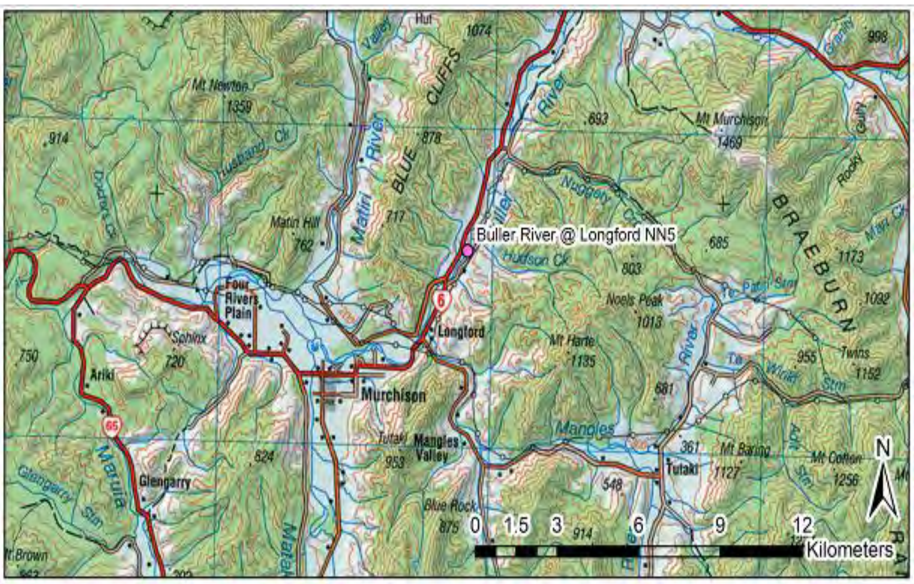


Figure 20 Site location map for Murchison area.

Figure 21 Site location map for Westport area

Figure 22 Site location map for Mokihinui area.

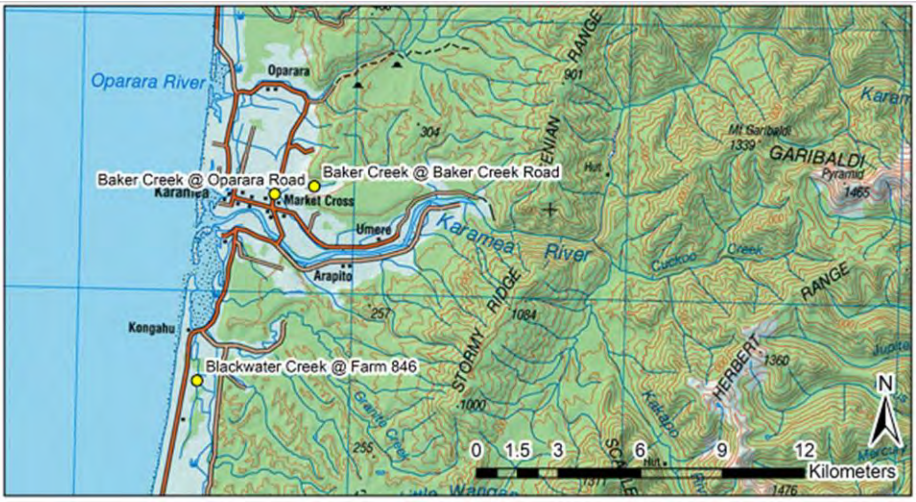


Figure 23 Site location map for Karamea area.

~~2.3~~5.2 List of sites, attributes, and sampling frequencies

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

Area		Site	Grid Ref		Continuous flow	Freq.	Summer			Autumn			Winter			Spring		
			Easting	Northing			Peri	Macro	Extra	Peri	Macro	Extra	Peri	Macro	Extra	Peri	Macro	Extra
Arnold Valley		Deep Ck@ Arnold Valley Rd Br	1473170	5287717	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Arnold Valley		Molloy Ck@ Rail line	1473620	5287356	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Brunner		Arnold Rv @ Blairs Rd	1466541	5295450	no	1/12	-	-	Nutrients & F/C & other	no	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	no	Yes	Nutrients & F/C & other
Brunner		Arnold Rv @ Kotuku Fish Access	1473618	5287233	yes	1/12	-	-	Nutrients & F/C & other	no	no	Nutrients & F/C & other	-	-	Nutrients & F/C & other	no	no	Nutrients & F/C & other
Grey Valley		Nelson Ck@Swimming hole	1478202	5304248	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Grey Valley		Ford Ck @ Blackball - Taylorville Rd	1469307	5306976	no	1/12	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & oth	-	-	Nutrients & F/C & SO4 & othe	4x5	Yes	Nutrients & F/C & SO4 & other
Reefton		Burkes Ck @ SH69 Reefton	1504696	5339809	no	1/12	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & oth	-	-	Nutrients & F/C & SO4 & othe	4x5	Yes	Nutrients & F/C & SO4 & other
Reefton		Mawheraiti Rv @ SH7 Maimai	1497321	5332529	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & E. coli & F/C	-	-	Nutrients & E. coli & F/C	4x5	Yes	Nutrients & E. coli & F/C
Reefton		Mawheraiti Rv @ Maimai	1490439	5319302	yes	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Greymouth		Sawyers Ck @ Dixon Park	1452464	5297885	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Greymouth		Sawyers Ck@Bush Fringe	1453257	5294215	no	1/12	-	-	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	1456421	5305492	no	1/4	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & oth	-	-	Nutrients & F/C & SO4 & othe	4x5	Yes	Nutrients & F/C & SO4 & other
Greymouth		Seven Mile Ck @ d/s Raleigh Ck	1456056	5305759	no	1/4	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & oth	-	-	Nutrients & F/C & SO4 & othe	4x5	Yes	Nutrients & F/C & SO4 & other
Greymouth		Seven Mile Ck @ u/s Tillers	1458749	5305858	no	1/2	-	-	Not sampled	4x5	Yes	Nutrients & F/C & SO4 & oth	-	-	Not sampled	4x5	Yes	Nutrients & F/C & SO4 & other
Greymouth		Seven Mile Ck @ SH6 Rapahoe	1455300	5306936	no	1/4	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & oth	-	-	Nutrients & F/C & SO4 & othe	4x5	Yes	Nutrients & F/C & SO4 & other
Hokitika		Duck Ck @ Kokatahi-Kowhitirangi Rd	1439192	5255878	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Hokitika		Harris Ck @ Mulvaney Rd	1437645	5253807	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Hokitika		Murray Ck @ Ford Rd South	1439079	5252920	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Westport		Bradshaws Ck @ Bradshaws Rd	1479072	5375830	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Westport		Bradshaws @ Martins Rd	1482190	5376517	no	1/12	-	-	Nutrients & F/C & other	no	no	Nutrients & F/C & other	-	-	Nutrients & F/C & other	no	no	Nutrients & F/C & other
Westport		Orowaiti Rv @ Excelsior Rd	1485712	5374719	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Westport		Orowaiti Rv @ Keoghans Rd	1579154	4813662	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Waitaha		Ellis Ck@Ferry Rd Bridge	1412781	5238086	no	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Whanganui		Berry Ck@N Branch (Wanganui flat Rd)	1401991	5226975	no	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Whanganui		La Fontaine @ Airstrip	1398082	5228598	no	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Whanganui		La Fontaine @ Heropo fishing access	1401990	5223689	no	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Whataroa		Okutua Rv @ Rd Br N Okarito forest	1377933	5213209	no	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Whataroa		Un-named Ck @ Adamson Rd	1386925	5216568	no	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)	1387444	5215699	no	1/4	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
North Buller		Baker Ck @ Baker Ck Rd	1528554	5433892	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
North Buller		Baker Ck @ Oparara Rd	1527107	5433583	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
North Buller		Page Stm @ Chasm Ck walkway	1514839	5400156	no	1/12	-	-	Nutrients & F/C & SO4 & other	4x5	Yes	Nutrients & F/C & SO4 & oth	-	-	Nutrients & F/C & SO4 & othe	4x5	Yes	Nutrients & F/C & SO4 & other
North Buller		Blackwater Ck @ Farm 846	1524426	5426752	no	1/12	-	-	Nutrients & F/C & other	no	no	Nutrients & F/C & other	-	-	Nutrients & F/C & other	no	no	Nutrients & F/C & other
Brunner		Crooked Rv @ Rotomanu-Bell Hill Rd	1484902	5279302	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Brunner		Crooked Rv @ Te Kinga / mouth	1477727	5281988	no	1/12	-	-	Abs,nutrients & F/C & other	4x5	Yes	Abs,nutrients & F/C & other	-	-	Abs,nutrients & F/C & other	4x5	Yes	Abs,nutrients & F/C & other
Brunner		Hohonu Rv @ Mouth	1469854	5281097	no	1/12	-	-	Abs,nutrients & F/C & other	4x5	Yes	Abs,nutrients & F/C & other	-	-	Abs,nutrients & F/C & other	4x5	Yes	Abs,nutrients & F/C & other
Brunner		Hohonu Rv @ Mitchells - Kumara Rd Br	1464991	5277313	no	1/12	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other	-	-	Nutrients & F/C & other	4x5	Yes	Nutrients & F/C & other
Brunner		Orangipuku Rv @ Mouth	1472080	5275934	no	1/12	-	-	Abs,nutrients & F/C & other	4x5	Yes	Abs,nutrients & F/C & other	-	-	Abs,nutrients & F/C & other	4x5	Yes	Abs,nutrients & F/C & other
Brunner		Poerua River @ Station Rd End	1478832	5278133	no	1/12	-	-	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	1460140	5298565	yes	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 @ Waipuna NIWA	1495184	5314254	yes	1/12	-	-	Flow, DO%, temp, clarity, BOD, colour (340&440 nm), NO3, NHx, TN, DRP, TP, *E. coli*						Macro's once a year	All data collected by NIWA		
Haast	NIWA	Haast Rv @ Roaring Billy NIWA	1302916	5127972	yes	1/12	-	-	Flow, DO%, temp, clarity, BOD, colour (340&440 nm), NO3, NHx, TN, DRP, TP, *E. coli*						Macro's once a year	All data collected by NIWA		
Buller	NIWA	Buller @ Te Kuha NIWA	1488438	5368188	yes	1/12	-	-	Flow, DO%, temp, clarity, BOD, colour (340&440 nm), NO3, NHx, TN, DRP, TP, *E. coli*						Macro's once a year	All data collected by NIWA		
Buller	NIWA	Buller @ Longford NIWA	1549087	5376174	yes	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		

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

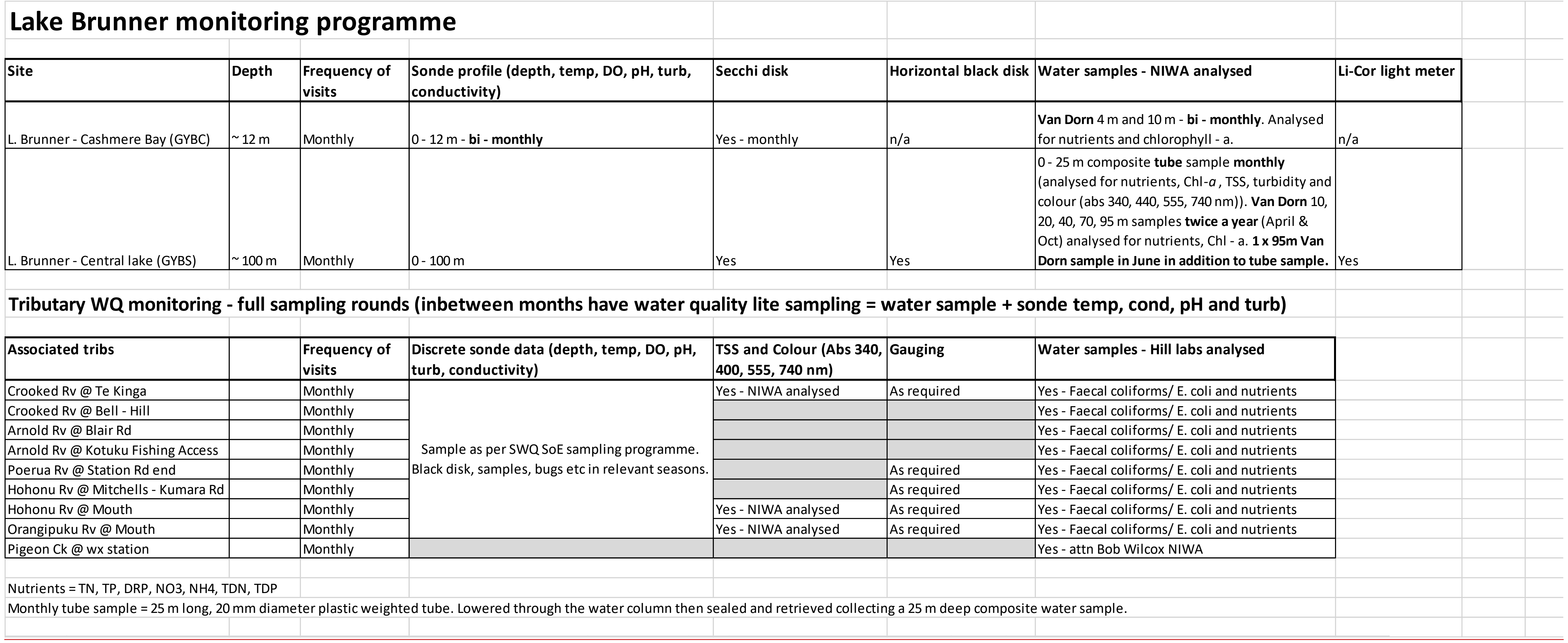
Macroinvertebrates (= macro): Like periphyton, macroinvertebrates can be indicative of longer term water and habitat quality regimes, even though they are measured at a single point in time. Numbers and types of bugs say a lot about conditions in the stream.

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

~~2.4~~5.3 List of sites, attributes, and sampling frequencies for Lake Brunner monitoring



Lake Brunner monitoring programme

Site	Depth	Frequency of visits	Sonde profile (depth, temp, DO, pH, turb, conductivity)	Secchi disk	Horizontal black disk	Water samples - NIWA analysed	Li-Cor light meter
L. Brunner - Cashmere Bay (GYBC)	~ 12 m	Monthly	0 - 12 m - **bi - monthly**	Yes - monthly	n/a	**Van Dorn** 4 m and 10 m - **bi - monthly**. Analysed for nutrients and chlorophyll - a.	n/a
L. Brunner - Central lake (GYBS)	~ 100 m	Monthly	0 - 100 m	Yes	Yes	0 - 25 m composite **tube** sample **monthly** (analysed for nutrients, Chl-*a* , TSS, turbidity and colour (abs 340, 440, 555, 740 nm)). **Van Dorn** 10, 20, 40, 70, 95 m samples **twice a year** (April & Oct) analysed for nutrients, Chl - a. **1 x 95m Van Dorn sample in June in addition to tube sample.**	Yes

Tributary WQ monitoring - full sampling rounds (inbetween months have water quality lite sampling = water sample + sonde temp, cond, pH and turb)

Associated tribs		Frequency of visits	Discrete sonde data (depth, temp, DO, pH, turb, conductivity)	TSS and Colour (Abs 340, 400, 555, 740 nm)	Gauging	Water samples - Hill labs analysed
Crooked Rv @ Te Kinga		Monthly	Sample as per SWQ SoE sampling programme. Black disk, samples, bugs etc in relevant seasons.	Yes - NIWA analysed	As required	Yes - Faecal coliforms/ E. coli and nutrients
Crooked Rv @ Bell - Hill		Monthly				Yes - Faecal coliforms/ E. coli and nutrients
Arnold Rv @ Blair Rd		Monthly				Yes - Faecal coliforms/ E. coli and nutrients
Arnold Rv @ Kotuku Fishing Access		Monthly				Yes - Faecal coliforms/ E. coli and nutrients
Poerua Rv @ Station Rd end		Monthly			As required	Yes - Faecal coliforms/ E. coli and nutrients
Hohonu Rv @ Mitchells - Kumara Rd		Monthly			As required	Yes - Faecal coliforms/ E. coli and nutrients
Hohonu Rv @ Mouth		Monthly		Yes - NIWA analysed	As required	Yes - Faecal coliforms/ E. coli and nutrients
Orangipuku Rv @ Mouth		Monthly		Yes - NIWA analysed	As required	Yes - Faecal coliforms/ E. coli and nutrients
Pigeon Ck @ wx station		Monthly				Yes - attn Bob Wilcox NIWA

Nutrients = TN, TP, DRP, NO3, NH4, TDN, TDP

Monthly tube sample = 25 m long, 20 mm diameter plastic weighted tube. Lowered through the water column then sealed and retrieved collecting a 25 m deep composite water sample.

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~~3.1~~5.4 Data analytical methods

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~~3.1.1~~5.4.1 Relationships between water quality and land use

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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 5.6 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).

~~3.1.2~~5.4.2 Comparison to water quality guidelines

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Percentage bar graphs have been used to illustrate how some of the key attributes measured at Regional Council monitoring program sites compared to the respective guidelines for those attributes. A guide to the interpretation of these figures is provided in Section 5.7 with more detail on these guidelines provided in Section 5.5.

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

We have calculated NOF scores using 5 year blocks of data. Individual NOF scores have been calculated in this way for the last five years e.g. 2017~~3~~ nitrate is based on 2013~~09~~-2017~~3~~ data ~~, and 2012 nitrate is based on 2008-2012 data,~~ etc. As a lot of the same data is involved in computing rolling percentiles from neighboring years, attribute scores often don’t change much between years. While it is of interest to compare attribute states from previous years, the ‘trend’ aspect of this should be ignored as it is superseded by better forms of statistical trend analysis. ~~As we didn’t have a full 2014 dataset at the time of analysis, the data was analysed up until December 2013.~~

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

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

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

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

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

DIN / DRP

~~3.1.3~~5.4.3 Impact/reference sites: Longitudinal patterns over time

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A number of rivers in the region are sampled at two or more locations. This consists of an upstream 'reference site' and downstream site impacted to a greater extent by one or more anthropogenic pressures. The difference between the upstream and downstream site was calculated by subtracting the value for an attribute at the upstream site from that of the downstream site, from the same day. The median, quartiles and maximums for these differences are shown in Error! Reference source not found. - Error! Reference source not found..

~~3.1.4~~5.4.4 Contact recreation

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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.

~~3.1.5~~5.4.5 Trend analysis: Regional Council and NIWA sites

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

The first?

The second used Seasonal Kendall tests carried out on individual Regional Council sites for the 2008~~0~~-2018~~0~~ period. For a trend to be significant it required a p value of <0.05. We defined a trend as 'meaningful' if it had statistical significance i.e. p <0.05, *and* had an annual rate of change of more than 1%. Refer to Vant (2007). It was also desired that at least 40 data points were utilised in the analysis (i.e., quarterly samples over 10 years) as per Scarsbrook (2008).

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

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

~~3.1.6~~5.4.6 Lake Brunner catchment

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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).

~~3.2~~5.5 Physical, chemical, and biological qualities

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~~3.2.1~~5.5.1 pH

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

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

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

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

~~3.2.2~~5.5.2 Temperature

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

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

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

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

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

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

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

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

~~3.2.3~~5.5.3Biochemical oxygen demand and dissolved oxygen

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

Unpolluted waters typically have BOD5 (5 day biochemical oxygen demand) values of 2 mg/L or less, whereas receiving waters of waste may have values up to 10 mg/L or more, particularly near a point of a wastewater discharge. Raw sewage has a BOD$_5$ of about 600 mg/L, whereas treated sewage effluents have BOD$_5$ values ranging from 20 to 100 mg/L depending on the level of treatment applied.

Aquatic heterotrophic bacteria and fungi (the main components of undesirable feathery, cotton-wool-like growths commonly referred to as "sewage fungus") grow in response to readily degradable organic compounds, such as short-chain organic acids, sugars, and alcohol, which are sometimes found in wastewater discharges (e.g., dairy shed, piggery, meat works, and cheese factory effluents). In doing so, they consume oxygen from the water and can detract from the aesthetic appeal of a water. Sewage fungus should not be visible to the naked eye as obvious plumes or mats. The MfE (1992) guideline suggests BOD$_5$ of <5 mg/L to avoid growth of nuisance bacterial slime.

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

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

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

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

~~3.2.4~~5.5.4 Suspended sediment, turbidity & clarity

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

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

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

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

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

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

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

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

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

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

Visual clarity change

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

Significant adverse effects on aquatic life

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

Water managed for contact recreation.

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

~~3.2.5~~5.5.5Conductivity

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

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

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

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

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

~~3.2.6~~5.5.6 Nutrients: nitrogen and phosphorus

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

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

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

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

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

~~3.2.7~~5.5.7 Ammoniacal nitrogen, ammonia, and ammonium

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Ammonia is a common constituent of aquatic environments. It is present both as a natural breakdown product of nitrogenous organic matter and as a contaminant from wastewater discharges and run-off. Ammoniacal nitrogen is the combination of ammonium ions (or ionised ammonia) (NH_4^+), and [un-ionised] ammonia (NH_3). The prevalence of these two forms is dependent on the pH, temperature, and salinity of the water. Concentrations are usually expressed either as total ammonia (or ammonia, the sum of NH_3 and NH_4^+), or as concentration of the un-ionised NH_3 only. NH_3 is the main poisonous component for aquatic organisms, so when ammonia is quoted, the pH and temperature are also relevant in determining toxicity (Figure 24).

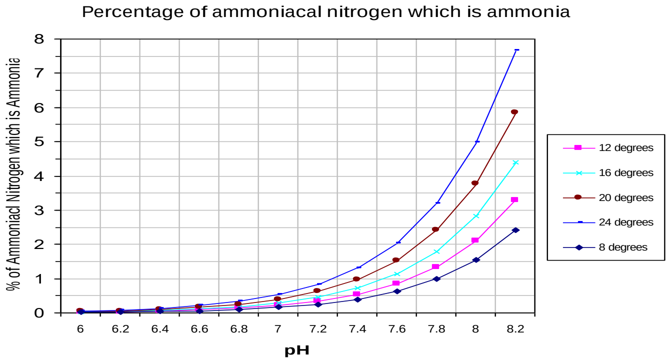

Figure 24 Percentage of ammonia which is ammonia depending on the water pH and temperature.

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

An ammonia value of 0.9 mg/L (at pH 8, 20 °C), has been suggested as a high reliability (95%) trigger value for freshwater (ANZECC 2000). This trigger value varies with pH and temperature (Table 12). 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 35). Based on an upper limit of pH 8.5, an ammonia guideline of 0.4 mg/L has been selected as a benchmark for analysis in this report (Table 12).

Table 12 2000 ANZECC freshwater trigger values for ammonia at different pH (temperature not taken into account).

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

~~3.2.8~~5.5.8Faecal microbiological indicators

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

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

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

The main water quality attributes used for monitoring Regional Council sites are faecal coliforms/*Escherichia coli* and Enterococci. The latter is used only at sites that have tidal influence or are located in marine waters. Individual values have been plotted for *E. coli* with values separated by the following criteria: circle = acceptable (< 260 *E. coli*/100 ml), triangle = alert (260 – 550 *E. coli* 100 ml), and square = action (> 550 *E. coli*) values in accordance with MfE (2003) contact recreation guidelines for individual values (Appendix 5.4.4).

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

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

~~3.2.9~~5.5.9Periphyton

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

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

Periphyton is assessed by the Regional Council once during autumn and once during spring using an approach similar to the Rapid Assessment Method 2 (RAM 2) (Biggs & Kilroy 2000). Four transects across the stream are used, each with five points where a stone is selected and the percentage cover of each category of periphyton is visually estimated for each stone. Categories are differentiated by colour and thickness, and are likely to represent certain groups of periphyton. Categories have an assigned score, and the combination of these can be used to calculate an enrichment indicator. A *low* score indicates *high* periphyton abundance. The New Zealand periphyton guideline (Biggs 2000) suggests biomass limits of 60 % cover of >3 mm thick diatoms/cyanobacteria and 30 % cover of >2 cm filamentous algae, to maintain contact recreation and aesthetic values. The same standard of 30 % cover of >2 cm filamentous algae is also promoted to maintain trout habitat and angling values. When computed into a RAM2 enrichment score, these thresholds equate to a score of between four and six. For analysis in this report a threshold of five has been chosen. Thus, enrichment scores of five or less are deemed likely to indicate periphyton biomass beyond that recommended by the guideline. Need to update this section as not using percentage bar graph this time.

~~3.2.10~~5.5.10Macroinvertebrates

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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 13)

Table 13 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 14).

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 14).

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

Table 14 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.

~~3.3~~5.6 What is REC?

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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 15. 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 15. Map distributions of source of flow, geology, and land cover are shown in Figure 25 to Figure 27

Table 15 REC classes found in the West Coast region. Classes are hierarchical starting at the top in order of: climate/source-of-flow/geology/land-cover/network position/valley landform. Those in bold are represented in the Regional Council SOE dataset.

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

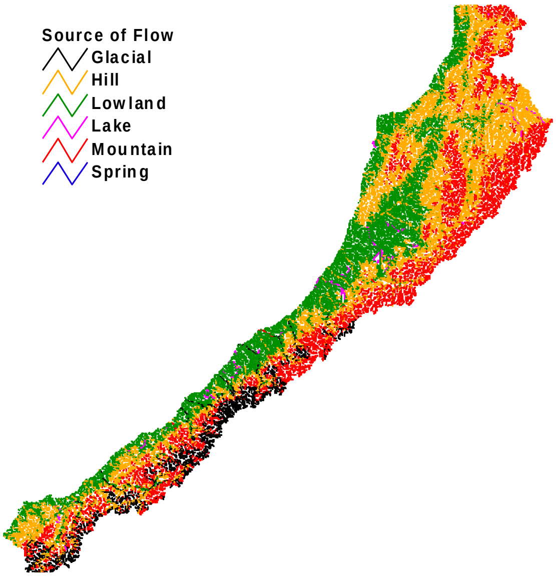

Figure 25 Map of the West Coast region showing source of flow according to REC.

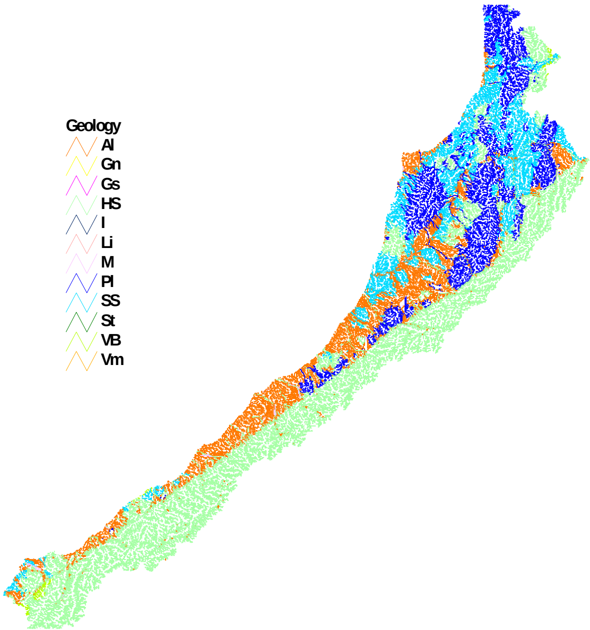

Figure 26 Map of the West Coast region showing geology class according to REC. From the key, only Al (alluvial), HS (hard sedimentary), M (metamorphic), Pl (plutonic), and SS (soft sedimentary), are present on the map.

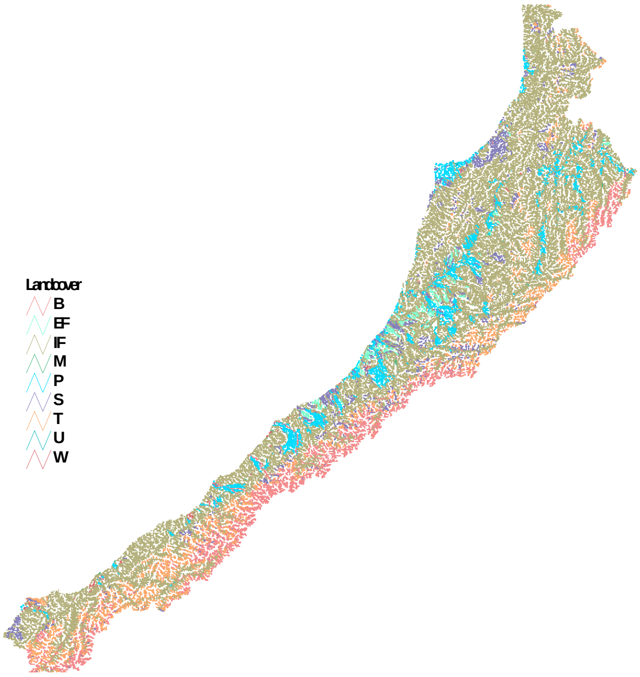

Figure 27 Map of the West Coast region showing land cover type according to REC.

~~3.4~~5.7 Percentage bar graphs: How they work

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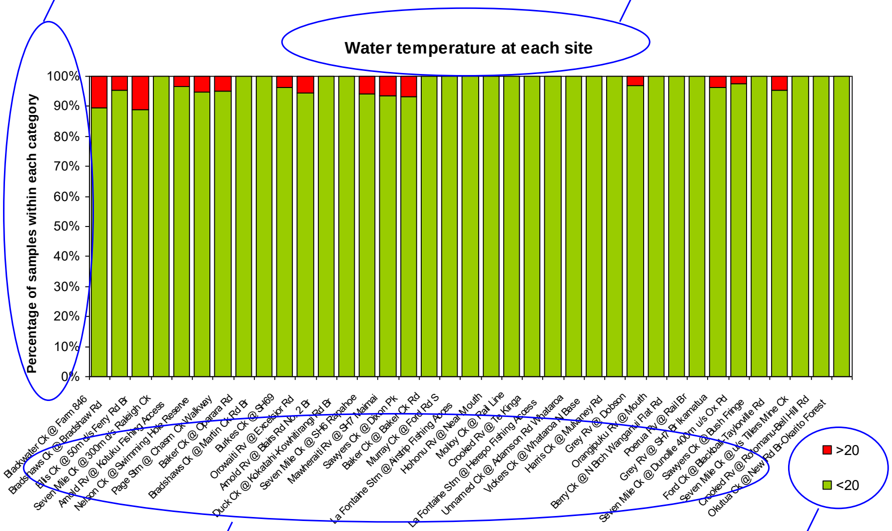
These are located in Section 2.2. Below is an example with some additional information to assist with their interpretation.

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

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



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

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

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

~~3.5~~5.8 Box and whisker plots - Regional Council sites

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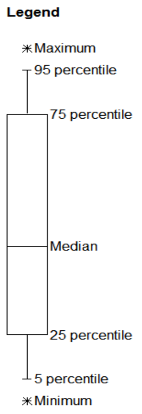
In each of the following box and whisker graphs sites are listed in alphabetical order along the X axis so comparison can be made between multiple sites on the same river.



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

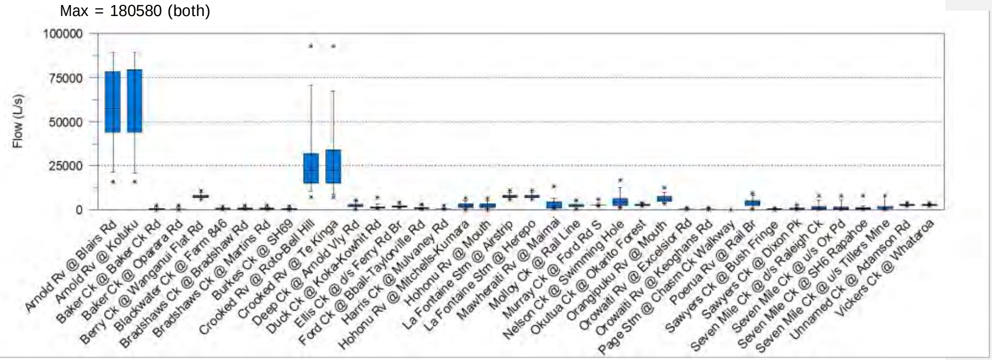


Figure 28 Box and whisker plot: Flow.

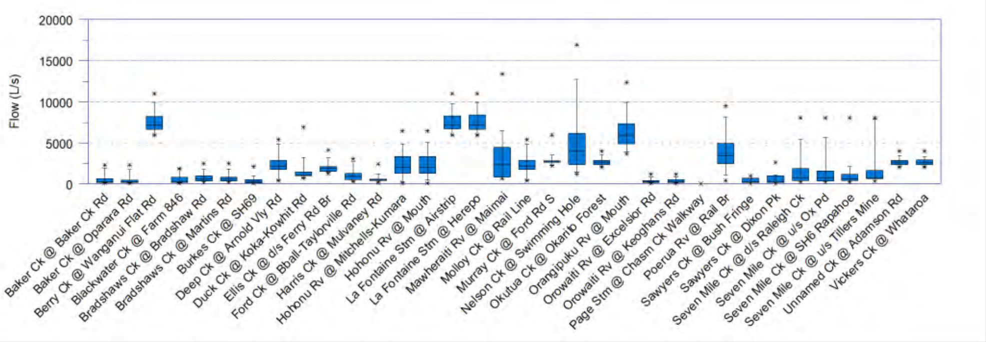


Figure 29 Box and whisker plot: Flow (Arnold and Crooked Rivers excluded).

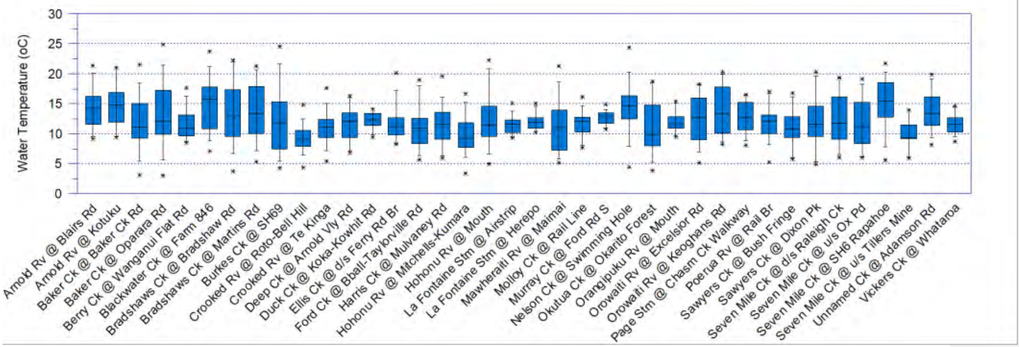


Figure 30 Box and whisker plot: Temperature

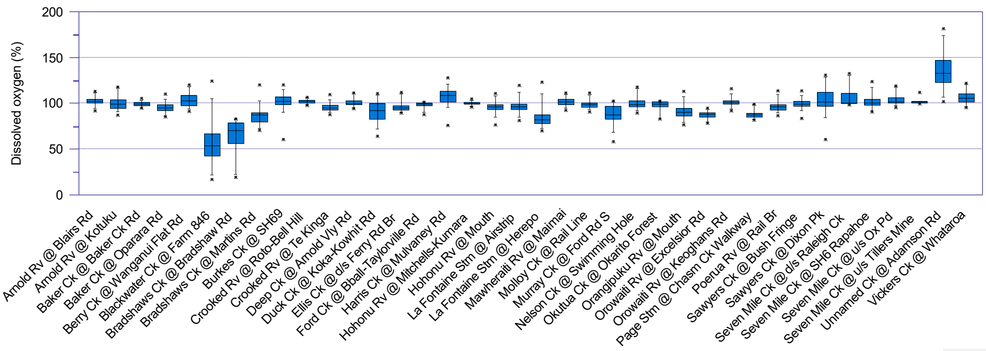


Figure 31 Box and whisker plot: Dissolved oxygen (% saturation).

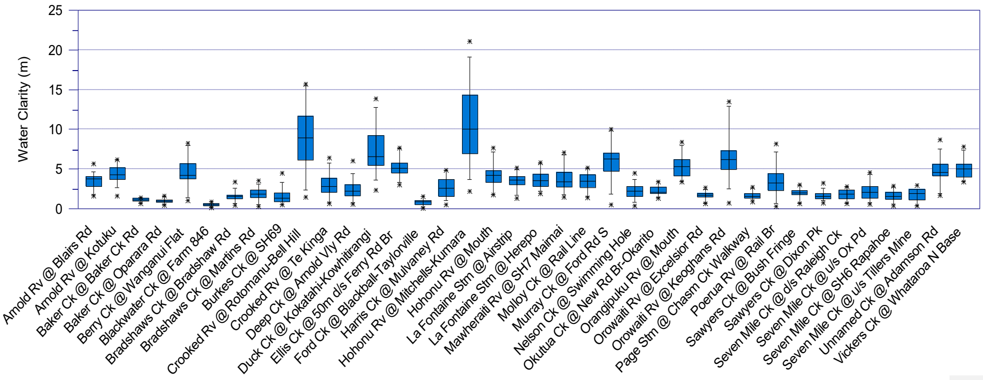


Figure 32 Box and whisker plot: Clarity 2013 – 2017.

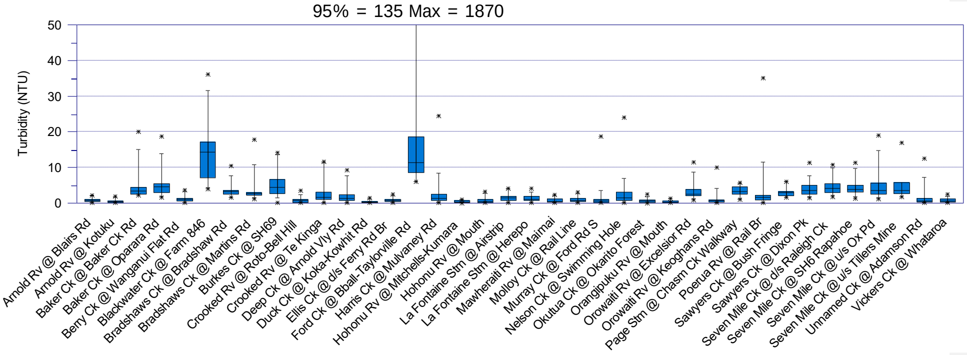


Figure 33 Box and whisker plot: Turbidity

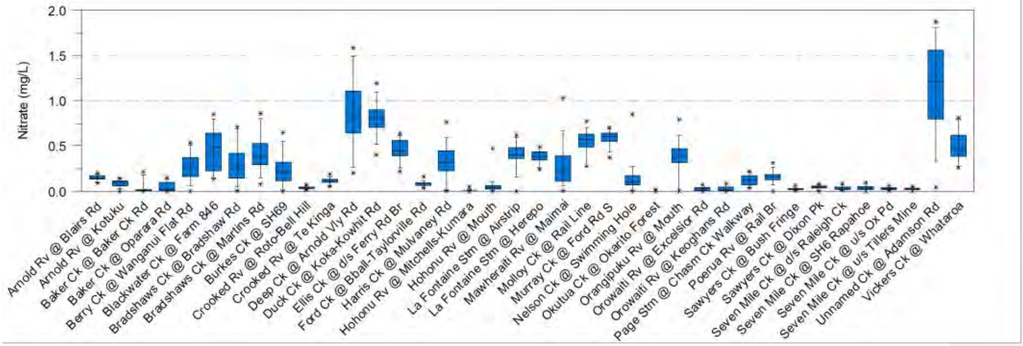


Figure 34 Box and whisker plot: Nitrate (NOx-N)

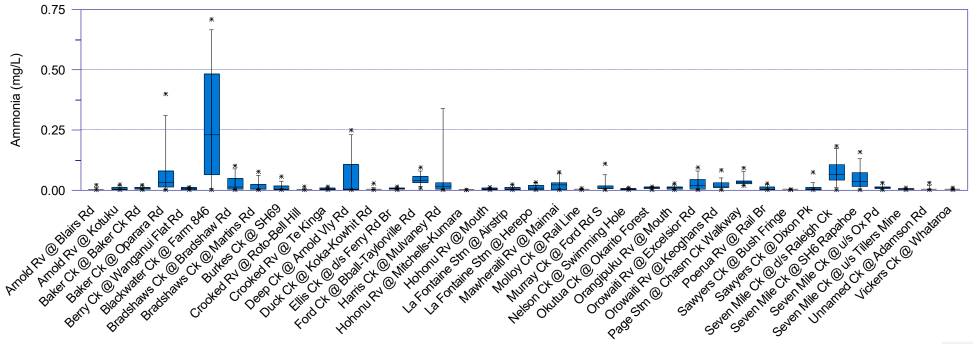


Figure 35 Box and whisker plot: Ammoniacal nitrogen (NH4-N)

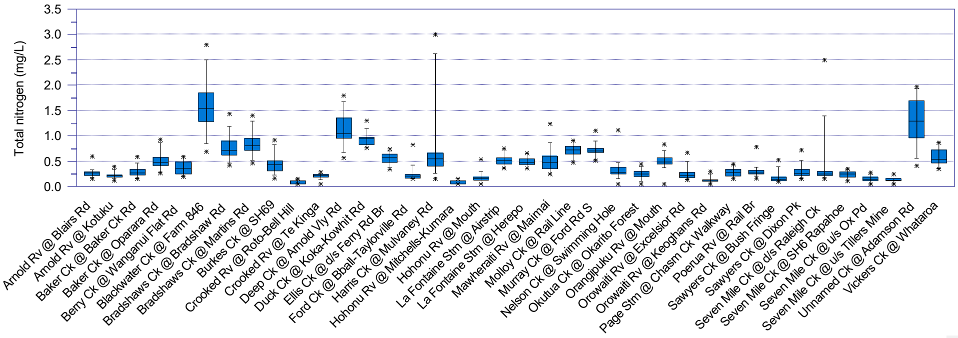


Figure 36 Box and whisker plot: Total nitrogen (TN).

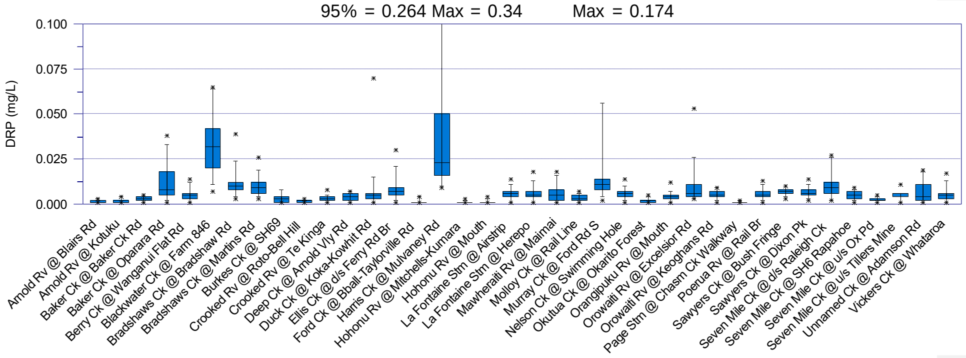


Figure 37 Box and whisker plot: Dissolved reactive phosphorus (DRP).

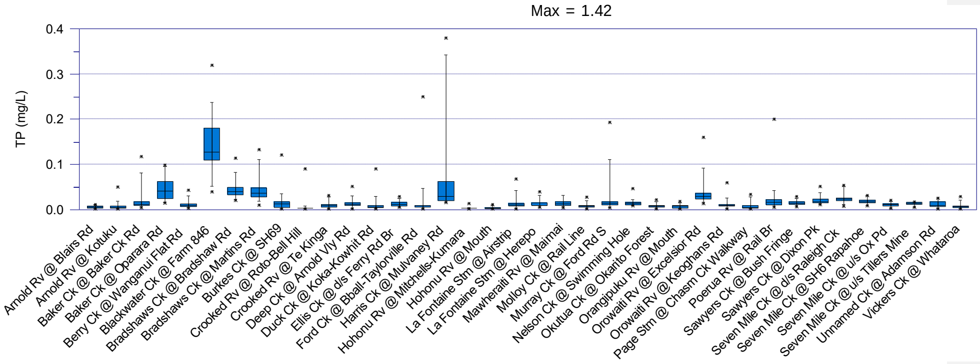


Figure 38 Box and whisker plot: Total phosphorus (TP).

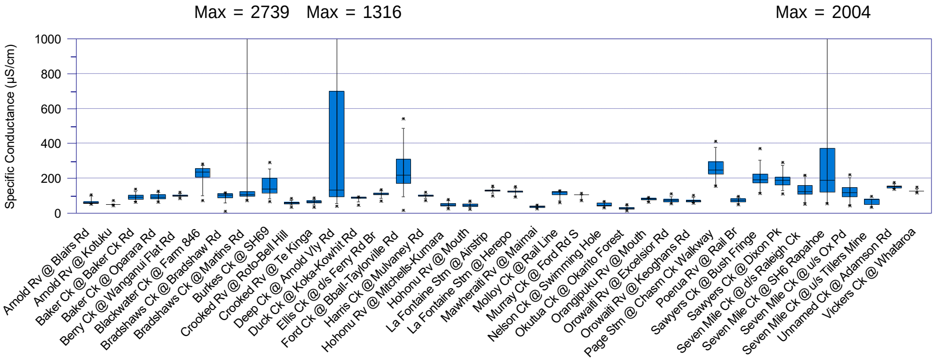


Figure 39 Box and whisker plot: Conductivity.

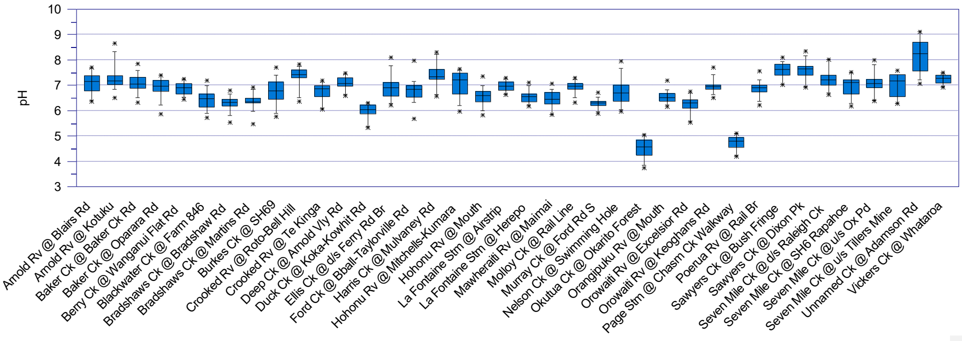


Figure 40 Box and whisker plot: pH.

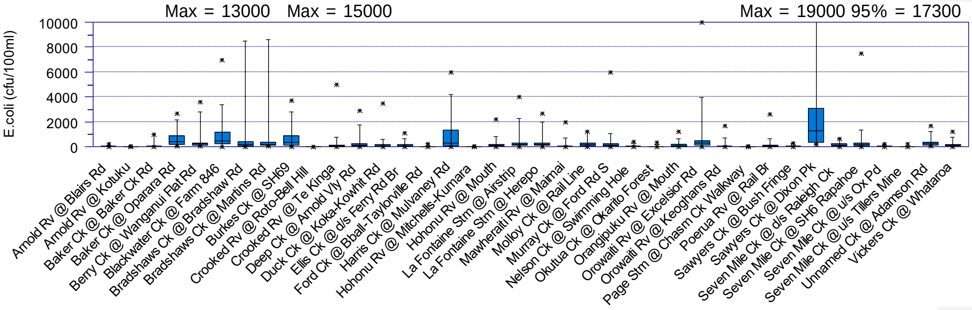


Figure 41 Box and whisker plot: E. coli.

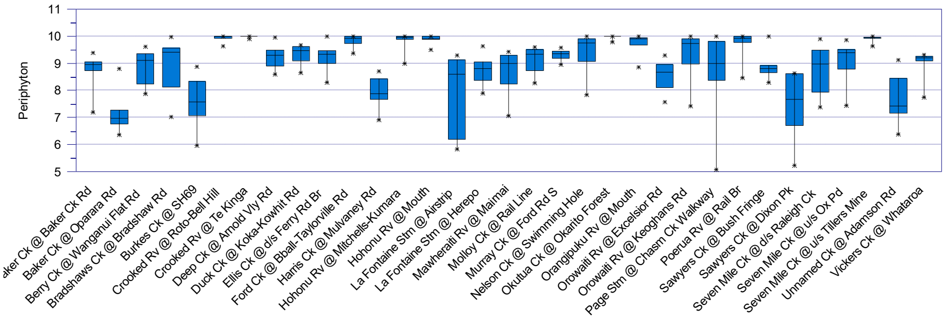


Figure 42 Box and whisker plot: Periphyton.

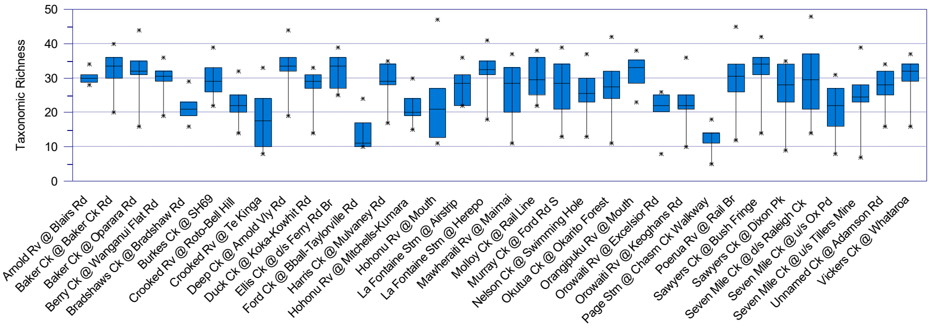


Figure 43 Box and whisker plot: Invertebrate taxonomic richness.

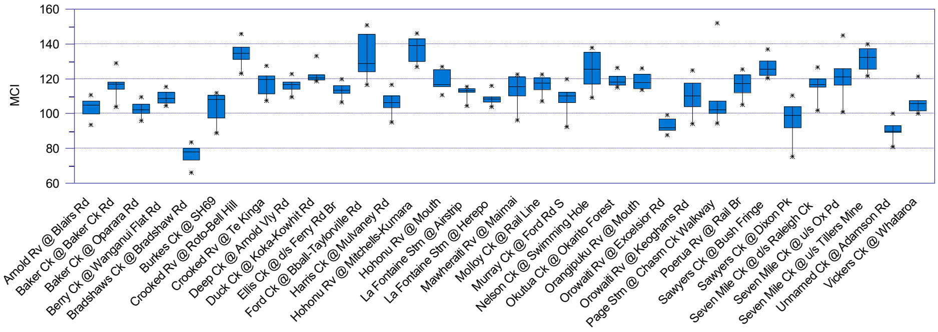


Figure 44 Box and whisker plot: Macroinvertebrate Community Index (MCI).

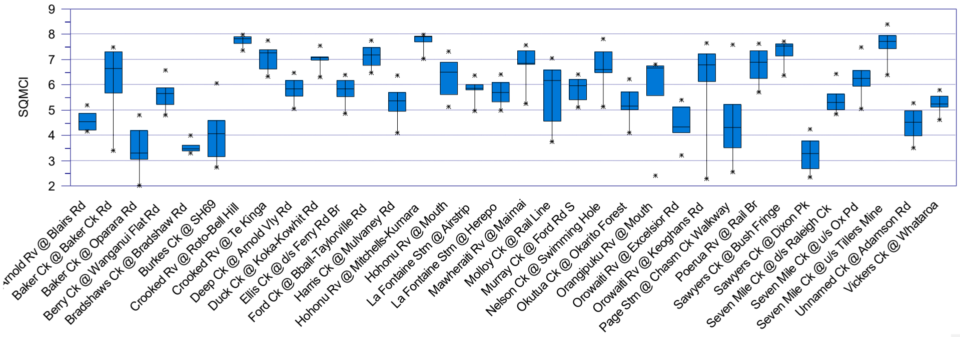


Figure 45 Box and whisker plot: Semi-Quantitative Macroinvertebrate Community Index (SQMCI).

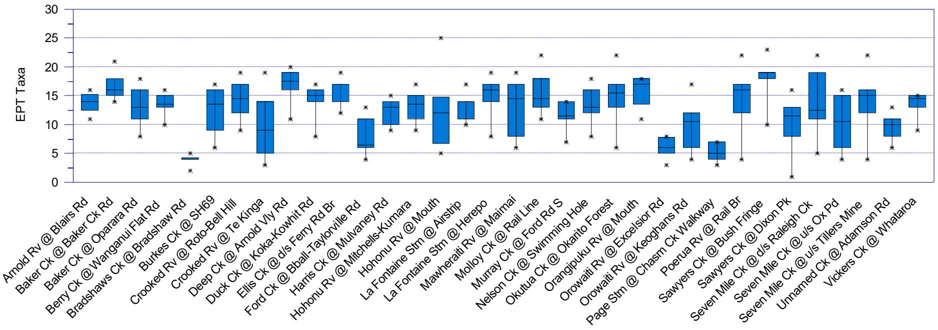


Figure 46 Box and whisker plot: EPT taxa.

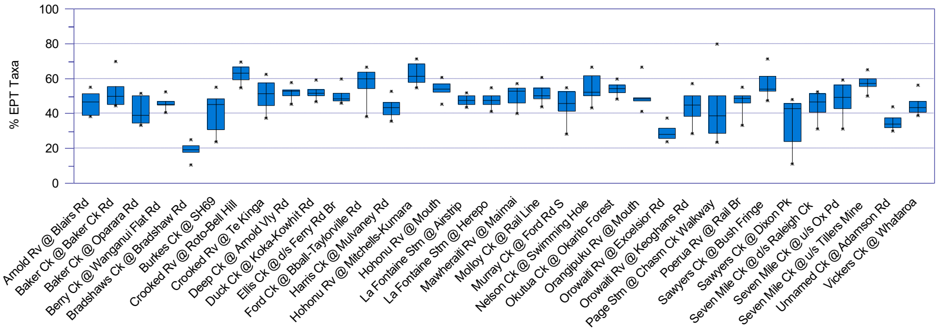


Figure 47 Box and whisker plot: % EPT.

~~3.6~~5.9 Individual contact recreation sites

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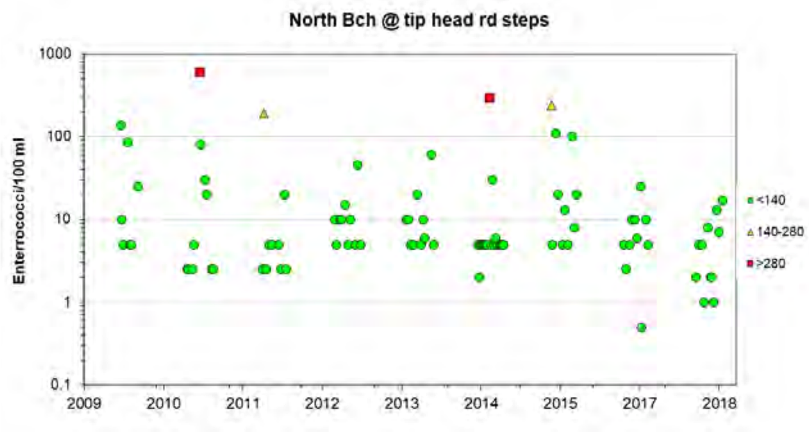

Figure 48 Single sample Enterococci levels for North Beach @ Tiphead Rd.

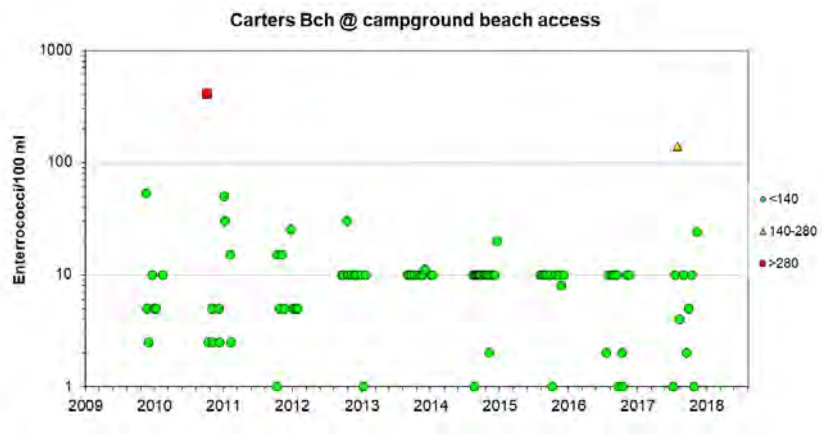

Figure 49 Single sample Enterococci levels for Carters Beach @ Campground beach access.

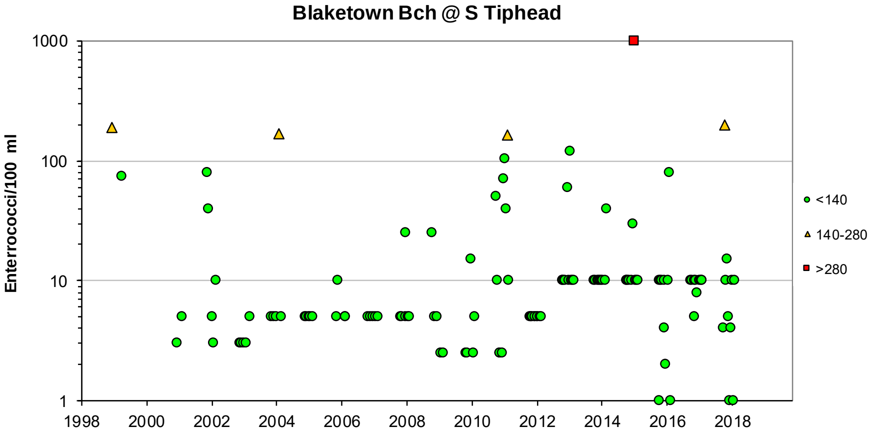

Figure 50 Single sample Enterococci levels for Blaketown Beach @ Tiphead.

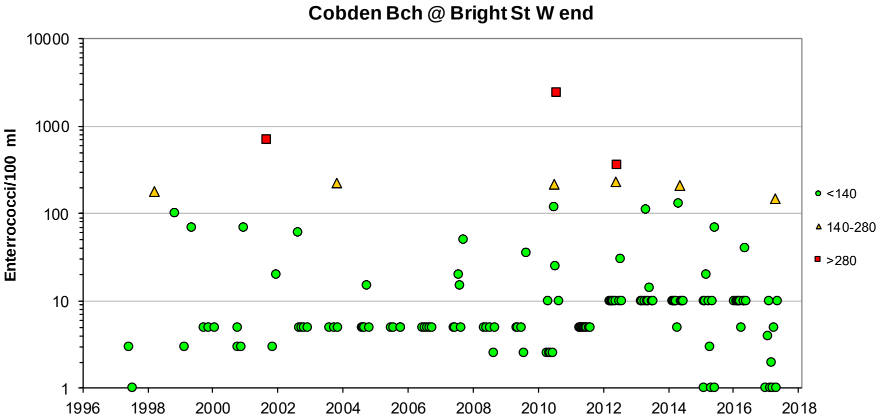

Figure 51 Single sample Enterococci levels for Cobden Beach @ west end Bright Street.

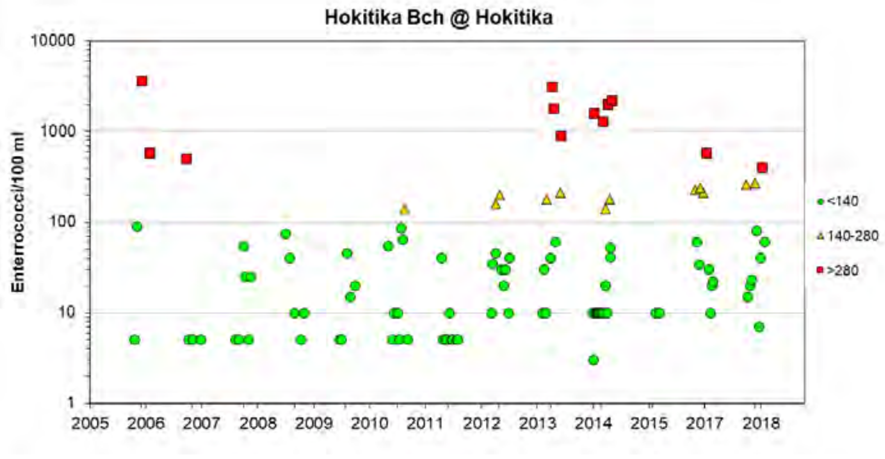

Figure 52 Single sample Enterococci levels for Hokitika Beach @ Hokitika.

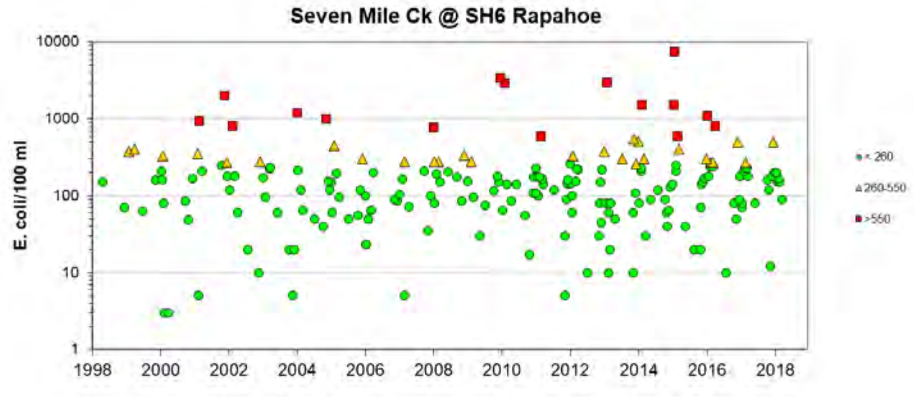

Figure 53 Single sample E. coli levels for Seven Mile Creek @ SH6 Rapahoe.

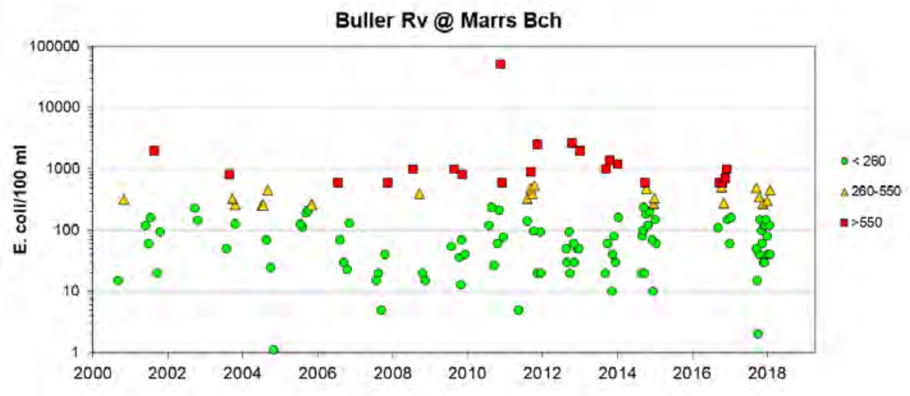

Figure 54 Single sample E. coli levels for Buller River @ Marrs Beach.

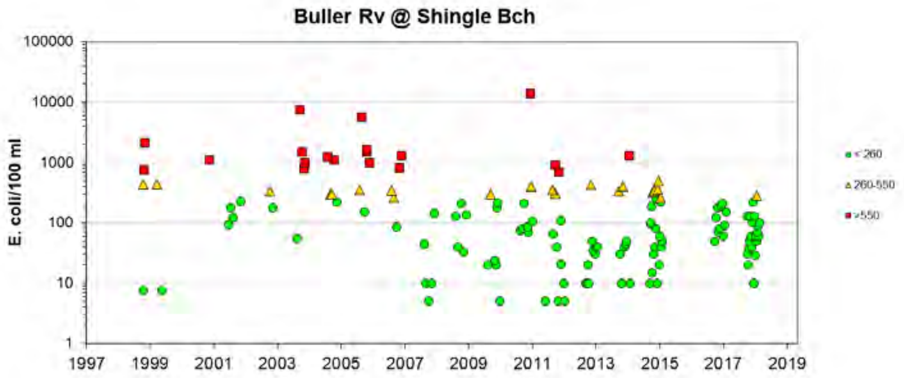

Figure 55 Single sample E. coli levels for Buller River @ Shingle Beach.

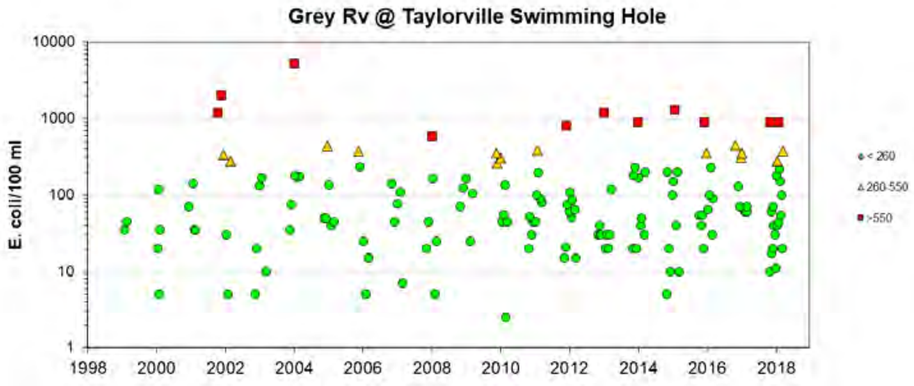

Figure 56 Single sample E. coli levels for Grey River @ Taylorville swimming hole.

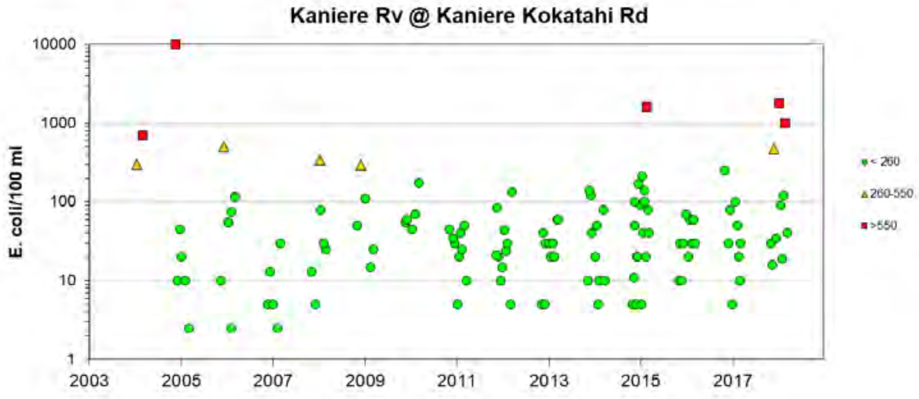

Figure 57 Single sample E. coli levels for Kaniere River @ Kaniere – Kokatahi Road.

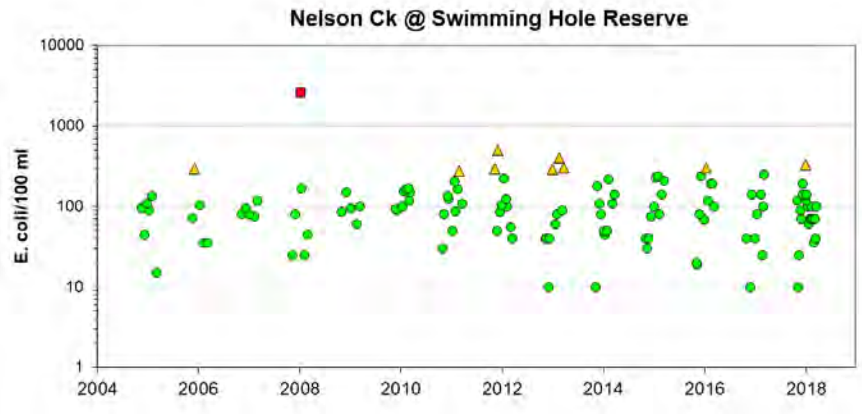

Figure 58 Single sample E. coli levels for Nelson Creek @ Swimming hole reserve.

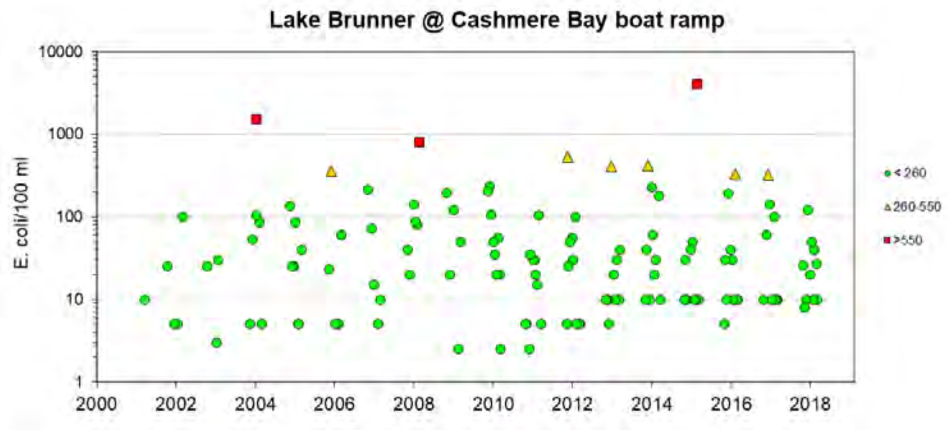

Figure 59 Single sample E. coli levels for Lake Brunner @ Cashmere Bay boat ramp.

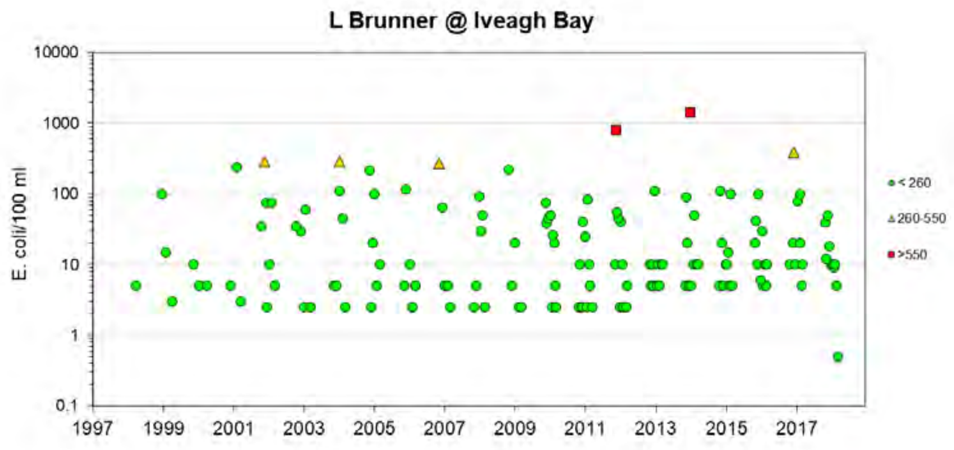

Figure 60 Single sample E. coli levels for Lake Brunner @ Iveagh Bay boat ramp.

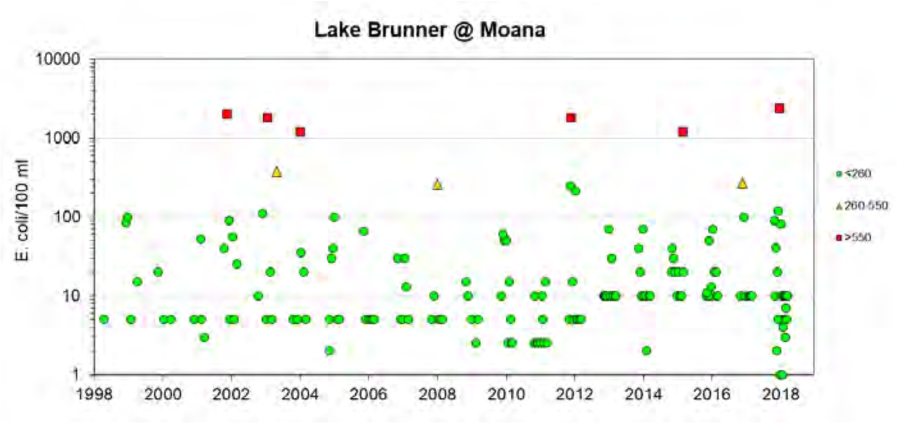

Figure 61 Single sample E. coli levels for Lake Brunner @ Moana boat ramp.

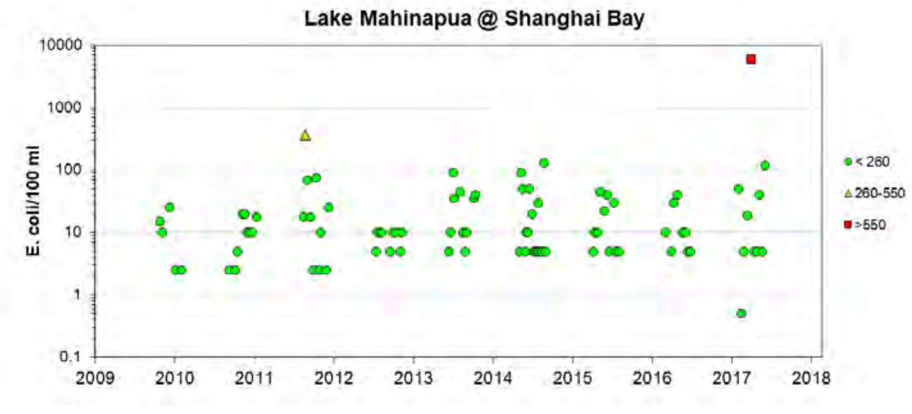

Figure 62 Single sample E. coli levels for Lake Mahinapua @ Shanghai Bay boat ramp.

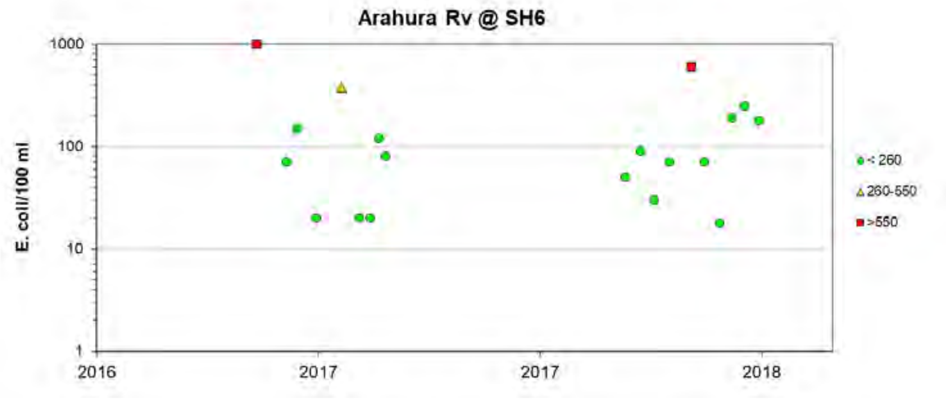

Figure 63 Single sample E. coli levels for Arahura River @ SH6.

~~3.7~~5.10 Water quality trends at NIWA sites

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Table 16 Seasonal Kendall trend test for ten years of data collected at West Coast NIWA water quality sites. Important trends are in red (undesirable) and blue (good).

Site	Variable	Samples used	Median	Percent annual change	Trend direction and confidence	Seasonality
Buller Rv @ Longford	**Ammonia-N**	120	0.002	1.766	likely	0.070
Buller Rv @ Te Kuha	**Ammonia-N**	120	0.003	0.706	about as likely as not	0.112
Grey Rv @ Dobson	**Ammonia-N**	119	0.005	-0.2	unlikely	0.000
Grey Rv @ Waipuna	**Ammonia-N**	117	0.003	-4.576	virtually certain	0.032
Haast Rv @ Roaring Billy	**Ammonia-N**	120	0.001	0	unlikely	0.428
Buller Rv @ Longford	**Dissolved Reactive Phosphorus**	120	0.001	0.901	about as likely as not	0.000
Buller Rv @ Te Kuha	**Dissolved Reactive Phosphorus**	120	0.002	-1.034	more likely than not	0.000
Grey Rv @ Dobson	**Dissolved Reactive Phosphorus**	118	0.003	-2.335	virtually certain	0.001
Grey Rv @ Waipuna	**Dissolved Reactive Phosphorus**	117	0.002	-2.131	likely	0.071
Haast Rv @ Roaring Billy	**Dissolved Reactive Phosphorus**	120	0.001	-2.713	extremely likely	0.159
Buller Rv @ Longford	**DO % saturation**	119	100	0.038	extremely likely	0.000
Buller Rv @ Te Kuha	**DO % saturation**	119	99.6	-0.063	extremely likely	0.630
Grey Rv @ Dobson	**DO % saturation**	117	101	0.047	about as likely as not	0.004
Grey Rv @ Waipuna	**DO % saturation**	116	101.9	0.022	unlikely	0.001
Haast Rv @ Roaring Billy	**DO % saturation**	120	98.6	0.006	unlikely	0.001
Buller Rv @ Longford	**Nitrate-N**	120	0.03	1.353	Increasing trend more likely than not	0.000
Buller Rv @ Te Kuha	**Nitrate-N**	120	0.072	-0.119	Decreasing trend extremely unlikely	0.000
Grey Rv @ Dobson	**Nitrate-N**	119	0.141	1.015	Increasing trend more likely than not	0.000
Grey Rv @ Waipuna	**Nitrate-N**	117	0.039	-1.306	Decreasing trend more likely than not	0.000
Haast Rv @ Roaring Billy	**Nitrate-N**	120	0.032	-0.494	Decreasing trend about as likely as not	0.000
Buller Rv @ Longford	**Nitrogen (Total)**	120	0.099	1.605	very likely	0.000
Buller Rv @ Te Kuha	**Nitrogen (Total)**	120	0.155	0.577	likely	0.000
Grey Rv @ Dobson	**Nitrogen (Total)**	118	0.26	0.394	more likely than not	0.000
Grey Rv @ Waipuna	**Nitrogen (Total)**	117	0.11	-1.726	likely	0.005
Haast Rv @ Roaring Billy	**Nitrogen (Total)**	119	0.046	-0.102	unlikely	0.000
Buller Rv @ Longford	**pH**	119	7.65	0.099	virtually certain	0.000
Buller Rv @ Te Kuha	**pH**	120	7.6	0.079	very likely	0.064
Grey Rv @ Dobson	**pH**	118	7.385	0.153	extremely likely	0.012
Grey Rv @ Waipuna	**pH**	117	7.44	0.057	likely	0.050
Haast Rv @ Roaring Billy	**pH**	120	7.74	0.011	unlikely	0.131
Buller Rv @ Longford	**Phosphorous (Total)**	120	0.005	2.875	extremely likely	0.002
Buller Rv @ Te Kuha	**Phosphorous (Total)**	120	0.008	1.721	likely	0.230
Grey Rv @ Dobson	**Phosphorous (Total)**	117	0.008	-1.412	more likely than not	0.729
Grey Rv @ Waipuna	**Phosphorous (Total)**	117	0.005	-3.061	extremely likely	0.759
Haast Rv @ Roaring Billy	**Phosphorous (Total)**	120	0.003	-5.009	virtually certain	0.007
Buller Rv @ Longford	**Specific Conductance**	120	57.9	0.144	more likely than not	0.004
Buller Rv @ Te Kuha	**Specific Conductance**	120	68.55	0.476	extremely likely	0.472
Grey Rv @ Dobson	**Specific Conductance**	119	58.6	0.211	more likely than not	0.195
Grey Rv @ Waipuna	**Specific Conductance**	117	53.8	-0.299	likely	0.116
Haast Rv @ Roaring Billy	**Specific Conductance**	120	84.5	-0.09	unlikely	0.012
Buller Rv @ Longford	**Turbidity**	120	1.085	6.047	extremely likely	0.001
Buller Rv @ Te Kuha	**Turbidity**	120	2.01	4.576	virtually certain	0.180
Grey Rv @ Dobson	**Turbidity**	119	1.96	1.247	about as likely as not	0.411
Grey Rv @ Waipuna	**Turbidity**	117	1	6.077	extremely likely	0.680
Haast Rv @ Roaring Billy	**Turbidity**	120	1.5	1.502	about as likely as not	0.009
Buller Rv @ Longford	**Water Clarity**	117	3.42	-5.898	virtually certain	0.001
Buller Rv @ Te Kuha	**Water Clarity**	120	1.575	2.395	extremely likely	0.211
Grey Rv @ Dobson	**Water Clarity**	119	1.97	4.101	virtually certain	0.478
Grey Rv @ Waipuna	**Water Clarity**	117	3.4	-0.962	more likely than not	0.396
Haast Rv @ Roaring Billy	**Water Clarity**	120	2.455	7.259	virtually certain	0.001

Table 17 Seasonal Kendall trend test for 25 years of data collected at West Coast NIWA water quality sites. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. Insert new.

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

~~3.8~~5.11Algal cover and macroinvertebrate indices over time – NIWA sites

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

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

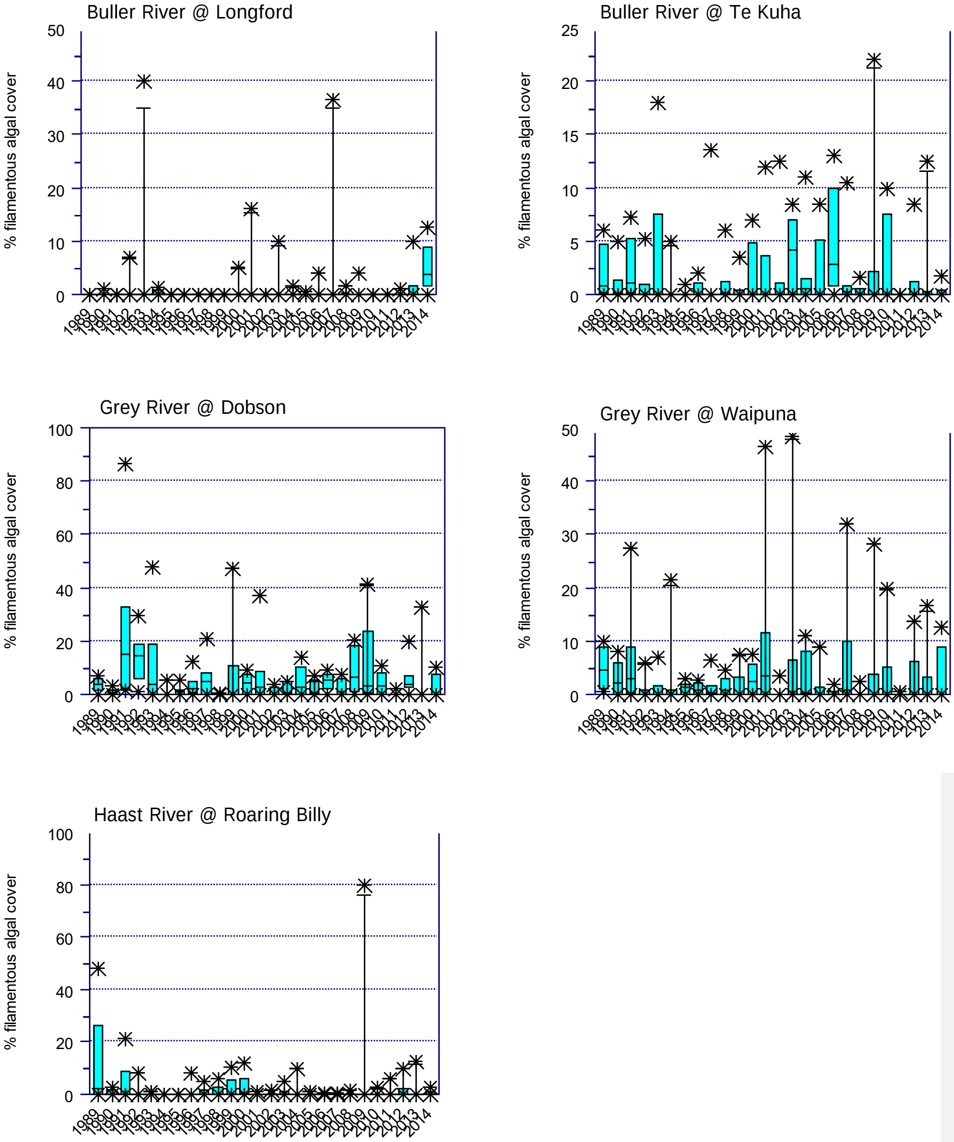

Figure 64 Percentage filamentous algal cover at NIWA sites by year.

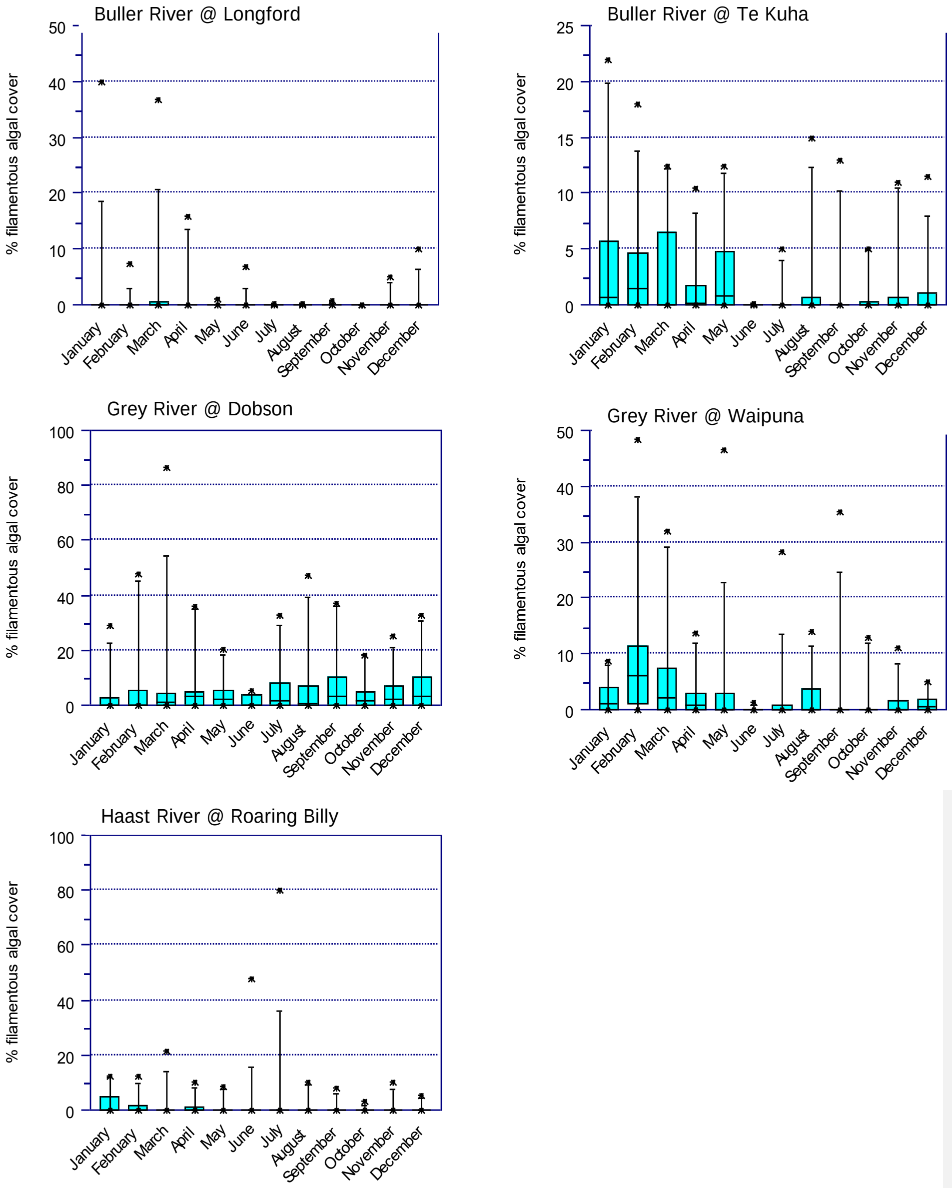

Figure 65 Percentage filamentous algal cover at NIWA sites by season. Data spans from 1998 to 2014.

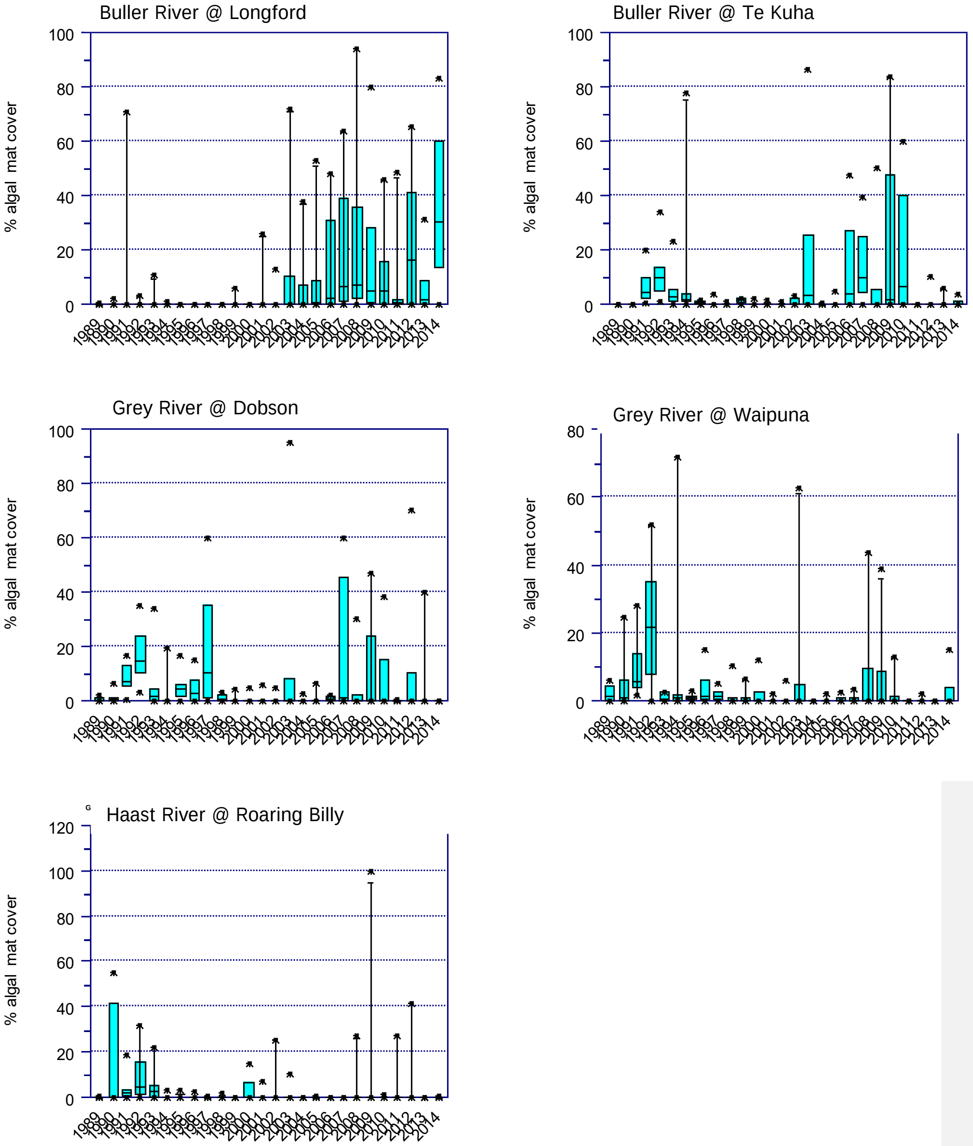

Figure 66 Percentage algal mat cover at NIWA sites by year.

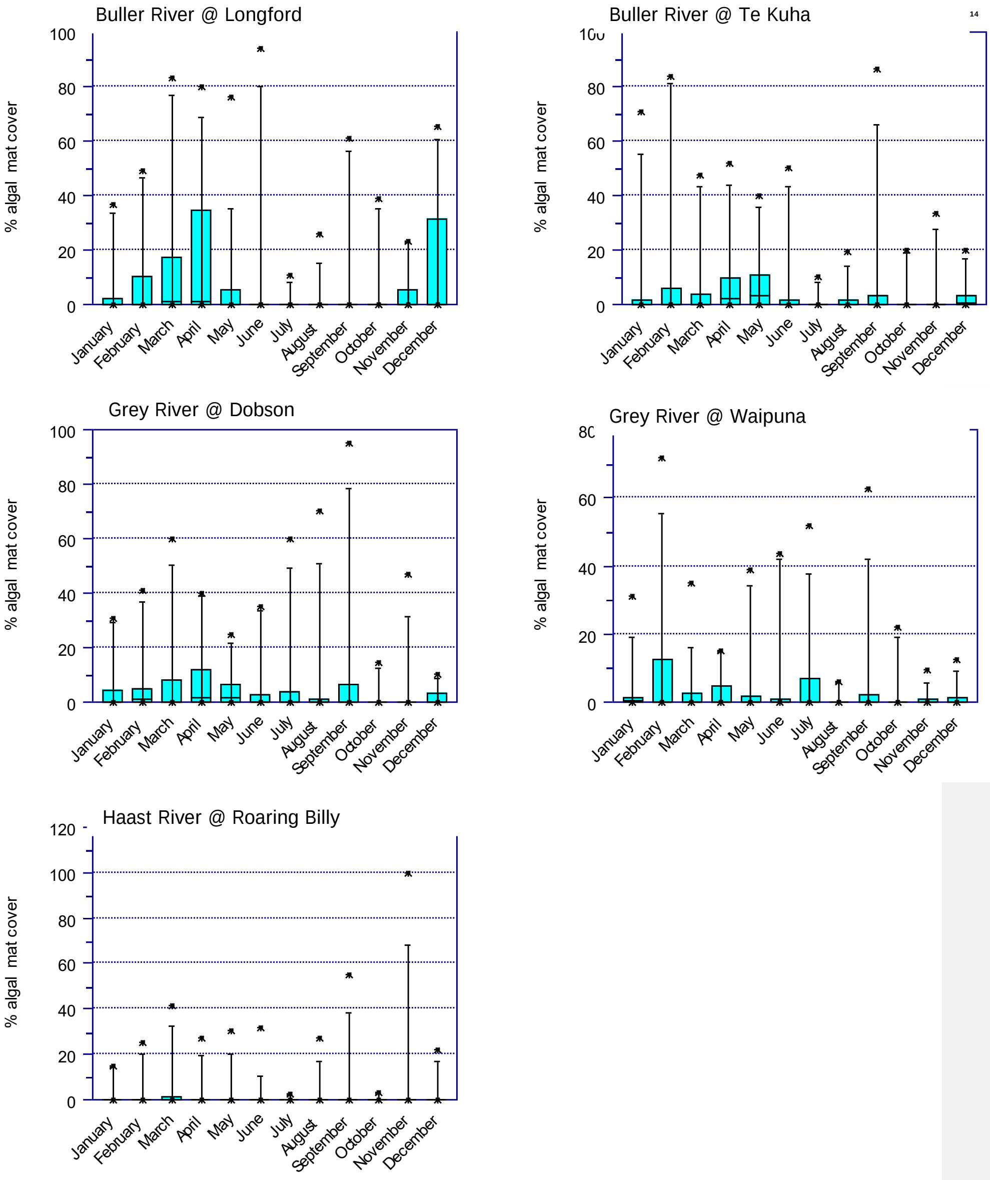

Figure 67 Percentage algal mat cover at NIWA sites by season. Data spans from 1998 to 2014.

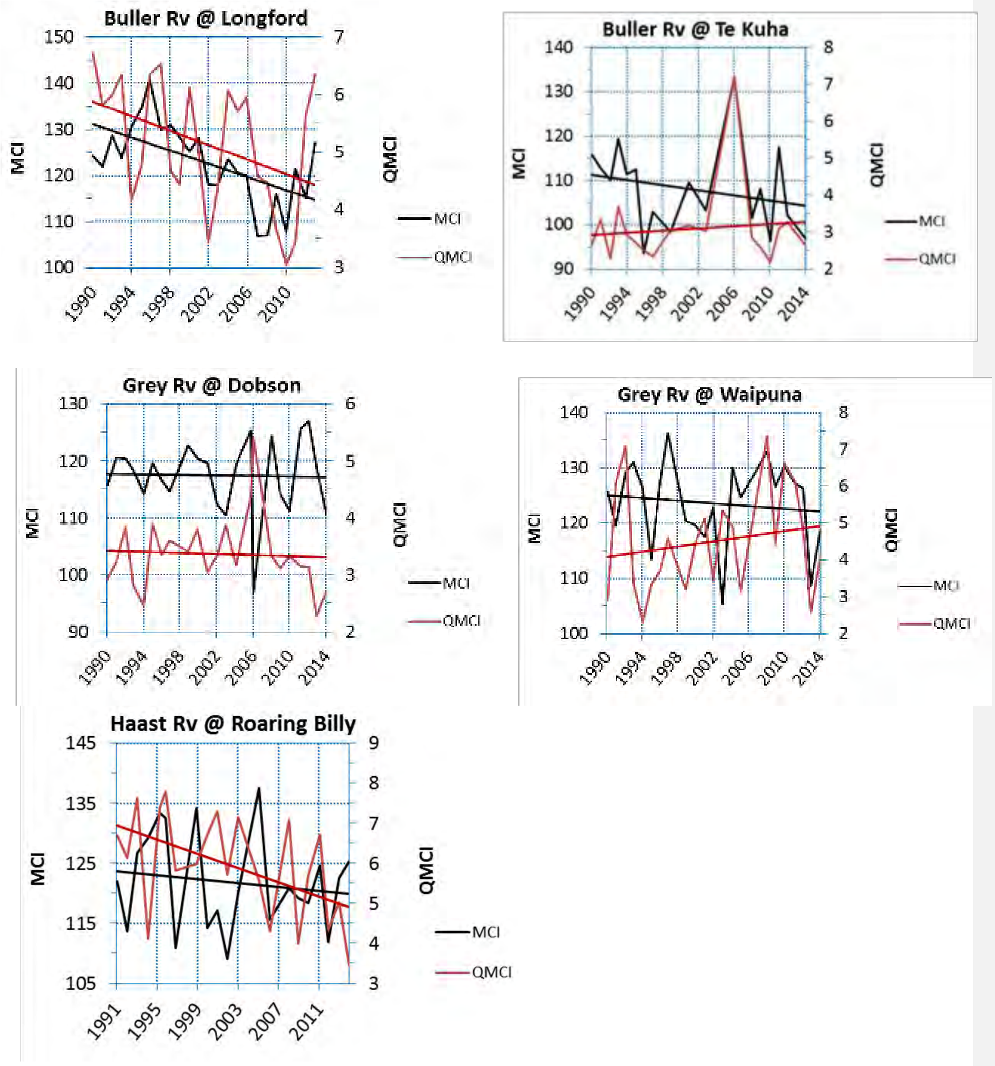

Figure 68 These plots show annual values for MCI (macroinvertebrate community index) and QMCI (quantitative macroinvertebrate community index) from 1990 to 2014. Linear regression lines are shown for both MCI and QMCI on each graph.

~~3.9~~5.12 Water quality trends at Regional Council sites

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Table 19 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible. Insert new.

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

Table 19 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible. Insert new.

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

Table 19 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible. Insert new.

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

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

Table 19 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible. Insert new.

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

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

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

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

Table 19 Seasonal Kendall trend test for Regional Council monitoring program sites. Ten year data span. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). PAC = percent annual change of the median. 20 or more samples are required before a trend will be considered eligible. Insert new.

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

Table 20 Seasonal Kendall trend test for degree of difference between paired impact-reference sites. Important trends are in red (undesirable) and blue (good). Slight trends are in pink (undesirable) and light blue (good). Ten year data span. PAC = percent annual change of the median. Insert new.

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

~~3.10~~5.13Limnology of Lake Brunner

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

Lake Brunner, like most large New Zealand Lakes, is a deep monomictic lake, meaning the lake mixes from top to bottom only once per year. For the rest of the year the lake is thermally stratified, being warmer at the surface and cooler at depth. Mixing from top to bottom (also called turnover) usually occurs during mid-winter (typically May-June) when inputs of solar energy are lowest and winter storms allow for deep wind-driven mixing of lake surface waters. The lake will remain largely un-stratified (or isothermal, i.e., the same temperature from top to bottom) over the winter (Figure 70). 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.

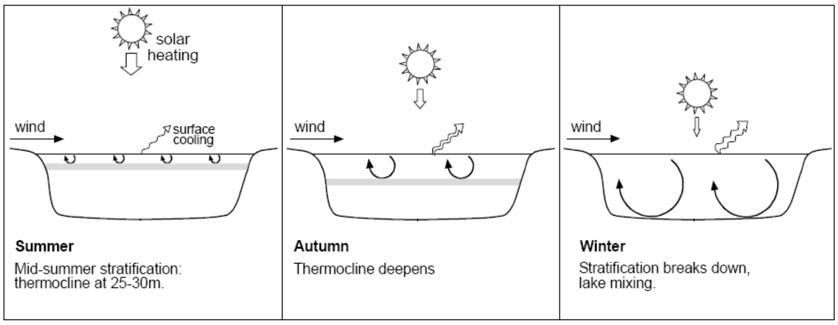
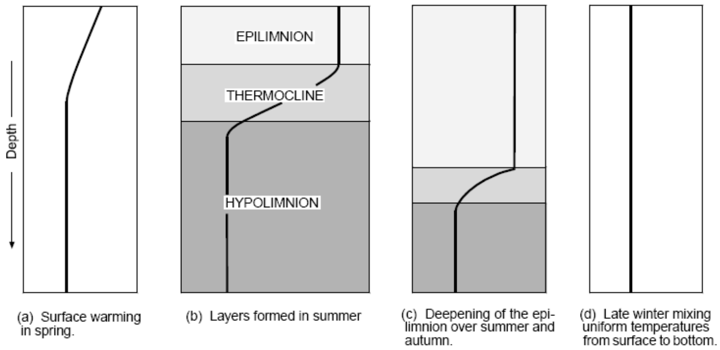


Figure 69 Lake stratification and mixing is dependent on the interactions of the sun's energy and wind energy and on the net effect of heating and cooling.

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



(a) Surface warming in spring.

(b) Layers formed in summer

(c) Deepening of the epilimnion over summer and autumn.

(d) Late winter mixing uniform temperatures from surface to bottom.

Figure 70 The mixing cycle of the water of Lake Brunner. Each panel represents water temperature with depth in the lake for a particular season: (a) spring, (b) summer, (c) late summer/autumn, (d) late winter. Water temperature is represented by the thick black line in each panel with temperature increasing from left to right in each panel (courtesy of Kelly and Howard-Williams, 2003).

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

~~4~~6 References

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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.

Burns, N. M., Bryers, G., and Bowman, E. (2000): Protocol for Monitoring Trophic Levels of New Zealand Lakes and Reservoirs. New Zealand Ministry for the Environment, Wellington NZ. 138 pp

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

MfE. (2014): The National Policy Statement for Freshwater Management 2014. Ministry for the Environment, July 2014.

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.

Vant, B. (2013): Trends in river water quality in the Waikato region, 1993 – 2012. Waikato Regional Council Technical Report 2013/20.

Verberg, P. (2009): Effects of nutrient loading in Lake Brunner. NIWA Client Report: HAM2009-137 Sept 2009.

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. 2010. Proposed Water Management Plan. The West Coast Regional Council, Greymouth, New Zealand.

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

Ballantine, D., D. Booker, M. Unwin, and T. Snelder, 2010. Analysis of National River Water Quality Data for the Period 1998–2007. Christchurch. http://www.mfe.govt.nz/publications/water/.

DairyNZ (2013). Making dairy farming work for everyone: strategy for sustainable dairy farming 2013–2020. Retrieved from www.dairynz.co.nz/dairystatistics. Jowett, I., 2017. Time Trends-Trend Analysis and Equivalence Testing for Environmental Data. Jowett Consulting. http://www.jowettconsulting.co.nz/home/time-1.

Larned, ST (2010). A Prospectus for periphyton: recent and future ecological research. Journal of the North American Benthological Society, 29,182–206. Retrieved from www.bioone.org.

Larned, S.T., T.H. Snelder, M. Unwin, G.B. McBride, P. Verburg, and H.K. McMillan, 2015. Analysis of Water Quality in New Zealand Lakes and Rivers. NIWA Client Report, NIWA, Christchurch, New Zealand.

Larned, S, Snelder, T, Unwin, M, McBride, G, Verburg, P, & McMillan, H (2015). Analysis of water quality in New Zealand lakes and rivers: Data sources, data sets, assumptions, limitations, methods and results. Prepared for the Ministry for the Environment. NIWA Client Report no. CHC2015-033.

MacLead, CJ, & Moller, H (2006). Intensification and diversification of New Zealand agriculture since 1960: An evaluation of current indicators of land use change. Agriculture, Ecosystems & Environment, 115(1-4), 201–218.

Ministry for the Environment & Statistics New Zealand (2015). New Zealand’s Environmental Reporting Series: Environment Aotearoa 2015. Available from www.mfe.govt.nz and www.stats.govt.nz.

Ministry for the Environment & Stats NZ (2017). New Zealand’s Environmental Reporting Series: Our fresh water 2017. Retrieved from www.mfe.govt.nz and www.stats.govt.nz.

Smith, D.G., G.B. McBride, G.G. Bryers, J. Wisse, and D.F. Mink, 1996. Trends in New Zealand’s National River Water Quality Network. New Zealand Journal of Marine and Freshwater Research 30:485–500.

Snelder, T., S. Woods, and J. Atalah, 2016. Strategic Assessment of New Zealand's Freshwaters for Recreational Use: A Human Health Perspective Escherichia Coli in Rivers and Planktonic Cyanobacteria in Lakes. LWP Client Report, LWP Ltd, Christchurch, New Zealand.

Stocker, T.F., D. Qin, G.-K. Plattner, L.V. Alexander, S.K. Allen, N.L. Bindoff, F.-M. Bréon, J.A. Church, U. Cubasch, S. Emori, P. Forster, P. Friedlingstein, N. Gillett, J.M. Gregory, D.L. Hartmann, E. Jansen, B. Kirtman, R. Knutti, K. Krishna Kumar, P. Lemke, J. Marotzke, V. Masson-Delmotte, G.A. Meehl, I.I. Mokhov, S. Piao, V. Ramaswamy, D. Randall, M. Rhein, M. Rojas, C. Sabine, D. Shindell, L.D. Talley, D.G. Vaughan and S.-P. Xie, 2013: Technical Summary. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.