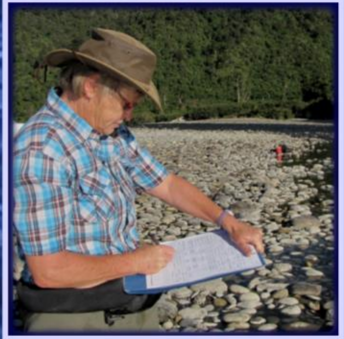
State of the Environment Report

River Water Quality in Tasman District

2015



State of the Environment Report

River Water Quality in Tasman District 2015

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A technical report presenting results of the Tasman District Council's 'State of the Environment' River Water Quality Monitoring Programme and additional data from the National River Water Quality Network. Indicators measured include: physical, chemical, and bacteriological characteristics of the water, macroinvertebrate indices and periphyton cover. The report highlights water quality condition and trends, from the Waimea, Motueka, Takaka, Aorere and Buller water management areas.

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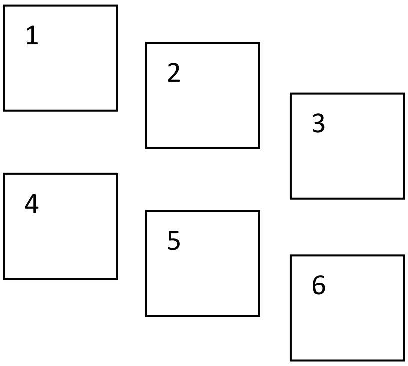
Cover photos:

1. Claire Webster at the Aorere River
2. Koura from Dall Ck, Golden Bay
3. Jimmy Lee Ck, Washbourne Gardens
4. Mouth of the Motueka River
5. McConnon Ck, Golden Bay
6. Bathers at the Lee River Reserve

Cover photos taken by Trevor James and Jonathan McCallum



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At a Glance

As part of its obligations under the Resource Management Act, Tasman District Council monitors the state of surface water quality and river health at more than 57 sites throughout the Tasman District.

State of our rivers

Tasman District is fortunate to have relatively few water quality issues compared to other parts of New Zealand, this is assisted due to the District's large rivers having a significant proportion of native forest in their headwaters. Therefore, any inputs of pollutants from developed land in the middle and lower reaches are substantially diluted by the large volume of high quality water from upstream. The main threats to water quality and stream health in the Tasman District relate to the intensification of agriculture in the district and, to a lesser extent, the expansion of residential development. The main problems with water quality are currently found in small streams whose catchments contain a large proportion (>50%) of intensively developed land. Small streams draining undeveloped areas are expected to have high ecological values, particularly high fish abundance. The effects of land use on water quality are widely recognised, and the results of this analysis are consistent with earlier surface water quality reports for the Tasman Region and nationwide studies of water quality patterns.

For the reporting period (2010 to 2014), sites with pastoral and urban land cover had higher concentrations of disease-causing organisms, greater quantities of deposited fine sediment and lower water clarity than sites with indigenous forest or exotic forest land cover. Focussing on the monitoring sites in pastoral catchments, 40% pose a high risk to people and animals from disease-causing organisms (20 of 52 sites; 95th percentile *E. coli* concentrations over 1000/100 ml) while 21% had excessive amounts of deposited fine sediment in the bed (11 of 52 sites; at least one resuspendable sediment score in attribute state D[1]).

Based on one-off but multiday monitoring deployments since 2002, 47% of sites in the smaller pastoral streams had very low dissolved oxygen concentrations (22 of 47 sites; 1-day minimum dissolved oxygen concentration in attribute state D). Similarly, half of the sites on smaller pastoral streams had high summer water temperatures (mid-point of daily mean and daily maximum temperature greater than 20°C[2]).

Generally, nitrogen concentrations (particularly ammonia and nitrate) remained low in rivers in Tasman, with the exception of spring-fed streams of the Waimea, Motueka and Takaka Plains.

Macro-invertebrate communities indicated good or very good ecosystem health (attribute states A or B[3]) at 60% of the sites sampled between 2010 and 2015, highest in streams draining mountain terrain and hill country. However, macro-invertebrate communities are poor in the remaining sites, including many of the small lowland streams that drain the intensively developed parts of the District (e.g. Motupipi , Watercress, lower Reservoir, Waiwhero, Little Sydney, Borck, Neimann, Moutere,

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[1] TDC preliminary guideline – see Table 1.

[2] TDC guideline based on Davies-Colley et al. 2013 – see Table 1.

[3] TDC guideline based on Stark & Maxted 2007 – see Table 1.

Seaton, Tasman, and Murchison) as indicated by low macroinvertebrate metric scores (MCI, %EPT taxa and SQMCI).

Models used to predict water quality across all streams in the district (not just at monitoring sites) show that 3% of pastoral streams (an estimated 100 to 150km of stream length) were predicted to have macro-invertebrate community index (MCI) scores below the bottom line (in attribute state D[4]). However, over all streams in the district, it is predicted that only 1% of streams are below this bottom line. These models correlate well with sample data. Water clarity models show that only 1% of streams overall had water clarity within the 'D' band[1].

Periphyton cover and scores (growth on the stream bed, mostly algae) were indicative of good ecosystem health (in band A or B) at the majority of sites. However, about 25% of small lowland streams draining intensively developed land often had excessive accumulations of nuisance algae in summer (Borck, Neimann, Pearl, Powell, Watercress, Kaituna, Motupipi).

Trends in our rivers

The core river water quality sites (57 in total) were tested for trends in water quality. Out of the 60 trends identified, across a set of water quality attributes, 41 showed an improvement and 19 showed a degradation. Thirteen of the improving trends (across 12 sites) were particularly pleasing as they were improving from a degraded state (less than attribute A). These trends were for water clarity (9 sites), *E. coli* (3 sites) and dissolved reactive phosphorus (1 site; Motupipi at Reillys Br). The other 28 improving trends were all in a very good state throughout the records. Of the degrading trends, 7 (across 7 sites) were of immediate concern due to levels reaching a much poorer state in the near future. Four of these trends were for water clarity, two were for the quantitative macroinvertebrate community index (QMCI) and one was for nitrate. Eleven of the other 12 degrading trends (8 nitrate and 3 *E.coli*) were considered of limited immediate concern because the concentrations were so low through the whole period of trend assessment and would only become a concern if these trends continued for several more decades or centuries.

The waterways with **improving trends** in **water clarity** included Buller at Longford, Motueka at Gorge and Motueka at Woodstock. These three sites have been monitored over the last 26 years as part of NIWA's National Water Quality Network and were sampled at all flows. Water clarity also improved in Reservoir Creek, Sherry, Onahau, Onekaka, and Mangles Rivers. Improving trends in **nitrate** were found in the Motupipi and Takaka Rivers and in **ammoniacal-nitrogen** at 16 sites (ammoniacal-nitrogen levels were low even at the start of the monitoring period). This decrease in ammonia concentrations is likely a sign that there is less fresh effluent getting into waterways. **Dissolved reactive phosphorus improved at one site** (Motupipi). ***E.coli* improved at three sites** (Sherry, Little Sydney and Motupipi).

There was one **degrading trend** for **nitrate** (Powell) that is of some concern as the trend is getting close to attribute state 'B' for nitrate toxicity and above levels likely to contribute to excessive periphyton growth. This site has intensive farming upstream. **Degrading trends in water clarity** were recorded at **four sites** (Little Sydney, Riwaka, Te Waikoropupū 600m downstream of the main spring

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[4] TDC preliminary guideline – see Table 1.

and Matakitaki). **Macroinvertebrate condition (QMCI) worsened** at Buller at Longford and Motueka at Woodstock, with average results falling from attribute state A to B.

To achieve the greatest immediate benefits restoration efforts should focus on the following:

- reducing faecal bacteria and fine sediment inputs to small streams (stock access and riparian buffers for earthworks and land cultivation).
- increasing the amount of bank-side vegetation along these streams to provide shading and to keep water temperatures below the critical levels required for protecting ecosystem health.
- Restoring wetlands in key locations where runoff enters streams.

A summary of river water quality results and trends are given in Table 1 and Table 2, below.

Summary versions of this report, in the form of report cards, are available at www.tasman.govt.nz.

Table 1. Summary of river water quality results for core sites in Tasman District (n = 57) over the period 2010 to 2014. Macroinvertebrate community index (MCI) results are over the period 2011 to Feb 2015. Note that not all attributes were measured at each site. Attributes highlighted in blue are included in the National Policy Statement for Freshwater Management 2014. Full details of the attribute states and statistics are available in the Methods section of this report.

Attribute	Statistic	# Sites in attribute state A	# Sites in attribute state B	# Sites in attribute state C	# Sites in attribute state D	Total number of sites
Water Clarity	5-year median	21	13	15	7	56
Ammonia-N	Highest annual median	44	1	0	0	45
Nitrate-N	Highest annual median	21	4	0	1	26
DRP	5-year median	22	5	-	-	27
E. coli	Highest annual median	37	9	6	5	57
MCI	5-year median	13	15	9	5	42
Periphyton score	5-year median	19	28	4	1	52
Dissolved Oxygen	Lowest 1-day minimum conc.	1	7	5	14	27
Water Temperature	Highest midpoint of daily mean and daily maximum temperature	6	8	12	0	26

Table 2. Summary of trend results for river water quality sites in Tasman District. Trends were analysed over the 10-year period 2005 to 2014 and over the full record (from 15 to 45 years depending on the site). 'Relevant' trends exclude nutrient and *E. coli* trends where the line was within attribute state A.

Attribute	Sites with improving trends	Relevant improving trends	Sites with degrading trends	Relevant degrading trends	Total sites	Notes
Water Clarity	9	9	4	4	49	The sites with degrading trends were Little Sydney at Factory Rd, Matakitaki at SH6 Murchison, Riwaka at Hickmotts and Te Waikoropupū Springs.
Ammonia-N	16	0	0	0	37	All improving trend lines were within **attribute state A** (< 0.03 g/m3). That is, there were no improvements in attribute state over the length of the trend line.
Nitrate-N	2	0	9	1	25	The degrading trend line for Powell at Glenview Rd was within **attribute state B**. The remaining sites had degrading trend lines within **attribute state A** (< 1.0 g/m3).
DRP	7	1	0	0	22	Motupipi at Reillys Br improved in attribute state from B to A over 10 years. The trend lines for the remaining sites were within **attribute state A** (< 0.01 g/m3).
E. coli	7	3	3	0	67	The sites with degrading trends were Reservoir Ck at 20 m d-s Salisbury Rd, Riwaka at Hickmotts and Waiwhero at Cemetery.
MCI	0	0	0	0	3	National River Water Quality network sites only
QMCI	0	0	2	2	3	The sites with degrading trends were Buller at Longford and Motueka at Woodstock.
# EPT Taxa	0	0	1	0	3	National River Water Quality network sites only
Total trends	41	13	19	7		

Disclaimer

In accordance with data access agreements, Tasman District Council and NIWA make no representations or warranties regarding the accuracy or completeness of the data collected through the Tasman River Water Quality Monitoring Programme (RWQMP) or National Rivers Water Quality Network (NRWQN). Both parties accept no liability for any loss or damage (whether direct or indirect) incurred by any person through the use of or reliance on these data.

Acknowledgements

Tasman District Council would like to thank all the people and organisations who have assisted in this monitoring programme. In particular, we would like to thank landowners who provide access to monitoring sites and the cooperation with trying to identify contaminant sources and invest in measures to improve the health of waterways.

Thank you to the summer students and volunteers who have worked alongside staff to collect river water quality information. A special thanks to Stuart Grange for helpful assistance with the preliminary data analyses for this report.

We are also grateful to Cawthron Laboratories and Hill Laboratories for excellent customer service with respect to sample analysis. Cawthron Institute’s Roger Young deserves special thanks for peer review of this report and the monitoring programme design. His expertise in aquatic ecology and water quality as well as his understanding of the RWQMP, over many years, make his critique all the more valuable.

We would also like to thank the following groups for providing river water quality data:

- NIWA for data from National River Water Quality Network sites.
- Ministry for the Environment for supplying national median water quality data.
- Consent holder’s river water quality data, such as; NZ King Salmon (and John Stark), Trustpower (Cobb Dam), Tasman District Council Wastewater Treatment Plants.

Glossary and List of Abbreviations

Br	Bridge
cfu	Coliform forming unit; unit of measurement for *E. coli*, per unit volume of water sampled
Ck	Creek
Disease-causing organisms	Micro-organisms such as bacteria, protozoa and viruses that cause disease in humans. Disease risk level is indicated by the concentration of *E.coli* or faecal coliforms
DO	Dissolved oxygen
DRP	Dissolved Reactive Phosphorus
d-s	Downstream
u-s	Upstream
E. coli	*Esherichia coli*, a species of bacteria indicative of faecal pollution
EM	Ecosystem metabolism
ER	Ecosystem Respiration
FSS	Fixed (inorganic) Suspended Solids
GPP	Gross Primary Production
MCI	Macroinvertebrate Community Index
NH_4-N	Ammoniacal nitrogen
NIWA	National Institute of Water & Atmospheric Research
NO_3-N	Nitrate nitrogen
NRWQN	National River Water Quality Network
Periphyton	Benthic (streambed) algae attached to submerged substrate
REC	River Environment Classification
RMA	Resource Management Act
Rd	Road
Rv	River
% sat	Percent saturation (with respect to dissolved oxygen)
SBSV	Suspendible Benthic Sediment Volume
SoE	State of the Environment
SQMCI	Semi-quantitative Macroinvertebrate Community Index
Stm	Stream
STP	Sewage Treatment Plant
TDC	Tasman District Council
TN	Total nitrogen
TP	Total phosphorus
TRMP	Tasman Resource Management Plan
TSS	Total suspended solids
Vly	Valley
VSS	Volatile (organic) suspended solids

Trends

Significant	A trend is significant when a p-value (used for testing a statistical hypothesis) is less than the significance level (we used 0.05).
Meaningful	A trend is meaningful if it has a change greater than one percent per year (RSKSE > 1%).
RSKSE	Relative Seasonal Kendall Slope Estimate

This report

This report is an update of *River Water Quality in Tasman District* (Young et al. 2010) and uses subsequent data up until February 2015. In this report, the **state** of river water quality in the Tasman District is discussed using data collected from a set of core sites between 2010 and 2015. River water quality **trends**, by comparison, are examined using data from the entire record (up to 45 years depending on the site). The results of the state and trend analyses are presented in five sections corresponding to five 'Water Management Areas' within the Tasman District (Figure 1). These Water Management Areas were developed for this report and, with the exception of the Takaka Water Management Area (which is the Freshwater Management Unit defined under the National Policy Statement for Freshwater Management), do not have the same boundaries as those that will be defined in the Tasman Resource Management Plan. An overview of the results for the core monitoring sites is provided at the beginning of each Water Management Area section, followed by a more detailed discussion for each catchment. This detail includes additional investigations to determine the cause of degraded water quality.

This report also provides insight into river water quality beyond the Council's own monitoring programmes, such as information from selected reports from sources external to Council and analysis of the regional-wide state using models for macro-invertebrates and water clarity.

Thorough internal and external peer review has been applied to this report (see external peer review letter in Appendix 9).

Council Duty to Monitor and Manage River Water Quality

Under the **Resource Management Act** 1991, local authorities, including the Tasman District Council, are required to monitor the overall state of the environment of their region. Section 35 states that Council must monitor the 'State of the Environment' to the extent "*as is necessary to carry out effectively its functions*". This is important because it tells the Council and the wider community how successful we have been as a community in achieving the purpose of the RMA – the sustainable management of our natural and physical resources.

Under the **Tasman Resource Management Plan** there are specific objectives, policies and methods for **river beds**, including banks (27.1.2) which include the "*maintenance, restoration and enhancement of aquatic habitats ... to (a) preserve their life-supporting capacity (including mauri of the water), (b) protect their values for native fisheries, trout fisheries and wildlife and (c) protect or enhance indigenous biodiversity values*". This plan also addresses water quality through objectives, policies and methods for **discharges** (Chapter 33). The objective is to *maintain existing water quality and enhance it where it is degraded for natural and human uses or values*. There are specific objectives and policies for discharges that are accidental or emergency (33.2), stormwater (33.3), domestic wastewater (33.4), and from contaminated sites (33.5). There is a general method (33.4.20.4 (b)) requiring *Monitoring of ground and surface water quality*.

The **Long Term Plan** (LTP) sets out '**Community Outcomes**' i.e. what the Council seeks to achieve in serving the people of the District through our various statutory and representative functions. The relevant outcomes relating to this report are:

- *Our unique natural environment is healthy and protected.*
- *Our urban and rural environments are people-friendly, well-planned, and sustainably managed.*

The LTP Part 3(i) says that in order to achieve these outcomes we will *"investigate significant environmental issues affecting or likely to affect the District and maintain an efficient resource information base to provide advice on environmental conditions and issues affecting the District."*

More specifically the LTP (pg 52) says it will do this by:

- *"having in place* ***policies*** *and plans that promote sustainable management of natural and physical resources and, where necessary, regulating activities which would over time degrade the environment or place resources under pressure, keeps Tasman District special.*

- ***monitoring and investigating*** *the state of the environment and the trends, risks, and pressures it faces, we can make better decisions and have in place policies and plans that promote sustainable management of natural and physical resources, and where necessary, that regulate activities which overtime would degrade the environment or place resources under pressure, keeps Tasman special.*

- *__managing animal and plant pests__, working with landowners and others to protect biodiversity, soil and water sustainability, and educating to encourage responsible environmental behaviours, we seek to ensure Tasman remains special*

- *ensuring __consent approvals__ for the development and use of the environment promote sustainable management of natural and physical resources. Where necessary, conditions can be imposed (and monitored) that regulate activities which overtime would degrade the environment or place resources under pressure.*

- *__educating people__ and providing them with information to enable them to live more sustainably and to be more resilient."*

Policy work in progress that will address the issues raised in this report include:

- Setting of limits for various attributes relating to water quality and quantity. This work is actively pursued using a collaborative governance model under the National Policy Statement for Freshwater Management.

- Production of the Sediment and Erosion Control Guidelines

- Review of the TRMP controls on land disturbance

Water Management Areas

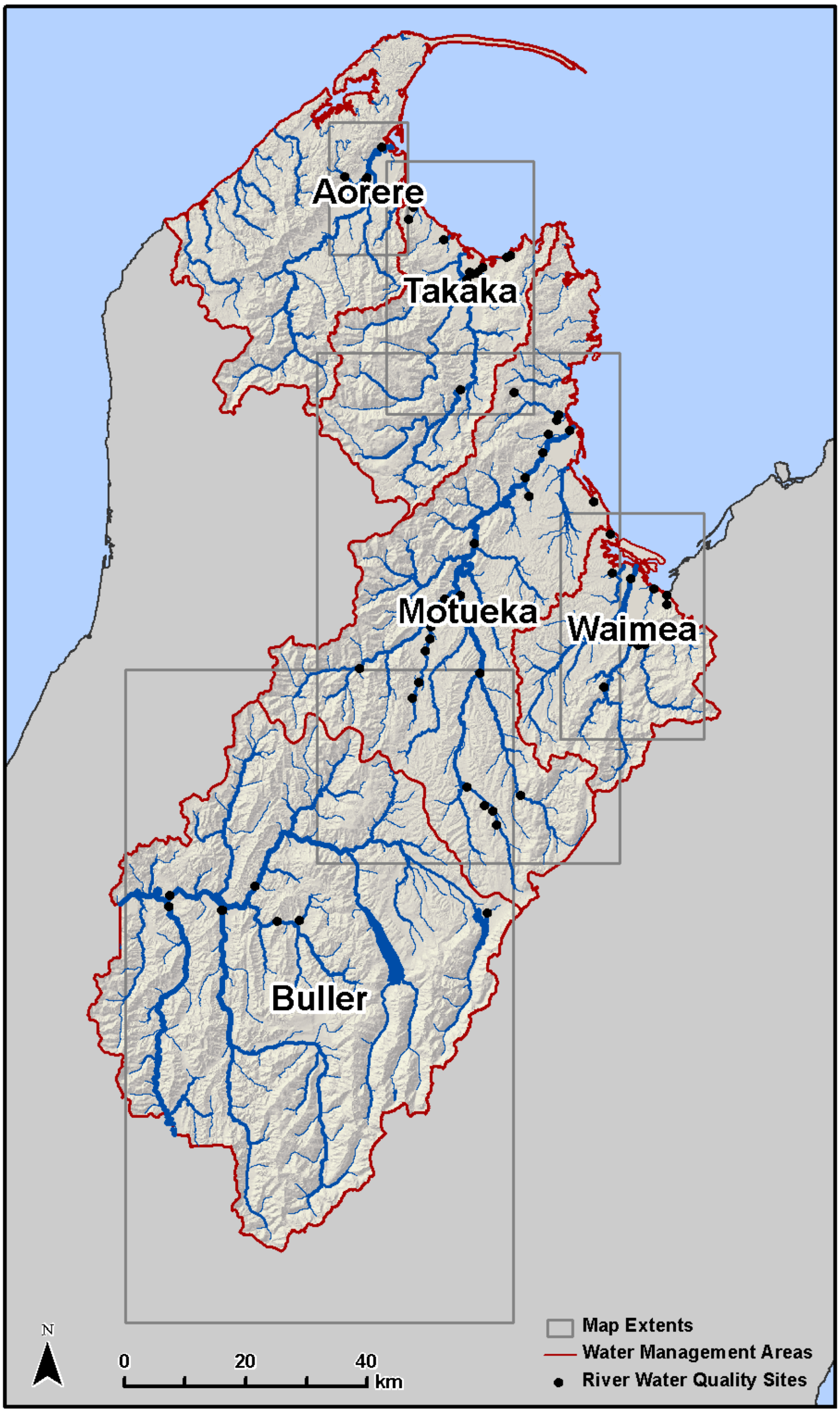


Figure 1. Overview map showing the five Water Management Areas within the Tasman District identified for this report.

Our Rivers

Tasman District covers an area of the northern South Island stretching from Golden Bay in the west to Richmond in the east, and to the upper Buller and Maruia rivers in the south. According to the river environment classification (REC) there are 14,300 kilometres of waterways in the District.

The influence of climate

Over 90% of Tasman's rivers drain areas that can be considered '**cool**' (mean annual temp <12 °C) and '**wet**' (annual precipitation >500 mm) (Snelder et al. 2004b). Small coastal streams between Richmond and Motueka are the only waterways in the district influenced by a '**warm dry**' climate (2.5% of all streams). Moutere Hill country streams are described as being '**cool and dry**' (about 3% of all streams), while several small coastal streams in Golden Bay are influenced by a '**warm wet**' climate (3% of all streams).

The influence of 'source of flow'

Just over half the streams in the district have their source of flow in **hill** country, a quarter of the streams are fed by **mountainous** areas (>1000 m in altitude), and most of the remainder (24%) are **lowland-fed**, with a few **spring-fed** streams. Hill-fed streams in the Moutere area tend to have intermittent or ephemeral flow. Flood peaks on the Buller (Kawatiri) River from Lake Rotoiti to Murchison are much more subdued than most rivers in the district, due to its lake-fed source of flow.

The influence of geology

Geology plays an important role in shaping aquatic communities, particularly in the upper Motueka catchment, where there are high concentrations of heavy metals such as iron, nickel and chromium in stream sediment. This is due to weathering of **ultramafic rock** found in the **Red Hills**. This occurs to a lesser extent in other streams draining the **Barnicoat** and **Bryant Ranges** in the eastern part of the district. Rivers draining **marble geology** of the **Mt Arthur Range** have substantial flow during low rainfall periods (due to water storage within the fractured marble) compared to **Moutere Gravel hill country** where a large proportion of streams dry up in summer. However, many of the deeper parts of Moutere streams where there is shade will continue to hold water through the summer. Catchments in **Separation Point Granite geology** (much of Abel Tasman through the Motueka Valley to Mt Murchison) are highly erodible and stream beds have a large component of mobile sand.

The influence of land cover

Almost two-thirds of the district is protected in conservation estate. Indigenous forest is the main land cover in the region (60%), while pasture (17%) and exotic forest (9%) are also important (see Figure 2).

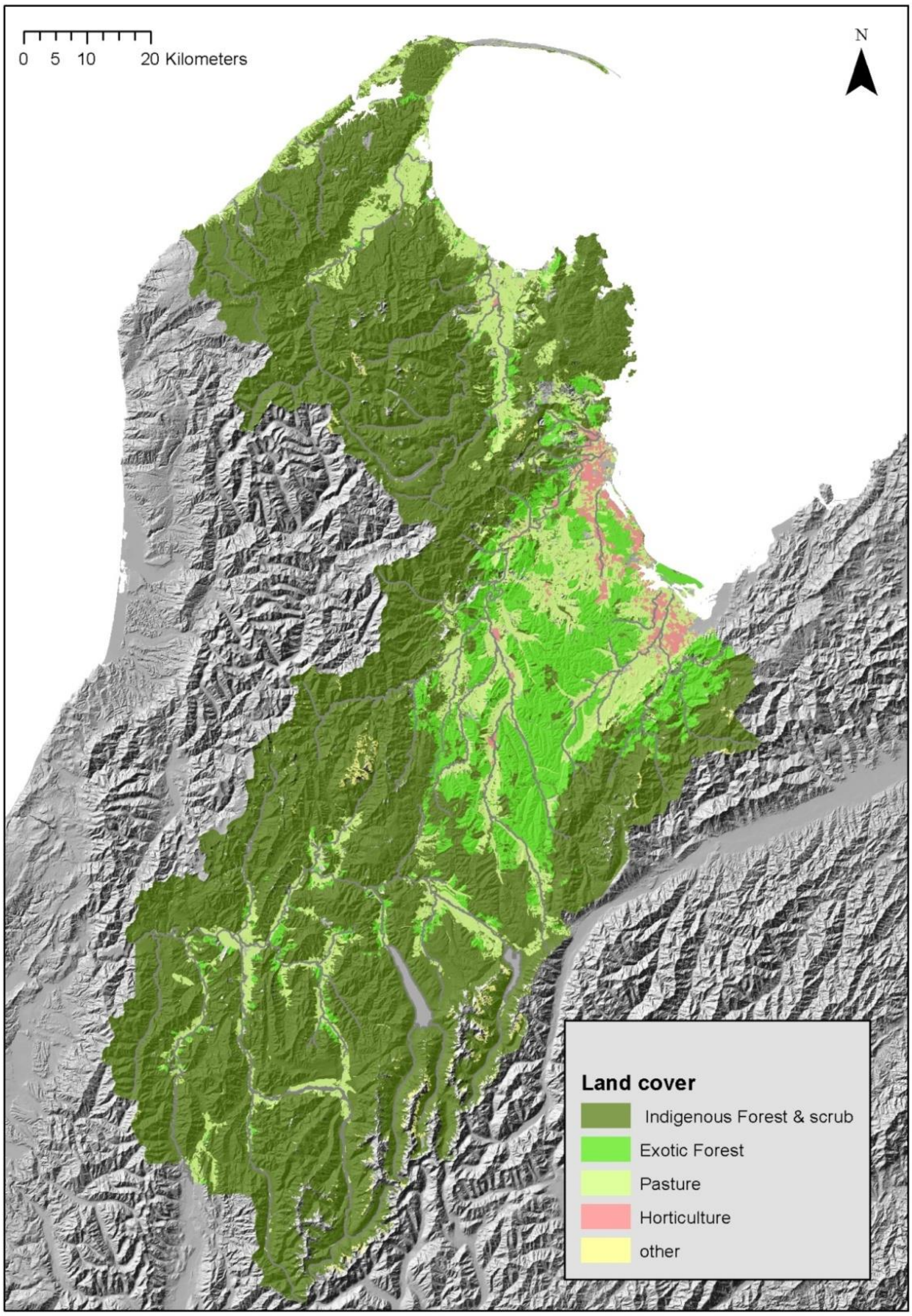


Figure 2. Land cover of the Tasman District, derived from LCDB3 in 2008

The State of the Environment (SoE) Monitoring Programme

Data on water quality has been gathered from selected rivers and streams since 1999 as part of TDC's State of the Environment (SoE) monitoring programme. Additional information has also been collected during the Council's bathing water surveys and as part of scientific studies carried out by other agencies in the District.

The specific aims of the SoE programme are:

1. To determine the quality of surface waters in the District in reference to accepted standards (for public health, recreational and ecological reasons).
2. To identify trends in water quality.
3. To identify cumulative environmental effects from multiple discharges into surface waters.
4. To understand the nature of surface water quality problems/issues in order to provide information for defensible management responses. Such responses include seeking reviews to Council resource management plans, regulations, and resource consent conditions.
5. To identify new issues and monitoring requirements.
6. To identify factors that cause change in surface water quality (i.e. impact monitoring).

This SoE programme was designed to achieve the six aims outlined above. However, the programme must work within a number of constraints. Given the resources available, quarterly sampling is undertaken at most sites, with monthly sampling at eight sites mostly near the mouth of major rivers (Waimea, Motueka (3 sites), Sherry, Takaka, Aorere, Kaituna and Buller at Longford). Because of the high variability of water quality data, sampling is only carried out at base flows at sites sampled quarterly. As a consequence of low frequency of sampling, it takes much longer to detect trends and relatively little is known about water quality after rain or during flood flow conditions. For the Contact Recreation Water Quality Monitoring Programme (mostly bathing beaches or swimming holes), sites are sampled weekly/fortnightly from November-March irrespective of rainfall, unless flooding makes it physically unsafe to swim.

While information from the SoE programme will give clues as to the cause of poor water quality, it is often only after intensive sampling within a catchment that clear conclusions of cause and effect relating to specific land-use activities can be drawn. Such follow-up investigations are undertaken on a prioritised basis.

The programme targets areas where the most significant human pressures, such as point source discharges, exist or are suspected, while maintaining a few sites (10%) in pristine areas as reference sites (i.e. sites that have little or no influence from the pressures experienced at sites further downstream). Sites in the programme were chosen to try to achieve a balance across the following criteria:

a) Geographical spread throughout the District;
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, the design of the SoE programme involved careful choice of indicators (measures) of water quality, sites and methods. Waterways have a wide variety of values including ecological, cultural, recreational and aesthetic values. Therefore, the choice of environmental indicators may differ from site to site depending on the values present. For example, one stretch of river may be highly valued as a fishery resource, but may be seldom used for swimming, while another may be popular for swimming and have limited fishery values. In this example water clarity, periphyton and macroinvertebrates would be the most important indicators for a river valued for its fishery, but faecal bacteria (*E. coli*), which are indicators of potential faecal contamination and health risk, and water clarity would be the most crucial indicator at monitoring sites valued for contact recreation. Indicators were, therefore, chosen partly to reflect community values, as well as to be consistent with indicators recommended by the Ministry for the Environment (1998). Further information on the design of the monitoring programme and methods used can be found in the Tasman District Council, Surface Water Quality Monitoring Programme document (Tasman District Council 2009).

Key Attributes of River Water Quality

Water Clarity

Clarity is important because it affects the recreational and aesthetic quality of water as well as the aquatic ecosystem. Poor water clarity adversely affects the ability of sight feeding predators, such as fish and birds, to locate prey and the ability of algae to photosynthesise and hence provide food for animals further up the food chain.

It is important to note:

a) there is a high natural variability in optical characteristics of New Zealand waters (more than one order of magnitude);
b) very clear water can still be contaminated with faecal bacteria, parasites, heavy metals, ammonia and nutrients.

Visual water clarity was measured using the horizontal sighting of a black disc (Davies-Colley 1988). Research has shown that people can detect small changes in clarity using this method.

E. coli

E. coli (*Escherichia coli*) is a type of faecal indicator bacteria used to assess the risk of disease for humans or livestock from interacting with waterways. *E.coli* is used because it is relatively cheap to test for and it is usually found in reasonable numbers when more serious disease-causing organisms are present such as *Campylobacter, Cryptosporidium, Giardia* and *Salmonell*a. While some *E. coli* strains cause serious disease (e.g. *E.coli* 0157:H7), typically they aren't in themselves the agent that makes a person sick.

Water-borne diseases are more common in New Zealand than in many other western countries (e.g. *Crytosporidiosis* is higher than the UK, US and Germany by 3, 8 and 15 times respectively). Rates of *Camplyobacter* increased from about 50 cases/year in the early 1980's, to over 400 cases in 2006. These rates have reduced after this time through better hygiene in the poultry industry, but are still high.

Filamentous Green Algae Cover & Periphyton Score

Excessive filamentous algae or "slime" in waterways adversely effects amenity value (aesthetic quality, odour, slipperiness), water quality (large fluctuations in dissolved oxygen caused by photosynthesis and respiration of live periphyton and degradation of dead periphyton) and habitat (water column or stream bed can be filled with periphyton to the point where there is reduced space for aquatic organisms to function normally).

Nutrients

The nutrient attributes we report on are Nitrate-N, Ammonia-N, Dissolved Inorganic Nitrogen (DIN) and Dissolved Reactive Phosphorus (DRP). We also report on the ratio between DIN and DRP as an indicator of which nutrient may be limiting.

Nitrate is an important nutrient for the growth of algae and aquatic plants and can lead to excessive coverage of algae if discharged to the stream when nitrogen is limiting. However, other factors such as substrate stability, sunlight, and temperature also affect plant growth. Elevated concentrations of nitrate can be toxic to fish and invertebrates. Farm animals, particularly young stock, can also be affected if concentrations are sufficiently high.

Nitrate is mainly derived from land and subsoil drainage. Elevated nitrate levels can occur naturally (e.g. leaching and erosion from some marine-derived sedimentary rock), or as a result of human activity. Lowest levels of nutrients are generally in mid-summer due to terrestrial and in-stream plant uptake being at its highest.

The un-dissociated form of ammonia (NH_3) is very toxic to aquatic life, with fish (especially trout) being particularly sensitive. Less than 0.1 ppm (0.1 mg/l) has been shown to affect fish. The concentration of NH_3 is controlled by the pH and temperature of the solution (more NH_3 under more alkaline conditions or higher temperatures).

Ammonia is a good indicator of recent pollution from organic discharges because it rapidly (within a few weeks) degrades to nitrate and then nitrogen gas through denitrification processes. Ammonia (NH_3 or NH_4+) is rarely found in natural waters, except in wetlands and geothermal springs, and therefore its presence is an excellent indicator of human pressure on rivers. Ammonia is also a source of nitrogen that, as a nutrient, can cause eutrophication (excessive plant and algae growth and enrichment) in waterways.

Dissolved Inorganic Nitrogen (DIN) is a measure of the total nitrogen available to plants. DIN = ammonia-N + nitrate-N. See above for application.

Dissolved reactive phosphorus (DRP) is a form of phosphorus that is available immediately for plant growth. DRP levels in water samples are often inversely related to periphyton cover (predominantly attached algae) due to uptake of the nutrient by periphyton (Smith et al., 1993).
DRP concentrations usually peak just before the peak flow in a flood and in autumn.
The ratio between DIN and DRP can be used to indicate which nutrient is limiting algal growth in stream ecosystems.

Dissolved Oxygen

Dissolved oxygen (DO) is fundamental to the survival of aquatic life (for “breathing”). DO concentrations of less than 50-60% saturation or 5.0 g/m^3 adversely affect trout and other fish, and less than 40% saturation or 2-3 g/m^3 are likely to result in fish deaths. The measurement of DO is

particularly important in slow flowing streams with excessive algal / aquatic plant growth and little riparian shading, where DO may reach low levels. Minimum DO levels usually occur around dawn (due to respiration of algae and higher plants) and in summer. Therefore, sampling over the whole day-night (diurnal cycle) using continuous or semi-continuous sampling is important.
Dissolved oxygen may be recorded as percentage saturation, or as a concentration in mg/L. To convert between the two, it is necessary to know both the temperature and salinity of the water. At equilibrium with the air above it, the amount of oxygen water can hold increases as the water temperature falls. A drop from 21°C to 10°C, for example, increases the equilibrium concentration of dissolved oxygen in freshwater (ie. freshwater at 100% saturation) from 8.9 mg/L to 11.3 mg/L. In the National Policy Statement for Freshwater Management 2014, dissolved oxygen is reported in terms of concentration. We therefore have mostly used concentration this report.

Some aquatic organisms can survive short periods of low oxygen conditions. The freshwater shrimp (*Paratya curvirostris*), for example, has reportedly survived in 1 mg/L of dissolved oxygen for 48 hours (Dean and Richardson 1999). At the same concentration, however, common smelt, juvenile common bully and torrentfish – three native fish species – did not survive. Inanga whitebait are also sensitive to low dissolved oxygen (Landman et al. 2005). Dissolved oxygen concentrations between 5 and 8 mg/L cause moderate stress to aquatic organisms while above 8 mg/L allow aquatic organisms to exist without oxygen stress (NPSFM 2014).

Methods

This section describes the monitoring programmes that fed this report, along with key details of the data collection protocols and the data analysis methods used in this report. Full detailed descriptions of the methods used in the Council programmes are provided in the monitoring programme manuals (Tasman District Council, 2015).

Monitoring Programmes

The river water quality dataset analysed in this report was collected as part of the following monitoring programmes:

1. 'State of the Environment' River Water Quality Monitoring Programme
2. Contact Recreation Water Quality and Toxic Algae Monitoring Programme
3. Sonde Deployment Programme
4. National River Water Quality Network
5. Compliance monitoring programmes

Tasman District Council has collected and managed all the data for the first three programmes since inception. The wastewater treatment plant compliance data was collected by consultants, but managed by Council's Engineering Department. Data from the National River Water Quality Network was collected and managed by NIWA.

The 'State of the Environment' **River Water Quality Monitoring Programme** (RWQMP) was established in 1999. The network currently has 60 sites, each visited quarterly. Six sites in the programme were sampled both monthly and quarterly: Kaituna at 500 m u-s Track start (since 2013), Aorere at Le Comte (since 2011), Takaka at Kotinga (since 2013), Motueka at SH60 bridge (since 2013), Sherry at Blue Rock (since 2003), and Waimea at SH60 Appleby (since 2013). By sampling monthly, the variation in water quality throughout the year can be better captured; samples may be collected over a wider range of flow conditions and trend information may be generated in a shorter time frame compared to quarterly sampling.

Some parameters were sampled at nearly all sites: faecal indicator bacteria (faecal coliforms and *E.coli*), ammoniacal-N, dissolved oxygen, temperature, pH, conductivity, and turbidity. Other parameters such as water clarity, periphyton, and fine sediment content of the bed were sampled at the vast majority of sites. Macroinvertebrates were generally only sampled in small to medium-sized waterways due to cost and the fact that all larger rivers in Tasman have the majority of the catchment in native forest which provides large dilution of contaminants. Nutrients are sampled at at least one site on all the major rivers in Tasman, including two reference sites, as well as sites where high filamentous green algal cover is an issue.

The **Contact Recreation Water Quality Monitoring Programme** (CRWQMP) began at a limited number of sites in 1999 and expanded in 2001. The aim of this programme is to assess the state of the most popular swimming sites (both beaches and rivers) that have an elevated risk of faecal contamination.

Parameters sampled in this programme include *E.coli* and water clarity (and more-recently monitoring of *Phormidium*). The core group of sites in the programme, four of them on rivers, were visited weekly or twice-weekly between November and March, coinciding with the peak season for river swimming. In addition, several less popular sites were sampled at least 15 times every second summer season (Wairoa Rv at WEIS weir, for example).

The **Sonde Deployment Programme** collects continuous dissolved oxygen and temperature data (and often conductivity and pH) for short periods (several days to 2-3 weeks) in summer and has run most summers since 2009 and occasionally prior to this. Sites for continuous measurements were generally on small to medium sized waterways where there was thought to be a risk of low oxygen levels or high temperatures.

At one site, Motupipi at Reilly Bridge, measurements of conductivity, temperature, and flow all-year have been taken every 15 minutes since late 2007. Dissolved oxygen has also been measured at 15 minute intervals from 2007, but since 2013 it has only been operating from December-March inclusive. This is due to dissolved oxygen only being an issue at this time of the year and an effort to reduce maintenance costs.

The **National River Water Quality Network** (NRWQN) has operated since 1989 making it one of the longest-running programmes in New Zealand (Davies-Colley et al. 2011). 77 sites are sampled across the country on a monthly basis. Three sites in the NRWQN are within the Tasman District (Buller at Longford, Motueka at Gorge and Motueka at Woodstock). The standardised sampling protocols used in the NRWQN are found in Smith & Maasdam (1994).

In addition to these sampling programmes, there were several targeted investigations conducted during the 5-year reporting period (for more information see Discussion of Specific Catchments).

Data from other resource consent compliance monitoring programmes or resource consent applications include:

- Collingwood Wastewater Treatment Plant discharge to Burton Ale Creek
- Electric Waters Ltd hydroelectric power on the Onekaka River
- Takaka Wastewater Treatment Plant, discharge to Takaka River (1km upstream Waitapu Bridge, SH60)
- Fonterra Takaka Dairy Factory discharge to Takaka River at Kotinga and streams in catchments where wastewater is applied to land
- NZ King Salmon discharge from salmon farm near Te Waikoropupū Springs
- Anatoki Salmon discharge to the Anatoki River

Sampling Protocols

The protocols used to collect water quality data from each site are broadly similar between sampling programmes and described in detail in Council's RWQMP – Volume 2. Where there are important differences, they are outlined below.

Timing of sampling

The RWQMP sites on a quarterly basis are sampled during "base-flow" conditions, after at least three days of dry weather. The six RWQMP sites and the three NRWQN sites (Motueka at Gorge and Woodstock and Buller at Longford) are sampled on a monthly basis and on set days each month, so therefore include measurements over a wide range of flow conditions.

River Flow

River flow data is collected during almost all sampling occasions. It is determined using either of the following methods: gauging (velocity and depth measurements across the river cross-section), from permanent stage-height recorders at either the sites or from a site relatively close that is known to correlate well to flow at the site. Accuracy required for these gaugings is +/- 15%, but it is typically better than this.

Water Clarity

Careful attention was paid not to contaminate or disturb the bed when taking a sample or measurement. A few sites have relatively small pools with insufficient sighting distance to determine the limit of water clarity (these include Onekaka upstream at Ironstone and Reservoir Creek upstream of Marlborough Cres). At these sites a mirror was used to increase this distance. In the case of spring-fed creeks with high coverage of macrophytes, a sighting laneway is cleared within this vegetation and left so any sediment is settled and the water cleared prior to measuring water clarity.

Monitoring staff at a training and quality control exercise. Here comparing black disc water clarity measurements to ensure inter-operator accuracy (Jan 2015).

Water Samples

Collecting water samples at Aorere at Devils Boots (Feb 2015)

The following variables were measured using a handheld water quality meter: Water Temperature (°C), Specific Conductivity (µS/cm), pH, Dissolved Oxygen Saturation (% and mg/L). Because dissolved oxygen and temperature vary naturally over a 24-hour period, the spot measurements were used as a guide as to whether these parameters may be an issue at a site. A separate programme of continuous measurements was undertaken to capture the natural variation in these parameters.

Nutrients and *E. coli*

Samples were collected for laboratory analyses of nitrate nitrogen (Nitrate-N), ammoniacal nitrogen (Ammonia-N), total nitrogen (TN), dissolved reactive phosphorus (DRP), total phosphorus (TP) and faecal indicator bacteria (*E. coli*). Samples were transported in chilly bins (~4 °C) to the laboratory. From 1999 to April 2012 the Cawthron laboratory in Nelson was used for all sample analysis. From May 2012 nutrient sample analysis was undertaken at Hill Lab in Hamilton. Microbiological sample analysis was moved from Cawthron to Hill Laboratory in Christchurch in July 2014. Nutrient and microbiological analyses were conducted using standard analytical techniques (APHA 2012). The only significant change to laboratory methods was between May 2012-June 2013 when samples analysed for total nitrogen used the APHA 21st Edn 4500-Norg C (mod) + 4500 NH3 F (mod) + APHA 4500-NO3-I (Mod) method. Before and after this time the direct method (APHA 22stEdn 4500-NO3- I) was used. Recent laboratory reporting limits for the chemical analyses were: Nitrate-N 0.002 mg/L; Ammonia-N 0.005 mg/L; TN 0.1 mg/L; DRP 0.005 mg/L; TP 0.005 mg/L and *E. coli* 5 cfu/100 mL (cfu = coliform forming units). Changes to these reporting limits are listed in the River Water Quality Monitoring Programme Manual.

In 2004, the State of the Environment Programme was reviewed and nutrient sampling was ceased at sites with low periphyton growth, including Reservoir Creek (Marlborough Cr and Salisbury Rd), Wairoa and Lee, Kikiwa/Motupiko, Little Sydney, Riwaka, Mangles/Matakitaki, Kaituna and Onekaka.

Annual median values were calculated for *E. coli*, Nitrate-N and Ammonia-N. Annual median Ammonia-N concentrations were adjusted to pH 8 using Equation 12 of USEPA (1999) and the mean pH concentration in a given year.

Periphyton community

The periphyton community was assessed in several ways. The percentage cover of didymo, toxic algae (*Phormidium)* and filamentous green algae (>2 cm) cover were visually estimated at each site after inspecting a length of streambed of approximately 50 m. This is carried out on every sampling occasion. A more detailed assessment of toxic algae (*Phormidium*) cover was performed at key sites using the method set out in section 4.4 of the NZ Guidelines for Cyanobacteria in Recreational Freshwaters (Wood et al. 2009). This is carried out weekly from mid-November-late March at key sites where *Phormidium* is an issue (i.e. regularly over 10% cover).


Sampling periphyton using a bathyscope at Aorere at Le Comte (Feb 2015)

Periphyton scores were measured and calculated using a modified version of RAM2 of the NZ Periphyton Monitoring Manual (Biggs & Kilroy, 2000). In the RAM2 protocol, the percentage cover of 12 periphyton groups, defined by growth form and colour, are recorded from stones collected in a grid pattern within the study site. In the modified version used by our field teams, the percentage cover of the periphyton groups was recorded from views of approximately one square-metre of streambed, rather than from stones. Periphyton scores are recorded in spring, summer and autumn but not in winter.

Macroinvertebrate community


Sampling macroinvertebrates using a kick net on the Onahau River (Feb 2015)

Macroinvertebrates (stream bugs) are generally sampled once per year using a kick-net, following national protocol C1 and samples were analysed according to Protocol P1 (Stark et al. 2001). The season in which samples were collected has changed over the record as follows: 2000-2005 in spring, 2005 in spring and autumn, 2007 to 2009 in autumn and 2012 onwards in summer. Sampling in summer has been settled on due to the higher rainfall in spring and autumn and the requirement for at least two weeks of base flows prior to sampling. Frequent flooding made it difficult to collect the samples with a timely manner. In 2006, 2010 and 2011 macroinvertebrate sampling was abandoned after almost 3 months of waiting for a two-week period of base flows (apart from sites in the Waimea area in 2010). The macroinvertebrate results for any particular site were only interpreted if there were at least three samples (over the 2000-2015 period).

Suspended Sediment

Total suspended solids (TSS) is not sampled at base flow as it is only in high flows when the vast majority of suspended sediment is evident. Suspended sediment yield can therefore only be generated from sites collected on a monthly frequency.

Resuspendable sediment

Two methods were used to assess fine sediment composition of the bed: the shuffle index (SAM5) and the Quorer method (SAM4) combined with an assay for Volumetric Suspendable Benthic Sediment Volume (SBSV). Both of these methods are detailed in Clapcott et al. 2011. The Shuffle Method produces a qualitative score from 1 to 5, with higher values indicating a greater degree of resuspendable solids on the streambed. This method is used on each sampling visit and if unexpectedly high results were found then follow-up sampling is considered. The Quorer method (using volumetric SBSV) is quantitative but time-consuming so it is only carried out annually in summer at sites where macroinvertebrate sampling occurs. This method is only used in streams with beds dominated by cobble-sized bed substrate. For this method a patch of streambed is isolated using a plastic barrel (400 or 500 mm diameter) and the sediment within the bed is stirred by working your boots vigorously into the bed to a depth of about 150-200 mm. A sample of the water and sediment mixture from the barrel was then collected. This procedure was repeated six times at each site. The volume of sediment in each sample was measured after settling for 1 hour in Imhoff cones. These raw measurements were then converted to Volumetric SBSV (litres of sediment per cubic metre of streambed).

Sampling re-suspendable fine sediment on the Onekaka River (Feb 2015)

Macroinvertebrates and SAM4 (quantitative measure of deposited fine sediment) are not sampled at all sites and more regularly due to time and cost demands. So the focus has been on the highest risk sites: generally smaller waterways with greater risk of poorer water quality.

Programme Reviews

In 2004, nine sites were also dropped from the monitoring programme including Buller at Lake Rotoiti (outlet), Matakitaki at Nardoo and Horse Terrace, Motueka d-s Graham, Glenroy Rv at Bridge; Wai-iti at Hiwipango, Pigeon Valley Rd and at Livingston Rd, and Tiraumea Rv at Track. Further detailed information about these changes can be found in RWQMP Vol 3 – Site Network.

Data Processing and Analysis

The R software environment (R Core Team 2014) was used to compile and analyse the river water quality data for this report. The following packages were used extensively: lubridate (Grolemund and Wickham 2011), dplyr (Wickham and Francois 2015) and ggplot2 (Wickham 2009).

Analysis of the 'state' of each site uses only data from 2010-2014 for all but the macroinvertebrate data which was from 2011-2015, apart from the more in-depth discussion about specific catchments. The reason for using only the most recent five years of data is that this more fairly represents the 'current' condition. Analysis of 'trends' generally uses the full record for a site or the last 10 years of record (the shorter record was used to try and pick up any shorter-term recent trends).

For sites in the RWQ monitoring programme sampled on a quarterly basis, the few flood-influenced samples were identified and removed prior to analysis. This quarterly sampling targets base flow conditions, but there have been occasions when targeted flood sampling was carried to investigate a particular issue. 'Flood-influenced samples' were defined as those collected within three days of a peak in river flow where the peak was at least three times the median flow in the river over the previous three months. A three month median flow was used rather than an annual median flow because winter base flows tend to be much higher than summer base flows. For sites in the NRWQN and monthly RWQMP, flood-influenced samples were not removed because that monitoring programme incorporates the full range of flow conditions at each site. Council's monthly programme has not been running for long enough to accurately describe water quality over the full flow range. In cases where water quality data were below the detection limit for a particular chemical analysis a value of half the reporting limit was substituted for the calculation of statistics. Where water quality data were above the upper detection limit for a particular analysis a value equal to the upper detection limit plus one was used.

Observations between 2010 and 2014 (5 years of data) were presented as pie-charts showing the proportion of measurements within each attribute state. Variables with fewer than 10 measurements, for a particular site, were not displayed.

Analysis of the difference between paired sites included spot measurements for dissolved oxygen and temperature because these were usually taken within a short time of each other. Comparisons were made between pairs of sites in the same catchment with different land cover types. Each pair consisted of a reference site with a native forest catchment and an impact site with an urban, forestry or farming catchment.

Continuous Measurements

The processing of water temperature, dissolved oxygen concentration and dissolved oxygen saturation continuous measurements proceeded as follows. Spikes caused by the initial deployment were removed from continuous records. For some sites, dissolved oxygen concentration data were missing but dissolved oxygen saturation data were available. For other sites the reverse was true (dissolved oxygen saturation without dissolved oxygen concentration). In these cases, the missing measurement was calculated using standard equations, assuming a salinity of 0.06 practical salinity units (PSU) and one atmosphere of pressure (760 mmHg).

Two statistics were then calculated from the raw continuous dissolved oxygen data:

1. The mean value of seven consecutive daily minima (7-day mean minimum). This was only calculated for sites which had a sensor installed for at least seven days.
2. The lowest daily minimum across all measurement-days at a site (1-day minimum).

Trend Analysis

Trend analysis is useful to determine whether a water quality attribute is improving or degrading at a particular site in the long term.
Sites with 10 years or more of water quality data were examined for trends in *E. coli*, water clarity and nutrient concentrations (Nitrate-N, Ammonia-N and Dissolved Reactive Phosphorus) over time.

We used the seasonal Kendall trend test to identify any trends in the data over a 10 year period (2005 to 2014) and over the full record (from 15 to 26 years, depending on the site and 45 years for Te Waikoropupū Springs). Only significant and meaningful trends are reported. That is, the reported trends meet the following three criteria:

1. The p-value for the Kendall trend test was less than 0.05 (significant)
2. The Relative Seasonal Kendall Slope Estimate (RSKSE), a statistic indicating the percentage change in the median value per year, was greater than 1% (meaningful)
3. The change in value between the start and end of the trend line was greater than the detection limit. Where the detection limit for an attribute changed in the past 10 years, due to improvements in the detection method for example, the higher (older) detection limit was used. This criterion eliminates false trends due to changes in the lab detection methods.

Detection limits used in trend analysis:

• Nitrate-N	0.002 g/m3
• Ammonia-N	0.005 g/m3
• DRP	0.002 g/m3
• E.coli	10 per 100 mL

Mann-Kendall trend tests were used to examine trends in invertebrate community metrics at National River Water Quality Network (NRWQN) sites. This test is similar to the seasonal Kendall trend test but does not account for seasonality in the data (the invertebrate samples were collected once per year, rather than in multiple seasons per year).

Water Quality Models

Macroinvertebrate community models

Predictive models were available for the macroinvertebrate community metrics MCI and EPT (Clapcott et al. 2013). This model used a dataset containing macroinvertebrate metrics from 1033 sites, predominantly in lowland areas, from all regions in New Zealand to construct the models. The median value for MCI and EPT over the five-year period 2007 to 2011 was used as the response. There were 23 predictor variables representing catchment geology, climate, flow, land cover, local habitat (run, riffle, pool) and bed sediment class (mud, sand, cobble). The predictors were available for all stream segments in the Freshwater Ecosystems of New Zealand network (FENZ; Leathwick et al. 2010). The stream segments in this network are not a fixed length but vary depending on the distance between tributary confluences (stream segments in the Tasman District have mean length = 650 m and SD = 560). Based on their performance, the authors used a Boosted Regression Tree (BRT) model to predict current MCI and EPT community metrics. In the model validation, the correlation (r) between predictions of both MCI and EPT with observed values was ‘excellent’ (r = 0.83 and 0.81, respectively).

Water clarity, *E. coli* and nutrient models

A modelling study of water quality in New Zealand rivers (Unwin et al. 2010), produced predictions for 11 water quality variables. The predictions relevant to this report were for water clarity, the concentration of *E. coli* and three nutrient variables (ammonia-N, nitrate-N and dissolved reactive phosphorus).

The authors of this study constructed models of each water quality variable using median values over the five-year period 2003 to 2007 recorded at 601 sites throughout New Zealand. They used 28 predictor variables representing catchment geology, climate, flow, land cover and topography. The modelling approach was to relate the predictor variables to each water quality variable (log-transformed) with Random Forest (RF) models.
They emphasise the importance of treating extrapolated predictions (outside the range of the data used to construct the models) with caution.

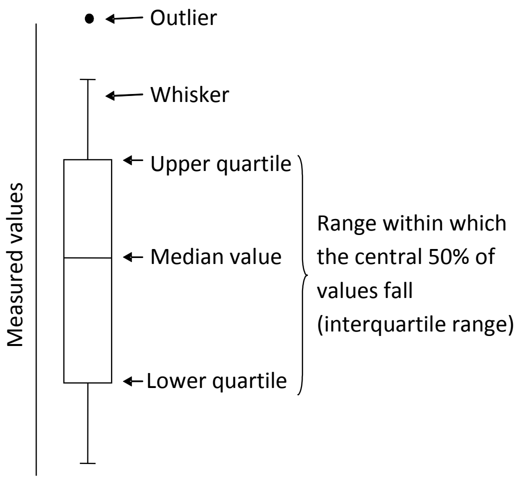
Fine sediment cover models

The percentage of fine sediment covering the streambed was modelled in New Zealand streams as part of a project to develop sediment assessment guidelines (Clapcott et al. 2011). In that study, a boosted regression tree model was developed using percentage fine sediment cover data from the New Zealand Freshwater Fisheries database. The resulting model predicts higher fine sediment cover in streams with lower slope, higher temperatures, lower rainfall, lower flow and soft catchment geology. When validating the performance of the model, the authors found a tendency for overestimation in stream reaches with very low sediment cover and underestimation in stream reaches with very high sediment cover.

Quality Control and Quality Assurance

Each sampling programme has its own quality control and quality assurance methods including inter-operator checks and training (RWQMP Vol 1 and 2).

Interpretation of Box Plots



Box and whisker plots illustrate how data are distributed around the central, or median, value. The ‘box’ represents the range of the central 50% of values around the median, which is shown as the line through the box.

Values that are further from the median are illustrated as whiskers or outliers, depending on how far the value is from the median and on the size of the interquartile range. The upper whisker extends to the highest value within 1.5x the interquartile range. Points beyond the end of the whiskers are outliers (plotted as points).

Data Interpretation

Each observation was assigned to one of four attribute states (A, B, C or D) according to the numerical attribute states in Table 3.

Table 3. Numerical attribute states for each water quality attribute for the protection of river ecosystem health, aesthetics, and human health. Attributes highlighted in blue are included in the National Policy Statement for Freshwater Management (NPSFM 2014).

Attribute	Statistic	Units	Attribute State				Source
			A	B	C	D	
Water clarity	Single measurement	m	≥5	3 - 5	1.6 - 3	<1.6	-
Turbidity	Single measurement	NTU	≤5.6	>5.6	N/A	N/A	ANZECC & ARMCANZ (2000)
Resuspendable solids	Shuffle score (1 to 5)	N/A	1	2	3	≥4	-
Dissolved oxygen concentration	7-day mean minimum	g/m^3	≥8	7 - 8	5 - 7	<5	NPSFM (2014)
	Lowest 1-day minimum	g/m^3	≥7.5	5 - 7.5	4 - 5	<4	
Water Temperature	Midpoint of daily mean and daily maximum	°C	≤18	18 - 20	20 - 24	>24	Davies-Colley et al. (2013)
pH	Single measurement	N/A	6.5 - 8.5	5 - 6.5, 8.5 - 9	>5 or >9	N/A	-
Ammonia-N	Annual median	g/m^3	≤0.03	0.03 – 0.24	0.24 - 1.3	>1.3	NPSFM (2014)
	Annual maximum	g/m^3	≤0.05	0.05 - 0.4	0.4 - 2.2	>2.2	
Nitrate-N	Annual median	g/m^3	≤1.0	1.0 - 2.4	2.4 – 6.9	>6.9	NPSFM (2014)
	Annual 95th percentile	g/m^3	≤1.5	1.5 - 3.5	3.5 - 9.8	>9.8	
Dissolved reactive phosphorus	Single measurement	g/m^3	<0.01	≥0.01	N/A	N/A	ANZECC & ARMCANZ (2000)
E. coli	Annual median	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	NPSFM (2014)
	95th percentile	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	
Macroinvertebrates	MCI	N/A	≥120	100 - 120	80 - 100	<80	Stark & Maxted (2007)
	SQMCI	N/A	≥6	5 - 6	4 - 5	<4	
Phormidium	Percentage cover	%	<20	≥20	N/A	N/A	MfE (2009)
Filamentous green algae	Percentage cover	%	<10	10-19	20-29	>30	Biggs and Kilroy (2000)
Periphyton	Periphyton score (1 to 10)	N/A	≥8	6 - 8	5 - 6	< 5	-

Regional Overview and National Comparison

Regional overview using predictive models

National-scale predictive models are useful tools for understanding the **general state of rivers across Tasman District**. This overall impression is not possible using the Council's monitoring programmes, in isolation, because the sites in this programme generally have a higher risk of lower water quality due to human pressures and there are relatively few of them. Additionally the focus for site selection in Tasman is geographic spread and targeted land use impact monitoring rather than randomised selection (RWQMP Vol 3). In contrast, national-scale predictive models are typically developed using hundreds of sites across a wider range of stream types in order to predict stream condition over a whole region. National-scale predictive models were available for the macroinvertebrate community metrics MCI and EPT (Clapcott et al. 2013), fine sediment cover (Clapcott et al. 2011), water clarity, the concentration of *E. coli* and three nutrient variables (ammonia-N, nitrate-N and dissolved reactive phosphorus; Unwin et al. 2010).

Models can still make inaccurate predictions, however. To decide which models are suitable for making comments about the general state of rivers in the District, we analysed their performance using data from our monitoring programmes (see Appendix 5).

Based on the macroinvertebrate models, nearly 80% of stream segments in Tasman District have MCI values over 120 (within band A). For pastoral streams, 3% of stream segments have predicted MCI values in band D (i.e. below the bottom line). A further result from the macroinvertebrate models was that approximately 60% of streams in the region had predicted EPT taxa (the number of mayflies, stoneflies and caddisflies) of 10 or more.

Based on the water clarity model, about half of stream segments in the Tasman District have median water clarity results greater than 5 m and only 1% of stream segments have predicted median water clarity less than 1.6 m (Table 4).

Table 4. The percentage of stream length with predicted median MCI and Water Clarity in each of the bands. For MCI: A= >120, B = 100-120, C= 80-100 and D = <80. For Water Clarity: A= >5 m, B= 3-5 m, C= 1.6-3 m, D= <1.6 m

Band	MCI (% of stream segments)	MCI (% of pastoral stream segments)	Water Clarity (% of stream segments)
A	78	23	52
B	15	38	33
C	6	36	14
D	1	3	1

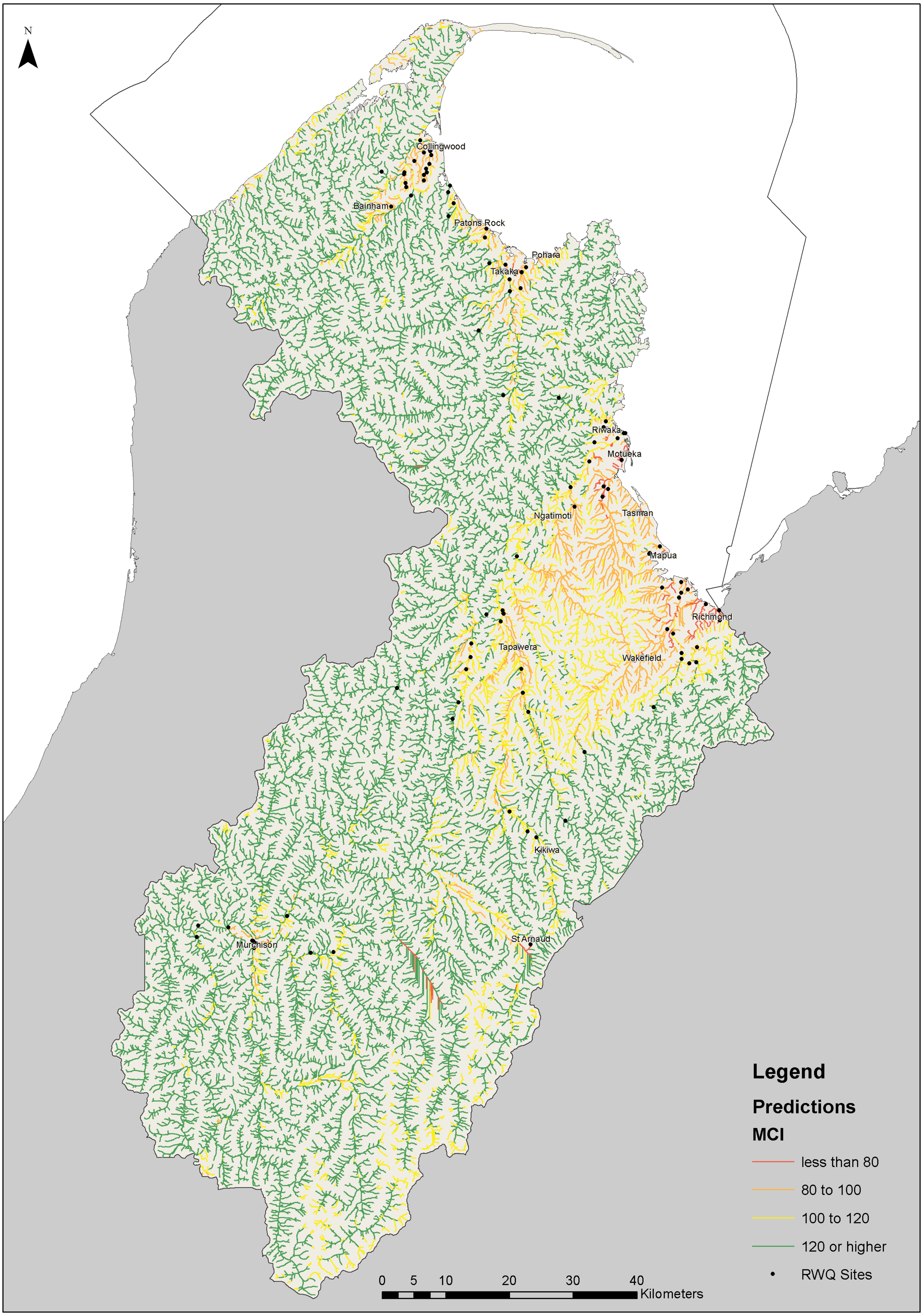


Figure 3. Predictions of macroinvertebrate community index (MCI) for river segments in the Tasman District based on a national-scale model (Clapcott et al. 2013).

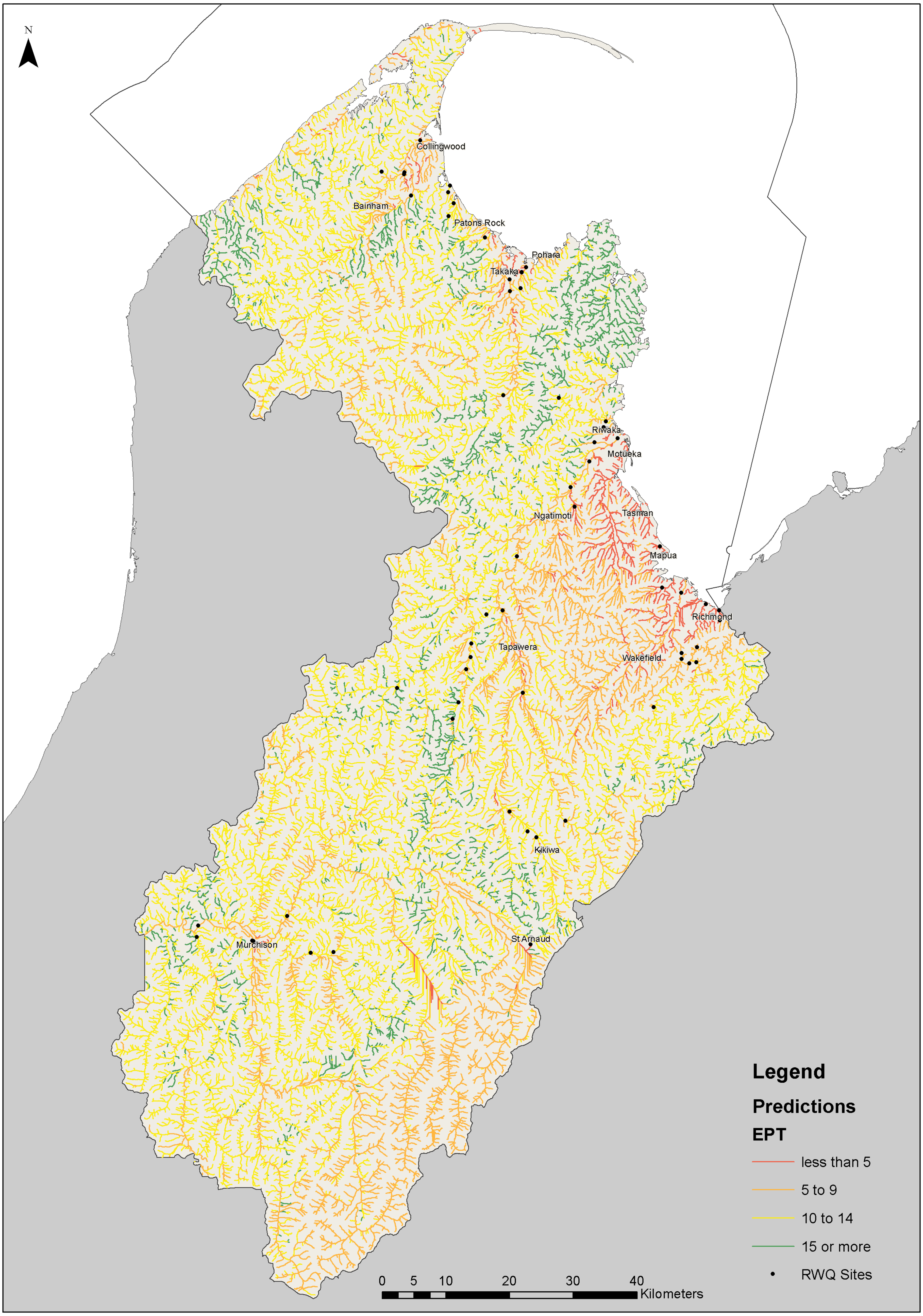


Figure 4. Predictions of the number of mayfly, stonefly and caddisfly groups (EPT taxa) for river segments in the Tasman District based on a national-scale model (Clapcott et al. 2013).

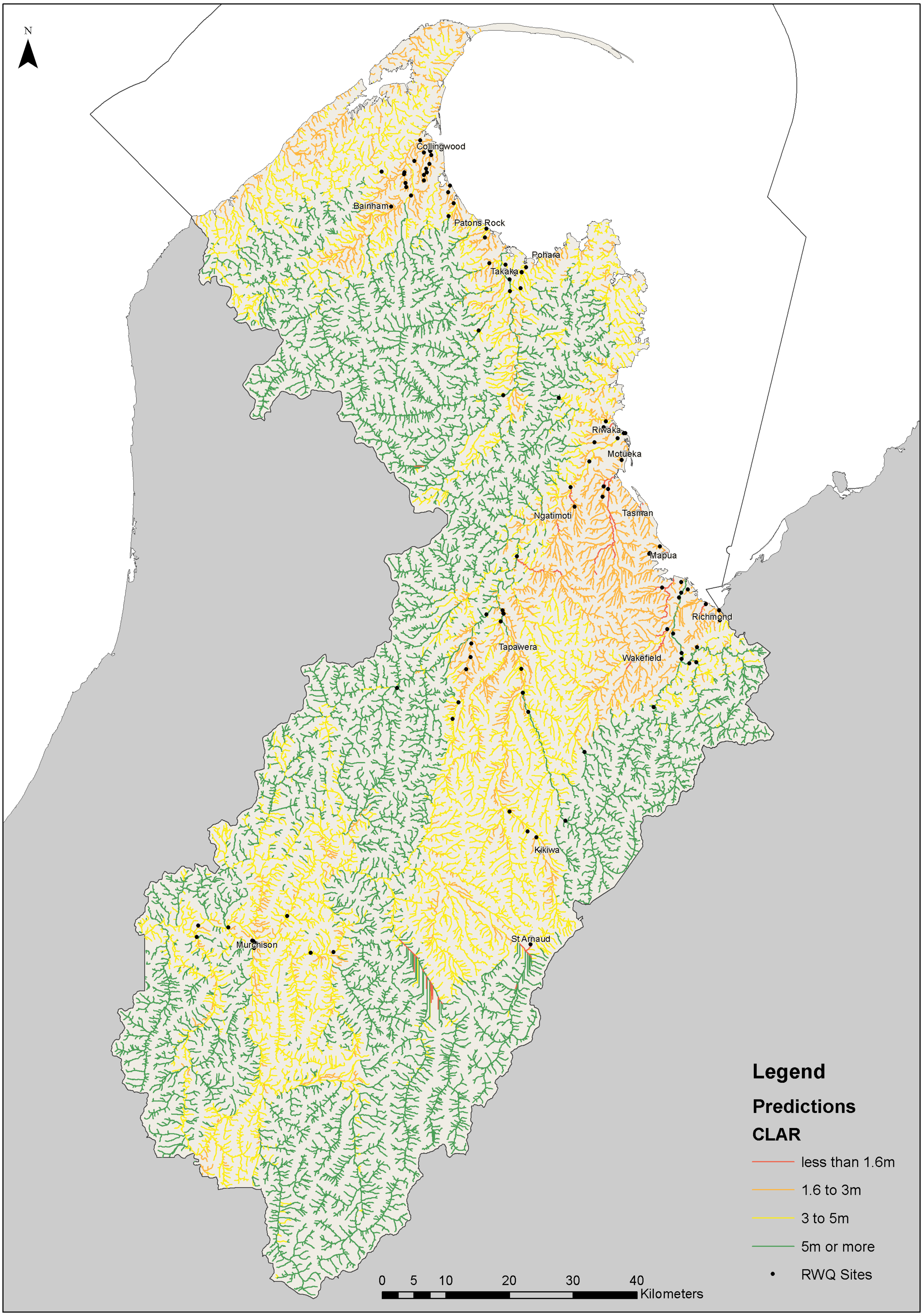


Figure 5. Predictions of median water clarity for river segments in the Tasman District based on a national-scale model (Unwin et al. 2010).

Disease-causing organisms

Disease risk levels in streams are indicated by the concentration of *E. coli*, a type of bacteria. There are two statistics, the annual median and 95th percentile, which can be used to assess the attribute state of *E. coli*.

For the period 2010 to 2014, five monitoring sites had at least one annual median *E.coli* concentration below the national bottom line (1000 *E.coli* per 100ml). They were Murchison Creek (in 2010 and 2014), Biggs at Hewitts Rd (2010), Powell at 40m u-s Motupipi Rv (2014), Seaton Vly at Stafford Dr (2010) and Borck at 400m ds Queen St (2012). All five sites are on smaller streams in pastoral catchments.

Approximately 40% of sites influenced by pastoral land use (20/52) had 95th percentile *E.coli* concentrations greater than 1000 *E.coli* per 100ml. The 95th percentiles were calculated from at least 10 samples collected between 2010 and 2014.

Disease-causing organisms are discussed further under each of the five water management areas identified for this report.

Deposited fine sediment

Fine sediment fills the spaces between cobbles and covers the surface of stones. Where large amounts of fine sediment have been deposited in a stream, there is little habitat left for fish and many macroinvertebrates like mayflies and stoneflies.

The shuffle method and Quorer method were used to assess deposited fine sediment in the streambed (SAM4 and SAM5 in Clapcott et al. 2011) at the river water quality monitoring sites.

From the shuffle method, 21% of monitoring sites (11/52) had at least one high result between 2010 and 2014 (shuffle score of 4 or 5). Over the same period, 47% of monitoring sites (16/34) had a high Quorer result (mean SBSV value greater than 50L/m3). At this stage, we believe the shuffle method provides a more accurate picture of the state of deposited fine sediment in the District because we have not used the Quorer method for long enough to establish an appropriate threshold. We have used 50L/m3 of streambed as an interim threshold, but more data are required to confirm the appropriateness of this value.

Didymo

Didymosphenia geminata (didymo) is a freshwater diatom (a type of alga) that forms thick (up to 20 cm), brown, unsightly mats on the bottom of streams, rivers and lake edges. A single cell of didymo is microscopic; therefore it takes a large number of cells to be present in the water before it is visible to the human eye, so the risk of spread will not always be obvious. Didymo has often been confused with New Zealand native algae. One difference between didymo and native species is the way it feels. Native algae feel slimy and will break apart in your fingers, whereas didymo is strong and feels like wet cotton wool.

Didymo in the upper Buller River near SH73 (Sept 2005)

Until recently, didymo was described as a relatively rare diatom that was only found in cold-water rivers in the northern parts of Europe, North America and Asia. Didymo blooms have been apparent in British and Scandinavian rivers for many years. However, for some reason didymo has expanded its range into new geographic areas and habitat types over the last decade. The sudden appearance of didymo blooms has been noted throughout Canada, U.S.A. and Iceland. It was first reported in New Zealand in the Lower Waiau and Mararoa Rivers in Southland in 2004 and first sighted in the Tasman District in the Buller River, just downstream of Lake Rotoiti, in September 2005. Since then it has spread down to the sea and is now found in several waterways in the Buller, Motueka/Riwaka and Takaka catchments (Figure 6). It is particularly prolific in rivers sourced from lakes, such as the Gowan River and upper part of the Buller. The coverage and thickness of growth in the Buller drops off progressively downstream of major tributaries, particularly the Howard and Matakitaki which carry a relatively high fine sediment load which helps to scour it out during floods. From an almost complete cover of thick mats within a few kilometres of the lake outlets, it becomes harder to spot downstream of the Howard River and it is hardly discernible downstream of the Matakitaki. While it appears that didymo coverage and thickness remains relatively consistent in the Buller catchment, large fluctuations occur in the Takaka River upstream of Harwoods. This may be due to the operation of the Cobb Hydro Electric Power Scheme. Within the Motueka River, didymo never seems to cover more than 5-10% of the bed at most. This could be due to water chemistry with harder (calcium-rich) water being introduced from the western tributaries that drain karst landscapes.

Once established, mats form flowing streamers that turn white at the ends and look similar to tissue paper. Thick growths can adversely affect freshwater fish, plant and invertebrate species by reducing the amount of suitable habitat. Didymo could also affect pH and dissolved oxygen concentrations (lower) to a degree that could be harmful for trout (Bickel & Closs 2008), although there is no clear evidence quantifying the effects on fish. Didymo is not considered a significant human health risk, but water extractors do have to go to more expense to screen pump intakes to avoid blockages.

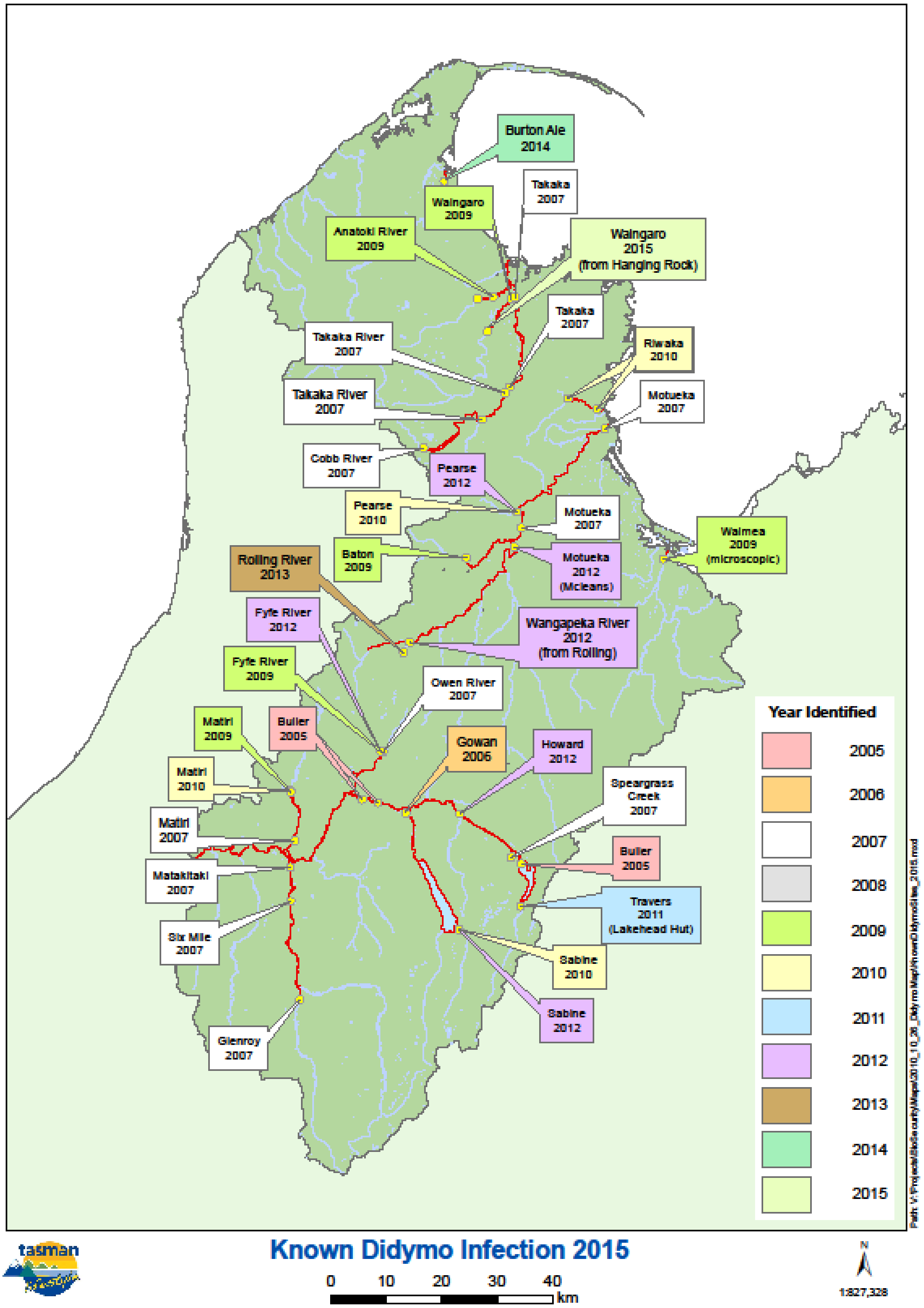


Figure 6. Known rivers infected with didymo (as at 2015)

Toxic Algae (Cyanobacteria)

Cyanobacteria in the genus *Phormidium* are the main toxin-producing algae that grow on river beds in New Zealand. The toxins produced by cyanobacteria (such as anatoxins) are some of the most toxic in the natural world. The toxins produced are diverse and can cause liver, nerve and skin damage, as well as nausea, diarrhoea, and gastroenteritis. In New Zealand, cyanobacteria have been implicated in numerous dog deaths. Fortunately, there have been very few reported health effects of *Phormidium* on humans in New Zealand, most likely because people rarely consume cyanobacterial mats directly from rivers. There remains, however, a reasonable risk for toddlers playing beside rivers due to their habit of exploring their environment by putting things in their mouth. National guidelines have been developed for monitoring and management of the risk caused by this organism (Ministry for the Environment and Ministry of Health 2009).

Phormidium is usually black or dark green/dark brown, is very soft and jelly-like to touch and has a characteristic earthy smell. It is particularly prevalent on rocks and boulders (e.g. weirs on the Wai-iti River) and in riffles. In Tasman this **toxic algae has been implicated in the deaths of five dogs from 2010-2015,** most of these being puppies (Table 5). No dog deaths were reported in the 2013-14 summer season partly due to shorter stable flow periods.

Table 5. Dog deaths in Tasman suspected to be due to *Phormidium*.

.	2010	Nov 2012-Feb 2013	Dec 2014
Dog Deaths	1	3	1
River	Takaka 5km u-s Paynes Fd	Waimea (2) Wai-iti (1)	Wai-iti

Phormidium autumnale is native to Tasman District and is even found in many of our pristine rivers in the conservation estate. *Phormidium* is known to proliferate during periods of stable flow (about three weeks without flushing flows) during October-April. During the rest of the year it is found at very low coverage and its growth is thought to be light limited. So far in Tasman District we have not recorded coverage above 20% (the current guideline limit) outside of the period of November to March. Its growth is greater in waterways with slightly elevated soluble nitrogen (mostly nitrate) and very low soluble phosphorus. It appears to have a competitive advantage over other algae in these conditions. In addition, elevated fine sediment levels in the waterway greatly promote its growth.

There are relatively few sections of river in New Zealand that regularly have *Phormidium* coverage over guidelines. Sections where coverage is high (regularly over 20% and sometimes up to 70-80%) include: Waimea, Wai-iti, Lower Motupiko, and Sherry Rivers. Some other rivers very occasionally get over 10% coverage (Takaka, Motueka and Riwaka Rivers) and most of these were associated with fine sediment discharges from known sources such as willow removal upstream on the Riwaka and earthworks in the Dove affecting the Motueka at Woodstock. Consistently very low coverage (<2% of wetted bed) has been found to date in all other rivers in the district. This includes the Roding, Lee and Wairoa Rivers that are monitored weekly during each bathing season.

Monitoring *Phormidium* in Tasman

Weekly sampling for *Phormidium* from November-March has occurred each year since 2012 at the following sites: Waimea River at SH60 (in addition to monthly sampling; total sample occasions 36x/year), Wai-iti at Waimea West Rd, Lee Reserve, Roding at Twin Bridges, Takaka at Paynes Ford. Motueka River is sampled on a less frequent basis because *Phormidium* coverage has only rarely been found to be an issue on this river. An exception to this occurred in spring-summer 2013-14 when the coverage became elevated downstream of the Dove River after a period of fine sediment discharges from the Dove River.

Council has been consistently collecting data on *Phormidium* coverage in rivers on a quarterly basis at over 60 sites as part of the River Water Quality Monitoring Programme since 2010 (prior to that it was only noted if coverage was greater than 20%).

In addition to coverage, the presence of detached toxic algae rafts of algae floating on the surface is also noted. The presence of these rafts is a key factor in considering whether to put up warning signs. Estimating the coverage of *Phormidium* in runs can be difficult when there is a mix of algal types present.

Samples for toxin analysis have been collected three times from the Waimea River and once from each of the Motueka River and Wai-iti Rivers (Table 6). This low level of sampling is due to very high sample analysis costs. A more extensive investigation into toxin variability was conducted in 2009 on the Waimea River at SH60 (Wood et al. 2010). Of the 15 samples of *Phormidium* mats collected at this site, **40% contained toxins in moderate concentrations.** These concentrations, however, were often greater than the Hutt River in the Wellington region where there have been many dog deaths.

Table 6. Concentrations of cyanotoxins from Phormidium mats in waterways in Tasman. * Wood et al 2010. # Wood unpub. ^Tasman District Council, results as wet weight (this explains why the values are so much lower than from the other sampling events listed in this table). Note: The reliability of toxicity data for HomoAnatoxin-a, dihydroAnatoxin-a and dihydroHomoAnatoxin-a is poor – the latter two are assumed to be 10 times less toxic. i.p. = intra-perotoneal.

	Site	Anatoxin-a (mg/kg)	Homo-anatoxin a (mg/kg)	Dihydro-anatoxin-a (mg/kg)	Dihydro-homo-anatoxin-a (mg/kg)	Comment
Jan-Mar 2009	Waimea at SH60*	0	0.23 av 0.47 max	0	0	14 discrete samples. ~40% of samples toxin producing
Feb 2013	Waimea at SH60#	Total anatoxin: 0.08 av				Discrete samples
	Motueka at Woodstock#	Total anatoxin: 0				Discrete samples
Jan 2014	Waimea at SH60^	0.0065^	0.032^	NA	NA	One composite sample. Non-detects for cylindrospermosin and deoxy-cylindrospermosin
Jan 2015	Wai-iti at Waimea West Rd#	0.3	3.7	68	59.7	10 samples pooled before analysis
Toxic concentration (i.p.LD_{50} mouse mg/kg)		0.25	0.32			

Managing the Risk from Toxic Algae

Toxic algal coverage information is posted within three days of sampling on the following page: http://tasman.govt.nz/environment/water/rivers/river-water-quality/monitoring-toxic-algae/

Warning signs are also placed at the main access points along the lower Wai-iti and Waimea Rivers during periods when *Phormidium* coverage is above guidelines. In June 2013 all dog owners in the district were sent a brochure explaining the dangers of contact with Phormidium which included photos of the algae.

Dissolved oxygen and water temperature

Continuous measurements of dissolved oxygen and water temperature were taken throughout the day, and usually over several days in summer, generally at 'high-risk' sites. The sites were predominantly located in smaller pastoral streams (stream order 3 or less). The results from deployments from summer 2002 to summer 2015 are reported together here.

Based on the sites sampled in the Tasman District, 47% (22/47) of small, pastoral streams had a 1-day minimum dissolved oxygen concentration less than 4mg/L (refer Table 28 for the list of sites). These low concentrations cause stress, and even death, to fish and other aquatic organisms. A concentration of less than 4mg/L is below the National Bottom Line for dissolved oxygen below point sources (NPSFM 2014).

Most of the sites where dissolved oxygen was found to be a significant issue, aquatic plants were dominant. While plants release oxygen into the water column during the day, at night they respire using oxygen and releasing carbon dioxide.

Tasman District has a significant issue with dissolved oxygen when compared to the rest of the country. The proportion of the 368 continuous-measured sites across the country that did not meet the proposed national bottom line dissolved oxygen daily minimum of 5g/m^3 was 14%, whereas it was over 30% for Tasman sites (Depree et al, 2015) (Figure 7). However, because this monitoring targeted sites with higher risk of low summertime dissolved oxygen, this proportion will be lower over all river classes.

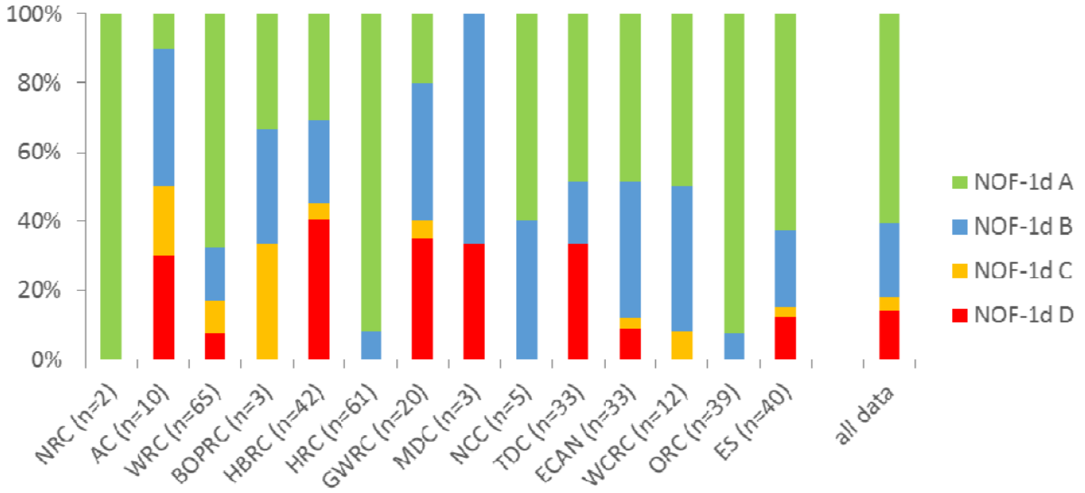


Figure 7 Distribution of NOF-1d dissolved oxygen bands by region. The number of sites in each region is given in parentheses on the x-axis. NRC = Northland Regional Council, AC = Auckland, WRC = Waikato, BOPRC = Bay of Plenty, HBRC = Hawke Bay, HRC = Horizons (Manawhatu-Whanganui), GWRC = Greater Wellington, MDC = Marlborough, NCC = Nelson, ECan = Canterbury, WCRC = West Coast, ORC = Otago, ES = Southland.

Sites with degraded dissolved oxygen quality were associated with 'warm-dry', 'warm-wet' and to a lesser extent 'cold-dry' climate classes; low elevation and pasture and urban dominated land cover classes.

For **water temperature**, 50% (22/44) of sites on smaller streams had the highest midpoint of daily mean and daily maximum temperature (also known as the Cox-Rutherford index) in attribute states C or D (>20°C). At these high temperatures, the growth and reproduction of fish and other aquatic organisms are adversely affected.

Values for the highest midpoint of daily mean and daily maximum temperature were greater than 24°C (attribute state D) at three sites (Powell at 40m u-s Motupipi Rv and Reservoir Ck at 20m d-s Salisbury Rd in February 2006 and Tasman at u-s Jesters Hse in February 2009). This is above the preferred temperature range for many native fish (Olsen et al. 2012). Results for each site are shown in Table 29.

Ecosystem metabolism

Recent advances in indicator development have highlighted the value of including functional measures for documenting the health of freshwater ecosystems (Young *et al.* 2008; Young & Collier 2009). Functional indicators measure the rates of ecosystem processes (i.e. what is happening there) and complement traditional measures of ecosystem structure (i.e. what is there), such as water quality analysis, periphyton cover and invertebrate community composition. Research has shown that **ecosystem metabolism** - the combination of algal productivity (photosynthesis) and ecosystem respiration **– is a useful functional indicator of river ecosystem health**.

Ecosystem metabolism is a measure of the main factors controlling dissolved oxygen dynamics in rivers and indicates how much organic carbon is produced and consumed in river systems. Concentrations of DO in the water are critical components affecting the life supporting capacity of a river system. DO concentrations are affected by three key processes:

1. Oxygen production associated with photosynthesis of algae and aquatic plants, which raises the oxygen concentrations within the water
2. Oxygen uptake associated with respiration of all river life including fish, invertebrates, algae, aquatic plants and microbes, which lowers the oxygen concentrations in the water, and
3. Oxygen diffusion through the water surface, which can either raise or lower oxygen concentrations.

Sites with very high rates of ecosystem metabolism are likely to have lower life supporting capacity than sites that are within the normal range. Sites with high rates of **ecosystem respiration (ER)** are normally characterised by high biomasses of algae and other aquatic plants, and/or large inputs of organic matter from point source discharges of sewage/waste water, and/or large diffuse inputs from sources such as agricultural run-off. Such sites will be prone to low minimum dissolved oxygen concentrations, which have the potential to kill fish and other aquatic life. Sites with high rates of **gross primary production (GPP)** will normally be characterised by a river bed covered with a high biomass of periphyton (algae and other slimes growing on the substrate) or other aquatic plants. The highest rates of production will occur in situations where there is plenty of light and nutrients available to support plant growth. Sites with high GPP are likely to experience algal and cyanobacterial blooms that can degrade aesthetic and recreational values, and have potential health impacts for humans and animals.

Ecosystem metabolism can vary seasonally in relation to temperature, river flow and light availability (Uehlinger 2006), and both seasonal variation and flow must be accounted for when establishing and assessing ecosystem health in relation to reference conditions. Based on trends observed elsewhere, we would expect metabolic rates to be higher in the warmer months and lower immediately after high flows, due to scouring and/or flushing of organic matter from the system (Uehlinger *et al.* 2003). However, ecosystem metabolism can also vary on a smaller temporal scale, i.e. from day to day, due to weather conditions. For example, clouds reduce the intensity of light reaching the river, which can result in lower gross primary productivity (Young & Huryn 1996).

Rates of ecosystem metabolism can be measured by monitoring the **daily changes in oxygen concentration** at a site. DO concentrations rise during the daytime, when sunlight facilitates photosynthesis, and then decline during the night, when only respiration is occurring. The size of the daily fluctuations depends on the amount of photosynthesis and respiration occurring within the river and also the flux of oxygen through the river surface. More oxygen diffuses through the surface of fast flowing, shallow, turbulent streams than the surface of slow flowing, deep rivers.

TDC have monitored dissolved oxygen concentrations semi-continuously (15 minute intervals for a period of several days) at several sites in 2002, 2006, 2009, 2010, 2013, 2014, 2015, (see Appendix 4). These data enable improved understanding of temporal variability in metabolism rates that are likely to be encountered in different river systems and the potential effects of environmental stressors on this variability. This information will be important for improving guidelines for interpreting what metabolism measurements mean in terms of ecosystem health.

Changes in the concentration of dissolved oxygen are the result of oxygen production from photosynthesising plants, oxygen uptake via respiration from all components of the ecosystem, and oxygen exchange through the water surface as described by the following equation:

$$\frac{dO}{dt} = P - R + kD$$

where dO/dt is the rate of change of oxygen concentration, P is the rate of gross primary production, R is the rate of ecosystem respiration, k is the reaeration coefficient and D is the oxygen deficit (or difference between the observed oxygen concentration and the concentration at 100% saturation). The reaeration coefficient is a measure of the potential for oxygen to diffuse through the surface of the waterbody. For example, a shallow, fast flowing, turbulent stream will have a high reaeration coefficient, while a deep, slow flowing river will have a low reaeration coefficient.

Estimates of daily ecosystem respiration (ER), gross primary production (GPP) and the reaeration coefficient (k) were initially calculated over 3-4 days, where possible, using the RiverMetabolismEstimator spreadsheet model (version 1.2) developed by Young & Knight (2005). Any random noise in the DO data sets was reduced before analysis using a moving average smooth with an interval of five measurements (i.e. all sites except Borck, Onahau, Mackay Ck @ 50 m u-s Kaituna Rd and Rosedale Stm).

Average ER rates ranged from 1.1 gO2/m2/day at Little Sydney at Factory Rd to 54.7 gO2/m2/day at Te Kakau at Feary (

Table 7). Twelve of the 35 sites where ecosystem metabolism analysis was possible had ER rates > 10 gO2/m2/day and were indicative of poor ecosystem health (e.g. Stanley Brk , Borck, Moutere River, Orinoco, Onahau), seven sites had rates >6 but <10 gO2/m2/day and were indicative of satisfactory ecosystem health (e.g. Horton Vly Stm, Rosedale Stm, Moutere River) and 16 had rates <6 gO2/m2/day and were indicative of good ecosystem health (e.g. Dove Rv, Tasman Vly Stm, Seaton Vly Stm @ Anderson, Little Sydney).

Average GPP rates ranged from 0.1 gO2/m2/day (Granity) to 20.5 gO2/m2/day (Motupipi River at 20 m u-s Watercress). At seven sites, average rates of GPP were >7 gO2/m2/day and indicative of poor ecosystem health (e.g. Borck Stm, Motupipi River). Seven sites had GPP rates above 4, but below 7 gO2/m2/day, indicating satisfactory ecosystem health (e.g. Moutere River, Powell River at Reilly's Bridge). The rest of the sites had GPP rates <4 gO2/m2/day and were indicative of good ecosystem health (e.g. McConnell, Powell Rv at Glenview Road, Rainy River (both sides), Figure 10).

ER and GPP rates at Borck and Onahau were indicative of poor ecosystem health, concurring with minimum DO values below 80% saturation. Similarly, sites with ER and GPP rates indicative of good ecosystem health, also had minimum DO saturation values above the 80% saturation guideline (i.e. Riwaka at North Branch Source, Seaton Vly Stream, Reservoir Ck at Marlborough). However, Dove Ck and Little Sydney at d-s SH60 had minimum DO saturation values below the recommended ecosystem health guidelines, but had ER and GPP indicative of good ecosystem health. Ecosystem metabolism rates could not be calculated for some of the sites. Moreover, as previously mentioned, dissolved oxygen data was influenced by sensor drift, reducing suitable data for ecosystem metabolism analysis to within the first 24 hours of sonde deployment.

Table 7. Average metabolism records from 41 sites in the Tasman District. Ecosystem Resipiration (ER) < 6 gO$_2$/m^2/day = healthy, > 10 gO$_2$/m^2/day = poor health and above 6, but below 10 gO$_2$/m^2/day = satisfactory. Gross Primary Production (GPP) < 4 gO$_2$/m^2/day = healthy, > 7 gO$_2$/m^2/day = poor health and above 4, but below 7 gO$_2$/m^2/day = satisfactory. Sites marked with an * indicate that the data was unsuitable for analysis.

Site	ID	Sampling period	k	Average Depth	ER (gO$_2$/m^2/day)	GPP (gO$_2$/m^2/day)	R^2
Borck	1	10 - 13.02.09	16.7	0.30	22.5	8.3	0.7
Dove Rv	2	26.02.10 - 01.03.10	3.2	0.25	5.8	1.4	0.8
Granity	3	13.03.02	7.9	0.3	0.3	0.1	0.7
Hinetai	4	20.02.02	11.7	0.5	7.6	9.8	0.6
Horton Vly Stm	5	06 - 08.02.09	3.0	0.30	8.1	2.1	0.6
Jimmy-Lee Ck	6	*					
Little Sydney @ d-s SH60	7	10 - 13.02.09	14.4	0.40	5.1	1.4	0.8
Little Sydney @ Factory Rd	8	10 - 13.02.09	5.1	0.30	1.1	0.3	0.6
Little Sydney @ u-s Johnson Barrier	9	*					
Mackay Ck @ 50 m u-s Kaituna Rv	10	11 - 13.02.10	8.8	0.35	11.1	1.6	0.8
Mackay Ck @ Coll-Bainham Rd	11	*					
McConnon	12	26.01.06 - 01.02.06	6.5	0.1	2.6	0.5	0.8
Motueka @ Woodmans Bend	13	27.02.02	10.0	0.6	4.0	5.8	0.7
Motueka @ Woodstock	14	13.03.02	22.2	0.4	4.9	6.9	1.0
Motupiko @ Quinneys Bush	15	25.02.02	31.8	0.2	5.5	2.7	0.8
Motupipi @ 20 m u-s Watercress	16	26.01.06 - 03.02.06	14.0	0.2	34.2	20.5	0.6
Motupipi @ Reilly's Bridge	17	26.01.06 - 2.02.06	11.3	0.2	22.7	13.8	0.9
Moutere Rv @ Edwards Rd	18	17 - 20.02.10	11.8	0.30	8.5	5.0	0.8

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Site	ID	Sampling period	k	Average Depth	ER (gO_2/m^2/day)	GPP (gO_2/m^2/day)	R^2
Moutere Rv @ Kelling Rd	19	16 - 18.02.10	20.4	0.40	19.6	5.6	0.8
Old House Stm @ Central Rd	20	*					
Old Moutere Rv	21	*					
Onahau Rv	22	10.02. - 13.02.10	19.3	0.40	13.2	7.7	0.5
Orinoco	23	15 - 17.02.09	9.5	0.40	15.8	2.8	0.8
Powell @ Glenview Rd	24	05 - 06.02.06	14.4	0.2	4.8	0.4	0.6
Powell @ Reilly's Bridge	25	26 - 28.01.06	3.3	0.4	6.9	4.6	0.6
Rainy River Lower	26	06.03.02	38.7	0.2	8.9	3.8	0.7
Rainy River Upper	27	06.03.02	30.0	0.1	6.5	2.3	0.9
Reservoir Ck @ 20 m d-s Salisb Rd	28	07 - 08.02.09	14.3	0.30	10.6	2.2	0.8
Reservoir Ck @ Marlborough Cr	29	06 - 08.02.09	15.4	0.20	1.9	0.2	0.7
Riwaka @ Hickmotts	30	15 - 17.02.09	20.9	0.50	2.4	19.7	1.0
Riwaka @ Northbranch Source	31	15 - 17.02.09	12.3	0.40	3.5	2.0	0.8
Rolling	32	05.03.02	17.7	0.4	2.7	1.5	0.6
Rosedale Stm @ Old House Rd	33	16 - 20.02.10	6.9	0.30	8.7	2.9	0.7
Seaton Valley Stm @ Andersons	34	10 - 14.02.09	8.4	0.20	4.6	0.5	0.4
Seaton Vly @ Stafford Drive	35	*		0.40			
Stanley Brk @ Barkers	36	15 - 17.02.09	21.2	0.40	33.9	3.9	0.7
Tasman Vly Stm @ u-s Jesters Hse	37	07 - 09.02.09	2.3	0.25	4.6	1.1	0.3
Te Kaukau @ Feary	38	04 - 06.02.06	15.7	0.5	54.7	14.5	0.8
Waiwhero @ Cemetery	39	15 - 17.02.09	3.9	0.35	11.4	3.2	0.9
Wangapeka @ 5km u-s Dart	40	05.03.02	21.6	0.5	11.3	7.0	0.6
Wangapeka @ Walters	41	20.02.02	19.0	0.9	4.8	4.8	0.8

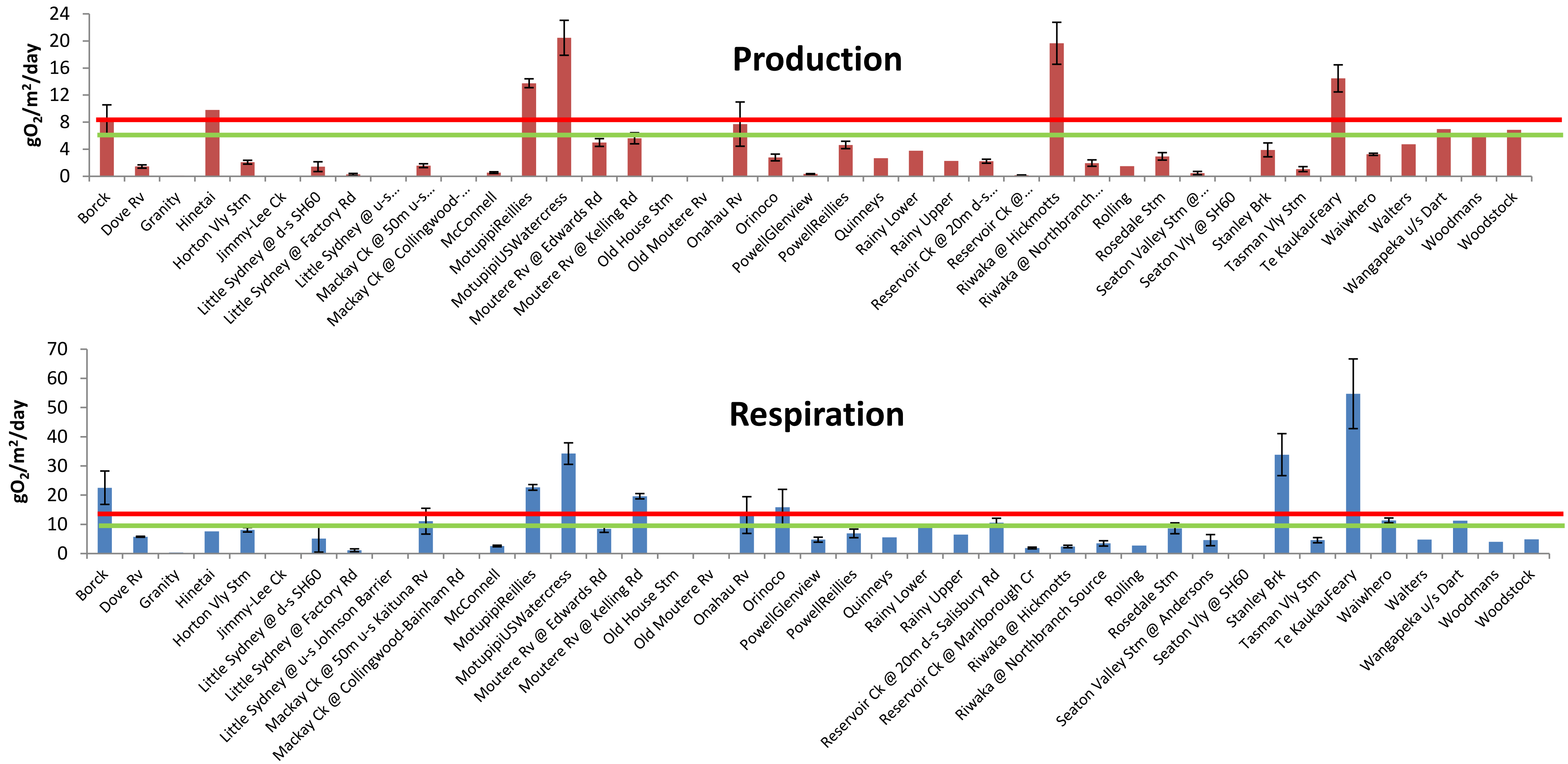


Figure 8. **Average production and respiration for 41 sites in the TDC region. Gaps in the graph indicate a lack of data or data unsuitable for analysis. Standard error bars were calculated using the observed variation within the sampling period for each site.**

Water Clarity

What's the clearest waterway in the district?

Of the rivers monitored in Tasman District the Te Waikoropupū River is 'clearly' ahead, followed by **Waingaro River** (at Hanging Rock), **Upper Motueka** (Gorge), **Upper Matakitaki** (upstream Nardoo Creek) and **Riwaka** (North Branch source). Median/maximum readings for these sites are: 22 m/41.5 m. 12.1 m/30.5 m, 11.1 m/23 m, 10.3 m/24.5 m, and 11.6 m/18.7 m, respectively. However, water clarity at most sites across the district ranged between 2 and 8 m. For comparison, the maximum recorded water clarity in New Zealand was the spring-fed Blue Lake/ Rotomairewhenua in Nelson Lakes National Park (over 80 m) followed by the lowland spring, Te Waikoropupū Springs in Golden Bay (62 m) (Davies-Colley & Smith 1995). The only place in the world where water with higher clarity has been recorded is in lakes in Antarctica that are permanently covered by ice.

Te Waikoropupū Springs is one of the world's largest cold-water springs with a mean flow of 13.2 m^3/sec with a stable mean temperature of 11.7 °C. The spring arises from one of the largest karst aquifers in New Zealand in terms of volume of water storage. The marble aquifer extends for 180 km^2 and is well over 500 m thick. Water takes many years to travel from the aquifer source (the upper Takaka and Waingaro rivers) before it emerges again at the Te Waikoropupū Springs.

There are a large number of karst springs in the Tasman District, particularly in Mt Arthur marble country, that have good water clarity. The alluvial spring sites such as Motupipi River and Murchison Creek would also be expected to have high water quality, but activities in the catchments of these streams are reducing water clarity. The poorest water clarity was found in small farmland streams, particularly those in the Moutere hills, due to the type of clay soils. Tasman's three National Water Quality Network sites are all in the top ten in the country with the Motueka at Gorge site being the best of all and the Buller at Longford and Motueka at Woodstock being number six and seven (respectively) on the league table.

The clearest rivers in the district: Waingaro (left) and Upper Matakitaki (right).

Deposited fine sediment in the Motueka Catchment

Fine sediments that settle out on the bed of waterways affects the life of the whole stream ecosystem. If the spaces between the stones in the bed (interstices) get filled, invertebrate communities get displaced and the whole stream ecosystem suffers. Of the twenty-five sites sampled throughout the Motueka catchment for coverage of fine sediment on the bed (part of the Motueka Integrated Catchment Management programme), around 75% had less than 5% fine sediment cover (particle size <2 mm) and only 7% had greater than 20% fines (Basher 2007). Most of the latter sites were within catchments dominated by Separation Point Granite geology.

A 50-year storm event in Easter 2005 raised sediment yields in the upper Motueka and Motupiko catchments by 10 times and by 2-3 times in the mainstem of the Motueka River at the coast. This effect has slowly reduced over the 4 years since the storm (Figure 9).

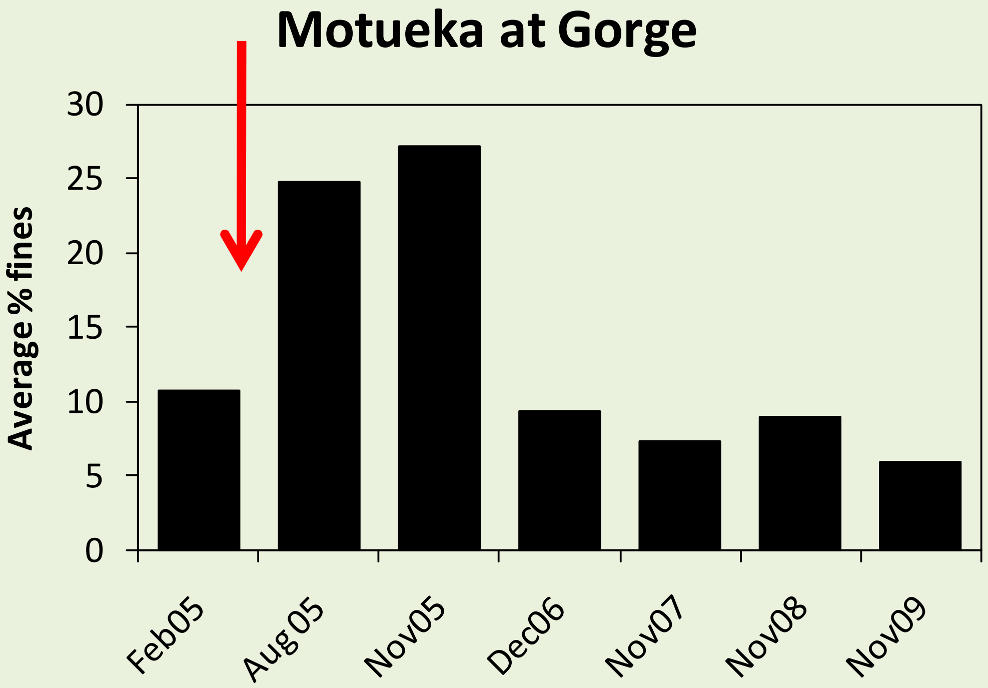


Figure 9. Changes in fine sediment cover at the Motueka at Gorge site before and after the 50-year March 2005 flood (indicated by the red arrow). Data provided by Les Basher (Landcare Research).

Iwi assessment of river health

There is an increasingly recognised need for information about **how to assess the state of the environment from a cultural perspective**, given the strong relationship of Māori with their environment. Iwi/hapū groups from the Motueka Catchment have adapted a **cultural health index** and applied it at sites throughout the Motueka and Riwaka catchments. This index scores a variety of attributes from 1 (poor) to 5 (excellent), with the overall cultural stream health measure calculated as the average of these scores. These attributes include:

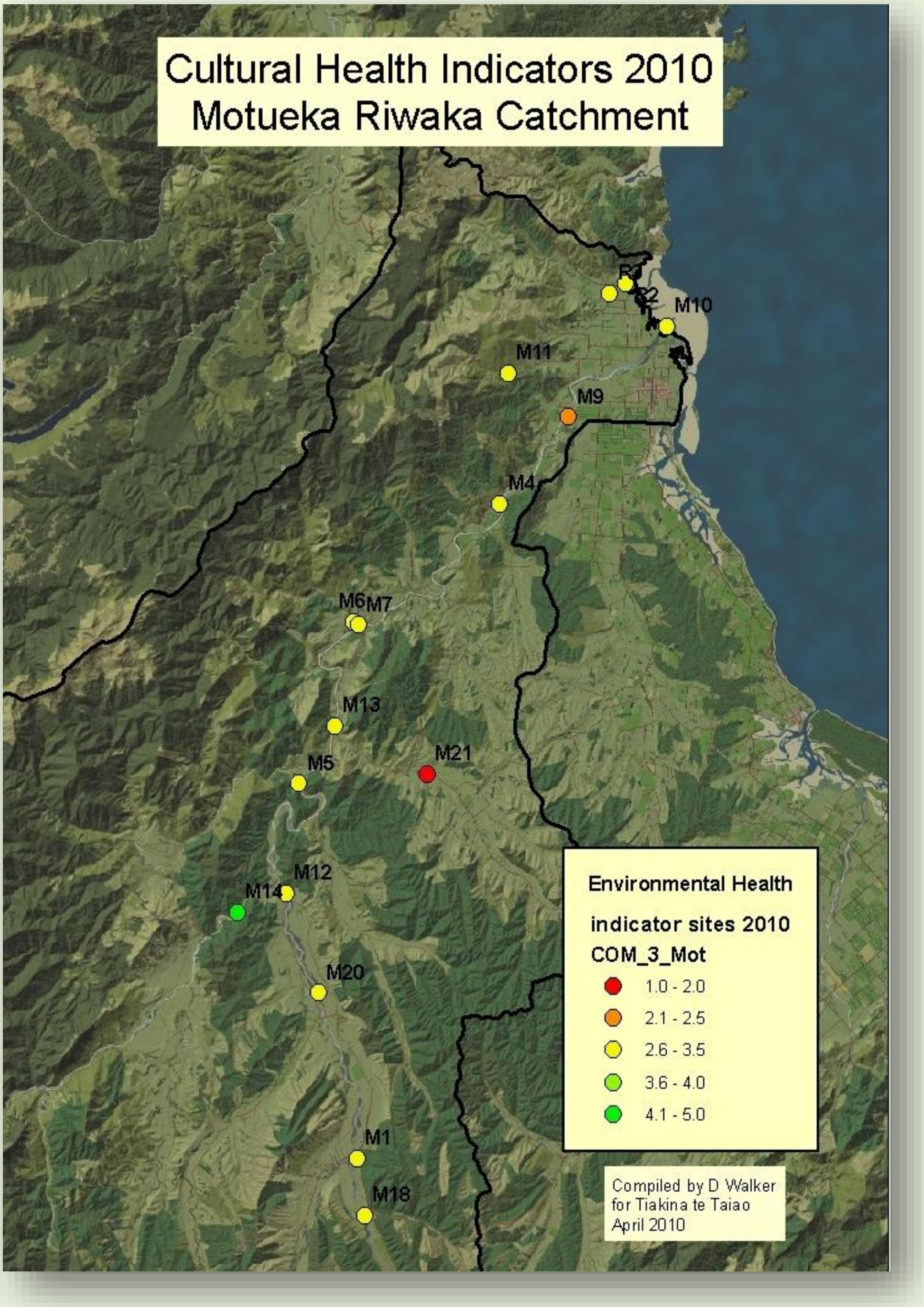
> Riverbank condition, riverbed composition, water clarity, water flow, water quality, channel shape, riparian and catchment vegetation, river modification/use, use of river margins, smell, mahinga kai (food) status, and traditional status of a site.

Research on links between scientific and cultural indicators showed there was a **strong correlation** between the cultural stream health measure and the percentage of the catchment above each site in native forest (r=0.75), but weaker relationships with a macroinvertebrate community index (SQMCI; r=0.66), and the concentration of faecal indicator bacteria (r=-0.49) (Harmsworth *et al.* 2011).

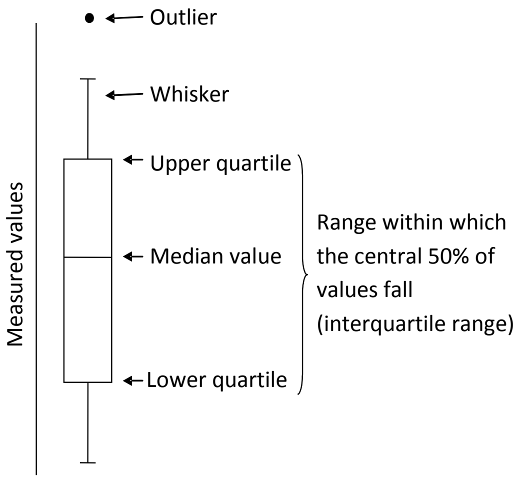
These relationships confirm that both science and cultural indicators are successfully capturing aspects of river and stream health and together **provide a more complete picture of river health**. The mahinga kai component incorporates a lot of historical knowledge of resources in the area and demonstrates the historical connections with the river.

Members of the cultural health monitoring team at the Riwaka River.

The Wangapeka River received the highest score of all the sites sampled in the Motueka catchment, due in part to clear water, riparian tawhai/beech forest, and a high percentage of native forest in the catchment upstream. The Motueka main stem achieved low-moderate scores, due to lack of native or food-bearing trees along the banks, gravel takes, and only moderate percentages (~35%) of native bush in the catchment. The Dove River scored very low because of large water takes (>50% of the flow during low flow periods), limited native riparian vegetation, and a low percentage of native forest in the catchment.



Interpretation of Box Plots



Box and whisker plots illustrate how data are distributed around the central, or median, value. The ‘box’ represents the range of the central 50% of values around the median, which is shown as the line through the box.

Values that are further from the median are illustrated as whiskers or outliers, depending on how far the value is from the median and on the size of the interquartile range. The upper whisker extends to the highest value within 1.5x the interquartile range. Points beyond the end of the whiskers are outliers (plotted as points).

Water Quality in Relation to the River Environment Classification groupings

Water quality in some types of river show a distinct character. For example, pristine streams draining Moutere gravel geology are likely to have lower clarity than spring or mountain-fed rivers, because of the naturally higher load of clays associated with the former geology type. This means that we need to use ‘stream class or type’ as a context for reporting water quality. The **New Zealand River Environment Classification (REC) system** provides this context, to compare like with like and so contrast the differences between the classes (Snelder *et al.* 2004a). The REC groups rivers, or parts of rivers, at six hierarchical levels according to their **climate, source of flow, geology, land cover, network position, and valley landform**. This system allows sections of rivers that are similar, with respect to these factors, to be grouped together for management purposes. The first four factors relate to the characteristics of the catchment upstream, while network position and valley landform are more specifically related to the site of interest. Within each factor there are a series of categories that are used to describe reaches of rivers throughout the country (Table 8).

For data from 2000-2010, median values for each water quality parameter, from each site, were calculated and then combined together to show the range of water quality found within each REC class. There is a considerable amount of inter-correlation among the different REC classes. For example, low elevation land is much more likely to have been developed into pasture than high elevation land. Therefore, significant differences among sites with different source of flow classes are likely to be due to differences in land cover, rather than a direct effect of source of flow. Given the problems of inter-correlation among REC classes, only comparisons among three REC classes (i.e. source of flow, land cover and network position (or stream order)) are presented here. Statistical comparisons among REC classes for each water quality parameter were made using non-parametric Kruskal-Wallis tests, which are not influenced by non-normal data distributions.

How does 'source of flow' influence our streams?

There were **significant differences** among streams from different source of flow classes. Two spring-fed streams, Borck and Motupipi, had the highest nutrient concentrations and we know that aquifers upstream of these sites have elevated nutrient concentrations. Spring-fed streams also had lower DO saturation, potentially due to the influence of low DO groundwater. Sites draining low elevation land had higher concentrations of NO_3-N, NH_4-N, DRP, *E. coli*, and suspended sediments, and lower DO saturation and clarity, than sites draining hill country or mountains (Figure 10). As mentioned above, these differences are probably due to variation in land cover, rather than a direct effect of source of flow.

How does land use influence our streams?

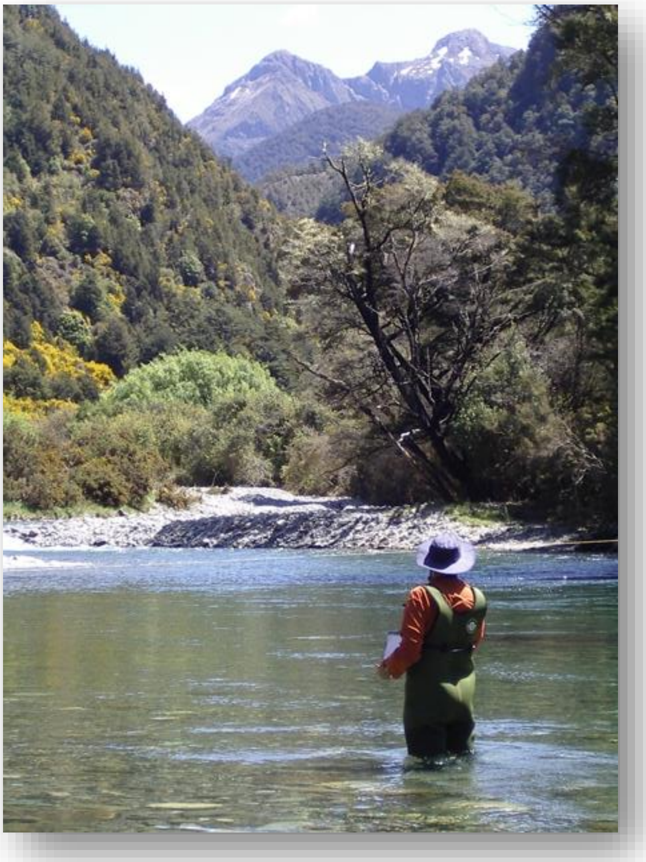
There were also **significant differences** found for all water quality parameters among the land cover classes, except for conductivity. Concentrations of nutrients, *E. coli,* and suspended sediment at sites classified as having pastoral land cover were significantly higher than at sites with indigenous forest or exotic forest land cover. Accordingly, water clarity was lower at pastoral sites than in forested sites. Watercress Creek was the only site with urban catchment land use and had similar water quality characteristics to pastoral streams. However, it had lower oxygen concentrations than sites in the other classes, probably due to its spring-fed nature (Figure 11). The effects of land use on water quality are widely recognised and the results of this analysis are consistent with other nationwide studies of water quality patterns (Larned *et al.* 2004; Ballantine *et al.* 2010).

How does stream size influence our streams?

All water quality parameters tested **varied significantly** among REC stream order classes. Oxygen saturation was lowest in first order streams, while nutrient concentrations, suspended solids and *E. coli* tended to be highest in the smaller streams (Figure 12). This result is somewhat contrary to the perception that small headwater streams are generally healthier than larger lowland rivers. However, this result is related to the high proportion of small streams, in the sampling programme, which drain areas that are heavily developed (*e.g.* Reservoir Ck, Watercress Ck). The large rivers in the Tasman District generally have relatively good water quality, probably due to the fact that much of their flow originates from areas of indigenous forest and, thus, run-off from developed lowland tributaries is diluted.

Table 8. Summary of factors and categories used in the REC classification (Snelder *et al.* 2004a).

Factor	Categories	Code	Criteria
Climate			Mean annual temperature:
	Warm extremely	WX	warm ≥12 °C
	wet	WW	Cool ≤12 °C
	Warm wet	WD	
	Warm dry		Mean annual effective precipitation:
		CX	Extremely wet ≥1500 mm
	Cool extremely	CW	Wet 500-1500 mm
	wet	CD	Dry ≤ 500 mm
	Cool wet		
	Cool dry		
Source of flow			Rainfall volume:
	Glacial Mountain	GM	% permanent ice: 1.5%
	Mountain	M	Mountain >50% above 1000 m
	Hill	H	Hill 50% between 400 – 1000 m
	Low elevation	L	Low elevation 50% below 400 m
	Lake	Lk	Lake influence index
	Spring	Sp	Others manually assigned
	Regulated	R	
	Wetland	W	
Geology	Alluvium	Al	Spatially dominant geology category, unless:
	Hard sedimentary	HS	soft sedimentary >25%, then classified as soft
	Soft sedimentary	SS	sedimentary
	Volcanic basic	VB	
	Volcanic acidic	VA	
	Plutonic	Pl	
	Miscellaneous	M	
Land cover	Bare	B	Spatially dominant land cover class, unless:
	Native forest	IF	
	Pastoral	P	pasture >25%, then classified as pasture
	Tussock	T	
	Scrub	S	
	Exotic forest	EF	
	Wetland	W	
	Urban	U	urban >15% then classified as urban
Network position	Low order	L	Low = 1 and 2
	Middle order	M	Medium = 3 and 4
	High order	H	High >5
Valley landform			Valley slope:
	High gradient	H	High >0.04
	Medium gradient	M	Medium 0.02 – 0.04
	Low gradient	L	Low <0.02



Wangapeka River downstream of the Rolling River.

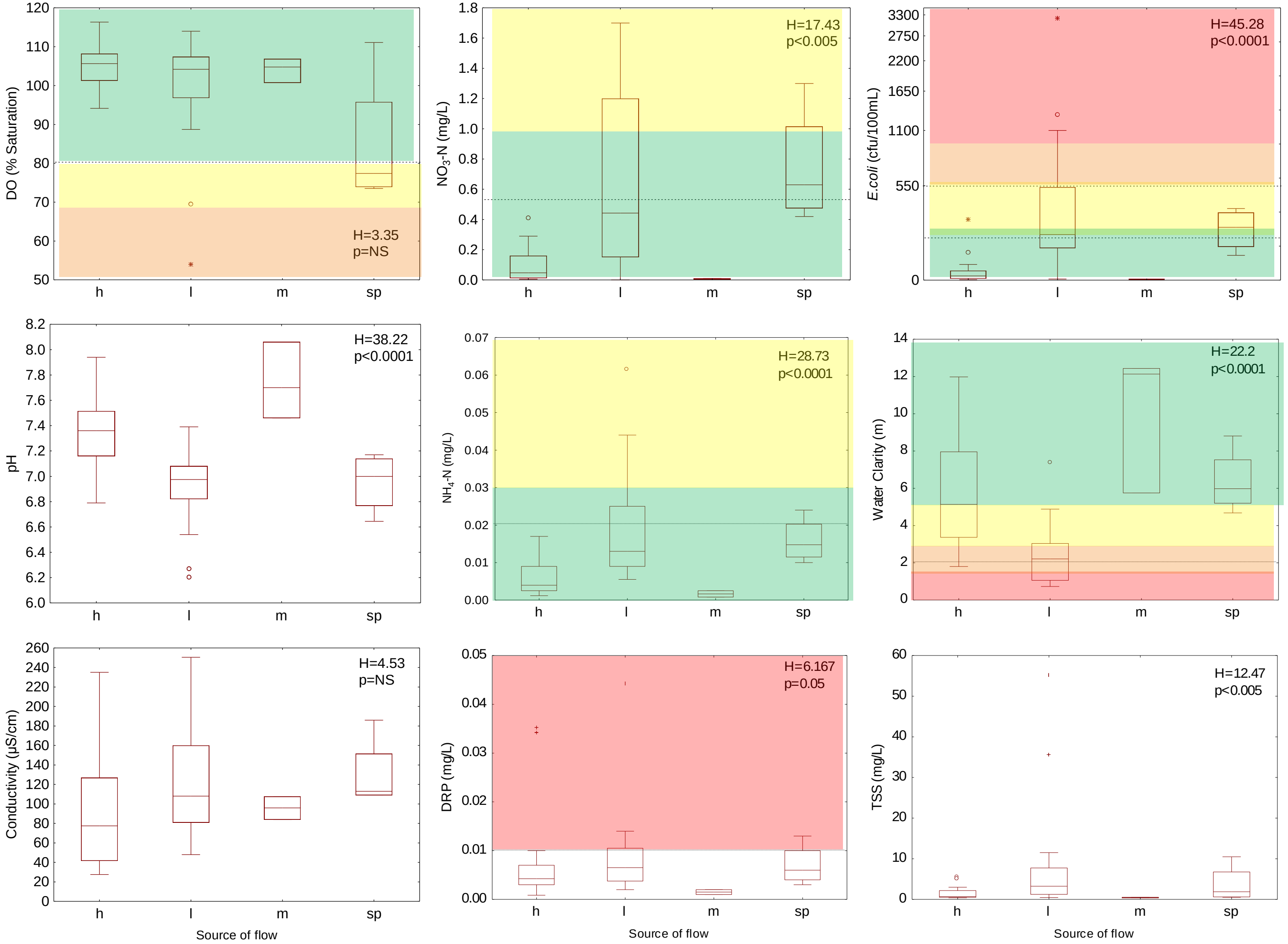


Figure 10. Comparison of median water quality parameters among REC Source of flow classes (2004-2009 only). h = hill country, l = low elevation, m = mountain, sp = spring-fed. H-statistics and p-values from the Kruskal-Wallis tests are shown for each water quality parameter. Water quality guidelines are shown with dotted lines where appropriate. Colour shading indicates values for 'D band' below the bottom line (red), 'C band' fair (orange), 'B band' good (yellow) and very good (green) water quality. Note: *E. coli* is on a log scale.

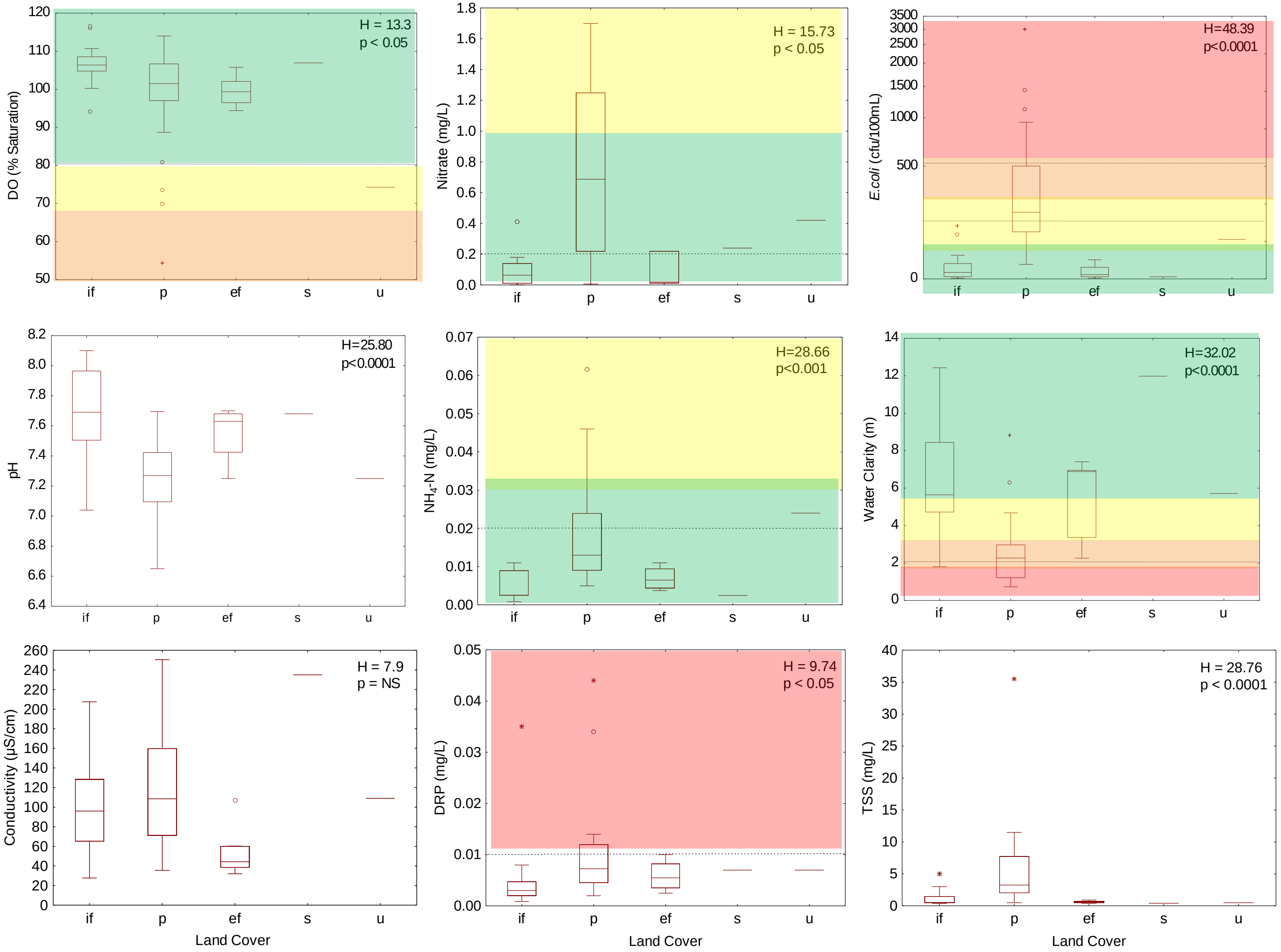


Figure 11. Comparison of median water quality parameters among REC Land cover classes (2004-2009 only). if = indigenous forest, p = pasture, ef = exotic forest, s = scrub, u = urban. H-statistics and p-values from the Kruskal-Wallis tests are shown for each water quality parameter. Water quality guidelines are shown with dotted lines where appropriate. Colour shading indicates values for poor (red), reasonable (orange) and good (green) water quality. Note: *E. coli* is on a log scale.

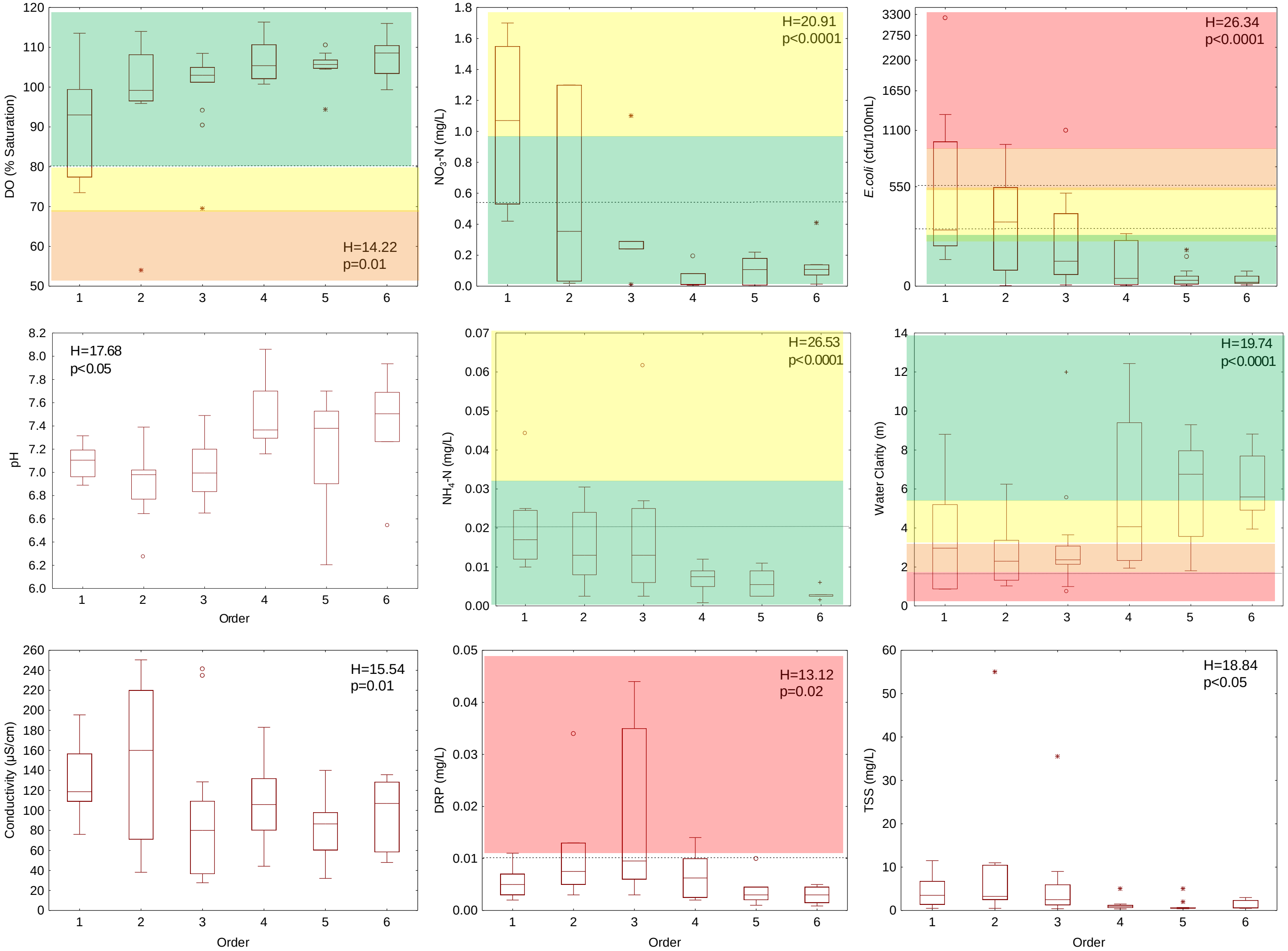


Figure 12. Comparison of median water quality parameters among REC Stream order classes (2004-2009 only). Two first order streams join to form a second order stream, two second order streams join to form a third order stream *etc*. H-statistics and p-values from the Kruskal-Wallis tests are shown for each water quality parameter. Water quality guidelines are shown with dotted lines where appropriate. Colour shading indicates values for poor (red), reasonable (orange) and good (green) water quality. Note: *E. coli* is on a log scale.

Macroinvertebrates in Relation to the REC Groupings

Significant differences among River Environment Classification (REC) **Source of flow classes** were found for the more sensitive macro-invertebrate indices %EPT, MCI and SQMCI (Figure 13). Scores were typically lower at sites draining lowland areas than at sites draining hill country or mountains. The two mountain-fed streams (i.e. Motueka River at Gorge and Waingaro River at Hanging Rock) had the highest scores for MCI, %EPT Taxa and SQMCI, however, only intermediate scores for the number of taxa. Sites that are spring-fed (i.e. Motupipi at Reillys Br and at 20 m u-s Watercress, and Watercress Creek had the lowest number of taxa and %EPT taxa. These sites also have low water quality.

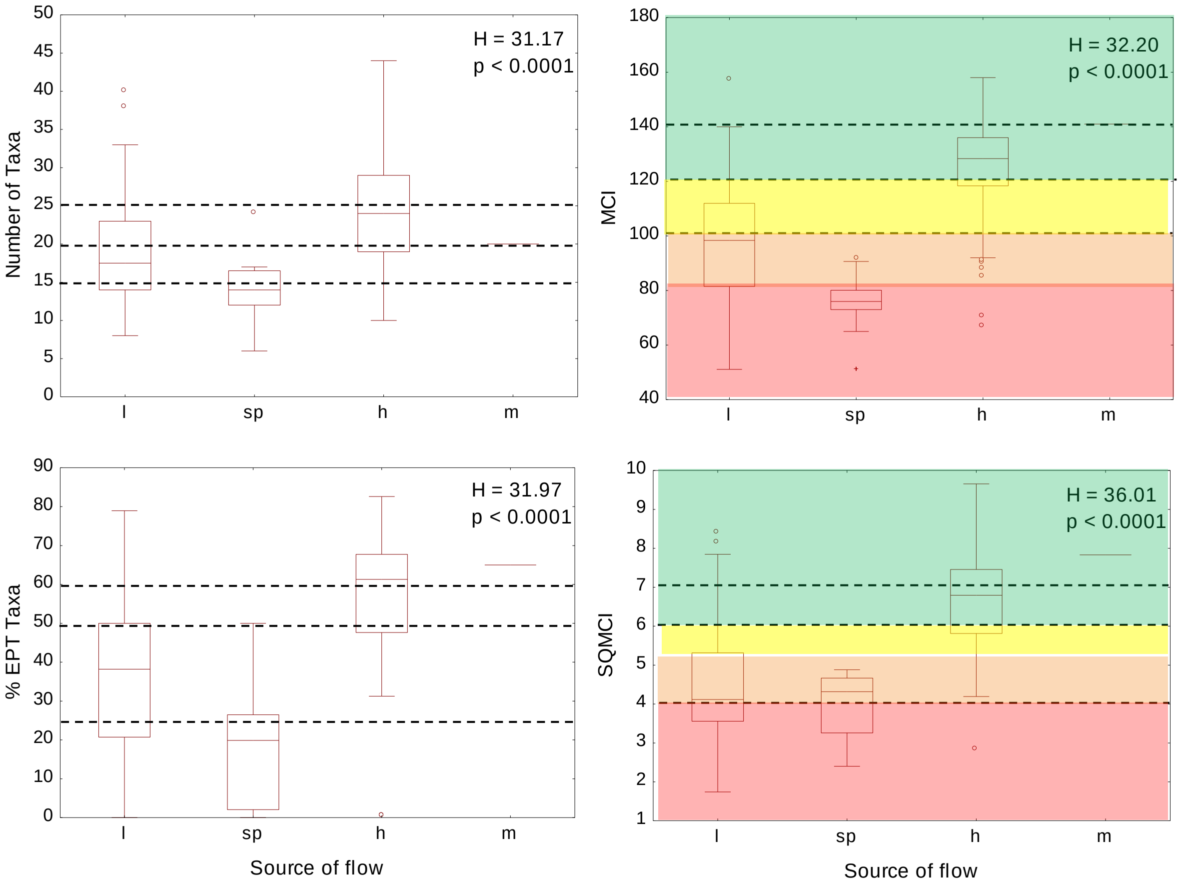


Figure 13. Comparison of average macro invertebrate indices among REC Source of flow classes. l = low elevation, sp = spring-fed, h = hill country, m = mountain. H-statistics and p-values from Kruskal-Wallis tests are shown for each index; colour coding: dark blue = excellent, light blue = good, green = average, red = poor.

There were also strong differences in invertebrate index scores among the REC land cover classes (Figure 14). The MCI and SQMCI (and %EPT) scores indicated relatively poor health in the urban stream (Watercress) and in many of the pastoral streams, while stream health in the indigenous forest, exotic forest and scrub sites was generally high.

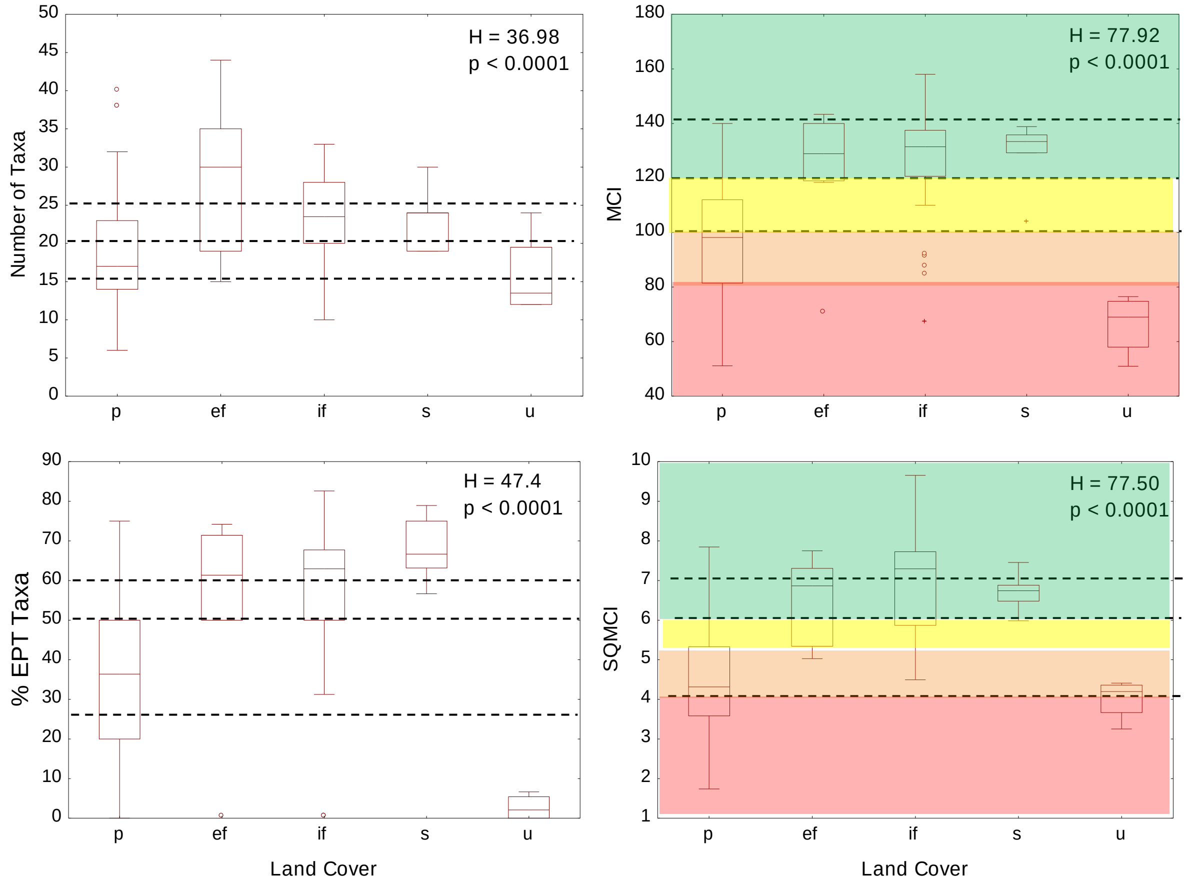


Figure 14. Comparison of average macroinvertebrate indices among REC land cover classes. p = pasture, ef = exotic forest, if = indigenous forest, s = scrub, u = urban . H-statistics and p-values from Kruskal-Wallis tests are shown for each index; colour coding: dark blue = excellent, light blue = good, green = average, red = poor.

There was little clear pattern in macroinvertebrate indices among REC **stream order classes** (Figure 15). The percentage of EPT taxa was lower in first order streams than in the larger streams and rivers, and some of the lowest MCI and SQMCI scores were also observed in these small streams. This is probably not a direct effect of stream size, but rather an indirect effect of land use, since most of the first order sites that have been sampled are in heavily developed pastoral or urban areas.

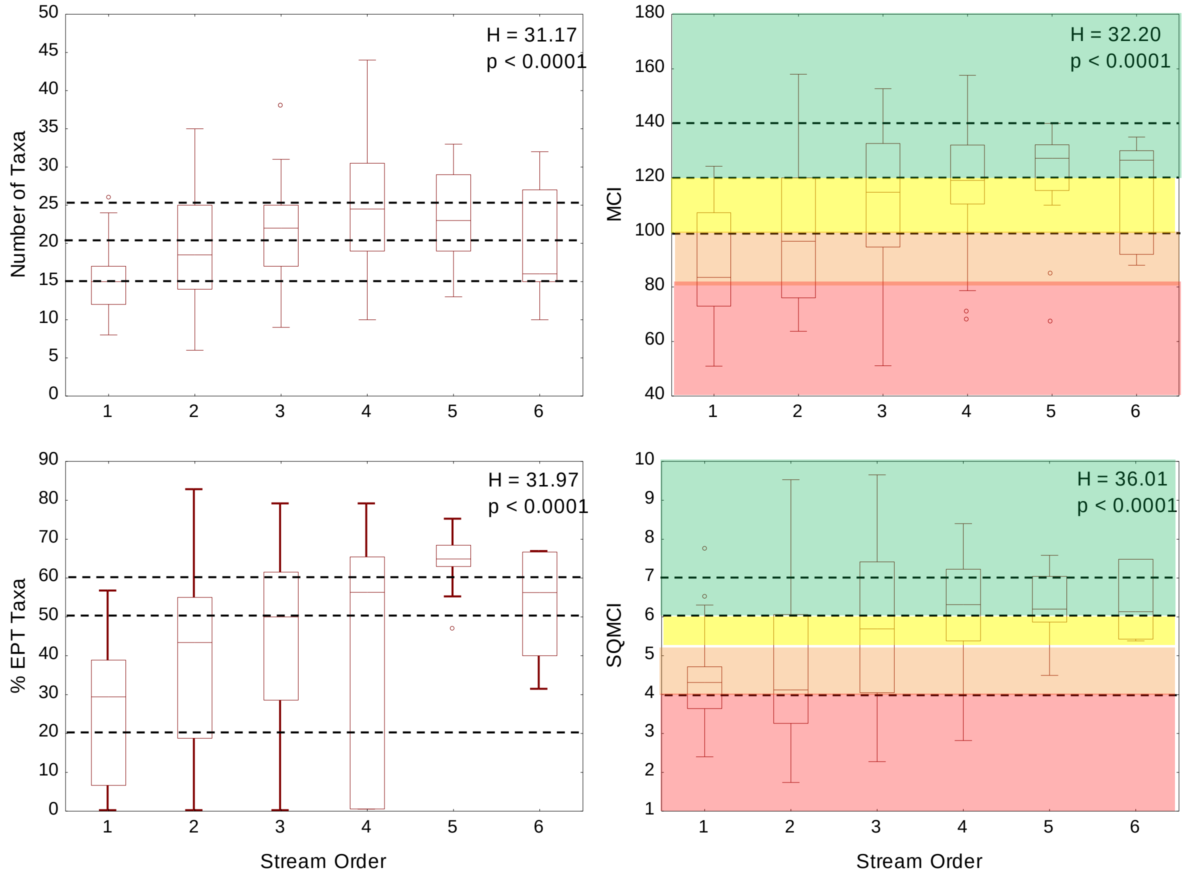


Figure 15. Comparison of average macroinvertebrate indices among REC stream order classes. Two first order streams join to form a second order stream, two second order streams join to form a third order stream, etc. H-statistics and p-values from Kruskal-Wallis tests are shown for each index; colour coding: dark blue = excellent, light blue = good, green = average, red = poor.

National Comparison

Comparisons were made between water quality measurements from the Tasman District and other regions using national indicator data for river condition in New Zealand (Unwin and Larned 2013). These data, for both the Tasman District and other regions of New Zealand, cover the period 2006 to 2012.

Based on this dataset, the range of *E. coli* concentrations in the Tasman District was similar to, but the **median *E. coli* value and inter-quartile range was slightly lower than other regions of New Zealand** (Figure 16).

Median water clarity in Tasman District was considerably higher ('better') than other regions (median 3.5 m whereas national median is below 1.5 m) (Figure 16). Note that data for many of Tasman's best performing rivers is not included in this data set because they are not being regularly sampled (e.g. Waingaro, and Upper Matakitaki).

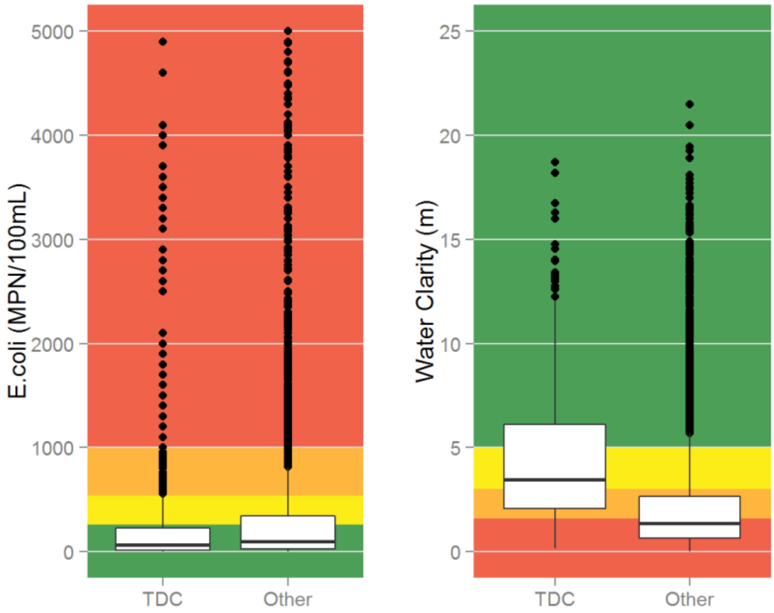


Figure 16. *E. coli* concentrations and water clarity measurements from the Tasman District (TDC) compared with data collected from all other regions in New Zealand (Other). These data are from Unwin and Larned (2013) over the period 2006 to 2012. The background colours indicate attribute states from A (green) to D (red).

The median value for Nitrate-N was higher ('worse') than in other regions (Figure 17). However, this needs to be put in context that Tasman District Council has chosen to only sample a few high-risk sites for Nitrate-N. The median dissolved reactive phosphorus for Tasman District was marginally lower than other regions.

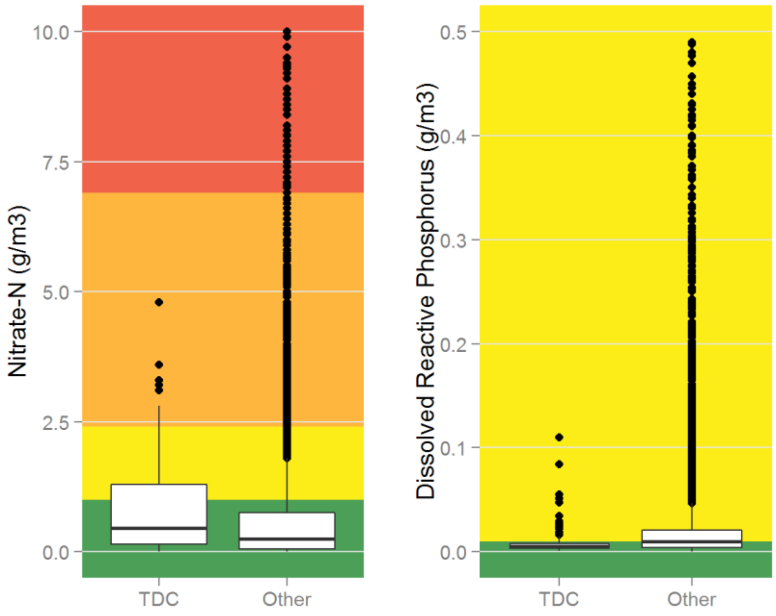


Figure 17. Nitrate-N and dissolved reactive phosphorus measurements from the Tasman District (TDC) compared with data collected from all other regions in New Zealand (Other). These data are from Unwin and Larned (2013) over the period 2006 to 2012. The background colours indicate attribute states from A (green) to D (red).

Discussion of Particular Activities

Effects of plantation forestry (particularly roading and harvesting)

The greatest potential effect from forestry is **fine sediment discharges** to streams and the coast for two-three years after harvesting (Leeks & Billi 1992). Also, **reduced water yield** (reduced flow in streams), particularly in summer, due to the high rate of evaporation and transpiration from pine trees, is another typical forestry effect on waterways. Water yield under pine canopy in the Moutere Hills was found to be about 80% less than in pasture (Duncan 1995). Harvesting large catchments within a short duration can also lead to **increased nitrate concentrations** (Fahey & Jackson 1997) and extensive **bank erosion** (Mosley 1980) and stream habitat disturbance due to flooding (Fahey *et al.* 2004).

In general, there has been a **significant improvement** in sediment and erosion control by larger forest management companies in Tasman **in the last 20 years**. Despite these efforts, there have been several rainfall-induced events that have caught these companies out and large sediment discharges to streams have resulted. Several incidents of failing to install cut-off drains after road construction have caused significant erosion over the years, including Eves Valley, Reservoir Creek and Clark Valley. In the two years prior to the Climate Change (Forestry Sector) Regulations (2008) coming into force there was a high rate of land use change from forestry to pasture and rural-residential land in the Moutere Hills, including Gardner Valley and small catchments feeding the Moutere Inlet. This land use change involved removing the root wad of the trees which greatly increases the risk of erosion compared to regular forest harvest operations. Significant volumes of silt were discharged to waterways and the Moutere estuary. Between the 2006 and 2013 broad-scale mapping of the Moutere Inlet there was a considerable increase (99 to 274 ha) in the area that is excessively **muddy and enriched with nutrients** (Stevens and Robertson 2013). Unfortunately sediment yields from the catchments through this period were not quantified.

In the late 1990's in Separation Point granite areas (Land Disturbance Area 2) studies showed that harvesting in larger catchments increased sediment yields by 7-10 times the pre-harvest rates (Hewitt 2002). A subsequent study on the same waterways found the range of storm sediment yield in the Motueka West Bank tributaries, Big and Little Pokororo, and Herring Streams, was large (Clapp 2009).

Higher sediment yield in Herring Stream (12 times the other catchments) was attributed to wind-throw and subsequent harvesting. In this catchment there was an exponential relationship of sediment compared to peak discharge (flow), whereas the relationship was linear for the other two catchments. Sediment yield in the Little and Big Pokororo was 5 times higher immediately after harvesting compared to two years after harvesting. Peak discharge was much more strongly related to sediment yield than rainfall totals, indicating that bank or mass-movement erosion rather than surface run-off results in the more significant percentage of sediment yield. The turbidity to suspended solids ratio was approximately 1:3 (NTU : g/m3), which reflects the coarser sediment sizes in granitic geologies.

An extreme heavy rainfall event in 2010 (May 16) centred near the lower Wangapeka River caused significant slips in recently-harvested pine forest. Three-hour rainfall return-periods of 90-250 years, depending on location in the catchment, have been estimated for this event. While some slips occurred in mature forest, the extent of erosion was far greater in the harvested forest and forest affected by wind-throw 5 years previously. The beds of about 30-50 km of stream were inundated with sand, with some streams, such as Kyfuiks (see picture below) and McRae Creek, inundated by up to 2 m of sand. This sand is likely to affect aquatic ecology in the mainstem Motueka to the coast for some time to come.

An example of very poor forestry practice occurred at near Pakawau in Golden Bay in 2012 (see Pakawau Creek discussed in the Aorere section). Roads were cut into slopes with side-cast material used to form the downslope side of the bench. With very few cutouts water spilled out onto side-cast material causing it to slip down the hillside and into a stream. Clean water was not diverted away from the main landing causing excessive sediment discharges to waterways from vehicle tracking.

Over 80% of plantation forests in New Zealand are owned and managed by members of the Forest Owners Association (NZFOA). In 2007 an Environmental Code of Practice was developed by the NZFOA and recommended to all members as a practical means to accomplish good environmental performance including water quality and sediment control. On top of this some 50% of New Zealand’s forests are eco-certified under the Forest Stewardship Council (FSC) international scheme for endorsing good forest management and sustainable land use. Participating forest owners are audited annually against an internationally agreed set of principles and criteria. However, relatively little effective sampling of streams occurs as part of this process.

Kyfuiks Creek near intersection of Phillips (Bennetts) Rd and Tapawera-Baton Rd (21 May 2010).

Results from Council's monitoring shows harvesting of the entire Graham Creek catchment, near Kikiwa (Moutere gravel geology), between 2005 and 2009 produced very little effect on water quality during base flows, or deposited fine sediment, compared to neighbouring catchments (although nutrient concentrations were rarely measured). While % cover of filamentous green algae has been high at this site, there appears to be no difference before and after harvesting.

Forestry in the high-erodable Separation Point granite in the Pohara-Ligar Bay area of Golden Bay starting in late 2014 was according to a harvest plan developed using terrain stability modelling in order to integrate economic and hazard mitigation techniques. Some of these techniques include:

- earthworks and landings restricted to land of low instability risk
- conventional *P. radiata* management possible on low to moderate instability risk areas
- extraction be hauler based on all steep and risky terrains
- minimise log scour in high hazard terrains.
- maximise slash 'carry away' from gully heads and sides
- retirement of areas of gully and stream areas from production forestry post harvest.

In addition to the rules in the Tasman Resource Management Plan, most of the larger forest companies operate other environmental protection systems, such as the ISO14000 quality system. Under this system, any identified environmental issue caused by the company requires an investigation involving agencies such as Council. Several of these companies now have **Forest Stewardship Council certification** that (as mentioned above) has strict environmental performance standards, that must be adhered to.

A **National Environmental Standard for Plantation Forestry** (NES-PF) is proposed (Ministry of Primary Industries 2015). If implemented, this NES will replace councils' existing plan rules for managing activities related to plantation forestry. It would provide a nationally consistent approach with several more stringent rules. Different rules are drafted for areas with different erosion susceptibility. About half of forestry land in Tasman District has been identified as having low erosion risk (Ministry of Primary Industries 2015). These areas are mainly north of Tapawera-Belgrove on gently undulating hillslopes or valley floors. However, the accuracy of this erosion risk model is questionable (Burton, A; pers.comm.). For example, one area marked as low risk, Pakawau in western Golden Bay, appears to be wrongly classified. This area was the subject of severe forestry-related erosion in 2012. The major problem came from road construction with cut material sidecast on the downward side of the road. Without cut-outs or properly-formed water tables stormwater runoff from roads spilled out over the sidecast material which then became water saturated and let go and slid into tributaries of Yellow-Pine Creek. This shows that, while it is useful to understand where the higher risk zones exist, it does show the need for effective sediment and erosion control plans in any area of earthworks, particularly on hill country.
Draft proposed permitted activity rules cover the following:

- **Erosion and sediment control.** ESC plans must be produced to avoid fine sediment discharges to waterways.
- **Slash** in streams that may cause a damming or diversion risk

- **River crossings** requiring bridges or cuvlerts
- **Crossings through wetlands** - crossings through wetlands are allowed provided the wetland is less than 2500 m^2 in size.
- **Rivers/streams** – setbacks of 5 m or 10 m are required depending if the stream is under or over 3 m wide (respectively). Full suspension is required if pulling logs across streams over 3 m wide.
- **Wetlands -** setbacks of 5 m are required
- **Coastal marine areas –** setbacks of 30 m are required.

Effects of dairy and intensive beef farming

Intensively-farmed land has a considerable potential to produce **elevated levels of faecal indicator bacteria, fine sediment** and in some cases, **nutrients**, in downstream waterways. Cows in creeks, mobs of stock crossing creeks, effluent discharges (from the dairy shed, feed/stand-off pads, or laneways), and pasture run-off are the biggest sources of these contaminants. Tasman has a total of 143 dairy farms with active discharges, about 1% of the nation's dairy farms. Only six of these have consents for discharge of dairy effluent to water, with the remaining discharging to land under permitted activity rules.

In general, poor water quality exists in catchments whose land area is dominated by intensive farming *e.g.*, Motupipi, Powell, Sherry and Mackay. Much of that will be through non-point source (mostly from paddocks) discharges. Flood-flow monitoring shows typically 10-100 times greater concentrations of faecal indicator bacteria from farm run-off. *E. coli* concentrations in the Sherry River halved between 2004-2011 following the installation of bridges and riparian fencing. This trend will be evident in many streams around the district where bridges have been installed. The incidence of disease in people in rural areas is very seasonal and almost mirrors milk production in dairy farming areas.

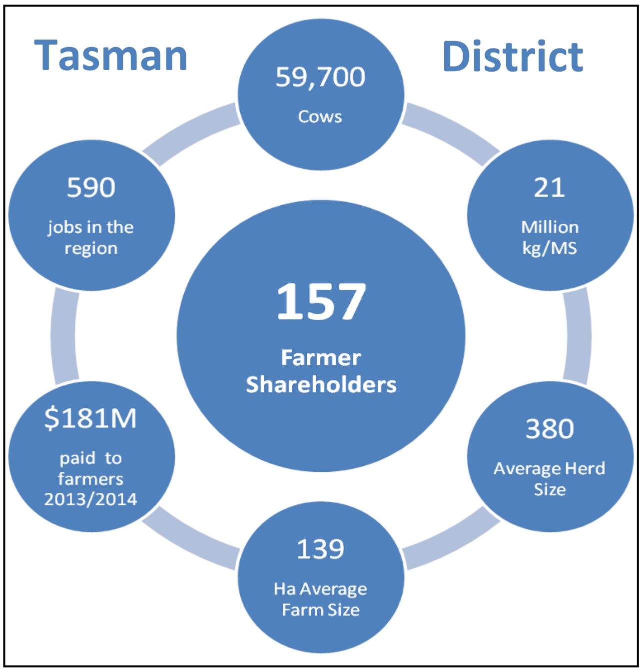


Figure 18 Statistics about the dairy industry in Tasman District. Source: NZ Dairy Statistics 2013-14 Season. NZIER.

A snapshot of the size of the dairy farming industry in Tasman is shown in Figure 18.

Since 2005, when the **'Dairying and Clean Streams Accord'** was signed in Tasman, steady progress has been demonstrated by the dairy farming industry towards fencing streams, bridging stock crossings, and upgrading effluent treatment systems.

A considerable amount of work has been done since 2012 by the dairy industry (Westland Milk, Fonterra, and Dairy NZ) by working one-on-one with farmers with respect to system and wet weather contingencies. This appears to be reflected in the rate of compliance with Tasman Resource Management Plan rules (Figure 19). This is particularly so in the Murchison area, where inspections made in

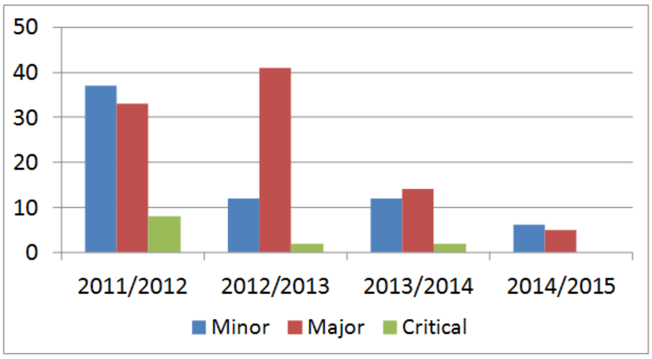


Figure 19 Non-compliance with plan rules in Tasman District. Source: Fonterra Farm Dairy Assessment 2011-2015.

past seasons identified that non-compliance associated with ponding was far more prevalent here than any other area of the District. Both supply companies have audited effluent systems that were of concern and recommendations made to the respective farmers as to how to improve them.

Compliance with Council rules was at an all-time high in the **2014-15** season with **no significant non-compliance events** reported (Bunting, 2015) (Figure 20). Of the six farms where “non-compliances” were reported, one was for minor effluent ponding on pasture (over an area of 10 m^2 and only a few centimetres deep), one was for spreading effluent slightly closer to drains or waterways (but with no discharge to water) and three were for storage of effluent solids on unsealed areas.

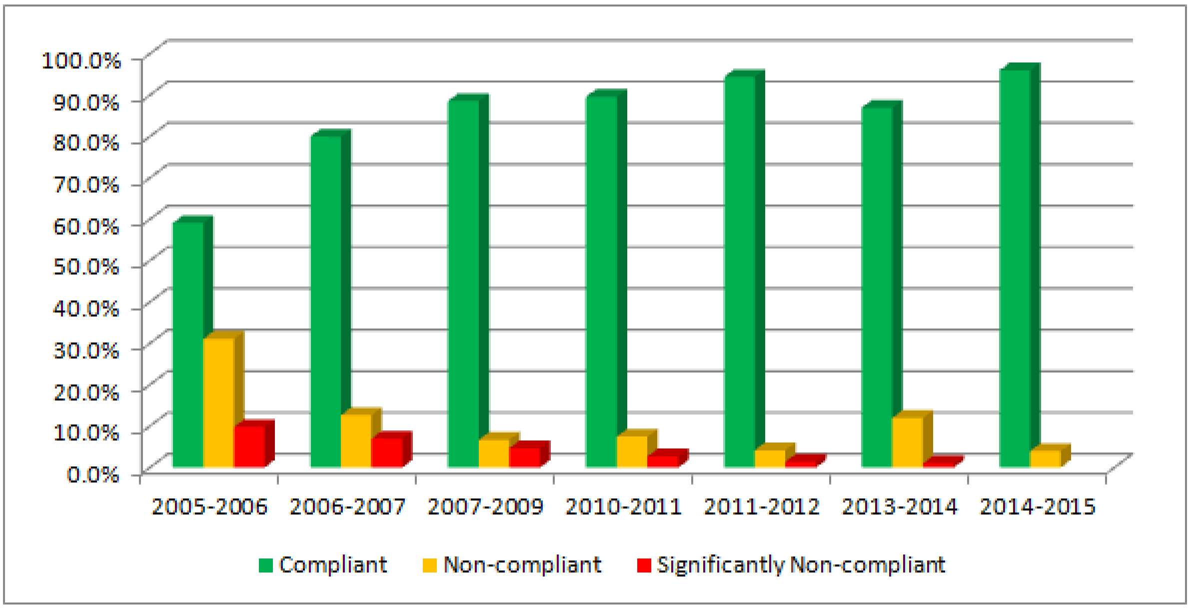


Figure 20 Comparison of Compliance with respect to discharge of animal effluent (Rule 36.1.2.3 of the Tasman Resource Management Plan), Resource Consent conditions, and Section 15(1) of the RMA 1991 from previous dairy seasons (from Bunting, 2015).

The pattern is similar with Fonterra’s own assessment of compliance (Figure 19). Note that twelve of the 143 dairy farms do not supply Fonterra and, therefore, are not subject to this Accord, and are not represented in Figure 19. These 12 farms supply Westland Milk Products and have been assessed by Council along with Fonterra supply farms as to compliance with Tasman’s Regional Management Plan rules.

The next generation accord, the ‘Sustainable Dairying: Water Accord’ brings in other requirements such as a production of Riparian Management Plans. Half of all farmers are required to produce these by 2016.

At the sites where disease-causing organisms were an issue, the **source of faecal matter was found to be ruminant animal** (cattle, sheep, goats and deer) **at 90% of sites** (17 of 19 sites; and 23 of 27 samples) with about 30% of sites (50% of samples) where wildfowl was a source. For wildfowl to make up a significant quantity of the *E.coli* there would have to be large flocks of wildfowl on a regular basis (Moriarty, E. *pers.comm.*).

From 2006-2013 Council compliance staff monitored a range of activities known to cause adverse effects on waterways such as stock access to waterways, bridging/culverting of stock crossings, shed effluent and nutrient budgets. However, Council's dairy compliance monitoring programme now only includes monitoring of rules relating to dairy shed effluent. This is because there is a high rate of compliance with stock access and crossings.

A limited number of farmers who have ignored the rules regarding effluent discharges have been forced by the environment court to upgrade, in order to improve water quality. According to Fonterra, there are only 0.4% of stock crossings yet to be bridged or culverted and almost all stock is excluded where it needs to be (Fonterra, June 2015).

The dairy sector proposes to work with Councils to investigate requirements for universal stock exclusion (and prioritise this) should voluntary measures be insufficient (Land and Water Forum 2010). The dairy sector also advocates the "Taranaki Region Model" of encouraging riparian planting, whereby the Council provides riparian management plans and provides native plants at cost price to implement the plan. The fertiliser industry is working to help the dairy sector meet its commitments by developing a training programme for fertiliser advisors.

Other issues related to intensive farming that are not specifically addressed in the Tasman Resource Management Plan include:

- Discharge from break feeding on winter crops close to waterways
- Discharge from raceways

Several instances of discharge of topsoil to waterways from winter cropping and break-feeding as well as feeding out beside a waterway were evident in winter 2013. Prior to the 2014, winter Fonterra and Council teamed up to present good practice on this aspect of farm management to farmers. Such good practice is to begin grazing furthest away from the stream first and progressively graze (break fence) toward waterways. The reverse had been happening and there was no grassy sward for sediment to get trapped into.

Examples of risk of sediment discharge to waterways. Left: Feed out area next to a waterway. Right: Evidence of run-off (the waterway is 180° from this view).

Discharges of sediment and faecal matter from dairy farm races are also a common issue in Tasman. The photo to the right shows the simple solution of ensuring the runoff from the race is diverted to the paddock and not the stream.

Discharges of sediment and disease-causing organisms from a lane-way. Note the berms on the raceway curbing the flow direct to the stream and the farmer breaching the curb to allow the discharge to pasture instead.

The Sheep and Beef industry, through Meat and Wool NZ, have developed a "**Land and Environmental Plan**" template for farmers. It includes a Land & Environmental Planning (LEP) tool kit, leading to ISO 14001 accreditation. Locally one group that includes sheep and beef farmers, **The Sherry River Group**, have had farm plans produced and are working through the implementation of those plans. The development and action of this group is well publicised regionally and nationally. The Meat and Wool funded "Monitor Farm" has an environmental component to it. The farm has an Environmental Plan developed and is currently being implemented. Unlike the dairy farming industry, the Sheep and Beef industry do not have any environmental performance targets at present.

A dairy farm effluent pond; this pond has good storage and a weeping wall for solids removal

An ideal location for a constructed wetland to intercept runoff from pasture

On an individual farm basis, Council works with any farmers in all catchments to provide advice on farm management best practices and provides assistance for riparian works that will improve surface water quality.

Examples of farming practice that have led to fine sediment run-off to waterways.

Effects of sewage treatment discharges

Sewage discharges from town sewage treatment plants (STPs) or household septic tanks can cause **elevated levels of faecal indicator bacteria and toxic ammonia** in streams and along the coast. The highest risk in much of Tasman is in late December to February, when there are the greatest numbers of holiday-makers present in the district.

Resource consent monitoring of STPs generally shows a high level of compliance. Several small townships without a community STP, such as Tasman, experience contaminated groundwater or waterways, particularly during periods with high groundwater levels. Murchison, Tapawera, and Collingwood have had significant upgrades to their STPs and the effects of the discharges are controlled. Raw sewage overflows from sewerage pipelines, such as from Pohara to Takaka, are much less frequent than in the past following significant investment in network upgrades. The Takaka STP, located west of Takaka township near the Takaka River, and the Motueka STP, located near the mouth of the Motueka River, are the last to receive such upgrades and these discharges will be improved in the very near future. Heavy rains can result in stormwater ingress to these systems, which in turn result in elevated flow. Previously there has been a risk of overtopping and discharge from the Takaka and Motueka waste water treatment plants. Significant upgrades to both systems are currently underway. Additionally the Department of Conservation have installed new STPs at most of the popular huts and campgrounds in Abel Tasman National Park.

Murchison Sewage Treatment Plant.

A number of older properties may still have direct discharge of primary treated domestic wastewater to a water course. These discharges are addressed through enforcement action as detected. Current health standards recognise this as an unacceptable practice.

Compliance staff have recently confirmed the presence of human wastewater in three small, independent, streams that discharge to a roadside drain at Tasman. Enquires are now underway in an attempt to locate the source of pollution in each of these streams.

Effects of discharges from urban environments

New Zealands' **urban streams often have poor water and sediment quality and degraded biological communities** (Suren and Elliot 2004). The most obvious difference of urban catchments is the proportion of land area in impervious surface (e.g. roofs, asphalt, concrete). **Impervious surfaces covering >10% of a catchment usually cause higher peak stream flows** and **lower base flows** which **adversely affects stream life** through increased bed and bank disturbance. To compensate for these high peak flows the stream channel needs to be wider, or if there is not enough space, the channel is armoured with rock or concrete where flow velocities are high. Urban streams typically lose their overhead tree canopies that are critical for shading/cooling, 'feeding' the stream and creating habitat for fish and invertebrates. This lack of shading often causes extensive algal blooms that also reduced dissolved oxygen, again adversely affecting stream life. Urban catchments also have extensive networks of stormwater gutters and pipes that are designed to quickly and efficiently transport that water to streams and the coast. This allows contaminants (mostly fine sediment, toxicants, nutrients, disease-causing organisms and rubbish) to be transported directly to the waterway without processing through the soil profile.

Discharge of heavy metals and hydrocarbons in runoff from roads and roofs appears to be one of the biggest water quality issues in Richmond (Easton and James 2010). However, there are many other contaminants that get tipped down drains on residential and commercial properties in urban areas that have had noticeable effects on water quality monitoring results. From domestic households these include the likes of the washings of cement, vehicles, paint, petroleum products, roof cleaning products and pesticides. Many of the chemicals discharged from these sources are highly toxic to aquatic life. Benzalkonium chloride and chlorine bleach for example are commonly used in mould, moss and lichen removal products and has been responsible for recent fish kills in this district (e.g. Ruby Bay, 2014).

Levels of **zinc, copper, and chromium** are generally the most concerning contaminants in Richmond's waterways due to their presence in high concentrations in stream sediments (Easton and James, 2010). The majority of the load of zinc and chromium will probably come from roofs and roads as this is common to urban areas throughout the country (e.g. Timperley et al, 2005). Relatively high vehicle emission factor estimates (greater than, or equal to, 0.12 mg/vehicle/km for copper and 0.87 mg/vehicle/km for zinc) largely coincide with roads on which brake and tyre wear are likely to be greater than elsewhere (Moores et al, 2009). Low- to mid-range estimates (less than 0.086 mg/vehicle/km for copper and 0.45 mg/vehicle/km for zinc) largely coincide with

Jimmy-Lee Creek near mouth, Richmond (June 2010).

roads on which traffic may be generally expected to move freely. Perhaps the greatest braking intensity would be the few hundred metres each side of the traffic lights at Queen St and Gladstone Rd (with particular braking intensity for south-bound traffic on Wakatu Drive nearing the Queen St intersection), intersection of SH60 and SH6 and Salisbury Rd near the schools.

The average amount of oil that is dripped onto roads is about 0.5 L/car/year. If there were an average of 2000 cars typically in circulation in Richmond on any one day of the year (excluding garaged vehicles), that would equate to 1,000 L of oil discharged to roads per year.

'Low impact urban (water sensitive) design' is a method, or practice, that is being employed by Councils around the country more and more often, particularly for 'greenfields' developments, where it is easier and more cost-effective to employ. Low impact urban design aims to avoid or mitigate significant impacts of urban development on the environment. In the case of stormwater, some of the methods include **reducing the impervious surface in a catchment, managing infiltration into the earth, increasing vegetative cover in strategic areas, and incorporating water storage and reuse** to manage peak flow and water quality. Some of these methods have been used in Tasman, but with varying success.

In urban developments in Tasman District there has been a demonstrable lack of treatment of stormwater. Several subdivisions developed in 2014-15 in Richmond direct stormwater from roofs, yards and roads directly into Eastern Hills Creek (a Borck Creek tributary) and Reservoir Creek respectively without any treatment. This is a practice needing much more attention in the future.

Around New Zealand many streams in new urban areas continue to be reticulated in stormwater pipes, resulting in very little attenuation of contaminants and removal of stream habitat. The main reason this happens is the cost of the land. Tasman District Council has been reasonably successful in retaining open ("daylighted") stream channels and maintaining a natural channel or naturalising new channels. Council is in the process of developing catchment management plans for Tasman's urbanised areas and the unregulated discharges of stormwater will be addressed within these plans, as will the need for adequate controls on new greenfield development. One outcome from the work will be council holding a resource consent to discharge from urban areas to waterways and a consequent need to manage the inputs to the stormwater network. It is hoped that this will lead to a step change in urban water quality.

Council actively monitors facilities that store or use hazardous substances. While at times there have been unauthorised discharges from such facilities, the standard of performance has improved markedly in the last 20 years with several companies in the district operating their own proactive environmental policies.

The discharge of **contaminated sediment from roads and roofs** is increasingly recognised as an issue New Zealand-wide. **Zinc** from stormwater runoff from industrial roofs comes particularly from the metal particles generated from drilling holes in situ for the screws holding the roofing iron to the roof. Treating this stormwater by such things at interceptors on downpipes is a relatively simple solution. **Zinc and copper** concentrations in road sweepings and catch-pit sediments are generally **above landfill acceptance criteria** (Depree, 2008). **Street sweeping** holds promise to reduce the contaminant load coming off roads (Depree, 2011 and 2012). Improvements of up to 30% in contaminant load have been measured. Such sweeping is the most cost-effective method compared to retrofitting structural stormwater treatment.

A vacuum sweep vehicle for removing road deposited sediment

However, particular attention needs to be given to the type of street sweeping machine (vacuum sweepers were much better than mechanical broom and regenerative air sweepers at removing the fine particles from the road surface and then depositing them in the truck rather than re-emitting the dust). The timing and frequency of sweeping is also important. The frequency needed to remove road contaminants is higher than for aesthetic sweeping (it is estimated that there about double the yield of contaminants removed by increasing the frequency of sweeping from 2 to 12 times/year). Sweeping is best carried out prior to rainfall events after a longer dry spell as road contaminants build up over time and then get effectively washed into waterways during rain.

Council engages in on-going education activities with households and industry to avoid discharging harmful chemicals to waterways. However, the level of care and awareness of urban stormwater quality by people in larger, more-dense populations is generally low and that education reach is seldom over 80%. So the risk of contamination to stormwater is moderately high without treatment. People in urban environments have a tendency to think that the effect of their activities only makes a small difference.

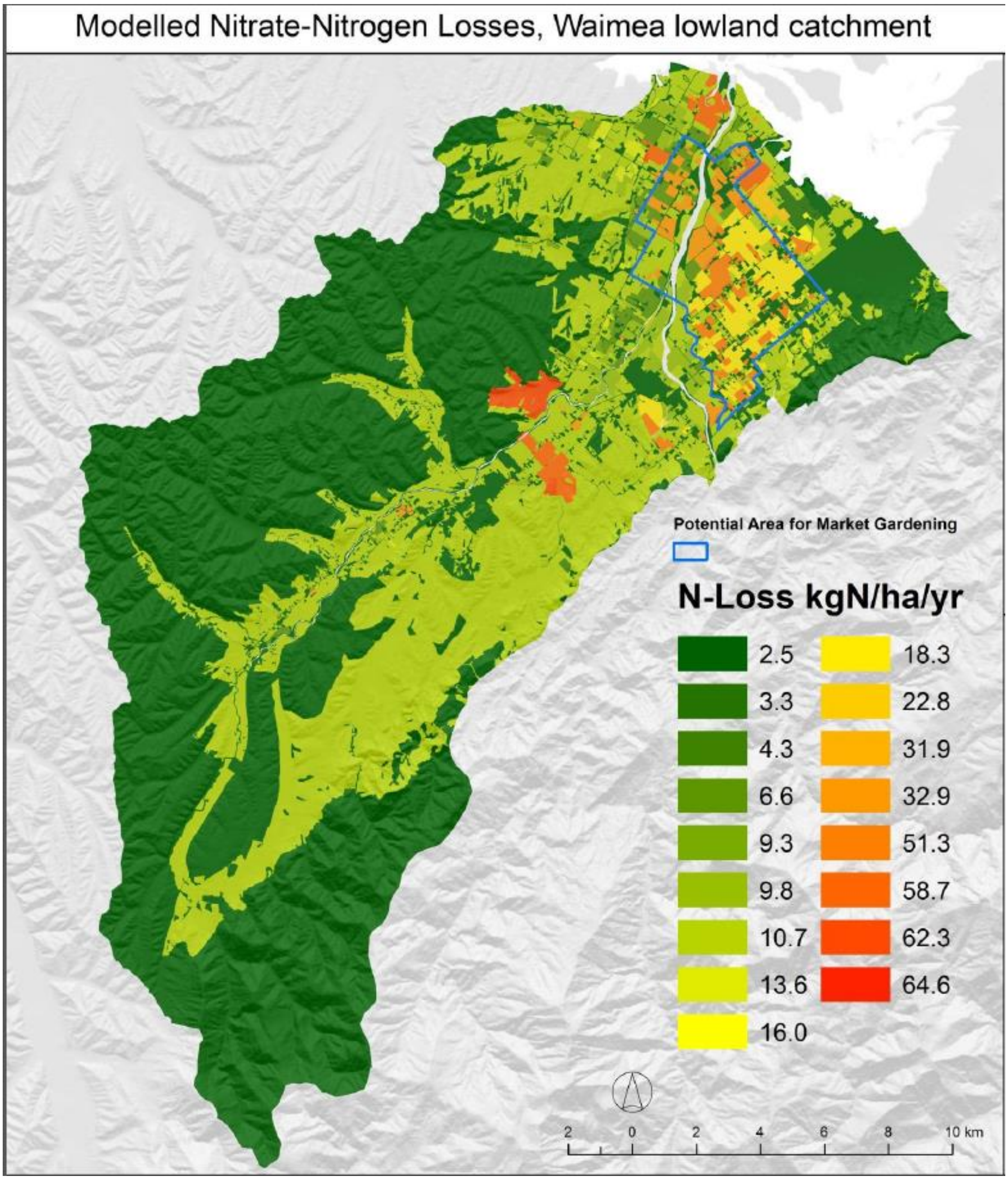
Effects of Horticulture Activities

Leaching rates of nitrogen to groundwater in the Waimea Plains has become a topic of much interest following increasing concern about high nitrate concentrations in the spring-fed streams of the Waimea Plains. Relatively high leaching rates are estimated to occur from outdoor market gardening and dairying. After dairy farming, the next greatest concern is market gardening on the free-draining gravelly silt loam Ranzau soils (Green, 2015). A lot of work is currently in train to refine these leaching estimates. Dairy practice is relatively well monitored, but practice within the market gardening sector is less understood.

Table 9. Leaching rates for various land uses on various soils (kgN/ha/year) (Green and Fenemor, 2015)

LAND USE/ FARM SYSTEM	Ranzau soil	Waimea & Motupiko soils	Wakatu & Dovedale soils	Richmond & Heslington soils
Dairy pasture	64.7	58.8	62.3	22.8
Apples (also applies to Berries, hops, kiwifruit, avocados)	18.3	6.6	9.3	3.1
Grapes (also applies to olives, small nuts)	18.3	9.8	13.6	4.3
Outdoor vegetables (also applies to nurseries, glasshouse)	56.4	35.3	34.7	18.5

While the horticultural practices have vastly improved we do still see the odd impact related to chemical usage. For example in the winter of 2009 there was a suspected discharge of the anti-budding chemical HiCane (used on Kiwifruit orchards) to the Riwaka River after landowners who pumped water from the river to ponds noticed that the fish in the ponds and the birds that drank from the ponds died.



Modelled Nitrate-N losses in the Lowland Waimea Catchment (Fenemor et al, 2015)

Discharges of fine sediment from earthworks

The Ruby Bay Bypass was a large roading project that occurred in 2008-10 and led the way with developing new standards for sediment and erosion control. This project continues to be the single largest earthworks project ever undertaken in the region. However, despite spending over ten times more money than originally budgeted on controlling sediment discharges and the installation of well-designed settling ponds, many with flocculent dosing systems, the systems could not cope with several of the larger rainfall events experienced during the construction period. However, without these devices the effects would have been much worse.

A sediment pond with decanter, Ruby Bay Bypass Gardner Valley Catchment, Moutere.

Silt fence for sediment control on flat terrain, Ford Creek, Tasman.

There has been a significant improvement in the standard of practice since 2009. This is due the combined efforts by Council to provide better advice (including running a sediment and erosion control workshop), tighter resource consent conditions (particularly through the submission of more robust Erosion and Sediment Control Plans) and follow-up compliance monitoring. Further improvements may come as a result of sediment and erosion control guidelines that are expected to be released in 2016. These will define good practice and provide useful information for earthworks operators. Credit needs to be given to many of the commercial operators also who have readily accepted best practice methods developed in other districts.

Sediment discharges to a small creek from **cultivating/ploughing moderate slopes** in the Moutere Hills. The result was that most of the pools and cobbly bed in this intermittently-flowing stream were filled with sediment. Preventative measures, such as re-seeding the ploughed grassland as soon as possible and leaving vegetation buffers, would have been appropriate. Horticulture NZ Good Agricultural Practice (NZGAP) promotes tools and codes of practice for the management of sediment from agricultural activities.

There are many examples of poor road construction and maintenance in non-forestry settings that lead to excessive sediment discharge to waterways in Tasman. Sediment discharges from roading in the Bencarri Stream catchment (a tributary of the Anatoki River, confluencing near the Bencarri Farm Park) were significant, with almost all the material side-cast on the roadside ending up in the stream. Farm tracking in the Motupipi catchment affected McConnon Creek and the lower Motupipi. The main reason for these heavy sediment discharges was the failure to install cut-off drains.

Sediment discharges from work in a salmon farm pond receiving heavy sediment load from a natural stream tributary of the Anatoki River failed to protect this river from excessive sediment load in 2013 (see photo below). While the December 2011 floods brought down a lot of sediment to this catchment, the works there were no sediment discharge controls in place during the works. Over subsequent years toxic algal cover has become a problem in the affected reach.

Heavy sediment load to the Anatoki River from discharges from works in a tributary (July 2013).

The risk of sediment generation from roading is particularly high in Separation Point Granite geology. An example is shown in the photos below. This occurred in 2011 at Pangatotara, Motueka Valley.

Erosion from poor sediment and erosion controls in road construction in granite geology.

Other issues

Some illustrative examples of problems encountered over the last 10 years relating to stream pollution events:

Pesticides

For Tasman District very low concentrations of **pesticides were found in seven of the 15 groundwater bores sampled** as part of a national 4-yearly programme (2 in the Waimea, 2 in the Moutere, 1 in Riwaka, 1 in central Motueka, and 1 in Spring Grove). All the detections were triazine herbicides (mostly terbuthylazine), except one (Simazine). Common triazine herbicides Simzine or Atrazine were very common field/crop sprays especially for broadleaf and annual weeds in our working landscape. These types of compounds are easily washed through soils and are slow to breakdown in groundwater.

Pesticides in groundwater are relevant to surface water as groundwater may make its way into streams or may be used for irrigation or other consumptive uses. The exact pathway from application to groundwater is often not known but most likely it is from surface application for weed control with the compounds being washed through the soil profile to below the root zone and into the groundwater. Forest Stewardship Council certification prevents terbuthylazine and hexazinone herbicides from being used in forestry operations using this environmental marketing label because they are considered to either move rapidly in the soil and/or bio-accumulate in aquatic organisms (Forest Stewardship Council, 2007). The justification of such prohibition in New Zealand was supported in a recent review based on soil testing (Rolando and Watt 2012). This review found that terbuthylazine should not be used on raw and recent soils which have low organic Carbon content.

Nationally there is a programme to test for acidic herbicides, organo-chlorines, organo-phosphates and organo-nitrogen based pesticides. Within this programme 165 groundwater bores (mostly accessing the more vulnerable unconfined aquifers) were tested in 2014 with many sites being tested four-yearly since 1990 (Humphreys and Close 2014). For the sites that have been tested four or more times since 1990, no pesticides were detected at 55% of the sites. At the remaining sites, concentrations of pesticides were generally very low. For the sites that have been tested four or more times increasing trends in concentration were found at 7% of sites and decreasing trends at 8% of sites.

Only one investigation of pesticides in streams in Tasman is known to date. A screen for pesticides in sediment from Neimann Creek, an intensively-farmed catchment in the Waimea Plains, found no trace of any pesticides (James, unpublished data, 2014). However there has been a lot of work on residual pesticides in our soils mostly related to historic orchard practices or sheep dips. It is likely that some of these recalcitrant spray residues may their way to waterways bound to the soils.

Studies of pesticides in streams in other regions include the following:

- In stream sediments in Southland, Otago and Canterbury, the organophosphate insecticide, Chlorpyrifos, which is currently used on conventional sheep/beef farms in New Zealand (but banned since 2001 in the USA), was the most frequently detected pesticide (Shahpoury et al, 2013). This study also found that both endosulfan and dieldrin were found at levels considerably below sediment quality guidelines (ANZECC 2000; maximum concentration 1-3 nanograms/g dry mass) but their presence is interesting since endosulfan has not been commonly used on sheep/beef farms in New Zealand and dieldrin was banned long before. A percentage of all individual samples had concentrations above guidelines: chlorpyrifos (1%), endosulfan sulfate (12%), DDT (13%), dieldrin (23%) or chlordane (2%). The presence of these "toxic hotspots," although not common, may be partly responsible for the deterioration of macroinvertebrate communities in streams on conventional farms.

- 67% of trout sampled in Otago rivers were found to contain very low levels (several nano grams/g of lipid) pesticides (Scholes 2015). The most common pesticides found in higher concentrations were Hexachlorobenzene, Endosulfan, Chlordane, Metribuzin, Dacthal and Nonachlor.

- Sediments from rivers and estuaries tested in the Waikato only very occasionally detect pesticides, but they have always been at levels that represent a low likelihood of effects on organisms (Waikato Regional Council website 2015).

These studies suggest that Council should take a 'watching brief' of the issues of pesticides in rivers but due to laboratory analysis cost and very low levels found in the region and nationally, a sampling programme is not considered worthwhile at this stage.

An on-going **acid mine drainage discharge** in the Maruia River catchment is adversely affecting an 800 m section of Flat Creek, until the confluence of another stream (James, May 2007). The diversity and abundance of macroinvertebrates was dramatically reduced by the leachate from the mine tailings.

The **effect of historic mining** activity has been investigated in the **Lake Otuihe** catchment with an investigation into metal concentrations (antimony, arsenic and mercury) in eel flesh and lake sediment (Tremblay and Champeau, 2013). The study found eel flesh metal concentrations below relevant standards or guidelines and therefore the consumption of Lake Otuhie eels is unlikely to cause adverse effects through dietary exposure.

Industrial discharges that have resulted in enforcement action include:
Potash humate, used in the production of an organic fertiliser, to Jimmy-Lee Creek
Concrete washdown water, with a pH of 9-10, from concrete pump trucks to Borck Creek
Grape lees (thick sediment waste produced from wine making), with a pH of around 4-5, was discharged through a failed treatment plant to a tributary of Redwood Valley Stream. A **spill of ammonia** to a small coastal stream, from a cool store in Motueka. The result was the death of over 100 eels and a similar number of inanga. There are **now measures in place** to prevent this happening again at this site.

Works in waterways can cause **significant adverse effects on fish populations and water quality** depending on how they are carried out. These effects can be very long term or permanent in the case of habitat loss or more temporary in the case of solely bed disturbance (e.g. gravel extraction/relocation or sediment removal for flood control).

- The **most significant effect** is for permanent or semi-permanent changes to the **meander and channel form** such as straightening or battering the banks and lining with hard materials. This can lead to the permanent reduction in overall area of the stream and important habitat features such as pools. Battering the banks at a slope of 1:3 (vertical to horizontal) and the requirement that trees only be planted at the top of the batter at the closest usually removes the possibility of overhanging trees that supply the waterway with an critical food source.

- **The full recovery from stream bed disturbance is typically 3-5 years** depending on the type of waterway (mountain-fed waterways recover fastest as fish populations are adapted to disturbance compared to spring or lowland-fed waterways). This provides good reason to minimise the frequency of such disturbance. One way to minimise the future need for such disturbance in smaller streams (<10 m wide) is by shading the waterway with trees. This is so aquatic plants don't dominant the waterway and cause the trapping and build-up of sediment.

- Discharges of sediment from these works can also cause adverse effects as the discharges are generally during low flows when a lot of the sediment will settle on and in the stream bed. It is important to try work in the dry - **over-pumping, along with fish recovery and transfer, is a very effective technique in smaller streams** at mitigating such effects.

Land use changes in the District

Understanding current states and trends in land use in Tasman provides us with a platform to draw linkages between the state and response of other connected resources such as soils and fresh water.

Changes in land use can be monitored now using data collected through the New Zealand Land Cover Database (LCDB). This is a classification of land cover and land use classes providing data at approximately 5-yearly intervals at a national scale. The first dataset was collected in 1996 with the fourth dataset has just been released.

The conservation estate administered by the Department of Conservation is a large part of the district and includes the Kahurangi, Nelson Lakes and Abel Tasman national parks and numerous scenic and conservation reserves. This area is primarily in a natural state, it covers 623,400 hectares, approximately 64% of the district. No significant changes in land cover are expected in this area because of the conservation based policy administered by the Department of Conservation.

The remaining 355,200 hectares encompasses our towns and rural areas available for productive purposes.

The data available for this report is from LCDB3 which is derived from 2008/9 satellite photography. This data indicates that exotic forests cover 107,200 hectares (11%) and is mainly situated on the Moutere Gravels and Eastern Hills. Pastoral areas cover 126,400 hectares (13%) and are found throughout the district on the valleys, plains and on the gentler Moutere Gravel hill country.

Horticulture, including market gardening, viticulture and cropping occupies 10,800 hectares (1.1%) and is mainly situated on the Waimea and Motueka Plains. Small areas of pipfruit and viticulture are still found on the coastal areas of the Moutere Gravels.

Urban areas occupy 3,034 hectares (0.31%) of the area.

From the LCDB datasets, between 1996 and 2008, the major changes in land cover have been:

- a 10% increase in exotic forestry by 9,750 hectares
- a 17% decrease in pasture by 21,152 hectares
- a 95% increase in horticulture, viticulture and cropping by 5,266 hectares
- a 55% increase in urban coverage by 1,073 hectares
-

Statistics NZ data suggest a much smaller increase in the amount of horticulture than the LCDB data. Accurate information is difficult to obtain for all sectors involved. Accurate information can be obtained from some of the industry bodies involved. New Zealand Winegrowers indicate a 100% increase in land used for viticulture from 480 ha in 2002 to 1,011 ha in 2012.

Although general land use change can be inferred from the LCDB data sets more specific information is required to understand the trends and relate them to what pressures are being placed on the land and soils in the region.

Dairy

Nationally dairy farming has increased in area and cow numbers. For the 10 year period 2003 to 2013 the national herd has increased by 28%, with the area dairying covers increasing by 15%. The stocking rate has increased 11% from 2.56 cows per hectare to 2.85 cows per hectare (Dairy NZ 2013). This expansion and intensification has put pressure on soil and water resources.

The trend in the Tasman district is quite different: Dairy cow numbers have increased 1.2% from 54,580 to 55,227 cows. The stocking rate has marginally increased from 2.6 to 2.63%.

Golden Bay contains 53% of the district's dairy herd, Murchison 27%, Upper Motueka 14%, Moutere and Waimea combined is 6 %.

Statistics NZ Agricultural (Statistics NZ, 2015) tables provides detail in the changes in stock numbers over the years. There has been a significant decline in the number of livestock in the region over the past 10 years.

Sheep

For the 10 year period 2003 to 2013, in Tasman the flock dropped 44% from 402,925 to 265,858 sheep.

Beef

For the 10 year period 2003 to 2013, in Tasman the beef herd dropped 35% from 56,155 to 42,268 cattle.

Deer

For the 10 year period 2003 to 2013, in Tasman the deer herd dropped 67% from 33,537 to 14,259 deer

Waimea Water Management Area

This area includes the Waimea and Wai-iti catchments as well as all the tributaries of the Waimea Inlet. This is the same as the Freshwater Management Unit set up under the National Policy Statement for Freshwater Management (2014) except for the addition of sites flowing into the eastern arm of the Waimea Inlet.

In this area, there were 12 River Water Quality sites monitored between 2010 and 2014 (Figure 21). There are no reference sites in this area without some potential impact upstream (Reservoir Creek upstream Marlborough Cres and Wairoa upstream Pig Valley both have relatively significant areas of exotic forestry upstream).

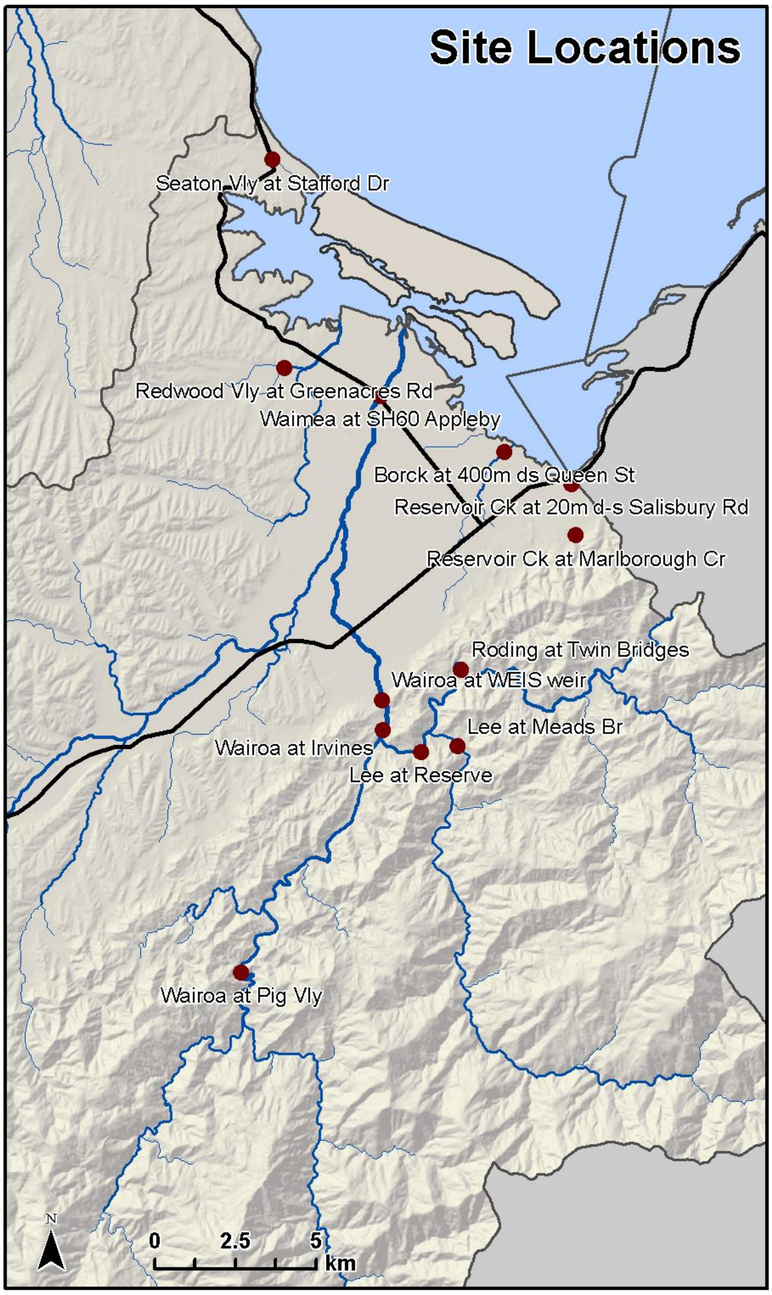


Figure 21. River Water Quality sites in the Waimea Water Management Area

Discussion of Specific Catchments/Areas

This section describes the more **notable aspects of water quality in a given catchment, actions taking place, and recommendations** for further action.

Attribute State
A (Excellent)
B
C
D (Poor)

The key to the colour-coding for each water quality attribute state (A to D) is shown to the right. The cut-offs used for each attribute are shown in Table 10.

The dataset used to determine the attribute states was collected at base-flow over the period from 2010-2014 unless a comment is made otherwise. White (no colouring) indicates there are no data available to determine the attribute state.

Trends in water quality attributes are reported if they are statistically significant (p-value<0.05) and ecologically meaningful (RSKSE>1%). An increasing trend can have a positive or negative effect on the stream ecosystem, depending on the attribute. To indicate the ecosystem effect of the trend, we have used a smile symbol (☺) for improving trends and a frown symbol (☹) for degrading trends.

Table 10. Numerical attribute states for each water quality attribute for the protection of river ecosystem health, aesthetics, and human health. Attributes highlighted in blue are included in the National Policy Statement for Freshwater Management (NPSFM 2014).

Attribute	Statistic	Units	Attribute State				Source
			A	B	C	D	
Water clarity	Single measurement	m	≥5	3 - 5	1.6 - 3	<1.6	-
Turbidity	Single measurement	NTU	≤5.6	>5.6	N/A	N/A	ANZECC & ARMCANZ (2000)
Resuspendable solids	Shuffle score (1 to 5)	N/A	1	2	3	≥4	-
Dissolved oxygen concentration	7-day mean minimum	g/m^3	≥8	7 - 8	5 - 7	<5	NPSFM (2014)
	Lowest 1-day minimum	g/m^3	≥7.5	5 - 7.5	4 - 5	<4	
Water Temperature	Midpoint of daily mean and daily maximum	°C	≤18	18 - 20	20 - 24	>24	Davies-Colley et al. (2013)
pH	Single measurement	N/A	6.5 - 8.5	5 - 6.5, 8.5 - 9	>5 or >9	N/A	-
Ammonia-N	Annual median	g/m^3	≤0.03	0.03 – 0.24	0.24 - 1.3	>1.3	NPSFM (2014)
	Annual maximum	g/m^3	≤0.05	0.05 - 0.4	0.4 - 2.2	>2.2	
Nitrate-N	Annual median	g/m^3	≤1.0	1.0 - 2.4	2.4 – 6.9	>6.9	NPSFM (2014)
	Annual 95th percentile	g/m^3	≤1.5	1.5 - 3.5	3.5 - 9.8	>9.8	
Dissolved reactive phosphorus	Single measurement	g/m^3	<0.01	≥0.01	N/A	N/A	ANZECC & ARMCANZ (2000)
E. coli	Annual median	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	NPSFM (2014)
	95th percentile	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	
Macroinvertebrates	MCI	N/A	≥120	100 - 120	80 - 100	<80	Stark & Maxted (2007)
	SQMCI	N/A	≥6	5 - 6	4 - 5	<4	
Phormidium	Percentage cover	%	<20	≥20	N/A	N/A	MfE (2009)
Filamentous green algae	Percentage cover	%	<10	10-19	20-29	>30	Biggs and Kilroy (2000)
Periphyton	Periphyton score (1 to 10)	N/A	≥8	6 - 8	5 - 6	< 5	-

How to read a site summary

The site summaries in this report are based on data collected quarterly (monthly for selected sites) from 2010-14, with two exceptions: (1) macroinvertebrate community index values were from 2011-2015 and (2) dissolved oxygen measurements were taken over several days in a summer period from 2005-2015.

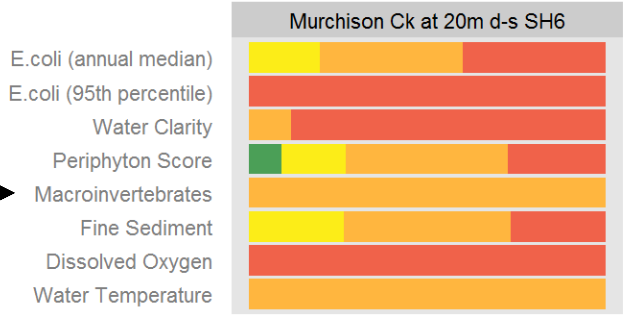
The rows of a site summary represent water quality attributes. The colours indicate attribute states **A** (very good), **B** (good), **C** (fair) and **D** (poor).

Proportion of periphyton scores in each attribute state.

Proportion of water clarity measurements (m) in each attribute state.

Attribute state for the 95th percentile *E. coli* concentration. Minimum 10 samples.

Attribute states for the annual median *E. coli* concentration. No minimum sample size.



Proportion of macroinvertebrate community index (MCI) values in each attribute state.

Attribute state for the highest midpoint of daily mean and daily maximum temperature from a continuous record.

Attribute state for the mean minimum dissolved oxygen concentration over 3 or more days during summer. For sites with fewer than 3 days of continuous measurements, the 1-day minimum value was used.

Proportion of resuspendable solids (fine sediment) scores in each attribute state.

Water Clarity

The Waimea River and tributaries has excellent water clarity for most of the time at base flows. However, in the lower reaches water clarity is one third less on average than at Irvines (the next site upstream) (median from 2010-2015:4.9 m compared to 7.3 m). Small creeks such as Reservoir, Borck, Redwood Valley and Seaton Valley all have much poorer water clarity and have recorded significant disturbance by various activities upstream and have soft, fine material in the banks that are susceptible to erosion.

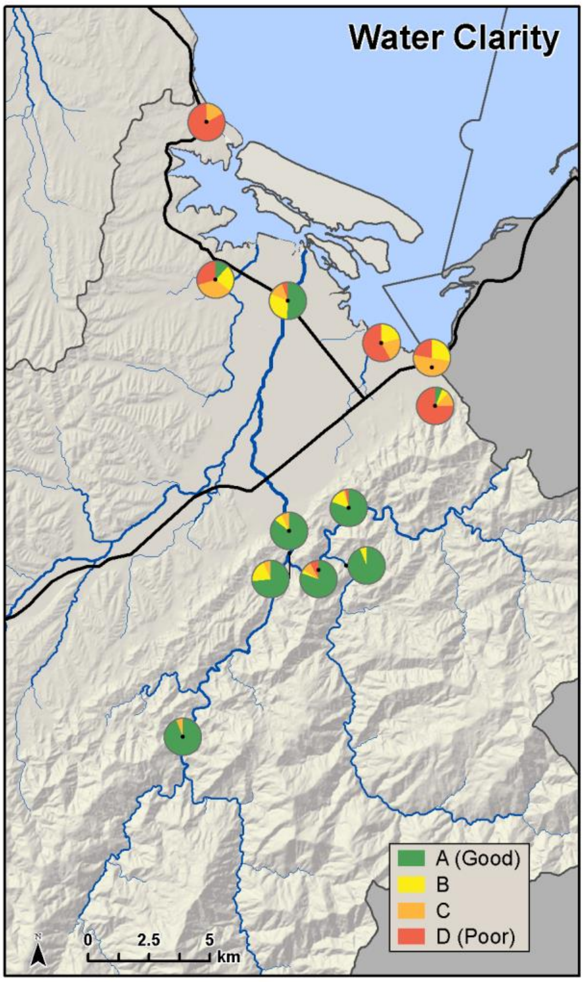


Figure 22. Proportion of water clarity records in each attribute state (A to D) for river water quality sites in the Waimea Water Management Area (sites shown have a minimum of 10 samples).

Disease-causing Organisms

Annual median *E. coli* concentrations were 'excellent' (less than 260 MPN/100 ml) at 7 of the 12 monitored sites. This is a welcome result as swimming and other contact recreation occurs at these sites. Two sites exceeded the National Bottom Line annual median *E. coli* concentration (1000 *E. coli*/100 ml) in any year: Seaton Vly at Stafford Dr (median value 1100 *E. coli per 100 ml* in 2010) and Borck at 400 m ds Queen St (median value 1050 *E. coli* per 100 ml in 2012).

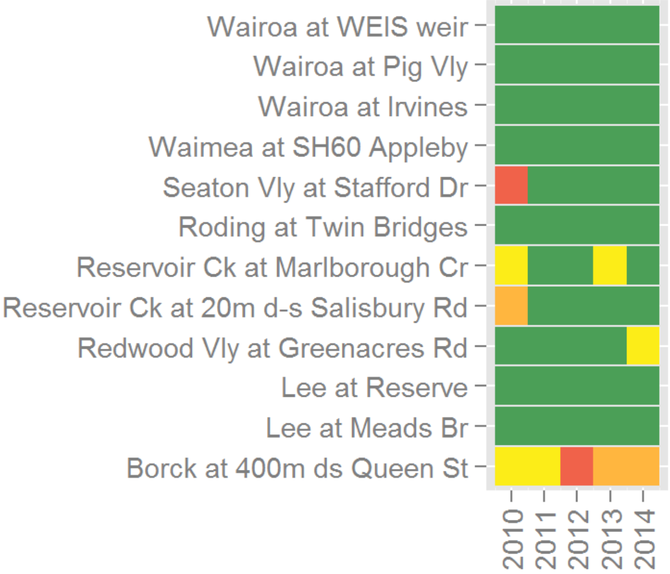


Figure 23. Tile plot of annual median *E. coli* values for sites in the Waimea Water Management Area. Colours indicate attribute states A (green), B (yellow), C (orange) and D (red). Annual median values were calculated for sites with three or more records in a given year.

Filamentous Green Algae Cover & Periphyton Score

For most of the time, the coverage of filamentous green algae in the Waimea Water Management Area was low (less than 10% coverage). On at least three occasions, more than 50% coverage (category D) was recorded for Borck at 400 m ds Queen St, Redwood Vly at Greenacres Rd and Seaton Vly at Stafford Dr.

In line with this high coverage these sites had relatively low periphyton scores[5]. The Redwood Vly and Borck Creek sites, in particular, had a high proportion of periphyton scores in category D, indicating poor water quality at this site. From about December-April Borck Creek is spring-fed and so does not get flushing flows. This coupled with relatively high nutrient concentrations and limited shading of the stream promotes filamentous green algae growth.

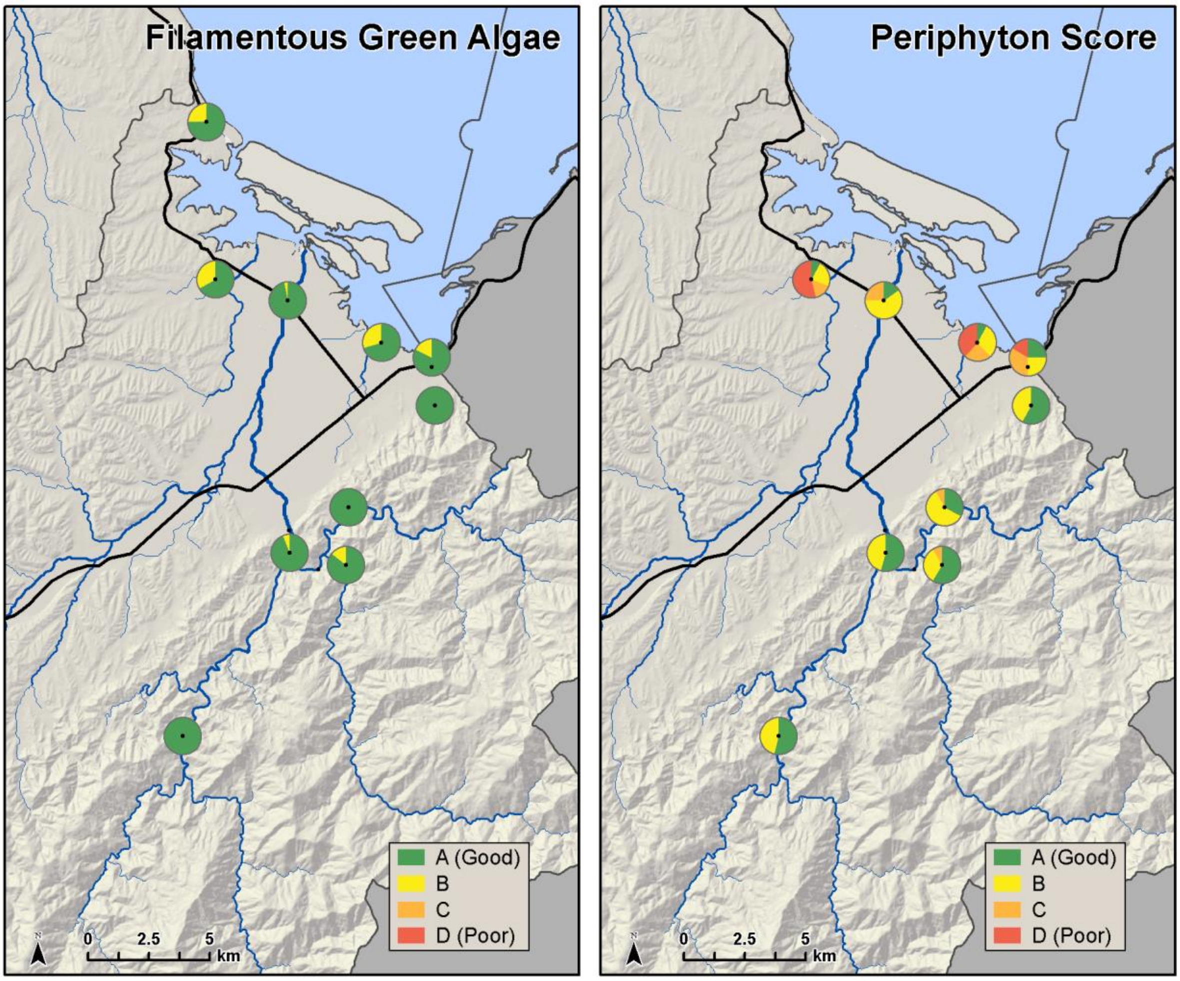


Figure 24. Coverage of filamentous green algae greater than 2cm in length (left) and periphyton community score (right) for sites in the Waimea Water Management Area. Pie charts show the proportion of estimates in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

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[5] Rapid Assessment Method 2, NZ Periphyton Monitoring Manual, 2000.

Nutrients

Annual median nitrate and ammonia concentrations were available for three sites in the Waimea Water Management Area. Annual median ammonia concentrations were within band A (less than 0.03 g/m^3) for all three sites. Waimea at SH60 Appleby and Redwood Vly at Greenacres Rd had annual median nitrate concentrations in band A (less than 1 g/m^3). High nitrate concentrations were recorded for Borck at 400 m ds Queen St, with annual median values in bands C (2.4 to 6.9 g/m^3) and band D (greater than 6.9 g/m^3). Band D is below the National Bottom Line and nitrate concentrations in this range are normally expected to impact the growth of multiple aquatic species.

Nitrate toxicity has recently been found to be mitigated strongly by water hardness (through high calcium carbonate content). All the waterways with the highest nitrate concentrations also had high hardness, high enough that toxicity is unlikely to ever be an issue (Hickey, 2015). This means that nitrate is only an issue with respect to promoting excessive filamentous green algae growth.
The dissolved reactive phosphorus (DRP) results were mixed. There was only one unsatisfactory result for Waimea at SH60 Appleby out of 31 samples (DRP greater than 0.01 g/m^3). For Redwood Vly at Greenacres Rd, however, 53% (10 out of 19) of the DRP records were unsatisfactory. And for Borck at 400 m ds Queen St, 37% (7 out of 19) of the DRP records were unsatisfactory. The highest single result was for Borck at 400 m d-s Queen St in Winter 2014 (0.038 g/m^3).

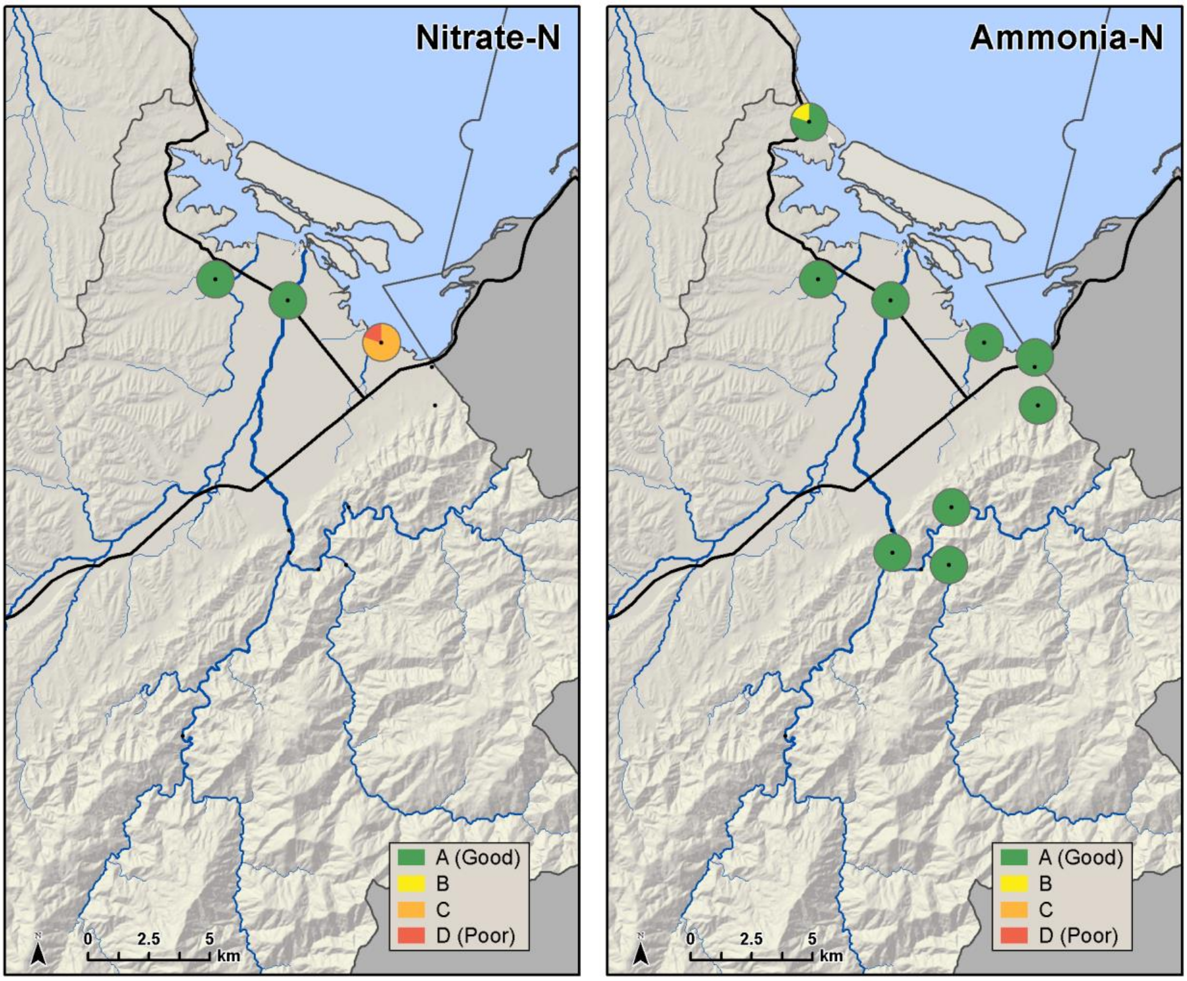


Figure 25. Nitrate (left) and ammonia (right) concentrations for sites in the Waimea Water Management Area. Pie charts show the proportion of annual medians in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

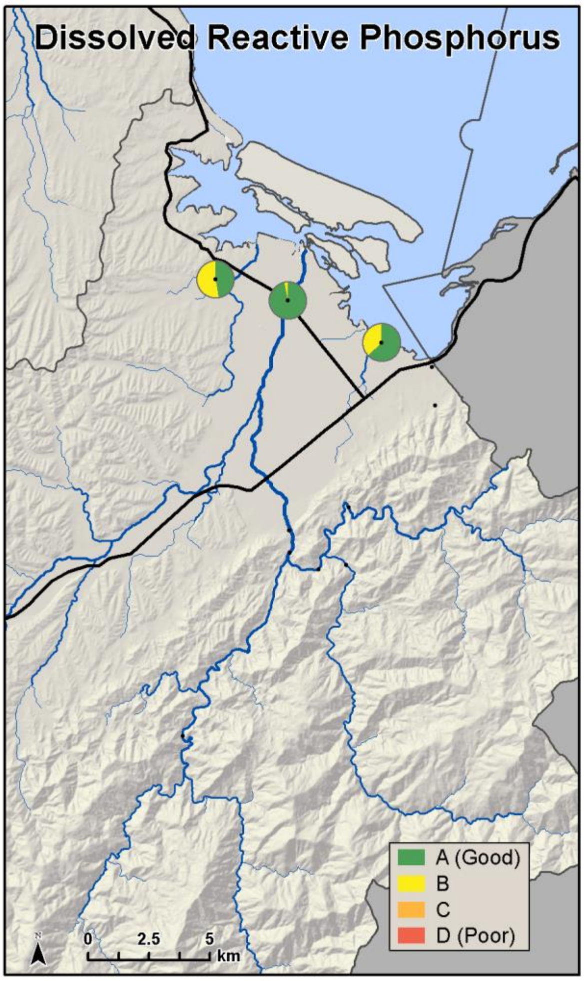


Figure 26. Dissolved reactive phosphorus (right) concentrations for sites in the Waimea Water Management Area. Pie charts show the proportion of records in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

Resuspendable Sediment

Volumetric SBSV data were available for three sites (Figure 27). Despite the large variation in mean volumetric SBSV at Reservoir Ck at Marlborough Cr, there was evidence of an increase in this measure between 2012 and 2015 maybe as a result of the reconstruction of the Reservoir dam in 2013 or sediment from forestry activity still making its way down the stream. The 2015 result for this site was one of the highest in the district (the mean SBSV across all 27 sites in 2015 was 70 L/m^3, SD = 78).

The worst performing site, in terms of resuspendable sediment scores (assessed on a semi-quantitative scale from 1-5), was **Seaton Vly at Stafford Dr**. At this site, about 90% of scores were four or above. In much of the lower section of this stream, for 1km upstream of Stafford Dr, there is fine sediment over a cobble base and upstream of that the bed is dominated by cobbles with very little fine sediment. Downstream of Stafford Dr the fine sediment is over a sand base. The only other site with a score in band D was Reservoir Ck at Marlborough Cr (Figure 28).

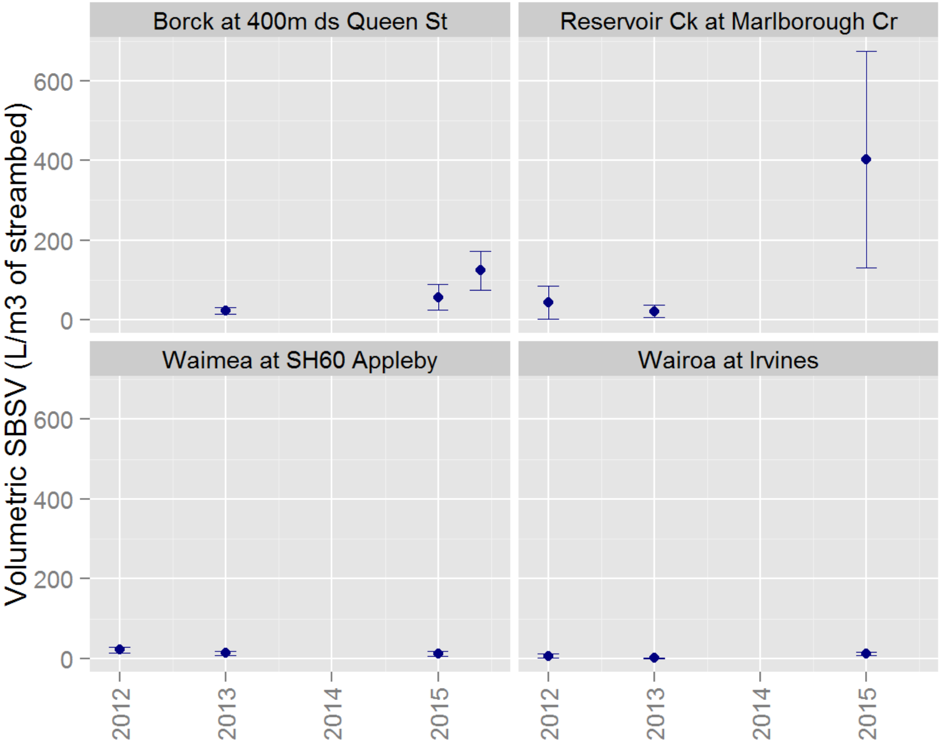


Figure 27. Mean volumetric suspendable benthic sediment volume (SBSV) from 2012 to 2015 (sampled during summer). The error bars show 95% confidence intervals.

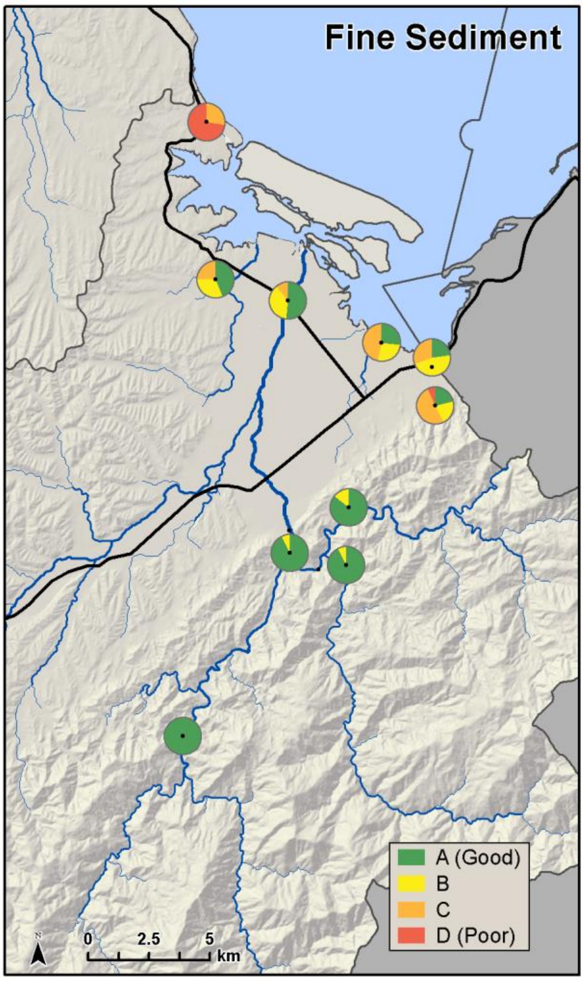


Figure 28. Proportion of fine sediment (resuspendable solids) scores in each attribute state (A to D) for sites in the Waimea Water Management Area.

Macroinvertebrate Community

From 2012 to 2015, there was a decrease in MCI values for Redwood Vly at Greenacres Rd from almost 100 to less than 50. This decrease places the two most recent results for the site in the poor category. The two most recent results for Borck at 400 m ds Queen St, Reservoir Ck at 20 m d-s Salisbury Rd and Seaton Vly at Stafford Dr were also in the poor category. Wairoa at Irvines had the highest MCI and SQMCI scores in the Waimea Water Management Area. Most monitored sites had SQMCI values in the poor range.

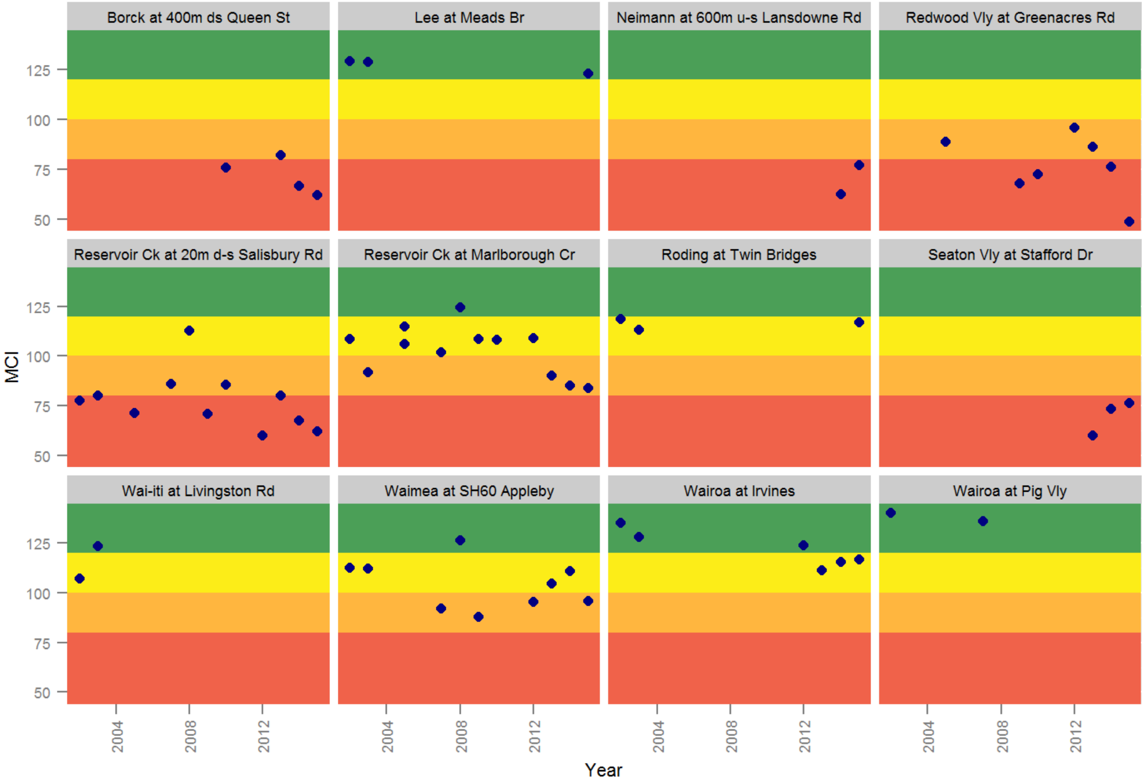


Figure 29. Macroinvertebrate community index (MCI) scores between 2001 and March 2015 for sites in the Waimea Water Management Area (larger blue dots). The background colours indicate these attribute states: excellent (green), good (yellow), fair (orange) and poor (red).

Differences between Paired Sites

This section compares the difference (increase or decrease) between two sites on a particular waterway on a particular day. The differences are then averaged to get the "mean difference". It is not the difference of the mean from each site calculated from the whole record for one site with the mean from the whole record from other site.

Wairoa at Irvines (upstream) was paired with Waimea at SH60 Appleby (downstream). The ***E. coli*** results, over the five-year reporting period, were similar (mean difference = -1.7 *E.coli*/100 mL, Figure 30). The macroinvertebrate community was in a slightly poorer condition at the downstream site (mean difference = -15 MCI units).

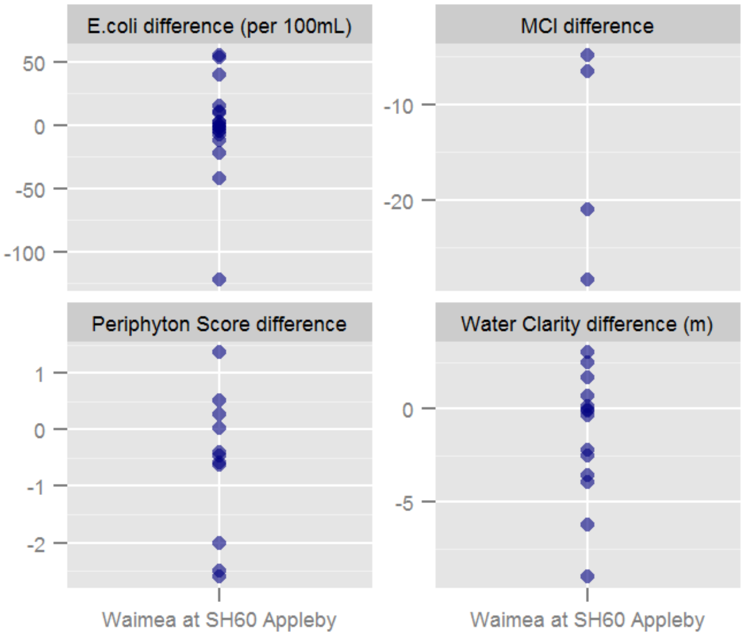


Figure 30. Difference between Wairoa at Irvines (upstream) and Waimea at SH60 Appleby (downstream) for water quality data collected at both sites on the same day. A positive difference means the downstream site had a higher value than the upstream site.

Trends in the Waimea WMA

For sites in the Waimea Water Management Area, there were trends in *E. coli*, water clarity, dissolved reactive phosphorus and ammonia-N measurements. The only site in this Area with degrading *E. coli* concentrations was Reservoir Ck at 20 m d-s Salisbury Rd. There was also only one site with improving *E. coli* concentrations (Wairoa at Irvines). An improving trend in dissolved reactive phosphorus concentrations was found for Waimea at SH60 Appleby over both 10 and 15 year time spans (**Error! Reference source not found.**).

Table 11. Water quality trend results for sites in the Waimea Water Management Area over the 10-year period 2005 to 2014 (highlighted in blue) and over the full record (15 to 26 years depending on the site). Seasonal Kendall trend tests were used for *E. coli* concentrations, water clarity measurements and nutrient concentrations (Ammonia-N, Nitrate-N and DRP). The trends shown are significant ($p < 0.05$), meaningful (RSKSE > 1% per year) and the change in value between the start and end of the trend line is greater than the detection limit for the attribute (refer to the Methods sections for the detection limits). Statistics are shown in the Appendices.

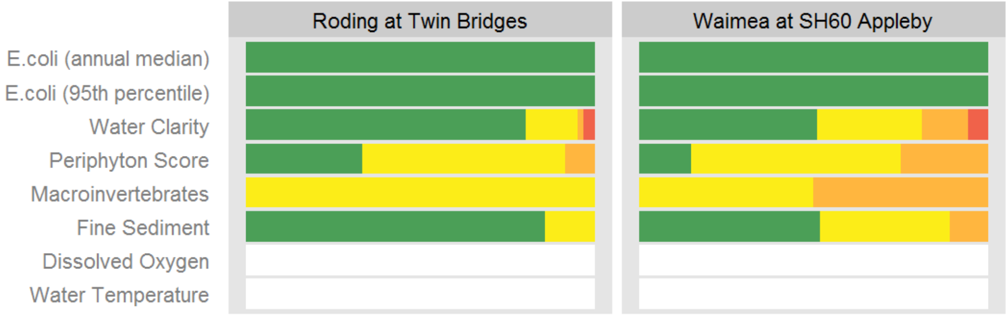
Site name	**Attribute**	**Effect** ☺ ☹	**N obs**	**N years**
Reservoir Ck at 20 m d-s Salisbury Rd	Ammonia-N	☺	56	15
Reservoir Ck at 20 m d-s Salisbury Rd	*E. coli*	☹	40	10
Reservoir Ck at Marlborough Cr	Ammonia-N	☺	38	10
Reservoir Ck at Marlborough Cr	Water Clarity	☺	36	10
Waimea at SH60 Appleby	DRP	☺	51	10
Waimea at SH60 Appleby	DRP	☺	69	15
Wairoa at Irvines	*E. coli*	☺	61	16

Waimea-Wairoa-Lee-Roding Catchment

Wairoa Rv upstream Pig Valley (October 2006)

Swimming and picnicking in this catchment are extremely popular with a total of 115,000 person swimmer days estimated over the 2009-10 season (James, 2010). That equates to almost two swims for every person in the Nelson and Richmond township (but visitors to the region will make up a proportion of this). Other contact recreation such as kayaking is also popular. After this level of contact recreation was discovered the monitoring frequency at the main Roding and Lee bathing water quality monitoring sites was increased to twenty times per year (November-March). Fish populations in the upper part of this catchment are sparse, possibly due to the influence of the ultramafic geology. The monitoring site upstream of Pig Valley is influenced by about 45km^2 of plantation forestry, much of which was harvested in the period 2005-2015.

Water quality meets standards or guidelines the vast majority of the time. It is good news that turbidity levels and faecal indicator bacteria are declining at the Irvines monitoring site on the Wairoa (downstream of the confluence of the Lee River).



**Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.**

Generally, rivers in this catchment have **very good water clarity** in base flows (medians: Roding 7.2 m, Lee 8 m, Wairoa at Irvines 7.5 m, Waimea SH60 5.1 m).

Daily maximum **water temperatures** regularly exceed 21.5°C in summer, with midpoint of daily mean and daily maximum at about 22°C (continuous sampling 17-21 Feb, 2014). Minimum daily **dissolved oxygen** was about 70 % saturation over this period.

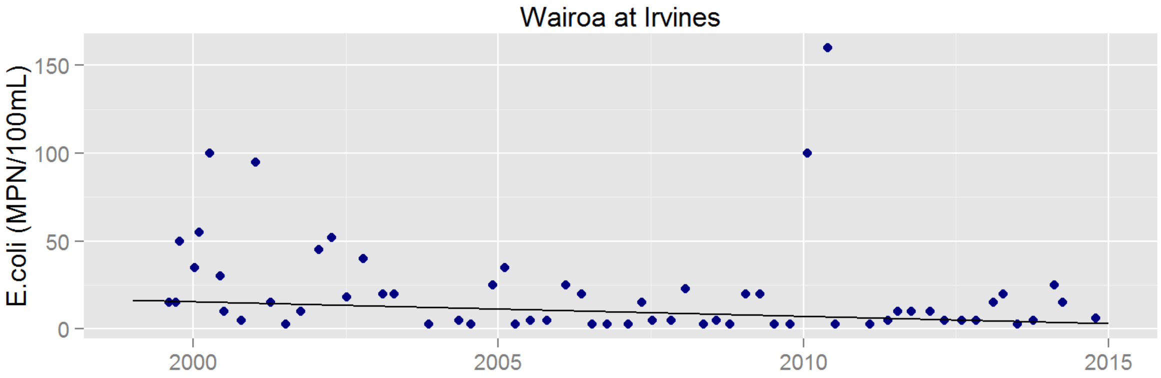


Figure 31. Wairoa at Irvines *E. coli* data with 16-year trend line (p = 0.0032, RSKSE = -8.3% per year). No significant meaningful trend was detected over the most recent 10 years of the record.

The 'State of the Environment' monitoring site on the lower river shows relatively few kinds of invertebrates and a limited number of the more sensitive kinds, resulting in lower than expected MCI scores (typically 90-115). However, there are also few of the pollution-tolerant taxa. A study by NIWA showed parts of the upper-mid Waimea River, that are highly disturbed by recreational and gravel-carting vehicles, have very poor macroinvertebrate condition (Kelly *et al.* 2005). Recreational 4WD vehicles regularly drive up and down the Waimea River, crossing through the water at the shallow areas (riffles). The **impact of vehicles on riffle-dwelling fish species** such as Torrentfish, blue-gilled and red-fin bullies is of concern as these species are recognised as “in decline”. Another potential reason for the relatively poor MCI is the elevated water temperatures.

High concentrations of dissolved nitrogen and phosphorus may stimulate periphyton growth leading to unsightly blooms that will potentially affect dissolved oxygen and pH, and reduce habitat quality. **Filamentous green algae cover in the Waimea River can get to nuisance levels (>30%) in summer**. During summer low flow periods the single-celled, phytoplanktonic algae, *Cryptomonas*, blooms in the lower Waimea River (see photo below). This single-celled algae proliferates in the saltier water near the mouths of waterways with elevated nutrients. Higher-nutrient groundwater could be upwelling in this area. To many people this algae looks unsightly. Higher up in the catchment (lower Wairoa and Lee Catchments) filamentous green algae can get to about 30% cover in riffles, but in the river as a whole coverage is <5%.

The Waimea River has one of the highest concentrations of *Phormidium* in Tasman district and two dogs are suspected to have died from ingesting this over the 2014-15 summer period. This **toxic algae covers as much as 60% of the bed of the Waimea River** downstream of Wai-iti River to about SH60. However, **coverage is very low (<2% of wetted bed) in the Wairoa, Lee and Roding rivers**. This could be due to the higher nitrate concentration in this area than in the Wairoa (typically increases from 0.5 to 1.5 g/m^3) and low phosphorus concentrations (typically <0.001g/m^3).

A Cryptomonad algal bloom in the lower Waimea River (November, 2014).

Water from the **Waimea plains** (particularly the lower Wairoa River, and Waimea River) and associated aquifers, is taken for irrigation and domestic use. However, this **water is over-allocated** and the current low flows have been shown to adversely affect the ecological health of the waterway (Young and Allen, 2013). In order to address this problem and meet the strong demand for more water, to increase land productivity and a growing population, a 13.4 million cubic meter capacity **dam** is proposed for the mid-upper reaches of the Lee River. Lower triggers for rationing of water takes have now been instituted for the Waimea River with or without the dam. Without the dam there will be a significant claw-back of water taken in order to reduce these adverse effects.

The **potential effects of the Lee dam** on water quality are considered minor or able to be mitigated by providing flushing flows (up to three flushing flows over 5 m^3/sec for >3 hours from November-April inclusive aimed at interrupting any periods of low flow >40 days) and good practice during dam construction (Young and Doehring, 2014). However, providing fish passage over the dam for red fin bully and longfin eel (downstream only with hydro-electric generation) will be challenging, and some off-set mitigation is recommended. There are potential indirect effects of the dam as more water available for irrigation could increase nitrogen leaching to groundwater, particularly on Ranzau soils where leaching rates are highest. Modelling (using SPASMO) has shown that, compared with nitrogen losses from current land uses, full irrigation within the Lee Dam service zone could increase nitrogen concentrations entering the groundwater by 23% and in a hypothetical worst case by up to 50% if the entire plains were converted to irrigated market gardening (Fenemor, 2013). These increases, however, are mitigated (diluted) by increased drainage rates to groundwater of 6% and 19% respectively caused by the increased irrigation. The effect of this on surface water would be most prominent in spring-fed streams in the lower Waimea Plains, particularly Neimann Creek.

Based on the ratios of nitrogen to phosphorus in the spring-fed streams (Figure 32), it is likely that algal growth in these systems is limited by phosphorus rather than nitrogen (i.e. N:P ratios >15), and therefore increases in nitrogen concentrations are unlikely to result in increased growth or biomass of nuisance algae within the spring-fed streams. Nevertheless, it can be difficult to predict if one particular nutrient is limiting.

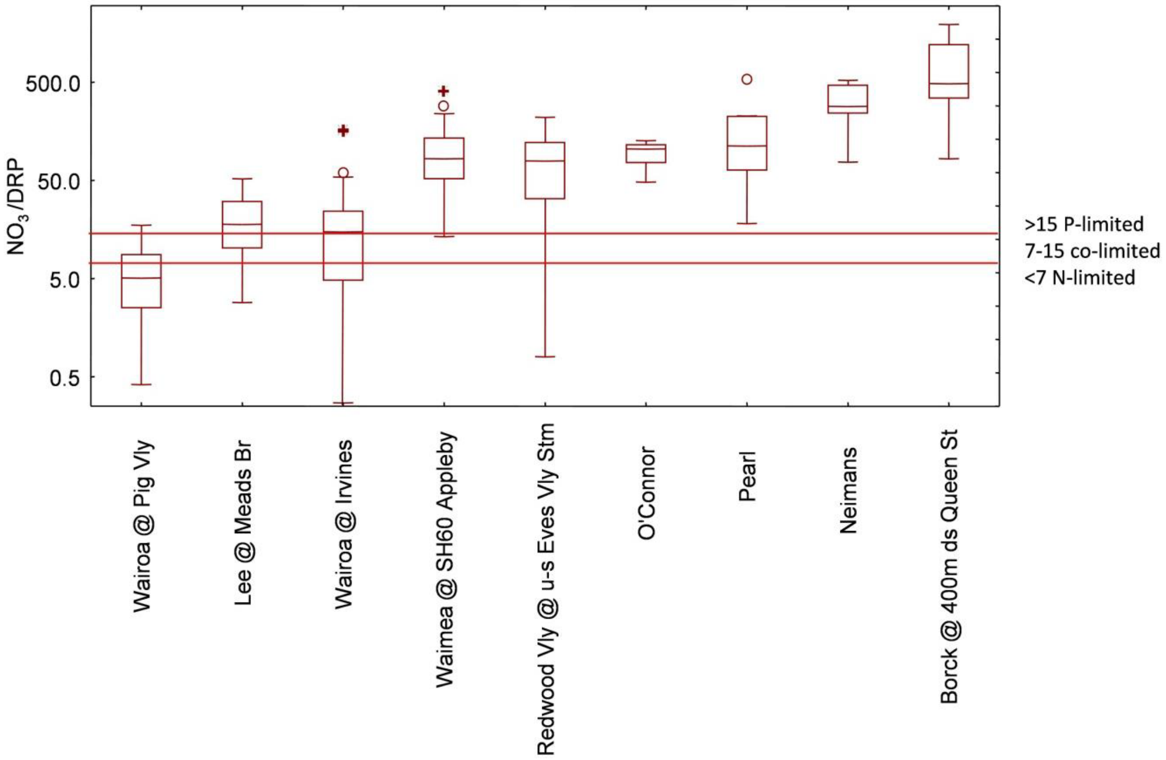


Figure 32. Patterns in the NO3/DRP ratio for sites around the Waimea Catchment. Algal growth at sites with ratios greater than 15 is likely to be phosphorus limited, while growth at sites with ratios less than 7 is likely to be nitrogen limited. Data are primarily from TDC state of the environment monitoring (1999–2012) and in the case of O'Connor, Pearl, Neimans and Borck from Gillespie et al. (2001).

Catchment Statistics	Waimea at SH60	Wairoa at Irvines	Lee at Meads Br	Roding at Twin Br	Wairoa at Pig Vly	Wai-iti at Livingston
River Environment Class	Cool wet Soft sedimentary Hill-fed Indigenous forest	Cool wet Hard sedimentary Hill-fed Indigenous forest	Cool wet Hard sedimentary Hill-fed Indigenous forest	Cool wet Hard sedimentary Hill-fed Indigenous forest	Cool wet Hard sedimentary Hill-fed Indigenous forest	Cool wet Soft sedimentary Lowland-fed Pasture
Catchment area (km^2)$^+$	780	462	114	129	164	285
Predominant land use upstream	Indigenous and exotic forest, pastoral, horticulture	Exotic forest	Indigenous and exotic forest	Indigenous and exotic forest	Indigenous and exotic forest	Indigenous and exotic forest, pastoral
Mean annual rainfall (mm)	1030	1090	2,100*	1,720*	2,249*	1080
Mean flow (l/sec)	18,445	16,133	3,696*	3,866*	4,906*	4,034
Median flow (l/sec)	6,780	6,724	NA	NA	NA	1,456
7 day mean annual low flow (l/sec)	1,200 approx	2,200	NA	NA	NA	104
Maximum flow (l/sec)	1,295,200	1,150,873	NA	NA	NA	344,176
Lowest recorded flow (l/sec)	0 (river completely dried in 2001)	1,294	NA	NA	NA	0
Water quality record	2000-present Monthly sampling began July 2013	2000-present	2000-present	2000-present	2000-present	2000-2006

* Estimate from WRENZ 2013. NA = not available

Above Left: Wairoa at Irvines (April 2005), Right: Waimea Rv at downstream of SH60 (May 2007)

Wai-iti River

Water quality in the **Wai-iti River** is also generally **good** (based on sampling from 2000-2005 and occasionally since). Base flow water clarity was high (median: almost 6 m), and concentrations of disease-causing organisms were low (80 E.coli/100 ml) However, both nitrate and phosphorus concentrations were slightly elevated (NO_3-N median: 0.75 g/m^3; DRP median: 0.007 g/m^3). It appears that the source of elevated phosphorus is natural as the upper Wai-iti site which has very little developed land is elevated (80% of dissolved reactive phosphorus samples over 0.01 g/m^3 ; maximum 0.016 g/m^3).

Base flows have increased following the commissioning of the Kainui Dam in 2006. As well as benefiting irrigators in this catchment, these higher base flows have benefited the aquatic ecosystem. Fish passage at this dam is provided for along with the minimum flows. Rock weirs in the lower Wai-iti have been found to restrict the migration of common smelt and inanga. One has been modified with a concrete ramp and others will be modified over time to restore this migration.

Like the lower Waimea River, the lower Wai-iti has relatively high coverage of the toxic algae *Phormidium* during stable base flows in late spring to early autumn. This toxic algae is implicated in the deaths of two young dogs on this river in November 2012 and December 2014. No dog deaths were reported for this catchment prior to that period. There is also the possibility of other factors to do with the nutrients from the Wai-iti River (may be related to the release of water from the Wai-iti dam) that might favour *Phormidium* growth. Another possibility would be the reduction in shear stress as the area coincides with the zone where river water is lost to ground (i.e. the river leaks to the groundwater below).

Phormidium **(the black growth) on the Wai-iti River weir downstream Waimea West Rd.**

Small coastal streams draining to Waimea Estuary

Streams draining coastal Moutere Hill Country with reasonable habitat including riparian tree cover have **valuable aquatic life.** The rare fish, giant kokopu, is still found in some slow-flowing wetland-fed streams in this area. 'Reasonable habitat', in this context, is best described as having natural stream channel meanders, variety of bed substrate sizes including woody debris, variety of water depth and width, variety of bank shape, native riparian tree cover and wetlands in the catchment. The potential for improving water quality and aquatic ecology by re-introducing these features in these streams is high. Even though many of these streams cease to flow for part of the summer, they still support important life in residual pools. Banded kokopu, eels, bullies and inanga, as well as koura and shrimp do well in such pools, provided they are shaded to keep the water cool. Stream-side vegetation will also supply food and 'cover' for stream life. These pool habitats can be degraded or destroyed by stream works, fine sediment discharges from earthworks, large-scale forest harvest and urban development. This sediment can fill the deeper parts of the stream. The presence of wetlands in the catchments in these streams is important to maintain higher flows in summer and reduce the damage to streams during floods.

Spring-fed streams with reasonable flow are not present in the Moutere Hill Country. However, a few alluvial **spring-fed streams** occur on the lower Waimea Plains, such as Borck, Neimann, Pearl and lower O'Connor Creeks. These streams are only short (1-2 km long) and, although historically highly modified, they have great potential for improved aquatic biodiversity. There is moderate risk of nitrate leaching from land uses on the Waimea Plains such as horticulture and dairying. Horticulture on the Waimea Plains is mostly apples (25%, 1257 ha), market gardening (14%, 710 ha), viticulture (13%, 634 ha), with dairy farming making up 5% (585 ha, approximately 1000 cows on the Waimea Plains) (Fenemor *et al*. 2013).

Waimea Estuary is dominated by poorly oxygenated, soft mud/sand sediments spread throughout the middle and upper estuary (Stevens and Robertson 2010 and 2014). The fine muds present mean that the water clarity within the estuary is low and it reduces the range of different habitats and species present. Sea grass, a species critical for creating habitat for many important commercial and recreational fish species, such as gurnard, snapper, kahawai, and flounder, has been displaced by this fine sediment. Best practice suggests that because there is a reasonable amount of urban and farming land-use in the catchments feeding the estuary that the shellfish should be considered unsafe for consumption due to disease-causing organisms (i.e. faecal coliforms) discharged from streams in the catchment. Shellfish sampling carried out off the plume of the sewage discharge from Bells Island shows that on average half are unsafe for human consumption (median 330 faecal coliforms/100g flesh) (Gillespie et al, 2014).

Soft and very soft mud cover was extensive (40%, 1195 ha), mostly in the upper parts of the central basin and sheltered arms (Stevens and Robertson 2014). Very soft mud had increased dramatically since 1999 (from 10 ha to 551 ha), a likely consequence of fine sediment inputs from natural and human-related catchment land disturbance. Opportunistic macroalgal growth was low overall (2.7% of the available intertidal habitat), but dense beds of both *Gracilaria* and *Ulva* were present in localised areas. The biomass, size of affected area (158 ha), and degree of macroalgal entrainment, reflected relatively poor conditions in these areas. Gross eutrophic conditions (combined symptoms of: a high mud content, a shallow apparent Redox Potential Discontinuity (aRPD) depth, elevated nutrient and total organic carbon concentrations, displacement of invertebrates sensitive to organic enrichment, and high (>50% cover) macroalgal growth) affected 28 ha and reflected an estimated increase of >50% since 1990. Seagrass cover (34 ha, 1% of estuary) was very low and had declined by 41% since 1990. Losses are attributed primarily to excessive fine mud.

While a lot of the source of this sediment within the estuary is very likely to be from historic practice on horticulture land, the current load is unknown. Projects are under way to determine this load. A high rainfall event in December 2011 (281 mm in 48 hours[6]) brought large amounts of sediment down waterways off the Barnicoat Range. Another very high rainfall event was experienced along the Barnicoat Range in April 2013 with rates of 100 mm/hour recorded at Roding at Caretakers.

Gravel and debris is collected in in-stream traps and ponds in most urban waterways in Richmond-Nelson. This starves the bed supply downstream and leads to increased erosion and habitat degradation. There is also an adverse effect on the estuary as this gravel is important substrate for many saltmarsh plants, as well as raising the estuary to help mitigate against sea level rise.

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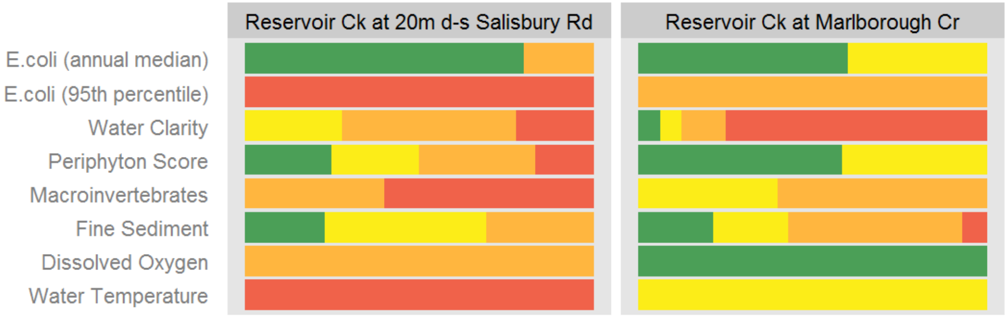
[6] Average December rainfall is 85 mm.

Reservoir Creek, Richmond

This creek begins in a steep gully on the Barnicoat Range below the rural fire service lookout and enters the Waimea Estuary near the ASB Aquatic Centre. The Creek is enjoyed by many who use the walking tracks that run alongside much of its length. Like most urban streams, Reservoir Creek is subject to contaminant discharges from private urban sections, as well as bigger flood flows and lower dry-weather flows because of the high percentage of impervious surface in the catchment. There are two sections of the creek that are piped (one under Hill St and one 180 m further upstream; 470 m total length), and two ponds, one of which was the old water supply reservoir for Richmond built in the 1800's about 1.3km upstream of Hill St. The riparian zone of the creek upstream of the Reservoir contains significant old-growth native trees and is an average of 150 m wide on both banks combined. This riparian zone was damaged by pine logs sliding or rolling down the steep hillsides when the forest harvest occurred in 2008. Floods in December 2011 and April 2013 caused widespread bank erosion on this stream.

Reservoir Creek at Easby Park (150 m upstream Marlborough Cres; July 2013)



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

Upstream of the Marlborough Crescent monitoring site (Easby Park) cattle have access to the creek resulting in high loads of fine sediment and disease-causing organisms (median: 200 *E.coli*/100 ml/100 ml (median for 2005-2009 was 75 *E.coli*/100 ml/100 ml) and exceedance of stock drinking water guidelines about 6% of the time). Stillwater Creek, a tributary of Reservoir Ck joining near Templemore Drive, had particularly high levels of *E.coli* at a site about 80 m downstream Hill St where many ducks frequent the wider sections of the creek, attracted by regular feeding. While the site at Marlborough Crescent shows no trend, there is a meaningful degrading trend in *E.coli* at the Salisbury Rd site.

Water clarity at the Marlborough Crescent site is amongst the lowest in the district (median 1.3 m). However, it does appear to be improving (although this could be because of more rigorous use of a mirror when using the black disc. Mirror is used at this site because there is limited length of deeper sections of this creek).

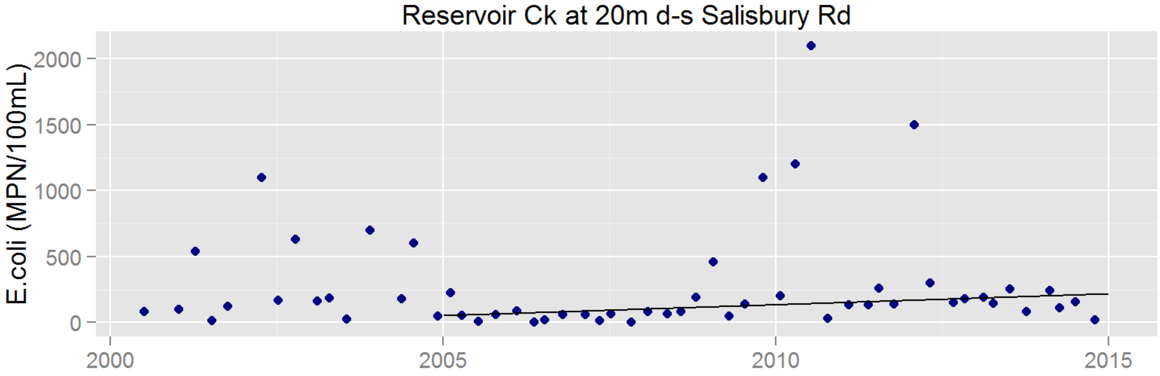


Figure 33. Reservoir Ck at 20 m d-s Salisbury Rd *E. coli* data with 10-year trend line (p = 0.0055, RSKSE = 12.2% per year). No significant meaningful trend was detected over the full record (15 years).

There was relatively **high fine sediment loading** to this creek relating to the following activities:

- Construction of the underpass at Salisbury Rd in November 2005 where 10-15 m^3 of fine sediment was estimated to have been discharged downstream.
- Earthworks, particularly road and skid site construction, associated with a forestry operation in the upper catchment from Autumn 2008 led to discharges of a considerable amount of fine sediment. Inadequate cut-outs on road water tables and lack of diversion of clean water onto skid sites probably gave rise to most of the sediment discharged. Council also received numerous complaints about the very poor water clarity at this time.
- Earthworks associated with decommissioning (lowering of the dam face) of the Reservoir in 2013. At one stage the only sediment trapping device (hay bales and geotextile) that was in place during a period of extensive land disturbance and top-soiling was in the creek below the works. Unfortunately when the works were completed this device was simply removed and the sediment collected behind it allowed to discharge downstream. This lead to several cubic meters of sediment discharging downstream.

Compared to other streams in the Richmond (and Nelson) urban area, concentrations of toxic chemicals, such as heavy metals and poly-aromatic hydrocarbons, in Reservoir Creek stream sediments are low and well within guidelines (Easton & James 2010).

Reservoir Creek at the Reservoir Spillway (Nov 2014)

Dissolved oxygen levels appear to be **satisfactory** (daily minima at Salisbury Rd of about 70% and 90% at upstream Marlborough Cres; measured continuously for five days in February

2009; daily plots show flat bottoms indicating good re-aeration rates which probably reflect the reasonable gradient and water turbulence of this stream).

Water temperature in Reservoir creek is elevated in summer (James, 2007). The midpoint of the daily mean and daily maximum water temperatures increased from 19.5°C upstream of Hill St to 25°C at Templemore Drive (about 700 m downstream; these temperatures were similar in both years). A further increase of up to 4.5°C was measured due to Templemore Ponds (built in the stream) downstream of Kareti Dr. There was surprisingly little difference in the patterns of water temperature over the two summers (measured continuously from Dec-Apr in 2005-06 and 2006-07).

Macroinvertebrate Community Index for the **lower reaches** is 60-80 which is **very poor**. High fine sediment content of the bed, uncontrolled discharges from residential areas and elevated stream temperatures are the most likely causes.

An **iwi river health** assessment of the waterway (Passl 2008) indicated that the Creek upstream of the Reservoir was in good health, downstream of the Reservoir it was in poor health due to cattle damage and from there down to Welsh Place the condition was average.

A restoration report (Tasman District Council 2007) was put together, following a four-year community-based project investigating the catchment. Various recommendations for **action to improve the state of this creek** have been documented in the iwi river health assessment (Passl 2008) and Restoration Report (Tasman District Council 2007). Much of the streamside planting along this waterway, within the urban area, has been completed. Fencing is required to exclude cattle within the section upstream of Easby Park. While this was recommended five years ago, there are a few places where cattle still have access to the creek.

Reservoir Ck at Marlborough Cres (January 2002, left) and downstream Salisbury Rd (July 2009, right).

Catchment Statistics	Reservoir Ck at Salisbury Rd	Reservoir Ck at Upstream Marlborough Cr
River Environment Class	Warm Dry Soft sedimentary Lowland-fed Urban	Cool wet Soft sedimentary Hill-fed Indigenous forest
Catchment area (km^2)$^+$	3.1	1.4
Predominant land use upstream	Urban 55% (1.7 km^2) Exotic forest 32% (1.0 km^2) Native forest 10% (0.3 km^2) Grassland 3% (0.1 km^2)	Exotic forest 71% (1.0 km^2) Native forest 21% (0.3 km^2) Grassland 7% (0.1 km^2)
Mean annual rainfall (mm)	1,174.6*	1,174.6*
Mean annual flow (l/sec)	571*	19.91*
Lowest recorded flow (l/sec)	NA	1
Water quality record	2000-present	2000-present

* Estimate from WRENZ 2013. NA = not available

Jimmy-Lee Creek

This small (2.9km^2) catchment is predominantly urban (65%) with about 20% in exotic forestry. The creek is confined to a straightened and walled drain in the lower reaches, then piped upstream of this for over 1 km from SH6 (Gladstone Rd) to almost Washbourne Gardens). In the upper reaches (upstream of Hill St) the creek and riparian zone is close to its natural state. The percentage of impervious surface in the catchment is over 10%.

This creek has **elevated concentrations of disease-causing organisms** throughout most of its length at high flows. Upstream of Hill St microbial source tracking confirmed the source as ruminants (there are a few cattle on a lifestyle bock upstream). Dog faeces is also a likely contributor as tracks along this stream are popular for dog walkers and dog faeces area a common contributor of disease-causing organisms at high flow in or near urban areas. High base-flow concentrations of disease-causing organisms downstream of Washbourne Gardens is most likely due to **high numbers of ducks** in a pond at Washbourne Gardens.

Sampling of sediments of Jimmy-Lee Creek and some ditches draining commercial/industrial areas show small discrete parts of the estuary are **contaminated with zinc** predominately, with some small areas also contaminated with **cadmium, chromium, and poly-aromatic hydrocarbons**.

Jimmy-Lee Creek upstream Washbourne Dr (February 2014)

Dissolved oxygen and **water temperature** were found suitable for ecosystem health when measured during a hot dry three-day period in February 2010.

At a site adjacent to 40 Beach Rd a scum can develop that is so thick that ducks can walk on top of it. It is formed during hot dry periods when algal cover (mostly *Melosira*) is high and the detached algae floats downstream and is flocculated when it drops over a 0.5 m vertical weir. The odour can be strong and has been subject of complaints.

Algal Scum on Jimmy Lee Creek, 27 January 2005

Macro-invertebrate condition in the mid and lower reaches of this waterway is **very poor** (one-off MCI at Washbourne Gardens was 68, and downstream of Queen St it was 56). However, this was much higher upstream of Hill Street (MCI 92). Water sampling shows that **zinc concentrations are up to 6 times** above ANZECC **guidelines** (for 90% level of protection) in the lower reaches and is likely to be coming from road run-off (Easton & James 2010). Zinc concentrations in sediments in Jimmy Lee Creek along Beach Rd were 50-80 g/m^3 (25-40%) higher than ANZECC low sediment quality guidelines and appear to be increasing since 1996 when such sampling first began. Zinc concentrations generally increase downstream, but a sharp increase occurs downstream of Gladstone Rd (SH6). This is presumably from vehicle brake linings and emissions, and this reflects the increase in traffic density in Richmond. The concentration of poly-aromatic hydrocarbons near the mouth of the creek was locally high.

Like most urban waterways without any interception of contaminants from unauthorised discharges (from domestic properties), this creek has experienced a number of incidents causing adverse effects on the stream ecosystem over the last 15 years. For example, a discharge of ant killing chemicals to the creek in 2002 caused the death of many fish (mostly banded kokopu and eels). A foamy white substance has been frequently discharged to the creek over 2014-15 but it has been difficult to trace.

Retro-fitting low-impact urban storm-water design in an urban area with much streamside space is often expensive. This is a much easier task when land is first developed. Given this creek is very highly modified, the benefit-cost ratio for improving the habitat and water quality is relatively low. However, it is recommended that run-off from the busiest roads (such as Gladstone Road, at 18-19,000 annual average daily vehicle count in 2009) be treated. As is encouraging **new buildings to use roofing products with lower leaching rates of zinc,** and the regular monitoring of facilities that use or store hazardous substances. Urban catchment management plans have been under development for some time and will be completed soon. These will support resource consent applications for stormwater discharge to waterways and assist with contaminant management.

In 2011 a trial was set up to determine the debris load in this stream using nets with 5 mm mesh size (see photos below). These were designed with a partial slit in the side to ensure fish could escape. Over the four months that the nets were installed, relatively little inorganic debris was caught (soft drink cans, bottles, cigarette packets etc) compared to the large amount of leaves. Such a device appears to be only effective at reducing a small amount of the rubbish entering the estuary from Richmond. A large proportion of the rubbish load to the estuary is tough to come from more diffuse sources (particularly rubbish blown in the wind).

Jimmy-Lee Ck downstream of Wakatu Dr and piped section. Left: View upstream from near 35 Beach Rd and Right: close-up of coarse rubbish traps (both photos from May 2011)

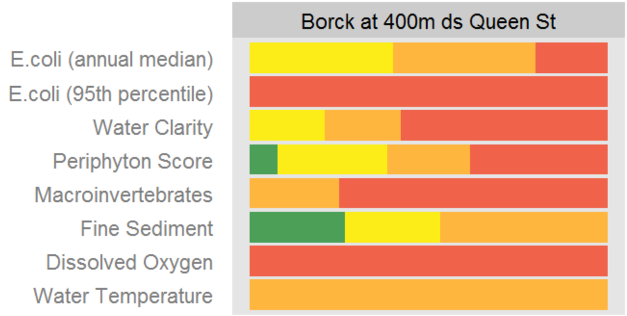
Jimmy-Lee Ck Left: at 35 Beach Rd (December 2009) Right: Upstream of Hill St (December 2009).

Borck Creek, Richmond

Typically for 4-5 months during the driest part of the year the lower 1.8km of Borck Creek is solely fed by water from the Hope Unconfined Aquifer. The groundwater feeding this creek was aged as being about one year old (using tritium and SF_6 methods). Tributaries such as Eastern Hills Creek (flows alongside Bateup and parts of Hart Rd) feed flows on the surface all the way down for the rest of the year. The lower reaches of the creek were straightened in the 1800's when the Waimea swamplands were drained.

Above: Borck Creek near the mouth looking upstream (March 2014)

Land use in the catchment is mostly **horticultural and rural-residential with exotic forest in the headwaters and a little native forest in gullies.** However, the catchment is fast being 'urbanised'. In anticipation of urban growth to the south of Richmond, the lower reaches of the creek are in the process of being widened (began in March 2015). This widening is because there will be increased flood flows with the greater percentage of impervious surface in the catchment. In conjunction with the widening new channels have been created that incorporate the most comprehensive ecological design the region has seen to date for any stream diversion project. In March 2015 this diversion work began by creating a near-natural meander for the low-flow channel, paying attention to achieving a natural variety of depth and width, installing clean gravels to the stream bed and woody debris into the banks to give critical and instant cover for fish, and installing riparian wetlands. Native trees and grasses will be planted right along the stream edge. It is expected that the diversity and abundance of fish and invertebrates in this stream will improve considerably with these measures. It will be important to protect this investment by installing wetlands, and stormwater treatment devices at key locations within the urban area further upstream to ensure water quality does not degrade further.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

The main water quality issues in Borck Creek are the **high nutrient concentrations, the low dissolved oxygen levels in summer, and fine sediment deposits** in the stream. While baseline monitoring of water quality only began in this creek in 2009, the creek water consistently shows very **high concentrations of nitrate** (median nitrate-N: 5.8 g/m^3 from 2009-2015, moderately high concentrations of disease-causing organisms (median 2009-2015: 380 *E.coli*/100 ml) and poor macroinvertebrate condition (MCI score 76).

Dissolved oxygen daily minima in lower Borck Creek were found to be regularly around 50% saturation (10-14 Feb, 2009). The bottom of the curves are reasonably flat indicating that there is reasonable aeration and limited reservoirs of organic matter with high biological oxygen demand.

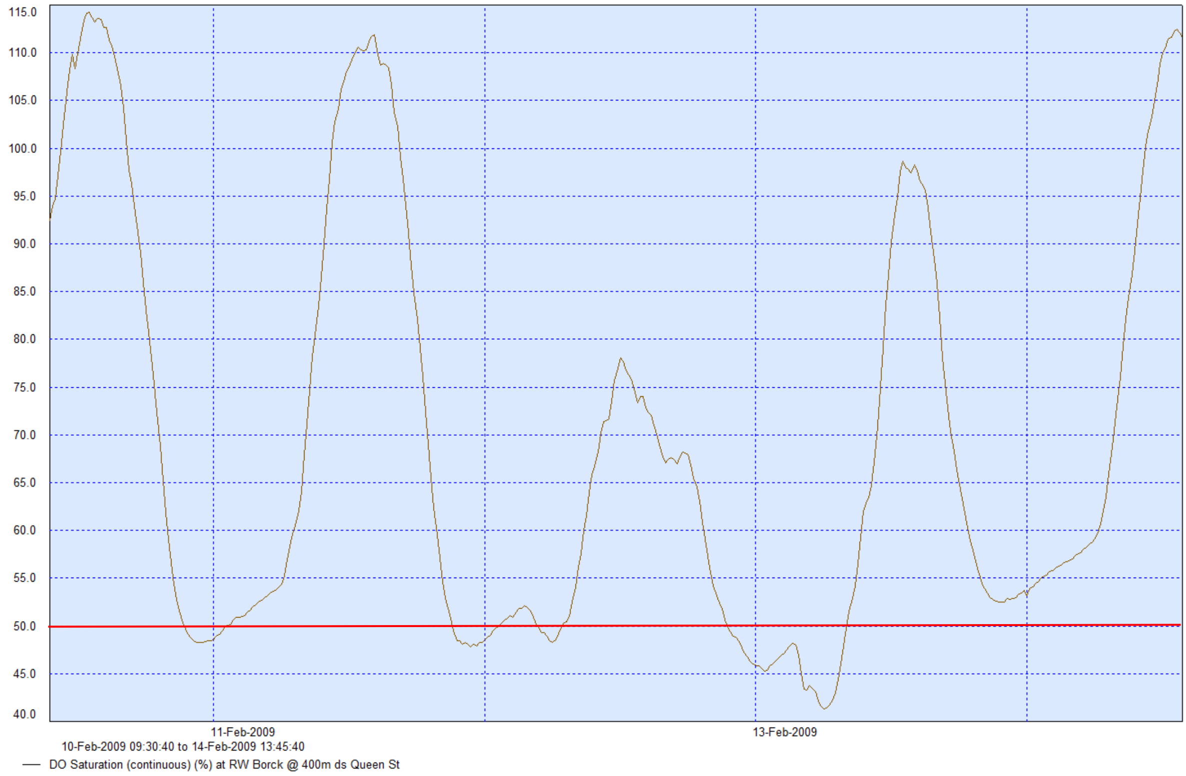


Figure 34. Dissolved oxygen percent saturation at Borck Creek at 400 m downstream Lower Queen St (10-4 February, 2009). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

The **nitrate-N** concentrations are consistent with that in groundwater from the Hope lower and upper confined aquifers so it is important that discharges to ground are controlled. A truck wash operation that discharged animal effluent to a soak pit was removed in 2011 after which time the average nitrate-N concentrations fell (7.8 g/m^3 from 2009-11) by about 40% but have since appear increased again (Figure 35).

Isotopic analysis using both the oxygen and nitrogen elements in samples from near the upper springs at low flow suggested both effluent and fertiliser sources (van der Raaj and Baisden, 2011). Investigations are continuing after allegations of excessive fertiliser discharges in this catchment.

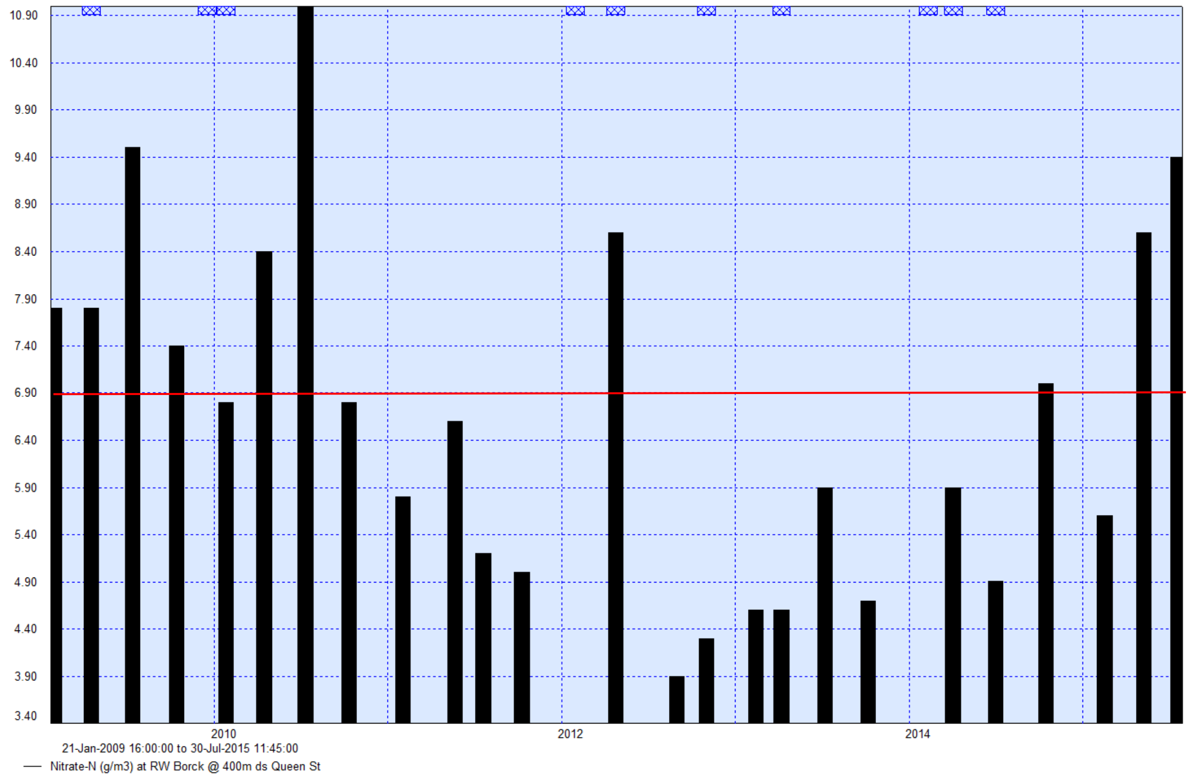


Figure 35 Nitrate-N concentrations in Borck Creek 400 m downstream Lower Queen St (2009-2015). The national bottom line is shown by the red line.

Fine sediment almost completely fills the spaces between the cobbles of the bed in Borck Creek. **Suspendable Bed Sediment Volume** (SBSV) **in lower Borck Creek is very high** (mean of 6 replicates range 23-57 l/m^3 (2013 and 2015); see photos below). Following the new channel commissioning an even greater proportion of fine sediment was found (69 and 124 l/m^3) even though 100 mm of clean gravel was added to the new stream bed. This seems to be because the fine sediment composition of the base layer is very high and the depth that this procedure stirred to was 150-180 mm (below the layer of clean gravels).

Resuspending the fine sediment in Borck Ck 400 m downstream Queen St. Left: May 2015 following diversion into a new channel, Right: Old straight channel January 2012.

Sediment quality sampling downstream of the commercial area along Gladstone Rd shows levels of chromium and copper above guidelines, but this is likely to be localised. The concentrations of all common **urban and industrial contaminants are low** near the mouth of the creek.

A Cultural Health Index assessment of Borck Creek highlighted “serious issues” with water clarity/turbidity, straight channels and the lack of habitat for fish and birds (Tiakina 2014).

Subdivisions granted consent in 2013 near the Hill-Hart corner of Eastern Hills Creek were created without any stormwater treatment devices (swales or wetlands) creating a greater risk of degradation of water quality in this stream.

Borck Ck 400 m downstream Queen St Left: May 2015 two months after the diversion into the meandering channel, Right: January 2009 showing extensive filamentous green algae cover.

Catchment Statistics	Borck Creek 400 m d-s Lower Queen St
River Environment Class	Warm Dry Alluvial Spring-fed Pasture
Catchment area (km^2)	15
Predominant land use upstream	Pasture and horticulture 75% Urban 15%, Exotic Forestry 10%
Mean annual rainfall (mm)*	1,086*
Mean annual flow (l/sec)*	321*
Lowest recorded flow (l/sec)	3 (2010/04)
Water quality record	Jan 2009-present

* Estimate from WRENZ 2013. NA = not available

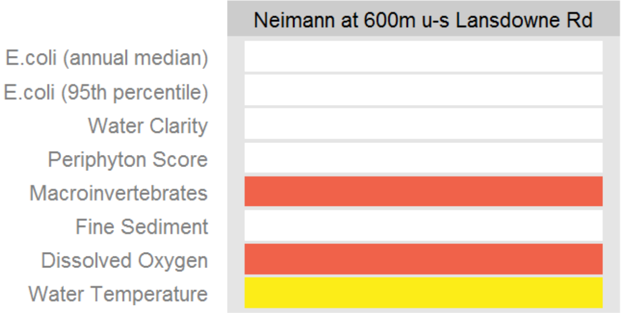
Neimann Creek, Waimea Plains

Like Pearl and Borck Creeks, Neimann Creek is a spring-fed stream of the Waimea Plains. Giant kokopu have been found in the creek several decades ago (Todd, pers.com.) but have not been found in more recent fish surveys. Some riparian planting was carried out in the lower reaches in the early 2000's (Department of Conservation and Tasman District Council) and more is anticipated.

Right: Neimann Ck at 600 m upstream Landsdowne Rd (February 2014)

The ecological potential of Neimann Creek is currently limited by excessive fine sediment in the stream bed. The average sediment depth is about 500 mm in the upper reaches of Neimann Creek (from between 400 and 700 m upstream of Landsdowne Rd).

E.coli concentrations are relatively high in this creek (median: 673 *E.coli*/100 ml over 8 samples; however there is insufficient data to show on the plot below).



	Neimann at 600m u-s Lansdowne Rd
E.coli (annual median)	
E.coli (95th percentile)	
Water Clarity	
Periphyton Score	
Macroinvertebrates	🟥
Fine Sediment	
Dissolved Oxygen	🟥
Water Temperature	🟨

**Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.**

The bed sediment in Neimann Creek was found to contain no trace of pesticides but concentrations of nickel were over five times the ANZECC (ISQG-High) sediment guidelines and chromium was over double the ANZECC ISQG-Low sediment guidelines. The concentration and ratio of these heavy metals is reflected in the surrounding soils indicating that this sediment originates from soil in the immediate area. These soils have been influenced by erosion from the ultramafic belt that extends along the Richmond Ranges. It is likely that this amount of soil has entered the creek from runoff due to land cultivation or other earthwork too close to the edge of the stream, or swales feeding the stream. The sediment is also made up of a reasonable proportion of organic matter from aquatic plants rooted in the bed. Disturbing this sediment releases relatively large amounts of methane and causing strong sulphide odours – not a good environment for most aquatic life. This sediment was sampled in 2014 to determine if it was safe to dispose of to pasture or garden use. An application for funding to remove the sediment in Neimann Creek is currently pending.

Nitrate concentrations in Neimann Creek are the highest in Tasman District. Groundwater feeding this waterway originates from a plume within the Waimea Lower Confined Aquifer and Upper Confined Aquifer which contain high nitrate concentrations due in part to historical discharges from a former piggery in the aquifer recharge area. The up-gradient extent of this plume is around the Ranzau Rd - Patons Rd intersection area. Nitrate concentrations in this creek are highest just upstream of Landsdowne Rd (average around 10g/m^3). The pattern of nitrate flux at this site is highly variable and follows closely that of bore #802 located 1.1km SW near SH60. Higher nitrate concentrations appear to follow high groundwater levels and periods of high rainfall. The source of this groundwater is unclear but investigations are underway.

Daily minimum dissolved oxygen levels are very low (around 20% saturation with maxima over 150%, based on continuous sampling in March 2014) (Figure 36). This high diurnal fluctuation is most likely due to the very high cover of aquatic plants in the stream upstream of the sampling site (in summer they can cover 70-80% of the channel).

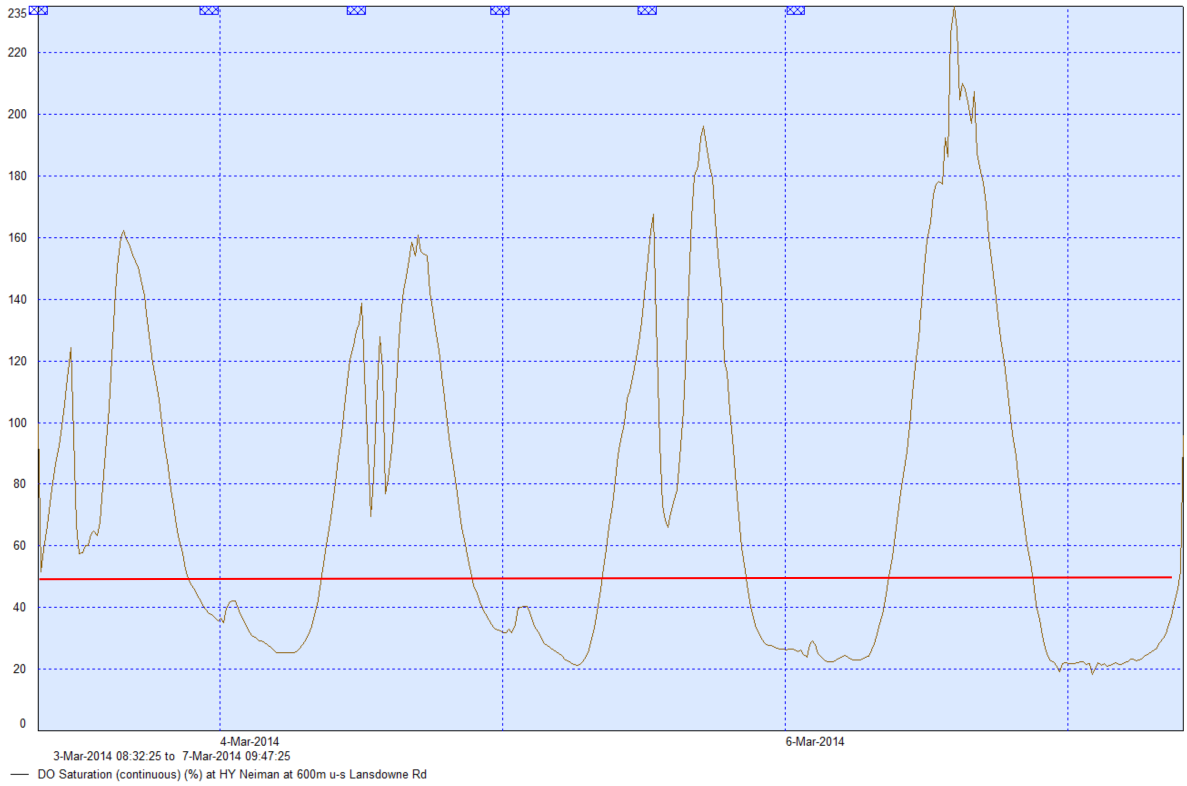


Figure 36 Dissolved oxygen percent saturation at Neimann Creek at 400 m upstream Landsdowne Rd (3-7 March, 2014). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Tidewater was found to influence the creek at the site 600 m upstream of Landsdowne Rd, as shown by the peaks in the conductivity plot (Figure 37). This tidewater temporarily lowered dissolved oxygen levels, hence the double peaks on 3, 4 and 5 March 2014. Without tidal influence this effect was not apparent i.e. on 6 March, 2014.

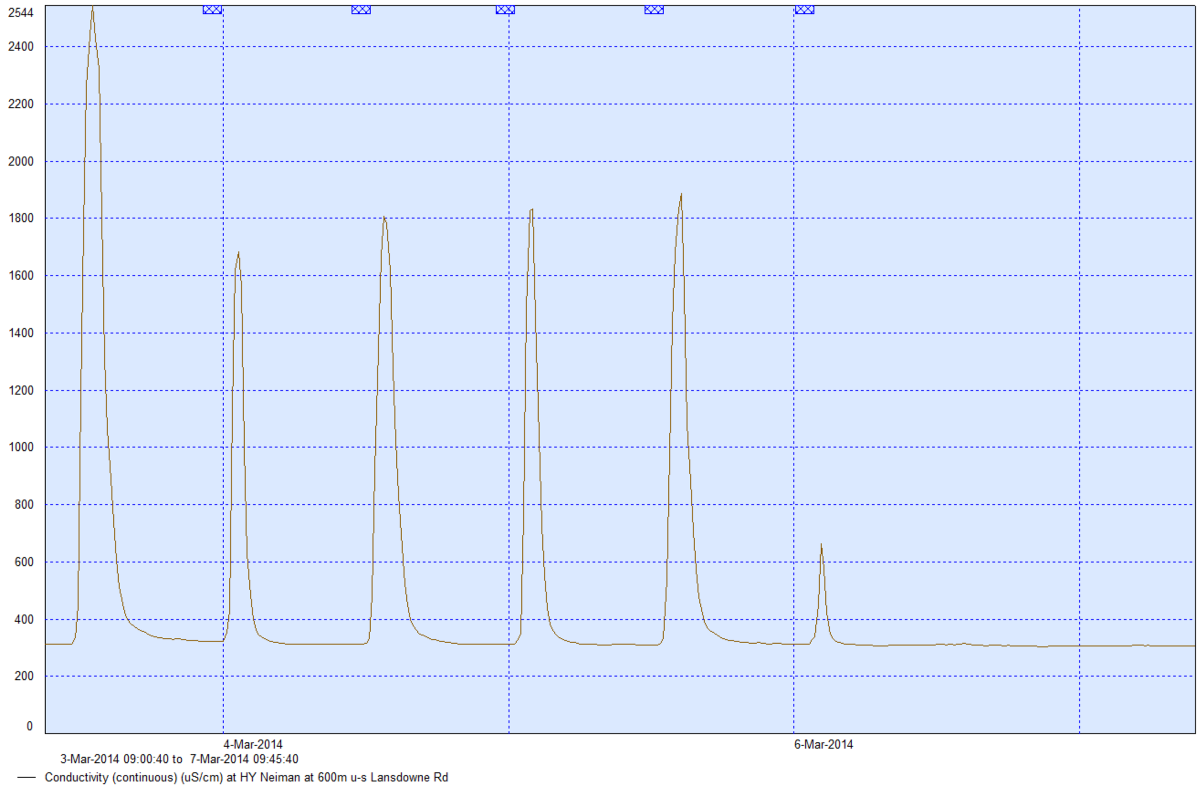


Figure 37 Conductivity at Neimann Creek at 400 m upstream Landsdowne Rd (3-7 March, 2014)

Stream temperatures were satisfactory (midpoint of daily mean and daily maxima: 20°C).

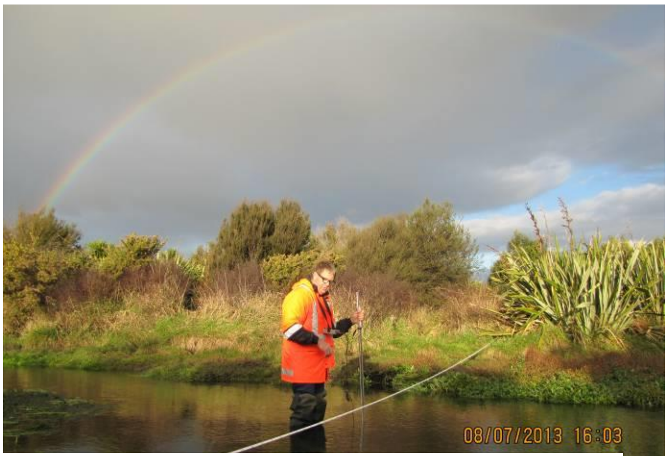
Neimann Creek viewed upstream Left: 550 m upstream Landsdowne Rd (April 2014) and Right: 600 m upstream Landsdowne Rd (May 2015)

Catchment Statistics	**Neimann Creek 600 m u-s Landsdown Rd**
River Environment Class	Warm Dry Alluvial Spring-fed Pasture
Catchment area (km^2)$^+$	1.4
Predominant land use upstream	Beef, sheep Horticulture (Grapes, nursery)
Mean annual rainfall (mm)*	~1000
Mean annual flow (l/sec)*	NA
Lowest recorded flow (l/sec)	26 (Jan 1998)
Water quality record	Apr 2013-present

* Estimate from WRENZ 2013. NA = not available

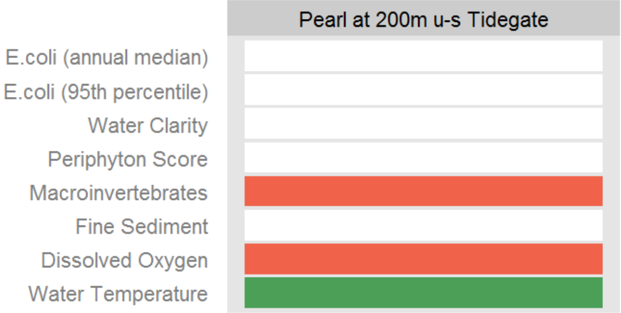
Pearl Creek, Waimea Plains

Like Neiman and Borck Creeks, Pearl Creek is a spring-fed stream of the Waimea Plains. The surrounding land use is mostly pasture. It has been subject of riparian planting since early 2000's as part of work to enhance a QEII covenant (mainly on the true right (eastern) bank). Giant kokopu have been recorded in the creek.



Pearl Creek 200 m upstream of the tidegate (July 2013)

Pearl Creek is expected to be ecologically compromised due to **excessive fine sediment deposits and low dissolved oxygen.** Re-suspendable sediment in riffles and wadeable runs in Pearl Creek is high (but the sediment depth has not been quantified in pools or deeper runs. Daily dissolved oxygen minima were consistently around 15% saturation with large daily fluctuations (continuous sampling in March 2014). Excessive aquatic plant growth, including the pest plant *Lagarosiphon major*, are the likely reason for this.



	Pearl at 200m u-s Tidegate
E.coli (annual median)	
E.coli (95th percentile)	
Water Clarity	
Periphyton Score	
Macroinvertebrates	🟥
Fine Sediment	
Dissolved Oxygen	🟥
Water Temperature	🟩

Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

Faecal indicator bacteria concentrations are high (over 1000 *E.coli*/100 ml about 30% of samples; however there is insufficient data to show on the plot below).

Occasionally the cover of **filamentous green algae** gets over 30%.

Dissolved oxygen levels were low in summer (daily minima less than 20%) (Figure 38). Like Neimann Creek, there appears to be an influence of tidal water backing up the freshwater flow and causing temporary reduction in dissolved oxygen (see plot below).

Maximum water temperatures recorded to date in Pearl Creek are under 17°C. Due to the presence of a tide gate there appears to be no seawater getting up to the monitoring site 200 m upstream.

Fish passage is limited due to the tide gate and schools of inanga mill around downstream of the gate. However, a small area of inanga spawning found 10 m upstream of the tidegate culvert suggests some fish do get through. Opening up the tidegate to facilitate better fish passage has the potential to reduce freshwater habitat for giant kokopu and reduce the quality of water taken for irrigation.

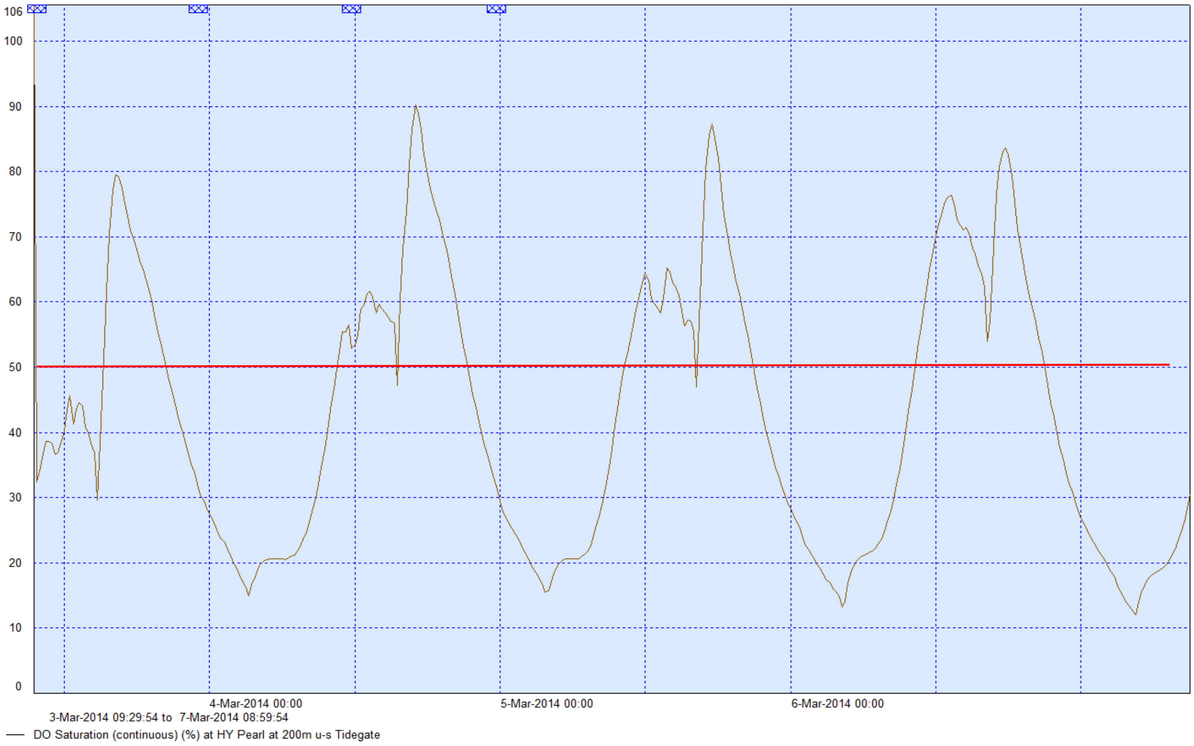


Figure 38 Dissolved oxygen at Pearl Creek at 200 m upstream tidegate (3-7 March, 2014). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Pearl Creek 200 m upstream tidegate, view downstream (March 2014). Note extensive aquatic plant growth including *Lagarosiphon major*.

Catchment Statistics	**Pearl Creek u-s tidegate**
River Environment Class	Warm Dry Alluvial Spring-fed Pasture
Catchment area (km^2)$^+$	0.9km^2
Predominant land use upstream	0.76
Mean annual rainfall (mm)*	NA
Mean annual flow (l/sec)*	NA
Lowest recorded flow (l/sec)	89 (Mar 2001)
Water quality record	July 2013-present

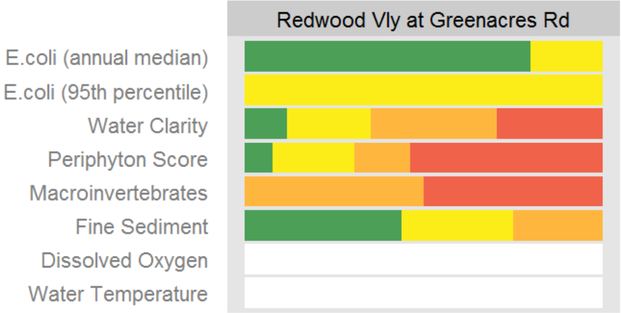
* Estimate from WRENZ 2013. NA = not available

Redwood Valley Stream, Waimea Plains


Redwood Valley Stream downstream Greenacres Rd North looking upstream (February 2013)

While the lower 500 m and upper tributaries of this stream stop flowing for 2-4 months in summer, **fish values are relatively high** in the middle reaches of the stream, where they survive in shaded residual pools that still contain water.

This stream has fairly typical land use for a Moutere Hill Country stream. The sampling site was moved to the Greenacres Rd North site in 2011 from a site about 600 m further downstream (about 30 m upstream of Eves Valley Stream) due to the downstream site drying every summer for a few months (flow at the Greenacres Rd site appears permanent all year). Water quality data from the two sites is analysed as if it was one site because there is no change in land use or discharges between the two sites.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

The **macroinvertebrate condition is poor with significant degradation** in the lower reaches of the waterway. The reason for this condition is currently unclear, but could be due to low dissolved oxygen (spot measurements of dissolved oxygen appear to have declined in a similar pattern). This suggests a source of organic matter with high Biological Oxygen Demand. Coverage of the bed by filamentous green algae is regularly excessive in all seasons except winter when its growth is light limited.

In May 2015 sampling further upstream in the catchment showed very poor macroinvertebrate condition in the northern tributary downstream of Redwood Valley Lane (MCI 60, EPT 0%, # taxa 8) (see map of sites on Figure 39). A sewage-type odour was evident in this tributary all the way down to the confluence of the main stem upstream of the Moutere Highway. The macroinvertebrate condition in the southern tributary flowing across Redwood Valley Lane was better, but still poor (MCI 83 & 88, EPT 33% & 26%, # taxa 15 & 23). This may because the flow in the northern tributary ceases for longer or discharges from industry or dams upstream. At a site on the northern tributary 360 m upstream of Redwood Valley Lane macroinvertebrate condition was higher (MCI 75, EPT 0%, # taxa 12). This suggests that there is an effect due to discharges from industry or other sources within 100 m upstream of Redwood Valley Lane. Discharges from vehicles crossing through the water at the ford on this road on the southern tributary of Redwood Valley Lane do not seem to be adversely affecting the macroinvertebrate community. This could be due to the flow over the concrete ford being very shallow most of the time or non-existent for several months over summer.

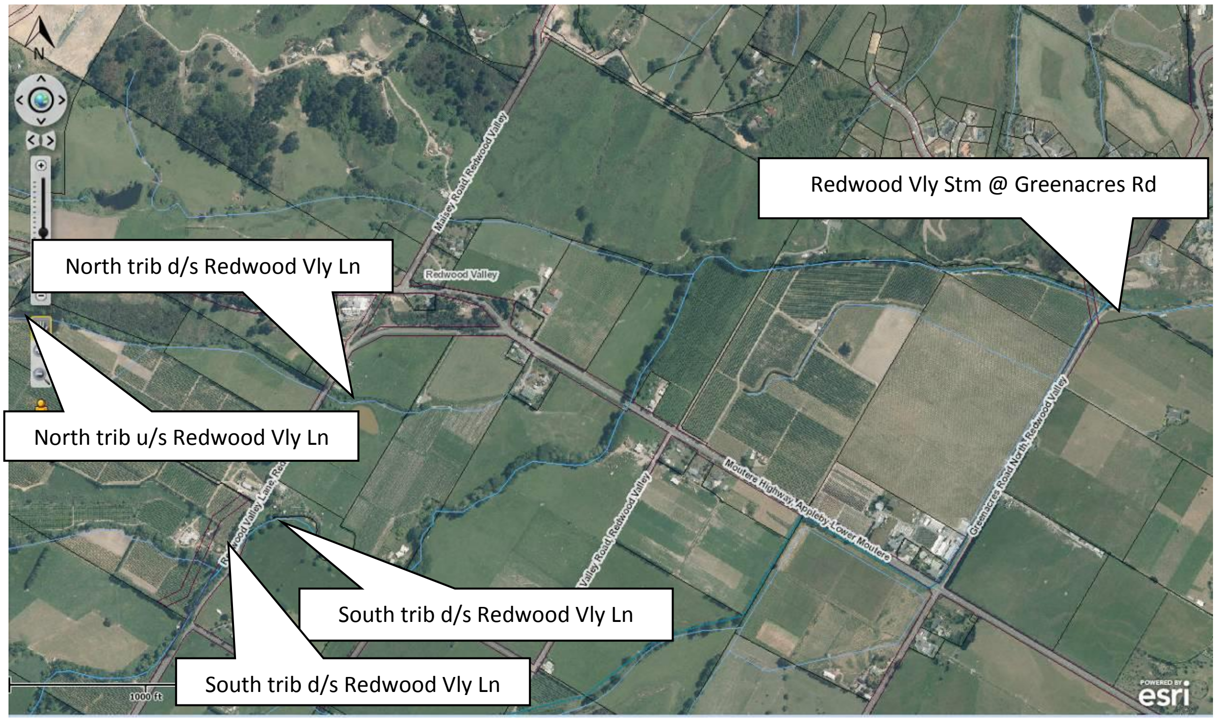


Figure 39 Map of macroinvertebrate sample sites on two upstream tributaries of Redwood Valley Stream in May 2015; Upstream and downstream of Redwood Valley Lane on the tributary adjacent to the Redwood Cellars wastewater treatment system; Upstream and downstream of ford on Redwood Valley Lane on the tributary to the south of the Redwood Cellars wastewater treatment system

Dissolved oxygen concentrations have not been measured continuously at this site, but two spot measurements at midday in summer were slightly below 60% suggesting there is a risk of low dissolved oxygen at times.

All other parameters are within guidelines or standards and have been reasonably stable over time, such as nutrient concentrations, water temperature, *E.coli*, faecal coliforms, and fine sediment deposits.

Like most Moutere streams, it is recommended that in this catchment stream-side planting occurs (particularly evergreen natives) and more wetlands are created.

A series of residual pools upstream Redwood Vly Rd (Left: November 2006), Redwood Vly Stm upstream Eves Vly Stm (Middle: November 2006, Right: April 2007).

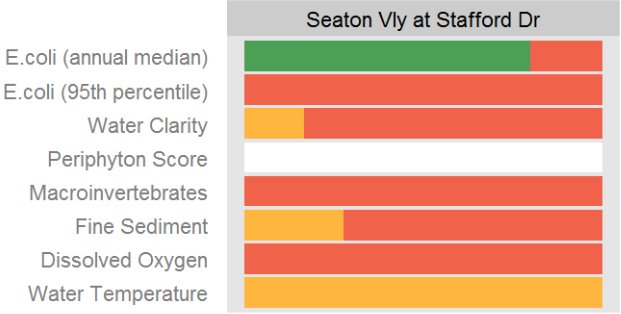
Catchment Statistics	Redwood Valley Stream
River Environment Class	Warm Dry Soft sedimentary Lowland-fed Pasture
Catchment area (km^2)$^+$	16
Predominant land use upstream	Pasture 80% Rural residential 8% Horticulture 6% Exotic forest 3% Indigenous forest 3%
Mean annual rainfall (mm)*	140*
Mean annual flow (l/sec)*	
Lowest recorded flow (l/sec)	1 (Apr 2010)
Water quality record	2005-present

* Estimate from WRENZ 2013. NA = not available

Seaton Valley Stream, near Mapua

Like Borck Creek in Richmond, and many creeks in the Moutere Hill country this waterway would have wound its way through a large flax swamp spanning the valley floor and may not have had a defined channel. The flax swamp was large enough to sustain a flax mill on site. The swamp was largely removed in the early 20th century (much of it by the Drainage Board) with the development of pastoral and horticultural farming in the area and the stream put into a straight channel. While contact recreation occurs in the Mapua Inlet downstream of the Toru St causeway, there is likely to be good mixing and significant dilution by clean sea water in that area.

Native fish and invertebrate populations are relatively diverse and abundant in the cobbly-bottomed shaded and mostly-natural channel upstream of the farmland, 1km upstream of Stafford Drive. Water quality upstream of this point is also good, whereas in the lower reaches (about 1 km upstream and downstream of Stafford Drive) water quality is in a poor state due to unrestricted stock access, vigorous aquatic plant growth, because of very limited stream shading, and regular disturbances by digging out.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

High levels of fine sediment in the water and stream bed, **high water temperatures,** and **low summertime dissolved oxygen** are the main issues.

Concentrations of faecal indicator bacteria in this stream declined over 10 years (median from 2010-2015: 66 *E.coli*/100 ml down from 220 *E.coli*/100 ml in 2006-2009 and with no exceedance of stock drinking water guidelines since May 2011 (Figure 40).

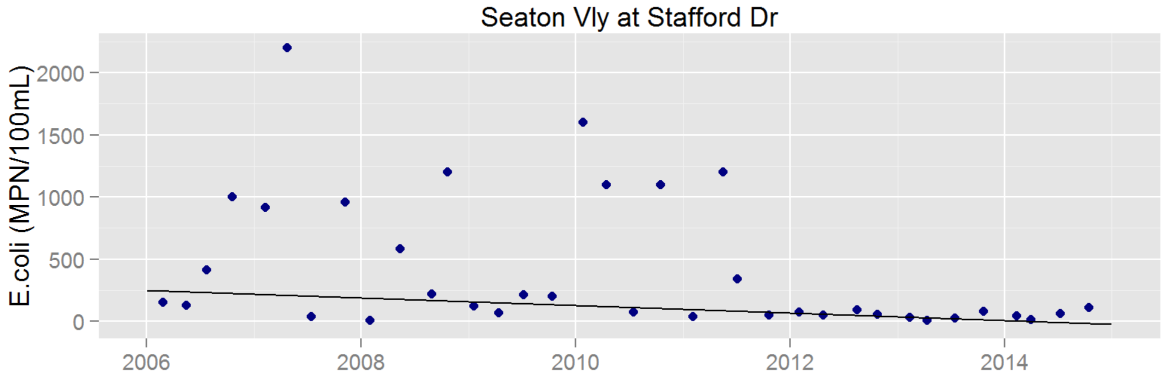


Figure 40. Seaton Vly at Stafford Dr *E. coli* data with 9-year trend line (p = 0.006, RSKSE = -26.5% per year).

Water temperature appears to increase about 3°C (to 22°C) from a site about 1.5km upstream Stafford Drive to Stafford Drive.

Dissolved oxygen levels are close to zero at the Stafford Drive site in summer, whereas they range from 60-70% saturation 1.5km upstream of Stafford Drive (Figure 41). While it may look as if there was instrument error due to drift in the dissolved oxygen data this was considered unlikely as a rain event on 11 February 2009 shows dissolved oxygen quickly recover to have daily minima consistently just above 8 mg/l. Methane bubbles and a waxy rainbow sheen on the water surface is often evident in this area, as well as a strong sulphide odour when the sediments are disturbed. Note the very limited daily fluctuation at the upstream site, probably due to very few aquatic plants in the creek upstream (Figure 42).

From left to right: Seaton Vly Stm 2km u-s Stafford Dr; upstream Stafford Drive looking upstream (November 2006); Anoxic sediment.

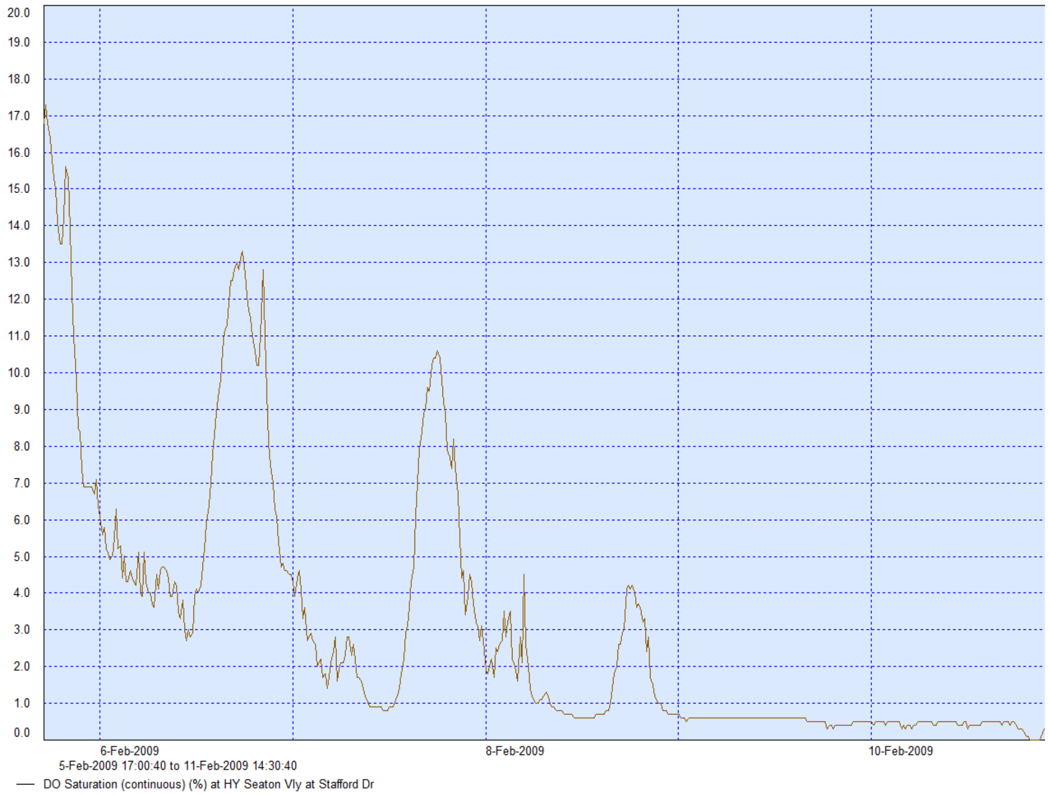


Figure 41. Dissolved oxygen saturation (%) at Seaton Valley Stream at Stafford Dr, February 2009. The proposed national bottom line is 5g/m3 (which usually equates to about 50% saturation).

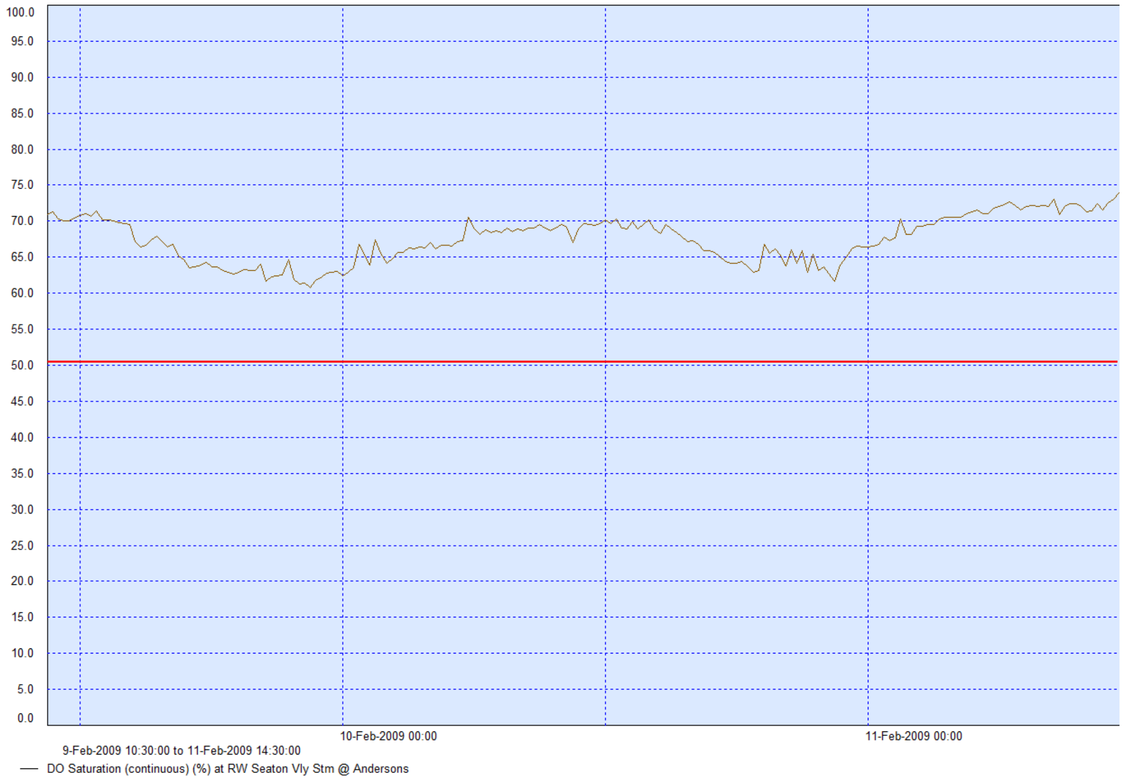


Figure 42. Dissolved oxygen saturation (%) at Seaton Valley Stream at 1.5km upstream Stafford Dr, February 2009 (simultaneous deployment with the Stafford Rd site). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Macroinvertebrate condition in lower Seaton Valley Stream is very poor probably due to the sand and fine sediment dominating the bed substrate, frequent dig-outs and low dissolved oxygen.

The benefits of wetlands to maintain higher summer flows are well illustrated in this catchment. **Two wetlands** protected by QE II covenants provide a year-round flow to this stream. Without these, the stream would probably dry for several months, like so many other streams in the Moutere hills.

It is recommended to fence this stream to exclude stock and plant trees close to the streamside, at least on the northern bank, to shade out the aquatic plants that trap and produce so much of the fine sediment, as well as cause the excessively low dissolved oxygen.

Early in 2016 the stream corridor downstream of Stafford Drive will be widened to provide greater flood carrying capacity, and the channel is designed to improve ecological health by creating meanders, a variety of bank shape, depths and widths, as well as installation of stream-side wetlands and the planting of native trees.

Catchment Statistics	Seaton Valley Stream
River Environment Class	Warm Dry Soft sedimentary Lowland-fed Pasture
Catchment area (km^2)$^+$	2.8
Predominant land use upstream	Rural residential Pasture
Mean annual rainfall (mm)*	995*
Mean annual flow (l/sec)	41.8*
Lowest recorded flow (l/sec)	0.5 (est Apr 2010)
Water quality record	Feb 2006-present

* Estimate from WRENZ 2013. NA = not available

Motueka Water Management Area

This area includes the whole of the Motueka catchment, along with the Moutere River and other tributaries of the Moutere Inlet, Riwaka and all waterways of Abel Tasman coast. There is a diverse range of geology with the ultramafic Red Hills in the headwaters of the Motueka River, the very erodible Separation Point Granite dominating Motueka River tributaries in the western part of the catchment and Motuere Gravel/Clay gentle hill-slopes of the Moutere, Waiwhero, Orinoco, and Dove areas.

As of 2015, a ‘Freshwater Management Unit’ (FMU) under the ‘National Policy Statement for Freshwater Management’ has not yet been formally set up for this area. Like the Takaka and Waimea FMU’s that have been operating from 2014, there will be a collaborative governance group from the community tasked with making recommendations for limits on water quality and quantity.

In the Motueka Water Management Area, there were 24 River Water Quality sites monitored between 2010 and 2014 (Figure 43). The reference sites were Hunters at Kikiwa, Motueka at Gorge, Riwaka at Northbranch source and Wangapeka at 5km u-s Dart.

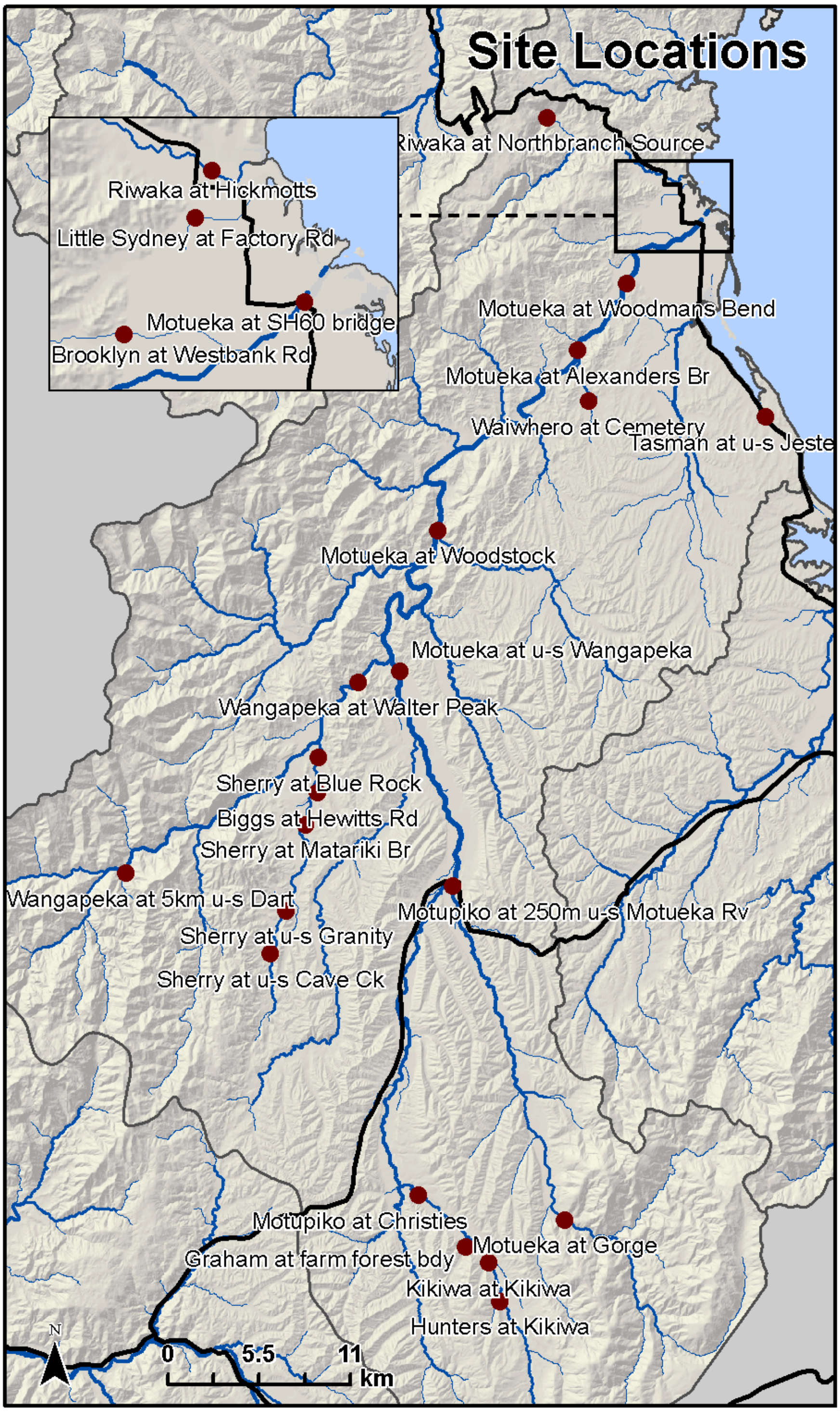


Figure 43. River Water Quality sites in the Motueka Water Management Area

Discussion of Specific Catchments/Areas

This section describes the more **notable aspects of water quality in a given catchment, actions taking place, and recommendations** for further action.

The key to the colour-coding for each water quality attribute state (A to D) is shown to the right. The cut-offs used for each attribute are shown in Table 12.

Attribute State
A (Excellent)
B
C
D (Poor)

The dataset used to determine the attribute states was collected at base-flow over the period from 2010-2014 unless a comment is made otherwise. White (no colouring) indicates there are no data available to determine the attribute state.

Trends in water quality attributes are reported if they are statistically significant (p-value<0.05) and ecologically meaningful (RSKSE>1%). An increasing trend can have a positive or negative effect on the stream ecosystem, depending on the attribute. To indicate the ecosystem effect of the trend, we have used a smile symbol (☺) for improving trends and a frown symbol (☹) for degrading trends.

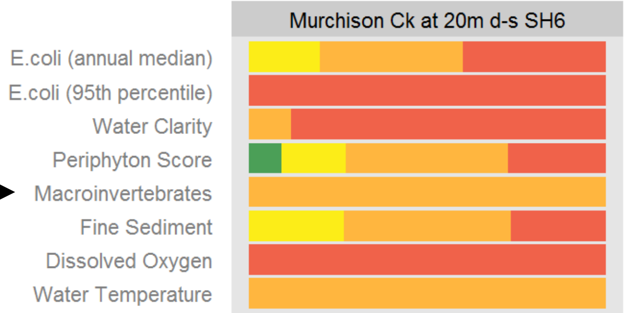
Table 12. Numerical attribute states for each water quality attribute for the protection of river ecosystem health, aesthetics, and human health. Attributes highlighted in blue are included in the National Policy Statement for Freshwater Management (NPSFM 2014).

Attribute	Statistic	Units	Attribute State				Source
			A	B	C	D	
Water clarity	Single measurement	m	≥5	3 - 5	1.6 - 3	<1.6	-
Turbidity	Single measurement	NTU	≤5.6	>5.6	N/A	N/A	ANZECC & ARMCANZ (2000)
Resuspendable solids	Shuffle score (1 to 5)	N/A	1	2	3	≥4	-
Dissolved oxygen concentration	7-day mean minimum	g/m^3	≥8	7 - 8	5 - 7	<5	NPSFM (2014)
	Lowest 1-day minimum	g/m^3	≥7.5	5 - 7.5	4 - 5	<4	
Water Temperature	Midpoint of daily mean and daily maximum	°C	≤18	18 - 20	20 - 24	>24	Davies-Colley et al. (2013)
pH	Single measurement	N/A	6.5 - 8.5	5 - 6.5, 8.5 - 9	>5 or >9	N/A	-
Ammonia-N	Annual median	g/m^3	≤0.03	0.03 – 0.24	0.24 - 1.3	>1.3	NPSFM (2014)
	Annual maximum	g/m^3	≤0.05	0.05 - 0.4	0.4 - 2.2	>2.2	
Nitrate-N	Annual median	g/m^3	≤1.0	1.0 - 2.4	2.4 – 6.9	>6.9	NPSFM (2014)
	Annual 95th percentile	g/m^3	≤1.5	1.5 - 3.5	3.5 - 9.8	>9.8	
Dissolved reactive phosphorus	Single measurement	g/m^3	<0.01	≥0.01	N/A	N/A	ANZECC & ARMCANZ (2000)
E. coli	Annual median	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	NPSFM (2014)
	95th percentile	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	
Macroinvertebrates	MCI	N/A	≥120	100 - 120	80 - 100	<80	Stark & Maxted (2007)
	SQMCI	N/A	≥6	5 - 6	4 - 5	<4	
Phormidium	Percentage cover	%	<20	≥20	N/A	N/A	MfE (2009)
Filamentous green algae	Percentage cover	%	<10	10-19	20-29	>30	Biggs and Kilroy (2000)
Periphyton	Periphyton score (1 to 10)	N/A	≥8	6 - 8	5 - 6	< 5	-

How to read a site summary

The site summaries in this report are based on data collected quarterly (monthly for selected sites) from 2010-14, with two exceptions: (1) macroinvertebrate community index values were from 2011-2015 and (2) dissolved oxygen measurements were taken over several days in a summer period from 2005-2015.

The rows of a site summary represent water quality attributes. The colours indicate attribute states **A** (very good), **B** (good), **C** (fair) **D** (poor).



Proportion of periphyton scores in each attribute state.

Proportion of water clarity measurements (m) in each attribute state.

Attribute state for the 95th percentile *E. coli* concentration. Minimum 10 samples.

Attribute states for the annual median *E. coli* concentration. No minimum sample size.

Proportion of macroinvertebrate community index (MCI) values in each attribute state.

Attribute state for the highest midpoint of daily mean and daily maximum temperature from a continuous record.

Attribute state for the mean minimum dissolved oxygen concentration over 3 or more days during summer. For sites with fewer than 3 days of continuous measurements, the 1-day minimum value was used.

Proportion of resuspendable solids (fine sediment) scores in each attribute state.

Water Clarity

Water clarity in the upper Motueka and Riwaka Rivers is very high by New Zealand standards (medians 11.1 m and 11.6 m; maxima 23 m and 18.7 m respectively). The Wangapeka River is not far behind (median 8.6 m; maxima 15.7 m). The unmonitored waterways that arise from karst springs (resurgences) of the west bank mid Motueka, such as the Pearse and Graham Rivers, also have very high water clarity. The Sherry River (west of Tapawera) is aptly named for its colour (like a rosy coloured tea) that forms from tannins leached from soils in the catchment. This causes water clarity to be naturally low.

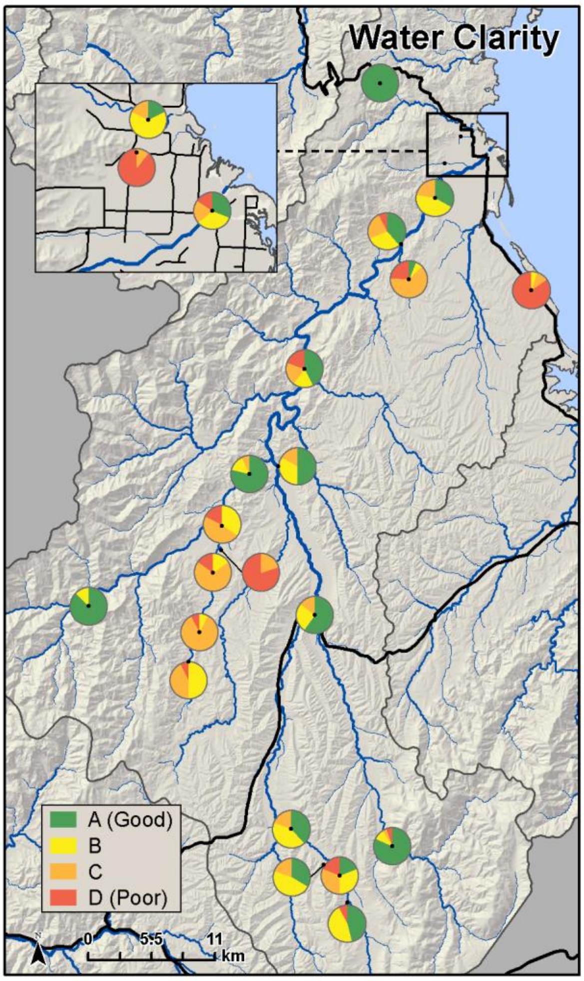


Figure 44. Proportion of water clarity records in each attribute state (A to D) for river water quality sites in the Motueka Water Management Area (sites shown have a minimum of 10 samples).

Disease-causing organisms

Of the 24 sites in the Motueka Water Management Area, 17 maintained ‘excellent' (less than *E. coli* 260 /100 ml) annual median *E. coli* concentrations. The National Bottom Line annual median *E. coli* concentration (1000 *E. coli*/100 ml) was exceeded at Biggs at Hewitts Rd twice (2008 and 2010). This site drains farmland and wetlands where deer and sheep have easy access to the waterway and exceeded secondary contact guidelines 30% of the time. Median for 2010-2015 was 618 *E. coli*/100 ml compared to 1350 *E. coli*/100 ml from 2007-2010. Tasman Valley Stream exceeded secondary contact guidelines 30% of the time. Stock access to waterways and failing septic tanks are the likely main cause of high *E.coli* concentrations.

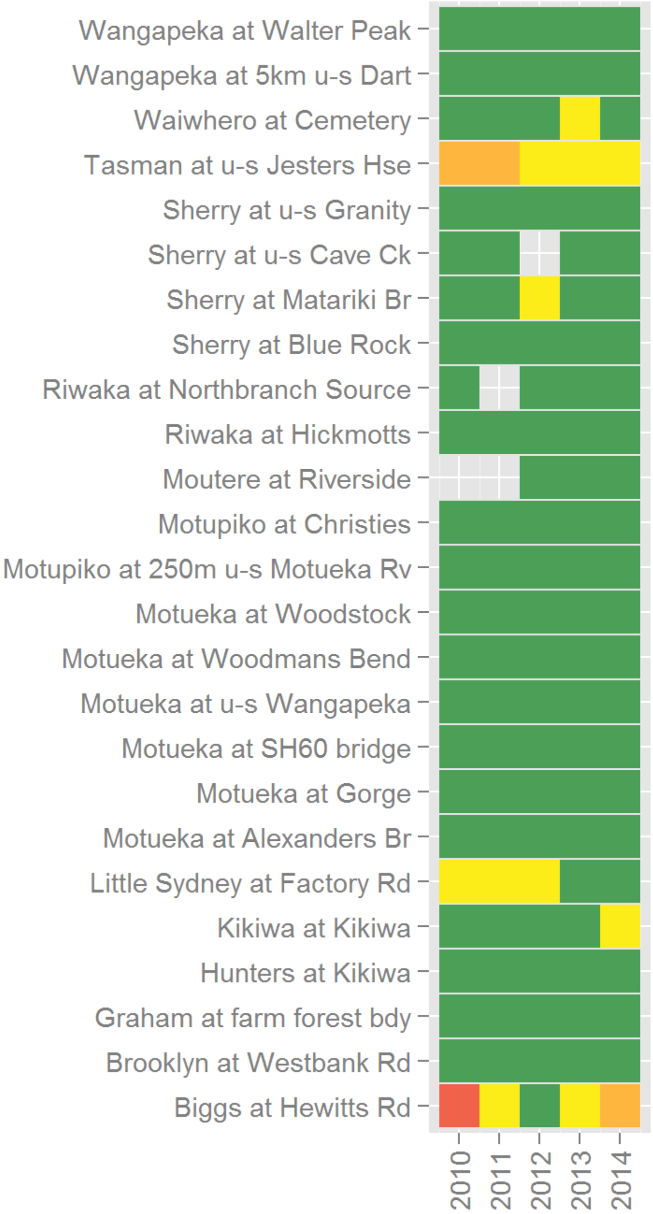


Figure 45. Tile plot of annual median *E. coli* values for sites in the Motueka Water Management Area. Colours indicate attribute states A (green), B (yellow), C (orange) and D (red). Blanks indicate insufficient data (less than three records in a given year).

Filamentous Green Algae & Periphyton Score

Most sites in the Motueka Water Management Area maintained A scores for filamentous green algae (less than 10% coverage). Graham at farm-forest boundary, however, had greater than 50% coverage (category D) on three occasions. This site is completely open to the light after a long mostly-shaded riparian strip for several kilometres upstream so any nutrients would likely be conserved to this location. No obvious source of nutrients from land use exists in the catchment apart from replanting pines after harvest from 2005-2009. Waiwhero at Cemetery and Tasman at u-s Jesters House also had coverage above this threshold on four and two sampling occasions, respectively. Poor sediment and erosion control in these catchments provides phosphorus that gets trapped and utilised for excessive growth by aquatic plants and algae.

There were periphyton scores[7] across the full range. Sites with consistently high periphyton scores, indicating good water quality, included Motueka at u-s Wangapeka, Hunters at Kikiwa and Motupiko at Christies. At least three periphyton scores less than seven (bands C or D) were recorded for Graham at farm forest boundary, Motueka at Woodmans Bend, Tasman at u-s Jesters House and Waiwhero at Cemetery. The site at Woodmans Bend has some of the highest cover of didymo which often acts as preferred substrate for filamentous green algae, causing a lower score.

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[7] Rapid Assessment Method 2, NZ Periphyton Monitoring Manual, 2000.

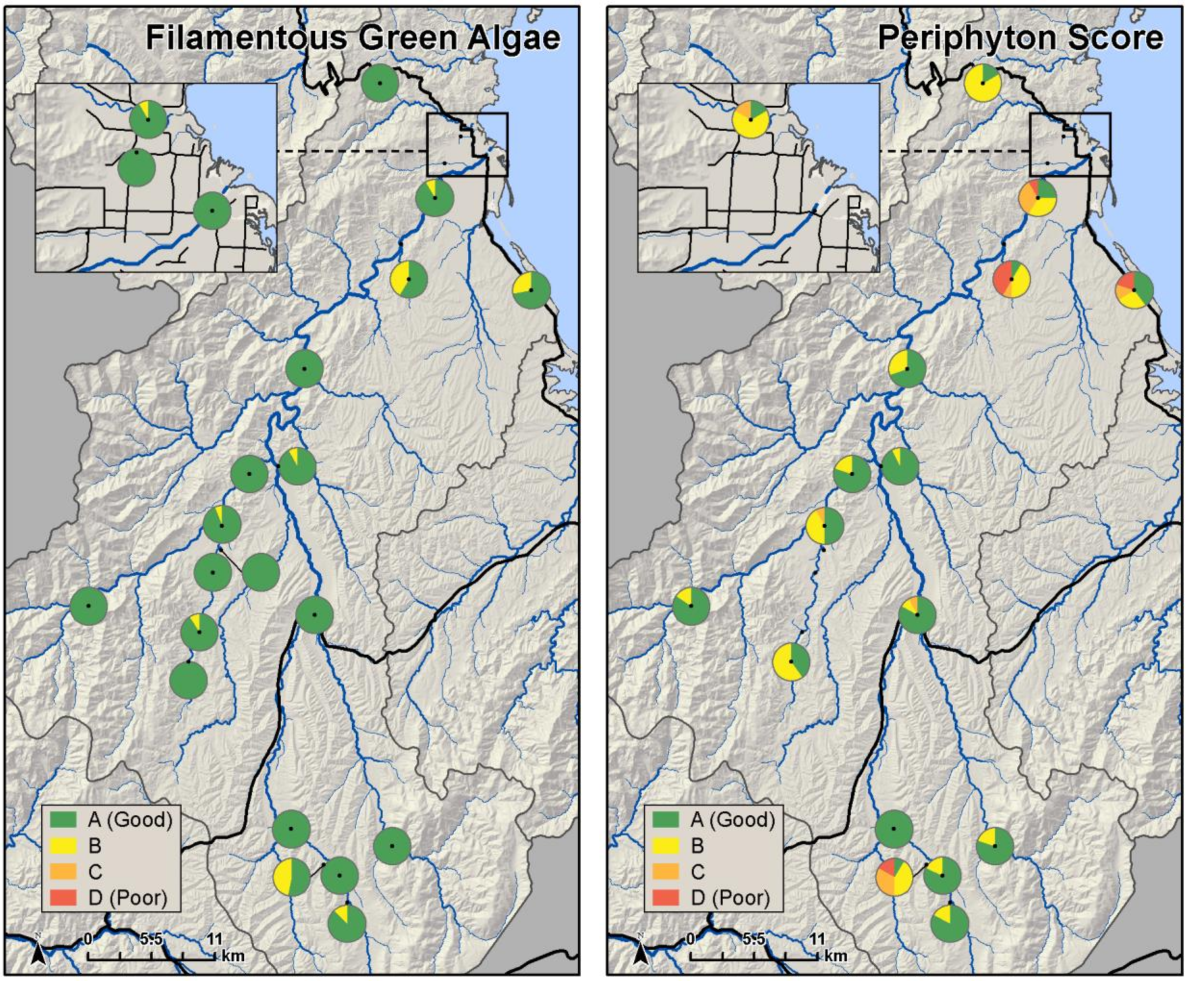


Figure 46. Coverage of filamentous green algae greater than 2cm in length (left) and periphyton community score (right) for sites in the Motueka Water Management Area. Pie charts show the proportion of estimates in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

Nutrients

Annual median nitrate concentrations for the Motueka and Wangapeka river sites were all in the A band (less than 1 g/m^3). Annual median ammonia concentrations were also in the A band for these sites (less than 0.03 g/m^3). Note that only one annual median was available for Wangapeka at Walter Peak for the reporting period (2010 to 2014).

Most dissolved reactive phosphorus records were satisfactory (less than 0.01 g/m^3). The exceptions were Motueka at Woodstock in Winter 2012, Spring 2013 and Winter 2014; Wangapeka at 5km u-s Dart in Winter 2011 and Wangapeka at Walter Peak in Spring 2013. All five were close to the satisfactory threshold (between 0.010 and 0.015 g/m^3) for DRP.

Generally Moutere soils are nutrient poor and that shows in stream waters in catchments dominated by Moutere soils.

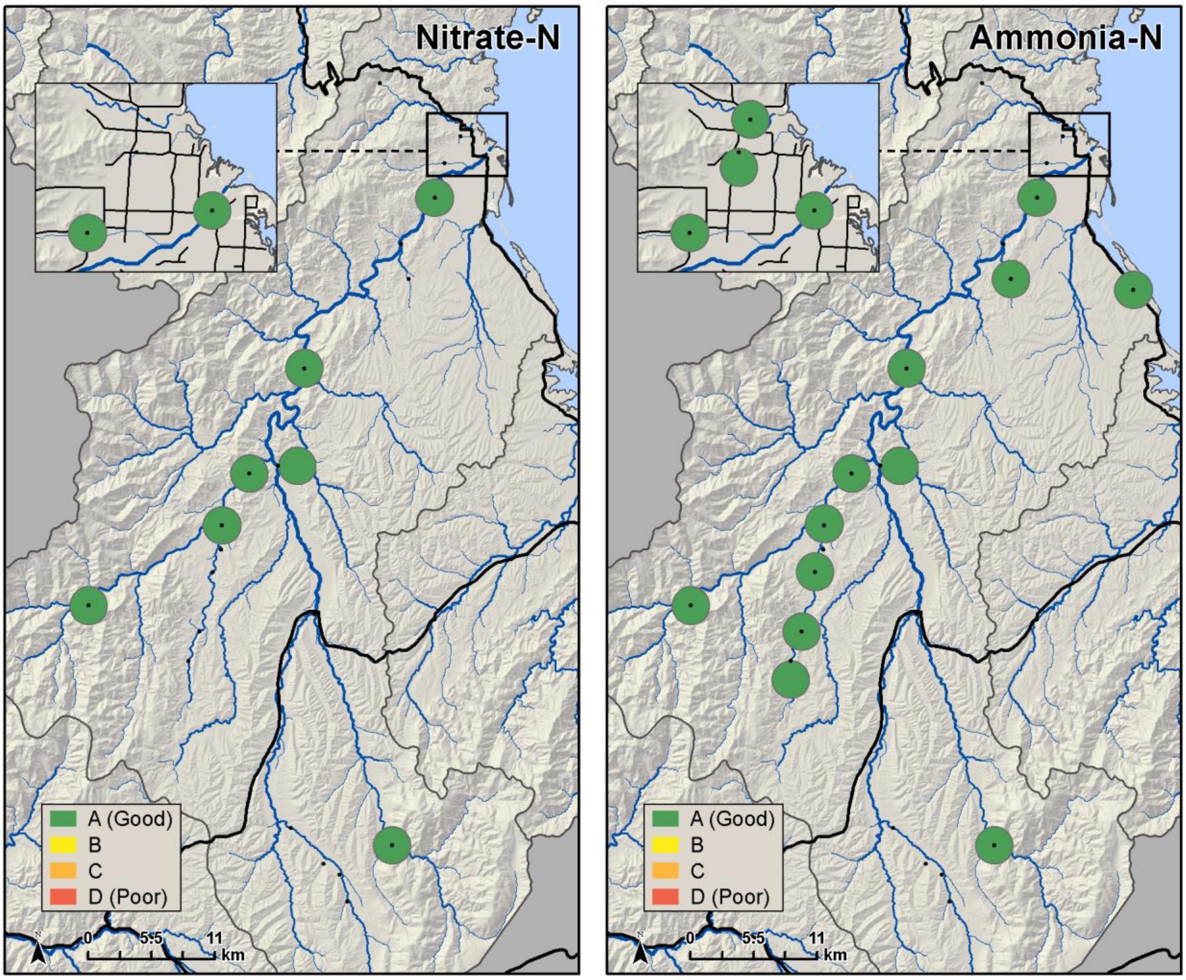


Figure 47. Nitrate (left) and ammonia (right) concentrations for sites in the Motueka Water Management Area. Pie charts show the proportion of annual medians in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

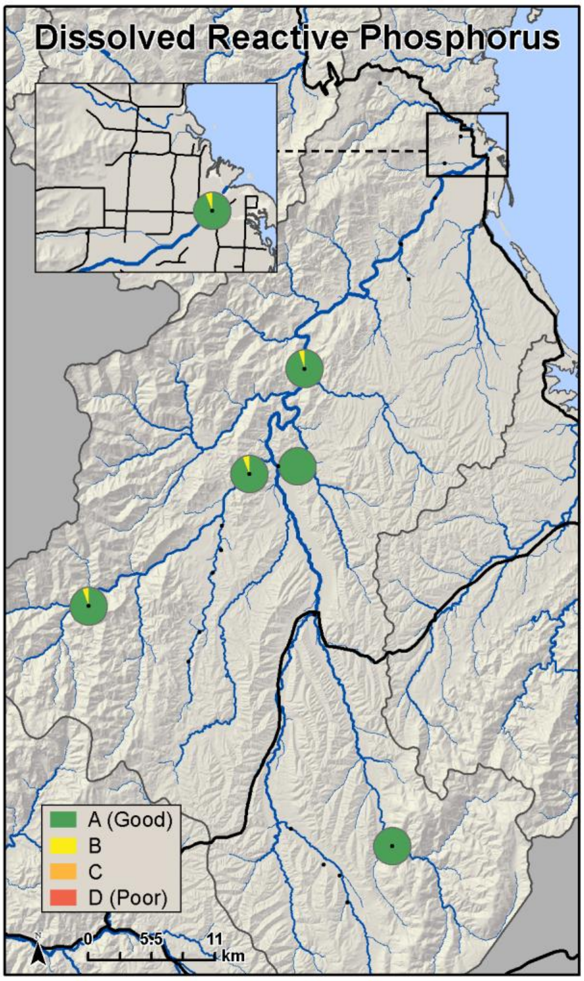


Figure 48. Dissolved reactive phosphorus concentrations for sites in the Motueka Water Management Area. Pie charts show the proportion of records in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

Resuspendable Sediment

In the five-year reporting period, four sites had resuspendable solids scores in band D (Figure 49). The majority of sites, however, had at least 50% of resuspendable solids scores in band A.

Ten sites in the Motueka Water Management Area had at least two volumetric SBSV samples, allowing greater confidence to compare sites. Most sites had SBSV of less than 50 l/m^3 of stream bed with the exceptions being Biggs at Hewitt Rd, Hunters at Kikiwa, Riverside and Riwaka at Hickmotts. Biggs at Hewitt Rd had high levels of fine sediment in the bed of the creek and high variability (mean volumetric SBSV 40 - 180 litres per cubic metre of streambed between 2013 and 2015. High standard error at this site probably reflects the diverse range of water depths sampled in this creek. In 2010 flooding in the Baton/ Wangapeka/Tapawera area caused many slips and high fine sediment loading to waterways.

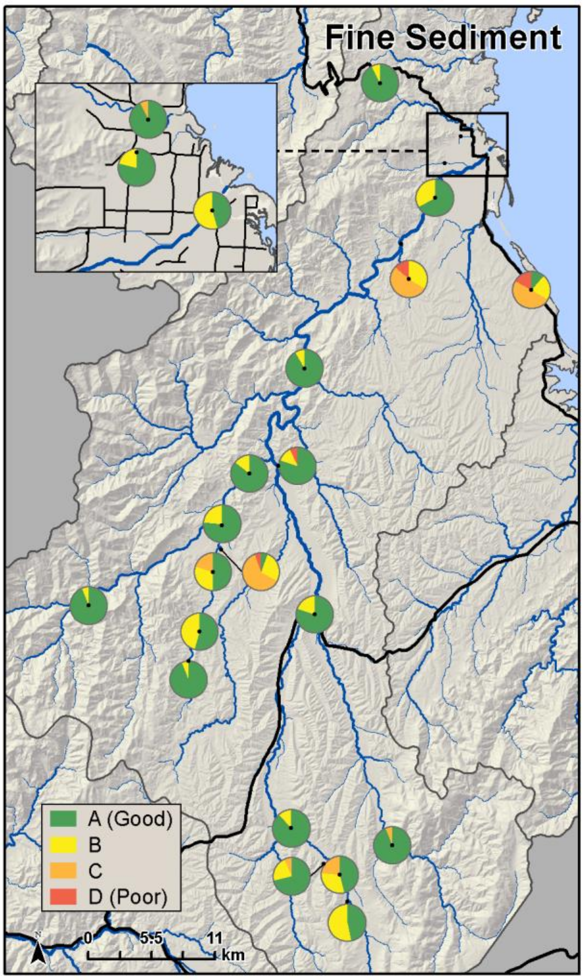


Figure 49. Proportion of fine sediment (resuspendable solids) scores in each attribute state (A to D) for sites in the Motueka Water Management Area.

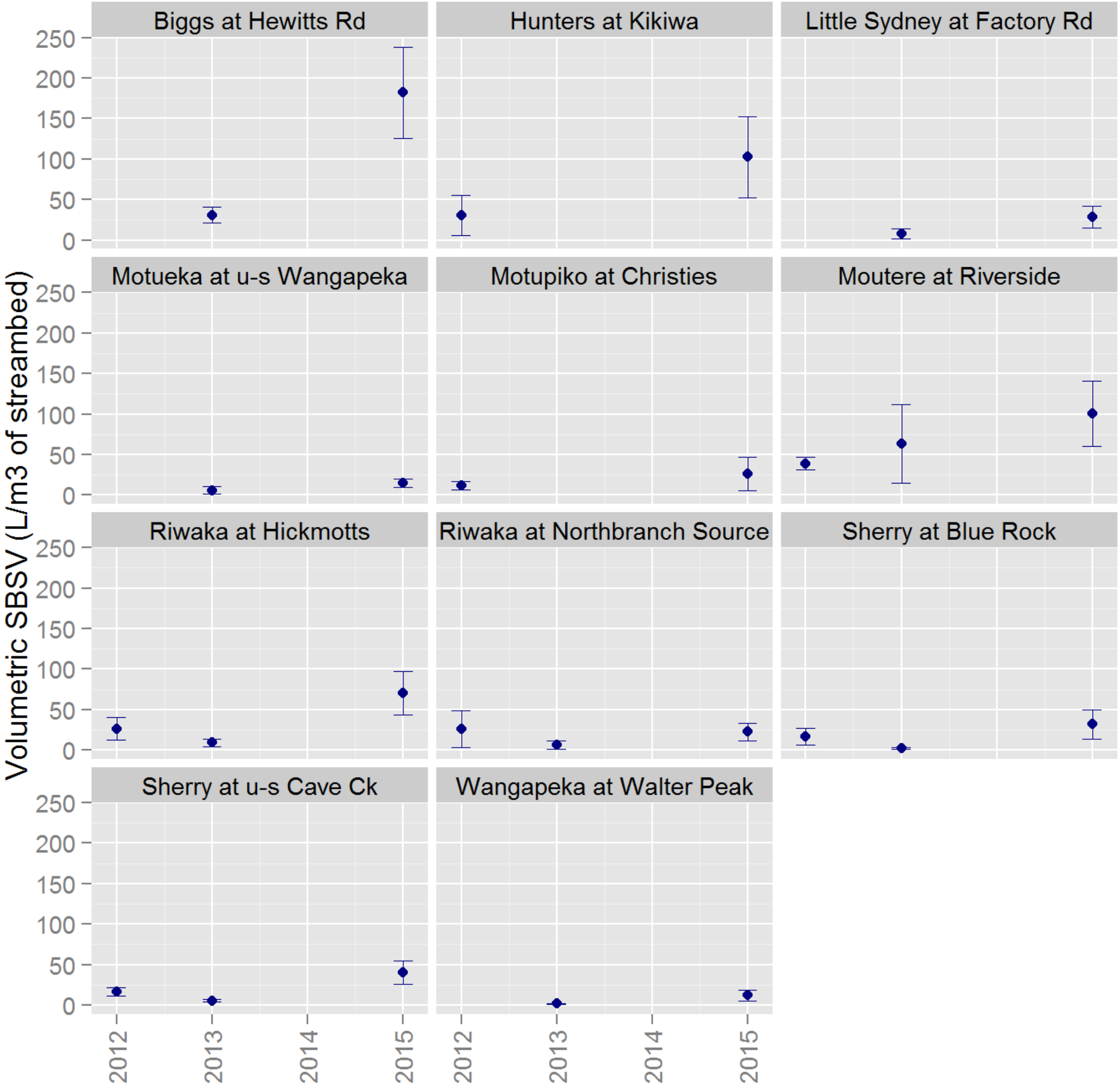


Figure 50. **Mean volumetric suspendable benthic sediment volume (SBSV) in each attribute state (A to D) for sites in the Motueka Water Management Area. The error bars show 95% confidence intervals around the mean.**

Macroinvertebrate Community

In the period 2010 to 2014, the macroinvertebrate community at Tasman at u-s Jesters House was consistently classified as poor (MCI less than 80). In the same period, Hunters at Kikiwa, Motueka at u-s Wangapeka, Motupiko at Christies, Riwaka at Northbranch Source and Sherry at u-s Cave Ck had excellent MCI values (greater than 119).

A decline in MCI over the last five years was evident for Motupiko at 250 m u-s Motueka Rv and Riwaka at Hickmotts. These patterns are largely mirrored in the SQMCI results. There was, however, a decline in SQMCI from excellent to fair for Motupiko at Christies between the latest two samples which coincided with high filamentous green algae cover. Kikiwa at Kikiwa had scores in the excellent range although slightly lower than Hunters at Kikiwa. A slight improvement was evident for the Tasman Vly Stream site.

Figure 51. Macroinvertebrate community index (MCI) scores between 2001 and March 2015 for sites in the Motueka Water Management Area (larger blue dots). The background colours indicate these attribute states: excellent (green), good (yellow), fair (orange) and poor (red).

Paired Site Differences

This section compares the difference (increase or decrease) between two sites on a particular waterway on a particular day. The differences are then averaged to get the "mean difference". It is not the difference of the mean from each site calculated from the whole record for one site with the mean from the whole record from other site.

There were three paired sites in the Motueka Water Management Area, permitting comparisons between the upstream reference site and the downstream impact site.

Riwaka at Hickmotts was paired with Riwaka at Northbranch Source (reference site). The concentration of *E. coli* was consistently higher at Riwaka at Hickmotts compared to the reference site (mean increase 70 *E. coli*/100 ml, Figure 52) but still well within bathing water quality guidelines. Macroinvertebrate indices were typically one attribute state lower at Hickmotts (mean decrease in MCI 21 units).

Kikiwa at Kikiwa had consistently higher *E. coli* concentrations compared to the reference site at Hunters at Kikiwa (mean increase 262 *E. coli*/100 ml, Figure 53). Slightly higher *E. coli* concentrations were also found at **Wangapeka at Walter Peak** compared to the reference site at Wangapeka at 5km u-s Dart (mean increase 16 *E. coli*/100 ml, Figure 54). Macroinvertebrate condition at Kikiwa at Kikiwa was poorer than the reference site (MCI average 15 units lower).

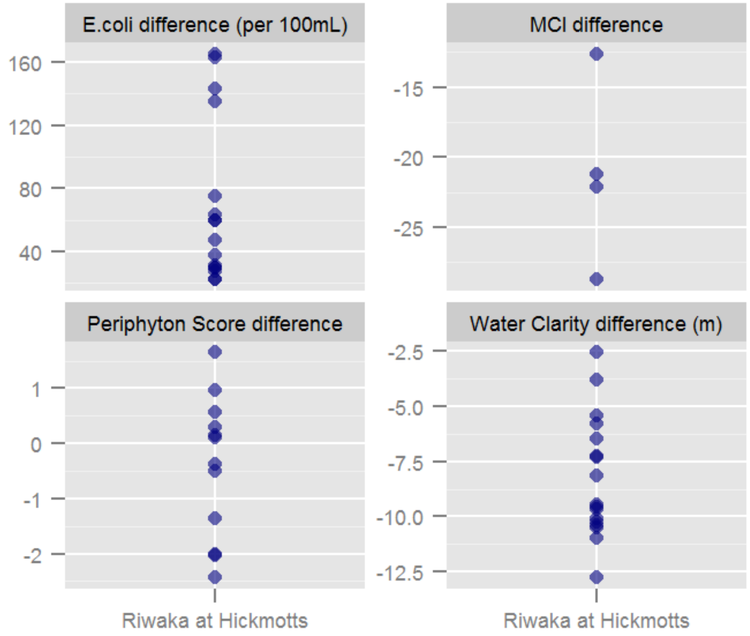


Figure 52. Difference between Riwaka at Northbranch Source (upstream) and Riwaka at Hickmotts (downstream) for water quality data collected at both sites on the same day. A positive difference means the downstream site had a higher value than the upstream site.

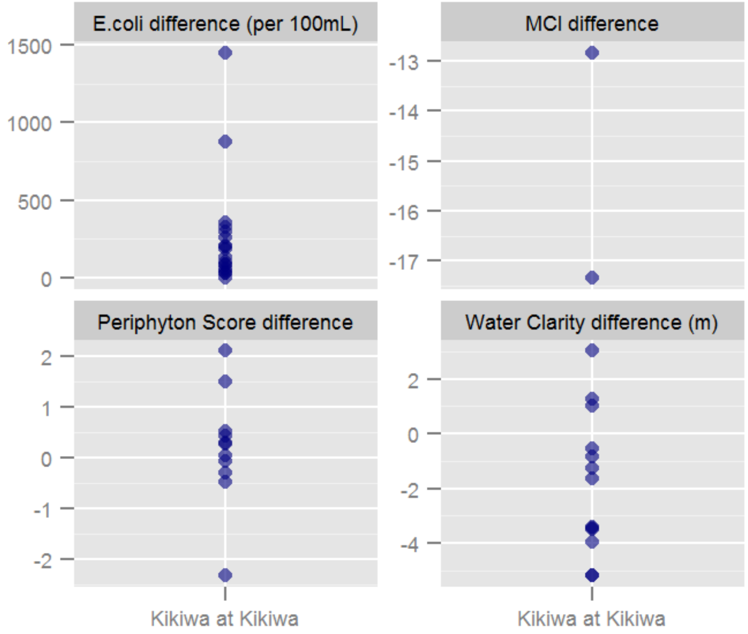


Figure 53. Difference between <u>Hunters at Kikiwa</u> (upstream) and <u>Kikiwa at Kikiwa</u> (downstream) for water quality data collected at both sites on the same day. A positive difference means the downstream site had a higher value than the upstream site.

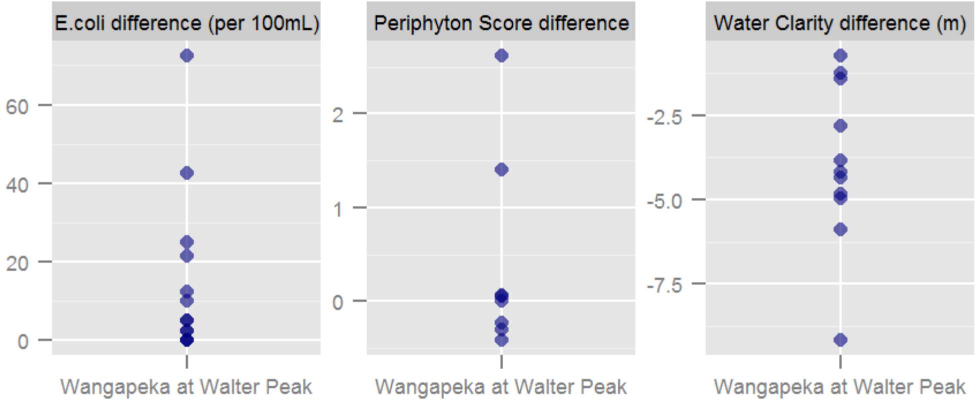


Figure 54. Difference between <u>Wangapeka at 5km u-s Dart</u> (upstream) and <u>Wangapeka at Walter Peak</u> (downstream) for water quality data collected at both sites on the same day. A positive difference means the downstream site had a higher value than the upstream site.

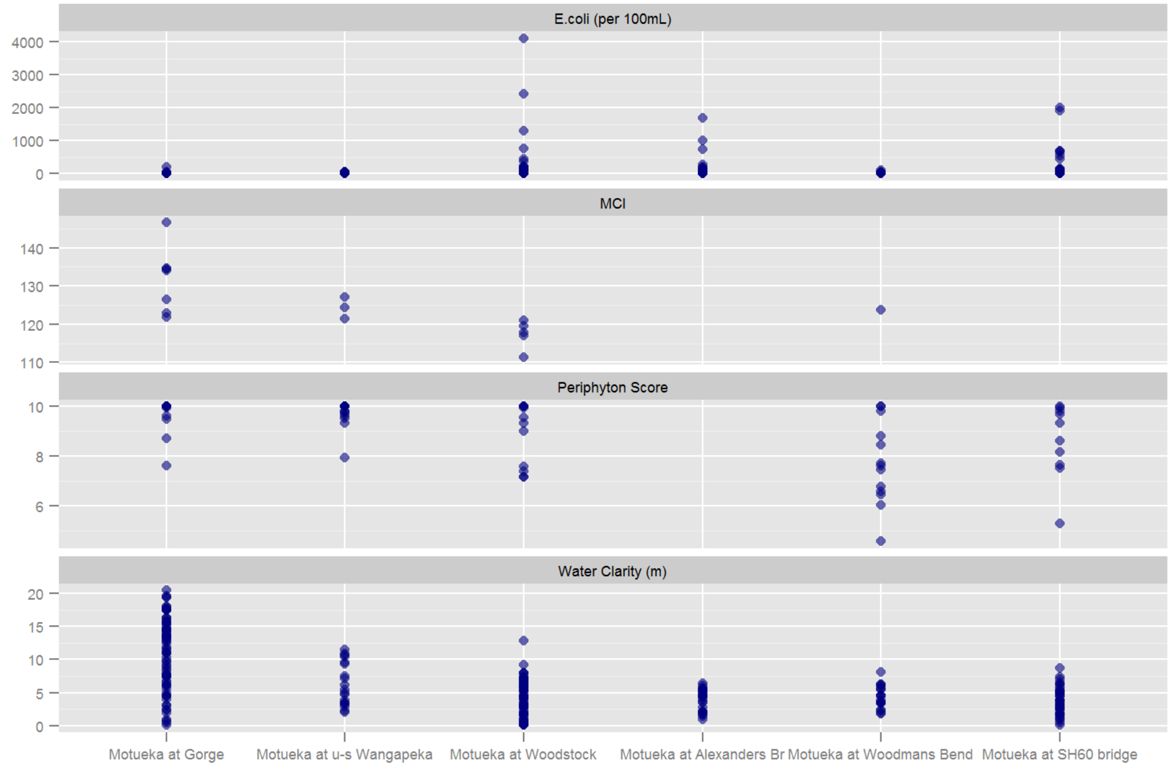


Figure 55. Motueka main stem sites along a gradient from Motueka at Gorge (upstream) to the SH60 bridge (downstream). Actual measured values shown (not differences). Data from 2010 to Feb 2015.

Trends in the Motueka WMA

The trend analysis for the Motueka Water Management Area showed a mix of improving and degrading water quality attributes. Improvements in *E. coli* concentrations occurred at two sites over the previous 10 years and five sites over the full record (15 years of more). There was a degrading trend in *E. coli* for Riwaka at Hickmotts and Waiwhero at Cemetery over 10 and 15 year time periods, respectively (Table 13).

Table 13. Water quality trend results for sites in the Motueka Water Management Area over the 10-year period 2005 to 2014 (highlighted in blue) and over the full record (from 15 to 26 years depending on the site). Seasonal Kendall trend tests were used for *E. coli* concentrations, water clarity measurements and nutrient concentrations (Ammonia-N, Nitrate-N and DRP). Mann-Kendall trend tests were used for invertebrate community metrics (for the NRWQN sites Motueka at Gorge and Motueka at Woodstock). The trends shown are significant ($p < 0.05$), meaningful (RSKSE > 1% per year) and the change in value between the start and end of the trend line is greater than the detection limit for the attribute (refer to the Methods sections for the detection limits). Statistics are shown in the Appendices.

Site name	Attribute	Effect ☺ ☹	N obs	N years
Little Sydney at Factory Rd	Ammonia-N	☺	37	10
Little Sydney at Factory Rd	*E. coli*	☺	38	10
Little Sydney at Factory Rd	*E. coli*	☺	60	15
Little Sydney at Factory Rd	Water Clarity	☹	60	15
Motueka at Gorge	# EPT Taxa	☹	27	26
Motueka at Gorge	Nitrate-N	☹	119	10
Motueka at Gorge	Water Clarity	☺	367	26
Motueka at u-s Wangapeka	DRP	☺	60	15
Motueka at u-s Wangapeka	Nitrate-N	☹	61	15
Motueka at Woodstock	Nitrate-N	☹	325	26
Motueka at Woodstock	QMCI	☹	25	25
Motueka at Woodstock	Water Clarity	☺	364	26
Motupiko at Christies	*E. coli*	☺	72	16
Riwaka at Hickmotts	Ammonia-N	☺	37	10
Riwaka at Hickmotts	Ammonia-N	☺	64	16
Riwaka at Hickmotts	*E. coli*	☹	37	10
Riwaka at Hickmotts	Water Clarity	☹	36	10
Sherry at Blue Rock	Ammonia-N	☺	61	10
Sherry at Blue Rock	Ammonia-N	☺	82	15
Sherry at Blue Rock	DRP	☺	60	15
Sherry at Blue Rock	*E. coli*	☺	141	10
Sherry at Blue Rock	*E. coli*	☺	186	15
Sherry at Matariki Br	Ammonia-N	☺	57	10
Sherry at u-s Cave Ck	Ammonia-N	☺	82	15
Sherry at u-s Cave Ck	*E. coli*	☺	63	15
Sherry at u-s Cave Ck	Water Clarity	☺	57	10
Waiwhero at Cemetery	Ammonia-N	☺	37	10
Waiwhero at Cemetery	*E. coli*	☹	61	15
Wangapeka at Walter Peak	*E. coli*	☺	67	16
Wangapeka at Walter Peak	Nitrate-N	☹	69	16

While Nitrate-N concentrations degraded at several sites, including Motueka at Woodstock and Wangapeka at Walter Peak, the percentage increase in Nitrate-N concentrations at the four sites with degrading trends was small (RSKSE less than 5% per year in all cases). Dissolved reactive phosphorus concentrations improved at Motueka at u-s Wangapeka and Sherry at Blue Rock.

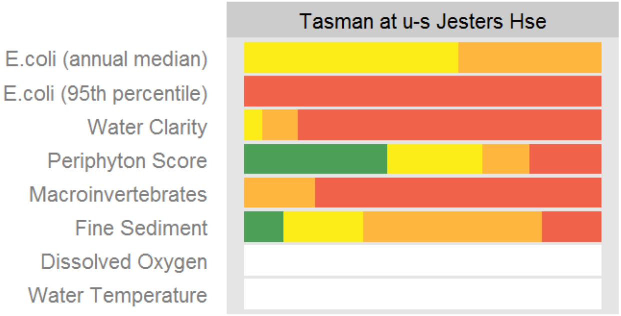
A degrading trend in QMCI was found for Motueka at Woodstock over the past 25 years but there were no trends in the other invertebrate metrics (MCI, the number of invertebrate taxa and EPT richness) at this site. Because the MCI results at this site have been consistently in attribute state A or B (MCI > 100) we are not concerned about the modest declining trend in QMCI.

Moutere Inlet Catchments

Tasman Valley Stream, near Tasman

This small stream has several reaches with **natural meander** and **small remnant riparian forest patches** within which fish such as banded kokopu and long-fin eel are abundant. The very rare giant kokopu also exists in a couple of these remnants with wetlands upstream. These fish survive well despite the stream almost ceasing to flow in the driest period of summer. The **Moutere Estuary** is popular for water skiing, fishing and an annual mud run.

Above: Tasman Valley Stream upstream Jester House (February 2006)



Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

The stream is **grouped with the worst 10 sites for water quality in the district** because of low dissolved oxygen, high concentrations of faecal indicator bacteria, high water temperatures, and moderately high nutrient concentrations.

High levels of potentially disease-causing organisms occur at this site (median: 423 *E.coli*/100 ml for 2010-2015, compared to 800 *E.coli*/100 ml over 2006-2009, and a third of samples are above stock drinking guidelines (consistent over the last five years and over the whole period). Microbial source tracking (a genetic technique for determining the source animal responsible for the faecal contamination) shows that both human and ruminant faecal sources are to blame and not wildfowl or gulls. There appear to be a number of older houses in the upper part of the catchment (Marriages and Mamaku Rd areas), as well as in Tasman township, with failing septic tanks, and cattle are farmed in about a third of the catchment. However, high levels of faecal indicator bacteria are surprising, considering that horticulture makes up a large proportion of the catchment’s land use (~40%). Investigations to narrow down the source of disease-causing organisms over 2010-12 (Figure 57) found that relatively high faecal indicator bacteria were present in both the main tributaries i.e. up in the Marriages Rd and Mamuku Rd areas (Figure 56). Tasman School students have also found similar concentrations around the Tasman township and Field Creek.

Dissolved oxygen levels regularly get below 25% saturation in summer and **water temperature** (midpoint of daily mean and daily maxima) **regularly reaches 25 °C in summer** (Figure 58). The solution to this problem is obvious: riparian trees. It will be effective and at the same time provide important habitat for fish.

Flow in this stream has increased after logging of the Carter Holt forests (~15% of the catchment) in 2008.

Large areas of the Moutere Inlet are excessively **muddy and enriched with nutrients** (Stevens and Robertson 2013). This is not only due to Tasman Valley Stream, but the Moutere River and other small streams. Heavy discharges of sediment from horticultural land in catchments draining to the Moutere and Waimea Inlets were described as common in the 1950s through 70s (Leighs, 1977).

While the **macroinvertebrate condition is currently described as very poor**, there are signs that it is improving.

A few landowners have, or are in the process of, planting native trees along the stream and new natural-like wetlands have been created to restore what was removed a century or more ago. Council has provided fencing material, to fence off 120 m of stream, and assistance with re-vegetating 220 m of stream. More of these actions are recommended to improve water quality to the point where reasonable life-supporting capacity of the stream is realised. Several large subdivisions have occurred in this catchment since 2010, and another large one is planned for the main valley upstream of Horton Valley Stream. As part of this latter development, it is likely that riparian forest buffers and wetlands will be restored and sewage discharges treated effectively.

Figure 56 Tasman Valley Stream *E.coli* Concentrations 2010-11 (note: log scale)

Tasman Valley Stm upstream Jester House in spring (October 2008, left) and in summer (January, 2008, right).

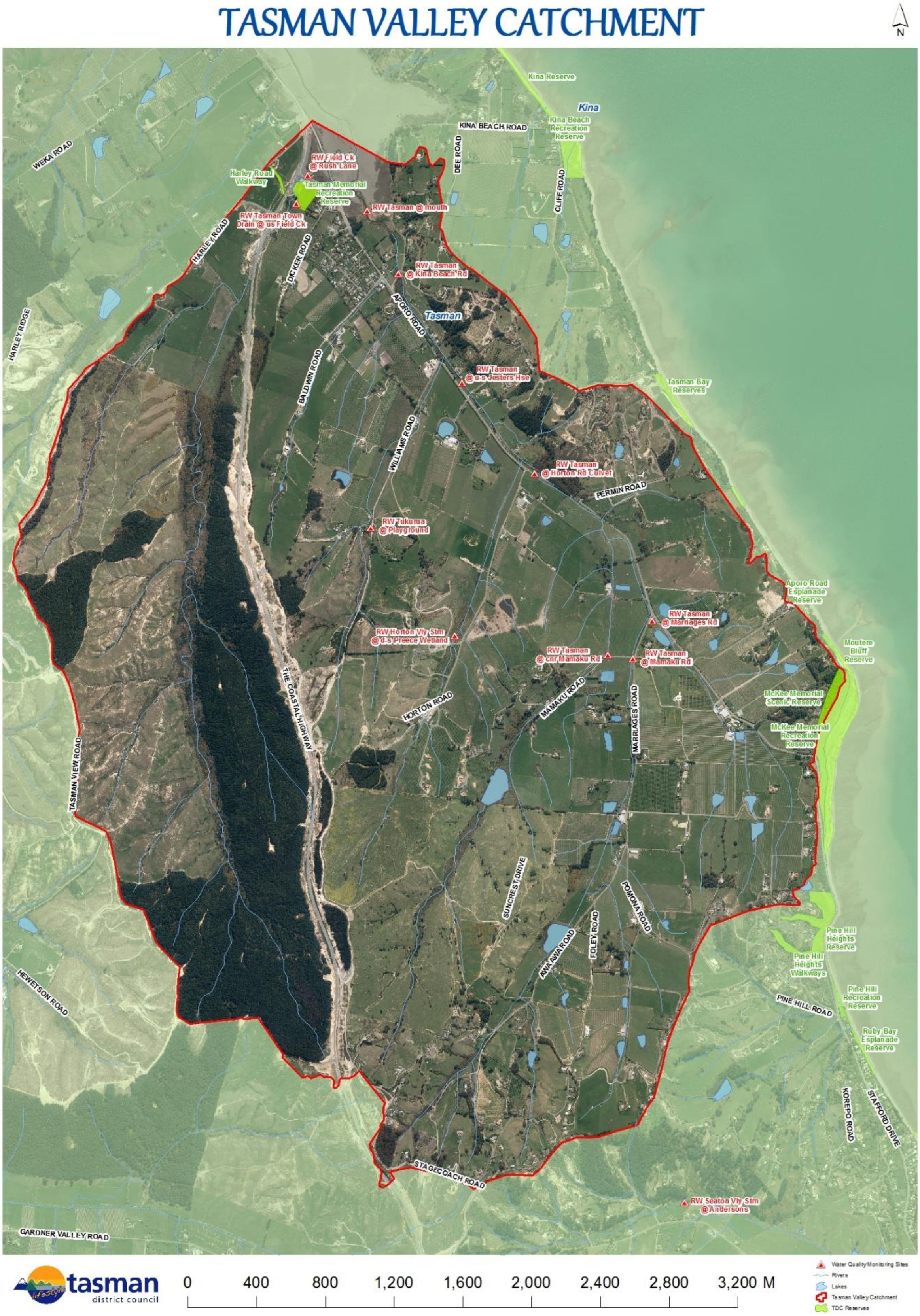


Figure 57 Tasman Valley Catchment showing sample sites for the investigation 2010-11

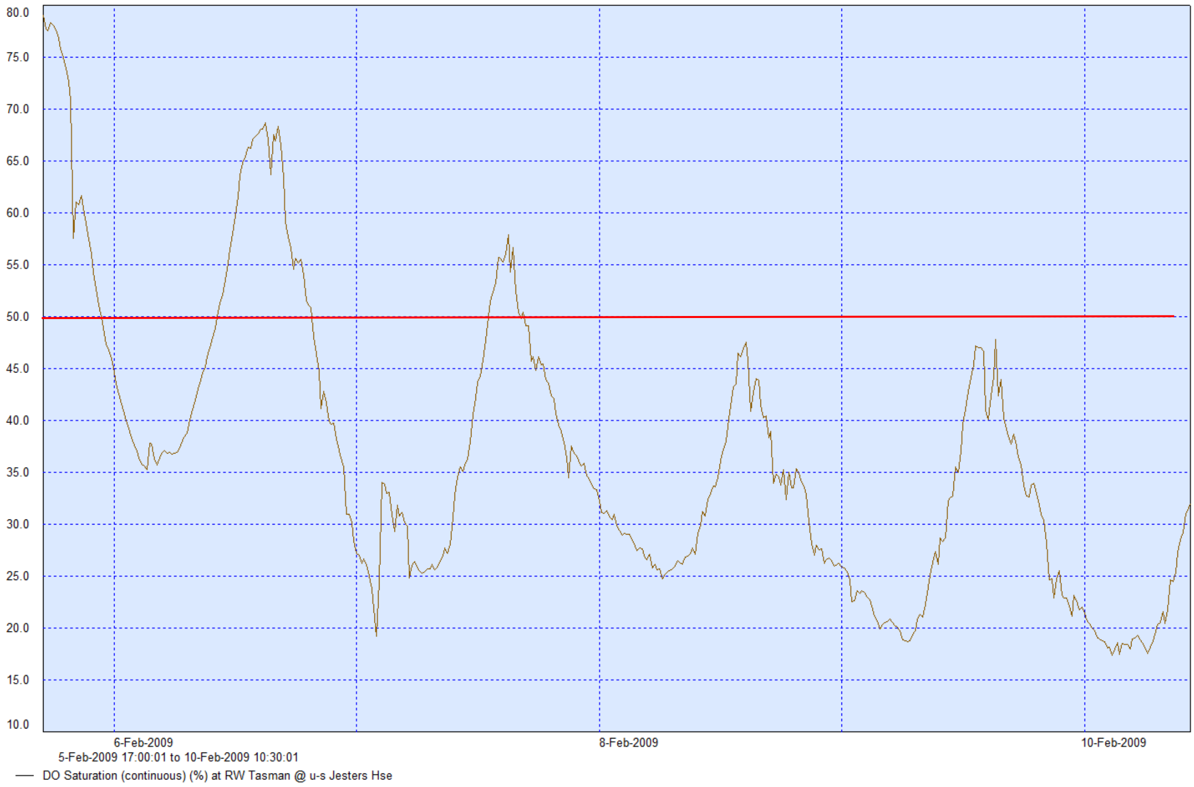


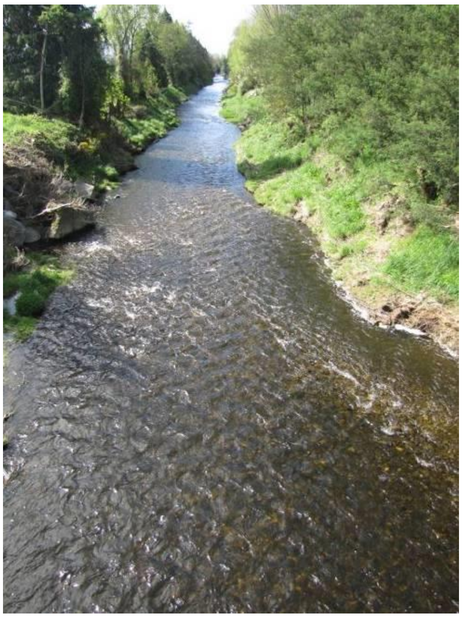
Figure 58 Dissolved oxygen percent saturation at Tasman Valley Stream (6-10 Feb, 2009). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Catchment Statistics	Tasman Valley Stream
River Environment Class	Warm Dry Soft sedimentary Lowland-fed Pasture
Catchment area (km^2)$^+$	8.5
Predominant land use upstream	Pasture
Mean annual rainfall (mm)*	1048*
Mean annual flow (l/sec)*	82.6*
Lowest recorded flow (l/sec)	3 (Apr 2010)
Water quality record	Feb 2006-present

* Estimate from WRENZ 2013. NA = not available

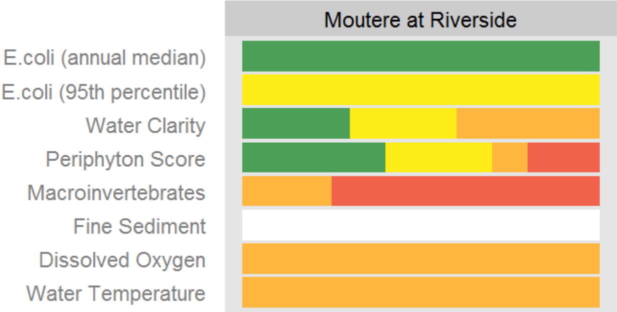
Moutere River catchment

Moutere at Riverside (Chings Rd), Lower Moutere



Moutere River at Edwards Rd looking downstream (February 2011)

The Moutere River generally flows north-west from the divide with the Waimea/Wai-iti catchment and meets the sea near Motueka. In the lower reaches it is an artificial straight channel dug in the late 1850's and 1860's to drain the flax swamp to provide more land for crops and farms. Very few wetlands remain in the catchment and summer low flows can be very low for a catchment this size (only a few 10's of litres/sec). In 2013 a minimum flow of 20 l/sec was set at the Chings Rd site below which all extraction for irrigation stops. Those catchments with remaining wetlands have much higher flows in summer dry periods and receiving streams have much higher fish abundance and diversity. Freshwater fish communities in this catchment are not as diverse as in the past. Surveys in 2012-13 targeting giant kokopu in the Moutere catchment did not find any. Common and giant bully are found in the catchment but no redfin or bluegill bully have been found in the catchment. Inanga, smelt, and eel are abundant and banded kokopu are found in streams where there are native trees overhanging.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

This stream has generally good water quality, apart from the macroinvertebrate condition. Levels of **disease-causing organisms** are low (Median: 81 *E.coli*/100 ml over 12 samples). Water clarity is relatively high (median: 4 m over 12 samples). One sample of **filamentous green algae** cover was recorded at 80% (March 2014) but all other records are under 30%. **Periphyton scores** were generally greater than 8.0 but two samples were just above 6.0. Daily **dissolved oxygen** minima were just over 60% (over 5 days in Feb 2014). **Water temperature** was elevated but just below the bottom line of 24 °C (midpoint of daily mean and daily maxima: 23°C). Resuspendable solids scores were slightly elevated (maxima of 3.0).

Macroinvertebrate metrics show poor ecological health (MCI 73, SQMCI 3.75, %EPT 14.5, # taxa 10.5; mean over 4 samples 2012-2015). *Orthoclad* flies, *Potamopyrgus* snails and axehead caddisflies are often abundant.

Above: Moutere River at Riverside. Left: View downstream (February 2014). Right: View upstream (February 2012)

Statistic	Moutere at Riverside
River Environment Class	Warm Dry Soft sedimentary Lowland-fed Pasture
Catchment area (km^2)$^+$	124.5
Predominant land use upstream	Pastoral, horticulture
Mean annual rainfall (mm)*	1097*
Mean annual flow (l/sec)*	1382*
Lowest recorded flow (l/sec)	11 (Feb 1993)
Water quality record	Aug 2012-present

* Estimate from WRENZ 2013. NA = not available

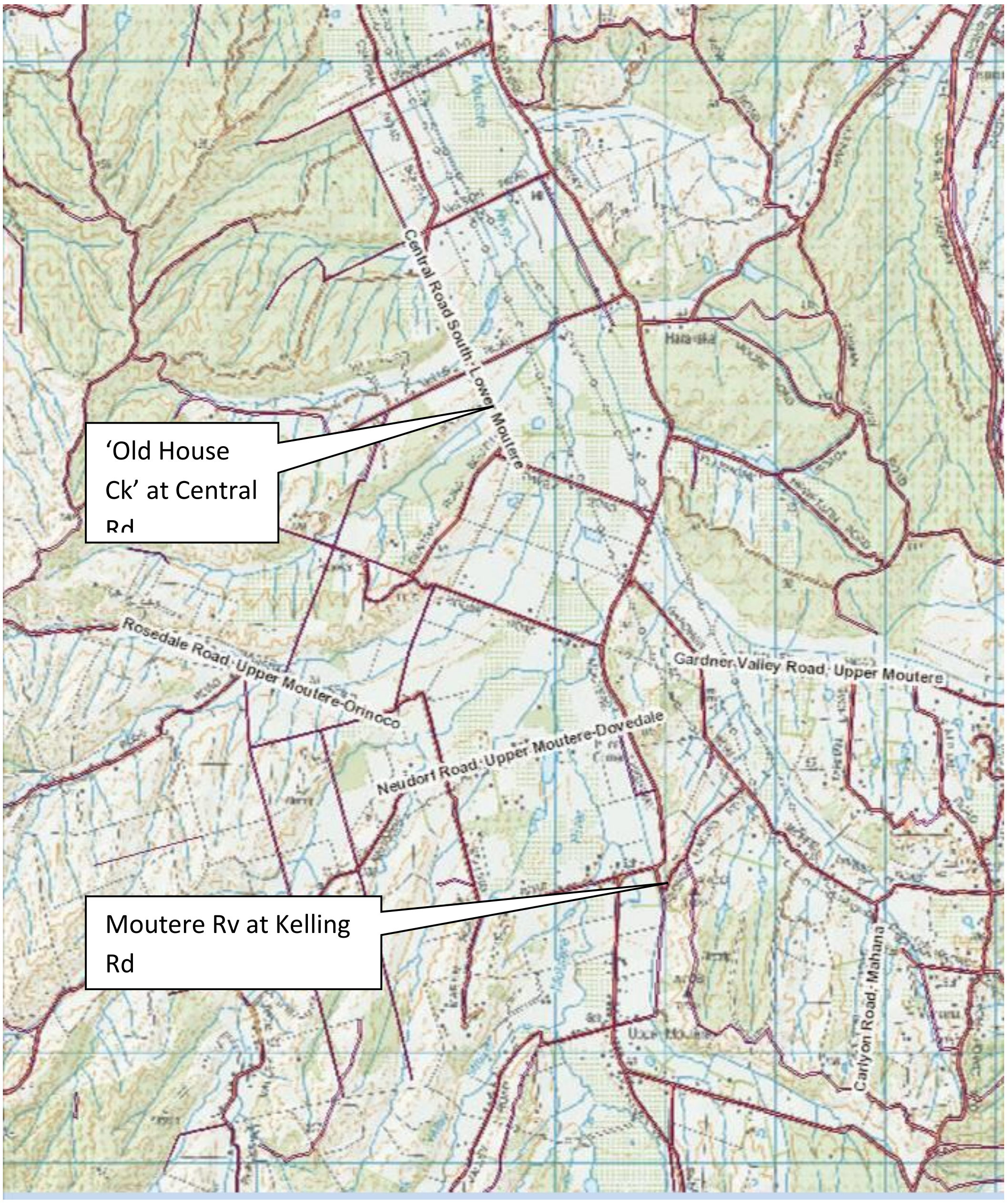


Figure 59. Map of central Moutere Valley sites where semi-continuous sampling has been carried out.

Old House Creek at Central Rd, mid Moutere

This small creek has a catchment area of 3.5km^2 and flows most of the year at this location. It is highly modified and has few riparian trees.

Low summer-time dissolved oxygen was an issue at this site (Figure 60). The pattern of dissolved oxygen over any 24 hour period was highly variable and erratic, possibly reflecting an intermittent water take. Daily minima tended to occur in the early afternoon and were below 30% saturation on three of the four days of sampling in February 2010).

Right: Old House Creek at Central Rd looking upstream (February 2010)

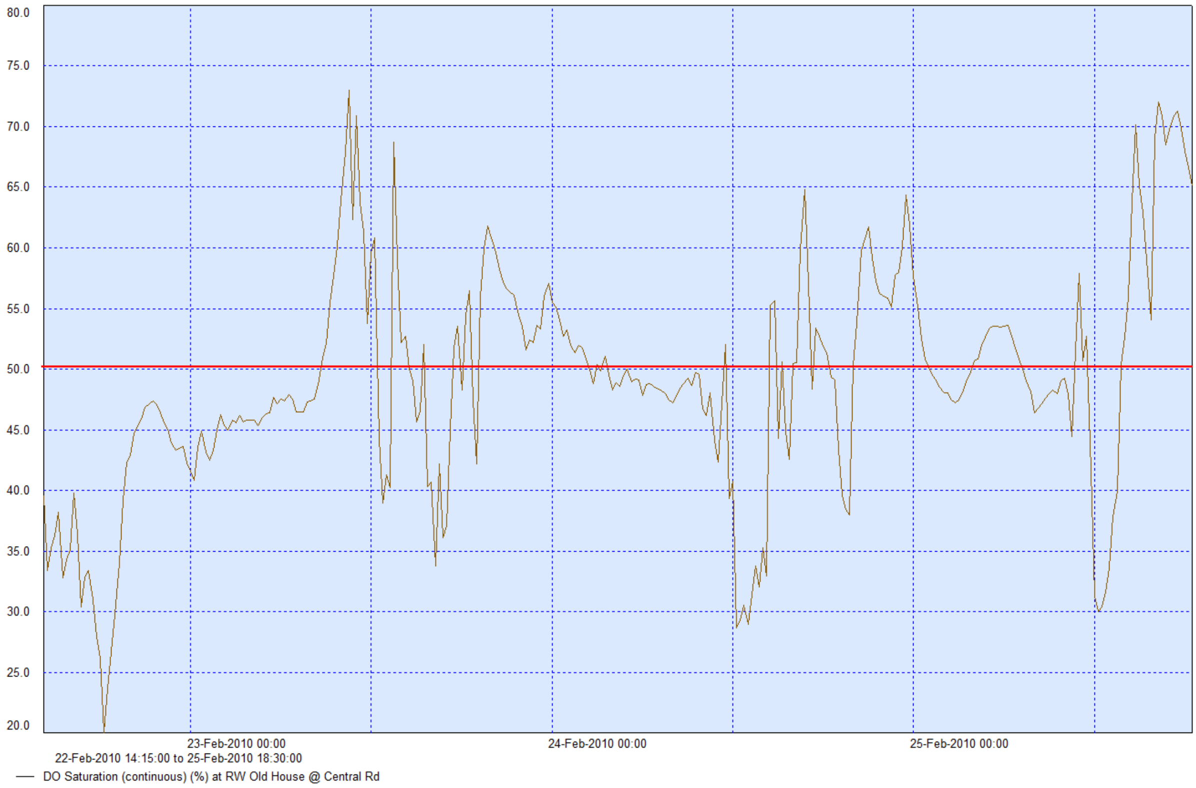


Figure 60 Dissolved oxygen percent saturation at Old House Creek at Central Rd (22-25 Feb, 2010). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Moutere River at Kelling Rd, Upper Moutere

At this site dissolved oxygen daily minima were over 70% and water temperature maxima under 19°C (February 2010). Water clarity was high (not measured) with very little filamentous green algae on the cobbly stream bed.

Above: Moutere River at Kelling Rd looking downstream (February 2010)

Old Moutere River (Blue Creek)

This waterway is the original channel for streams draining the Moutere Valley. For the reaches between Edwards and Ching Rd the stream has good stream habitat including natural meander, mature overhanging tree cover and variety of bank shape and substrate.

Dissolved oxygen was recorded at near zero over several days in the summers of 2010 and 2014 (Figure 62). In 2014 there was little daily fluctuation (below 1% for over 3 days) compared to 2010 when dissolved oxygen fluctuated between just above zero to about 30%. The cause of this low dissolved oxygen was found in late 2014; two discharges direct to the stream from two fruit processing industries (Figure 61). These discharges have since been removed and it is hoped that future monitoring will show an improvement.

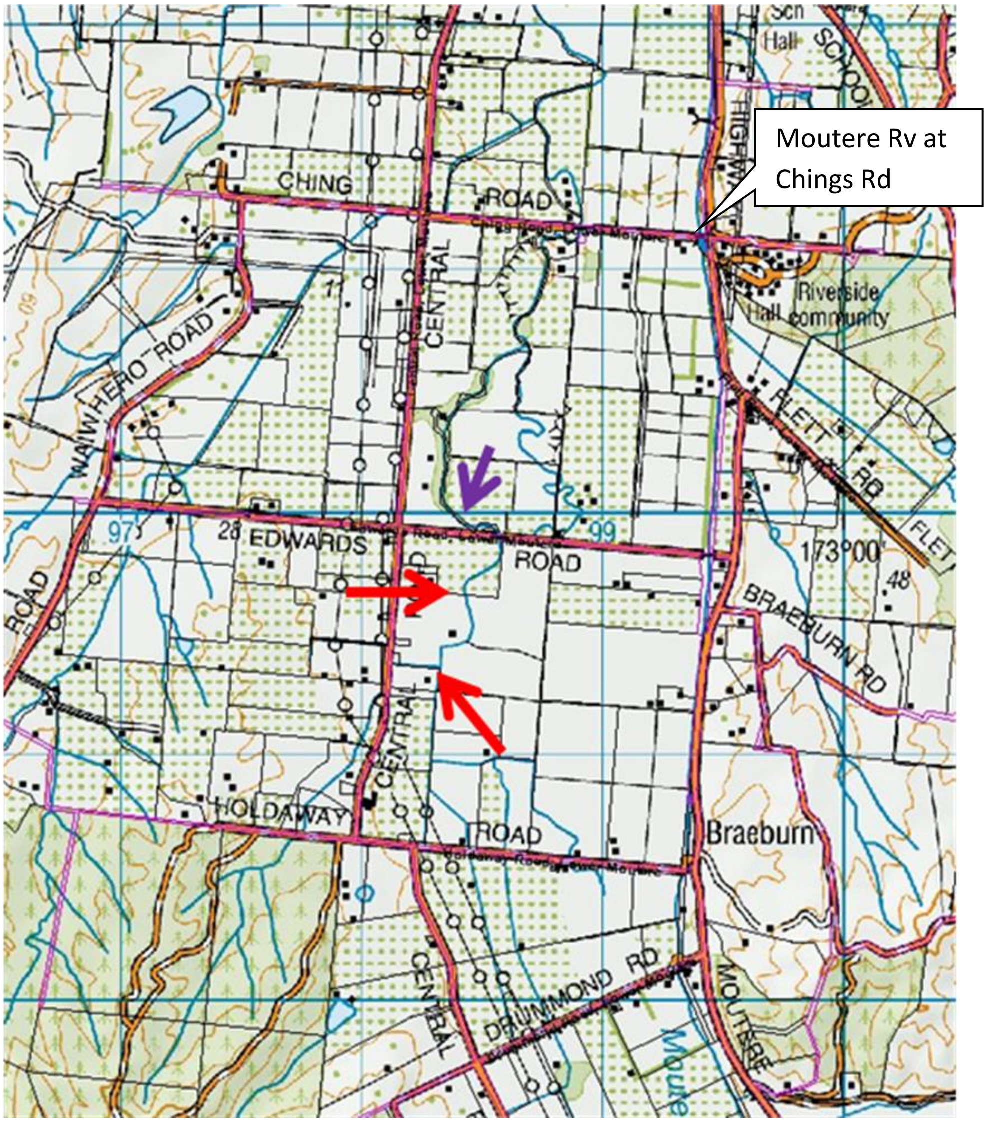


Figure 61 Location of water quality logger in purple (February 2010 and February 2014). Location of fruit industry discharges in red.

Discharges to Old Moutere Creek upstream Edwards Rd (December 2014). Lower right: methane bubbles and sheen on water surface.

Water temperatures were very suitable for aquatic life (daily maxima under 17.5^{o}C).

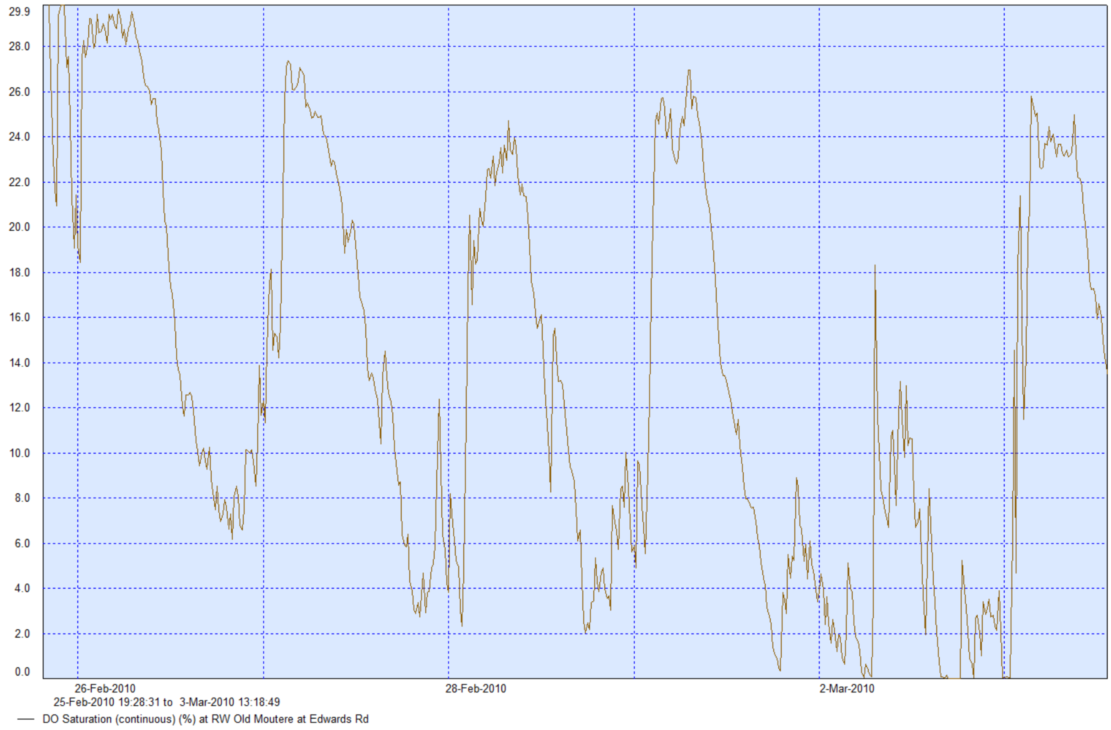


Figure 62 Dissolved oxygen percent saturation at Old Moutere Rv at Edwards Rd (26 February – 3 March, 2010). Note the scale with daily maxima well below national bottom lines.

Dissolved oxygen levels were also very low at times at a site about 500 m downstream Ching Rd (near Riverside) about 4 m upstream of the outlet of the dam (see graph below). The variability and 'spikiness' over this period in February 2014 were possibly due to the very low flows, thermal stratification of the water column and water takes from this stream. There was no correlation between solar radiation and dissolved oxygen with dissolved oxygen peaking at midnight on one occasion. There is one in-stream dam located upstream of Ching Rd and one downstream.

Old Moutere River at Wratten Weir looking upstream (sonde installed on the left of the photo).

Figure Dissolved oxygen at Old Moutere River at Wratten Weir sampled continuously from 24-28 February, 2014). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Water temperatures were high (midpoint of daily mean-maximum was almost 23°C). This is likely to compromise the aquatic ecology in this stream but is typical for ponded water in summer.

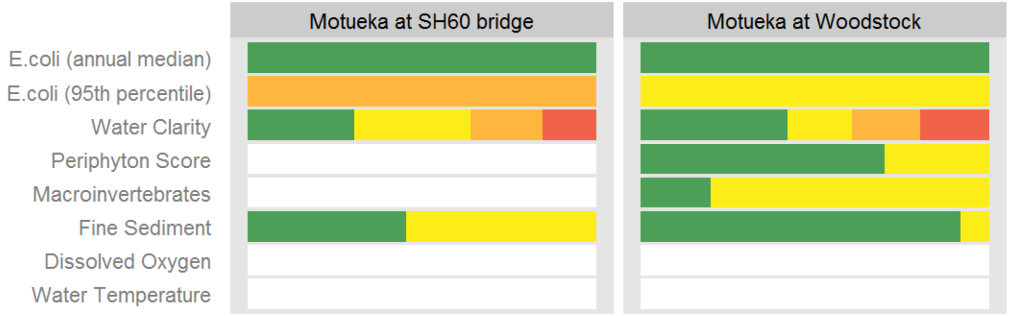
Motueka-Riwaka Catchments

Motueka River Main Stem and River Plume

Motueka catchment land cover is **dominated by native (35%) and exotic (25%) forest, pasture (19%), and scrub (12%)**. The Motueka catchment has a Water Conservation Order protecting trout angling and blue duck values, as well as recreation and wild and scenic values. The main stem from Tapawera to the mouth is used extensively for swimming and boating. The river starts at 1800 m in alpine headwaters and flows 110 km from source to the sea. It delivers 62% of the freshwater inflow to Tasman Bay. The Motueka River is braided in the approximately 10km reach between Kohatu and Wangapeka River and is used by river-nesting birds such as Oystercatchers, Black-billed gulls, Banded Dotterels and Pied stilts. This reach was used by Black-fronted terns, but these birds have not been seen nesting here since the 1990's, probably due to predators. Only about 45km of rivers in Tasman District are braided. A lot of information has been produced about this catchment as the Motueka Integrated Catchment Management research programme was focused here from 2000 until 2010 (see http: //icm.landcareresearch.co.nz/knowledgebase/publications/).

Motueka River at Gorge (April 2005, left) and at Woodstock looking downstream (February 2005, right).

Water quality is generally good in the catchment. However, **excessive fine sediment discharges** and **high summer water temperature** in many tributaries are probably the biggest pressures on water quality. Base-flow water clarity at Motueka Gorge tops the list for the best of the 77 National Water Quality Monitoring Network sites, monitored over 20 years (median 11.6 m, 95th percentile 17 m). **Excellent water clarity** also exists in waterways draining the west bank (*e.g.* Wangapeka, Baton, Pearse, and Graham Rivers (medians: 7.9 m, 7.0 m, 3.9 m, and 4.5 m, respectively).



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

While a lot of data exists for dissolved oxygen, these are only spot measurements taken towards the middle of the day and so are not representative of the issue dissolved oxygen potentially pose. However, there is no cause for concern from any of the spot measurements.

Base-flow levels of faecal indicator bacteria are low, but at high-flows levels almost always exceed guidelines. Faecal indicator bacteria were found in elevated concentrations after a rainfall event in the Motueka River plume 6 km out into Tasman Bay. This contamination was linked to ruminant animal sources using genetic markers (Cornelisen *et al.* 2010). No human markers were found in this study, indicating that the influence of sewage treatment plants, such as the one at the Motueka River mouth, are not having a widespread impact.

The concentration of faecal indicator bacteria during rain events in the Motueka at Woodmans is typically 10-30 times higher than in base flow conditions (McKergow & Davies-Colley 2010). From these data a model was developed that accurately predicts *E.coli* concentrations at Woodmans for a given flow (Wilkinson *et al.* 2011). Average *E. coli* concentrations at Woodmans Bend for flood events where rainfall was centred on the middle of the catchment were much higher than when rainfall mainly occurred on the steep-lands. Sampling will continue at the river and swimming beaches around floods in the hope that we will be able to produce a successful model that will predict faecal indicator bacteria concentrations at beaches along the Tasman Bay coast (Jiang and Knight 2013).

The Motueka River contributes about the same nitrogen to Tasman Bay as all other freshwater sources put together. However, freshwater sources are only about 10% of the nitrogen in the bay with 90% coming from Cook Straight. Total nitrogen loads to Tasman Bay via the Motueka River ranged from about 200-300 tonnes/year, with the dissolved inorganic fraction making up 65-70% of this (Clark *et al.* 2007). At these loadings, nutrients delivered to the Bay would likely contribute to greater coastal ecosystem productivity in a beneficial way, with little potential for adverse ecological effects. Dissolved reactive phosphorus loads were very low (4-6 tonnes) compared to dissolved inorganic nitrogen, suggesting that algal growth in the river may be phosphorus limited. While nutrient concentrations are low in this catchment, there has been a significant increase in nitrate at Woodstock over the last 26 years (2.2% of the median per year, all weather data not flow adjusted).

If the current rate of increase continued for all sources of nitrogen to the Bay, it would take about 60 years before the risk of severe adverse effects in Tasman Bay are likely to be identified.

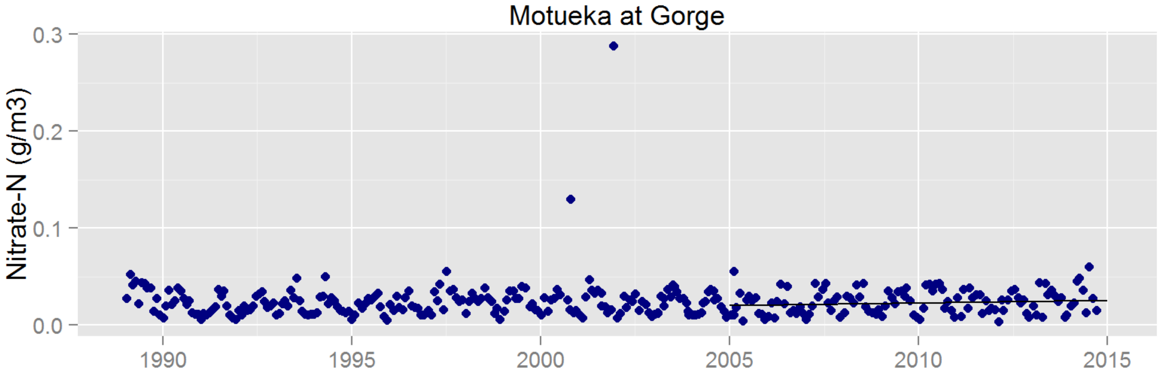


Figure 63. Motueka at Gorge Nitrate-N concentration data with 10-year trend line (p = 0.0384, RSKSE = 2.2% per year). No significant meaningful trend was detected over the full record (26 years).

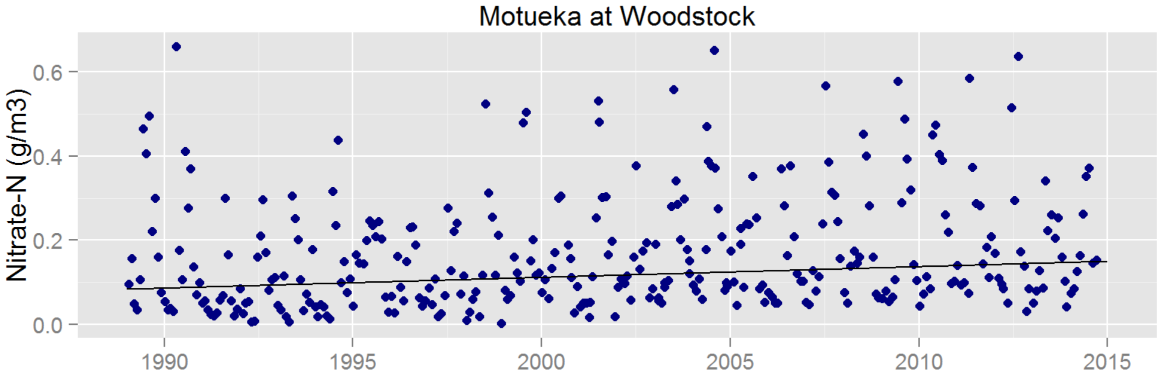


Figure 64. Motueka at Woodstock Nitrate-N concentration data with 26-year trend line (p = <0.0001, RSKSE = 2.2% per year). No significant meaningful trend was detected over the most recent 10 years of the record.

The concentrations of nickel, copper, and chromium in the sediments deposited along the river margin at Motueka Gorge were up to 20 times the ISQG-Low guidelines (ANZECC 2000), suggesting “probable biological effects”. In the **Easter 2005 flood** significant amounts of **sediment were eroded from the Red Hills mineral belt** in the upper Motueka River (Forrest & Gillespie 2009). Although this sediment became progressively more diluted in the main stem of the river further downstream, as they were mixed with sediments from other catchments, they were still above guidelines in the lower reaches of the catchment. Sediment heavy metal concentrations in all tributaries of the Motueka catchment were well below guidelines.

The detectable sediment plume from the Motueka River covers an area of sea bed of about 180 km^2, with plume-affected nickel concentrations up to six times higher than guidelines (up to 300 mg/kg; six times the ISQG-High, ANZECC 2000)(Clement et al 2010). Macro-fauna samples at sites in Tasman Bay affected by these heavy metals contained fewer species, but greater abundances of opportunistic, disturbance-tolerant species. The boundary of elevated sediment metal concentrations lies just inside the spat-collecting and proposed mussel farming areas in Tasman Bay, but it is conceivable that large floods could circulate high concentrations of metals into those areas.

This area extends northwards almost to Anchorage/Torrent Bay, in Abel Tasman National Park, and up to 4 km off the coast (Clement et al 2010).

It was thought that water quality, particularly fine sediment discharges (not metals), were the main cause of the significant decline in the Motueka trout fishery in the mid 1990's. However, repeated small to moderate floods in smaller headwater tributaries, during critical periods (e.g. when juveniles are emerging from gravels) were the most likely reason for these declines (Young *et al.* 2012).

Motueka River plume from the Motueka Plains after a moderate flood event (6 October 2007; view NE).

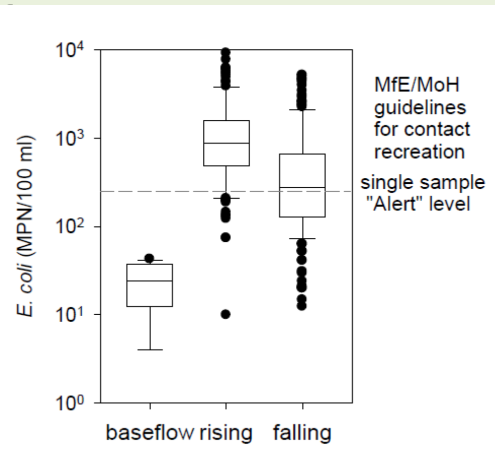
Catchment Statistics	Motueka at Gorge	Motueka at u-s Wangapeka	Motueka at Woodstock	Motueka at Woodmans Bend	Motueka at SH60 (Mouth)
River Environment Class	Cool Wet Hard sedimentary Mountain-fed Indigenous forest	Cool Wet Soft sedimentary Hill-fed Exotic forest	Cool Wet Soft sedimentary Hill-fed Exotic forest	Cool Wet Soft sedimentary Hill-fed Indigenous forest	Cool Wet Soft sedimentary Hill-fed Indigenous forest
Catchment area (km^2)$^+$	167.7	842	1757	2,047	2,170
Predominant land use upstream					Native forest, scrub and grassland in headwaters: (40%) Commercial forestry (25%) Pasture & horticulture (35%)
Mean annual rainfall (mm)	1180	1100	1290	1400	1200
Mean flow (l/sec)	7,069	20,486*	56,830	61,137	NA
Median flow (l/sec)	3,875	NA	33,232	37,052	NA
7-day Mean annual low flow (l/sec)	1,522	NA	10,030	10,980	NA
Highest recorded flood event (l/sec)	800,000	NA	2,148,709 (1983)	1,605,277 (hydro site began in 2001)	NA
Lowest recorded flow (l/sec)	744	NA	4,841	7,854	NA
Water quality record	Monthly 1989-present Quarterly 2000-present	2000-present	Monthly 1989-present Quarterly: 2000-present	2000-present Flood event sampling: 2003-04	2001-present bathing water sampling Monthly: Aug 2013-present

* Estimate from WRENZ 2013. NA = not available

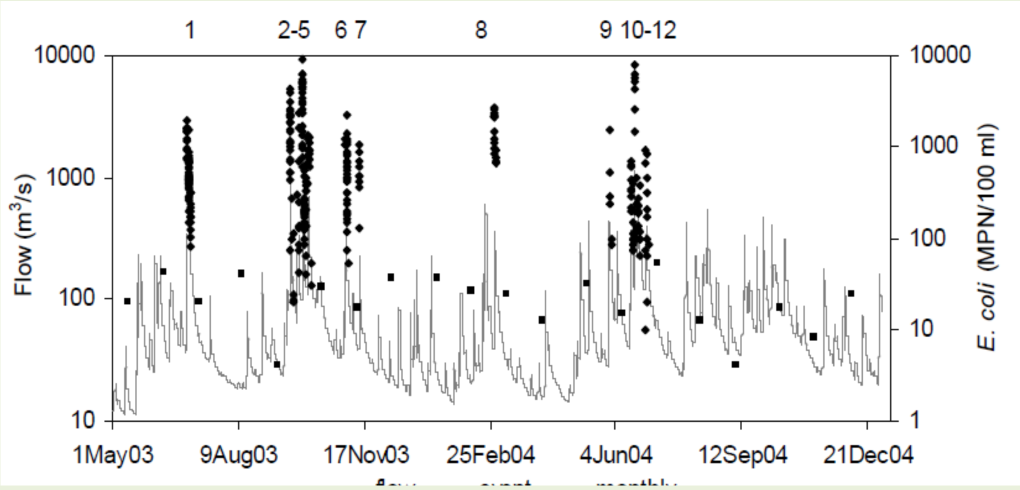
DISEASE CAUSING ORGANISMS (*E. COLI*) IN THE MOTUEKA RIVER

In an extensive study carried out in the **Motueka River**, annual exports of disease-causing organisms (*E. coli)* were predicted to be in the order of 10^{16} *E. coli*/year, which is equivalent to an average annual specific yield of about 10^{12} *E. coli*/km^2/year (McKergow & Davies-Colley 2010). This is an order of magnitude lower than catchments dominated by intensive dairy farming land use in the Waikato. The concentration of disease-causing organisms during rain events is typically 10-30 times higher than in base flow conditions (Figure 65A), and most (>98%) of the annual load of *E. coli* is exported to the lower river and coast during flood events (McKergow & Davies-Colley 2010). All peak *E. coli* concentrations occurred on the rising limb of the hydrograph (Figure 65B and C). Knowing this information, people who like to swim or get immersed in rivers can avoid the risky periods during and after rain. The river flow rate was found to be the best surrogate for disease-causing organisms in the Motueka catchment, rather than turbidity, which has been found to be more useful in smaller catchments. **Run-off from grazed pasture and direct deposition from livestock** are the most likely sources of disease-causing organisms in this catchment. Average *E. coli* concentrations for flood events where rainfall was centered on the middle Motueka catchment were much higher than for rainfall that mainly occurred on the steep lands.

A



B



C

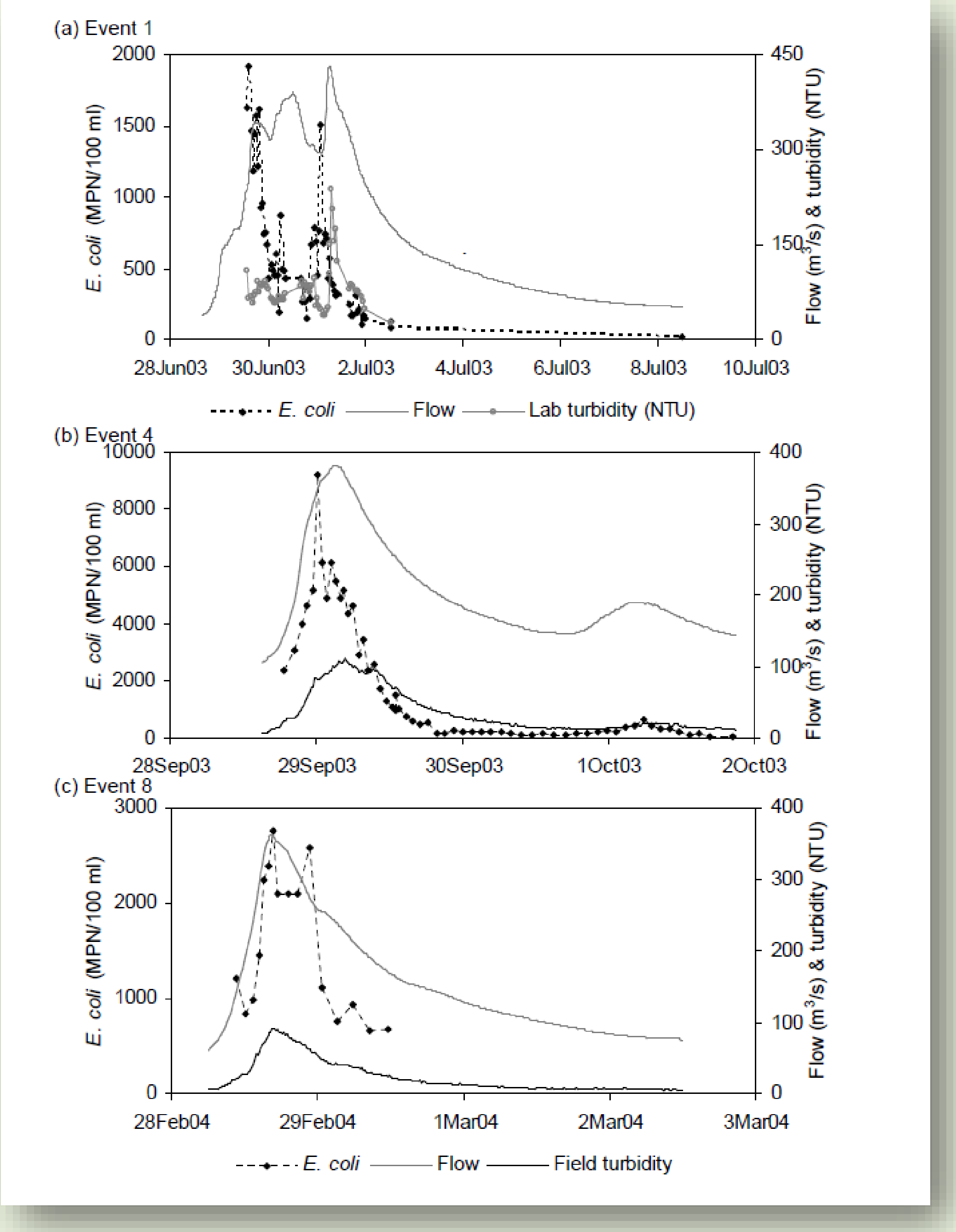


Figure 65. Relationships between *E. coli* levels and flow events in the Motueka River.
Note: X-axes are on a log scale except for C.

WATER QUALITY CHANGES FROM THE TOP TO THE BOTTOM OF THE MOTUEKA?

To provide a picture of how water quality patterns vary throughout a catchment models were used for predicting water quality (Clapcott *et al.* 2009; Clapcott *et al.* 2010). As expected, the models predict that concentrations of nitrogen will generally increase downstream in the Motueka catchment, although there are a few predicted hotspots in some sub-catchments associated with agricultural land use. Conversely, water clarity and MCI scores are predicted to be highest in the upper reaches (Figures Figure 67Figure 68). The Motueka catchment has comparatively more data with wide coverage, making the model more robust.

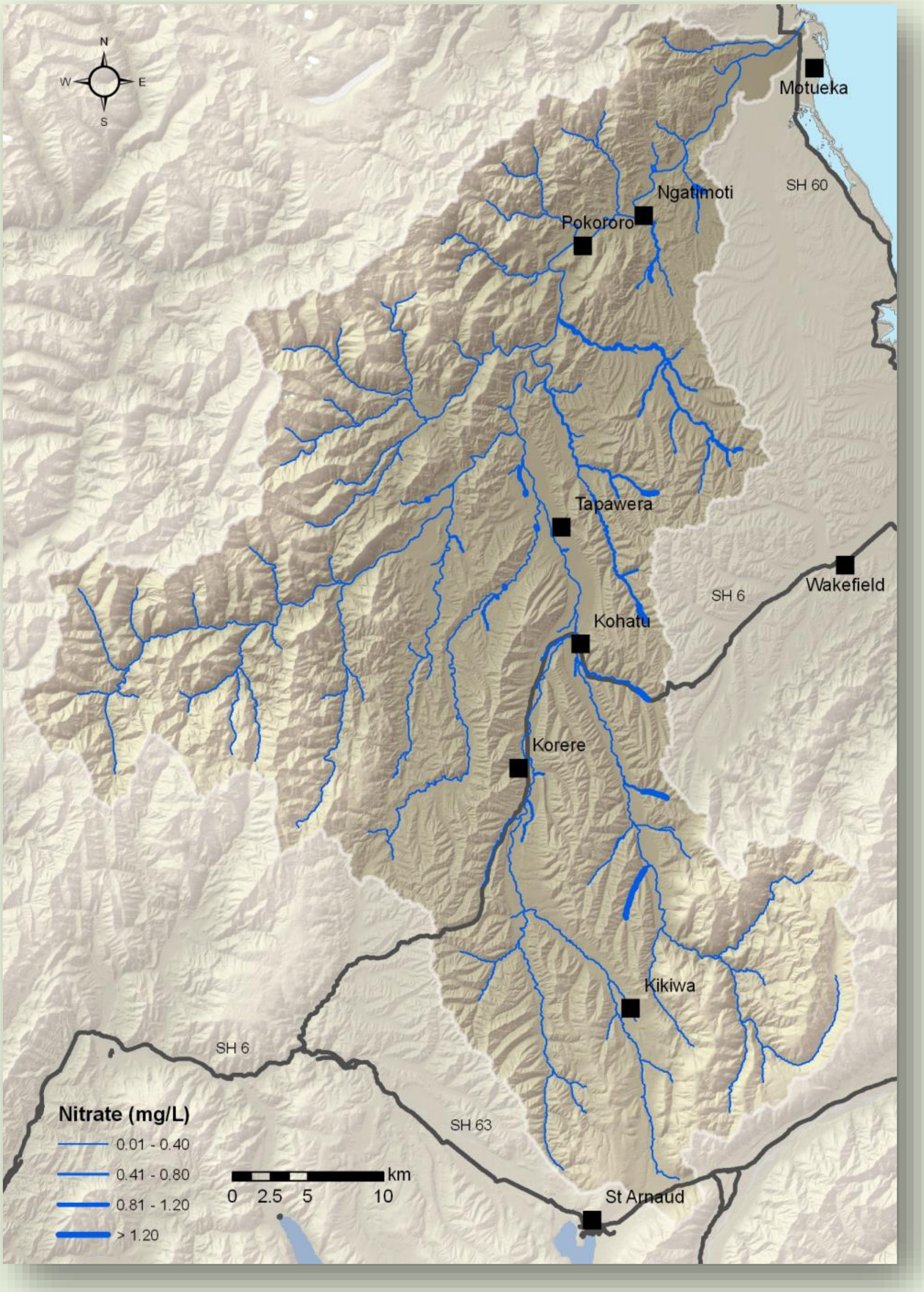


Figure 66. Predicted downstream changes in Nitrate-N in the Motueka River catchment. Note: The thicker the river line, the higher the nitrate concentration.

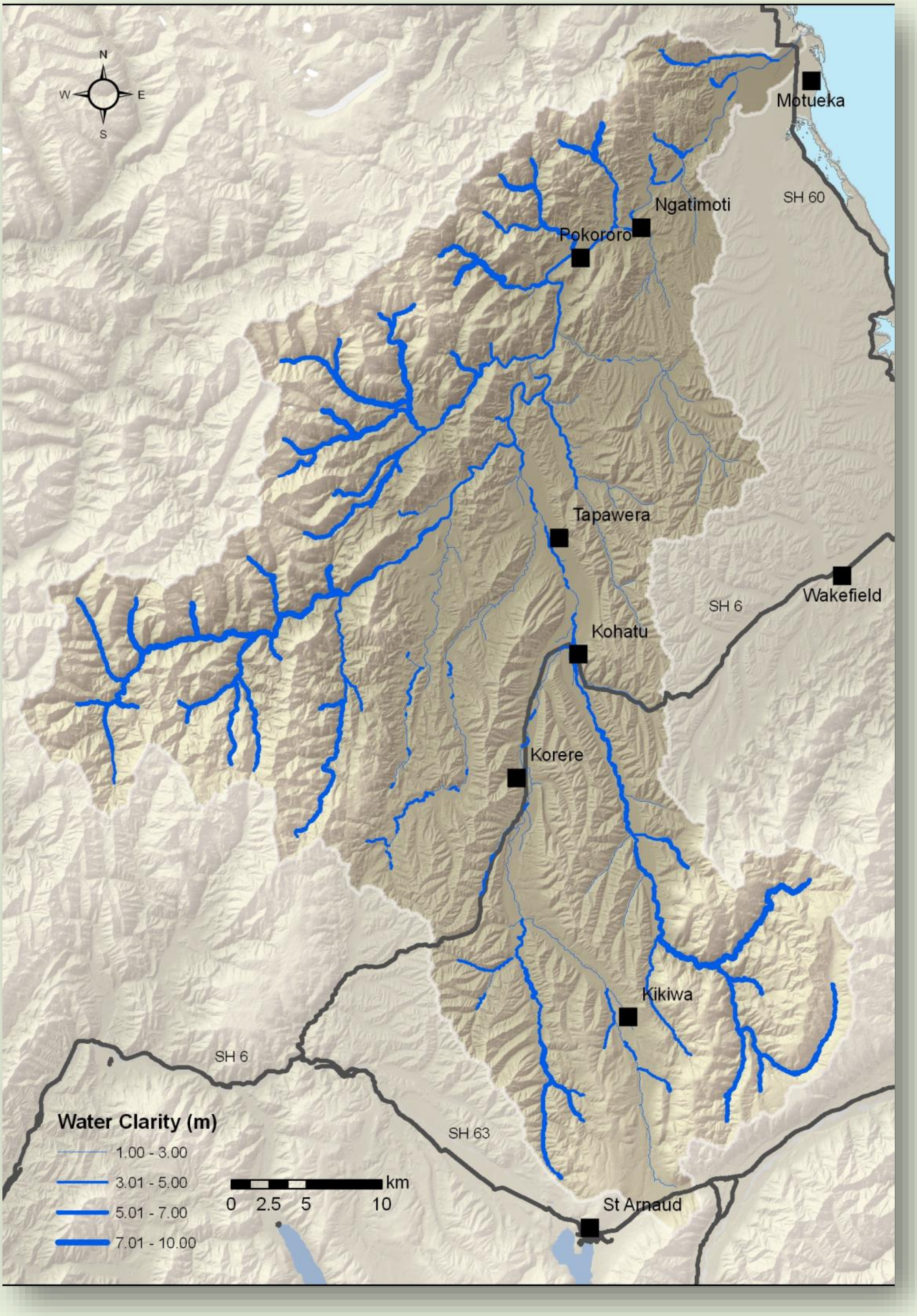


Figure 67.Predicted downstream changes in Water Clarity in the Motueka River catchment.
Note: The thicker the river line, the higher the water clarity.

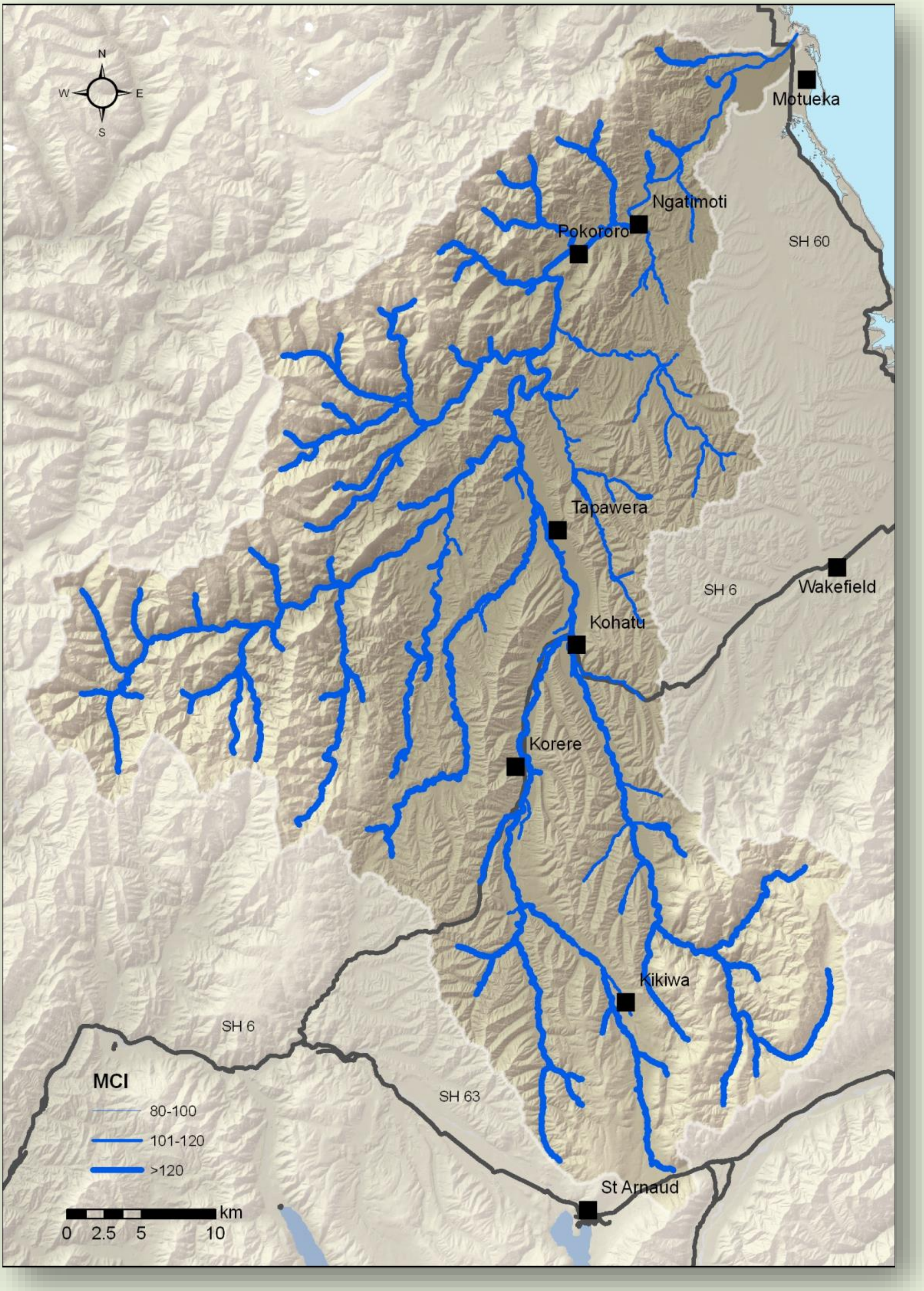


Figure 68. Predicted downstream changes in the Macroinvertebrate Community Index in the Motueka River catchment. Note: The thicker the river line, the higher the MCI.

Sherry Catchment, tributary of Wangapeka River

The local community identified swimming and ecological values as important in this catchment. The pattern of landuse is shown in Figure 69.

The catchment was identified in the early 2000's as having high concentrations of **disease-causing organisms.** However, this has improved (reduced) at all sites (median *E. coli* /100 ml from 2010-15 for u-s Cave Ck, u-s Granity Ck, Matariki, and Blue Rock were 15, 95, 190, 209, respectively; for 2000-2010 they were 30, 203, 253, and 311). Trends in *E. coli* over the full period show a decline since 2000 (Figure 70). Over the last five years the Blue Rock site has met bathing water guidelines only 60% of the time (< 260 E.coli/100 ml).

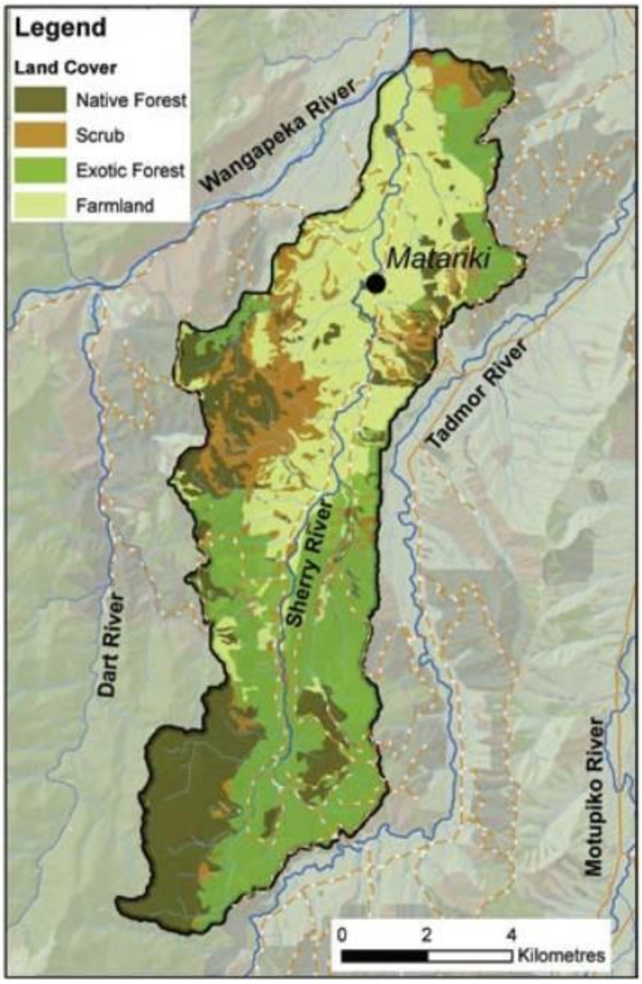
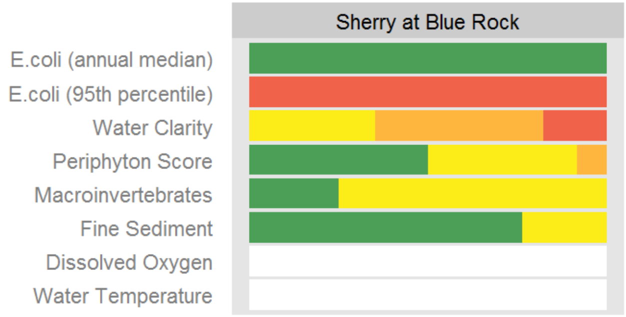


Figure 69 Land cover in the Sherry River catchment

Biggs Creek a small tributary, about 2km upstream of the confluence with the Wangapeka River, has been shown to have consistently high *E.coli* loading (the 2nd highest median of all streams regularly sampled in the region, with samples exceeding guidelines for secondary contact 40% of the time). In addition, fine sediment loading to this creek is very high. Biggs Creek is a small creek within a deer and sheep farm where very little fencing has been undertaken to prevent stock access to the creek and wetlands. Further fencing will be needed to see any improvement in water quality.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

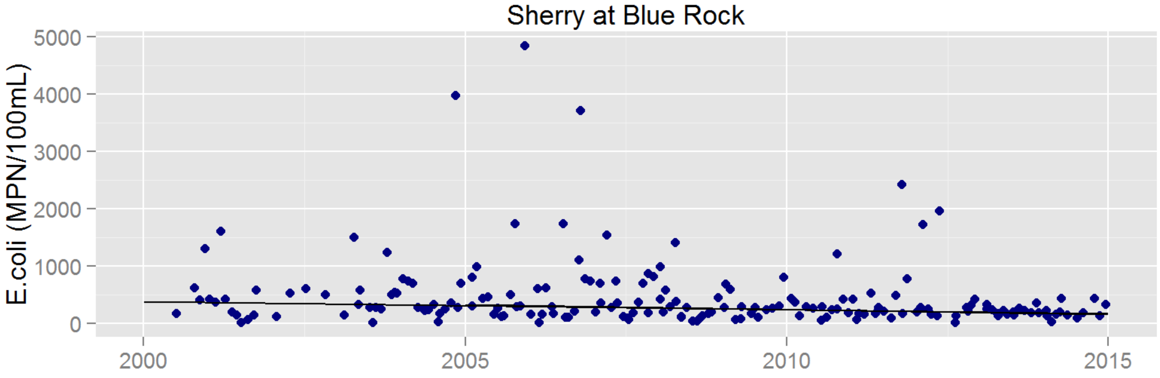


Figure 70 Sherry at Blue Rock E. coli data with 10-year (p = 0.0013, RSKSE = -6.9% per year) and 15-year trend lines (p = 0.0001, RSKSE = -5.2% per year).

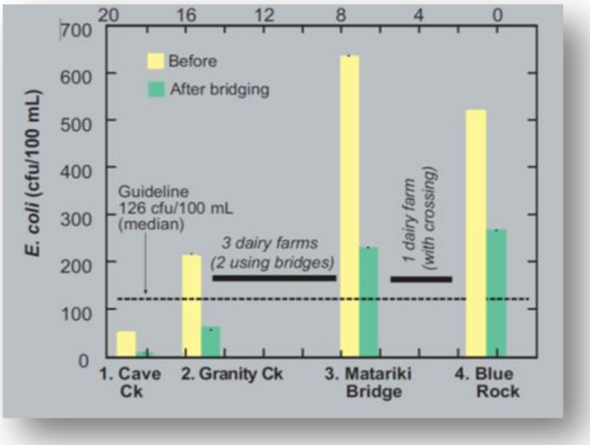


Figure 71. *E.coli* at four sites along the Sherry River (Davies-Colley et al. 2003). A guideline for median E. coli is shown for comparison.

THE SHERRY RIVER CATCHMENT GROUP

Water quality sampling throughout the Motueka Catchment in 2000-2001 identified the Sherry River as a **'hot spot' of relatively high faecal contamination,** at concentrations well above swimming guidelines. This contamination was attributed to dairying in the Sherry Valley, particularly the frequent dairy herd crossings needed to move cows between paddocks and milking sheds on different sides of the channel. As well as depositing manure and urine directly into the water, cows disturb stream bottom sediments, causing release of fine sediment, leading to water cloudiness or turbidity.

Research suggested that bridging of raceways to keep cows out of the stream water should have major water quality benefits (Figure 71). All four dairy farms in the Sherry Valley have subsequently constructed bridges, so cows are no longer regularly crossing the river. With Council support providing materials and advice, over 5 km of fencing has been installed in this catchment to exclude stock from streams and wetlands on five properties. Sampling in several tributaries of the catchment found definite hotspots of poorer water quality and appropriate priority has been given to improve water quality.

All farms in the catchment now have farm environmental plans (with the exception of some small lifestyle blocks) and all dairy farms have bridges over streams that are regular stock crossings. Willow removal along 1 km of the Sherry River in 2007-2008 is likely to have raised summertime water temperatures, but native trees were planted along this section in 2009-2010 and this is likely to bring the water temperatures down again within 15-20 years of this planting.

Water **quality has been markedly improved as a result of these efforts**, with faecal contamination at the Matariki monitoring site within the A attribute state (annual median < 260 *E. coli*/100 ml) during the most recent two years. However, the lower reaches of the Sherry River are still only safe for contact recreation approximately 80% of the time, most likely reflecting continuing access of dairy cattle and other livestock to unfenced tributaries, together with wash-in of faecal matter from riparian areas (stream banks) during rainstorms in the catchment. This is where customised farm environmental plans come in. Sixteen plans were prepared for all farms and forestry operations from 2008-2010. Such farm plans have been a very important tool for improving water quality. With *E.coli* concentrations plateauing off it would be useful to revisit those plans and see if there are further areas where water quality could be improved at reasonable cost.

There was a significant improving trend in dissolved reactive phosphorus in the Sherry River over the period 2000-2015 (Figure 72)

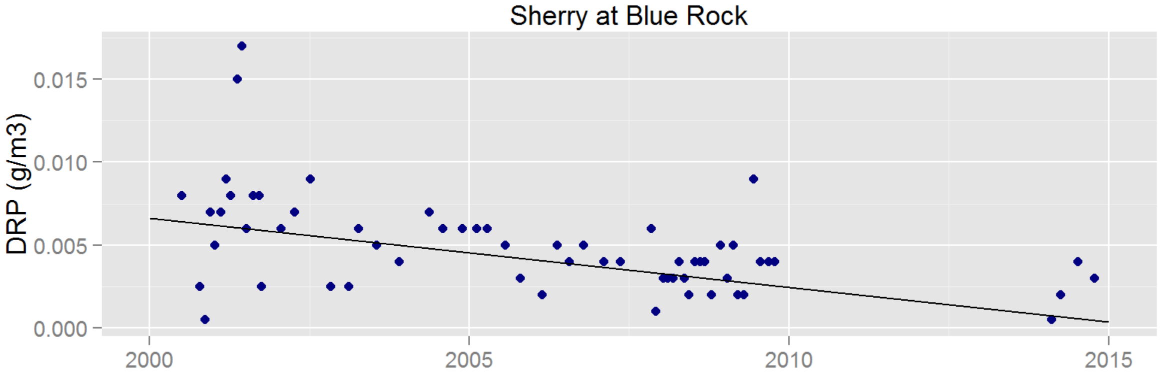


Figure 72. Sherry at Blue Rock dissolved reactive phosphorus (DRP) concentration data with 15-year trend line ($p < 0.0001$, RSKSE = -10.4% per year). No significant meaningful trend was detected over most recent 10 years of the record.

Water temperatures are also high enough during the hottest few weeks of the year to adversely affect aquatic communities (see water temperature section).

Water clarity in the Sherry River is naturally lower than most streams **due to its dark brown, tannin-stain colour**, rather than suspended sediment. The comparison of water clarity across the four sites on a particular day is very variable (the percentage difference between u-s Cave Ck and Blue Rock varies from +94% to -54% with a mean of 4%). Stock and vehicle crossings are likely to have been a contributor of fine sediment in the earlier part of the record (the final regular crossing was bridged in 2005). Forestry activity in the upper catchment was found to contribute fine sediment during harvesting in 2007-08 (considerable erosion around landing sites for example). However, re-suspendable solids assessments (SAM4) from 2012-2015 at the furthest upstream and downstream sites do not show any significant difference.

Farmers in the catchment have made huge inroads into improving water quality for swimming, starting with bridging the crossings on dairy farmland in 2002-04 (Figure 71).

For further information on managing water quality and other environmental issues in this catchment see: http://www.landcare.org.nz/files/file/9/3354-the-sherry-river-story.pdf

WATER TEMPERATURE IN THE SHERRY RIVER CATCHMENT

Water temperatures in the upper Sherry River catchment were consistently cool and below the criterion for ecological protection. However, downstream of Matariki, temperatures were high enough to cause adverse ecological effects during January and early February (Figure 73). The furthest upstream site (Noddy's Rd) had the third highest peak temperatures, probably due to riparian cover removal through forest harvesting (occurred in 2004-05). In addition, riparian willows were removed in 2005-06 because of their impact on the channel flood capacity and the cost of maintenance. Cool water from karst systems and effective riparian shading between the Noddy Rd and Granity Ck sites is probably the reason for lowered temperatures at the u-s Cave and u-s Granity sites. There was a significant increase in water temperature between the u-s Granity Ck site and Sailor Creek site and between the Slippery Road intersection and Matariki. This is likely to be due to **reduced shading** in these areas due to willows removal from these reaches two years prior to this investigation. Once the willows were removed the riparian corridor was planted with native trees. It will take at least 10 years before these native trees provide effective shading. There was very little change in stream temperature between Sailor Creek and Slippery Road intersection. This is probably because of the shading by willows through this section. The highest stream temperature recorded in the river was 26.5 °C at Blue Rock. Trees providing riparian shade are considered very important to the health of this waterway. Additionally, the insects that 'rain off' these plants can provide a large proportion of the diet to resident fish.

While poorly managed willows can cause adverse effects with respect to flooding, particularly on small to medium-sized waterways, well managed willows on larger waterways such as the Motueka and Wangapeka Rivers provide significant bank protection and they are beneficial for providing shade and food to the water way.

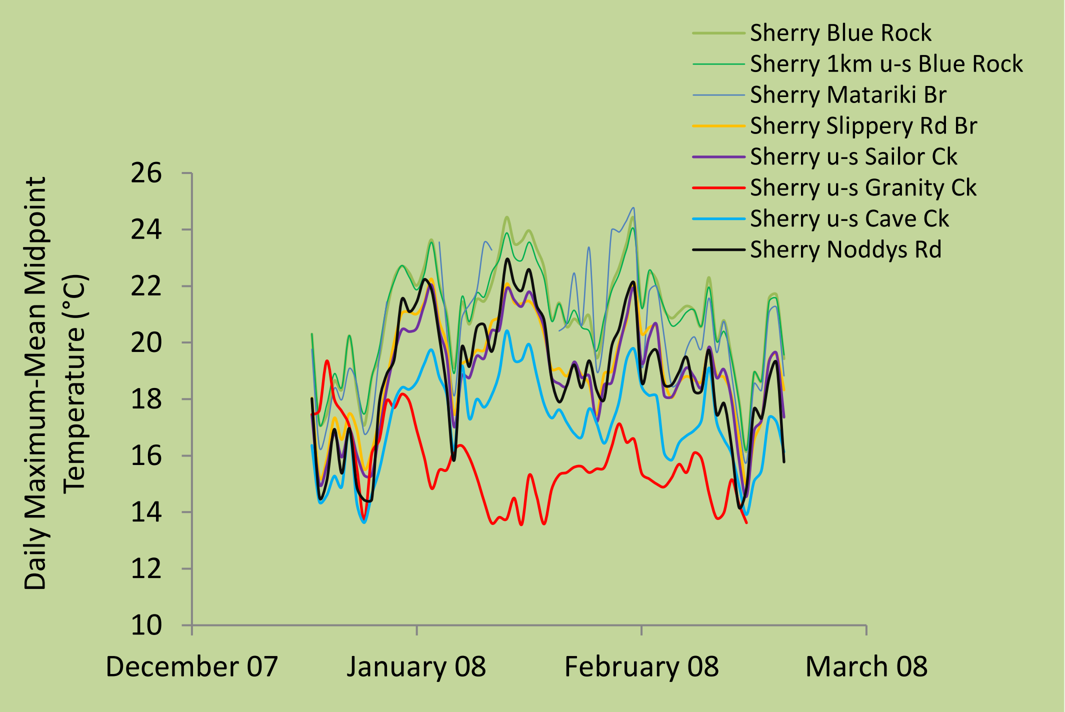


Figure 73 Stream temperature data for sites on the main stem of the Sherry River. Note: The key shows sites in order from furthest downstream at the top to furthest upstream at the bottom; data plotted are the midpoint of the daily maximum and the daily mean.

Catchment Statistics	Sherry at Blue Rock
River Environment Class	Cool Wet Soft sedimentary Hill-fed Pasture (u-s Cave Ck = Exotic forest)
Catchment area (km^2)$^+$	78
Predominant land use upstream	40% farmland, 40% exotic forest 20% native forest and scrub.
Mean annual rainfall (mm)	1300 (est)
Mean flow (l/sec)	1,910
Median flow (l/sec)	874
7 day mean annual low flow (l/sec)	150 (approx)
Lowest recorded flow (l/sec)	97
Water quality record	Monthly 2000-present Quarterly: 2000-present

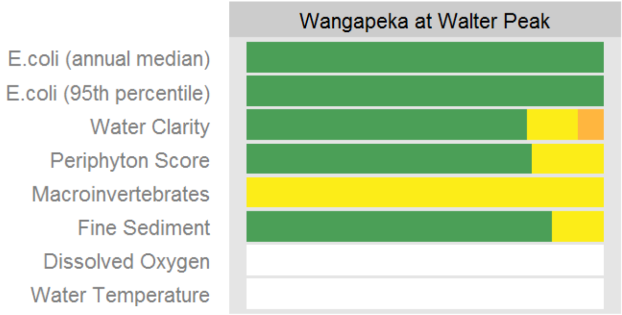
Sherry Rv at Blue Rock (July 2007, left), Upstream Cave Ck (January 2008, middle), Reading the black disc water clarity at Matariki (right).

Wangapeka River

The Wangapeka River catchment is dominated by native bush and is popular for tramping and fishing.

Wangapeka River 5km u-s Dart Rv (July 2007)

Water quality at both sites on the Wangapeka **is very good** during base flows. Concentrations of faecal indicator bacteria in the river just downstream of the Rolling River are below detection levels 85% of the time. Even in the lower reaches faecal bacteria concentrations are low (Median at Walter Peak: 15 *E. coli*/100 ml from 2010-2015 (was 20 *E. coli* /100 ml for 2000-2010), with about 3% of samples over alert level guidelines of 260 *E. coli*/100 ml).



Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

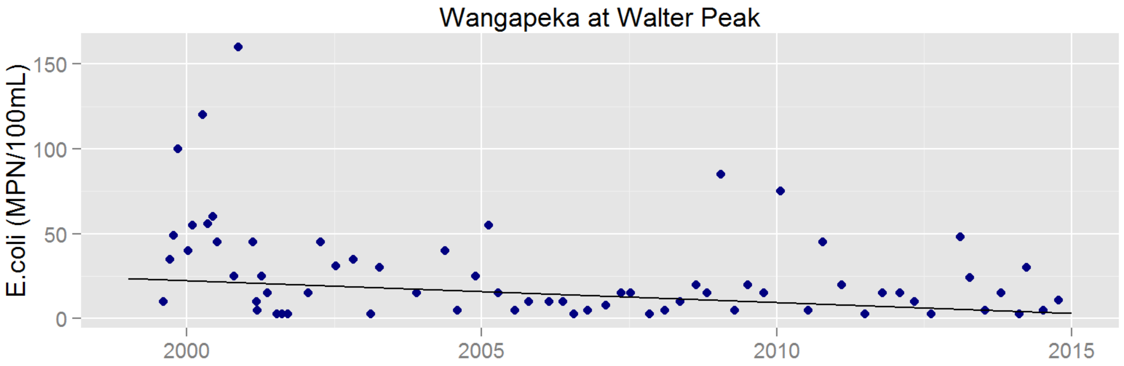


Figure 74. Wangapeka at Walter Peak *E. coli* data with 16-year trend line (p = 0.0055, RSKSE = -8.6% per year). No significant meaningful trend was detected over the most recent 10 years of the record.

Water clarity is moderately high (medians for upper and lower site 8 m and 5 m, respectively). The lower part of this river was affected greatly by fine sediment and sand discharges from slips after an extreme rainfall event in May 2010. In 2012 there was a massive slip 5 km upstream of the start of the Wangapeka Track. The debris temporarily dammed the river and formed a 1 km long lake. During 2013 there was considerable harvesting of the blocks on the true right of the Wangapeka downstream of the Sherry River. Many slips were evident following this harvest. Also in 2012 a diversion of Coal Creek led to a discharge of fine sediment which appeared to result in low water clarity and high resuspendable solids in winter and spring 2012.

Wangapeka River at Walters Peak (February 2015)

Catchment Statistics	Wangapeka at Walter Peak	Wangapeka at 5km u-s Dart
River Environment Class	Cool Wet Hard sedimentary Hill-fed Indigenous forest	Cool Extremely Wet Hard sedimentary Hill-fed Indigenous forest
Catchment area (km^2)$^+$	479	208
Predominant land use upstream		
Mean annual rainfall (mm)	1360	2967
Mean flow (l/sec)	22,973	11,989*
Median flow (l/sec)	13,268	
7 day mean annual low flow (l/sec)	4,526	
Lowest recorded flow (l/sec)	2,924	
Water quality record	2000-present	

* Estimate from WRENZ 2013. NA = not available

Tadmor River, Tapawera Area

Water quality and macroinvertebrate condition of this waterway was slightly poorer in 2006 & 2007, compared to 1986, in the lower catchment (Olsen 2007). The macroinvertebrate condition is considered ‘good’ or ‘fair’ according to guidelines at a site about 4 km (by river) upstream of the Tapawera-Baton Rd, compared to ‘excellent’ in the upper Tadmor and Hope catchments.

Tadmor River 80 m downstream Bushend Road Bridge.

Glenrae Stream, Tapawera Area

This hill-fed stream flows into the Motueka River from the valley immediately to the north of the Tadmor valley. Flows get very low in dry summers.

Glenrae Steam, Tapawera Area. Right: looking upstream from bridge.

Daily minimum dissolved oxygen levels are low but just above proposed national bottom lines on occasion (4-day sampling period in February 2015; Figure 75).

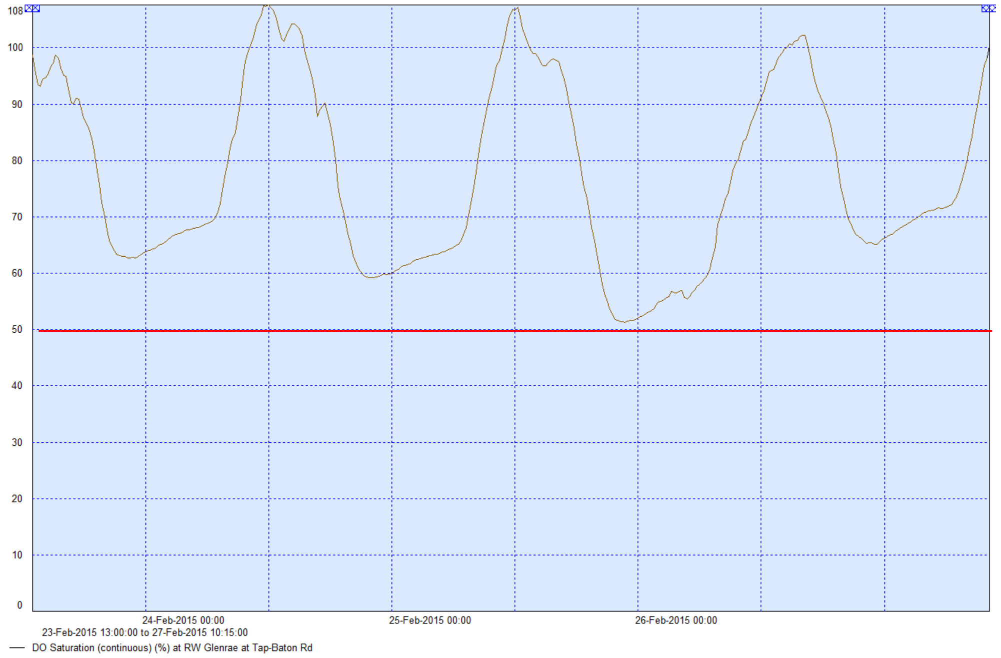


Figure 75 Dissolved oxygen percent saturation at Glenrae Stream at Tapawera-Baton Rd (23-27 Feb, 2015). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Water temperatures were elevated above levels likely to cause adverse effects but not above the bottom line (midpoint of daily mean and daily maximum: 22.5^{o}C).

Macroinvertebrate metrics show degraded water quality (MCI 80, SQMCI 3.1, %EPT 20%, # taxa 20, Physa snails very very abundant; one sample in February 2015). There were no mayflies or stoneflies with only a few cased caddisflies.

'Old School Creek', Kohatu

This permanently-flowing spring-fed creek is on the true left of the Motueka River joining it about 3.6 km (in a straight line) downstream of the Kohatu Bridge (SH6). Spring-fed streams are relatively rare and vulnerable. They also support particular fish and invertebrate communities.

Monitoring in February 2015 showed **low dissolved oxygen levels** (daily minima below 40%) (Figure 77) but **satisfactory temperatures** (maxima below 20^{o}C).

Right: 'Old School Creek' 180 m upstream Motueka River (February 2015).

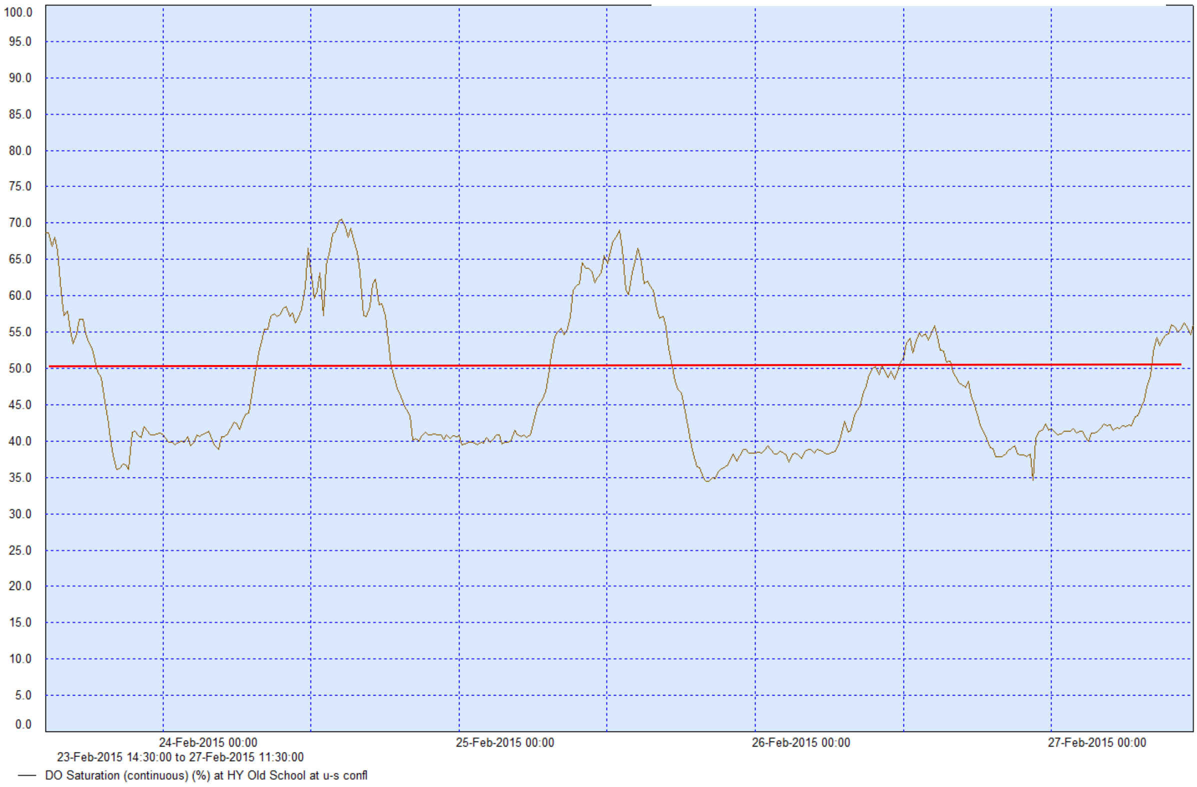


Figure 77 Dissolved oxygen percent saturation at Old School Creek 180 m upstream Motueka River (23-27 Feb, 2015). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Hinetai Springs

'Hinetai Creek' is spring-fed and joins the Motueka River just under 1 km upstream of the Wangapeka River. It was sampled for dissolved oxygen and temperature in February 2015.

'Hinetai Creek' approx 720 m upstream Motueka River (February 2015)

Dissolved oxygen was very low (daily minimum of 25-35%) (Figure 78). This was probably due to the prolific growth of aquatic plants (including *Lagarosiphon major*) and limited shading of the creek for most of its length (although the meter was installed under willows in the lower reaches). Water temperatures were very acceptable for a healthy aquatic ecosystem (midpoint of daily mean and daily maximum of 19°C).

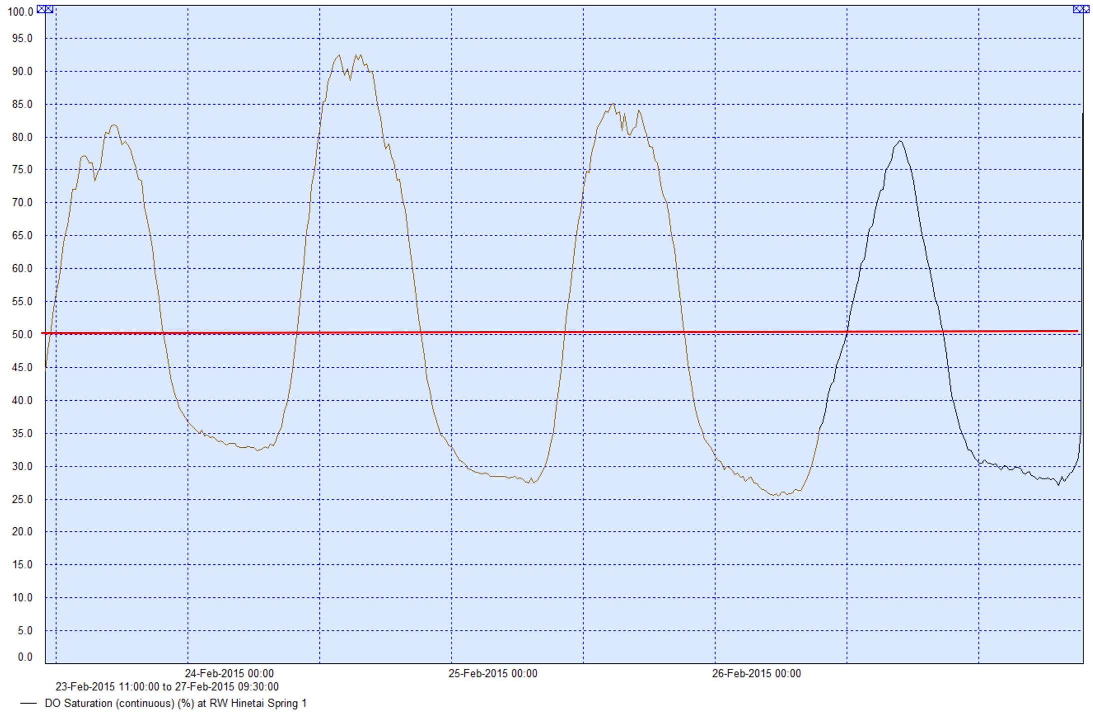


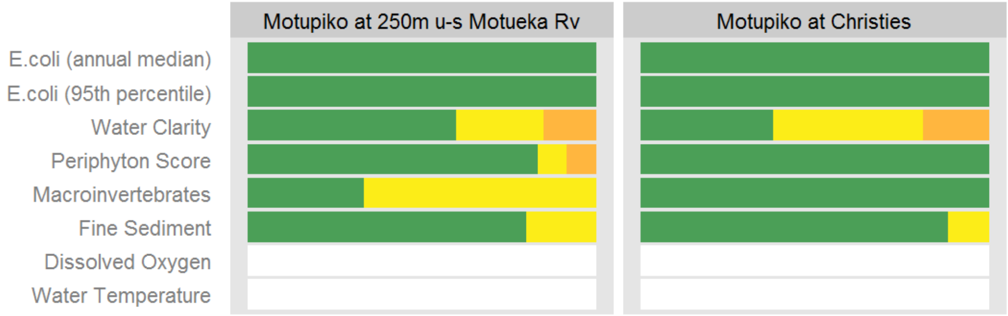
Figure 78 Dissolved oxygen percent saturation at Hinetai Creek (23-27 Feb, 2015). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Motupiko River

The Motupiko River is a regionally important trout fishery. Trout numbers have declined to very low levels over the last decade, possibly due to reduced habitat diversity in this river. Tributaries, such as the Rainy River draining Big Bush, are important trout spawning and rearing streams. A popular campground (Quinney's Bush) maintains a swimming hole in this river. Many streams of the upper Motupiko are wetland-fed and have stream beds with high coverage of moss. The bed of the river in the lower reaches is used by 4WD vehicles for recreation. The river regularly dries up in summer for a few hundred metres upstream from the confluence with the Motueka River. Two sites are monitored on the Motupiko, one right at the bottom of the catchment (upstream Motueka River) and one upstream of the Rainy River, but downstream of the Kikiwa suite of monitoring sites (Christies).

Above: Motupiko at Christies looking downstream from bridge (February 2014), Above right: Motupiko at 250 m upstream Motueka River (February 2006)

There is potential for intensification of farmland on the flatter areas of this catchment if more water were available via water storage. If this does occur, the water quality information from the Motupiko sites will be useful to determine effects.



**Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.**

There are **very low levels of disease-causing organisms** at both sites (Christies: 30 *E.coli*/100 ml, maximum 160 *E.coli*/100 ml; u-s Motueka: median 10 *E.coli*/100 ml, maximum: 95 *E.coli*/100 ml 2006-2015).

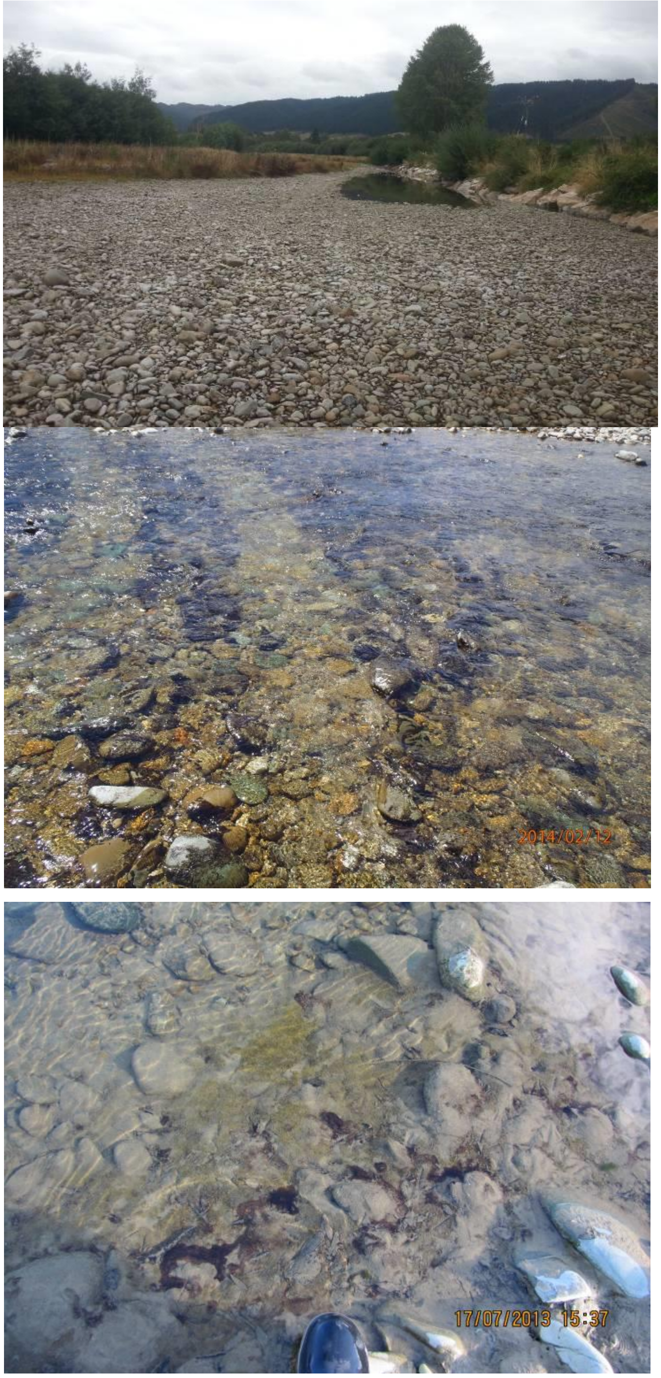
Water clarity at Christies and upstream Motueka River is good (median 4.5 m and 6.4 m respectively 2006-2015).

At times there has been high coverage of fine sediment deposits on the river bed surface but the fine sediment trapped in the cobbly bed (resuspendable solids) is low (median 2, max: 3).

One of the **main issues in the lower reaches is toxic algae** (*Phormidium*) which regularly gets over 10-20% and once recorded at 60%. This could be due in part to fine sediment discharges as a result of a gravel take in this area. *Phormidium* is also present in riffles at Christies at up to 20-30% cover but over a whole reach the maximum coverage recorded is only 5%.

Levels of filamentous green algae are generally very low at Christies (coverage records all below 7%, except for February 2015 when coverage was 30%; median periphyton score: 10). At the lower site filamentous green algae is generally low (coverage: only 2 records above 5%, max 15%; Median periphyton score: 9.21).

Water temperatures were occasionally over 21.5^{o}C and up to 23.4^{o}C in summer at the lower site (spot measurements only) suggesting that temperature could be an issue. Temperatures loggers will be deployed to confirm this.



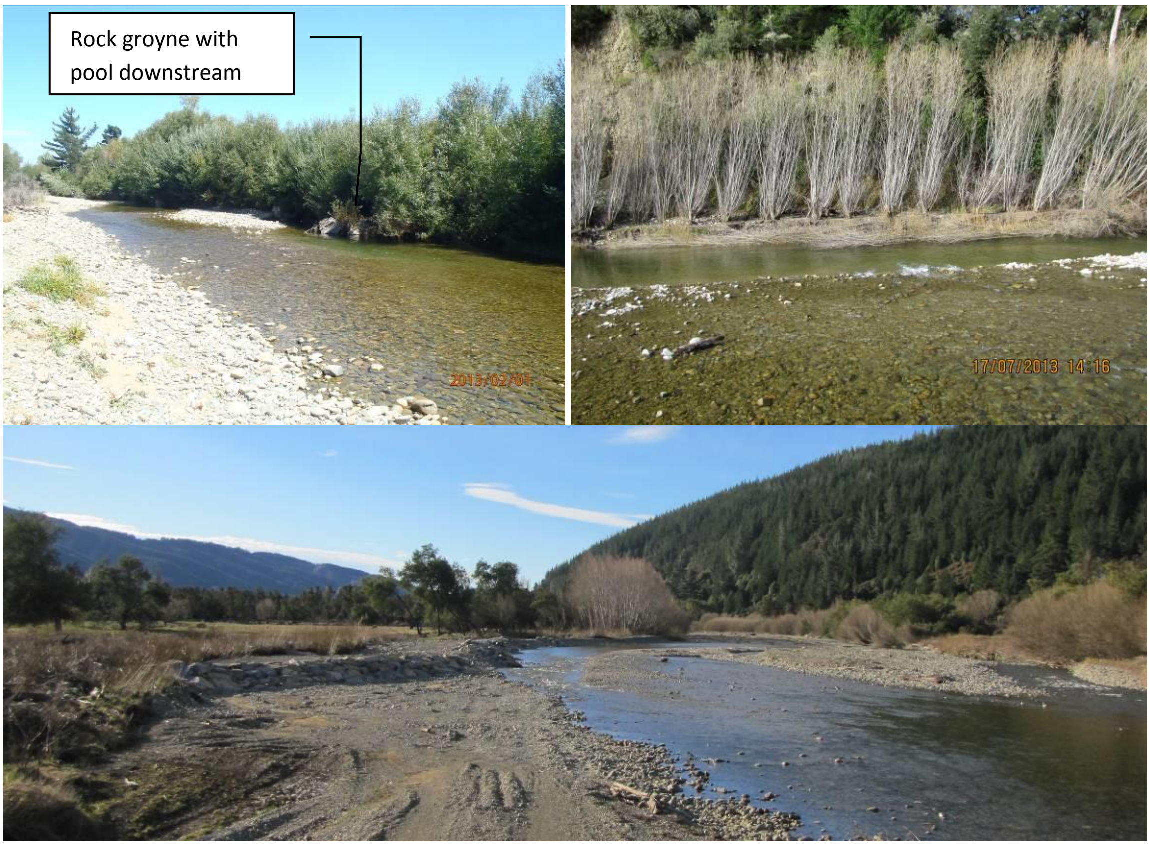
Motupiko River.
Top: 500 m upstream Motueka River (February 2015).
Middle: Tyre tracks through *Phormidium* bloom on the bed of Motupiko at 200 m upstream Motueka (February 2014)
Bottom: Heavy fine sediment deposits with *Phormidium* growth (July 2013).

There **appears to be a reduction in quality of trout habitat** with a shift to more uniform water depth and fewer pools in this river than 10-20 years ago, particularly from around Korere to the Motueka River. Variety of depth and frequency of pools in a river is a critical habitat component for many fish species. One of the reasons for this change could be replacement of crack willow with shrub willow and the consequent reduction in scour potential. This is because floodwaters seep evenly through the shrubby willows that are planted relatively uniformly down the river banks, rather than ricocheting off the large trunks of crack willow (either standing or fallen) and causing scour on the downstream side of the trunk. Another reason is the narrowing of the river corridor and the design of much longer radii of meanders which creates much lower opportunity for scour in the bed.

Above left: Motupiko River 300 m upstream Graham Ck showing a source of the catchment in the St Arnaud Range (October 2010). Above right: Erosion of Moutere gravels along cliffs. This is a relatively common occurrence between Korere and Quinneys Bush (2km downstream Korere Bridge, July 2013).

Catchment Statistics	Motupiko at Christies	Motupiko at u-s Motueka
River Environment Class	Cool Wet Soft sedimentary (Moutere Gravel) Hill-fed Pasture moderate gradient	Cool Wet Soft sedimentary (Moutere Gravel) Hill-fed Pasture moderate gradient
Catchment area (km^2)$^+$	102.6	337
Predominant land use upstream	Sheep and beef Forestry	Sheep and beef Forestry
Mean annual rainfall (mm)	1200	1200
Mean flow (l/sec)	2,080	6,979*
Median flow (l/sec)	1103	NA
Maximum recorded flow (l/sec)	169,651	NA
7-day Mean Annual Low Flow (l/sec)	304	NA
Lowest recorded flow (l/sec)	137	Dries in lower reach most summers
Water quality record	2000-present	2006-present

* Estimate from WRENZ 2013. NA = not available

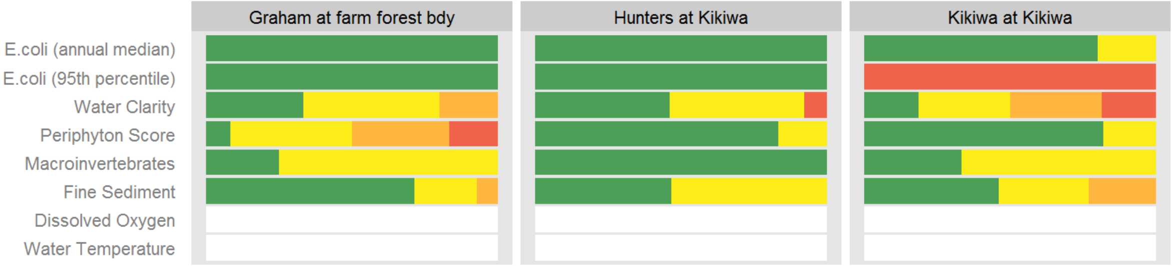


<u>Above left</u>: Motupiko River approx 2 km downstream Korere Bridge (February 2013). Note: Shrub willow plantings and a rock groyne creating a pool downstream in an otherwise very even and shallow water depth. <u>Above right:</u> Shrub willow plantings in a way that reduces opportunity for scour thereby possibly reducing pool formation (July 2013). <u>Bottom</u>: Approx 6 km downstream Korere Bridge looking downstream (July 2013).

Kikiwa Suite (Kikiwa, Hunters, Graham Streams)

Kikiwa, Hunter, and Graham streams, draining into the upper Motupiko catchment, were subject to an intensive study in the 1970's and 80's into different water yields (total quantity of water per unit area) arising from the different land uses. These neighbouring catchments are all within the same geology, similar slope and aspect, and similar size. While **Kikiwa Stream** flows all year at the monitoring site, it does flow below ground in the upper reaches and lower reaches for much of the period from December to April.

Graham Creek, whose catchment is dominated by *Pinus radiata* forest, had lower annual water yields and less than 30% of the mean annual low flow of Hunters or Kikiwa (native forest and pasture, respectively). Graham Creek was also observed to dry up on average for about 17 days/year (over the about nine years of record), whereas the other two streams did not. Reduced stream flows caused by pine afforestation in the Moutere Hill country may have more serious impacts than short term effects of sediment discharges (Graynoth 1992). Harvesting of the whole Graham Creek catchment progressively occurred from 2005-09. A 25 m native riparian buffer (mostly kanuka forest) exists on each side of the main stem of Graham Creek in the lower 1.7 km of the valley, as well as up most of the tributaries particularly on the eastern side.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

Levels of **faecal indicator bacteria in Kikiwa Stream** (Figure 79) were higher than those of Hunters or Graham Creeks (median 185 *E. coli* /100 ml for 2010-2015, and compared to 5 *E. coli* /100 ml at each of Hunters and Graham; n=44), and exceeded stock drinking water guidelines just over 10% of the time. This result is slightly better than the average for streams draining extensive sheep and beef catchments. The farmer in the Kikiwa catchment has never grazed beef stock intensively in the catchment and has fenced off ponds near the creek, that the cattle wallow in, and has installed reticulated stock water. The sheep and beef industry are encouraging farmers to establish environmental quality management systems, but the rate of buy-in is still very low regionally.

Water clarity in Kikiwa Creek is about a third of that for the neighbouring catchments but there are signs of improvement (median for Kikiwa is 3 m for the period from 2010-2015; up from 2 m over the period from 2000-2010).

Graham Creek had similar fine sediment deposits compared to Hunters (the reference site) indicating that the effects of forest harvesting were well managed in this catchment. However, flood flow load of fine sediment was not measured. Periphyton scores were relatively low (10% of records less than a score of 5 and over 50% of records less than 6) and filamentous green algae cover relatively high in this creek. The reasons for this are unknown.

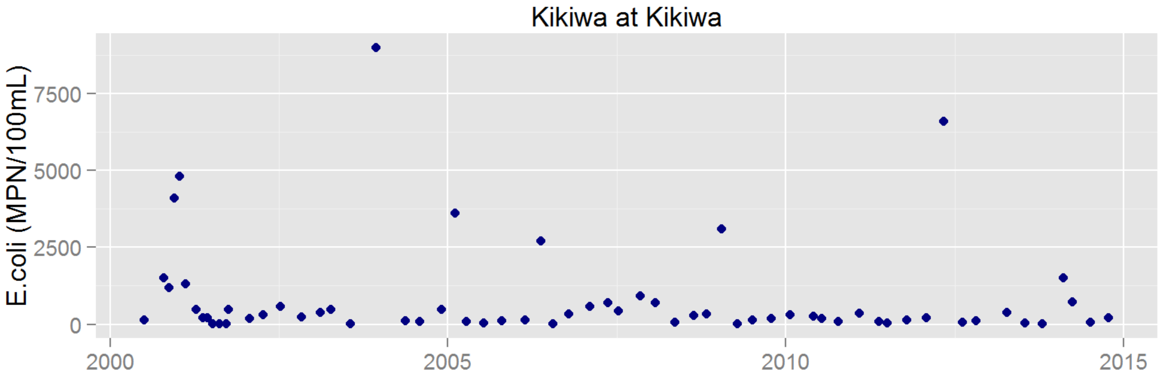


Figure 79. Kikiwa at Kikiwa *E. coli* data from 2000 to 2014.

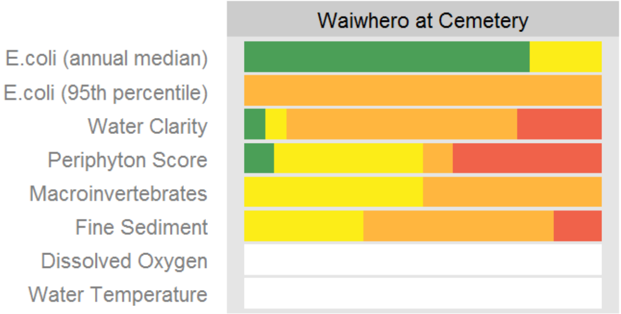
'The Kikiwa Suite': From Left: Kikiwa Ck (April 2005), Hunters Ck (January 2002), Graham Ck (January 2002)

Catchment Statistics	Kikiwa Ck	Graham Ck	Hunter Ck
River Environment Class	Cool Wet Soft sedimentary (Moutere Gravel), Hill-fed moderate gradient	Cool Wet Soft sedimentary (Moutere Gravel), Hill-fed moderate gradient	Cool Wet Soft sedimentary (Moutere Gravel), Hill-fed moderate gradient
Catchment area (km^2)$^+$	2.85	4.74	5.02
Predominant land use upstream	Pasture	Exotic Forest (95%)	Indigenous Forest
Mean annual rainfall (mm)	1300 est	1290	1300 est
Mean flow (l/sec)	52.1	84.4	76.8
Median flow (l/sec)	22.1	34.7	28.4
Maximum recorded flow (l/sec)	2,846	3,755	14,010
7-day Mean Annual Low Flow (l/sec)	1.5	1.2	28.0
Lowest recorded flow (l/sec)	0.24	0 (when in mature plantation forest)	0
Water quality record	2000-present	2000-present	2000-present

Waiwhero Creek

The catchment upstream of this monitoring site is almost entirely within one landholding and used for farming sheep and beef. A large dam was built in the upper catchment in the late 1990's.

Waiwhero Creek at Cemetery. Left: view downstream to Waiwhero Rd Bridge (January 2008). Right: View upstream (February 2005)



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

In mid to late summer the level of disease-causing organisms cause regular spikes in *E.coli* (mostly in February to March) (Figure 80). The most likely reason for this is the wildfowl, which are particularly prevalent during the moult (several hundred ducks use the lake in the upper catchment from February to March). The landowner has been allowing harvesting of the ducks (which does not need a permit during the season from 1 May to 26 July. Most of the farm is fenced and one side of the creek is completely fenced. However, further fencing could make a positive difference including small areas where runoff from pasture funnels into the stream. Microbial source tracking in May 2015 determined the source to be ruminant and wildfowl but not human.

In summertime dissolved oxygen levels in this creek are consistently low (daily minima around 30% and daily maxima around 60%) (Figure 81). The low daily maxima suggests that the low dissolved oxygen level is not solely driven by aquatic plants or discharges of organic contaminants, but more likely the discharge of the reservoir bottom water which is low in dissolved oxygen and is used to provide residual flow as part of the resource consent. While low daily maxima can also be due to a strong influence from groundwater, in the Moutere hill country there is very little groundwater input in summer. To attempt to alleviate this problem the intake for the dam discharge was elevated in the water column in January 2015 from near the bottom to 1.5 m from the water surface.

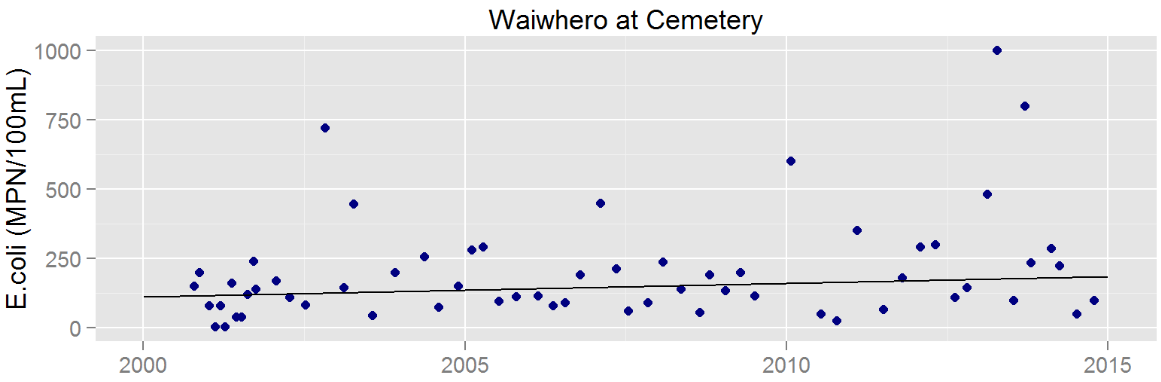


Figure 80. Waiwhero at Cemetery *E. coli* data with 15-year trend line (p = 0.0231, RSKSE = 3.4% per year). No significant meaningful trend was detected over the most recent 10 years of the record.

The reservoir and its resident duck population in this catchment could also be a reason for the excessive filamentous green algae cover (over 50% at times) as it will reduce flushing flows and has until recently released bottom water which could contain higher concentrations of nutrients.

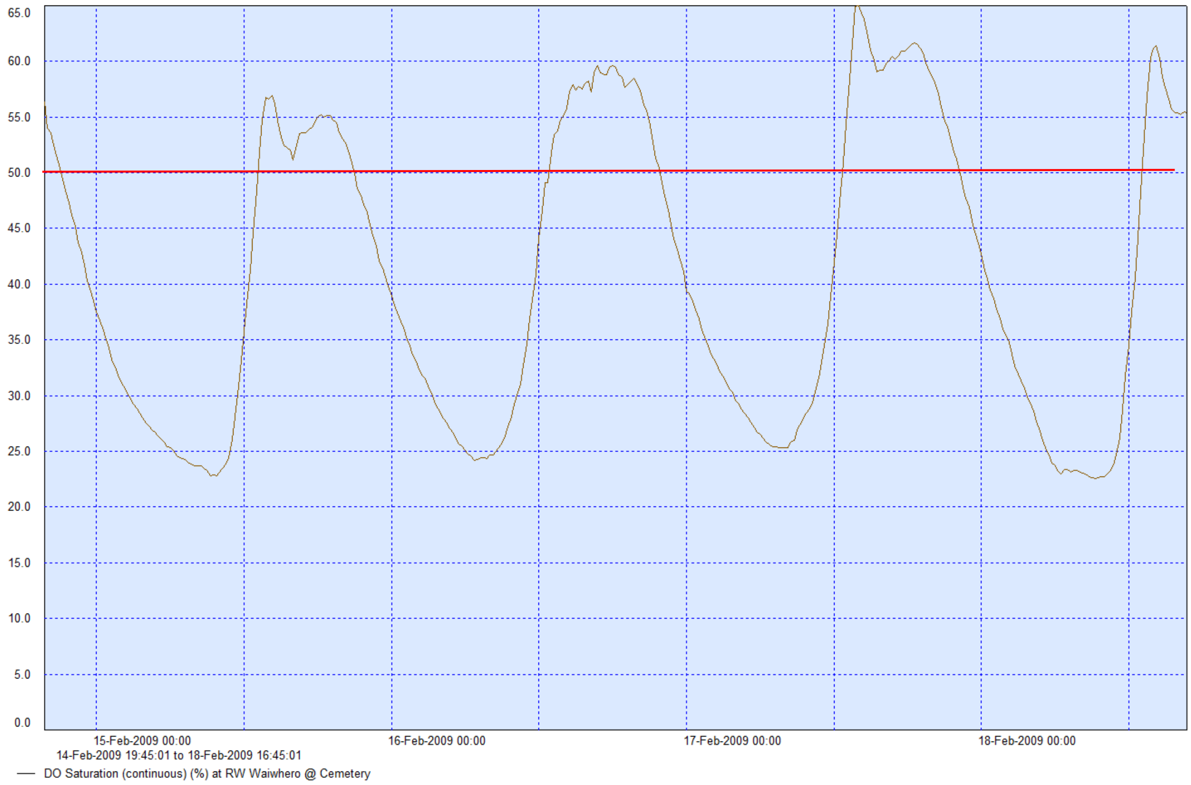


Figure 81 Dissolved oxygen percent saturation at Waiwhero Creek at Cemetery (Waiwhero Rd) (22-25 Feb, 2010). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Water temperature is generally low enough in summer to support a healthy ecosystem (maximums recorded usually under 20°C but up to 23°C).

Doing the Suffle test in Waiwhero Ck

There is a lot of **fine sediment** in the bed of Waiwhero Creek (shuffle index regularly 4 and sometimes 5). A proportion of this sediment will be from bank erosion but unfenced riparian areas are also likely to contribute.

Macroinvertebrate condition is fair to poor (MCI 80-110, SQMCI 2-5, %EPT 20-40). The low dissolved oxygen in the water and large amount of fine sediment in the bed will be major reasons for this.

Habitat for fish and invertebrates is generally poor in much of this catchment. This is an issue in many farmland streams in the district and is a legacy from when land was cleared. Planting trees along the streamside and re-establishing wetlands in key locations is well known to be effective at improving the biodiversity and abundance of life in waterways.

Catchment Statistics	Waiwhero at Cemetery
River Environment Class	Cool Wet??? Soft sedimentary (Moutere Gravel) Hill-fed???
Catchment area (km^2)$^+$	8.6
Predominant land use upstream	
Mean annual rainfall (mm)*	1,189
Mean annual flow (l/sec)*	1,161*
Lowest recorded flow	1 (Feb 2011)
Water quality record	2000-present

* Estimate from WRENZ 2013. NA = not available

Motueka Spring-fed Creeks

On the northern side of Motueka there are Moon and Doctors creeks that flow into the Kumara Inlet (Figure 82).

Thorpe and Woodlands drains are artificially-straightened streams flowing through Motueka township south into the Moutere Inlet (Figure 83).

Dissolved oxygen levels in Thorpe Creek 300 m upstream of Old Wharf Rd varied greatly over a 24-hour period with daily minimums being moderately low (around 6 mg/L) (Figure 84) and then this was further lowered by high tides (we expected the site to be just upstream of the tidal influence).

Thorpe Creek about 200 m upstream Old Wharf Rd (February, 2014)

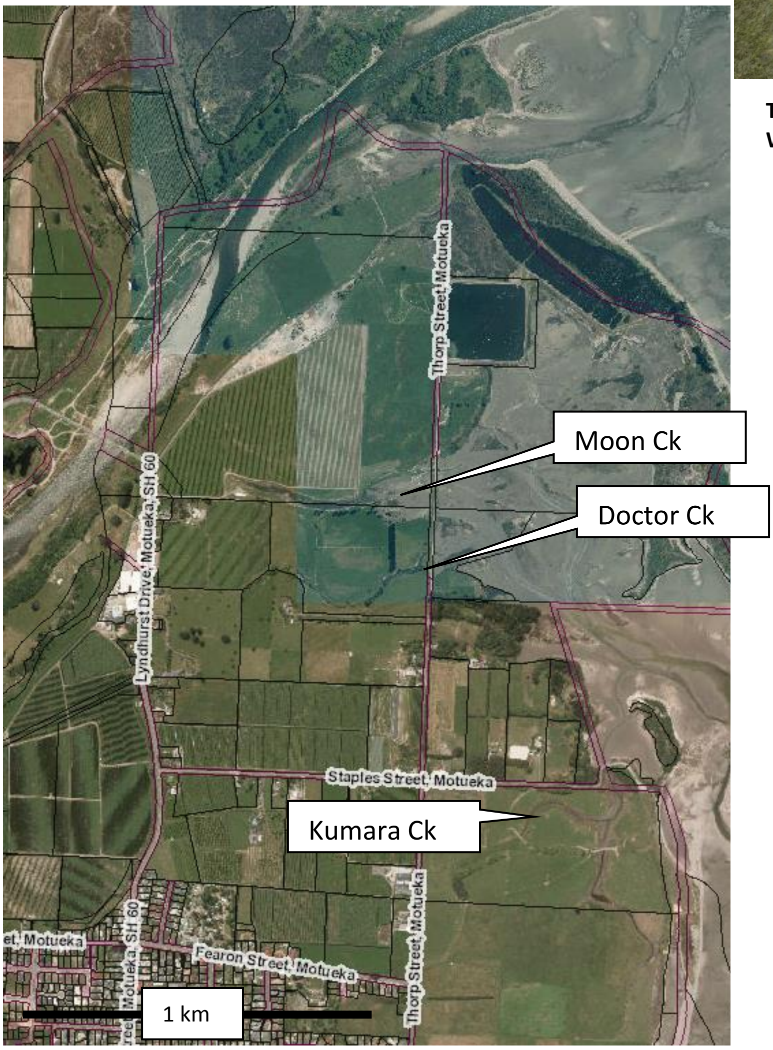


Figure 82 North Motueka Spring-Fed Creeks

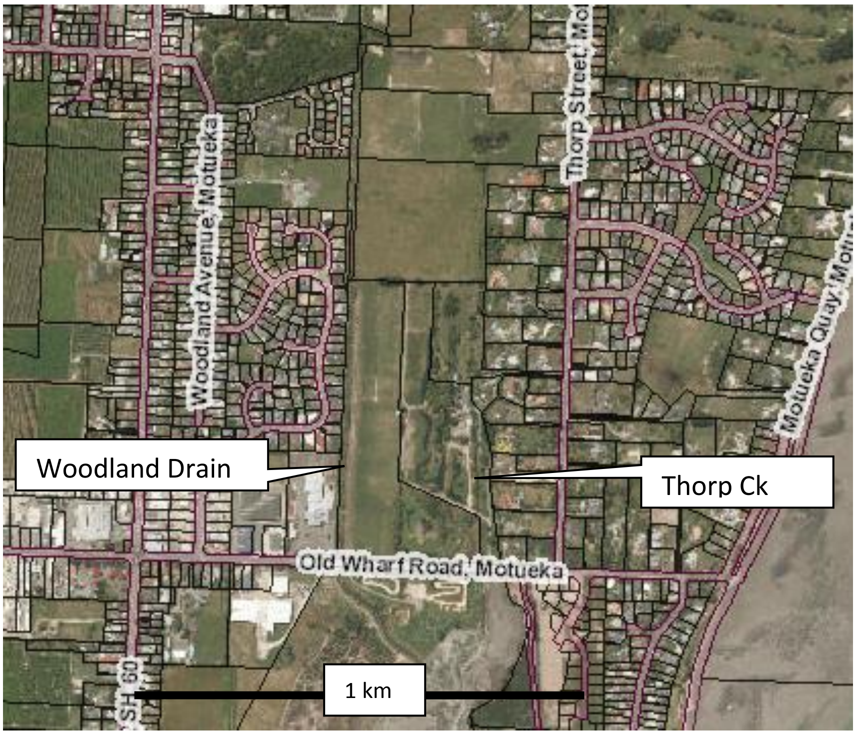


Figure 83 South Motueka Spring-Fed Creeks

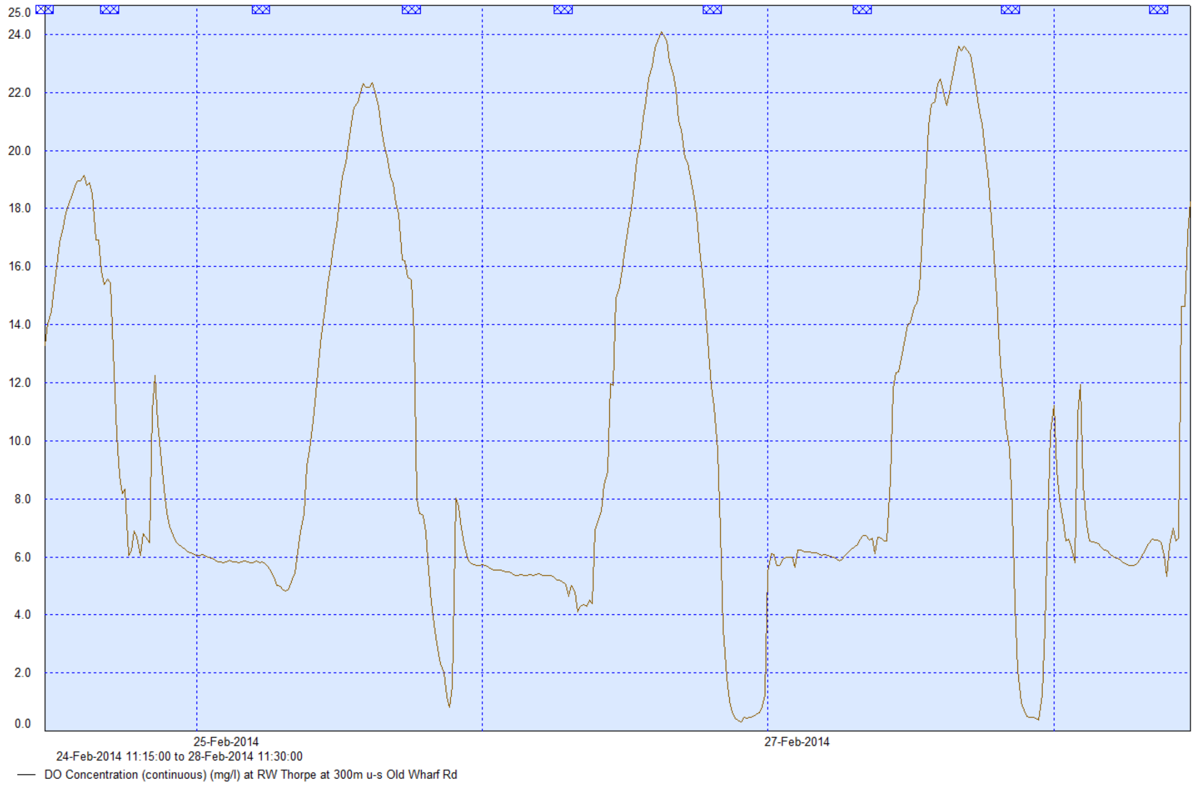
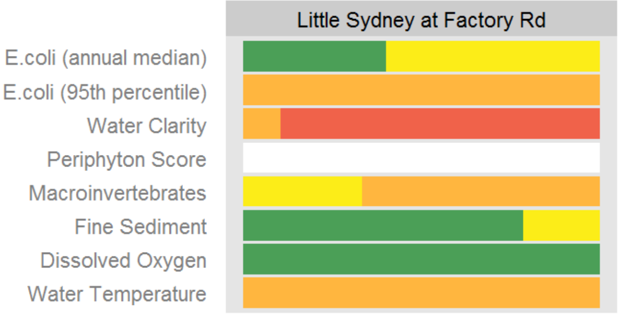


Figure 84 Dissolved oxygen percent saturation at Thorpe Creek at 300 m upstream Old Wharf Rd (24-28 Feb, 2014). Note: dissolved oxygen concentration was used as % saturation data was inadvertently not logged. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Little Sydney Stream, near Riwaka

Fish commonly found in the lower reaches are inanga, common bully, shortfin and longfin eel. Shortjaw kokopu and koaro are reasonably likely to be present further up in the catchment and banded kokopu are very likely to be present (freshwater fish distribution model; Leathwick 2006). These native fish are sensitive to degraded water quality and habitat. A large tidegate is present at the mouth of this stream. This waterway is not considered large or deep enough to be used for regular contact recreation but most streams will have children playing in them at times.

Right: Little Sydney Stm at Factory Rd (January 2002).



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

Dissolved oxygen, water temperature, macroinvertebrates and water flows are good. The **levels of faecal indicator bacteria have improved greatly** (median: 282 *E. coli* /100 ml (2010-2015); down from 427 *E. coli* /100 ml from 2000-2010 and exceeding stock drinking water guidelines 6% of the time (was 25% of the time from 2000-2010) (Figure 85). It is likely that the **fixing of a failing septic tank discharge** located 30 m upstream of the Factory Road monitoring site (110 m east of Swamp Rd) **in early 2009** is the reason for much of this improvement. However, there are additional sources upstream, possibly from dwellings off Little Sydney Rd. Microbial source tracking sampling on 18 May 2011 showed multiple sources of disease-causing organisms: ruminant, human and wildfowl.

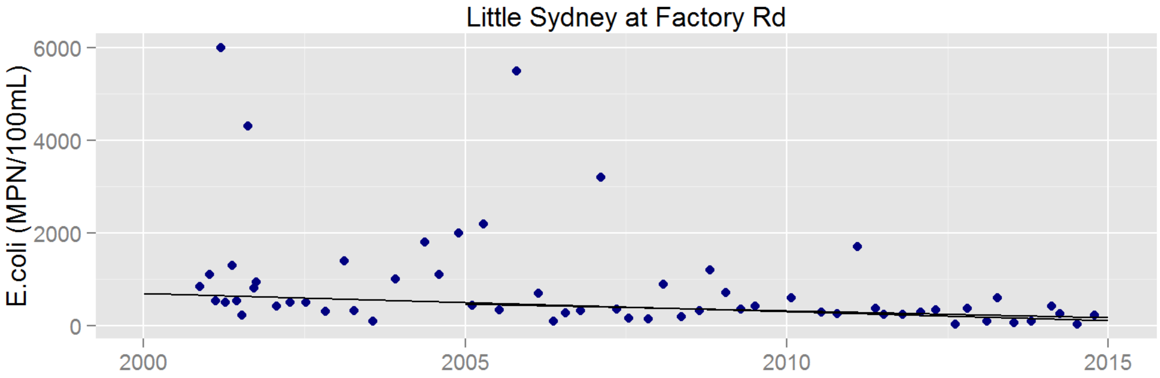


Figure 85. Little Sydney at Factory Rd *E. coli* data with 10-year (p = 0.0144, RSKSE = -9.2% per year) and 15-year trend lines (p = 0.0002, RSKSE = -9.0% per year).

Water clarity is relatively low (median: 1.1 m) and trends are remaining relatively steady. Resuspendable solids levels are moderate (2-3/5).

The **fair-poor macroinvertebrate condition** at this site (MCI 80-115, SQMCI 4.5-6, %EPT 40-60%) could be due to the high proportion of sand in the stream bed and level of fine sediment.

Given the potentially high aquatic ecology values and largely good water quality for this stream, any effort to improve fish habitat in the lowland reaches is very likely to improve these values. There is a need to maintain or enhance the flood carrying capacity of the flood-flow channel in the lowland reaches. Any opportunity for habitat improvement, such as cover by plants should be seriously considered.
The stream banks are sprayed periodically and dug out every 10-15 years releasing reasonable amounts of sediment into the waterway (see photo below). During the most recent digout spoil piles were searched for fish, but only a few eels were recovered for re-release.

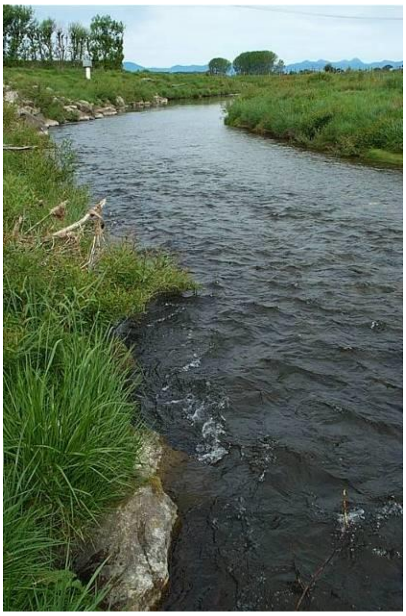
Above: Little Sydney Stm at Factory Rd (October 2008). Below: The stream bed showing the dominance of sand **substrate.**

Little Sydney Stm along Swamp Rd (December 2013)

Catchment Statistics	Little Sydney at Factory Rd
River Environment Class	Cool Wet Plutonic (Separation Pt Granite) Hill-fed moderate gradient
Catchment area (km^2)$^+$	9.9
Predominant land use upstream	
Mean annual rainfall (mm)*	1,452
Mean annual flow (l/sec)*	264*
Lowest recorded flow	11 (Jan 1998)
Water quality record	2000-present

* Estimate from WRENZ 2013. NA = not available

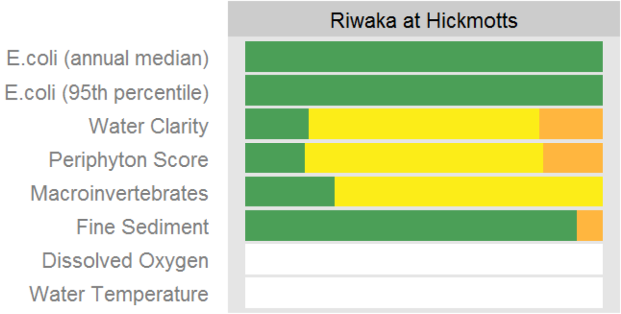
Riwaka River



Riwaka River at Hickmotts (hydrology monitoring site) (October 2008)

The Riwaka River is fed by one large karst spring (resurgence) in the north branch and a series of smaller karst springs in the south branch. Like most spring-fed rivers there is lower variability of flow, summer low flows relatively high and peak flows relatively low in this river, compared to most rivers in the region.

During base flows water from the north branch source is **very clear** (median: 11.65 m, maximum 18.7 m). It is possible that water clarity in the north branch source measured at the site about 280 m downstream of the resurgence, is slightly lower than the water at the resurgence itself as the water gets coloured from the "tea" from water leaching through leaf litter under extensive podocarp forest in the catchment. Water clarity at Hickmotts has degraded over the last 10 years, but the most recent samples show an improvement. Possible reasons for this include the willow removal around 2008-10 and forest harvesting from about 2010-12.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

Probably due to the clarity of the water, people think the water is 'pure' to drink and collect water for drinking from the resurgence just upstream of the monitoring site. ***E. coli* levels are usually zero** during low flows which is safe for drinking, however, about five percent of the time they are over 50 *E. coli* /100 ml. This represents a moderate to high health risk (if used regularly for drinking) and it is advised that this water is boiled or filtered before drinking.

There has been an increase in *E.coli* concentrations at Riwaka at Hickmotts from 2005-2015 (Figure 86). However, such concentrations are still relatively low.

Ammonia concentrations decreased significantly over the record. This could be due to stock exclusion from streams and better treatment of domestic wastewater. Ammonia is found in high concentrations in urine.

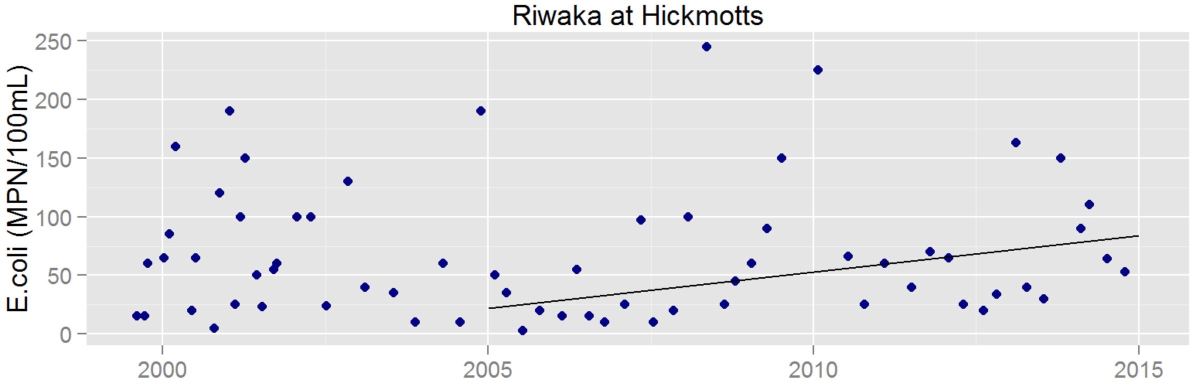


Figure 86. Riwaka at Hickmotts *E. coli* data with 10-year trend line (p = 0.0009, RSKSE = 12.4% per year). No significant meaningful trend was detected over the full record (16 years).

In winter 2009 there was a suspected discharge of the anti-budding chemical HiCane (used on Kiwifruit orchards) to the Riwaka River after landowners who pumped water from the river to ponds noticed that the fish in the ponds and the birds that drank from the ponds all died. While testing was undertaken there wasn't enough evidence to conclude the exact source of the toxicant.

In the 1980's and 1990's the Riwaka River had one of the highest levels of brown trout biomass in NZ. Currently trout biomass is very low and most anglers are pointing to the willow removal and rocked stopbanks in the lower reaches as the reason why. Some planting of shrubs such as *Coprosma robusta* are being planted into the rock stopbanks to try and create fish cover. This is being trialled in case there is an adverse effect on the integrity of the rock structure. It is desired that in time there will be a greater capacity to accommodate larger pools in order to accommodate larger fish.

There is very limited space for inanga spawning due to the design of the stopbanks and lack of areas of rank grass in the area of the tidal saltwater wedge. This may be the reason why inanga egg surveys have failed to find any sign of spawning activity in the lower reaches.

Riwaka Rv at North Branch Source (January 2008, left) and at Hickmotts (April 2005, right).

Macroinvertebrate condition at the north branch source indicates very good water quality. Unfortunately, this condition was on average 21 MCI units lower at the Hickmotts site compared to the north branch source site. MCI has also declined at the Hickmott site from >120 units (excellent) in 2002-2005 to 100-115 more recently.

Cavers have, in the past, complained of dirty caves which they perceive to be due to sediment discharges from roading and forestry in the upper catchment.

Some in the caving community perceive that the colour has changed over the years from blue to yellow-green. An analysis of colour shows that from 2013-15 there have been fewer pure blue colours recorded and more blue colours tinged with green (blue-green) and in a few cases green has dominated over blue (green-blue).

	Riwaka at Hickmotts
River Environment Class	Cool Wet Hard sedimentary - karst Indigenous forest Low gradient
Catchment area (km^2)$^+$	85
Predominant land use upstream	Indigenous forest and scrub (5940 ha), forestry (~1650 ha), horticulture (~300 ha) and sheep and beef farming (~360 ha).
Mean annual rainfall (mm)	1000 est
Mean annual flow (l/sec)	4,379
Median annual flow (l/sec)	2,300
7-day Mean Annual Low Flow (l/sec)	916
Lowest recorded flow	503
Water quality record	2000-present

Riwaka at North Branch source	
Date Collected	**Water colour**
2006-05	Blue- green
2006-07	Blue
2006-10	Blue
2007-05	Green-blue
2007-07	Blue
2007-11	Blue
2008-01	Blue
2008-05	Blue-green
2008-08	Blue-green
2008-10	Blue
2009-01	Blue
2009-04	Blue
2009-07	Blue
2009-10	Blue-green
2010-01	Blue
2010-05	Blue
2010-07	Blue
2010-10	Blue
2011-02	Blue
2011-05	Blue
2011-07	Blue
2012-02	Blue
2012-04	Blue
2012-08	Green-blue
2012-10	Green-blue
2013-02	Blue
2013-04	Green-blue
2013-07	Blue
2013-10	Green-blue
2014-02	Green-blue
2014-03	Blue-green
2014-07	Blue-green
2014-10	Blue-green
2015-02	Blue-green
2015-05	Blue-green

Table 14 Water colour at Riwaka at North Branch Resurgence

Kaiteriteri Stream to Marahau River

Like all streams draining catchments dominated by Separation Point geology these waterways have a bed dominated by coarse sand substrate.

The concentration of **disease-causing organisms** over a range of flows in both these streams was found to be **low** (based on 20 samples taken on an outgoing tide at each site as part of BWQMP; Kaiteriteri lagoon outlet median: 7.5 *Enterococci*/100 ml in 2012-13; Marahau River mouth median: 105 *Enterococci*/100 ml in 2011-12). A relatively low cover of periphyton was recorded at each of these sites.

Kaiteriteri Lagoon Outlet (February 2011)

Marahau River downstream Sandy Bay Rd (January 2011)

Takaka Water Management Area

This area covers the whole Takaka catchment and all streams from Wainui Bay in the east to Tukurua in the north-west. This is the same area as covered by the Freshwater Management Unit set up under the National Policy Statement for Freshwater Management.

Between 2010 and 2014, there were 15 core River Water Quality sites monitored within the Takaka Water Management Area (Figure 87). There was one reference site, Takaka at Harwoods.

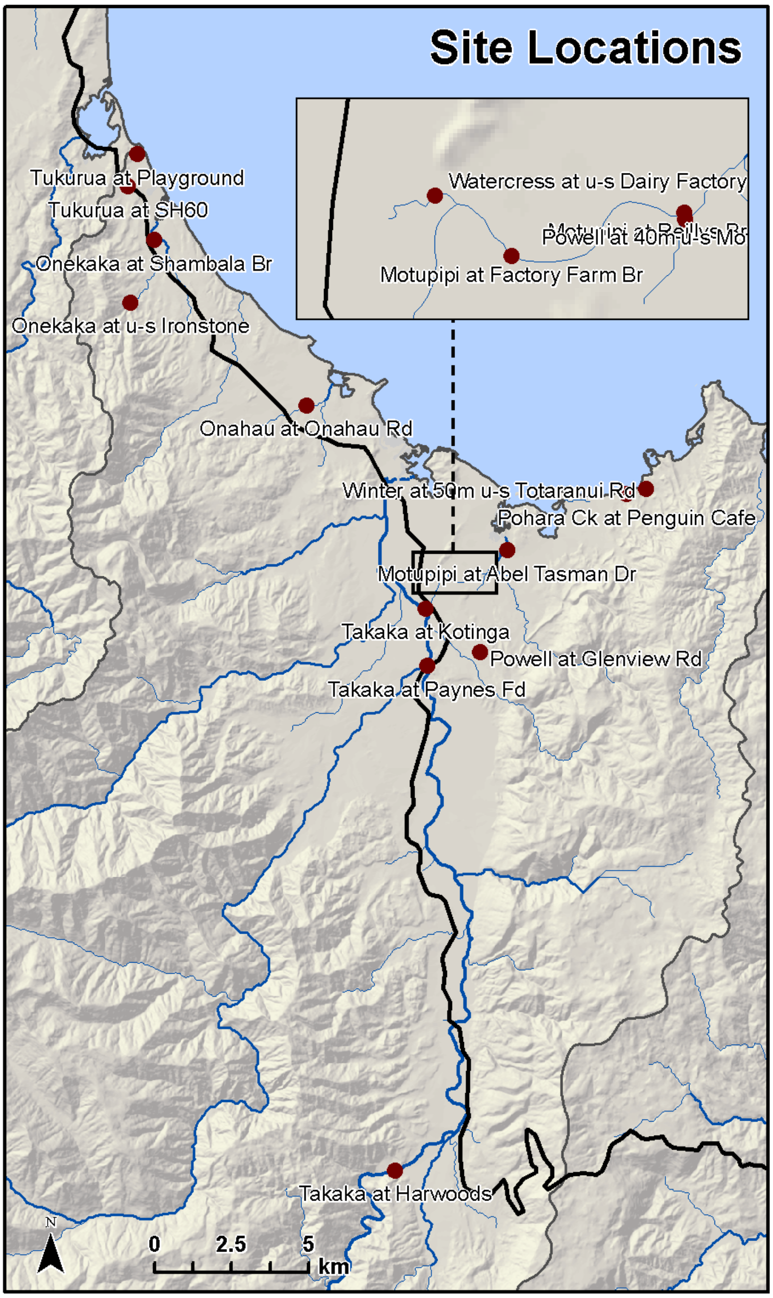


Figure 87. River Water Quality sites in the Takaka Water Management Area

Discussion of Specific Catchments/Areas

This section describes the more **notable aspects of water quality in a given catchment, actions taking place, and recommendations** for further action.

The key to the colour-coding for each water quality attribute state (A to D) is shown to the right. The cut-offs used for each attribute are shown in Table 3.

The dataset used to determine the attribute states was collected at base-flow over the period from 2010-2014 unless a comment is made otherwise. White (no colouring) indicates there are no data available to determine the attribute state.

Attribute State
A (Excellent)
B
C
D (Poor)

Trends in water quality attributes are reported if they are statistically significant (p-value<0.05) and ecologically meaningful (RSKSE>1%). An increasing trend can have a positive or negative effect on the stream ecosystem, depending on the attribute. To indicate the ecosystem effect of the trend, we have used a smile symbol (☺) for improving trends and a frown symbol (☹) for degrading trends.

Table 15. Numerical attribute states for each water quality attribute for the protection of river ecosystem health, aesthetics, and human health. Attributes highlighted in blue are included in the National Policy Statement for Freshwater Management (NPSFM 2014).

Attribute	Statistic	Units	Attribute State				Source
			A	B	C	D	
Water clarity	Single measurement	m	≥5	3 - 5	1.6 - 3	<1.6	-
Turbidity	Single measurement	NTU	≤5.6	>5.6	N/A	N/A	ANZECC & ARMCANZ (2000)
Resuspendable solids	Shuffle score (1 to 5)	N/A	1	2	3	≥4	-
Dissolved oxygen concentration	7-day mean minimum	g/m^3	≥8	7 - 8	5 - 7	<5	NPSFM (2014)
	Lowest 1-day minimum	g/m^3	≥7.5	5 - 7.5	4 - 5	<4	
Water Temperature	Midpoint of daily mean and daily maximum	°C	≤18	18 - 20	20 - 24	>24	Davies-Colley et al. (2013)
pH	Single measurement	N/A	6.5 - 8.5	5 - 6.5, 8.5 - 9	>5 or >9	N/A	-
Ammonia-N	Annual median	g/m^3	≤0.03	0.03 – 0.24	0.24 - 1.3	>1.3	NPSFM (2014)
	Annual maximum	g/m^3	≤0.05	0.05 - 0.4	0.4 - 2.2	>2.2	
Nitrate-N	Annual median	g/m^3	≤1.0	1.0 - 2.4	2.4 – 6.9	>6.9	NPSFM (2014)
	Annual 95th percentile	g/m^3	≤1.5	1.5 - 3.5	3.5 - 9.8	>9.8	
Dissolved reactive phosphorus	Single measurement	g/m^3	<0.01	≥0.01	N/A	N/A	ANZECC & ARMCANZ (2000)
E. coli	Annual median	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	NPSFM (2014)
	95th percentile	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	
Macroinvertebrates	MCI	N/A	≥120	100 - 120	80 - 100	<80	Stark & Maxted (2007)
	SQMCI	N/A	≥6	5 - 6	4 - 5	<4	
Phormidium	Percentage cover	%	<20	≥20	N/A	N/A	MfE (2009)
Filamentous green algae	Percentage cover	%	<10	10-19	20-29	>30	Biggs and Kilroy (2000)
Periphyton	Periphyton score (1 to 10)	N/A	≥8	6 - 8	5 - 6	< 5	-

How to read a site summary

The site summaries in this report are based on data collected quarterly (monthly for selected sites) from 2010-14, with two exceptions: (1) macroinvertebrate community index values were from 2011-2015 and (2) dissolved oxygen measurements were taken over several days in a summer period from 2005-2015.

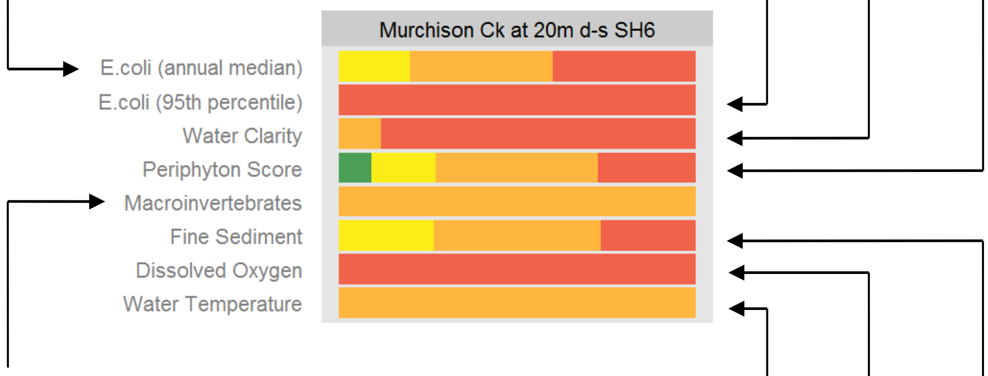
The rows of a site summary represent water quality attributes. The colours indicate attribute states **A** (very good), **B** (good), **C** (fair) **D** (poor).

Proportion of periphyton scores in each attribute state.

Proportion of water clarity measurements (m) in each attribute state.

Attribute state for the 95th percentile *E. coli* concentration. Minimum 10 samples.

Attribute states for the annual median *E. coli* concentration. No minimum sample size.



Proportion of macroinvertebrate community index (MCI) values in each attribute state.

Attribute state for the highest midpoint of daily mean and daily maximum temperature from a continuous record.

Attribute state for the mean minimum dissolved oxygen concentration over 3 or more days during summer. For sites with fewer than 3 days of continuous measurements, the 1-day minimum value was used.

Proportion of resuspendable solids (fine sediment) scores in each attribute state.

Water Clarity

Two sites had at least three water clarity records below the guideline value of 1.6 m during the five-year reporting period (Powell at 40 m u-s Motupipi Rv and Winter at 50 m u-s Totaranui Rd). This indicates a pattern of poor water clarity at these sites. There were six other sites with one or two water clarity records below the 1.6 m guideline value. The clearest river water in the Takaka catchment is the Te Waikoropupū River (median: 22 m, maximum: 41.5 m, measured at a site 600 m downstream of the main spring) followed by Onekaka at u-s Ironstone (Median: 10 m, Maximum: 15.8 m).

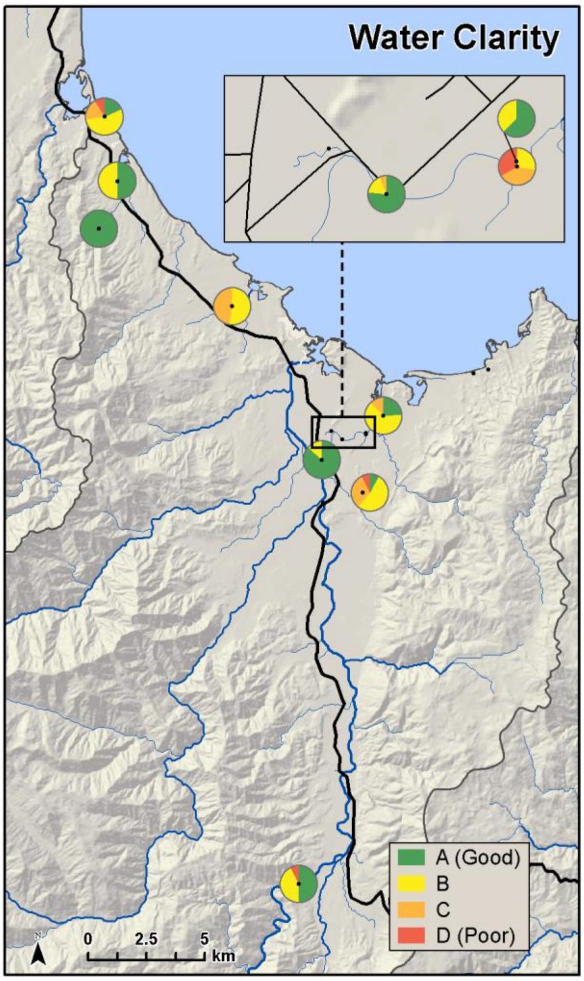


Figure 88. Proportion of water clarity records in each attribute state (A to D) for river water quality sites in the Takaka Water Management Area (sites shown have a minimum of 10 samples).

Disease-causing Organisms

The National Bottom Line annual median *E. coli* concentration (1000 *E. coli*/100 ml) was exceeded at Powell at 40 m u-s Motupipi Rv in 2014 (median value 1080 *E. coli*/100 ml). In the same year, the annual median *E. coli* concentrations for three sites used for contact recreation, or that flow into estuaries or beaches used for contact recreation, exceeded the contact recreation limit (540 *E. coli*/100 ml): Tukurua at Playground, Onahau at Onahau Rd and Motupipi at Abel Tasman Dr.

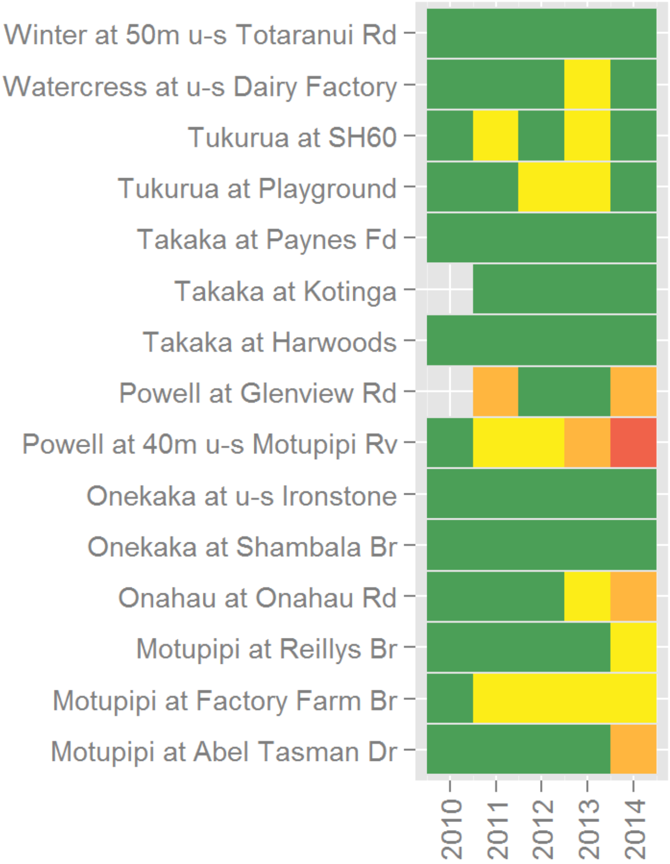


Figure 89. Tile plot of annual median *E. coli* values for sites in the Takaka Water Management Area. Colours indicate attribute states A (green), B (yellow), C (orange) and D (red). Annual median values were calculated for sites with three or more records in a given year.

Filamentous Green Algae Cover & Periphyton Score

The coverage of filamentous green algae in the Takaka Water Management Area was generally low (Figure 90). On two occasions, however, Watercress at u-s Dairy Factory had coverage greater than 50%. High coverage was also recorded on one occasion at Motupipi at Reillys Bridge (during Spring 2014).

Periphyton scores (Rapid Assessment Method 2, NZ Periphyton Monitoring Manual, 2000) were generally good (in the A or B bands). However, both Motupipi sites, both Powell sites and Takaka at Harwoods had at least three periphyton scores less than seven (bands C or D). The cover of didymo is extensive at Harwoods and Paynes Ford, and filamentous green algae seem to grow better on didymo than a clean stream bed.

Macro-algal cover in the Motupipi and Onekaka Inlets is generally low, except in the western arm of the Motupipi Inlet where there are significant areas of localised nuisance algae (Stevens and Robertson, 2007).

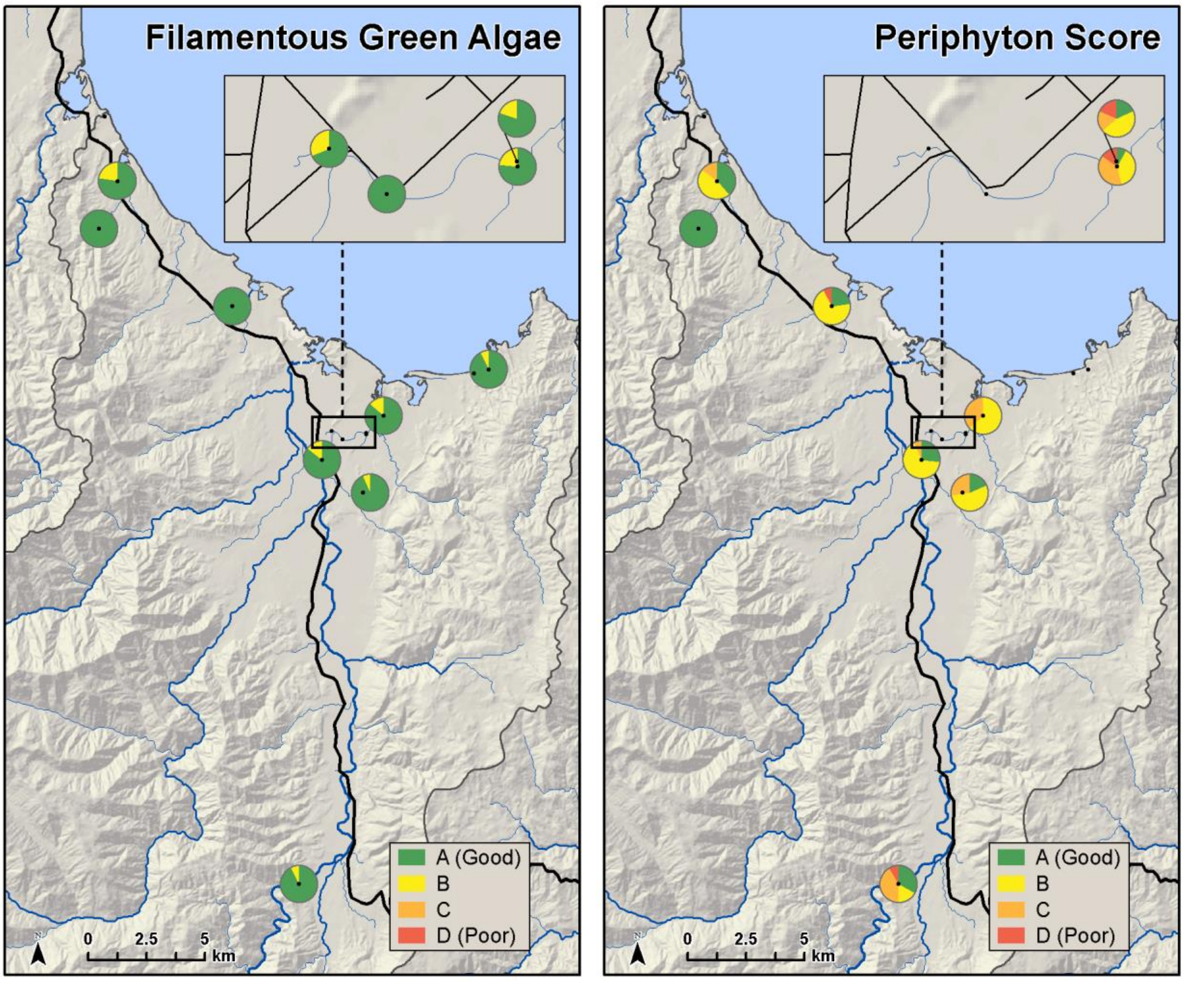


Figure 90. Coverage of filamentous green algae greater than 20 mm in length (left) and periphyton community score (right) for sites in the Takaka Water Management Area. Pie charts show the proportion of estimates in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

Nutrients

The annual median **nitrate-N** concentrations in the Takaka Water Management Area were all in the A or B bands (less than 1.0 and 2.4 g/m^3 respectively) (Figure 91). The Motupipi and Powell catchments had higher annual median nitrate-N concentrations than the Takaka or Watercress catchments, though within the acceptable range. These sites have the highest recorded nitrate concentrations in Tasman District after the spring-fed streams of the Waimea plains (near Richmond). Some limited nutrient records for the Waingaro at Hanging Rock and Onekaka and Shambala show very low levels. Nitrate toxicity has recently been found to be mitigated strongly by water hardness (as calcium carbonate). All the waterways with the highest nitrate concentrations also had high hardness, enough that toxicity is unlikely to ever be an issue (Hickey, 2015). This means that nitrate is only an issue with respect to promoting excessive filamentous green algae growth.

Annual median **ammonia** concentrations were within the A band (less than 0.03 g/m^3).

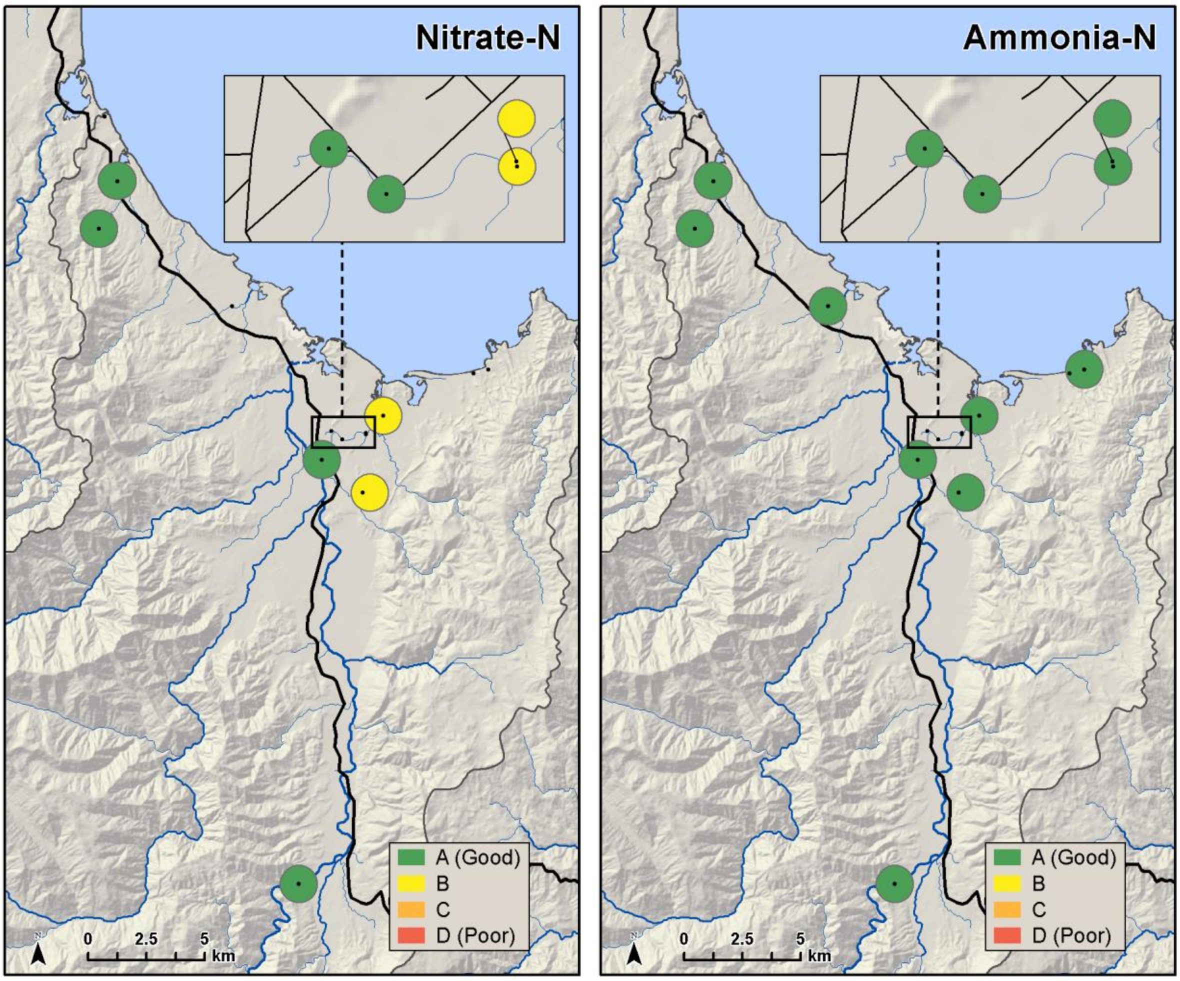


Figure 91. Nitrate (left) and ammonia (right) concentrations for sites in the Takaka Water Management Area. Pie charts show the proportion of annual medians in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

Most dissolved reactive phosphorus (DRP) concentrations were satisfactory (less than 0.01 g/m^3) (Figure 92). At least three DRP sample concentrations, however were unsatisfactory (above 0.01 g/m^3), at the Motupipi River sites as well as Powell at 40 m u-s Motupipi and Watercress at u-s Dairy Factory.

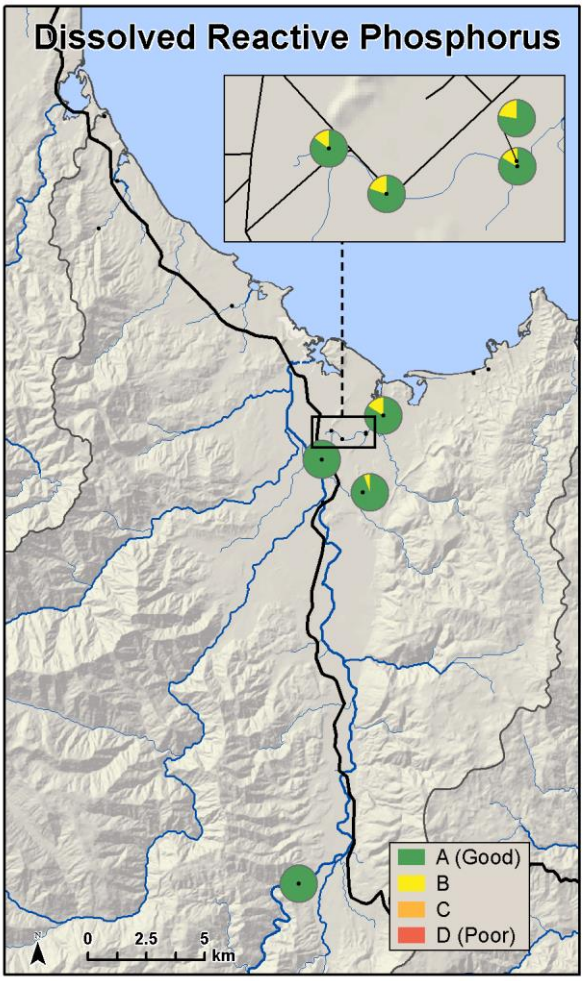


Figure 92. Dissolved reactive phosphorus concentrations for sites in the Takaka Water Management Area. Pie charts show the proportion of records in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

Resuspendable Sediment

Volumetric SBSV were examined for three high risk sites on smaller waterways in the Takaka catchment and found to be relatively high compared to others across the district. There were no differences found between the sampling years (2012 to 2015) at these sites (Figure 93).

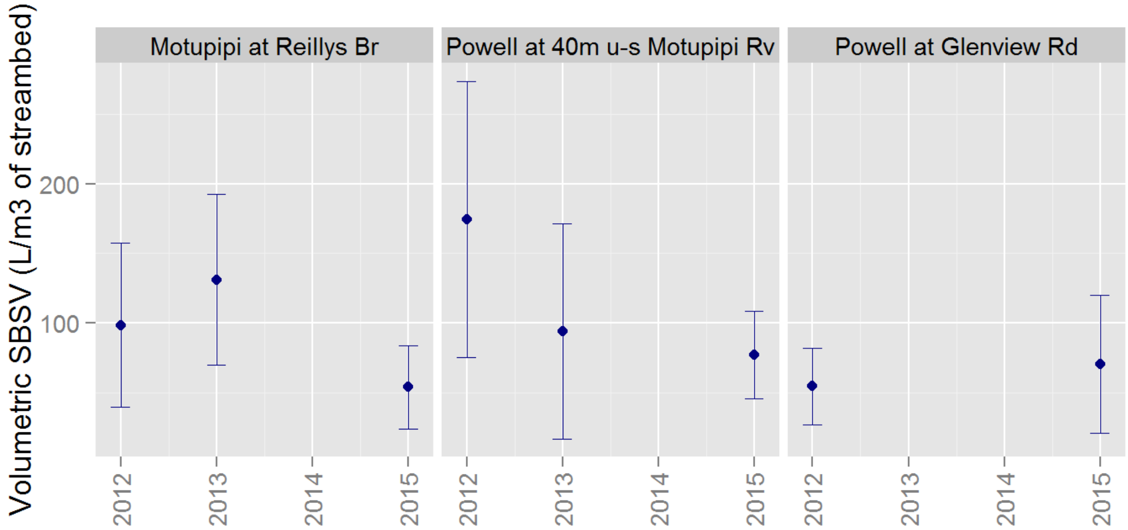


Figure 93. Mean volumetric suspendable benthic sediment volume (SBSV) from 2012 to 2015 (sampled during Summer). The error bars show 95% confidence intervals.

Of the three sites in the Motupipi catchment (Motupipi at Reillys Br, Motupipi at Factory Farm Br and Powell at 40 m u-s Motupipi Rv) where resuspendable solids were measured, all recorded a score of poor at least once and greater than 10 % of records have a 'C' (fair) score (Figure 94).The depth of fine sediment measured at about 100 m intervals in the bed of the Motupipi from Watercress Creek to Able Tasman Drive showed a maximum dept of over 1 m in some pools downstream of the Powell Creek confluence) and 300 mm depth on average over this 3 km reach. Sites on the Takaka, Onekaka and Onahau rivers had much better resuspendable solids score with the Takaka at Harwoods site recording 100% of samples in the 'A' band.

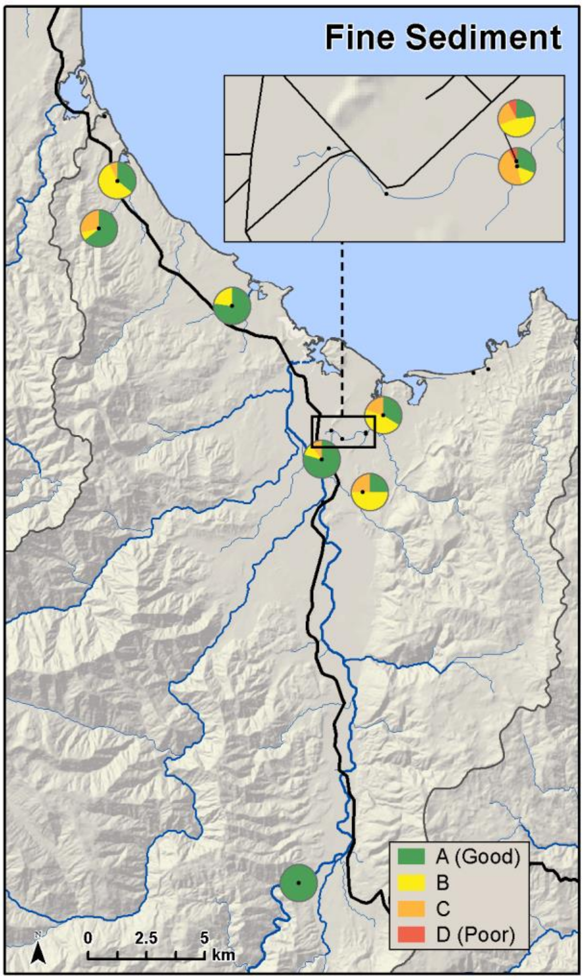


Figure 94. Proportion of resuspendable solids scores in each attribute state (A to D) for sites in the Takaka Water Management Area.

Macroinvertebrate Community

There was a wide range of MCI results in the Takaka Water Management Area over the last five years (Figure 95). Onahau at Onahau Rd and Onekaka at Shambala Br had MCI values in the good to excellent range. In contrast, Watercress at u-s Dairy Factory had poor MCI values and Motupipi at Reillys Br was poor/fair.

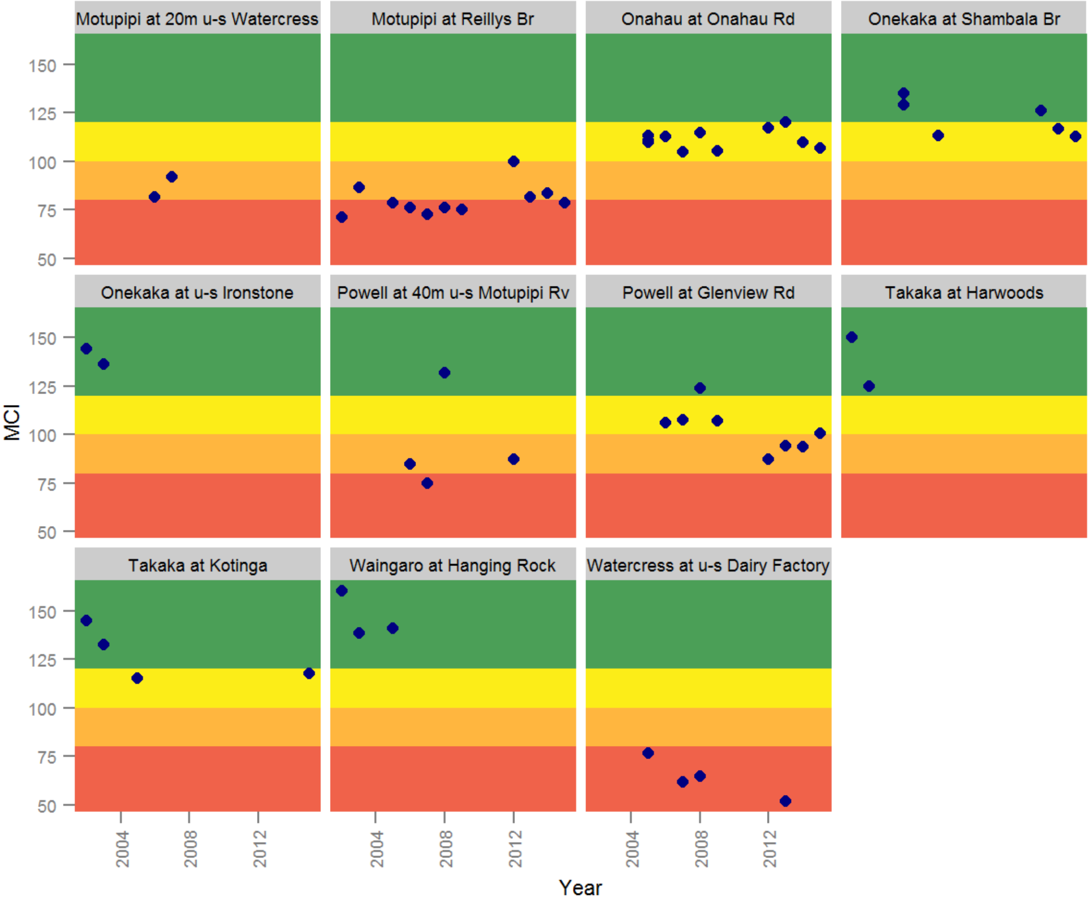


Figure 95. Macroinvertebrate community index (MCI) scores between 2001 and March 2015 for sites in the Takaka Water Management Area (blue dots). The background colours indicate these quality classes: excellent (green), good (yellow), fair (orange) and poor (red).

Paired Site Differences – Takaka River

This section compares the difference (increase or decrease) between two sites on a particular waterway on a particular day. The differences are then averaged to get the "mean difference". It is not the difference of the mean from each site calculated from the whole record for one site with the mean from the whole record from other site.

When comparing the records from Takaka at Kotinga with the reference site at Takaka at Harwoods, there were **relatively large differences in nutrient concentrations** (Figure 96). Takaka at Kotinga had Nitrate-N records more than 200 times higher 0.193 g/m^3, SD = 0.10, n = 18) than the reference site. However, nitrate is still at very low levels. For **dissolved inorganic nitrogen** there was a similar pattern (mean increase 0.192 g/m^3, SD = 0.10, n = 18).

Interestingly, the coverage of didymo at Kotinga was consistently lower than at the reference site (mean decrease 32%, SD = 31%, n = 10). A further difference between Takaka at Kotinga and the reference site was in the concentration of ***E. coli*.** At Kotinga, *E. coli* concentrations were up to 40 times higher (mean increase 47 *E. coli*/100 ml, Figure 96). Water clarity was higher downstream, probably due to clear water from the Waingaro River and sediment getting trapped in the Takaka River drying zone.

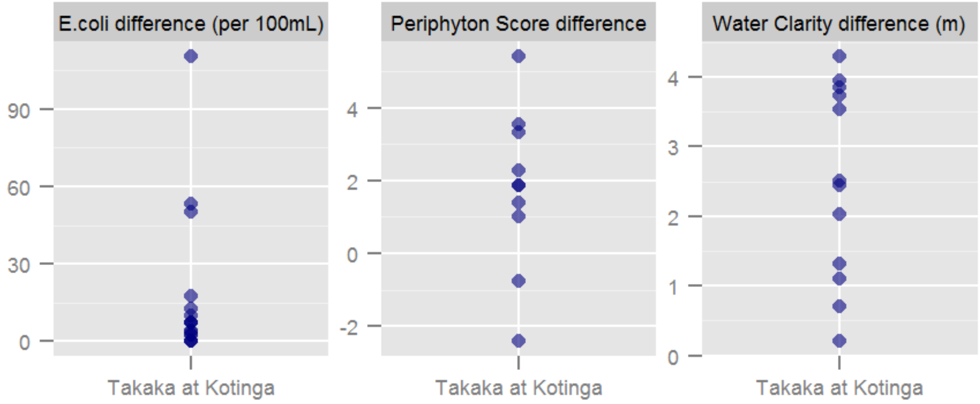


Figure 96. Difference between Takaka at Harwoods (upstream) and Takaka at Kotinga (downstream) for water quality data collected at both sites on the same day. A positive difference means the downstream site had a higher value than the upstream site.

Trends in the Takaka WMA

The analysis of trends in the Takaka Water Management Area revealed several improvements over the past 10 years (Table 16). Dissolved reactive phosphorus concentrations improved in the Motupipi and Powell catchments. For nitrate-N concentrations, there were improving trends in the Takaka river sites but degradation in Powell at Glenview Rd, Watercress at u-s Dairy Factory and Te Waikoropupū Springs.

Table 16. Water quality trend results for sites in the Takaka Water Management Area over the 10-year period 2005 to 2014 (highlighted in blue) and over the full record (from 15 to 45 years depending on the site). Seasonal Kendall trend tests were used for *E. coli* concentrations, water clarity measurements and nutrient concentrations (Ammonia-N, Nitrate-N and DRP). The trends shown are significant ($p < 0.05$), meaningful (RSKSE > 1% per year) and the change in value between the start and end of the trend line is greater than the detection limit for the attribute (refer to the Methods sections for the detection limits). Statistics are shown in the Appendices.

Site name	Attribute	Effect ☺ ☹	N obs	N years
Motupipi at Factory Farm Br	Ammonia-N	☺	39	10
Motupipi at Reillys Br	Ammonia-N	☺	39	10
Motupipi at Reillys Br	Ammonia-N	☺	58	15
Motupipi at Reillys Br	DRP	☺	40	10
Motupipi at Reillys Br	DRP	☺	58	17
Motupipi at Reillys Br	*E. coli*	☺	60	17
Onahau at Onahau Rd	Water Clarity	☺	36	10
Onekaka at Shambala Br	Water Clarity	☺	36	10
Powell at 40 m u-s Motupipi Rv	Ammonia-N	☺	43	10
Powell at 40 m u-s Motupipi Rv	DRP	☺	45	10
Powell at Glenview Rd	Ammonia-N	☺	43	10
Powell at Glenview Rd	Nitrate-N	☹	45	10
Takaka at Harwoods	Nitrate-N	☺	63	17
Takaka at Kotinga	Nitrate-N	☺	42	10
Te Waikoropupū Springs	Nitrate-N	☹	40	10
Te Waikoropupū Springs	Nitrate-N	☹	103	45
Te Waikoropupū Springs	Water Clarity	☹	107	18
Watercress at u-s Dairy Factory	Ammonia-N	☺	37	10
Watercress at u-s Dairy Factory	Nitrate-N	☹	38	10

Takaka Catchment

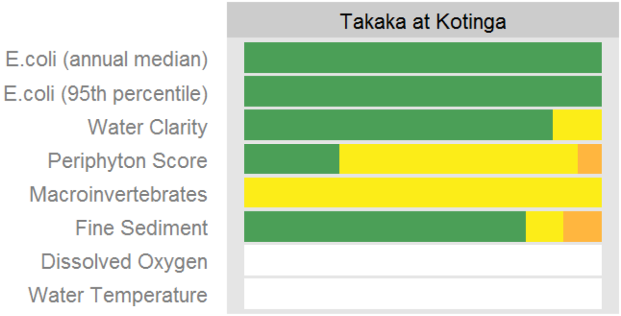
Above: Takaka River at Paynes Ford looking downstream to SH60 (December 2010)

The Takaka catchment area is 940km^2 with land cover dominated by native forest and subalpine tussock land. The Takaka River is a regionally important trout fishery and demand for water for irrigation is high. On average about 8,000 l/sec from the river downstream of Lindsay's Bridge (about 7km downstream of the Takaka at Harwoods site) is lost through the gravel river bed. When the flows at Harwood site fall below 7,000 l/sec the Takaka River can be anticipated to dry from 0.5-1km downstream of Lindsay's Bridge (upper crossing of SH60) for a stretch of several kilometres downstream through to about 1 km upstream of Paynes Ford bridge (SH60).

The Waingaro, Anatoki and Takaka rivers have excellent or good base flow water clarity. However, the Takaka River is one of the few rivers in the district which has much lower water clarity in its headwaters compared to the lower reaches (median at Harwoods is 5.1 m compared to 7.7 m at Kotinga over the period of 2010-2015). This is probably due to one or more of the following factors:

- the impounded water released into the Takaka River from the Cobb reservoir, via the Cobb hydro-electric power scheme, upstream of the Harwoods site (at low lake levels and windy conditions the fine sediment on the bed of the lake gets re-suspended)
- the input of very clear water, from the Waingaro (12.1 m median, 30.5 m maximum) above the Takaka Rv at the Kotinga site
- greater settling of fine sediment in the area of the river that loses water to ground (mid reaches downstream of Lindsay's Bridge).

While median water clarity has remained about the same at Harwoods and Kotinga sites.
The power scheme is not managed to reduce the discharge of fine sediment to the Takaka River and the relationship between water clarity or turbidity of Takaka downstream of the Cobb discharge with lake level and wind has not been looked at (Lilley,P: pers.comm.). However, it is in the interest of the power scheme to limit the fine sediment input due to the erosive force on the plant e.g. pelton wheel abrasion. Metals such as iron and manganese in solution from the sediments of Lake Cobb can also cause decreased water clarity.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

Average levels of **faecal indicator bacteria** at base-flows are low at both the Takaka Rv sites (Kotinga median *E. coli*/100 ml: 15, Harwoods median *E. coli*/100 ml: 2 (below detection) with occasional high readings in the lower reaches. The results for weekly sampling during the summer bathing season (2010-15 only) at **Paynes Ford** show it is safe for contact recreation for the vast majority of the time (median: 20 *E. coli*/100 ml; 260 *E. coli*/100 ml alert guideline met more than 92% of the time and the 550 *E. coli*/100 ml alarm guideline met 98% of the time).

Nutrient concentrations are low at Harwoods and **Kotinga** as well as the **Waingaro River** at Hanging Rock (Median NO_3-N in g/m^3: 0.009, 0.01 and 0.01 respectively, Median DRP in g/m^3: 0.001, 0.002 and 0.032). Nitrate-N concentrations are also decreasing at the Harwoods site (Figure 97). The reason for this trend is unclear at this stage.

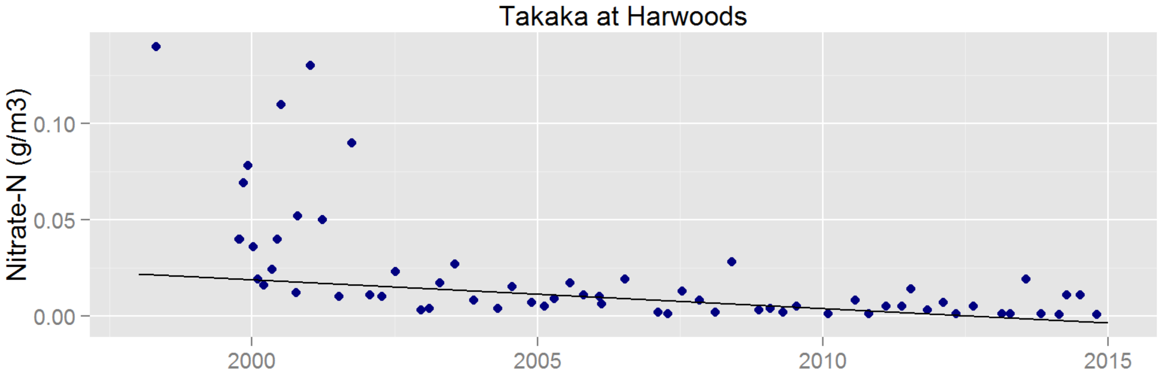


Figure 97. Takaka at Harwoods Nitrate-N concentration data with 17-year trend line ($p < 0.0001$, RSKSE = -15% per year). No significant meaningful trend was detected over the most recent 10 years of the record.

However, **the coverage of filamentous green algae Takaka River upstream of Paynes Ford can be high in summer** (see photo below). This is partly due to the presence of didymo (first discovered in Dec 2007) which protects the filamentous green algae from sheer stress allowing it to grow back faster after floods.

There are several intensive dairy farms in this catchment with sophisticated monitoring systems for soil moisture associated with their irrigation systems to avoid leaching of nutrients.

1

2

3

4

From left to right:

1 - Takaka Rv at Kotinga (January 2005).
2 - Takaka Rv upstream Paynes Ford (November 2007). Showing heavy filamentous algae growth.
3 - Waingaro Rv at Hanging Rock (January 2009). Water clarity maximum 30.5 m.
4 - Takaka Rv at Harwoods (February 2005).

Table 17. Summary statistics for sites in the Takaka catchment

	Takaka at Harwoods	**Takaka at Kotinga**	**Waingaro at Hanging Rock**
River Environment Class	Cool Extremely Wet Volcanic basic Mountain-fed Low gradient	Cool Extremely Wet Hard sedimentary Hill-fed Low gradient	Cool Extremely Wet Hard sedimentary Mountain-fed Low gradient
Catchment area (km^2)$^+$	259	714	
Predominant land use upstream	98% native forest and tussock	Upstream of Mouth: Indigenous Forest: 78.4% or 785km^2 (635km^2 in National Park) Exotic pasture: 14.9% or 151km^2 of which dairying makes up 49.68 km^2 (14,465 cows)	100% native forest or alpine tussock
Mean annual rainfall (mm)	2,230	1,980	3110
Mean annual flow (l/sec)	14,425	37,664	18,298
Median annual flow (l/sec)	10,084	17,439	10,517
7-Day Mean Annual Low Flow (l/sec)	2,380	3,310	3,685
Lowest recorded flow (l/sec)	483	1,668	2,226
Water quality record	2000-present	Quarterly: 2000-present Monthly: 2013-present	Quarterly: 2000-2010

Te Waikoropupū River

This river is fed by one of the largest springs in the Southern Hemisphere (mean flow in main spring is almost 10 m^3/sec (8.5-15 m^3/s range), with Fish Creek Springs contributing 3.3 m^3/sec (Thomas and Harvey, 2013). The waters emanating from the spring arise from the Arthur Marble Aquifer, karst system that takes leaked water from rivers such as the Takaka (below Lindsay's Bridge) and lower Waingaro and many tributaries in the mid and upper Takaka Valley.

Te Waikoropupū Main Spring (March 2004)

Te Waikoropupū Main Spring has the **second-highest clarity of freshwater in New Zealand** (after Blue Lake and the Sabine River in Nelson Lakes National Park) and amongst the highest in the world at over 60 m. At a monitoring site on Te Waikoropupū River about 600 m downstream of the spring (upstream of a salmon farm discharge) the median is 22 m, but is decreasing (Figure 98). This natural reduction is from a number of sources such as: dissolved organic carbon (colour) from soil leaching (mostly from the Fish Creek catchment) and exudates from the aquatic plants that have extensive coverage of the bed in the spring and river. The higher the clarity the more reduction you get in clarity for a given amount of dissolved or particulate material in the water. The water clarity median downstream of the salmon farm discharge from 2012 to 2015 is 18.5 m.

The **water temperature** in Te Waikoropupū Springs is very constant (around 11.7^{o}C), but since 1994 they are often over 12.1^{o}C during the summer season, but this is well below the level when any adverse ecological effects occur.

A statistically significant **increase in Nitrate-N concentration** is evident in the **main spring** water over the period from 1970 to 2014 (Figure 99) (Stark, 2015; Mead, 2015). On average, nitrate-N values have increased by about 40 to 50% in 44 years (Stark, 2015). It seems as if nitrate concentrations are levelling off. . It is highly unlikely that nitrate concentrations in Te Waikoropupū Springs will ever get to toxic levels. Nitrate-N in the Fish Creek spring is about 20% higher than the main spring. This reflects the higher proportion of younger (average of one year) and more shallow groundwater feeding the Fish Creek springs. The recharge for the Fish Creek springs has been estimated to be about 50% from the Takaka River and 25% from the karst uplands, whereas for the main spring the proportions are 18.5% and 74% respectively (Thomas and Harvey, 2013).

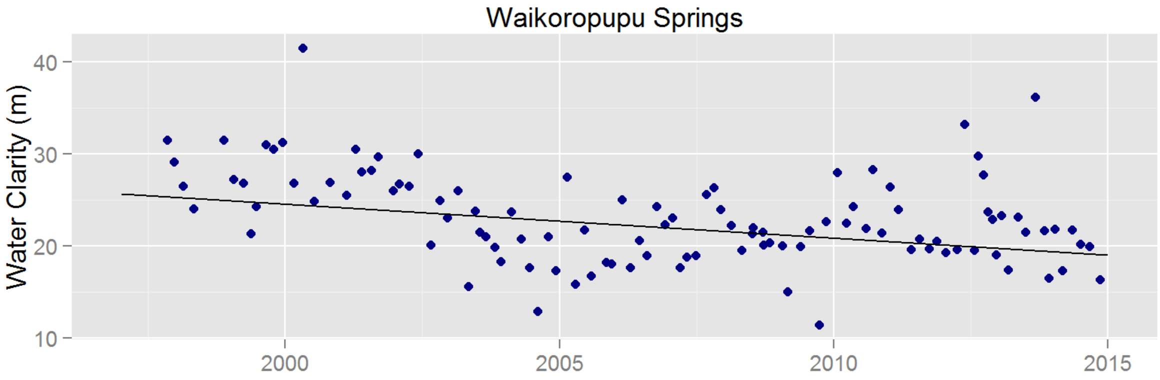


Figure 98. Water Clarity at Te Waikoropupū River 600 m downstream main spring and upstream NZ King Salmon Discharge with 18-year trend line (p = 0.0001, RSKSE = -1.7% per year). No significant meaningful trend was detected over the most recent 10 years of the record. Data from NZ King Salmon (2015).

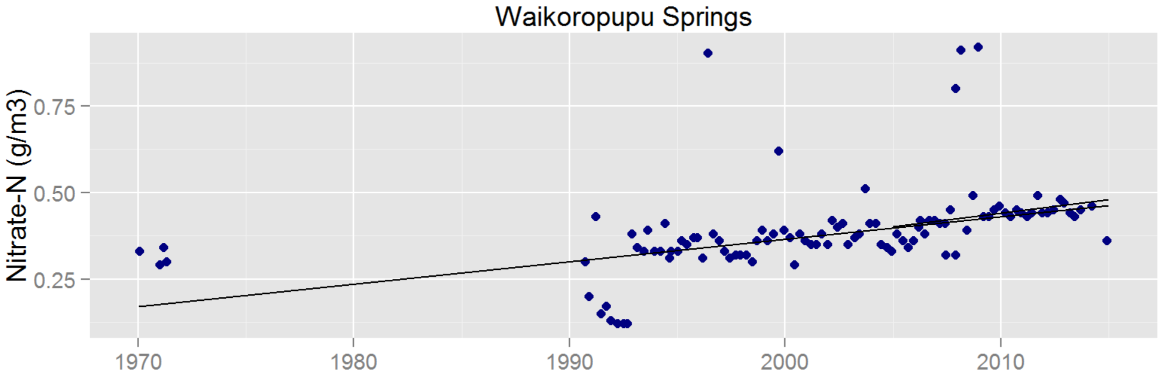


Figure 99. Trend in nitrate-N concentrations in Te Waikoropupū Springs from Michaelis (1974) for 1970-71 and TDC/GNS data from 1990 to 2014. The trend lines are for 10 years (p = 0.0002, RSKSE = 1.8% per year) and 45 years (p < 0.0001, RSKSE = 1.7% per year).

Ammonia-N concentrations in the main spring are **very low** (median 0.005 g/m^3).

While the **total phosphorus** concentration has increased over the period from 1994 to 2004, **dissolved reactive phosphorus concentrations have not changed from 1990** (median for March: 0.005 g/m^3). While base flow total phosphorus concentrations in the Takaka River are low, they can be very high in floods.

It is important to manage both nitrate and phosphorus to ensure that filamentous green algae growth is not excessive. In spring-fed rivers with very stable flow, phosphorus is particularly important as once it enters the system it usually remains in the sediment where is it available for plant growth. Phosphorus is usually strongly bound to sediment and so managing sediment inputs to the catchment is probably one of the most important management methods.

While the **cover of filamentous green algae** in the Te Waikoropupū Catchment is very limited, in the **Fish Creek springs** it is usually **very high** (often >90% except for winter when it is light limited) (Murray, *pers.com*.). Such algae **coverage** in the **main spring is very low**. The potential for flushing flows in the main spring basin are very low given that there are no streams flowing into it. This means that this site is vulnerable to increased nutrient concentrations and stimulation of plant and algal growth. In the Te Waikoropupū River there is potential for some flushing flows from floods in the Fish Creek catchment. However, this is limited by the relatively small size of the catchment (216 ha) compared to the flow in all the springs.

Annual monitoring of macroinvertebrates in the Te Waikoropupū River as part of NZ King Salmon's resource consent has been ongoing since 1988. Overall there has been no statistically significant trend in MCI values in Springs River upstream of the salmon farm outflow channel (Site 3/3a sampled as part of RM110270) (Stark, 2015) (Figure 100). The low MCI in 2001 was considered to be due to a prolonged period of low flows prior to sampling. The increased nutrient content of the waters of the Springs River does not seem to have had any noticeable effect on macroinvertebrate communities or river 'health' as determined by the MCI.

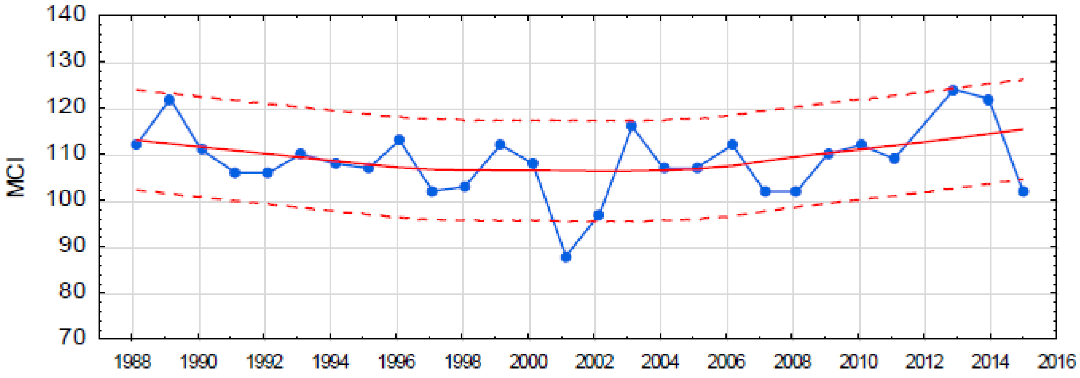


Figure 100. MCI versus time (23 February 1988 – 29 December 2014) for Site 3/3a in the Springs River upstream of the NZKS discharge. Data from August – September collected prior to 2000 have been excluded. The fitted line is a LOWESS trend (tension = 0.7) with dashed red lines indicated error of ±10.83 MCI units (Stark, 2015).

No *E.coli* has been detected in the main spring of this river showing that this water is suitable for drinking (although the main spring water is not accessible, and drinking from the river is not recommended due to wildfowl influence). However, sampling in Fish Creek and the Fish Creek spring consistently detect faecal indicator bacteria in the range of 5-30 *E.coli*/100 ml (N.Murray, 2014, unpublished). A drinking water supply from the river was set up at Te Waikoropupū Springs car park, but later removed as the Department of Conservation could not guarantee that the water would contain no *E.coli*.

The water quality at the Te Waikoropupū Spring has limited vulnerability to discharges to the unconfined aquifer of the Takaka Valley floor. Despite pastoral farming having increased in intensity there is no evidence of a subsequent change in water quality at the spring. Dairy farming in 2014 covered 24km^2 of the recharge area of the spring. The number of dairy cows having increased from an estimated 5500 to 6700 between 2005 and 2014 (density 2.3 to 2.8 cows/Ha) (Mead, 2015). The area irrigated has increased from 2-10 km^2 from 2003 to 2012 (Mead, 2015).

Te Waikoropupū River at biomonitoring Site 3a upstream of the NZ King Salmon discharge. Top: January 2009, Bottom: February 2010. Photos: Courtesy John Stark. Note the variability in aquatic plant growth.

Table 18. Flow Statistics in l/sec for the Te Waikoropupū River (MALF = Mean Annual Low Flow)

Mean	Median	7 day low flow (l/s)			
		MALF	5 yr	10 yr	20 yr
14630	14030	8683	7101	6563	6168

Lake Kilarney

Lake Kilarney is located within Takaka township. It is a sinkhole filled with water from ground water and has occasional surface water entering but no regular streams in or out. There is a steep slope from the bank into the water. *Lagarosiphon* is the dominant aquatic plant with an average height of 4 m within the water column.

Some surface water flows into the lake during rain from two storm water pipes – Commercial Street and Meihana Street that were piped to the lake in 1970. However, in December 2004 a new sump was installed in the paddock on the Fonterra Factory land that allowed runoff from pasture into the pipes that feed into the lake. This has now been removed but it was possible that runoff from this paddock is responsible for an increase in nutrient and sediment discharges to the land. There is often a long lag time until nutrients accumulate in the lake sediments to the point that algal growth becomes prolific. Uncontrolled storm water and paddock discharge to the lake is not desirable as there is limited ability for the lake to flush so it acts as a dead end of inputs. There is some limited potential for bores down gradient of Lake Kilarney to be affected by water in the lake and this is an area to be followed up as part of the lake monitoring recently started.

Left: Looking south over Lake Kilarney on 10 March, 2014 showing an algal bloom. Note that the bloom is not so prevalent near the shaded edge of the lake. Right: Looking west over Lake Kilarney on 19 February, 2015. Whole lake is highly turbid looking due to an algal bloom.

In the past Lake Kilarnery in Takaka was a clear blue colour. In the mid 1950's it was considered very clear by the locals, now it is a murky brown colour due to algal growth and there is concern expressed by many locals. The algal blooms are likely to because of eutrophication (nutrient enrichment). Blue lake in Rototai was formed in similar geological process but has no storm water connections and the colour of the water is still blue.

The brown coloured plume observed on Lake Kilarney on 10/3/2014 was due to the microalgae, *Peridinium*. This is a motile algae and so explains why it was found only in part of the lake (the sunniest part). This is not an uncommon occurrence, but there are no previous records of this microalgae for this lake. *Microcystis* was also found in the sample at lower concentrations. *Microcystis* can be a concern due to its ability to produce toxins and so contact recreation and stock drinking is not recommended if this alga were to build up in the lake. The present concentration of this species was probably not high enough to need to warn the public. There is a need to sample nutrient concentrations in the lake and also any input drains.

Nutrient concentrations appear to be very low in the near surface waters of the lake. Results from a water sample taken on 19 February, 2015, 2 m out from the eastern shore failed to detect any dissolved nutrients (nitrate + nitrite <0.001, dissolved reactive phosphorus <0.001, total ammonia <0.005).

Continuous sampling of dissolved oxygen and temperature during 10-18 March 2015 showed regular diurnal fluctuations of 80-120% saturation and 21-25°C respectively. The dissolved oxygen flux of this order in a lake indicates significant photosynthetic activity, probably from the phytoplankton which may explain why there were very low nutrient concentrations with the surface waters.

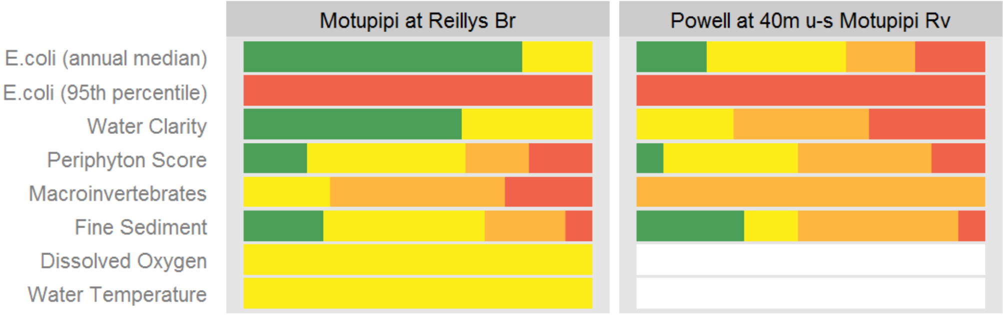
Location map of Lake Kilarney

Motupipi Catchment, near Takaka

Motupipi River at Factory Farm Bridge looking upstream (February 2005)

The values in the Motupipi waterway are whitebaiting and kayaking in the lower reaches. There is a reasonable abundance of eel and inanga in this river and its tributaries as well as a few redfin bullies in the riffles of the Motupipi River.

Land use in this catchment is primarily intensive farming on the flat land with extensive farming on the hill country. The Takaka Dairy Factory ceased its discharge to Watercress Creek after a fire at the plant in June 2005. In addition, the washwater sprayed to land within the catchment is much less concentrated than prior to this period.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

The Motupipi, with its tributaries (**Watercress, Powell, McConnon, and Berkett Creeks)**, have consistently elevated **nitrogen concentrations** (James 2007). Nitrate-N is moderately elevated in the lower catchment (Reilly Bridge site median 1.53 g/m^3-NO$_3$). This, combined with stable flows, is why **filamentous green algae form such extensive growths** (particularly upstream of Powell Creek) and the brown soupy algal blooms (*Cryptomonas*) near the Abel Tasman Drive bridge (the top of the estuary, see photo below). The major source of these nutrients is groundwater that emerges as springs (particularly the karst springs) in the mid-reaches and headwaters of the Motupipi, with pasture run-off also contributing (James & Stevens, 2008). No clear source of the nitrate in these springs has been determined from isotopic analysis, but could be both fertiliser and effluent and from geological sources. The karst spring water feeding the Motupipi near Sunbelt Cres has been aged at 6-7 years (using tritium and sulphur hexafluoride dating methods) (van der Raaj and Baisden, 2011). This suggests either a source relatively remote from the Motupipi River or very low groundwater permeability slowing down travel times. Nitrate concentrations have increased at both the Powell Creek upstream site at Glenview Rd (Figure 102) and at Watercress Creek at the dairy factory (Figure 103). Neither of these sites are far from the spring source of each of these creeks.

Dissolved (soluble) **phosphorus** concentrations in the Motupipi (including Watercress Creek) were found to be **relatively low at all sites** (medians in g/m^3: Watercress Ck 0.008, Factory Farm Br 0.006, Reilly Br 0.013 and Abel Tasman Dr 0.008) (Figure 101). It is pleasing to see that dissolved reactive phosphorus concentrations have **declined** at the Motupipi at Reilly's site (almost 10% per year over the whole 17-year record (1999-2015). This result led this river to become a finalist in the "River of the Year Award, 2014" (http://nzriverawards.org.nz/2014-new-zealand-river-awards/). This decline is likely to be related to the discharge of washwater and whey from the Takaka dairy factory to pasture on farms in the catchment in the 1970's and 80's. Olsen P levels in soils in paddocks in the upper Motupipi River and Watercress Creek catchments were routinely very high (about 200-300 g/m^3) in the 1990's but have been reducing ever since (range 44-121 g/m^3 in 2011) (data supplied by Jeff Riordan, Fonterra Glendale Farm). Olsen-P concentrations of about 25 mg/kg are ample for good plant growth. No phosphate fertiliser has been used on this farm (and probably others in the catchment) since that time.

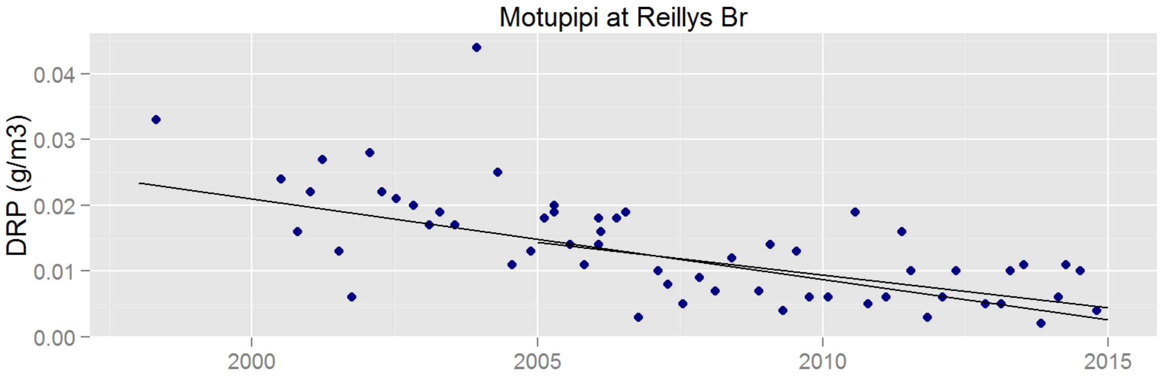


Figure 101. Motupipi at Reillys Br dissolved reactive phosphorus (DRP) concentration data with 10-year ($p < 0.0001$, RSKSE = -10% per year) and 17-year trend lines ($p < 0.0001$, RSKSE = -9.8% per year).

A programme sampling water quality, monthly, for a year (2006-2007 over all flows) in the **Powell Creek** Catchment showed soluble nitrogen concentrations were also high, with 90% of samples across all sites being above guidelines. It is likely that groundwater feeding upper Powell Creek is the cause (the source of this groundwater could be the same as the Motupipi). Soluble phosphorus concentrations were found to be relatively low at all sites (medians in g/m^3: Powell at Glenview Rd 0.002, Powell at Reilly Br 0.006, Berkett u-s Powell 0.005, McConnon u-s Powell 0.007).

Filamentous green algae cover in the lower Powell is often over 30% in summer.

A **wetland was constructed** and fenced over the period of a few years from 2009 in the upper part of this catchment.

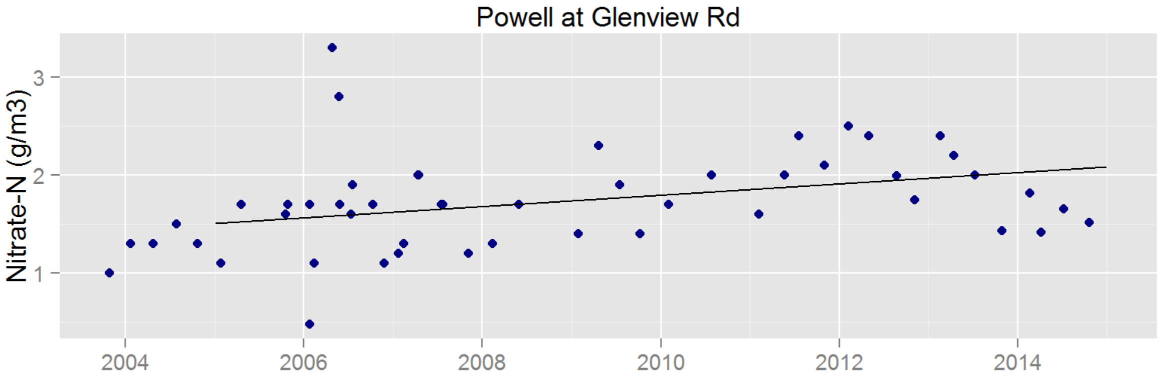


Figure 102. Powell at Glenview Rd Nitrate-N concentration data with 10-year trend line (p = 0.013, RSKSE = 3.4% per year).

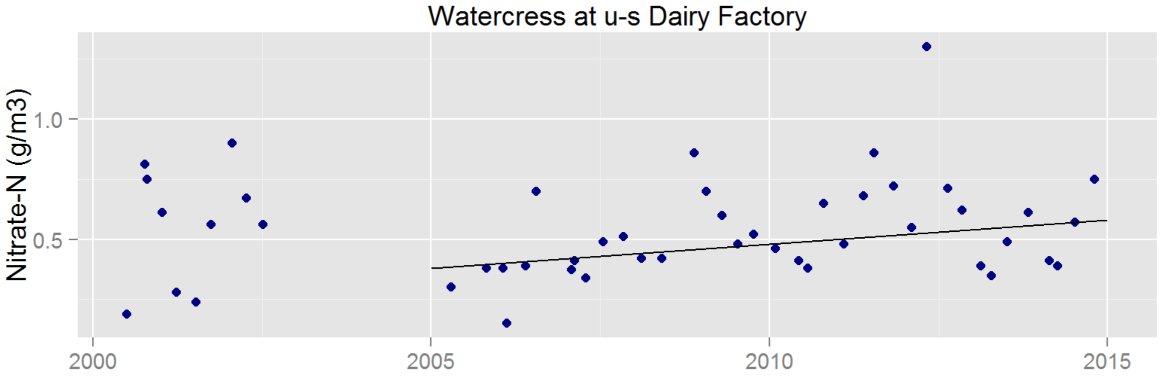


Figure 103. Watercress at u-s Dairy Factory Nitrate-N concentration data with 10-year trend line (p = 0.013, RSKSE = 4.1% per year). There was no significant meaningful trend over the full record (15 years).

If there is sufficient light algae can grow to nuisance levels it has sufficient quantities of both nitrogen and phosphorus in soluble form, as well as stable flows and warmer water temperatures. **Filamentous green algae** cover exceeded nuisance levels (30%) for about 20% of the records for Motupipi at Reilly Br and 25% of records for Powell at Reilly Br (spring-autumn records only; no excessive algal growth has been observed in winter). It appears that the level of cover is decreasing, maybe in relation to the decrease in dissolved reactive phosphorus.

Above: *Cryptomonas* algae bloom in the lower Motupipi. Left: April 2007; Right: February 2014

The concentrations of **faecal indicator bacteria** in smaller tributaries (Berkett, McConnon and Powell) are amongst the highest in the District at low flows. Over the 2006-07 period the stream water was unsuitable for stock drinking for just under half the time (James 2008, reported under the Dairying and Clean Streams Accord Tier II monitoring programme). In the base flows of May 2011 the source faecal bacteria in the lower catchment were identified as being from ruminants (such as cows and goats) and wildfowl, without any trace of human genetic material. At Watercress Creek the source was only ruminant. It is disappointing that there has not been a significant improvement in faecal indicator bacteria in Powell or Motupipi Rivers given the amount of fencing in the catchment. However, some large areas have only recently been fenced and some are still to be fenced. It may be that the thick sediment deposits known to occupy the bed of these waterways is a significant reservoir of these disease-causing organisms and the stability of the sediments due to aquatic plants rooted in the bed means that they do not get flushed out.

During each of two flood events in August 2010 lower Powell Creek and Motupipi at Reilly Bridge were estimated to discharge 10^{11}-10^{13} *E. coli* /100 ml. This combined load is high for a small catchment, considering that the Aorere River was estimated to discharge 10^{16} *E. coli* /100 ml over a whole year and over a much bigger catchment. In 2008 the tributary Berkett Creek, consistently had the highest concentrations of faecal bacteria. It would be interesting to resample this creek following fencing in 2009.

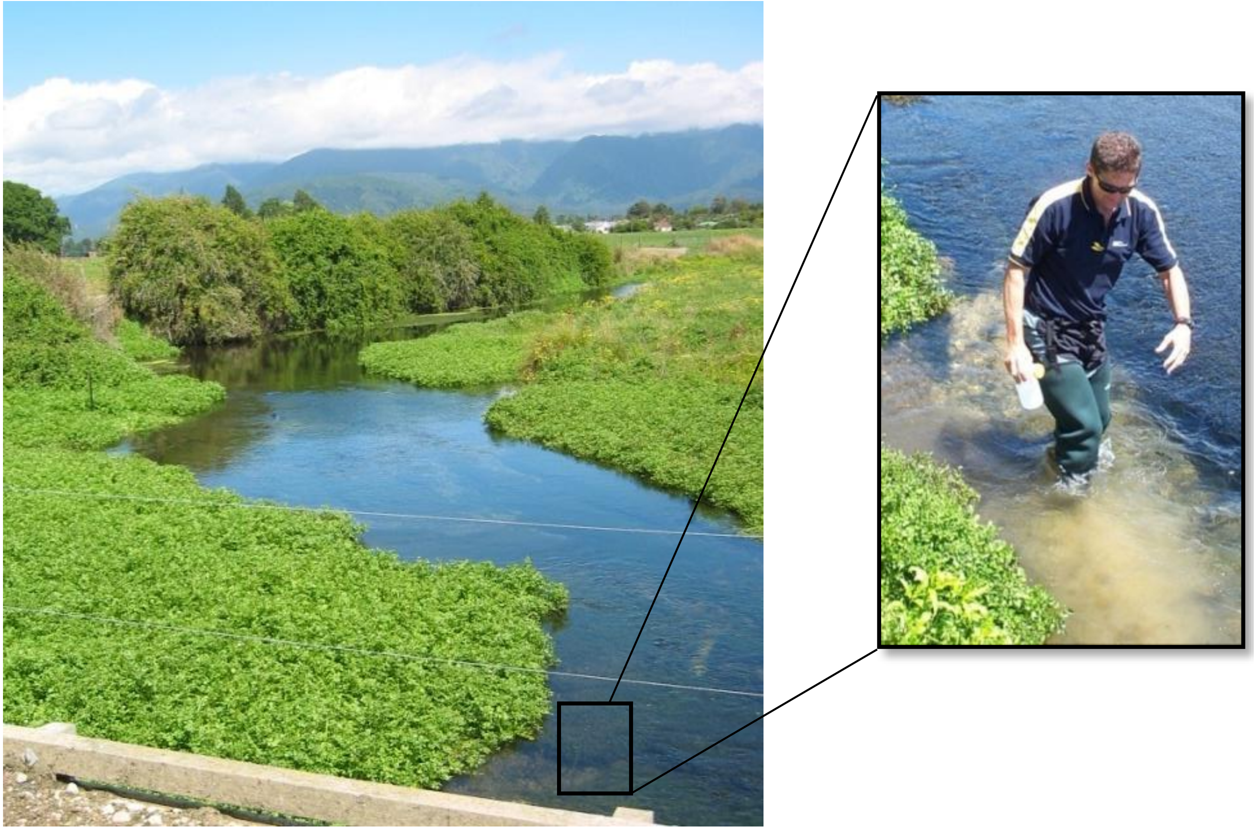
Summer-time **dissolved oxygen levels are very low** in the lower and upper reaches of the Motupipi River (daily minima averaging 45-50% but going as low as 35% saturation at times) (Figure 107) at the Motupipi Water Quality Monitoring Station. This does not appear to have changed (Figure 109). Aquatic plant growth rates and oxygen uptake rates are much higher than many other streams draining intensive agriculture in New Zealand and internationally (Young 2006). Daily minimum dissolved oxygen does not correlate well with flow (r^2=0.0396), so flow is not the main driver of dissolved oxygen in this river (Allen and Young 2012). The seasonal increase in respiration caused by the increased biomass of aquatic macrophytes during summer often has a strong influence on dissolved oxygen in spring-fed streams. This is likely to be the case in the Motupipi River, as ecological monitoring in the upper reach (approximately 1.3 km upstream from the affected reach) has shown that the median summer coverage of macrophytes was 80%. Reduced flow in the river has the potential to reduce dissolved oxygen concentrations. The environmental effects of removing 51 L/s from groundwater from a point about 50 m from the stream upstream of Reilly Bridge (began in 2014) was predicted to have minimal effect on water level, habitat availability and water quality, especially in reaches dominated by macrophyte beds (Allen and Young 2012). Monitoring data before and after confirms that this take is not having an effect. However, there will be a point at which flow reductions will affect dissolved oxygen levels.

Water clarity in the Motupipi River is moderately high (median 5.45 m, 95th percentile 9.8 m) but expected to be higher given that the source is mostly alluvial spring water. Water clarity appears to have changed little from 2000 to 2015. Median water clarity was low at the bottom of Powell Catchment (1.6 m), but was even lower in Berkett Creek (1.2 m).

Fine sediment deposits in this stream are relatively thick, with an average of 200-300 mm over the original cobble bed and a layer over 1.2 m thick for a 450 m reach downstream of Powell Creek. Aquatic plants in the stream cause the build up of large amounts of fine sediment both by increasing the retention and settling of sediment washed into the stream and from dead plant matter. Shading the stream using riparian trees is recommended as the best method to manage this issue. While this is of concern in the shallow areas of the waterway, it must be expected that sediment will build up naturally in the deeper pools as these were created when this river was part of the Takaka River about 200-300 years ago when stream power and velocities would have been much greater. As velocities are now much lower, these pools are unlikely to be flushed unless the river returns through this previous course. Sediment sampling in this drain was also above guidelines for zinc and chromium indicating that runoff from roads is entering the drain.

Sediment in a stormwater drain near Orange Engineering on the edge of the Takaka township was found to be contaminated with **high concentrations of copper, chromium, and zinc** (all over an order of magnitude higher than ANZECC guidelines for 90% level of protection (ANZECC & ARMCANZ 2000)).

Macroinvertebrate condition was mostly **poor or very poor in the lower parts of this catchment, including lower Powell Creek**, except for upper Powell Creek, which was good in 2004 but has declined since. The excessive levels of fine sediment and elevated nitrate (median 1.5 g/m^3) are probably the reason for this. Powell Creek at Glenview Rd showed a decline in most macroinvertebrate indices (MCI, % mayflies, stoneflies and caddisflies) which seems to coincide with the removal of a peat bog wetland upstream of this site in September 2008 and a change to cropping maize.



Motupipi Rv at Reilly's Bridge (January 2006, left and November 2004, right).

The ecological health of the upper and mid-western arms of the Motupipi estuary are impaired by high nitrate and sediment from the Motupipi River (Robertson and Stevens 2008). Shellfish collected in these areas are likely to be unsafe to eat most of the time due to the level of disease-causing organisms. The health of the eastern arm of the estuary is generally good.

Due to the high percentage of intensive farming in this catchment (almost 40% of the land area) water quality guidelines will always be difficult to meet, although **considerable improvement is expected** through implementing better environmental practice. Despite some best management practices being employed on several farms, there is still a lot more that could be done to benefit water quality of the stream. An effective method is the **installation of wetlands in key locations** to filter run-off and seepage from the land.

Another factor affecting the state of water quality in the Motupipi River is the **lower frequency of overflows of floodwater** from the Takaka River into the Motupipi compared to 10-20 years ago, most probably due to lower bed levels in the Takaka River. Takaka River currently overflows into the Motupipi at about 1400 m^3/sec, providing flushing of fine sediment deposits and aquatic plants and algae. Anecdotal evidence suggests that the overflow from the Takaka River in 2008 (24 November) resulted in reduced algal blooms for the two years following (reports from whitebaiters). The **lack of flushing flows, over recent years, leads to greater levels of fine sediment** in the bed and more prolific aquatic plant growth. Controlled release of Takaka floodwaters to the Motupipi River through automatically controlled gates could produce a significant gain for water quality and aquatic ecology.

Above: Overflow from the Takaka River to the Motupipi during a flood in November 2008.

Table 19. Summary statistics for sites in the Motupipi catchment.
Note: Flow statistics for the Motupipi River from continuous measurements (November 2006 to May 2015).

	Motupipi (includes Powell Ck)	**Powell Creek**
River Environment Class	Warm Wet Alluvial Spring-fed - alluvial	Warm Wet Soft sedimentary Lowland-fed (spring-fed upstream Glenview Rd)
Catchment area (km²)⁺	2856 (based on mouth at Rototai)	560
Predominant land use upstream	Dairy 36% (over 200 cows)	Dairy 56.6% Sheep and beef ~30%
Mean annual rainfall (mm)	1840	1500
Mean annual flow (l/sec)	466	-
Median flow (l/sec)	385	-
Mean annual low flow (MALF) (l/sec)	210 approx	-
Lowest recorded flow	126	
Water quality record	Quarterly: 2000-present Continuous dissolved oxygen, conductivity, temperature, rainfall and flow from 2007-present (dissolved oxygen Dec-Mar only from 2014).	2005-present

MOTUPIPI RIVER WATER QUALITY MONITORING STATION

To be able to continuously monitor water quality in the Motupipi River, Council installed a permanent monitoring station at the Motupipi at Reilly's Bridge site in December 2006. This station records dissolved oxygen saturation, conductivity, temperature, air temperature, flow, turbidity, and rainfall at 15-minute intervals, thus providing useful continuous water quality data over the three years and ten months of operation. This monitoring station was set up because of the very poor water quality and in conjunction with dairy industry clean streams monitoring programme. Data for 2010-2015 is available but not shown as it is almost identical to the pattern shown in the early period of the data..

Between December 2006 and August 2010, **temperature** records showed clear seasonal patterns, with warmer temperatures in summer and cooler ones in winter (Figure 105A). The highest temperature halfway between the daily mean and maximum recorded was 18.8 °C (15/01/2008) and the lowest 10.25 °C (06/07/08) with an average of 13.85 °C. Therefore, the site never exceeded the recommended guidelines for aquatic ecosystem protection of 20°C.

Turbidity analyses showed that recommended guidelines for contact recreation (i.e. 5.6 NTU) were only exceeded for 2.5 % of the time, with the majority of the records (97.5%) being between 1 and 5 NTU (Figure 104). The lowest daily average turbidity recorded was 0.11 NTU (12/08/2010) and the highest 36.5 NTU (23/07/2009). **Time trend analyses** showed a statistically (P=0.02) and ecologically significant (RSKSE = -13.82%) **decrease in turbidity** at the site over the monitoring period (Figure 105B). Average monthly turbidity was highest in July and November 2008, following major floods and lowest in September 2010 (Figure 105B).

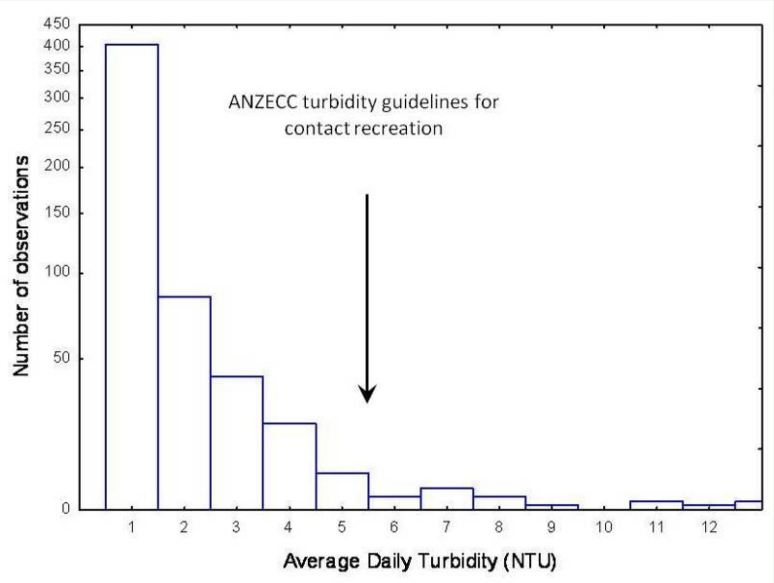


Figure 104.Frequency of average daily turbidity recorded between December 2006 and August 2010. Note: The X-axis is on a log scale.

Flow ranged from 0.2 m^3/sec (26/04/2007) to 7.2 m^3/sec (24/11/08) with an average of 0.45 m^3/sec (Figure 105). Turbidity was positively correlated with flow (Figure 106), although the

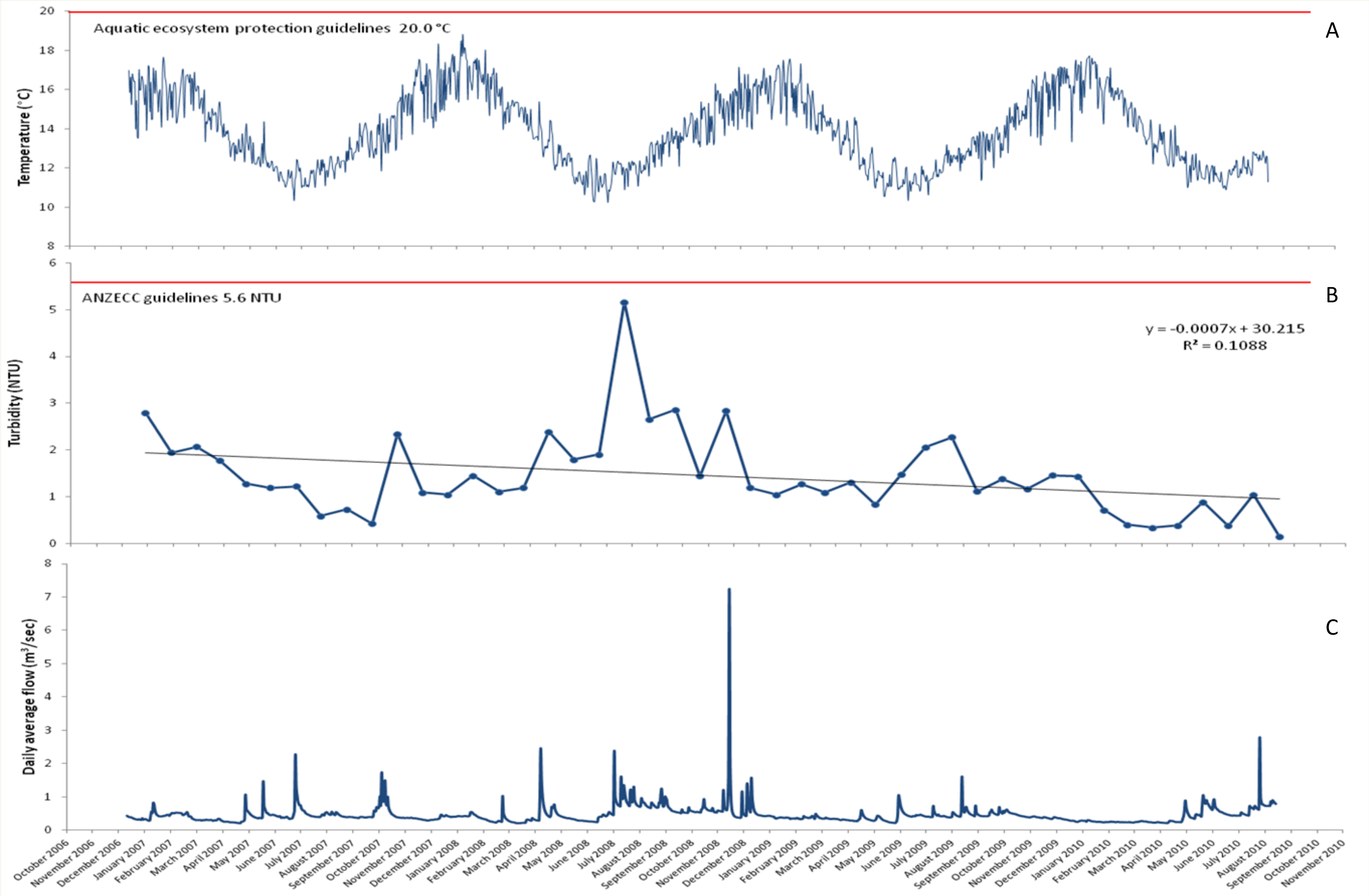


Figure 105. A) Average daily temperature records halfway between the daily mean and daily maximum, B) monthly average turbidity and C) daily average flow recorded between December 2006 and August 2010 at Motupipi at Reilly's Bridge.

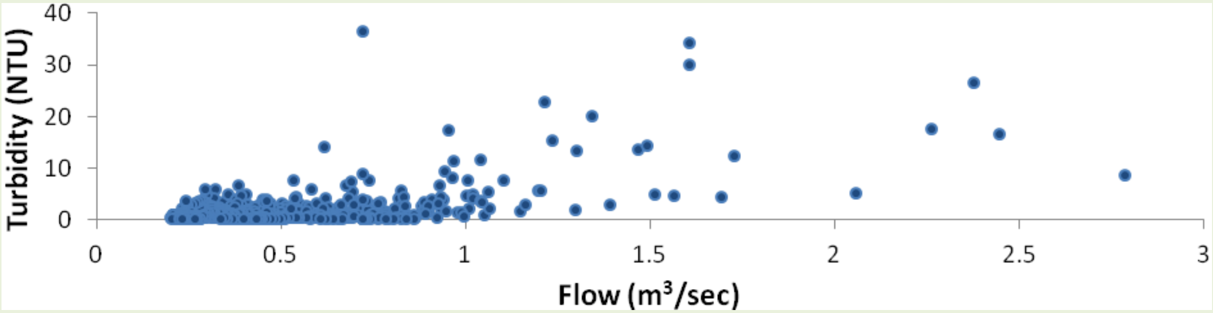


Figure 106. Relationship between average daily turbidity and average daily flow in the Motupipi River at Reilly's Bridge.

Dissolved oxygen saturation records showed characteristic annual patter**ns (Figure 107**). DO saturation ranged from a minimum of 36% (02/03/2008) to a maximum of 168% (19/09/2007) with an average of 90.9% between December 2006 and August 2010. Daily fluctuations in DO saturation were greatest in summer and smallest in winter (Figure 107). Similar patterns were observed between 2010 and 2014. DO is fundamental to the survival of aquatic life, and the 1992 ANZECC guidelines recommended that DO should not normally be permitted to fall below concentrations of 6 g/m3 or 80-90% saturation (ANZECC 1992). Daily minimum dissolved oxygen saturations were below 60% saturation for 12% of the sampling period, indicating substantial concerns with low dissolved oxygen levels for most of the time that may be affecting aquatic life.

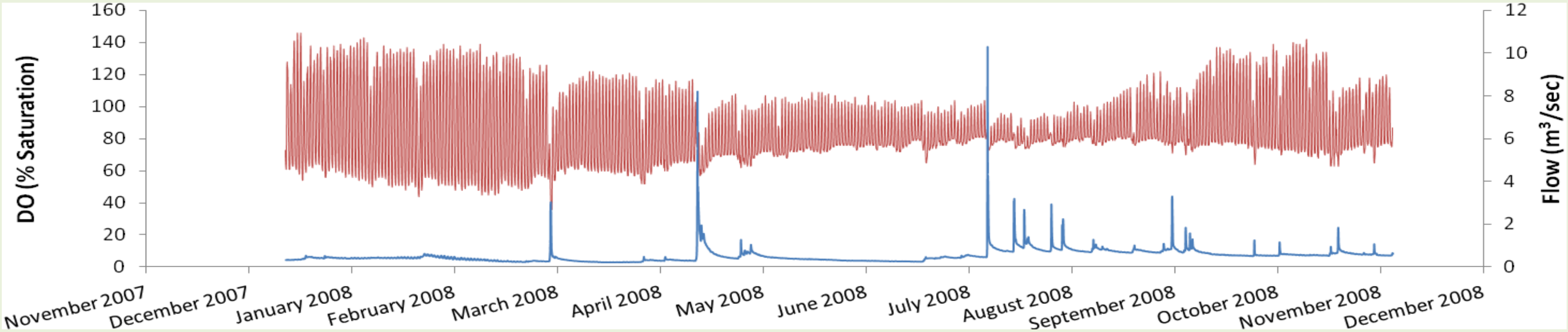


Figure 107. Daily dissolved oxygen and daily flow patterns over a one-year period from December 2007 to November 2008 at Motupipi at Reilly's Bridge.

Ecosystem metabolism was successfully calculated for a five-day period for each season during the earlier sampling period (i.e. 15 seasons between December 2006 and August 2010) (Figure 108). Daily ecosystem respiration (ER) rates ranged from 4.2 $gO_2/m^2/day$ (winter 2010, 25/08/2010) to 19.2 $gO_2/m^2/day$ (summer 2008, 24/02/2008) with an average of 11.8 $gO_2/m^2/day$, reflecting generally poor ecosystem health. Daily gross primary production (GPP) rates ranged from 2.2 $gO_2/m^2/day$ (25/08/2010, winter 2010) to 15.6 $gO_2/m^2/day$ (summer 2009, 25/02/2010), with an average of 7.9 $gO_2/m^2/day$ (Figure)), reflecting satisfactory to poor ecosystem health.

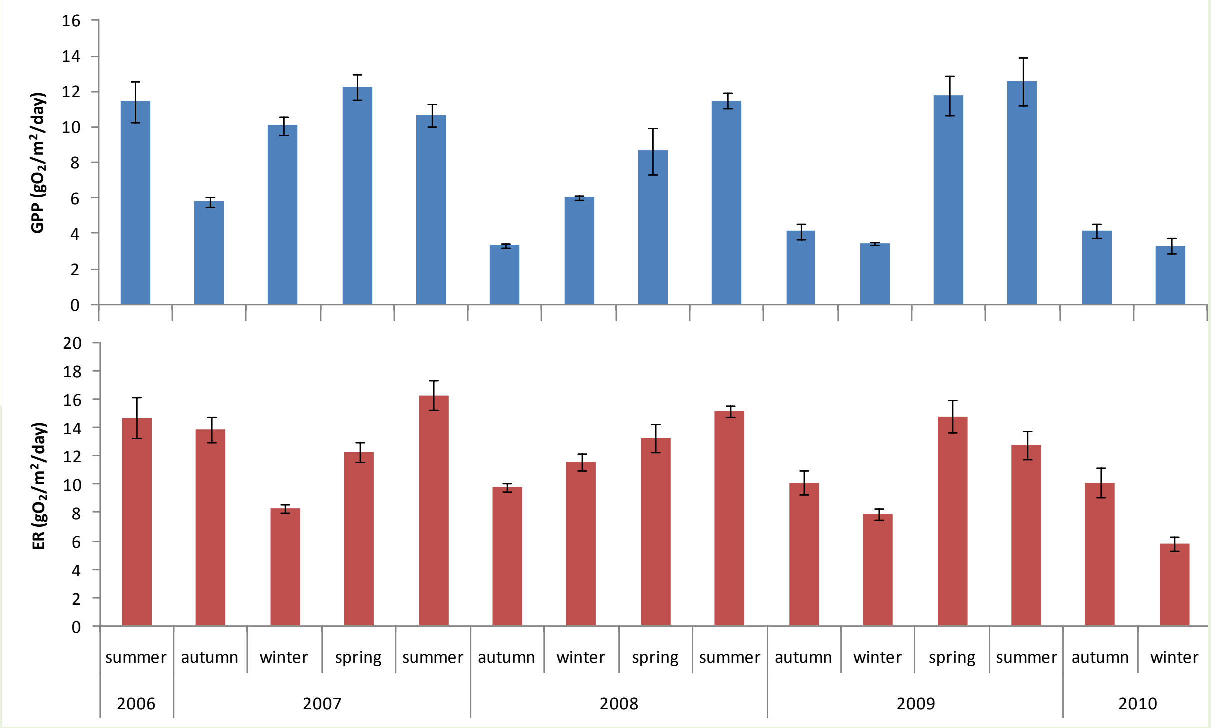


Figure 108. Average seasonal ecosystem respiration (ER) and gross primary production (GPP) rates between December 2006 and August 2010; Note: seasons were categorised as summer = December, January, February; autumn = March, April, May; winter = June, July, August; spring = September, October, November.

Below is a graph of dissolved oxygen over a typical period in summer which has changed little from the decade previous (Figure 109).

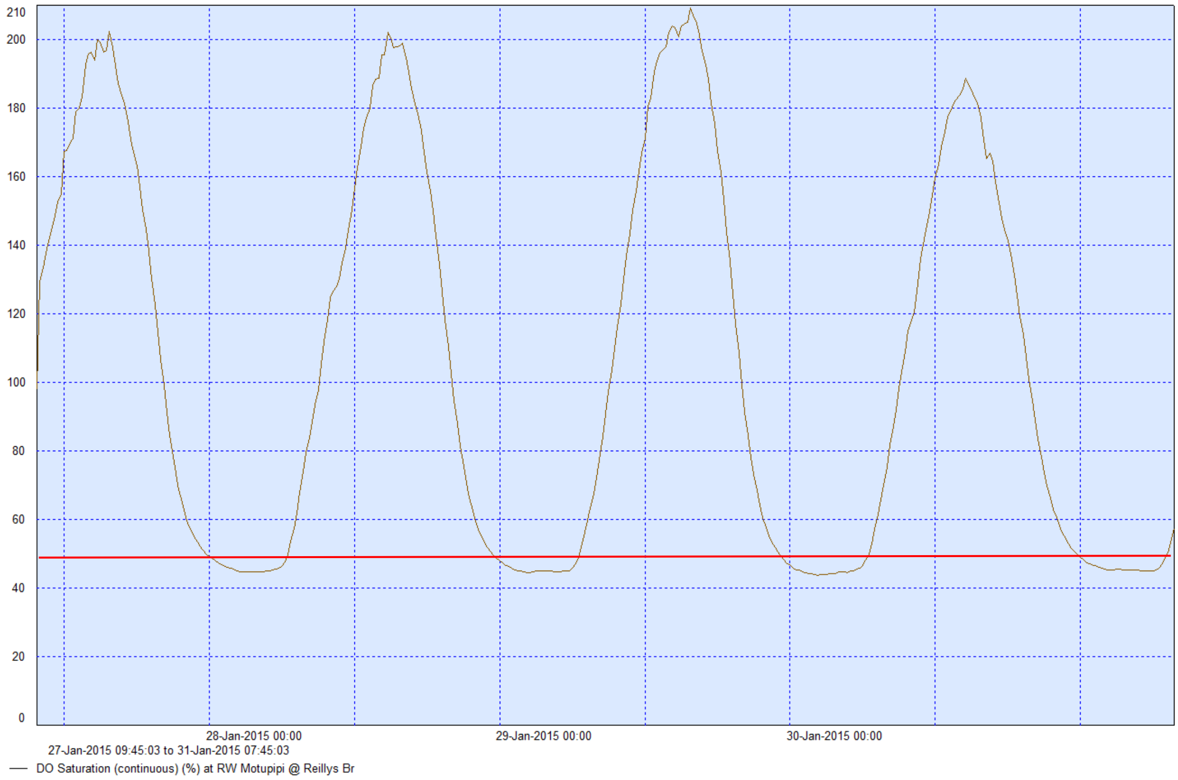


Figure 109. A representative sample of continuous dissolved oxygen saturation data for Motupipi at Reilly Bridge (27-31 January, 2015). Note how similar the patterns are to the earlier part of the record. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

There has been reasonable effort to try and improve the water quality of this river and its tributaries. These include:

- Most streams in the catchment were fenced off from stock progressively between 2000 and 2007 with Berkett Creek being fenced in 2009 and Powell Creek from Glenview Rd to 1.7km downstream Glenview Rd fenced in 2014.
- Much lower loading of nutrients from the Fonterra dairy factory discharge to land and water after June 2005.
- Golden Bay Streamcare Group planted 12,000 plants in riparian zones in this catchment between 2006 and 2014.

Despite these good efforts at this stage the only improving trend is for dissolved reactive phosphorus. Within the next decade it is expected that there will be reduced growth of filamentous green algae in the areas where the plantings have occurred.

Te Kakau Stream, near Takaka

Te Kakau Stream is spring fed and flows along the western edge of Takaka township. The invasive and prolific waterweed *Lagarosiphon major* was accidentally released into the waterway in a flood during the 1960's. To date water quality sampling has only been carried out at this site over the period from 2005-07.

Te Kakau Stm downstream Rose Rd, January 2006

Summer-time minimum **dissolved oxygen levels** were (3-10 February 2006) were found to be **extremely low** (40% saturation for the middle reaches of Te Kakau Stream, as shown in Figure 110, and 0% saturation for the lower reaches of Te Kakau Stream, as shown in Figure 111). Aquatic plant growth rates at the Feary Crescent site are over double the rates for the median for streams draining intensive agriculture in New Zealand and internationally (Young 2006).

Figure 110 Continuous dissolved oxygen saturation data for Te Kakau Stream at Feary Cres (3-12 February, 2006). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

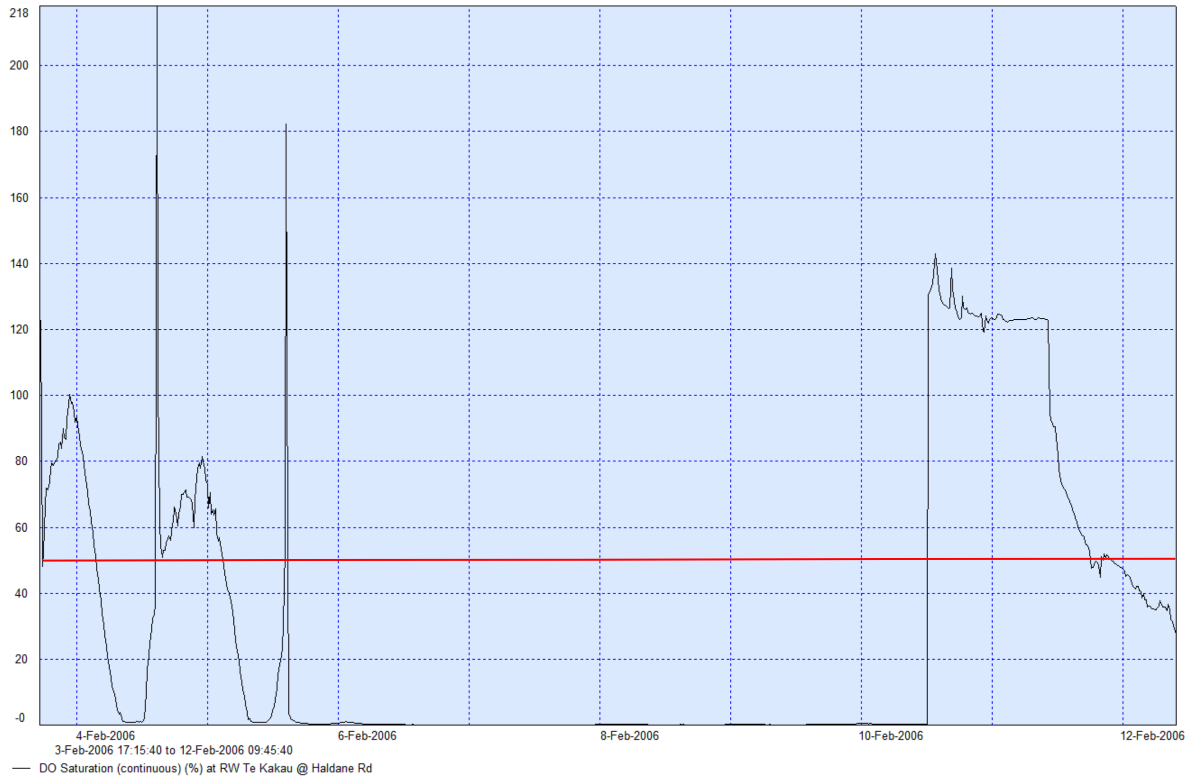


Figure 111 Continuous dissolved oxygen saturation data for Te Kakau Stream at Haldane Rd (3-12 February, 2006). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Oxygen uptake rates at the Feary Crescent site are among the highest recorded previously. The vigorous growth of the aquatic weed, *Lagarosiphon major* (an oxygen weed), is a major reason for this condition. Of all the methods considered to solve this problem, shading of this stream with overhanging evergreen trees is the most effective and low-cost (James and Clayton 2007). The benefits to fish and invertebrate habitat by using this method are significant and much greater than other methods. Despite riparian planting in all the Council reserve land and some private properties, the offer to have trees planted along the waterway has not been taken up by the majority of landowners with land adjacent to the waterway. The low dissolved oxygen is likely to be little changed from 2007 as the amount of shading of the water needs to increase from the current level of about 20% of the waterway, to >70% to have a reasonable impact.

Fine sediment deposits in this stream are a problem, with an average of 200-300 mm over the original cobble bed. More care needs to be taken right across the district to avoid sediment discharges to spring-fed creeks as they do not get flushed out in floods like hill or mountain-fed rivers.

Like the Motupipi, this waterway would also gain considerably from increased flushing flows from the Takaka River, as happened in the past.

A management plan was drafted in 2004 that aims to facilitate increased public use and enjoyment of the stream environment through a combination of actions, including revegetation, rubbish removal and prevention, minimisation of contaminant run-off, and weed control.

The local community has participated in the management plan process and on-the-ground work. Trials of different methods of aquatic weed control were trialled in 2007-08. While two layers of weed mat was shown to be very effective, the cheapest effective method is shading by streamside plantings. Council reserve land adjacent to the waterway has been largely planted (see photo from 2010 below) as well as several properties. Council has offered native trees for planting along the stream.

Te Kakau Stm at Haldane Rd looking upstream(Top left: October 2005, Top right: September 2005, Bottom Left: July 2010, bottom right: May 2012).

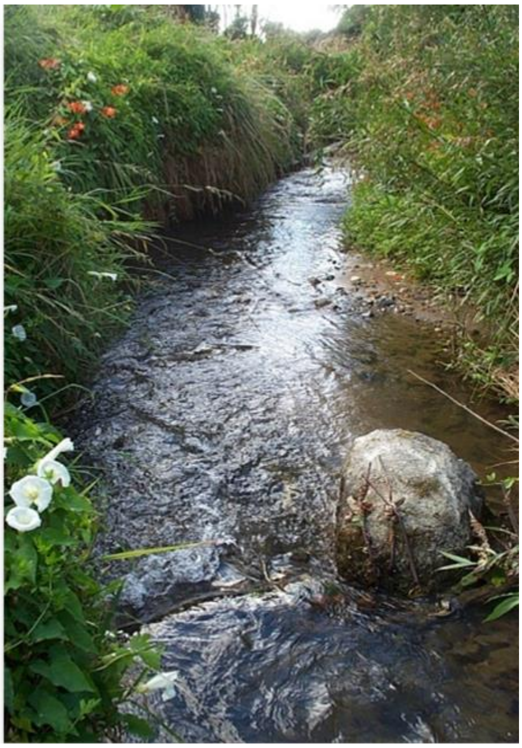
There used to be other spring-fed streams in the Takaka delta. Wigo and Mason Creeks used to flow prior to about 1990, but are now dry and grassed over. These creeks lie to the east of SH60 at the north end of Takaka township and originated from about 2km south-east of the Takaka River. . The reason for this reduced level may be the lower bed level of the Takaka River particularly in the area between south end of Reilly St and 500 m downstream of the Kotinga Bridge. There does appear to be a decline of about 200-300 mm at the Council monitoring bore that would support this theory.

Small coastal streams of Golden Bay

Winter Creek, Pohara

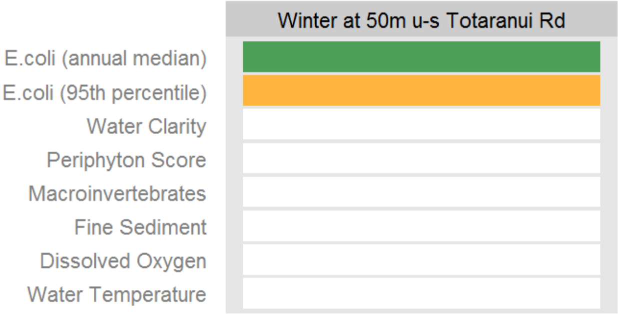
This creek flows out onto Pohara Beach at its eastern end, and so can potentially affect water quality at this beach.

Winter Creek has generally low to moderate levels of faecal indicator bacteria at base flows (median for 2010-15: 97 *E.coli*/100 ml; compared to median for 2000-2010 of 197 *E.coli*/100 ml), and only about 2% of samples are over the guidelines for stock drinking. While the stream itself is not deep enough to swim in, it flows into a partly enclosed area of a very popular beach.



Winter Ck at 500 m upstream Abel Tasman Drive (February 2005).

Conductivity is very high (700-800 µS/cm) in a tributary running out of a limestone cave that joins Winter Creek about 220 m upstream of Abel Tasman Drive, potentially explaining the low macroinvertebrate indices scores. Aluminium and iron concentrations in sediment in this tributary are elevated (10,900 and 33,400 mg/kg dry weight respectively. No other heavy metals were detected. Neither were any hydrocarbons (including poly-aromatic hydrocarbons), volatile organic compounds or semi-volatile organic compounds, or phenols. ketones. This sampling was carried out after allegations that there may be leachate from materials on the former Golden Bay Cement Works site causing the high conductivity.



	Winter at 50m u-s Totaranui Rd
E.coli (annual median)	🟩
E.coli (95th percentile)	🟧
Water Clarity	
Periphyton Score	
Macroinvertebrates	
Fine Sediment	
Dissolved Oxygen	
Water Temperature	

Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

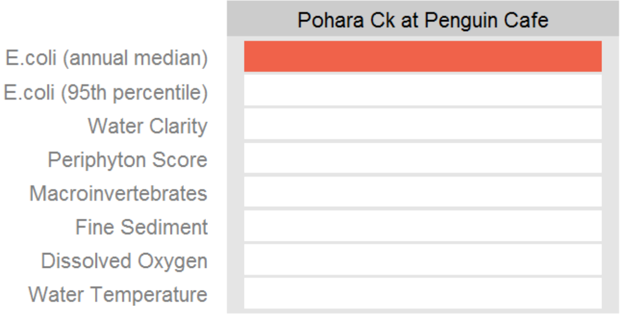
A one-off macroinvertebrate sample (in 2008) showed water quality for Winter Creek was satisfactory to poor (MCI 101, SQMCI 4.1).

In December 2011 the largest ever recorded 48-hour rainfall event in an urban area in New Zealand was recorded in the Pohara-Takaka area (674 mm, when the average rainfall for all of December is 207 mm). This caused wide-scale land slips and heavy silt and sand deposits to the creek and surrounding land. While water quality seems to be little affected, the fish and invertebrate communities are likely to only now be recovering to a state approaching that of prior to this disturbance.

Pohara Creek, Pohara

This small stream also flows out onto Pohara Beach and, being adjacent to a very popular campground (Pohara Beach Holiday Park), it is popular for young children to play in. Land use in the catchment is dominated by sheep and beef farming and residential housing. There are several sink holes and tomos in the limestone that extends for about 500 m upstream from the coast. After a survey in 2009-10 Pohara Beach was found to be one of the most popular in Tasman.

Above: Pohara Beach view ENE (February 2011)



	Pohara Ck at Penguin Cafe
E.coli (annual median)	🟥
E.coli (95th percentile)	
Water Clarity	
Periphyton Score	
Macroinvertebrates	
Fine Sediment	
Dissolved Oxygen	
Water Temperature	

Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

Since records began in 2003 faecal indicator bacteria concentrations at Pohara Beach over summer have exceeded guidelines about 10% of the whole record (234 samples) and occasionally well over the alarm level. Pohara Creek was confirmed as a potential source of this contamination in 2005-06 and a sanitary survey (intensive investigation to try to find the source(s)) was undertaken over the 2006-07 summer. A significant faecal discharge was discovered and the household’s sewerage system was repaired to ensure it connected with the municipal system. After this faecal indicator bacteria results improved for a while, with only 4% of samples exceeding in the period from 2007-2010, but then results worsened again over the last three years (Figure 112). Almost 13% of samples exceeded and the magnitude of the exceedences has increased with many more samples over 1000 *Enterococci*/100 ml. The sampling frequency at Pohara Beach was increased to 20 samples per year in every year (as recommended in the guidelines for a popular site with higher risk) in 2010-11. This precipitated another sanitary survey of the creek in 2014-15 to again attempting to determine the source.

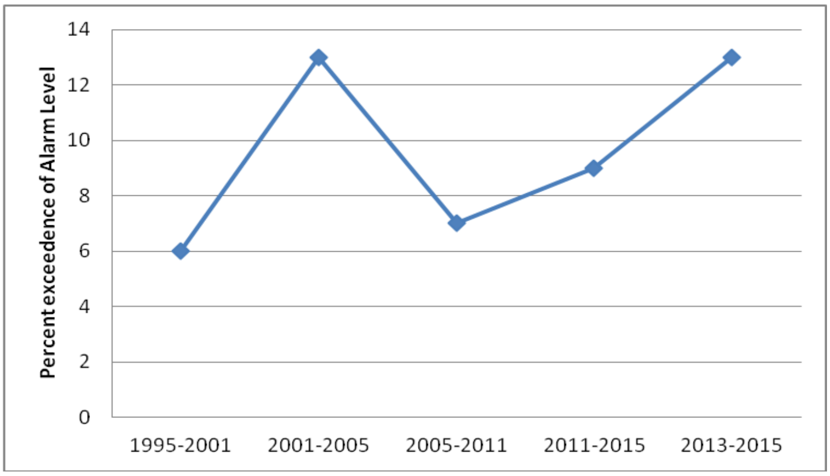


Figure 112. Rate of exceedence of alarm levels at Pohara Beach (Camp East site)

Results of microbial source tracking on 2 February 2015 were inconclusive showing only a weak possum signal and that the source was not bovine, human, dog, sheep, wildfowl, or gull. This is the only such analysis performed to date, but further work will be carried out this coming season.

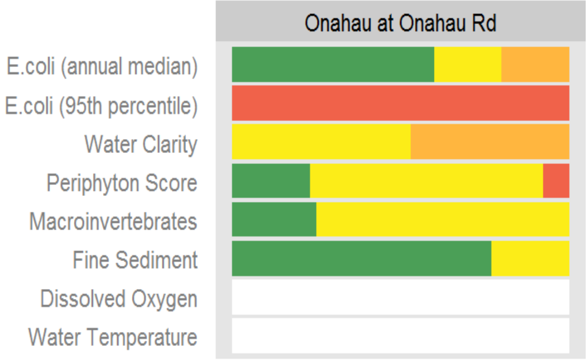
Faecal indicator bacteria (*E.coli* and *Enterococci*) have recently been found to survive in the New Zealand environment outside of the gut of a warm-blooded animal (Devane, 2015). Even more recently it has been found that overseas these bacteria don’t just survive in the environment, but can reproduce and support reasonable numbers. These ‘naturalised’ bacteria are not usually disease-causing and so the faecal indicator bacteria data from these sites may not be useful in managing a public health risk. It has been found overseas that the particular environments they prefer are those with a lot of fine sand, mud, and algal accumulations. These environments are relatively common at Pohara Creek and beach. There are a few of these situations arising around New Zealand and research will be needed to determine if such a ‘naturalised’ faecal indicator bacteria population exists at Pohara.

Pohara Ck upstream Abel Tasman Drive (behind the Penguin Cafe) viewed downstream (January 2007).

Onahau River, Puremahia

Onahau River at Onahau Rd (January 2005).

About 95% of the 710 Ha catchment upstream of Onahau Road is in native forest with the remaining land use on the flat land in dairy farming. The waterway is incised (cut down through the land with steep banks). Because there is limited mixing of water from this creek with the sea at the mouth, and that since swimming (primary contact recreation) occurs at the mouth, this creek was assessed against contact recreation guidelines. Very good habitat for fish and invertebrates exists in this creek and being close to the coast it is expected to hold high numbers and high diversity of fish.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

When monitoring began at this site in 2005 it was evident that water quality was poor in this stream, with high concentrations of faecal indicator bacteria. The average has now halved (median for 2010-15: 250 *E.coli*/100 ml, median for 2005-2009: 500 *E.coli*/100 ml). However, the higher peaks are similar (for 2010-15 and 2005-09 respectively there were 15% and 13% of samples over 1000 *E.coli*/100 ml), high cover of filamentous green algae and poor macroinvertebrate condition. Council received complaints about dairy effluent solids on the beach east of the stream mouth. The effluent treatment systems of the two farms upstream of Onahau Rd were substantially upgraded and a regular stock crossing was bridged in 2010 following court action.

Puremahia Stream, near Paton Rock

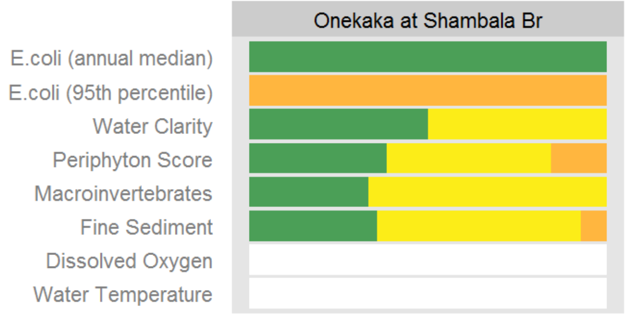
The upper ~20% of this catchment is in native forest, with the remainder in pasture, which is mostly dairy farmland. This stream was found to have high levels of faecal indicator bacteria in two sampling campaigns in 2005 and 2009 (median *E. coli:* 2001/100 ml). Most of the contamination appears to be coming from dairy farmland, both above and below SH60. Since 2005, over 1 km of this waterway has been fenced off upstream of SH60 to exclude stock. This stream is used for contact recreation in the lower reaches.

**Puremahia Rv at 500 m downstream bush line (February 2005, left)
and 50 m upstream Battery Rd (right).**

Onekaka River

This stream has **outstanding native fish values** with the highest species richness for a particular reach known in the district, (one 300 m reach had 12 native fish species plus trout). Most fish species were also abundant. Prolific inanga spawning has been found to occur at a site about 600 m downstream of Shambala Rd. A hydro-electric power scheme operates in the catchment with a 10.7 m high dam (built in 1928) about 4km upstream of the monitoring site at Shambala Road.

Above left: Onekaka Estuary looking to the catchment upstream (June 2010). Above right: Inanga spawning sites on the lower Onekaka River (March 2013).



Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

The lower section of this river has **moderate concentrations of faecal indicator bacteria** (Median at low flows: 172 *E. coli* /100 ml; ~8% of samples over alarm levels for contact recreation and ~7% over the secondary contact national bottom line). Median *E. coli* loadings in the lower reaches are 100 times higher than the upper reaches (Median low flow load at Shambala: 10^5 *E.coli*/sec). No investigations have been undertaken to date to determine the cause of this issue, which could be dairy farming, or septic tank discharges, or both.

Moderate levels of fine sediments deposited in the bed matrix are found in the lower reaches. Prior to 2005 sediment was dug out and discharged downstream of the dam at low flows resulting in heavy load of fine sediment in the stream bed. This practice is now not permitted under condition of resource consent.

On average, **water clarity is halved in the 2km below Ironstone Creek** (median: 10 m to 5 m; u-s Ironstone to Shambala) (Figure 113). The reasons for this are unclear. It may be the geology, inputs from farmland and roads, or tannins from wetlands or particular forest type.

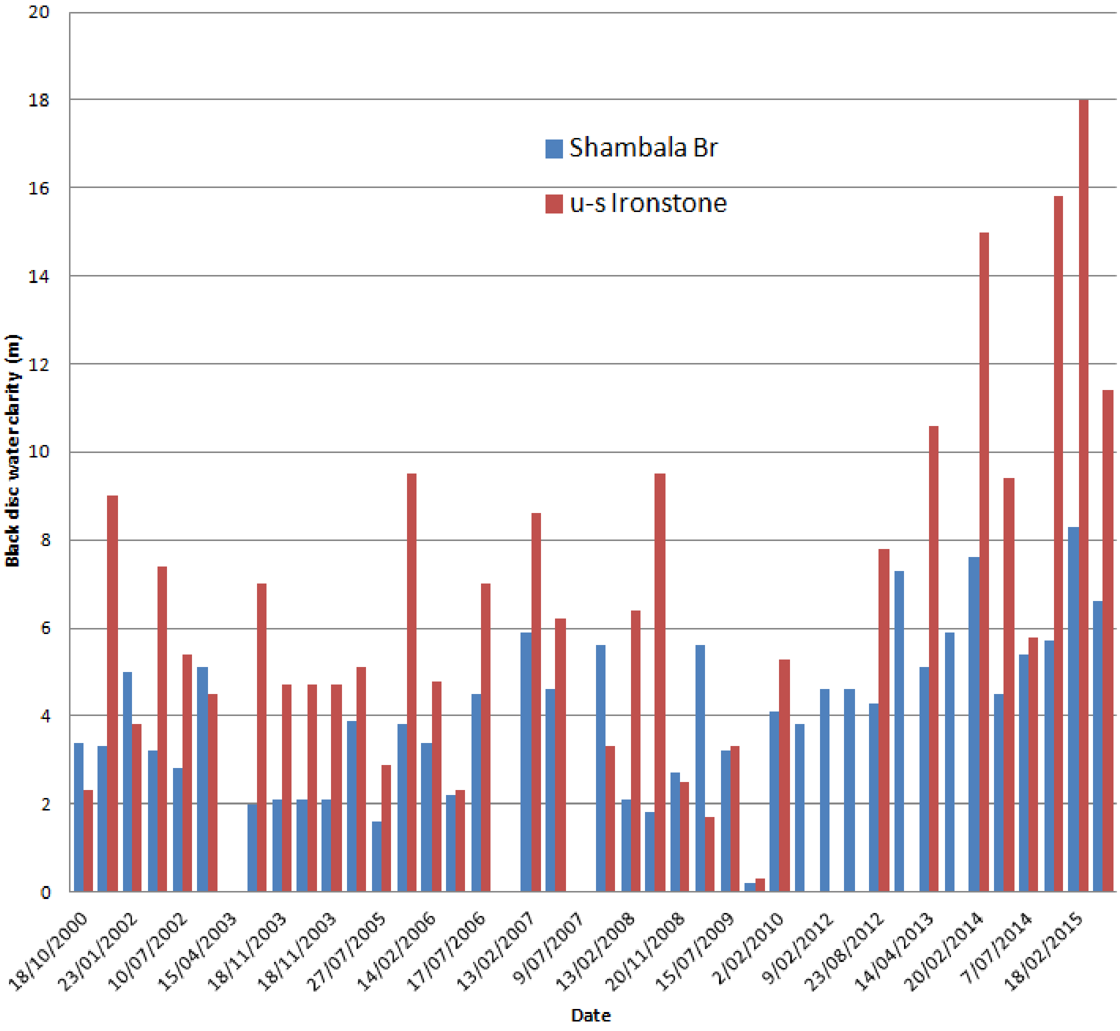


Figure 113. Comparison of water clarity in the Onekaka River between the upstream site (upstream Ironstone Creek) and the downstream site (Shambala).

Above: Electric Waters Dam on the Onekaka River (January 2009)

Onekaka River at the lower site at Shambala ford, November, 2004 (top left) and at the upstream site at Ironstone Ck January 2002 (bottom left), typical sediment plume from kicking in the stream bed at Shambala Rd, November, 2004 (right).

Table 20. Summary statistics for sites in the Onekaka catchment.

	Onekaka u-s Ironstone Ck	Onekaka at Shambala
River Environment Class	Cool Extremely Wet Hard sedimentary Hill-fed Indigenous forest	Cool Extremely Wet Hard sedimentary Lowland-fed Pasture
Catchment area (km^2)	2.3	16
Predominant land use upstream		680 ha (43%) in indigenous forest 800 ha (50%) in dairy farming
Mean annual rainfall (mm)	2,200 est	
Mean flow (l/sec)	345	627*
Median flow (l/sec)	80.6	
7-day Mean Annual Low Flow (l/sec)	44	
Lowest recorded flow	12	112 (Apr 2001)
Water quality record	2000-present	2000-present

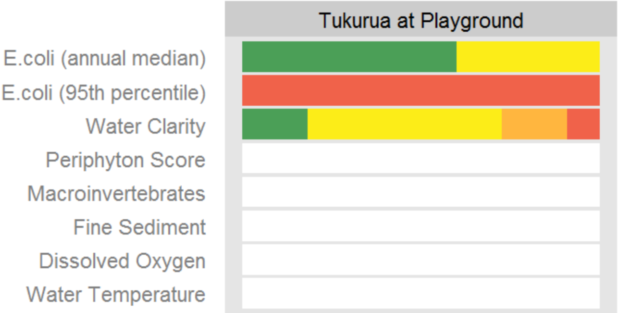
* Estimate from WRENZ 2013. NA = not available

Tukurua Stream


Tukurua Stream approximately 1.5km upstream SH60 (July 2010)

About 85% of the 5.2 km^2 catchment of this hill-fed stream is in native forest with the remainder being a dairy run-off block (0.4km^2), and rural-residential blocks and a campground in the lower catchment (0.4km^2). A pool in the stream near the mouth (adjacent to Golden Bay Holiday Park) is popular for swimming when the tide is half out. Like many small-medium sized streams that drain direct to the coast there is high fish diversity. Importantly the abundance of fish in the stream is also high, particularly for torrentfish.

Monitoring in this stream began in 2010 and concentrations of faecal indicator bacteria were found to be moderate-high at SH60 (median: 271 *E.coli* /100 ml) and moderate at the swimming hole near the mouth and adjacent to Tukurua campground (median: 207 *E.coli*/100 ml). Sampling at the beach only about 150 m southeast of the mouth has only recorded five exceedences of alert levels (over 140 *Enterococci*/100 ml) in 129 samples from 1995 to 2014. Several of these exceedences were due to rain events or particularly high tides.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

Four out of five Microbial Source Tracking samples from the stream identified ruminant animals (*e.g.*, cattle, sheep, deer, goat) as a major source, with the last two effective samples showing it was the only source. Wildfowl was found to be a source in 2010-11, but not in the two effective samples since. Wildfowl are considered relatively uncommon in the catchment (Hindmarsh and Bennett pers comm.) they are very unlikely to be a source. A human source was identified in May 2011, but not in the two effective samples since. This shows that the upgrade to the two failing domestic septic tanks discharging to the waterway in 2011-12 has been enduring. Throughout the period the environmental practice at the farm upstream of SH60 was reasonably good with all regular stock crossings fenced and no other less frequently used stock crossings identified. In late summer 2014 a drinking trough located very close to the stream was relocated to a site 50 m away from the stream and fences moved back away from the stream in areas where paddock run-off funnels to the stream allowing for better filtering of contaminants. These latter measures appear to have resulted in an improvement in *E.coli* concentrations (Figure 114 and Figure 115).

Tukurua Stream swimming hole, 50 m upstream mouth (July 2010)
Tukurua Stream approximately 500 m upstream SH60 (January 2012)

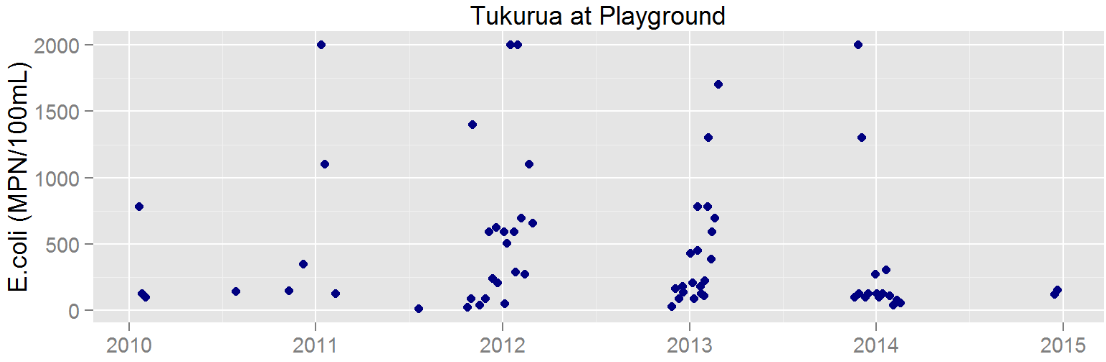


Figure 114. Concentration of *E. coli* at Tukurua at Playground from 2010 to 2015

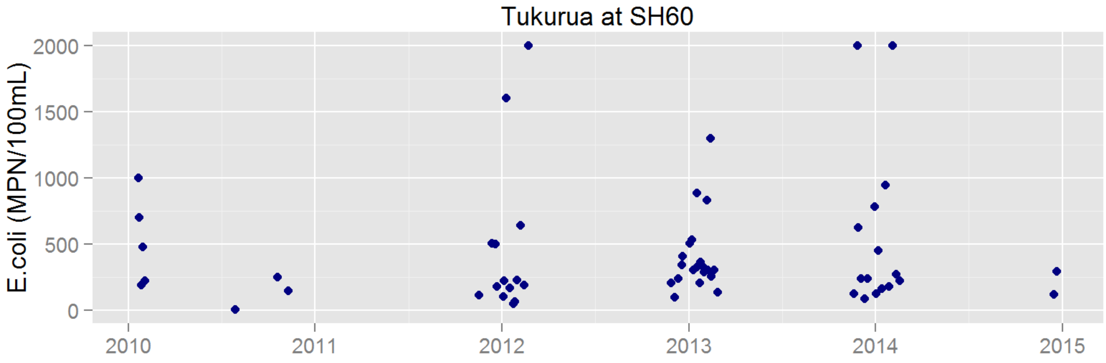


Figure 115. Concentration of *E. coli* at Tukurua at SH60 from 2010 to 2015

Aorere Water Management Area

This area covers the whole of the Aorere catchment, Parapara, and north to Puponga and west to Westhaven Inlet south to Kahurangi Point (Figure 116). As of 2015, a 'Freshwater Management Unit' (FMU) under the 'National Policy Statement for Freshwater Management' has not yet been formally set up for this area. Like the Takaka and Waimea FMU's that have been operating from 2014, there will be a collaborative governance group from the community tasked with making recommendations for limits on water quality and quantity.

There were five core River Water Quality sites monitored between 2010 and 2014 (Figure 116). There was one reference site at the Kaituna River, 500 m up stream of the start of the Track.

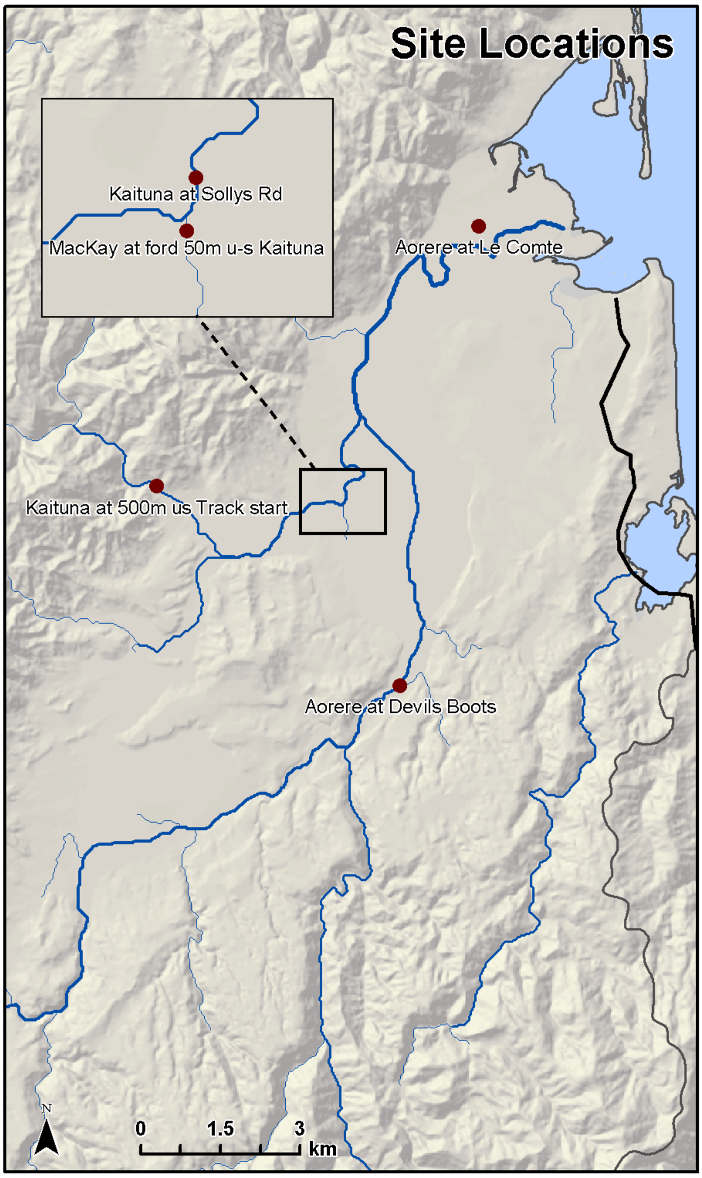


Figure 116. River Water Quality sites in the Aorere Water Management Area

Discussion of Specific Catchments/Areas

This section describes the more **notable aspects of water quality in a given catchment, actions taking place, and recommendations** for further action.

The key to the colour-coding for each water quality attribute state (A to D) is shown to the right. The cut-offs used for each attribute are shown in Table 21.

Attribute State
A (Excellent)
B
C
D (Poor)

The dataset used to determine the attribute states was collected at base-flow over the period from 2010-2014 unless a comment is made otherwise. White (no colouring) indicates there are no data available to determine the attribute state.

Trends in water quality attributes are reported if they are statistically significant (p-value<0.05) and ecologically meaningful (RSKSE>1%). An increasing trend can have a positive or negative effect on the stream ecosystem, depending on the attribute. To indicate the ecosystem effect of the trend, we have used a smile symbol (☺) for improving trends and a frown symbol (☹) for degrading trends.

Table 21. Numerical attribute states for each water quality attribute for the protection of river ecosystem health, aesthetics, and human health. Attributes highlighted in blue are included in the National Policy Statement for Freshwater Management (NPSFM 2014).

Attribute	Statistic	Units	Attribute State				Source
			A	B	C	D	
Water clarity	Single measurement	m	≥5	3 - 5	1.6 - 3	<1.6	-
Turbidity	Single measurement	NTU	≤5.6	>5.6	N/A	N/A	ANZECC & ARMCANZ (2000)
Resuspendable solids	Shuffle score (1 to 5)	N/A	1	2	3	≥4	-
Dissolved oxygen concentration	7-day mean minimum	g/m^3	≥8	7 - 8	5 - 7	<5	NPSFM (2014)
	Lowest 1-day minimum	g/m^3	≥7.5	5 - 7.5	4 - 5	<4	
Water Temperature	Midpoint of daily mean and daily maximum	ºC	≤18	18 - 20	20 - 24	>24	Davies-Colley et al. (2013)
pH	Single measurement	N/A	6.5 - 8.5	5 - 6.5, 8.5 - 9	>5 or >9	N/A	-
Ammonia-N	Annual median	g/m^3	≤0.03	0.03 – 0.24	0.24 - 1.3	>1.3	NPSFM (2014)
	Annual maximum	g/m^3	≤0.05	0.05 - 0.4	0.4 - 2.2	>2.2	
Nitrate-N	Annual median	g/m^3	≤1.0	1.0 - 2.4	2.4 – 6.9	>6.9	NPSFM (2014)
	Annual 95th percentile	g/m^3	≤1.5	1.5 - 3.5	3.5 - 9.8	>9.8	
Dissolved reactive phosphorus	Single measurement	g/m^3	<0.01	≥0.01	N/A	N/A	ANZECC & ARMCANZ (2000)
E. coli	Annual median	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	NPSFM (2014)
	95th percentile	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	
Macroinvertebrates	MCI	N/A	≥120	100 - 120	80 - 100	<80	Stark & Maxted (2007)
	SQMCI	N/A	≥6	5 - 6	4 - 5	<4	
Phormidium	Percentage cover	%	<20	≥20	N/A	N/A	MfE (2009)
Filamentous green algae	Percentage cover	%	<10	10-19	20-29	>30	Biggs and Kilroy (2000)
Periphyton	Periphyton score (1 to 10)	N/A	≥8	6 - 8	5 - 6	< 5	-

How to read a site summary

The site summaries in this report are based on data collected quarterly (monthly for selected sites) from 2010-14, with two exceptions: (1) macroinvertebrate community index values were from 2011-2015 and (2) dissolved oxygen measurements were taken over several days in a summer period from 2005-2015.

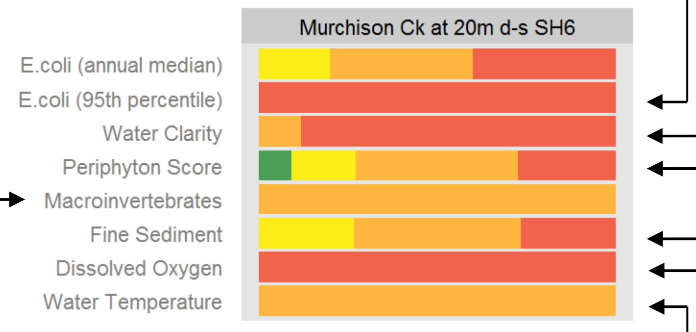
The rows of a site summary represent water quality attributes. The colours indicate attribute states **A** (very good), **B** (good), **C** (fair) **D** (poor).

Proportion of periphyton scores in each attribute state.

Proportion of water clarity measurements (m) in each attribute state.

Attribute state for the 95th percentile *E. coli* concentration. Minimum 10 samples.

Attribute states for the annual median *E. coli* concentration. No minimum sample size.



Proportion of macroinvertebrate community index (MCI) values in each attribute state.

Attribute state for the highest midpoint of daily mean and daily maximum temperature from a continuous record.

Attribute state for the mean minimum dissolved oxygen concentration over 3 or more days during summer. For sites with fewer than 3 days of continuous measurements, the 1-day minimum value was used.

Proportion of resuspendable solids (fine sediment) scores in each attribute state.

Water Clarity

Over the five-year reporting period, approximately 75% of water clarity records at the two Aorere River sites were 'excellent' (Figure 117). In contrast, Kaituna at 500 m u-s Track start had less than 25% of water clarity records in the 'excellent' state. Even though this site has no human land use upstream (i.e. a good reference site) it has relatively poor water clarity due to natural tannin staining from the leaf litter. Approximately 25% of water clarity records at this site were in band C (1.6 to 3 m). Also in band C were more than 30% of water clarity records for at Kaituna at Sollys Rd and MacKay at ford 50 m u-s Kaituna.

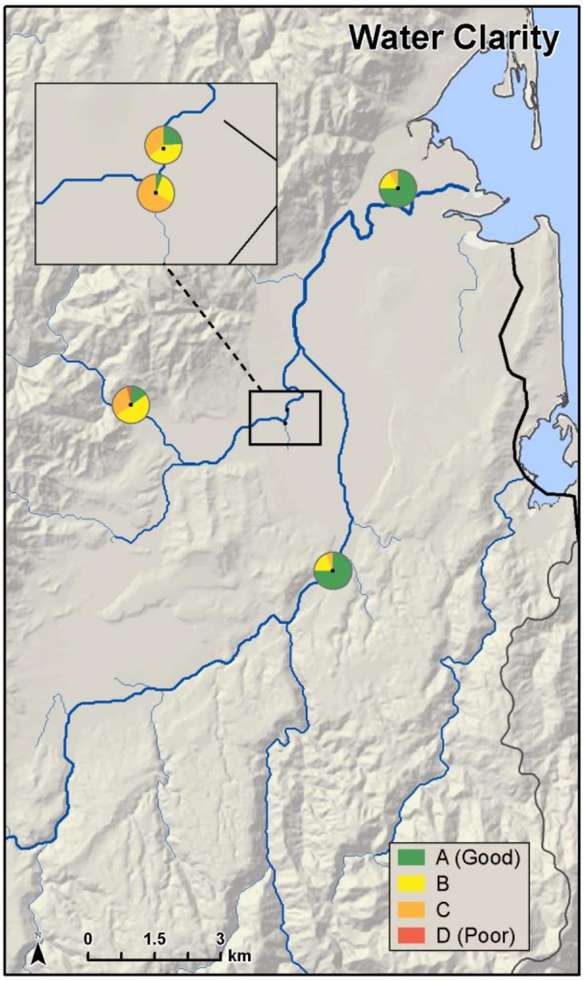


Figure 117. Proportion of water clarity records in each attribute state (A to D) for river water quality sites in the Aorere Water Management Area (sites shown have a minimum of 10 records).

Disease-causing organisms

For all core sites, annual median *E. coli* concentrations were better than the National Bottom Line of 1000 *E. coli* per 100 ml (NPSFM, 2014; Figure 118). However, some tributaries investigated in the catchment have recorded annual medians over this bottom line (e.g. Clay Creek). In 2014, MacKay at ford 50 m u-s Kaituna had a median *E. coli* concentration exceeding the guideline value for contact recreation (540 *E. coli*/100 ml). While this site is not known as a contact recreation (swimming) site, swimming is an important local value for the Kaituna River not far downstream from the confluence of Mackay Creek.

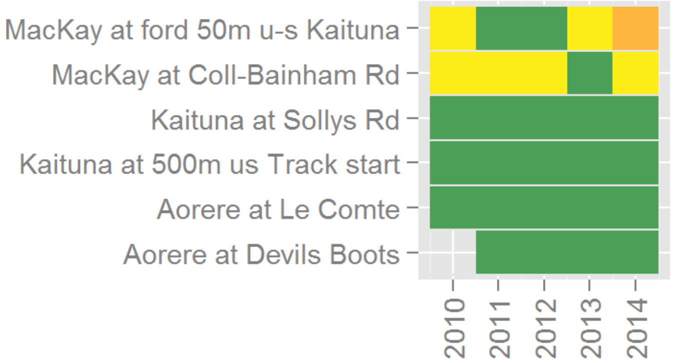


Figure 118. Tile plot of annual median *E. coli* values for sites in the Aorere Water Management Area. Colours indicate attribute states A (green), B (yellow), C (orange) and D (red). Annual median values were calculated for sites with three or more records in a given year.

Filamentous Green Algae Cover & Periphyton Score

With a few exceptions, sites in the Aorere Water Management Area had A scores for filamentous green algae cover (less than 10% cover; Figure 119). Kaituna at Sollys Rd had three records of filamentous green algae in the D band (greater than 50% coverage). Aorere at Le Comte had high cover of filamentous green algae only on one occasion (during Spring 2013 after a period of dry weather). A similar pattern was seen in the periphyton scores[8] (Figure 119). That is, most sites had periphyton scores above 7 (in the A or B bands) but Kaituna at Sollys Rd and Aorere at Le Comte recorded two periphyton scores less than 5 (band D). These two findings, high filamentous green algae cover and low periphyton scores, indicate poorer water quality at Kaituna at Sollys Rd and Aorere at Le Comte compared to the other sites in the Aorere catchment.

Macro-algae cover in the Ruataniwha Inlet is low (Stevens and Robertson, 2015).

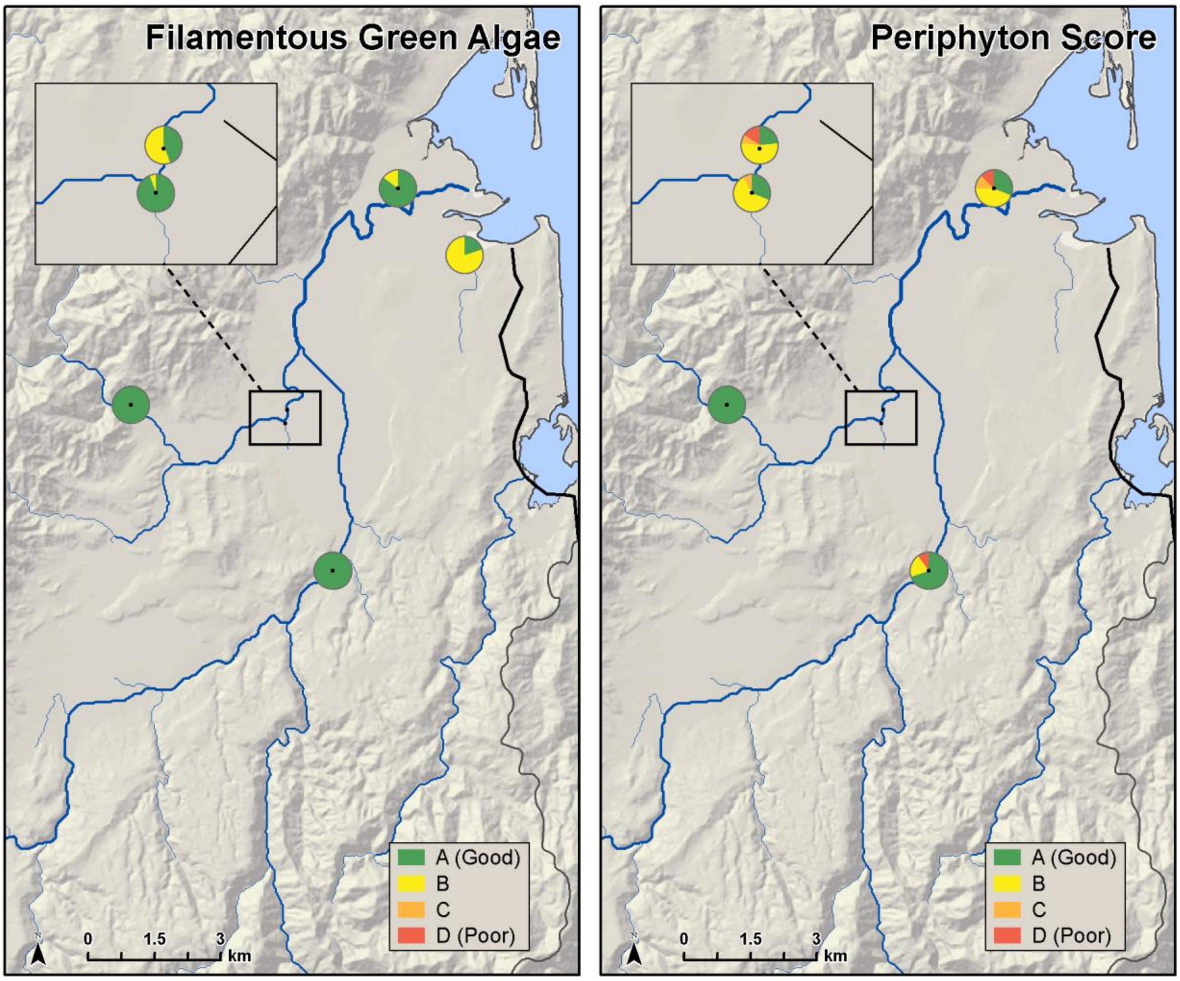


Figure 119. Coverage of filamentous green algae greater than 2cm in length (left) and periphyton community score (right) for sites in the Aorere Water Management Area. Pie charts show the proportion of estimates in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

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[8] Rapid Assessment Method 2, NZ Periphyton Monitoring Manual, 2000.

Nutrients

For the 2010-15 monitoring period nutrient data, apart from ammonia, were only available for Aorere at Le Comte (this is considered the 'sentinel site' for the catchment and to determine loading to the coast; other sites aren't sampled as nutrients are so seldom an issue in the catchment). **Nutrient concentrations were low** at the **Le Comte site,** (annual median nitrate concentrations and annual median ammonia concentrations were consistently in the A band (less than 1 g/m^3 and less than 0.03 g/m^3, respectively; Figure 120)). Dissolved reactive phosphorus concentrations were satisfactory at Le Comte (less than 0.01 g/m^3) except for one record in Winter 2014 (0.02 g/m^3; Figure 121). The only streams where nutrients have been found to be a concern are those draining catchments with large proportions in pakihi soils such as **Burton Ale and James Cutting Creeks** where there were consistently **dissolved reactive phosphorus concentrations five times guidelines**. The mass load of nutrients from the Aorere to the coastal marine area is only 10% of that coming from Cook Straight. This means that the load from the Aorere would have to be 5-10 times higher and sustained to make much of a difference (Paul Gillespie, pers.com.).

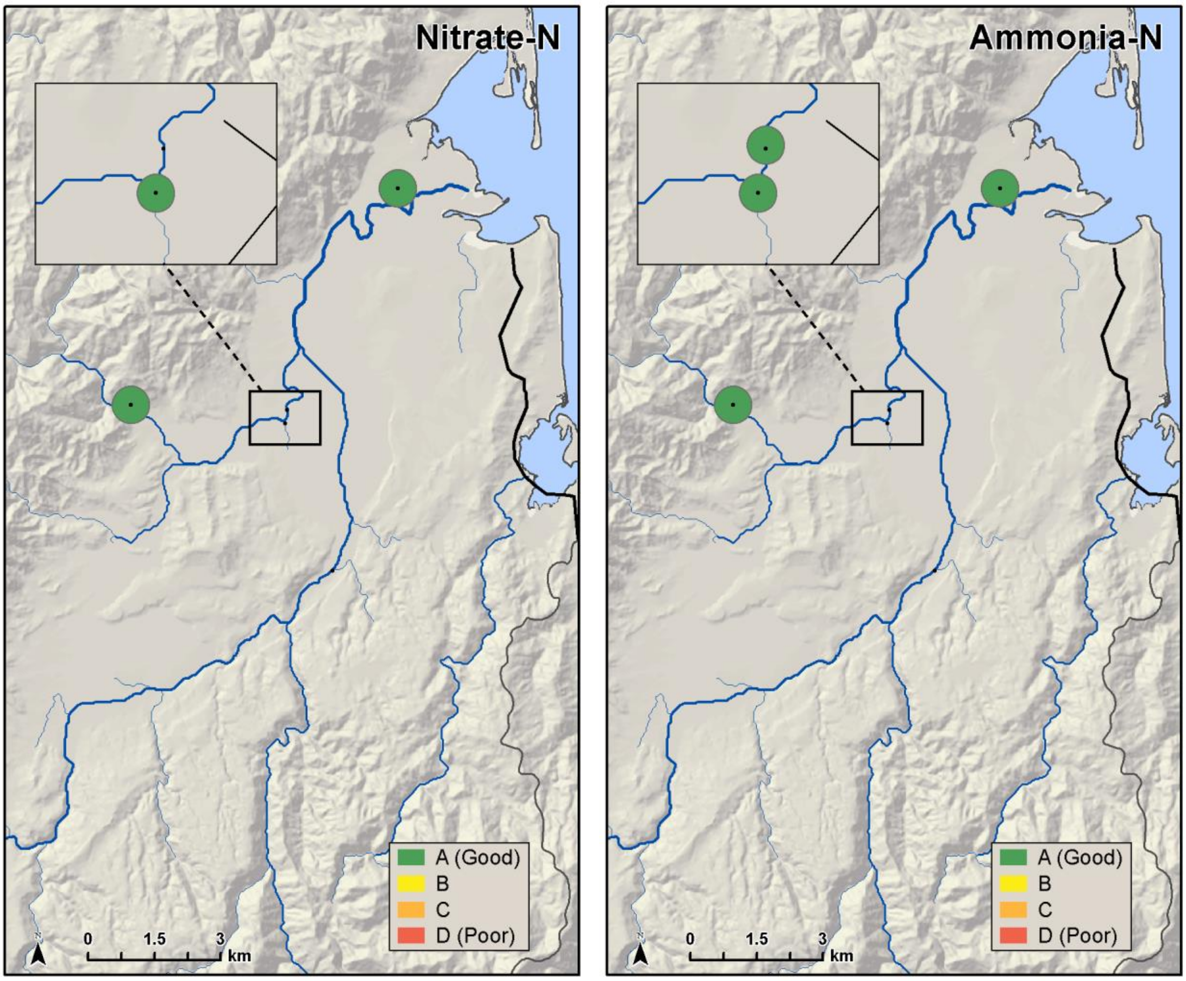


Figure 120. Nitrate (left) and ammonia (right) concentrations for sites in the Aorere Water Management Area. Pie charts show the proportion of annual medians in each attribute state (A to D) for 2010-15.

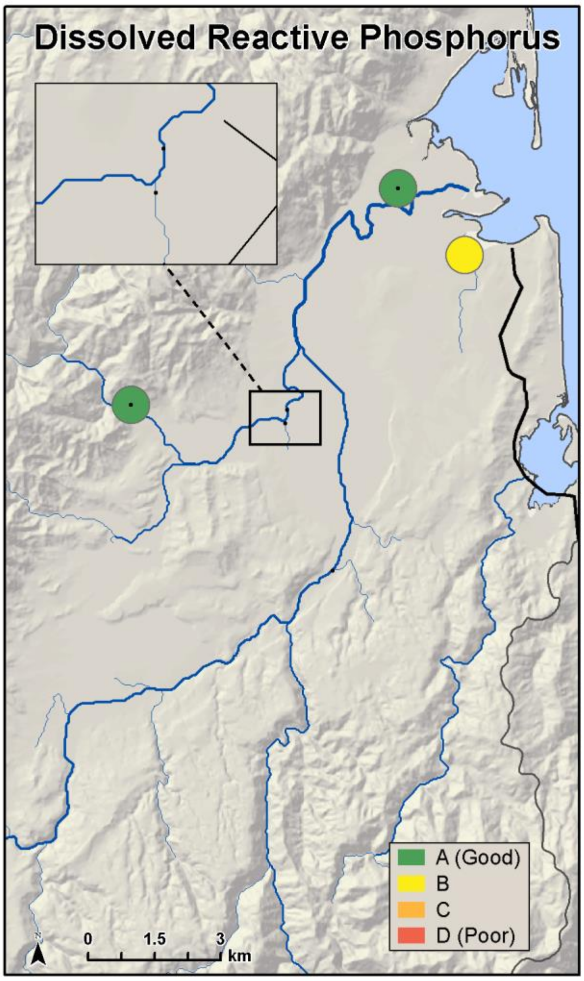


Figure 121. Dissolved reactive phosphorus concentrations for sites in the Aorere Water Management Area. Pie charts show the proportion of records in each attribute state (A to D) for 2010-15.

Resuspendable sediment

At least 75% of resuspendable solids scores were in attribute state A for four out of five sites (Figure 122). The remaining site was MacKay at ford 50 m u-s Kaituna. This site had resuspendable solids scores in attribute states A to C. Data were not collected for volumetric SBSV in this catchment.
The soft mud coverage of the Ruataniwha Inlet appeared to have increased from 12.9% to 18.5% between 2000-2015 with the 700 ha area of unvegetated intertidal habitat (Stevens and Robertson, 2015).

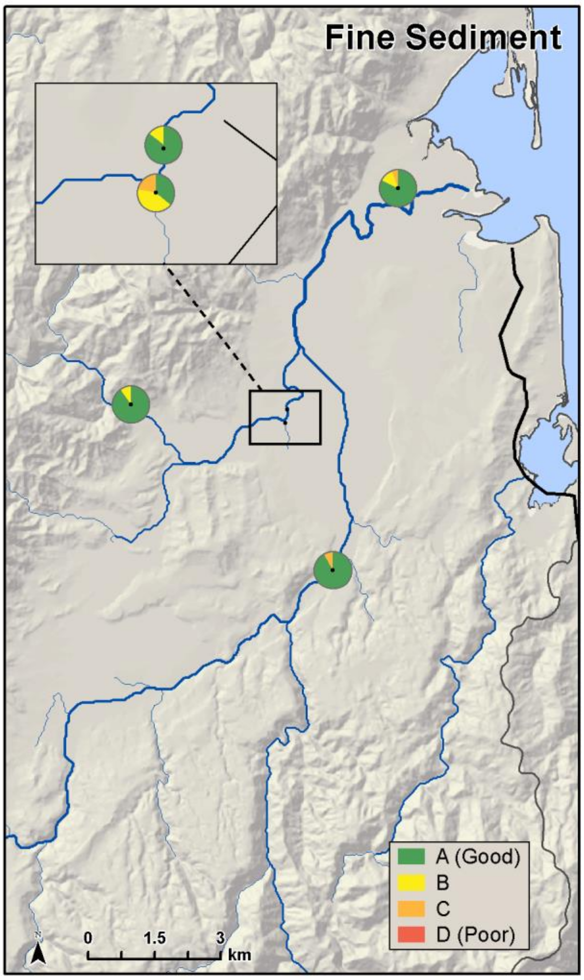


Figure 122. Proportion of resuspendable solids scores in each attribute state (A to D) for sites in the Aorere Water Management Area.

Macroinvertebrate Community

Based on MCI scores, the **invertebrate community was 'excellent' at Aorere at Le Comte and Kaituna at Sollys** (MCI greater than 119); Note: these are the only two sites in the Aorere Water Management Area with at least three recorded macroinvertebrate samples; Figure 123). The SQMCI scores, however, shifted from 'excellent' to 'poor' for Aorere at Le Comte and 'excellent' toward 'fair' for Kaituna at Sollys Rd in recent years. After 2005 at the Kaituna site there were notable reductions in sensitive macroinvertebrate taxa (particularly *Deliatidium* and *Helicopsyche*) while there were marked increases in pollution-tolerant taxa (snails (*Potamopyrgus*), true flies (*Orthoclad* and *Aphrophila*), axe-head caddisflies (*Oxythira*)).

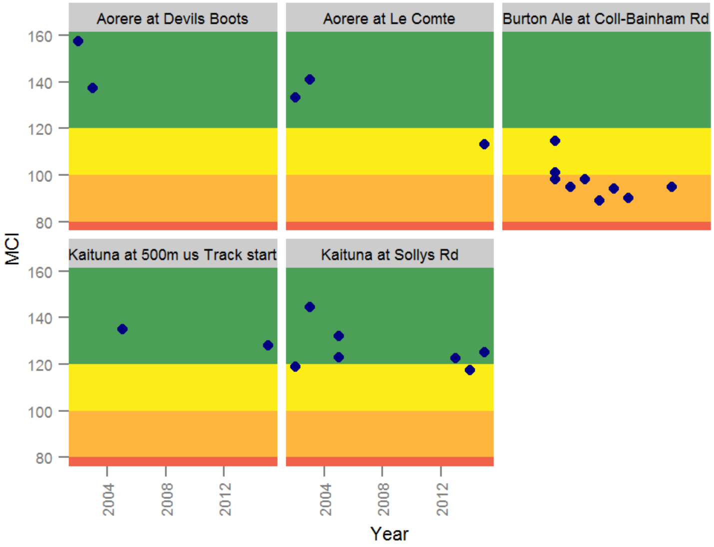
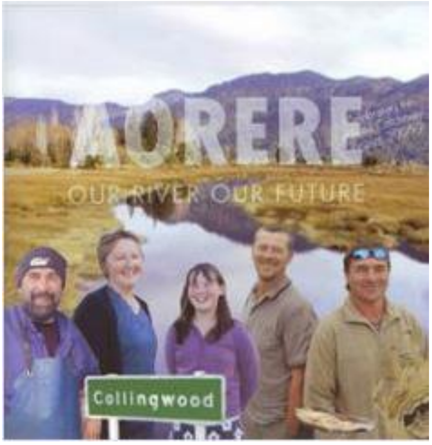


Figure 123. Macroinvertebrate community index (MCI) scores between 2001 and March 2015 for sites in the Aorere Water Management Area (blue dots). The background colours indicate these quality classes: excellent (green), good (yellow), fair (orange) and poor (red).

The Aorere Catchment Project
One of the biggest efforts to improve water quality in Tasman

The Aorere catchment project was a community-led initiative supported by Landcare Trust that began in 2005. Farm environmental plans were developed for 24 farms of the 35 farms in the catchment. These plans provide advice on the appropriate actions for a particular farm and prioritise them in order to maximise the benefits of actions in the initial phases. Fencing off dairy cows from streams was completed in the catchment by 2013 and between 2006 and 2014 over 23,000 plants were established by the Golden Bay Streamcare Group. Over $1.6 million was invested in on-farm best management practices (www.landcare org.nz/ArorereProject).



Paired Site Differences

This section compares the difference (increase or decrease) between two sites on a particular waterway on a particular day. The differences are then averaged to get the "mean difference". It is not the difference of the mean from each site calculated from the whole record for one site with the mean from the whole record from other site.

Kaituna at Sollys Rd was paired with Kaituna at 500 m u-s Track start (reference site). Comparisons between these sites revealed two main differences (Figure 124). First, *E. coli* concentrations at Sollys Rd were higher than the reference site (mean increase = 148 *E. coli*/100 ml, SD = 195, n = 19, comparing each site on each sampling event). This difference would be expected even with best practice followed on each farm. The concentration of *E. coli* was more than 50 times higher on three sampling occasions. Second, the resuspendable solids scores were higher at Sollys Rd compared to the reference site (mean increase = 0.7, SD = 0.6, n = 10). A higher resuspendable solids score indicates higher fine sediment deposition.

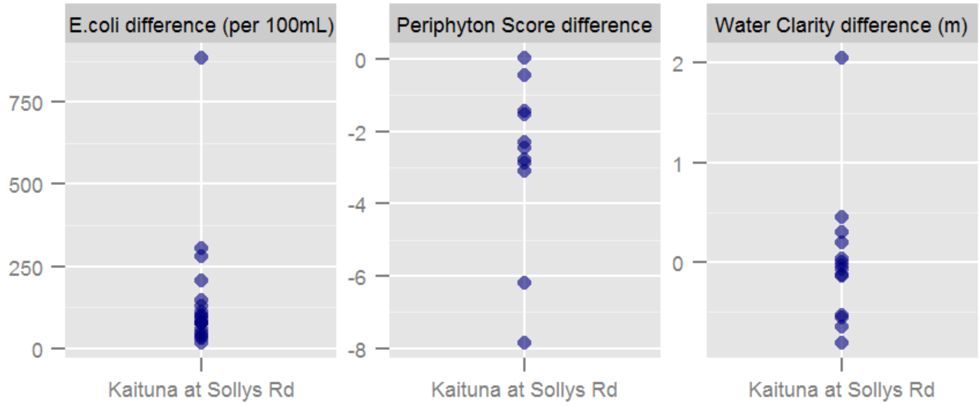


Figure 124. Difference between Kaituna at 500 m u-s Track start (upstream) and Kaituna at Sollys Rd (downstream) for water quality data collected at both sites on the same day. A positive difference means the downstream site had a higher value than the upstream site.

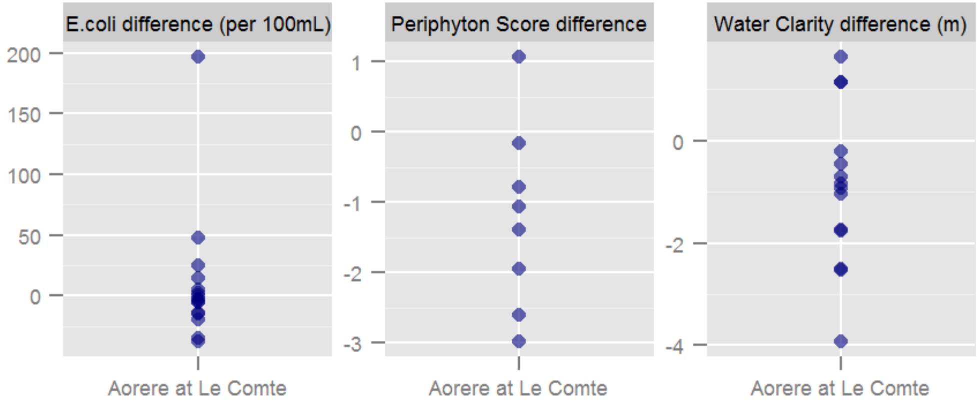


Figure 125. Difference between Aorere at Devils Boots (upstream) and Aorere at Le Comte (downstream) for water quality data collected at both sites on the same day. A positive difference means the downstream site had a higher value than the upstream site.

Trends in the Aorere Water Management Area

For sites in the Aorere Water Management Area, there were no trends in *E. coli* or water clarity over the past 10 years or over the full record. There was an improvement in dissolved reactive phosphorus and Ammonia-N concentrations at the Aorere at Le Comte site. At the same site, however, there was an indication of degrading Nitrate-N concentrations (Table 22).

Table 22. Water quality trend results for sites in the Aorere Water Management Area over the 10-year period 2005 to 2014 (highlighted in blue) and over the full record (from 15 to 26 years depending on the site). Seasonal Kendall trend tests were used for *E. coli* concentrations, water clarity measurements and nutrient concentrations (Ammonia-N, Nitrate-N and DRP). The trends shown are significant ($p < 0.05$), meaningful (RSKSE > 1% per year) and the change in value between the start and end of the trend line is greater than the detection limit for the attribute (refer to the Methods sections for the detection limits). Statistics are shown in the Appendices.

Site name	Attribute	Effect ☺ ☹	N obs	N years
Aorere at Le Comte	Ammonia-N	☺	62	15
Aorere at Le Comte	DRP	☺	61	15
Aorere at Le Comte	Nitrate-N	☹	45	10
Kaituna at Sollys Rd	Ammonia-N	☺	36	10

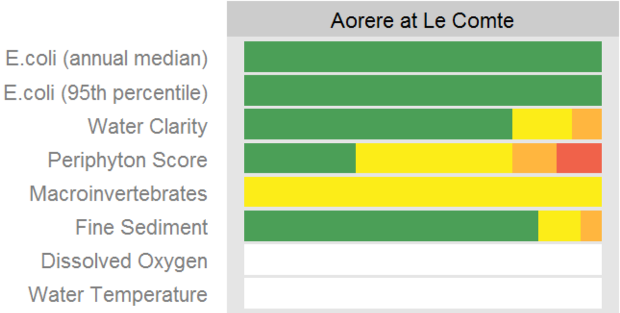
Aorere Catchment, near Collingwood

Main Stem Aorere River

There are two long-term monitoring sites on the Aorere River, Le Comte (which is near the bottom of the catchment, just upstream of the saline influence) and Devils Boots (which is influenced by about half the farmed area compared to Le Comte). The river exits into the Ruataniwha estuary (1610 ha) which is listed as being nationally important.

Aorere Rv at Le Comte (February 2005).

A large amount of effort to improve water quality has been undertaken, particularly by dairy farmers in this catchment. This effort has been acknowledged nationally.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

With 80% of the Aorere catchment in native forest there is a lot of clean water to provide dilution for any contaminants running off the remaining land. Despite this, the level of faecal indicator bacteria during rainfall events can be moderate to high. However, base flow concentrations of faecal indicator bacteria are low (median for 2011-15: 32 *E. coli*/100 ml; compared to 39 *E.coli*/100 ml for the previous 10 years). Just over 10% of samples exceeded the 260 *E.coli*/100 ml alert guideline for contact recreation. The trend in *E.coli* is not statistically significant (p=0.18) (Figure 126).

In 2005 faecal contamination became a significant issue for the shellfish farming industry. This may have been the case since the marine farms were established but increased monitoring showed this more definitely. The bathing area near the Collingwood boat ramp also relatively frequently breached guidelines (for contact recreation).

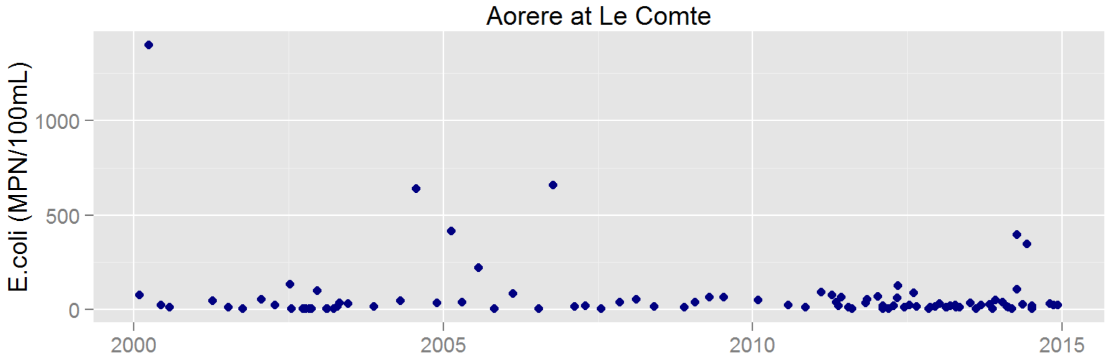


Figure 126. Concentration of *E. coli* from 2000 to 2015 at Aorere at Le Comte

In a flood in September 2000 *E.coli* concentrations were shown to peak about five hours prior to the flow peak with a total loading over the 10 hour flood of over 40,000 *E.coli* (Figure 127). The separation of the *E.coli* and flow peak also indicates a contaminant source within 5-10 kilometres of the monitoring site. Given the rainfall intensity was less than 10mm/hour during this storm it is unlikely that much of the contribution of *E.coli* was from paddock run-off, but more likely to be run-off from hard surfaces such as races and yards as well as re-suspension of fine sediment in the stream bed. Although this data is relatively old it is still provides relevant information on the impacts expected in Golden Bay today. This is because land use and cow numbers have remained similar (Robertson & Stevens 2008). However, it would be expected that peak concentrations and total loading will be reduced through excluding stock from waterways via improved base flow water quality and a reduced reservoir of disease-causing organisms in stream beds.

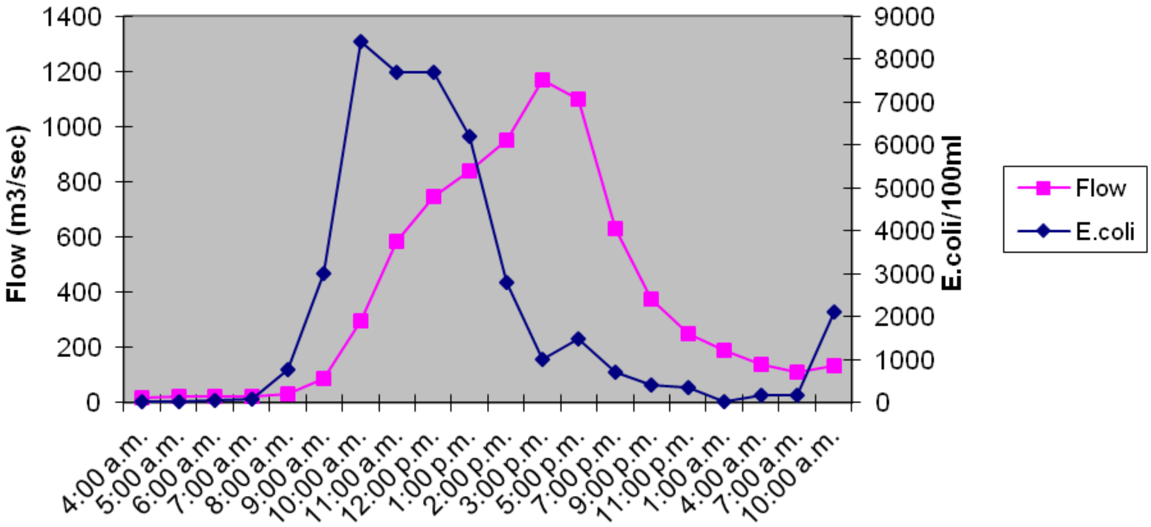


Figure 127. *E.coli* versus flow at Aorere River at Devils Boots (28 – 29 Sep 2000). Nottage 2001.

Dairying was identified as a significant contributor (53%) to faecal contamination with an estimated annual total load of faecal coliforms of 2 x 10^{16}/year (Robertson & Stevens 2008). Sheep and beef farming were estimated to contribute 42% of faecal load (assuming this land use covers the same area as dairying). Black swan contribute a faecal bacteria load estimated at 0.9% (based on 10,000 swans resident all year round) with human sewage 0.09%. It would be useful to repeat this survey now that there has been so much improvement in farm practice.

The dairy farming community responded very proactively and with Landcare Trust formed the Aorere Catchment Group. This was largely in response to mussel farms in the coastal area only a few kilometres off the river mouth. Mussel farm harvesting rates have ranged from 60% to 95% (check with MSQP) of the time over the past 5 years, compared to as low as 28% of the time in 2005 (Figure 128). Despite the improvements in farm management practices in the Catchment, trends in *E.coli* are not apparent at the Aorere at Le Comte site since 2000 when monitoring started at quarterly frequency (at base flows) or since monthly sampling began in 2011 (all flows). Quarterly sampling during baseflow conditions (which occurs at all sites, except Le Comte since 2011) does not capture storm related events, where most contaminants would be liberated and where the greatest improvements are most likely to be observed.

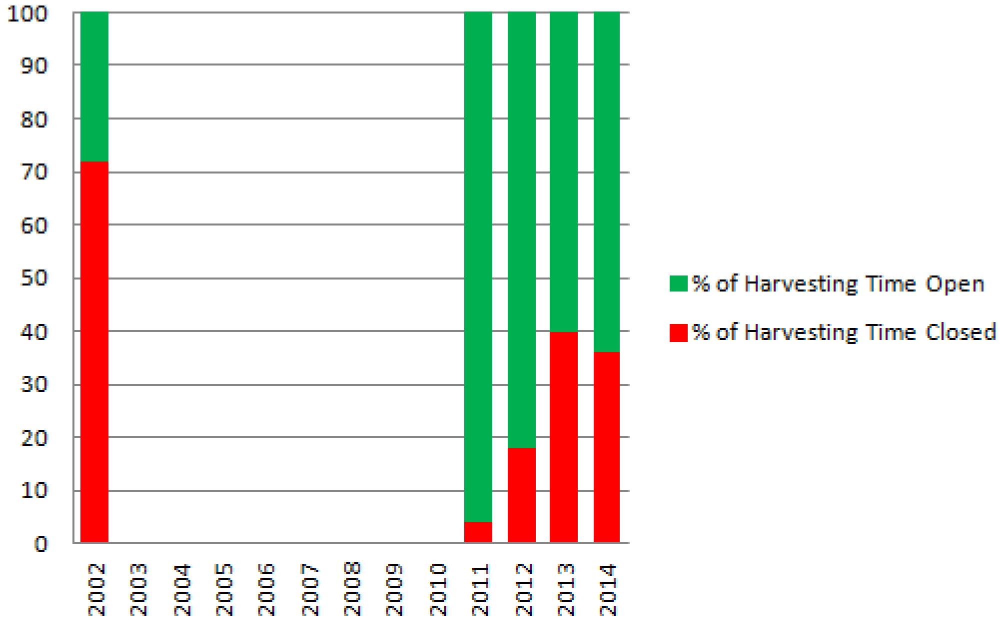


Figure 128. Proportion of harvesting time that the Collingwood mussel farms are closed due to water quality issues.

Over this period there has be significant focus on dairy effluent treatment systems, particular with respect to increasing effluent storage to allow disposal in more suitable weather. **Rainfall in the Aorere Valley is high** (2.5-3.0 m annually in the lower valley and up to 5 m during some years in the upper valley). This makes intercepting and treating effluent discharged to pasture difficult.

The **total suspended solid load** from the Aorere River to the coast is considered low-moderate when compared across New Zealand (measured at 46,876 tonnes SS/yr) but the specific yield of suspended solids is around average for NZ rivers (607 kg/ha/yr) (Nottage 2001). A moderate flood over the period 28 – 29 September 2000 saw 2430 tonnes of sediment pass the Devils Boots monitoring site in just 28 hours (compared to 9 ton for stable low flows).

The Aorere River currently has moderately low levels of nutrients. However, nitrate concentrations are increasing (Figure 130). With dissolved reactive phosphorus at Le Comte decreasing (Figure 129), it suggests that sediment discharges from farms are improving. **Nutrient loads to Golden Bay are relatively low** (total nitrogen load to the coast is predicted to be low (440T/year) (Robertson and Stevens, 2007).

Sampling by Nottage in 2000 showed **very good macroinvertebrate condition** at Le Comte (MCI 140, QMCI 7.8, # taxa 9; mean of 3 samples) and 11 other sites around the catchment (MCI range: 158-139, QMCI range: 8.3-6.8, # taxa range: 8.7-15.6). This compared well to the reference site on the Aorere at 900 m downstream Brown River (MCI 158, QMCI 8.0, # taxa 9.6; mean of 3 samples). The limited macroinvertebrate sampling in the Aorere River at Le Comte as part of the RWQMP also shows good water quality (the most recent sample is an exception and further sampling is required to confirm if this is a downward trend. The sampling frequency has been lower at this site because it was felt that land uses in the catchment are less likely to adversely affect the river given the high dilution, allowing resources to be diverted to other sites.

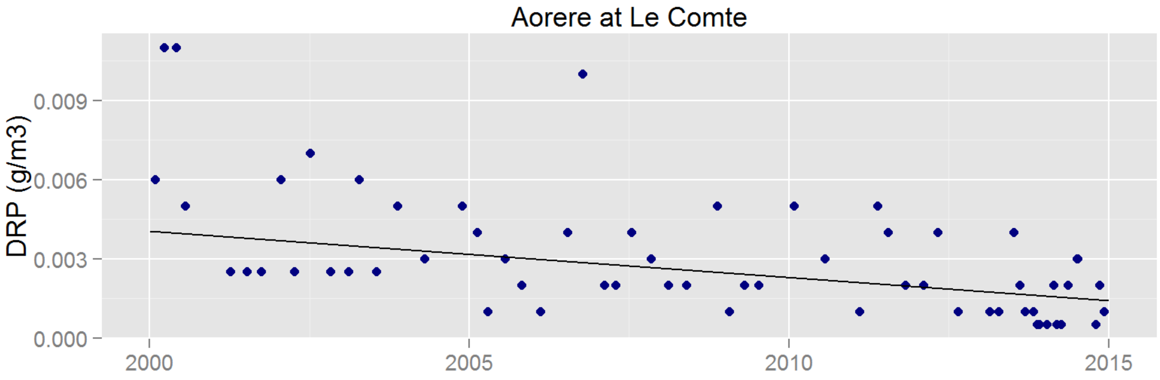


Figure 129. Aorere at Le Comte dissolved reactive phosphorus (DRP) concentration data with 15-year trend line ($p < 0.0001$, RSKSE = -7.0% per year). There was no significant meaningful trend over the most recent 10 years of the record.

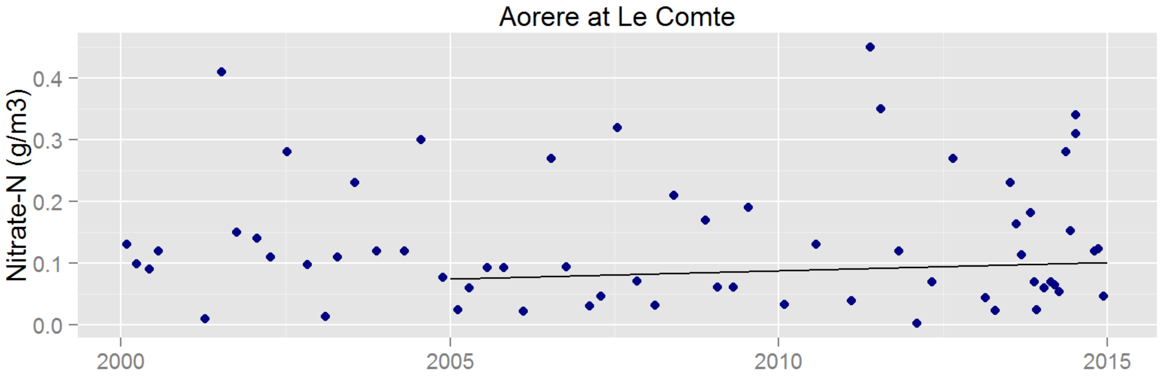


Figure 130. Aorere at Le Comte Nitrate-N concentration data with 10-year trend line ($p = 0.0245$, RSKSE = 2.9% per year). There was no significant meaningful trend over the full record (15 years).

Aorere Rv at Devils Boots (February 2005)

	Devils Boots	**Le Comte**
River Environment Class	Cool Extremely Wet Hard sedimentary Indigenous forest Low gradient	Cool Extremely Wet Hard sedimentary Indigenous forest Low gradient
Catchment area (km^2)$^+$	561	681
Predominant land use upstream		80% native forest 16 % agriculture (11,000-13,500 dairy cows in the catchment) 3 % scrub 1 % exotic forestry
Mean annual rainfall (mm)	2490	
Mean flow (l/sec)	69,274	
Median flow (l/sec)	31,816	NA
7-day Mean Annual Low Flow (l/sec)	11,300	NA
Lowest recorded flow (l/sec)	5,969	NA
Highest recorded flow (l/sec)	3,560,550 (one of the highest specific discharges in NZ)	NA
Water quality record	2000-present	Quarterly: 2000-present Monthly: 2011 - present

* Estimate from WRENZ 2013. NA = not available

Clay Creek, Bainham

This small creek flows into the Aorere River about 1.1 km downstream of James Bridge. Over 90% of the catchment land use is in intensive dairy farming. The flow in the middle reaches (around Mackay Pass Rd) and upper reaches regularly dry up in summer but flows are permanent in the lower 600-700 m (lowest recorded flow of 50 L/sec. The creek flows into a large recirculating pool in the Aorere River that is used for swimming.

Concentrations of disease-causing organisms are generally very high (median 3100 *E.coli*/100 ml).

Daily **dissolved oxygen** minima were **below standard** for ecosystem health at around 53-55% (continuous sampling March 2015) (Figure 131). However, it is likely that it won't take much effort to improve this (to bring it up to over 60%) by further removing dairy effluent discharges from raceways to the stream and more riparian planting. The relatively flat bottom to the daily dissolved oxygen curves shows that there is reasonable re-aeration – in this case from turbulent flow over riffles in the lower reaches. The low daily maxima are consistent with this creek having reasonable shading and therefore less extensive aquatic plant coverage. Water temperatures were very suitable for aquatic ecosystem protection (daily maxima: 18°C).

Above: Clay Ck 30 m upstream Aorere Rv. Below: Clay Ck 550 m upstream Aorere Rv. Both photos taken in February 2015.

Macroinvertebrate metrics indicate this creek is in relatively poor condition (MCI 93, SQMCI 3.88, snails very abundant; based on one sample in February 2014). However, there was relatively high number of taxa (20) and a 'satisfactory' proportion of sensitive taxa in the sample (%EPT: 55%), mostly cased caddisflies.

The source of faecal contamination and the reason for low dissolved oxygen could be discharges of dairy cow effluent from stand-off areas and a raceway in the mid-upper catchment. Effluent runoff from this raceway will be treated from August 2015. All creeks in the catchment are fenced and stock crossings are bridged or culverted.

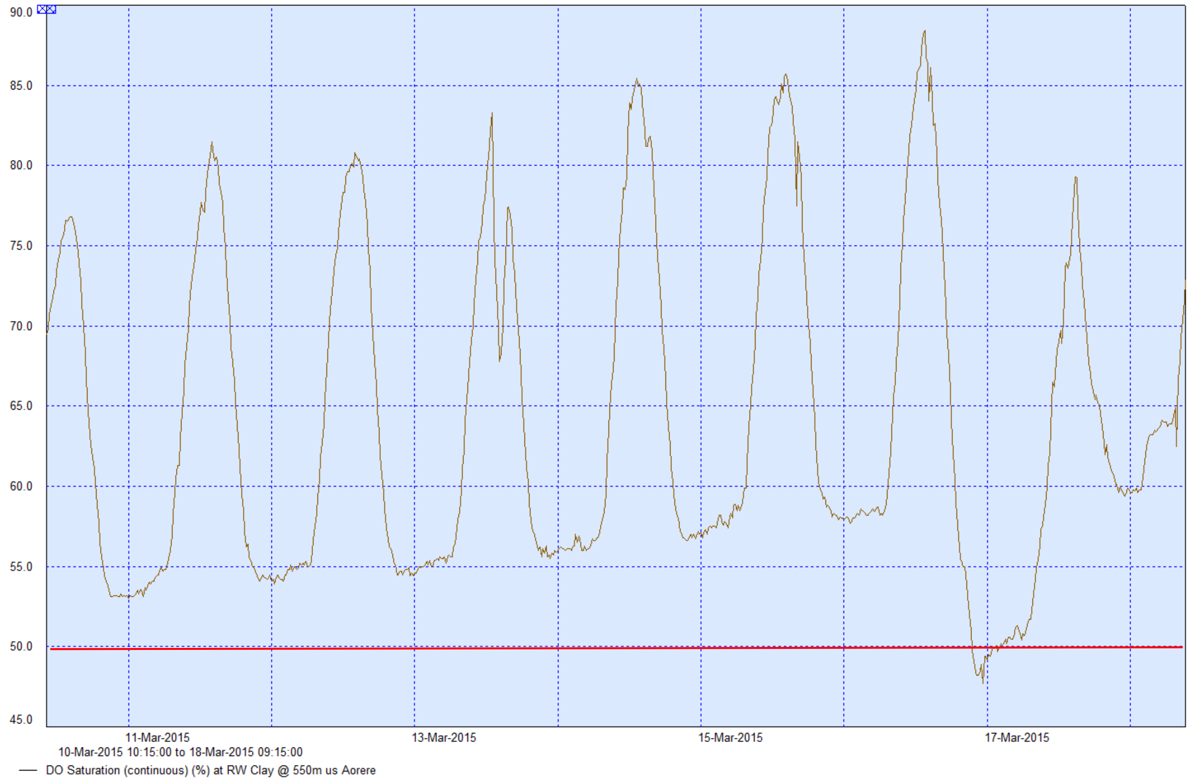


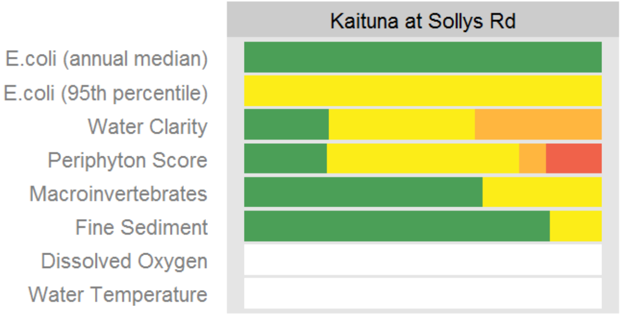
Figure 131. Dissolved oxygen saturation at Clay Creek about 500 m upstream Aorere River measured continuously from 10-18 March, 2015. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Kaituna River

Kaituna Rv 200 m upstream Track Start (February 2015)

There are two long-term sampling sites on this river. One upstream of the start of the Kaituna Track (upstream of "The Naked Possum") which has a catchment entirely in native forest, much of which is dominated by podocarp and rata. The site at Solly Rd is downstream of several dairy and beef farms and Bonny Doon Creek, a significant tributary. Local farming families use the Kaituna River for swimming.

There is a significant difference in levels of base-flow **faecal indicator bacteria** between the upstream (reference site) and the lower reaches (Sollys Rd) (median 5 *E. coli* /100 ml upstream reference site compared to 92 *E. coli* /100 ml at Solly Rd, 2010-2014; median at Solly Rd 2001-2009: 150 *E. coli* /100 ml). Alert level guidelines are exceeded over 15% of the time. Mackay Creek, a tributary that joins the Kaituna upstream Solly Rd, is likely to be a contributor to this condition.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

From 2007 until present the percent cover of **filamentous green algae** on the bed of the river at the Solly Rd site each summer has been well above nuisance levels (75% cover in each of 2007 and 2010). It is obvious that Mackay Creek is the cause of this, as there are very low (<10% cover) levels upstream of this stream confluence. The mixing profile is also very visually apparent from the presence of bright green algae (i.e. the algae spreads across the streambed as the waters of the two streams progressively mix downstream of the confluence), with almost complete mixing downstream of the stock bridge and complete mixing downstream of the next riffle. The original source of the problem was traced to **dairy effluent** treatment pond sludge that was placed near the stream and ran off into MacKay Creek. This issue has been resolved by removing the sludge as it is not an acceptable practice. In 2000, Nottage also noted sporadic accumulation of filamentous green algae at the Solly Rd site.

Water clarity is often naturally low in this stream (median: 3.5 m, 25th percentile 2.2 m) due to dissolved colour from water percolating through the leaf and bark litter on the podocarp forest floor. At the Solly's Rd site water clarity is similar to the upstream site (median: 3.3 m, 25th percentile 2.1 m).

Good or excellent macroinvertebrate condition was found in the **lower Kaituna River** (MCI generally greater than 119). The SQMCI scores, however, shifted from excellent toward fair for Kaituna at Sollys Rd in recent years. Sampling by Nottage in 2000 showed at Solly Rd (MCI 141, QMCI 6.9, # taxa 14.3; mean of 3 samples). This was not much less than the reference site on at Kaituna at Track Start (MCI 149, QMCI 8.3, # taxa 15.6; mean of 3 samples).

Kaituna Rv at Sollys Rd (June 2010)

	Kaituna u-s track start	Kaituna at Sollys Rd
River Environment Class	Cool Extremely Wet Soft sedimentary Indigenous forest Lowland-fed Low gradient	Cool Extremely Wet Soft sedimentary Indigenous forest Lowland-fed Low gradient
Catchment area (km²)⁺	44.6	79
Predominant land use upstream	100% native forest	73% native forest
Mean annual rainfall (mm)	3621*	NA
Mean annual flow (l/sec)	2,274*	4,277
Lowest recorded flow	NA	519 (Mar 2003)
Water quality record	Monthly: 2000-01 and 2013-present Quarterly: 2005-present	2000-present

* Estimate from WRENZ 2013. NA = not available

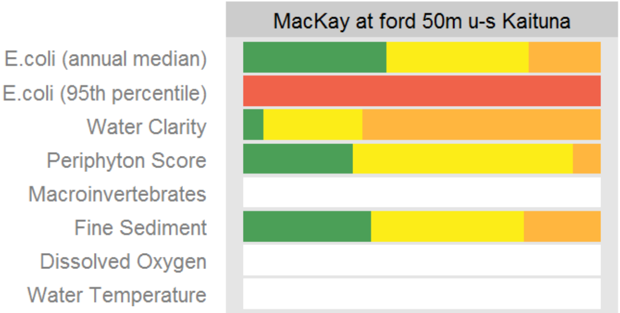
Kaituna Rv at Sollys Rd taken from stock bridge. Left: Filamentous green algae cover at 75% cover (April 2007) Right: View upstream with filamentous green algae cover at 50% (February 2013). Note there are very little filamentous algae on the true left side of the river (right side of the photo).

Mackay Creek, Rockville

While this creek is too small to be used for swimming, it can affect the Kaituna River which is used for this purpose. Giant kokopu are found in the deep pools in the lower reaches where there is ecologically significant riparian podocarp forest enclosing the stream. With over **80% of the catchment in intensive pastoral land use**, it consequently is likely going to struggle to meet water quality guidelines. Monitoring of this creek began in 2007 because of the effect the creek had on the Kaituna River, particularly the filamentous green algae coverage. The flow in this creek can be as little as 1-2 L/sec in the driest summers.

The **level of disease-causing organisms is moderately high** at base flows at the 50 m upstream Kaituna site (median 280 *E. coli*/100 ml (2010-2015), and exceed the guideline for contact recreation more than half the time. Stock drinking water and secondary contact guidelines are exceeded just over 20% of the time. Compared to a site in the upper catchment on mostly sheep and beef farmland (1 km upstream Collingwood-Bainham Rd) the *E. coli* concentration at Collingwood-Bainham Rd was on average 1.8 times greater (comparing samples collected from the sites within hours of each other). Only 15% of samples were lower at the downstream site. Two results in 2014 were particularly concerning (13,000 *E. coli*/100 ml on 14 April and 20,000 *E. coli*/100 ml on 21 October with results 2.2x and 75x less upstream). In late 2014 another site on Mackay Creek downstream of a tributary above Gillies Rd was sampled and found to have levels on average 1.5x lower than the Collingwood-Bainham Rd site (average difference of each sampling event over 8 events).

Above: Mackay Creek 30 m upstream Kaituna Rv showing high filamentous green algae coverage (January 2009). Below: 50 m upstream Kaituna Rv (February 2007).



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

In 2011 the source of faecal contamination was determined as ruminant e.g. cows, with no other animal faecal material. Initially it was thought that the cause was dairy effluent sludge oozing into the creek after being removed from the effluent ponds and stockpiled in the riparian area in 2006. However, almost 10 years after the material was pulled back from the creek *E.coli* concentrations still spike high at base flows. Dairy effluent ponds appear to be functioning well with no overflows or leaks evident. While the stream has been mostly fenced for the monitoring period, a small amount of fencing was completed in the area upstream of Gillies Rd in 2015.

Daily **dissolved oxygen** minima measured over 5 days in February 2010 was **very low** in the mid reaches (Collingwood-Bainham Rd; Figure 133 and Figure 134), at 35-40% saturation, but improved to about 60% saturation near the confluence of the Kaituna River (Figure 132). The irregular spike at 2-4am on 11/2/2010 could suggest a discharge or a water take. The reduced peak at mid-afternoon on 13/2/2010 at the site close to the Kaituna in the dissolved oxygen trace could be due to heavy cloud cover. The sonde deployment in 2015 at Collingwood-Bainham showed dissolved oxygen levels less variable and with considerably higher daily minima than in 2010.

Median water clarity is fair (median 2.9 m 2010-2015), but just over 5% of records in base flow have been below the 1.6 m guideline for contact recreation.

Filamentous green algae at the site 30 m upstream of the Kaituna River is high at times (40 and 50% cover have been recorded; see photo at top of previous page) but due to shading by tree cover at this site is on average is likely to be lower than other sites.

In 2015 a source of high nitrate was found coming from a drain from the true right about 920 m downstream of Collingwood-Bainham Rd. The origin for this has not been found but may be due to something buried within the paddock.

Above: Mackay Ck at Collingwood-Bainham Rd, looking downstream (Left: April 2005, Right: February 2015)

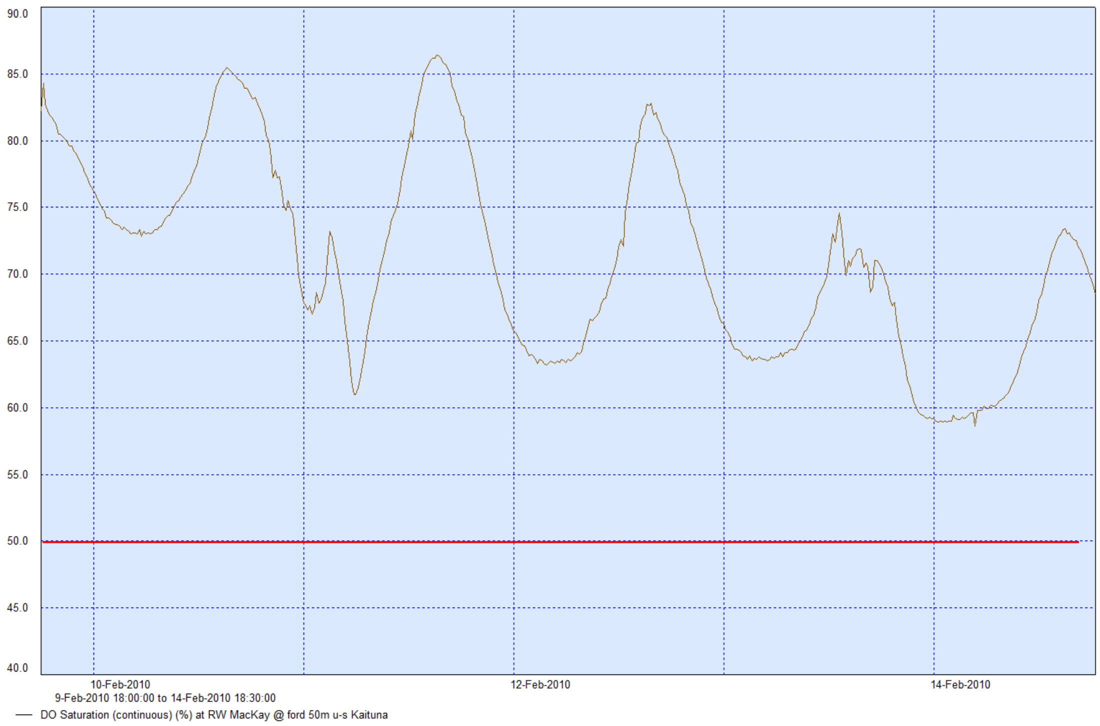


Figure 132. Dissolved oxygen saturation at Mackay Creek 50 m upstream Kaituna River measured continuously from 9-14 February, 2010. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

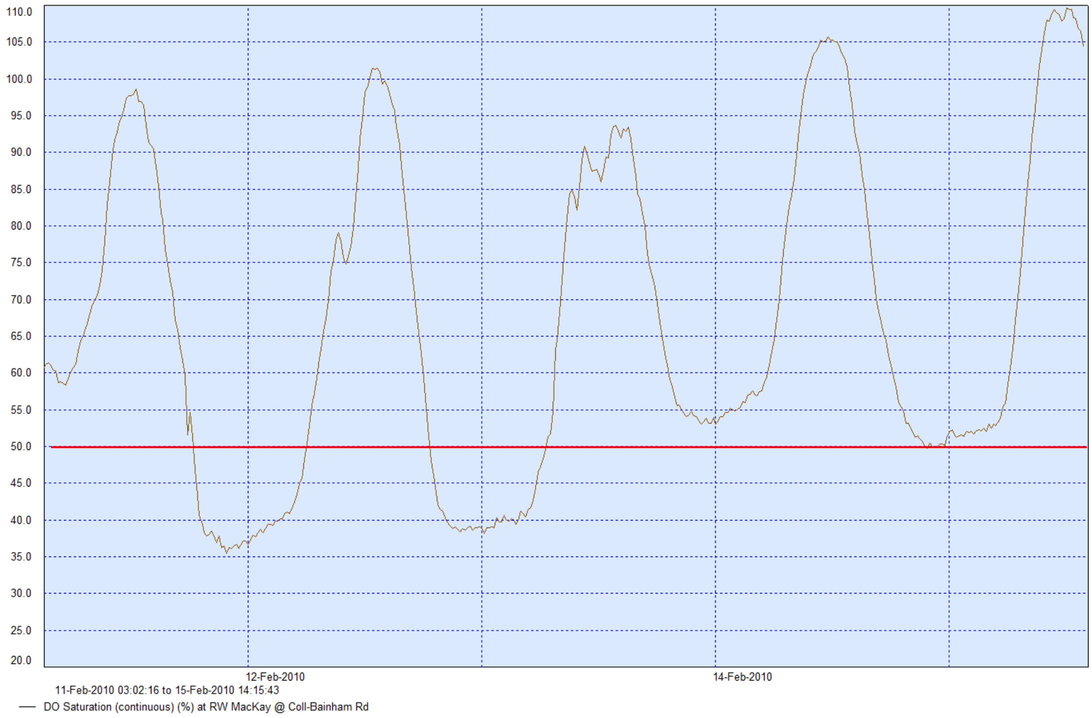


Figure 133. Dissolved oxygen saturation at Mackay Creek at Collingwood-Bainham Rd measured continuously from 11-15 February, 2010. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Figure 134. Dissolved oxygen saturation at Mackay Creek Collingwood-Bainham Rd measured continuously from 17-23 February, 2014. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

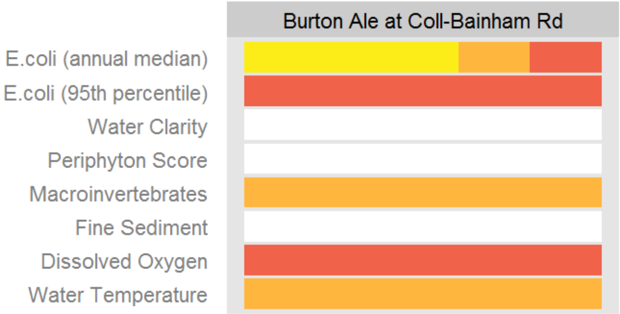
Burton Ale Creek

Burton Ale Ck 60 m downstream Collingwood-Bainham Rd, looking downstream (Left: February 2005)

This creek, and the neighbouring James Cutting Creek, are unique in that their catchments are dominated by farmland on pakihi soils. Phosphorus retention in these soils is extremely low (1%) leading to high rates of leaching of this nutrient. The land use in this catchment is dominated by dairy and sheep farming. **Stream habitat is generally good** i.e. natural meander, water depth variety, cobbly/bouldery bed and regenerating riparian scrub overhanging the stream. Reasonable numbers of native fish reside in this stream where the habitat is good, including short-jaw kokopu and red-fin bully. Because of the limited mixing of water from this creek with the Aorere River at the mouth, and that swimming and other contact recreation occurs in the area near the mouth, this creek has been assessed against the contact recreation guidelines. The total area of this catchment is 802 ha with 247 ha in sheep and beef, 450 ha in dairy farming and about 65 ha in scrub and forest. The flow in this creek can be as little as 5 L/sec in the driest summers.

This stream receives tertiary treated **effluent from the Collingwood wastewater treatment plant** (WWTP) and diffuse discharges from dairy farmland.

In 2010-12 this catchment was the subject of an investigation to determine the source of high levels of disease-causing organisms and high cover of filamentous green algae (James and Mullis 2012).



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

High concentrations of faecal indicator bacteria are found in this stream, as measured monthly over all flows as part of resource consent monitoring of the WWTP (Figure 135; 2014 annual median =

475 *E.coli*/100 ml). A failure of the wetland tertiary treatment system of the WWTP resulted in a temporary failure (subsequently fixed) to comply with the discharge consent in 2009. The concentrations of faecal indicator bacteria are usually very similar upstream of the WWTP discharge, compared to downstream. This suggests the likely cause of this situation is activities on dairy farms, such as regular stock crossings, upstream in the catchment. It is understood that bridging these regular crossings is imminent.

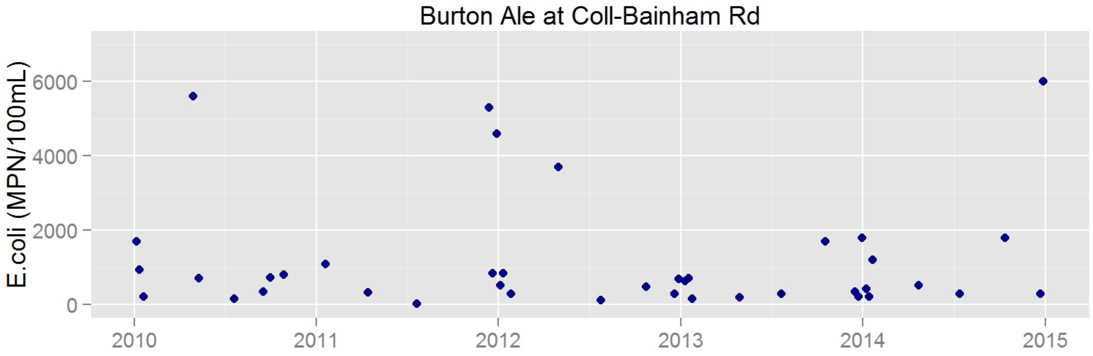


Figure 135. Concentration of *E. coli* downstream of the Collingwood wastewater treatment plant discharge into Burton Ale Ck from 2010 to 2015. Two samples greater than 7000 E. coli/100ml excluded (from 2010 and 2013).

Filamentous green algae cover is high at times during summer (median summer: 25% cover, 5 of 15 samples over 30% cover and 2 of 15 samples over 90% cover at Collingwood-Bainham Rd). There was often a marked difference between filamentous green algae cover in tributaries dominated by dairy (e.g. Southern tributary) versus those dominated by sheep farming (Northern tributary) (see photos below).

Dissolved reactive phosphorus concentrations were very high in this stream (in dry weather typically 0.1-0.2g/m^3; 10-20 times guidelines) even during dry periods as a result of farming on pakihi soils with very low phosphorus retention. The ANZECC guidelines are 0.01 g/m^3 and excessive algal growth usually occurs when dissolved reactive phosphorus concentrations are over 0.015-0.03g/m^3 in the presence of sufficient nitrogen. Wet weather phosphorus concentrations were 2-3 times higher than dry weather. A tributary of Burton Ale Creek that is dominated by sheep farming has dissolved reactive phosphorus concentrations less than half that of tributaries dominated by dairy farming. At lower catchment sites increases in phosphorus concentrations were often matched by increases in dissolved nitrogen (r^2=0.47). **Nitrate-N concentrations are relatively low** (typically around 0.1-0.3g/m^3 except for two sites on two southern tributaries where they cross Plain Rd where they were 0.4-0.6 g/m^3).

Above left: Northern tributary Burton Ale Ck (9 February 2012). Above right: Southern tributary Burton Ale Ck (9 February 2012)

Macroinvertebrate metrics indicate moderate pollution (MCI 90-100; Cawthron reports related to sewage treatment plant consent monitoring).

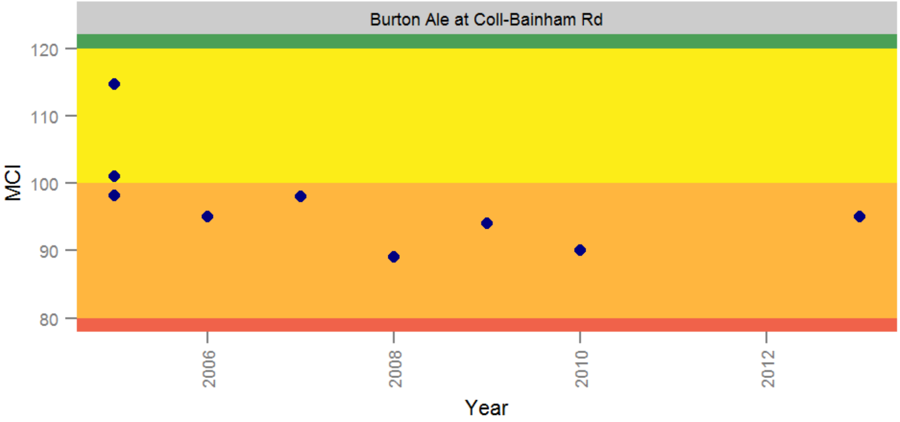


Figure 136. Macroinvertebrate community index (MCI) results for Burton Ale at Coll-Bainham Rd. Data from sewage treatment plant consent monitoring.

Burton Ale Ck at Collingwood-Bainham Rd, looking downstream (Left: January 2009, Right: February 2015).

Dissolved oxygen levels get very low in summer in the lower part of the catchment (daily minima of about 40% saturation over a week in March 2015; Figure 137). There appears to be very little re-aeration in this stream at this site as shown by the deep ‘V’ shape at the bottom of the daily curve. This shows that this stream is vulnerable to discharges with high biological oxygen demand in these lower reaches. Spot measurements in earlier years have occasionally recorded a low result.

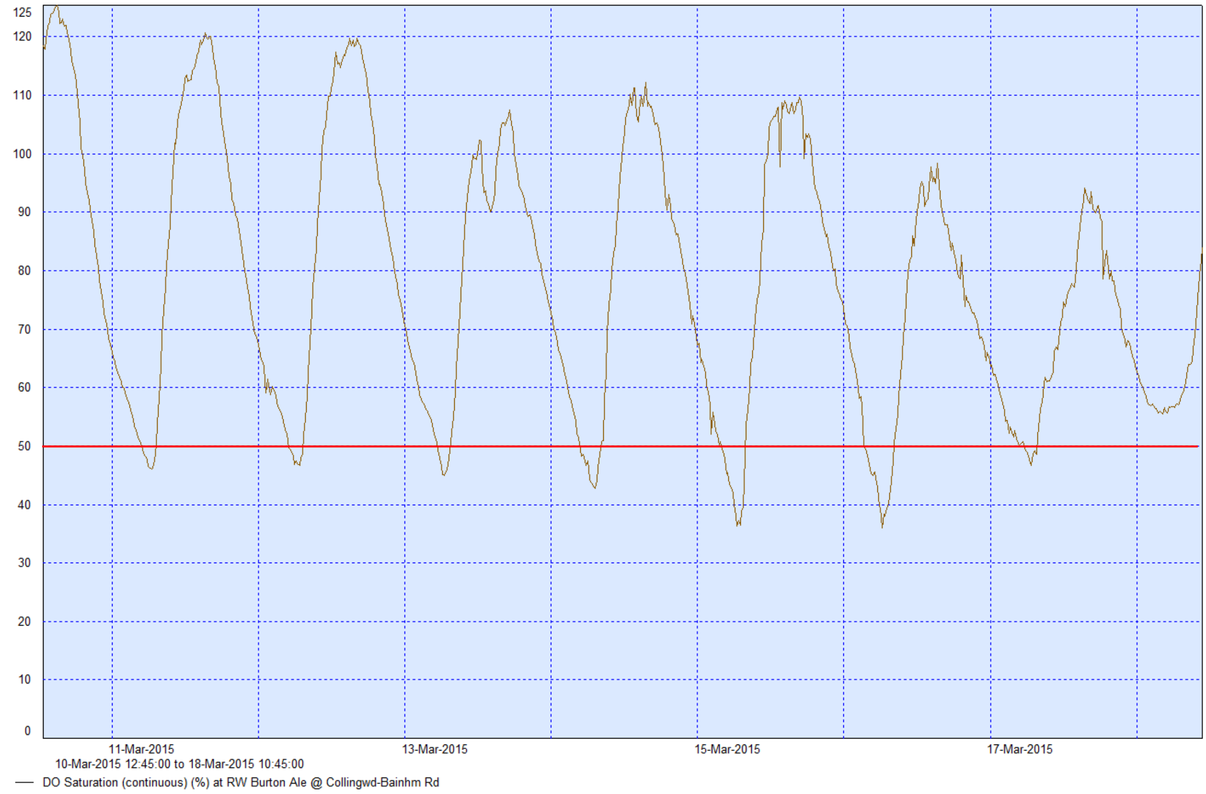
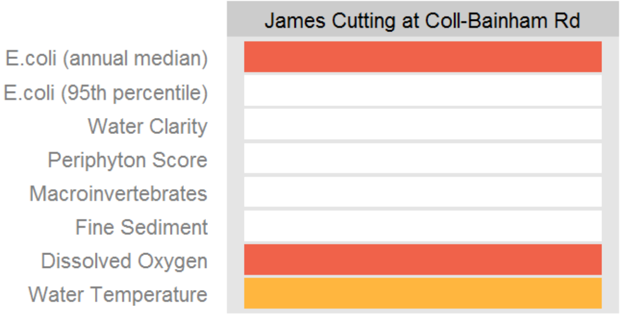


Figure 137. Dissolved oxygen saturation at Burton Ale Creek Collingwood-Bainham Rd measured continuously from 10-18 February, 2014. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

James Cutting Creek

This small creek flows through a catchment comprising, almost entirely, **dairy farmland.** The flow in this creek can be as little as 1 L/sec in the driest summers.

The creek has **high concentrations of faecal indicator bacteria** (median: 900 *E.coli*/100 ml and ~40% of samples above stock drinking guidelines at base flow). The few high flow samples recorded levels of faecal indicator bacteria over 10,000 *E. coli* /100 ml.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

This creek has **extensive cover of filamentous green algae,** indicating high nutrient concentrations. Like Burton Ale Creek, dissolved reactive phosphorus concentrations are high in this creek. In 2008 the riparian zone upstream of Collingwood-Bainham Rd was fenced and planted, which has improved habitat greatly. However, water quality would particularly benefit from the installation of wetlands in key parts of the catchment, to act as filter strips. In 2014-15 further planting was carried out after the diversion of the creek for the 800 m reach downstream of Collingwood-Bainham Rd.

Riparian planting began in 2007 and by 2015 the shading and habitat in the stream was greatly improved and is a credit to those involved in restoring in stream habitat and overland flow interception (see photo sequence below).

James Cutting Ck viewing upstream of Collingwood-Bainham Rd (from left October 2005, January 2009, and February 2015 right).

Daily minimum dissolved oxygen concentrations in the creek measured over eight days in March 2015 were consistently very low (Figure 138), and indicate either significant groundwater influence or high biological demand within the waterway. Given the high daily maxima it is likely that aquatic plants in the unshaded parts of the waterway (upstream of the area planted) are the cause.

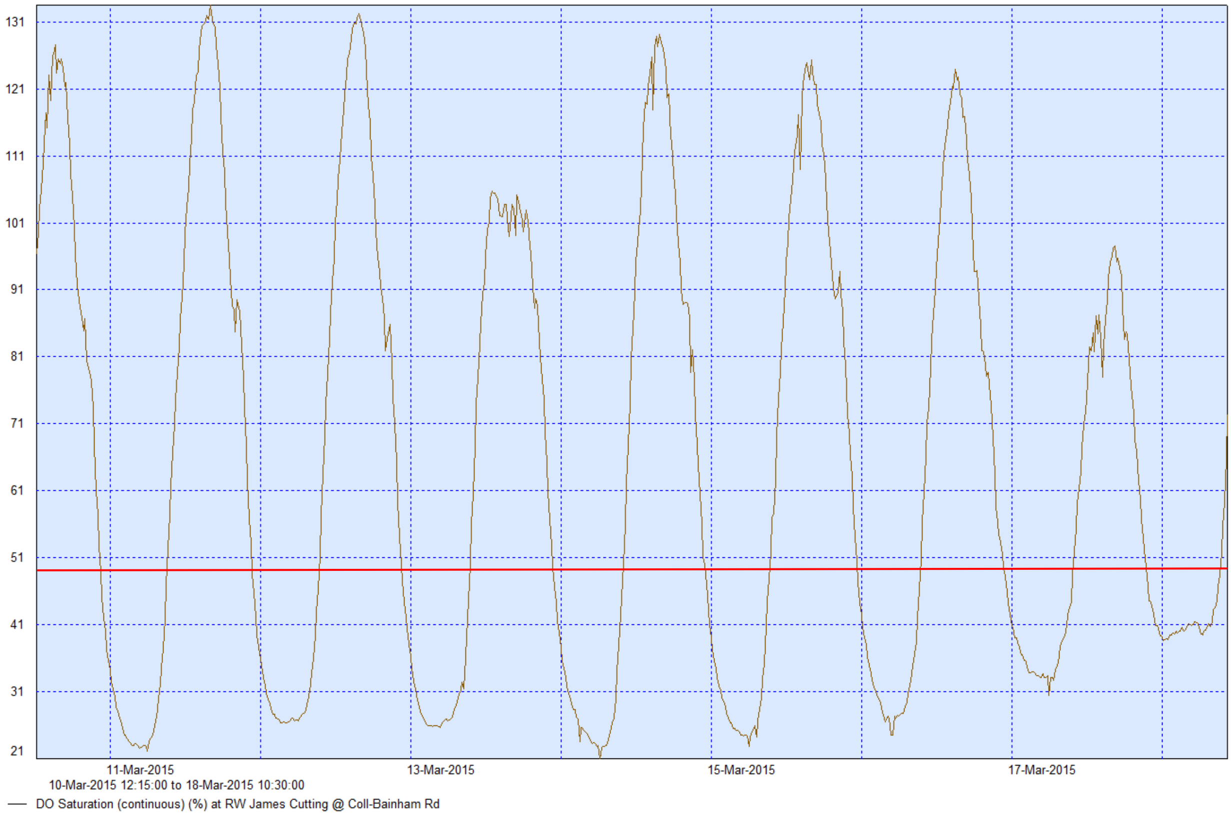


Figure 138. Dissolved oxygen saturation at James Cutting Creek at Collingwood-Bainham Rd measured continuously from 10-18 March, 2015. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Water temperatures (midpoint of daily maxima and daily mean) were **within guidelines** (Figure 139) and appear to be similar to the few spot sample records available (no semi-continuous data has been collected other than shown here).

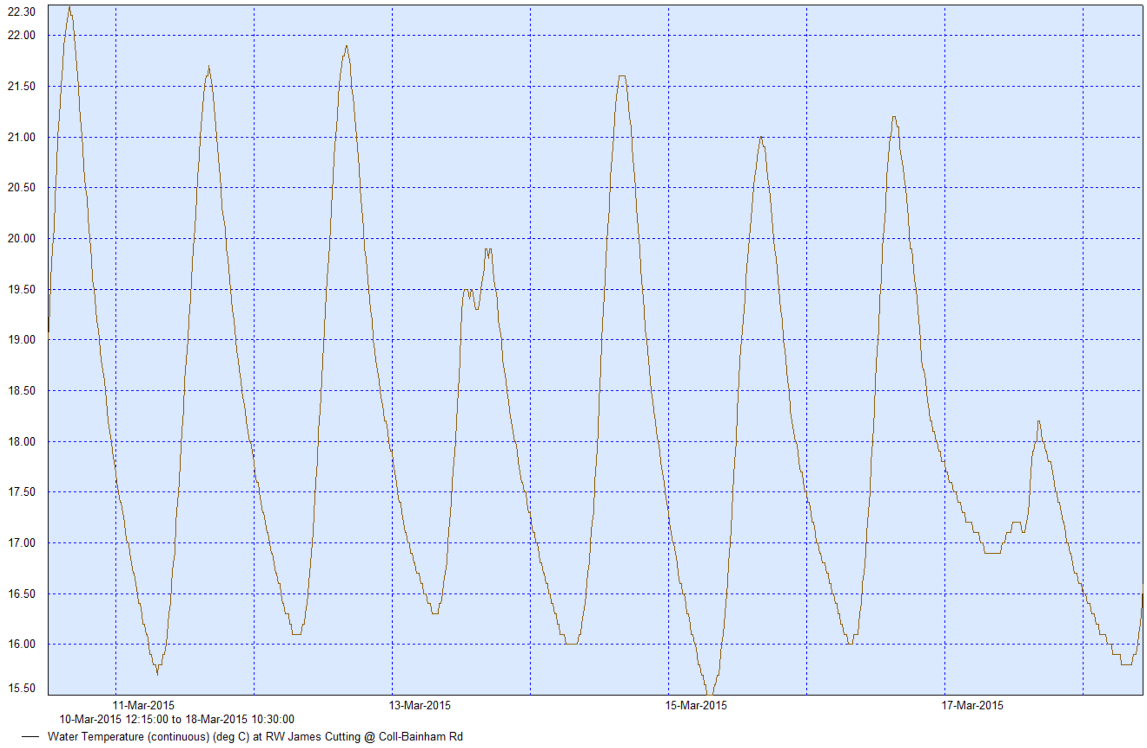


Figure 139. Water temperature at James Cutting Creek at Collingwood-Bainham Rd measured continuously from 10-18 March, 2015.

Conductivity peaked regularly late in the evening and again in the morning (Figure 140).

Figure 140. Conductivity at James Cutting Creek at Collingwood-Bainham Rd measured continuously from 10-18 March, 2015.

Pakawau (Yellow Pine) Creek, Pakawau Inlet

Yellow Pine Creek is the largest stream flowing into the Pakawau Inlet and has a catchment with over 3.5 km^2 in native bush (total catchment area of 4.4 km^2 catchment). Exotic forestry makes up most of the remaining land use. A natural waterfall about 900 m upstream of the estuary is most likely a barrier to all non-climbing fish, however Koaro, banded kokopu, eel and koura are abundant in the catchment upstream of the waterfall.

Historic coal mining occurred in this catchment and there is heavy iron-oxide precipitate where old adits (horizontal mining tunnels) discharge and a light iron oxide coating on the bed of 'Culvert 15 Creek' a small tributary (second creek up from the mouth on the true right). The pH of the discharges from the adits into this creek ranged from 5.3-6.7 so are mildly acidic.


Yellow Pine Creek ~1.2 km upstream estuary (Sept 2013)

A heavy discharge of fine sediment (estimated at least 50 m^3) to Yellow-Pine Creek occurred in 2012 as a result of logging and tracking operations causing slips and erosion into 'Culvert 15 Creek' (James, Sept 2013). Sampling the effects of this discharge took place in February 2013. Fine sediment volumes in Yellow Pine Creek were much higher downstream of Culvert 15 Creek (7.5 m^3/100 m reach), compared to upstream (0.2 m^3/100 m reach). This activity resulted in a prosecution for the company involved.

It would appear from the results of macroinvertebrate samples that the effects of mining masked that of any affect of the forestry operation. No mayfly, stonefly or caddisfly taxa were found in the sample downstream of mining but were found upstream of the mining and forestry. The acid mine drainage index showed a marked difference between the upstream reference site (above known mining discharges) and downstream of the mining discharges. The macroinvertebrate community index (MCI) also showed this trend but not to a degree considered significant. Four koura were caught upstream of forestry and mining but not in any of the downstream samples.

Overall the results from macroinvertebrate samples collected in February 2013 show an adverse effect on Yellow Pine Creek from the Culvert 15 Stream, but these effects are not considered large. Downstream of the Culvert 15 Stream confluence compared to upstream there was a 30% reduction (14 compared to 20) in the pollution sensitive taxa (mayflies, stoneflies, and caddisflies) and a macroinvertebrate community index (MCI) of 10 points lower.

Above left: Yellow Pine Creek tributary ('Culvert 15 Ck') showing the effect of mine drainage. Above right: 'Culvert 15 Ck' showing a sediment depth of about 300 mm. Middle: Yellow Pine Ck downstream of Culvert 15 Ck sediment depths 100-200 mm.

Pakawau-Puponga Creeks

Extremely **low dissolved oxygen** was found in several streams (flowing out of culverts 74-80) on the Pakawau-Puponga Road (about half way between these settlements; 3.5-4 km north-west of Pakawau Hall) in summer. Anoxic or near anoxic conditions were found at some of these sites. Bubbles of **Methane** were observed in the area and a white precipitate was noticed on the cobbles and sand at the mouth which is likely to be caused by a natural methane discharge related to coal deposits in the area. These bubbles may be a symptom of anoxia (i.e. produced by methanogenic bacteria living under anoxic conditions). Summer flows in most of these streams are low but not stagnant (0.5-2 L/sec).

The streams are fully fenced and the stream's headwaters are in native bush. A large-scale riparian planting programme was initiated in 2009 (see photos below).

Buller Water Management Area

This area includes the whole of the Buller catchment that is within the Tasman District boundary (Figure **141**). This includes from Nelson Lakes, Owen, Matiri, Mangles, Matakitaki, Maruia Valley up to Boundary Rd, and Buller main stem about half way to Lyell from Maruia confluence. As of 2015, a ‘Freshwater Management Unit’ (FMU) under the ‘National Policy Statement for Freshwater Management’ has not yet been formally set up for this area. Like the Takaka and Waimea FMU’s that have been operating from 2014, there will be a collaborative governance group from the community tasked with making recommendations for limits on water quality and quantity.

Between 2010 and 2014, there were eight River Water Quality sites monitored in the Buller Water Management Area. There were no reference sites in this Water Management Area.

The Buller catchment contains the majority (about 35 km) of braided river in the district, a habitat that is used by the following threatened birds: Black-billed gull, Banded dotterel, Oystercatchers, and Black-fronted tern. The main braided sections exist in the Buller from Teetotal Flat to Kawatiri Junction, lower Howard River, and Matakitaki River from Nardoo Creek to Mammoth Flat.

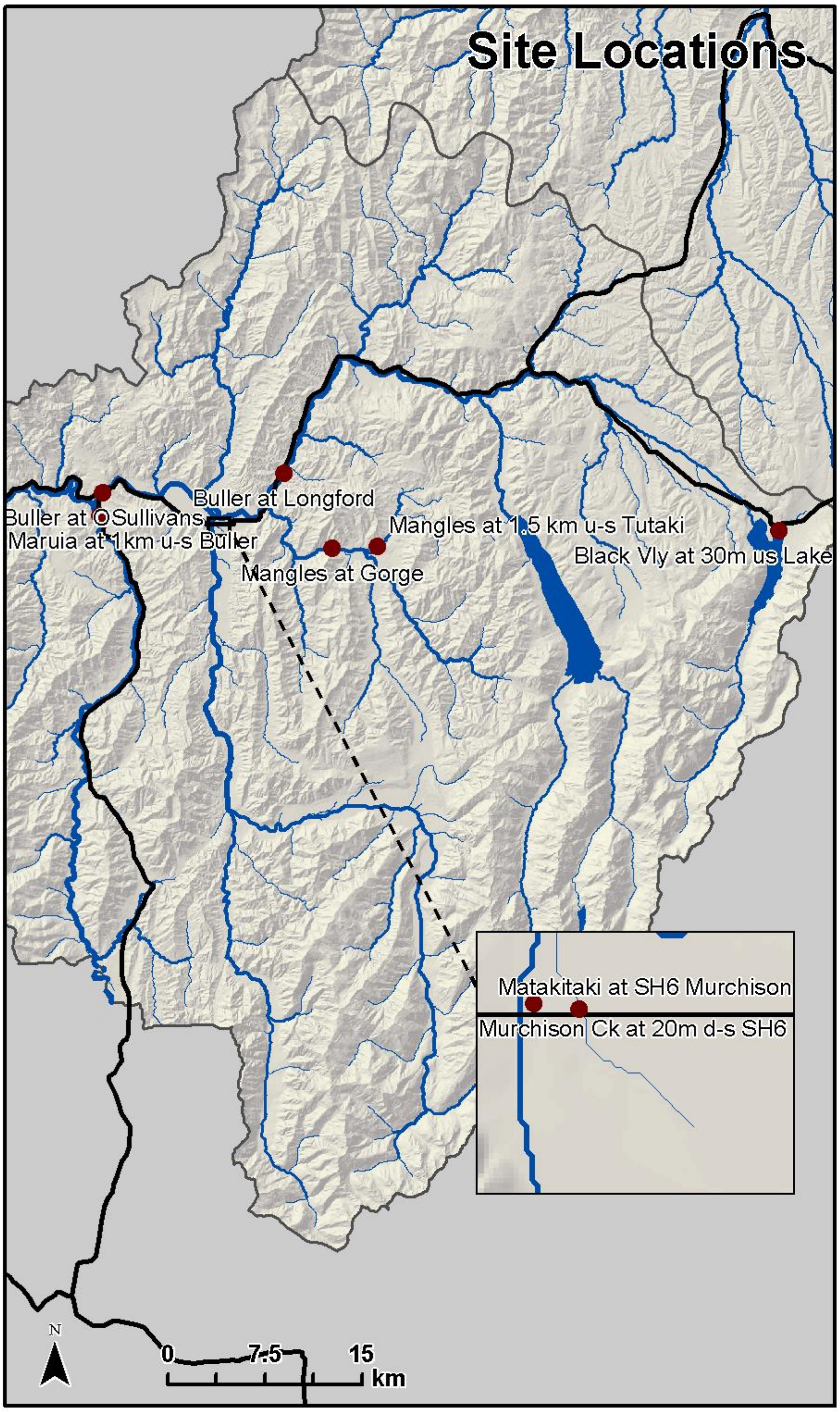


Figure 141**. River Water Quality sites in the Buller Water Management Area. Note the Buller at Longford site is sampled at over the full range of river flows whereas the other sites are not.**

Discussion of Specific Catchments/Areas

This section describes the more **notable aspects of water quality in a given catchment, actions taking place, and recommendations** for further action.

The key to the colour-coding for each water quality attribute state (A to D) is shown to the right. The cut-offs used for each attribute are shown in Table 23.

Attribute State
🟩 A (Excellent)
🟨 B
🟧 C
🟥 D (Poor)

The dataset used to determine the attribute states was collected at base-flow over the period from 2010-2014 unless a comment is made otherwise. White (no colouring) indicates there are no data available to determine the attribute state.

Trends in water quality attributes are reported if they are statistically significant (p-value<0.05) and ecologically meaningful (RSKSE>1%). An increasing trend can have a positive or negative effect on the stream ecosystem, depending on the attribute. To indicate the ecosystem effect of the trend, we have used a smile symbol (☺) for improving trends and a frown symbol (☹) for degrading trends.

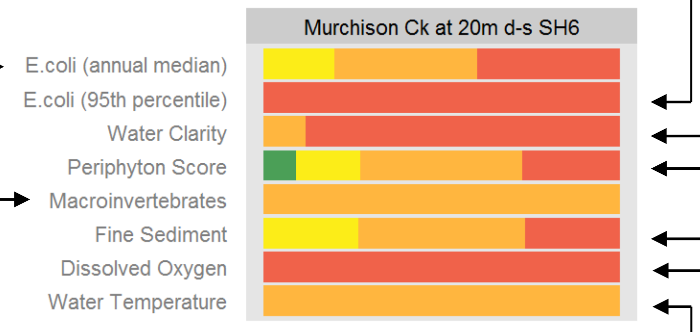
Table 23. Numerical attribute states for each water quality attribute for the protection of river ecosystem health, aesthetics, and human health. Attributes highlighted in blue are included in the National Policy Statement for Freshwater Management (NPSFM 2014).

Attribute	Statistic	Units	Attribute State				Source
			A	B	C	D	
Water clarity	Single measurement	m	≥5	3 - 5	1.6 - 3	<1.6	-
Turbidity	Single measurement	NTU	≤5.6	>5.6	N/A	N/A	ANZECC & ARMCANZ (2000)
Resuspendable solids	Shuffle score (1 to 5)	N/A	1	2	3	≥4	-
Dissolved oxygen concentration	7-day mean minimum	g/m^3	≥8	7 - 8	5 - 7	<5	NPSFM (2014)
	Lowest 1-day minimum	g/m^3	≥7.5	5 - 7.5	4 - 5	<4	
Water Temperature	Midpoint of daily mean and daily maximum	°C	≤18	18 - 20	20 - 24	>24	Davies-Colley et al. (2013)
pH	Single measurement	N/A	6.5 - 8.5	5 - 6.5, 8.5 - 9	>5 or >9	N/A	-
Ammonia-N	Annual median	g/m^3	≤0.03	0.03 – 0.24	0.24 - 1.3	>1.3	NPSFM (2014)
	Annual maximum	g/m^3	≤0.05	0.05 - 0.4	0.4 - 2.2	>2.2	
Nitrate-N	Annual median	g/m^3	≤1.0	1.0 - 2.4	2.4 – 6.9	>6.9	NPSFM (2014)
	Annual 95th percentile	g/m^3	≤1.5	1.5 - 3.5	3.5 - 9.8	>9.8	
Dissolved reactive phosphorus	Single measurement	g/m^3	<0.01	≥0.01	N/A	N/A	ANZECC & ARMCANZ (2000)
E. coli	Annual median	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	NPSFM (2014)
	95th percentile	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	
Macroinvertebrates	MCI	N/A	≥120	100 - 120	80 - 100	<80	Stark & Maxted (2007)
	SQMCI	N/A	≥6	5 - 6	4 - 5	<4	
Phormidium	Percentage cover	%	<20	≥20	N/A	N/A	MfE (2009)
Filamentous green algae	Percentage cover	%	<10	10-19	20-29	>30	Biggs and Kilroy (2000)
Periphyton	Periphyton score (1 to 10)	N/A	≥8	6 - 8	5 - 6	< 5	-

How to read a site summary

The site summaries in this report are based on data collected quarterly (monthly for selected sites) from 2010-14, with two exceptions: (1) macroinvertebrate community index values were from 2011-2015 and (2) dissolved oxygen measurements were taken over several days in a summer period from 2005-2015.

The rows of a site summary represent water quality attributes. The colours indicate attribute states **A** (very good), **B** (good), **C** (fair) **D** (poor).



Proportion of periphyton scores in each attribute state.

Proportion of water clarity measurements (m) in each attribute state.

Attribute state for the 95th percentile *E. coli* concentration. Minimum 10 samples.

Attribute states for the annual median *E. coli* concentration. No minimum sample size.

Proportion of macroinvertebrate community index (MCI) values in each attribute state.

Attribute state for the highest midpoint of daily mean and daily maximum temperature from a continuous record.

Attribute state for the mean minimum dissolved oxygen concentration over 3 or more days during summer. For sites with fewer than 3 days of continuous measurements, the 1-day minimum value was used.

Proportion of resuspendable solids (fine sediment) scores in each attribute state.

Water Clarity

Water clarity in the main stem and major tributaries of the Buller catchment is good or excellent (Band A >5 m or B > 3 m) for the majority of the record (Figure 142). The lower Matakitaki site at SH6 has some lowered water clarity at times, most likely due to on-going slips in the upper Glenroy catchment. Water clarity in the upper Matakitaki (upstream of Glenroy River) is exceptionally high (maximum recorded 24.5 m upstream of Nardoo Creek). Slips in the upper Howard River (within Nelson Lakes National Park) appear to have affected the Longford water clarity results and slips in indigenous forest in the upper Mangles catchment have affected the Mangles water clarity results. Unlike the Matakitaki, these slips appear to have stabilised and water clarity is improving again. The Buller at Longford site is sampled over the full range of river flows, wheras the other sites are not.

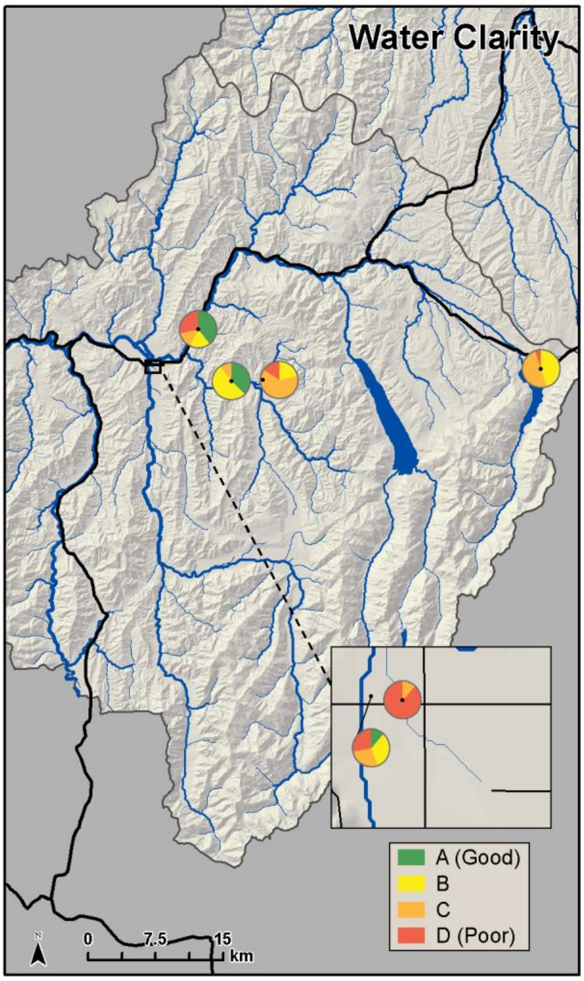


Figure 142. Proportion of water clarity records in each attribute state (A to D) for river water quality sites in the Buller Water Management Area (sites shown have a minimum of 10 samples).

Disease-causing organisms

At all sites monitored in the Buller Water Management Area, except Murchison Creek, the annual median *E. coli* concentrations were in the A band (less than 260 *E. coli*/100 ml) (Figure 143).

The overall median for Murchison Creek at SH6 was 960 (2005-2015). The annual median *E. coli* concentration for this site was over double the National Bottom Line (1000 *E. coli*/100 ml) in 2010 (median value 2200 *E. coli*/100 ml). The annual median value for 2014 was right on the National Bottom Line (median value 1000 *E. coli*/100 ml). These results make this site the worst performing, in terms of *E. coli* concentrations, in the Tasman District.

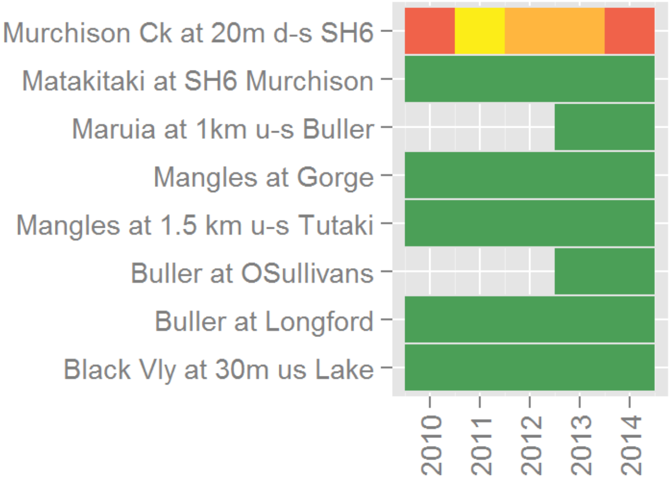


Figure 143. Tile plot of annual median *E. coli* values for sites in the Buller Water Management Area. Colours indicate attribute states A (green), B (yellow), C (orange) and D (red). Blanks indicate insufficient data (less than three records in a given year).

Filamentous Green Algae Cover & Periphyton Score

The coverage of filamentous green algae was most often in the A band (less than 10% coverage) or B band (less than 30% coverage) at all sites in the Buller Water Management Area (Figure 144). The exceptions were one record of moderate filamentous algae coverage from Mangles at 1.5km u-s Tutaki and two records of high coverage (greater than 50%) from Murchison Ck at 20 m d-s SH6. A similar pattern was seen in the periphyton scores[9]. That is, most periphyton scores were in the A or B bands across the Buller Water Management Area. Murchison Ck at 20 m d-s SH6 had a high proportion of periphyton scores in the C (< 30% coverage) or D bands (> 30% coverage), indicating poor water quality at this site.

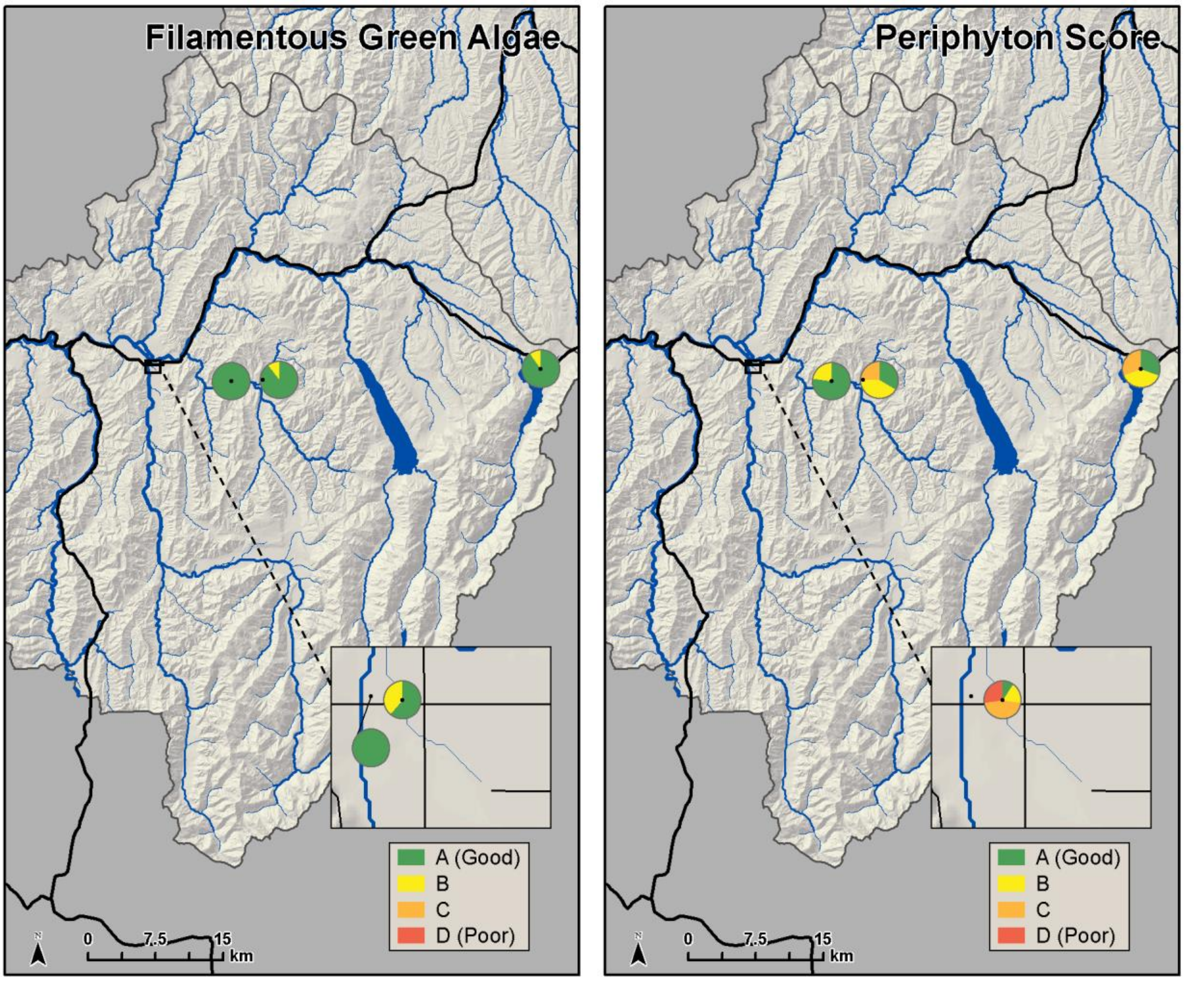


Figure 144. Coverage of filamentous green algae greater than 2cm in length (left) and periphyton community score (right) for sites in the Buller Water Management Area. Pie charts show the proportion of estimates in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

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[9] Rapid Assessment Method 2, NZ Periphyton Monitoring Manual, 2000.

Nutrients

At the two sites with nutrient results, Black Vly at 30 m u-s Lake and Buller at Longford, annual median nitrate concentrations were in band A (less than 1 g/m^3). Annual median ammonia concentrations at both sites were in band A (less than 0.03 g/m^3) and dissolved reactive phosphorus concentrations were satisfactory (less than 0.01 g/m^3).

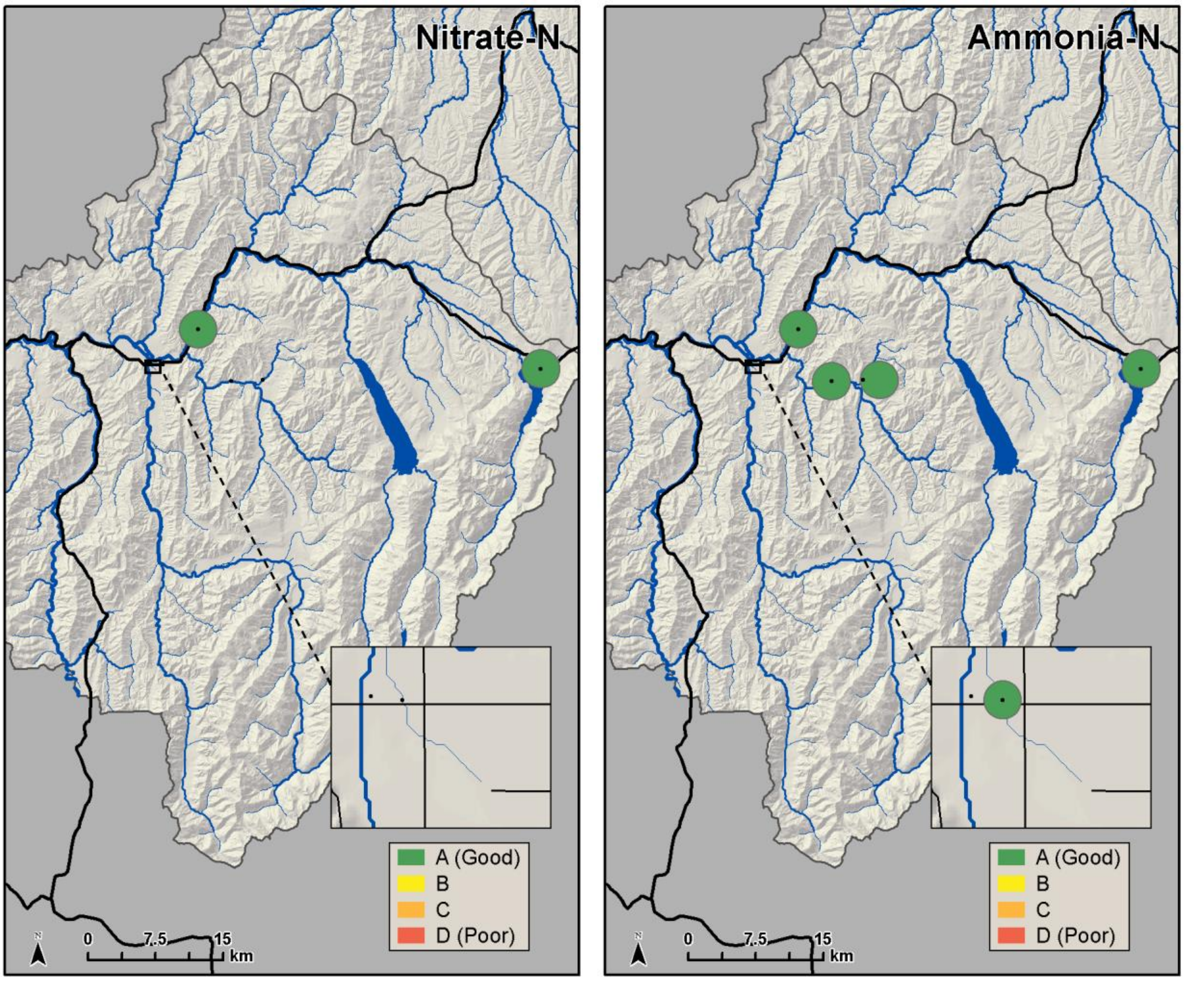


Figure 145. Nitrate (left) and ammonia (right) concentrations for sites in the Buller Water Management Area. Pie charts show the proportion of annual medians in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data). Note that nitrate was not sampled in the Matakitaki and Murchison Creek in the inset box.

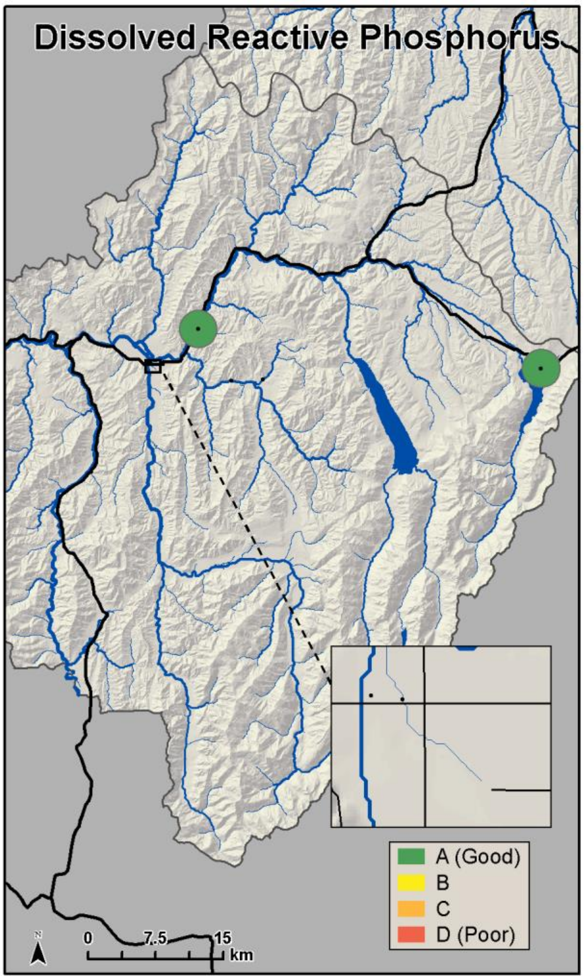


Figure 146. Dissolved reactive phosphorus concentrations for sites in the Buller Water Management Area. Pie charts show the proportion of records in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

Resuspendable Sediment

There were several ‘poor’ re-suspendable solids scores recorded here (only 4 out of 18 scores were less than 2) indicating persistent problems with fine sediment deposition (Figure 147). While re-suspendable solids were not assessed in pools, fine sediment depths were measured with some areas over 500 mm. This is a rapid test and therefore can be easily achieved at a larger number of sites than the volumetric SBSV which is generally carried out at sites where there are sediment issues.

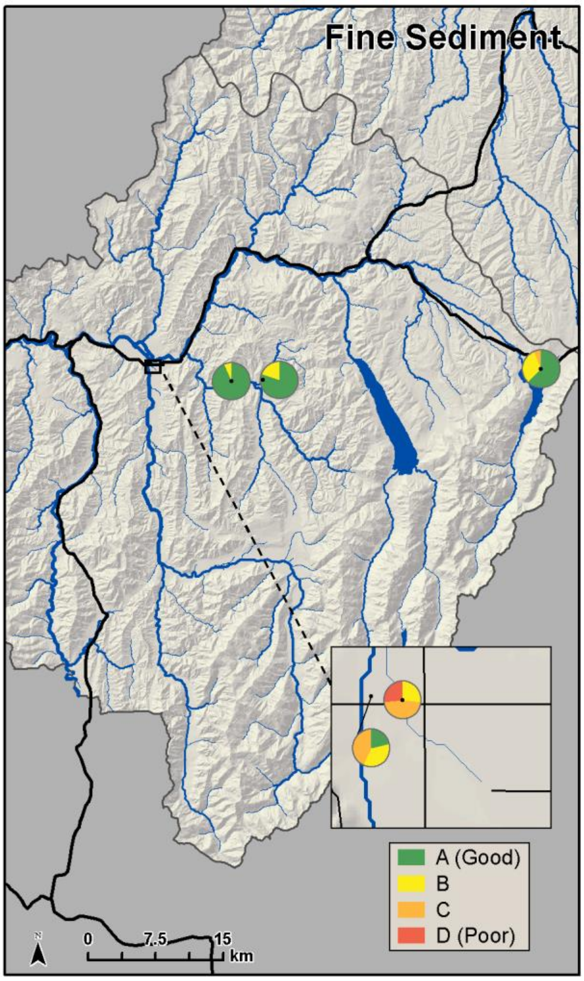


Figure 147. Proportion of resuspendable solids scores in each attribute state (A to D) for sites in the Buller Water Management Area.

Murchison Ck at 20 m d-s SH6 was the only site in the Buller Water Management Area for which there were records of volumetric SBSV (Figure 148). At this site, there was no difference in mean volumetric SBSV between 2013 and 2015.

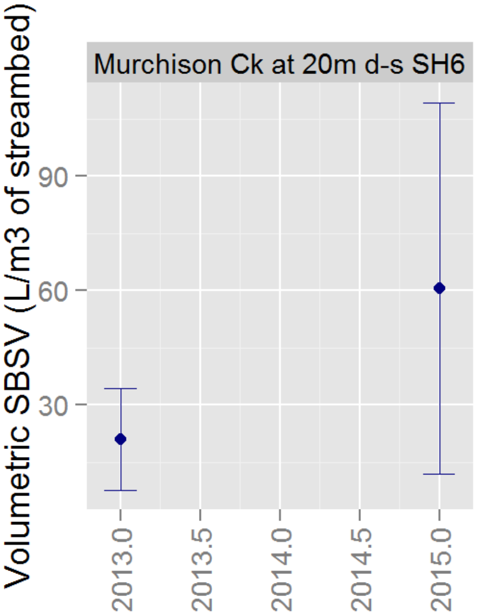


Figure 148. Mean volumetric suspendable benthic sediment volume (SBSV) from 2013 to 2015 (sampled during summer). The error bars show 95% confidence intervals.

Macroinvertebrate Community

At least three macroinvertebrate samples were collected from five sites in the Buller catchment from 2001 to March 2015 (Figure 149). During this period, the invertebrate community for Matakitaki at SH6 Murchison was excellent (MCI greater than 119, SQMCI greater than 6, n = 4). The most recent MCI result for this was within 5 units of the excellent quality class which allows it to be included in that quality class (using the fuzzy boundary concept recommended by Stark & Maxted, 2007). The invertebrate communities from Black Vly at 30 m u/s Lake and Mangles at Gorge were in the highest quality class for MCI but fell into the second-highest quality class for SQMCI in recent years. This should not be interpreted as a meaningful decline in the invertebrate community, however, as there is considerable variation in both MCI and SQMCI results for these sites.

By far, the worst performing site in terms of invertebrate community indices was Murchison Ck at 20 m d-s SH6. At this site, MCI values in the last five years were fair (between 80 and 100) and SQMCI values alternated between fair and poor. The most recent results suggested a downward trend in the health of the invertebrate community at this site.

The decline in macroinvertebrate metrics at the Buller at Longford site over the period between 2006-2010 could be due to slips in the upper Howard River catchment, that appear to have stabilised now.

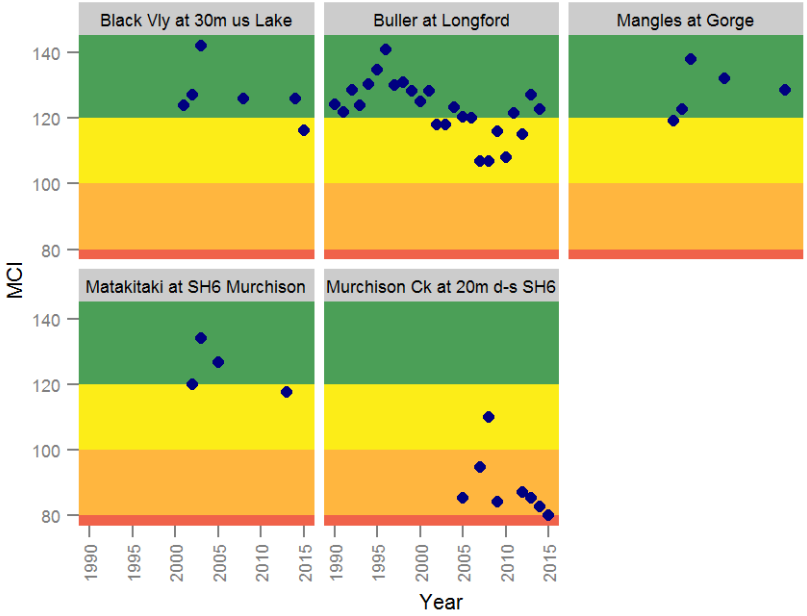


Figure 149. Macroinvertebrate community index (MCI) scores between 1990 and March 2015 for sites in the Buller Water Management Area. The background colours indicate quality classes: excellent (green), good (yellow), fair (orange) and poor (red).

Trends in the Buller WMA

The trend analysis for the Buller Water Management Area revealed meaningful changes in water clarity and Nitrate-N measurements over time (Table 24). Specifically, there was a degradation in Nitrate-N at Buller at Longford over the previous 10 years. Water clarity measurements improved at three sites and degraded at one site (Matakitaki at SH6 Murchison).

Table 24. Water quality trend results for sites in the Buller Water Management Area over the 10-year period 2005 to 2014 (highlighted in blue) and over the full record (from 15 to 26 years depending on the site). Seasonal Kendall trend tests were used for *E. coli* concentrations, water clarity measurements and nutrient concentrations (Ammonia-N, Nitrate-N and DRP). Mann-Kendall trend tests were used for invertebrate community metrics (for the NRWQN site Buller at Longford). The trends shown are significant ($p < 0.05$), meaningful (RSKSE > 1% per year) and the change in value between the start and end of the trend line is greater than the detection limit for the attribute (refer to the Methods sections for the detection limits). Statistics are shown in the Appendices.

Site name	Attribute	Effect ☺ ☹	N obs	N years
Buller at Longford	Nitrate-N	☹	117	10
Buller at Longford	QMCI	☹	25	25
Buller at Longford	Water Clarity	☺	312	26
Mangles at 1.5 km u-s Tutaki	Water Clarity	☺	36	10
Mangles at Gorge	Water Clarity	☺	37	10
Matakitaki at SH6 Murchison	Water Clarity	☹	37	10

A degrading trend in QMCI (quantitative MCI) was found for Buller at Longford over the past 25 years. There was also a significant (but not meaningful) decline in MCI at this site over the same time period ($p = 0.004$, RSKSE = -0.5% per year). Because the MCI results at this site have been consistently in attribute state A (MCI > 120) or B (MCI > 100), however, we are not currently concerned about the modest declining trends in QMCI and MCI at this site.

Black Valley Stream

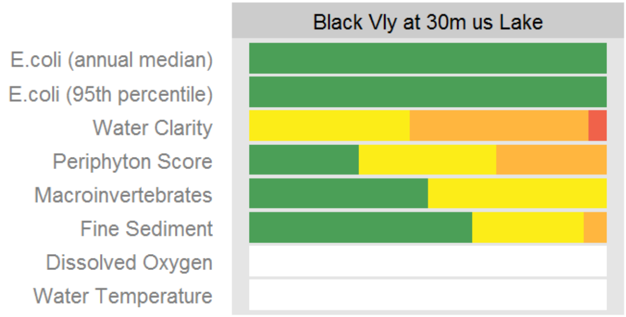
While a large proportion of this catchment is mountain-fed, there is about 70 ha of wetlands including Black Valley Swamp (60 ha). Swimming is popular in Kerr Bay including around the mouth of this stream.

Above: Black Valley Stream, looking upstream from Kerr Bay Rd (May 2008)

Black Valley stream has generally had **very good water quality** since the late 1990's when the St Arnaud sewage treatment scheme was installed. Median is 15 *E.coli*/100 ml, which is equivalent to a pristine forested stream.

The Easter 2005 rains caused the largest amount of flooding in this area in decades and caused a large amount of bank erosion in Black Valley Stream.

The **macroinvertebrate community** remained 'excellent' three years after this event but has **declined to 'good'** since. We cannot rule out this decline could be due to increasing urbanisation in the catchment as many of the common chemicals used in the urban area are deleterious to freshwater organisms (e.g. hydrocarbons, concrete residues, cleaning agents).



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

Willow clearance and riparian plant replacement with natives on Black Valley Stream downstream SH63.
From top: November 2002, October 2012, May 2015.

	Black Valley Stream
River Environment Class	Cool Wet Alluvial Hill-fed Pasture (probably includes wetland)
Catchment area (km²)	18
Predominant land use upstream	Beach forest 50% (9 km²) Wetland 33% (6km²) Pasture 15% (2.7 km²) Residential 1.5% (0.3 km²)
Mean annual rainfall (mm)	1433
Mean annual flow (l/sec)*	NA
Lowest recorded flow (l/sec)	39 (Feb 2014)
Water quality record	Monthly: 200-present

* Estimate from WRENZ 2013. NA = not available

Above left: Looking downstream to mouth. Above right: About 100 m upstream of the lake

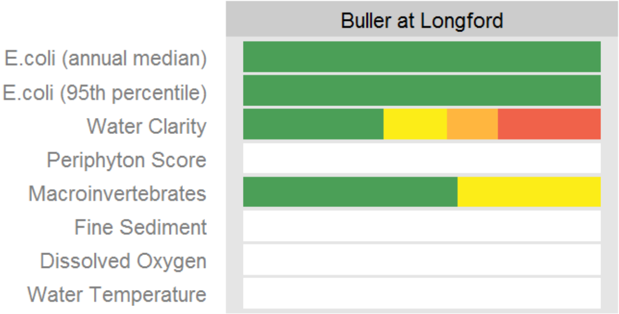
Buller River / Kawatiri Main Stem

Buller River near Harleys Rock, downstream Howard River (September 2007). Clear water from the Buller River can be seen on the left of the photo (true right), and turbid water from the Howard River is coming in on the right of the photo (true left).

The Buller River has the fifth largest average flow in New Zealand but has the highest flood flow record. It is 170km long with a 6500km^2 catchment. It is recognised for its outstanding wild and scenic values, as well as swimming, fishing and whitewater recreation (e.g. kayaking and rafting). A Water Conservation Order was placed on many parts of this catchment in 2001 placing restrictions on damming, altering flow, or water quality.

The Buller at Longford site upstream of Murchison is part of the National River Water Quality Network and is sampled monthly and at all flows. The Buller is used for contact recreation (kayaking) over most flows <100 m^3/sec. The **Buller River main stem is generally reasonably clear** (median water clarity: 3.64 m; data from 2010-2015), and is increasing at 1.8% of the median value per year. This is despite the existence of major active slips within the conservation estate in the upper Howard Valley, causing very poor water clarity at times in the Howard River.

Heavy fine sediment load to the Howard River, and then on down the Buller River, occurred for several years from 2006. Farmers in the Howard Valley (Basher, G. *pers. comm.*) explained that the sediment was coming from the true right branch of the Howard River about 6-8 km upstream of Howard Head Station, after a heavy downpour in 2006. While the stream mostly cleared within a week, the river became very discoloured after 20-30 mm of rain, and this lasts for 2-3 days with the effect slowly diminishing over the 5-6 years afterwards.



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

Macroinvertebrate condition seems to have been adversely affected by this sediment as all metrics have showed a degrading trend from 2006 and then a slow and full recovery by 2014.

The river is suitable for contact recreation approximately 95% of the time (Figure 150; 2014 annual median = 19 *E.coli* /100 ml). This 95% suitability is still too low in our view because it is a river that is very popular for whitewater kayaking (particularly from Gowan Bridge to below the Tasman District Council boundary) and swimming (particularly at the Riverview Campground in Murchison).

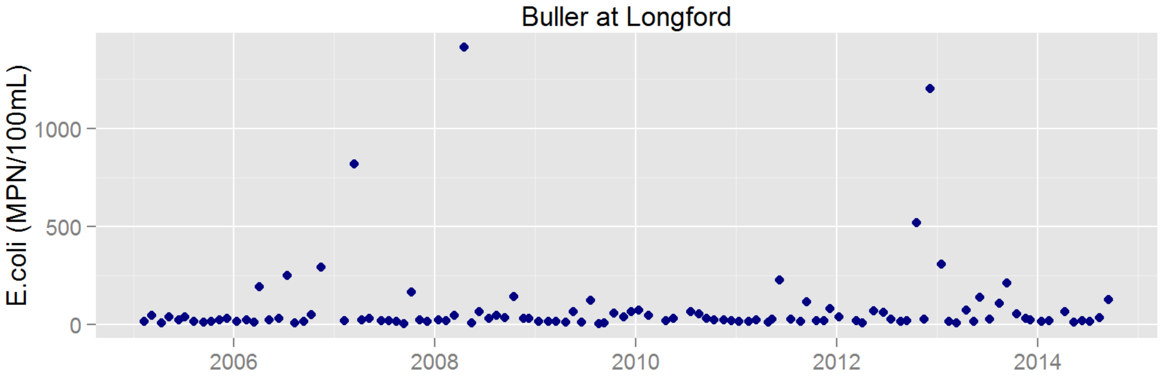


Figure 150. Buller at Longford *E. coli* concentration data from 2005 to 2014.

Nitrate concentrations are increasing at this site but are currently at relatively low levels (less than 1 g/m3; Figure 151).

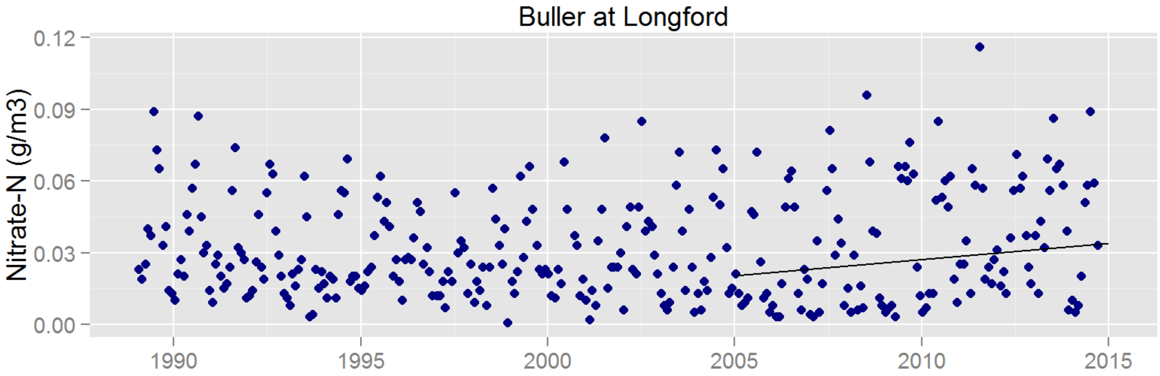


Figure 151. Buller at Longford Nitrate-N concentration data with 10-year trend line (p = 0.0005, RSKSE = 4.9% per year). There was no significant meaningful trend over the full record (26 years).

Howard River at Howard Head Station (February 2008), looking south to the Angelus Range where the source of the sediment is located.

	Buller at Longford
River Environment Class	Cool Wet Hard sedimentary Hill-fed Indigenous forest
Catchment area (km^2)	1410
Predominant land use upstream	Indigenous forest and alpine tussock and rock covers >85%
Mean annual rainfall (mm)	1560
Mean flow (l/sec)	73,829
Median flow (l/sec)	56,156
7-day Mean Annual Low flow (l/sec)	22,370
Lowest recorded flow (l/sec)	13,380
Water quality record	Monthly: 1989-present (NIWA) *E.coli* data from 2005

Mangles and Tutaki Rivers

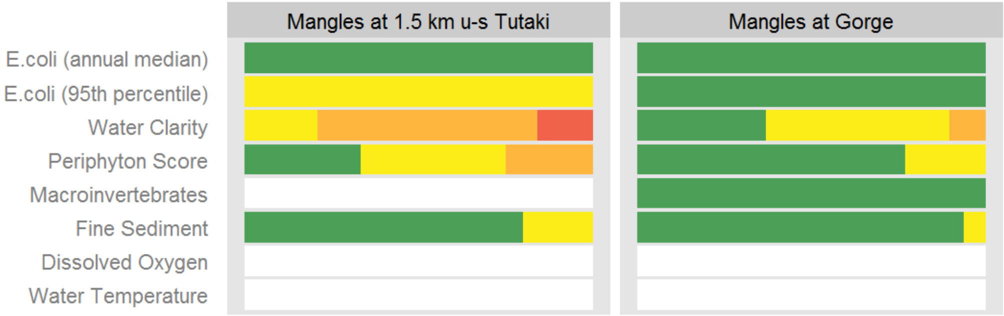
The bed in the upper reaches of this river has relatively high sand content as the geology is within the southern-most extent of the Separation Point Granite geological belt. This belt extends from the northern end of Abel Tasman National Park, including much of the tributaries of the west bank of the Motueka River, Lower Wangapeka, and the Sherry River.

Above: Mangles Rv at Gorge (May 2008).

The Mangles River is popular for whitewater boating activity when water levels are higher (usually in spring or within a few days after rain), and is a popular waterway for trout fishing

Faecal indicator bacteria concentrations in this river are generally low. The Mangles River upstream of the Tutaki River is consistently higher (median: 100 *E. coli* /100 ml) than downstream (Gorge site median: 40 *E. coli* /100 ml). This is because of dilution from the Tutaki River which has higher flows than the Mangles and lower average *E.coli* concentrations. Faecal indicator bacteria were sampled in the Tutaki River from 2002-03 and 2011-12 and were found to be very low (median 23 and 21 *E. coli* /100 ml respectively).
After 20-30 mm of rain in the catchment the site can quickly become unsuitable for contact recreation (typically 1000-2000 *E.coli*/100 ml; sampled over three flood events in 2012-13) but fortunately becomes suitable again within 24-36 hours of the rain ceasing.

Water clarity shows a similar pattern, with the upstream Tutaki site being, on average, almost half (median: 1.8 m) that of the downstream site (median: 3.5 m).



**Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.**

Slips in the steep native forest land in the Upper Mangles (Te Patiti Stream) were responsible for relatively heavy fine sediment loading to this river in the 2010 to 2011 period. This effect seems to be reducing now.

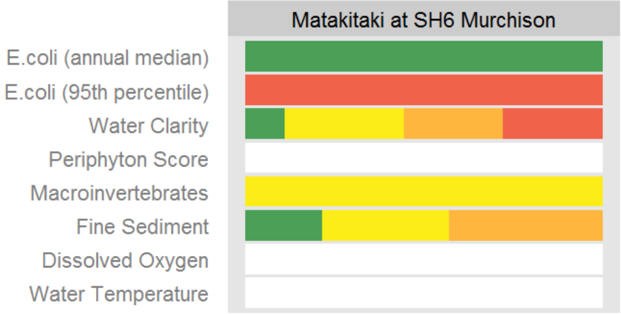
Mangles Rv u-s Tutaki Rv (April 2005)

	Mangles at Gorge
River Environment Class	Cool Wet Soft sedimentary (Separation Pt granite component also) Hill-fed Indigenous forest
Catchment area (km^2)	61
Predominant land use upstream	Indigenous forest ~78%
Mean annual rainfall (mm)	1600 (est)
Mean flow (l/sec)	9,860
Median Flow(l/sec)	6,019
7-day Mean Annual Low Flow (l/sec)	2,160
Lowest recorded flow	1,018
Water quality record	2000-present

Matakitaki River

The Matakitaki River is fed from mountainous terrain largely within Nelson Lakes National Park. The river is one of the most popular for whitewater kayaking in New Zealand (>2000 paddler days/year) and is used all year round and at all flows. Trout fishing is also popular in the catchment. Braided sections of the waterway are used for nesting by black-fronted terns, banded dotterel, black-billed gulls and oystercatchers.

Matakitaki River downstream SH6 (April 2005)



Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

Water in this river is **extremely clear in the upper reaches** (median/max water clarity: 10.15 m/24.5 m upstream of Horse Terrace), but less clear downstream of the Glenroy River (median clarity at SH6: 2.7 m for 2010-2015 compared to 3.6 m for 2000-2015). Natural slips in the upper Glenroy River catchment (30 km upstream of the confluence of the Matakitaki River) are the cause of this lowered water clarity and high levels of fine sediment deposited on and within the bed. Sediment discharges from alluvial gold mining operations downstream of the Glenroy have been minimal over the period from 2005 to 2015 due to limited mining activity. This fine sediment is grey sandy silt with reasonable amounts of mica. As a consequence of the excessive sediment, the macroinvertebrate community condition is poor in this lower part of the river. Water clarity is degrading at this site (Figure 152).

E. coli concentrations at base flows are very low (median: 5 *E. coli*/100 m*l*) but at high flows levels are high enough (typically 2000-5000 *E. coli*/100 m*l*) to be a potential health risk if boaters inadvertently consume river water.

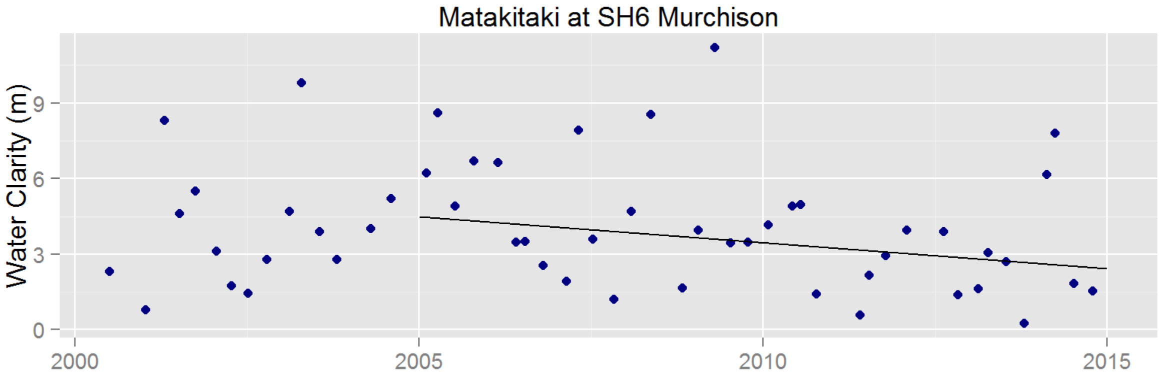


Figure 152. Matakitaki at SH6 Murchison water clarity data with 10-year trend line (p = 0.01, RSKSE = -5.9% per year). No significant meaningful trend was detected over the full record (15 years).

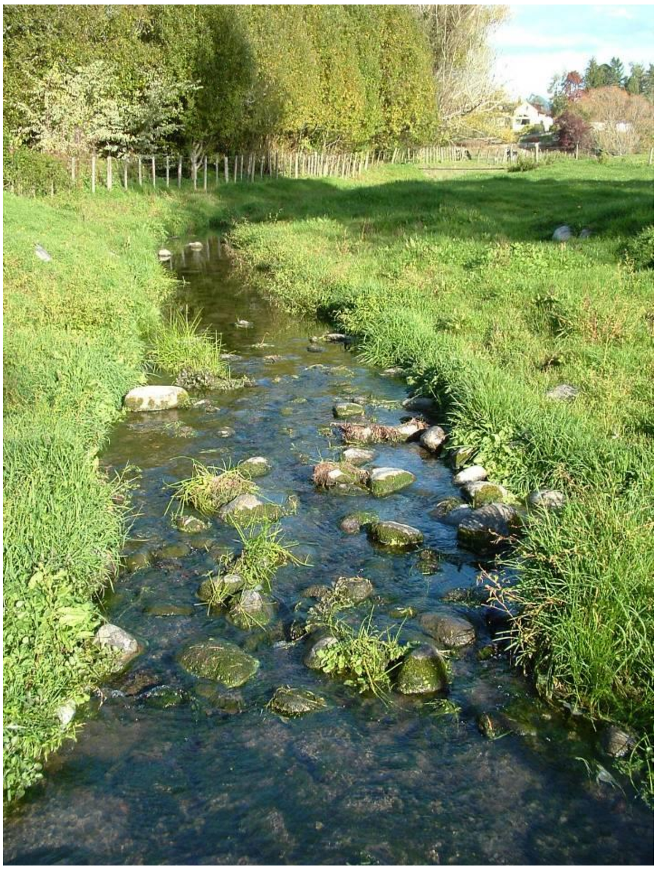
Fine sediment deposits, common at this site.

Table 25. Summary statistics for the Matakitaki River

	Matakitaki River at SH6
River Environment Class	Cool Extremely Wet Soft sedimentary Hill-fed Indigenous forest
Catchment area (km²)	898.7
Predominant land use upstream	Beach forest 65% Bare and tussock alpine 30% Pasture 5%
Mean annual rainfall (mm)	1,999*
Mean annual flow (l/sec)	54,266*
Lowest recorded flow	NA
Water quality record	

* Estimate from WRENZ 2013. NA = not available

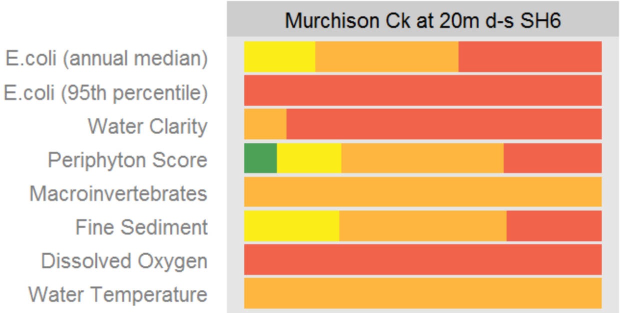
Murchison (Ned's) Creek, Murchison



Above: Murchison Creek 20 m upstream SH6 (April 2012)

This spring-fed creek drains farmland and residential areas to the south and east of Murchison.

The creek has the **highest level of faecal indicator bacteria of any long-term monitoring site in the District** (median from 2010-2015: 960 *E.coli*/100 ml). The main risk to public health is through contact with creek water and then handling food, or by any other means consuming some of the contaminated water. This is particularly likely for children who play in the creek and people handling dogs after they have been in the creek. Faecal contamination appears to be widespread in this catchment with high levels in both the eastern (median 1950 *E.coli*/100 ml) and western tributaries (3300 *E.coli*/100 ml) (based on 4-6 samples). These branches confluence about 180 m upstream of SH6. Both branches have recorded *E.coli* concentrations over five times the secondary contact standard (Figure 153) for median *E.coli* at the various sampling points in the catchment).



Site data summary plot. Colours indicate attribute states from A (good) to D (poor). Refer to the interpretation guide for full details.

Microbial source tracking shows ruminant animal and wildfowl faecal matter as the main contributors to the faecal contaminant load in the stream. A human faecal source was found in September 2009, but not in March 2014 or May 2015 (dog faeces were not detected in the latter sample either). This shows that streams flowing through farmland in the catchment need to be fenced, and crossings need to be culverted to mitigate this issue. A stock truck effluent discharge to ground, about 2km due east of the SH6 monitoring site (mid-way along and about 50 m north of Canton Rd), may also contribute to the high faecal indicator bacteria levels (however, this operation ceased in June 2013, Lon Bradley, *pers com.*). Being spring-fed, this stream should be relatively clear, but water clarity is relatively low (median: 1.3 m). Deposits of sediment in the creek bed are over 500 mm thick in pools and deep runs within the creek.

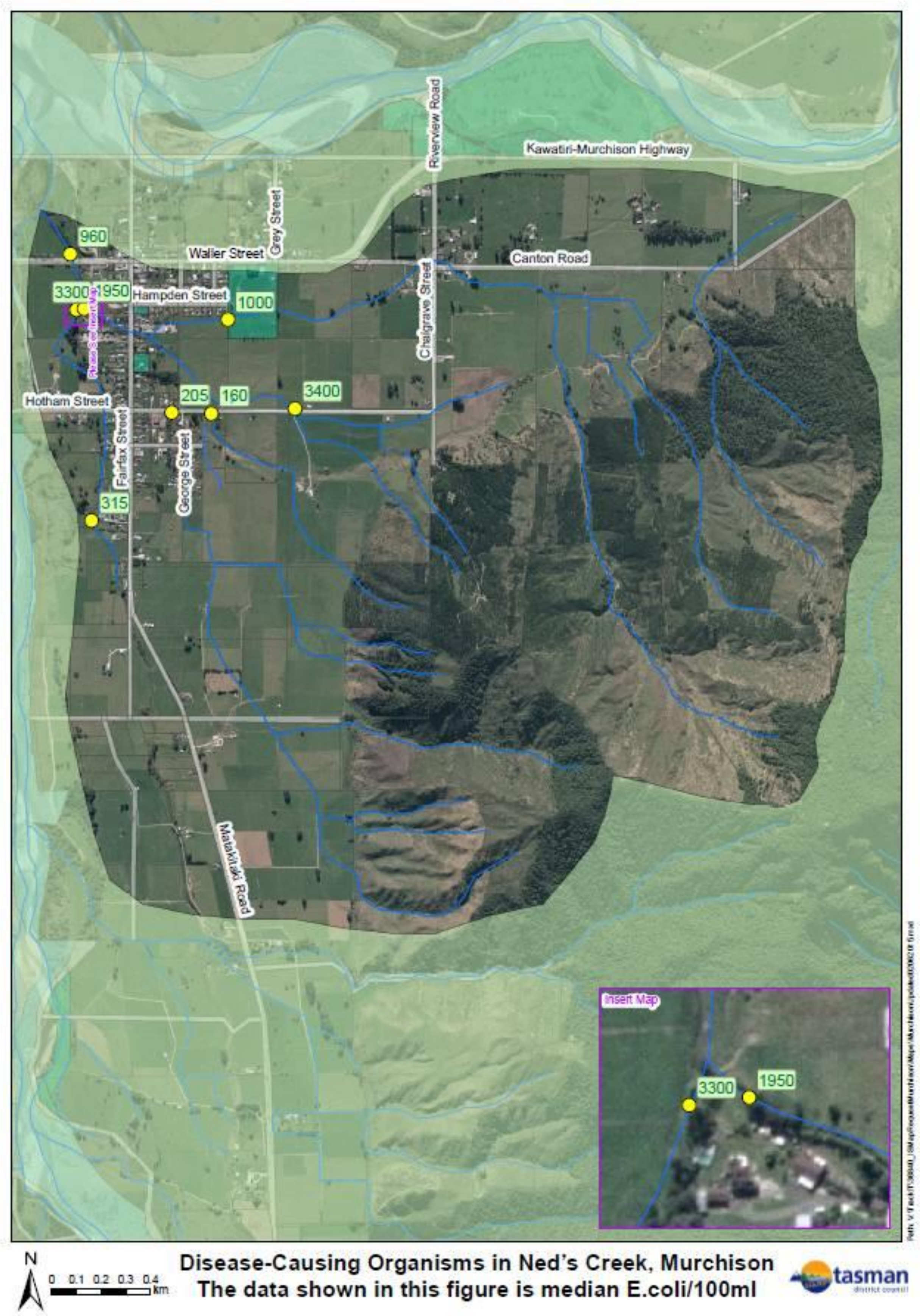


Figure 153 Disease-causing organisms (median *E.coli*/100 ml) in Murchison (Ned's) Creek

Above: Murchison (Ned's) Creek showing the thick fine sediment deposits and filamentous green algae (April 2012)

Fine sediment volume has averaged 60L/m^3 of the bed volume, which is considerable. The main sources of fine sediment are from discharges from transport operations (a truck wash facility discharging into the creek ceased in 2008), slips in the hill country to the south east of the township in 2011-12 (this loading of sediment reduced to almost nil by mid 2014, even at high flows) and farming activities (particularly stock trampling the banks). Its spring-fed nature, with relatively stable flows, also means that sediment in the creek is not readily flushed.

Dissolved oxygen levels were measured in March 2015. Daily minima were found to be generally over 60% (Figure 154). The spiky and erratic dissolved oxygen plot shown below is probably due to rain in the middle of the monitoring period (6 March), and possibly stock in the stream. This pattern is more closely reflected in the dissolved oxygen profile for the true right branch upstream of Fairfax (Figure 156) rather than the true left branch at the Kiwi Park Motels (Figure 155).

Figure 154. Dissolved oxygen % saturation at Murchison Creek 20 m downstream of SH6 from 2-9 March 2015. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

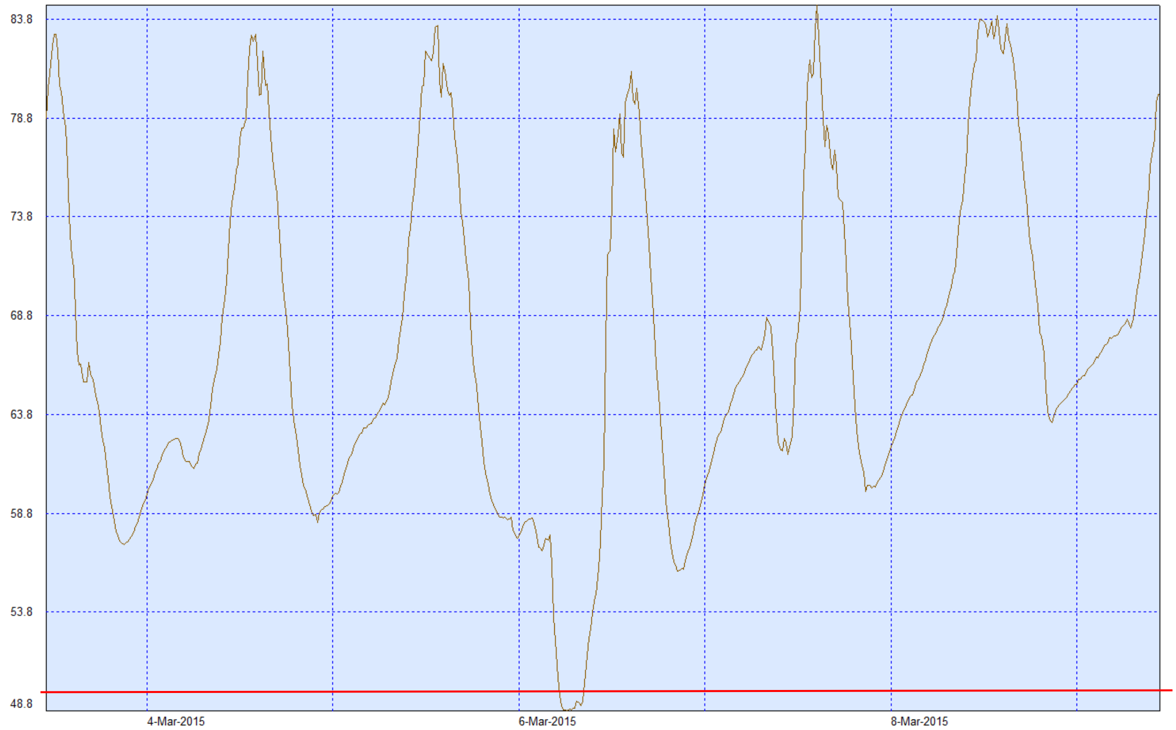


Figure 155. Dissolved oxygen % saturation at Murchison Creek upstream Kiwi Park Motel from 2-9 March 2015. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

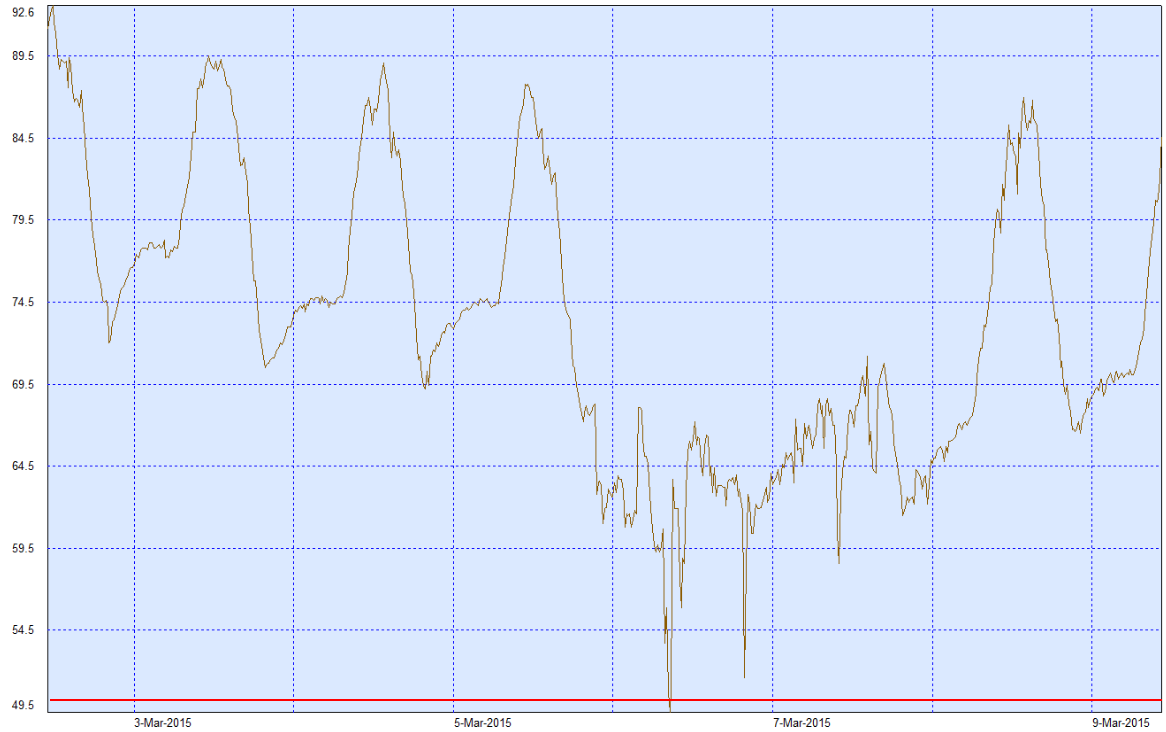


Figure 156. Dissolved oxygen % saturation at Murchison Creek upstream Fairfax St from 2-9 March 2015. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Periphyton cover in this creek from spring to autumn exceeds 30% for almost 30% of samples. Scums are a common occurrence.

The Buller Catchment Group led by Landcare Trust and farming leaders has begun work to improve water quality in this catchment. Council provided a total of 4.22 km of fencing materials to landowners in this catchment (2005-10: 1.27 km, 2010-15: 2.95km).

Left and bottom-right: Murchison Ck at SH6 (October 2008 and April 2007 (sediment discharge event)). Top right: Murchison Ck upstream Fairfax St (July 2007).

Table 26. Summary statistics for Murchison Creek

	Murchison Ck
River Environment Class	Cool Wet Alluvial Spring-fed Pasture
Catchment area (km^2)	7.8
Predominant land use upstream	Pasture 56% (4.4 km^2) Forestry & scrub on hills 37% (2.9 km^2) Urban 6.5% (0.5 km^2)
Mean annual rainfall (mm)	1,555*
Mean annual flow (l/sec)	270*
Lowest recorded flow (l/sec)	8.7
Water quality record	2005-present

* Estimate from WRENZ 2013. NA = not available

Doughboy Creek, 5km west of Murchison

Above: Doughboy Creek 200 m upstream Buller River (March 2014)

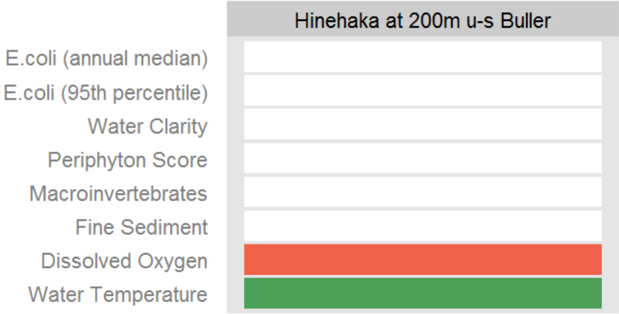
This small to medium sized hill-fed stream has a catchment area of almost 20 km^2 about 80% of which is in native forest, about 10% in sheep and beef farming in the headwaters and 7.5% in intensive dairy farming on Four Rivers Plain. The stream bed has a high proportion of sand due to the geology of the catchment.

While this stream has only been sampled since late 2013, *E.coli* concentrations are all within the stock drinking water guideline (median: 182 *E.coli*/100 ml). Water clarity is relatively poor in this stream at base flows (median: 1.7 m) when it would be expected to be good because of the relatively large amount of indigenous forest in the catchment.

Resuspendable solids (Shuffle method) indicate moderate-high levels of fine sediment in the bed. Conductivity is consistently high ranging from 240-250 µS/cm indicating a strong groundwater influence or other discharges from the catchment. Heavy trampling and soil loss from banks of this stream were evident in winter 2013. Better stock exclusion is required along this stream.

‘Hinehaka’ Creek, 5 km west of Murchison

This creek is fed by groundwater from under the Four Rivers Plain. The land cover is almost completely intensive pasture in this 1.7 km^2 catchment. There are almost no riparian trees in the catchment. In summer the bed is covered with aquatic plants rooted in the bed. Spring-fed creeks draining to large rivers often have high value to fish, particularly for rearing of juveniles and providing refuge during floods. These creeks are relatively rare in Tasman District.



	Hinehaka at 200m u-s Buller
E.coli (annual median)	
E.coli (95th percentile)	
Water Clarity	
Periphyton Score	
Macroinvertebrates	
Fine Sediment	
Dissolved Oxygen	🟥
Water Temperature	🟩

Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

While this stream has only been sampled since late 2013, most *E.coli* concentrations are within stock drinking water (median: 355 *E.coli*/100 ml, maxima: 1600 *E.coli*/100 ml). It is very difficult to measure water clarity in this waterway due to the growth of aquatic plants across the whole channel for much of the year and fine sediment depths of about 500 mm.

View upstream of Hinehaka Road (February 2014), note the lack of adequate riparian fencing.

Left: View upstream of Hinehaka Road (July 2014). Right: view downstream (October 2014)

Dissolved oxygen levels were measured in March 2015 revealing very low daily minima (commonly below 10% (Figure 157). The spiky and erratic dissolved oxygen plot shown below is probably due to rain in the middle of the monitoring period (6 March), and possibly stock in the stream. In a stream with almost complete coverage of aquatic plants it would be expected that daily maxima dissolved oxygen would be supersaturated due to photosynthetic activity. However, this is not the case; maybe because of high organic content (degrading plant matter) of the sediment or a groundwater influence with very low dissolved oxygen content.

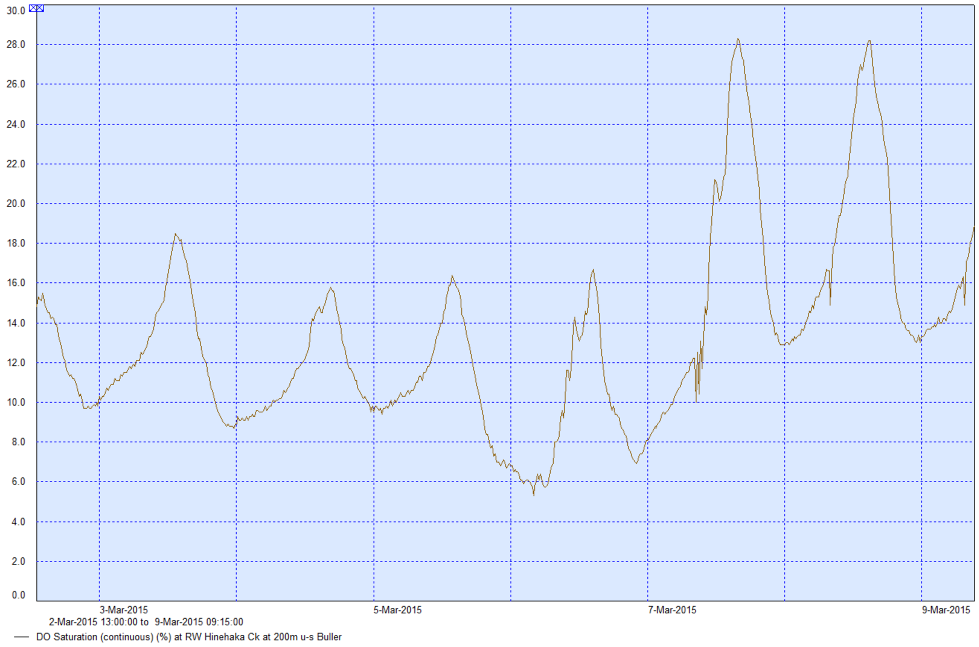


Figure 157 Dissolved oxygen (% saturation) for Hinehaka Creek near Hinehaka Rd (3-9 March, 2015). These concentrations are well below the national proposed bottom line for the daily 1-day minimum.

Maximum water temperatures recorded over the March 2015 was 19°C which is very suitable for aquatic life.

Buller River at O’Sullivans, 11 km west of Murchison

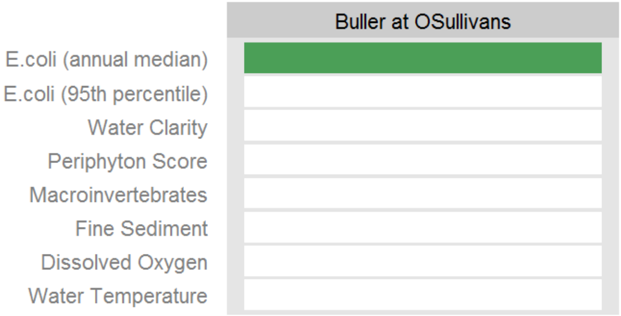
This reach of the Buller is particularly popular with whitewater kayakers and rafters.

It is very suitable for this purpose at base flows (median: 5 *E.coli*/100 ml, maxima: 75 *E.coli*/100 ml; based on 10 samples since November 2012). Water clarity is variable ranging from 0.3 to 6.8 m (median: 1.9 m).

Above: Buller River upstream O’Sullivan Bridge (SH6) (November 2012)

After 20-30 mm of rain in the catchment the site can quickly become unsuitable for contact recreation due to high faecal bacterial counts (typically 1500-4000 *E.coli*/100 ml; sampled over three flood events in 2012-13) but becomes suitable again within 24 to 36 hours of the rain ceasing. Sampling over these events showed this site to have about 30-50% higher *E.coli* concentrations than at the Riverview Campground site on the northern side of Murchison.

Median base flow water clarity at this site was relatively low compared to Buller and Mangles sites further upstream (median of 2 m over 9 samples from 2013-2015, compared to median of 3.6 m at Longford from 2010-2015).



	Buller at OSullivans
E.coli (annual median)	🟩
E.coli (95th percentile)	
Water Clarity	
Periphyton Score	
Macroinvertebrates	
Fine Sediment	
Dissolved Oxygen	
Water Temperature	

Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

Maruia River 1.5km upstream Buller

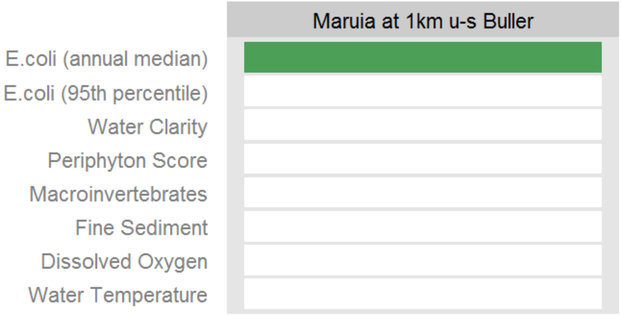
The Maruia River is 80 km long and begins in the Spenser Mountains near Lewis Pass. It has high trout fish and boating values.

Faecal indicator bacteria concentrations at base flows are very low (median: 12 *E.coli*/100 ml, maxima: 75 *E.coli*/100 ml; based on 10 samples since November 2012).

Water clarity is very variable ranging from 0.4 to 8.8 m (median: 3.5 m).

Above: Maruia River 1.5 km upstream Buller River (November 2012)

After 20-30 mm of rain in the catchment this site can quickly become unsuitable for contact recreation due to high faecal bacteria counts (typically 1000-2000 *E.coli*/100 ml; sampled over three flood events in 2012-13) but become suitable again within 24 to 36 hours of the rain ceasing.



	Maruia at 1km u-s Buller
E.coli (annual median)	🟩
E.coli (95th percentile)	
Water Clarity	
Periphyton Score	
Macroinvertebrates	
Fine Sediment	
Dissolved Oxygen	
Water Temperature	

Site data summary plot. Colours indicate attribute states from A (good) to D (poor).
Refer to the interpretation guide for full details.

What is Council Doing about it

Water quality improvements in Tasman are largely thanks to the combined effort of private landowners, community groups, Department of Conservation and others as caretakers of their streams. Council investment and effort is aimed at assisting the endeavours of the community rather than driving any improvements per se.

Between **2010-2014** Council **undertook** the following in order **to improve water quality** in Tasman's rivers:

- Provided many landowners with advice and **108 km of fencing materials for riparian areas** in order to reduce faecal and sediment contamination to waterways. Council has achieved 284 km over the last 15 years. Most of the fencing material was applied for by dairy farmers. However, once the rule requiring stock exclusion from streams where dairy cows are grazed over one metre wide and 300 mm deep came in these funds have only been used for small streams and drains (i.e. farmers going beyond compliance).

- **Discovered** and **controlled** many operations causing significant **pollution or disturbance of waterways**.

- Monitoring of hazardous facilities, dairy farms, sewage treatment plants, earthworks, forestry and many other activities to ensure that pollution is prevented.

- **Restoration of lower Borck Creek**. This project provided the most comprehensive restoration undertaken by Council (a cross-departmental project led by the Engineering Department) and included diverted the channel into a meandering channel, installing clean gravels in place of the existing fine sediment-choked stream bed, installing woody debris and installing riparian wetlands. Riparian planting will occur over the 2016-2018 period.

- **Fish passage restored at** approximately **200 culverts and weirs**, mostly in coastal areas.

- Council's Parks and Reserves Department have **planted nearly 40,000 plants in riparian areas** (see table below).

Year	Waimea	Motueka	Golden Bay
2010	3550	1277	912
2011	4202	816	510
2012	2598	1320	624
2013	13092	1176	576
2014	3736	2588	1104
Total	27178	7177	3726

- **Pest plant control** – *Glyceria maxima* control carried out in several streams in the Buller (e.g. Howard and Rait Rd area), and Golden Bay (Powell Creek). Hornwort still considered eradicated.

- **Community education** – talks to schools, scout groups etc, as well as Ecofest and Environmental awards scheme and media articles. **Waimaori Programme** facilitator continues to provide hands-on support for kindergartens and schools to grow understanding of how waterways work including Maori perspective. Tamariki Wai programme encourages schools to adopt a section of waterway to monitor and provide protection as a long term project – all 7 Enviroschools in Golden Bay, 10 schools and 1 kindergarten in rest of Tasman

- **New rules** relating to activities in the beds of rivers and lakes became operative in March 2014 including:
    - Stock exclusion of all streams over 1 m wide and 300 m deep on farms where dairy cows are grazed
    - straightening of streams explicitly not permitted
    - protection of spawning and nesting areas in rivers
    - fish passage is required for all structures by March 2019 (this had been a requirement only for new structures)

- Reviewed water takes in the Moutere catchment and provided a higher minimum flow.

- **Mapped all wetlands on private land in the Buller catchment** and communicated this with landowners.

- **Sediment and Erosion Control Guidelines drafted**

- **Set up two collaborative governance groups** (Freshwater and Land Advisory Group, FLAG) to develop limits for water quality and water quantity. One for the Takaka area and one for the Waimea catchment.

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Appendices

Appendix 1: Key Attributes of River Water Quality

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
Dissolved oxygen	% saturation and g/m^3	Discharge of most organic contaminants to water but particularly leachate from silage or compost.	Dissolved oxygen (DO) is fundamental to the survival of aquatic life (for "breathing"). DO concentrations of less than 60% saturation or 5.0 g/m^3 adversely affect trout and less than 40% saturation or 2-3 g/m^3 may result in fish deaths. The measurement of DO is particularly important in slow flowing streams with excessive algal/ aquatic plant growth and little riparian shading, where DO may reach low levels. Minimum DO levels usually occur early in the morning (due to respiration of algae and higher plants) and in summer. Therefore, consistency of sampling time, in the diurnal cycle, or continuous or semi-continuous sampling, is important.	Most natural waters 7-12 g/m^3 (90-100% saturation)
Water Temperature	Degrees Celsius for midpoint of daily mean and daily maximum.	Removing riparian vegetation, in-line ponds	Water temperature has a substantial effect on the functioning of aquatic ecosystems and the physiology of the biota. Physiological processes have thermal optima, and alterations to ambient temperatures may affect the species exposed in a variety of ways. Growth and metabolism, timing and success of reproduction, mobility and migration patterns, and production may all be altered by changes in ambient temperature regimes. Effects may be direct through changes to the metabolism, or indirect through the influence on the solubility of oxygen in water. Toxicity of ammonia-N increases with increasing temperature. Temperature also influences the amount of dissolved oxygen in water and how much oxygen plants and animals consume. Higher water temperatures mean less oxygen dissolved but more consumed. Extremely high temperatures normally occur in unshaded, shallow, slow moving water during peak summer. Temperatures over 21.5°C have been demonstrated to cause adverse effects to native macroinvertebrates and fish.	Well-shaded waterways seldom peak over 20°C in summer. Spring-fed waterways near the spring source typically have stable water temperatures of 10-12°C. Mountain-fed waterways (particularly in the Buller catchment) can be as cold as 2-4 °C in winter.
Conductivity	micro-Siemens/cm	Discharge of most contaminants to water but particularly those high in nutrients or metals	Conductivity relates to the ability of a water sample to carry an electric current. This depends on the total concentration of ionised substances (minerals) dissolved in water and the temperature at which this measurement was made. Most contaminants will augment the conductivity of a water body, making this indicator widely applicable.	Seawater: 50,000 Raw meat processing waste: 5000-10,000 Dairy shed ponds: 2000-3000 Sewage oxidation ponds: 200-400 Natural freshwater: 40-70 (occasionally up to 100) Chlorinated tap water: 100 Distilled water: 2.0
pH	pH units	Hard rock gold and coal mining Concrete manufacturing and construction sites Drainage of wetlands (*e.g.,* humping and hollowing and v-blading)	pH (acidity and alkalinity) will impact upon freshwater ecosystems and may change through the course of a day. Particularly high (alkaline) or low (acidic) pH levels may have an adverse impact on aquatic biota directly. Alkaline conditions may also increase the toxicity of other pollutants such as ammonia-N, which in turn may adversely impact upon aquatic fauna. A sudden change outside the range of 6.5 – 8.5 may prove lethal to fish life in particular.	Battery acid: 0-1 Vinegar: 4-5 "Healthy" rivers: 6.5-8.5 Some natural creeks draining pakihi wetlands: as low as 4.5 Dairy shed effluent: 7-8

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
				Cement or lime: 10-12 Chemical drain cleaner: 14
Visual Water Clarity (by Black Disc)	meters	Land disturbance that adds sediment to the water body, wastewater discharges, highly-coloured discharges e.g. leachate from bark or compost processing operations	Clarity is important because it affects the recreational and aesthetic quality of water as well as the aquatic ecosystem. Poor water clarity adversely affects the ability of sight feeding predators, such as fish and birds, to locate prey and the ability of algae to photosynthesise and hence provide food for animals further up the food chain Spring-fed streams originating in alluvial material generally have the highest water clarity. Can be used in combination with suspended solids and turbidity, as all these indicators are not always correlated. Clarity can be affected by dissolved solids unlike suspended solids and turbidity. This indicator has the advantage over turbidity that it is cheap and field measurable. Research has shown that people can detect small changes in clarity. Protection of visual clarity will often protect other optical values and avoid regulatory and monitoring complexity. It is important to note: (a) there is a high natural variability in optical characteristics of New Zealand waters (more than one order of magnitude); (b) very clear water can still be contaminated with faecal bacteria, parasites, heavy metals, ammonia and nutrients.	Median/maximum baseflow readings for the clearest sites in Tasman are: Blue Lake/ Upper Sabine 82 m/?, Te Waikoropupū Springs 63 m/?, Waingaro River 12.1 m/30.5 m, Upper Motueka 11.1 m/23 m, Upper Matakitaki 10.3 m/24.5 m and Riwaka North Branch source 11.6 m/18.7 m. Typical base-flow range for waterways in Tasman 3-6 m Rivers during flood events 0.2-0.3 m Sewage oxidation ponds and dairy shed effluent 0.2 m (range 0.05-0.45) Gravel washing or mining wastewater 0.01-0.05 m
Turbidity	Nephalometric turbidity units (NTU)	Any land disturbance such as: • Mining/quarrying • Roadworks • Stockpiling of gravel and soil	Important for same reasons as water clarity. Turbidity is defined as the relative tendency of water to scatter light. This indicator is particularly important in relation to alluvial gold mining and quarrying. It should be used in combination with suspended solids and visual clarity, as all these indicators are not always correlated. Fine sediment discharges during low flows cause much greater impact than at higher flows because of greater settling in the stream bed.	Good quality drinking water: <1NTU In very pristine waters discolouration may be detected when there is as little as a 2 NTU change. Trout and salmon avoid turbid water as low as 10 NTU. Noticeable cloudiness: 5-10 Rivers in flood: > 100 Dairy shed and sewage oxidation pond effluent: typically 30 (Range 10-150) Alluvial mining effluent: 2000-4000
Suspended Solids	g/m^3	Land disturbance such as mining, roadworks, humping and hollowing, v-blading, stockpiling of gravel and soil	Important for same reasons as water clarity. This is a measure of the particles in suspension. Determined by filtration and weighing of dry material. Suspended solids affect colour, clarity, taste, as well as plant and animal life. Suspended solids may also cause an increase in temperature in the water body. Sediments may settle out and smother aquatic life or prevent light penetrating the water, preventing plant and algal growth. This indicator is particularly important in relation to alluvial gold mining and quarrying. It should be used in combination with turbidity and visual clarity, as all these indicators are not always correlated. Roughly linear relationship between suspended solids and turbidity (particle size dependent).	Good quality drinking water: < 5 Natural freshwater: 0.5-1.0 Rivers in flood: 200-300 Oxidation pond effluent: 50-150 Domestic sewage: 200-300
Faecal Coliforms	Coliform forming	Sewage or animal effluent	Faecal coliforms are useful for determining the suitability of water for contact recreation,	

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
	units/ 100 ml	discharge (treated or untreated)	shellfish-gathering, and stock drinking. The most common diseases associated with swimming areas are eye, ear, nose, and throat infections, skin diseases, and gastrointestinal disorders. A number of pathogens and parasites can be transmitted by contaminated water to livestock, which may result in reduced growth, morbidity, or mortality. Faecal coliforms are indicator organisms only. This means their presence in water is indicative of harmful pathogens and not always harmful themselves. Measurement of harmful pathogens themselves is costly and can be impossible. Faecal coliforms are the preferred indicator for assessments of discharges from oxidation ponds/waste stabilisation ponds to marine or freshwater (L Sinton, ESR). In this context all the following indicators should be used in brackish water, or for sanitary surveys along the freshwater-marine continuum: faecal coliforms, *E. coli* and *Enterococci*.	
E. coli	Colony forming units/ 100 ml	Sewage or animal effluent discharge (treated or untreated), birds/wildfowl, dog (particularly from urban areas after rain),	*E. coli* are useful indicators in risk to human health from interacting with waterways because they are almost always found in reasonable numbers when more serious disease-causing organisms are present (such as *Camplyobacter, Cryptosporidium, Giaridia* and *Salmonella*). One type of *E.coli, E.coli* 0157:H7, causes serious health effects including kidney failure and death.	Natural freshwater: 1-50 Oxidation pond effluent: 10,000 Treated dairy shed effluent: 100,000 Raw domestic sewage: 10,000,000 NZ Drinking Water Standards: 0
Invertebrate community metrics: Macro-macroinvertebrate Community Index (SQMCI and MCI), %EPT, number of EPT, Species Richness, Relative Abundance, Total density (surber sampler)	Metric dependent	Discharge of contaminants from most human activities will affect this indicator, particularly discharges of organic effluent or fine sediment.	Macroinvertebrates are a good indicator of water quality for ecosystem health because they are always present in the stream and many taxa are sensitive to contaminant discharges integrating effects on the ecosystem from about two to four weeks prior to sampling. By contrast, chemical indicators only give an indication or environmental effects, and unless large numbers of samples are taken over the whole 24 hour period and for several days/ weeks, the results can only be regarded as a very short "snapshot" in time. In addition to contaminants, habitat limiting factors can also adversely affect invertebrate populations. These factors include: reduced stream flow, warm temperatures, low dissolved oxygen, or algae. Koura are a valued food for people.	MCI: Pristine rivers > 120 Good Fair Poor % EPT (range): <25% (very poor) to >70% (pristine) Number of taxa (kick net method): 20 (range 5-43)
Periphyton % Cover	% cover (measured in runs and averaged over a 150 m reach)	Discharges with high concentrations of nutrients such as sewage or animal effluent discharge (treated or untreated)	Excessive filamentous algae or "slime" in waterways has an adverse effect on amenity value (aesthetic quality, odour, slipperiness), water quality (large fluctuations in dissolved oxygen caused by photosynthesis and respiration of live periphyton and degradation of dead periphyton) and habitat (water column or stream bed can be filled with periphyton to the point where there is reduced space for aquatic organisms to function normally). Note: The Periphyton attribute specified in the NPS-FWM is Chlorophyl-a (measured in: mg chl-a/m^2). Council does not recommend this for the following reasons: There is very limited Chl-a data available in Tasman (as at Nov2014), Chl-a data is expensive to collect and analyse (requires monthly sampling over 3 years), high variability over a reach,	Filamentous green algae: Pristine waters: < 30% cover Moderate nutrient status: 30%-50% High nutrient water: >50% cover
Dissolved Reactive Phosphorus (DRP)	g/m^3	Fertilising operations on farms	Dissolved reactive phosphorous (DRP) is a form of phosphate that is available immediately for plant growth. DRP levels in water samples are often inversely related to periphyton cover	Natural waters: <0.001 Catchments with soils with low anion

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
			(predominantly attached algae) due to uptake of the nutrient by periphyton (Smith *et al.*, 1993). DRP concentrations usually peak just before the peak flow in a flood situation and in autumn.	exchange capacity e.g. pakihi 0.05 Above 0.15-0.03 excessive nutrient enrichment (eutrophication) is likely to occur. However, other factors such as substrate stability, sunlight, and temperature may affect plant growth.
Ammonia * (NH_3-N) or Ammonium-N (NH_4-N)	g/m^3	Dairy shed effluent sewage, sewage/septage, and some industrial discharges (e.g. leaks from cool stores).	The un-dissociated form of ammonia (NH_3) is very toxic to aquatic life, with fish (especially trout) being particularly sensitive. Less than 0.1 ppm (0.1 mg/l) has been shown to affect fish species. The concentration of NH_3 is controlled by the pH and temperature of the solution (more NH_3 under more alkaline conditions or higher temperatures). Ammonia is a good indicator of recent pollution from organic discharges because it rapidly (within a few weeks) degrades to nitrate and then nitrogen gas through denitrification processes. Ammonia (NH_3 or NH_4^+) is rarely found in natural waters, except in wetlands and geothermal springs, and therefore its presence is an excellent indicator of human pressure on rivers. Ammonia is also a source of nitrogen that, as a nutrient, can cause eutrophication (excessive growth and enrichment) in waterways. Ammonia reacts with oxygen to form nitrate, and in so doing consumes large amounts of oxygen.	Natural freshwater: <0.03 g/m^3 Raw sewage: 30-50 g/m^3 Oxidation pond effluent: 20-30 g/m^3 Treated abattoir effluent: 50-150 g/m^3 Geothermal springs up to: 10.0 g/m^3
Nitrate-N (NO_3-N)	g/m^3	Fertiliser application (e.g. farms/market gardens), sewage/manure waste discharges, landfills	Nitrate is an important nutrient for the growth of algae and other aquatic plants and can lead to excessive coverage if discharged to the stream when nitrogen is limiting. However, other factors such as substrate stability, sunlight, and temperature also affect plant growth. Nitrate also affects growth and is toxic at high concentrations. Farm animals, particularly young stock, can also be affected in sufficient concentrations. Nitrate is mainly derived from land and subsoil drainage. Elevated nitrate levels can occur naturally (e.g. leaching and erosion from some marine-derived sedimentary rock), or as a result of human activity. Lowest levels of nutrients are generally in mid-summer due to terrestrial plant uptake being at its highest.	Natural range: 0.01 - 0.1 WHO Drinking water limit: 11.3 Effect on aquatic organisms: > 1.5g/m^3: some growth effect on up to 5% of aquatic organisms >2.4 g/m^3: Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects. >6.9 g/m^3: Impacts on growth of multiple species, and starts approaching acute impact level (ie risk of death) for sensitive species at higher concentrations (>20 mg/L)
Dissolved Inorganic Nitrogen	g/m^3	Fertiliser application (e.g. farms/market gardens), sewage/manure waste discharges, landfills	Dissolved Inorganic Nitrogen (DIN) is a measure of the total nitrogen available to plants. DIN = ammonia-N + nitrate-N. See above for application.	Natural range: 0.01-0.03 Above 0.04-0.10 eutrophication likely to occur
Flow Regime	l/sec, cubic meters per second (cumec)	Water takes, diversions (including for hydro-generation) , dams and structures can affect flow regime.	Recognised ecologically important components of the flow regime include: **1. Large floods** to maintain channel form, large scale sediment transport, and control encroachment of woody weeds.	

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
			Likely to be in the order of the mean annual maximum flow, with flows of more than about ten times the mean flow or 40% of the mean annual maximum flow beginning to move a substantial portion of the river bed . **2. Smaller floods and freshes** to flush fine sediment, periphyton and other aquatic vegetation. Usually about 3–6 times the median flow (or 3–6 times the low flow in a highly regulated river) **3. Low flows**, the period of minimum wetted habitat availability. The MALF is a potential limiting factor for trout populations and native fish species with generation cycles longer than one year, at least in small rivers where the amount of suitable habitat declines at flows less than MALF . **4. Flow recessions**, the median flow is often viewed as providing an approximation of the typical habitat conditions experienced, and able to be utilised, by benthic invertebrates, which in turn may help define carrying capacity for fish and birds populations that feed on invertebrates. **5. Flow variability,** at a range of scales. It has been found to be an important predictor of fish community structure in New Zealand rivers and may also provide a stimulus for fish migrations. Flows in the order of 2-4 times the median or preceding base flow have been associated with movement of several fish species in New Zealand.	
Stream Habitat Score (e.g. Multi-Value Assessment)	Score out of 10	Stream “cleaning”, flood protection works, recreational vehicles (on larger rivers). Historic vegetation clearance and stream straightening/ drainage schemes.	Without suitable habitat in the stream and adjacent to the stream fish and invertebrate life is unlikely to be abundant or diverse. Critical habitat features include: • Variety of meander pattern • Variety of depth and width • Variety of bank shape • Variety of substrate sizes, including woody debris • Variety of riparian vegetation	Very good: 10 Very poor: 1
Assessment of Mauri (e.g. Cultural Health Index)				
Groundwater Level	mm	Water takes		
Toxic Cyanobacteria (toxic algae)	% cover of *Phormidium*	Fine sediment from activities such as earthworks, nitrogen from sources such as fertiliser	*Phormidium* is a natural component of the periphyton community found pristine streams, usually at coverage <5%. During extended low-flow periods (>2-3 weeks) in spring-autumn the coverage in some streams with slightly-elevated dissolved inorganic nitrogen, low phosphorus and fine sediment discharges, can get over 10% and in rare cases get over 50%. *Phormidium* is very soft and fragile, and is easily dislodged by floods thereby making the greatest coverage after longer dry periods. After several weeks in warm, slow-flowing water the *Phormidium* mats can detach and float downstream and get caught on the stream margins where they are more accessible to animals and humans. *Phormidium* mats can be	Pristine streams usually <5% Risk to dogs and toddlers considered significant when >20%

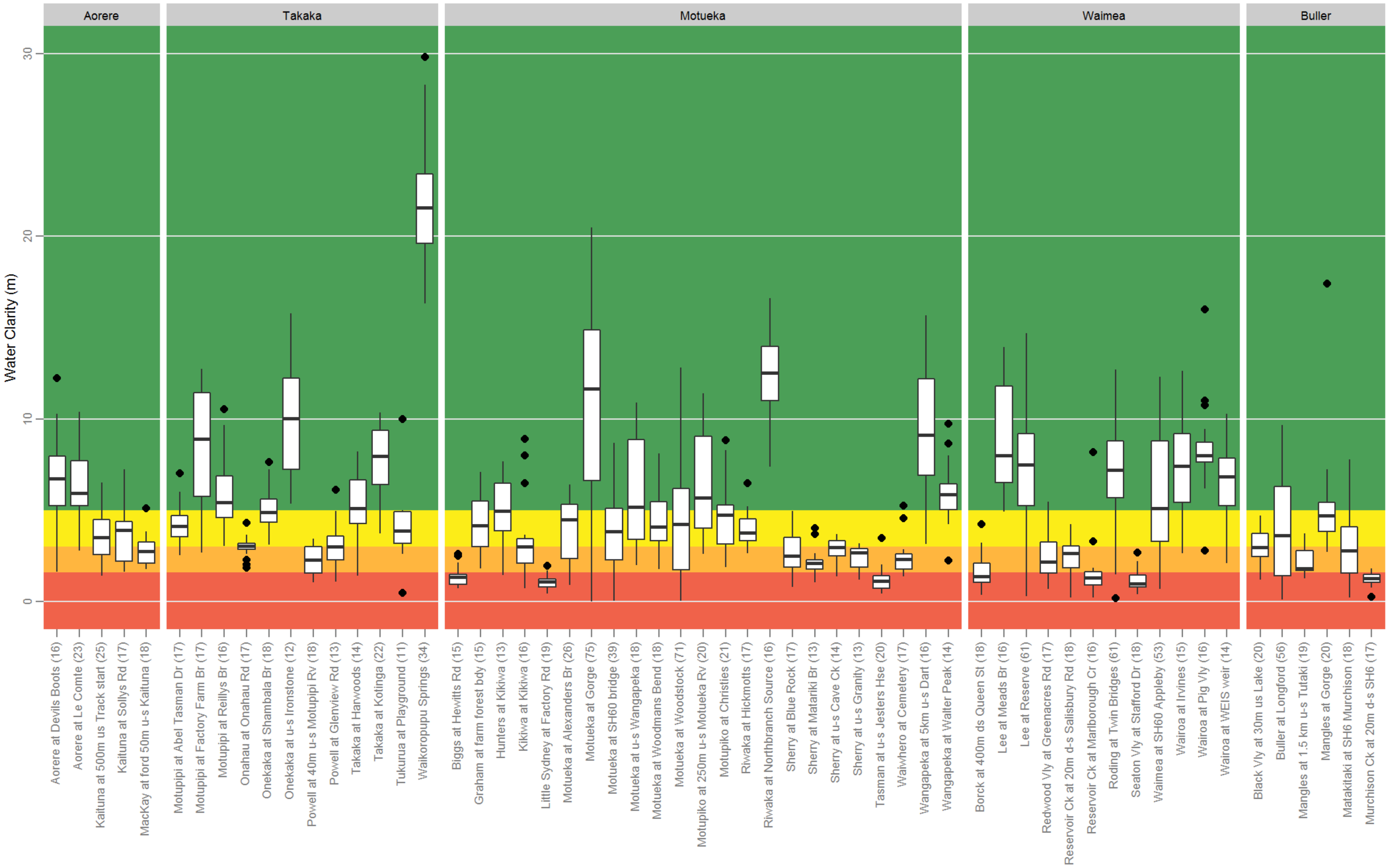
Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
			extremely toxic to animals by direct consumption. Many dog deaths have occurred throughout NZ (issues first came to light in late 1990's). Young dogs and children have a propensity to explore their environment by consuming material in their mouths.	
Freshwater fish abundance and diversity	# species (ratio of observed to expected) Abundance of each species	Habitat degradation (from adult habitat through to spawning areas). Reduction in wetted usable area. Toxic chemical and fine sediment discharges. Structures creating barriers to fish migration.	Eel (tuna) and whitebait are important as food for people. Fish are an important component of stream ecosystems and are very vulnerable to habitat disturbance or degradation, as well as toxic or sediment discharges. Many freshwater fish support bird species such as shags, stilts, kingfisher, dotterel, gulls, and terns.	Pristine: All species expected to be present are present (Observed divided by Expected close to 1.0). Impact probable: Observed/expected ratio <0.66
Riparian Vegetation	% cover of trees (on each bank) % cover rushes/long grass in inanga spawning zones.	Stock grazing. Vegetation clearance (usually historic)	Over-hanging woody trees are essential for providing food (rain of invertebrates and leaves) to fish and invertebrates in the stream. Trees also supply woody debris to streams and stabilise banks to create undercuts which provides very important fish habitat. Long grass/rushes near the top of the tidal zone (saltwater wedge) are critical for inanga spawning. Mature riparian vegetation reduces erosion from riparian zones. Generally native riparian plants provide for the most productive stream ecosystem, rather than exotic plants. However, tall fescue usually makes the best inanga spawning habitat and willows create better shade and bank stability in larger rivers (willows often block stream flow and poor insect producers).	Pristine: >70% bank cover
Number of direct sewage discharges to water	#	Households on septic tanks (particularly old or poorly-maintained systems and/or during peak holiday periods). Municipal sewage treatment discharges.		

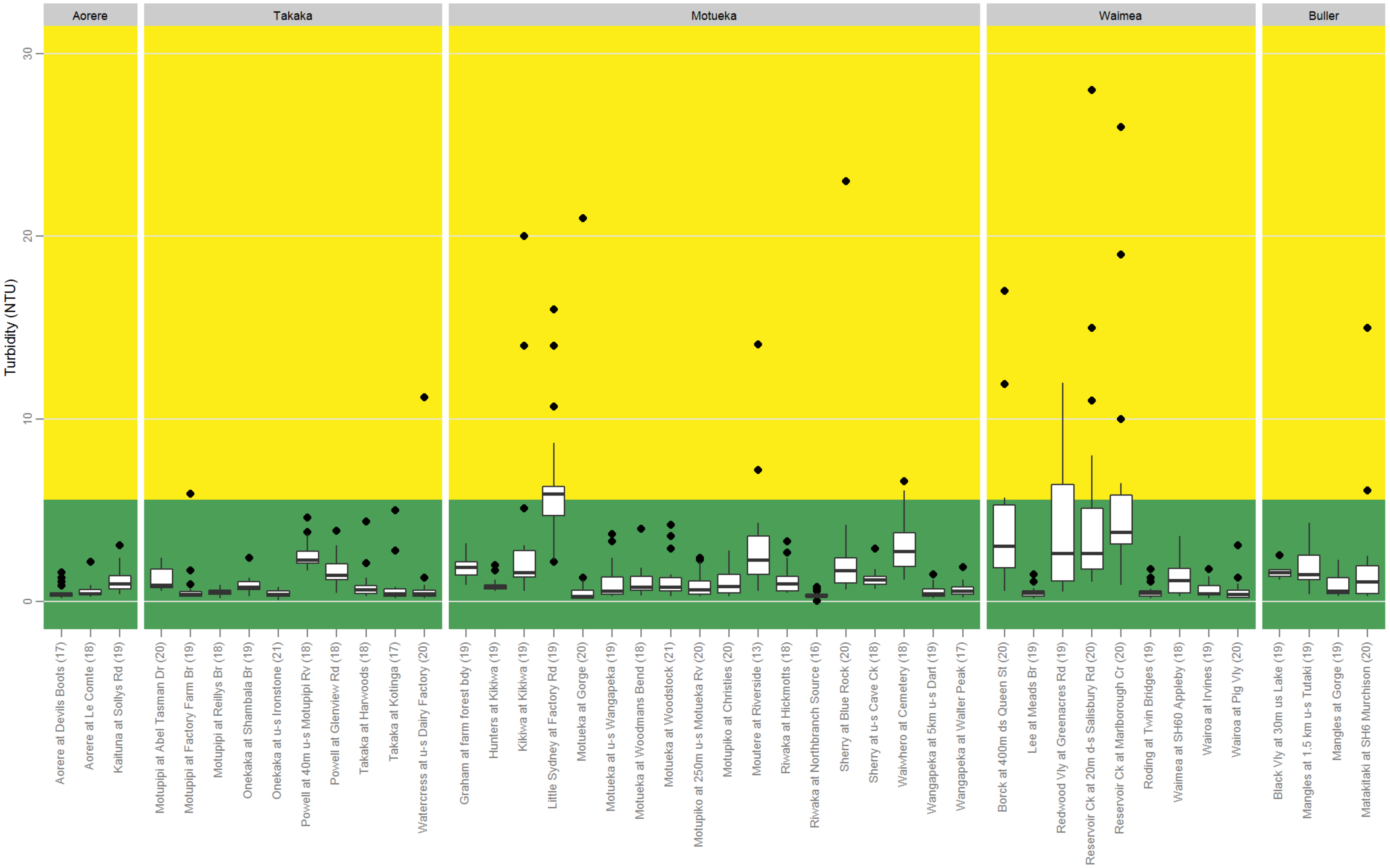
Appendix 2: Boxplots of Water Quality Variables

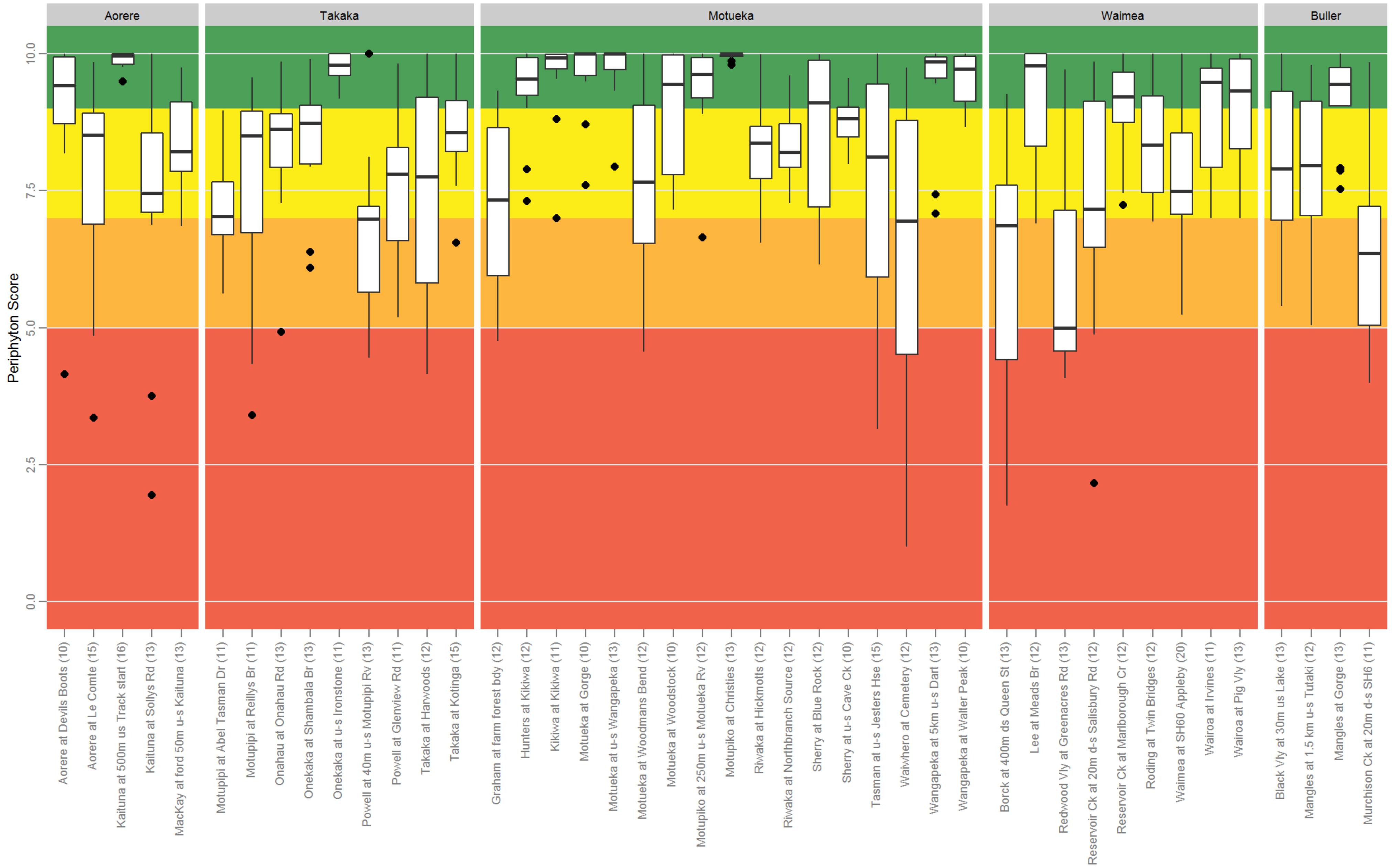
Boxplots are shown for River Water Quality sites using data collected from January 2010 to December 2014. Sites shown have at least 10 measurements of the water quality attribute. Black dots indicate potential outliers (data points more than 1.5x the inter-quartile range from the top or bottom of the box). The background colours indicate attribute states from A (green) to D (red). Sample sizes are shown in brackets beside the site names.

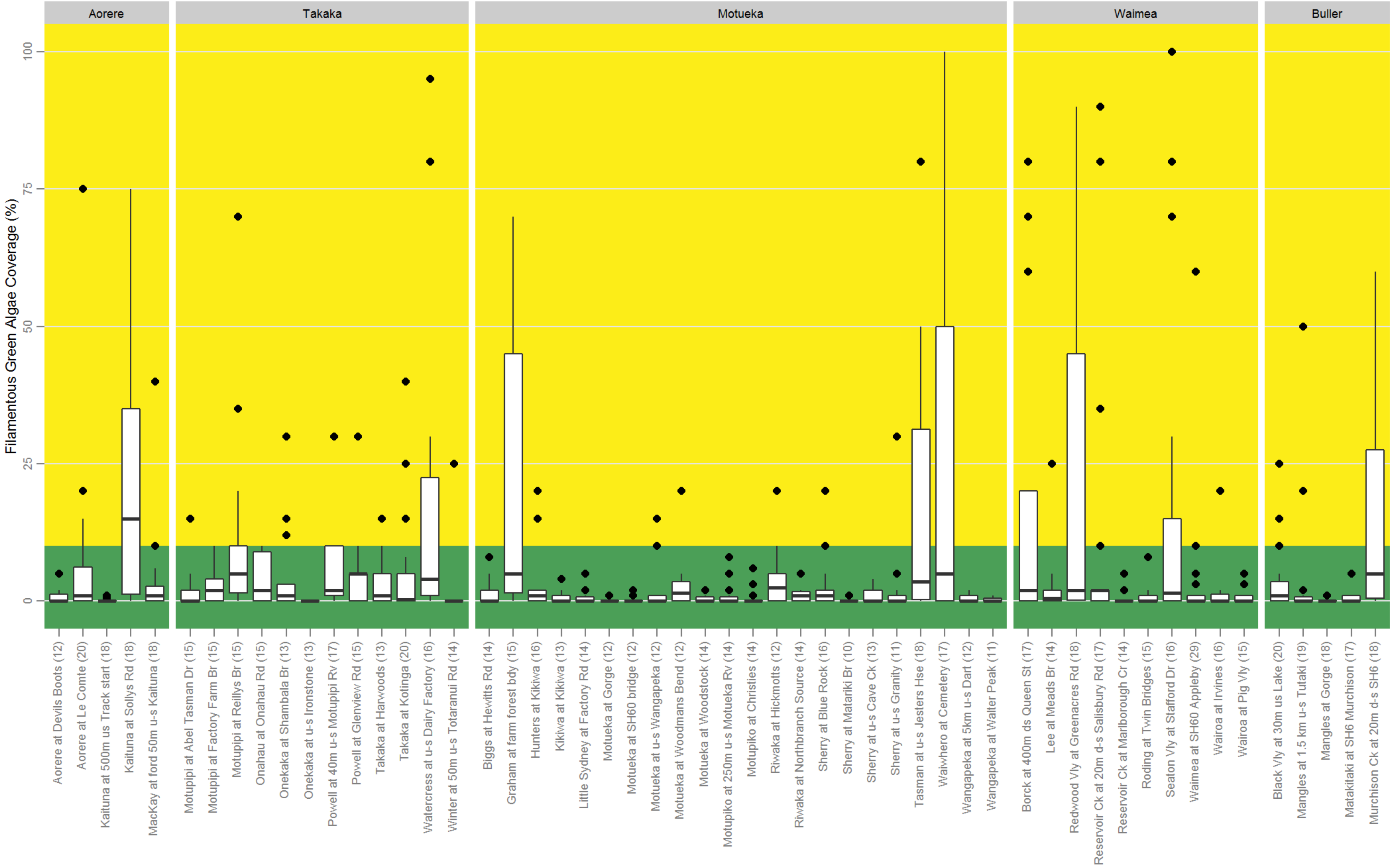
Variables displayed:

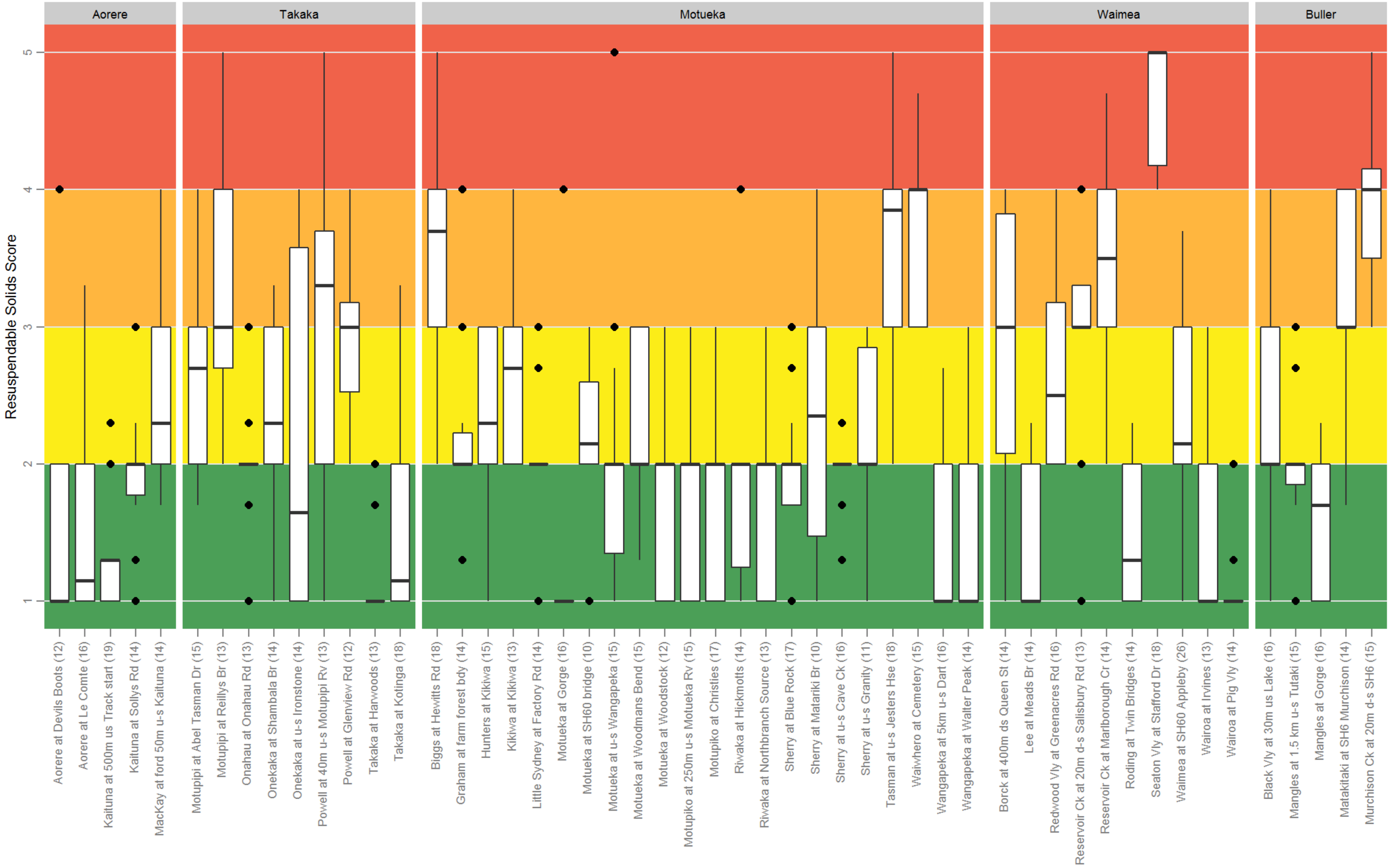
- Water clarity
- Turbidity
- Periphyton score
- Filamentous green algae cover
- Resuspendable solids score
- pH
- Conductivity
- *E. coli*
- Dissolved reactive phosphorus (DRP)
- Dissolved inorganic nitrogen (DIN)
- DIN to DRP ratio
- Nitrate-N
- Ammonia-N

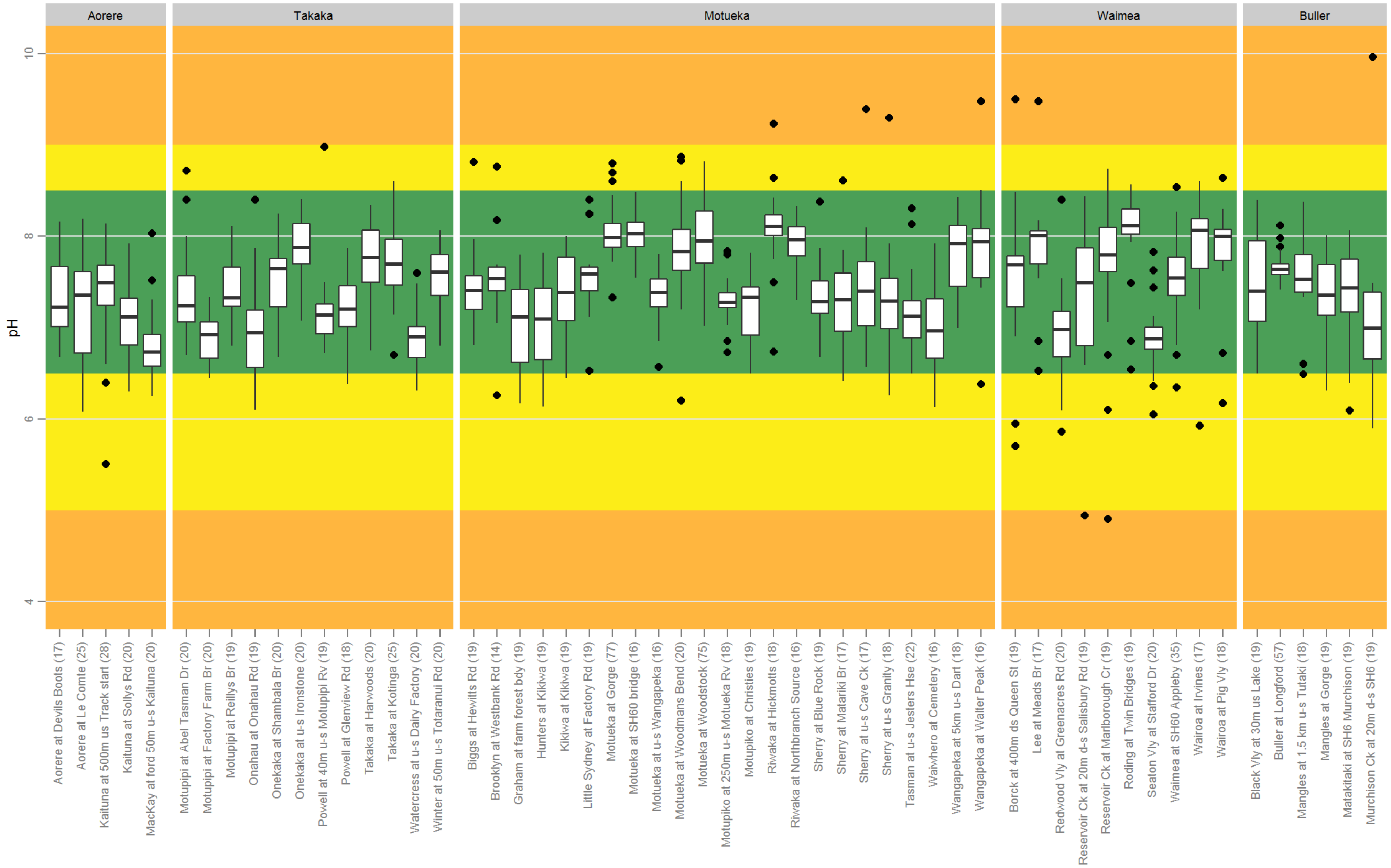

Aorere
Takaka
Motueka
Waimea
Buller
Water Clarity (m)
30
20
10
0
Aorere at Devils Boots (16)
Aorere at Le Comte (23)
Kaituna at 500m us Track start (25)
Kaituna at Sollys Rd (17)
MacKay at ford 50m u-s Kaituna (18)
Motupipi at Abel Tasman Dr (17)
Motupipi at Factory Farm Br (17)
Motupipi at Reillys Br (16)
Onahau at Onahau Rd (17)
Onekaka at Shambala Br (18)
Onekaka at u-s Ironstone (12)
Powell at 40m u-s Motupipi Rv (18)
Powell at Glenview Rd (13)
Takaka at Harwoods (14)
Takaka at Kotinga (22)
Tukurua at Playground (11)
Waikoropupu Springs (34)
Biggs at Hewitts Rd (15)
Graham at farm forest bdy (15)
Hunters at Kikiwa (13)
Kikiwa at Kikiwa (16)
Little Sydney at Factory Rd (19)
Motueka at Alexanders Br (26)
Motueka at Gorge (75)
Motueka at SH60 bridge (39)
Motueka at u-s Wangapeka (18)
Motueka at Woodmans Bend (18)
Motueka at Woodstock (71)
Motupiko at 250m u-s Motueka Rv (20)
Motupiko at Christies (21)
Riwaka at Hickmotts (17)
Riwaka at Northbranch Source (16)
Sherry at Blue Rock (17)
Sherry at Matariki Br (13)
Sherry at u-s Cave Ck (14)
Sherry at u-s Granity (13)
Tasman at u-s Jesters Hse (20)
Waiwhero at Cemetery (17)
Wangapeka at 5km u-s Dart (16)
Wangapeka at Walter Peak (14)
Borck at 400m ds Queen St (18)
Lee at Meads Br (16)
Lee at Reserve (61)
Redwood Vly at Greenacres Rd (17)
Reservoir Ck at 20m d-s Salisbury Rd (18)
Reservoir Ck at Marlborough Cr (16)
Roding at Twin Bridges (61)
Seaton Vly at Stafford Dr (18)
Waimea at SH60 Appleby (53)
Wairoa at Irvines (15)
Wairoa at Pig Vly (16)
Wairoa at WEIS weir (14)
Black Vly at 30m us Lake (20)
Buller at Longford (56)
Mangles at 1.5 km u-s Tutaki (19)
Mangles at Gorge (20)
Matakitaki at SH6 Murchison (18)
Murchison Ck at 20m d-s SH6 (17)

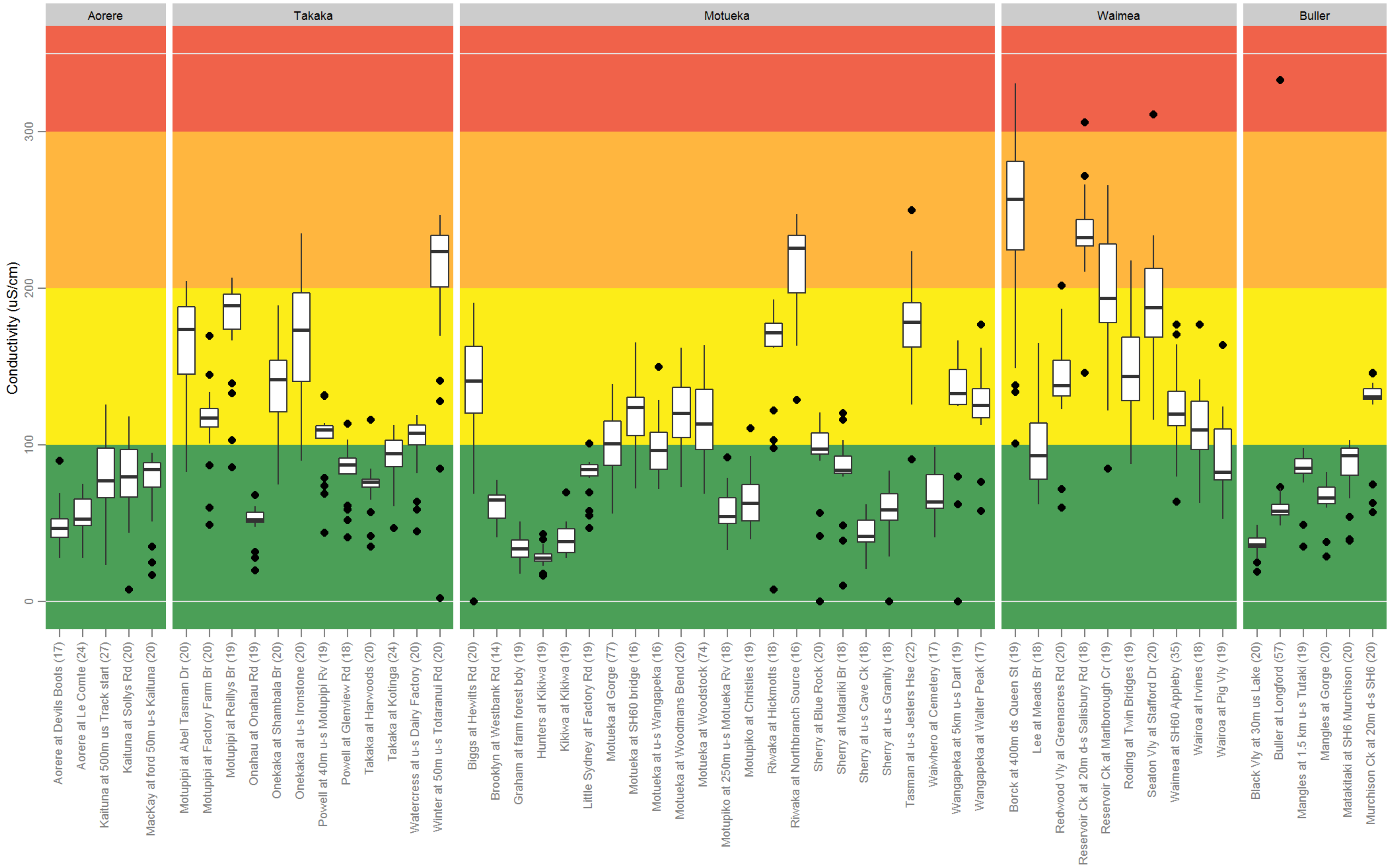

Aorere
Takaka
Motueka
Waimea
Buller
Turbidity (NTU)
0
10
20
30
Aorere at Devils Boots (17)
Aorere at Le Comte (18)
Kaituna at Sollys Rd (19)
Motupipi at Abel Tasman Dr (20)
Motupipi at Factory Farm Br (19)
Motupipi at Reillys Br (18)
Onekaka at Shambala Br (19)
Onekaka at u-s Ironstone (21)
Powell at 40m u-s Motupipi Rv (18)
Powell at Glenview Rd (18)
Takaka at Harwoods (18)
Takaka at Kotinga (17)
Watercress at u-s Dairy Factory (20)
Graham at farm forest bdy (19)
Hunters at Kikiwa (19)
Kikiwa at Kikiwa (19)
Little Sydney at Factory Rd (19)
Motueka at Gorge (20)
Motueka at u-s Wangapeka (19)
Motueka at Woodmans Bend (18)
Motueka at Woodstock (21)
Motupiko at 250m u-s Motueka Rv (20)
Motupiko at Christies (20)
Moutere at Riverside (13)
Riwaka at Hickmotts (18)
Riwaka at Northbranch Source (16)
Sherry at Blue Rock (20)
Sherry at u-s Cave Ck (18)
Waiwhero at Cemetery (18)
Wangapeka at 5km u-s Dart (19)
Wangapeka at Walter Peak (17)
Borck at 400m ds Queen St (20)
Lee at Meads Br (19)
Redwood Vly at Greenacres Rd (19)
Reservoir Ck at 20m d-s Salisbury Rd (20)
Reservoir Ck at Marlborough Cr (20)
Roding at Twin Bridges (19)
Waimea at SH60 Appleby (18)
Wairoa at Irvines (19)
Wairoa at Pig Vly (20)
Black Vly at 30m us Lake (19)
Mangles at 1.5 km u-s Tutaki (19)
Mangles at Gorge (19)
Matakitaki at SH6 Murchison (20)

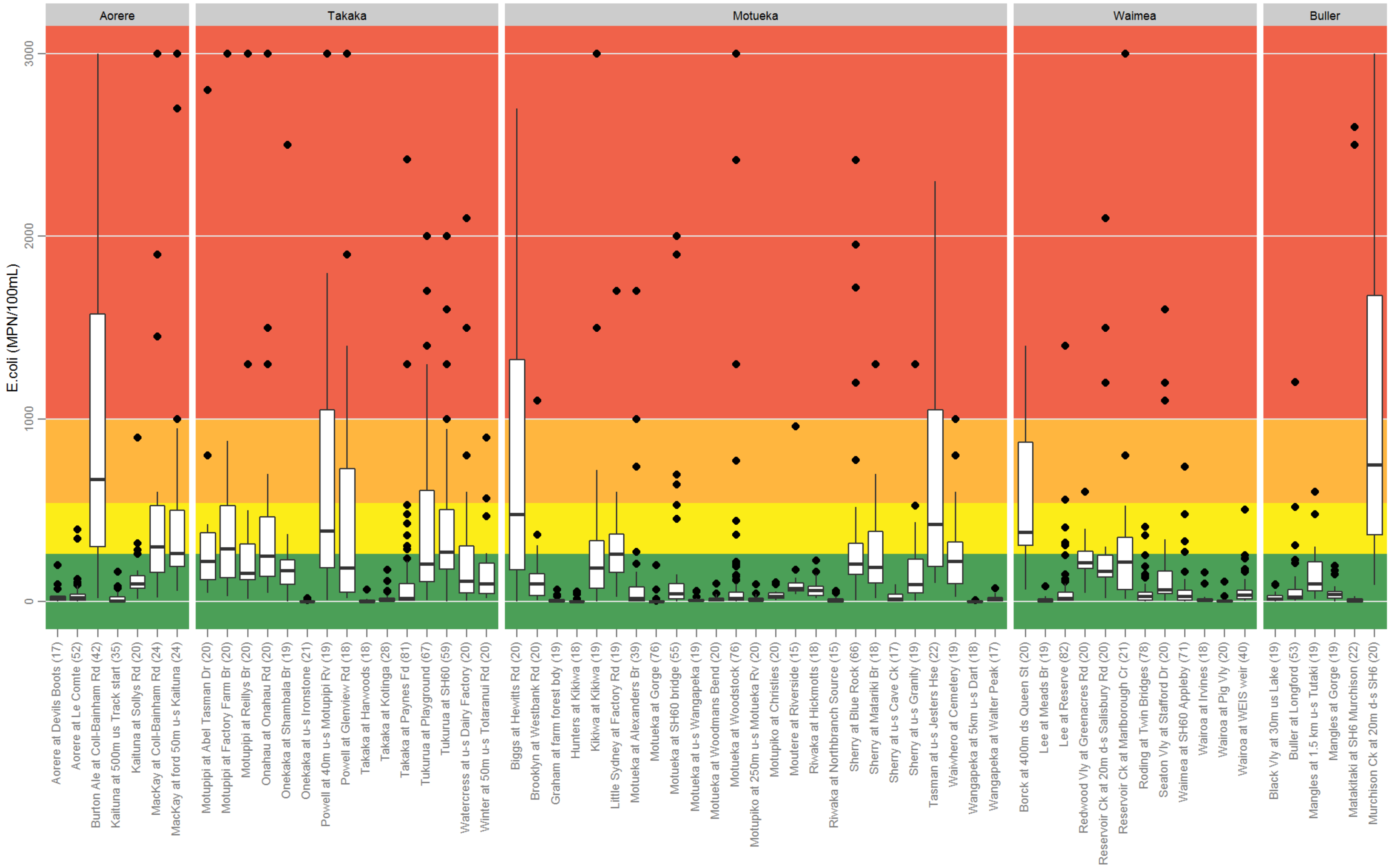

Aorere
Takaka
Motueka
Waimea
Buller
Periphyton Score
10.0
7.5
5.0
2.5
0.0
Aorere at Devils Boots (10)
Aorere at Le Comte (15)
Kaituna at 500m us Track start (16)
Kaituna at Sollys Rd (13)
MacKay at ford 50m u-s Kaituna (13)
Motupipi at Abel Tasman Dr (11)
Motupipi at Reillys Br (11)
Onahau at Onahau Rd (13)
Onekaka at Shambala Br (13)
Onekaka at u-s Ironstone (11)
Powell at 40m u-s Motupipi Rv (13)
Powell at Glenview Rd (11)
Takaka at Harwoods (12)
Takaka at Kotinga (15)
Graham at farm forest bdy (12)
Hunters at Kikiwa (12)
Kikiwa at Kikiwa (11)
Motueka at Gorge (10)
Motueka at u-s Wangapeka (13)
Motueka at Woodmans Bend (12)
Motueka at Woodstock (10)
Motupiko at 250m u-s Motueka Rv (12)
Motupiko at Christies (13)
Riwaka at Hickmotts (12)
Riwaka at Northbranch Source (12)
Sherry at Blue Rock (12)
Sherry at u-s Cave Ck (10)
Tasman at u-s Jesters Hse (15)
Waiwhero at Cemetery (12)
Wangapeka at 5km u-s Dart (13)
Wangapeka at Walter Peak (10)
Borck at 400m ds Queen St (13)
Lee at Meads Br (12)
Redwood Vly at Greenacres Rd (13)
Reservoir Ck at 20m d-s Salisbury Rd (12)
Reservoir Ck at Marlborough Cr (12)
Roding at Twin Bridges (12)
Waimea at SH60 Appleby (20)
Wairoa at Irvines (11)
Wairoa at Pig Vly (13)
Black Vly at 30m us Lake (13)
Mangles at 1.5 km u-s Tutaki (12)
Mangles at Gorge (13)
Murchison Ck at 20m d-s SH6 (11)

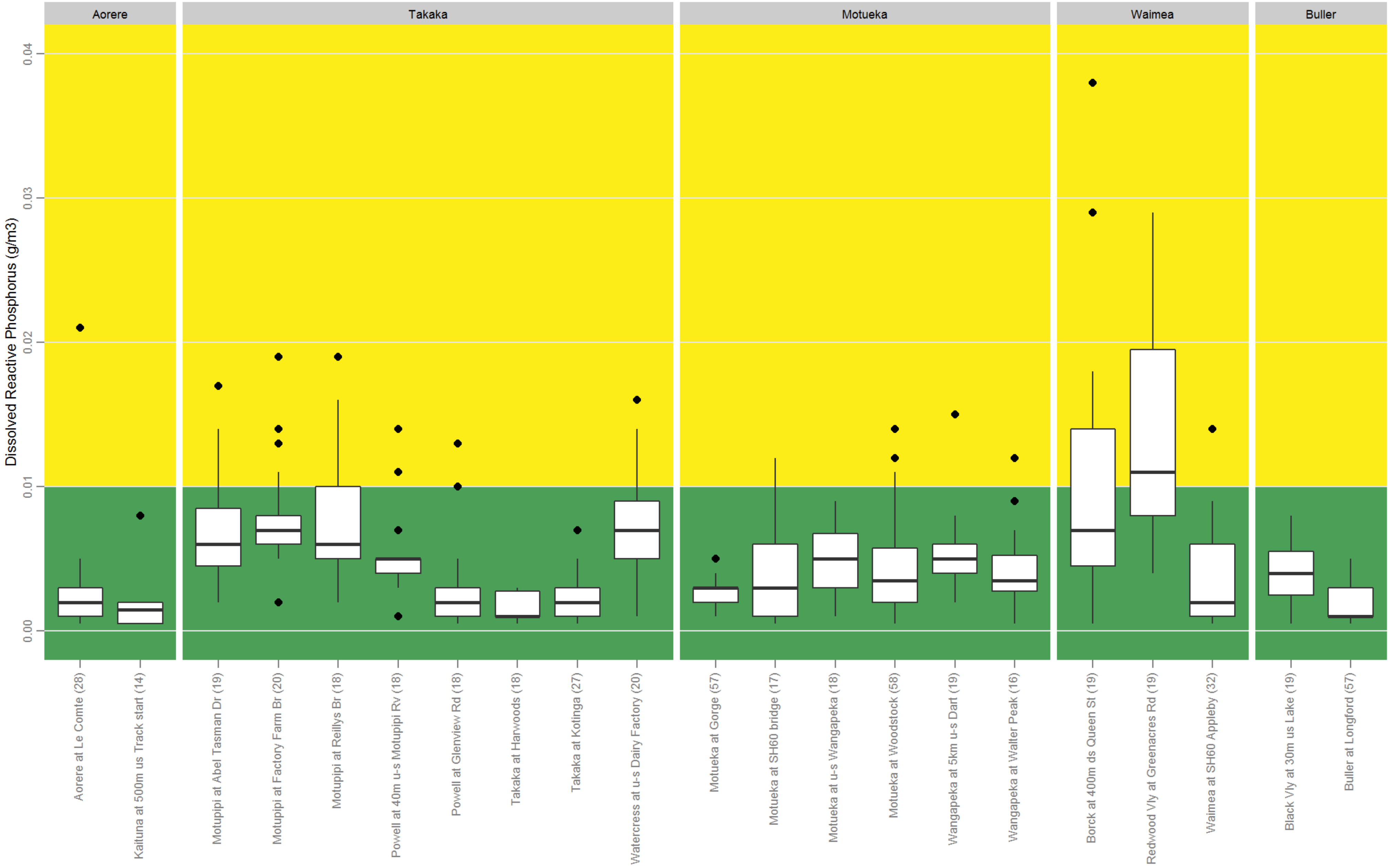

Aorere
Takaka
Motueka
Waimea
Buller
Filamentous Green Algae Coverage (%)
100
75
50
25
0
Aorere at Devils Boots (12)
Aorere at Le Comte (20)
Kaituna at 500m us Track start (18)
Kaituna at Sollys Rd (18)
MacKay at ford 50m u-s Kaituna (18)
Motupipi at Abel Tasman Dr (15)
Motupipi at Factory Farm Br (15)
Motupipi at Reillys Br (15)
Onahau at Onahau Rd (15)
Onekaka at Shambala Br (13)
Onekaka at u-s Ironstone (13)
Powell at 40m u-s Motupipi Rv (17)
Powell at Glenview Rd (15)
Takaka at Harwoods (13)
Takaka at Kotinga (20)
Watercress at u-s Dairy Factory (16)
Winter at 50m u-s Totaranui Rd (14)
Biggs at Hewitts Rd (14)
Graham at farm forest bdy (15)
Hunters at Kikiwa (16)
Kikiwa at Kikiwa (13)
Little Sydney at Factory Rd (14)
Motueka at Gorge (12)
Motueka at SH60 bridge (12)
Motueka at u-s Wangapeka (12)
Motueka at Woodmans Bend (12)
Motueka at Woodstock (14)
Motupiko at 250m u-s Motueka Rv (14)
Motupiko at Christies (14)
Riwaka at Hickmotts (12)
Riwaka at Northbranch Source (14)
Sherry at Blue Rock (16)
Sherry at Matariki Br (10)
Sherry at u-s Cave Ck (13)
Sherry at u-s Granity (11)
Tasman at u-s Jesters Hse (18)
Waiwhero at Cemetery (17)
Wangapeka at 5km u-s Dart (12)
Wangapeka at Walter Peak (11)
Borck at 400m ds Queen St (17)
Lee at Meads Br (14)
Redwood Vly at Greenacres Rd (18)
Reservoir Ck at 20m d-s Salisbury Rd (17)
Reservoir Ck at Marlborough Cr (14)
Roding at Twin Bridges (15)
Seaton Vly at Stafford Dr (16)
Waimea at SH60 Appleby (29)
Wairoa at Irvines (16)
Wairoa at Pig Vly (15)
Black Vly at 30m us Lake (20)
Mangles at 1.5 km u-s Tutaki (19)
Mangles at Gorge (18)
Matakitaki at SH6 Murchison (17)
Murchison Ck at 20m d-s SH6 (18)

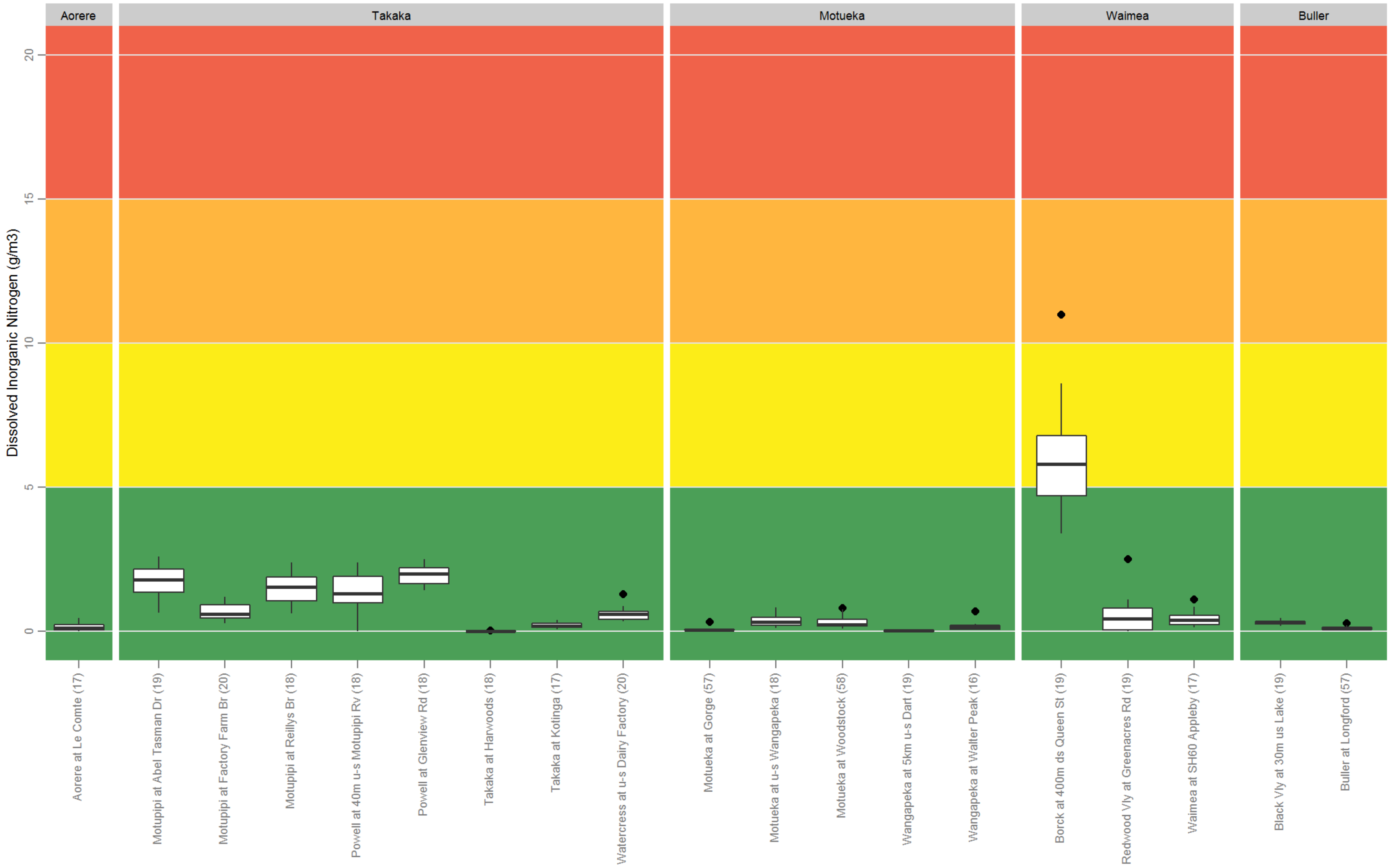

Resuspendable Solids Score
5
4
3
2
1
Aorere
Aorere at Devils Boots (12)
Aorere at Le Comte (16)
Kaituna at 500m us Track start (19)
Kaituna at Sollys Rd (14)
MacKay at ford 50m u-s Kaituna (14)
Takaka
Motupipi at Abel Tasman Dr (15)
Motupipi at Reillys Br (13)
Onahau at Onahau Rd (13)
Onekaka at Shambala Br (14)
Onekaka at u-s Ironstone (14)
Powell at 40m u-s Motupipi Rv (13)
Powell at Glenview Rd (12)
Takaka at Harwoods (13)
Takaka at Kotinga (18)
Motueka
Biggs at Hewitts Rd (18)
Graham at farm forest bdy (14)
Hunters at Kikiwa (15)
Kikiwa at Kikiwa (13)
Little Sydney at Factory Rd (14)
Motueka at Gorge (16)
Motueka at SH60 bridge (10)
Motueka at u-s Wangapeka (15)
Motueka at Woodmans Bend (15)
Motueka at Woodstock (12)
Motupiko at 250m u-s Motueka Rv (15)
Motupiko at Christies (17)
Riwaka at Hickmotts (14)
Riwaka at Northbranch Source (13)
Sherry at Blue Rock (17)
Sherry at Matariki Br (10)
Sherry at u-s Cave Ck (16)
Sherry at u-s Granity (11)
Tasman at u-s Jesters Hse (18)
Waiwhero at Cemetery (15)
Wangapeka at 5km u-s Dart (16)
Wangapeka at Walter Peak (14)
Waimea
Borck at 400m ds Queen St (14)
Lee at Meads Br (14)
Redwood Vly at Greenacres Rd (16)
Reservoir Ck at 20m d-s Salisbury Rd (13)
Reservoir Ck at Marlborough Cr (14)
Roding at Twin Bridges (14)
Seaton Vly at Stafford Dr (18)
Waimea at SH60 Appleby (26)
Wairoa at Irvines (13)
Wairoa at Pig Vly (14)
Buller
Black Vly at 30m us Lake (16)
Mangles at 1.5 km u-s Tutaki (15)
Mangles at Gorge (16)
Matakitaki at SH6 Murchison (14)
Murchison Ck at 20m d-s SH6 (15)

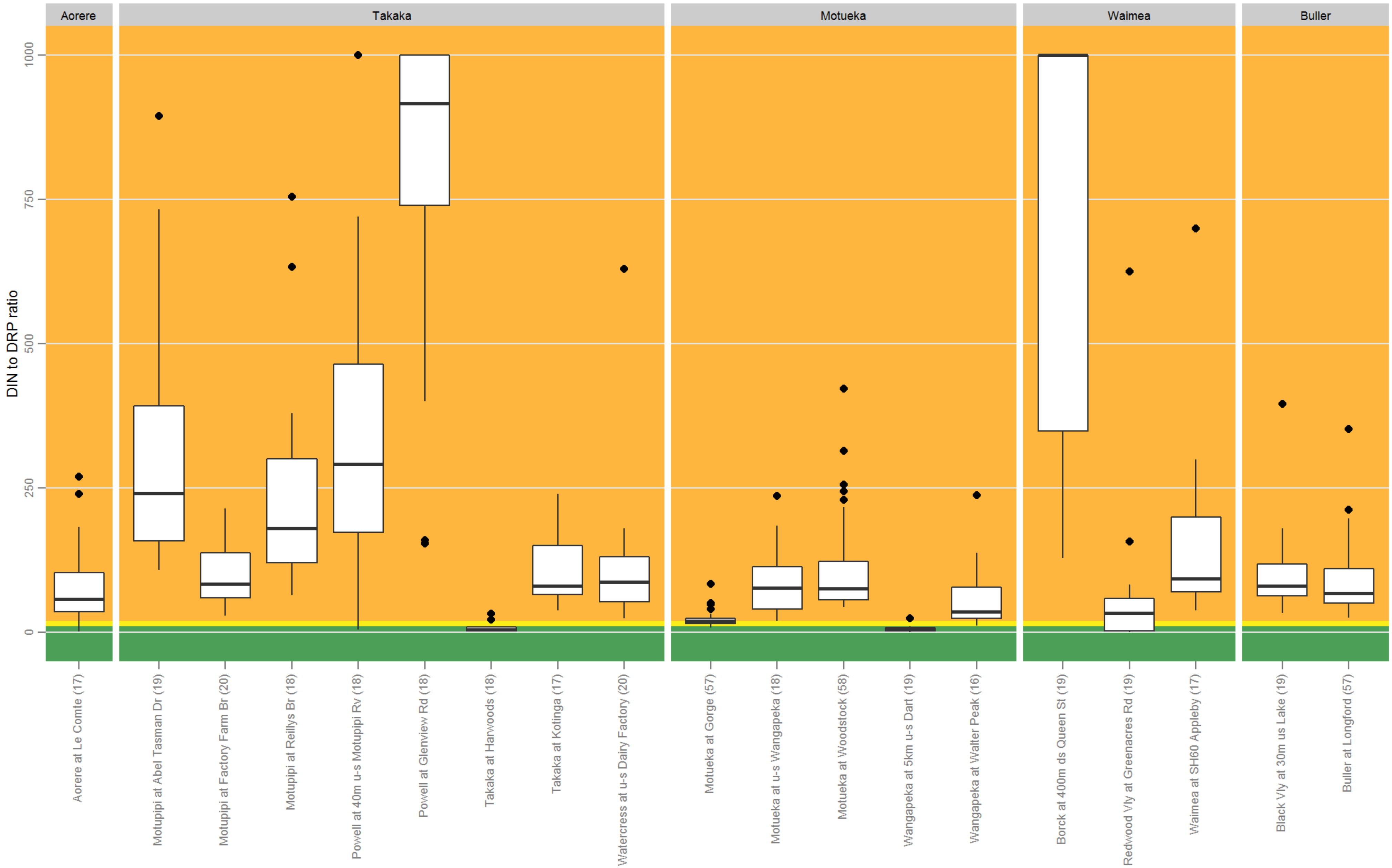

Aorere
Takaka
Motueka
Waimea
Buller
pH
10
8
6
4
Aorere at Devils Boots (17)
Aorere at Le Comte (25)
Kaituna at 500m us Track start (28)
Kaituna at Sollys Rd (20)
MacKay at ford 50m u-s Kaituna (20)
Motupipi at Abel Tasman Dr (20)
Motupipi at Factory Farm Br (20)
Motupipi at Reillys Br (19)
Onahau at Onahau Rd (19)
Onekaka at Shambala Br (20)
Onekaka at u-s Ironstone (20)
Powell at 40m u-s Motupipi Rv (19)
Powell at Glenview Rd (18)
Takaka at Harwoods (20)
Takaka at Kotinga (25)
Watercress at u-s Dairy Factory (20)
Winter at 50m u-s Totaranui Rd (20)
Biggs at Hewitts Rd (19)
Brooklyn at Westbank Rd (14)
Graham at farm forest bdy (19)
Hunters at Kikiwa (19)
Kikiwa at Kikiwa (19)
Little Sydney at Factory Rd (19)
Motueka at Gorge (77)
Motueka at SH60 bridge (16)
Motueka at u-s Wangapeka (16)
Motueka at Woodmans Bend (20)
Motueka at Woodstock (75)
Motupiko at 250m u-s Motueka Rv (18)
Motupiko at Christies (19)
Riwaka at Hickmotts (18)
Riwaka at Northbranch Source (16)
Sherry at Blue Rock (19)
Sherry at Matariki Br (17)
Sherry at u-s Cave Ck (17)
Sherry at u-s Granity (18)
Tasman at u-s Jesters Hse (22)
Waiwhero at Cemetery (16)
Wangapeka at 5km u-s Dart (18)
Wangapeka at Walter Peak (16)
Borck at 400m ds Queen St (19)
Lee at Meads Br (17)
Redwood Vly at Greenacres Rd (20)
Reservoir Ck at 20m d-s Salisbury Rd (19)
Reservoir Ck at Marlborough Cr (19)
Roding at Twin Bridges (19)
Seaton Vly at Stafford Dr (20)
Waimea at SH60 Appleby (35)
Wairoa at Irvines (17)
Wairoa at Pig Vly (18)
Black Vly at 30m us Lake (19)
Buller at Longford (57)
Mangles at 1.5 km u-s Tutaki (18)
Mangles at Gorge (19)
Matakitaki at SH6 Murchison (19)
Murchison Ck at 20m d-s SH6 (19)

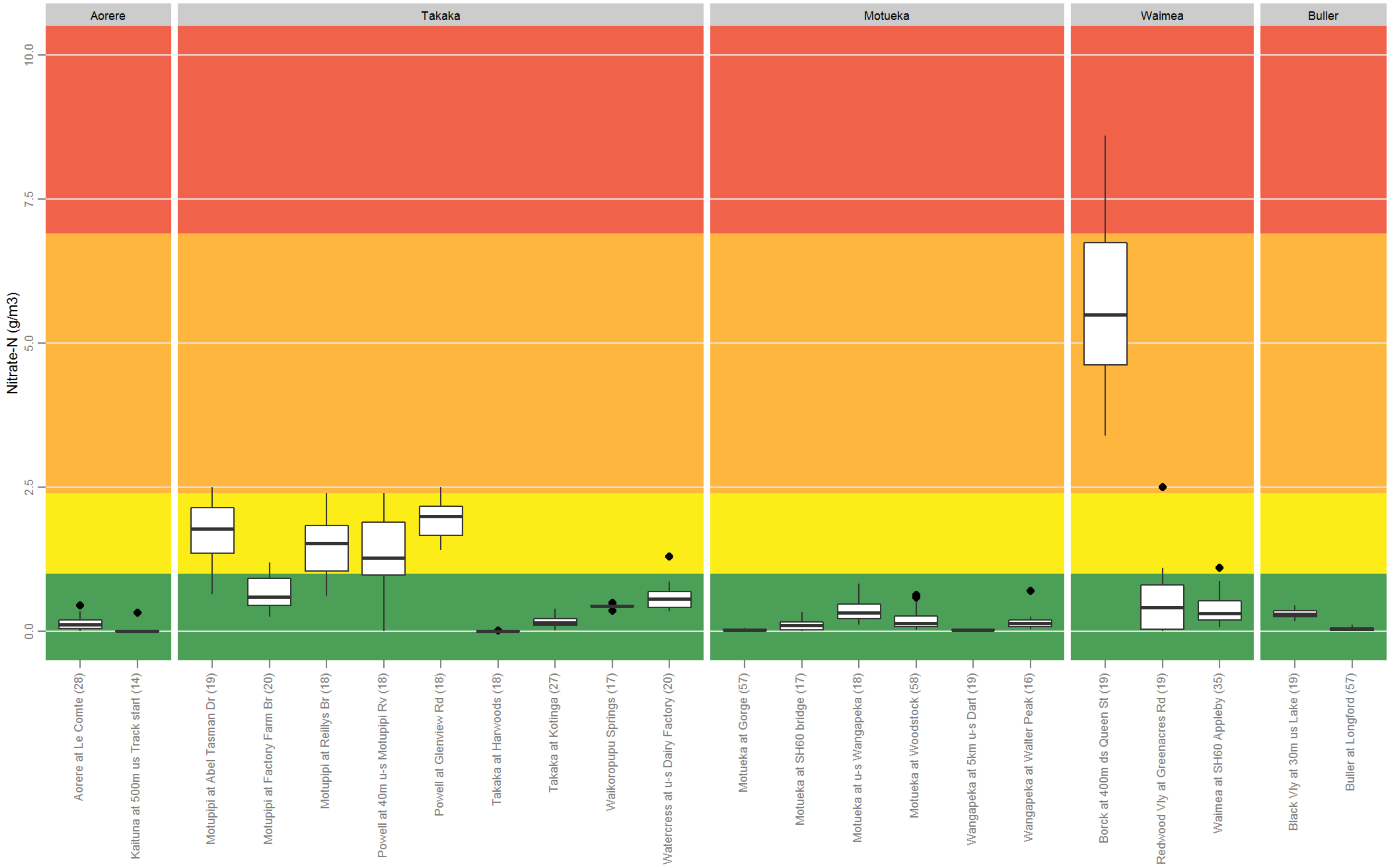

Aorere
Takaka
Motueka
Waimea
Buller
Conductivity (uS/cm)
0
100
200
300
Aorere at Devils Boots (17)
Aorere at Le Comte (24)
Kaituna at 500m us Track start (27)
Kaituna at Sollys Rd (20)
MacKay at ford 50m u-s Kaituna (20)
Motupipi at Abel Tasman Dr (20)
Motupipi at Factory Farm Br (20)
Motupipi at Reillys Br (19)
Onahau at Onahau Rd (19)
Onekaka at Shambala Br (20)
Onekaka at u-s Ironstone (20)
Powell at 40m u-s Motupipi Rv (19)
Powell at Glenview Rd (18)
Takaka at Harwoods (20)
Takaka at Kotinga (24)
Watercress at u-s Dairy Factory (20)
Winter at 50m u-s Totaranui Rd (20)
Biggs at Hewitts Rd (20)
Brooklyn at Westbank Rd (14)
Graham at farm forest bdy (19)
Hunters at Kikiwa (19)
Kikiwa at Kikiwa (19)
Little Sydney at Factory Rd (19)
Motueka at Gorge (77)
Motueka at SH60 bridge (16)
Motueka at u-s Wangapeka (16)
Motueka at Woodmans Bend (20)
Motueka at Woodstock (74)
Motupiko at 250m u-s Motueka Rv (18)
Motupiko at Christies (19)
Riwaka at Hickmotts (18)
Riwaka at Northbranch Source (16)
Sherry at Blue Rock (20)
Sherry at Matariki Br (18)
Sherry at u-s Cave Ck (18)
Sherry at u-s Granity (18)
Tasman at u-s Jesters Hse (22)
Waiwhero at Cemetery (17)
Wangapeka at 5km u-s Dart (19)
Wangapeka at Walter Peak (17)
Borck at 400m ds Queen St (19)
Lee at Meads Br (18)
Redwood Vly at Greenacres Rd (20)
Reservoir Ck at 20m d-s Salisbury Rd (18)
Reservoir Ck at Marlborough Cr (19)
Roding at Twin Bridges (19)
Seaton Vly at Stafford Dr (20)
Waimea at SH60 Appleby (35)
Wairoa at Irvines (18)
Wairoa at Pig Vly (19)
Black Vly at 30m us Lake (20)
Buller at Longford (57)
Mangles at 1.5 km u-s Tutaki (19)
Mangles at Gorge (20)
Matakitaki at SH6 Murchison (20)
Murchison Ck at 20m d-s SH6 (20)

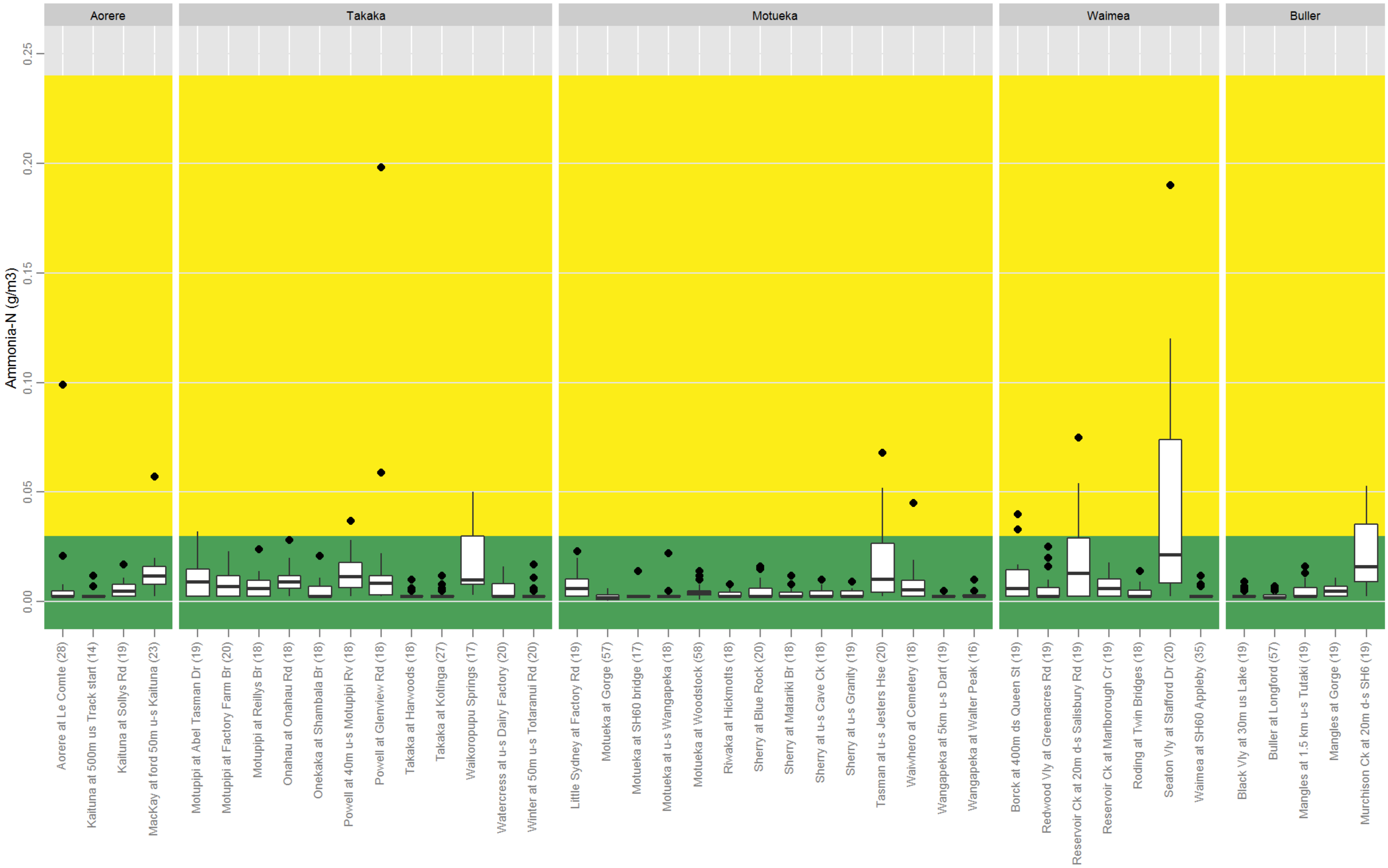

Aorere
Takaka
Motueka
Waimea
Buller
E.coli (MPN/100mL)
3000
2000
1000
0
Aorere at Devils Boots (17)
Aorere at Le Comte (52)
Burton Ale at Coll-Bainham Rd (42)
Kaituna at 500m us Track start (35)
Kaituna at Sollys Rd (20)
MacKay at Coll-Bainham Rd (24)
MacKay at ford 50m u-s Kaituna (24)
Motupipi at Abel Tasman Dr (20)
Motupipi at Factory Farm Br (20)
Motupipi at Reillys Br (20)
Onahau at Onahau Rd (20)
Onekaka at Shambala Br (19)
Onekaka at u-s Ironstone (21)
Powell at 40m u-s Motupipi Rv (19)
Powell at Glenview Rd (18)
Takaka at Harwoods (18)
Takaka at Kotinga (28)
Takaka at Paynes Fd (81)
Tukurua at Playground (67)
Tukurua at SH60 (59)
Watercress at u-s Dairy Factory (20)
Winter at 50m u-s Totaranui Rd (20)
Biggs at Hewitts Rd (20)
Brooklyn at Westbank Rd (20)
Graham at farm forest bdy (19)
Hunters at Kikiwa (18)
Kikiwa at Kikiwa (19)
Little Sydney at Factory Rd (19)
Motueka at Alexanders Br (39)
Motueka at Gorge (76)
Motueka at SH60 bridge (55)
Motueka at u-s Wangapeka (19)
Motueka at Woodmans Bend (20)
Motueka at Woodstock (76)
Motupiko at 250m u-s Motueka Rv (20)
Motupiko at Christies (20)
Moutere at Riverside (15)
Riwaka at Hickmotts (18)
Riwaka at Northbranch Source (15)
Sherry at Blue Rock (66)
Sherry at Matariki Br (18)
Sherry at u-s Cave Ck (17)
Sherry at u-s Granity (19)
Tasman at u-s Jesters Hse (22)
Waiwhero at Cemetery (19)
Wangapeka at 5km u-s Dart (18)
Wangapeka at Walter Peak (17)
Borck at 400m ds Queen St (20)
Lee at Meads Br (19)
Lee at Reserve (82)
Redwood Vly at Greenacres Rd (20)
Reservoir Ck at 20m d-s Salisbury Rd (20)
Reservoir Ck at Marlborough Cr (21)
Roding at Twin Bridges (78)
Seaton Vly at Stafford Dr (20)
Waimea at SH60 Appleby (71)
Wairoa at Irvines (18)
Wairoa at Pig Vly (20)
Wairoa at WEIS weir (40)
Black Vly at 30m us Lake (19)
Buller at Longford (53)
Mangles at 1.5 km u-s Tutaki (19)
Mangles at Gorge (19)
Matakitaki at SH6 Murchison (22)
Murchison Ck at 20m d-s SH6 (20)


Aorere
Takaka
Motueka
Waimea
Buller
Dissolved Reactive Phosphorus (g/m3)
0.04
0.03
0.02
0.01
0.00
Aorere at Le Comte (28)
Kaituna at 500m us Track start (14)
Motupipi at Abel Tasman Dr (19)
Motupipi at Factory Farm Br (20)
Motupipi at Reillys Br (18)
Powell at 40m u-s Motupipi Rv (18)
Powell at Glenview Rd (18)
Takaka at Harwoods (18)
Takaka at Kotinga (27)
Watercress at u-s Dairy Factory (20)
Motueka at Gorge (57)
Motueka at SH60 bridge (17)
Motueka at u-s Wangapeka (18)
Motueka at Woodstock (58)
Wangapeka at 5km u-s Dart (19)
Wangapeka at Walter Peak (16)
Borck at 400m ds Queen St (19)
Redwood Vly at Greenacres Rd (19)
Waimea at SH60 Appleby (32)
Black Vly at 30m us Lake (19)
Buller at Longford (57)


Aorere
Takaka
Motueka
Waimea
Buller
Dissolved Inorganic Nitrogen (g/m3)
20
15
10
5
0
Aorere at Le Comte (17)
Motupipi at Abel Tasman Dr (19)
Motupipi at Factory Farm Br (20)
Motupipi at Reillys Br (18)
Powell at 40m u-s Motupipi Rv (18)
Powell at Glenview Rd (18)
Takaka at Harwoods (18)
Takaka at Kotinga (17)
Watercress at u-s Dairy Factory (20)
Motueka at Gorge (57)
Motueka at u-s Wangapeka (18)
Motueka at Woodstock (58)
Wangapeka at 5km u-s Dart (19)
Wangapeka at Walter Peak (16)
Borck at 400m ds Queen St (19)
Redwood Vly at Greenacres Rd (19)
Waimea at SH60 Appleby (17)
Black Vly at 30m us Lake (19)
Buller at Longford (57)


Aorere
Takaka
Motueka
Waimea
Buller
DIN to DRP ratio
1000
750
500
250
0
Aorere at Le Comte (17)
Motupipi at Abel Tasman Dr (19)
Motupipi at Factory Farm Br (20)
Motupipi at Reillys Br (18)
Powell at 40m u-s Motupipi Rv (18)
Powell at Glenview Rd (18)
Takaka at Harwoods (18)
Takaka at Kotinga (17)
Watercress at u-s Dairy Factory (20)
Motueka at Gorge (57)
Motueka at u-s Wangapeka (18)
Motueka at Woodstock (58)
Wangapeka at 5km u-s Dart (19)
Wangapeka at Walter Peak (16)
Borck at 400m ds Queen St (19)
Redwood Vly at Greenacres Rd (19)
Waimea at SH60 Appleby (17)
Black Vly at 30m us Lake (19)
Buller at Longford (57)


Aorere
Takaka
Motueka
Waimea
Buller
Nitrate-N (g/m3)
10.0
7.5
5.0
2.5
0.0
Aorere at Le Comte (28)
Kaituna at 500m us Track start (14)
Motupipi at Abel Tasman Dr (19)
Motupipi at Factory Farm Br (20)
Motupipi at Reillys Br (18)
Powell at 40m u-s Motupipi Rv (18)
Powell at Glenview Rd (18)
Takaka at Harwoods (18)
Takaka at Kotinga (27)
Waikoropupu Springs (17)
Watercress at u-s Dairy Factory (20)
Motueka at Gorge (57)
Motueka at SH60 bridge (17)
Motueka at u-s Wangapeka (18)
Motueka at Woodstock (58)
Wangapeka at 5km u-s Dart (19)
Wangapeka at Walter Peak (16)
Borck at 400m ds Queen St (19)
Redwood Vly at Greenacres Rd (19)
Waimea at SH60 Appleby (35)
Black Vly at 30m us Lake (19)
Buller at Longford (57)


Aorere
Takaka
Motueka
Waimea
Buller
Ammonia-N (g/m3)
0.25
0.20
0.15
0.10
0.05
0.00
Aorere at Le Comte (28)
Kaituna at 500m us Track start (14)
Kaituna at Sollys Rd (19)
MacKay at ford 50m u-s Kaituna (23)
Motupipi at Abel Tasman Dr (19)
Motupipi at Factory Farm Br (20)
Motupipi at Reillys Br (18)
Onahau at Onahau Rd (18)
Onekaka at Shambala Br (18)
Powell at 40m u-s Motupipi Rv (18)
Powell at Glenview Rd (18)
Takaka at Harwoods (18)
Takaka at Kotinga (27)
Waikoropupu Springs (17)
Watercress at u-s Dairy Factory (20)
Winter at 50m u-s Totaranui Rd (20)
Little Sydney at Factory Rd (19)
Motueka at Gorge (57)
Motueka at SH60 bridge (17)
Motueka at u-s Wangapeka (18)
Motueka at Woodstock (58)
Riwaka at Hickmotts (18)
Sherry at Blue Rock (20)
Sherry at Matariki Br (18)
Sherry at u-s Cave Ck (18)
Sherry at u-s Granity (19)
Tasman at u-s Jesters Hse (20)
Waiwhero at Cemetery (18)
Wangapeka at 5km u-s Dart (19)
Wangapeka at Walter Peak (16)
Borck at 400m ds Queen St (19)
Redwood Vly at Greenacres Rd (19)
Reservoir Ck at 20m d-s Salisbury Rd (19)
Reservoir Ck at Marlborough Cr (19)
Roding at Twin Bridges (18)
Seaton Vly at Stafford Dr (20)
Waimea at SH60 Appleby (35)
Black Vly at 30m us Lake (19)
Buller at Longford (57)
Mangles at 1.5 km u-s Tutaki (19)
Mangles at Gorge (19)
Murchison Ck at 20m d-s SH6 (19)

Appendix 3: Trend Analysis Results

Table 27. Water quality trend results for the Tasman District over the 10-year period 2005 to 2014 (highlighted in blue) and over the full record (from 15 to 45 years depending on the site). Seasonal Kendall trend tests were used for *E. coli* concentrations, water clarity measurements and nutrient concentrations (Ammonia-N, Nitrate-N and DRP). Mann-Kendall trend tests were used for invertebrate community metrics (only for the NRWQN sites Motueka at Gorge, Motueka at Woodstock and Buller at Longford). The trends shown are significant ($p < 0.05$), meaningful (RSKSE > 1% per year) and the change in value between the start and end of the trend line (Δ value) is greater than the detection limit for the attribute (refer to the Methods sections for the detection limits).

Site name	WMA	Attribute	Effect ☺ ☹	N obs	N years	Median value	p-value	RSKSE (% per year)	Δ value
Aorere at Le Comte	Aorere	Ammonia-N	☺	62	15	0.0050	<0.0001	-8.5	0.0063
Kaituna at Sollys Rd	Aorere	Ammonia-N	☺	36	10	0.0080	0.0402	-7.4	0.0059
Little Sydney at Factory Rd	Motueka	Ammonia-N	☺	37	10	0.0110	0.0001	-12.5	0.0138
Motupipi at Factory Farm Br	Takaka	Ammonia-N	☺	39	10	0.0090	0.0076	-11.1	0.0100
Motupipi at Reillys Br	Takaka	Ammonia-N	☺	39	10	0.0090	0.0319	-5.6	0.0050
Motupipi at Reillys Br	Takaka	Ammonia-N	☺	58	15	0.0095	0.0002	-7.9	0.0113
Powell at 40 m u-s Motupipi Rv	Takaka	Ammonia-N	☺	43	10	0.0160	0.0025	-10.4	0.0167
Powell at Glenview Rd	Takaka	Ammonia-N	☺	43	10	0.0100	0.0113	-10.0	0.0100
Reservoir Ck at 20 m d-s Salisbury Rd	Waimea	Ammonia-N	☺	56	15	0.0200	0.0030	-6.3	0.0188
Reservoir Ck at Marlborough Cr	Waimea	Ammonia-N	☺	38	10	0.0070	0.0173	-11.6	0.0081
Riwaka at Hickmotts	Motueka	Ammonia-N	☺	37	10	0.0050	0.0030	-13.1	0.0065
Riwaka at Hickmotts	Motueka	Ammonia-N	☺	64	16	0.0070	<0.0001	-9.4	0.0105
Sherry at Blue Rock	Motueka	Ammonia-N	☺	61	10	0.0070	0.0001	-12.9	0.0090
Sherry at Blue Rock	Motueka	Ammonia-N	☺	82	15	0.0080	<0.0001	-8.8	0.0105
Sherry at Matariki Br	Motueka	Ammonia-N	☺	57	10	0.0050	<0.0001	-20.0	0.0100
Sherry at u-s Cave Ck	Motueka	Ammonia-N	☺	82	15	0.0050	0.0001	-7.5	0.0056
Waiwhero at Cemetery	Motueka	Ammonia-N	☺	37	10	0.0090	0.0021	-12.7	0.0115
Watercress at u-s Dairy Factory	Takaka	Ammonia-N	☺	37	10	0.0100	<0.0001	-30.0	0.0300
Aorere at Le Comte	Aorere	DRP	☺	61	15	0.0025	<0.0001	-7.0	0.0026

Site name	WMA	Attribute	Effect ☺ ☹	N obs	N years	Median value	p-value	RSKSE (% per year)	Δ value
Motueka at u-s Wangapeka	Motueka	DRP	☺	60	15	0.0055	0.0256	-3.0	0.0025
Motupipi at Reillys Br	Takaka	DRP	☺	40	10	0.0100	<0.0001	-10.0	0.0100
Motupipi at Reillys Br	Takaka	DRP	☺	58	17	0.0125	<0.0001	-9.8	0.0208
Powell at 40 m u-s Motupipi Rv	Takaka	DRP	☺	45	10	0.0050	0.0236	-5.0	0.0025
Sherry at Blue Rock	Motueka	DRP	☺	60	15	0.0040	<0.0001	-10.4	0.0063
Waimea at SH60 Appleby	Waimea	DRP	☺	51	10	0.0030	0.0235	-6.9	0.0021
Waimea at SH60 Appleby	Waimea	DRP	☺	69	15	0.0030	0.0008	-6.7	0.0030
Little Sydney at Factory Rd	Motueka	*E. coli*	☺	38	10	332.5000	0.0144	-9.2	304.2857
Little Sydney at Factory Rd	Motueka	*E. coli*	☺	60	15	425.0000	0.0002	-9.0	575.9615
Motupiko at Christies	Motueka	*E. coli*	☺	72	16	50.0000	0.0001	-10.0	80.0000
Motupipi at Reillys Br	Takaka	*E. coli*	☺	60	17	257.5000	0.0037	-6.0	261.0714
Reservoir Ck at 20 m d-s Salisbury Rd	Waimea	*E. coli*	☹	40	10	134.0000	0.0055	12.2	163.2500
Riwaka at Hickmotts	Motueka	*E. coli*	☹	37	10	50.0000	0.0009	12.4	61.8750
Sherry at Blue Rock	Motueka	*E. coli*	☺	141	10	248.9000	0.0013	-6.9	171.2143
Sherry at Blue Rock	Motueka	*E. coli*	☺	186	15	266.5000	0.0001	-5.2	207.4286
Sherry at u-s Cave Ck	Motueka	*E. coli*	☺	63	15	30.0000	0.0004	-5.7	25.6250
Wairoa at Irvines	Waimea	*E. coli*	☺	61	16	10.0000	0.0032	-8.3	13.3333
Waiwhero at Cemetery	Motueka	*E. coli*	☹	61	15	145.0000	0.0231	3.4	75.0000
Wangapeka at Walter Peak	Motueka	*E. coli*	☺	67	16	15.0000	0.0055	-8.6	20.6667
Motueka at Gorge	Motueka	# EPT Taxa	☹	27	26	12.0000	0.0258	-1.4	4.3333
Aorere at Le Comte	Aorere	Nitrate-N	☹	45	10	0.0930	0.0245	2.9	0.0271
Buller at Longford	Buller	Nitrate-N	☹	117	10	0.0270	0.0005	4.9	0.0133
Motueka at Gorge	Motueka	Nitrate-N	☹	119	10	0.0230	0.0384	2.2	0.0050
Motueka at u-s Wangapeka	Motueka	Nitrate-N	☹	61	15	0.2300	0.0033	4.3	0.1500
Motueka at Woodstock	Motueka	Nitrate-N	☹	325	26	0.1160	<0.0001	2.2	0.0664
Powell at Glenview Rd	Takaka	Nitrate-N	☹	45	10	1.7000	0.0129	3.4	0.5800
Takaka at Harwoods	Takaka	Nitrate-N	☺	63	17	0.0100	<0.0001	-15.0	0.0255

Site name	WMA	Attribute	Effect ☺ ☹	N obs	N years	Median value	p-value	RSKSE (% per year)	Δ value
Takaka at Kotinga	Takaka	Nitrate-N	☺	42	10	0.1600	0.0158	-6.3	0.1000
Te Waikoropupū Springs	Takaka	Nitrate-N	☹	40	10	0.4350	0.0002	1.8	0.0775
Te Waikoropupū Springs	Takaka	Nitrate-N	☹	103	45	0.3800	<0.0001	1.7	0.2912
Wangapeka at Walter Peak	Motueka	Nitrate-N	☹	69	16	0.0990	0.0454	2.4	0.0387
Watercress at u-s Dairy Factory	Takaka	Nitrate-N	☹	38	10	0.4850	0.0127	4.1	0.2000
Buller at Longford	Buller	QMCI	☹	25	25	5.0034	0.0183	-1.4	1.7138
Motueka at Woodstock	Motueka	QMCI	☹	25	25	4.9059	0.0377	-1.1	1.3108
Buller at Longford	Buller	Water Clarity	☺	312	26	3.7050	0.0004	1.8	1.7308
Little Sydney at Factory Rd	Motueka	Water Clarity	☹	60	15	1.1900	0.0069	-3.3	0.5813
Mangles at 1.5 km u-s Tutaki	Buller	Water Clarity	☺	36	10	1.8065	0.0325	4.5	0.8125
Mangles at Gorge	Buller	Water Clarity	☺	37	10	4.0000	0.0072	3.7	1.4786
Matakitaki at SH6 Murchison	Buller	Water Clarity	☹	37	10	3.5000	0.0100	-5.9	2.0588
Motueka at Gorge	Motueka	Water Clarity	☺	367	26	10.3500	<0.0001	1.6	4.3008
Motueka at Woodstock	Motueka	Water Clarity	☺	364	26	4.0465	0.0014	1.3	1.3907
Onahau at Onahau Rd	Takaka	Water Clarity	☺	36	10	2.8500	0.0145	4.4	1.2671
Onekaka at Shambala Br	Takaka	Water Clarity	☺	36	10	4.5750	0.0285	5.0	2.2938
Reservoir Ck at Marlborough Cr	Waimea	Water Clarity	☺	36	10	0.9750	0.0435	8.5	0.8300
Riwaka at Hickmotts	Motueka	Water Clarity	☹	36	10	4.3415	0.0261	-3.8	1.6556
Sherry at u-s Cave Ck	Motueka	Water Clarity	☺	57	10	2.2330	0.0319	5.7	1.2750
Te Waikoropupū River	Takaka	Water Clarity	☹	107	18	21.9500	0.0001	-1.7	6.6600

Appendix 4: Dissolved Oxygen Results

Summary statistics for continuous measurements of dissolved oxygen are shown in Table 28.

Table 28. Dissolved oxygen summary statistics from continuous measurements. Recorders were installed during the summer months. Colours indicate attribute state (Green = A, Yellow = B, Orange =C, Red = D). Smaller pastoral streams are indicated with Type = P.

Site	Type	Month	N days	1-day minimum saturation (%)	1-day minimum concentration (mg/L)	7-day mean minimum concentration (mg/L)
Borck at 400m ds Queen St	P	Feb-09	4	48	4.2	NA
Burton Ale at Coll-Bainham Rd	P	Mar-15	7	36	3.4	4
Clay at 550 m u-s Aorere	P	Mar-15	7	47.7	4.9	5.4
Dall at Coll-Bainham Rd	P	Mar-15	7	29.3	2.8	3.6
Dominion at SH60	P	Feb-14	2	58.9	5.8	NA
Dove Rv	P	Feb-10	6	68	6.9	NA
Glenrae at Tap-Baton Rd	P	Feb-15	3	51.3	5	NA
Granity		Mar-02	2	97	8.2	NA
Hinehaka at 200 m u-s Buller	P	Mar-15	6	5.3	0.5	NA
Hinetai Spring 1	P	Feb-15	3	25.4	2.5	NA
Hinetai Spring 2	P	Feb-15	1	44.1	4.4	NA
Horton Vly Stm	P	Feb-09	4	27	2.7	NA
James Cutting at Coll-Bainham Rd	P	Mar-15	7	21.3	2.1	2.5
Jimmy-Lee Ck at d-s Hill St	P	Feb-10	3	85	8.4	NA
Little Sydney at d-s SH60	P	Feb-09	4	77	6.8	NA
Little Sydney at Factory Rd	P	Feb-09	4	86	7.7	NA
Little Sydney at u-s Johnson Barrier	P	Feb-09	4	97	9	NA
MacKay at Coll-Bainham Rd	P	Dec-14	6	65	6.6	NA
MacKay at d-s Gillies Rd	P	Dec-14	5	67.6	6.9	NA
Mackay Ck at 50 m u-s Kaituna Rv	P	Feb-10	5	73	7	NA
McConnon at 20m u-s Powell	P	Jan-06	6	14	1.3	NA
Motueka at Woodmans Bend		Feb-02	1	93	8	NA
Motueka at Woodstock		Mar-02	2	97	8.8	NA
Motupiko at Quinneys Bush		Feb-02	1	89	7.8	NA
Motupipi at 20 m u-s Watercress	P	Jan-06	6	11	1.2	NA
Motupipi at Reillys Br	P	Jan-15	24	34	3.5	4.3
Moutere at Riverside	P	Feb-14	3	63.2	6	NA
Moutere Rv at Kelling Rd	P	Feb-10	3	71	6.7	NA
Murchison Ck at 20 m d-s SH6	P	Mar-15	6	23.9	2.4	NA
Murchison Ck at Kiwi Park	P	Mar-15	5	48.8	4.9	NA

Murchison Ck at u-s Fairfax St	P	Mar-15	6	49.5	5	NA
Neimann at 600 m u-s Lansdowne Rd	P	Mar-14	3	19.3	3.2	NA
Nile Ck at u-s SH60	P	Feb-14	2	32.5	3.3	NA
North at Gravel Pit Crossing	P	Mar-15	6	61.5	6	NA
Old House Stm	P	Feb-10	3	18	1.6	NA
Old Moutere at Edwards Rd	P	Feb-14	4	0.5	0.1	NA
Old Moutere at Wratten Weir	P	Feb-14	3	0	0	NA
Old School at u-s Confl	P	Feb-15	3	34.5	3.4	NA
Onahau at Onahau Rd	P	Feb-10	5	70	6.7	NA
Orinoco	P	Feb-09	4	79	7.8	NA
Pearl at 200 m u-s Tidegate	P	Mar-14	3	13.2	1.4	NA
Powell Ck at Glenview Rd	P	Feb-06	1	72	4.1	NA
Powell Ck at Reilly's crossing	P	Jan-06	3	15	1.5	NA
Rainy Rv Lower		Mar-02	1	88	8.4	NA
Rainy Rv Upper		Mar-02	1	87	7.8	NA
Reservoir Ck at 20 m d-s Salisbury Rd		Feb-09	4	71	6.4	NA
Reservoir Ck at Marlborough Cr		Feb-09	4	92	8.7	NA
Riwaka at Hickmotts		Feb-09	3	97	9.7	NA
Riwaka at Northbranch Source		Feb-09	4	106	11.9	NA
Rolling		Mar-02	1	98	8.2	NA
Rosedale Stm at Old House Rd	P	Feb-10	5	50	5	NA
Seaton Valley Stm at Andersons	P	Feb-09	5	61	5.7	NA
Seaton Vly at Stafford Drive	P	Feb-09	2	86	8.2	NA
Stanley Brk	P	Feb-09	3	60	6	NA
Tasman at u-s Jesters Hse	P	Feb-09	4	35	3.4	NA
Te Kaukau Stm at Feary	P	Feb-06	4	39	0.3	NA
Thorpe at 300 m u-s Old Wharf Rd	P	Feb-14	3	3.1	0.3	NA
Wai-iti at Livingston Rd		Feb-14	3	52.8	5.1	NA
Waimea at 1.5km u-s SH60		Feb-14	2	72.1	6.7	NA
Wairoa at Bryant Rd		Feb-14	3	95	8.6	NA
Waiwhero at Cemetery	P	Feb-09	4	23	2.3	NA
Wangapeka at Walters		Feb-02	1	97	8.7	NA
Wangapeka u-s Dart		Mar-02	1	92	8.3	NA

Appendix 5: Water Temperature Results

Summary statistics for continuous measurements of water temperature are shown in Table 29. The midpoint of the daily mean and daily maximum temperature is also known as the Cox-Rutherford Index.

Table 29. Results of continuous measurements of water temperature. Recorders were installed during the summer months. Colours indicate attribute state (Green-A, Yellow-B, Orange-C, Red-D). Smaller pastoral streams are indicated with Type = P.

Site	Type	Month	N days	Highest midpoint of daily mean and daily maximum temperature (°C)
Borck at 400m ds Queen St	P	Feb-09	3	🟧 22.0
Burton Ale at Coll-Bainham Rd	P	Mar-15	7	🟧 21.0
Clay at 500 m u-s Aorere	P	Mar-15	7	🟩 16.9
Dall at Coll-Bainham Rd	P	Mar-15	7	🟨 19.1
Dominion at SH60	P	Feb-14	2	🟨 18.9
Glenrae at Tap-Baton Rd	P	Feb-15	3	🟧 22.6
Hinehaka at 200 m u-s Buller	P	Mar-15	6	🟩 17.9
Hinetai Spring 1	P	Feb-15	3	🟨 18.9
Hinetai Spring 2	P	Feb-15	1	🟩 15.8
Horton Vly Stm at d-s Preece Wetland	P	Feb-09	4	🟧 21.7
James Cutting at Coll-Bainham Rd	P	Mar-15	7	🟧 20.2
Jimmy-Lee Ck at d-s Hill St	P	Feb-10	2	🟩 18.0
Little Sydney at Factory Rd	P	Jan-02	338	🟧 20.8
Little Sydney at d-s SH60	P	Feb-09	3	🟧 21.9
Little Sydney at u-s Johnson Barrier	P	Feb-09	3	🟨 18.5
MacKay at Coll-Bainham Rd	P	Dec-14	6	🟧 21.1
MacKay at d-s Gillies Rd	P	Dec-14	5	🟧 20.4
MacKay at ford 50m u-s Kaituna	P	Feb-10	4	🟧 20.3
McConnon at 20m u-s Powell	P	Feb-06	6	🟧 22.5
Motupipi at 20m u-s Watercress	P	Feb-06	7	🟩 15.9
Motupipi at Reillys Br	P	Feb-06	7	🟨 19.0
Moutere at Riverside	P	Feb-14	3	🟧 22.6
Murchison Ck at 20 m d-s SH6	P	Mar-15	6	🟧 21.1
Murchison Ck at Kiwi Park	P	Mar-15	5	🟨 18.4
Murchison Ck at u-s Fairfax St	P	Mar-15	6	🟨 19.0
Neimann at 600 m u-s Lansdowne Rd	P	Mar-14	3	🟨 19.4
Nile Ck at u-s SH60	P	Feb-14	2	🟨 19.9
North at Gravel Pit Crossing	P	Mar-15	6	🟨 19.5
Old House at Central Rd	P	Feb-10	2	🟧 20.4
Old Moutere at Edwards Rd	P	Feb-14	4	🟩 16.9
Old Moutere at Wratten Weir	P	Feb-14	3	🟧 22.7
Old School at u-s Confl	P	Feb-15	3	🟩 17.9
Onahau at Onahau Rd	P	Feb-10	5	🟨 19.1

Orinoco at 800m u-s Motueka Rv	P	Feb-09	3	18.3
Pearl at 200 m u-s Tidegate	P	Mar-14	3	15.2
Powell at 40m u-s Motupipi Rv	P	Feb-06	7	26.2
Reservoir Ck at 20m d-s Salisbury Rd		Feb-06	188	24.5
Reservoir Ck at Marlborough Cr		Jan-07	207	19.4
Riwaka at Northbranch Source		Feb-09	3	10.9
Rosedale Stm at Old House Rd	P	Feb-10	5	21.1
Seaton Vly at Andersons	P	Feb-09	4	18.8
Seaton Vly at Stafford Dr	P	Feb-09	8	21.6
Stanley Brk at Barkers	P	Jan-02	380	18.5
Tasman at u-s Jesters Hse	P	Feb-09	4	24.8
Te Kakau at Feary Cr	P	Feb-06	8	22.9
Thorpe at 300 m u-s Old Wharf Rd	P	Feb-14	3	20.7
Wai-iti at Livingston Rd		Feb-14	3	22.9
Waimea at 1.5km u-s SH60		Feb-14	2	22.1
Wairoa at Bryant Rd		Feb-14	3	23.3
Waiwhero at Cemetery	P	Jan-02	336	20.9

Appendix 6: Fine Sediment Results

From 2010 to Feb 2015, 12 out of 58 sites (21%) had resuspendable solids scores in attribute state D (score >4). The sites in attribute state D are shown in the table below:

Site	Date	Resuspendable solids score
Biggs at Hewitts Rd	20/05/2011	5
Biggs at Hewitts Rd	11/02/2015	5
Borck at 400 m ds Queen St	17/02/2015	5
Motueka at u-s Wangapeka	4/07/2011	5
Motupipi at Factory Farm Br	28/07/2010	5
Motupipi at Factory Farm Br	1/11/2011	5
Motupipi at Reillys Br	20/07/2011	5
Murchison Ck at 20 m d-s SH6	14/02/2013	4.7
Murchison Ck at 20 m d-s SH6	15/07/2013	4.3
Murchison Ck at 20 m d-s SH6	13/02/2014	5
Murchison Ck at 20 m d-s SH6	31/03/2014	5
Murchison Ck at 20 m d-s SH6	4/02/2015	4.7
Powell at 40 m u-s Motupipi Rv	20/07/2011	5
Reservoir Ck at Marlborough Cr	2/07/2014	4.7
Seaton Vly at Stafford Dr	27/01/2010	5
Seaton Vly at Stafford Dr	16/07/2010	5
Seaton Vly at Stafford Dr	18/10/2010	5
Seaton Vly at Stafford Dr	4/02/2011	5
Seaton Vly at Stafford Dr	18/05/2011	5
Seaton Vly at Stafford Dr	5/07/2011	5
Seaton Vly at Stafford Dr	1/02/2012	5
Seaton Vly at Stafford Dr	24/04/2012	5
Seaton Vly at Stafford Dr	12/02/2013	5
Seaton Vly at Stafford Dr	11/02/2014	5
Seaton Vly at Stafford Dr	31/03/2014	4.7
Seaton Vly at Stafford Dr	9/07/2014	5
Seaton Vly at Stafford Dr	15/10/2014	4.7
Tasman at u-s Jesters Hse	18/10/2010	5
Tasman at u-s Jesters Hse	12/02/2013	5
Tasman at u-s Jesters Hse	11/02/2014	5
Tasman at u-s Jesters Hse	12/02/2015	5
Waiwhero at Cemetery	15/08/2012	4.7
Waiwhero at Cemetery	15/10/2014	4.3
Waiwhero at Cemetery	12/02/2015	5
Watercress at u-s Dairy Factory	3/02/2010	5
Watercress at u-s Dairy Factory	8/06/2010	5
Watercress at u-s Dairy Factory	1/11/2011	5

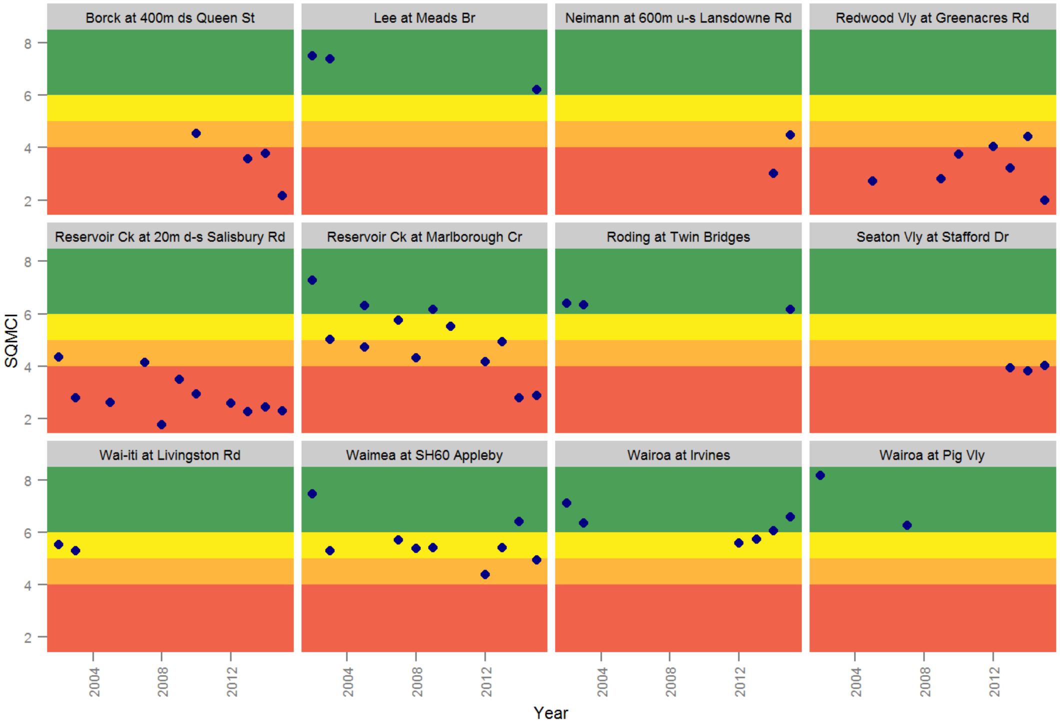
Over the same period, 16 out of 34 sites (47%) had a mean SBSV value greater than 50L/m3. Sites shown in the table below:

Site	**Date**	**Mean Volumetric SBSV (L/m3)**
Biggs at Hewitts Rd	11/02/2015	182.1
Borck at 400 m ds Queen St	17/02/2015	57.2
Borck at 400 m ds Queen St	26/05/2015	124.3
Hunters at Kikiwa	11/02/2015	102.6
Motupipi at Reillys Br	8/02/2012	98.7
Motupipi at Reillys Br	18/02/2013	131.2
Motupipi at Reillys Br	17/02/2015	54.2
Moutere at Riverside	12/02/2013	63.4
Moutere at Riverside	12/02/2015	100.5
Murchison Ck at 20 m d-s SH6	4/02/2015	60.6
Neimann Ck at 600 m u-s Lansdowne Rd	17/02/2015	79.1
Pearl Ck at 200 m u-s tidegate	17/02/2015	54.0
Powell at 40 m u-s Motupipi Rv	8/02/2012	174.5
Powell at 40 m u-s Motupipi Rv	18/02/2013	94.3
Powell at 40 m u-s Motupipi Rv	17/02/2015	77.5
Powell at Glenview Rd	8/02/2012	54.7
Powell at Glenview Rd	17/02/2015	70.7
Redwood Vly at Greenacres Rd	17/03/2015	89.6
Reservoir Ck at 20 m d-s Salibury Rd	7/02/2012	98.0
Reservoir Ck at Marlborough Cr	17/02/2015	402.8
Riwaka at Hickmotts	12/02/2015	70.4
Tasman at u-s Jesters Hse	12/02/2015	136.0
Waiwhero at Cemetery	12/02/2015	60.2

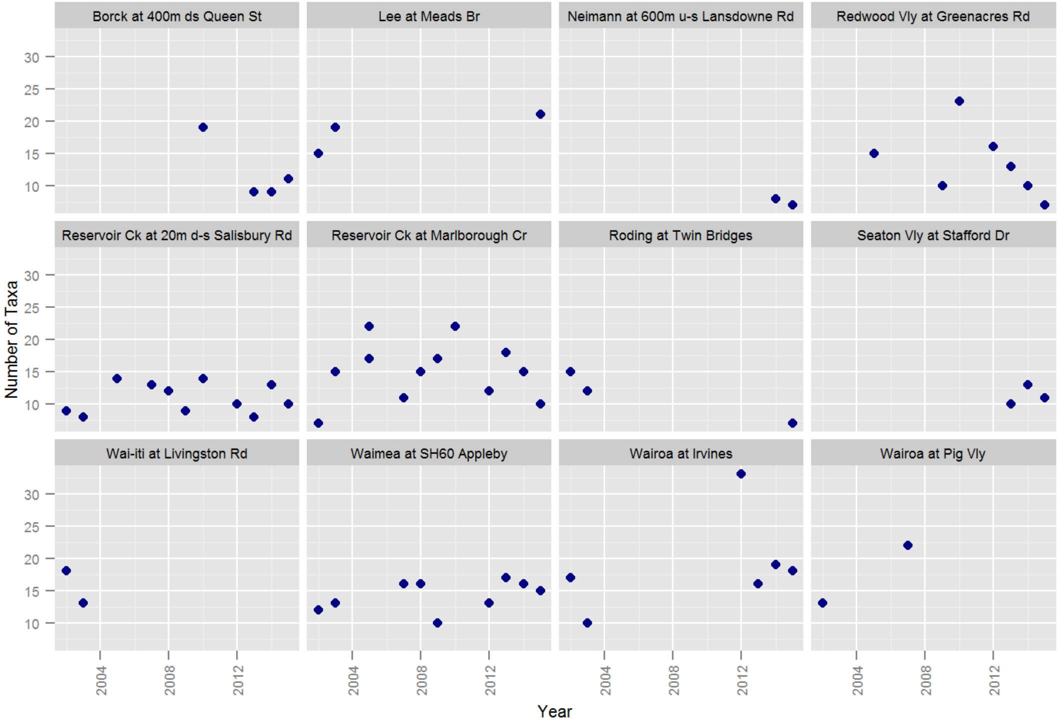
Appendix 7: Additional Macro-Invertebrate Results

This appendix shows the results for three macroinvertebrates indices: semi-quantitative MCI (SQMCI), number of taxa, and percent of mayflies, stoneflies and caddisflies in a sample (%EPT). These are additional to the macroinvertebrate community index (MCI) results shown in the main body of this report.

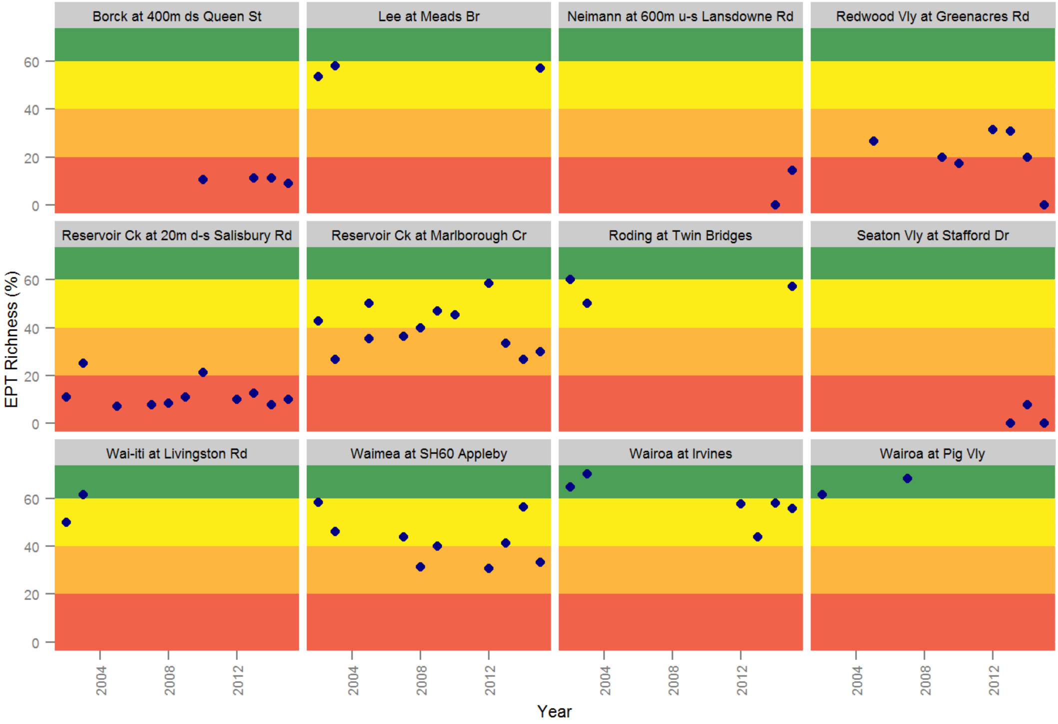
Waimea Water Management Area



Semi-quantitative macroinvertebrate community index (SQMCI) scores between 2001 and March 2015 for sites in the Waimea Water Management Area. The background colours indicate these quality classes: excellent (green), good (yellow), fair (orange) and poor (red).

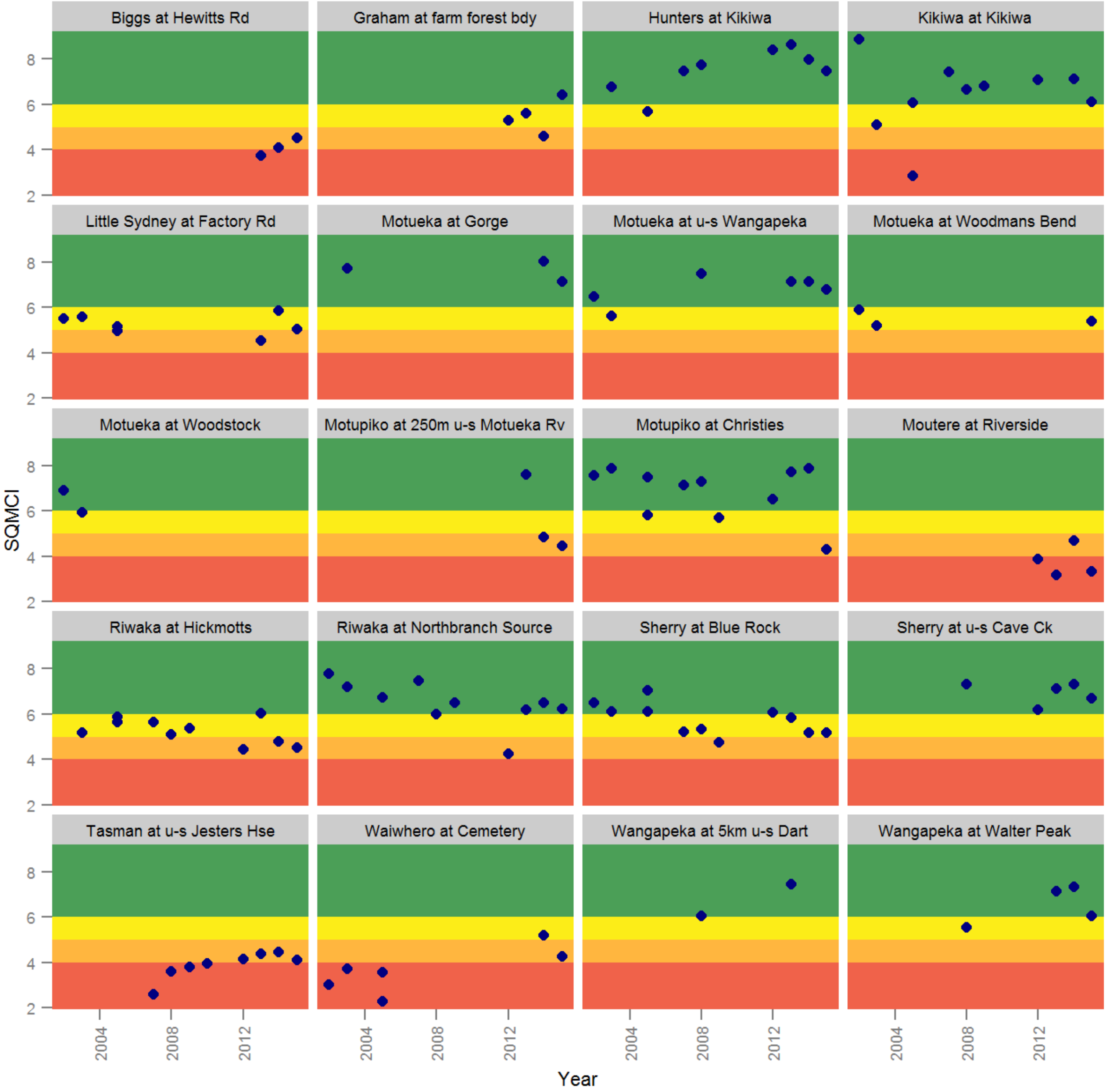


Number of macroinvertebrate species (number of taxa) for sites in the Waimea Water Management Area.

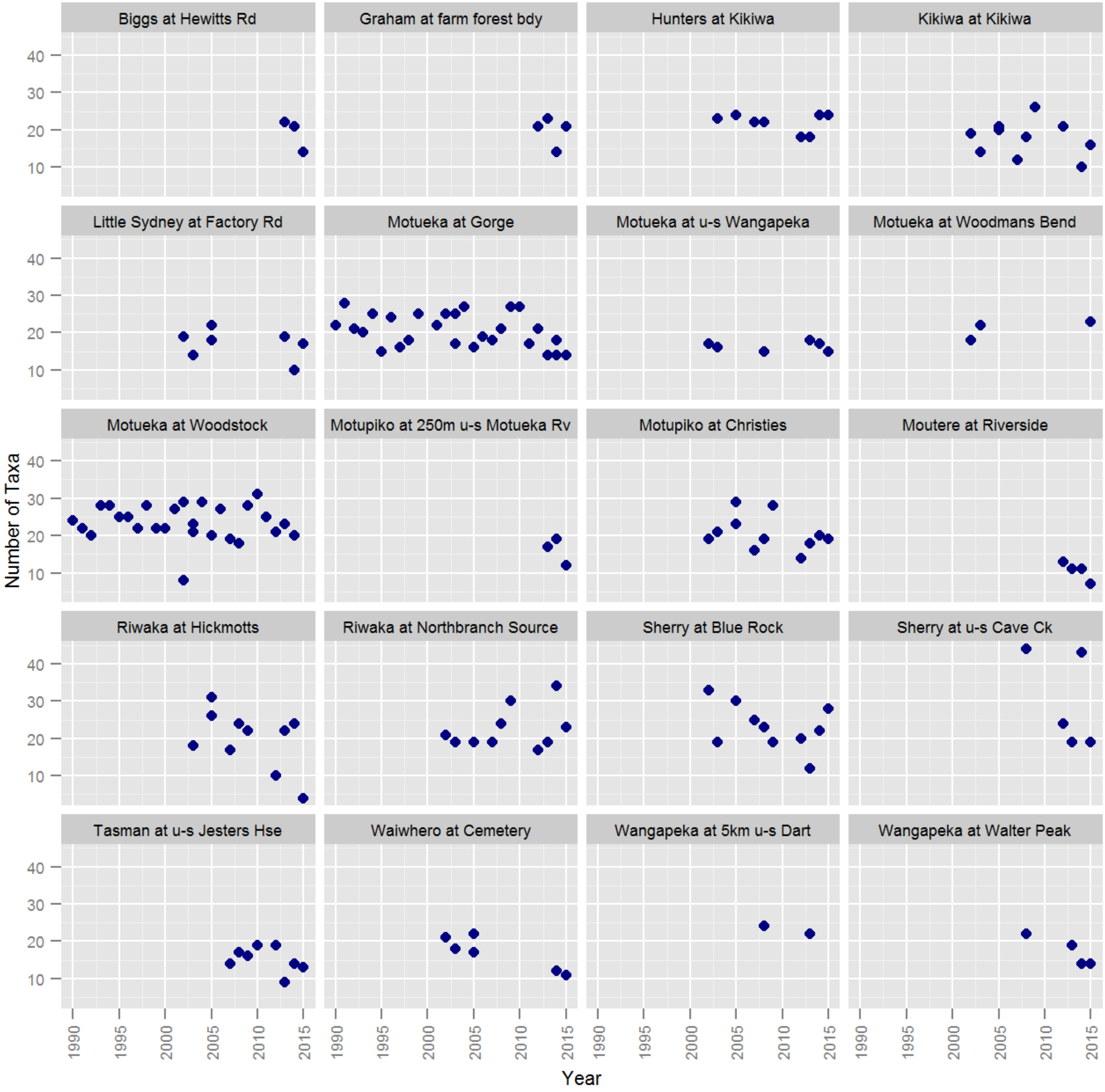


EPT richness (percentage mayflies, stoneflies and caddisflies compared to total of macroinvertebrate taxa) for sites in the Waimea Water Management Area.

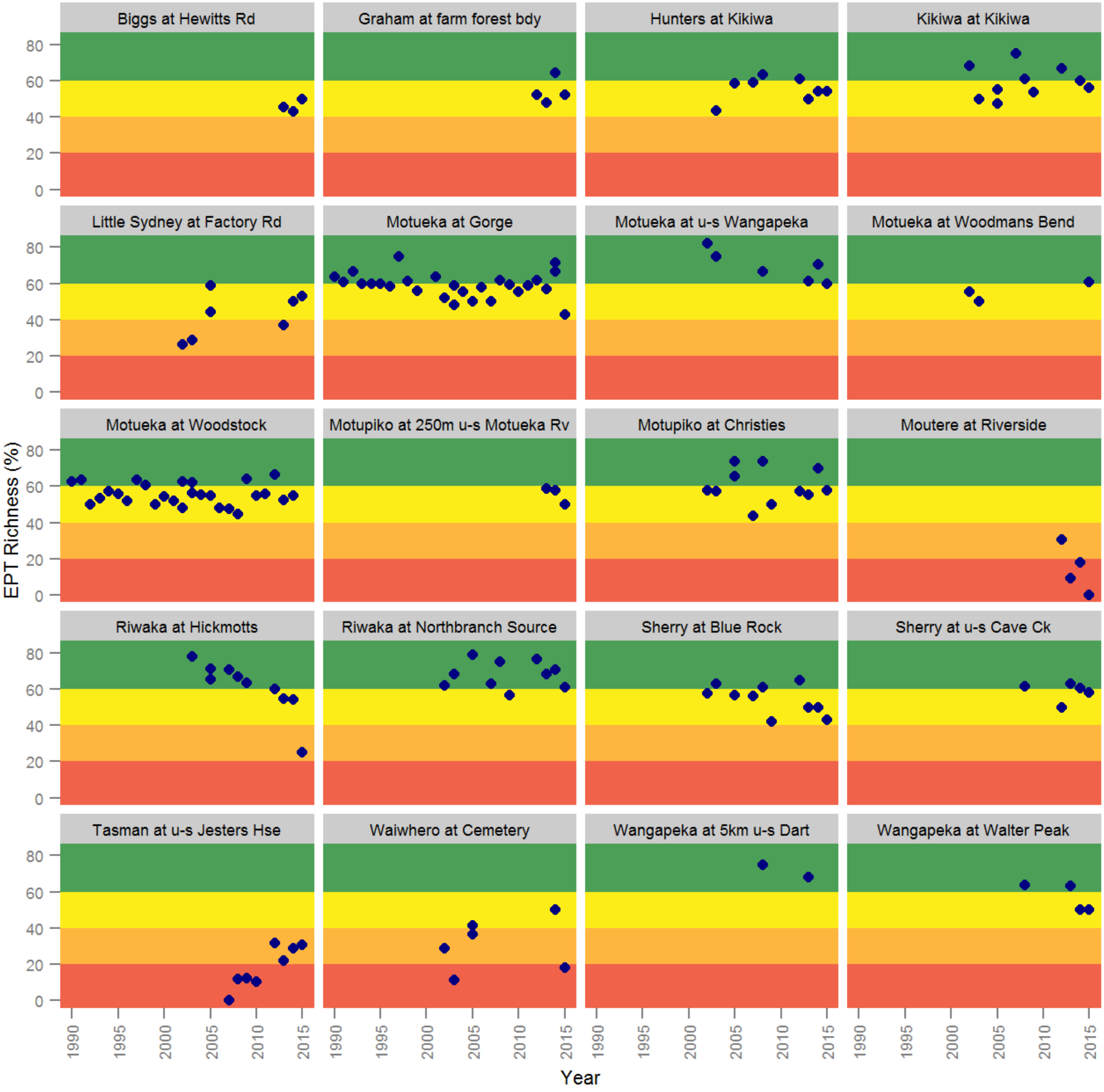
Motueka Water Management Area



Semi-quantitative macroinvertebrate community index (SQMCI) scores between 2001 and March 2015 for sites in the Motueka Water Management Area. The background colours indicate these quality classes: excellent (green), good (yellow), fair (orange) and poor (red).

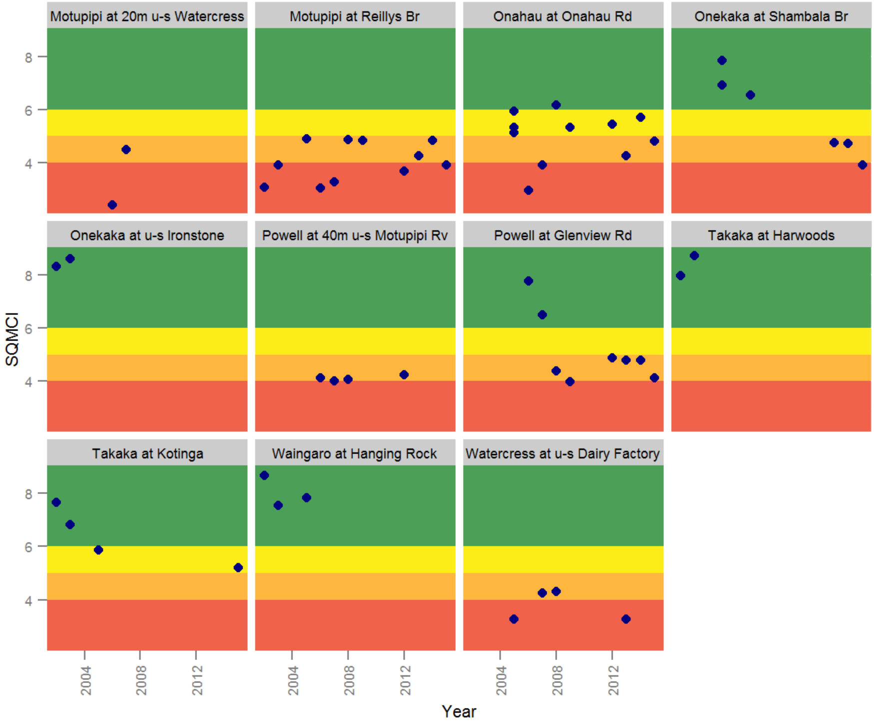


Number of macroinvertebrate species (number of taxa) for sites in the Motueka Water Management Area.

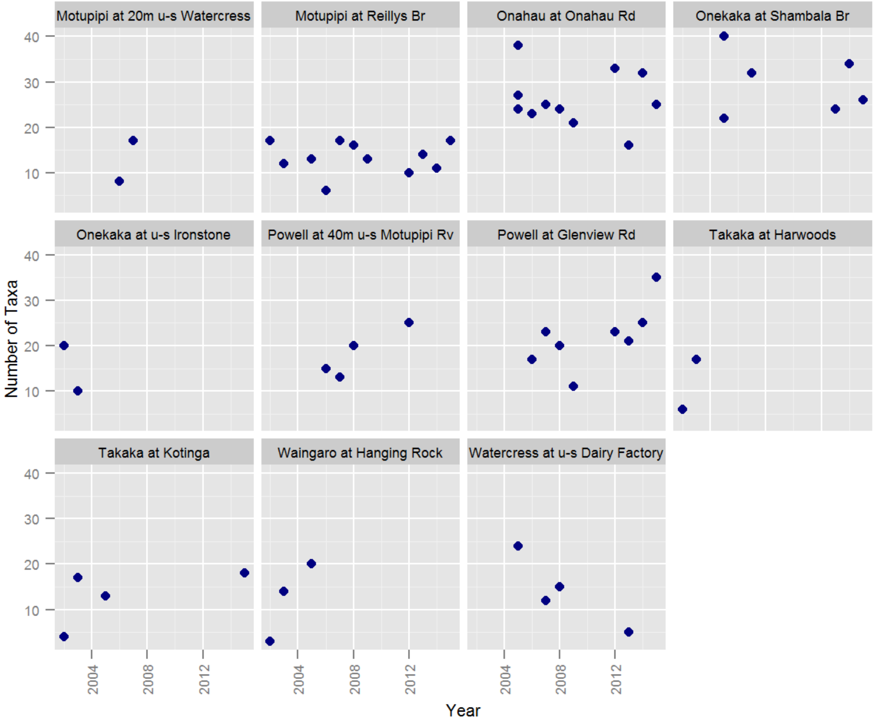


EPT richness (percentage of mayflies, stoneflies and caddisflies compared to total macroinvertebrate taxa) for sites in the Motueka Water Management Area.

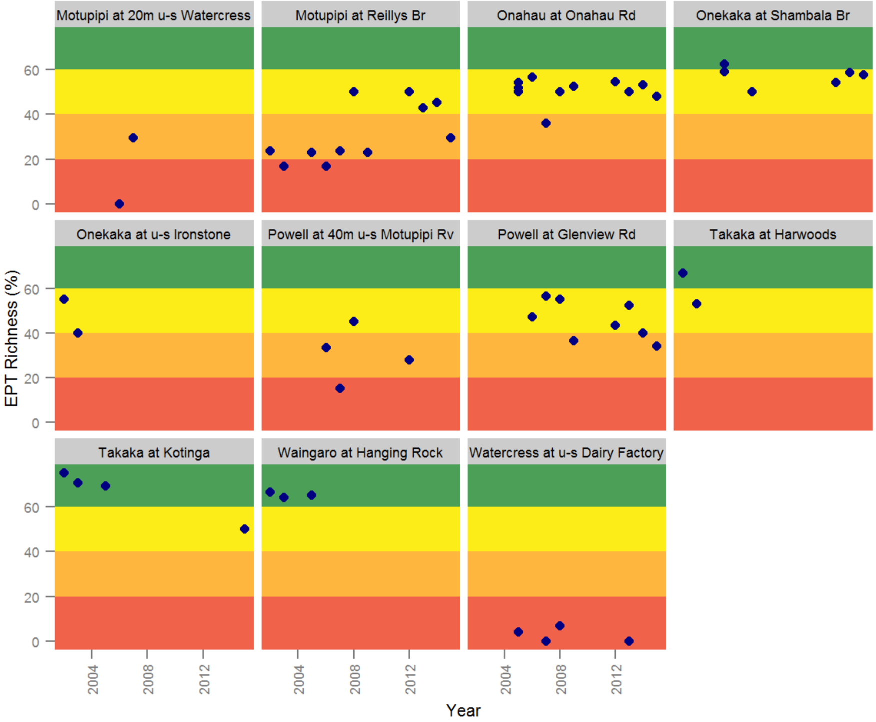
Takaka Water Management Area



Semi-quantitative macroinvertebrate community index (SQMCI) scores between 2001 and March 2015 for sites in the Takaka Water Management Area. The background colours indicate these quality classes: excellent (green), good (yellow), fair (orange) and poor (red).

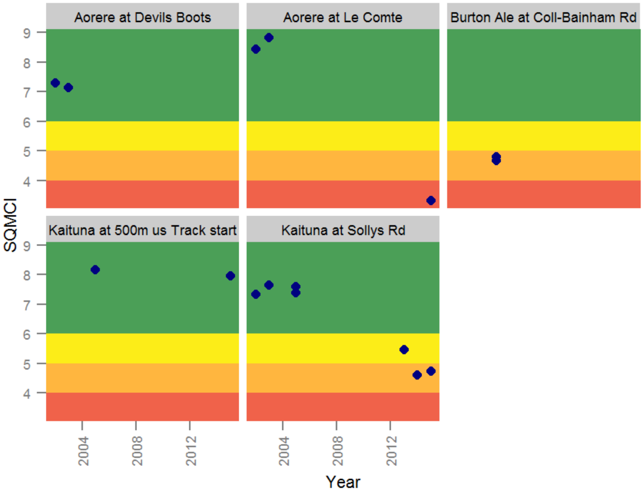


Number of macroinvertebrate species (number of taxa) for sites in the Takaka Water Management Area.

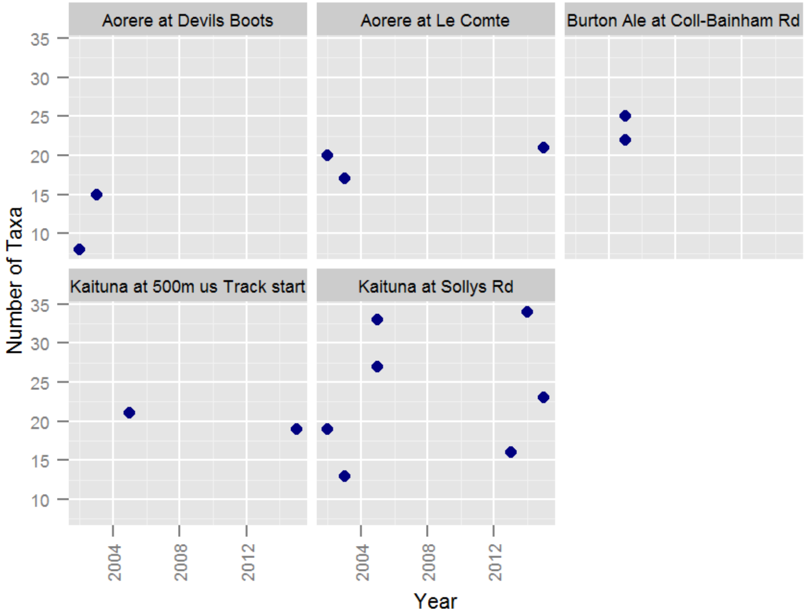


EPT richness (percentage of mayflies, stoneflies and caddisflies compared to total macroinvertebrate taxa) for sites in the Takaka Water Management Area.

Aorere Water Management Area

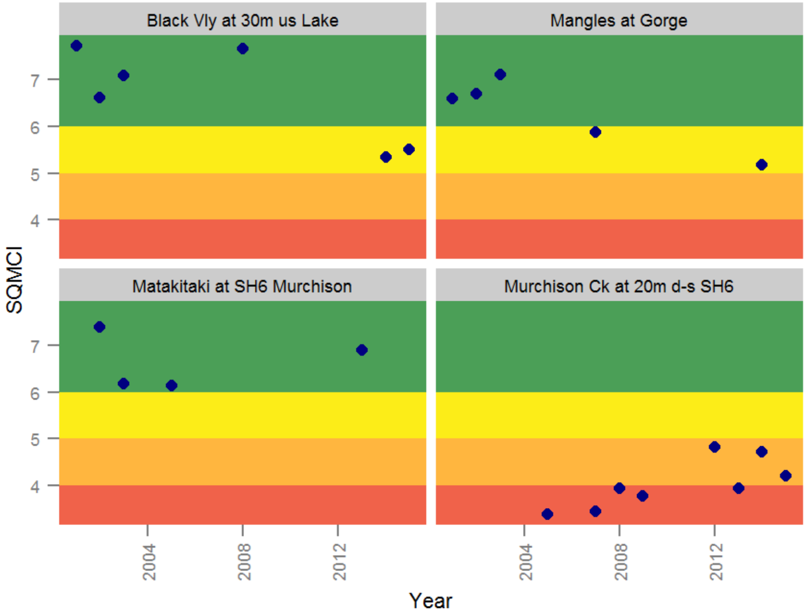


Semi-quantitative MCI (SQMCI) scores between 2001 and March 2015 for sites in the Aorere Water Management Area. The background colours indicate these quality classes: excellent (green), good (yellow), fair (orange) and poor (red).

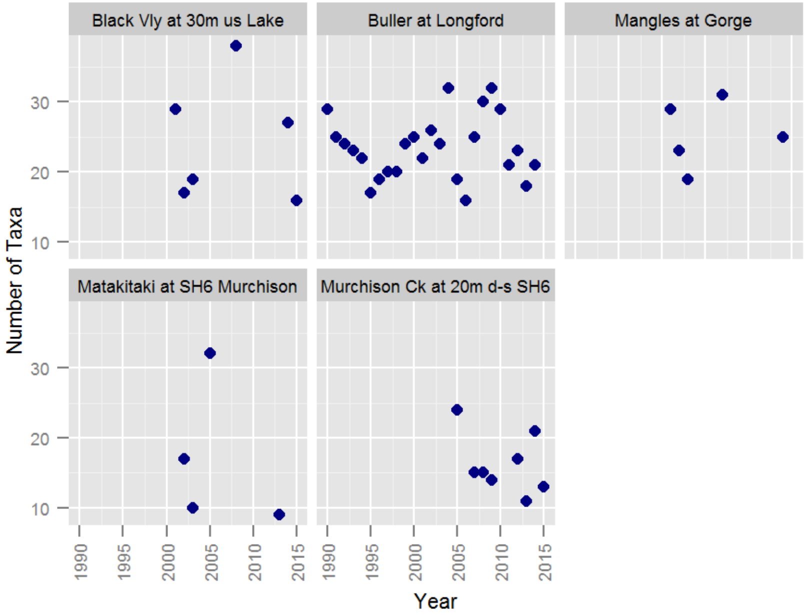


Number of macroinvertebrate taxa (top) and EPT richness (bottom) for sites in the Aorere Water Management Area. EPT richness is the percentage of mayflies, stoneflies and caddisflies compared to total macroinvertebrate taxa.

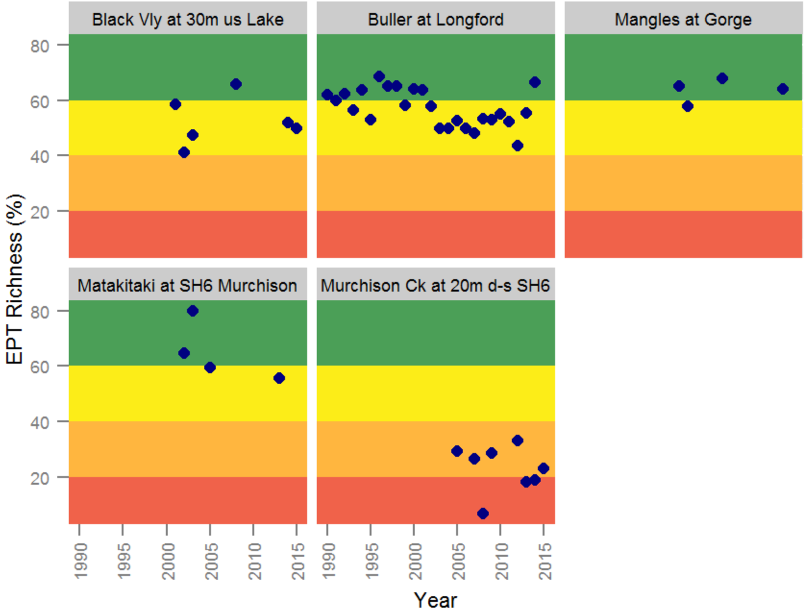
Buller Water Management Area



Semi-quantitative macroinvertebrate community index (SQMCI) scores between 1990 and March 2015 for sites in the Buller Water Management Area. The background colours indicate quality classes: excellent (green), good (yellow), fair (orange) and poor (red).



Number of macroinvertebrate species (number of taxa) for sites in the Buller Water Management Area.



EPT richness (percentage of mayflies, stoneflies and caddisflies compared to total macroinvertebrate taxa) for sites in the Buller Water Management Area.

Appendix 8: Microbial Source Tracking (MST) Data Register

Site	Date	Source
Buller		
Murchison Creek	16/9/2009	Ruminant and human.
	31/3/2014	Ruminant and wildfowl. Not human.
	20/05/2015	Ruminant and wildfowl. Not human or dog.
Golden Bay		
Mackay Ck 50 m u-s Kaituna	24/5/2011	Ruminant. Not human, gull or wildfowl.
James Cutting @ Coll-Bainham Rd	24/5/2011	Ruminant (weak). Not human, gull or wildfowl.
Collingwood @ Boatramp	23/5/2011	Ruminant. Not human, gull or wildfowl.
Tukurua Stm @ Playground	24/3/2010	Ruminant, wildfowl. Not human or gull.
	24/5/2011	Ruminant, wildfowl and human
	17/1/2013	Ruminant. Not human or wildfowl.
	18/2/2014	(*Not enough genetical material*). Not ruminant, wildfowl or human
	3/2/2015	Ruminant only. Not wildfowl, gull or human
Onekaka @ Shambala	23/5/2011	Ruminant. Not human, gull or wildfowl.
Motupipi @ Abel Tasman Dr	23/5/2011	Ruminant and wildfowl. Not human or gull.
Motupipi u-s Watercress	23/5/2011	Not ruminant, human, gull or wildfowl
Powell u-s Motupipi	23/5/2011	Ruminant and wildfowl. Not human or gull.
Pohara Ck u-s Abel Tasman Dr	3/2/2015	Possum (weak). Not ruminant, human, dog, sheep, wildfowl or gull.
Winter Ck @ 50 m u-s Abel Tasman Dr	23/5/2011	Ruminant (weak) and human. Not gull or wildfowl.
Moutere		
Tasman Vly Stm @ u-s Jester House	31/5/2010	Ruminant, human. Not gull.
	18/5/2011	Ruminant, not human, wildfowl, or gull.
Horton Vly Rd	1/7/2010	Ruminant, human. Not wildfowl gull.
Marriages	1/7/2010	Ruminant, human, wildfowl. Not gull.
Williams Rd u-s Aporo Rd	1/7/2010	Ruminant, human, wildfowl. Not gull.
Motueka		
Little Sydney	18/5/2011	Ruminant, human, wildfowl. Not gull.
Waiwhero	18/5/2011	Not ruminant, human, gull or wildfowl
	27/05/2015	Ruminant and wildfowl. Not human.
Seaton Vly	18/5/2011	Ruminant, wildfowl. Not gull or human
Sherry @ Blue Rock	20/5/2011	Ruminant, not human, wildfowl, or gull.
Sherry @ u-s Granite Ck	20/5/2011	Ruminant (weak), not human, wildfowl, or gull.
Biggs @ Hewitt Rd	20/5/2011	Ruminant, wildfowl. Not human, or gull.
Waimea		
Reservoir Ck @ Salisbury Rd	23/5/2011	Ruminant, human, wildfowl. Not gull.
Jimmy-Lee Ck 300 m u-s Hill St	25/5/2011	Ruminant, not human, wildfowl, or gull

Appendix 9: Performance of regional overview using predictive models

The predictions from a set of national-scale models were compared to the river water quality data collected in the Tasman District. Comparisons were made with all sites (the full dataset) and excluding spring-fed or macrophyte-dominated sites (the reduced dataset). The reason for undertaking the analysis without spring-fed or macrophyte-dominated sites was because the models are not able to distinguish these types of waterways which have very different macroinvertebrate communities and aspects of water quality.

Model performance assessment

Predictions for each river segment in the Tasman District, based on the above models, were provided by the Cawthron Institute. These predictions were compared to two water quality datasets, one with all sites (the full dataset) and one excluding sites in spring-fed and macrophyte-dominated streams (the reduced dataset). Two datasets were used because the models were expected to perform poorly in spring-fed streams. Poor performance was expected in spring-fed streams because the network of stream segments for New Zealand (the REC network) does not identify spring-fed streams and spring-fed streams have markedly different habitats compared to other streams. These differences in habitat include very stable flow regimes permitting higher fine sediment deposits and macrophyte cover.

For the fine sediment model (Clapcott et al. 2011), two comparisons were made, one with the median value of fine sediment cover in riffle habitats and one with the median value of fine sediment cover in run habitats for the five-year period 2010 to 2014. Both variables (riffle and run fine sediment cover) were collected in the RWQMP. All other model predictions were compared with their respective water quality variable from the River Water Quality dataset analysed in this report (median values for the five-year period 2010 to 2014).
The performance of the predictive models was assessed using Pearson’s correlation coefficient (r). We considered correlations greater than 0.8 to represent ‘excellent’ model performance, correlations between 0.6 and 0.8 to represent ‘good’ model performance and less than 0.6 to represent ‘poor’ model performance.

Results of model performance

The MCI model predictions had the highest correlation with the observed values from the Tasman District. The EPT, water clarity and *E.coli* predictions had ‘good’ correlations with the observed values.

According to the Pearson correlations, the MCI model had the closest match between observed and predicted values. This result suggests that the MCI model can be used to make general statements about the state of macroinvertebrate communities in the District. Although the performance of the MCI model is described as ‘excellent’, there are two limitations of our comparison:

1. The comparison dataset contains predominantly lowland sites. The MCI model was created using a national dataset which was also dominated by lowland sites. This means we have greater confidence that the model performs well when making predictions for lowland streams than we do for upland streams.
2. Sites closer together tend to have similar values for MCI. In the comparison dataset, several sites are separated from each other by short distances (less than 1km). This effect (spatial autocorrelation) can inflate the correlations between observed and predicted values. Despite these limitations, the predictive model for MCI provides information on macroinvertebrate community condition beyond the limited number of regularly-monitored sites.

Table 30. Pearson correlations (r) between predictive models and observed water quality measurements in the Tasman District. Predictions were compared to the median values for the five-year period 2010 to 2014. The reduced dataset has sites in spring-fed or macrophyte-dominated streams excluded.

Variable	Dataset	Num of sites	r	Interpretation
MCI	Full	37	0.88	Excellent
	Reduced	33	0.87	
EPT	Full	37	0.82	Good to Excellent
	Reduced	33	0.76	
Water clarity	Full	63	0.78	Good
	Reduced	57	0.82	
E. coli	Full	63	0.69	Good
	Reduced	57	0.70	
Ammonia-N	Full	46	0.41	Poor
	Reduced	40	0.45	
Nitrate-N	Full	27	0.47	Poor
	Reduced	23	0.63	
Dissolved reactive phosphorus	Full	28	0.19	Poor
	Reduced	24	0.25	
Fine sediment cover (riffles)	Full	48	0.50	Poor
	Reduced	45	0.49	
Fine sediment cover (runs)	Full	51	0.57	Poor
	Reduced	47	0.50	

The observed and predicted values for each model are shown in Figure 158.

Sites with the greatest difference between observed and predicted values are shown in Table 31.

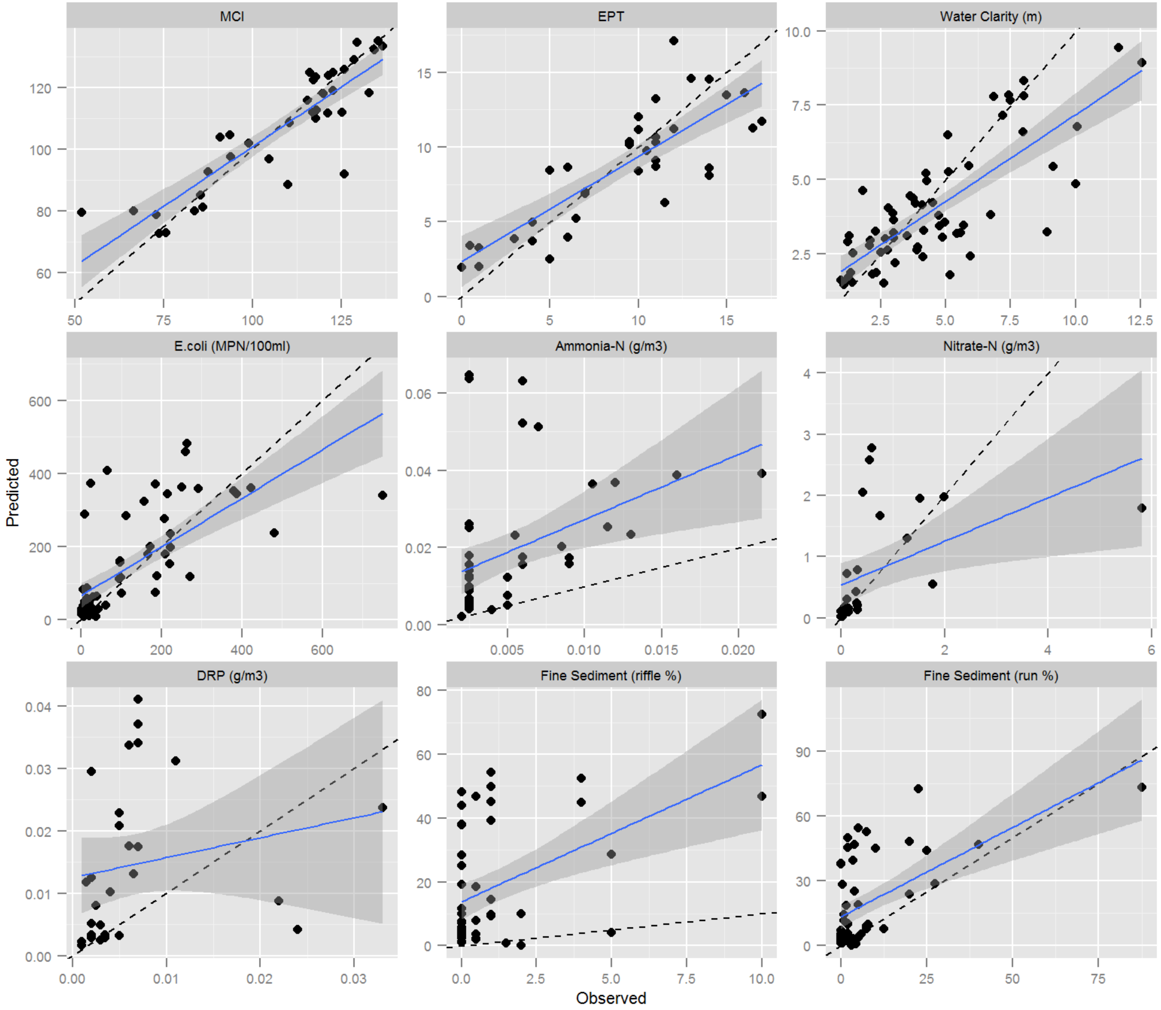


Figure 158. Observed water quality data (full dataset) from the Tasman District plotted against national-scale model predictions. Observed values are the median over the 5-year period 2010 to 2014 for each site. Blue lines represent the line of best fit and the shading shows 95% confidence bands around the lines. The dashed lines show a 1:1 relationship, for reference.

Table 31. Sites where the model predictions and the observed water quality measurements in the Tasman District (medians) are furthest apart. These correspond to points furthest from the 1:1 relationship lines in Figure 158.

Variable	Site	Observed	Predicted
MCI	Motueka at u-s Wangapeka	125	92
	Watercress at u-s Dairy Factory	52	80
	Waiwhero at Cemetery	110	88
	Motupiko at Christies	133	118
	Seaton Vly at Stafford Dr	67	80
EPT	Kaituna at Sollys Rd	14	8.6
	Onahau at Onahau Rd	17	11.7
	Onekaka at Shambala Br	16.5	11.2
	Motueka at u-s Wangapeka	11.5	6.3
	Sherry at u-s Cave Ck	12	17.1
Water Clarity (m)	Motupipi at Factory Farm Br	8.9	3.2
	Onekaka at u-s Ironstone	10.0	4.8
	Wangapeka at 5km u-s Dart	9.1	5.4
	Riwaka at Northbranch Source	12.5	8.9
	Aorere at Le Comte	5.9	2.4

Appendix 10: Peer Review Letter

CAWTHRON
INSTITUTE

1 October 2015

Trevor James
Tasman District Council
Private Bag 5
Richmond

Dear Trevor,

Re: Peer review of TDC Surface Water Quality Report

Thank you for the opportunity to review the 2015 TDC Surface Water Quality report. This report represents an up-to-date, thorough and accurate picture of the state and trends in surface water quality throughout the Tasman District.

As highlighted in previous reports, water quality is very good in much of the Tasman District, but there are water quality issues in the smaller streams that drain agricultural and urban land. It is great to see that the data record you have assembled is now sufficiently long to allow robust identification of trends in water quality over time. The attributes used in the programme and the methods of data analysis are appropriate. The report thoroughly and accurately describes the likely causes of water quality concerns and highlights actions that can be used to help mitigate effects.

As mentioned in my detailed comments on an earlier version of the full report, it is important to emphasise the status of the numbers (thresholds) that have been used to define the different bands or states for each water quality attribute. Some of these numbers are specified in the National Policy Statement for Freshwater Management (2014) – ammoniacal nitrogen, nitrate nitrogen, *E. coli* and dissolved oxygen. For sites that fall into the 'D' band for these attributes there is a legislative requirement for actions to be put in place to return these sites to at least 'C' band condition over a certain time period. For other water quality attributes, the definition of the boundaries between classes is based on a range of water quality guideline documents, but do not have the same 'legislative grunt' as the National Policy Statement numbers.

Overall, I commend you, Jonathan and your team for the efforts that have gone into the production of this report.

Yours sincerely,

Roger S Young

Dr Roger Young
Coastal Freshwater Group Manager (Freshwater)

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