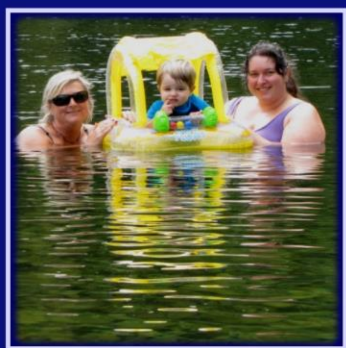
tasman district council

State of the Environment Report

River Water Quality in Tasman District

2015



State of the Environment Report

River Water Quality in Tasman District 2015

Document Status: Final

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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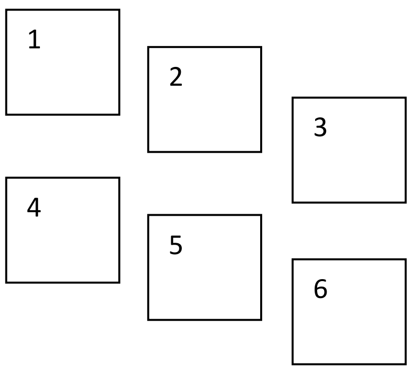
Cover photos:

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

Photos taken by Trevor James and Jonathan McCallum.



Contents

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 1). The reference sites were Hunters at Kikiwa, Motueka at Gorge, Riwaka at Northbranch source and Wangapeka at 5km u-s Dart.

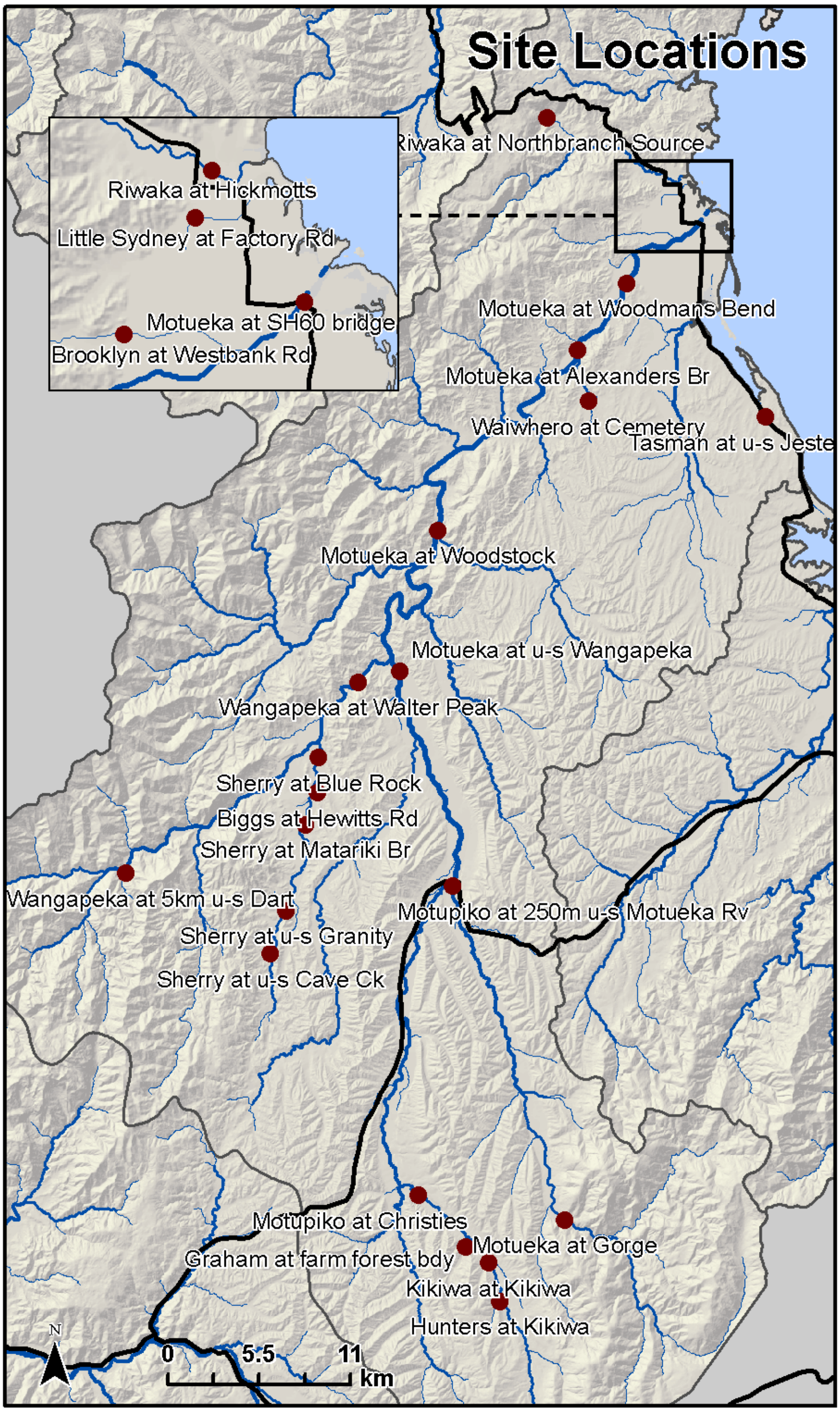


Figure 1. River Water Quality sites in the Motueka Water Management Area

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 1.

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 1. 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.

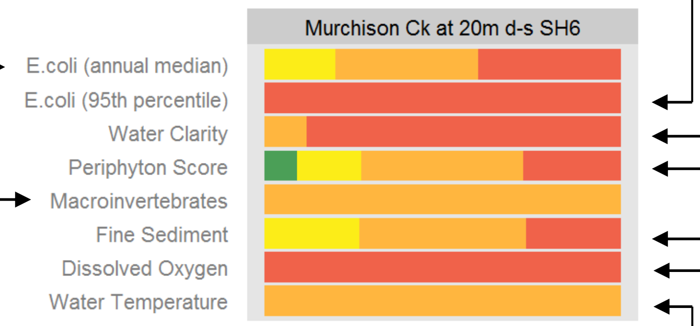
The rows of a site summary represent water quality attributes. The colours indicate attribute states **A** (very good), **B** (good), **C** (fair) **D** (poor).

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.

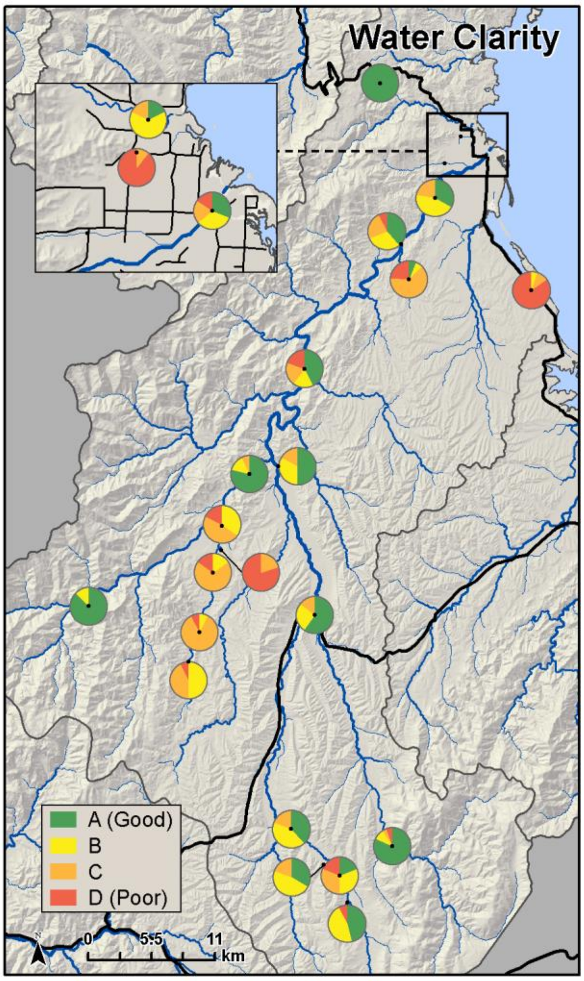


Figure 2. Proportion of water clarity records in each attribute state (A to D) for river water quality sites in the Motueka Water Management Area (sites shown have a minimum of 10 samples).

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.

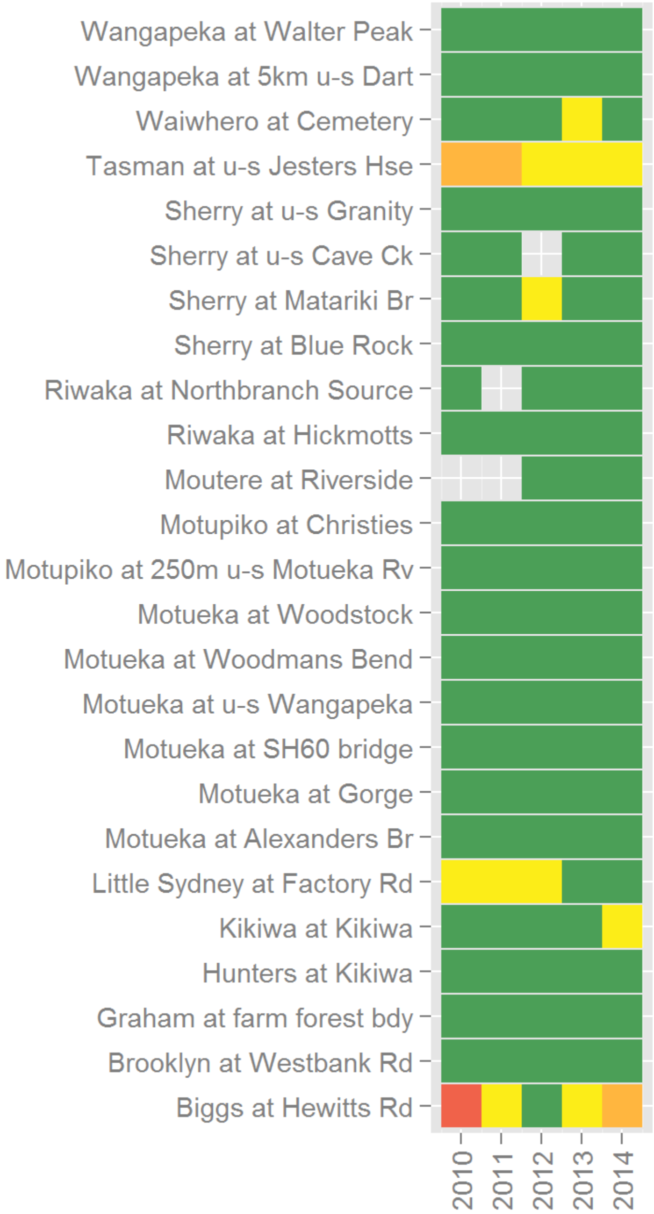


Figure 3. Tile plot of annual median *E. coli* values for sites in the Motueka Water Management Area. Colours indicate attribute states A (green), B (yellow), C (orange) and D (red). Blanks indicate insufficient data (less than three records in a given year).

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[1] 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.

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

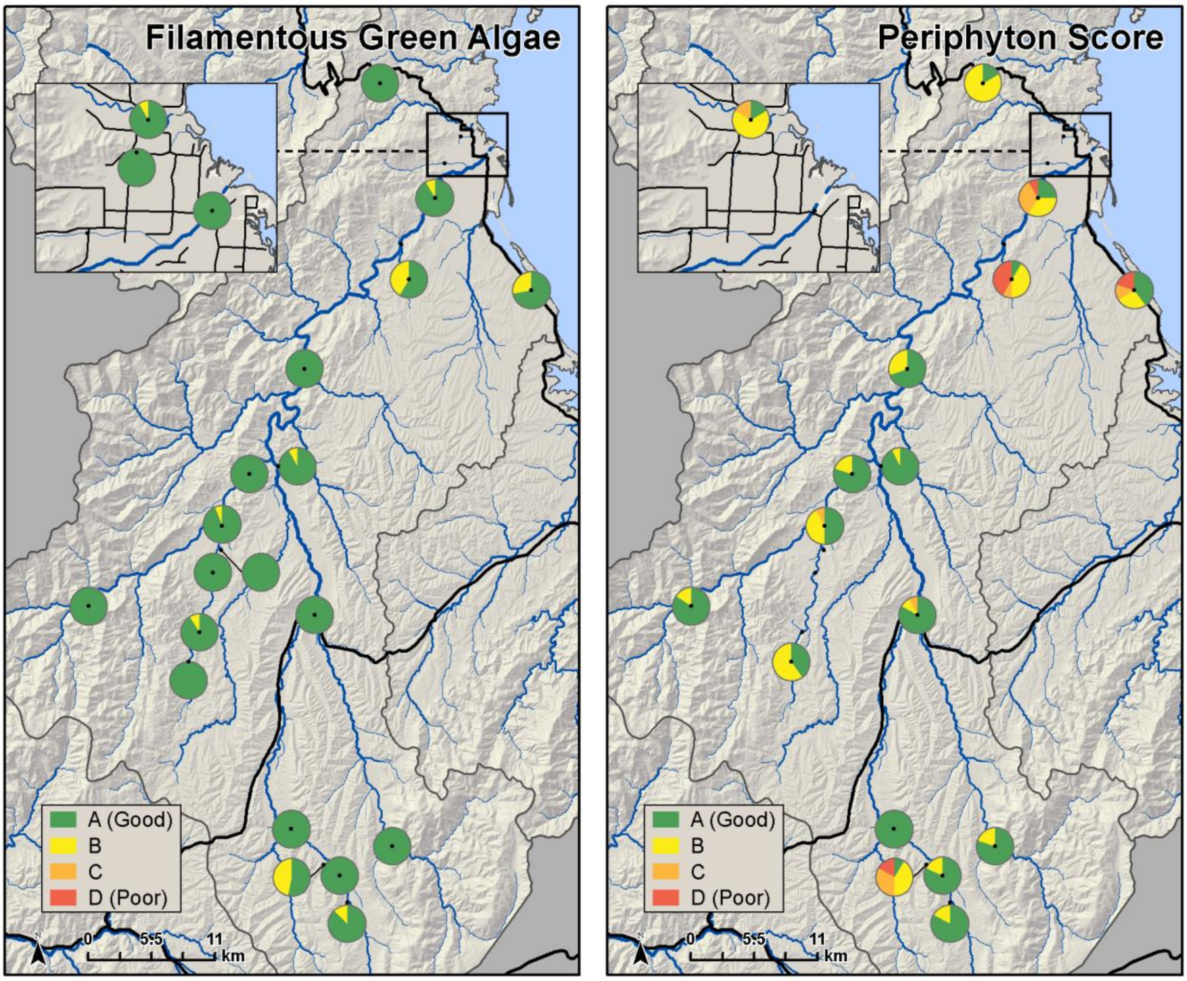


Figure 4. Coverage of filamentous green algae greater than 2cm in length (left) and periphyton community score (right) for sites in the Motueka Water Management Area. Pie charts show the proportion of estimates in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

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.

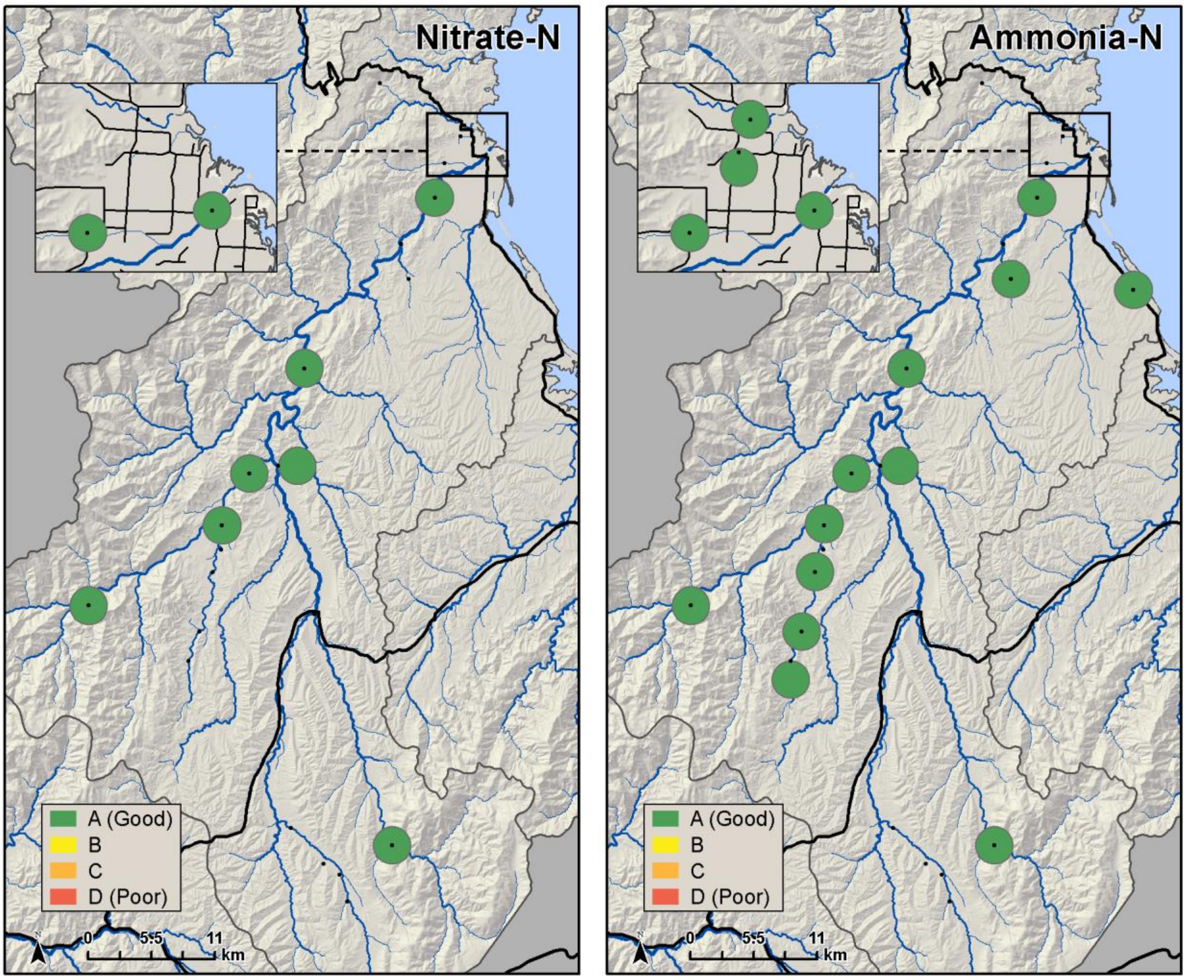


Figure 5. Nitrate (left) and ammonia (right) concentrations for sites in the Motueka Water Management Area. Pie charts show the proportion of annual medians in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

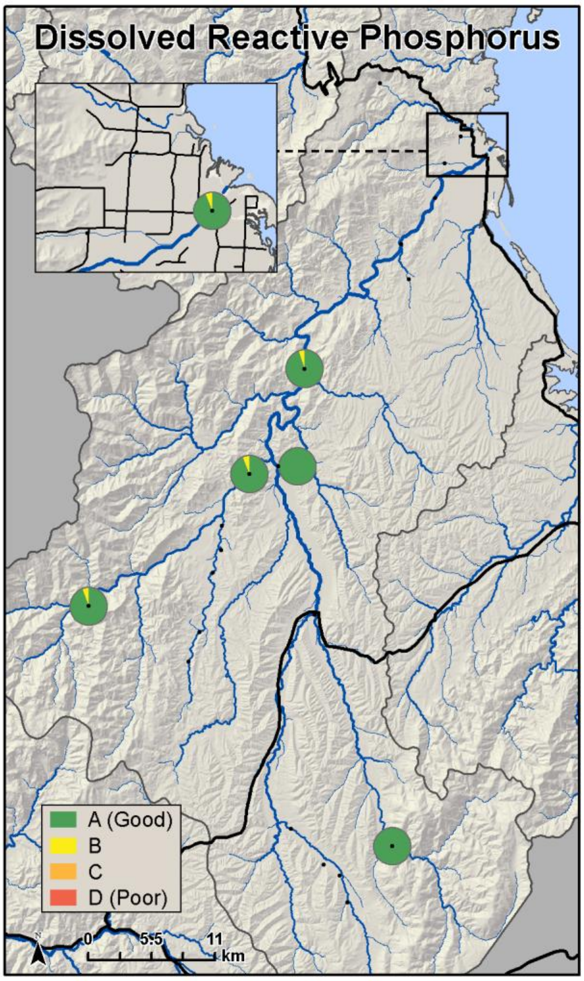


Figure 6. Dissolved reactive phosphorus concentrations for sites in the Motueka Water Management Area. Pie charts show the proportion of records in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

Resuspendable Sediment

In the five-year reporting period, four sites had resuspendable solids scores in band D (Figure 7). 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.

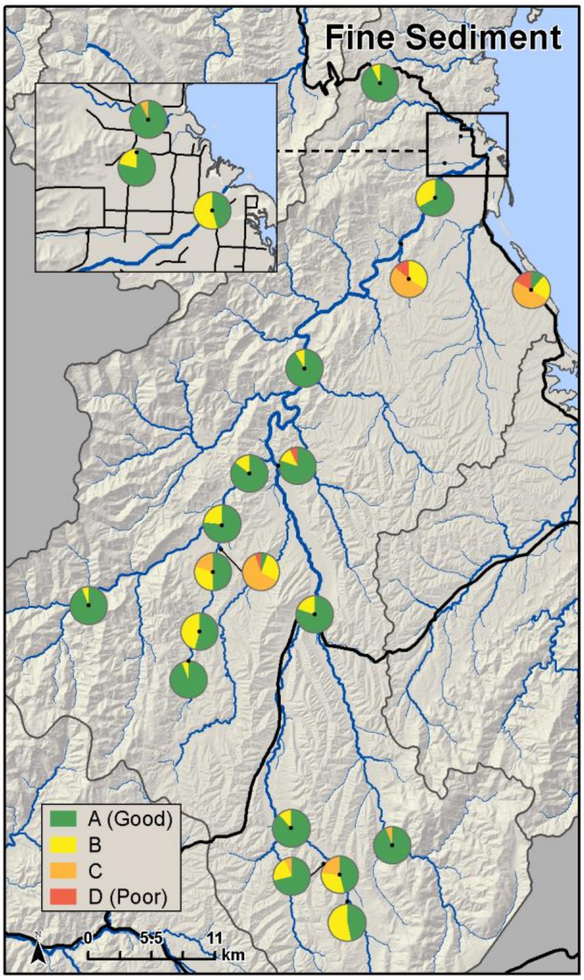


Figure 7. Proportion of fine sediment (resuspendable solids) scores in each attribute state (A to D) for sites in the Motueka Water Management Area.

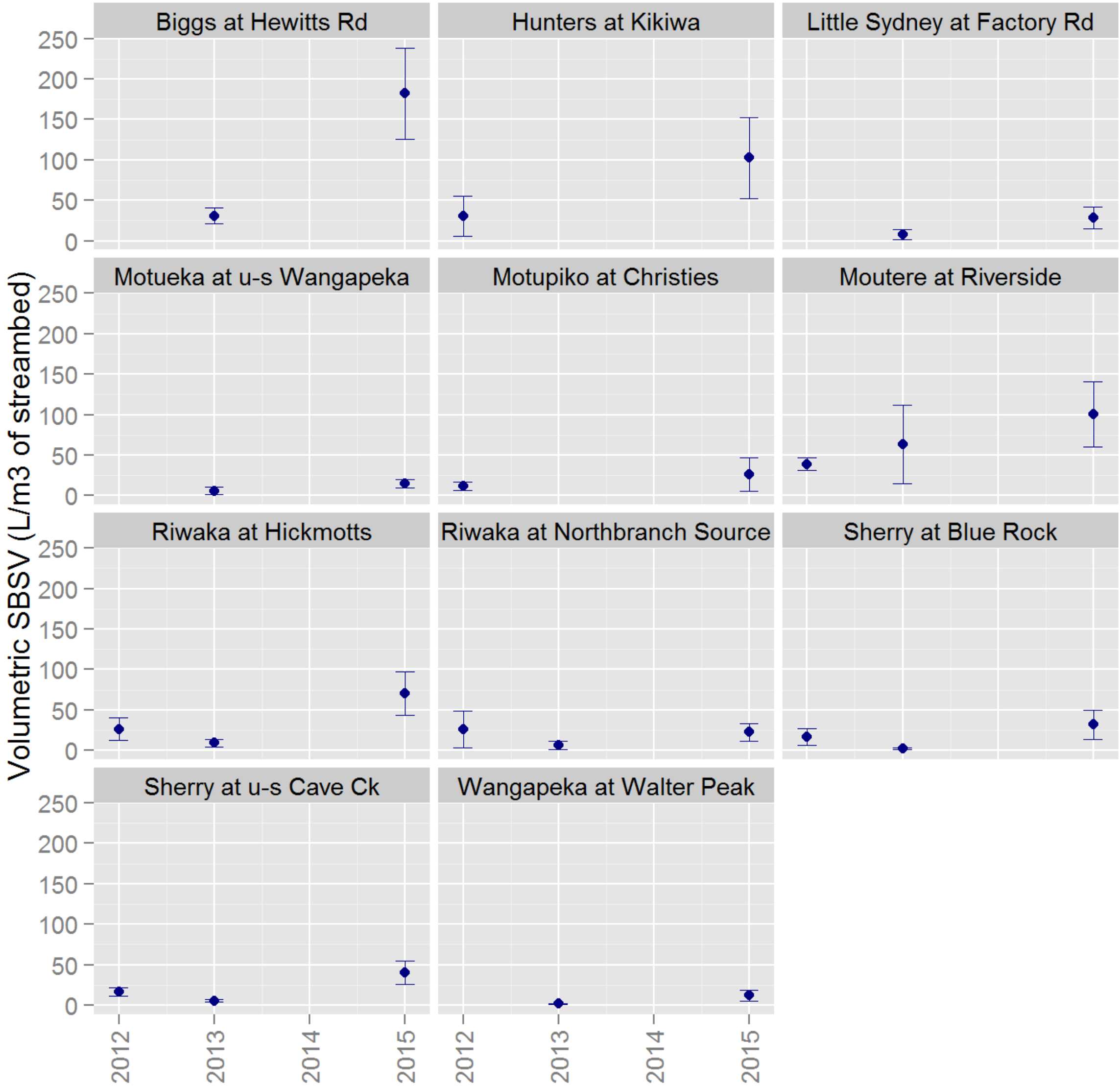


Figure 8. Mean volumetric suspendable benthic sediment volume (SBSV) in each attribute state (A to D) for sites in the Motueka Water Management Area. The error bars show 95% confidence intervals around the mean.

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.

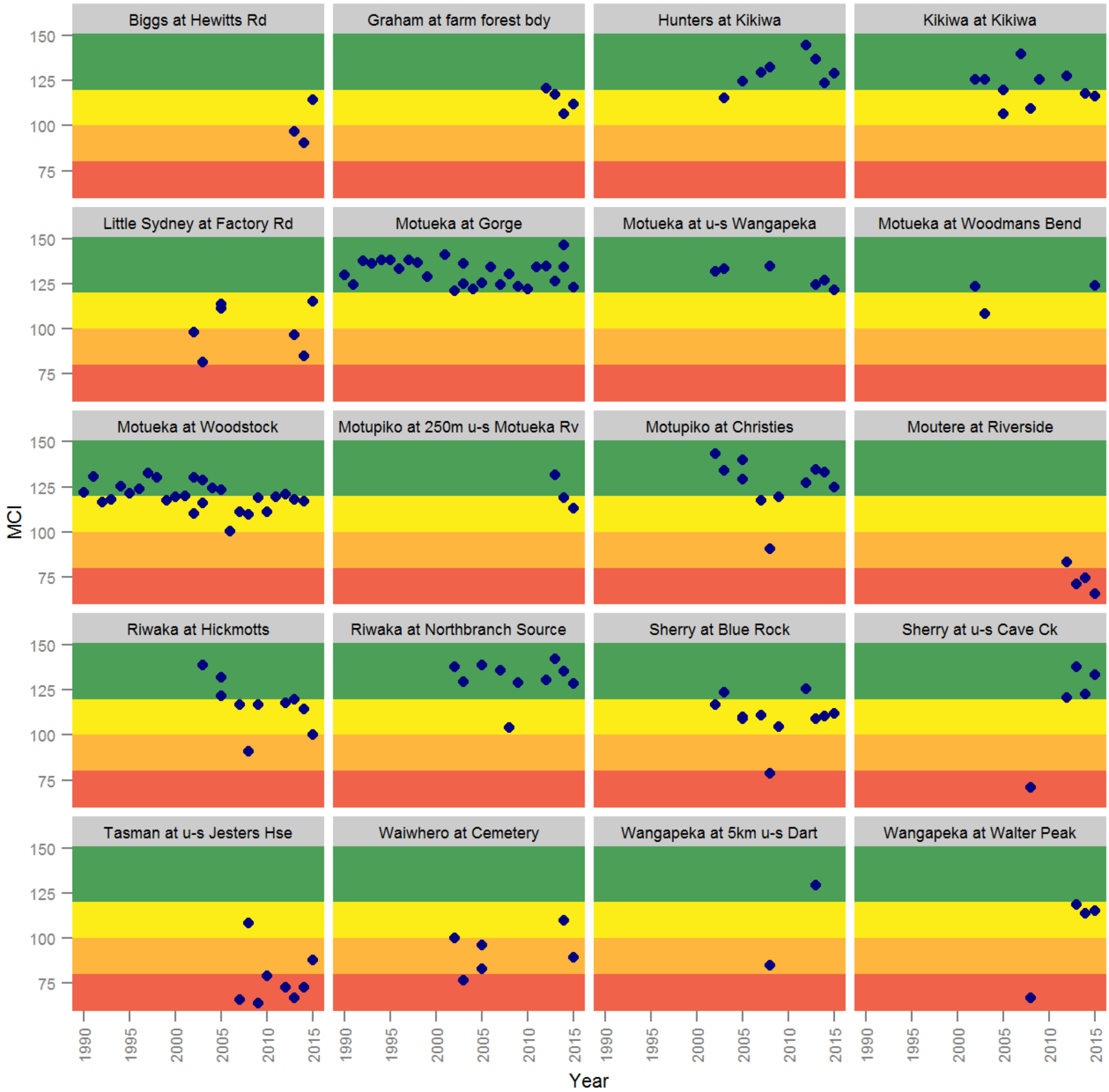


Figure 9. Macroinvertebrate community index (MCI) scores between 2001 and March 2015 for sites in the Motueka Water Management Area (larger blue dots). The background colours indicate these attribute states: excellent (green), good (yellow), fair (orange) and poor (red).

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 10) 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 11). 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 12). Macroinvertebrate condition at Kikiwa at Kikiwa was poorer than the reference site (MCI average 15 units lower).

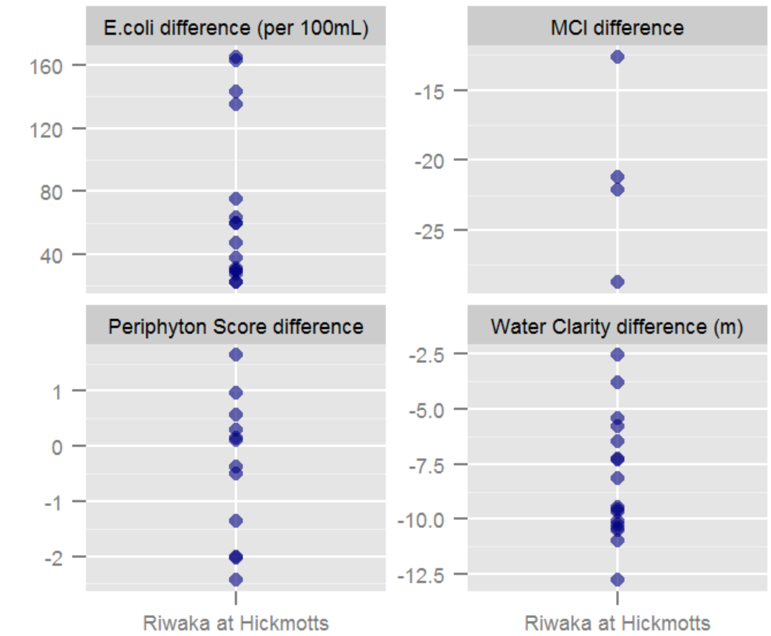


Figure 10. Difference between Riwaka at Northbranch Source (upstream) and Riwaka at Hickmotts (downstream) for water quality data collected at both sites on the same day. A positive difference means the downstream site had a higher value than the upstream site.

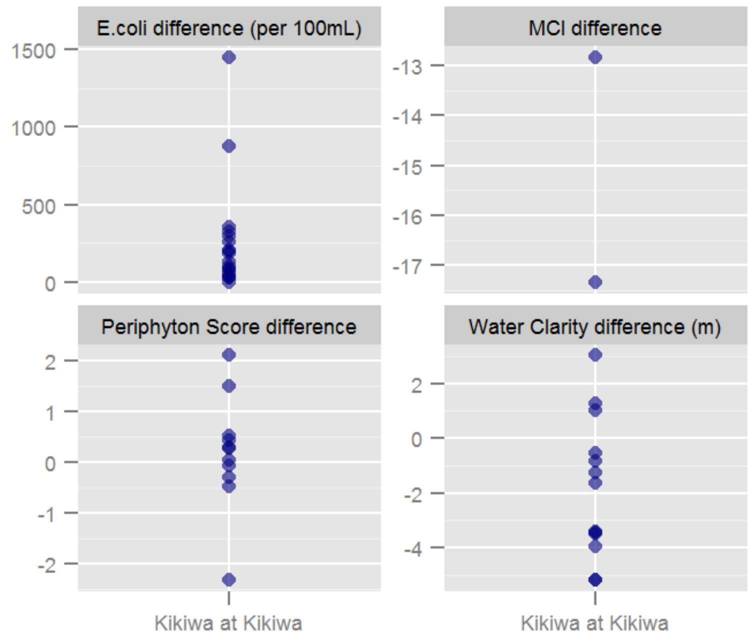


Figure 11. Difference between <u>Hunters at Kikiwa</u> (upstream) and <u>Kikiwa at Kikiwa</u> (downstream) for water quality data collected at both sites on the same day. A positive difference means the downstream site had a higher value than the upstream site.

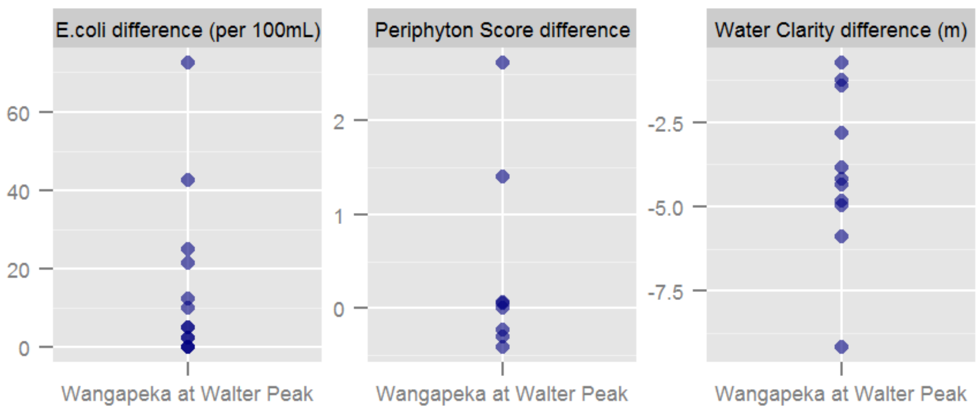


Figure 12. Difference between <u>Wangapeka at 5km u-s Dart</u> (upstream) and <u>Wangapeka at Walter Peak</u> (downstream) for water quality data collected at both sites on the same day. A positive difference means the downstream site had a higher value than the upstream site.

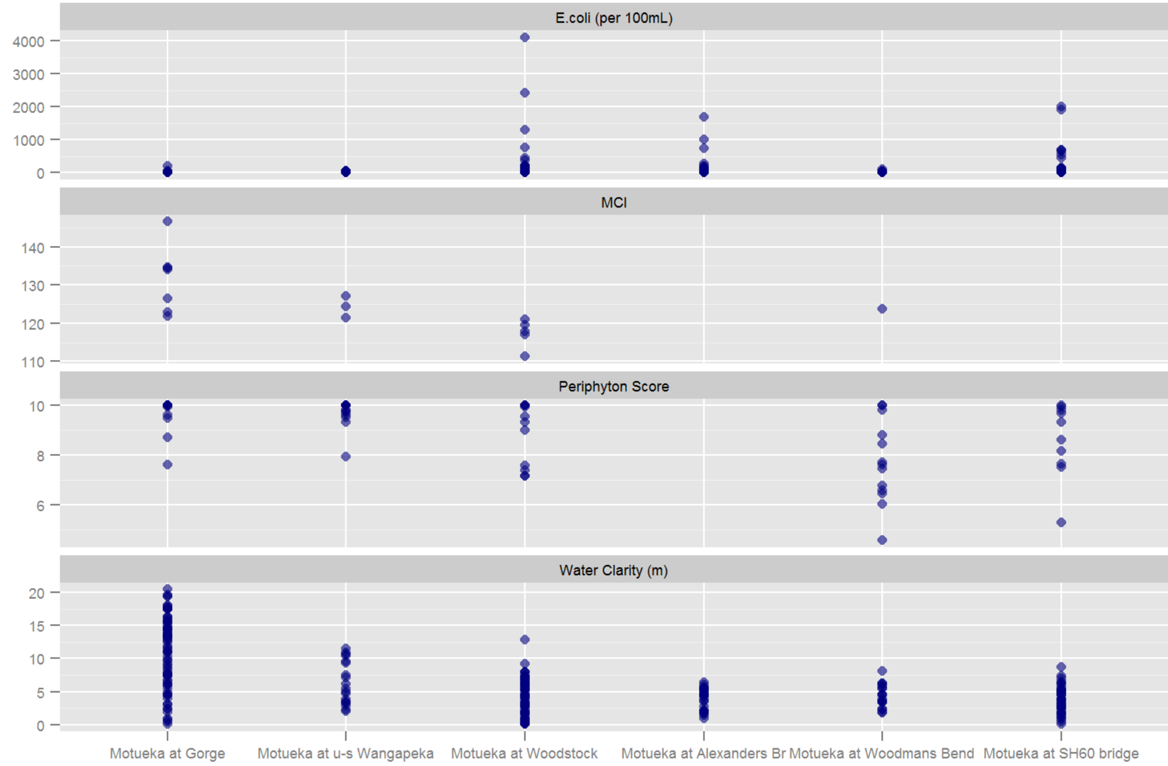


Figure 13. Motueka main stem sites along a gradient from Motueka at Gorge (upstream) to the SH60 bridge (downstream). Actual measured values shown (not differences). Data from 2010 to Feb 2015.

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 2).

Table 2. 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.

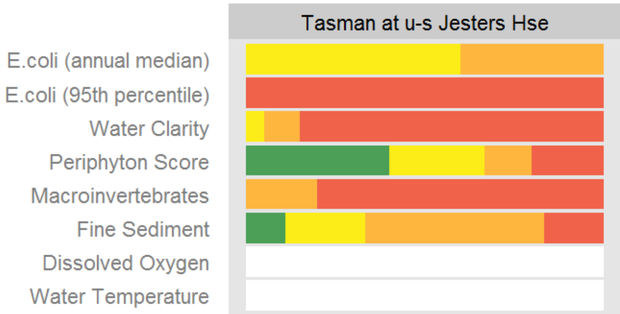
A degrading trend in QMCI was found for Motueka at Woodstock over the past 25 years but there were no trends in the other invertebrate metrics (MCI, the number of invertebrate taxa and EPT richness) at this site. Because the MCI results at this site have been consistently in attribute state A or B (MCI > 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 15) 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 14). 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 16). 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.

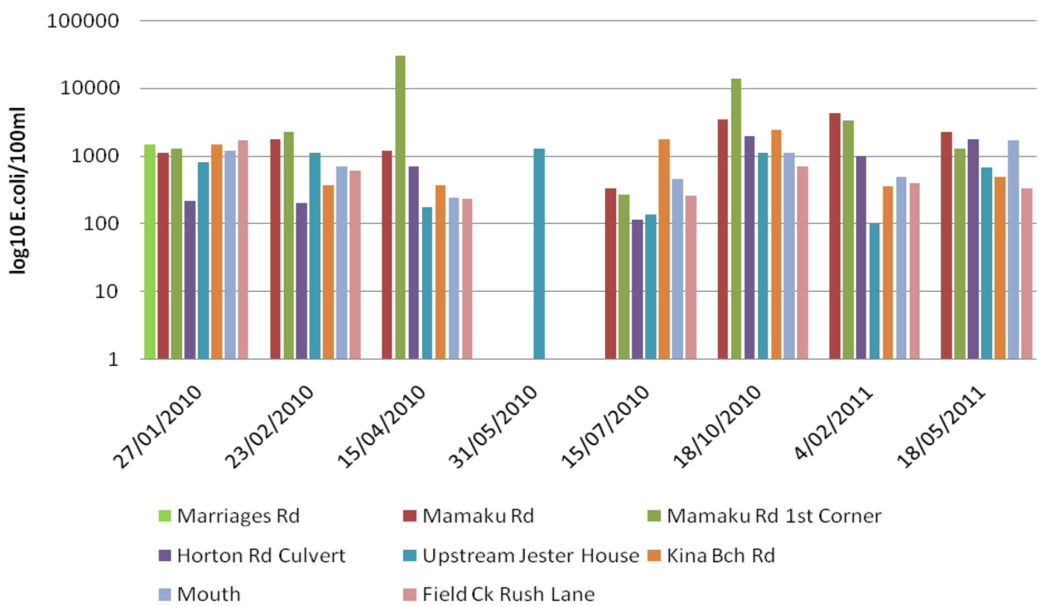


Figure 14 Tasman Valley Stream *E.coli* Concentrations 2010-11 (note: log scale)


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

Figure 15 Tasman Valley Catchment showing sample sites for the investigation 2010-11

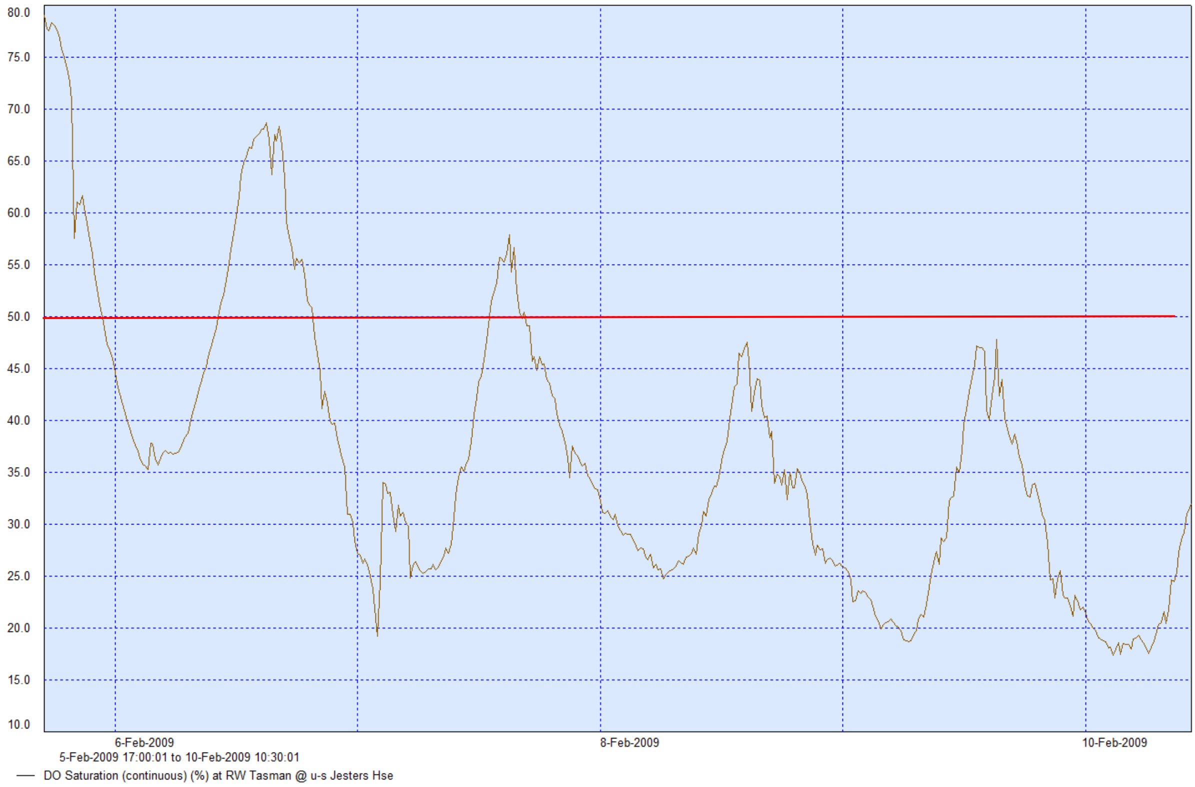


Figure 16 Dissolved oxygen percent saturation at Tasman Valley Stream (6-10 Feb, 2009). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

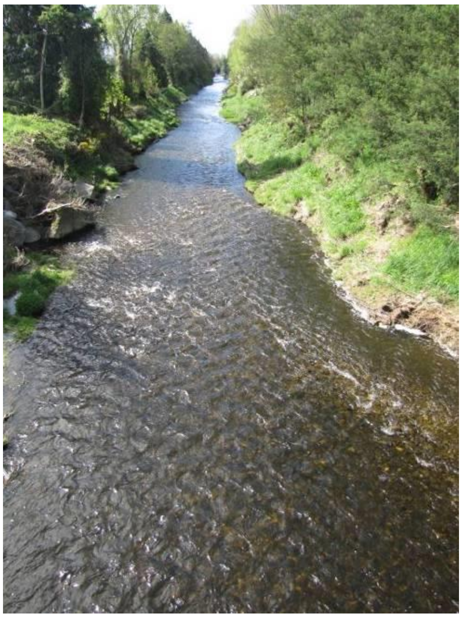
Catchment Statistics	Tasman Valley Stream
River Environment Class	Warm Dry Soft sedimentary Lowland-fed Pasture
Catchment area (km^2)⁺	8.5
Predominant land use upstream	Pasture
Mean annual rainfall (mm)*	1048*
Mean annual flow (l/sec)*	82.6*
Lowest recorded flow (l/sec)	3 (Apr 2010)
Water quality record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

* Estimate from WRENZ 2013. NA = not available

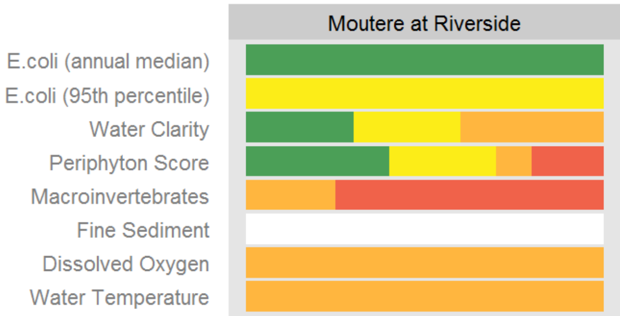
Moutere River catchment

Moutere at Riverside (Chings Rd), Lower Moutere

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.



Moutere River at Edwards Rd looking downstream (February 2011)



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

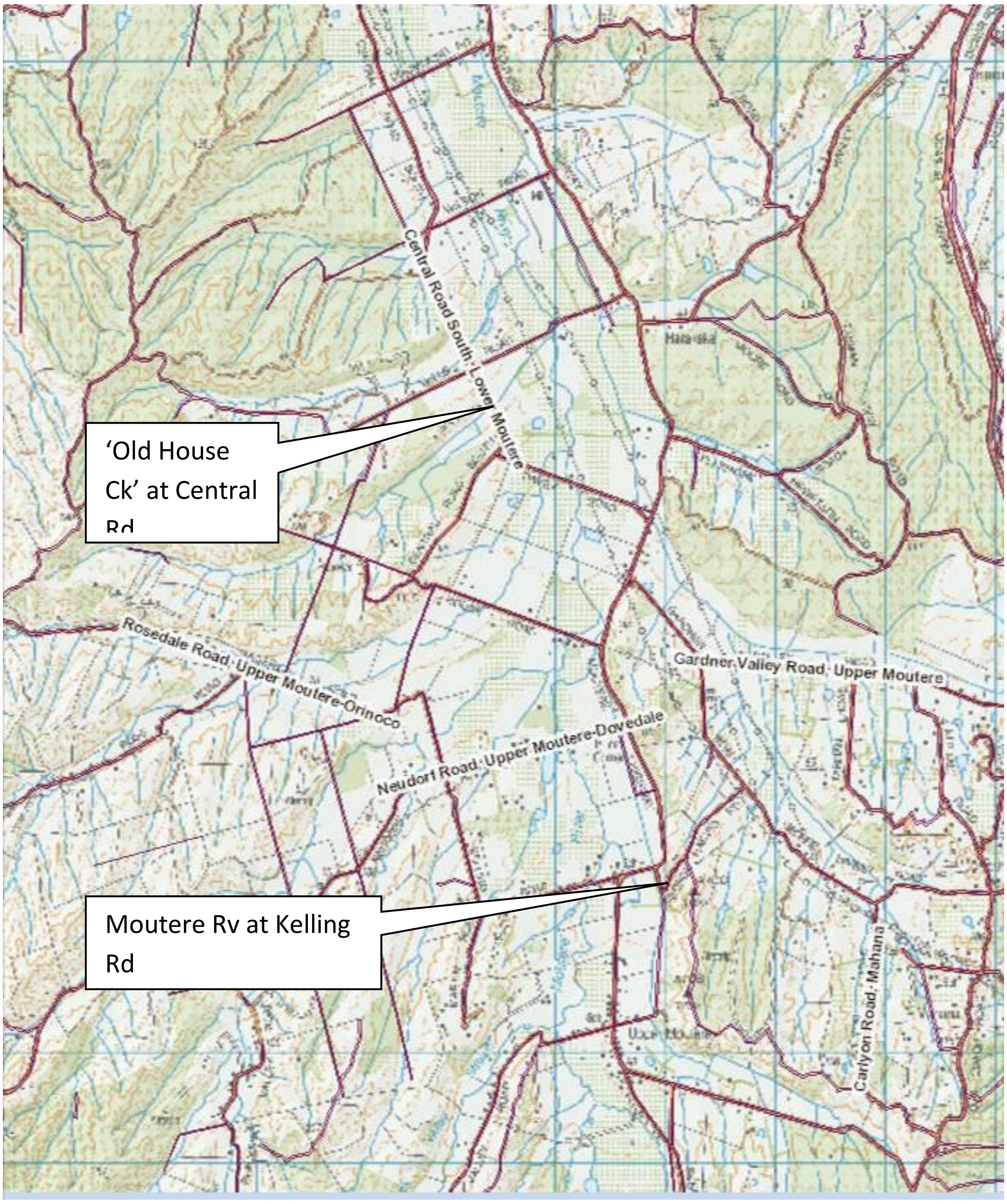


Figure 17. Map of central Moutere Valley sites where semi-continuous sampling has been carried out.

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 18). 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)

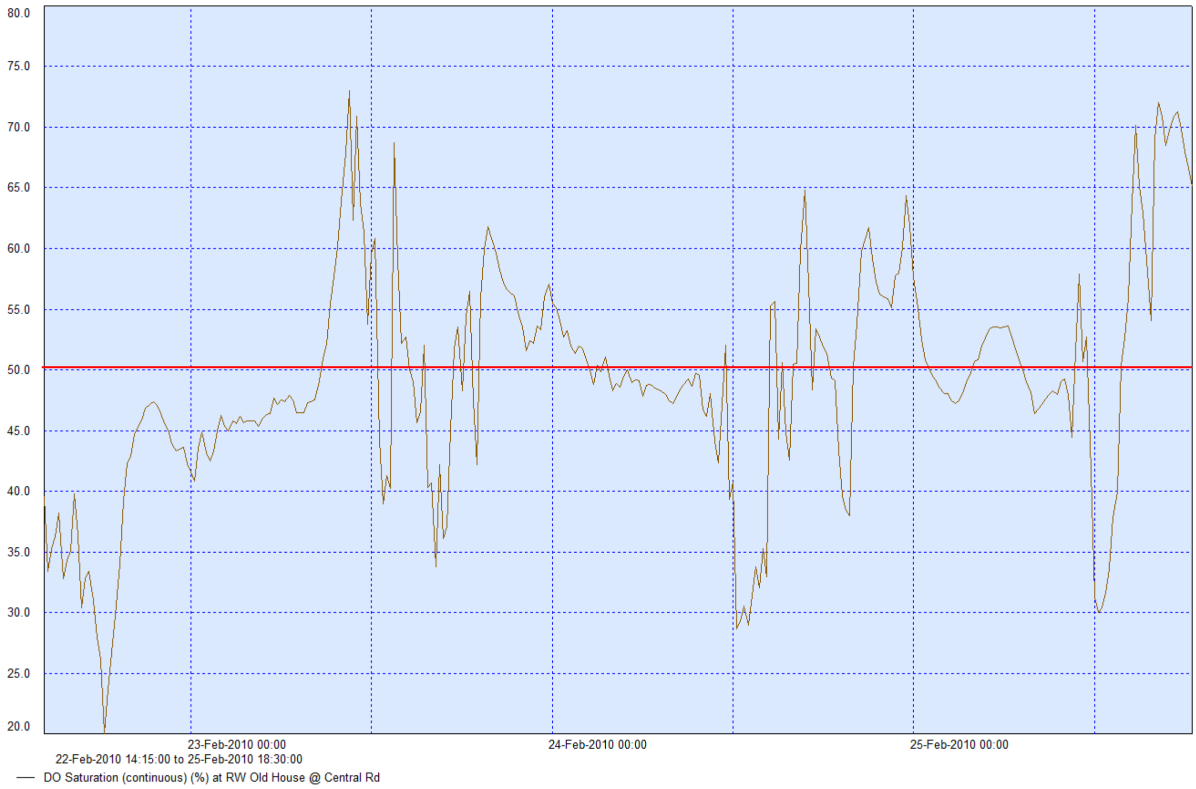


Figure 18 Dissolved oxygen percent saturation at Old House Creek at Central Rd (22-25 Feb, 2010). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

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 20). 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 19). These discharges have since been removed and it is hoped that future monitoring will show an improvement.

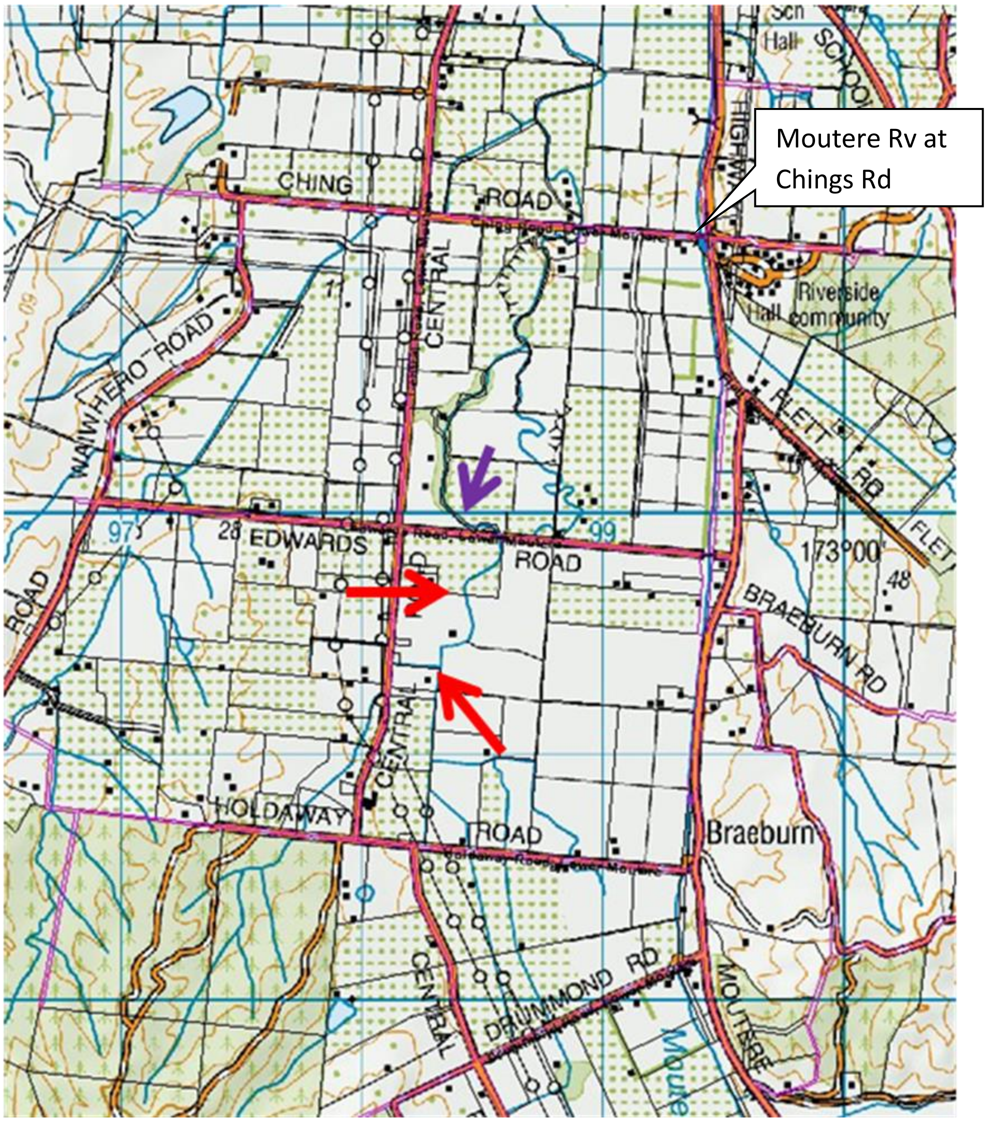


Figure 19 Location of water quality logger in purple (February 2010 and February 2014). Location of fruit industry discharges in red.

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°C).

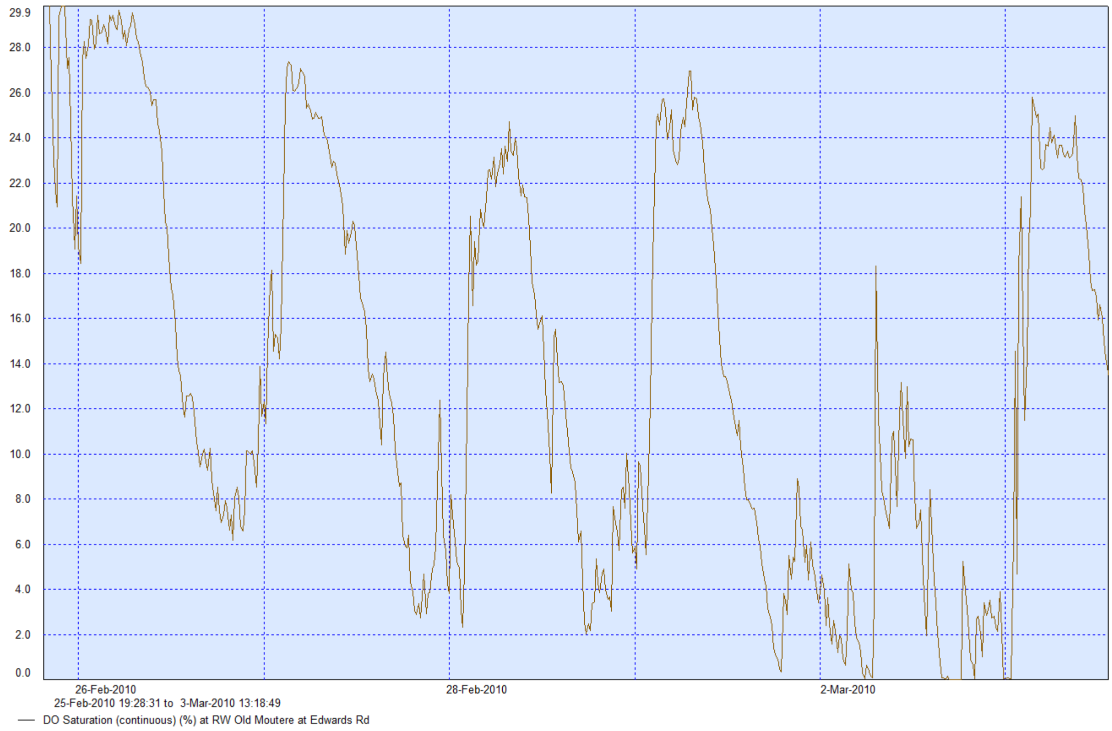


Figure 20 Dissolved oxygen percent saturation at Old Moutere Rv at Edwards Rd (26 February – 3 March, 2010). Note the scale with daily maxima well below national bottom lines.

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.

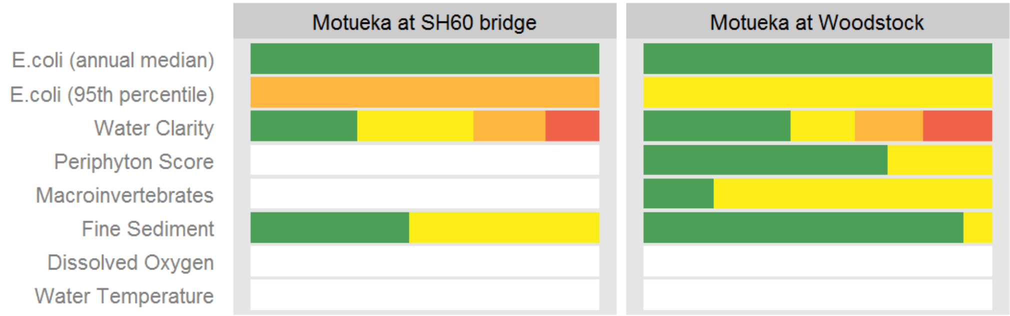
Motueka-Riwaka Catchments

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.

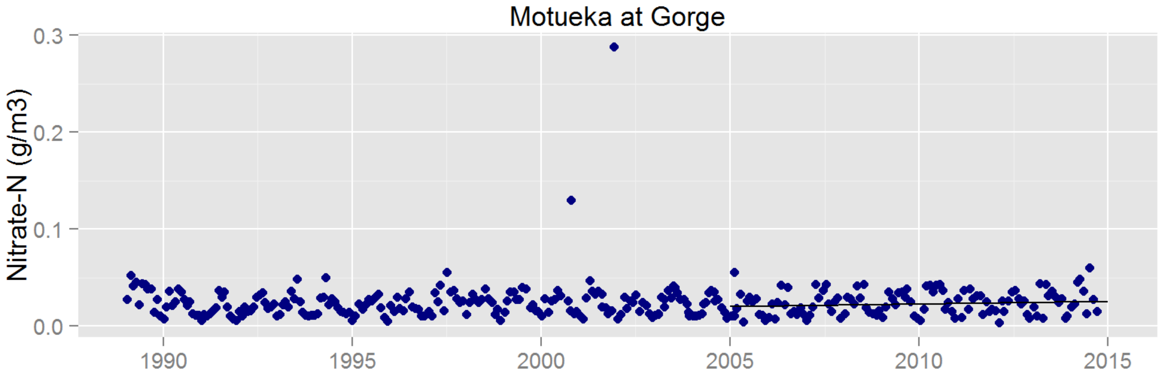


Figure 21. Motueka at Gorge Nitrate-N concentration data with 10-year trend line (p = 0.0384, RSKSE = 2.2% per year). No significant meaningful trend was detected over the full record (26 years).

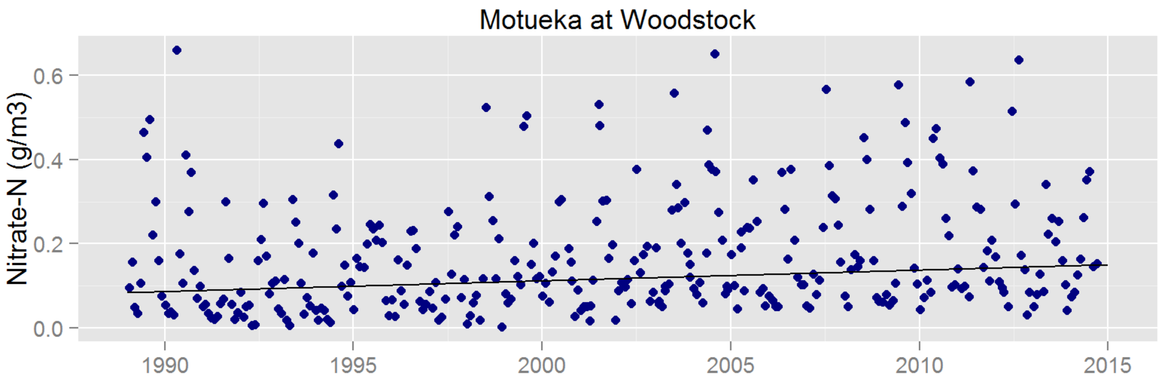


Figure 22. Motueka at Woodstock Nitrate-N concentration data with 26-year trend line (p = <0.0001, RSKSE = 2.2% per year). No significant meaningful trend was detected over the most recent 10 years of the record.

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).

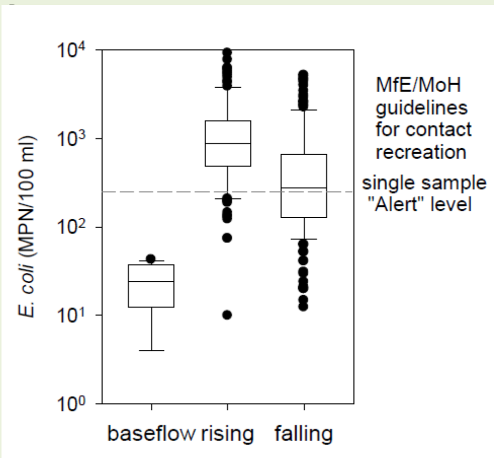
Catchment Statistics	Motueka at Gorge	Motueka at u-s Wangapeka	Motueka at Woodstock	Motueka at Woodmans Bend	Motueka at SH60 (Mouth)
River Environment Class	Cool Wet Hard sedimentary Mountain-fed Indigenous forest	Cool Wet Soft sedimentary Hill-fed Exotic forest	Cool Wet Soft sedimentary Hill-fed Exotic 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

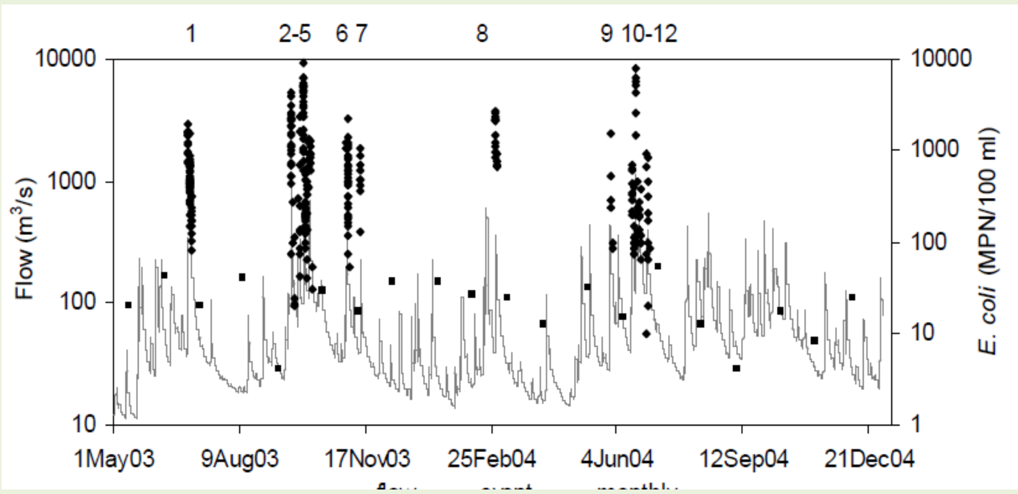
DISEASE CAUSING ORGANISMS (*E. COLI*) IN THE MOTUEKA RIVER

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 23A), 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 23B 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

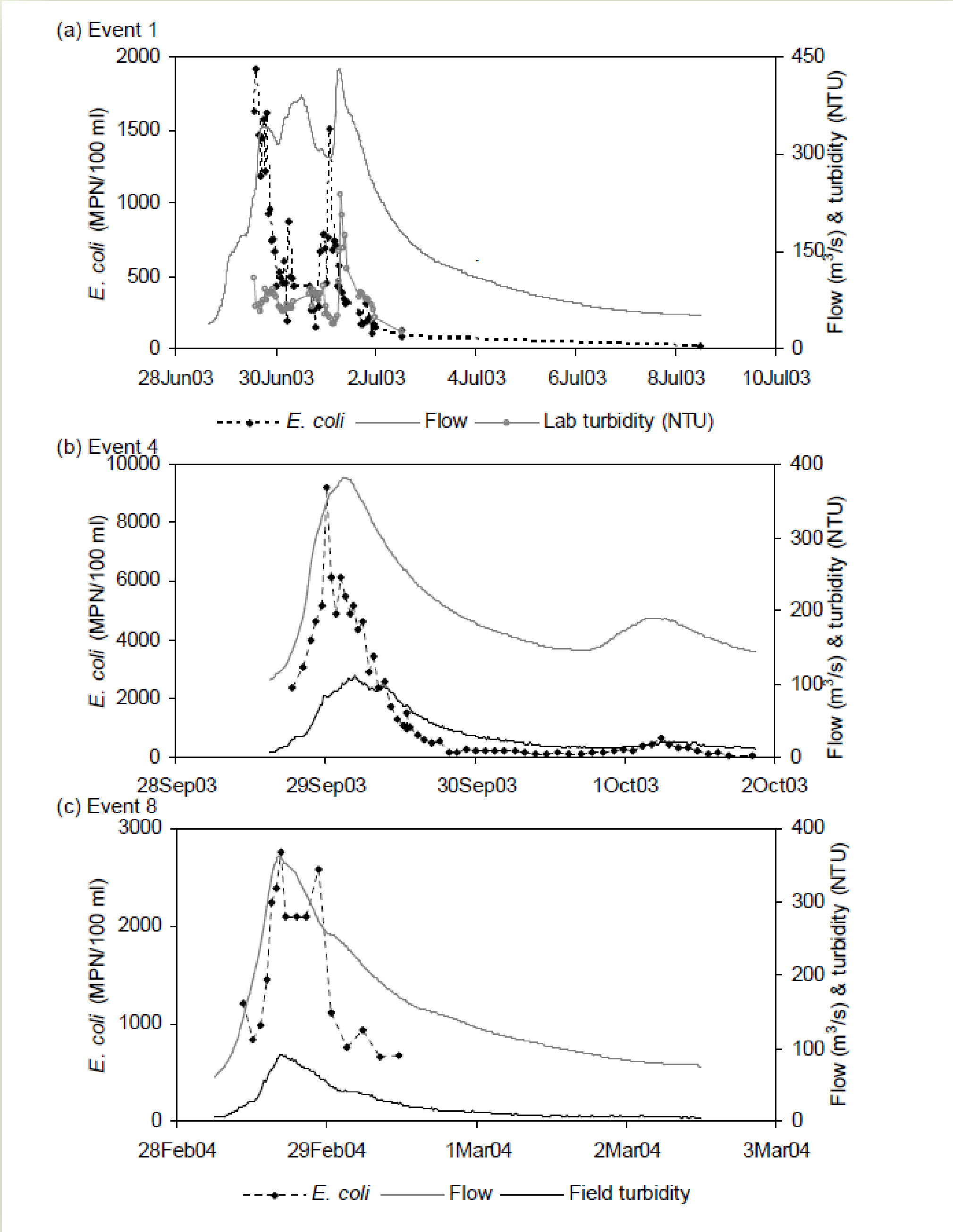


Figure 23. Relationships between *E. coli* levels and flow events in the Motueka River.
Note: X-axes are on a log scale except for C.

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 25Figure 26). The Motueka catchment has comparatively more data with wide coverage, making the model more robust.

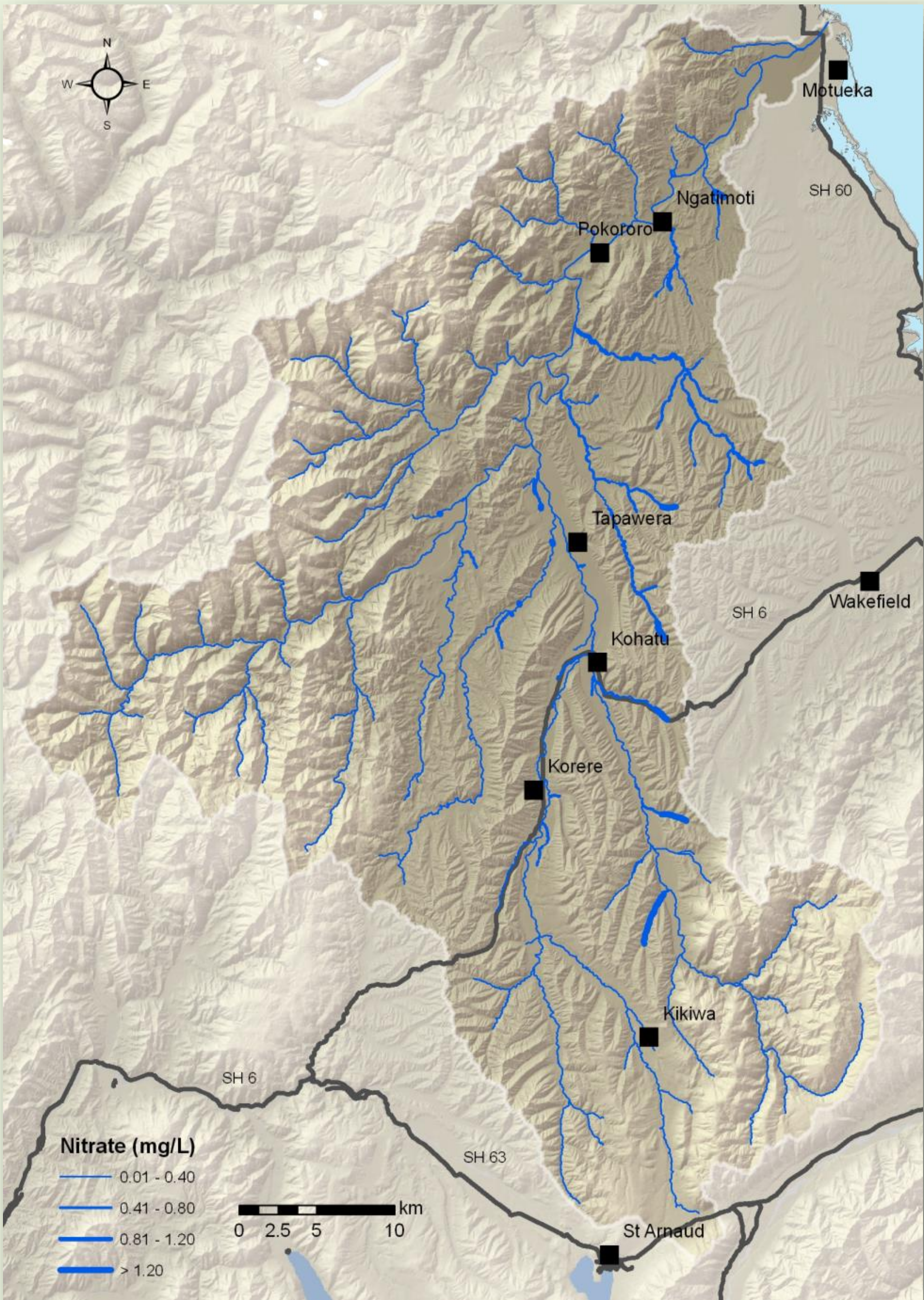


Figure 24. Predicted downstream changes in Nitrate-N in the Motueka River catchment. Note: The thicker the river line, the higher the nitrate concentration.

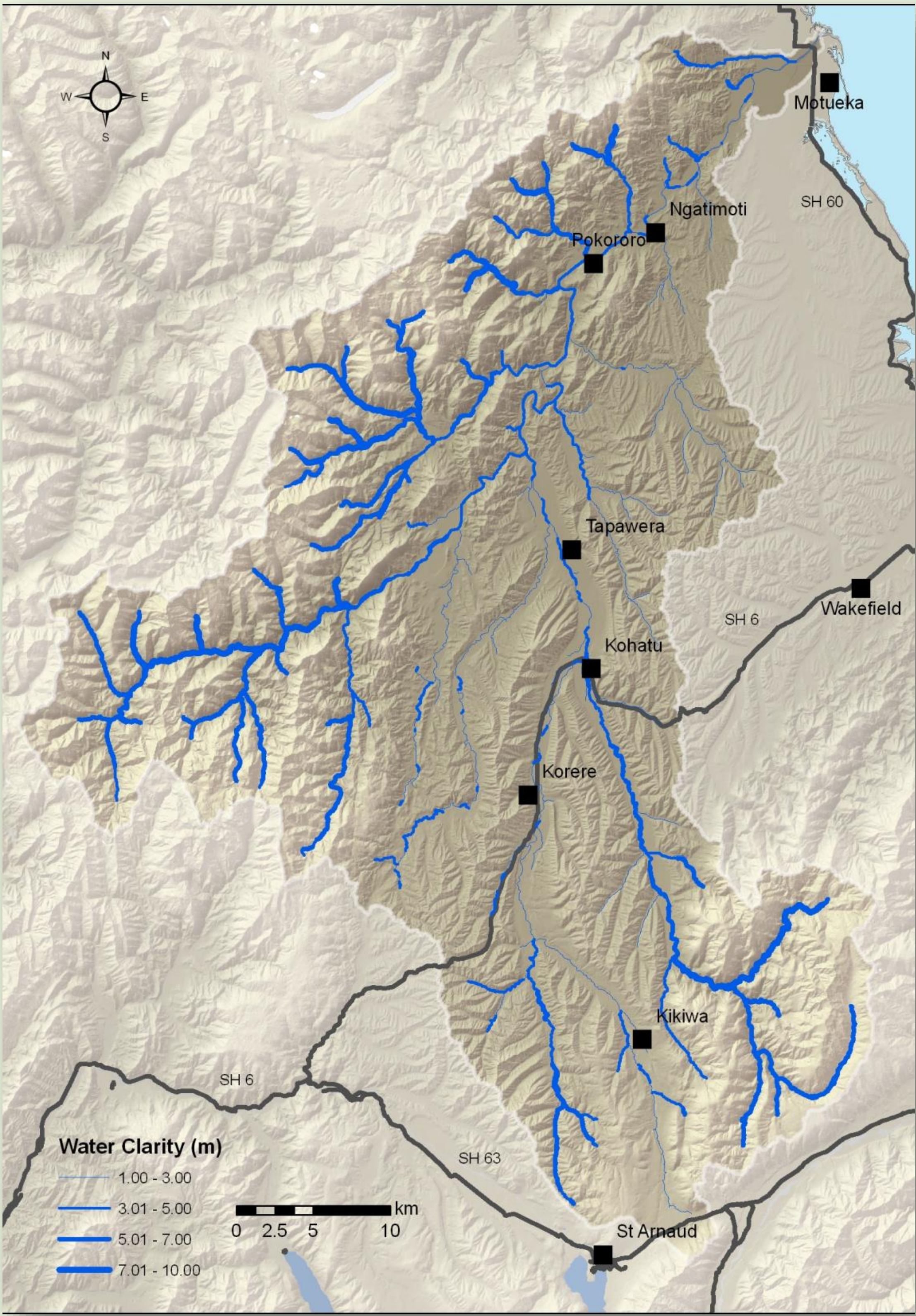


Figure 25.Predicted downstream changes in Water Clarity in the Motueka River catchment. Note: The thicker the river line, the higher the water clarity.

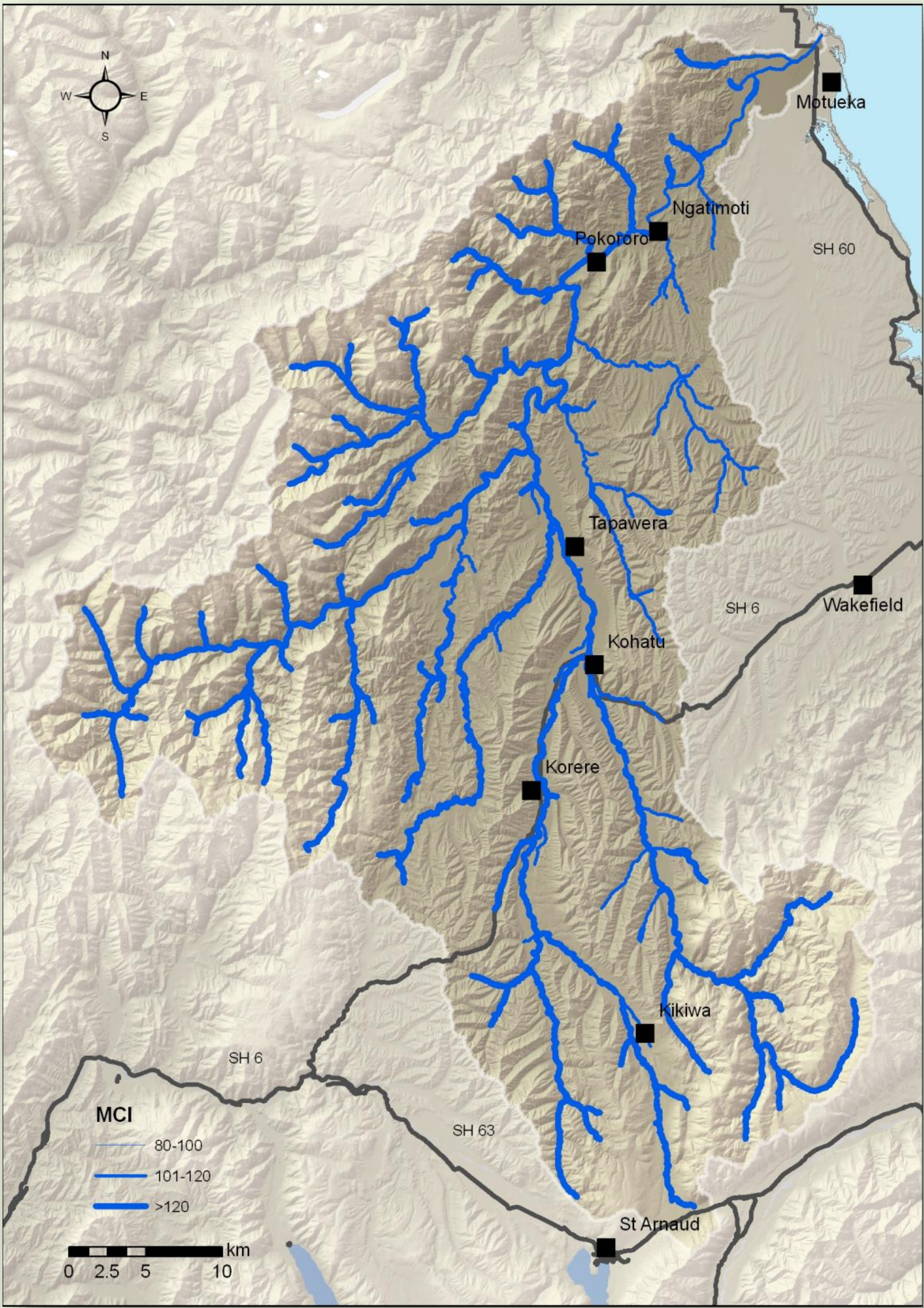


Figure 26. Predicted downstream changes in the Macroinvertebrate Community Index in the Motueka River catchment. Note: The thicker the river line, the higher the MCI.

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 28). Over the last five years the Blue Rock site has met bathing water guidelines only 60% of the time (< 260 E.coli/100 ml).

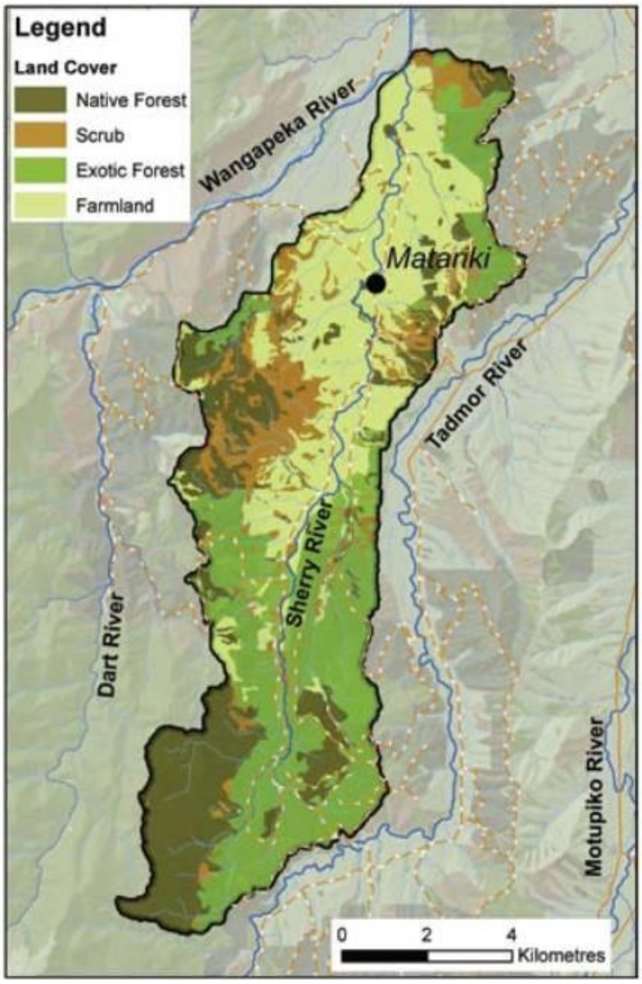
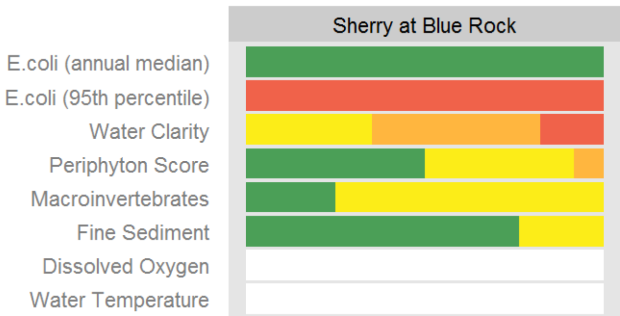


Figure 27 Land cover in the Sherry River catchment

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.

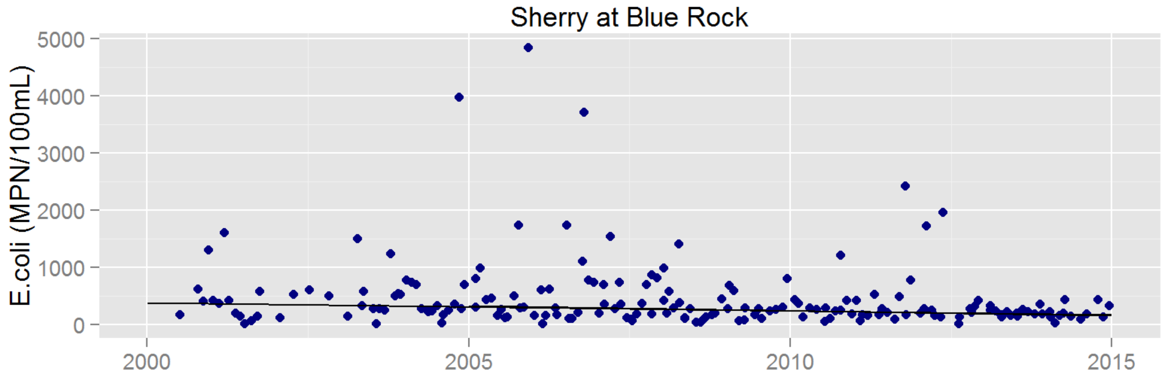


Figure 28 Sherry at Blue Rock E. coli data with 10-year (p = 0.0013, RSKSE = -6.9% per year) and 15-year trend lines (p = 0.0001, RSKSE = -5.2% per year).

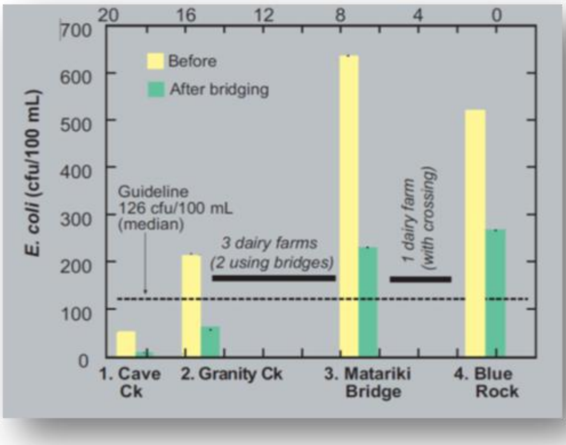


Figure 29. ***E.coli*** **at four sites along the Sherry River (Davies-Colley et al. 2003). A guideline for median E. coli is shown for comparison.**

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 29). 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 30)

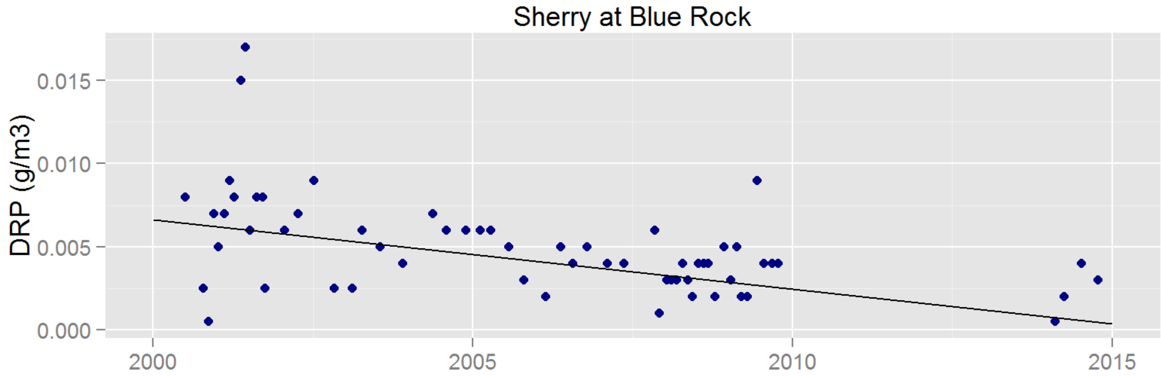


Figure 30. Sherry at Blue Rock dissolved reactive phosphorus (DRP) concentration data with 15-year trend line ($p < 0.0001$, RSKSE = -10.4% per year). No significant meaningful trend was detected over most recent 10 years of the record.

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 29).

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 31). 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.

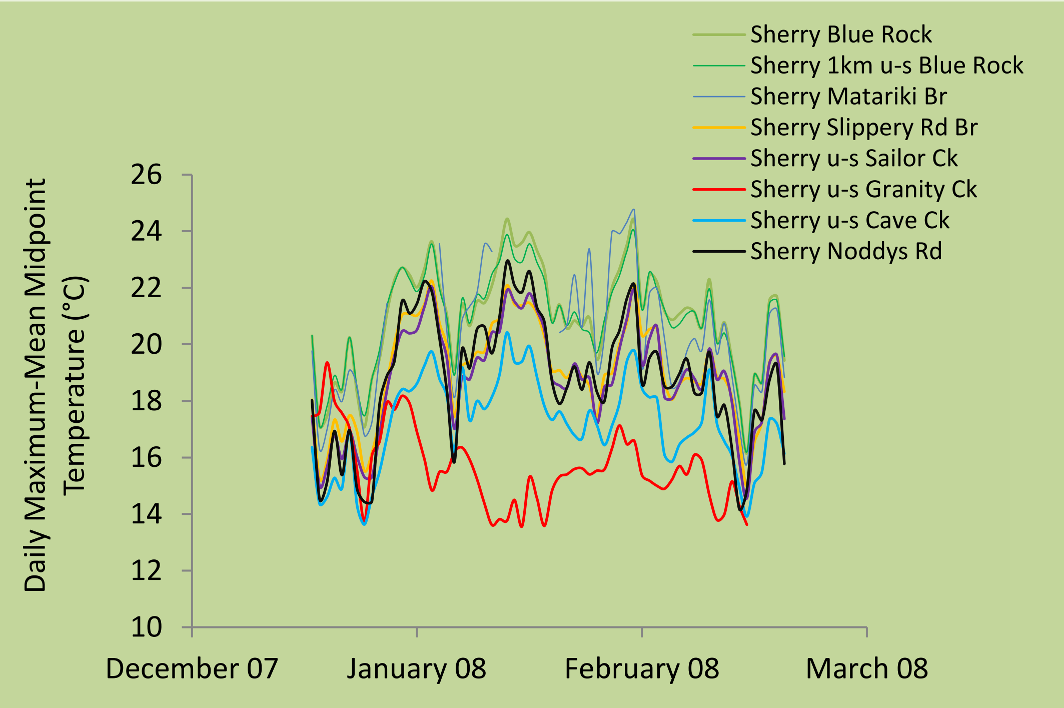


Figure 31 Stream temperature data for sites on the main stem of the Sherry River. Note: The key shows sites in order from furthest downstream at the top to furthest upstream at the bottom; data plotted are the midpoint of the daily maximum and the daily mean.

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

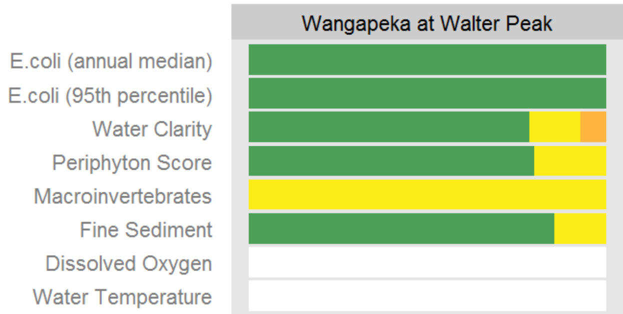
Sherry Rv at Blue Rock (July 2007, left), Upstream Cave Ck (January 2008, middle), Reading the black disc water clarity at Matariki (right).

Wangapeka River

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

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).

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



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

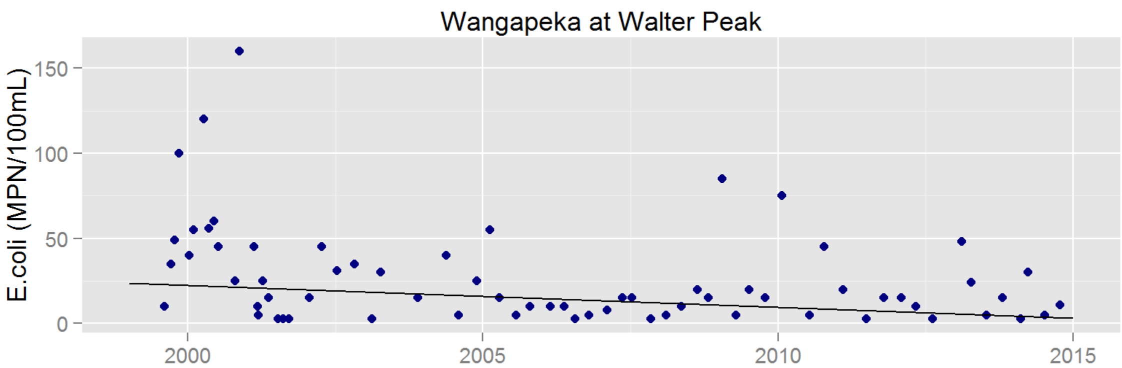


Figure 32. Wangapeka at Walter Peak *E. coli* data with 16-year trend line (p = 0.0055, RSKSE = -8.6% per year). No significant meaningful trend was detected over the most recent 10 years of the record.

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 33).

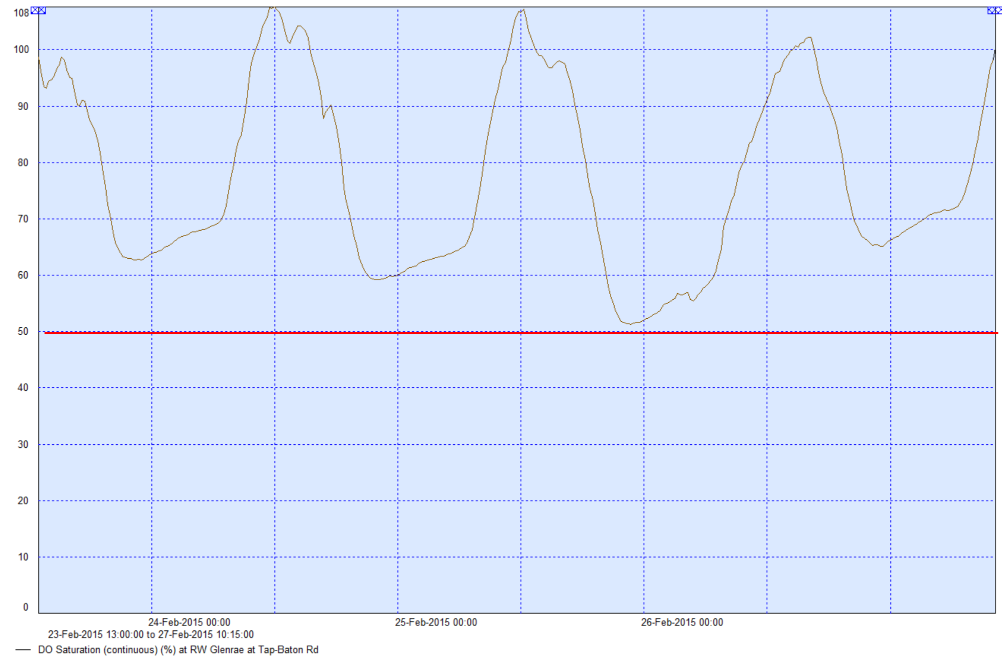


Figure 33 Dissolved oxygen percent saturation at Glenrae Stream at Tapawera-Baton Rd (23-27 Feb, 2015). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

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°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 35) but **satisfactory temperatures** (maxima below 20^{o}C).

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

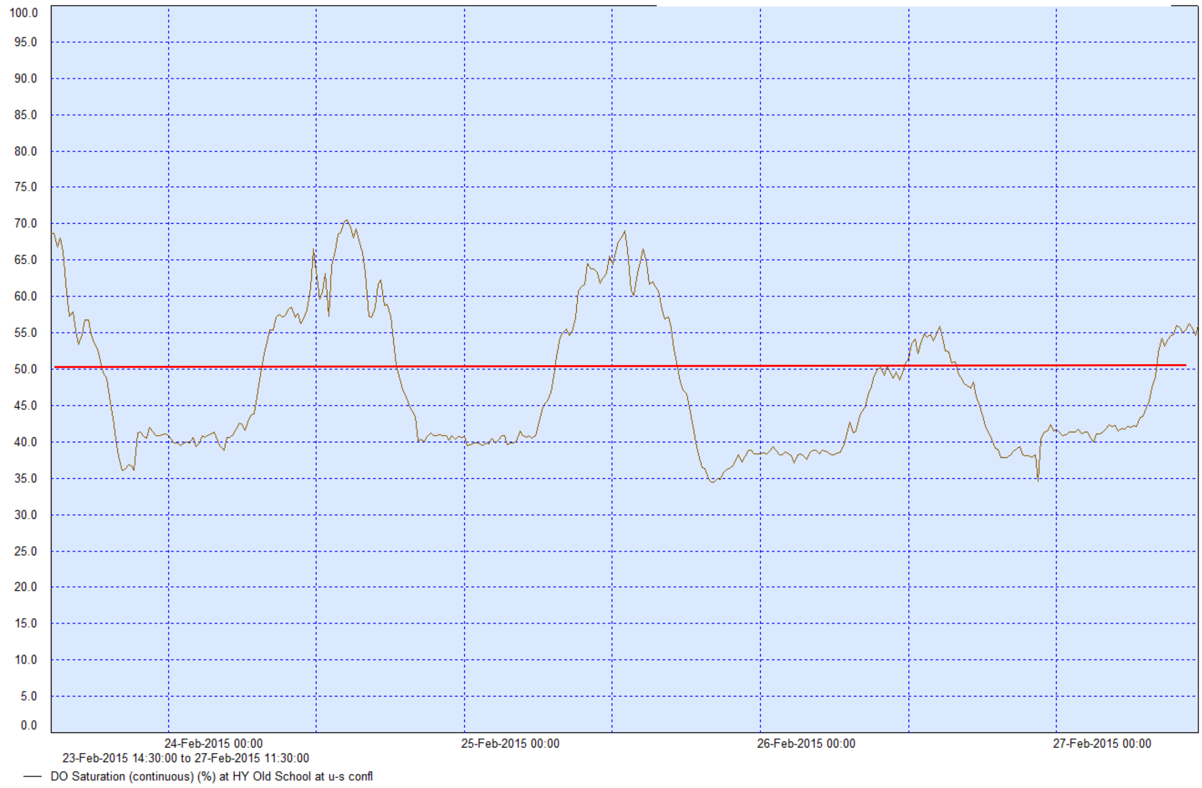


Figure 35 Dissolved oxygen percent saturation at Old School Creek 180 m upstream Motueka River (23-27 Feb, 2015). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

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 36). 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).

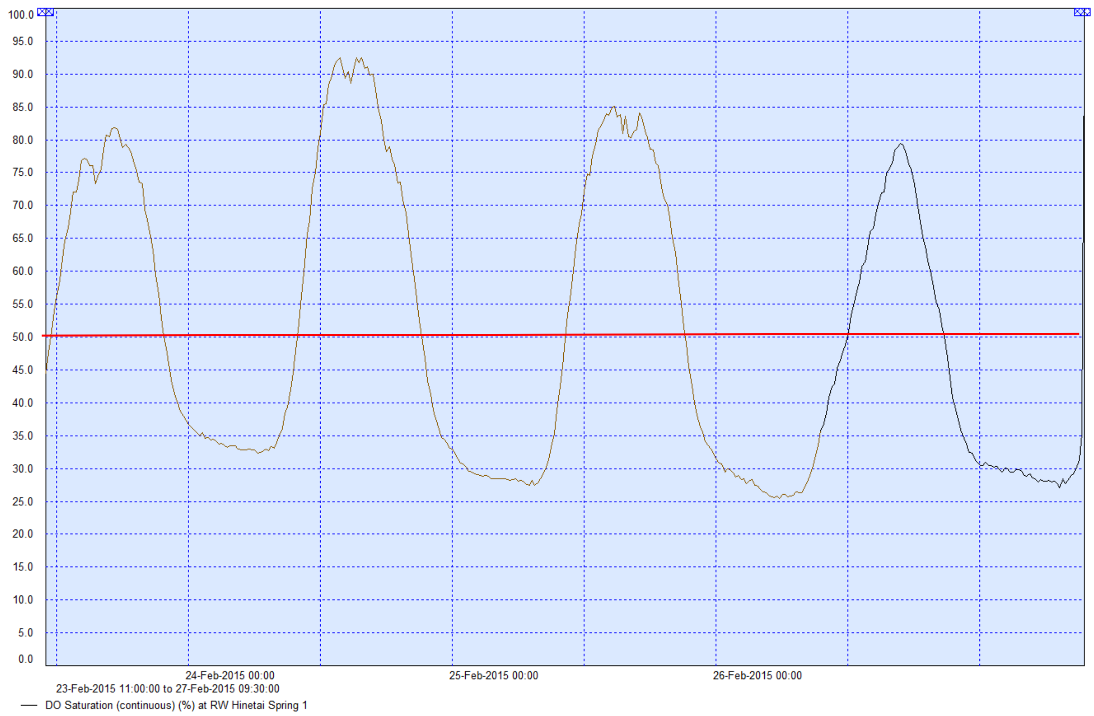


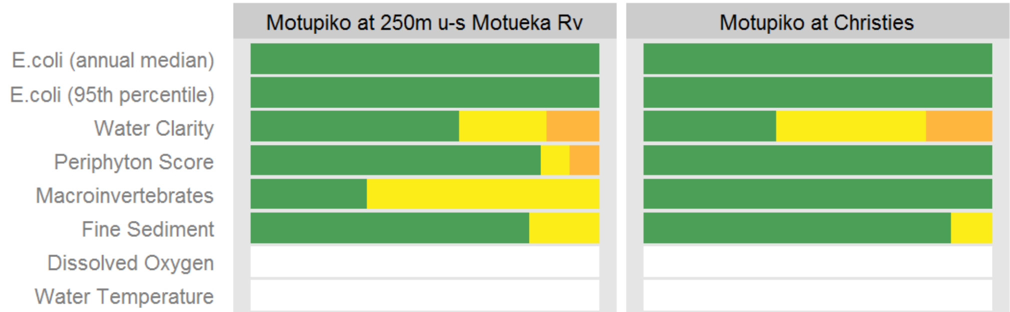
Figure 36 Dissolved oxygen percent saturation at Hinetai Creek (23-27 Feb, 2015). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

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).

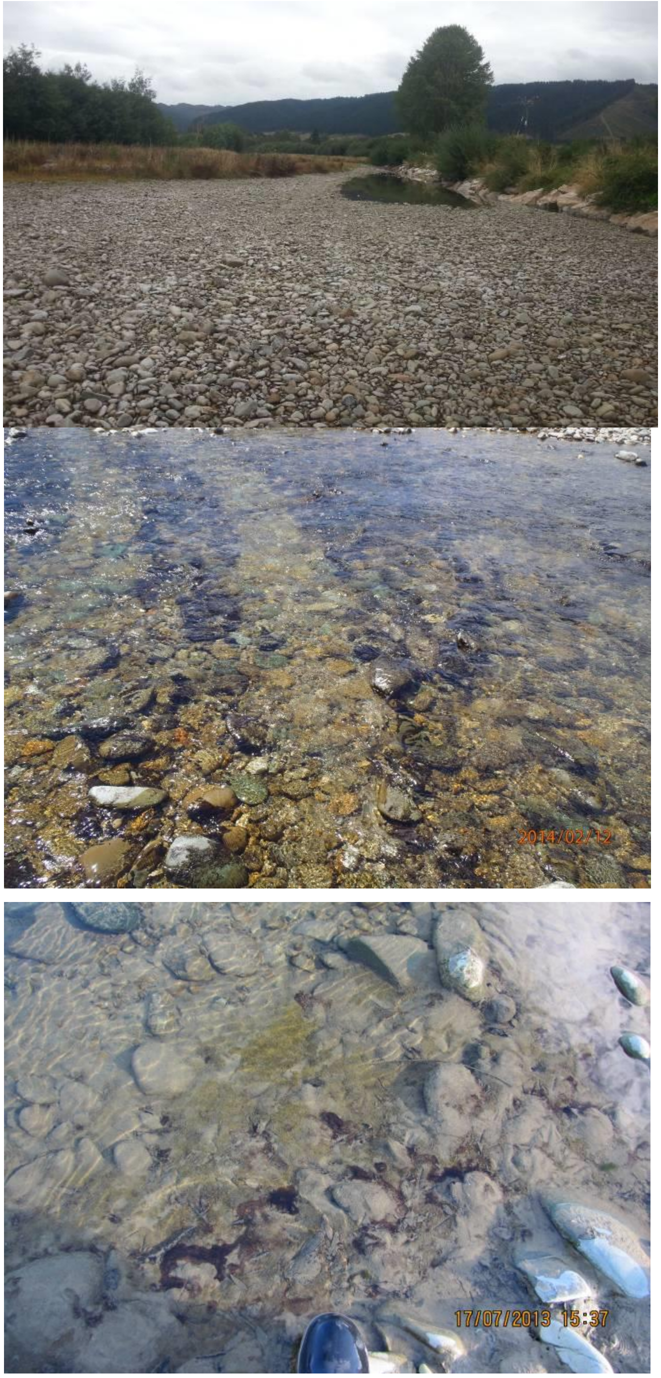
Water clarity at Christies and upstream Motueka River is good (median 4.5 m and 6.4 m respectively 2006-2015).

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%.

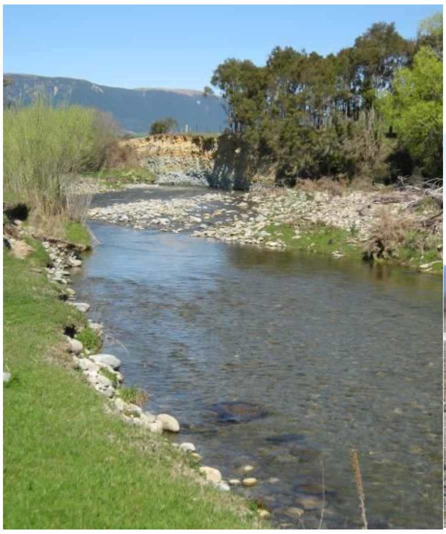
Levels of filamentous green algae are generally very low at Christies (coverage records all below 7%, except for February 2015 when coverage was 30%; median periphyton score: 10). At the lower site filamentous green algae is generally low (coverage: only 2 records above 5%, max 15%; Median periphyton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

Water temperatures were occasionally over 21.5°C and up to 23.4°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).

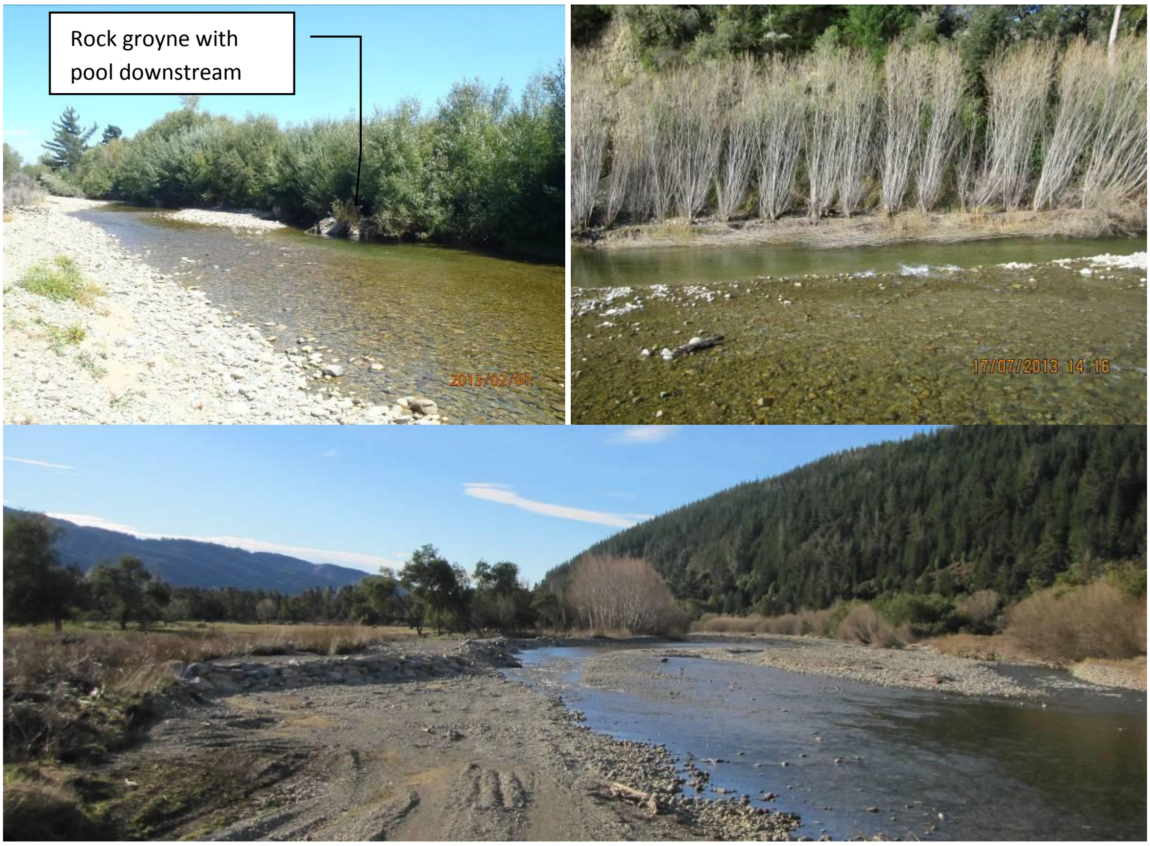
There **appears to be a reduction in quality of trout habitat** with a shift to more uniform water depth and fewer pools in this river than 10-20 years ago, particularly from around Korere to the Motueka River. Variety of depth and frequency of pools in a river is a critical habitat component for many 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

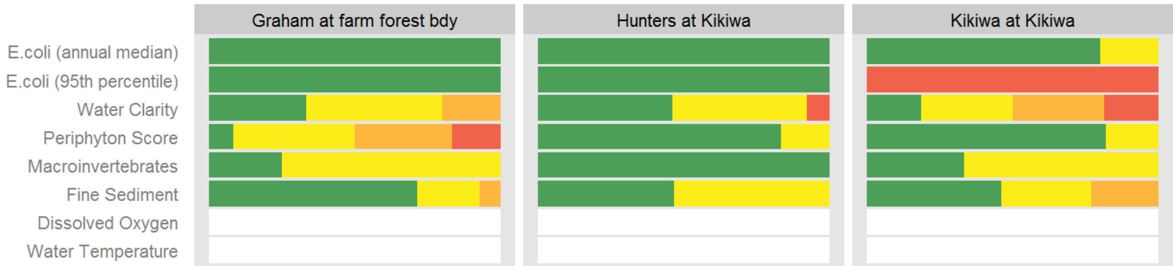


<u>Above left</u>: Motupiko River approx 2 km downstream Korere Bridge (February 2013). Note: Shrub willow plantings and a rock groyne creating a pool downstream in an otherwise very even and shallow water depth. <u>Above right:</u> Shrub willow plantings in a way that reduces opportunity for scour thereby 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 37) 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.

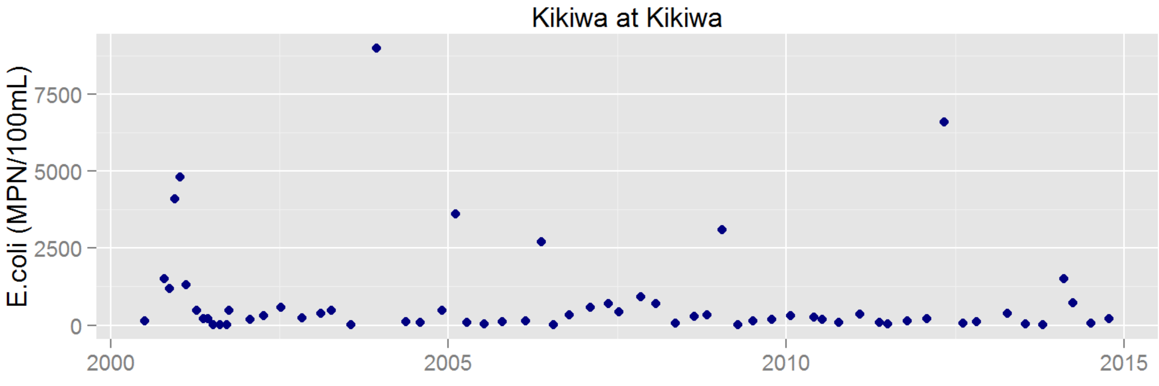


Figure 37. Kikiwa at Kikiwa *E. coli* data from 2000 to 2014.

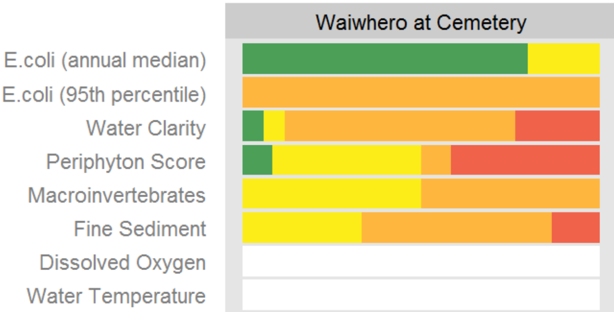
'The Kikiwa Suite': From Left: Kikiwa Ck (April 2005), Hunters Ck (January 2002), Graham Ck (January 2002)

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 38). 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 39). 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.

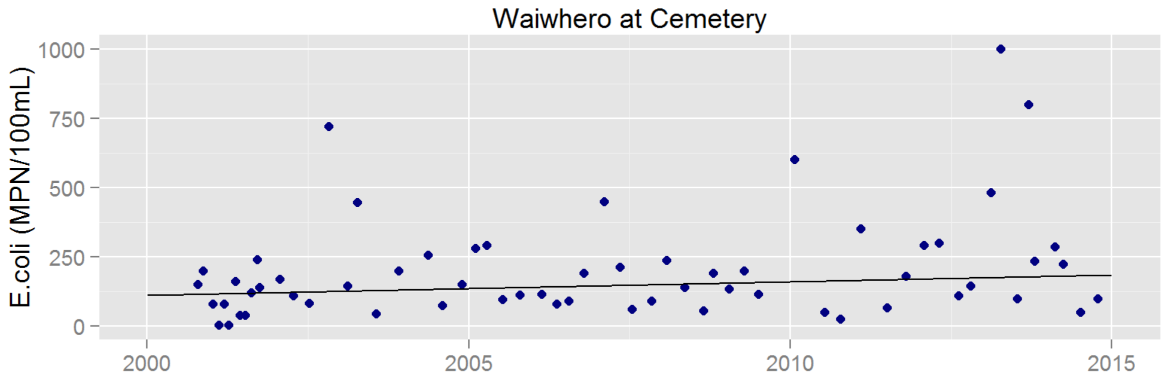


Figure 38. Waiwhero at Cemetery *E. coli* data with 15-year trend line (p = 0.0231, RSKSE = 3.4% per year). No significant meaningful trend was detected over the most recent 10 years of the record.

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.

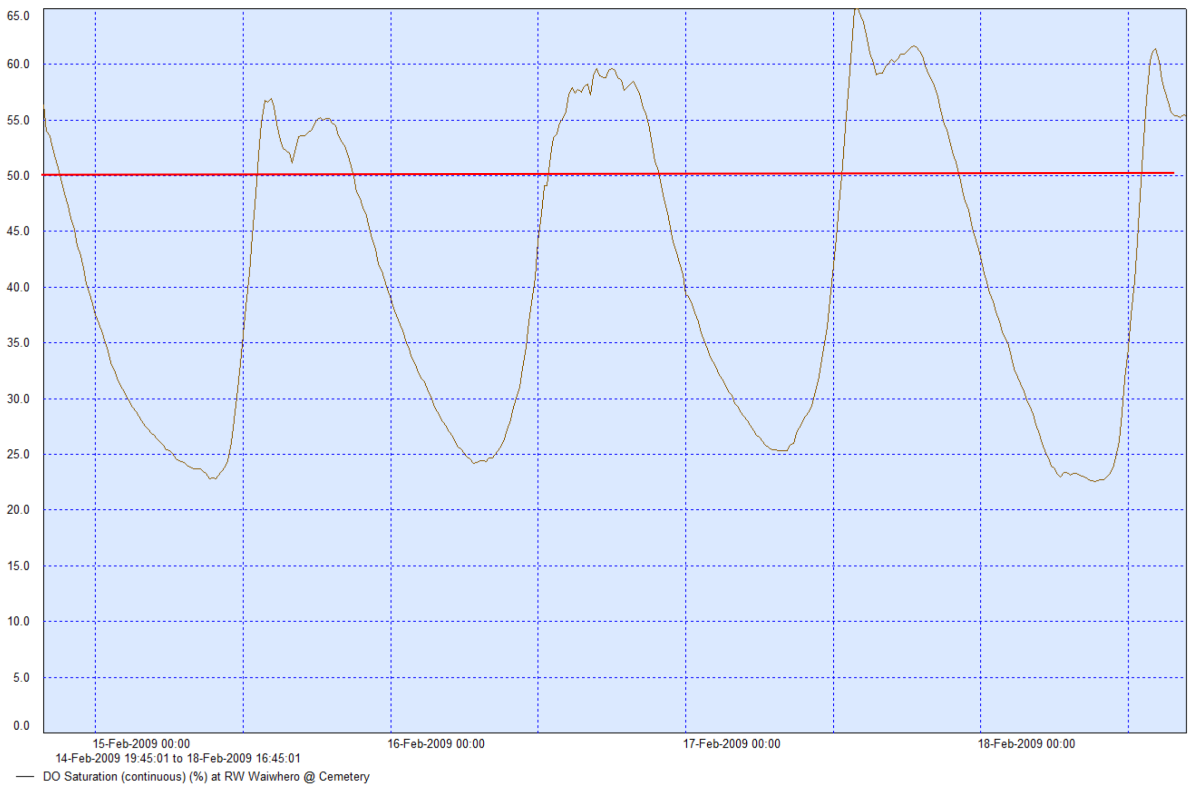


Figure 39 Dissolved oxygen percent saturation at Waiwhero Creek at Cemetery (Waiwhero Rd) (22-25 Feb, 2010). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

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 40).

Thorpe and Woodlands drains are artificially-straightened streams flowing through Motueka township south into the Moutere Inlet (Figure 41).

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 42) 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)

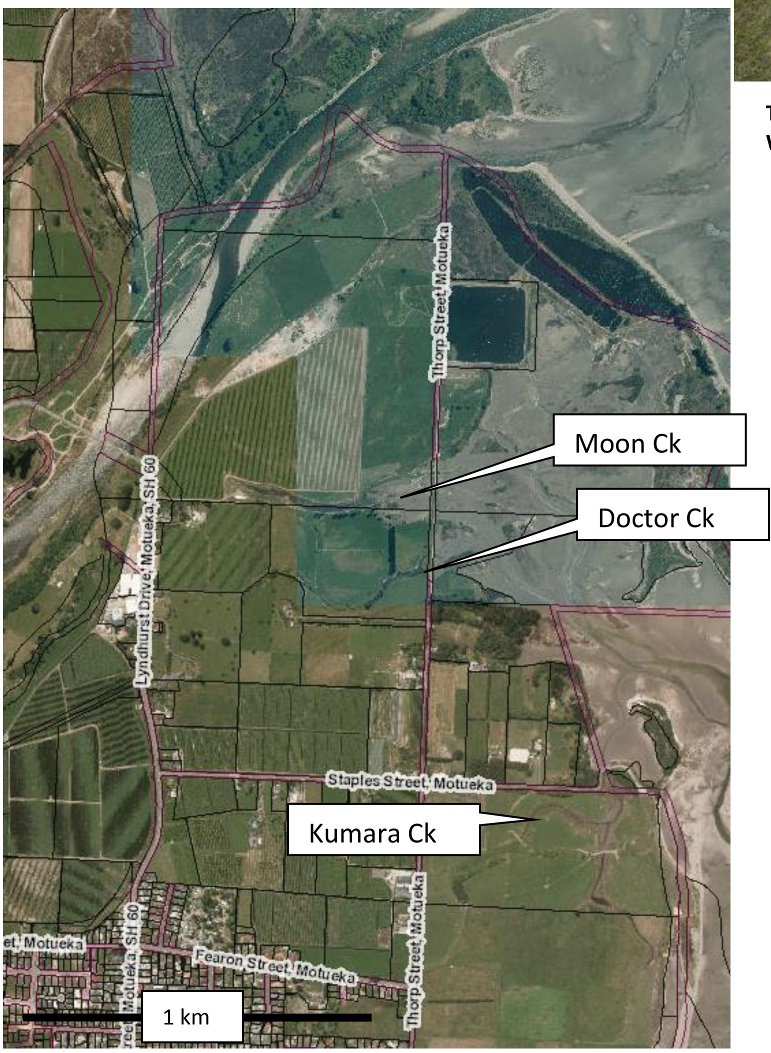


Figure 40 North Motueka Spring-Fed Creeks

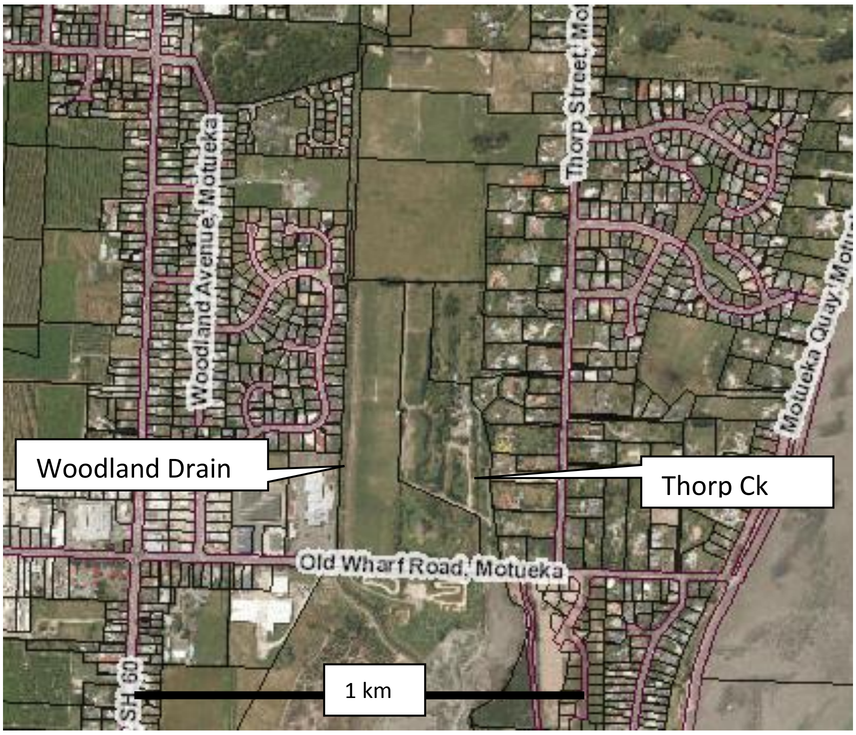


Figure 41 South Motueka Spring-Fed Creeks

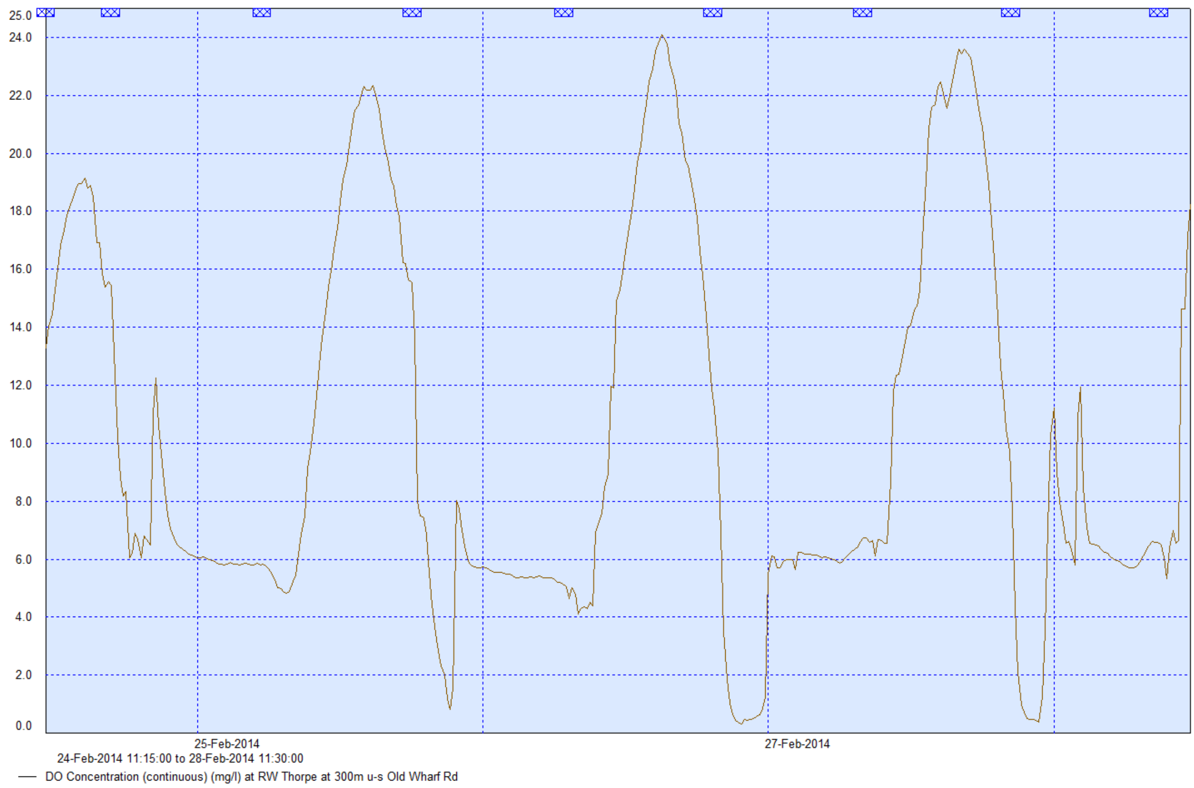
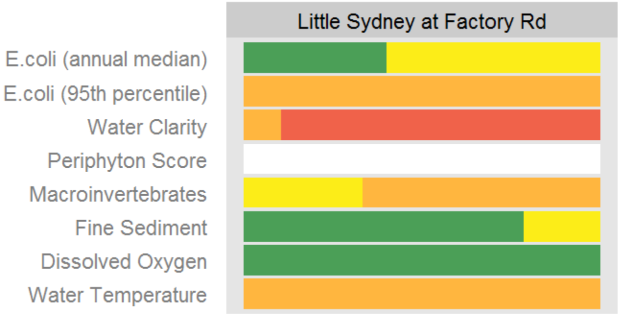


Figure 42 Dissolved oxygen percent saturation at Thorpe Creek at 300 m upstream Old Wharf Rd (24-28 Feb, 2014). Note: dissolved oxygen concentration was used as % saturation data was inadvertently not logged. The national proposed bottom line for the daily 1-day minimum is shown by the red line.

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 43). 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.

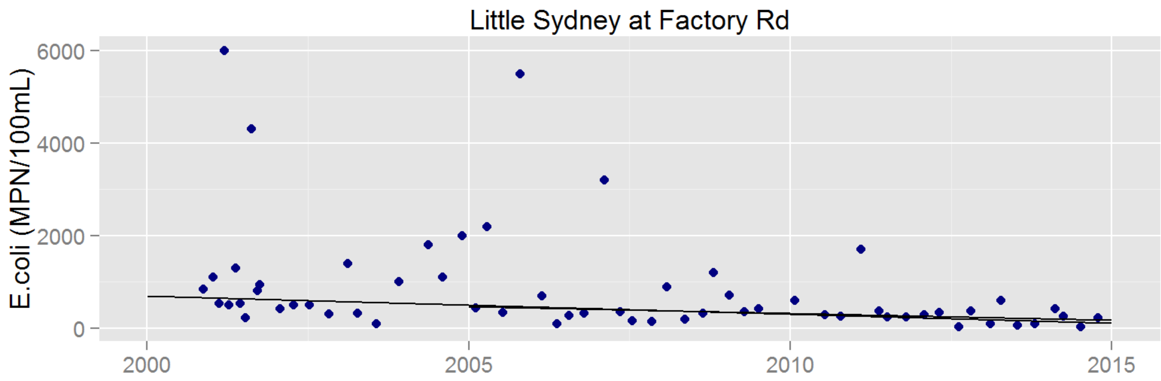


Figure 43. Little Sydney at Factory Rd *E. coli* data with 10-year (p = 0.0144, RSKSE = -9.2% per year) and 15-year trend lines (p = 0.0002, RSKSE = -9.0% per year).

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.

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

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.

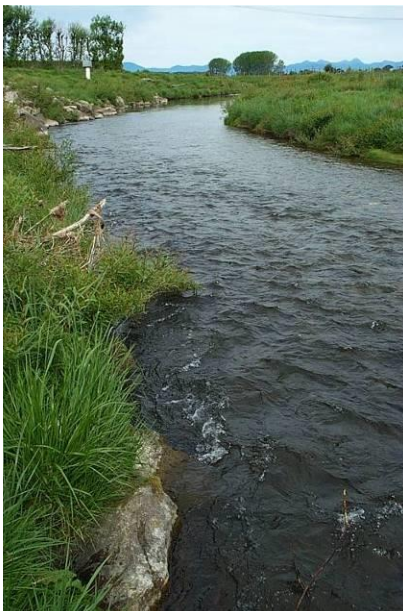
Little Sydney Stm along Swamp Rd (December 2013)

Catchment Statistics	Little Sydney at Factory Rd
River Environment Class	Cool Wet Plutonic (Separation Pt Granite) Hill-fed moderate gradient
Catchment area (km²)⁺	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

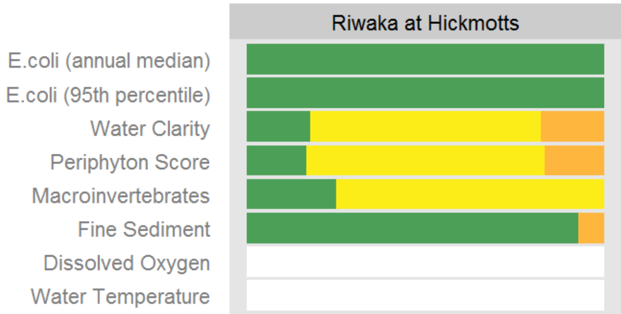
Riwaka River

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.



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

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 44). 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.

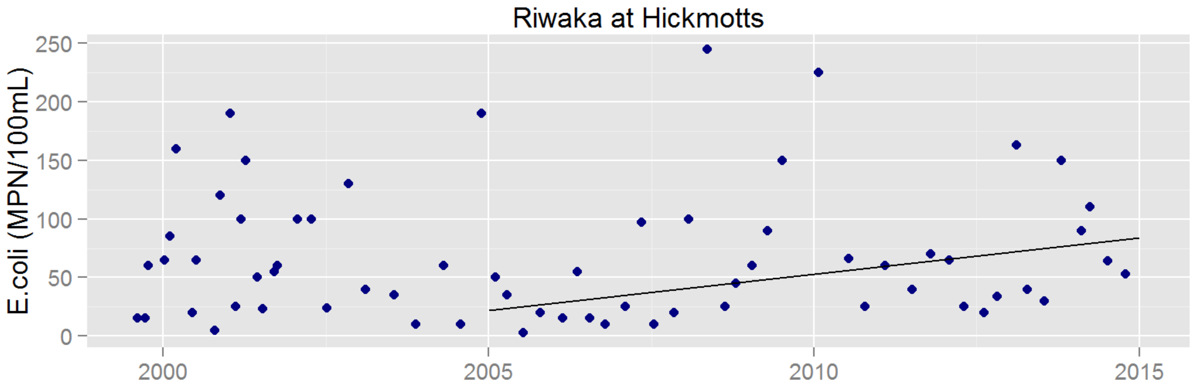


Figure 44. Riwaka at Hickmotts *E. coli* data with 10-year trend line (p = 0.0009, RSKSE = 12.4% per year). No significant meaningful trend was detected over the full record (16 years).

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 (km²)⁺	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 3 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)