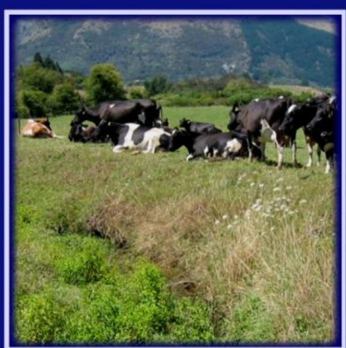
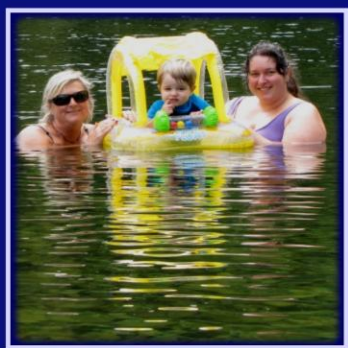
State of the Environment Report

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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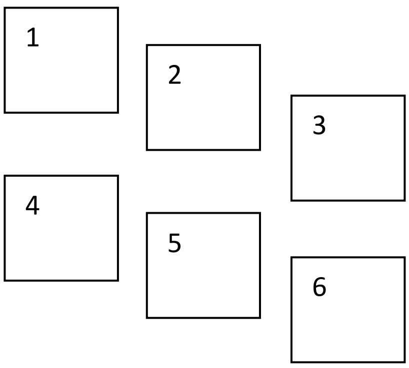
Cover photos:

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

Waimea Water Management Area

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

In this area, there were 12 River Water Quality sites monitored between 2010 and 2014 (Figure 1). There are no reference sites in this area without some potential impact upstream (Reservoir Creek upstream Marlborough Cres and Wairoa upstream Pig Valley both have relatively significant areas of exotic forestry upstream).

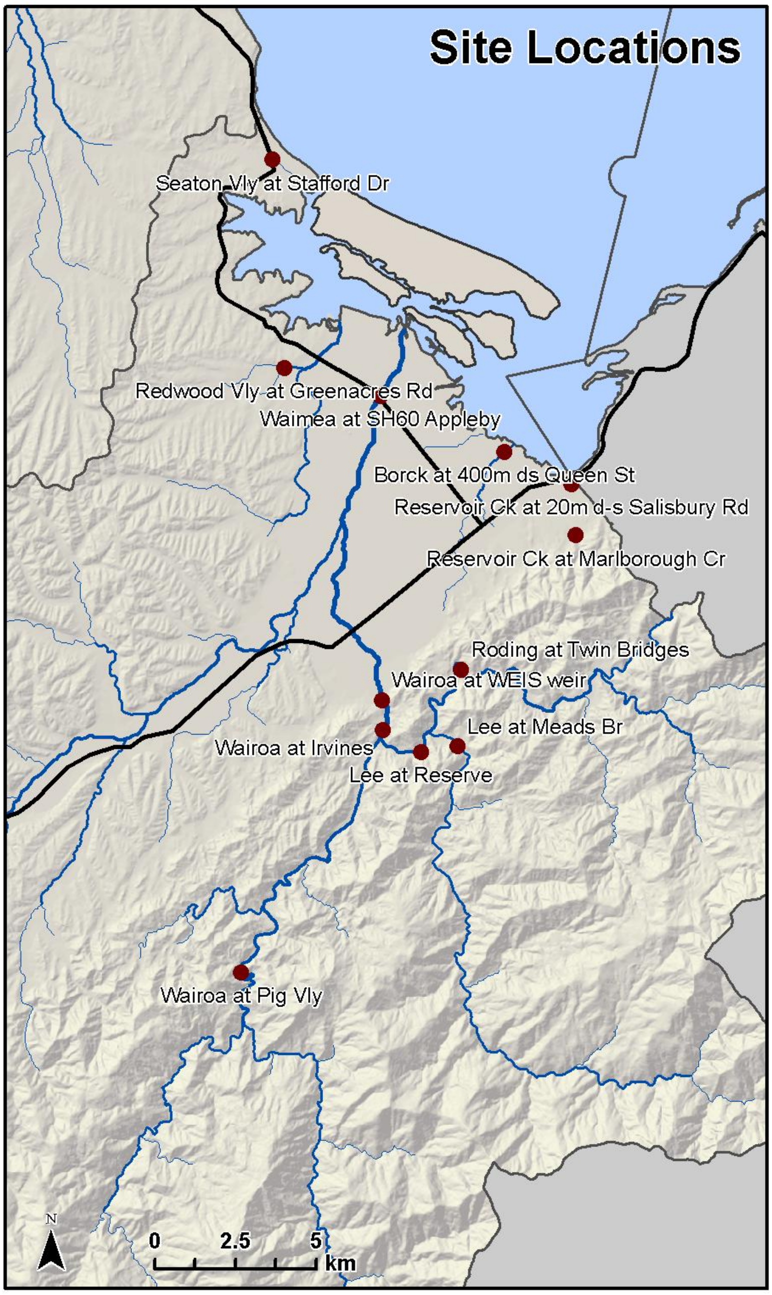


Figure 1. River Water Quality sites in the Waimea Water Management Area

Discussion of Specific Catchments/Areas

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

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	^oC	≤18	18 - 20	20 - 24	>24	Davies-Colley et al. (2013)
pH	Single measurement	N/A	6.5 - 8.5	5 - 6.5, 8.5 - 9	>5 or >9	N/A	-
Ammonia-N	Annual median	g/m^3	≤0.03	0.03 – 0.24	0.24 - 1.3	>1.3	NPSFM (2014)
	Annual maximum	g/m^3	≤0.05	0.05 - 0.4	0.4 - 2.2	>2.2	
Nitrate-N	Annual median	g/m^3	≤1.0	1.0 - 2.4	2.4 – 6.9	>6.9	NPSFM (2014)
	Annual 95^{th} 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)
	95^{th} percentile	CFU/100 ml	≤260	260 - 540	540 - 1000	>1000	
Macroinvertebrates	MCI	N/A	≥120	100 - 120	80 - 100	<80	Stark & Maxted (2007)
	SQMCI	N/A	≥6	5 - 6	4 - 5	<4	
Phormidium	Percentage cover	%	<20	≥20	N/A	N/A	MfE (2009)
Filamentous green algae	Percentage cover	%	<10	10-19	20-29	>30	Biggs and Kilroy (2000)
Periphyton	Periphyton score (1 to 10)	N/A	≥8	6 - 8	5 - 6	< 5	-

How to read a site summary

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

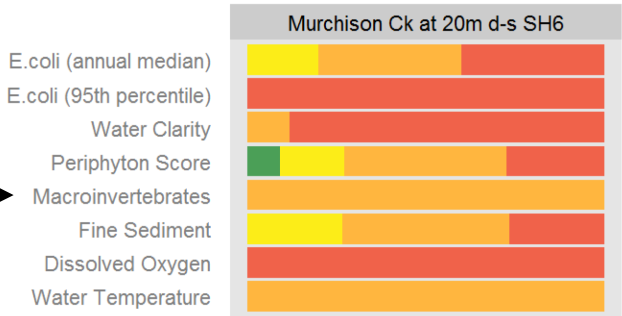
The rows of a site summary represent water quality attributes. The colours indicate attribute states **A** (very good), **B** (good), **C** (fair) and **D** (poor).

Proportion of periphyton scores in each attribute state.

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

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

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



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

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

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

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

Water Clarity

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

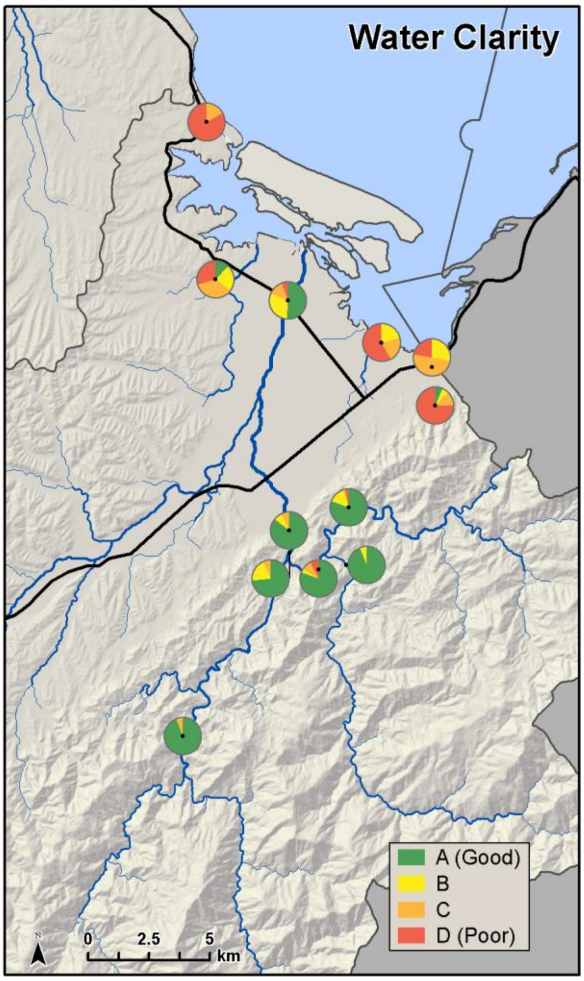


Figure 2. Proportion of water clarity records in each attribute state (A to D) for river water quality sites in the Waimea Water Management Area (sites shown have a minimum of 10 samples).

Disease-causing Organisms

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

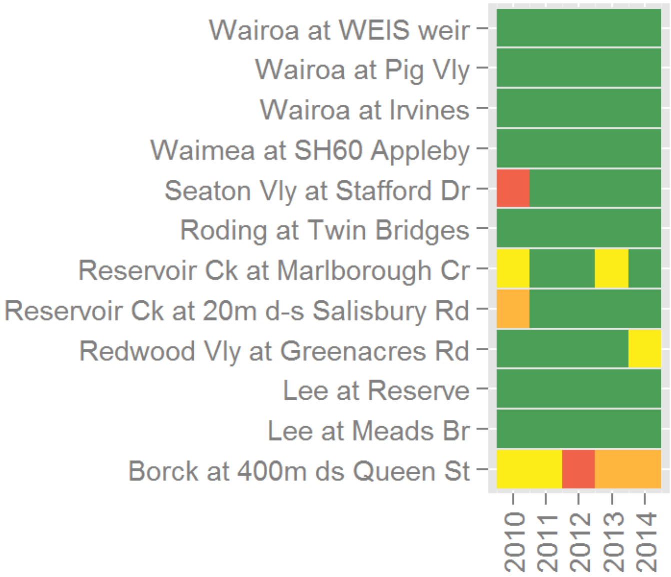


Figure 3. Tile plot of annual median *E. coli* values for sites in the Waimea Water Management Area. Colours indicate attribute states A (green), B (yellow), C (orange) and D (red). Annual median values were calculated for sites with three or more records in a given year.

Filamentous Green Algae Cover & Periphyton Score

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

In line with this high coverage these sites had relatively low periphyton scores[1]. The Redwood Vly and Borck Creek sites, in particular, had a high proportion of periphyton scores in category D, indicating poor water quality at this site. From about December-April Borck Creek is spring-fed and so does not get flushing flows. This coupled with relatively high nutrient concentrations and limited shading of the stream promotes filamentous green algae growth.

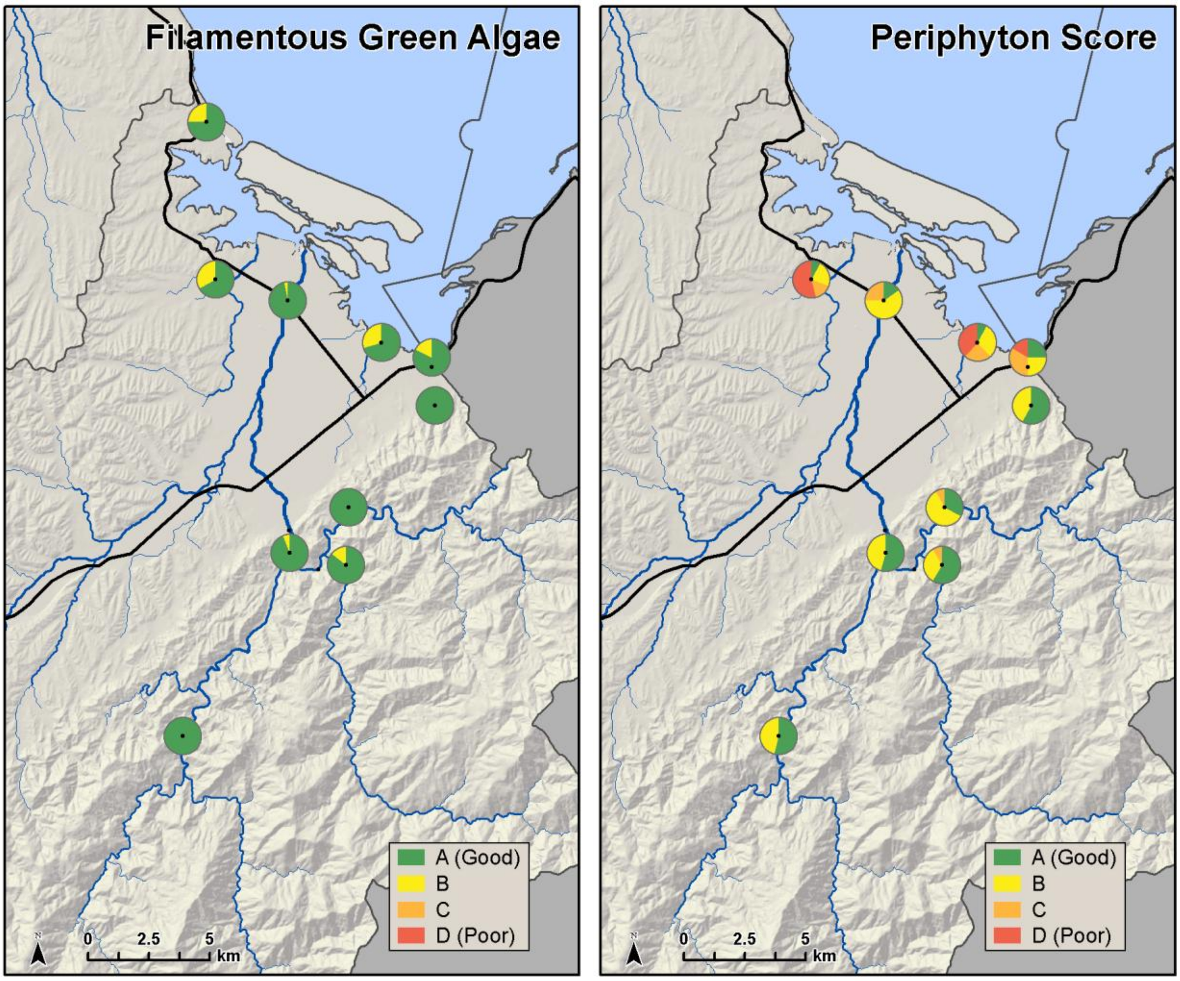


Figure 4. Coverage of filamentous green algae greater than 2cm in length (left) and periphyton community score (right) for sites in the Waimea Water Management Area. Pie charts show the proportion of estimates in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

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

Nutrients

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

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

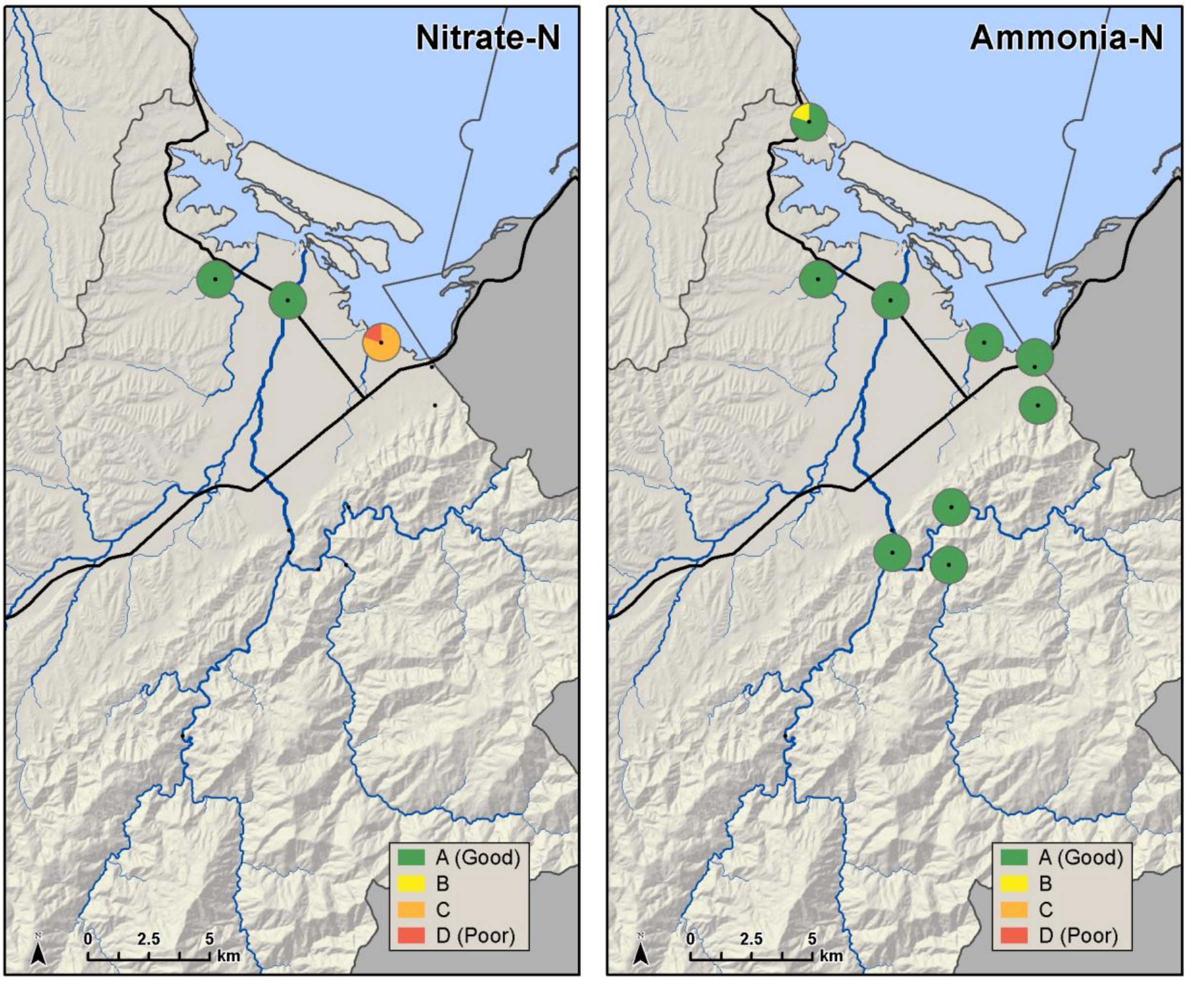


Figure 5. Nitrate (left) and ammonia (right) concentrations for sites in the Waimea Water Management Area. Pie charts show the proportion of annual medians in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

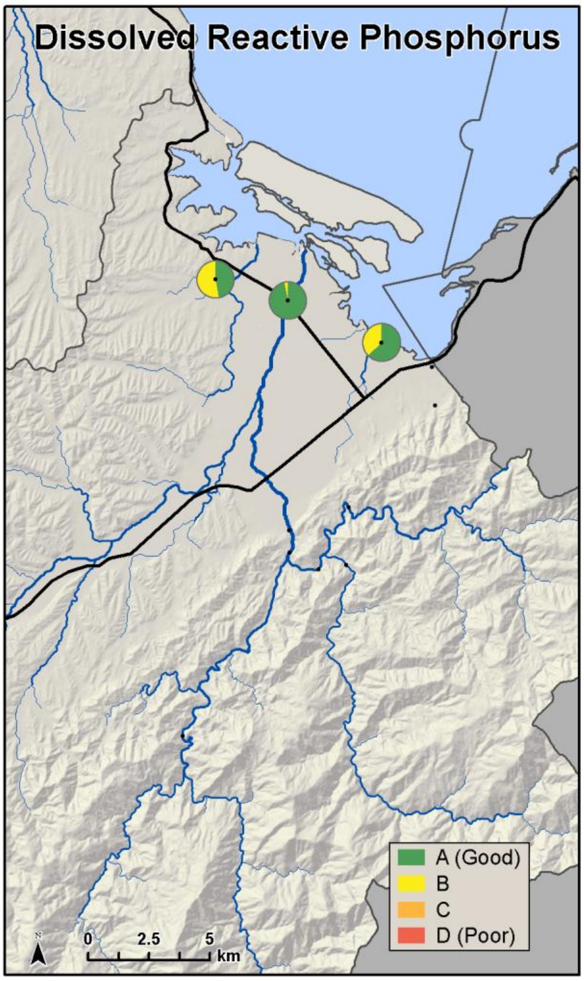


Figure 6. Dissolved reactive phosphorus (right) concentrations for sites in the Waimea Water Management Area. Pie charts show the proportion of records in each attribute state (A to D) for sites with 10 or more observations (2010 to 2014 data).

Resuspendable Sediment

Volumetric SBSV data were available for three sites (Figure 7). Despite the large variation in mean volumetric SBSV at Reservoir Ck at Marlborough Cr, there was evidence of an increase in this measure between 2012 and 2015 maybe as a result of the reconstruction of the Reservoir dam in 2013 or sediment from forestry activity still making its way down the stream. The 2015 result for this site was one of the highest in the district (the mean SBSV across all 27 sites in 2015 was 70 L/m^3, SD = 78).

The worst performing site, in terms of resuspendable sediment scores (assessed on a semi-quantitative scale from 1-5), was **Seaton Vly at Stafford Dr**. At this site, about 90% of scores were four or above. In much of the lower section of this stream, for 1km upstream of Stafford Dr, there is fine sediment over a cobble base and upstream of that the bed is dominated by cobbles with very little fine sediment. Downstream of Stafford Dr the fine sediment is over a sand base. The only other site with a score in band D was Reservoir Ck at Marlborough Cr (Figure 8).

Figure 7. Mean volumetric suspendable benthic sediment volume (SBSV) from 2012 to 2015 (sampled during summer). The error bars show 95% confidence intervals.

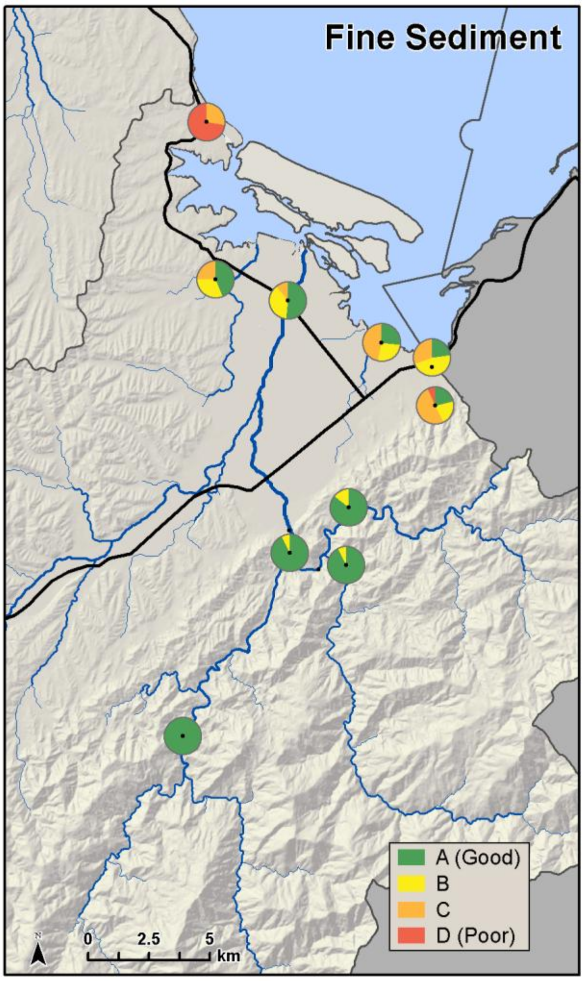


Figure 8. Proportion of fine sediment (resuspendable solids) scores in each attribute state (A to D) for sites in the Waimea Water Management Area.

Macroinvertebrate Community

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

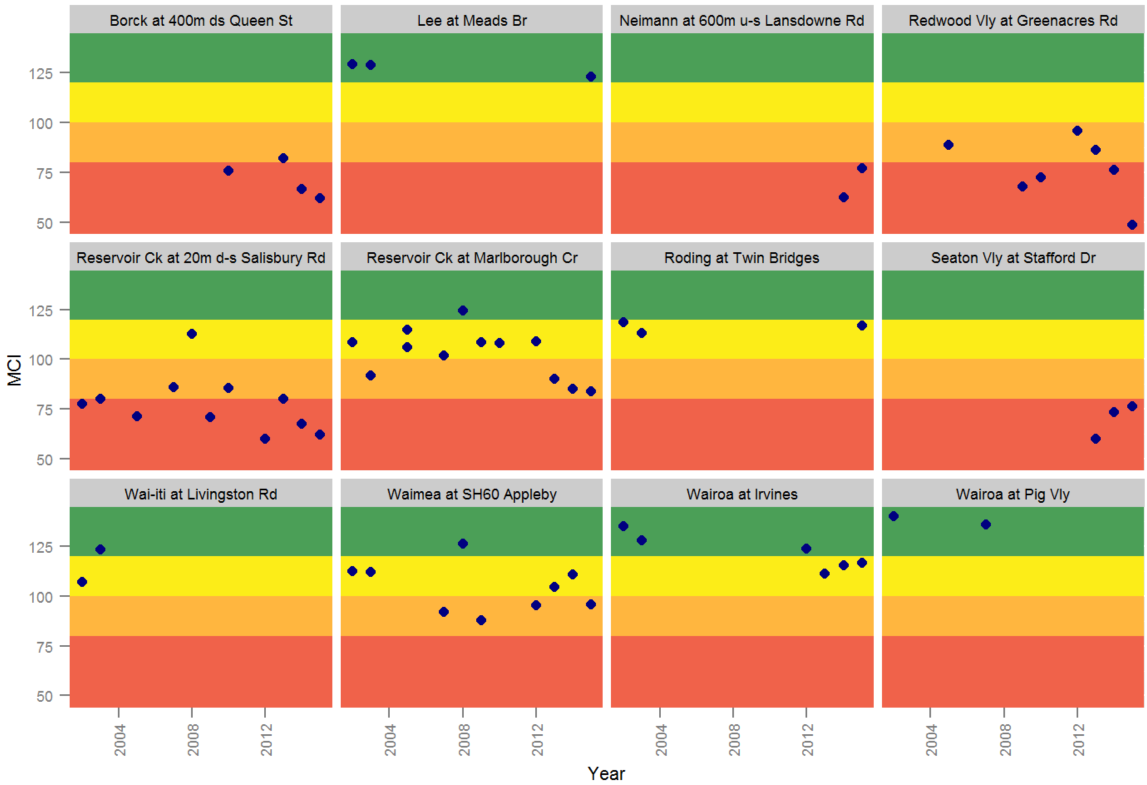


Figure 9. Macroinvertebrate community index (MCI) scores between 2001 and March 2015 for sites in the Waimea Water Management Area (larger blue dots). The background colours indicate these attribute states: excellent (green), good (yellow), fair (orange) and poor (red).

Differences between Paired Sites

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

Wairoa at Irvines (upstream) was paired with Waimea at SH60 Appleby (downstream). The ***E. coli*** results, over the five-year reporting period, were similar (mean difference = -1.7 *E.coli*/100 mL, Figure 10). The macroinvertebrate community was in a slightly poorer condition at the downstream site (mean difference = -15 MCI units).

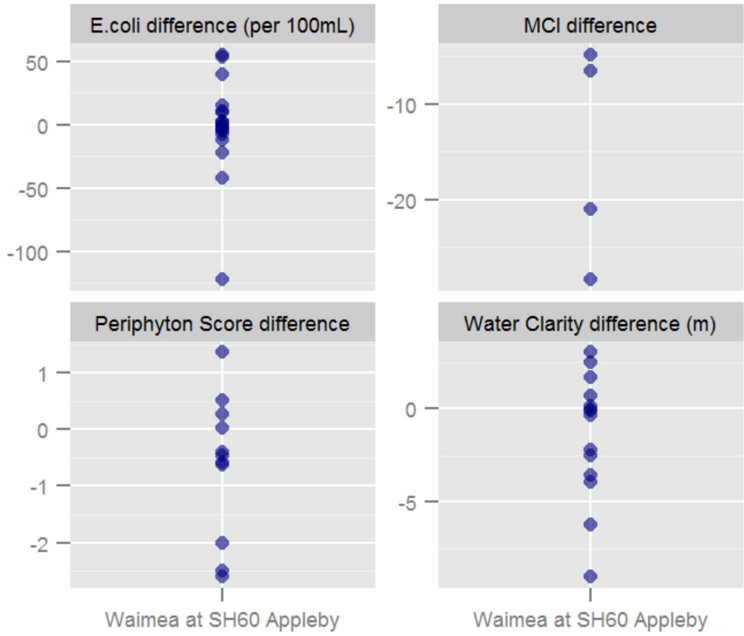


Figure 10. Difference between Wairoa at Irvines (upstream) and Waimea at SH60 Appleby (downstream) for water quality data collected at both sites on the same day. A positive difference means the downstream site had a higher value than the upstream site.

Trends in the Waimea WMA

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

Table 2. Water quality trend results for sites in the Waimea Water Management Area over the 10-year period 2005 to 2014 (highlighted in blue) and over the full record (15 to 26 years depending on the site). Seasonal Kendall trend tests were used for *E. coli* concentrations, water clarity measurements and nutrient concentrations (Ammonia-N, Nitrate-N and DRP). The trends shown are significant ($p < 0.05$), meaningful (RSKSE > 1% per year) and the change in value between the start and end of the trend line is greater than the detection limit for the attribute (refer to the Methods sections for the detection limits). Statistics are shown in the Appendices.

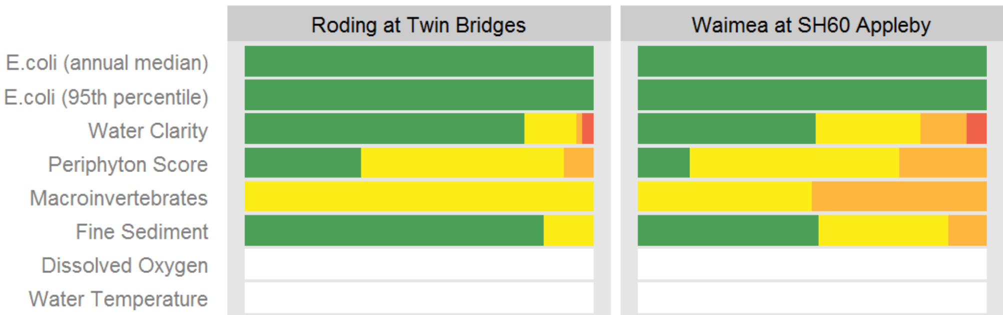
Site name	Attribute	Effect ☺ ☹	N obs	N years
Reservoir Ck at 20 m d-s Salisbury Rd	Ammonia-N	☺	56	15
Reservoir Ck at 20 m d-s Salisbury Rd	*E. coli*	☹	40	10
Reservoir Ck at Marlborough Cr	Ammonia-N	☺	38	10
Reservoir Ck at Marlborough Cr	Water Clarity	☺	36	10
Waimea at SH60 Appleby	DRP	☺	51	10
Waimea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

Waimea-Wairoa-Lee-Roding Catchment

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

Wairoa Rv upstream Pig Valley (October 2006)

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



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

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

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

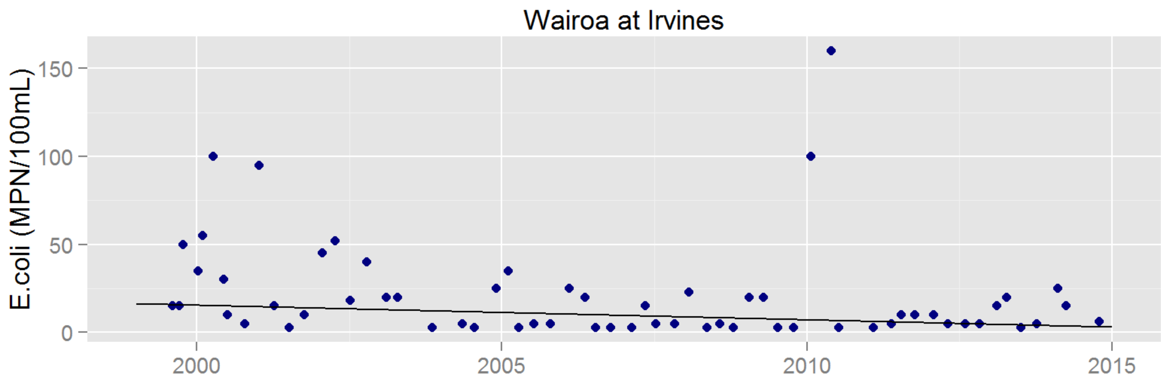


Figure 11. Wairoa at Irvines *E. coli* data with 16-year trend line (p = 0.0032, RSKSE = -8.3% per year). No significant meaningful trend was detected over the most recent 10 years of the record.

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

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

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

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

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

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

Based on the ratios of nitrogen to phosphorus in the spring-fed streams (Figure 12), it is likely that algal growth in these systems is limited by phosphorus rather than nitrogen (i.e. N:P ratios >15), and therefore increases in nitrogen concentrations are unlikely to result in increased growth or biomass of nuisance algae within the spring-fed streams. Nevertheless, it can be difficult to predict if one particular nutrient is limiting.

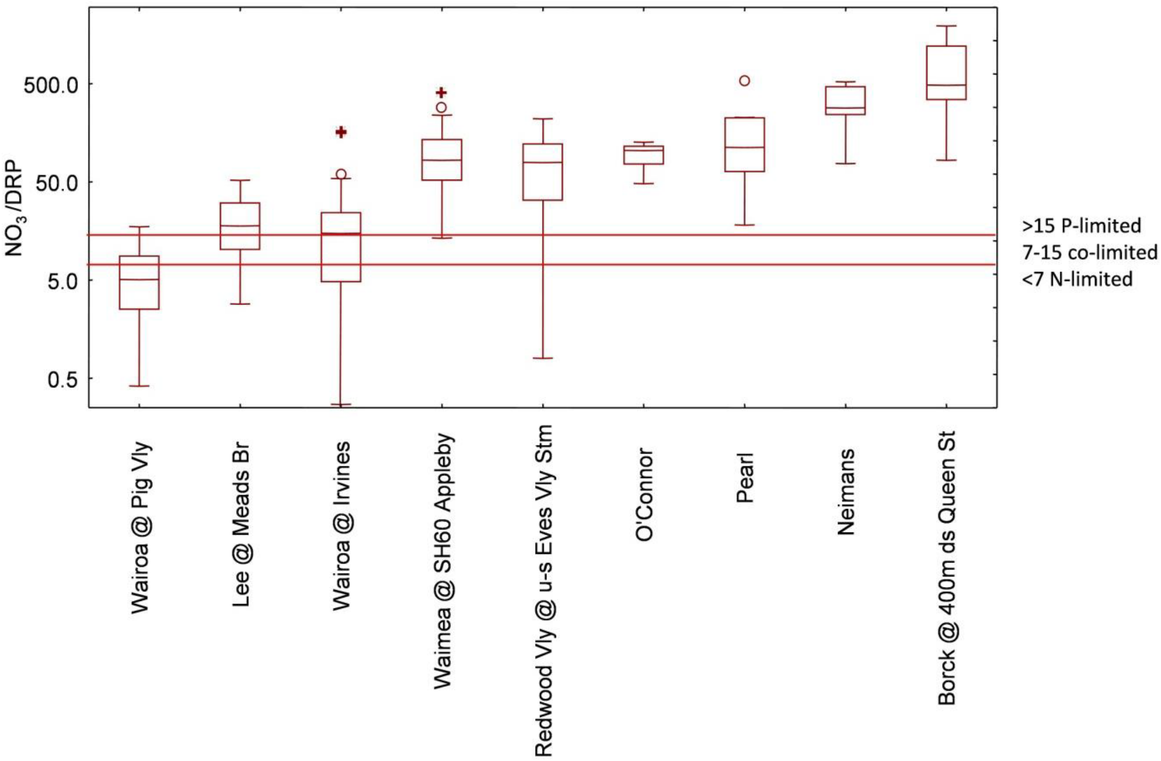


Figure 12. Patterns in the NO3/DRP ratio for sites around the Waimea Catchment. Algal growth at sites with ratios greater than 15 is likely to be phosphorus limited, while growth at sites with ratios less than 7 is likely to be nitrogen limited. Data are primarily from TDC state of the environment monitoring (1999–2012) and in the case of O'Connor, Pearl, Neimans and Borck from Gillespie et al. (2001).

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

* Estimate from WRENZ 2013. NA = not available

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

Wai-iti River

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

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

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

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

Small coastal streams draining to Waimea Estuary

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

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

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

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

While a lot of the source of this sediment within the estuary is very likely to be from historic practice on horticulture land, the current load is unknown. Projects are under way to determine this load. A high rainfall event in December 2011 (281 mm in 48 hours[2]) brought large amounts of sediment down waterways off the Barnicoat Range. Another very high rainfall event was experienced along the Barnicoat Range in April 2013 with rates of 100 mm/hour recorded at Roding at Caretakers.

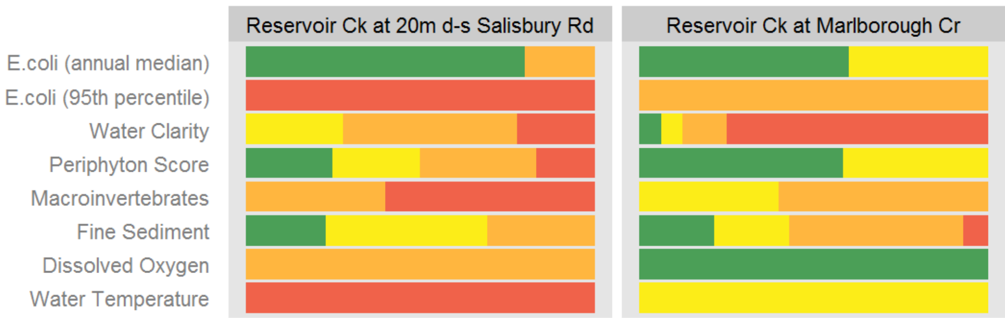
Gravel and debris is collected in in-stream traps and ponds in most urban waterways in Richmond-Nelson. This starves the bed supply downstream and leads to increased erosion and habitat degradation. There is also an adverse effect on the estuary as this gravel is important substrate for many saltmarsh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

[2] Average December rainfall is 85 mm.

Reservoir Creek, Richmond

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

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



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

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

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

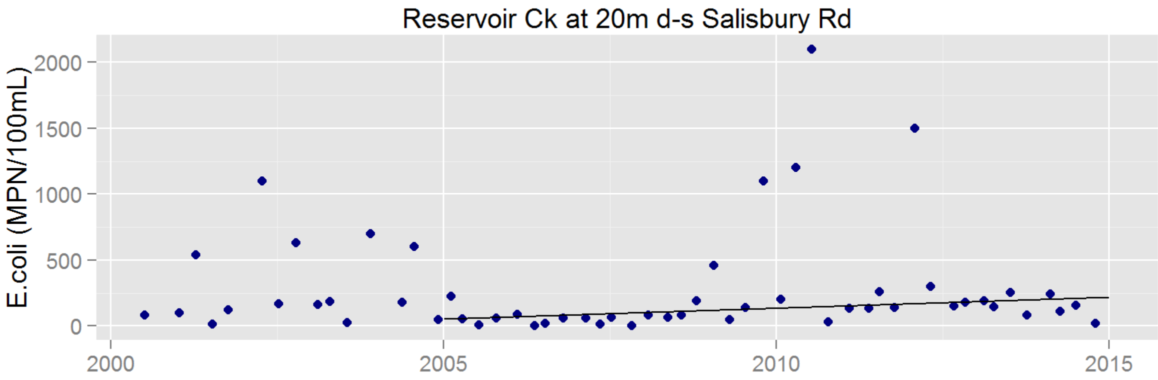


Figure 13. Reservoir Ck at 20 m d-s Salisbury Rd *E. coli* data with 10-year trend line (p = 0.0055, RSKSE = 12.2% per year). No significant meaningful trend was detected over the full record (15 years).

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

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

Reservoir Creek at the Reservoir Spillway (Nov 2014)

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

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

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

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

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

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

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

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

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

* Estimate from WRENZ 2013. NA = not available

Jimmy-Lee Creek

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

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

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

Jimmy-Lee Creek upstream Washbourne Dr (February 2014)

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

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

Algal Scum on Jimmy Lee Creek, 27 January 2005

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

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

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

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

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

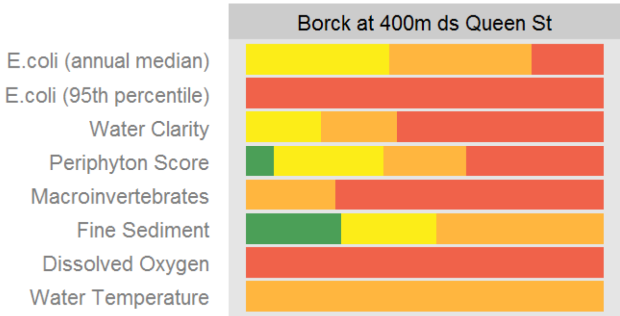

Jimmy-Lee Ck Left: at 35 Beach Rd (December 2009) Right: Upstream of Hill St (December 2009).

Borck Creek, Richmond

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

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

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



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

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

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

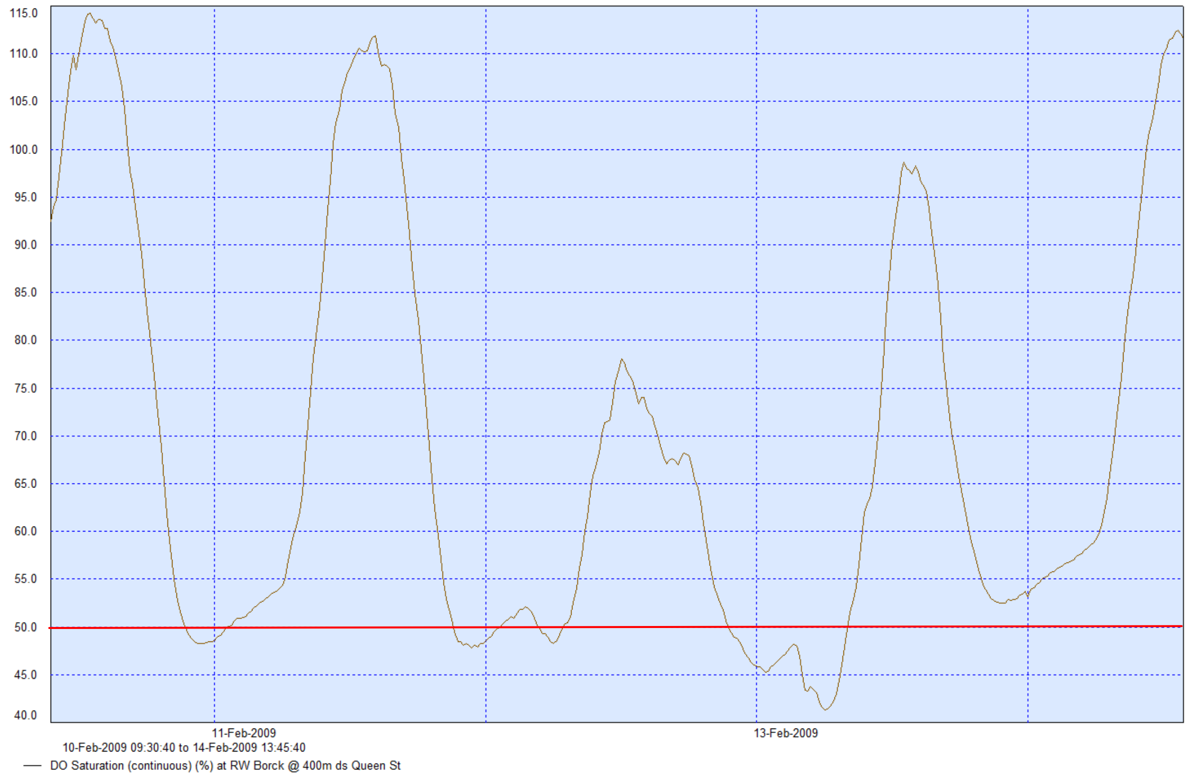


Figure 14. Dissolved oxygen percent saturation at Borck Creek at 400 m downstream Lower Queen St (10-4 February, 2009). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

The **nitrate-N** concentrations are consistent with that in groundwater from the Hope lower and upper confined aquifers so it is important that discharges to ground are controlled. A truck wash operation that discharged animal effluent to a soak pit was removed in 2011 after which time the average nitrate-N concentrations fell (7.8 g/m^3 from 2009-11) by about 40% but have since appear increased again (Figure 15).

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

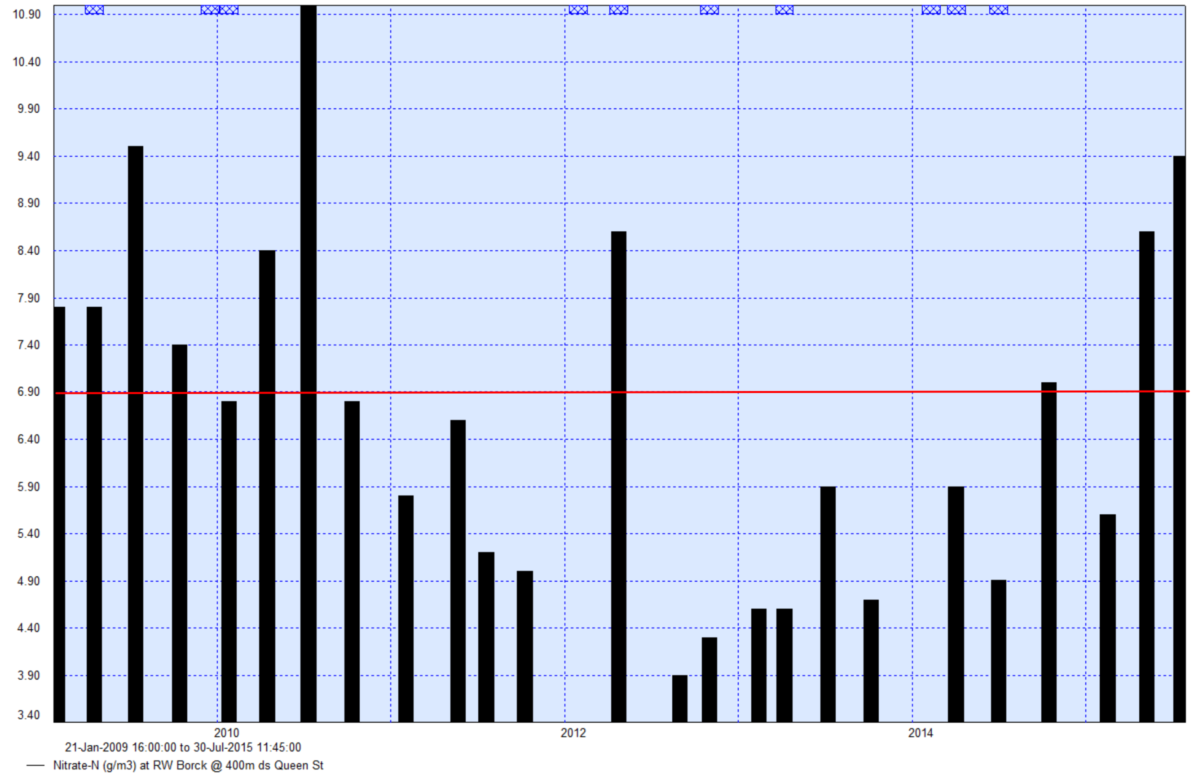


Figure 15 Nitrate-N concentrations in Borck Creek 400 m downstream Lower Queen St (2009-2015). The national bottom line is shown by the red line.

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

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

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

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

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

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

Catchment Statistics	Borck Creek 400 m d-s Lower Queen St
River Environment Class	Warm Dry Alluvial Spring-fed Pasture
Catchment area (km^2)	15
Predominant land use upstream	Pasture and horticulture 75% Urban 15%, Exotic Forestry 10%
Mean annual rainfall (mm)*	1,086*
Mean annual flow (l/sec)*	321*
Lowest recorded flow (l/sec)	3 (2010/04)
Water quality record	Apr 2013-present

* Estimate from WRENZ 2013. NA = not available

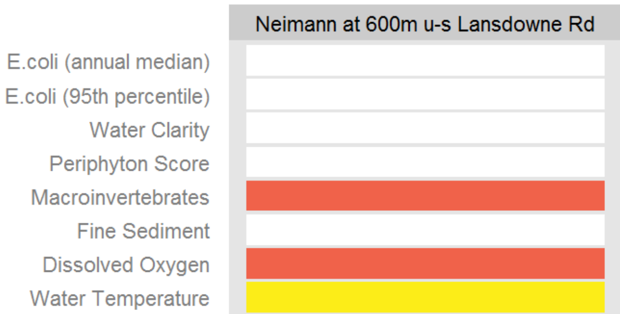
Neimann Creek, Waimea Plains

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

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

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

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



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

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

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

Daily minimum dissolved oxygen levels are very low (around 20% saturation with maxima over 150%, based on continuous sampling in March 2014) (Figure 16). This high diurnal fluctuation is most likely due to the very high cover of aquatic plants in the stream upstream of the sampling site (in summer they can cover 70-80% of the channel).

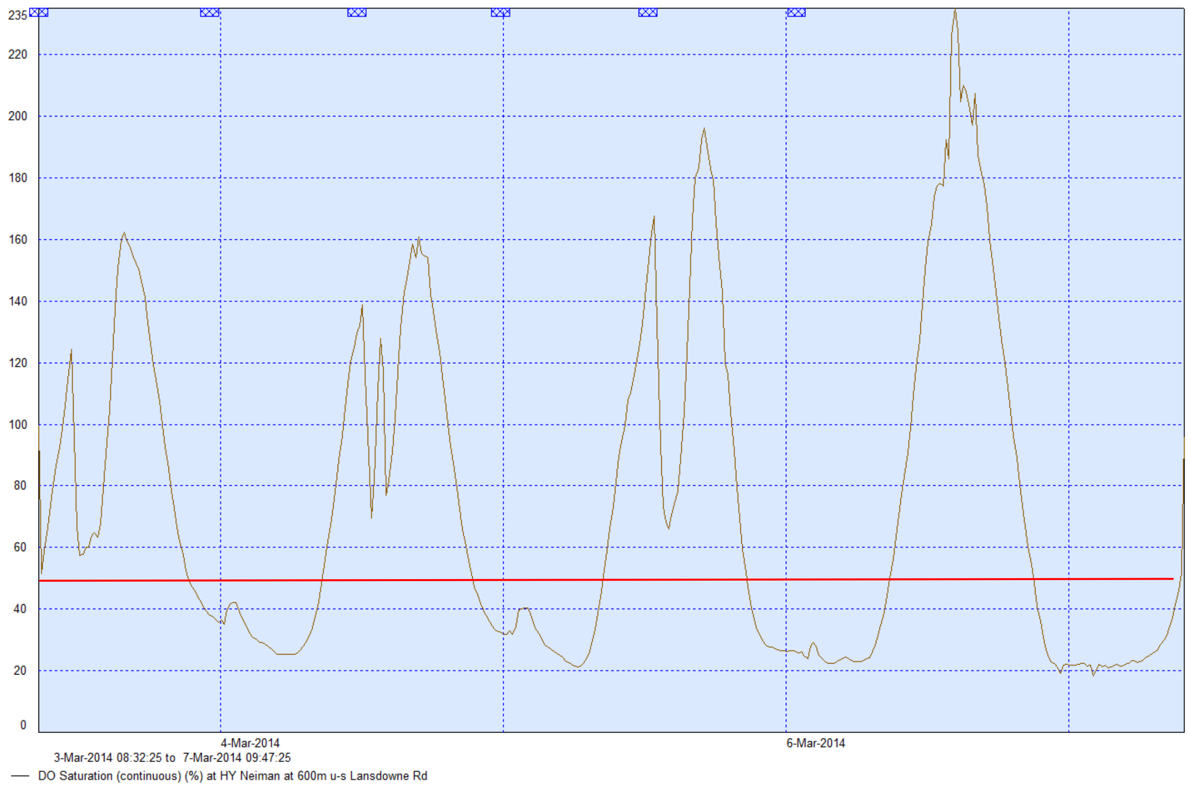


Figure 16 Dissolved oxygen percent saturation at Neimann Creek at 400 m upstream Landsdowne Rd (3-7 March, 2014). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

Tidewater was found to influence the creek at the site 600 m upstream of Landsdowne Rd, as shown by the peaks in the conductivity plot (Figure 17). This tidewater temporarily lowered dissolved oxygen levels, hence the double peaks on 3, 4 and 5 March 2014. Without tidal influence this effect was not apparent i.e. on 6 March, 2014.

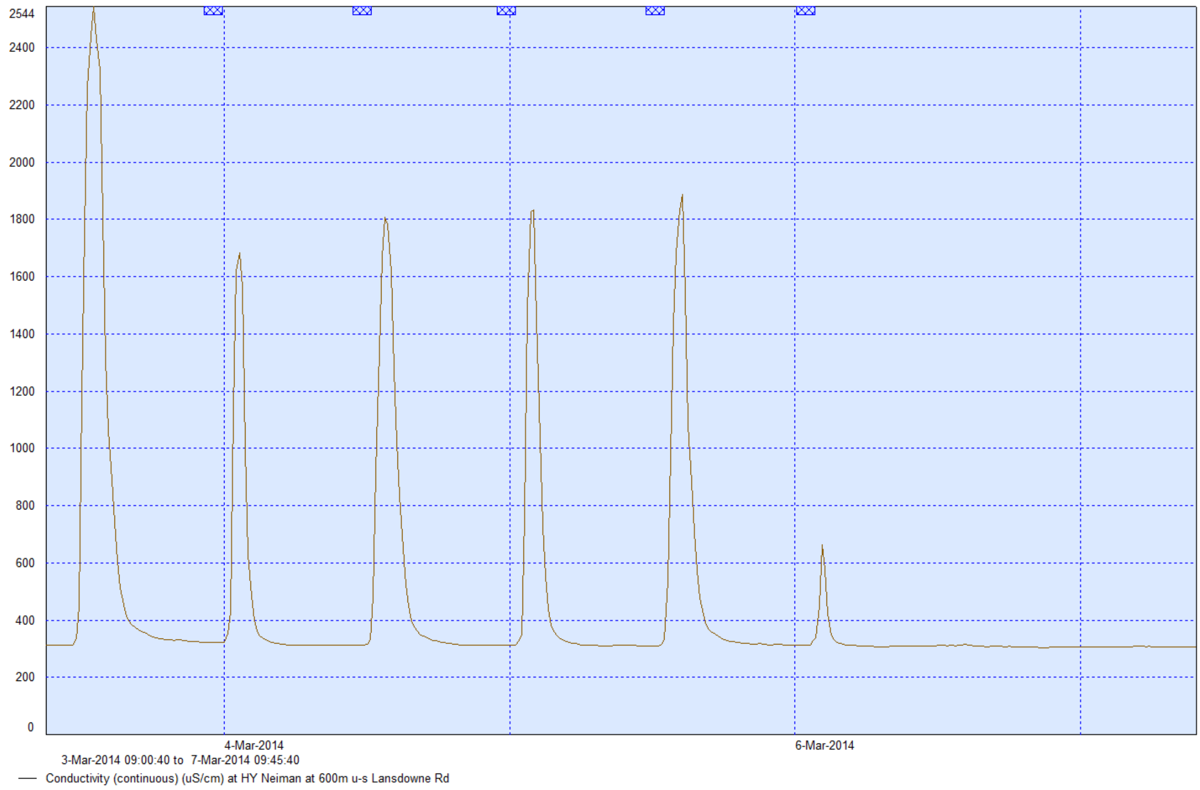


Figure 17 Conductivity at Neimann Creek at 400 m upstream Landsdowne Rd (3-7 March, 2014)

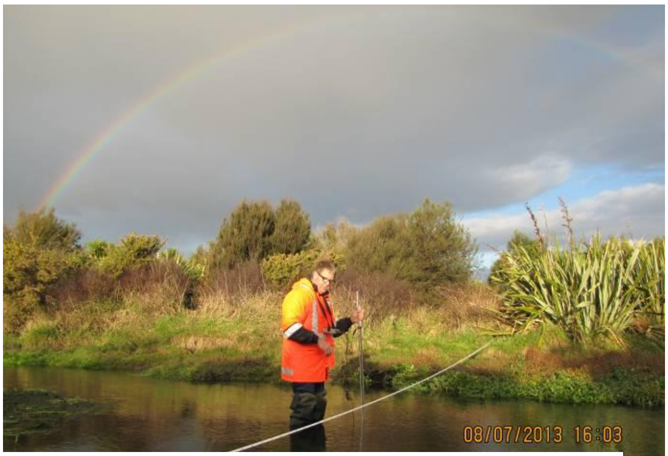
Stream temperatures were satisfactory (midpoint of daily mean and daily maxima: 20°C).

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

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

* Estimate from WRENZ 2013. NA = not available

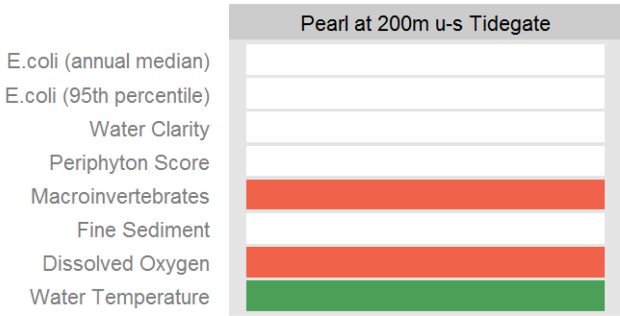
Pearl Creek, Waimea Plains



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

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

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



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

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

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

Dissolved oxygen levels were low in summer (daily minima less than 20%) (Figure 18). Like Neimann Creek, there appears to be an influence of tidal water backing up the freshwater flow and causing temporary reduction in dissolved oxygen (see plot below).

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

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

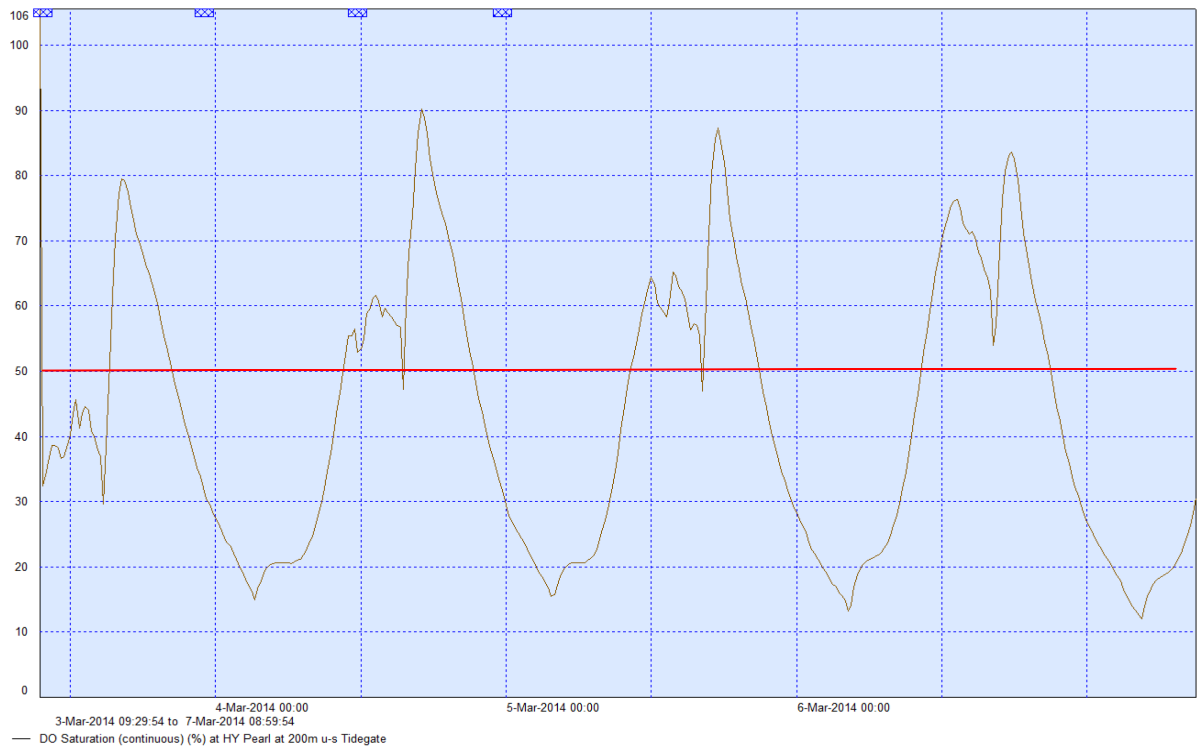


Figure 18 Dissolved oxygen at Pearl Creek at 200 m upstream tidegate (3-7 March, 2014). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

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

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

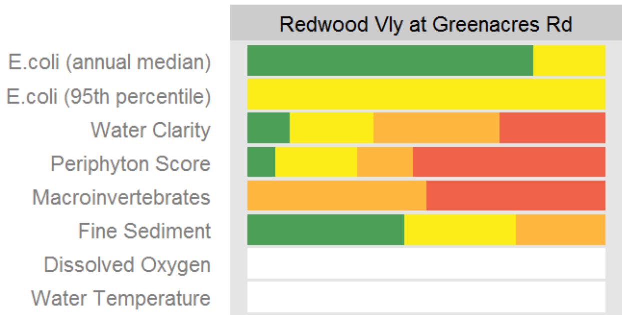
* Estimate from WRENZ 2013. NA = not available

Redwood Valley Stream, Waimea Plains

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

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

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



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

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

In May 2015 sampling further upstream in the catchment showed very poor macroinvertebrate condition in the northern tributary downstream of Redwood Valley Lane (MCI 60, EPT 0%, # taxa 8) (see map of sites on Figure 19). A sewage-type odour was evident in this tributary all the way down to the confluence of the main stem upstream of the Moutere Highway. The macroinvertebrate condition in the southern tributary flowing across Redwood Valley Lane was better, but still poor (MCI 83 & 88, EPT 33% & 26%, # taxa 15 & 23). This may because the flow in the northern tributary ceases for longer or discharges from industry or dams upstream. At a site on the northern tributary 360 m upstream of Redwood Valley Lane macroinvertebrate condition was higher (MCI 75, EPT 0%, # taxa 12). This suggests that there is an effect due to discharges from industry or other sources within 100 m upstream of Redwood Valley Lane. Discharges from vehicles crossing through the water at the ford on this road on the southern tributary of Redwood Valley Lane do not seem to be adversely affecting the macroinvertebrate community. This could be due to the flow over the concrete ford being very shallow most of the time or non-existent for several months over summer.

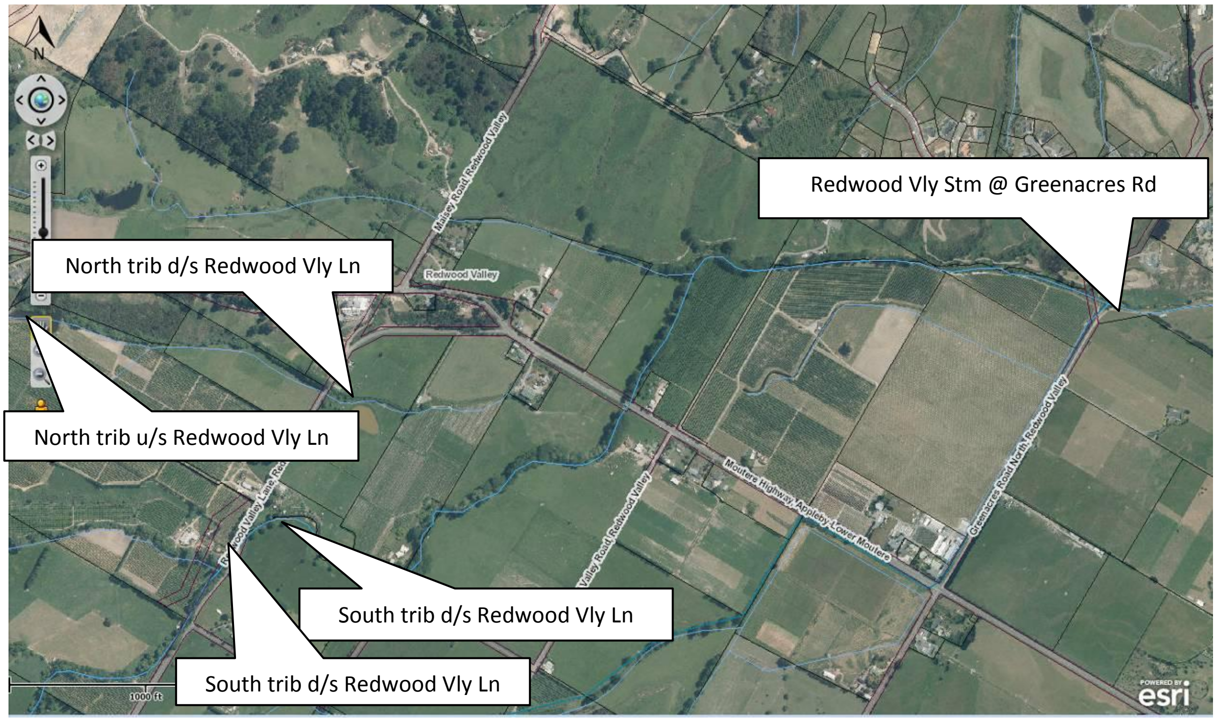


Figure 19 Map of macroinvertebrate sample sites on two upstream tributaries of Redwood Valley Stream in May 2015; Upstream and downstream of Redwood Valley Lane on the tributary adjacent to the Redwood Cellars wastewater treatment system; Upstream and downstream of ford on Redwood Valley Lane on the tributary to the south of the Redwood Cellars wastewater treatment system

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

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

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

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

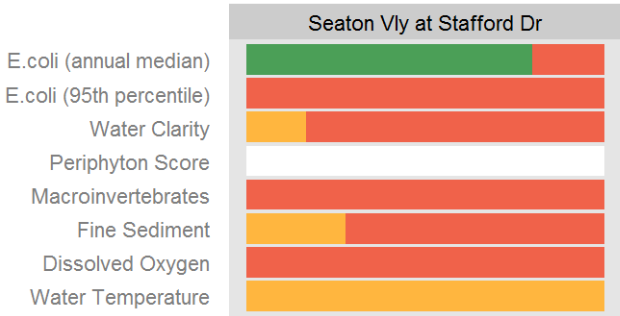
Catchment Statistics	Redwood Valley Stream
River Environment Class	Warm Dry Soft sedimentary Lowland-fed Pasture
Catchment area (km^2)$^+$	16
Predominant land use upstream	Pasture 80% Rural residential 8% Horticulture 6% Exotic forest 3% Indigenous forest 3%
Mean annual rainfall (mm)*	140*
Mean annual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

* Estimate from WRENZ 2013. NA = not available

Seaton Valley Stream, near Mapua

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

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



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

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

Concentrations of faecal indicator bacteria in this stream declined over 10 years (median from 2010-2015: 66 *E.coli*/100 ml down from 220 *E.coli*/100 ml in 2006-2009 and with no exceedance of stock drinking water guidelines since May 2011 (Figure 20).

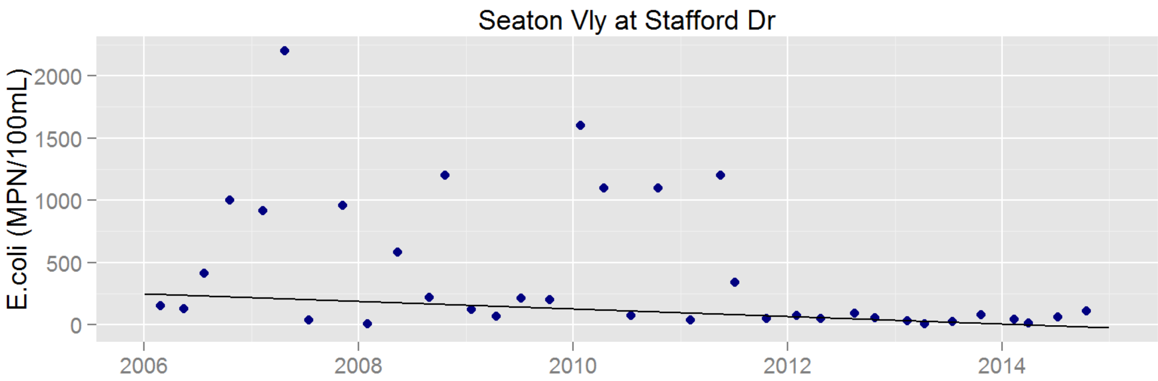


Figure 20. Seaton Vly at Stafford Dr *E. coli* data with 9-year trend line (p = 0.006, RSKSE = -26.5% per year).

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

Dissolved oxygen levels are close to zero at the Stafford Drive site in summer, whereas they range from 60-70% saturation 1.5km upstream of Stafford Drive (Figure 21). While it may look as if there was instrument error due to drift in the dissolved oxygen data this was considered unlikely as a rain event on 11 February 2009 shows dissolved oxygen quickly recover to have daily minima consistently just above 8 mg/l. Methane bubbles and a waxy rainbow sheen on the water surface is often evident in this area, as well as a strong sulphide odour when the sediments are disturbed. Note the very limited daily fluctuation at the upstream site, probably due to very few aquatic plants in the creek upstream (Figure 22).



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

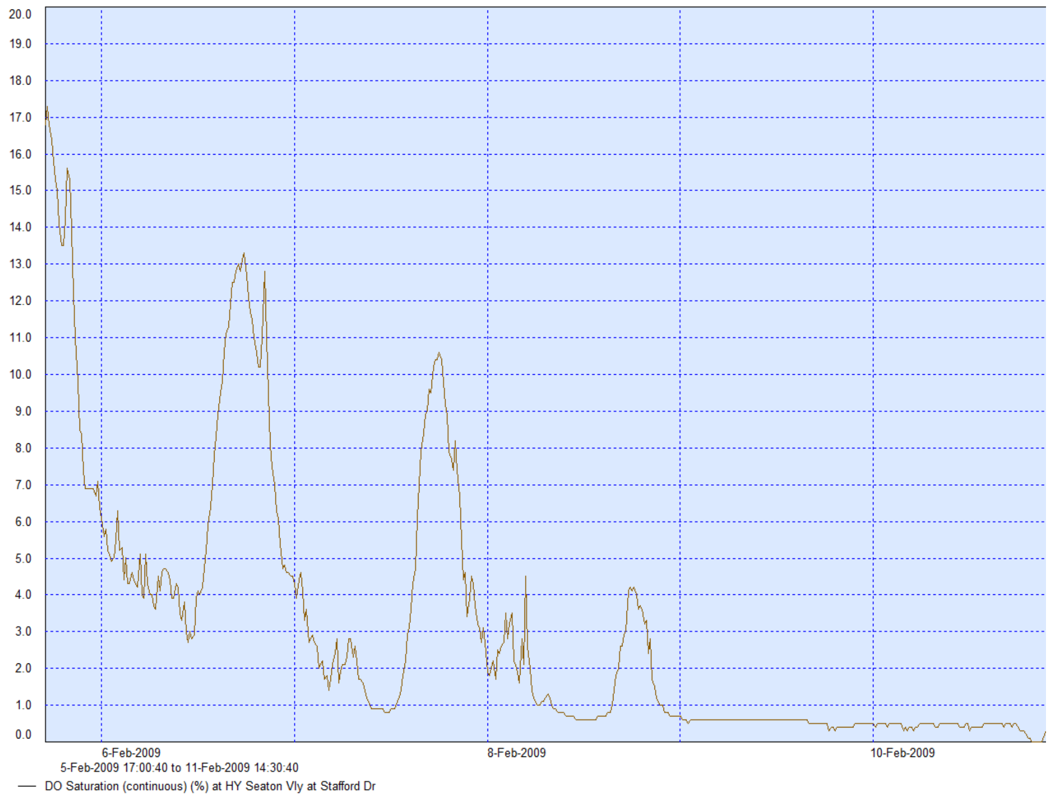


Figure 21. Dissolved oxygen saturation (%) at Seaton Valley Stream at Stafford Dr, February 2009. The proposed national bottom line is 5g/m3 (which usually equates to about 50% saturation).

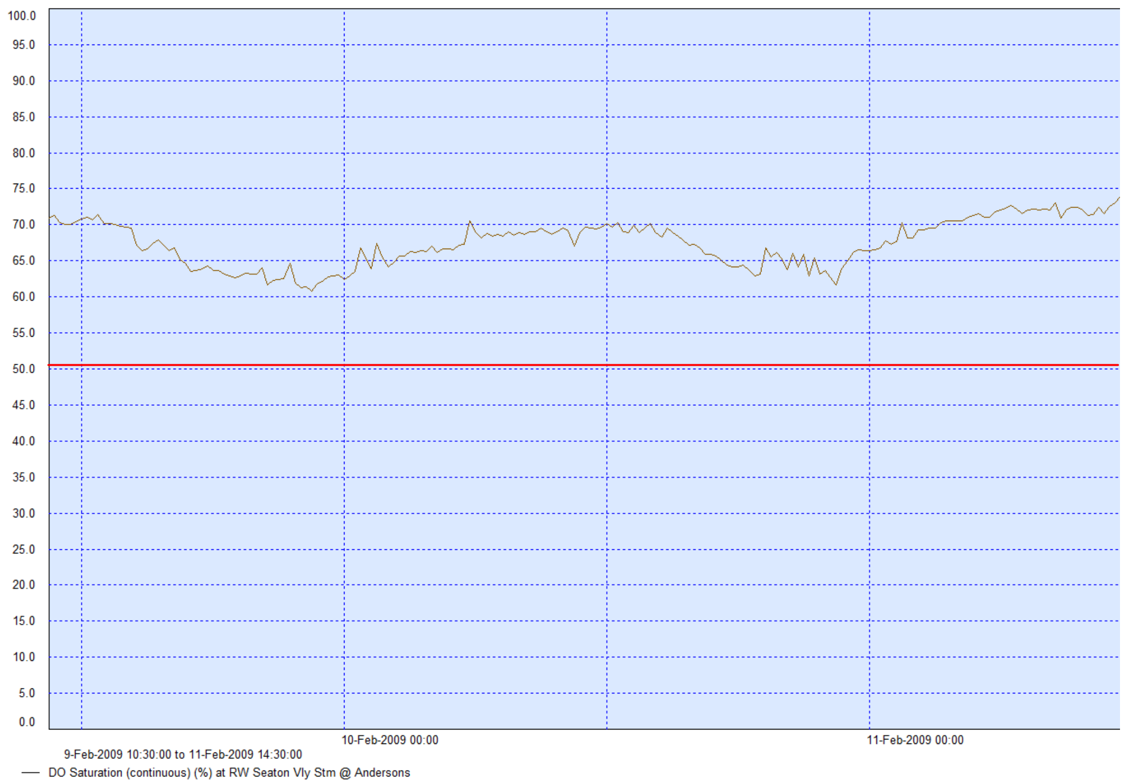


Figure 22. Dissolved oxygen saturation (%) at Seaton Valley Stream at 1.5km upstream Stafford Dr, February 2009 (simultaneous deployment with the Stafford Rd site). The national proposed bottom line for the daily 1-day minimum is shown by the red line.

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

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

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

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

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

* Estimate from WRENZ 2013. NA = not available