Freshwater Physicochemical Programme
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Executive summary

Section 35 of the Resource Management Act requires local authorities to undertake monitoring of the region's environment, including land, air, and fresh and marine water quality. The freshwater physicochemical component of the State of Environment Monitoring (SEM) programme for Taranaki was initiated by the Taranaki Regional Council in the 1995-96 monitoring year and subsequently has been continued in each year. Data from this programme was used as the basis for the first five-year SEM report published in 2003, for trending purposes over the ten year period, 1995 to 2005 and the thirteen year period 1995 to 2008 as presented in the third SEM report published in 2009, and the nineteen year period 1995-2014 as presented in the fourth SEM report (TRC, 2015a)

In the year under review, surveys continued to be performed regularly in the second week of every month from July 2014 to June 2015, under a narrower range of flow conditions than typical, ranging through some moderate freshes, to very low late summer-autumn flows. This year was characterised by slightly higher median flows sampled by the programme in most rivers and streams. Each sampling run measured up to 22 physical and chemical water quality parameters at eleven sites representing seven selected ring plain catchments and one eastern hill-country catchment.

The twelve months of water quality data are presented for each of the sites together with a statistical summary for both the year and accumulated data to date. Results are discussed on a site-by-site basis, and more briefly, on a comparative parameters' basis. Data from the three Taranaki sites included in the NIWA national network monitoring programme are also presented and discussed.

Variability in site water quality occurred in response to flow conditions and with season. Generally there was some spatial deterioration in most aspects of water quality in a downstream direction. This was illustrated by poorer water clarity (increased turbidity), increased bacteriological counts and nutrient levels, and wider water temperature and pH ranges at downstream sites. This was usually coincident with increases in substrate algal cover during summer-autumn low flow conditions, a feature of Taranaki ring plain streams (and surface waters elsewhere in New Zealand); a response to elevated nutrient runoff, and warmer more open conditions in lower reaches of developed and farmland catchments. Higher turbidity and suspended solids levels (and therefore poorer visual clarity) characterised the eastern hill country Mangaehu and Waitara Rivers site in these rivers' lower reaches.

Over the 2014-2015 monitoring year, in general terms, flows at times of sampling were higher than typical; this in turn meant water quality was compromised, and in turn meant that the rolling seven-year trend analysis data was not as strongly positive as it has been at other times over the past few years. On a parameter by parameter review, water quality was comparatively similar to slightly poorer in clarity, with some deterioration in median faecal coliform and enterococci bacteria numbers at a majority of sites. Narrower temperature ranges, but similar median water temperatures, were measured in the 2014-2015 period compared with ranges and medians measured during the first nineteen years of the SEM programme. Median dissolved reactive phosphorus levels were elevated at five sites and total phosphorus levels were elevated at three sites. The site in the lower Waingongoro River downstream of the recent diversion of the Eltham WWTP discharge (by pipeline) out of the catchment showed minimal significant improvement in the recent year, coincident with a deterioration in three median nutrient concentrations and median faecal coliform bacteria at the upstream Eltham Road site. Median nitrate, total nitrogen and total phosphorus species' levels were lower at two sites, while median ammonia nitrogen levels were higher at six sites and lower at one site.

The report also provides an assessment of each site's statistical water quality in terms of appropriate guidelines and standards for various usages based upon a summary of the record for the complete 1995-2015 period.

For the first time, results are also compared with the compulsory national water quality criteria set out in the National Objectives Framework (NOF) that is part of the National Policy Statement for Freshwater Management 2014 (NPS-FW). The NOF assigns grades ('attribute states') for indicators ('attributes'), from A (best) to D (worst), with a National Bottom Line of acceptability being a C state.

The Resource Management Act requires that particular regard be given to the *'maintenance and enhancement of the quality of the environment'*. Therefore a key determinant for the Council is to identify where trends in water quality show no change and/or improvement, or alternatively show decline. With the availability of a suitable period (minimum of ten years) of robust data and access to appropriate statistical software, temporal trend analyses were performed for state of the environment reporting purposes and reported elsewhere during 2006. Regular updates of these temporal trends subsequently have been prepared at appropriate intervals and reported separately, and data for the period 1995 to 2014 are summarised and presented for all eleven sites briefly in the current Annual Report.

Also, for the first time, trends over the most recent period (the last seven years) have been incorporated into this report. Previously they were calculated and presented separately; for the sake of convenience and completeness they have now been included herein. This data helps identify and evaluate the current state of flux in water quality, rather than those trends that are more historical in nature.

Long term (20-year) physicochemical trends have shown some significant deterioration in some aspects of water quality (particularly phosphorus) in many of the middle and lower catchments (e.g. the Mangaoraka Stream at Corbett Road, Punehu Stream at SH 45, and Waiwhakaiho River at SH3). On the other hand, there has been a significant long term improvement in total nitrogen at six of the eleven sites monitored, with only one site that is showing deterioration in this measure. Long term trends for faecal coliforms and enterococci bacteria showed statistically significant changes over the 20-year period for both species at two sites, out of eleven (Waiwhakaiho River at SH3 and Mangaoraka Stream at Corbett Road)- that is, over 80% of sites show no trend of deterioration. Significant deteriorations in black disc clarity were recorded at three sites, two of which reflected historical erosion events in the headwaters.

The most improvement in long term water quality has been illustrated in the Waingongoro River at SH 45 with significantly improving trends in DRP, total phosphorus, nitrate, and total nitrogen. This improvement has been coincident with land-irrigation of a major industrial (meatworks) discharge and the diversion of Eltham's WWTP discharge out of the river in recent years. Most long term deterioration in aspects of water quality have been found in the lower reaches of the Mangaoraka Stream where six parameters have significantly deteriorated (both phosphorus species, both bacteriological species, black disc, and BOD_5) and no parameters show significant long term improvement. More recent data for this site shows the deterioration has ceased.

Analysis of recent trends shows a much more encouraging picture than historical trends, although generally poorer water quality in the year under review means that the latest rolling seven-year trend data, while still much more positive than historical trend data, do not show the same wide-spread improvements that have been evident in recent years. The number of sites and measures showing recent improvement in nutrient concentrations match those showing deterioration; other measures (bacteria, organics, aesthetics) show no regional pattern of change in either direction.

This report on the results of the 2014-2015 monitoring period also includes recommendations for the 2015-2016 period and the results of internal and external laboratory quality control exercises, which, with relatively few exceptions, resulted in good inter and intra-laboratory precision.

Recommendations provide for the continuation of this programme together with the inclusion of an additional two sites representative of larger hill country catchments (Waitara and Whenuakura Rivers) due to the new impositions under the NPS-FW for representative monitoring in all Water Management Units.

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1. Introduction

The Resource Management Act 1991 ('the RMA') established new requirements for local authorities to undertake environmental monitoring. Section 35 of the RMA requires local authorities to monitor, among other things, the state of the environment of their region or district, to the extent that is appropriate to enable them to effectively carry out their functions under the Act.

To this effect, the Taranaki Regional Council ('the Council') established a state of the environment monitoring ('SEM') programme for the region. This programme is outlined in the Council's 'State of the Environment Monitoring Procedures Document', which was prepared in 1997. The monitoring programme is based on the significant resource management issues that were identified in the Council's Regional Policy Statement for Taranaki (1994). The relevant issues are presented in Appendix II.

The SEM programme is comprised of a number of individual monitoring activities, many of which are undertaken and managed on an annual basis (from 1 July to 30 June). For these annual monitoring activities, summary reports are produced following the end of each monitoring year. Where possible, individual consent monitoring programmes have been integrated with the SEM programme to save duplication of effort and minimise costs. The purpose of annual SEM reports is to summarise monitoring activity results for the year and provide a brief interpretation of these results.

Annual SEM reports act as 'building blocks' towards the preparation of the regional state of the environment report every five years. The Council's first, or baseline, state of the environment report was prepared in 1996 (TRC, 1996b), summarising the region's progress in improving environmental quality in Taranaki over the past two decades. The second report (for the period 1995-2000) was published in 2003 (TRC, 2003). Data spanning the ten year period 1995 to 2005 have been used in the preparation of a trend report (TRC, 2006). The third State of the Environment report (for the period 1995 to 2007) was published (TRC, 2009a) and included trend reporting and the fourth report (for the 1995 to 2014 period) has recently been published (TRC, 2015a). The provision of appropriate computer software statistical procedures now allows regular reporting on trends in the environmental quality over time, in relation to Council's ongoing monitoring activities, now that there has been an accumulation of a comprehensive dataset of sufficient duration to permit a meaningful analysis of trends (i.e. minimum of 10 years).

This report summarises the results for the sites surveyed in the freshwater physicochemical SEM programme over the 2014-2015 monitoring year, the nineteenth year of the programme. Previous years' results have been presented in the TRC Technical Reports listed in the References section.

A network of nine freshwater sites was established in mid-1995 for physicochemical monitoring on a long-term basis to provide information on trends in the state of Taranaki's regional surface water quality and this network was maintained with the addition (for various purposes) of one site during the 1998-99 period and another site in the 2003-2004 period.

The Taranaki Regional Council's SEM programme also includes a freshwater biological component encompassing the same eleven sites plus forty-six additional sites, which is reported separately (see TRC, 2014a).

The physicochemical programme has been designed to provide a general picture of water quality for eight different catchments in the region affected by a range of different land uses and industries, and recognising cumulative impacts. This monitoring is undertaken in addition to consent compliance monitoring and will enable the Council to report on trends in water quality over time for the Taranaki region. The monitoring programme covers eight of the sixty-nine catchments in the Taranaki region and 39% of the total area of the region (Figures 1 and 2). Given that a number of the largest catchments in the region are included in the network, it provides a relatively representative indication of the state of surface water in the region.

The sites were specifically selected to be representative of major/significant waterways and positioned in the upper, middle, and lower reaches of catchments. Both ringplain and eastern hill country catchments were represented with a mixture of land uses including waterways under industrial discharge pressures.

The existing programme also meshes with the national programme, which has been operated by the National Institute of Water and Atmospheric Research (NIWA) since January 1989. This National Water Quality Network (NWQN) was designed to monitor changes in water quality by sampling physical and chemical parameters monthly at 77 river sites around New Zealand (Smith, et al, 1989). The programme includes three sites in Taranaki (Figure 1); one upper/mid catchment site (Manganui River at State Highway 3, incorporating some farm land area) and two lower catchment sites (Waitara River at Bertrand Road and Waingongoro River at State Highway 45). Data from these sites is presented within this report (sections 4.2.2 and 4.4)

However, it should be noted that as of January 2016 (ie following the year under review), NIWA have withdrawn from water quality sampling and analysis at the Waingongoro River site on SH45, following a rationalisation of their monitoring network nation-wide. NIWA have noted that part of their rationale for ceasing monitoring at this site was that the Council data is seen by them as robust and reliable, and hence NIWA's work could be viewed as unnecessary duplication from the perspective of national water quality reporting. From this Council's perspective, it means the loss of a quality control measure, although a large number of other QA/QC measures remain in place.

The design of the TRC SEM programme was deliberately chosen to follow the design of the NIWA national programme although the actual sampling days in each monthly survey do not coincide for the two programmes. However, the two programmes are complementary and each is designed for robust trend detection purposes using similar methodologies.

Physicochemical water quality monitoring is performed to obtain an understanding of the physical and chemical characteristics of water by means of statistical sampling (Ward & McBride, 1986). It requires repetitive measurements of such characteristics through time. The complex variations of those characteristics in the natural, and more especially the modified environment, makes it difficult to obtain accurate understandings, and therefore the monitoring systems employed must be designed to supply the required information at the necessary sensitivity, accuracy and precision (Ward & McBride, 1986).

2. Sites

The Council has chosen sites which are within the existing hydrological flow monitoring network where possible. Hydrological information is vital to the interpretation of physicochemical data. Generally, sites have been positioned strategically within representative catchments in the region, with industrial and/or intensive farming land uses, and including both the higher and lower quality waterways of the region (Figures 1 and 2).

The sites selected and maintained for the monitoring of physicochemical water quality by Taranaki Regional Council are listed in Table 1, with comments relating to selection criteria following the table.

Table 1 Sample sites for TRC network programme

Stream	Location	Site code
Maketawa Stream	at Tarata Road	MKW000300
Mangaoraka Stream	at Corbett Road	MRK000420
Waiwhakaiho River	at SH3	WKH000500
Stony River	at Mangatete Road	STY000300
Punehu Stream	at Wiremu Road	PNH000200
Punehu Stream	at SH45	PNH000900
Waingongoro River	at Eltham Road	WGG000500
Waingongoro River	at SH45	WGG000900
Patea River	at Barclay Road	PAT000200
Patea River	at Skinner Road	PAT000360
Mangaehu River	at Raupuha Road	MGH000950

All sites are described in detail and referenced with location maps, photographs, GPS and map references on the internal electronic TRC site index card system which is integrated into the existing LABSYS water quality computer and Taradise GIS databases.

A brief description of all sites in the Taranaki Regional Council and NIWA programmes follows.

Site Maketawa Stream at Tarata Road

The site in the lower reaches of a developed farmland catchment is representative of a sub-catchment of the Manganui and Waitara Rivers catchments, with valued trout and native fish habitat. The stream drains into the Manganui River below the principal abstractions for the Motukawa HEP scheme. This site requires flow gauging on each sampling occasion for rating purposes.

Site Mangaoraka Stream at Corbett Road

This site is representative of a northern Taranaki ringplain stream, (but with its source outside the National Park), draining an agricultural catchment. The site is also a hydrological recording station. It is located toward the lower catchment and is the principal tributary of the lower Waiongana Stream. The Mangaoraka Stream is a trout fishery of local importance.

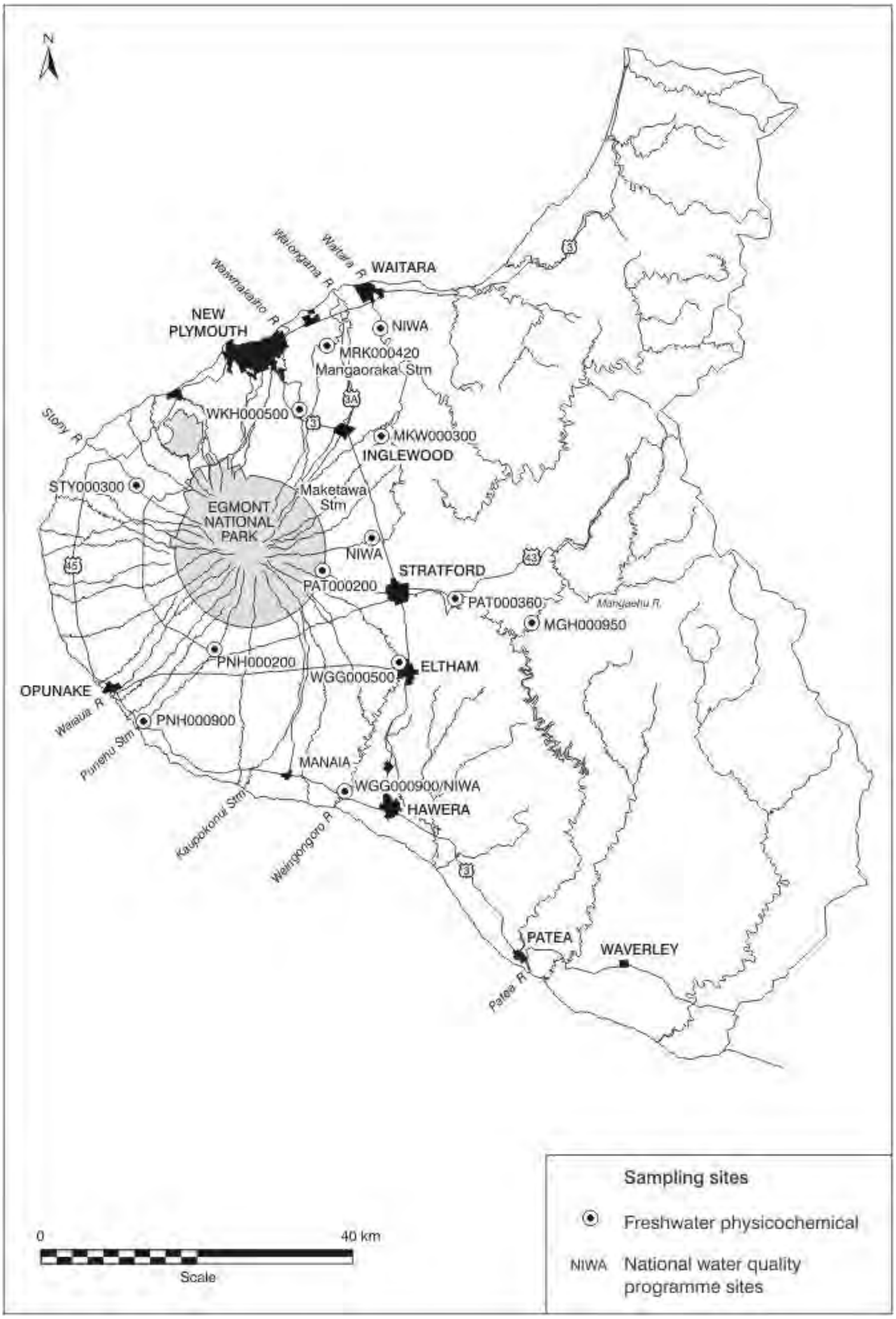

Figure 1 Freshwater physicochemical SEM sampling sites

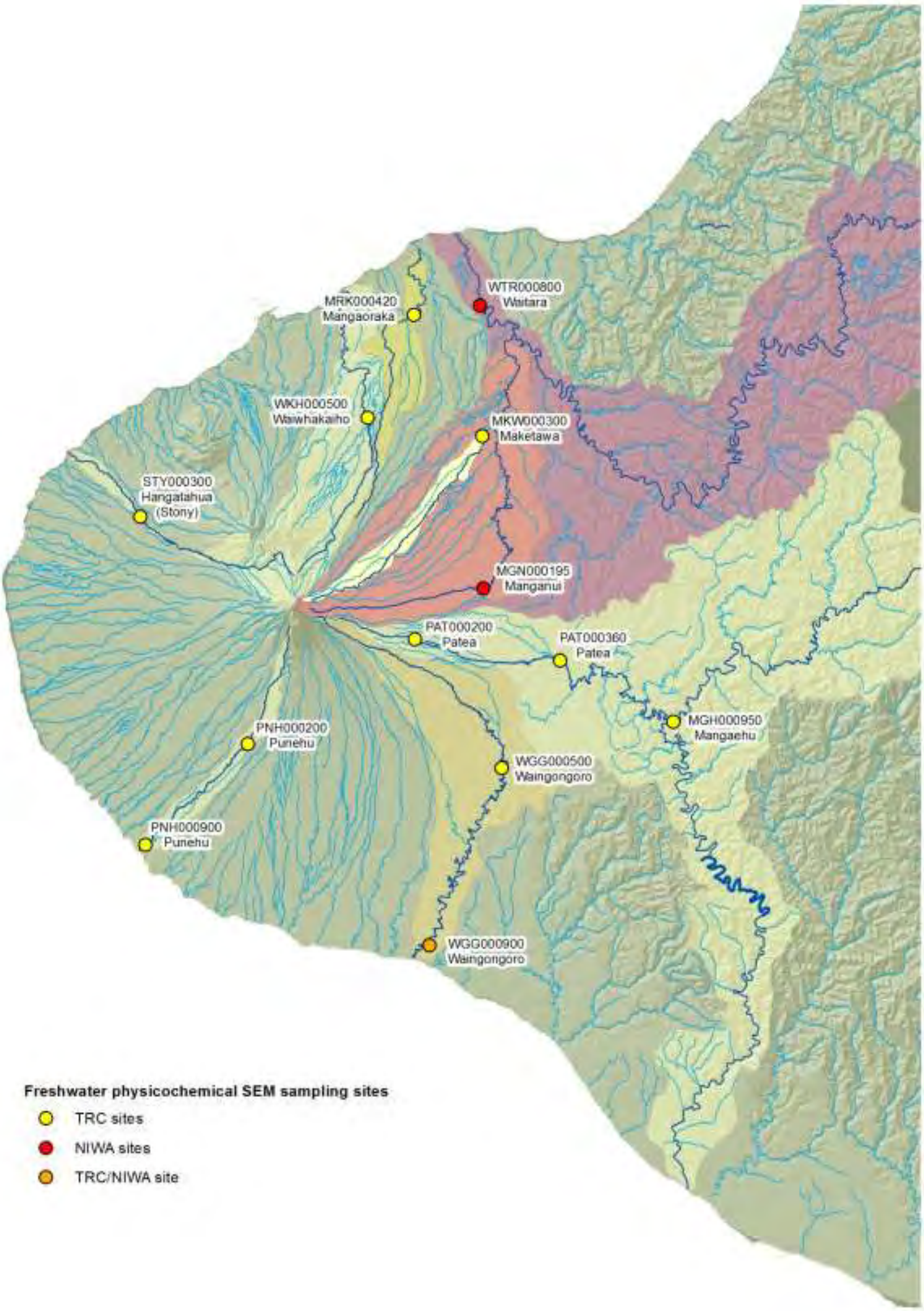

Figure 2 Freshwater physicochemical SEM sampling sites aerial map

Site Waiwhakaiho River at SH3

This site is an existing hydrological recording station and was included in the Taranaki ring plain survey (TRC 1984). It is representative of the mid catchment of a National Park-sourced river draining developed farmland and is immediately upstream of the major diversion site for the New Plymouth water supply and the Mangorei HEP scheme. This site has also been integrated into compliance monitoring programmes related to the diversion consent. The lower river is markedly influenced by HEP generation releases and industrial impacts and is further monitored by way of a site specific monitoring programme. Occasional natural headwater erosion events may affect water quality from time to time (including iron-oxide release from tributary streams).

Site Hangatahua (Stony) River at Mangatete Road

This river is protected in its natural state by way of a Local Conservation Order. This site is as close to the National Park Boundary (within 7 km) as realistically possible, given the need for regular access. The site was used during the ring plain survey (TRC, 1984). This river is notoriously difficult to rate (hydrologically) and regular flow gauging is necessary although, more recently, a hydrological recording station has been established. The river has also been affected by significant natural erosion events in the headwaters from time-to-time. Several of these events have occurred since the SEM programme commenced particularly in the latter part of 2006, during mid 2008 and mid 2009, and early 2014.

Sites Punehu Stream at Wiremu Road (1) and at SH45 (2)

This stream is representative of a south-western Taranaki catchment subjected primarily to intensive agricultural land use with water quality potentially affected by diffuse source run-off and point source discharges from dairy shed treatment pond systems in the lower reaches of the catchment and Mangatawa Stream sub-catchment in particular. No industrial discharges in the catchment are known to occur. Both sites were included in the Taranaki ring plain survey and the lower site near the coast remained a NIWA hydrological recording station as a representative basin until 2011 when the station was closed. The upstream site (located approximately 2 km from the National Park boundary) is representative of relatively unimpacted stream water quality although this reach is in open farmland, and requires regular flow rating. Flow gaugings at this site are therefore necessary on each sampling occasion and flow gaugings were implemented at the lower reach site in 2011 after hydro station closure.

Sites Waingongoro River at Eltham Road (1) and at SH45 (2)

Both sites were Taranaki ring plain survey sites and are existing hydrological recording stations. Site 1 is representative of agricultural impacts in the upper catchment and provides a control site for monitoring the impacts of major industrial/municipal discharges which occur in the vicinity of Eltham. The site is therefore also included in a consent compliance monitoring programme.

Site 2 is representative of the combined impacts of industrial/municipal and agricultural point source discharges plus diffuse run-off, in the lower reaches of a principal Taranaki trout fishery river and the longest river confined to the ring plain. One of the major industrial (meatworks) point-source discharges to the mid reaches of the river has been partially re-directed to land irrigation during summer-autumn low flow periods since January 2001 and the Eltham WWTP discharge was diverted out of the catchment (by pipeline to the Hawera WWTP) from July, 2010.

This site is also currently part of the NIWA (NZ rivers) survey network and NIWA data will continue to be utilised as well as data collected by the Council since July 1998.

Sites Patea River catchment: Patea River at Barclay Road, Skinner Road, and Mangaehu River at Raupuha Road bridge

The Barclay Road site is representative of the upper catchment adjacent to the National Park above agricultural impacts and requires flow ratings to be established. The Skinner Road site, which is integrated with consent compliance monitoring programmes, was a ring plain survey site, and is representative of developed farmland drainage and is downstream of Stratford (urban run-off, closed landfill and up-graded (in 2009) oxidation pond discharges and the combined cycle power station discharge). It is also an established hydrological recorder station. The Mangaehu River site, in the lower reaches of one of the largest hill country catchments, represents the principal eastern hill country tributary flowing into the Patea River and has an established hydrological recorder station.

Site Waitara River at Bertrand Road

This site is currently part of the NIWA (NZ rivers) survey network and is an existing hydrological recording station. It was also a Taranaki ring plain survey site, and is representative of the lower reaches of the largest Taranaki catchment (draining both ring plain and eastern hill country catchments) but upstream of any tidal influence. NIWA data is utilised for this site.

Site Manganui River at SH3

This site was a Taranaki ring plain survey site and is currently one of the three Taranaki sites in the NIWA (NZ rivers) survey network in conjunction with the existing hydrological recording station. The site is representative of the upper/mid reaches (approximately 7 km from the National Park boundary) of a high quality river receiving limited agricultural run-off. NIWA data is utilised for this site.

3. Sampling procedure and analytical parameters

Sampling has been performed monthly on the second Wednesday of each calendar month, to allow for typical variations in relation to fluctuating flows and seasonal trends. This is consistent with the scientifically established sampling frequency that is required for long-term trend analysis. It has been performed by trained Council Technical Officers under the supervision of the designated Scientific Officer and according to standard TRC field methodology outlined in an appropriate manual (TRC 2004a) which was last revised in 2012.

Analyses have been performed in the TRC IANZ-registered chemistry laboratory using standard methods. The parameters analysed and site of measurements are listed in Table 2.

Table 2 SEM physicochemical parameters and site of measurement

Parameter	Unit	Location
Time	NZST	On site
Temperature	˚C	On site
Flow	m^3/s	On site recorder or rated SG or gauging
Dissolved oxygen	g/m^3	On site
BOD_5 (total)	g/m^3	Laboratory
pH	-	Laboratory
Conductivity @ 20°C	mS/m	Laboratory
Black disc clarity	m	On site
Turbidity	NTU	Laboratory
Absorbance @ 770, 440, 340 nm	/cm	Laboratory (membrane filtration)
Ammonia-N	g/m^3N	Laboratory
Nitrate-N	g/m^3N	Laboratory
Total-N	g/m^3N	Laboratory
Dissolved reactive phosphorus	g/m^3P	Laboratory
Total phosphorus	g/m^3P	Laboratory
Alkalinity	g/m^3CaCO_3	Laboratory
Suspended solids	g/m^3	Laboratory
Faecal coliform and *E. coli* bacteria (mTech)	nos/100 ml	Laboratory
Enterococci bacteria	nos/100 ml	Laboratory

The precision of the laboratory analyses has been checked regularly by the collection of split samples from one randomly chosen site on selected sampling runs (generally every 3 months). These samples were unidentified for laboratory purposes and included with the other samples in the normal manner for laboratory analysis. Comparative results have been stored in the appropriate database and a separate internal report prepared for quality control purposes (see Appendix III).

Stream flow gaugings have been performed at the five sites where no permanent hydrological stations exist and/or the rating is unstable, in conjunction with each monthly sampling survey run.

All samples were logged into the TRC computer database following receipt by the laboratory with subsequent analytical results and audited flow data stored in this database.

4. Water quality results

Water quality data accumulated for the period July 2014 to June 2015 are presented for each of the eleven sites. Statistical summaries of this data and the cumulative data for nine sites (July 1995 to June 2015), one site in the lower Waingongoro River (July 1998 to June 2015), and one site in the lower Maketawa Stream (July 2003 to June 2015) are also presented on a site-by-site basis, together with a general discussion of water quality at each site. A comparison of water quality through the region is provided following the individual sites' discussions (Section 4.2).

4.1 Sites' water quality

Maketawa Stream at Tarata Road (site: MKW000300)

Analytical data from the monthly samples are presented in Table 3.

Table 3 Analytical results from monthly samples: Maketawa Stream at Tariki Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ CaCO₃)	Black disc (m)	BOD₅ (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
09 Jul 2014	0800	0.012	0.002	0.000	30	1.56	<0.5	8.9	11.5	100	0.019	84	19
13 Aug 2014	0800	0.022	0.004	0.000	21	2.11	<0.5	7.1	11.9	101	0.021	80	15
10 Sep 2014	0800	0.012	0.002	0.000	32	2.82	<0.5	8.8	11.6	103	0.020	590	48
08 Oct 2014	0700	0.014	0.003	0.000	30	2.47	<0.5	8.4	10.9	100	0.027	340	100
12 Nov 2014	0705	0.025	0.006	0.000	29	2.05	0.9	8.6	10.6	101	0.030	2700	250
10 Dec 2014	0710	0.016	0.004	0.000	31	1.96	0.7	9.0	9.8	102	0.031	2200	350
14 Jan 2015	0700	0.016	0.004	0.000	32	3.70	<0.5	9.0	9.7	103	0.032	360	180
11 Feb 2015	0700	0.017	0.004	0.000	32	3.32	<0.5	8.9	10.1	98	0.042	270	400
11 Mar 2015	0700	0.019	0.004	0.000	30	2.99	0.6	8.9	9.6	97	0.040	200	520
08 Apr 2015	0800	0.026	0.007	0.001	30	1.41	<0.5	9.0	9.5	98	0.045	5700	5300
13 May 2015	0805	0.036	0.008	0.000	20	1.63	0.5	7.7	10.6	100	0.027	520	280
10 Jun 2015	0800	0.012	0.002	0.000	27	2.37	<0.5	9.2	10.5	98	0.021	200	92

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m³/s)	NH₄ (g/m³N)	NO₂ (g/m³N)	NO₃ (g/m³N)	pH	SS (g/m³)	Temp (°C)	TKN (g/m³N)	TN (g/m³N)	TP (g/m³P)	Turb (NTU)
09 Jul 2014	0800	84	2.093	0.005	0.002	0.608	7.5	<2	8.6	0.00	0.61	0.022	0.8
13 Aug 2014	0800	80	3.651	0.014	0.002	0.438	7.5	<2	7.5	0.04	0.48	0.032	1.1
10 Sep 2014	0800	590	1.228	0.008	<0.001	0.059	7.7	<2	9.6	0.07	0.13	0.022	0.7
08 Oct 2014	0700	340	2.540	0.026	0.003	0.427	7.7	<2	10.5	0.09	0.52	0.030	0.9
12 Nov 2014	0705	2700	2.594	0.015	0.006	0.474	7.6	<2	11.5	0.13	0.61	0.050	1.4
10 Dec 2014	0710	2200	1.340	0.014	0.003	0.187	7.6	<2	16.2	0.06	0.25	0.044	1.2
14 Jan 2015	0700	360	1.097	0.006	0.001	0.059	7.5	<2	17.0	0.05	0.11	0.038	0.6
11 Feb 2015	0700	280	1.082	0.005	<0.001	0.039	7.6	2	14.2	0.08	0.12	0.045	0.6
11 Mar 2015	0700	200	1.194	0.008	0.001	0.149	7.7	<2	14.3	0.10	0.25	0.059	0.7
08 Apr 2015	0800	5700	1.890	0.022	0.004	0.196	7.5	3	16.1	0.12	0.32	0.058	1.1
13 May 2015	0805	520	5.334	0.048	0.005	0.795	7.1	3	11.5	0.16	0.96	0.044	1.2
10 Jun 2015	0800	200	2.294	<0.003	0.002	0.508	7.6	4	11.0	-0.01	0.50	0.024	1.2

The statistical summary of this data is presented in Table 4.

Table 4 Statistical summary of data from July 2014 to June 2015: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.012	0.036	0.016	12	0.007
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.008	0.004	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity total	g/m^3 $CaCO_3$	20	32	30	12	4
BLACK DISC	Black disc transparency	m	1.41	3.70	2.24	12	0.72
BOD_5	Biochemical oxygen demand 5 day	g/m^3	< 0.5	0.9	< 0.5	12	0.1
CONDY	Conductivity @ 20°C	mS/m	7.1	9.2	8.9	12	0.6
DO	Dissolved oxygen	g/m^3	9.5	11.9	10.6	12	0.8
PERSAT	Dissolved oxygen saturation	%	97	103	100	12	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.019	0.045	0.028	12	0.009
ECOL	E. coli bacteria	nos/100 ml	80	5700	350	12	1680
ENT	Enterococci bacteria	nos/100 ml	15	5300	215	12	1480
FC	Faecal coliform bacteria	nos/100 ml	80	5700	350	12	1679
FLOW	Flow	m^3/s	1.082	5.334	1.992	12	1.26
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.048	0.011	12	0.013
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.006	0.002	12	0.002
NO_3	Nitrate nitrogen	g/m^3N	0.04	0.80	0.31	12	0.25
pH	pH		7.1	7.7	7.6	12	0.2
SS	Suspended solids	g/m^3	< 2	4	< 2	12	1
TEMP	Temperature	°C	7.5	17.0	11.5	12	3.2
TKN	Total kjeldahl nitrogen	g/m^3N	< 0.01	0.16	0.08	12	0.05
TN	Total nitrogen	g/m^3N	0.11	0.96	0.40	12	0.26
TP	Total phosphorus	g/m^3P	0.022	0.059	0.041	12	0.013
TURB	Turbidity	NTU	0.6	1.4	1.0	12	0.28

A statistical summary of the twelve years' data collected since 1 July 2003 is presented in Table 5.

Table 5 Statistical summary of data from July 2003 to June 2015: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.002	0.141	0.018	144	0.023
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.031	0.004	144	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	144	0
ALKT	Alkalinity total	g/m^3 $CaCO_3$	7	34	28	144	6
BLACK DISC	Black disc transparency	m	0.21	5.23	2.55	144	1.12
BOD_5	Biochemical oxygen demand 5 day	g/m^3	< 0.5	2.3	< 0.5	144	0.3
CONDY	Conductivity @ 20°C	mS/m	3.2	12.6	8.6	144	1.2
DO	Dissolved oxygen	g/m^3	9.0	12.5	10.6	144	0.8
PERSAT	Dissolved oxygen saturation	%	90	103	98	144	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.045	0.022	144	0.007
ECOL	E. coli bacteria	nos/100 ml	50	26000	310	144	2699
ENT	Enterococci bacteria	nos/100 ml	6	9700	155	144	1384
FC	Faecal coliform bacteria	nos/100 ml	50	26000	320	144	2708
FLOW	Flow	m^3/s	0.838	17.200	1.958	144	2.584
NH_4	Ammoniacal nitrogen	g/m^3N	0.003	0.093	0.009	144	0.016
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.009	0.002	144	0.002
NO_3	Nitrate nitrogen	g/m^3N	< 0.01	0.92	0.25	144	0.21
pH	pH		6.8	7.9	7.6	144	0.2
SS	Suspended solids	g/m^3	< 2	55	< 2	144	7
TEMP	Temperature	°C	4.8	17.6	11.5	144	3
TKN	Total kjeldahl nitrogen	g/m^3N	< 0.01	0.52	0.07	144	0.11
TN	Total nitrogen	g/m^3N	0.05	0.96	0.39	144	0.23
TP	Total phosphorus	g/m^3P	0.018	0.18	0.034	144	0.025
TURB	Turbidity	NTU	0.5	14	0.9	144	1.82

Discussion

2014-2015 period

Good aesthetic water quality was indicated by a median black disc clarity of 2.24 metres, in the lower reaches of this ring-plain stream near to its confluence with the Manganui River. The maximum clarity (black disc value of 3.70 m) was recorded in mid-summer under low flow conditions (1.10 m^3/s). No significant floods, but several small freshes, were sampled during the year, with minimal elevations in turbidity (1.2 to 1.4 NTU) and in suspended solids concentrations (4 g/m^3) under fresh flow conditions (2.59 and 2.29 m^3/sec) sampled in spring 2014 and early winter 2015. Slightly poorer water quality conditions apparent at the time of these fresh flows were recorded with increases in bacterial number (2700 faecal coliforms/100ml), BOD_5 (0.9 g/m^3), and some nutrients (e.g. TN [0.96 g/m^3]) recorded when black disc visibility decreased slightly to 1.63 m.

pH was relatively stable (7.1 to 7.7), although it would be expected that pH would have reached a higher maximum later in the day than at the usual times of sampling (i.e. prior to 0805 NZST), particularly during summer low flow conditions.

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 97% saturation) and low BOD_5 levels (median: < 0.5 g/m^3). Bacteriological quality was typical of the lower reaches of developed ring plain catchments subject to agricultural impacts, with median faecal coliform and enterococci numbers of 350 and 215 (per 100 mls) respectively. Water temperature varied over a moderate range of 9.5 °C with a maximum late summer (early morning) river temperature of 17.0 °C recorded in January 2015.

Brief comparison with the previous 2003-2014 (eleven year) period

Generally, stream water quality at this site during the 2014-2015 period was slightly poorer in appearance/clarity (lower median black disc clarity [by 0.36 m], higher median turbidity [by 0.1 NTU], but no difference in median suspended solids level). Bacterial water quality was poorer, with an increase in median faecal coliform number of 35 per 100 mls and an increase in median enterococci number of 65 per 100 mls. Median water temperatures were identical while the maximum water temperature (17.0 °C) was 0.6 °C lower than the previous maximum recorded. Other physicochemical aspects of water quality were very similar for the two periods. Relatively narrow ranges for parameters such as suspended solids, conductivity, turbidity, pH and total phosphorus reflected the lack of significant flood events sampled during the 2014-2015 period. Median flow sampled during 2014-2015 was slightly higher (by 34 l/sec) than the median of flows sampled over the previous eleven-year period due in part to the several fresh flow conditions sampled during the latest period despite several low flows sampled during the mid-summer to autumn period. Median pH values were identical and the maximum pH value was within 0.2 unit of that of the past eleven-year record. All nutrient species had slightly higher median values (by 3 to 27%) during the monitoring year in comparison with the medians of the previous eleven year record.

Mangaoraka Stream at Corbett Road (site: MRK000420)

Analytical data from the monthly samples are presented in Table 6 and the stream flow record is illustrated in Figure 3.

Table 6 Analytical results from monthly samples: Mangaoraka Stream at Corbett Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ CaCO₃)	Black disc (m)	BOD₅ (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
09 Jul 2014	0830	0.020	0.004	0.000	35	1.57	0.5	13.6	11.0	99	0.004	80	74
13 Aug 2014	0830	0.019	0.003	0.000	32	1.50	<0.5	12.6	11.3	100	0.009	380	80
10 Sep 2014	0840	0.023	0.004	0.000	57	2.04	0.5	18.2	11.7	103	0.009	1000	230
08 Oct 2014	0740	0.018	0.004	0.000	36	1.77	0.5	12.7	10.5	99	0.019	800	430
12 Nov 2014	0735	0.028	0.006	0.000	41	1.15	1.5	14.0	10.3	99	0.018	5800	830
10 Dec 2014	0735	0.029	0.006	0.000	51	1.06	1.7	16.3	9.6	99	0.006	8100	3200
14 Jan 2015	0745	0.028	0.006	0.000	70	2.35	0.7	20.0	9.1	97	0.005	370	260
11 Feb 2015	0730	0.032	0.007	0.000	59	1.68	0.8	17.4	9.9	96	0.012	830	1300
11 Mar 2015	0730	0.036	0.007	0.000	66	1.85	0.8	19.7	9.3	94	0.019	910	1200
08 Apr 2015	0830	0.038	0.008	0.001	57	1.04	1.3	18.0	9.0	95	0.016	13000	17000
13 May 2015	0845	0.029	0.006	0.000	25	1.02	0.8	11.7	10.3	99	0.012	1400	1600
10 Jun 2015	0825	0.020	0.004	0.000	34	1.56	<0.5	13.7	10.4	99	0.012	750	1700

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m³/s)	NH₄ (g/m³N)	NO₂ (g/m³N)	NO₃ (g/m³N)	pH	SS (g/m³)	Temp (°C)	TKN (g/m³N)	TN (g/m³N)	TP (g/m³P)	Turb (NTU)
09 Jul 2014	0830	84	2.041	0.019	0.003	1.287	7.5	4	10.7	0.11	1.40	0.015	1.5
13 Aug 2014	0830	380	2.334	0.017	0.003	1.027	7.6	3	9.4	0.11	1.14	0.025	1.6
10 Sep 2014	0840	1000	0.476	0.008	<0.003	0.727	7.8	<2	11.3	0.27	1.00	0.013	1.2
08 Oct 2014	0740	800	1.910	0.024	0.005	0.825	7.7	4	12.1	0.28	1.11	0.031	1.5
12 Nov 2014	0735	5800	1.609	0.062	0.013	0.977	7.6	5	12.1	0.27	1.26	0.051	2.2
10 Dec 2014	0735	8300	0.783	0.010	0.004	0.606	7.6	4	16.6	0.19	0.80	0.032	2.5
14 Jan 2015	0745	390	0.351	<0.003	0.004	0.356	7.7	<2	17.8	0.13	0.49	0.013	1.2
11 Feb 2015	0730	870	0.476	0.005	0.002	0.408	7.6	<2	14.8	0.10	0.51	0.025	1.4
11 Mar 2015	0730	960	0.336	0.028	0.005	0.695	7.7	<2	15.4	0.17	0.87	0.032	1.4
08 Apr 2015	0830	13000	0.799	0.058	0.008	0.852	7.5	5	17.6	0.30	1.16	0.034	2.5
13 May 2015	0845	1400	5.230	0.028	0.006	1.244	7.1	<2	13.3	0.06	1.31	0.049	2.8
10 Jun 2015	0825	780	1.942	0.034	0.003	1.037	7.5	3	13.0	0.18	1.22	0.018	1.5

The statistical summary of this data is presented in Table 7.

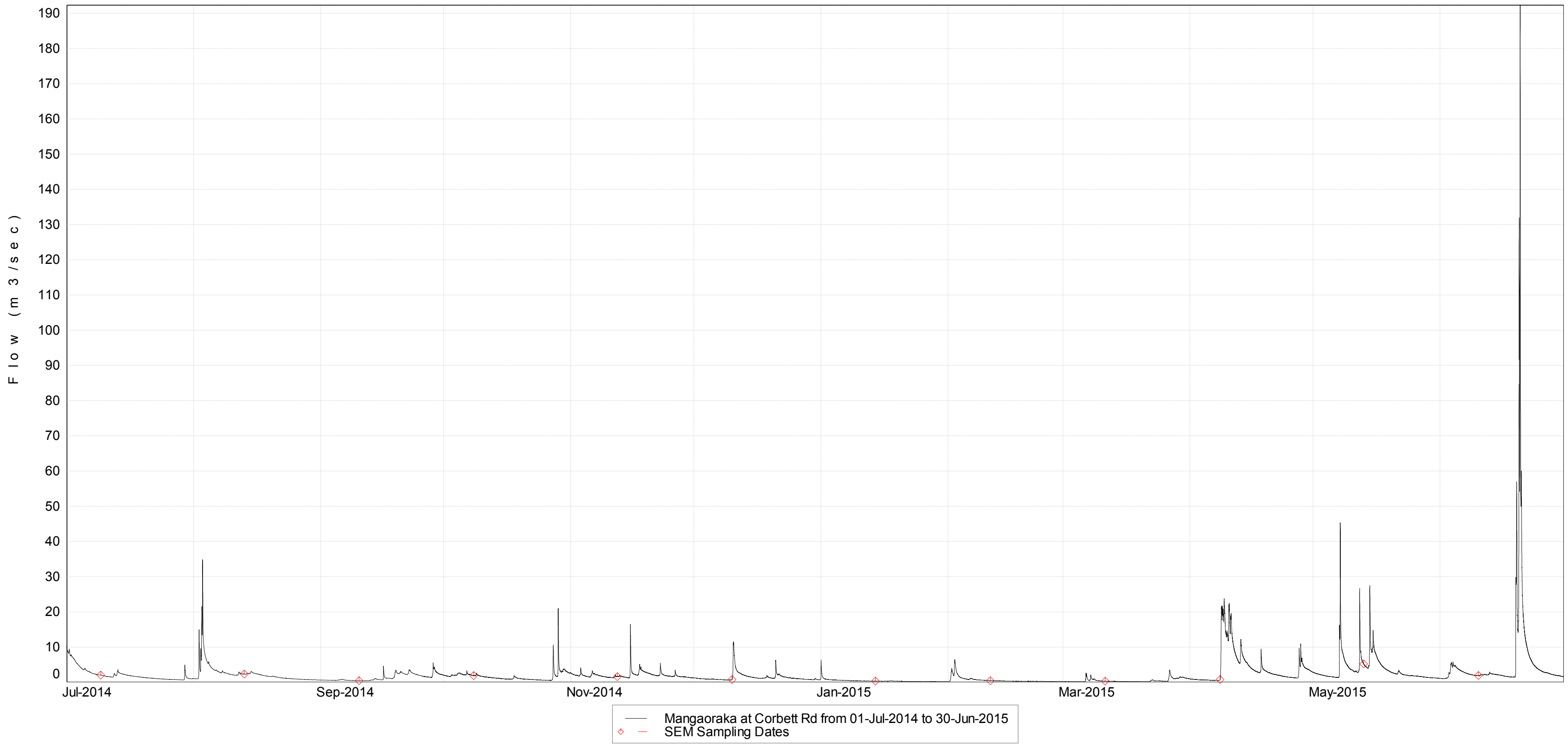

Figure 3 Flow record for the Mangaoraka Stream at Corbett Road

Table 7 Statistical summary of data from July 2014 to June 2015: Mangaoraka Stream at Corbett Road

Parameter		Units	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.018	0.038	0.028	12	0.007
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.008	0.006	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity total	g/m^3 CaCO^3	25	70	46	12	15
BLACKDISC	Black disc transparency	m	1.02	2.35	1.56	12	0.42
BOD$_5$	Biochemical oxygen demand 5 day	g/m^3	< 0.5	1.7	0.8	12	0.4
CONDY	Conductivity @ 20°C	mS/m@20C	11.7	20.0	15.2	12	2.9
DO	Dissolved oxygen	g/m^3	9.0	11.7	10.3	12	0.9
PERSAT	Dissolved oxygen saturation	%	94	103	99	12	2
DRP	Dissolved reactive phosphorus	g/m^3 P	0.004	0.019	0.012	12	0.005
ECOL	E. coli bacteria	/100ml	80	13000	870	12	4058
ENT	Enterococci bacteria	/100ml	74	17000	1015	12	4709
FC	Faecal coliform bacteria	/100ml	84	13000	915	12	4076
FLOW	Flow	m^3/s	0.336	5.23	1.204	12	1.383
NH$_4$	Ammoniacal nitrogen	g/m^3 N	< 0.003	0.062	0.022	12	0.019
NO$_2$	Nitrite nitrogen	g/m^3 N	0.002	0.013	0.004	12	0.003
NO$_3$	Nitrate nitrogen	g/m^3 N	0.36	1.29	0.84	12	0.296
PH	pH	pH	7.1	7.8	7.6	12	0.2
SS	Suspended solids	g/m^3	< 2	5	3	12	1
TEMP	Temperature	°C	9.4	17.8	13.2	12	2.8
TKN	Total kjeldahl nitrogen	g/m^3 N	0.06	0.3	0.18	12	0.08
TN	Total nitrogen	g/m^3 N	0.49	1.4	1.12	12	0.3
TP	Total phosphorus	g/m^3 P	0.013	0.051	0.028	12	0.013
TURB	Turbidity	NTU	1.2	2.8	1.5	12	0.6

A statistical summary of the twenty years' data collected since 1 July 1995 is presented in Table 8.

Table 8 Statistical summary of data from July 1995 to June 2015: Mangaoraka Stream at Corbett Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.014	0.074	0.025	240	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.019	0.005	240	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	240	0.001
ALKT	Alkalinity total	g/m^3 CaCO$_3$	14	108	40	240	18
BLACK DISC	Black disc transparency	m	0.055	4.73	1.80	240	0.899
BOD$_5$	Biochemical oxygen demand 5 day	g/m^3	< 0.5	14	0.7	240	1.4
CONDY	Conductivity @ 20°C	mS/m	5.6	28.7	14.4	240	3.8
DO	Dissolved oxygen	g/m^3	7.8	11.8	10.1	239	0.8
PERSAT	Dissolved oxygen saturation	%	83	107	96	239	4
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.003	0.074	0.009	240	0.008
ECOL	E. coli bacteria	nos/100 ml	80	60000	785	216	7146
ENT	Enterococci bacteria	nos/100 ml	31	180000	375	240	13744
FC	Faecal coliform bacteria	nos/100 ml	84	60000	790	240	7786
FLOW	Flow	m^3/s	0.16	34.1	1.182	240	3.05
NH$_4$	Ammoniacal nitrogen	g/m^{3}N	< 0.003	0.308	0.021	240	0.048
NO$_2$	Nitrite nitrogen	g/m^{3}N	< 0.001	0.039	0.005	240	0.006
NO$_3$	Nitrate nitrogen	g/m^{3}N	0.05	1.73	0.84	240	0.304
pH	pH		6.9	8.1	7.6	240	0.2
SS	Suspended solids	g/m^3	< 2	310	2	240	27
TEMP	Temperature	°C	5.8	20.5	13	240	2.9
TKN	Total kjeldahl nitrogen	g/m^{3}N	< 0.01	4.46	0.20	240	0.449
TN	Total nitrogen	g/m^{3}N	0.28	5.18	1.10	240	0.526
TP	Total phosphorus	g/m^{3}P	0.007	0.86	0.023	240	0.092
TURB	Turbidity	NTU	0.8	100	1.6	239	8.68

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

Discussion

2014-2015 period

Black disc clarity and turbidity results continued to indicate a reasonable standard of aesthetic water quality for the lower reaches of a developed, agricultural catchment although it is noted that turbidity levels were slightly higher (minimum: 1.2 NTU; median: 1.5 NTU) than might be expected given the concentration of suspended solids (minimum: <2 g/m^3; median: 3 g/m^3). This was due to the very fine, colloidal nature of suspended material in the stream at this site partly due to the headwaters being situated below the National Park. The moderate maximum black disc value of 2.35 m coincided with mid summer, low flow conditions (following no fresh events in the previous ten days), while the poorest turbidity conditions (2.8 NTU and 1.02 m black disc) were recorded after a fresh in late autumn 2015, although there was minimal change in suspended sediment , or BOD_5 concentrations, but some increase in faecal coliform number . Some nutrient species indicated poorest water quality during this fresh, particularly total nitrogen and phosphorus levels, although higher bacteria numbers were recorded on three other occasions. One of these occurred in April 2015 on the rising stage of the first fresh after a lengthy very low flow period, resulting in marked elevation in bacterial numbers, decreased clarity, and some small increases in BOD_5 and suspended solids concentrations.

The relative absence of freshes during mid-summer to autumn contributed to the slightly elevated pH values (7.6 to 7.7) and these levels were similar to those recorded previously through late summer-autumn months. It should be noted all levels were recorded prior to mid-morning and were not representative of higher pH levels that might be expected later in the day when algal photosynthetic activity would be likely to raise pH more significantly.

Generally, high dissolved oxygen concentrations, high percentage saturation, and low BOD_5 levels (< 1.8 g/m^3) were indicative of relatively good physicochemical water quality, but the very high median bacterial numbers (1015 enterococci and 915 faecal coliforms per 100 ml), although lower than in the 2013-2014 period, were much higher than typical of the lower reaches of a stream draining an intensively developed catchment, although the Mangaoraka Stream is essentially a lowland catchment as its headwaters do not extend as far towards the upper slopes of Mt Taranaki as most ring plain rivers and streams. [Investigative work in the lower catchment has identified stock access to streams as a probable primary contributor to these elevated numbers although the cumulative impacts of consented dairy pond discharges also contribute, particularly under lower flow conditions]. Water temperatures varied over a moderate range of 8.4 °C with a maximum (mid-morning) temperature of 17.8 °C in January 2015 during a period of very low flow conditions. Dissolved oxygen saturation did not fall below 94% during the period, with this minimum recorded during a period of lengthy, very low flow conditions (Figure 3).

Brief comparison with the previous 1995-2014 period

Aesthetic stream water quality at this site during the 2014-2015 period was poorer [median black disc clarity lower by 0.30 m, median suspended solids level slightly higher, and median turbidities within 0.1 NTU]. Bacterial water quality deteriorated as reflected in increases in median faecal coliform number of 140 per 100 mls and median enterococci number which increased by 650 per 100 mls. Median water temperature was 0.2 °C higher in the 2014-2015 period although the maximum water temperature (17.8 °C) was 2.7 °C lower than the previous maximum recorded. Median conductivity was higher and reflected the absence of very high flow conditions and lengthy low flow period sampled during the latest period. The median flow sampled during 2014-2015 (1.20 m^3/sec) was slightly higher (by 22 l/sec) than the median of flows sampled over the previous nineteen-year period. Moderate ranges for parameters such as suspended solids, turbidity, pH, and BOD_5 reflected the few smaller freshes sampled on occasions during the 2014-2015 period (Figure 3), rather than high floods occasionally sampled in the past. Median pH values were identical and maximum pH was 0.3 unit lower than the past record. Most nitrogen nutrient species had very similar median values during the monitoring year in comparison with the previous nineteen-year record while phosphorus nutrient species had higher median values (by 21 to 33%) over the 2014-2015 period.

Waiwhakaiho River at SH 3 (site: WKH000500)

Analytical data from the monthly samples are presented in Table 9 and the river flow record is illustrated in Figure 4.

Table 9 Analytical results from monthly samples: Waiwhakaiho River at SH3

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ $CaCO_3$)	Black disc (m)	BOD_5 (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
09 Jul 2014	08:55	0.010	0.002	0.000	50	4.74	<0.5	12.4	11.6	101	0.023	43	21
13 Aug 2014	0905	0.020	0.004	0.000	24	1.79	<0.5	7.3	12.1	103	0.016	130	84
10 Sep 2014	0910	0.009	0.002	0.000	67	2.81	<0.5	15.9	12.4	110	0.043	170	240
08 Oct 2014	0810	0.012	0.003	0.000	44	2.62	<0.5	11.1	11.2	102	0.025	460	140
12 Nov 2014	0805	0.042	0.009	0.000	25	1.08	0.8	6.8	11.2	103	0.016	3000	340
10 Dec 2014	0810	0.015	0.003	0.000	56	1.94	0.8	13.9	10.0	102	0.030	3000	640
14 Jan 2015	0815	0.011	0.003	0.000	66	3.35	<0.5	15.7	10.3	107	0.037	140	43
11 Feb 2015	0800	0.012	0.003	0.000	62	3.96	<0.5	14.9	10.9	104	0.040	200	160
11 Mar 2015	0800	0.014	0.003	0.000	62	3.26	<0.5	14.8	10.4	101	0.034	280	190
08 Apr 2015	0900	0.085	0.020	0.001	20	0.57	5.0	6.4	10.0	101	0.026	27000	33000
13 May 2015	0915	0.024	0.005	0.000	24	2.74	<0.5	8.4	10.7	100	0.022	310	420
10 Jun 2015	0900	0.011	0.002	0.000	47	3.58	<0.5	12.9	11.0	102	0.021	300	28

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m³/s)	NH_4 (g/m³N)	NO_2 (g/m³N)	NO_3 (g/m³N)	pH	SS (g/m³)	Temp (°C)	TKN (g/m³N)	TN (g/m³N)	TP (g/m³P)	Turb (NTU)
09 Jul 2014	0855	43	3.815	0.006	0.002	0.278	7.7	<2	8.0	0.01	0.29	0.025	0.60
13 Aug 2014	0905	130	10.191	0.009	0.001	0.139	7.7	<2	7.2	0.04	0.18	0.023	0.80
10 Sep 2014	0910	170	2.060	<0.003	<0.001	0.019	8.2	<2	9.4	0.03	0.05	0.048	1.0
08 Oct 2014	0810	480	5.341	0.016	0.002	0.218	7.9	<2	9.8	0.10	0.32	0.031	0.80
12 Nov 2014	0805	3000	10.728	0.018	0.002	0.078	7.7	4	9.7	0.18	0.26	0.032	1.5
10 Dec 2014	0810	3000	3.400	0.013	0.003	0.047	7.8	<2	14.9	0.06	0.11	0.044	1.2
14 Jan 2015	0815	140	2.080	<0.003	0.001	0.019	8.1	<2	16.2	0.03	<0.05	0.044	0.60
11 Feb 2015	0800	200	2.457	0.006	<0.001	0.029	8.0	<2	13.1	0.06	0.09	0.048	0.60
11 Mar 2015	0800	280	2.190	0.004	<0.001	0.049	8.0	<2	13.4	0.02	0.07	0.043	0.60
08 Apr 2015	0900	27000	78.597	0.030	0.004	0.196	7.4	71	14.8	0.62	0.82	0.102	15
13 May 2015	0915	310	10.473	0.027	0.002	0.368	7.3	<2	11.5	0.03	0.40	0.025	0.80
10 Jun 2015	0900	300	4.546	<0.003	0.0001	0.199	7.9	<2	11.0	-0.01	0.19	0.024	0.65

The statistical summary of this data is presented in Table 10.

Table 10 Statistical summary of data from July 2014 to June 2015

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.009	0.085	0.013	12	0.022
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.020	0.003	12	0.005
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	20	67	48	12	18
BDISC	Black disc transparency	m	0.57	4.74	2.78	12	1.2
BOD_5	Biochemical oxygen demand 5day	g/m³	< 0.5	5.0	<0.5	12	1.3
CONDY	Conductivity @ 20'C	mS/m	6.4	15.9	12.6	12	3.6
DO	Dissolved Oxygen	g/m³	10.0	12.4	11.0	12	0.8
PERSAT	Dissolved Oxygen Saturation %	%	100	110	102	12	3
DRP	Dissolved reactive phosphorus	g/m³P	0.016	0.043	0.026	12	0.009
ECOL	E.coli bacteria	nos/100 ml	43	27000	290	12	7659
ENT	Enterococci bacteria	nos/100 ml	21	33000	175	12	9468
FC	Faecal Coliforms	nos/100 ml	43	27000	290	12	7659
FLOW	Flow	m³/s	2.060	78.597	4.180	12	21.452
NH_4	Ammoniacal nitrogen	g/m³N	< 0.003	0.030	0.008	12	0.009
NO_2	Nitrite nitrogen	g/m³N	< 0.001	0.004	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m³N	0.02	0.37	0.11	12	0.115
PH	pH		7.3	8.2	7.8	12	0.3
SS	Suspended solids	g/m³	< 2	71	< 2	12	20
TEMP	Temperature	°C	7.2	16.2	11.3	12	2.9
TKN	Total Kjeldahl nitrogen	g/m³N	< 0.01	0.62	0.04	12	0.17
TN	Total nitrogen	g/m³N	< 0.05	0.82	0.18	12	0.22
TP	Total phosphorus	g/m³P	0.023	0.102	0.038	12	0.022
TURB	Turbidity	NTU	0.6	15	0.8	12	4.1

A statistical summary of the twenty years' data collected since 1 July 1995 is presented in Table 11.

Table 11 Statistical summary of data from July 1995 to June 2015: Waiwhakaiho River at SH3

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.005	0.095	0.015	240	0.019
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.022	0.003	240	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.007	0.000	240	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	8	76	49	240	17
BDISC	Black disc transparency	m	0.13	8.05	3.06	240	1.419
BOD_5	Biochemical oxygen demand 5day	g/m³	< 0.5	5	< 0.5	240	0.6
CONDY	Conductivity @ 20'C	mS/m	3.4	17.4	12.2	240	3.3
DO	Dissolved Oxygen	g/m³	9.1	12.8	10.8	240	0.7
PERSAT	Dissolved Oxygen Saturation %	%	91	110	100	240	3
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.108	0.024	240	0.011
ECOL	E.coli bacteria	nos/100 ml	23	56000	200	216	4627
ENT	Enterococci bacteria	nos/100 ml	1	33000	97	240	2875
FC	Faecal Coliforms	nos/100 ml	23	83000	210	240	6922
FLOW	Flow	m³/s	1.705	83.44	3.746	240	10.114
NH_4	Ammoniacal nitrogen	g/m³N	< 0.003	0.148	0.008	240	0.021
NO_2	Nitrite nitrogen	g/m³N	< 0.001	0.010	0.002	240	0.001
NO_3	Nitrate nitrogen	g/m³N	< 0.01	0.47	0.11	240	0.104
PH	pH		6.8	8.5	7.9	240	0.3
SS	Suspended solids	g/m³	<2	89	< 2	240	10
TEMP	Temperature	°C	4.8	18.3	11.0	240	2.8
TKN	Total Kjeldahl nitrogen	g/m³N	< 0.01	1.95	0.07	240	0.211
TN	Total nitrogen	g/m³N	0.02	2.10	0.20	240	0.239
TP	Total phosphorus	g/m³P	0.014	0.437	0.034	240	0.045
TURB	Turbidity	NTU	0.4	26	0.7	239	2.81

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

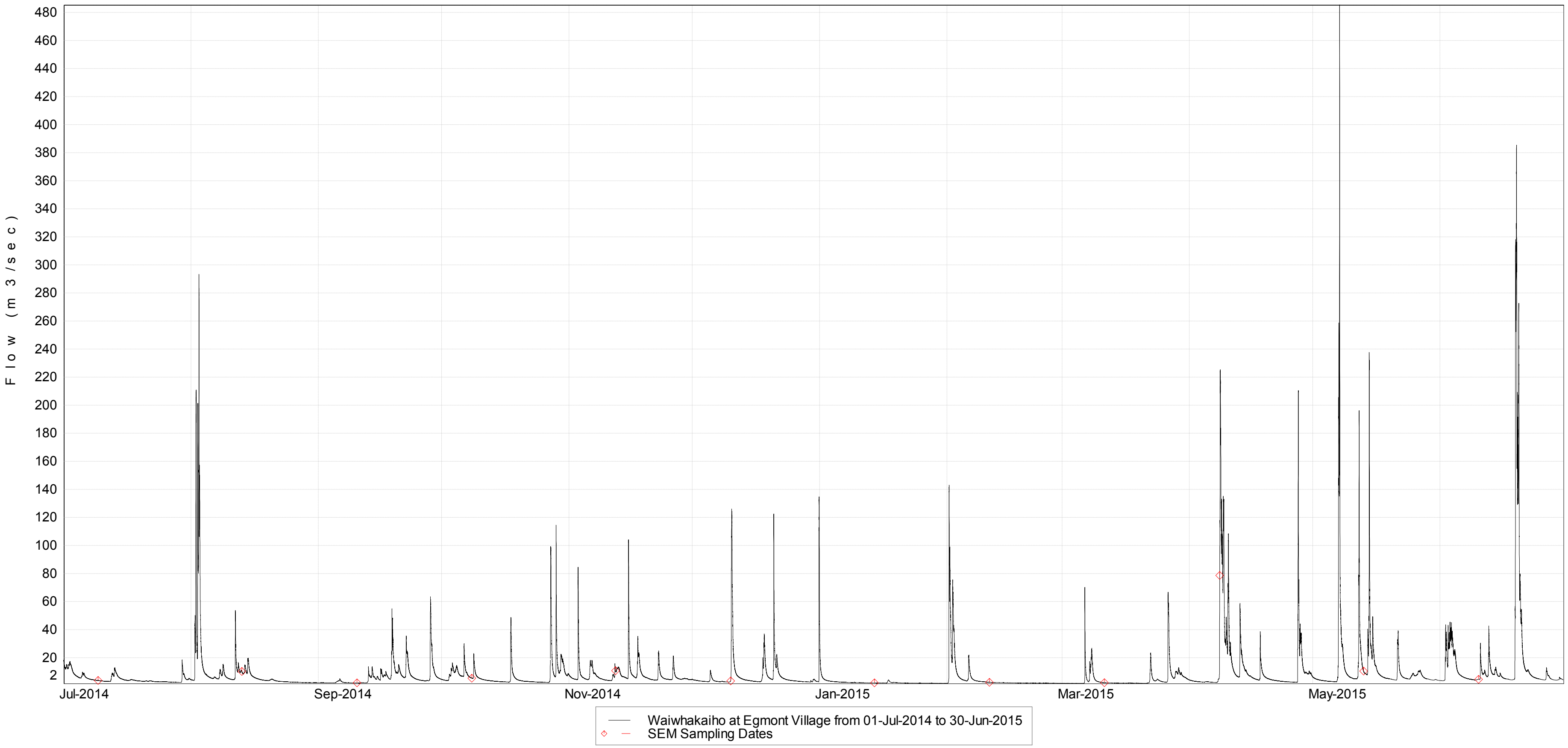

Figure 4 Flow record for the Waiwhakaiho River at SH3 Egmont Village

Discussion

2014-2015 period

During the 2014-2015 period there was no re-occurrence of the severe orange discolouration of the river which occurred in November 2013 when an iron-oxide laden seepage discharge from the Kokowai Stream entered the main river within the National Park. Discolouration had extended downstream beyond the mid reaches, but the river cleared within a few days of this event (TRC, 2014.) [Note: Similar events had occurred in the past (e.g. 1975) but none had been recorded since the inception of the SEM programme in mid-1995].

During the 2014-2015 period, black disc clarity and turbidity results indicated relatively good water quality in terms of appearance, particularly for the mid reaches of a developed ringplain agricultural catchment. This was emphasised by median black disc and turbidity values of 2.78 m and 0.8 NTU respectively. The maximum black disc value (4.74 metres) was recorded in mid winter relatively low flow conditions (3.82 m^3/sec) (Figure 4), with the worst conditions (black disc clarity of 0.57 m) on the rising stage of a flood flow (79 m^3/sec) in April 2015 when the turbidity increased (15 NTU) and there was a marked increase in suspended solids concentration (71 g/m^3). Generally, poorer water quality was recorded at the time of this flood flow when significantly elevated faecal coliform bacterial numbers (27000 number/100 ml) and increased colour (absorbances @ 340 nm and 440 nm), together with decreased clarity and conductivity, were recorded.

A maximum pH value of 8.2 was recorded under low flow conditions in early spring with values above 7.9 units during very low summer flow conditions. pH values could be expected to have risen further later in the day, as all sampling at this site was undertaken no later than 0915 hrs.

Very good water quality was indicated by high dissolved oxygen concentrations (median saturation of 102%) and low BOD_5 levels (median of < 0.5 g/m^3). Bacteriological quality was moderate, with median faecal coliform and enterococci numbers (290 and 175 per 100 mls respectively) typically reflecting agricultural catchment influences in the relative infrequency of freshes during, or immediately prior to, sampling surveys during 2014-2015.

River water temperatures recorded a moderate range of 9.0 °C during the period with a maximum mid-morning water temperature of 16.2 °C recorded in January 2015 during a lengthy period of low flow conditions.

Brief comparison with the previous 1995-2013 period

River water quality measured by the 2014-2015 survey in many aspects was generally slightly poorer than that recorded over the previous nineteen-year period. Median black disc clarity was worse (by 0.28 m) with median turbidity higher by 0.1 NTU, but median suspended solids levels were identical between periods. Bacteriological water quality was poorer in terms of median faecal coliform number (by 80 per 100 mls) and for median enterococci number (by 81 per 100mls). A much narrower range of water temperatures (by 4.5 °C) was recorded in the most recent twelve-month period. Median water temperature was 0.3 °C higher in the most recent period while the maximum temperature was 2.1 °C lower than that recorded during the previous nineteen years.

Median sampled flow over the 2014-2015 period was higher (by 439 l/sec) than for the flows sampled in the previous nineteen-year period coincident with a few fresh events despite the low flows between mid-summer and autumn sampled during the latest period.

Median concentrations for nitrogen nutrient species were slightly lower or very similar in the 2014-2015 period to those in the longer period while there were small increases in the median phosphorus species in more recent period.

No significant differences were recorded in terms of the medians of BOD_5 and percentage dissolved oxygen between the two periods although the latter rose by 2% over the most recent period.

Stony River at Mangatete Road (site: STY000300)

Analytical data from the monthly samples are presented in Table 12.

Table 12 Analytical results from monthly samples: Stony River at Mangatete Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ CaCO₃)	Black disc (m)	BOD₅ (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
09 Jul 2014	0955	0.006	0.001	0.000	42	4.53	<0.5	10.0	11.8	101	0.016	21	1
13 Aug 2014	1030	0.014	0.004	0.001	26	0.16	<0.5	7.3	12.1	102	0.014	1	<1
10 Sep 2014	1010	0.005	0.001	0.000	52	3.23	<0.5	12.3	11.6	104	0.019	1	62
08 Oct 2014	0915	0.006	0.001	0.000	39	3.26	<0.5	9.8	11.5	103	0.028	5	8
12 Nov 2014	0905	0.038	0.009	0.000	21	1.02	<0.5	5.6	11.3	102	0.010	31	7
10 Dec 2014	0930	0.008	0.002	0.000	38	1.60	<0.5	9.6	10.4	102	0.016	640	250
14 Jan 2015	0915	0.005	0.001	0.000	52	5.47	<0.5	12.4	10.4	100	0.020	5	8
11 Feb 2015	0900	0.006	0.001	0.000	49	6.81	<0.5	11.8	10.4	101	0.029	7	13
11 Mar 2015	0915	0.006	0.001	0.000	45	5.83	<0.5	11.3	10.4	101	0.021	9	12
08 Apr 2015	0950	0.070	0.016	0.001	11	0.17	1.8	3.3	10.1	101	0.006	700	870
13 May 2015	1015	0.019	0.006	0.000	25	0.22	<0.5	7.2	10.9	101	0.016	2	4
10 Jun 2015	1000	0.009	0.002	0.000	32	2.72	<0.5	8.8	11.0	101	0.013	4	4
Date	**Time (NZST)**	**FC (Nos/ 100ml)**	**Flow (m³/s)**	**NH₄ (g/m³N)**	**NO₂ (g/m³N)**	**NO₃ (g/m³N)**	**pH**	**SS (g/m³)**	**Temp (°C)**	**TKN (g/m³N)**	**TN (g/m³N)**	**TP (g/m³P)**	**Turb (NTU)**
09 Jul 2014	0955	21	3.280	<0.003	<0.001	0.079	7.7	<2	7.9	0.03	0.11	0.018	0.65
13 Aug 2014	1030	1	5.807	<0.003	<0.001	0.029	7.7	54	7.0	0.02	<0.05	0.096	27
10 Sep 2014	1010	1	2.400	<0.003	<0.001	0.009	8.1	<2	9.7	0.04	<0.05	0.019	0.65
08 Oct 2014	0915	5	3.329	0.004	<0.001	0.009	7.9	<2	9.3	0.04	<0.05	0.028	0.65
12 Nov 2014	0905	33	7.780	0.003	<0.001	0.009	7.6	12	8.7	0.04	<0.05	0.022	3.2
10 Dec 2014	0930	640	4.114	0.006	0.001	0.019	7.8	7	13.1	0.03	<0.05	0.028	2.0
14 Jan 2015	0915	5	2.355	0.006	<0.001	0.009	8.0	<2	13.8	0.04	<0.05	0.024	0.50
11 Feb 2015	0900	8	2.544	<0.003	<0.001	0.009	7.9	<2	13.3	0.04	<0.05	0.030	0.45
11 Mar 2015	0915	9	2.507	<0.003	<0.001	0.019	8.0	<2	13.2	0.03	<0.05	0.028	0.60
08 Apr 2015	0950	830	55	<0.003	<0.001	0.009	7.2	88	14.3	0.21	0.22	0.070	32
13 May 2015	1015	2	4.485	<0.003	<0.001	0.059	7.3	51	10.8	0.04	0.10	0.090	18
10 Jun 2015	1000	4	6.509	0.006	<0.001	0.049	7.6	7	10.5	0.00	<0.05	0.020	1.3

The statistical summary of this data is presented in Table 13.

Table 13 Statistical summary of data from July 2013 to July 2014 Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.005	0.070	0.007	12	0.019
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.016	0.002	12	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	11	52	38	12	13
BDISC	Black disc transparency	m	0.16	6.81	2.98	12	2.35
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	1.8	< 0.5	12	0.4
CONDY	Conductivity @ 20˚C	mS/m	3.3	12.4	9.7	12	2.8
DO	Dissolved oxygen	g/m^3	10.1	12.1	11	12	0.7
PERSAT	Dissolved oxygen saturation %	%	100	104	101	12	1
DRP	Dissolved reactive phosphorus	g/m^3P	0.006	0.029	0.016	12	0.007
ECOL	E.coli bacteria	nos/100 ml	1	700	6	12	258
ENT	Enterococci bacteria	nos/100 ml	< 1	870	8	12	251
FC	Faecal coliforms	nos/100 ml	1	830	6	12	286
FLOW	Flow	m^3/s	2.355	55	3.722	12	14.8
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.006	< 0.003	12	0.001
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.001	< 0.001	12	0
NO_3	Nitrate nitrogen	g/m^3N	< 0.01	0.08	0.015	12	0.024
pH	pH		7.2	8.1	7.8	12	0.3
SS	Suspended solids	g/m^3	< 2	88	4	12	29
TEMP	Temperature	°C	7.0	14.3	10.6	12	2.5
TKN	Total kjeldahl nitrogen	g/m^3N	< 0.01	0.21	0.04	12	0.05
TN	Total nitrogen	g/m^3N	< 0.05	0.22	< 0.05	12	0.05
TP	Total phosphorus	g/m^3P	0.018	0.096	0.028	12	0.029
TURB	Turbidity	NTU	0.5	32	1.0	12	11.54

A statistical summary of the nineteen years' data collected since 1 July 1995, is presented in Table 14.

Table 14 Statistical summary of data from July 1995 to June 2014: Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.000	0.077	0.009	240	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.028	0.002	240	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.007	0.000	240	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	5	57	38	240	12
BDISC	Black disc transparency	m	0.01	13.12	3.25	240	2.739
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	1.8	< 0.5	240	0.1
CONDY	Conductivity @ 20˚C	mS/m	2.8	13.3	9.7	240	2.4
DO	Dissolved oxygen	g/m^3	9.4	12.2	10.8	240	0.6
PERSAT	Dissolved oxygen saturation %	%	87	104	99	242	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.210	0.018	240	0.014
ECOL	E.coli bacteria	nos/100 ml	< 1	950	7	216	106
ENT	Enterococci bacteria	nos/100 ml	< 1	870	5	240	74
FC	Faecal coliforms	nos/100 ml	< 1	1000	8	240	107
FLOW	Flow	m^3/s	1.988	55.50	3.592	240	7.733
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.020	< 0.003	240	0.003
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.004	<0.001	240	0
NO_3	Nitrate nitrogen	g/m^3N	< 0.01	0.11	0.02	240	0.018
pH	pH		7.0	8.2	7.8	240	0.2
SS	Suspended solids	g/m^3	< 2	2500	< 2	240	312
TEMP	Temperature	°C	5.7	16.6	10.8	240	2.5
TKN	Total kjeldahl nitrogen	g/m^3N	< 0.01	1.78	0.04	240	0.167
TN	Total nitrogen	g/m^3N	0.02	1.82	0.06	240	0.168
TP	Total phosphorus	g/m^3P	0.008	3.38	0.024	240	0.304
TURB	Turbidity	NTU	0.2	700	0.8	239	67.14

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

Discussion

2013-2014

Black disc clarity and turbidity results, which more often in the past have indicated generally good river water quality in terms of appearance for the mid-reaches of a Taranaki ring plain river, have also showed significant deterioration in aesthetic quality from time to time as a result of severe erosion in the headwaters of this river during winter and spring floods in 1998-1999 and again following an intensive, prolonged wet period in February 2004. Some improvement occurred in 2004-2005 and continued through most of the 2005-2006 period but conditions deteriorated markedly following the very wet spring conditions in 2006, near mid winter 2008, and in mid winter 2009. No significant headwater erosion events were identified over the 2009-2010 period, but headwater erosion was recorded again in late May - early June 2011. Further erosion events in the headwaters were recorded during a dry period in February 2014 (see Photo 3, TRC 2014), and briefly late in November 2015. Some headwater erosion was indicated in autumn, 2015 when the minimum black disc value (0.17) and elevated turbidity (32 NTU) and suspended solids (88 g/m^3) values were recorded under flood conditions (55 m^3/sec). Wet weather and fresh flow conditions in August and November 2014 were reflected in black disc clarities of 0.16 and 0.2 m and turbidity values of 27 NTU and 3.2 NTU with a elevations in suspended solids concentrations (54 g/m^3 and 128 g/m^3) and increase in faecal coliform bacterial level (33 nos/100 mls) on one occasion but not to the extent found in other ringplain streams following such freshes. The maximum black disc clarity of 6.81 m was measured in late summer under very low flow conditions coincident with the very low suspended solids and turbidity (0.5 NTU) levels.

Maximum mid-morning pH (8.1) under early spring relatively low flow conditions while the median pH (7.8) was equivalent with the median of past years' results. Dissolved oxygen concentrations were consistently high with a minimum saturation of 100% and BOD_5 levels were below the detectable limit on all but one occasion the elevated result (1.8 g/m^3) recorded under flood conditions; a further indication of high water quality when not influenced by severe erosion events.

Bacteriological water quality was very high with median faecal coliform and enterococci numbers (6 and 8 per 100 mls respectively) indicative of minimal impact of upstream developed farmland at this site near mid-catchment, although there were two instances of elevation in counts under fresh flow conditions.

River water temperatures varied over a moderate range of 7.3 °C during the period, with a maximum mid-morning temperature of 14.3 °C recorded in autumn (April 2015) under flood flow conditions.

Nutrient levels were generally very low in terms of median ammoniacal nitrogen, nitrate-N, and dissolved reactive phosphorus concentrations (all ≤0.02 g/m^3). Total nitrogen and total phosphorus concentrations were also relatively low throughout the year, with the exception of elevations in TP and TN at the time of the April 2015 flood event coincident with increased suspended solids concentrations and also elevations in TP and suspended solids concentrations coincident with freshes in August, 2014 and May, 2015 freshes.

Brief comparison with the previous 1995-2014 period

Water quality measured during the 2014-2015 survey period, in comparison with the previous nineteen years' survey results, was poorer aesthetically in terms of median black disc clarity (which was lower by 0.34 m), median turbidity (higher by 0.2 NTU), and suspended solids level which was higher (by 2 g/m^3) than the historical median.

Median bacteriological water quality was very similar in the latest period, as both periods had very high quality with all median faecal coliform and enterococci counts below 10 per 100 mls.

Water temperature range was narrower (by 3.6 °C) mainly due to a lower maximum temperature during 2014-2015, with the median slightly low (0.2 °C cooler) in the 2014-2015 period to that in the earlier nineteen-year period. All median nutrient species were lower or relatively similar to the previous longer period medians with the exception of TP which was 17% higher in the most recent period.

Median sampled flow during the 2014-2015 period was slightly higher (by 0.13 m^3/sec) than the median of flows sampled over the previous nineteen-year period, with a few freshes and one flood event (in excess of 50 m^3/sec) and a relatively lengthy mid-summer early autumn low flow period sampled in 2014-2015. The relative similarities in median flows was reflected in the identical median conductivity values over the 2014-2015 period and longer term periods.

Punehu Stream at Wiremu Road (site: PNH000200)

Analytical data are presented in Table 15 from the monthly samples.

Table 15 Analytical results from the monthly samples: Punehu Stream at Wiremu Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ $CaCO_3$)	Black disc (m)	BOD_5 (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
09 Jul 2014	1025	0.029	0.006	0.000	25	1.43	<0.5	9.0	11.8	101	0.014	150	5
13 Aug 2014	1055	0.058	0.012	0.001	13	1.49	<0.5	7.4	11.8	102	0.014	17	4
10 Sep 2014	1050	0.023	0.005	0.000	23	1.60	<0.5	8.8	11.6	103	0.027	24	4
08 Oct 2014	0950	0.028	0.006	0.000	21	1.50	<0.5	8.7	11.2	103	0.027	40	1
12 Nov 2014	0945	0.080	0.018	0.001	13	1.01	0.6	6.4	11.0	103	0.015	2100	140
10 Dec 2014	1000	0.034	0.008	0.001	24	1.74	<0.5	8.6	9.8	103	0.023	240	28
14 Jan 2015	0945	0.024	0.005	0.000	25	3.20	<0.5	8.6	9.5	101	0.033	74	17
11 Feb 2015	0950	0.027	0.005	0.000	25	2.99	<0.5	8.8	10.4	103	0.039	85	48
11 Mar 2015	0955	0.026	0.006	0.000	22	1.58	1.2	9.6	10.1	103	0.031	810	360
08 Apr 2015	1020	0.028	0.007	0.001	24	1.34	0.5	9.6	9.8	103	0.030	430	690
13 May 2015	1050	0.060	0.013	0.000	12	1.98	<0.5	8.9	10.6	101	0.012	40	28
10 Jun 2015	1035	0.031	0.007	0.000	17	1.76	<0.5	9.4	10.9	102	0.016	16	12
Date	**Time (NZST)**	**FC (Nos/ 100ml)**	**Flow (m³/s)**	**NH_4 (g/m³N)**	**NO_2 (g/m³N)**	**NO_3 (g/m³N)**	**pH**	**SS (g/m³)**	**Temp (°C)**	**TKN (g/m³N)**	**TN (g/m³N)**	**TP (g/m³P)**	**Turb (NTU)**
09 Jul 2014	1025	150	0.463	0.017	0.002	0.108	7.4	<2	7.1	0.09	0.20	0.058	2.8
13 Aug 2014	1055	17	1.245	0.020	0.001	0.089	7.4	3	7.5	0.12	0.21	0.022	2.5
10 Sep 2014	1050	24	0.305	0.007	<0.001	0.029	7.8	<2	9.0	0.05	0.08	0.030	2.1
08 Oct 2014	0950	58	0.477	0.024	<0.001	0.039	7.7	<2	10.0	0.12	0.16	0.029	2.4
12 Nov 2014	0945	2100	1.588	0.011	0.002	0.018	7.4	3	9.8	0.19	0.21	0.038	2.3
10 Dec 2014	1000	250	0.409	0.021	0.002	0.028	7.6	<2	15.8	0.04	0.07	0.029	2.6
14 Jan 2015	0945	77	0.242	<0.003	<0.001	0.009	7.7	<2	16.6	0.04	<0.05	0.038	1.2
11 Feb 2015	0950	86	0.292	0.004	<0.001	0.009	7.7	<2	13.7	0.04	<0.05	0.044	1.2
11 Mar 2015	0955	810	0.274	0.006	<0.001	0.029	7.8	2	14.6	0.21	0.24	0.044	1.8
08 Apr 2015	1020	430	0.356	0.004	<0.001	0.009	7.6	3	16.4	0.07	0.08	0.039	2.7
13 May 2015	1050	40	0.988	0.020	0.002	0.198	7.0	15	11.5	0.10	0.30	0.022	1.6
10 Jun 2015	1035	16	0.588	0.052	0.001	0.099	7.6	2	11.1	0.05	0.15	0.022	3.3

The statistical summary of this data is presented in Table 16.

Table 16 Statistical summary of data from July 2014 to June 2015 Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.023	0.080	0.028	12	0.018
A440F	Absorbance @ 440nm filtered	/cm	0.005	0.018	0.006	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	12	25	22	12	5
BDISC	Black disc transparency	m	1.01	3.20	1.59	12	0.65
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	1.2	< 0.5	12	0.2
CONDY	Conductivity @ 20˚C	mS/m	6.4	9.6	8.8	12	0.9
DO	Dissolved oxygen	g/m^3	9.5	11.8	10.8	12	0.8
PERSAT	Dissolved oxygen saturation %	%	101	103	103	12	1
DRP	Dissolved reactive phosphorus	g/m^3P	0.012	0.039	0.025	12	0.009
ECOL	E.coli bacteria	nos/100 ml	16	2100	80	12	603
ENT	Enterococci bacteria	nos/100 ml	1	690	22	12	209
FC	Faecal coliforms	nos/100 ml	16	2100	82	12	602
FLOW	Flow	m^3/s	0.242	1.588	0.436	12	0.436
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.052	0.014	12	0.014
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.002	0.001	12	0
NO_3	Nitrate nitrogen	g/m^3N	< 0.01	0.20	< 0.03	12	0.058
pH	pH		7.0	7.8	7.6	12	0.2
SS	Suspended solids	g/m^3	< 2	15	< 2	12	4
TEMP	Temperature	°C	7.1	16.6	11.3	12	3.4
TKN	Total kjeldahl nitrogen	g/m^3N	0.04	0.21	0.08	12	0.06
TN	Total nitrogen	g/m^3N	0.05	0.30	0.16	12	0.08
TP	Total phosphorus	g/m^3P	0.022	0.058	0.034	12	0.011
TURB	Turbidity	NTU	1.2	3.3	2.4	12	0.7

A statistical summary of the twenty years' data collected since 1 July 1995, is presented in Table 17.

Table 17 Statistical summary of data from July 1995 to July 2015: Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.017	0.144	0.033	240	0.023
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.032	0.007	240	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.005	0.000	240	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	6	27	22	240	5
BDISC	Black disc transparency	m	0.080	4.53	1.81	240	0.871
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	3.0	< 0.5	240	0.3
CONDY	Conductivity @ 20˚C	mS/m	4.0	10.9	8.6	240	1.2
DO	Dissolved oxygen	g/m^3	8.9	12.5	10.4	239	0.8
PERSAT	Dissolved oxygen saturation %	%	87	106	100	239	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.007	0.389	0.023	240	0.026
ECOL	E.coli bacteria	nos/100 ml	3	6100	110	216	830
ENT	Enterococci bacteria	nos/100 ml	< 1	1200	34	240	161
FC	Faecal coliforms	nos/100 ml	3	6100	120	240	845
FLOW	Flow	m^3/s	0.180	12.380	0.437	240	1.12
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.078	0.006	240	0.01
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.014	0.001	240	0.001
NO_3	Nitrate nitrogen	g/m^3N	< 0.01	0.20	0.03	240	0.042
pH	pH		6.9	8.3	7.6	240	0.2
SS	Suspended solids	g/m^3	< 2	160	< 2	240	13
TEMP	Temperature	°C	5.0	19.2	11.8	240	3.3
TKN	Total kjeldahl nitrogen	g/m^3N	0.010	0.850	0.090	240	0.124
TN	Total nitrogen	g/m^3N	< 0.05	0.870	0.15	240	0.136
TP	Total phosphorus	g/m^3P	0.015	0.413	0.034	240	0.039
TURB	Turbidity	NTU	0.5	29	1.7	239	3.15

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

Discussion

2014-2015

Although black disc clarity and turbidity results were indicative of relatively good water quality in terms of aesthetic appearance, these values continued to be poorer than might be anticipated for the upper reaches of a ring plain stream, i.e. medians of 1.59 m (black disc) and 2.4 NTU (turbidity). This was related to the open nature of the reaches of both the stream and the upstream tributary draining developed farmland catchment immediately downstream of the National Park through the 2 km reach upstream of this site. This area had also been subject to stock access in the past (see photos in TRC 2000 and 2011) although in recent years the banks have been fenced and planted in the immediate vicinity of the site.

Minimum black disc clarity (1.01 m) was recorded during a small fresh in November 2014 following a number of freshes in the preceding two weeks and coincidental with a minor increase in suspended solids concentration (3 g/m^3) and minimal change in turbidity (2.3 NTU). A small increase in total phosphorus concentration, but marked increase in E coli and faecal coliform bacteria number were also recorded on this one occasion. A maximum black disc value of 3.20 m was measured under very low flow conditions in mid-summer (January 2015).

The maximum pH (7.8) was recorded (in mid morning) on two occasions during early spring and early autumn, under low flow conditions (305 L/sec and 274 L/sec respectively).

Dissolved oxygen concentrations were consistently high (101 to 103% saturation for the period) and BOD_5 levels were very low and less than 0.5 g/m^3 on the majority of occasions; further indications of generally high water quality. An elevation in BOD_5 (1.2 g/m^3) was coincident with very low flow conditions in early autumn.

A moderate median faecal coliform bacterial count for the upper reaches of a ring plain stream (82 per 100 mls) indicated some impacts of upstream farmland run-off (and possible stock access) on stream water quality at this site, and represented some deterioration below the National Park boundary in this aspect of water quality. Surface runoff from surrounding farmland has been a common feature in the past in this reach of the stream and three small freshes were sampled during the 2014-2015 period, similar to many previous periods, resulting in a relatively typical median for the latest period.

Water temperatures varied over a relatively wide range (9.5 °C) for the upper reaches of a ring plain stream, reflecting the bouldery, open nature of the reach below the National Park. A maximum mid morning water temperature of 16.6 °C was recorded in January 2015, relatively high for the upper reaches of a ring plain stream at this time of the day (0945 hrs).

Brief comparison with the previous 1995-2014 period

Stream water quality measured during the 2014-2015 period, was relatively poorer in terms of median turbidity (which increased by 0.7 NTU) and median black disc clarity (which decreased by 0.29 m) than the previous overall record. Median suspended solids concentration remained low and in the recent year was equivalent with the median of the previous nineteen-year period. Median dissolved oxygen percentage saturation levels were very similar (within 3%) for both periods.

Bacteriological water quality improved over the most recent period in terms of median faecal coliform number (by 38 °C 100 ml) and median numbers of enterococci (by 14 per 100 ml). Most nitrogen species' median concentrations tended to be very similar in the recent year, while median ammonia-N was markedly higher (by 133%) and median DRP was slightly higher.

The water temperature range was narrower (by 4.7 °C) compared with surveys prior to the latest twelve-month period; with the median flow sampled almost identical higher in the 2014-2014 period. The narrower temperature range was partly caused by a lower maximum temperature (by 2.6 °C) in 2014-2015 than the previous maximum recorded.

Median pH values were within 0.1 unit during the two sampling periods but the maximum pH was 0.5 unit lower than the maximum recorded in the previous nineteen-year period.

Punehu Stream at SH45 (site: PNH000900)

Analytical data are presented in Table 18 from the monthly samples. The flow data in Table 18 presents actual flows at the site at the time of sampling. Previously, data from a NIWA flow recording station elsewhere in the catchment was used by the Council to provide a synthesized flow rate at this site, but the station in this stream is no longer operated by NIWA.

Table 18 Analytical results from monthly samples: Punehu Stream at SH45

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ $CaCO_3$)	Black disc (m)	BOD_5 (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
09 Jul 2014	1045	0.029	0.005	0.000	34	1.07	1.0	19.9	11.6	100	0.021	130	46
13 Aug 2014	1120	0.044	0.009	0.001	24	0.82	0.7	15.7	11.8	102	0.025	330	60
10 Sep 2014	1130	0.032	0.006	0.000	39	1.50	1.2	19.1	11.4	102	0.062	1200	7300
08 Oct 2014	1020	0.029	0.006	0.000	34	1.23	0.7	18.5	10.9	101	0.055	340	62
12 Nov 2014	1015	0.058	0.013	0.001	31	0.30	3.8	14.4	10.8	102	0.044	21000	4200
10 Dec 2014	1020	0.040	0.008	0.000	38	1.32	1.4	17.1	9.7	101	0.068	830	480
14 Jan 2015	1015	0.042	0.009	0.000	42	2.12	1.0	17.4	9.3	100	0.084	1200	3600
11 Feb 2015	1025	0.041	0.008	0.000	38	2.32	1.1	15.1	10.1	100	0.080	850	2600
11 Mar 2015	1020	0.043	0.009	0.000	35	2.10	0.8	14.9	9.5	99	0.058	740	2700
08 Apr 2015	1045	0.052	0.012	0.001	37	1.38	1.3	15.6	9.2	97	0.082	2200	14000
13 May 2015	1120	0.048	0.010	0.000	21	1.27	1.8	18.5	10.6	100	0.042	870	760
10 Jun 2015	1105	0.026	0.005	0.000	30	1.48	1.0	21.2	10.6	100	0.028	230	120

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m³/s)	NH_4 (g/m³N)	NO_2 (g/m³N)	NO_3 (g/m³N)	pH	SS (g/m³)	Temp (°C)	TKN (g/m³N)	TN (g/m³N)	TP (g/m³P)	Turb (NTU)
09 Jul 2014	1045	130	1.133	0.040	0.014	2.596	7.5	3	8.9	0.45	3.06	0.041	2.4
13 Aug 2014	1120	350	2.797	0.072	0.011	2.189	7.5	7	8.5	0.32	2.52	0.062	3.4
10 Sep 2014	1130	1200	0.582	0.114	0.040	1.640	7.8	<2	10.8	0.32	2.00	0.086	2.3
08 Oct 2014	1020	350	1.107	0.110	0.046	1.964	7.7	3	11.8	0.42	2.43	0.071	2.1
12 Nov 2014	1015	21000	2.579	0.168	0.031	1.019	7.5	15	11.7	0.93	1.98	0.174	14
10 Dec 2014	1020	830	0.693	0.034	0.033	1.277	7.6	2	17.0	0.17	1.48	0.102	2.3
14 Jan 2015	1015	1200	0.385	0.026	0.016	0.984	7.7	2	18.7	0.34	1.34	0.121	2.0
11 Feb 2015	1025	850	0.419	0.018	0.003	0.457	7.6	3	15.5	0.08	0.54	0.100	1.6
11 Mar 2015	1020	800	0.394	0.026	<0.004	0.376	7.7	<2	17.7	0.11	0.49	0.081	1.2
08 Apr 2015	1045	2200	0.455	0.024	0.006	0.504	7.5	2	18.2	0.30	0.81	0.110	2.0
13 May 2015	1120	870	2.984	0.070	0.016	3.404	7.1	5	12.6	0.14	3.56	0.078	2.2
10 Jun 2015	1105	250	1.597	0.041	0.010	3.020	7.6	4	13.1	0.32	3.35	0.050	2.6

The statistical summary of this data is presented in Table 19.

Table 19 Statistical summary of data from July 2014 to June 2015 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.026	0.058	0.042	12	0.01
A440F	Absorbance @ 440nm Filtered	/cm	0.005	0.013	0.008	12	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	21	42	34	12	6
BDISC	Black disc transparency	m	0.30	2.32	1.35	12	0.57
BOD_5	Biochemical oxygen demand 5day	g/m³	0.7	3.8	1.0	12	0.8
CONDY	Conductivity @ 20'C	mS/m	14.4	21.2	17.2	12	2.2
DO	Dissolved Oxygen	g/m³	9.2	11.8	10.6	12	0.9
PERSAT	Dissolved Oxygen Saturation %	%	97	102	100	12	1
DRP	Dissolved reactive phosphorus	g/m³P	0.021	0.084	0.056	12	0.022
ECOL	E.coli bacteria	nos/100 ml	130	21000	840	12	5855
ENT	Enterococci bacteria	nos/100 ml	46	14000	1680	12	4125
FC	Faecal Coliforms	nos/100 ml	130	21000	840	12	5852
FLOW	Flow	m³/s	0.385	2.984	0.900	12	0.995
NH_4	Ammoniacal nitrogen	g/m³N	0.018	0.168	0.040	12	0.047
NO_2	Nitrite nitrogen	g/m³N	0.003	0.046	0.015	12	0.015
NO_3	Nitrate nitrogen	g/m³N	0.38	3.40	1.46	12	1.025
PH	pH		7.1	7.8	7.6	12	0.2
SS	Suspended solids	g/m³	< 2	15	3	12	4
TEMP	Temperature	°C	8.5	18.7	12.8	12	3.6
TKN	Total Kjeldahl nitrogen	g/m³N	0.08	0.93	0.32	12	0.22
TN	Total nitrogen	g/m³N	0.49	3.56	1.99	12	1.06
TP	Total phosphorus	g/m³P	0.041	0.174	0.084	12	0.036
TURB	Turbidity	NTU	1.2	14	2.2	12	3.6

A statistical summary of the twenty years' data collected since 1 July 1995, is presented in Table 20.

Table 20 Statistical summary of data from July 1995 to June 2015 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.015	0.115	0.040	240	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.027	0.008	240	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.006	0.000	240	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	10	46	34	240	7
BDISC	Black disc transparency	m	0.055	3.57	1.50	240	0.685
BOD_5	Biochemical oxygen demand 5day	g/m³	< 0.5	8.1	1.0	240	0.9
CONDY	Conductivity @ 20'C	mS/m	5.8	21.8	16.0	240	2.4
DO	Dissolved Oxygen	g/m³	8.6	12.8	10.4	240	0.8
PERSAT	Dissolved Oxygen Saturation %	%	90	114	99	240	3
DRP	Dissolved reactive phosphorus	g/m³P	0.013	0.212	0.044	240	0.027
ECOL	E.coli bacteria	nos/100 ml	48	21000	485	214	2563
ENT	Enterococci bacteria	nos/100 ml	15	14000	320	239	1528
FC	Faecal Coliforms	nos/100 ml	51	21000	520	240	2816
FLOW	Flow	m³/s	0.242	12.300	0.803	240	1.556
NH_4	Ammoniacal nitrogen	g/m³N	0.004	0.376	0.040	240	0.061
NO_2	Nitrite nitrogen	g/m³N	< 0.001	0.110	0.014	240	0.015
NO_3	Nitrate nitrogen	g/m³N	0.07	3.4	0.93	240	0.673
PH	pH		7.1	8.6	7.7	240	0.2
SS	Suspended solids	g/m³	< 2	220	3	240	21
TEMP	Temperature	°C	5	21.0	13.2	240	3.5
TKN	Total Kjeldahl nitrogen	g/m³N	0.040	1.990	0.320	240	0.27
TN	Total nitrogen	g/m³N	0.26	3.96	1.38	240	0.772
TP	Total phosphorus	g/m³P	0.026	0.531	0.080	240	0.061
TURB	Turbidity	NTU	0.9	50	1.9	239	5

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

Discussion

2014-2015 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.35 m, this clarity being typical of the lower reaches of developed ringplain catchments. A median suspended solids concentration of 3 g/m^3 and turbidity of 2.2 NTU were also more typical of the lower reaches of a ring plain catchment. Minimum clarities (black disc of 0.30 m, turbidity of 14 NTU, and suspended solids concentration of 15 g/m^3) were recorded during a small fresh (of 2.58 m^3/sec) in November 2014. Deterioration in other water quality parameters under these conditions was shown by elevations in total phosphorus, and BOD_5 concentrations and marked increases in bacterial numbers.

pH peaked at 7.8 (in early spring) and 7.7 (in early autumn) under low and very low flow conditions respectively, but these values were recorded in late morning and would be expected to have reached a higher level later in the day. These values were up to 0.8 unit lower than the maximum recorded previously at a similar time of the day.

Although dissolved oxygen concentrations remained consistently high (minimum of 97% saturation), BOD_5 concentrations often indicated low levels of organic enrichment (ie $\geq$1 g/m^3).

The very high median bacteriological numbers (1680 enterococci and 840 faecal coliforms per 100 mls) were further indicative of the impacts of developed farmland run-off and point source discharges on the water quality of the lower reaches of a ring plain catchment. The wide range of faecal coliform numbers (800 to 2,200 per 100 mls) found during spring to autumn lower flow conditions were indicative of point source discharges of pond system treated dairy sheds' wastes and/or stock access (see TRC, 2011). Relatively high median nutrient levels were consistent with such impacts.

Water temperature varied over a moderate range of 10.2 ˚C with a maximum summer (late morning) temperature of 18.7 ˚C recorded in January 2015 and the lowest temperature (8.5 ˚C) recorded in August 2014; the former 2.3 ˚C below the previous maximum temperature and the latter 3.5˚C above the previous minimal temperature.

Brief comparison of upper and lower Punehu Stream sites during the 2014-2015 period

Downstream deterioration in certain aspects of water quality in the lower stream reaches was emphasised by a very significant increase in median bacteriological numbers (758 faecal coliforms per 100 mls and 1658 enterococci per 100 mls), and median nutrient concentrations (particularly nitrogen species), with nitrate, total nitrogen, and total phosphorus increasing by factors of about 50, 12, and 2.5 times respectively. These downstream spatial trends may be compared with median twenty-year historical data which indicate bacterial increases of 390 per 100 mls (faecal coliforms) and 286 per 100 mls (enterococci) and increases in nitrate, total nitrogen, and total phosphorus of 31, 9, and 2 times respectively. Relatively similar median (2014-2015) turbidity levels and suspended solids concentrations were found, with a very small decrease in median black disc clarity (15% reduction) between sites compared with the historical median turbidity increase of only 0.2 NTU and decrease in median black disc clarity of 0.31 m. Some of these changes are more apparent when mass loadings are calculated, taking into account the increased flow at the lower site (e.g. median flow increased by 84% in the lower reaches of the stream). The downstream water temperature range increased by only 1.8 ˚C while the median increased by only 1.4 ˚C. The long term median pH increased by only 0.1 unit in the lower reaches.

The differences between upper and lower stream clarity (black disc), turbidity, pH and temperature ranges may have been greater but for the impact of the open, developed farmland on the reach between the National Park and the upper site at Wiremu Road.

Brief comparison with the previous 1995-2014 period

Very similar aesthetic water quality was indicated with a small increase in median turbidity recorded during the more recent twelve-month survey period, decrease in median black disc clarity of 0.19 m, but no change in median suspended solids concentration.

In the more recent survey period a marked deterioration was recorded in median faecal coliform bacterial number (of 325 per 100 mls) and in median enterococci bacteria number (by 1360 per 100 mls). Marked deterioration in median nutrient species concentrations were recorded for nitrate N, and total nitrogen which increased by about 58 %, and 46 % of the long term medians respectively, with slightly lower increase of 27 % in dissolved reactive phosphorus, much lower increase of 5 % for total phosphorus, and minimal change in ammonia nitrogen.

Median dissolved oxygen saturation levels were within 1% and median BOD_5 levels were identical for the most recent and longer term periods.

There was minimal difference in median pH for the 2014-2015 period although the maximum pH was 0.8 unit lower in comparison with the previous nineteen-year period.

Water temperature range was much narrower (by 5.8 ˚C); this decrease due to both higher minimum and lower maximum water temperatures (both by at least 2.3 ˚C) over the recent survey period, with the 2014-2015 median water temperature 0.5 ˚C lower than the median nineteen year temperature.

Median sampled flow over the 2014-2015 period was above the median sampled (by 97 l/sec) flow for the previous nineteen-year period, despite a very low flow period over mid-summer to autumn 2015.

Waingongoro River at Eltham Road (site: WGG000500)

Analytical data are presented in Table 21 from the monthly sampling programme. The river flow recorded at this site for the twelve-month period is presented in Figure 5.

Table 21 Analytical results from monthly samples: Waingongoro River at Eltham Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ $CaCO_3$)	Black disc (m)	BOD_5 (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
09 Jul 2014	11:55	0.011	0.002	0.000	30	0.91	0.6	11.4	11.3	101	0.014	92	21
13 Aug 2014	1235	0.015	0.003	0.000	25	1.33	<0.5	10.0	11.4	102	0.023	200	51
10 Sep 2014	1245	0.015	0.003	0.000	33	2.14	<0.5	11.6	12.0	110	0.025	14	15
08 Oct 2014	1145	0.012	0.003	0.000	29	2.13	<0.5	10.6	11.1	108	0.028	20	17
12 Nov 2014	1145	0.016	0.004	0.000	31	1.22	1.1	10.7	10.8	106	0.025	330	24
10 Dec 2014	1130	0.022	0.005	0.000	36	1.30	1.2	11.9	9.8	103	0.036	460	160
14 Jan 2015	1125	0.026	0.006	0.000	39	2.28	0.9	12.0	10.1	111	0.035	190	44
11 Feb 2015	1140	0.028	0.006	0.000	43	2.00	<0.5	12.4	10.2	105	0.064	280	260
11 Mar 2015	1130	0.029	0.007	0.001	36	2.30	0.8	10.9	10.0	103	0.032	370	440
08 Apr 2015	1205	0.032	0.009	0.001	40	1.79	0.8	11.6	9.5	100	0.043	720	2200
13 May 2015	1240	0.022	0.005	0.000	22	1.02	1.4	9.9	10.5	100	0.030	480	850
10 Jun 2015	1220	0.013	0.003	0.000	27	1.56	0.8	11.8	10.9	102	0.019	150	54

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m³/s)	NH_4 (g/m³N)	NO_2 (g/m³N)	NO_3 (g/m³N)	pH	SS (g/m³)	Temp (°C)	TKN (g/m³N)	TN (g/m³N)	TP (g/m³P)	Turb (NTU)
09 Jul 2014	1155	96	2.853	0.013	0.006	1.944	7.5	6	9.3	0.11	2.06	0.056	2.0
13 Aug 2014	1235	200	4.125	0.038	0.005	1.535	7.6	6	9.2	0.25	1.79	0.046	2.1
10 Sep 2014	1245	14	1.087	0.012	0.007	1.273	8.1	<2	10.6	0.04	1.32	0.025	1.3
08 Oct 2014	1145	20	3.007	0.033	0.009	1.541	7.9	2	12.7	0.26	1.81	0.042	1.2
12 Nov 2014	1145	340	2.481	0.056	0.013	1.187	7.8	4	12.3	0.42	1.62	0.056	1.8
10 Dec 2014	1130	470	0.851	0.030	0.016	1.084	7.7	4	16.2	0.14	1.24	0.059	2.1
14 Jan 2015	1125	190	0.478	0.009	0.006	0.554	8.1	<2	18.6	0.22	0.78	0.054	1.3
11 Feb 2015	1140	280	0.409	0.012	0.008	0.582	7.9	<2	16.1	0.15	0.74	0.084	1.2
11 Mar 2015	1130	380	0.446	0.006	0.002	0.458	7.8	<2	15.7	0.10	0.56	0.050	0.9
08 Apr 2015	1205	740	0.497	0.012	0.003	0.517	7.5	<2	17.0	0.22	0.74	0.058	1.4
13 May 2015	1240	480	7.340	0.066	0.010	1.620	7.2	11	11.9	0.34	1.97	0.076	2.7
10 Jun 2015	1220	150	3.240	0.042	0.005	1.815	7.7	5	11.7	0.24	2.06	0.033	1.8

The statistical summary of this data is presented in Table 22.

Table 22 Statistical summary of data from July 2014 to June 2015: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.011	0.032	0.019	12	0.007
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.009	0.004	12	0.002
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	22	43	32	12	6
BDISC	Black disc transparency	m	0.91	2.30	1.68	12	0.5
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	1.4	0.8	12	0.3
CONDY	Conductivity @ 20'C	mS/m	9.9	12.4	11.5	12	0.8
DO	Dissolved Oxygen	g/m^3	9.5	12.0	10.6	12	0.7
PERSAT	Dissolved Oxygen Saturation %	%	100	111	103	12	4
DRP	Dissolved reactive phosphorus	g/m^3P	0.014	0.064	0.029	12	0.013
ECOL	E.coli bacteria	nos/100 ml	14	720	240	12	209
ENT	Enterococci bacteria	nos/100 ml	15	2200	52	12	635
FC	Faecal Coliforms	nos/100 ml	14	740	240	12	214
FLOW	Flow	m^3/s	0.409	7.340	1.784	12	2.079
NH_4	Ammoniacal nitrogen	g/m^3N	0.006	0.066	0.022	12	0.02
NO_2	Nitrite nitrogen	g/m^3N	0.002	0.016	0.006	12	0.004
NO_3	Nitrate nitrogen	g/m^3N	0.46	1.94	1.23	12	0.536
PH	pH		7.2	8.1	7.8	12	0.3
SS	Suspended solids	g/m^3	< 2	11	3	12	3
TEMP	Temperature	°C	9.2	18.6	12.5	12	3.2
TKN	Total Kjeldahl nitrogen	g/m^3N	0.04	0.42	0.22	12	0.11
TN	Total nitrogen	g/m^3N	0.56	2.06	1.47	12	0.57
TP	Total phosphorus	g/m^3P	0.025	0.084	0.055	12	0.016
TURB	Turbidity	NTU	0.9	2.70	1.6	12	0.52

A statistical summary of the twenty years' data collected since 1 July 1995, is presented in Table 23.

Table 23 Statistical summary of data from July 1995 to June 2015: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.009	0.100	0.021	240	0.013
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.024	0.005	240	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.003	0.000	240	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	11	49	30	240	7
BDISC	Black disc transparency	m	0.1	4.39	1.69	240	0.813
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	7.3	0.7	240	0.9
CONDY	Conductivity @ 20'C	mS/m	4.6	14.7	11.2	240	1.6
DO	Dissolved Oxygen	g/m^3	9.2	13.0	10.6	241	0.7
PERSAT	Dissolved Oxygen Saturation %	%	92	121	103	241	5
DRP	Dissolved reactive phosphorus	g/m^3P	0.003	0.146	0.019	240	0.014
ECOL	E.coli bacteria	nos/100 ml	6	59000	180	216	4169
ENT	Enterococci bacteria	nos/100 ml	3	7700	100	240	930
FC	Faecal Coliforms	nos/100 ml	6	100000	190	240	7608
FLOW	Flow	m^3/s	0.326	28.797	1.654	240	3.331
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	1.720	0.018	240	0.115
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.033	0.007	240	0.005
NO_3	Nitrate nitrogen	g/m^3N	0.14	2.31	1.13	240	0.476
PH	pH		7.1	8.6	7.8	240	0.3
SS	Suspended solids	g/m^3	< 2	180	3	240	17
TEMP	Temperature	°C	5.6	20.8	12.4	240	3.2
TKN	Total Kjeldahl nitrogen	g/m^3N	<0.01	2.41	0.2	240	0.3
TN	Total nitrogen	g/m^3N	0.27	3.22	1.44	240	0.513
TP	Total phosphorus	g/m^3P	0.013	0.829	0.038	240	0.077
TURB	Turbidity	NTU	0.7	36	1.5	239	3.88

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

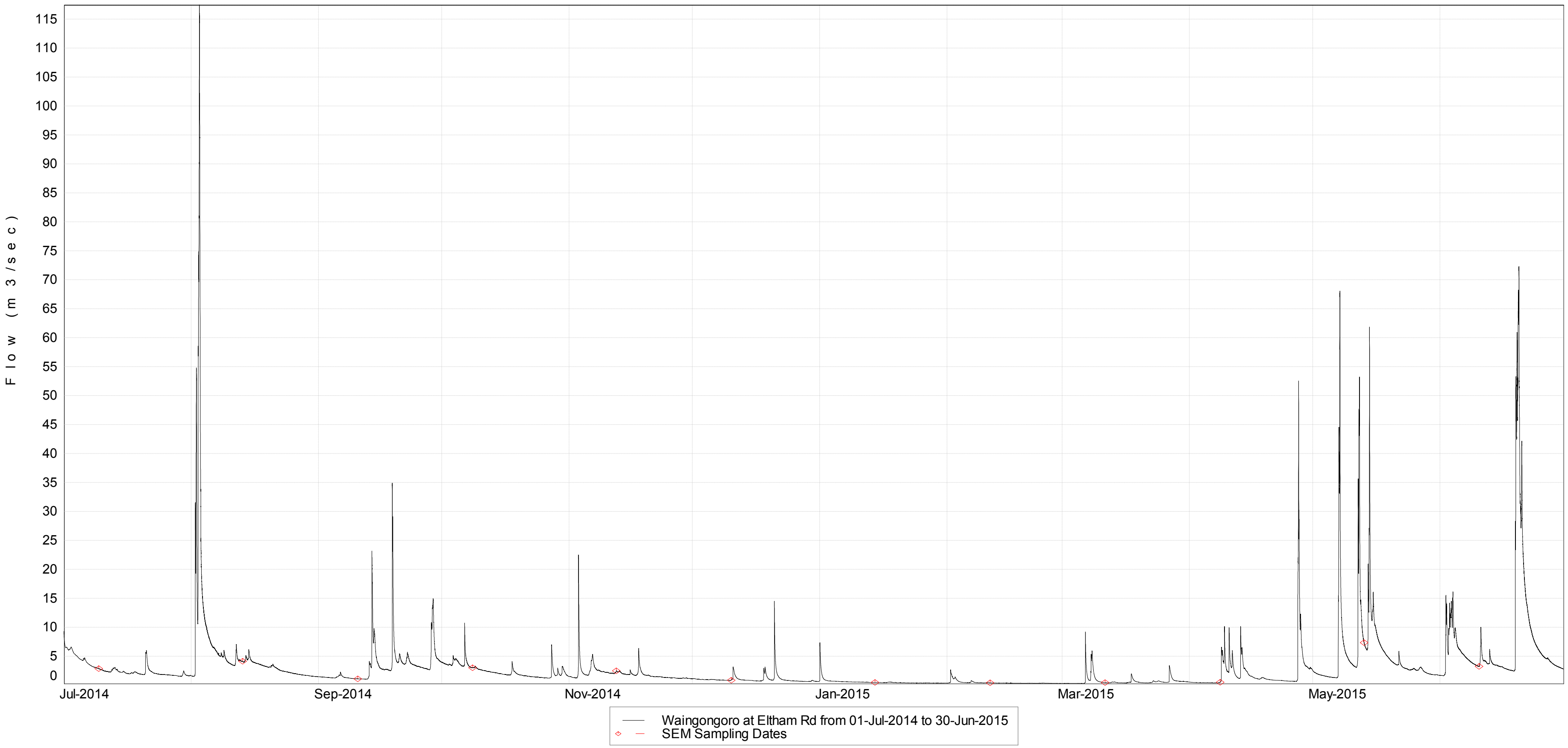

Figure 5 Flow record for the Waingongoro River at Eltham Road

Discussion

2014-2015

Moderate aesthetic water quality (more similar to lower ringplain reaches' aesthetic quality) was indicated by a median black disc clarity of 1.68 m and median turbidity of 1.6 NTU, in the mid-reaches of the longest ring-plain river in Taranaki but recognising that this site (altitude: 200 m asl) is 23 km from the National Park boundary. The maximum clarity (black disc of 2.30 m), 2.09 m lower than the historical maximum, was recorded in early autumn during a period of very low flow conditions (0.45 m^3/s), while worst black disc clarities (0.96 and 1.02 m) occurred on the falling stages of small to moderate freshes coincident with turbidities of 2.0 and 2.9 NTU and suspended solids concentrations of 6 and 11 g/m^3 sampled in July 2014 and May 2015 (Figure 5). Generally, poorer water quality conditions monitored during freshes (elevated bacterial numbers, some elevated nutrients, discolouration, and decreased clarity) were apparent on up to two occasions during the 2014-2015 period with the May, 2015 event following three moderate freshes after a lengthy period of low flow conditions.

pH reached a maximum of 8.1 in early spring and mid-summer coincident with supersaturation (111%) of dissolved oxygen, although it would be expected that pH would have risen further later in the day, particularly in mid to late summer, than the value measured at the time of sampling (near midday).

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 100% saturation recorded in autumn) and low BOD_5 levels (median: 0.8 g/m^3). Bacteriological quality was more typical of the mid reaches of developed ring plain catchments, subject to agricultural impacts, with median faecal coliform and enterococci numbers of 240 and 52 (per 100 mls) respectively. Water temperature varied over a moderate range of 9.4 ˚C with a maximum summer (late morning) river temperature of 18.6 ˚C recorded in January 2015 under very low flow conditions (Figure 5).

Brief comparison with previous 1995-2013 period

The latest twelve-month period sampled a narrower range of flow conditions with median sampled flow higher (by 130 /sec) than the median of flows sampled over the previous nineteen-year period. Aesthetic river water quality was very similar in terms of median black disc clarity (which was identical between periods), median suspended solids level (no change), and median turbidity level (which increased by 0.1 NTU) during the 2014-2015 period.

In general, some deterioration in faecal coliform bacteriological water quality was recorded in the 2014-2015 period with a higher median number (by 50 per 100 mls) but some improvement in median enterococci number (by 48 per 100 mls). Some increases were indicated in median nutrient species' concentrations over the 2014-2015 period particularly ammoniacal nitrogen, nitrate N, dissolved phosphorus, and total phosphorus which rose by 22% 11%, 53%, and 45% respectively.

The range in water temperature was much narrower (by 6.2 ˚C) over the 2014-2015 period mainly due to a warmer (by 3.6 ˚C) minimum water temperature although the median water temperature was only 0.1 ˚C lower in the 2014-2015 period.

Median pH values were identical but the maximum pH previously recorded (over 19 years) was 0.5 unit higher than that measured in the 2014-2015 period.

Waingongoro River at SH45 (site: WGG000900)

Analytical data are presented in Table 24 from the monthly sampling programme. The river flow recorded at this site for the twelve-month period at this SH45 site is presented in Figure 6.

Table 24 Analytical results from monthly samples: Waingongoro River at SH45

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ $CaCO_3$)	Black disc (m)	BOD_5 (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
09 Jul 2014	1130	0.017	0.003	0.000	36	1.03	1.4	15.6	11.4	100	0.036	120	46
13 Aug 2014	1200	0.024	0.006	0.000	33	0.79	1.4	15.1	11.4	101	0.041	410	74
10 Sep 2014	1215	0.024	0.005	0.000	42	1.61	1.0	17.9	12.3	113	0.048	74	94
08 Oct 2014	1100	0.021	0.004	0.000	36	1.21	0.8	15.5	10.8	103	0.050	190	46
12 Nov 2014	1105	0.026	0.005	0.000	41	1.13	1.5	15.9	10.4	104	0.043	860	180
10 Dec 2014	1100	0.035	0.008	0.000	48	1.04	1.2	18.1	9.4	99	0.051	310	210
14 Jan 2015	1100	0.040	0.008	0.000	56	1.98	1.0	19.0	10.1	113	0.055	120	46
11 Feb 2015	1100	0.040	0.008	0.000	60	1.74	1.2	20.0	10.4	108	0.073	150	280
11 Mar 2015	1100	0.054	0.012	0.001	41	2.13	1.2	16.4	9.6	101	0.072	300	400
08 Apr 2015	1130	0.050	0.012	0.001	53	0.52	1.6	19.0	8.7	92	0.096	4800	5900
13 May 2015	1205	0.032	0.008	0.000	22	0.58	2.2	13.1	10.3	97	0.042	700	1200
10 Jun 2015	1145	0.020	0.004	0.000	32	1.00	1.8	16.1	10.8	100	0.054	120	69
Date	**Time (NZST)**	**FC (Nos/ 100ml)**	**Flow (m³/s)**	**NH_4 (g/m³N)**	**NO_2 (g/m³N)**	**NO_3 (g/m³N)**	**pH**	**SS (g/m³)**	**Temp (°C)**	**TKN (g/m³N)**	**TN (g/m³N)**	**TP (g/m³P)**	**Turb (NTU)**
09 Jul 2014	1130	120	8.767	0.053	0.029	2.431	7.6	9	9.3	0.28	2.74	0.068	2.8
13 Aug 2014	1200	410	11.926	0.127	0.111	2.189	7.6	12	9.7	0.72	3.02	0.094	4.0
10 Sep 2014	1215	74	4.057	0.021	0.029	2.411	8.2	2	11.7	0.09	2.53	0.053	2.1
08 Oct 2014	1100	200	9.124	0.046	0.020	2.130	7.8	5	12.2	0.41	2.56	0.070	2.3
12 Nov 2014	1105	860	6.399	0.053	0.022	1.718	7.7	7	14.3	0.52	2.26	0.084	2.3
10 Dec 2014	1100	310	2.786	0.026	0.016	1.794	7.7	5	17.6	0.33	2.14	0.087	2.5
14 Jan 2015	1100	120	1.563	0.009	0.012	0.928	8.0	2	20.8	0.35	1.29	0.079	1.6
11 Feb 2015	1100	160	1.299	0.034	0.009	0.921	7.8	5	17.8	0.23	1.16	0.101	1.6
11 Mar 2015	1100	300	1.362	0.043	0.013	0.917	7.7	2	17.9	0.44	1.37	0.106	1.0
08 Apr 2015	1130	4800	1.677	0.101	0.018	1.032	7.5	9	18.0	0.59	1.64	0.150	4.6
13 May 2015	12:05	700	24.723	0.114	0.017	1.873	7.2	18	12.3	0.31	2.20	0.129	5.3
10 Jun 2015	11:45	120	10.194	0.066	0.043	2.277	7.7	11	11.8	0.43	2.75	0.084	3.1

The statistical summary of this data is presented in Table 25.

Table 25 Statistical summary of data from July 2014 to June 2015: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.017	0.054	0.029	12	0.012
A440F	Absorbance @ 440nm Filtered	/cm	0.003	0.012	0.007	12	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m3 CaCO3	22	60	41	12	11
BDISC	Black disc transparency	m	0.52	2.13	1.08	12	0.53
BOD_5	Biochemical oxygen demand 5day	g/m3	0.8	2.2	1.3	12	0.4
CONDY	Conductivity @ 20'C	mS/m	13.1	20.0	16.2	12	2
DO	Dissolved Oxygen	g/m3	8.7	12.3	10.4	12	1
PERSAT	Dissolved Oxygen Saturation %	%	92	113	101	12	6
DRP	Dissolved reactive phosphorus	g/m3P	0.036	0.096	0.050	12	0.017
ECOL	E.coli bacteria	nos/100 ml	74	4800	245	12	1321
ENT	Enterococci bacteria	nos/100 ml	46	5900	137	12	1665
FC	Faecal Coliforms	nos/100 ml	74	4800	250	12	1320
FLOW	Flow	m3/s	1.299	24.723	5.228	12	6.777
NH_4	Ammoniacal nitrogen	g/m3N	0.009	0.127	0.050	12	0.038
NO_2	Nitrite nitrogen	g/m3N	0.009	0.111	0.019	12	0.028
NO_3	Nitrate nitrogen	g/m3N	0.92	2.43	1.83	12	0.61
PH	pH		7.2	8.2	7.7	12	0.2
SS	Suspended solids	g/m3	2	18	6	12	5
TEMP	Temperature	°C	9.3	20.8	13.3	12	3.8
TKN	Total Kjeldahl nitrogen	g/m3N	0.09	0.72	0.38	12	0.17
TN	Total nitrogen	g/m3N	1.16	3.02	2.23	12	0.63
TP	Total phosphorus	g/m3P	0.053	0.150	0.086	12	0.027
TURB	Turbidity	NTU	1.0	5.3	2.4	12	1.3

This was the seventeenth year of state of the environment data collection by the Taranaki Regional Council for this site, and these data are provided in Table 26 for reference or comparative purposes.

Table 26 Statistical summary of data from July 1998 to June 2014: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.078	0.032	204	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.019	0.007	204	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	204	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	21	62	39	204	9
BDISC	Black disc transparency	m	0.12	4.34	1.16	204	0.589
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	6.7	1.0	204	0.9
CONDY	Conductivity @ 20°C	mS/m	9.8	23.2	16.4	204	2.2
DO	Dissolved oxygen	g/m^3	8.4	12.9	10.5	204	0.8
PERSAT	Dissolved oxygen saturation %	%	89	141	101	204	6
DRP	Dissolved reactive phosphorus	g/m^3P	0.015	0.223	0.055	204	0.034
ECOL	E.coli bacteria	nos/100 ml	3	41000	220	203	3323
ENT	Enterococci bacteria	nos/100 ml	6	5900	150	204	666
FC	Faecal coliforms	nos/100 ml	3	41000	220	204	3316
FLOW	Flow	m^3/s	0.997	50.341	4.818	204	6.882
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.305	0.034	204	0.041
NO_2	Nitrite nitrogen	g/m^3N	0.003	0.132	0.021	204	0.019
NO_3	Nitrate nitrogen	g/m^3N	0.74	2.98	1.87	204	0.526
pH	pH		7.2	9.1	7.8	204	0.3
SS	Suspended solids	g/m^3	< 2	120	5	204	16
TEMP	Temperature	°C	5.4	22.0	13.7	204	3.7
TKN	Total kjeldahl nitrogen	g/m^3N	0.02	1.51	0.40	204	0.24
TN	Total nitrogen	g/m^3N	0.97	3.59	2.40	204	0.57
TP	Total phosphorus	g/m^3P	0.042	0.325	0.100	204	0.05
TURB	Turbidity	NTU	1.0	36.0	2.3	203	4.1

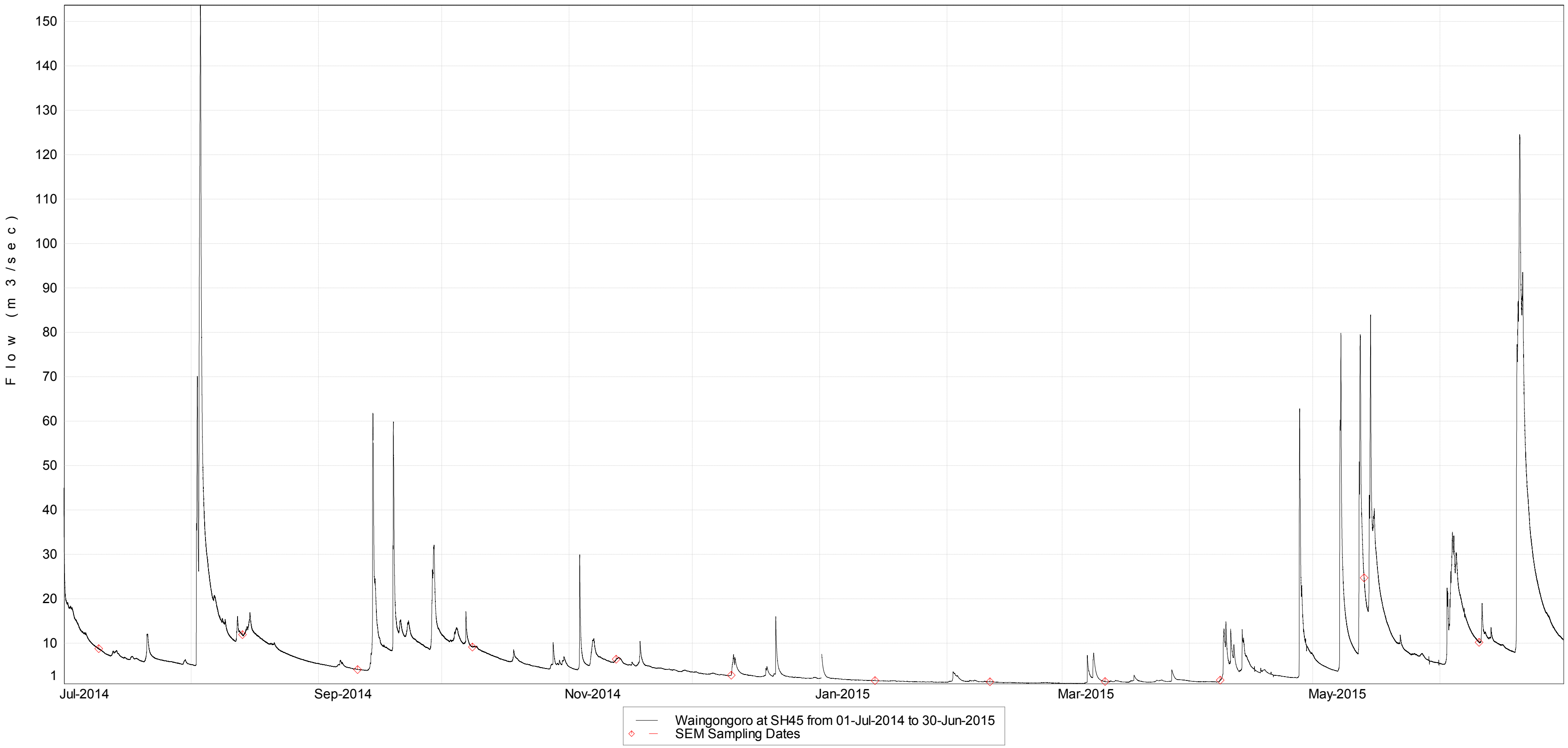

Figure 6 Flow record for the Waingongoro River at SH45

Discussion

2014-2015 period

Relatively poor aesthetic water quality was indicated by a median black disc clarity of 1.08 m and median turbidity of 2.4 NTU, in the lower reaches of the longest ring-plain confined river or stream in Taranaki. The moderately low maximum clarity (black disc value of 2.13 m) was recorded in early autumn during very low flow conditions (1.36 m^3/s). The lowest black disc clarities of 0.52 m and 0.58 m, highest turbidities of 4.6 NTU and 5.3 NTU, and suspended solids concentrations of 19 g/m^3 and 18 g/m^3 were sampled during the rising stage of a small fresh in April 2015 and falling stage of a much larger fresh in May 2015 respectively. Poorest water quality conditions were apparent at times of fresh flows (Figure 6) when elevated bacterial numbers, nutrients, and/or discolouration, and decreased clarity were typical.

pH reached 8.5 in early spring during a lengthy recession period, and 8.0 in mid-summer under very low flow conditions coincidental with highest dissolved oxygen saturation levels (113 %), although it would be expected that pH would have risen further during summer/autumn later in the day (i.e. after 1125 NZST), than values recorded at the earlier sampling times.

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 92% saturation) and moderately low BOD_5 levels (median: 1.4 g/m^3). Bacteriological quality was relatively poor at this site with numbers typical for the lower reaches of developed ring plain catchments, subject to agricultural impacts, with median faecal coliform and enterococci numbers of 250 and 137 (per 100 mls) respectively. These numbers reflected, to some degree, the proximity of preceding river freshes on several sampling survey occasions during the period. Median nutrient levels were relatively high and typical of the lower reaches of ring plain rivers receiving agricultural and industrial point-source discharges. Water temperatures varied over a moderate range of 11.5 ˚C with a maximum mid-summer (late morning) river temperature of 20.8 ˚C recorded in January 2015.

Brief comparison of upper and lower Waingongoro River sites during the 2014-2015 period

Downstream deterioration in aspects of water quality over the 40 km length between the mid reaches and the lower reaches of the river was emphasised by more turbid conditions [lower median black disc clarity by 0.60 m (35 % decrease), increased median turbidity level (by 0.8 NTU), and an increase in median suspended solids concentration of 3 g/m^3]. Bacteriological quality, in terms of the median faecal coliform count, remained poor (of 10 per 100 mls) at the lower river site whereas the median enterococci count deteriorated by 85 per 100 mls (compared with historical median deteriorations of 30 per 100 ml for faecal coliforms and 50 per 100 mls for enterococci). The lower river site's pH range was wider (but only by 0.1 unit) over the 2014-2015 period but the median pH level was lower (by 0.1 unit) at the downstream site. However, in maximum pH recorded was 0.1 unit higher at the downstream site which was atypical of downstream increases in pH in ringplain streams.

Median BOD_5 was higher by 0.5 g/m^3 at the SH45 site where all median nutrient species' concentrations also showed significant increases (by 49 % to 127%)

compared with upstream concentrations. Historical median data indicate from 67% to 200% increases in nutrient species concentrations in a downstream direction.

Water temperature range was wider (by 2.1 ˚C) at the lower site although median water temperature was only 0.8 ˚C warmer at this site in the lower reach of the river in comparison with the mid reach site. Historical median temperatures have increased downstream by 1.3 ˚C and ranges have been wider by 1.4 ˚C. Median flow increased by 193 % at the lower reach site in the 2014-2015 period compared with 191% over the previous 16-year period.

Brief comparison with the previous 1998-2013 period

The most recent twelve-month period sampled a narrower range of flow conditions but the median sampled flow was higher by 410 l/sec than that sampled over the previous sixteen-year period. This was due in part to several freshes, despite the mid summer-autumn low flow period, sampled in the 2014-2015 year.

Water clarity was very slightly poorer with the medians for suspended solids higher by 1 g/m^3, turbidity higher by 0.1 NTU, and black disc clarity lower by 0.10 m in the 2014-2015 period.

Median faecal coliform bacterial number showed a marked deterioration by 30 per 100 ml but enterococci improved slightly by 13 per 100 ml. While pH median values were within 0.1 unit, a much narrower range (by 0.8 unit) was recorded in the recent twelve-month period due to the absence of very elevated summer pH values which had been recorded at times in the previous sixteen-year period. Dissolved oxygen saturation median values were identical. Both median phosphorus species nutrient levels deceased (by 12 % to 14 %) in the recent one year period and two of the median nitrogen nutrient species' levels were slightly lower in the recent year. The exception was the median ammonia nitrogen which increased by 47 % over the 2014-2015 year.

The 2014-2015 range in water temperatures was much narrower (by 5.1 ˚C) due to a higher minimum temperature (by 3.9 ˚C) and lower maximum temperature (by 1.2 ˚C) while the median was only 0.4 ˚C higher in the 2014-2015 sampling period than that recorded over the previous sixteen-year period.

Patea River at Barclay Road (site: PAT000200)

Analytical data are presented in Table 27 from the monthly sampling programme.

Table 27 Analytical results from monthly samples: Patea River at Barclay Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ CaCO₃)	Black disc (m)	BOD₅ (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
09 Jul 2014	1225	0.011	0.002	0.000	23	5.40	<0.5	5.9	11.7	101	0.014	25	<1
13 Aug 2014	1305	0.027	0.006	0.000	11	6.88	<0.5	4.0	11.9	102	0.012	3	1
10 Sep 2014	1315	0.010	0.002	0.000	24	5.41	<0.5	6.7	11.8	103	0.024	17	4
08 Oct 2014	1215	0.012	0.002	0.000	16	5.70	<0.5	5.3	11.3	102	0.023	4	<1
12 Nov 2014	1215	0.019	0.004	0.000	21	3.24	<0.5	5.5	11.1	102	0.017	96	5
10 Dec 2014	1200	0.022	0.005	0.000	27	2.36	1.8	7.0	10.2	102	0.028	360	44
14 Jan 2015	1230	0.015	0.003	0.000	27	4.44	<0.5	7.3	9.7	100	0.032	54	23
11 Feb 2015	1235	0.016	0.004	0.000	29	5.74	<0.5	7.3	10.2	98	0.039	27	82
11 Mar 2015	1210	0.017	0.004	0.000	24	4.31	<0.5	6.8	10.4	100	0.025	210	33
08 Apr 2015	1235	0.046	0.012	0.001	22	1.00	0.7	6.4	9.9	100	0.024	260	300
13 May 2015	1315	0.038	0.008	0.000	10	3.92	<0.5	3.9	10.8	100	0.009	16	6
10 Jun 2015	1300	0.022	0.005	0.000	15	1.16	<0.5	5.9	10.9	99	0.022	440	98
Date		**FC (Nos/ 100ml)**	**Flow (m³/s)**	**NH₄ (g/m³N)**	**NO₂ (g/m³N)**	**NO₃ (g/m³N)**	**pH**	**SS (g/m³)**	**Temp (°C)**	**TKN (g/m³N)**	**TN (g/m³N)**	**TP (g/m³P)**	**Turb (NTU)**
09 Jul 2014	1225	25	0.218	<0.003	<0.001	0.039	7.5	<2	6.5	0.01	<0.05	0.017	0.45
13 Aug 2014	1305	3	0.606	<0.003	<0.001	0.029	7.3	<2	5.8	0.02	<0.05	0.012	0.50
10 Sep 2014	1315	17	0.175	<0.003	<0.001	0.019	7.7	<2	7.2	0.06	0.08	0.024	0.65
08 Oct 2014	1215	4	0.326	0.004	<0.001	0.009	7.5	<2	7.6	0.10	0.11	0.024	0.50
12 Nov 2014	1215	96	0.303	0.003	<0.001	0.009	7.5	<2	7.7	0.04	<0.05	0.021	0.65
10 Dec 2014	1200	360	0.163	0.009	0.001	0.009	7.6	<2	12.5	0.05	0.06	0.037	0.85
14 Jan 2015	1230	56	0.124	<0.003	<0.001	0.009	7.7	<2	13.6	0.04	<0.05	0.038	0.50
11 Feb 2015	1235	27	0.138	0.004	<0.001	0.009	7.6	<2	11.1	0.05	0.06	0.044	0.45
11 Mar 2015	1210	210	0.156	0.004	<0.001	0.019	7.7	<2	11.0	0.03	<0.05	0.029	0.60
08 Apr 2015	1235	260	0.797	<0.003	<0.001	0.019	7.4	4	12.6	0.09	0.11	0.038	1.9
13 May 2015	1315	16	0.562	0.004	0.001	0.049	7.0	<2	9.4	0.05	0.10	0.014	0.55
10 Jun 2015	1300	440	0.450	0.039	<0.001	0.129	7.5	5	8.8	0.12	0.25	0.043	2.0

The statistical summary of this data is presented in Table 28.

Table 28 Statistical summary of data from July 2014 to June 2015: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.010	0.046	0.018	12	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.012	0.004	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	10	29	22	12	6
BDISC	Black disc transparency	m	1.00	6.88	4.38	12	1.87
BOD_5	Biochemical oxygen demand 5day	g/m³	< 0.5	1.8	< 0.5	12	0.4
CONDY	Conductivity @ 20°C	mS/m	3.9	7.3	6.2	12	1.2
DO	Dissolved oxygen	g/m³	9.7	11.9	10.8	12	0.8
PERSAT	Dissolved oxygen saturation %	%	98	103	100	12	1
DRP	Dissolved reactive phosphorus	g/m³P	0.009	0.039	0.024	12	0.009
ECOL	E.coli bacteria	nos/100 ml	3	440	40	12	153
ENT	Enterococci bacteria	nos/100 ml	< 1	300	14	12	85
FC	Faecal coliforms	nos/100 ml	3	440	42	12	153
FLOW	Flow	m³/s	0.124	0.797	0.260	12	0.221
NH_4	Ammoniacal nitrogen	g/m³N	0.003	0.039	0.004	12	0.01
NO_2	Nitrite nitrogen	g/m³N	< 0.001	0.001	< 0.001	12	0
NO_3	Nitrate nitrogen	g/m³N	< 0.01	0.13	0.02	12	0.034
pH	pH		7.0	7.7	7.5	12	0.2
SS	Suspended solids	g/m³	< 2	5	< 2	12	1
TEMP	Temperature	°C	5.8	13.6	9.1	12	2.6
TKN	Total kjeldahl nitrogen	g/m³N	0.01	0.12	0.05	12	0.03
TN	Total nitrogen	g/m³N	< 0.05	0.25	0.06	12	0.06
TP	Total phosphorus	g/m³P	0.012	0.044	0.026	12	0.011
TURB	Turbidity	NTU	0.5	2.0	0.6	12	0.55

A statistical summary of the twenty years' data collected since 1 July 1995, is presented in Table 29.

Table 29 Statistical summary of data from July 1995 to June 2014: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.006	0.112	0.016	240	0.022
A440F	Absorbance @ 440nm filtered	/cm	0.00	0.024	0.004	240	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0	240	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	3.0	31.0	22	239	7.1
BDISC	Black disc transparency	m	0.09	9.1	4.38	239	1.807
BOD_5	Biochemical oxygen demand 5day	g/m³	< 0.5	3.7	< 0.5	240	0.3
CONDY	Conductivity @ 20°C	mS/m	2.5	8.2	6.1	240	1.4
DO	Dissolved oxygen	g/m³	9.1	12.4	10.6	240	0.7
PERSAT	Dissolved oxygen saturation %	%	90	103	98	240	2
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.042	0.018	240	0.008
ECOL	E.coli bacteria	nos/100 ml	< 1	10000	20	216	742
ENT	Enterococci bacteria	nos/100 ml	< 1	2200	8	240	174
FC	Faecal coliforms	nos/100 ml	< 1	10000	20	240	706
FLOW	Flow	m³/s	0.084	18.000	0.217	240	1.5319
NH_4	Ammoniacal nitrogen	g/m³N	< 0.003	0.057	< 0.003	240	0.006
NO_2	Nitrite nitrogen	g/m³N	< 0.001	0.003	< 0.001	240	0
NO_3	Nitrate nitrogen	g/m³N	< 0.01	0.14	0.02	240	0.018
pH	pH		6.5	8	7.5	240	0.2
SS	Suspended solids	g/m³	< 2	160	< 2	240	11
TEMP	Temperature	°C	3.7	14.7	9.2	240	2.5
TKN	Total kjeldahl nitrogen	g/m³N	< 0.01	2.70	0.05	240	0.206
TN	Total nitrogen	g/m³N	< 0.05	2.72	0.08	240	0.206
TP	Total phosphorus	g/m³P	< 0.01	0.281	0.024	240	0.022
TURB	Turbidity	NTU	0.3	31	0.5	239	2.21

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

Discussion

2014-2015 period

Aesthetic water quality was very high, as emphasised by median black disc and turbidity values of 4.38 m and 0.6 NTU respectively, and a maximum black disc clarity of 6.88 m measured under late winter, moderate flow conditions (606 l/sec). The lowest black disc clarity (1.00 m) was recorded in April 2015, coincident with the rising stage of the first (moderate) fresh (0.797 m^3/s) in the river, for some weeks with increases in colour and bacteria, but much smaller increases in BOD_5, turbidity, and suspended solids recorded.

Maximum pH (7.7) at this shaded site was measured under very low flow conditions on three occasions. pH range however was relatively narrow under all flow conditions (varying by only 0.7 unit) over the period, although measurements were confined to near midday.

Dissolved oxygen concentrations were consistently high with a minimum saturation of 98% recorded. The high water quality was also emphasised by very low BOD_5 levels (below 0.5 g/m^3 for the majority of the period) and generally low nutrient concentrations under normal flow conditions. Dissolved reactive phosphorus levels were typical of National Park sourced rivers.

Bacterial water quality was relatively high (median faecal coliform and enterococci numbers of 42 and 14 per 100 mls respectively). There was some evidence of the slightly elevated counts found in past years in summer-autumn during periods of stable flow conditions, which may have been due to stock access upstream of the site noted previously in this short reach of the river below the National Park boundary.

River water temperatures varied over a moderate range (7.8 ˚C) at this relatively shaded site during the period. A maximum mid-day temperature of 13.6 ˚C was recorded under very low flow conditions in January 2014.

Brief comparison with the previous 1995-2014 period

A much narrower range but a higher median of river flows was sampled during the 2014-2015 period, with a few small to moderate freshes sampled, in comparison with the previous nineteen-year period. Median flow for the 2014-2015 sampling occasions was 44 l/sec higher than the median of sampled flows over the previous nineteen-year period. Aesthetic river water quality was very similar in terms of median turbidity and identical with median black disc clarity during the 2014-2015 period. Median suspended solids concentrations were very low (below 2 g/m^3) in both periods.

Median nutrient species levels were comparatively similar between the two periods, although there was an increase in median dissolved reactive phosphorus (of 33%) over the latest twelve-month sampling period.

Median faecal coliform bacterial number increased (by 22 per 100 mls) and median enterococci number increased (by 5 per 100 mls) over the recent sampling period. Median pH values were identical for the two periods while the maximum pH value was only 0.3 unit lower in the 2014-2015 period.

Median water temperature over the past twelve-month period was within 0.1 ˚C of the median for the previous nineteen-year period but the maximum temperature was 1.1 ˚C lower, and the minimum temperature was 2.1 ˚C in the latest period than previously recorded. Therefore, a narrower range of temperatures (by 3.2 ˚C) was recorded in the 2014-2015 period.

Patea River at Skinner Road (site: PAT000360)

Analytical data are presented in Table 30 from the monthly sampling programme and the flow illustrated in Figure 7.

Table 30 Analytical results from monthly samples: Patea River at Skinner Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ $CaCO_3$)	Black disc (m)	BOD_5 (g/m³)	Cond @ 20 ˚C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
09 Jul 2014	1335	0.013	0.002	0.000	27	2.20	0.6	9.7	11.3	102	0.016	96	24
13 Aug 2014	1355	0.016	0.004	0.000	23	1.60	0.5	8.6	11.2	102	0.020	500	180
10 Sep 2014	1405	0.018	0.004	0.000	30	1.56	0.8	9.9	12.4	115	0.033	54	31
08 Oct 2014	1310	0.014	0.003	0.000	24	2.12	0.6	9.1	11.1	109	0.030	60	80
12 Nov 2014	1310	0.017	0.004	0.000	31	1.57	0.9	9.5	10.8	106	0.032	160	80
10 Dec 2014	1315	0.028	0.006	0.000	33	1.10	1.7	10.3	10.2	108	0.058	800	210
14 Jan 2015	1300	0.029	0.006	0.000	32	2.35	1.1	10.6	10.2	113	0.063	40	54
11 Feb 2015	1305	0.031	0.007	0.000	37	2.47	1.0	11.1	10.9	115	0.079	300	260
11 Mar 2015	1300	0.034	0.008	0.001	32	2.25	1.3	10.6	10.3	107	0.066	600	2000
08 Apr 2015	1330	0.045	0.012	0.001	33	1.10	2.9	10.6	9.5	100	0.075	2500	9700
13 May 2015	1405	0.020	0.005	0.000	21	1.40	0.9	9.4	10.3	100	0.026	1100	450
10 Jun 2015	1355	0.015	0.003	0.000	24	2.08	0.6	9.9	10.8	103	0.024	78	35
Date	**Time (NZST)**	**FC (Nos/ 100ml)**	**Flow (m³/s)**	**NH_4 (g/m³N)**	**NO_2 (g/m³N)**	**NO_3 (g/m³N)**	**pH**	**SS (g/m³)**	**Temp (˚C)**	**TKN (g/m³N)**	**TN (g/m³N)**	**TP (g/m³P)**	**Turb (NTU)**
09 Jul 2014	1335	96	3.765	0.042	0.009	1.251	7.5	<2	9.5	0.06	1.32	0.026	1.3
13 Aug 2014	1355	850	8.357	0.082	0.008	1.052	7.5	3	9.4	0.33	1.39	0.040	1.6
10 Sep 2014	1405	54	1.509	0.026	0.014	0.776	8.7	<2	11.1	0.15	0.94	0.042	1.4
08 Oct 2014	1310	60	5.889	0.039	0.009	0.891	7.7	<2	13.0	0.28	1.18	0.036	1.2
12 Nov 2014	1310	160	4.167	0.086	0.015	0.935	7.6	2	12.2	0.22	1.17	0.051	1.6
10 Dec 2014	1315	800	1.374	0.042	0.024	0.776	7.7	3	16.6	0.24	1.04	0.089	2.1
14 Jan 2015	1300	40	1.112	0.008	0.026	0.714	8.2	2	19.3	0.24	0.98	0.088	1.6
11 Feb 2015	1305	300	0.821	0.018	0.019	0.691	8.1	<2	17.1	0.12	0.83	0.286	1.3
11 Mar 2015	1300	660	0.893	0.024	0.012	0.518	8.0	<2	15.9	0.16	0.69	0.096	1.2
08 Apr 2015	1330	2500	1.673	0.055	0.022	0.738	7.4	6	16.8	0.52	1.28	0.138	2.5
13 May 2015	1405	1200	14.736	0.116	0.010	1.370	7.2	4	12.8	0.34	1.72	0.052	1.8
10 Jun 2015	1355	78	4.665	0.098	0.013	1.107	7.6	2	12.1	0.16	1.28	0.034	1.9

The statistical summary of this data is presented in Table 31.

Table 31 Statistical summary of data from July 2014 to June 2015: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.013	0.045	0.019	12	0.01
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.012	0.004	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	21	37	30	12	5
BDISC	Black disc transparency	m	1.10	2.47	1.84	12	0.48
BOD_5	Biochemical oxygen demand 5day	g/m³	0.5	2.9	0.9	12	0.7
CONDY	Conductivity @ 20°C	mS/m	8.6	11.1	9.9	12	0.7
DO	Dissolved oxygen	g/m³	9.5	12.4	10.8	12	0.7
PERSAT	Dissolved oxygen saturation %	%	100	115	106	12	5
DRP	Dissolved reactive phosphorus	g/m³P	0.016	0.079	0.032	12	0.023
ECOL	E.coli bacteria	nos/100 ml	40	2500	230	12	711
ENT	Enterococci bacteria	nos/100 ml	24	9700	130	12	2766
FC	Faecal coliforms	nos/100 ml	40	2500	230	12	725
FLOW	Flow	m³/s	0.821	14.736	2.719	12	4.1
NH_4	Ammoniacal nitrogen	g/m³N	0.008	0.116	0.042	12	0.035
NO_2	Nitrite nitrogen	g/m³N	0.008	0.026	0.014	12	0.006
NO_3	Nitrate nitrogen	g/m³N	0.52	1.37	0.83	12	0.251
pH	pH		7.2	8.7	7.6	12	0.4
SS	Suspended solids	g/m³	< 2	6	2	12	1
TEMP	Temperature	°C	9.4	19.3	12.9	12	3.2
TKN	Total kjeldahl nitrogen	g/m³N	0.06	0.52	0.23	12	0.12
TN	Total nitrogen	g/m³N	0.69	1.72	1.18	12	0.28
TP	Total phosphorus	g/m³P	0.026	0.286	0.052	12	0.072
TURB	Turbidity	NTU	1.2	2.5	1.6	12	0.4

A statistical summary of the twenty years' data collected since 1 July 1995 is presented in Table 32.

Table 32 Statistical summary of data from July 1995 to June 2015: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.095	0.023	240	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.023	0.005	240	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	240	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	10	57	28	240	6
BDISC	Black disc transparency	m	0.05	4.68	1.83	240	0.841
BOD_5	Biochemical oxygen demand 5day	g/m³	0.5	16.0	0.9	240	1.5
CONDY	Conductivity @ 20°C	mS/m	5.0	14.3	9.9	240	1.5
DO	Dissolved oxygen	g/m³	8.9	12.9	10.6	240	0.7
PERSAT	Dissolved oxygen saturation %	%	87	121	102	240	6
DRP	Dissolved reactive phosphorus	g/m³P	0.010	0.160	0.038	240	0.031
ECOL	E.coli bacteria	nos/100 ml	2	25000	200	216	3218
ENT	Enterococci bacteria	nos/100 ml	4	19000	115	240	1754
FC	Faecal coliforms	nos/100 ml	2	63000	230	240	5152
FLOW	Flow	m³/s	0.650	77.530	3.012	240	7.631
NH_4	Ammoniacal nitrogen	g/m³N	0.003	0.329	0.053	240	0.051
NO_2	Nitrite nitrogen	g/m³N	0.001	0.051	0.016	240	0.008
NO_3	Nitrate nitrogen	g/m³N	0.21	1.54	0.92	240	0.216
pH	pH		7.0	8.8	7.8	240	0.4
SS	Suspended solids	g/m³	2	360	2	240	28
TEMP	Temperature	°C	5.3	21.8	12.8	240	3.4
TKN	Total kjeldahl nitrogen	g/m³N	0.010	4.070	0.240	240	0.362
TN	Total nitrogen	g/m³N	0.69	4.50	1.22	240	0.341
TP	Total phosphorus	g/m³P	0.022	1.390	0.066	240	0.112
TURB	Turbidity	NTU	0.2	80	1.5	239	7

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I

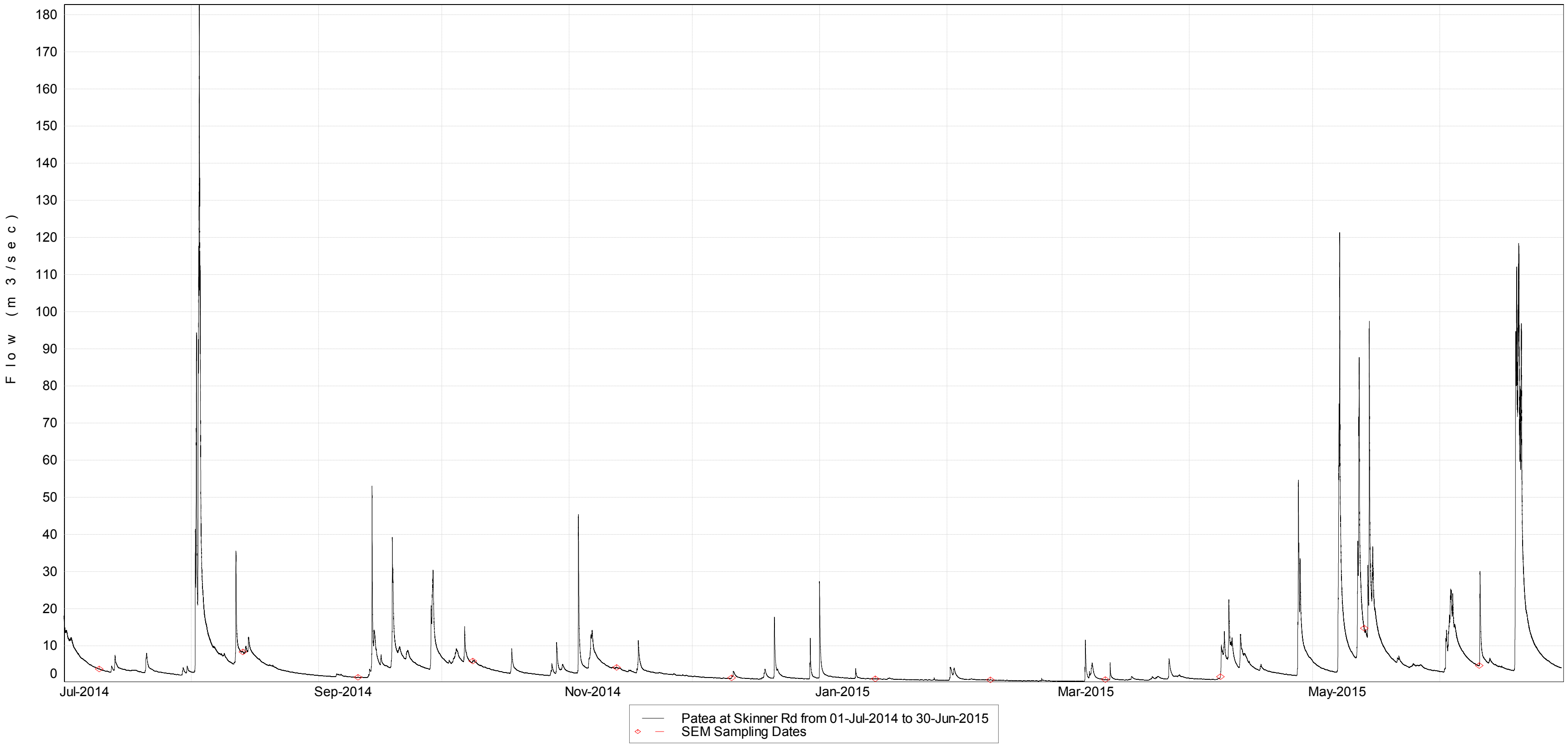

Figure 7 Flow record for the Patea River at Skinner Road

Discussion

2014-2015 period

Moderate median black disc clarity (1.84 metres) and median turbidity (1.6 NTU) were slightly lower than typical of the mid reaches of a ring plain river draining a developed catchment and receiving various point source discharges. However, this clarity and a low median suspended solids concentration (2 g/m^3), were indicative of moderate aesthetic water quality at this site. Minimal clarity (black disc of 1.10 m and turbidity of 2.5 NTU) and very small increase in suspended solids concentrations 6 g/m^3) were recorded on the rising stage of a fresh sampled in April 2015 after a period of low flows (Figure 7). Deterioration in other water quality parameters during this event was also illustrated by high bacterial numbers and elevated BOD_5 and total phosphorus concentrations.

Early afternoon pH levels reached a maximum of 8.7 units in early spring (after nearly a month with no freshes) coincidental with dissolved oxygen saturation peaking at 115%. Dissolved oxygen levels were consistently high (100% or higher saturation) with supersaturation recorded particularly during late summer to autumn low flow conditions coincident with more extensive algal cover and elevated pH levels (≥ 8.0 units). BOD_5 concentrations under normal to low recession flow conditions were generally indicative of moderately low organic contamination (i.e. up to 1.5 g/m^3).

The moderately poor median bacteriological numbers (130 enterococci and 230 faecal coliforms per 100 mls) may be attributed to the high proportion of developed catchment, urban runoff, proximity of the municipal oxidation ponds system discharge to this site, and dairy farm waste disposal in the upper catchment. The wide range of faecal coliform numbers recorded under lower river flow conditions probably reflected some seasonal variability in the recently upgraded municipal oxidation pond performance due to the relative proximity of this discharge, together with other point source and non-point source discharges.

Water temperatures varied over a moderately wide range of 9.9 °C with a maximum (early afternoon) summer temperature of 19.3 ˚C recorded in January 2015 (coincident with a pH of 8.2 and 113% dissolved oxygen saturation).

Brief comparison of upper and mid Patea River catchment sites during the 2014-2015 period

Some deterioration from the high upstream water quality conditions measured at the Barclay Road site was apparent at the Skinner Road site nearly 19 km (river distance) below the National Park boundary. This was emphasised particularly by elevated median bacterial species' numbers (six to nine-fold increases) and increases in median nutrient species concentrations (2 to 40 fold) compared with historical (19-year) downstream increase in median bacterial numbers (11 to 12 fold) and nutrient species concentrations (2 to 46 fold). The pH range increased by 0.8 unit at the Skinner Road site with a maximum pH 1.0 unit higher than at the upstream site. A moderate increase in median turbidity levels (1.0 NTU) was measured in mid catchment identical to the historical median increase. Median BOD_5 increased by about 0.5 g/m^3 although maximum BOD_5 was 1.0 g/m^3 higher downstream. A deterioration in black disc clarity (median clarity decreased significantly by 2.54 m and maximum clarity to a larger degree by 4.41 m) was recorded, as a result of increased turbidity from run-off and point source discharges within the developed catchment of the river between the two sites. This may be compared with an 19-year median black disc deterioration of 2.56 m and maximum clarity deterioration of 4.42 m.

Water temperature range increased (by 2.1 ˚C) at the Skinner Road site where median water temperature was higher (by 3.0 ˚C) and maximum water temperature was higher (by 5.7 ˚C) than at the Barclay Road site. In comparison, the historical 19-year median and maximum water temperatures have shown downstream increases of 3.6 ˚C and 7.1 ˚C respectively.

Brief comparison with the previous 1995-2014 period

The median of sampled flows in the recent twelve-month period was 2931 l/sec lower than the median of flows sampled over the 1995-2014 period due partly to a lengthy low flow period sampled in the 2014-2015 year and the range of river flows sampled was much narrower in the most recent period. Aesthetic water quality was vert similar to historical conditions with median black disc clarity higher by 0.02 m although and was no difference in the median suspended solids concentrations and minimal difference in turbidity (0.1 NTU) between periods.

There was a narrower pH range (by 0.3 pH unit) and lower maximum pH (by 0.1 pH unit) during the 2014-2015 period. Median dissolved oxygen percentage saturation was higher by an insignificant 4% in the 2014-2015 period.

Bacterial water quality did not alter for faecal coliform and deteriorated slightly for enterococci bacteria during the more recent sampling period, with the median enterococci number increasing by 15 (per 100 mls). Variability in municipal oxidation ponds' system performance and dairy shed wastes disposal would have been expected to have contributed to any differences in bacterial quality between periods.

Water temperature range was much narrower (by 6.6 ˚C) during the more recent sampling period although the median water temperature was within 0.1 ˚C of the longer term median. The maximum water temperature recorded was 2.5 ˚C lower than previously recorded and the minimum water temperature was higher (by 4.1 ˚C) in the latest twelve-month period.

Median BOD_5 was identical in the two periods and median nutrient species showing decreases (ranging from 3% to 22%) during the more recent twelve-month sampling period. No increases median in median concentrations were recorded over the latest period.

Mangaehu River at Raupuha Road (site: MGH000950)

Analytical data are presented in Table 33 from the monthly sampling programme. The flow record for the period is illustrated in Figure 8.

Table 33 Analytical results from monthly samples: Mangaehu River at Raupuha Road

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m^3 $CaCO_3$)	Black disc (m)	BOD_5 (g/m^3)	Cond @ 20 °C (mS/m)	DO (g/m^3)	DO Sat (%)	DRP (g/m^3P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
09 Jul 2014	1410	0.038	0.007	0.000	34	1.35	<0.5	9.1	11.7	100	<0.003	110	100
13 Aug 2014	1425	0.069	0.015	0.001	17	0.10	0.7	6.2	11.6	99	0.006	440	180
10 Sep 2014	1435	0.045	0.009	0.000	49	1.88	<0.5	11.9	11.5	108	0.007	26	16
08 Oct 2014	1345	0.050	0.010	0.001	32	0.82	<0.5	8.5	10.9	105	0.009	80	17
12 Nov 2014	1340	0.044	0.009	0.000	37	0.61	0.5	9.3	10.2	102	0.006	560	60
10 Dec 2014	1345	0.050	0.010	0.000	51	0.71	1.0	11.8	9.8	106	0.006	220	34
14 Jan 2015	1330	0.047	0.009	0.000	60	1.39	0.8	13.7	9.4	109	0.005	23	33
11 Feb 2015	1340	0.054	0.011	0.000	61	2.20	0.9	14.2	9.7	107	0.005	62	95
11 Mar 2015	1330	0.078	0.016	0.001	36	1.43	1.0	11.3	9.5	101	0.005	170	240
08 Apr 2015	1405	0.050	0.011	0.001	62	1.50	0.6	14.8	9.6	100	0.004	660	970
13 May 2015	1440	0.076	0.017	0.001	9	0.11	1.1	5.8	9.4	90	0.008	2400	990
10 Jun 2015	1430	0.040	0.008	0.000	31	0.90	<0.5	9.3	10.8	100	<0.003	200	66

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m^3/s)	NH_4 (g/m^3N)	NO_2 (g/m^3N)	NO_3 (g/m^3N)	pH	SS (g/m^3)	Temp (°C)	TKN (g/m^3N)	TN (g/m^3N)	TP (g/m^3P)	Turb (NTU)
09 Jul 2014	1410	120	7.716	0.018	0.002	0.268	7.5	4	7.9	0.08	0.35	0.010	2.7
13 Aug 2014	1425	450	26.002	0.015	0.002	0.178	7.4	54	9.8	0.36	0.54	0.103	23
10 Sep 2014	1435	28	3.426	0.009	0.002	0.088	8.2	<2	12.4	0.10	0.19	0.011	2.4
08 Oct 2014	1345	80	8.052	0.016	0.002	0.078	7.6	3	12.8	0.15	0.23	0.022	3.2
12 Nov 2014	1340	570	12.337	0.018	0.001	0.109	7.6	8	13.7	0.38	0.49	0.024	3.8
10 Dec 2014	1345	220	3.777	0.019	0.003	0.017	7.8	<2	18.6	0.28	0.30	0.016	2.6
14 Jan 2015	1330	23	2.250	<0.003	0.001	0.009	8.2	3	21.8	0.09	0.10	0.012	2.1
11 Feb 2015	1340	62	1.976	0.012	<0.001	0.009	8.0	3	20.1	0.26	0.27	0.014	2.0
11 Mar 2015	1330	180	2.616	0.008	0.001	0.089	7.9	2	17.9	0.17	0.26	0.020	2.1
08 Apr 2015	1405	660	1.937	0.006	0.001	0.009	7.6	2	17.1	0.11	0.12	0.008	2.4
13 May 2015	1440	2500	72.339	0.029	0.003	0.427	6.8	150	12.7	0.47	0.90	0.206	55
10 Jun 2015	1430	200	11.249	0.016	0.002	0.268	7.5	8	11.6	0.05	0.32	0.013	4.4

The statistical summary of this data is presented in Table 34.

Table 34 Statistical summary of data from July 2014 to June 2015: Mangaehu River at Raupuha Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.038	0.078	0.050	12	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.007	0.017	0.010	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	9	62	36	12	17
BDISC	Black disc transparency	m	0.10	2.20	1.12	12	0.66
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	1.1	0.6	12	0.2
CONDY	Conductivity @ 20˚C	mS/m	5.8	14.8	10.3	12	3
DO	Dissolved oxygen	g/m^3	9.4	11.7	10.0	12	0.9
PERSAT	Dissolved oxygen saturation %	%	90	109	102	12	5
DRP	Dissolved reactive phosphorus	g/m^3P	< 0.003	0.009	0.006	12	0.002
ECOL	E.coli bacteria	nos/100 ml	23	2400	185	12	661
ENT	Enterococci bacteria	nos/100 ml	16	990	80	12	355
FC	Faecal coliforms	nos/100 ml	23	2500	190	12	687
FLOW	Flow	m^3/s	1.937	72.34	5.746	12	19.976
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.029	0.016	12	0.007
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.003	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.43	0.09	12	0.132
pH	pH		6.8	8.2	7.6	12	0.4
SS	Suspended solids	g/m^3	< 2	150	3	12	43
TEMP	Temperature	°C	7.9	21.8	13.2	12	4.3
TKN	Total kjeldahl nitrogen	g/m^3N	0.05	0.47	0.16	12	0.14
TN	Total nitrogen	g/m^3N	0.10	0.90	0.28	12	0.22
TP	Total phosphorus	g/m^3P	0.008	0.206	0.015	12	0.059
TURB	Turbidity	NTU	2.0	55.0	2.6	12	15.7

A statistical summary of the twenty years' data collected since 1 July 1995 is presented in Table 35.

Table 35 Statistical summary of data from July 1995 to June 2015: Mangaehu River at Raupuha Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.027	0.181	0.054	240	0.018
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.056	0.011	240	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.025	0.000	240	0.002
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	9	79	38	240	13
BDISC	Black disc transparency	m	0.01	4.04	0.85	240	0.754
BOD_5	Biochemical oxygen demand 5day	g/m^3	< 0.5	5.6	0.6	240	0.6
CONDY	Conductivity @ 20˚C	mS/m	4.3	16.1	9.8	240	2.3
DO	Dissolved oxygen	g/m^3	7.7	12.9	10.0	240	0.9
PERSAT	Dissolved oxygen saturation %	%	83	118	100	240	6
DRP	Dissolved reactive phosphorus	g/m^3P	< 0.003	0.026	0.006	240	0.004
ECOL	E.coli bacteria	nos/100 ml	6	16000	220	216	1898
ENT	Enterococci bacteria	nos/100 ml	1	6000	68	240	740
FC	Faecal coliforms	nos/100 ml	6	16000	235	240	2022
FLOW	Flow	m^3/s	1.658	111.87	6.830	240	16.017
NH_4	Ammoniacal nitrogen	g/m^3N	< 0.003	0.081	0.012	240	0.011
NO_2	Nitrite nitrogen	g/m^3N	< 0.001	0.016	0.002	240	0.001
NO_3	Nitrate nitrogen	g/m^3N	< 0.01	0.43	0.092	240	0.089
pH	pH		6.8	8.4	7.7	240	0.3
SS	Suspended solids	g/m^3	< 2	1300	4	240	118.6
TEMP	Temperature	°C	4.3	24.0	13.7	240	4.3
TKN	Total kjeldahl nitrogen	g/m^3N	0.020	1.900	0.170	240	0.258
TN	Total nitrogen	g/m^3N	0.07	2.10	0.30	240	0.285
TP	Total phosphorus	g/m^3P	0.003	0.786	0.020	240	0.1
TURB	Turbidity	NTU	1.4	850	3.5	239	62.5

These are provided for reference and comparative purposes and are discussed in Section 4.2 in association with appropriate graphical ('box and whisker' plots) presented in Appendix I.

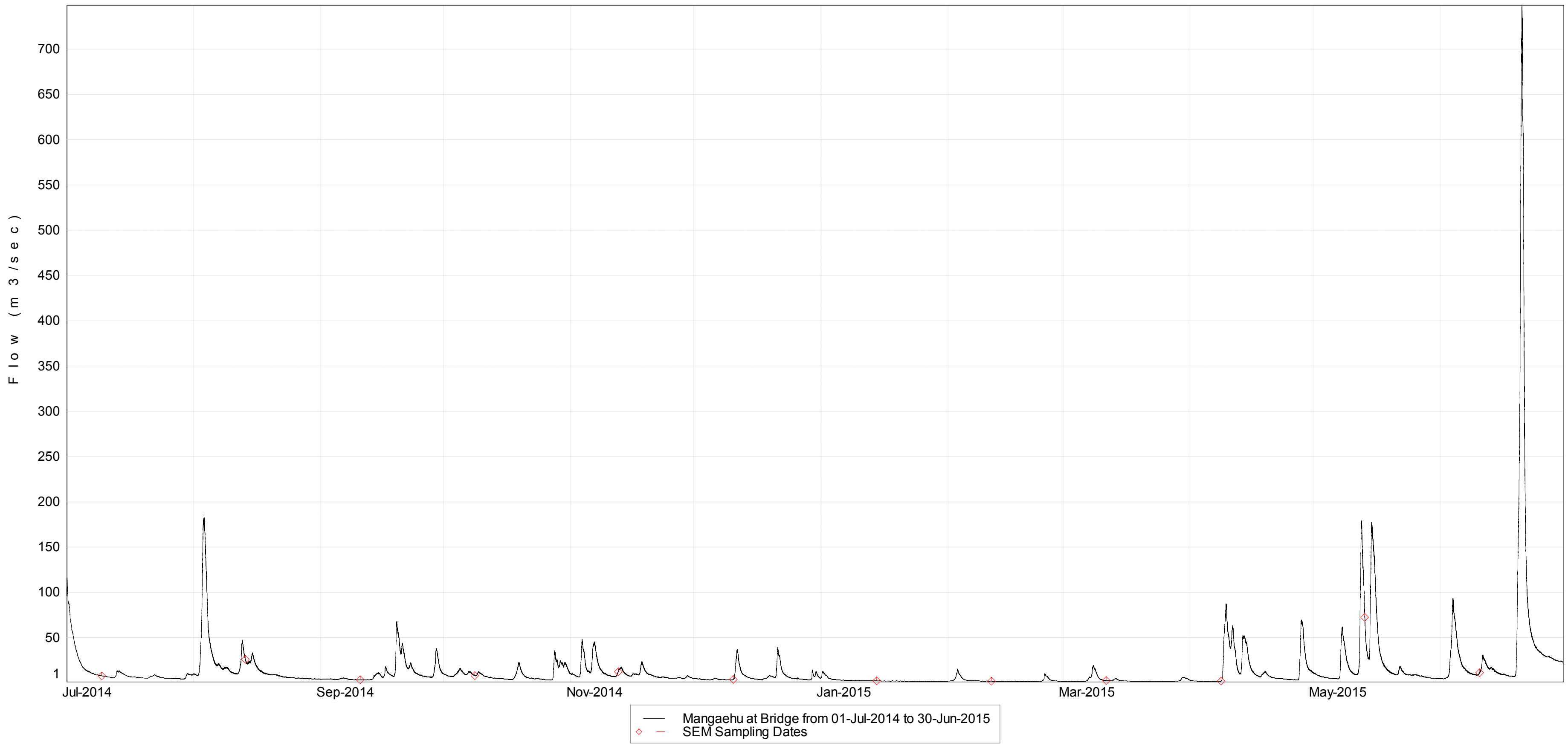

Figure 8 Flow record for the Mangaehu River at Raupuha Road

Discussion

2014-2015 period

The relatively poor visual appearance which characterises the mid and lower reaches of this eastern hill-country catchment river was emphasised by a low median black disc clarity of 1.12 metres with a maximum of 2.20 metres measured under a lengthy low flow period in February 2015. Clarity was seldom more than 1.5 metres (on two occasions) due to the presence of very fine, colloidal, suspended particles. The median suspended solids concentration was 3 g/m^3 which was slightly lower than typical for this river, as few fresh or flood events were sampled during the period. Absorbances (at 340 and 440 nm) were also relatively high (in excess of 0.037/cm and 0.006/cm respectively) at all times, indicative of slight dissolved colour in the river water (e.g. yellow-brown appearance) at this site in the lower reaches of the river. Minimum clarities (0.10 and 0.11 m black disc values) were coincident with turbidity levels of 33 and 55 NTU and suspended solids concentrations of 54 and 150 g/m^3, during flood flows of 26 and 72 m^3/s recorded in August 2014 and May 2015 respectively. Fresh flows (in excess of 12 m^3/s) were usually coincident with a general deterioration in water quality as emphasised by elevated turbidity, suspended solids, some nutrient species' (particularly total phosphorus) levels and bacterial counts (e.g. in November 2014 and May 2015 Figure 8).

Maximum mid-afternoon pH values in the mid to late summer period (8.0 to 8.2 units) were moderate for the lower reaches of a Taranaki river in early afternoon, an indication of the limited influence of algal photosynthetic activity on water quality (despite significant algal substrate cover) in this reach of the river system where more turbid conditions and silt deposition on the substrate have been typical of the site. A minimum pH (6.8 units) was found under flood conditions in May 2015 which was equivalent with the lowest value found to date.

Dissolved oxygen concentrations, were consistently high (median of 10.0 g/m^3) with a median saturation level of 102%. On the majority of occasions BOD_5 concentrations were indicative of relatively low organic content (i.e. less than 1.0 g/m^3). The median bacteriological numbers (80 enterococci and 190 faecal coliforms per 100 ml) were more reflective of the impacts of developed farmland run-off and possibly stock access to the lower reaches of this eastern hill country river.

Water temperatures varied over a moderately wide range of 13.9 ˚C with a maximum (early afternoon) summer temperature of 21.8 ˚C recorded in January 2015 under low flow conditions, at which time dissolved oxygen saturation was 109% and pH was 8.2 units.

Brief comparison with the previous 1995-2014 period

The range of flows sampled during the 2014-2015 period was relatively wide but narrower than the range sampled over the previous nineteen-year period. The median sampled flow in the 2014-2015 period was lower (by 1084 l/sec) than that sampled over the longer term partly as a result of the lengthy mid summer-autumn low flow period in early 2015. Median black disc clarity was better (by 0.28 m) and median turbidity was slightly lower (by 0.9 NTU) in the most recent period, while the median suspended solids concentration was lower by 1 g/m^3.

Most nitrogen nutrient species' median concentrations were slightly lower in the latest period, while phosphorus species were similar to lower compared to the medians for the previous nineteen-year period with total phosphorus (25%) showing the principal decrease and median ammoniacal nitrogen an increase (of 33%). Median bacterial numbers increased slightly for enterococci (by 12 per 100 mls) whereas faecal coliforms decreased (by 60 per 100 ml) in the 2014-2015 period.

Median dissolved oxygen saturation level was relatively similar (2% higher) in the 2014-2015 period while median pH levels were within 0.1 unit between periods. Maximum pH was 0.2 unit lower than the maximum previously recorded while minimum pH was identical for the two periods.

The range of water temperatures was narrower (by 5.8 ˚C) in the latest twelve-month period than over the previous nineteen-year period, due to a lower maximum temperature (by 2.2 ˚C) and higher minimum temperature (by 3.6 ˚C) recorded in the 2014-2015 sampling year, while median water temperature was 0.6 ˚C lower during 2014-2015.

4.2 Comparative water quality for the twenty-year (1995-2015) period

4.2.1 TRC data

In addition to the site descriptions of water quality measured during the 2014-2015 monthly sampling programme, a general comparison between the eleven sites of the programme may be made for the twenty-year sampling period to date (1995-2015) using statistical (tabular and graphical) data summaries. These have been provided for each individual site in Tables 5, 8, 11, 14, 17, 20, 23, 26, 29, 32 and 35. Comparative statistics for selected parameters are provided in Table 36 and in the form of the 'box and whisker' plots of Appendix II.

These site comparisons for the summary data over the twenty year record are discussed within groupings of parameters as follows.

Appearance (turbidity, black disc clarity, suspended solids, absorbance)

The water quality at all but two of the sites has been clean and clear with very low median suspended solids concentrations (3 g/m^3 or lower) and low median turbidity levels (less than 2 NTU) except during flood flow conditions. The exceptions have been the sites in the lower reaches of the Mangaehu River and the Waingongoro River. The former is an eastern hill-country catchment which was typically slightly cloudy due to fine colloidal solids and yellow-brown in appearance under most flow conditions. A slightly elevated median suspended solids concentration (4 g/m^3) has been recorded at this site, but median turbidity level (3.5 NTU) is significantly higher for this river than at any other site. The site in the lower reaches of the longest ringplain river (Waingongoro) also has elevated median suspended solids concentration (5 g/m^3) and turbidity (2.3 NTU). The site in the mid-reaches of the Stony River has shown marked variability, with erosion events in the headwaters the major contributing factor.

Generally upper catchment sites have exhibited higher aesthetic quality with a gradual deterioration toward the mid to lower reaches of the streams and rivers sampled.

Black disc clarity has shown greater variation between sites although similar trends of decreasing clarity down catchments occurred. Highest clarity was found in the upper reaches of the Patea River and the mid reaches of the Stony River (when not impacted by upper catchment erosion events) and the Waiwhakaiho River, with these sites' median clarities greater than 3.0 metres and maxima in excess of 8 metres at times. All but two other sites have achieved a median black disc clarity in excess of 1.4 metres. Due to the elevated turbidity of the Mangaehu River, the median clarity in the lower reaches of the river was only 0.85 metre while the site in the lower reaches of the Waingongoro River also had a relatively low median black disc value of 1.16 metres. Greatest variability was found at the Stony River site which has been the subject of several severe upper catchment erosion events at irregular intervals during the twenty year period.

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Table 36 Some comparative water quality data for the eleven TRC SEM sites for the twenty-year period July 1995 to June 2015 (n = 240 samples)

Site	Black disc		BOD_5	Conductivity @ 20°C	Faecal coliform bacteria		Nutrients: Ammonia	Nutrients: Nitrate	Nutrients: Total N	Nutrients: DRP	Nutrients: Total P	pH		Dissolved oxygen saturation			Suspended solids	Temperature			Turbidity
Unit	(m)		(g/m^3)	(mS/m)	(nos per 100 ml)		(g/m^3N)	(g/m^3N)	(g/m^3N)	(g/m^3P)	(g/m^3P)			(%)			(g/m^3)	(°C)			(NTU)
	Maximum	Median	Median	Median	Minimum	Median	Median	Median	Median	Median	Median	Maximum	Median	Min	Med	Range	Median	Maximum	Median	Range	Median
Maketawa Stream at Tarata Road*	5.23	2.55	<0.5	8.6	50	320	0.009	0.25	0.39	0.022	0.034	7.9	7.6	90	98	13	<2	17.6	11.4	12.8	0.9
Mangaoraka Stream at Corbett Road	4.73	1.80	0.7	14.4	84	790	0.021	0.84	1.10	0.009	0.023	8.1	7.6	83	96	24	2	20.5	13.0	14.7	1.6
Waiwhakaiho River at SH3	8.05	3.06	<0.5	12.2	23	200	0.008	0.11	0.20	0.024	0.034	8.5	7.9	91	100	19	<2	18.3	11.0	13.5	0.7
Stony River at Mangatete Road	13.2	3.25	<0.5	9.7	<1	8	<0.003	0.02	0.06	0.018	0.024	8.2	7.8	87	99	17	<2	16.6	10.8	10.9	0.8
Punehu Stream at Wiremu Road	4.53	1.81	<0.5	8.6	3	110	0.006	0.03	0.15	0.023	0.034	8.3	7.6	87	100	19	< 2	19.2	11.8	14.2	1.7
Punehu Stream at SH45	3.57	1.50	1.0	16.0	51	520	0.040	0.93	1.38	0.044	0.080	8.6	7.7	90	99	24	3	21.0	13.2	16.0	1.9
Waingongoro River at Eltham Road	4.39	1.69	0.7	11.2	6	180	0.018	1.13	1.44	0.019	0.038	8.6	7.8	92	103	29	3	20.8	12.4	15.2	1.5
Waingongoro River at SH45 **	4.34	1.16	1.0	16.4	3	220	0.034	1.87	2.40	0.055	0.100	9.1	7.8	89	101	52	5	22.0	13.7	16.6	2.3
Patea River at Barclay Road	9.10	4.38	<0.5	6.1	<1	20	<0.003	0.02	0.08	0.018	0.024	8.0	7.5	90	98	13	<2	14.7	9.2	11.0	0.5
Patea River at Skinner Road	4.68	1.83	0.9	9.9	2	230	0.053	0.92	1.22	0.038	0.066	8.8	7.8	87	102	34	2	21.8	12.8	16.5	1.5
Mangaehu River at Raupuha Road	4.04	0.85	0.6	9.8	6	235	0.012	0.19	0.30	0.006	0.020	8.4	7.7	83	100	35	4	24.0	13.7	19.7	3.5

[Notes: * for the period July 2003 to June 2015 (n = 144 samples); ** for the period July 1998 to June 2015 (n = 204 samples)]

Absorbances (at 340 nm /cm) have been generally relatively low. They are indicative of slight dissolved colour particularly at the Mangaehu River site, and also at both the upper and lower Punehu Stream sites, and to a slightly lesser extent at the site in the lower Waingongoro River. Absorbances at 770 nm /cm were very low indicating that any apparent dissolved colour was seldom due to the scattering effects of small colloidal particles.

Water temperature, pH, and conductivity

Coldest median water temperature (9.2 ˚C) has been measured at the upper site on the Patea River (altitude: 500 m asl) with increased median water temperatures in a downstream direction as might be expected. Highest maximum water temperatures have been recorded in the lower reaches of the Mangaehu River (24.0 ˚C), the Waingongoro River (22.0 ˚C), and the smaller Punehu Stream (21.0 ˚C), and in the mid reaches of the Patea River (21.8 ˚C); these four sites also exhibiting four of the five highest medians (13.7 ˚C, 13.7 ˚C, 13.2 ˚C, and 12.8 ˚C respectively) and widest ranges (19.7 ˚C, 16.6 ˚C, 16.0 ˚C and 16.5 ˚C respectively) of water temperatures. Atypically, relatively high median (11.8 ˚C), maximum (19.2 ˚C) and a wide range (14.2 ˚C) of water temperatures have been recorded in the upper reach of the Punehu Stream at Wiremu Road, probably due to the open, bouldery nature of the 2 km reach between the National Park and the sampling site (altitude: 270 masl).

Highest pH values (8.5 to 9.1) have been recorded at the mid and lower ringplain river and stream sites due to algal photosynthetic effects coincidental with more extensive substrate algal cover under warmer, mid to late summer, low flow conditions. pH values at all sites were slightly alkaline i.e., medians ranging from 7.5 to 7.9, typical of ring plain rivers and streams. (Note: diurnal temperature and pH variability is limited by the sampling regime for each site – see below).

Conductivity, a measure of the degree of mineralisation of the water, increased with distance downstream but median values were all indicative of relatively low total ionic content (i.e. <16.5 mS/m @20 °C). Greatest variability was generally recorded in the mid to lower reaches of the larger rivers and streams which were subject to wider ranges of flow.

Dissolved oxygen and biochemical oxygen demand

Very high median dissolved oxygen concentrations characterised all ten ring plain sites and the lower reach site in the Mangaehu River. Ranges were relatively narrow at most sites (< 30% at eight sites) and median values were 96% saturation or higher at all sites. Summer-autumn lower flow conditions, coincident with more extensive algal substrate cover, resulted in supersaturation on occasions at various sites in the mid to lower reaches of streams and rivers. The narrowest saturation range (<13%) was found in the upper reaches of the Patea River and the mid reaches of the Maketawa Stream, with wider saturation ranges (>16%) recorded at mid and lower catchment sites, and the widest (52%) in the lower reaches of the longest ringplain river where substrate periphyton cover often has been more extensive. (Note: Wider ranges may occur at all sites, but particularly lower reach sites, as the nature of the sampling regime does not provide for diurnal variability; rather sampling is confined to a narrow fixed time window for each site.)

Biochemical oxygen demand (BOD_5), a measure of the amount of biodegradable matter present, was generally less than 1 g/m^3 (i.e. no medians greater than 1.0 g/m^3), indicative of low organic enrichment at all sites. Median values were highest in the lower reaches of the Punehu Stream (1.0 g/m^3) and Waingongoro River (1.0 g/m^3) and the mid reaches of the Mangaoraka Stream, Waingongoro and Patea Rivers, all sites downstream of point and non-point source discharges. Elevated BOD_5 levels (>2 g/m^3) have been measured from time to time at most sites during fresh and flood flow conditions reflecting the influence of non point source farmland and stormwater run-off and have reached 2.4 g/m^3 under summer low flow conditions downstream of Stratford in the Patea River at the Skinner Road site.

Nutrients (nitrogen and phosphorus)

Nutrients such as nitrate, ammoniacal nitrogen and dissolved reactive phosphorus may readily be taken up by the flora of rivers and streams. An abundance of these nutrient forms may result in prolific and objectionable growths of attached filamentous algae (periphyton) particularly when in combination with low river flows, increased temperatures, and a plentiful supply of energy in the form of light (autotrophic growths) and/or organic matter (heterotrophic growths). Highest nutrient concentrations were recorded at the lower sites in the ring plain rivers and streams sampled, consistent with increased non-point source run-off and point source discharges through each ring plain catchment e.g., increases of 820% and 135% in median total nitrogen and total phosphorus respectively over the length of the Punehu Stream; 1425% and 175% respectively from the upper to the mid reaches of the Patea River; and 66% and 160% respectively through the mid to lower reaches of the Waingongoro River. Elevated nitrate concentrations often reflect high groundwater inputs, particularly after very wet weather (winter-spring) conditions when groundwater levels are higher and therefore contribute more proportionately to river/stream baseflows. Highest median concentrations of dissolved reactive phosphorus (DRP), total phosphorus, ammoniacal, nitrate and total nitrogen were generally found at the lower Punehu Stream site, mid Patea River (Skinner Road) site, mid and lower Waingongoro River sites, and to a slightly lesser degree at the site in the Mangaoraka Stream. However, relatively low dissolved reactive phosphorus concentrations (median of <0.01 g/m^{3}P) in the Mangaoraka Stream reflect the source of this ring plain stream which rises outside of the National Park, compared with the documented natural sources of dissolved phosphorus from within the park found in ringplain rivers and streams (TCC, 1984 and TRC, 2010). Relatively low dissolved reactive phosphorus (median of <0.01 g/m^{3}P) measured at the site in the lower reaches of the Mangaehu River reflect the river's eastern hill country catchment source.

Bacteria

Poor bacteriological water quality (median faecal coliform numbers from 220 to 790 per 100 mls) has been recorded at the sites in the lower reaches of the Maketawa Stream, Punehu Stream, Waingongoro River, Mangaehu River, and particularly the Mangaoraka Stream. Relatively poor bacteriological quality (medians from 180 to 230 per 100 mls) in the mid reaches of the Waiwhakaiho, Waingongoro, and Patea Rivers, also reflect non-point source run-off and point source discharges (and possibly stock access) to these developed farmland river and streams. The cumulative impacts of several dairy pond treatment systems’ discharges to the Mangatawa Stream have impacted upon Punehu Stream quality (TRC, 2011). One of the site’s (Mangaoraka Stream) counts has continuously exceeded 80 faecal coliforms per 100 mls indicative of consistently poor bacteriological quality.

The sites in the mid reaches of the Waiwhakaiho, Waingongoro and Patea Rivers have had comparatively good bacteriological water quality on occasions.

The sites in the Patea River's upper reaches (at Barclay Road) and the Stony River in mid-reach (at Mangatete Road) generally recorded very high bacteriological water quality with median faecal coliform numbers of 20 and 8 per 100 mls respectively.

The upper site in the Punehu Stream (at Wiremu Road) however has had an unexpectedly high median faecal coliform count of 110 per 100 mls, probably reflecting stock access to this stream and farm seepage and surface run-off over the 2 km reach between the National Park and Wiremu Road.

Enterococci numbers reflected the trends outlined above for faecal coliform bacteria, with the highest median counts generally recorded at the sites in the lower reaches of the Mangaoraka Stream and the Punehu Stream and lowest median counts in the Stony River and in the upper reaches of the Patea River.

4.2.2 NIWA data

A summary of the comparable twenty years of data for the three Taranaki region sites included in the NIWA national network (see Figure 1) is presented in Table 37. One of the sites (Waingongoro River at SH45) is also a TRC SEM site sampled under similar protocols by both TRC and NIWA but six days later in each month by NIWA (until 2014 and thereafter on the same day as TRC sampling).

Table 37 Some comparative water quality data for the three NIWA SEM sites for the twenty-year period July 1995 to June 2015 (n = 240 samples)

Site Unit	Black disc (m)		BOD_5 (g/m^3)	Conductivity @ 20°C (mS/m)	Nutrients Amm-N (g/m^3N)	Nitrate (g/m^3N)	Total N (g/m^3N)	DRP (g/m^3P)	TP (g/m^3P)	pH		Dissolved oxygen saturation %	Temperature (°C)			Turbidity (NTU)	Flow (m^3/sec)
	Maximum	Median	Median	Median	Median	Median	Median	Median	Median	Maximum	Median	Median	Maximum	Median	Range	Median	Median
Waitara River at Bertrand Road	3.2	0.48	0.7	8.8	0.011	0.31	0.56	0.006	0.034	8.6	7.7	102	23.2	13.8	16.7	8.6	29.5
Manganui River at SH3	7.7	4.07	<0.5	6.4	0.006	0.09	0.18	0.009	0.015	7.9	7.5	101	18.7	10.6	14.6	0.9	0.95
Waingongoro River at SH45	2.9 [2.9] (4.34)	1.30 [1.30] (1.16)	1.0 [1.0] (1.0)	16.5 [16.5] (16.4)	0.028 [0.03] (0.034)	1.90 [1.9] (1.87)	2.19 [2.19] (2.40)	0.048 [0.048] (0.055)	0.096 [0.096] (0.100)	9.1 [9.1] (9.1)	7.9 [7.8] (7.8)	103 [103] (101)	23.0 [23.0] (22.0)	13.7 [13.9] (13.7)	16.7 [16.7] (16.6)	2.5 [2.5] (2.3)	4.89 [4.92] (4.82)

[Notes ( ) = TRC data for the period July 1998 to June 2015 (n = 204 samples); [ ] = NIWA data for period July 1998 to June 2015]

These data indicate more turbid (cloudier) appearance in the lower reach of the Waitara River (median black disc clarity of 0.48 metres and turbidity of 8.6 NTU) with very clear conditions toward the upper reach of the Manganui River. Lower Waitara River median clarity and particularly turbidity were the worst of all thirteen sites monitored in the region, reflecting the significant impact of the eastern hill country component of this large river's catchment. (Similar patterns are noted in the Mangaehu River [Table 36]). Median water temperatures were typical of those found at comparable sites elsewhere in the region (Tables 36 and 37), while median pH, conductivity, dissolved oxygen and BOD_5 levels were also typical. Median nutrient concentrations were within the range of medians found at other regional sites monitored by TRC and were comparable with similarly located sites (in terms of position in the river reach).

A comparison of data for the Waingongoro River site in the lower reach (at SH45) between seventeen years of TRC state of the environment monitoring and the same years of NIWA network monitoring (Table 37) indicates very similar median water quality for all parameters despite the (six day) sampling protocol difference between programmes. Allowing for this difference in timing, sampled median flow conditions were also very similar, providing greater validity to the physicochemical water quality comparisons.

4.2.3 Comparisons with guideline values for various usages

The twenty years of state of the environment monitoring (SEM) data may be summarised and compared with various published guidelines and standards for different water usages (TRC, 2006a and TRC, 2009). As the monitoring programme samples all weather conditions on a systematically random basis there will always be data which fail to meet standards on some occasions. Therefore, the median statistic has been used to assess compliance with guidelines and standards in Table 38.

Table 38 Comparison of 1995-2015 SEM (TRC and NIWA) sites' median water quality with guideline values for various usages

Usage	Aesthetics		Contact recreation		Prevention of undesirable growths			Stock water		Aquatic ecosystems					Irrigation	Drinking water	
Parameter	Black disc	BOD_5	*E.coli*	BOD_5	DRP	TP	TN	Faecal coliforms	Faecal coliforms	Black disc	DO Saturation	NO_3	NH_4	Temp	TN	TP	NO_3
Guideline	>1.6 m	<3g/m³	<550/ 100mls	<3g/m³	<0.03 g/m³P	<0.03 g/m³P •	<0.6 g/m³N •	<1000/ 100mls	Median <100/100 mls	>0.8m	>80%	<0.4 g/m³N	<0.9 g/m³N	<25 °C	<25 g/m³N	<0.8 g/m³P	<11.3 g/m³N
Reference	1,2	2,3	2,3	2	1,2	1	1	1,2	1			1,2	1	2	1	1	1,2
Site																	
Maketawa Stream at Tarata Road	✓	✓✓	✓	✓✓	✓	x	✓	✓	x	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Mangaoraka Stream at Corbett Road	✓	✓	x	✓	✓	✓	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓	✓✓
Waiwhakaiho River at SH3	✓	✓	✓	✓	✓	x	✓	✓	x	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Stony River at Mangatete Road	✓	✓✓	✓	✓✓	✓	✓	✓	✓	✓	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓	✓✓
Punehu Stream at Wiremu Road	✓	✓	✓	✓	✓	x	✓	✓	x	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Punehu Stream at SH45	x	✓	✓	✓	x	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓✓	✓✓
Waingongoro River at Eltham Road	✓	✓	✓	✓	✓	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓	✓✓
Waingongoro River at SH45	x	✓	✓	✓	x	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓✓	✓✓
Patea River at Barclay Road	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Patea River at Skinner Road	✓	✓	✓	✓	x	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓	✓✓
Mangaehu River at Raupuha Road	x	✓	✓	✓	✓✓	✓	✓	✓	x	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Manganui River at SH3	✓	✓✓	✓	✓✓	✓	✓	✓	✓	✓	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Waitara River at Bertrand Road	x	✓✓	✓	✓✓	✓	x	✓	✓	x	x	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Summary of sites (13) in compliance	9	13	12	13	10	6	8	13	3	12	13	8	13	13	13	13	13

Key:
✓✓ = maximum (*minimum) value also meets usage guideline
✓ = median value, meets usage guideline
x = median value, does not meet usage guideline
• = 80% of values to meet usage guidelines

References:
1 = ANZECC, 2000
2 = TRC, 2003 & TRC, 2009
3 = MfE, 2003

4.2.3.1 Aesthetics

Most sites met the aesthetic quality guidelines although the four sites which did not achieve the black disc clarity were all situated in the lower reaches of catchments, two of which (Mangaehu and Waitara Rivers) are eastern hill country catchments.

4.2.3.2 Contact recreation

The Council's and NIWA's programmes do not necessarily collect samples representative of water quality typical of conditions at times when contact recreation is likely, as is stipulated in the MfE guidelines, and therefore care should be taken when comparing results against the guideline. It should also be noted that most of the SEM sites in the programme are not contact recreational sites; the streams are too shallow, cold and/or small at these locations. A specific recreational water quality SEM programme is structured around the requirements of the MfE guidelines and reported separately (TRC, 2014), and on the Council's website (www.trc.govt.nz). However, the sites' data presented in Table 38 are indicative of bacteriological conditions likely to exist at contact recreational sites in the vicinity of the reaches of the streams/rivers monitored.

One site (in the lower reaches of the Mangaoraka Stream) consistently failed to meet the guideline, while most of the other sites have failed to meet instantaneous guidelines ('Alert' and 'Action' modes (TRC, 2014) occasionally under spring-summer low flow conditions (refer to individual tables of 2014-2015 data) and under flood flow conditions (when contact recreation suitability is not an issue).

4.2.3.3 Undesirable growths

Algal growth smothers habitat and food sources for aquatic life and looks unattractive. Exceedance of guideline values at some sites is therefore of concern. However, exceedances of the guidelines for the prevention of undesirable nuisance growths will not necessarily result in nuisance growths occurring in the region's streams. Rather, excessive algal growths are most likely to occur in mid to late summer-autumn under conditions of warm, low flows, absence of recent rain events to scour the growths, and strong sunlight.

In the lower reaches of most Taranaki catchments, elevated nutrient levels are high enough to promote algal growth under low flow conditions. Most lower river/stream sites illustrated exceedances of nutrient guideline values (Table 38). This is true particularly of total nitrogen and total phosphorus species which generally increased in concentration downstream. Dissolved reactive phosphorus levels were more variable with levels decreasing or remaining relatively stable downstream of the National Park boundary (where dissolved reactive phosphorus is present from natural sources).

The Council has a separate SEM programme that focuses specifically on nuisance growths at various freshwater indicator locations in the region (TRC, 2006b and TRC, 2014a). In general, periphyton growths are more likely and more prolific in drier summers, when flows decrease and there is less scouring and disturbance of stream beds, more sunlight, higher temperatures, less grazing by macroinvertebrates, and less dilution of discharges containing nutrients. The lower reaches of ring plain streams in southern and western Taranaki particularly can experience nuisance growths particularly in the mid summer-early autumn period.

4.2.3.4 Stock water

The bacteriological guideline for stock water was previously 1000 faecal coliforms per 100 mls. All median values at all sites comfortably met this guideline. Given that higher faecal coliform levels in streams generally occur under conditions of heavy rainfall, when stream water is less likely to be utilized, individual results above this guideline generally do not indicate a need for concern.

The ANZECC (2000) water quality guideline stipulates a limit of 100 thermo-tolerant coliforms (which includes faecal coliforms) per 100 mls, for median values. As noted above, with many Council samples gathered at times when stock would not need water, the guideline is not necessarily appropriate as a basis for evaluating the regional water quality data. It may be noted that at five of the ten sites shown in Table 38 as otherwise exceeding the bacteriological guidelines, the 25th percentile result (see Appendix I) satisfies the criterion. All sites complied with the nitrate-N guideline.

4.2.3.5 Aquatic ecosystems

While all sites complied with the ammonia-N and temperature guidelines, five sites (in the middle to lower reaches of catchments) had median values above the guideline for nitrate-N and one site under the visibility guideline. The Council has a separate SEM programme that focuses specifically on the macroinvertebrate fauna of 57 sites in the region (including all of the eleven sites in the physicochemical programme and the two NIWA sites) and none of these sites' communities have illustrated significant deterioration, while five (two middle and three lower reach) of the 11 sites in the physicochemical programme have shown significant improvements in stream 'health' trends over the nineteen years (1995 to 2014) to date (TRC, 2006c, Stark and Fowles, 2006 and TRC, 2014a).

4.2.3.6 Irrigation

All sites met the relevant nutrient guidelines for irrigation water.

4.2.3.7 Drinking water

The drinking water nitrate standard was complied with at all sites, although all sites would require treatment to achieve bacteriological drinking water standards.

4.2.4 National Objectives Framework

In 2014, Ministry for the Environment released a National Policy Statement for Freshwater Management (NPS-FW) which sets out objectives and policies that direct local government to manage water in an integrated and sustainable way, while providing for economic growth within set water quantity and quality limits. The national policy statement is a first step to improve freshwater management at a national level.

This national policy statement provides a National Objectives Framework (NOF) to assist regional councils and communities to more consistently and transparently plan for freshwater objectives. The national policy statement acknowledges iwi and community values by recognising the range of iwi and community interests in fresh water, including environmental, social, economic and cultural values.

The national policy statement sets national bottom lines for two compulsory values – ecosystem health and human health for recreation – and minimum acceptable states for other national values.

Overall freshwater quality within a region must be maintained or improved. The national policy statement allows some variability in terms of freshwater quality, including between freshwater management units, as long as the overall freshwater quality is maintained within a region.

Based on 'A Draft Guide to Attributes in Appendix 2 of the National Policy Statement for Freshwater Management 2014', the recommended number of samples to determine the sample statistic for assessing progress towards freshwater objectives is at least 30 samples collected on a monthly basis over three years. While the NOF documentation discusses an 'annual median' as the basis for determining compliance, the measure is rather the median of 3 years' worth of data, rather than just one. What that means in practice is that if the dataset encompasses one year of poor water quality and two years of relatively good quality, then the median of the full dataset will overall show a poorer quality than if the 3 individual annual medians were calculated and then the median of the annual medians used as the point of compliance determination.

SEM monitoring data from 2012 - 2015 was used to analyse the NOF attribute state (36 data points). The results for the 11 SEM sites with the NOF are summarised in Table 39 and illustrated in Figure 9.

Table 39 Summary result for water quality data from 2012-2015 against National Objective Framework attribute states (n=36 samples).

Value	Ecosystem health				Human health
Attribute	Nitrate-N (g/m^3)		Ammoniacal-N		E.*coli*
	Annual median	Annual 95th percentile	Annual median	Annual maximum	Annual median
Maketawa Stream at Tarata Rd	A	A	A	A	B
Mangaoraka Stream at Corbett Rd	A	A	A	A	D
Waiwhakaiho River at SH3	A	A	A	A	A
Stony River at Mangatete Rd	A	A	A	A	A
Punehu Stream at Wiremu Rd	A	A	A	A	A
Punehu Stream at SH45	B	B	A	B	C
Waingongoro River at Eltham Rd	B	A	A	C	B
Waingongoro River at SH45	B	B	B	B	A
Patea River at Barclay Rd	A	A	A	A	A
Patea River at Skinner Rd	A	A	B	B	B
Mangaehu River at Raupuha Rd	A	A	A	A	A

4.2.4.1 Ecosystem health

The national policy statement specifies attributes to manage long term exposure for two toxicants, nitrate and ammoniacal nitrogen. These toxicants can cause both lethal and sub-lethal (e.g. reducing growth rates or reproductive success) effects to aquatic species. It is recommended for councils to set freshwater objectives in the A or B attribute states when sensitive species are present that maybe at risk of lethal effects. All sites met the NOF standard set for toxicants nitrate and ammoniacal nitrogen. More than half the sites (64%) achieved 'A' grade for both attributes.

4.2.4.2 Human health

Infection risk profiles have been developed to relate E.*coli* levels and the proportion of population at risk of *Campylobacter* infection for two types of recreational activity (McBride, 2012):

- Activities with occasional immersion (such as wading and boating)
- Activities likely to involve full immersion (such as swimming or white-water rafting)

A sampling statistic is associated with each type of activity. A median is used to characterise sites used for activities with occasional immersion, while a 95th percentile is defined for full immersion activities. The use of different sample statistics means that there are different levels of confidence that the objective is achieved. As mentioned previously (Section 4.2.3.2), most of the SEM sites in the programme are not considered contact recreational sites; the streams are too shallow, cold and/or small for recreational bathing activities.

All sites met the NOF attribute state for E.*coli* except Mangaoraka Stream at Corbett Rd. The annual median E.*coli* at this site exceeded the national bottom line limit of 1000 E.*coli*/100ml. Investigative work on the Mangaoraka Stream in the past has attributed high E.*coli* and faecal coliform to direct stock access to streams and the cumulative impacts of consented dairy pond discharges, particularly under low flow conditions.

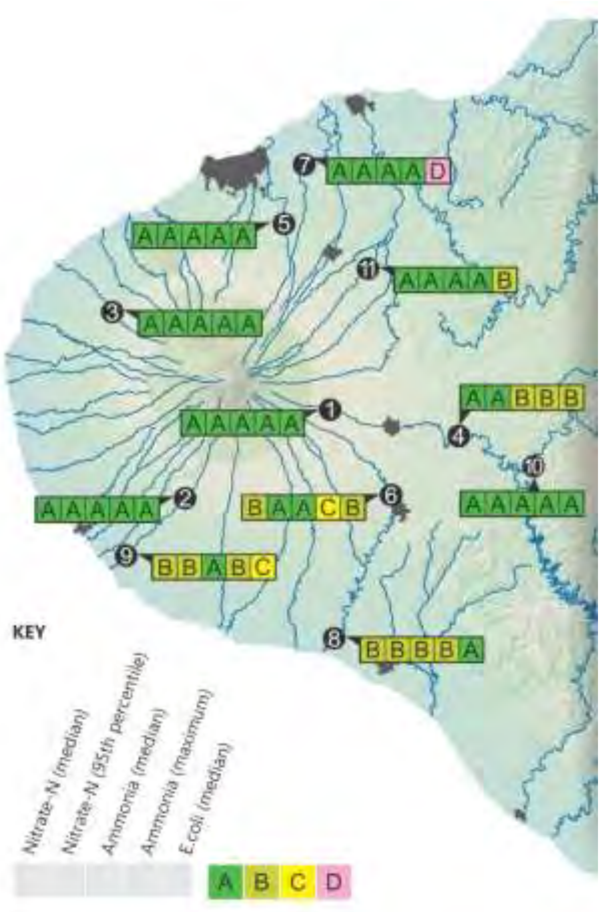

Figure 9 Results for NOF attribute states for the 11 SEM sites in Taranaki

4.3 Trends in physicochemical water quality data from 1995 to 2015

4.3.1 Introduction

Twenty years of physicochemical water quality data have been collected up to 30 June 2015. The complete data set to date has been analysed each year for trends since the accumulation of 10 year's data. Previous trend analysis has been reported in TRC (2006, 2009, 2009a, 2010, 2011, 2012, 2013, 2014, and 2015a). An update of the trends including data from the 2014-2015 monitoring year can now be provided. It does not include a detailed interpretation of the results. This has been provided in the most recent five yearly State of the Environment Report (TRC, 2015a).

4.3.2 Trend analysis methods

The trend analysis involves a flow adjustment of the raw data for each variable at each site, followed by trend analysis accounting for any seasonal pattern. This analysis has been adopted throughout New Zealand for water quality trend analysis (Scarsbrook and McBride, 2007).

Flow adjustment is necessary because most water quality variables are subject to either dilution (decreasing concentration with increasing flow) or land run-off (increasing concentration with increasing flow). Flow adjustment was performed using LOWESS (LOcally WEighted Scatterplot Smoothing), within the Time Trends software[1], with a 30% span. Every data-point in the record was then adjusted depending on the value of flow (adjusted value=raw value – smoothed value + median value (where the smoothed value is that predicted from the flow using LOWESS)).

The non-parametric trend analysis was then applied to the whole data set for each parameter at each site which takes into account the seasonal variability in the data.

This analysis is based on two key measures:

- The seasonal Kendall slope estimator (SKSE) which measures the magnitude of the trend, and
- The associated seasonal Kendall trend test which determines whether the trend is significant.

Statistically significant trends were determined using a p-value < 0.05 or <0.01. If a p-value is less than 0.05 (or 0.01), then there is a less than 5% (or 1%) chance of finding a trend when there is not one. In the data presented below, p-values are expressed as a percentage and highlighted if the percentage is less than 5% (statistically significant) or less than 1% (very statistically significant).

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[1] Trend analysis prior to 2009 has been conducted with Datadesk software. A comparison of the Time trends and Datadesk software was undertaken during the 2009 trend analysis to ensure that the different software packages produced similar results. Refer to Hope (2009) for details of this analysis.

The slope of the trend (SKSE) is expressed in units of change per year, and can also be expressed in terms of relative change (RSKSE) which is the percent of change per year. A positive SKSE or RSKSE indicates a positive (increasing) trend, and a negative SKSE or RSKSE indicates a negative or decreasing trend. The RSKSE allows comparisons in the slope between parameters and sites and is used in the tables below.

It is recognised that the statistical significance of a trend does not necessarily imply a 'meaningful' trend i.e., one that is likely to be relevant in a management sense. Ballantine and Davies-Colley (2009) have determined a 'meaningful' trend as one for which the RSKSE is statistically significant and has an absolute magnitude > 1 percent per year. This approach has also been adopted below.

4.3.3 Results of trend analysis

Table 40 summarises the significant trends recorded for each water quality parameter at the 11 sites monitored in the physicochemical state of the environment monitoring programme where there is sufficient data. This year's trend includes the Maketawa Stream at Tarata Road as there are now twelve years of data for this site. Figure 10 shows the trends graphically for a selected number of sites and parameters where significant trends were recorded.

Of the nutrients, DRP and to a lesser extent total phosphorus, have shown a significantly deteriorating trend at a number of sites, including the upper and middle catchments which would be less subject to anthropogenic pressures. Six out of eleven sites have shown a significant deterioration in DRP. Where deterioration in total phosphorus, nitrate and ammonia-N has occurred, this has occurred in the middle and lower catchment where more land use intensification and urbanisation occurs.

Nitrate showed significant deteriorating trends at two sites out of eleven, one in the mid catchment and one in the lower catchment. However, total nitrogen improved significantly at six sites mainly at the upper (Patea River at Barclay Road and Punehu Stream at Wiremu Road), middle (Stony River at Mangatete Road and Maketawa Stream at Tarata Road) and the lower catchment (Waingongoro at SH45 and Mangaehu River at Raupuha Road). On the whole, total nitrogen remained stable at the rest of the sites. Ammonia-N showed generally stable trends at all sites throughout all catchment levels with the exception of the Waiwhakaiho River at SH3 and Waingongoro at SH45 where significant trends of deterioration are apparent.

Generally, mid catchment sites appear to be showing the most deterioration in nutrients, although even here deterioration is apparent in less than one-third of all nutrient measures and although the lower catchment sites show almost a similar number and proportion of deteriorations there is notable improvement in the Waingongoro River at SH45 (significant improvement in DRP, total phosphorus, nitrate and total nitrogen). This is a positive aspect as the lower catchment would be under the most pressure from land use intensification and upstream influences. The Mangaehu River is also stable in all nutrients except for total nitrogen, which is showing improvement. The Waiwhakaiho River at SH3 and the Punehu Stream at SH45 have the greatest number of deteriorating trends in relation to nutrients (three out of five nutrients are deteriorating significantly for these two sites) (Table 40).

Deterioration in phosphorus parameters appeared to be increasing at a steady but slow rate at the Waingongoro at Eltham Rd site, Mangaoraka Stream at Corbett Rd and Punehu Stream at SH45 (Figure 10). The Patea River at Barclay Road site also shows an increasing DRP trend. The Punehu Stream at SH45 has only recently shown very significant deteriorating trends in dissolved reactive phosphorus; this analysis also details a deteriorating trend in total phosphorus, nitrate and total nitrogen (Table 41). Nitrogen parameters appear to have peaked between 2003 and 2005, and particularly in the Waingongoro River have been steadily improving (decreasing) since then (Figure 10). The Waingongoro River at SH45 is showing a very significant improving trend in dissolved reactive phosphorus, total phosphorus, nitrate and total nitrogen (Figure 10). It is probable that this is due to the more recent reduction in meatworks' discharges to the river at Eltham and the elimination of all Eltham WWTP municipal discharges in the catchment (since mid-2010). However, significant increasing trends were detected for ammonia-nitrogen and BOD at this site.

Faecal coliforms and enterococci bacteria generally showed little statistically significant change over the 20 year period, although sites Waiwhakaiho at SH3 and Mangaoraka Stream at Corbett Rd indicated a deteriorating level in faecal coliforms and enterococci. There is a very significant deteriorating trend in enterococci in the lower catchment sites of the Mangaoraka Stream at Corbett Road and this has now been reflected in faecal coliform levels during this year's trend analysis. There is a significant decrease in faecal coliform to a lesser degree at Mangaehu River River at Raupuha Road which was not detected in last year's analysis (2014).

Traditional indicators of pollution, organic matter (BOD), suspended solids, clarity (black disc), conductivity (dissolved matter) generally show no apparent trends at most sites over the 20 year period. However, the Stony River shows deterioration in clarity and suspended solids as a result of the significant erosion events that have occurred in the headwaters of this catchment in recent years and the LOWESS curve (Figure 10) indicates periods of erosion and recovery over time. Deterioration in clarity has also been significant at Waiwhakaiho River (SH3) and the Mangaoraka Stream (Corbett Road), where steady declines throughout the period are apparent (Figure 10). There is no longer an improvement in clarity at the Waingongoro SH45 site but a continued improvement in suspended solids at Punehu Stream SH 45. There have been a continued deterioration trends in BOD at two sites i.e. Mangaoraka Stream at Corbett Rd and Waingongoro SH45 since the 2014 year. Maketawa Stream at Tarata Road showed no significant deterioration in BOD for this year's analysis. Some significant trends in water temperature and pH have been noted (Table 41) however the rates of change per year in most of these cases are less than 1% and are not 'meaningful' changes.

Figure 10 shows the trends graphically for a selected number of sites and parameters where significant trends were recorded.

Table 40 'Meaningful' trends in surface water quality at 11 State of the Environment Monitoring sites in Taranaki- 1995-2015 (p<5% and RSKSE (%change/yr) >1%)

		Water Quality Variable															
Catchment Level	**Location**	Dissolved Reactive P	Total Phosphorus	Nitrate	Ammonia-N	Total Nitrogen	Faecal coliforms	Enterococci	Conductivity	Black Disc	Suspended Solids	Temp °C	Biochemical O_2 Demand	pH	**Total no. sites: Improvement** 😃	**No change** 😐	**Deterioration** ☹
Upper	**Patea River Barclay Rd**	☹	😐	😐	😐	😃	😐	😐	😐	😐	😐	😐	😐	😐	**1**	**11**	**1**
Upper/ Middle	**Punehu Stream Wiremu Rd**	😐	😐	😐	😐	😃	😐	😐	😐	😐	😐	😐	😐	😐	**1**	**12**	**0**
Middle	**Stony River Mangatete Road**	😐	🙁	😐	😐	😃	😐	😐	😐	☹	☹	😐	😐	😐	**1**	**9**	**3**
Middle	**Maketawa Stream Tarata Road***	☹	😐	😐	😐	😃	😐	😐	😐	😐	😐	😐	😐	😐	**1**	**11**	**1**
Middle	**Patea River Skinner Rd**	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	**0**	**13**	**0**
Middle	**Waiwhakaiho SH3**	☹	😐	☹	☹	😐	☹	☹	😐	☹	😐	😐	😐	😐	**0**	**7**	**6**
Middle	**Waingongoro Eltham Rd**	☹	☹	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	**0**	**11**	**2**
Lower	**Mangaoraka Stream Corbett Rd**	☹	☹	😐	😐	😐	☹	☹	😐	☹	😐	😐	🙁	😐	**0**	**7**	**6**
Lower	**Waingongoro SH45****	😃	😃	😃	☹	😃	😐	😐	😐	😐	😐	😐	☹	😐	**4**	**7**	**2**
Lower	**Punehu Stream SH45**	☹	☹	☹	😐	☹	😐	😐	😐	😐	🙂	😐	😐	😐	**1**	**8**	**4**
Lower	**Mangaehu River Raupuha Rd**	😐	😐	😐	😐	😃	🙂	😐	😐	😐	😐	😐	😐	😐	**2**	**11**	**0**
	Total no. sites: Improvement 😃	1	1	1	0	6	1	0	0	0	1	0	0	0			
	No change 😐	4	6	8	9	4	8	9	11	8	9	11	9	11			
	Deterioration ☹	6	4	2	2	1	2	2	0	3	1	0	2	0			

Key:

*Matetawa Tarata Road: Data for this site only for the past 11 years: 2003 - 2015

**Waingongoro SH45: Data for this site only for the past 16 years: 1998 - 2015

😃 statistically very significant **improvement** P<0.01 (1%)

🙂 statistically significant **improvement** P<0.05 (5%)

😐 **no statistically significant change**

🙁 statistically significant **deterioration** P<0.05 (5%)

☹ statistically very significant **deterioration** P<0.01 (less than 1% probability that the trend is due to natural variability and doesn't represent an actual change)

Upper catchment site **Mid-catchment site** **Lower catchment site**

Table 41 *p*-values (%) and trend slopes (% change per year) for flow and seasonally adjusted water quality variables at 11 Taranaki sites. Significant deteriorations are shown in orange (*p*<5%) and red (*p*<1%) and significant improvements are shown in light green (p<5%) and dark green (p<1%). 'Real' trends (i.e., the change is ecologically significant) are highlighted [ ] (>1% change per year).

Catchment Level	Location	Water Quality Variable													
		Dissolved Reactive P		Total Phosphorus		Nitrate		Ammonia-N		Total Nitrogen		Faecal coliforms		Enterococci	
		p-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr
Upper	Patea River Barclay Rd	0.01	1.24	17.44	0.38	0.38	-0.40	97.76	-0.03	0.00	-3.43	44.25	-0.79	45.22	-1.54
Upper/ Middle	Punehu Stream Wiremu Rd	25.71	0.35	61.96	-0.14	36.86	0.89	5.60	2.16	0.00	-2.21	8.65	-1.73	31.62	-1.26
Middle	Stony River Mangatete Road	0.48	0.73	1.53	1.03	74.31	-0.24	36.36	-0.09	0.00	-4.45	75.73	-0.46	79.14	-0.36
Middle	Maketawa Stream Tarata Road	0.36	1.88	18.47	1.19	17.20	-1.56	10.88	2.03	1.49	-1.56	79.69	0.43	88.98	0.35
Middle	Patea River Skinner Rd	13.64	-0.58	14.14	-0.56	16.29	0.34	44.81	0.45	91.79	-0.02	11.78	-2.03	24.82	-1.43
Middle	Waiwhakaiho SH3	0.10	0.97	1.97	0.55	0.13	2.00	0.07	2.74	10.12	-0.75	0.57	2.73	0.74	2.83
Middle	Waingongoro Eltham Rd	0.00	4.13	0.00	2.86	2.91	0.65	27.32	1.01	16.29	0.35	12.23	-1.91	23.94	-1.45
Lower	Mangaoraka Stream Corbett Rd	0.01	2.58	0.25	1.63	10.52	-0.35	14.66	1.04	1.31	-0.59	0.48	2.54	0.28	3.05
Lower	Waingongoro SH45*	0.00	-2.54	0.05	-1.93	0.00	-1.25	0.21	2.49	0.00	-0.91	95.26	-0.15	85.75	-0.32
Lower	Punehu Stream SH45	0.00	2.64	0.04	1.46	0.00	1.95	93.28	-0.11	0.19	1.10	35.38	-1.05	48.00	-0.91
Lower	Mangaehu River Raupuha Rd	28.14	0.49	96.26	-0.06	91.79	-0.04	50.61	-0.46	0.48	-1.14	4.81	-2.12	9.34	-1.95
Total no. sites: Improvement ☺		1		1		1		0		6		1		0	
No change 😐		4		6		8		9		4		8		9	
Deterioration ☹		6		4		2		2		1		2		2	

Table 41 (cont) *p*-values (%) and trend slopes (% change per year) for flow and seasonally adjusted water quality variables at 11 Taranaki sites. Significant deteriorations are shown in orange (*p*<5%) and red (*p*<1%) and significant improvements are shown in light green (p<5%) and dark green (p<1%). 'Real' trends (i.e., the change is ecologically significant) are highlighted (>1% change per year).

Catchment Level	Location	Water Quality Variable											
		Conductivity		Black Disc		Suspended Solids		Temp °C		Biochemical O_2		pH	
		p-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr
Upper	Patea River Barclay Rd	10.52	-0.13	95.49	0.02	78.58	0.00	19.94	-0.23	55.02	0.00	80.03	-0.01
Upper/ Middle	Punehu Stream Wiremu Rd	0.00	0.31	15.73	-0.60	88.83	0.01	5.03	-0.41	20.94	-0.09	0.00	-0.09
Middle	Stony River Mangatete Road	68.71	-0.05	0.00	-3.15	0.03	11.43	14.66	-0.23	18.31	0.00	4.03	-0.04
Middle	Maketawa Stream Tarata Road	56.59	0.06	41.70	-0.68	44.01	0.72	92.12	-0.01	5.48	1.71	85.86	0.00
Middle	Patea River Skinner Rd	99.25	0.00	18.05	-0.50	56.78	-0.14	74.31	-0.05	13.16	0.76	11.35	-0.05
Middle	Waiwhakaiho SH3	1.97	-0.21	0.16	-1.03	60.65	0.03	3.05	-0.42	13.64	0.39	0.00	-0.09
Middle	Waingongoro Eltham Rd	84.41	-0.04	14.14	-0.60	51.81	0.15	8.32	-0.27	9.36	0.90	0.38	-0.07
Lower	Mangaoraka Stream Corbett Rd	12.69	0.15	0.00	-2.15	14.92	0.91	11.35	-0.27	1.18	1.32	5.98	-0.04
Lower	Waingongoro SH45*	87.71	-0.02	11.38	0.73	94.31	-0.07	7.26	-0.36	0.00	3.08	0.00	-0.16
Lower	Punehu Stream SH45	3.51	0.27	85.88	-0.06	4.40	-1.51	3.51	-0.32	27.73	0.43	0.00	-0.12
Lower	Mangaehu River Raupuha Rd	18.05	-0.14	37.36	-0.48	28.99	-0.56	0.80	-0.46	19.94	-0.36	44.81	0.02
Total no. sites: Improvement ☺		0		0		1		0		0		0	
No change 😐		11		8		9		11		9		11	
Deterioration ☹		0		3		1		0		2		0	

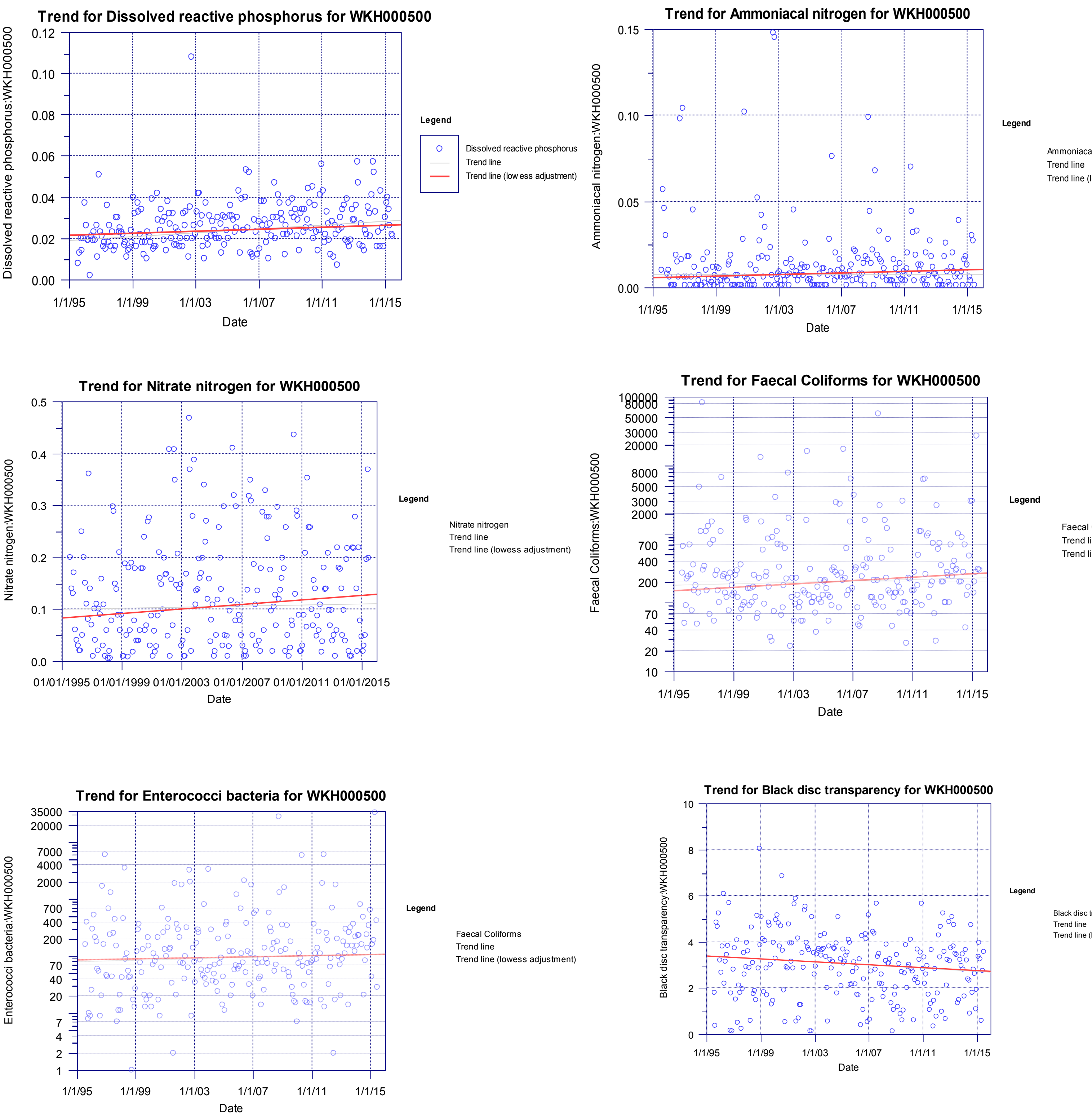


Figure 10 Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

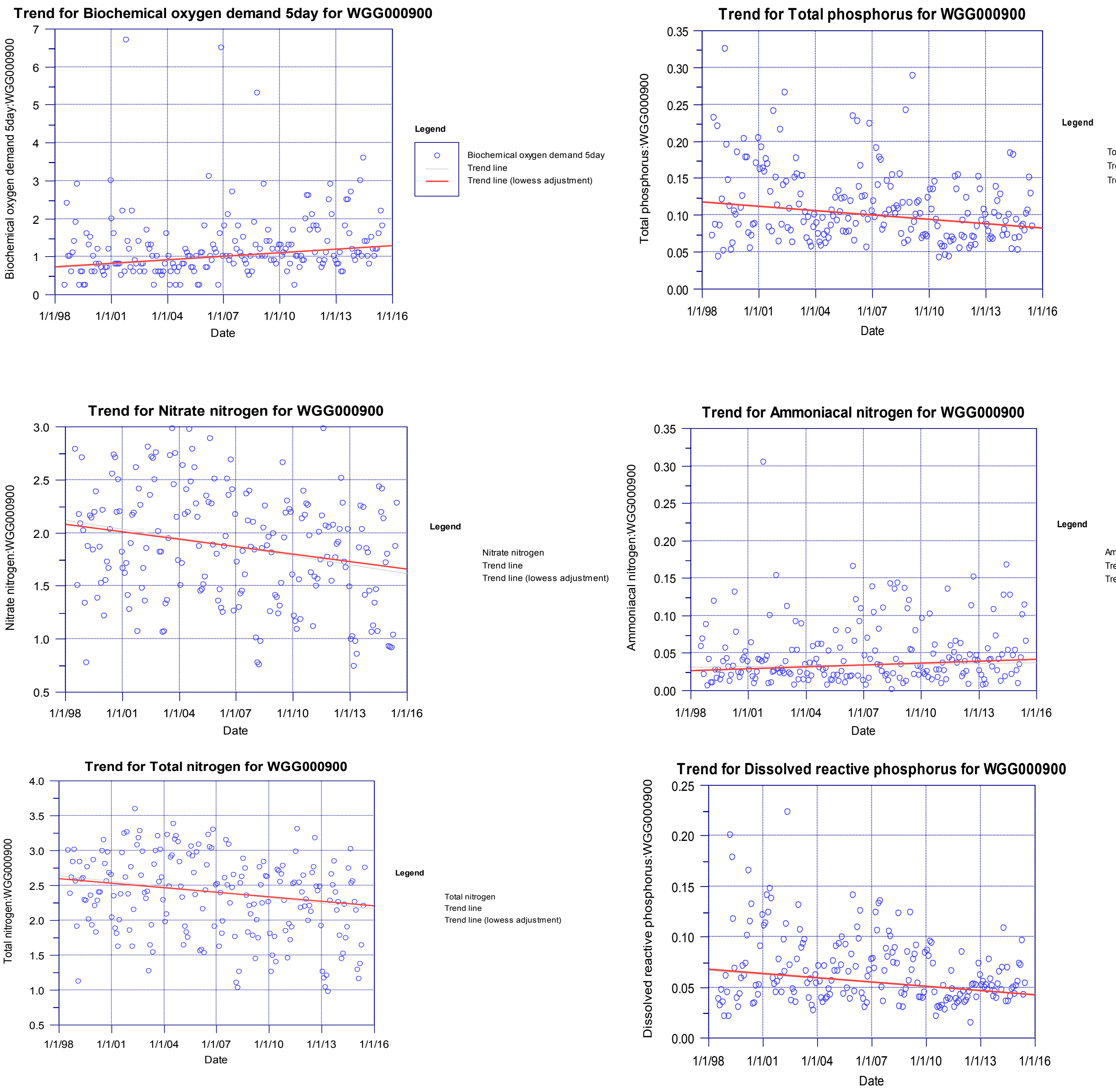
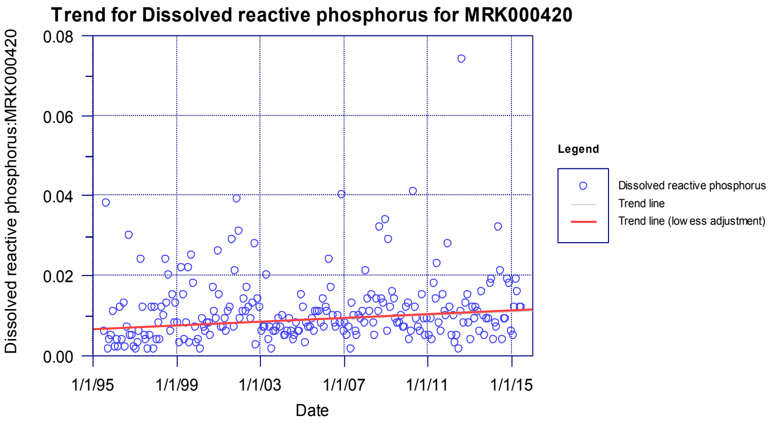
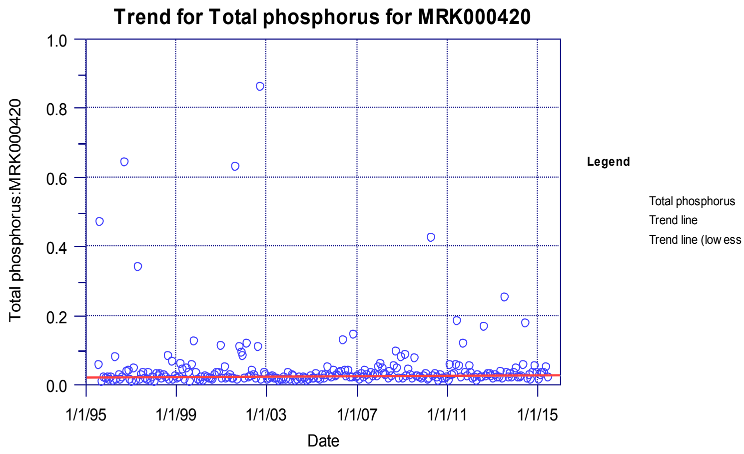
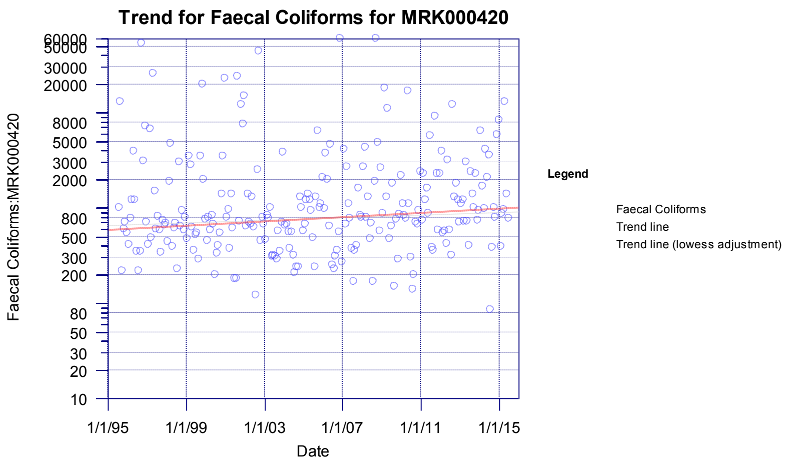
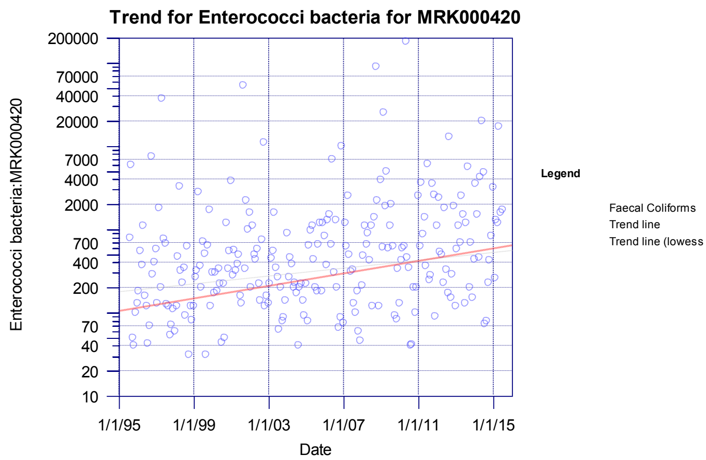


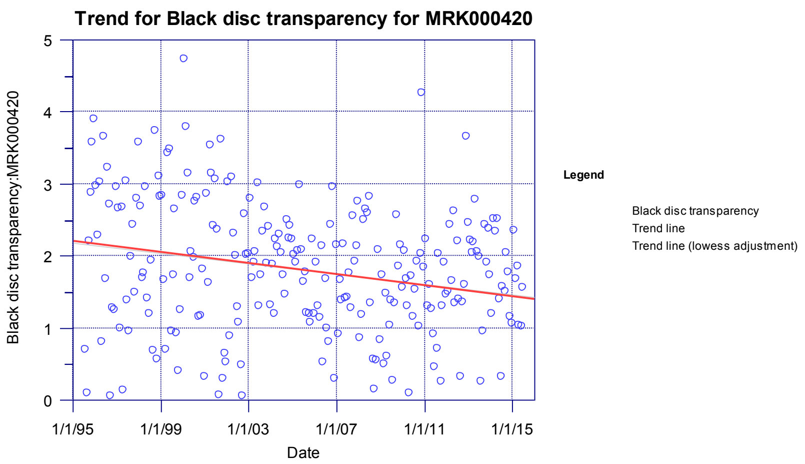
Figure 10 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

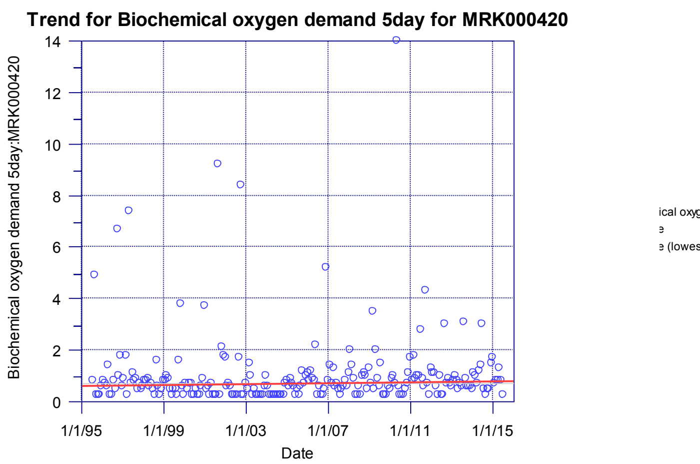

Trend for Dissolved reactive phosphorus for MRK000420
Dissolved reactive phosphorus:MRK000420
Date
Legend
Dissolved reactive phosphorus
Trend line
Trend line (lowess adjustment)


Trend for Total phosphorus for MRK000420
Total phosphorus:MRK000420
Date
Legend
Total phosphorus
Trend line


Trend for Faecal Coliforms for MRK000420
Faecal Coliforms:MRK000420
Date
Legend
Faecal Coliforms
Trend line
Trend line (lowess adjustment)


Trend for Enterococci bacteria for MRK000420
Enterococci bacteria:MRK000420
Date
Legend
Faecal Coliforms
Trend line


Trend for Black disc transparency for MRK000420
Black disc transparency:MRK000420
Date
Legend
Black disc transparency
Trend line
Trend line (lowess adjustment)


Trend for Biochemical oxygen demand 5day for MRK000420
Biochemical oxygen demand 5day:MRK000420
Date

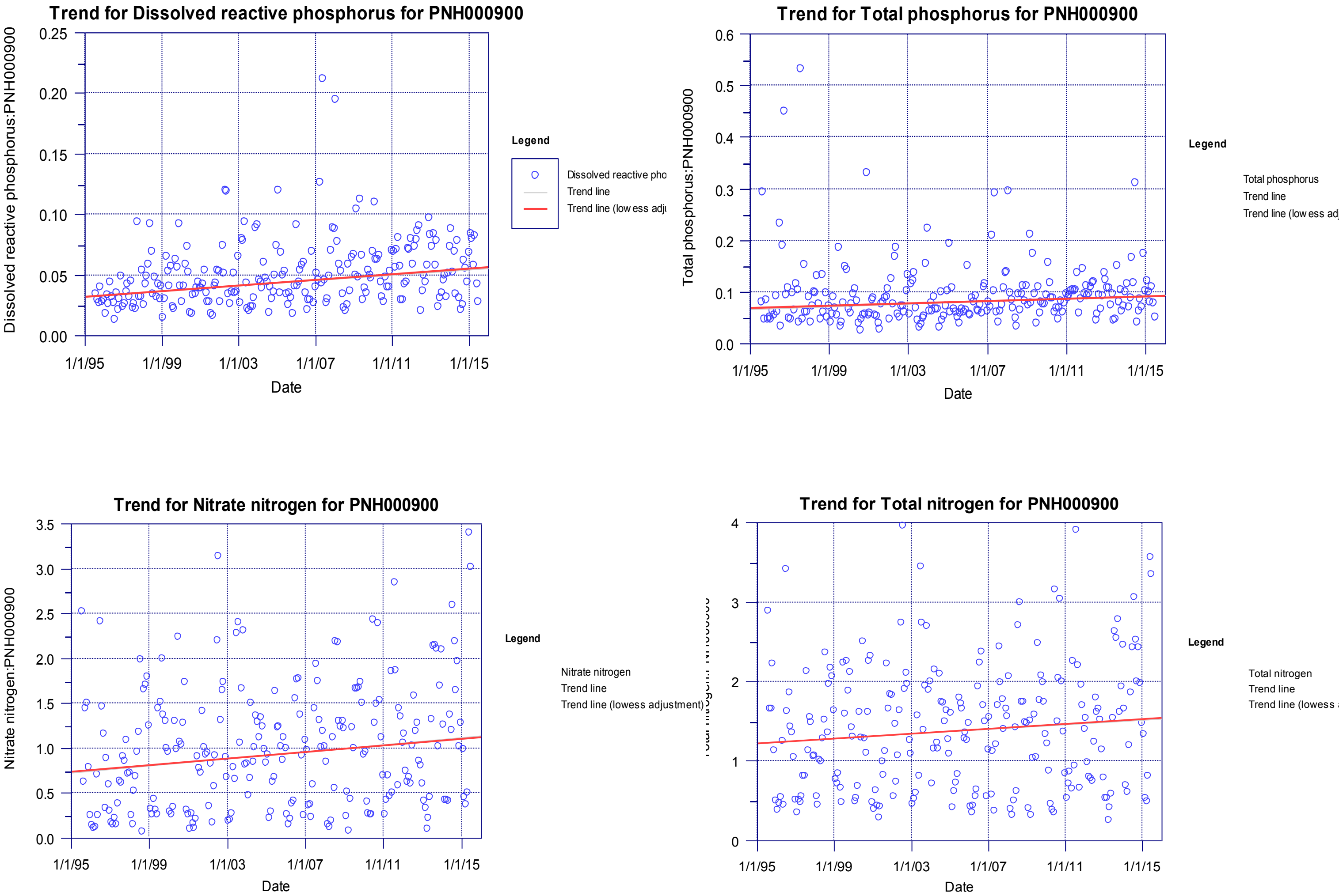


Figure 10 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

4.4 Trends in physicochemical water quality data from 2008 to 2015

4.4.1 Introduction

Data from State of the Environment physicochemical water quality monitoring programme at 11 sites around the region was trended over the full 20 years' record (1995 – 2015), as presented in the previous section of this report, and also over the most recent 7 recent period (July 2008 – June 2015) to observe if there were any changes over in trends in recent years. The latter is the more meaningful feedback for effectiveness of current policies and interventions.

4.4.2 Trend analysis methods

The trend analysis involves a flow adjustment of the raw data for each variable at each site, followed by trend analysis accounting for any seasonal pattern. This analysis has been adopted throughout New Zealand for water quality trend analysis (Scarsbrook and McBride, 2007).

Flow adjustment is necessary because most water quality variables are subject to either dilution (decreasing concentration with increasing flow) or land run-off (increasing concentration with increasing flow). Flow adjustment was performed using LOWESS (LOcally WEighted Scatterplot Smoothing), within the Time Trends software[2], with a 30% span. Every data-point in the record was then adjusted depending on the value of flow (adjusted value=raw value – smoothed value + median value (where the smoothed value is that predicted from the flow using LOWESS)).

The non-parametric trend analysis was then applied to the whole data set for each parameter at each site which takes into account the seasonal variability in the data.

This analysis is based on two key measures:

- The seasonal Kendall slope estimator (SKSE) which measures the magnitude of the trend, and
- The associated seasonal Kendall trend test which determines whether the trend is significant.

Statistically significant trends were determined using a p-value < 0.05 or <0.01. If a p-value is less than 0.05 (or 0.01), then there is a less than 5% (or 1%) chance of finding a trend when there is not one. In the data presented below, p-values are expressed as a percentage and highlighted if the percentage is less than 5% (statistically significant) or less than 1% (very statistically significant).

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[2] Trend analysis prior to 2009 has been conducted with Datadesk software. A comparison of the Time trends and Datadesk software was undertaken during the 2009 trend analysis to ensure that the different software packages produced similar results. Refer to Hope (2009) for details of this analysis.

4.4.3 Results of trend analysis

Overall there were some changes between the long term and short term record, in relation to the number of deteriorating trends (Table 42).There are fewer measures of deterioration in the short term trends compared to the long term trends across the board for nutrients, bacteria, organics and aesthetics. Short term trend is also showing less deterioration measures with larger measures being maintained or showing no significant trend. That is, recent trends show wider stability and less deterioration than is apparent in the long term trends.

Specific changes in trends for nutrients, bacteria, organics and aesthetics are shown in Figure 11.

Table 42 Summary of physicochemical trends between 20 years and 7 years of data

Statistical level	Total number of trends	
	20 years	7 years
Improvement (p<0.01)	9	1
Improvement (p<0.05)	2	5
Being maintained	74	95
Deterioration (p<0.05)	2	5
Deterioration (p<0.01)	23	4
Total	110	110

Comparison of long term trends 1995-2015 (20 years) and 2008-2015 (7 years) analysis.

<u>Nutrients</u>

- 40 of 55 measures of the nutrients (72%) showed maintenance (56%) or improvement (16%) in the long term trend.
- 50 of 55 measures of the nutrients (91%) showed maintenance (82%) or improvement (9%) in the recent 7 year trend.

<u>Bacteria</u>

- 18 of 22 measures of bacterial levels (82%) showed maintenance (77%) or improvement (5%) in the long term trend.
- 18 of the 22 measures of the bacterial levels (82%) showed maintenance in the recent 7 year trend.

<u>Organics</u>

- 9 of 11 measures (82%) of organics contamination showed maintenance (77%) or improvement (5%) in the long term trend.
- All measures of organics (100%) showed maintenance in the recent 7 year trend.

<u>Aesthetics</u>

- 18 of 22 measures (82%) of aesthetics showed maintenance of improvement in the long-term trend.
- 22 of 22 measures of aesthetics (100%) showed maintenance (95%) or improvement (5%) or improvement in the recent 7 year trends.

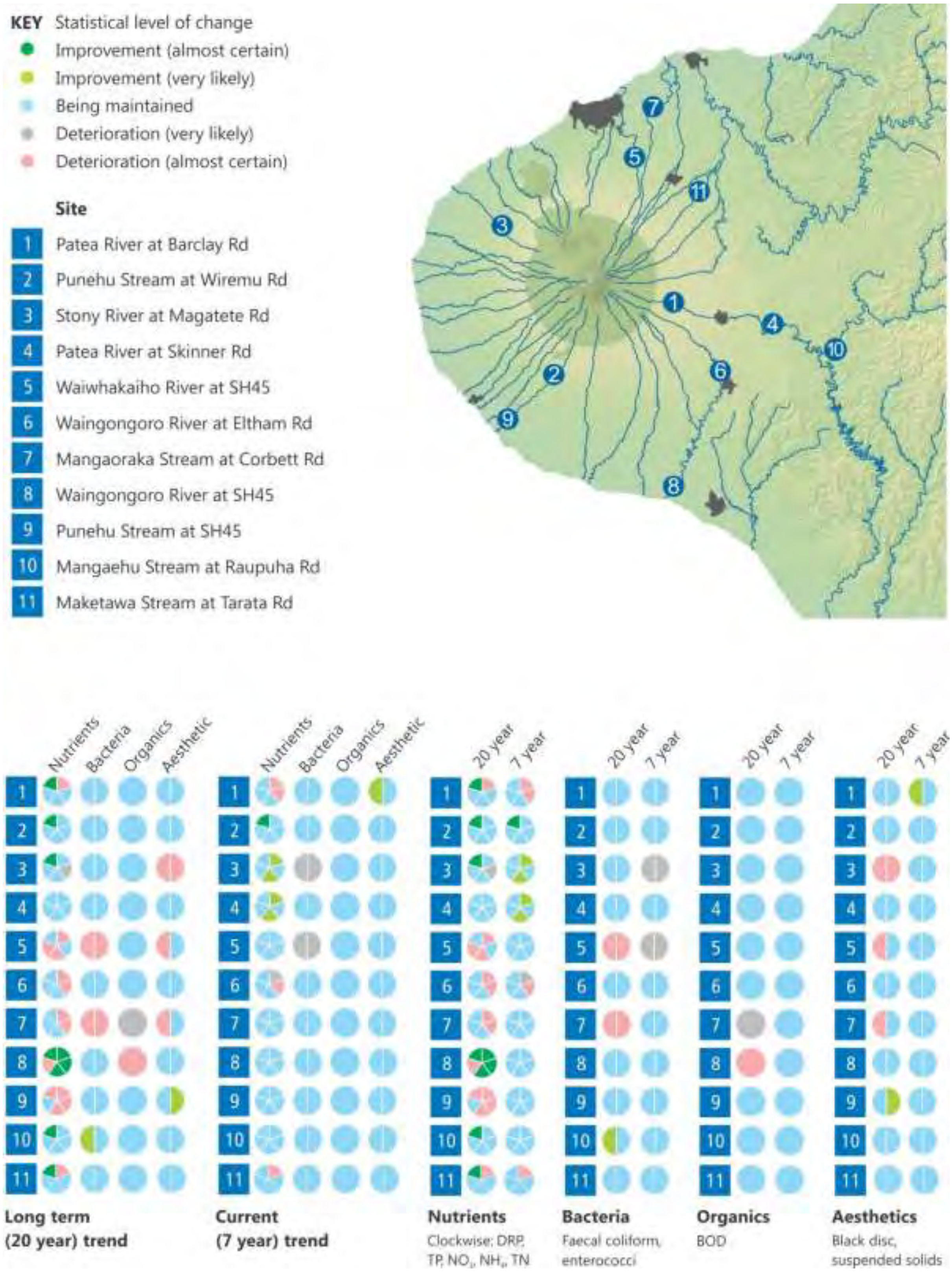
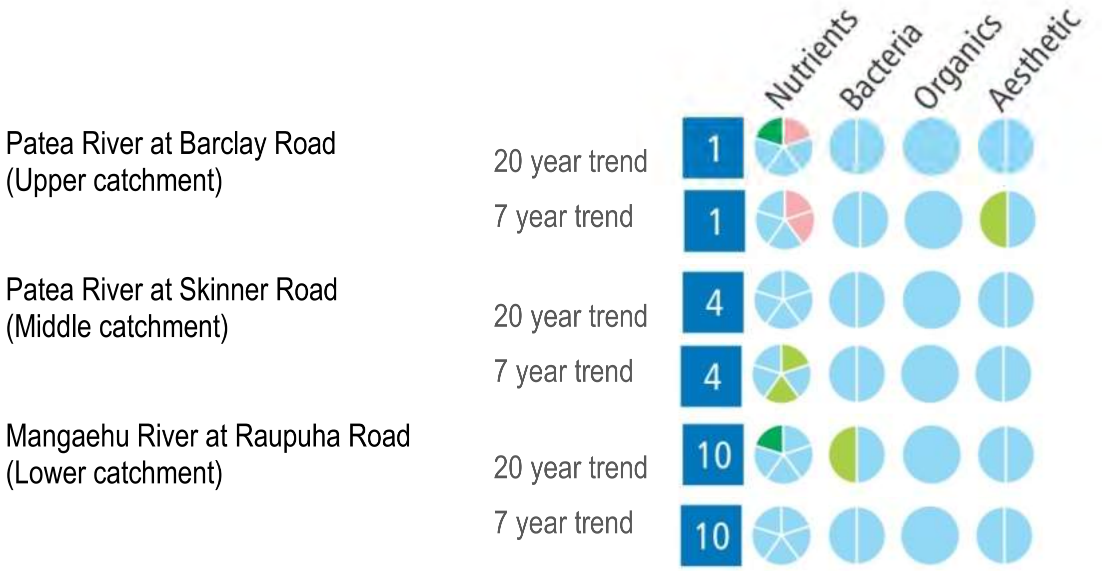


Figure 11 Specific changes in trend for nutrients, bacteria, organics and aesthetic parameters in the long term (20 years) and current (7 years) trend.

Generally poorer water quality in the year under review than is typical means that the latest rolling seven-year trend data, while still much more positive than historical trend data, do not show the same wide-spread improvements that have been evident in recent years. The number of sites and measures showing improvement in nutrient concentrations match those showing deterioration; other measures (bacteria, organics, aesthetics) show no regional pattern of change in either direction.

4.4.3.1 Patea River catchment

- At the upper site Barclay Road, significant long term deterioration in DRP continued in the 7 year trend. Significant improvement in TN has tapered off in the 7 year trend. Improvement in clarity was also recorded in the 7 year trend.
- At the middle site Skinner Road, DRP and NO_3 is showing significant improvement in the 7 year trend. Other parameters are not changing significantly.
- In the Mangaehu River, long term improvements in total nitrogen and faecal coliform have tapered off in the 7 year trend.



4.4.3.2 Punehu Stream catchment

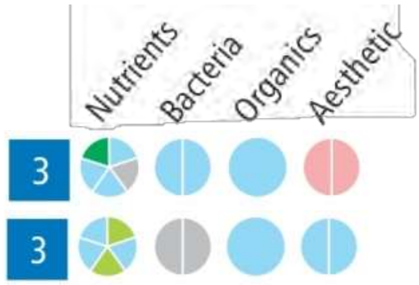
- At the upper site Wiremu Road, significant long term improvement in TN continued in the short term trends. Other parameters are not changing significantly.
- At the lower site SH45, the long term deteriorating trends in DRP, TP, NO_3 and TN have been arrested in the 7 year trend. Significant long term improvement in suspended solid has also tapered off in the 7 year trend.

4.4.3.3 Stony River catchment

- Significant deterioration in TP, clarity and suspended solids were recorded in the long term trend. Significant improvement in TN has tapered off in the recent trend.
- DRP and nitrate are showing significant improvement in the 7 year trend. Faecal coliforms and enterococci are showing significant deterioration in the 7 year trend.

Stony River at Mangatete Road
(Middle catchment)

20 year trend
7 year trend

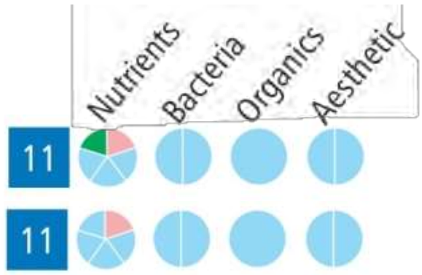


4.4.3.4 Maketawa River catchment

- Significant long term deterioration in DRP continued to show in the 7 year trend.
- Significant improvement in TN has tapered off in the 7 year trend.

Maketawa River at Tarata Road
(Middle catchment)

20 year trend
7 year trend

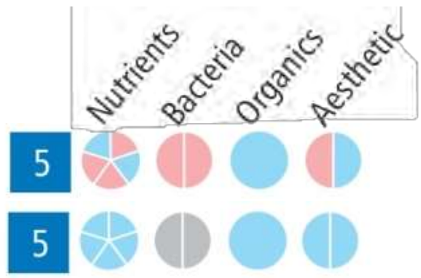


4.4.3.5 Waiwhakaiho River

- Significant long term deterioration were recorded for DRP, NO3, NH_4, faecal coliforms, enterococci and black disc at this mid catchment site.
- Deterioration for faecal coliform and enterococci continued in the recent 7 year trend. Other parameters are not changing significantly. That is, past deterioration has been arrested.

Waiwhakaiho River at SH3
(Middle catchment)

20 year trend
7 year trend



4.4.3.6 Mangaoraka Stream (Waiongana Stream catchment)

- Significant long term deteriorations were recorded for DRP, TP, faecal coliforms, enterococci, BOD and black disc. These trends had tapered off in the 7 year trend, with no significant trends recorded for all parameter measured. That is, past deterioration has been arrested.

4.4.3.7 Waingongoro River catchment

- At the upper site Eltham Road, significant long term deterioration in DRP and TP continued in the 7 year trend. Other parameters are not changing significantly.
- At the lower site SH45, significant improvements in DRP, TP, nitrate and TN were recorded in the long-term trend. NH_4 and BOD showed deterioration in the long-term trends. These trends had tapered off in the recent 7 year trend, with no significant trend recorded for any parameter measured.

4.4.4 NIWA State of the Environment sites

Physicochemical data from three NIWA sites in the Taranaki region were also assessed over a 7 year (July 2008 – June 2015) and the full record spanning from January 1989 to June 2015. In order to accurately compare the TRC and NIWA data from the Waingongoro site at SH45, a 17 year trend has been compiled (TRC data spans from 1998)(Table 43). Summary of trend results for NIWA sites is as follows:

- In the Waitara River, long term deterioration for the nutrients (DRP, NO_3, NH_4 and TN) have tapered off and appear to be stable in the last 7 years.
- In the Manganui River, recent significant deteriorations for DRP, TP, NH_4, and conductivity were recorded in the 7 year trend.
- The Waingongoro River has shown deteriorating nutrient trends (DRP, TP and NH_4) evident over the 26 year period. These trends have tapered off in the recent 7 year period.
- Note that suspended solids and BOD are not recorded by NIWA, and bacteria had been recorded only since 2005; as such these parameters are not included in the tables below.

Table 43 'Meaningful' trends in surface water quality at NIWA's monitoring sites in Taranaki

Site	Record (years)	Dissolved Reactive P	Total Phosphorus	Nitrate	Ammonia-N	Total Nitrogen	Conductivity	Black Disc	Temp°C	pH	Total no. sites: Improvement	No change	Deterioration
Waitara River at Bertrand Rd Bridge	26	deterioration P<0.01	no change	deterioration P<0.01	no change	deterioration P<0.01	no change	no change	no change	no change	0	6	3
	17	deterioration P<0.05	no change	no change	deterioration P<0.01	deterioration P<0.01	no change	no change	no change	no change	0	6	3
	7	no change	no change	no change	no change	no change	no change	no change	no change	no change	0	9	0
Manganui River at SH3	26	no change	no change	no change	no change	no change	no change	no change	no change	no change	0	9	0
	17	no change	no change	no change	deterioration P<0.01	no change	no change	no change	no change	no change	0	8	1
	7	deterioration P<0.01	deterioration P<0.01	no change	deterioration P<0.05	no change	deterioration P<0.01	no change	no change	no change	0	5	4
Waingongoro River at SH45	26	deterioration P<0.01	deterioration P<0.01	no change	deterioration P<0.01	no change	no change	no change	no change	no change	0	6	3
	17	improvement P<0.01	improvement P<0.01	improvement P<0.01	deterioration P<0.01	improvement P<0.01	no change	no change	no change	no change	4	4	1
	7	no change	no change	no change	no change	no change	improvement P<0.05	no change	no change	no change	1	8	0

Key:

- ● statistically significant improvement P<0.01
- ● statistically significant improvement P<0.05
- ● no statistically significant change
- ● statistically significant deterioration P<0.05
- ● statistically significant deterioration P<0.01

4.4.4.1 Comparison of NIWA and TRC data at Waingongoro River at SH45

A comparison of NIWA and TRC trends at the Waingongoro River at SH45 (WGG000900) is presented in Table 44. Meaningful (statistically significant) statistical graphs for the trend results are presented in Figure 12. It should be noted that samples are collected monthly via same protocols, but on different days of the month. Summary of trend results is as follows:

- Both sets of data (TRC and NIWA) showed similar trends for long term and short term period.
- In the long term trend, all nutrients showed similar significant improving trends (DRP, total phosphorus, NO3 and total nitrogen) except for nitrate.
- In the shorter 7 year trend, no significant trend was recorded for all parameters with the exception of conductivity level in NIWA's dataset.

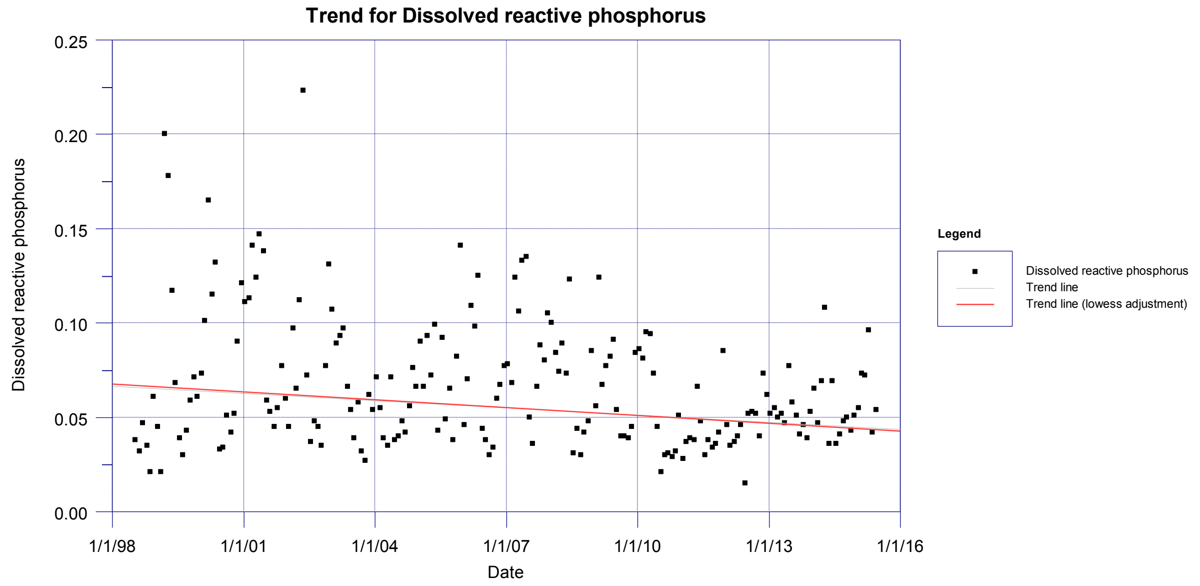
Table 44 Comparison between TRC and NIWA water quality trends at Waigongoro River at SH45 over the last 17 and 7 years.

Record	Data from	Water Quality Variable											
		Dissolved Reactive P	Total Phosphorus	Nitrate	Ammonia-N	Total Nitrogen	Conductivity	Black Disc	Temp°C	pH	Total no. sites: Improvement	No change	Deterioration
17 years	TRC	●	●	●	●	●	●	●	●	●	4	4	1
	NIWA	●	●	●	●	●	●	●	●	●	4	4	1
7 years	TRC	●	●	●	●	●	●	●	●	●	0	9	0
	NIWA	●	●	●	●	●	●	●	●	●	1	8	0

Key:

- ● statistically significant improvement P<0.01
- ● statistically significant improvement P<0.05
- ● no statistically significant change
- ● statistically significant deterioration P<0.05
- ● statistically significant deterioration P<0.01

TRC data



NIWA data

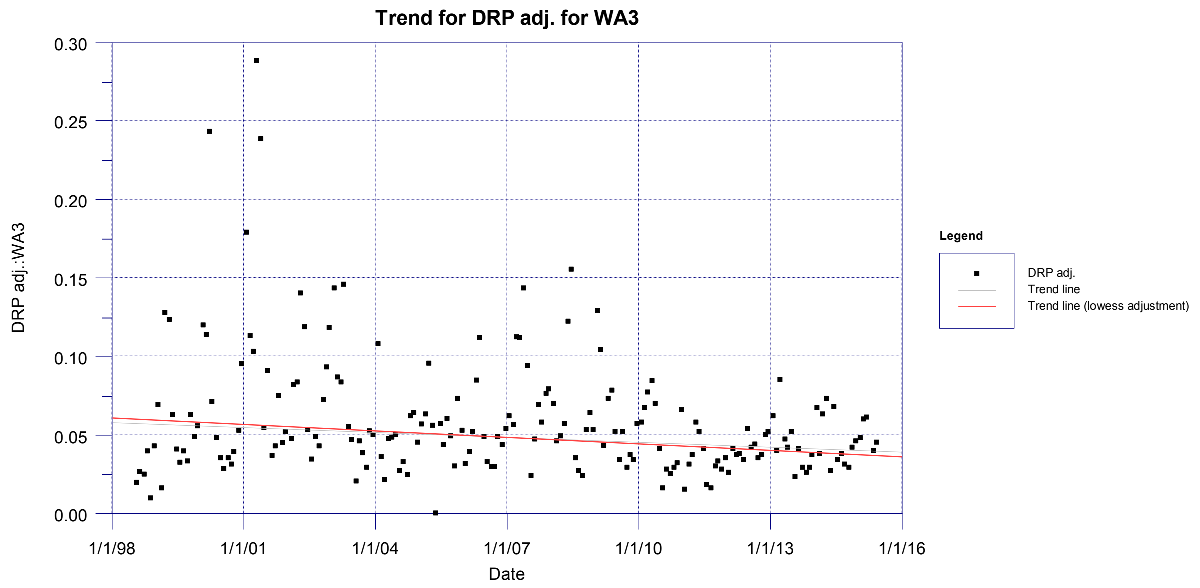
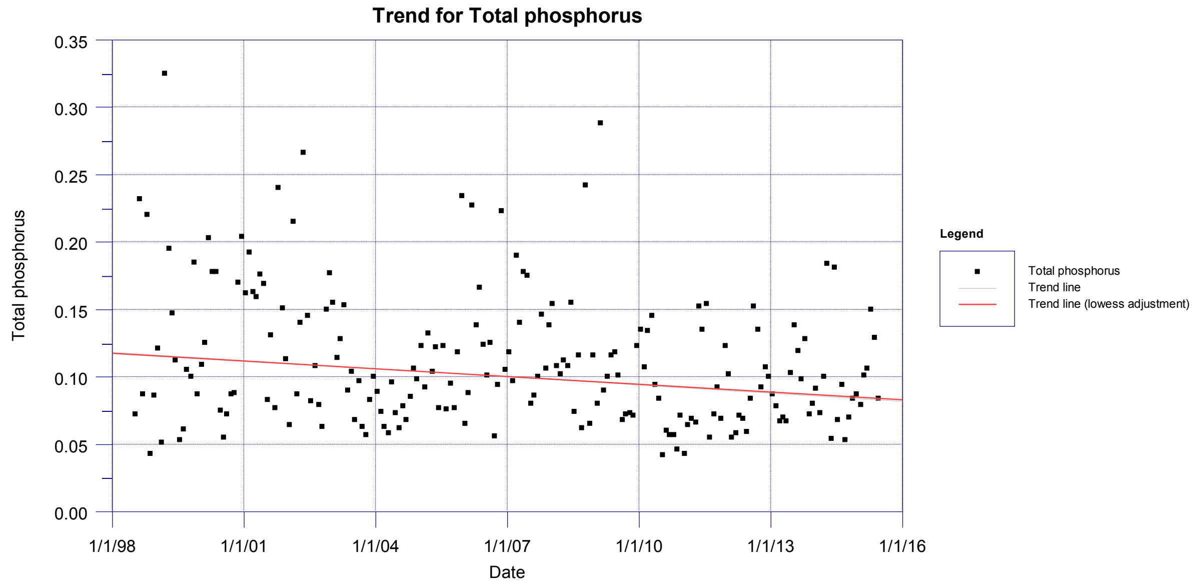


Figure 12 Scatterplots for selected parameters for TRC and NIWA data at Waingongoro River at SH45 where significant trends have been reported (flow adjusted and LOWESS trend line (span 30%))

TRC data



NIWA data

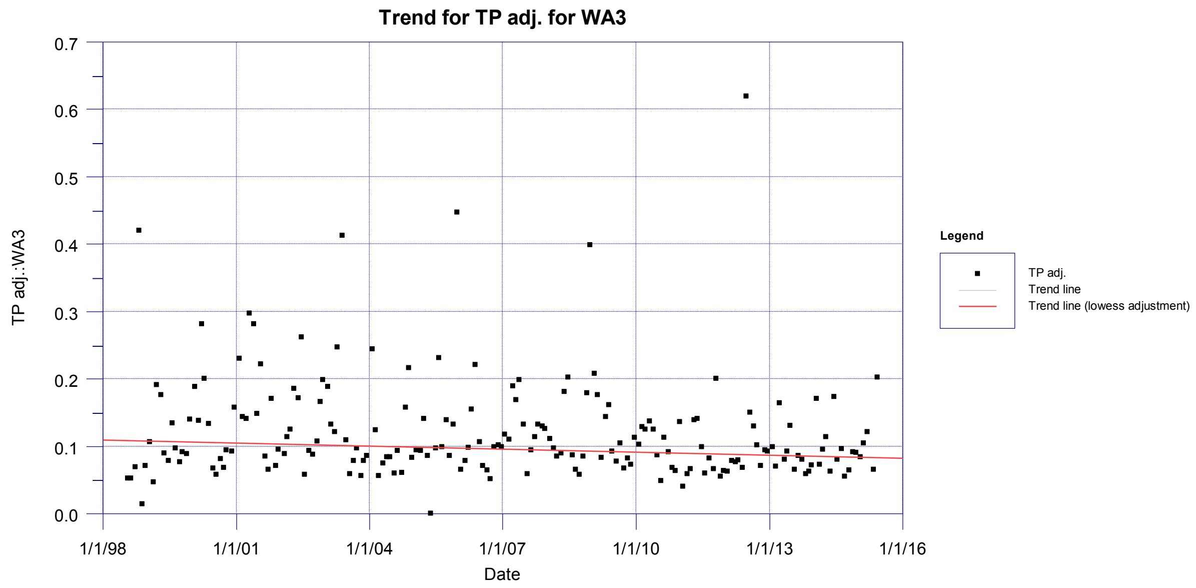
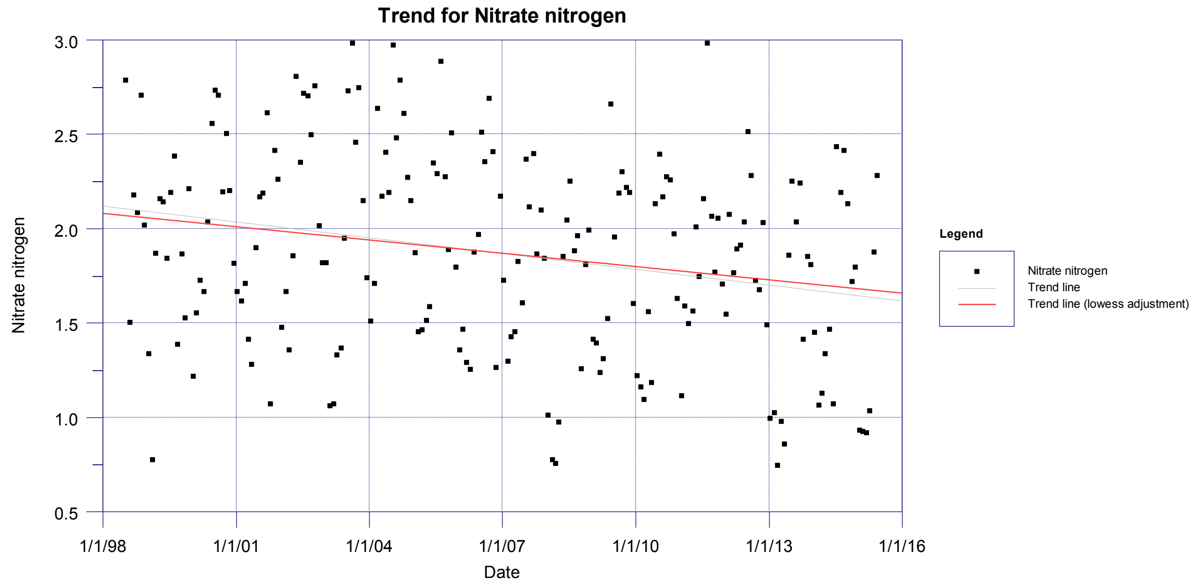


Figure 12 (cont) Scatterplots for selected parameters for TRC and NIWA data at Waingongoro River at SH45 where significant trends have been reported (flow adjusted and LOWESS trend line (span 30%))

TRC data



NIWA data

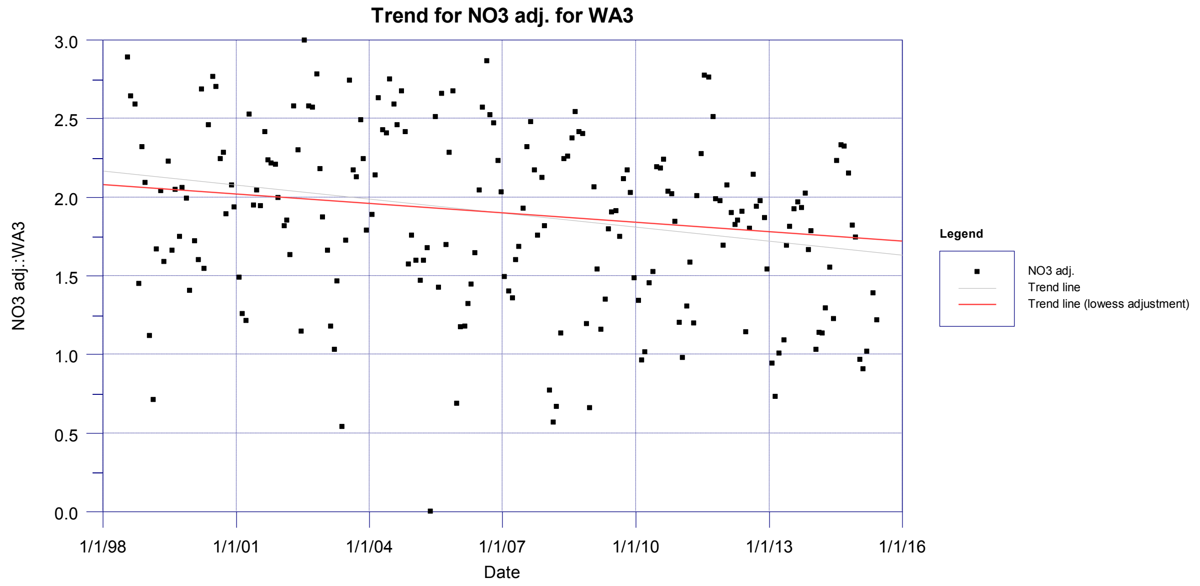
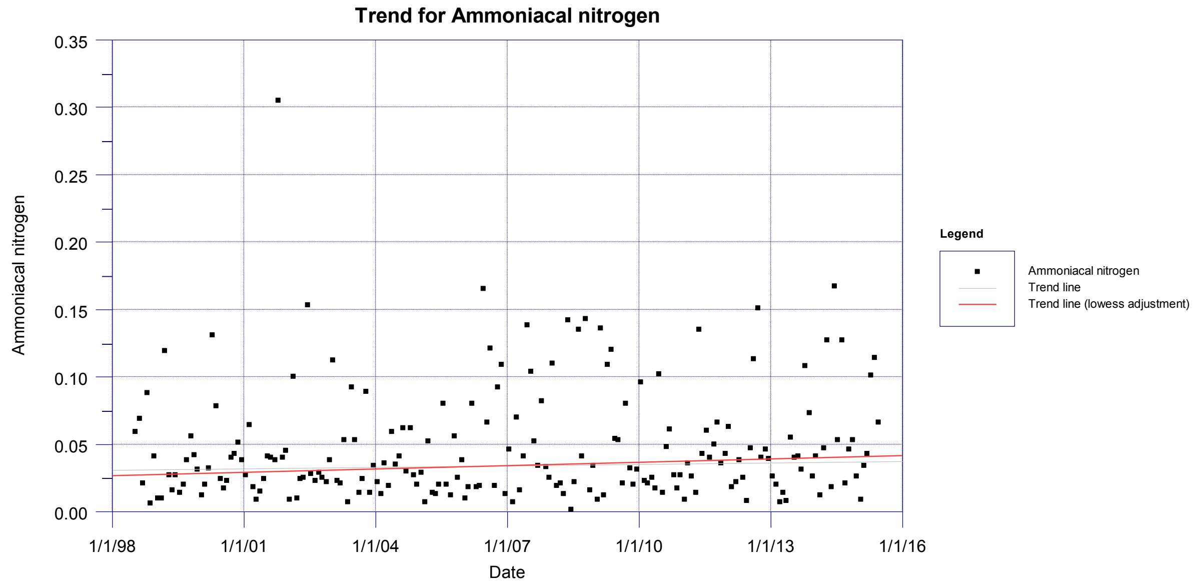


Figure 11 (cont) Scatterplots for selected parameters for TRC and NIWA data at Waingongoro River at SH45 where significant trends have been reported (flow adjusted and LOWESS trend line (span 30%))

TRC data



NIWA data

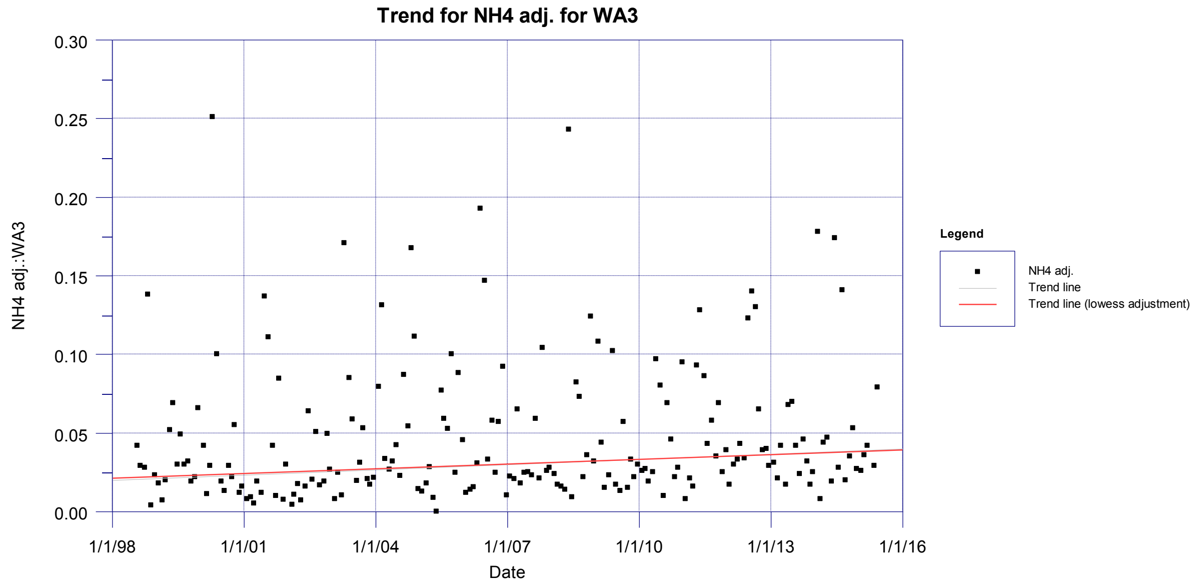
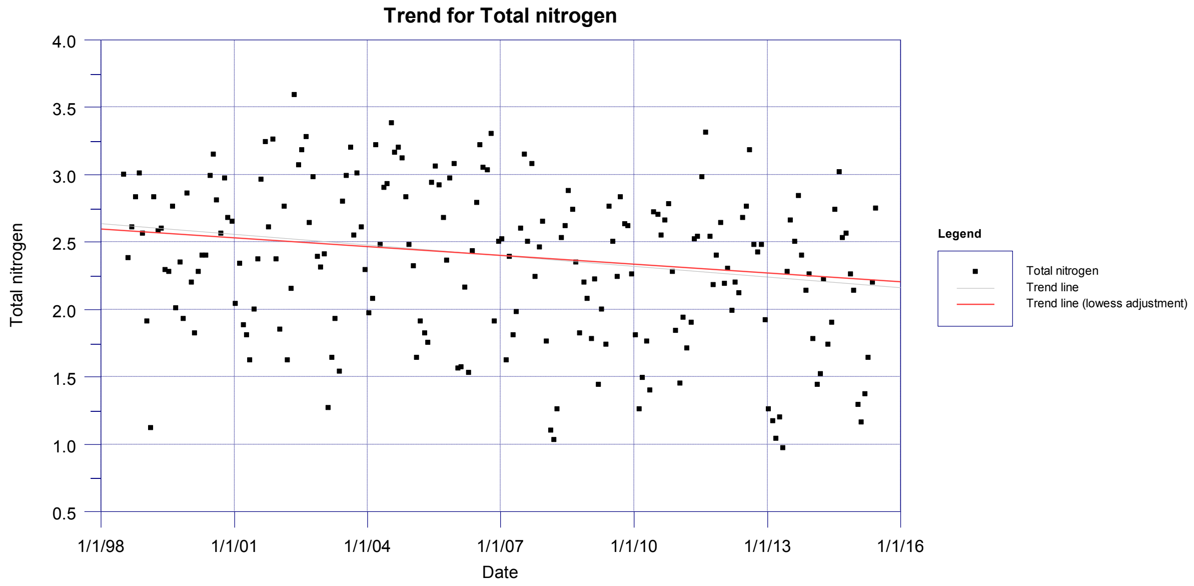


Figure 12 (cont) Scatterplots for selected parameters for TRC and NIWA data at Waingongoro River at SH45 where significant trends have been reported (flow adjusted and LOWESS trend line (span 30%))

TRC data



NIWA data

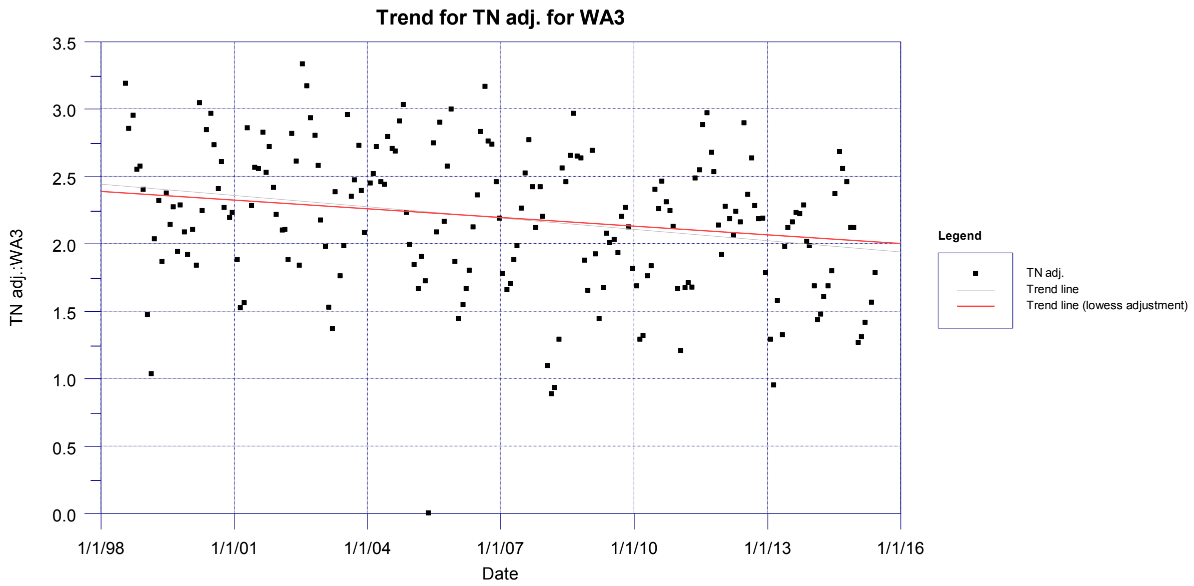


Figure 12 (cont) Scatterplots for selected parameters for TRC and NIWA data at Waingongoro River at SH45 where significant trends have been reported (flow adjusted and LOWESS trend line (span 30%))

4.5 Addition of new water quality sites for NPS-FW monitoring purposes

The RMA requires [Section 35 (2)(a)] the Council to:
'*monitor the state of* ***the whole or any part of*** *the environment of its region…. .****to the extent that is appropriate*** *to enable the local authority to effectively carry out its functions under this Act;…*'.

The Council has had SEM monitoring of fresh water in place since 1996, through a number of specific programmes. These have been audited by the Office of the Auditor-General, as well as by other independent experts, and found each time to be fit for purpose. The programmes have targeted areas with the greatest pressures upon or changes in the water resources of the region, to determine how and why water quality might be changing and the effectiveness of the Council's interventions.

However, the NPS-FW now requires in addition, that the Council *'identifies a site or sites at which monitoring will be undertaken that are* ***representative for each freshwater management unit'*** [Policy CB1 (b)]. All freshwater in every region musty be incorporated into a Freshwater Management Unit (FMU) as defined within the NPS. This Council has identified four FMUs for the Taranaki region: water bodies of outstanding value; the ring plain; the coastal terraces; and the eastern hill country. In terms of the distribution of the current SEM sites for monitoring fresh water, Council staff determined that two more sites within the eastern hill country were needed for the purpose of representativeness. Accordingly, since July 2015 (ie outside the year under review herein), Council staff have been undertaking sampling for water quality monitoring purposes at two new sites: Waitara River near Tarata in the northern hill country, and the Whenuakura River at SH 3, on the southern borders of the hill country. Results from these sites will be reported in due course.

5. Conclusions

The physicochemical component of the SEM programme which commenced in July 1995, with monthly sampling performed at nine river and stream sites, in seven selected catchments, continued from July 2014 through to June 2015. From mid 1998 an additional site in the lower reaches of the Waingongoro River was included and a site in the lower reaches of the Maketawa Stream was added in mid 2003. Sampling in the year under review coincided randomly with a narrower range of flow conditions in the 2014-2015 period (in comparison with the previous nineteen year period), ranging from moderate freshes through to a period of very low flow conditions but was characterised by a few fresh events. This report provides monthly data for up to 22 parameters and a statistical summary of the twelve months' data for each of the sites, and compares this period's water quality with the previous 19 years' data. It also provides an up-to-date statistical summary of the twenty years' data to date for all sites and discusses, in brief, comparative water quality at these sites.

River and stream waters were generally of moderate to good quality, particularly at sites in the upper reaches of ring plain catchments with some deterioration in a downstream direction coincident with increased run-off, possible stock access and point source discharges. This was illustrated particularly by decreased clarity and increased nutrient levels and bacteriological numbers, and wider water temperature and pH ranges in a downstream direction. Aesthetic quality deterioration was also coincident with increased flows following, or during, the several freshes. However, dissolved oxygen levels remained high and there was little evidence of significant organic contamination (i.e. BOD_5 concentrations were generally less than 1.0 g/m^3 except during freshes).

The eastern hill country river (Mangaehu River) site in the lower reaches of the river was characterised by some dissolved colour, relatively high turbidity, poorer clarity, and slightly elevated suspended sediment concentrations.

Although the upper site in the Punehu Stream was located within 3 km of the National Park boundary, influence of the open developed farmland section of the relatively short reach below the National Park boundary on aspects of water quality has been documented. This was illustrated by poorer clarity, and higher temperature and bacteriological numbers than might be expected for a ring plain stream sampled in the reach near the National Park boundary. The relatively open nature of the reach between the National Park and the sampling site contributed to these aspects of the water quality measured, although more recently riparian planting has been performed in this reach.

During the 2014-2015 period, median flows sampled were mainly higher than typical of those sampled during the previous nineteen-year period with median flows higher over the latest period (by 2 to 20%) at eight sites, and lower (by < 1 to 16%) at the other three sites compared with the long-term sampled flow records.

Table 45 Comparison of 2014-2015 water quality with previous long-term (1995-2014) data (using median values) for each SEM site

Parameter Site	Black disc	Conductivity @ 20°C	BOD_5	Faecal coliform bacteria	Enterococci bacteria	Nutrients					pH	Dissolved oxygen saturation	Suspended solids	Temperature	Turbidity	Flow (l/sec)	Flow (%)
						Ammonia -N	Nitrate-N	Total N	DRP	Total P							
Maketawa Stream at Tarata Road	=	=	=	=	X	X	X	=	X	X	=	=	=	=	=	+34	2↑
Mangaoraka Stream at Corbett Road	=	=	XX	=	XX	=	=	=	X	X	=	=	X	=	=	+22	2↑
Waiwhakaiho River at SH3	=	=	=	X	XX	=	=	=	=	=	=	=	=	=	=	+439	12↑
Stony River at Mangatete Road	=	=	=	✓	XX	=	✓	✓	=	=	=	=	XX	=	X	+130	4↑
Punehu Stream at Wiremu Road	=	=	=	✓	✓	XX	=	=	=	=	=	=	=	=	X	-1	<1↓
Punehu Stream at SH45	=	=	=	XX	XX	=	XX	X	X	=	=	=	=	=	X	+97	12↑
Waingongoro River at Eltham Road	=	=	=	X	✓	X	=	=	XX	X	=	=	=	=	=	+130	8↑
Waingongoro River at SH45	=	=	X	=	=	X	=	=	=	=	=	=	=	=	=	+410	9↑
Patea River at Barclay Road	=	=	=	XX	XX	X	=	✓	X	=	=	=	=	=	=	+44	20↑
Patea River at Skinner Road	=	=	=	=	=	✓	=	=	=	✓	=	=	=	=	=	-293	10↓
Mangaehu River at Raupuha Road	=	=	=	✓	=	X	=	=	=	✓	=	=	✓	=	✓	-1084	16↓

[KEY: Improvement by ≥50% (✓✓); 21-49% (✓): no significant change (=): deterioration by 21 to 49% (X); ≥ 50% (XX)]

[Notes: Maketawa Stream data collection commenced in mid 2003; Waingongoro River at SH45 data collection commenced in mid 1998]

Generally water quality in the 2014-2015 period (Table 45) showed similar black disc clarity and suspended solids levels, and similar to slightly poorer turbidity levels compared with the long-term monitoring record. Median water temperatures at mid and lower catchment sites were similar during the latest period but narrower temperature ranges were measured at all of the eleven sites in the year under review mainly due to both lower maximum and higher minimum temperatures (in comparison with the longer period) during the 2014-2015 sampling period.

Median dissolved oxygen saturation and pH showed no significant differences in the latest period (Table 41), but BOD_5 concentrations increased at two lower reach sites (particularly in the Mangaoraka Stream) although they remained relatively low.

A majority of sites' median nutrient levels remained similar in the 2014-2015 period to those over the longer period. A few improvements in median nutrient species (nitrate N at two sites, total P at two sites, and total N at two sites) were recorded. The Waingongoro River site in the lower reaches showed minimal further improvement in median nutrient levels following the diversion of the major point source discharge (Eltham WWTP) out of the catchment coincident with three median nutrient concentrations deteriorating at the upstream Eltham Road site. Deterioration was found in median dissolved reactive phosphorus (at five sites), total phosphorus (at three sites) and ammonia N (at six sites) [Table 45].

Bacteria numbers showed improvement at two sites in terms of median enterococci numbers but there was deterioration at six sites during the 2014-2015 period. Three sites showed improvement in median faecal coliform bacteria numbers while four sites showed deterioration. This general trend of deterioration in bacteriological water quality during 2014-2015 probably in part reflected an increased proportional frequency of sampling of freshes during the 2014-2015 period compared with that over the longer period.

This TRC programme is complemented by the three sites surveyed by NIWA as a component of the New Zealand surface water quality network (Smith et al, 1989). These sites' data have been made available for TRC usage and a brief summary and discussion have been provided in this report. Other aspects (e.g. trends) will be reported upon elsewhere by NIWA.

A further trend assessment has been performed upon eleven TRC sites over the 1995-2015 period (including one site for the 1998-2015 period and one site for the 2003-2015 period) and summarised in this Annual Report. This complements the reports prepared for the 1995 to 2008 period presented in TRC, 2009a, the period 1995 to 2009 presented in TRC, 2009, and the period 1995 to 2014 presented in TRC, 2015a. A significant improvement in aspects of temporal water quality (mainly nutrients) has been found at the site in the lower Waingongoro River, coincident with the relatively more recent reductions in waste loadings discharged by industry and/or the township to the river in mid catchment at Eltham (TRC, 2015a).

In conclusion, long term (twenty-year) physicochemical trends have indicated significant deterioration for some parameters at some sites, especially for nutrients mainly in the middle and lower catchments, alongside stability in most measures and some improvements. Dissolved reactive phosphorus, and total phosphorus, have been the main nutrients showing significant deterioration in the Waingongoro River at

Eltham Road and Punehu Stream at SH 45 where nitrate has also deteriorated. The Waiwhakaiho River site at SH3 has also recorded a significant deterioration in DRP, nitrate, and ammonia-N. The trend for these three sites has indicated that phosphorus level is increasing at a steady but slow rate. All three sites are situated in catchments with intensive agricultural land use. However there has been a significant improvement in total nitrogen at six of the eleven sites monitored, with the lower Punehu being the only site showing any degree of deterioration in total nitrogen.

Two lower reach sites (of eleven) have shown significant long term deterioration in BOD_5 although concentrations have remained consistently below $2g/m^3$ at these sites.

Faecal coliforms and enterococci trends generally have not altered significantly over the twenty-year period at the majority of sites. However, two sites have shown significant deterioration, one in each of the lower or mid reaches. Fluctuating trends for black disc clarity and suspended solids reflect the historical erosion events in the headwaters of the Stony River. Significant deteriorations in black disc clarity were also recorded for the Waiwhakaiho River at SH3 and the Mangaoraka Stream at Corbett Road. All sites have had insignificant trends for conductivity, temperature, and pH.

On a site specific basis comparing the 2014-2015 period with the previous 19-year historical record, the Maketawa Stream, Mangaoraka Stream, and Punehu Stream (at SH45 sites) showed most variability in water quality with five to six of the fifteen parameters recording lower quality and none showing a better than usual quality. These sites are representative of developed farmland lower catchments. Other sites with at least four parameters showing lower than usual quality included the upper reach site in the Patea River (at Barclay Road), although water quality remained high; and the mid-reach site in the Waingongoro River. Main differences were found for ammoniacal nitrogen, dissolved reactive phosphorus, and enterococci bacterial species. Least differences in comparative water quality were found at the Patea River (mid-reach) and Waingongoro River (lower reach) sites whereas the highest number of parameters that were better than usual were found at the Stony River (mid-reach) and Mangaehu River (lower reach) sites.

Overall, during the 2014-2015 period water quality parameters' medians differed by more than 20% from 19-year medians for 29% of comparisons (21% deterioration; 9% improvement), and by more than 50% from historical medians for 7% of comparisons (all showing a lower quality). This was coincident with higher median flows (2 to 20%) at eight sites and lower median flows (< 1 to 16%) at three sites over the 2014-2015 period.

6. Recommendations

1. THAT the existing freshwater physicochemical component of the SEM programme continue in a similar format for the 2015-2016 monitoring year.
2. THAT an additional (split) sample be collected on at least one occasion during the monitoring year, in conjunction with the intra-laboratory quality control programme, for analysis by an external, accredited laboratory.
3. THAT the appropriate trend analysis reported on the datasets for all Taranaki sites over the 1995-2015 period (provided in the current report), be updated for the 1995-2016 period at the conclusion of the 2015-2016 year.
4. THAT two sites, representative of large hill country catchments (Waitara River near Tarata; Whenuakura River at SH 3) be added to the programme to be monitored in similar format to the existing sites, commencing in July 2015.

7. Acknowledgements

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Bibliography

ANZECC, 2000: Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Ballantine, DJ and RJ Davies-Colley, 2009: Water quality trends at national river water quality network sites for 1989-2007. Prepared by NIWA for Ministry for the Environment.

Connolly, A, 2011. Trends in regional physicochemical water quality data for Taranaki: a comparison of 1995-2010 (15 year data set) with 2002-2010 (8 year data set). TRC Internal Memorandum.

Connolly, A, 2012. Trends in regional physicochemical water quality data for Taranaki: 2004-2011. TRC Internal Memorandum.

Connolly, A, 2012. Trends in regional physicochemical water quality data for Taranaki: 1995-2012. TRC Internal Memorandum.

Hope, KJ, 2009. Physicochemical trend software comparison. TRC Internal memorandum.

Hope, KJ, 2009a. Physicochemical water quality trend report 1995-2009. TRC Internal memorandum.

McBride, G, 1996: 'Trends at the Taranaki sites of the New Zealand National River Water Quality Network'. NIWA Consultancy Report TRC302.

MfE, 2003: Microbiological water quality guidelines for marine and freshwater recreational areas. Ministry for the Environment publication.

Scarsbrook and McBride, 2007: Best practice guidelines for the statistical analysis of freshwater quality data, version 1. Prepared by NIWA for Ministry for the Environment.

Smith, D G; McBride, G.B; Bryers, G.G; Davies-Colley, R.J; Quinn, J.M; Vant, W.N; 1989. A National Water Quality Network for New Zealand. Consultancy Report 80`5/1. Prepared for the Manager, Water Resources Survey, DSIR.

Stark, J D, 2003: 'The water quality and biological condition of the Maketawa catchment'. Cawthron Report No. 742 70 pp.

Stark, JD and Fowles, CR, 2006: An approach to the evaluation of temporal trends in Taranaki state of the environment macroinvertebrate data. Cawthron Institute Report No 113 88pp.

TCC, 1984: 'Taranaki Ring Plain Water Resources Survey: Water Quality. TCC report.

TRC, 1996a: 'Statement of the Environment: Taranaki Region'. TRC Publication.

TRC, 1997: 'Annual SEM Report 1995-96: Freshwater Biological Monitoring Programme'. TRC Report 97-96.

TRC, 1998: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 1995-96. TRC Technical Report 97-105.

TRC, 1998: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 1996-97. TRC Technical Report 98-19.

TRC, 1999: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 1997-98. TRC Technical Report 98-90.

TRC, 2000: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 1998-99. TRC Technical Report 99-91.

TRC, 2001: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 1999-2000. TRC Technical Report 2000-52.

TRC, 2002: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2000-2001. TRC Technical Report 2001-85.

TRC, 2002: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2001-2002. TRC Technical Report 2002-41.

TRC, 2003: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2002-2003. TRC Technical Report 2003-56.

TRC, 2003: Taranaki - our place, our future, Report on the state of the environment of the Taranaki region - 2003. TRC 206 pp.

TRC, 2004: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2003-2004. TRC Technical Report 2004-54.

TRC, 2004a: 'State of the Environment: Regional Water Quality Monitoring for Taranaki. Physicochemical sampling techniques for freshwater rivers and streams: TRC Internal Report

TRC, 2005: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2004-2005. TRC Technical Report 2005-68.

TRC, 2006: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2005-2006. TRC Technical Report 2006-74.

TRC 2006a: Trends in the quality of the surface waters of Taranaki. TRC Internal Report.

TRC 2006b: Freshwater nuisance periphyton monitoring programme. State of the environment monitoring report 2002-2006. TRC Technical Report 2006-69.

TRC 2006c: An interpretation of the reasons for statistically significant temporal trends in macroinvertebrate (MCI) SEM data in the Taranaki region 1995-2005. TRC internal report.

TRC, 2007: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2006-2007. TRC Technical Report 2007-69.

TRC, 2008: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2007-2008. TRC Technical Report 2008-100.

TRC, 2009: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2008-2009. TRC Technical Report 2009-54.

TRC 2009a: Taranaki Where We Stand. State of the Environment Report 2009. Taranaki Regional Council ,284p.

TRC, 2010: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2009-2010. TRC Technical Report 2010-15.

TRC 2011: An evaluation of dairy shed wastes discharge consent compliance - a comparison of visual inspection and field physicochemical sampling methods 2010-2011. TRC internal Report 56pp.

TRC, 2012: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2011-2012. TRC Technical Report 2012-27.

TRC, 2013: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2012-2013. TRC Technical Report 2013-49.

TRC 2013a: Freshwater macroinvertebrate fauna biological monitoring programme. State of the environment monitoring report 2012-2013. TRC Technical Report 2013-48.

TRC, 2014: Freshwater Physicochemical Programme, State of the Environment Monitoring Annual Report 2013-2014. TRC Technical Report 2014-23.

TRC, 2014a: Freshwater macroinvertebrate fauna biological monitoring programme. State of the Environment Monitoring Annual Report 2013-2014. TRC Technical Report 2014-20.

TRC 2014b: Freshwater nuisance periphyton monitoring programme. State of the environment monitoring report 2012-2014. TRC Technical Report 2014-42.

TRC 2015: Freshwater contact recreational monitoring programme. State of the environment monitoring report 2014-2015. TRC Technical Report 2015-01.

TRC 2015a: Taranaki As One. State of the Environment Report 2015. Taranaki Regional Council, 268p.

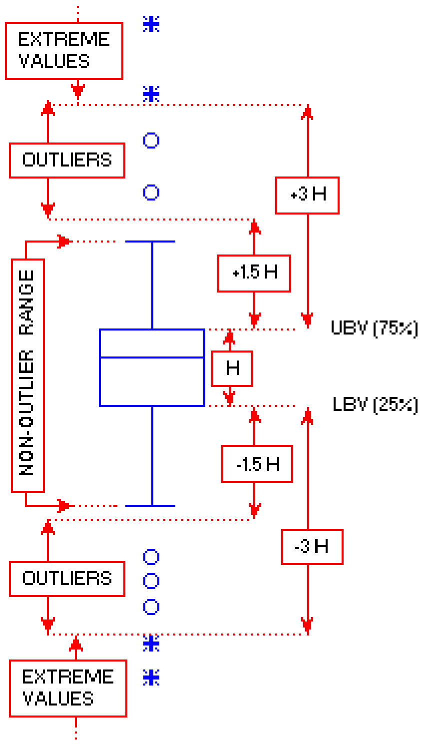
Ward, R C; and McBride, G B, 1986: 'Design of water quality monitoring systems in New Zealand'. Water Quality Centre, MOW&D, Hamilton Publication No 8.

Appendix I

Statistical ‘Box & Whisker’ Plots of 1995-2015 Water Quality Parameters for all SEM sites

Interpretation of Box and Whisker Plots (produced using STATISTICA)

Box and whisker plots are a useful method of summarising data in a graphical form that allows rapid comparisons of data groups. The data is represented as a box with a whisker from each end.



The median (middle value of the sorted data; half of the data is either side of the median) is represented by a single horizontal line (or ◊ point).

The top and bottom of the box represent the upper (UBV) and lower (LBV) hinges respectively. The median splits the ordered group of data in half and the hinges split the remaining halves in half again. This means that 50% of the data lies within the box.

Hspread, comparable to the interquartile (25% and 75%) range is the difference between the values of the two hinges, i.e., Upper hinge – Lower hinge = Hspread. The inner fences (within whiskers) are defined as follows:

Lower fence = lower hinge - (1.5 x Hspread)
Upper fence = upper hinge + (1.5 x Hspread)

The outer fences (outside whiskers) are defined as follows:

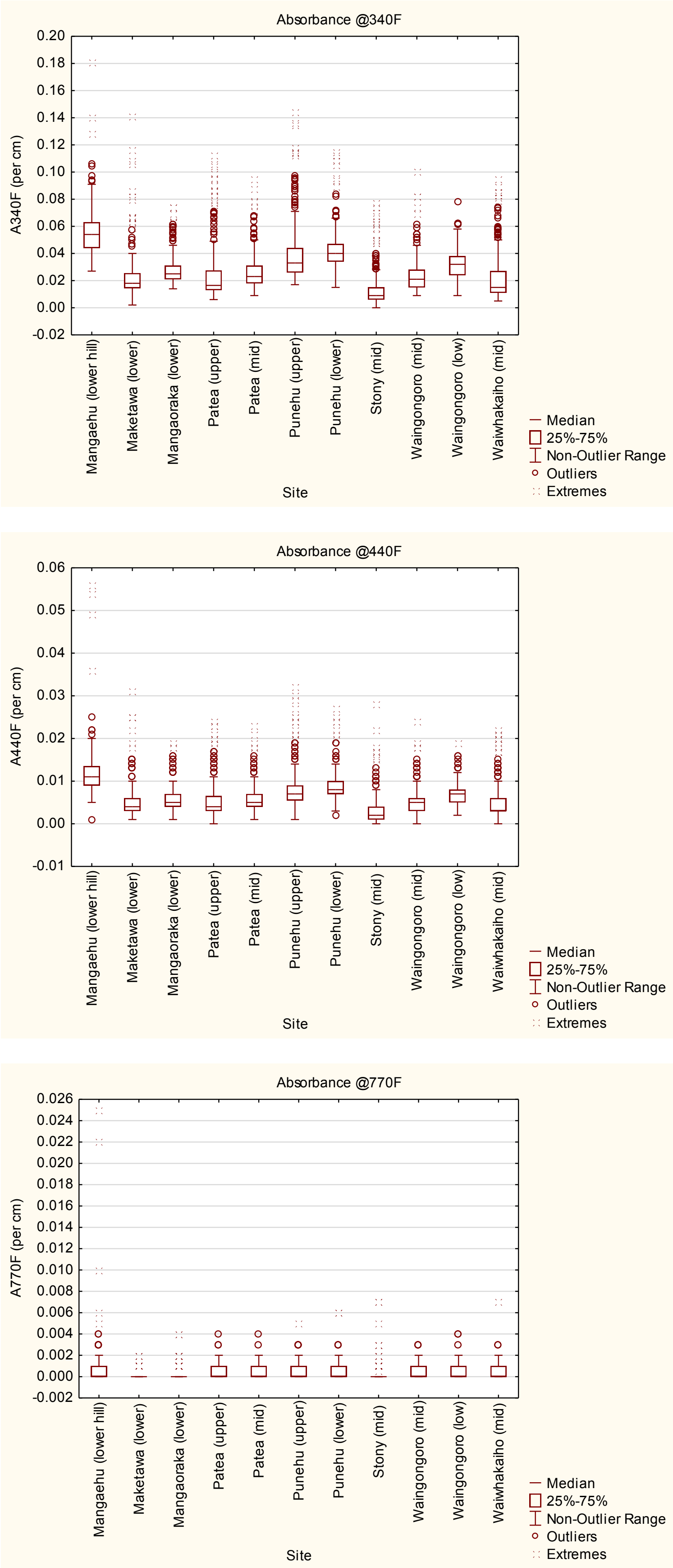
Lower fence = lower hinge - (3 x Hspread)
Upper fence = upper hinge + (3 x Hspread)

The whiskers show the range of values that lie within the inner fences. Values outside the inner fence are plotted as open circles (o). Values outside the outer fence are plotted as asterisks (*).

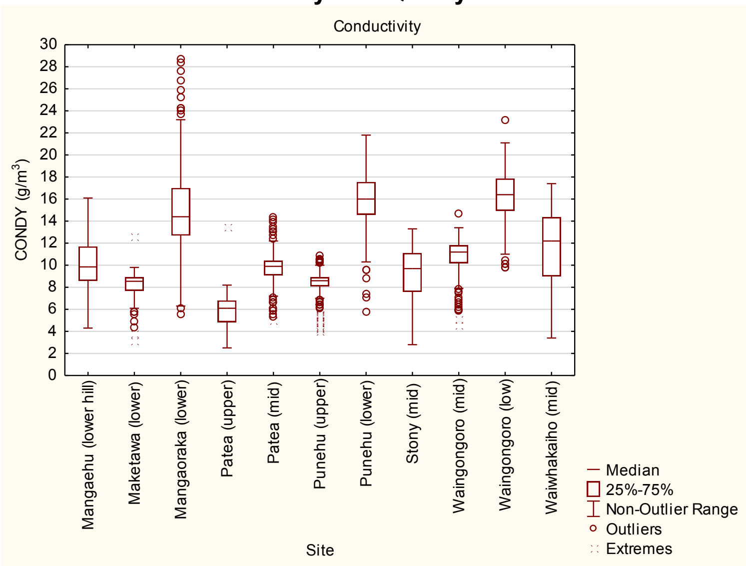
Site locations

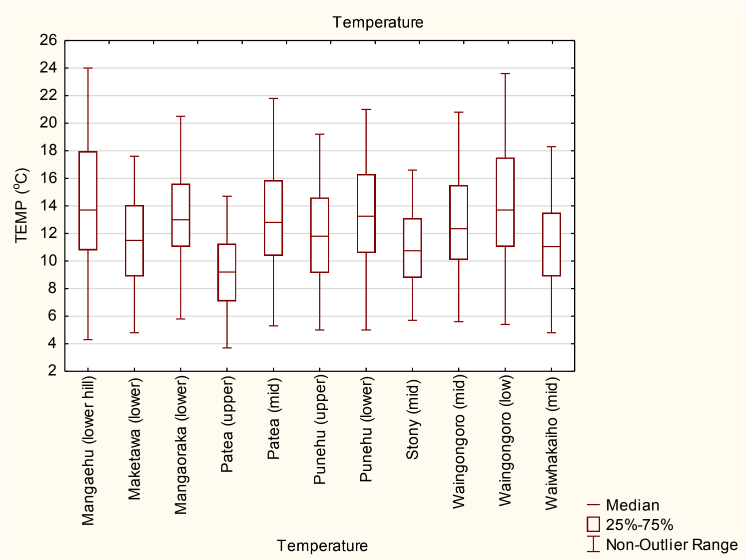
Stream	Location
Maketawa Stream	at Tarata Road
Mangaehu River	at Raupuha Road
Mangaoraka Stream	at Corbett Road
Patea River	at Barclay Road
Patea River	at Skinner Road
Punehu Stream	at Wiremu Road
Punehu Stream	at SH45
Stony River	at Mangatete Road
Waingongoro River	at Eltham Road
Waingongoro River	at SH45
Waiwhakaiho River	at SH3

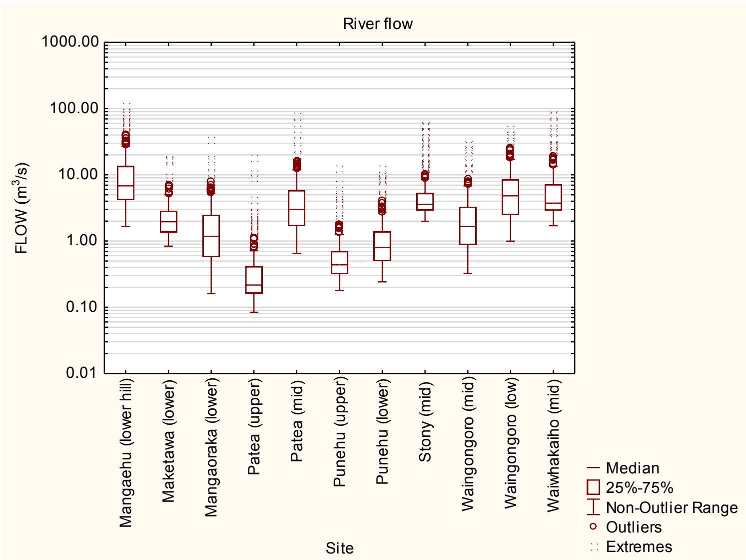
Absorbance (1cm)

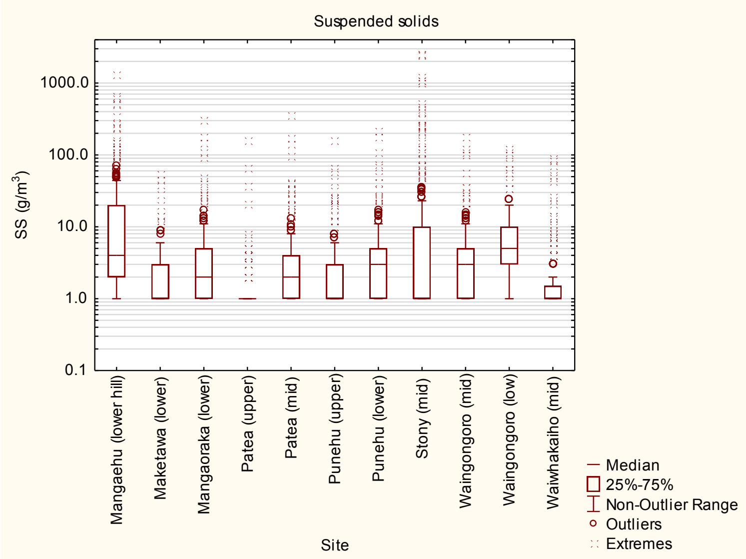


Physical Quality

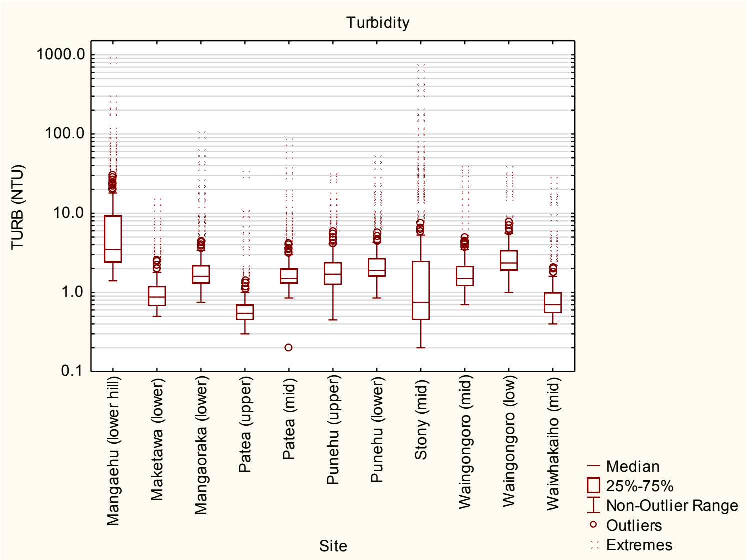




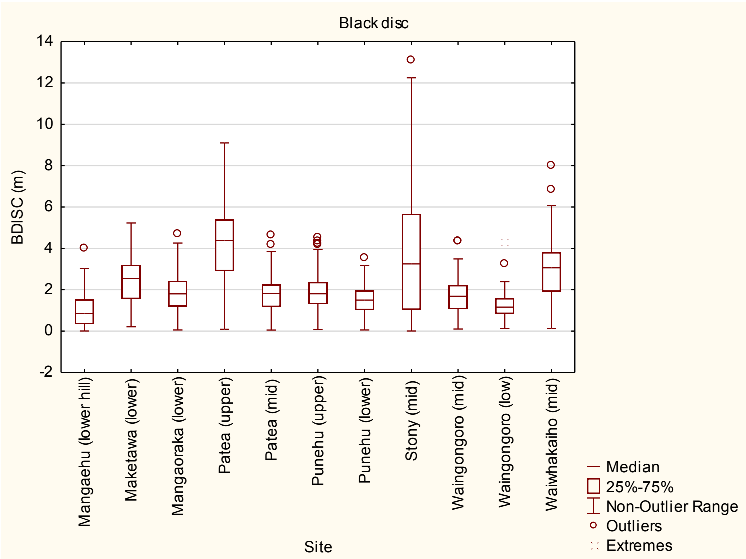




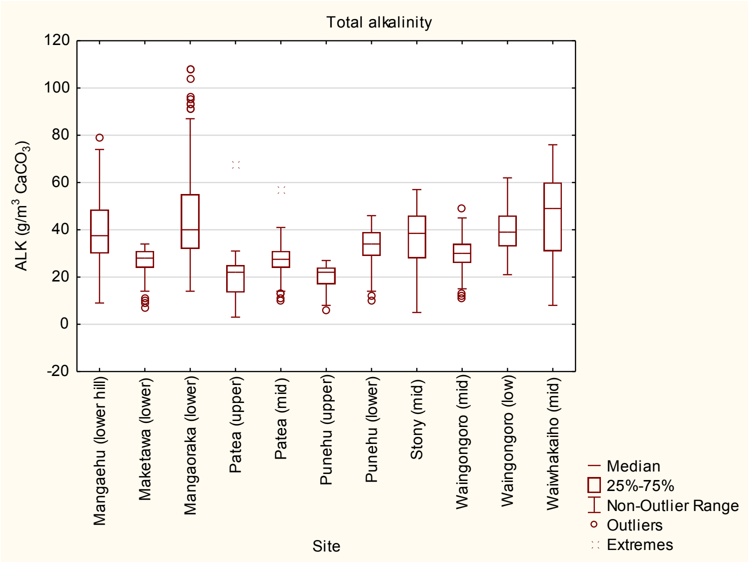
Suspended solids
SS (g/m^3)
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

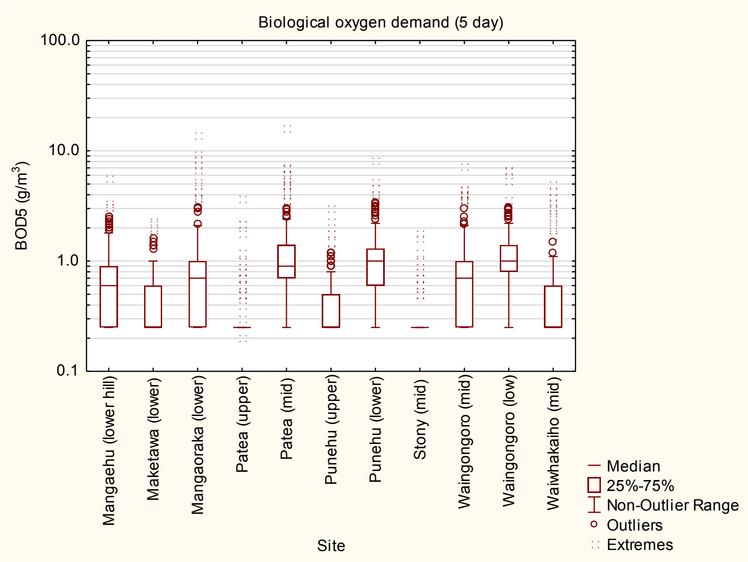


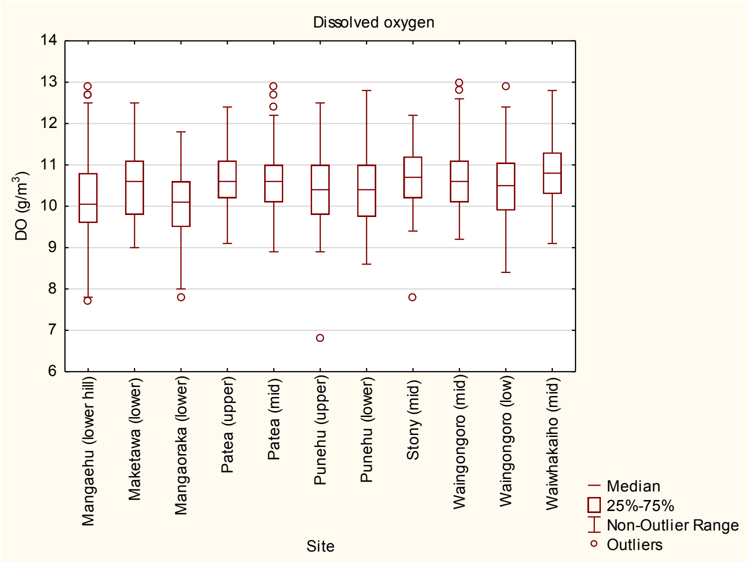
Turbidity
TURB (NTU)
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

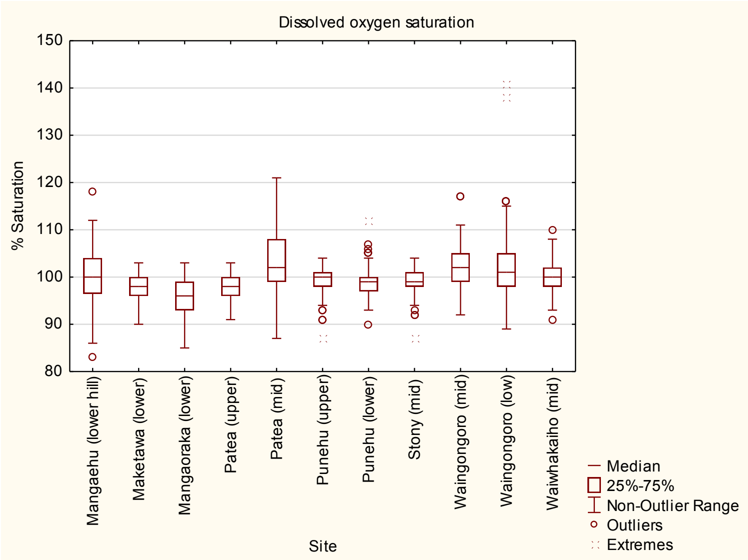


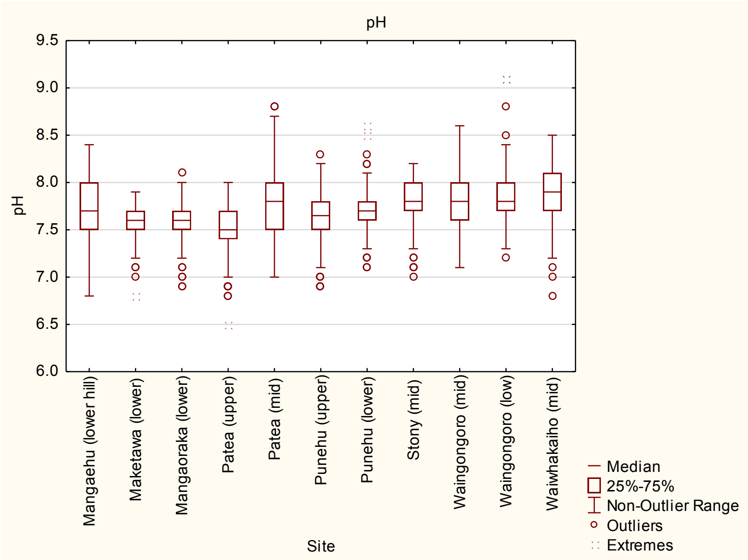
Black disc
BDISC (m)
14
12
10
8
6
4
2
0
-2
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Total alkalinity
120
100
80
60
40
20
0
-20
ALK (g/m3 CaCO3)
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

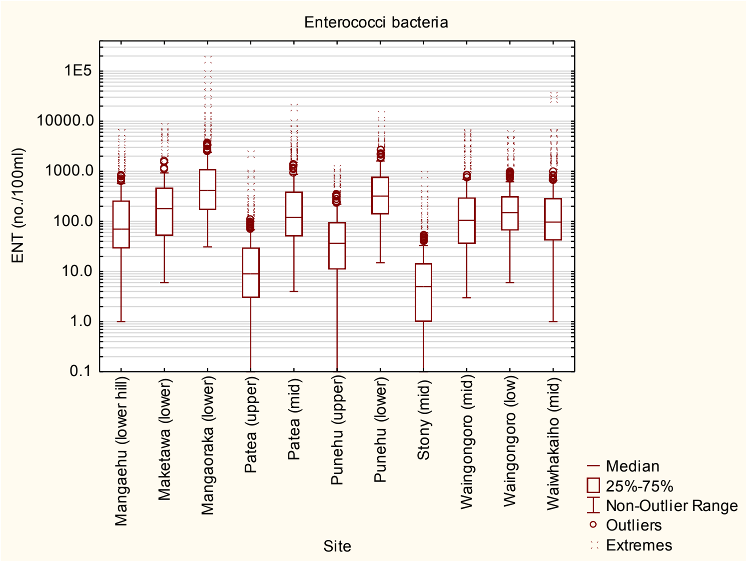

Biological oxygen demand (5 day)
100.0
10.0
1.0
0.1
BOD5 (g/m3)
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Dissolved oxygen
14
13
12
11
10
9
8
7
6
DO (g/m3)
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers

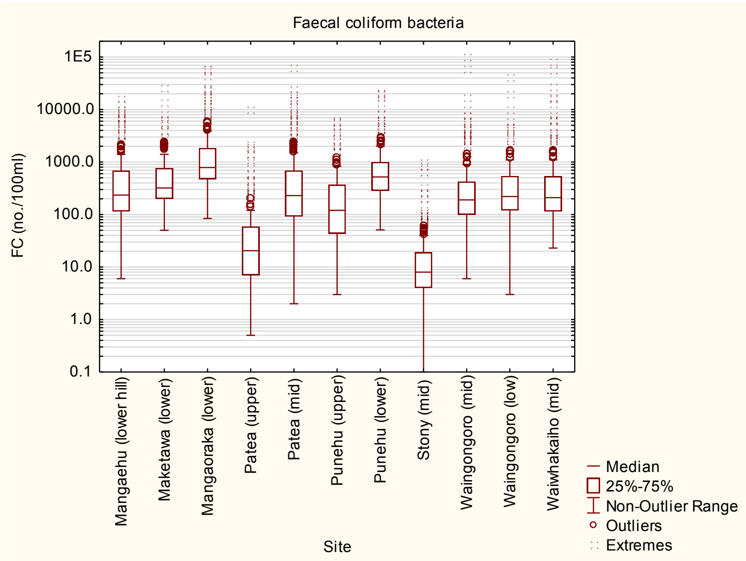

Dissolved oxygen saturation
% Saturation
150
140
130
120
110
100
90
80
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pH
pH
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

Bacteria

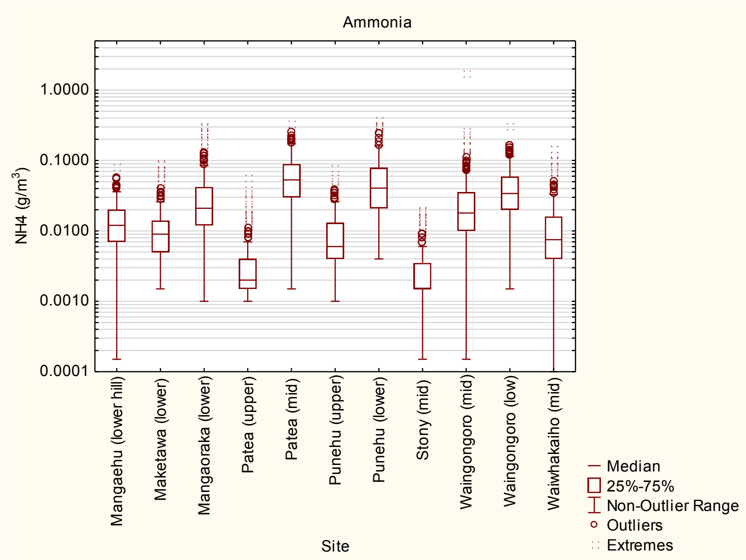


Enterococci bacteria
ENT (no./100ml)
1E5
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

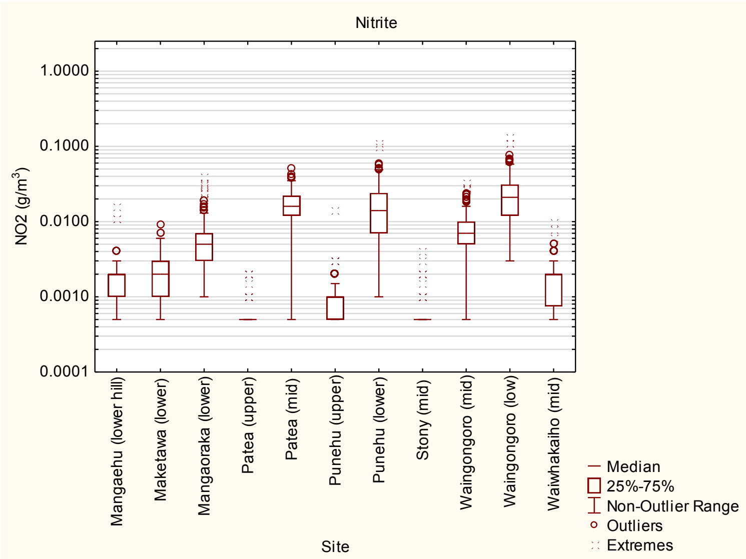


Faecal coliform bacteria
FC (no./100ml)
1E5
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

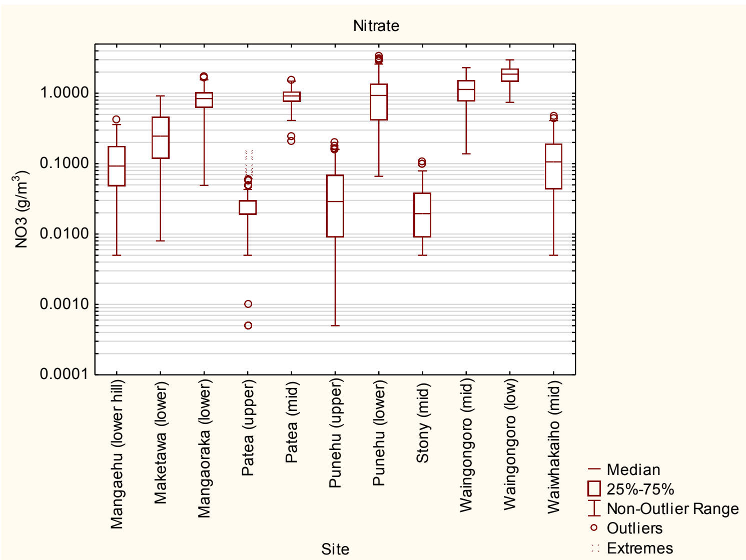
Nutrients



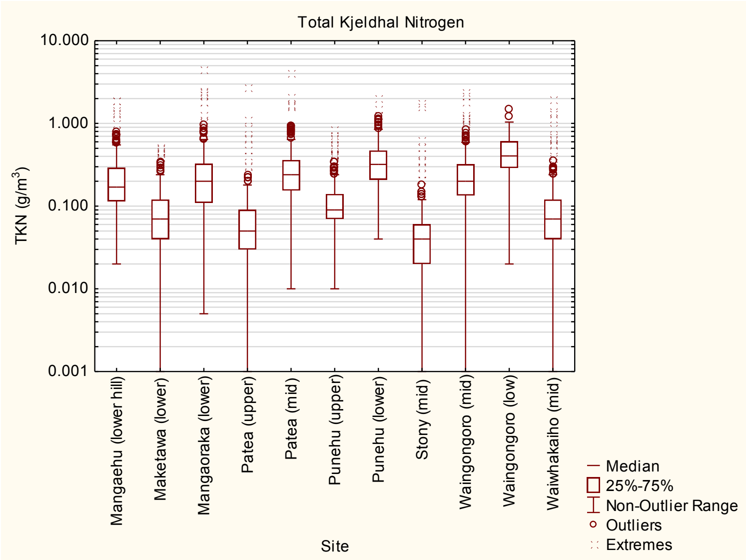
Ammonia
NH4 (g/m^3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

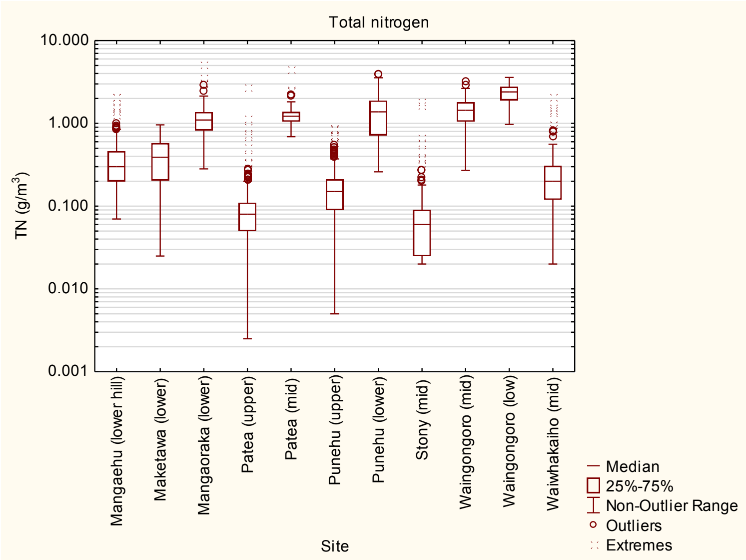


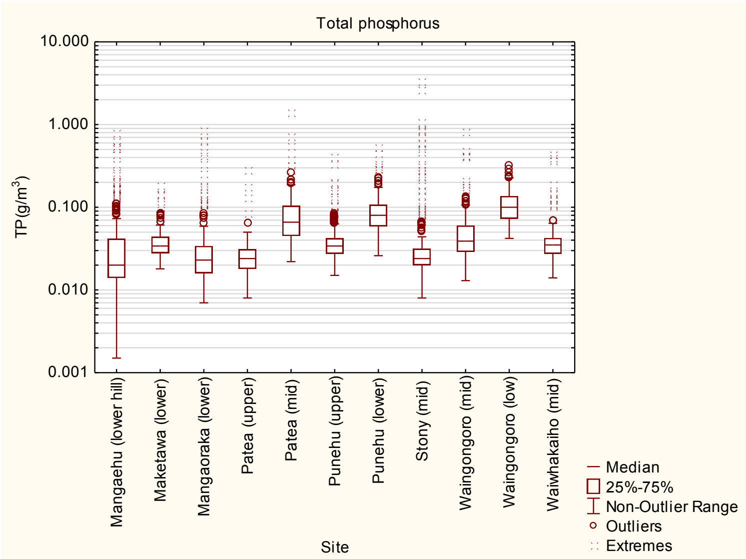
Nitrite
NO2 (g/m^3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

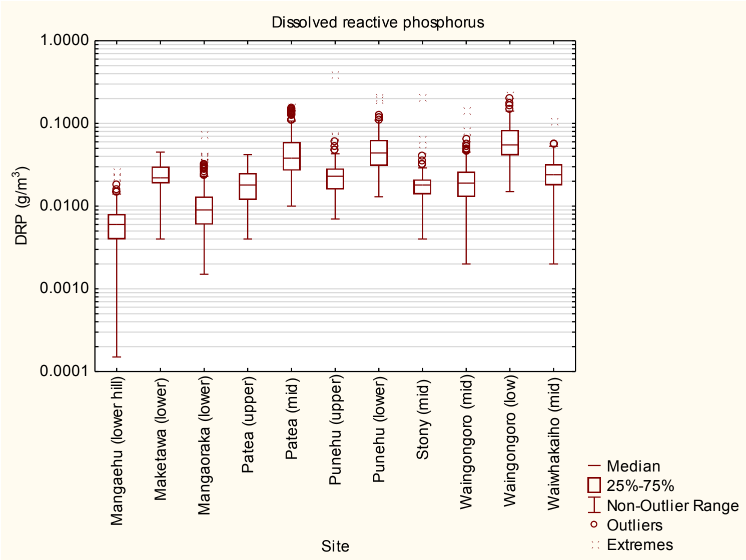


Nitrate
NO3 (g/m^3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Total Kjeldhal Nitrogen
TKN (g/m3)
10.000
1.000
0.100
0.010
0.001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Total nitrogen
TN (g/m3)
10.000
1.000
0.100
0.010
0.001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Total phosphorus
TP(g/m3)
10.000
1.000
0.100
0.010
0.001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Dissolved reactive phosphorus
DRP (g/m3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

Appendix II

Issues 3.3.6 & 3.3.7 of the TRC Regional Policy Statement

3.3.6 *<u>ISSUE</u>: Water quality degradation resulting from diffuse source contamination*

OBJECTIVE

To maintain and enhance the quality of the water resources of Taranaki for water supply purposes, contact recreation, shellfish gathering for human consumption, aesthetic purposes, cultural purposes and aquatic ecosystems by avoiding, remedying or mitigating the adverse effects on water quality of diffuse source runoff of sediment, nutrients or other contaminants from land.

POLICIES

<u>Policy One</u>: Land use and management practices

Land use practices which reduce adverse effects on water quality and which maintain and enhance the quality and life-supporting capacity of water will be encouraged and promoted including:

- *the careful application of the correct types and quantity of fertiliser;*
- *the careful use of agrichemicals;*
- *land development and restoration of disturbed land to reduce diffuse source discharge of contaminants to water;*
- *stock control procedures to avoid, remedy or mitigate the effects of stock entry to rivers, trampling and pugging by stock and accelerated erosion from overgrazing; and*
- *land management practices, including the discharge of contaminants to land, that avoid or reduce contamination of groundwater aquifers.*

<u>Policy Two</u>: Management of riparian margins

The vegetation along riparian margins of all Taranaki lakes and rivers will, as far as is practicable, be retained and enhanced and, where appropriate, the retirement and planting of riparian margins will be promoted on all or parts of the following priority ring plain catchments:

*Waingongoro**	*Waiaua**
*Manganui**	*Taungatara*
Te Henui	*Mangatoki**
Huatoki	*Kaupokonui**
Mangorei	*Kai Auai*
*Patea**	*Maketawa*
Oakura	*Kahouri*
Timaru	*Mangaoraka*
*Waitara**	*Warea*
*Waiwhakaiho**	*Okahu*
*Kapuni**	*Punehu**
Hangatahua/Stony	*Ngatoro-nui*
*Waiongana**	*Ngatoro**
Tapuae	*Pungareere**
Tawhiti	

** Waterways which are also community water supply catchments*

In addition, regard shall be had to the following criteria in determining other priority catchments, subcatchments or reaches of rivers and lakes for the promotion of riparian vegetation:
- *existing degraded water quality including high water temperature, suspended solids, nitrate levels and dissolved reactive phosphate levels;*
- *existing degraded habitat quality including instream habitat and the extent or loss of existing vegetation;*
- *the intensity of land uses, their proximity to watercourses and the actual or potential contamination from diffuse sources;*
- *the actual or potential use of water for community, industrial and domestic water supplies;*
- *spiritual and cultural values and customary uses of tangata whenua;*
- *actual or potential scenic, amenity and recreational values including fishery values, indigenous fish and their habitat and the habitat of trout; and*
- *actual or likely conflicts among competing water uses and values and the potential for riparian management to reduce those conflicts.*

In determining what is `practicable' and `appropriate' in relation to the retention or planting of riparian vegetation in all catchments the following criteria will apply:
- *the physical characteristics of the site and catchment;*
- *the riparian management objectives and benefits sought;*
- *the costs of establishing riparian margins relative to the benefits.*

METHODS OF IMPLEMENTATION

In relation to land use and management practices:

_ The Taranaki Regional Council will:

- **Encourage** the preparation of **waste management codes of practices** by the industries that may generate liquid and solid waste by-products which may be applied or disposed of to land, including **poultry, piggery and other similar farming operations** and, when appropriate, include such codes in a regional discharges to land plan.

- **Prepare and distribute guidelines** related to the management practices to be adopted to reduce the effects of organic waste discharges from **silage pits** and feed lots and to reduce the effects of river crossings by stock.

- Until new regional plans are prepared, continue to **implement, administer and monitor** the rules and conditions outlined in the Taranaki Regional Council Transitional Regional Plan regarding the application of registered **fertilisers** to land and the use of **herbicides and pesticides.**

- **Prepare** a **regional discharges to land plan** containing rules and other methods to effectively manage the **discharge of contaminants to land** including drilling muds and cuttings, sludges, fertiliser, agrichemicals, spray irrigated piggery and dairy effluent, poultry effluent storage and disposal and discharges from silage pits and feedlots.

- **Discuss** with manufacturers and suppliers of **agrichemicals and other chemicals,** the strengthening of the education and information provision role they play with a view to minimising the likelihood and potential effects of spray application on water quality.

- **Consider,** in conjunction with relevant authorities, the merits of the location, methods of application and subsequent management of the discharge of contaminants to land, in a way that avoids adverse effects on receiving water quality.

- **Recognise** that the actual and potential effects of **agricultural waste discharges** to land will vary according to proximity to and assimilative capacity of water bodies, stock numbers and type and size of operation and **adopt,** within a **discharges to land plan**, a graded approach for rule making discretion to reflect the varying effects which might arise.

- **Recognise** that the quantity and quality of **agricultural waste** discharged to land will vary and use the public notification and non-notification provisions of the Act to reflect the magnitude of potential effects.

- Prepare **guidelines** and farm management plans, and generally **promote** and provide **advice** on methods to assist land users and developers to avoid or minimise accelerated erosion and associated runoff to waterways resulting from the use and development of land.

- **Promote and encourage** community awareness of the need to protect groundwater quality, particularly in those areas recognised as being important for **recharge** of groundwater aquifers.

- **Recognise** local **nitrate contamination** of shallow groundwater aquifers as an inevitable product of intensive agricultural production and **promote** land management practices, including those related to the discharge of contaminants to land and the application of nitrogen-based fertilisers to land, which have the effect of reducing levels of this contamination.

- **Prepare and include in a regional sustainable land use plan,** rules designed to control or prohibit **vegetation clearance** on steep or erodible land and the effects of the use and development of land on those classes of land where significant erosion may occur or where excessive sediment runoff to waterways could result.

- **Promote,** through the **provision of free advisory services** and model demonstration areas (in co-operation with selected land-holders), **sustainable land use** practices which do not give rise to excessive sediment and nutrient runoff and consequent water quality effects.

- **Promote appropriate control of land use** by other agencies under **other legislation** including the Conservation Act 1987, the Reserves Act 1977, and the Queen Elizabeth the Second National Trust Act 1977 for the purpose of maintaining and enhancing water quality.

_ Territorial authorities may wish to consider the following methods:

- **Include** in **district plans**, policies, rules, guidelines or other information to avoid, remedy or mitigate the adverse effects of land use activities and management practices on water quality.

- Generally **encourage and promote**, as appropriate, land use practices which maximise the quality of water.

In relation to the management of riparian margins:

_ The Taranaki Regional Council will:

- **Promote** the protection and planting of riparian margins through **education and advocacy** to **land owners**.

- **Advocate** as appropriate to relevant agencies, the use of **other legislation** (such as the Conservation Act 1987, the Reserves Act 1977 and the Queen Elizabeth the Second National Trust Act 1977) for the purpose of promoting the protection and planting of riparian margins.

- **Promote the planting of riparian margins** by offering technical advice and assistance, preparing riparian management plans in conjunction with landowners and by establishing joint venture programmes for specific catchments and coastal strips.

- **Promote** the planting of riparian margins as a member of the **Taranaki Tree Trust.**

- **Prepare** and implement, in conjunction with interested and affected parties, a **riparian management and implementation strategy** to outline a regional approach to riparian management in the Taranaki region.

- **Include in regional plans** and **resource consents**, rules, criteria, conditions, guidelines or information for the maintenance or enhancement of riparian vegetation.

_ Territorial authorities may wish to consider the following methods:

- **Include** in **district plans** and **resource consents**, provisions or conditions for the retention or planting of riparian vegetation, including rules for the creation of esplanade reserves and esplanade strips when land is subdivided.

- **Provide riparian buffer zones** for land uses such as aggregate extraction adjacent to waterways.

- **Plant** riparian margins on **land owned** by the territorial authority.

EXPLANATION

The objective, policies and methods of implementation in relation to diffuse source contamination of water have been adopted to maintain and enhance water quality by avoiding, remedying or mitigating the adverse effects of land use and management practices on the quality of water including freshwater in rivers and in groundwater and coastal water. This is a major *issue for Taranaki because of the actual and potential adverse effects on water resources arising from intensive agricultural land use. The methods of implementation described contain a mix of advocacy, codes of practice, information provision and a stated intention to prepare rules within plans and the consideration of consent applications.*

With respect to Policy One, the preparation of a regional discharges to land plan will establish standards for agricultural waste discharges to land, to avoid or mitigate adverse effects on water quality. The effects of such discharges on water quality will vary according to stock numbers and the type of discharge method used. A graded approach to decision-making will be adopted to reflect this variation. Those operations with few or minor adverse effects will be `permitted' or `controlled' while discharge activities with more significant actual or potential effects will be made `discretionary' or `prohibited'.

The preparation of a regional sustainable land use plan will recognise the impacts on water quality of activities on land. The plan will contain rules to control activities on certain classes of land but will emphasise advice and education, codes of practice and the preparation of individual farm management plans to prevent or minimise adverse effects on water quality.

Management of riparian zones and the protection of streambank vegetation is important in controlling diffuse source contamination from land and improving the water quality of adjacent waterways and coastal water. The purpose of Policy Two concerning the management of riparian margins is to avoid, remedy or mitigate the adverse water quality effects resulting from the removal of riparian vegetation and to maximise the benefits of riparian margins. The catchments listed in Policy Two have been selected because they already receive relatively high volumes of diffuse source contamination and because of the potential benefits of riparian management in enhancing the value of these catchments for water supply purposes, scenic and recreational use, Maori cultural and spiritual values and instream habitat.

Emphasis in implementing Policy Two is placed on education, advocacy and advice and on voluntary agreements with landowners to establish and maintain suitable riparian vegetation and the preparation, by the Taranaki Regional Council, of a riparian management strategy.

Rules could be incorporated into regional and district plans and conditions attached to resource consents to retain or establish riparian vegetation.

The criteria for determining priority catchments provide the basis for a consistent and coordinated approach to riparian management in Taranaki.

The criteria in Policy Two for determining what is practicable and appropriate provide the basis for judging the practicality and appropriateness of implementing the policy in any particular case. The criteria recognise that it may not be practical or appropriate to require the retention or planting of riparian margins to the same extent in all localities because of differing physical characteristics from place to place, because of different riparian management objectives or because of different costs that may be involved relative to the benefits that will be obtained. Some flexibility is required.

However riparian management is of considerable importance to Taranaki because of the benefits of riparian vegetation and riparian management to the achievement of a number of the region's environmental objectives. It is the desire of the Taranaki Regional Council that progress be made in implementing riparian management objectives throughout Taranaki.

Related policies

Section 3.2.1, *All policies relating to land degradation and loss of the productive capabilities of land through accelerated erosion;* ***Section 3.2.3,*** *All policies relating to the actual or potential loss of indigenous and other vegetation and the habitats of indigenous fauna;* ***Section 3.2.10,*** *Policy One, Protection of natural features and landscapes;* ***Section 3.2.11,*** *Policy One, Amenity values, and Policy Two, Heritage values;* ***Section 3.3.7,*** *All policies relating to the discharge of contaminants from point sources;* ***Section 3.5.1,*** *Policy One, Protection of natural character (of the coastal environment).*

ENVIRONMENTAL RESULTS ANTICIPATED

- Improvement in water quality and instream habitat.
- Enhanced scenic, amenity, landscape and recreational values and spiritual and cultural values of tangata whenua.
- Reduced streambank erosion.

Appendix III

SEM Physicochemical Programme TRC Intra-lab Quality Control Report 2014-2015

Background

The Resource Management Act 1991 (RMA) established a requirement for local authorities to undertake environmental monitoring. Section 35 of the RMA requires, among other things, that the state of the environment in the region be monitored to an extent which enables local authorities to effectively carry out the functions under the RMA. In 1995, the Taranaki Regional Council (the 'Council') established a state of the environment monitoring (SEM) programme for the region. This programme is outlined in the Council's 'State of the Environment Monitoring Procedures Document', 1997.

A network of nine freshwater sites was developed in mid-1995 for physiochemical monitoring on a long-term basis to provide information on trends in the state of surface water quality in the Taranaki region. This network was extended to ten sites in the 1998-99 period and eleven sites in the 2003-2004 period. Sampling is carried out on the second Wednesday of each month for the entire year. The programme also meshes with a similar national programme operated by the National Institute of Water and Atmospheric Research (NIWA) since 1989, which includes three sites in Taranaki.

As a quality control measure of the TRC laboratory precision for this programme, and as part of general quality assurance practices at the Council, a sample is collected from one of the eleven monitoring sites (chosen randomly) every three to four months and split on site for duplicate analyses. For quality control purposes, this sample is unidentified and is analysed in exactly the same way and at the same time as other samples, and recorded on the Council's database. In conjunction with the sampling undertaken by NIWA, a sample from one of the three network sites is split in the field from time to time as a quality control procedure for TRC laboratory analytical accuracy assessment. These comparisons between Council and NIWA results are reported in Appendix IV. The results of the internal Taranaki Regional Council quality control sampling for the 2014-2015 period are presented and discussed in this Appendix (III) to the report.

Introduction

Quality assurance (for precision and accuracy) is an essential aspect of any laboratory and monitoring programme. Quality control is an essential tool in this assurance, and is carried out by the Council for the SEM programme at up to four times per year, and annually for NIWA monitoring.

This report presents the results from the QC sample and precision results for the routine sample from which it was split, and compares the difference of each result from the mean of the two results. The difference is presented as a percentage of the mean and levels of these differences are expressed as follows:

Difference from mean (%)	Symbol/Comment
<10%	✓
10-20%	*
21-50%	**
>50%	***

The acceptability of the precision of pairs of analyses varies from parameter to parameter and the symbols defined above are only a guideline. For instance a 20% difference is acceptable for bacteriological samples, as there can be considerable variation in bacteriological counts, whereas pH measurements should not vary by more than 0.2 unit between subsamples.

There are various reasons why sub-sample results may differ, including discrepancies in laboratory equipment and/or techniques and general within sample variation. Sampling variation should be minimal as only a single sample has been collected for splitting into duplicate sub-samples prior to analyses. The amount of variation in results can differ from one type of analysis to another, and this report identifies those techniques that are more prone to variation. Once these methods are identified, it is possible to determine whether differences in results are significant and if so, whether these are due to laboratory discrepancies. Attempts to eliminate these problems can then be made wherever possible.

Results

Comparisons of split samples are presented in chronological order for the annual sampling period between July 2014 and June 2015.

First QC exercise

These split samples were collected from the Waiwhakaiho River site at SH3 on 13 August 2014 under slightly turbid, recession flow conditions (10.2 m^3/sec), following several recent freshes, and in fine, partly cloudy conditions. Results are presented in Table 1.

Table 1 Results of SEM QC sampling on 13 August 2014

Site: WKH000500					
Date: 13 August 2014				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.020	0.020	0	✓
A440F	/cm	0.004	0.005	11	*
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	24	25	2	✓
BOD5	g/m^3	< 0.5	< 0.5	0	✓
CONDY	mS/m @ 20°C	7.3	7.4	<1	✓
DRP	g/m^3-P	0.016	0.015	3	✓
ENT	/100ml	84	48	27	**
ECOL	/100ml	130	92	17	*
FC	/100ml	130	100	13	*
NH4	g/m^3-N	0.009	0.009	0	✓
NO2	g/m^3-N	0.001	0.001	0	✓
NO3	g/m^3-N	0.139	0.129	4	✓
pH	pH	7.7	7.7	0	✓
SS	g/m^3	< 2	< 2	0	✓
TKN	g/m^3-N	0.04	0.04	0	✓
TN	g/m^3-N	0.18	0.17	3	✓
TP	g/m^3-P	0.023	0.017	15	*
TURB	NTU	0.8	0.8	0	✓

Comments:

The difference of 0.001 units in filtered absorbance readings at 440 mm was not significant as it was within acceptable equipment performance tolerance. The difference between enterococci counts for the paired samples was outside acceptable tolerance levels for bacteriological samples (20%), whereas the differences between paired *E.coli* and faecal coliform counts was within this tolerance level. The difference between paired TP results was significant (at low concentrations) but neither result was an outlier in terms of the site's historical record.

Overall results showed relatively good laboratory analytical precision performance, with 14 of 19 pairs of results being within the 10% guideline each of which showed < 5% difference in paired results.

Second QC exercise

These split samples were collected from the Waingongoro River site at SH45 on 12 November 2014 under slightly turbid, steady recession flow (5.83 m^3/sec), and fine, partly cloudy weather conditions. Results are presented in Table 2.

Table 2 Results of SEM QC sampling on 12 November 2014

Site: WGG000900					
Date: 12 November 2014				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.026	0.026	0	✓
A440F	/cm	0.005	0.005	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	41	40	1	✓
BOD5	g/m^3	1.5	1.3	8	✓
CONDY	mS/m @ 20°C	15.9	15.9	0	✓
DRP	g/m^3-P	0.043	0.043	0	✓
ENT	/100ml	180	100	29	**
ECOL	/100 ml	860	520	25	**
FC	/100ml	860	520	25	**
NH4	g/m^3-N	0.053	0.054	< 1	✓
NO2	g/m^3-N	0.022	0.022	0	✓
NO3	g/m^3-N	1.718	1.648	2	✓
pH	pH	7.7	7.7	0	✓
SS	g/m^3	7	6	8	✓
TKN	g/m^3-N	0.52	0.55	3	✓
TN	g/m^3-N	2.26	2.22	< 1	✓
TP	g/m^3-P	0.084	0.076	5	✓
TURB	NTU	2.3	2.3	0	✓

Comments:

The differences between pairs of each of the three bacterial counts were from 5 to 9% outside the acceptable tolerance level for bacteriological samples (20%) but issues of clumping/incomplete mixing within bacteriological samples during the sample splitting/sub sampling processes can be typical of such samples.

Otherwise, overall laboratory analytical precision performance was good, with 16 of the 19 pairs of results recorded within the 10% guideline.

Third QC exercise

These split samples were collected from the site in the Punehu Stream at Wiremu Road on 11 February 2015 under very low, clear flow (0.292 m^3/sec), and fine, sunny weather conditions. Results are presented in Table 3.

Table 3 Results of SEM QC sampling on 11 February 2015

Site: PNH000200					
Date: 11 February 2015				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.027	0.027	0	✓
A440F	/cm	0.005	0.005	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	25	25	0	✓
BOD5	g/m^3	< 0.5	< 0.5	0	✓
CONDY	mS/m @ 20°C	8.8	8.8	0	✓
DRP	g/m^3-P	0.039	0.037	3	✓
ENT	/100ml	48	52	8	✓
ECOL	/100ml	85	71	9	✓
FC	/100ml	86	71	9	✓
NH4	g/m^3-N	0.004	0.008	33	**
NO2	g/m^3-N	< 0.001	< 0.001	0	✓
NO3	g/m^3-N	0.009	0.009	0	✓
PH	pH	7.7	7.7	0	✓
SS	g/m^3	< 2	< 2	0	✓
TKN	g/m^3-N	0.04	0.07	27	**
TN	g/m^3-N	< 0.05	0.08	≥ 33	**
TP	g/m^3-P	0.044	0.045	1	✓
TURB	NTU	1.2	1.2	0	✓

Comments:

The differences between ammonia N, TKN, and TN paired results was significant (27 to 33%) at low concentrations. None of these results were outliers in terms of the historical record for this site.

Otherwise 16 pairs of parameters analysed were well within acceptable agreement, representing good laboratory analytical precision for these samples.

Fourth QC exercise

These split samples were collected from the site in the Maketawa Stream at Tarata Road on 13 May 2015 under slightly turbid, fresh recession flow conditions (5.33 m^3/sec), and fine, sunny weather. The results are presented in Table 4.

Table 4 Results of SEM QC sampling on 13 May 2015

Site: MKW000300					
Date: 13 May 2015				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.036	0.036	0	✓
A440F	/cm	0.008	0.008	0	*
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m³ $CaCO_3$	20	20	0	✓
BOD5	g/m³	0.5	0.8	23	**
CONDY	mS/m @ 20°C	7.7	7.6	< 1	✓
DRP	g/m³-P	0.027	0.025	4	✓
ENT	/100ml	280	240	8	✓
ECOL	/100ml	520	380	16	*
FC	/100ml	520	380	16	*
NH4	g/m³-N	0.048	0.046	2	✓
NO2	g/m³-N	0.005	0.005	0	✓
NO3	g/m³-N	0.795	0.815	1	✓
PH	pH	7.1	7.2	< 1	✓
SS	g/m³	3	2	20	*
TKN	g/m³-N	0.16	0.16	0	✓
TN	g/m³-N	0.96	0.98	1	✓
TP	g/m³-P	0.044	0.043	1	✓
TURB	NTU	1.2	1.2	0	✓

Comments:

The differences between pairs of *E.coli* and faecal coliform bacterial counts were within acceptable tolerance levels (20%) for bacteriological samples.

The 23% difference in BOD_5 results (0.3 g/m³) was relatively insignificant at this very low concentration (< 1 g/m³) and the 20% difference in suspended solids results (1 g/m³) was also insignificant at these low concentrations (i.e. 2-3 g/m³)

Otherwise 15 of the 19 parameters' pairs of results were within the 10% guideline representing good laboratory analytical precision.

Summary

Four split samples were collected and analysed during this one-year (2014-2015) period for the assessment of internal laboratory analytical precision. The following table summarises the number of times each category of differences from the mean occurred for all analyses commonly performed on SEM samples.

	Difference from mean of pairs of split samples							
Parameter ID	**<10%**		**10-20%**		**21-50%**		**>50%**	
A340F	4	(94)	-	(7)	-	(0)	-	(0)
A440F	3	(72)	1	(19)	-	(7)	-	(2)
A770F	4	(76)	-	(0)	-	(9)	-	(15)
ALKT	4	(100)	-	(0)	-	(0)	-	(0)
BOD5	3	(85)	-	(13)	1	(1)	-	(1)
CONDY	4	(100)	-	(0)	-	(0)	-	(0)
DO*	-	(100)	-	(0)	-	(0)	-	(0)
DRP	4	(94)	-	(5)	-	(0)	-	(1)
ENT	2	(44)	-	(23)	2	(27)	-	(6)
ECOL	1	(48)	2	(34)	1	(16)	-	(2)
FC	1	(49)	2	(33)	1	(15)	-	(3)
NH4	3	(78)	-	(13)	1	(6)	-	(3)
NO2	4	(96)	-	(3)	-	(1)	-	(0)
NO3	4	(85)	-	(5)	-	(9)	-	(1)
pH	4	(100)	-	(0)	-	(0)	-	(0)
SS	3	(87)	1	(9)	-	(4)	-	(0)
TKN	3	(49)	-	(22)	1	(24)	-	(5)
TN	3	(81)	-	(11)	1	(8)	-	(0)
TP	3	(85)	1	(8)	-	(4)	-	(3)
TURB	4	(98)	-	(1)	-	(1)	-	(0)

[NB: () = % of QC samples for 1995 to 2015 period; * Winkler method to 2012]

This summary for the 2014-2015 period indicated:

- results from pairs of all three bacteriological species' samples varied in precision with up to four sets of results falling just outside the acceptable variability (20%). This follows the historical trend for paired bacteriological analyses which have found at least 44% of the period's quality control samples within the 10% difference of the mean (for all three species), and from 67% to 72% of samples within 20% of the mean for paired samples in all species.
- TKN analytical variability greater than 20% was recorded on one occasion, due to reliance on calculations from another nitrogen species which, however, was within acceptable precision tolerance. TKN duplicates have traditionally shown this variability with only 49% and 71% to date within 10% and 20% of the mean respectively.
- BOD$_5$ analytical variability of 21% was recorded on one occasion at very low concentrations and the difference of 0.3 g/m^3 was considered insignificant at this level.
- variability in split samples agreement for filtered absorbances at 340 nm, 440 nm, and 770 nm which had occurred occasionally, but almost entirely within equipment performance tolerance values, was only once recorded (at 440 nm) over the 2014-2015 period.

In general, laboratory analytical performance has been acceptable, with very good precision of results shown for the majority of parameters following the continuation of split-sampling field methodology to remove any sampling bias in the quality control programme. Some exceptions in analytical precision have been identified and these are being addressed by the laboratory. Additional inter-laboratory analyses are recommended as part of this process. No results from this exercise were statistical outliers in the context of the twenty year historical database for all sites in the programme. The dissolved oxygen measurement was undertaken by field meter during the year and therefore has been removed from the intra-lab programme.

Appendix IV

SEM Physicochemical Programme
Inter-lab Quality Control Report 2014-2015

Introduction

A network of nine freshwater sites was developed in mid-1995 for physiochemical monitoring on a long-term basis to provide information on trends in the state of surface water quality in the Taranaki region. One further site was added to this network in the 1998-99 period and another in the 2003-2004 period (see Introduction). Sampling is carried out on the second Wednesday of each month for the entire year. The programme also meshes with a similar national programme operated by the National Institute of Water and Atmospheric Research (NIWA) since 1989, which includes three sites in Taranaki and is performed on the third Tuesday of each month throughout the year although part way through the 2013-2014 period NIWA adjusted the Waingongoro River site sampling to coincide with the timing of the TRC sampling protocol.

As a quality control measure for this programme, and as part of general quality assurance practices at the Council, a sample is collected randomly from one of the eleven monitoring sites every three to four months and split for duplicate analyses (see Appendix III). The additional sample is analysed in exactly the same way and at exactly the same time as other samples, and recorded on the Council's database. In conjunction with the sampling undertaken by NIWA, the Council also shares a duplicate sub-sample from time to time as a quality control procedure to assess accuracy of laboratory analytical performance. Normally a single sample is collected from one of the three sites and then split for sub-samples' analyses by each of the laboratories. A sample was collected from one of the three sites, on one occasion in the 2014-2015 year for the inter-lab comparison exercise.

Quality assurance is an essential aspect of any laboratory and monitoring programme. Quality control is an essential tool in this assurance, and is carried out by the Council from time-to-time with NIWA monitoring.

This report presents the results from NIWA and TRC samples and compares the difference of each result from the mean of the two results. The difference is presented as a percentage of the mean, and levels of these differences are expressed as follows:

Difference from mean (%)	Symbol/Comment
<10%	✓
10-20%	*
21-50%	**
>50%	***

The acceptability of the precision of pairs of analyses varies from parameter to parameter and the symbols defined above are only a guideline. These differences may also be related to the precision of various methods, which can vary between laboratories.

There are various reasons why sample results may differ, including discrepancies in laboratory equipment and/or techniques and general sample variation. Sampling variation should be minimal as samples are normally collected and split into subsamples by both parties. The amount of variation in results can differ from one type of analysis to another, and this report identifies those techniques that are more prone to variation. Once these methods are identified, it is possible to determine whether differences in results are significant and if so, whether these are due to sample variability or laboratory discrepancies. Attempts to eliminate these problems can then be made wherever possible.

One quality control sampling run was performed with NIWA field staff during the 2014-2015 period on 21 April 2015. Sampling was performed during a steady recession flow (0.83 m^3/sec), eight days after a fresh flow (18 m^3/sec) in fine, overcast weather at the Manganui River site at SH3.

Results

2014-2015 exercise

Comparisons of the individual sample's analytical results for the Manganui River (at SH3) site are presented in Table 1.

Table 1 Results of SEM QC sampling by TRC & NIWA on 21 April 2015

MGN000195					
		Time:1145 (NZST)		**Difference from mean (%)**	**Comments**
Parameter	Units	TRC	NIWA		
A340F	/cm	0.012	0.013	4	✓
A440F	/cm	0.002	0.003	20	*
BDISC	m	4.25	4.15	1	✓
CONDY	mS/m @ 20^{0}C	7.5	7.5	0	✓
DO	g/m^3	10.6	10.5	< 1	✓
DRP	g/m^3-P	0.010	0.009	5	✓
ECOL	nos/100 ml	40	45	6	✓
NH4	g/m^3-N	0.006	0.007	7	✓
NO3	g/m^3-N	0.17	0.16	3	✓
pH	pH	7.2	7.6	3	✓
TEMP	°C	11.8	11.8	0	✓
TN	g/m^3-N	0.23	0.20	7	✓
TP	g/m^3-P	0.014	0.015	3	✓
TURB	NTU	0.9	1.1	10	*

[**Note:** N/A = not available; N/R = not reported]

Comments:

A significant difference in paired measurements between the two laboratories was recorded for filtered absorbance at 440 nm but this difference (0.001 units) was within the acceptable equipment performance tolerance. A marginally significant difference (0.2 NTU) was found between paired turbidity measurements under very clean river conditions. Otherwise good analytical agreement was recorded for all other parameters.

Good operator field agreement was indicated by the similarity in the pairs of temperature, dissolved oxygen, and black disc measurements.

	Difference from mean of pairs of split samples			
Parameter ID	**<10%**	**10-20%**	**20-50%**	**>50%**
A340F	1 (91)	- (4)	- (5)	- (0)
A440F	- (61)	1 (35)	- (0)	- (4)
CONDY	1 (92)	- (4)	- (0)	- (4)
DO	1 (100)	- (0)	- (0)	- (0)
DRP	1 (42)	- (25)	- (29)	- (4)
ECOL	1 (22)	- (44)	- (33)	- (0)
NH4	1 (33)	- (20)	- (20)	- (24)
NO3	1 (88)	- (8)	- (4)	- (0)
pH	1 (100)	- (0)	- (0)	- (0)
TEMP	1 (100)	- (0)	- (0)	- (0)
TN	1 (87)	- (4)	- (9)	- (0)
TP	1 (61)	- (26)	- (13)	- (0)
TURB	- (36)	1 (44)	- (20)	- (0)

[NB: () - % of QC samples over the 1995 to 2014 period]
This summary indicates:

- generally good inter-laboratory analytical performance for most parameters while taking into account variations in laboratory methods and equipment performance tolerances.

- ammonia nitrogen and dissolved reactive phosphorus nutrient analyses and turbidity measurements have showed greatest variability between laboratories, while *E.coli* bacteriological counts have tended to vary more widely with lower counts more often recorded by the NIWA laboratory.

Acceptable inter-laboratory agreement has been apparent for most of the parameters analysed. An exception has been identified from time to time for DRP and further comparisons will be performed during future SEM programmes. Good field agreement was recorded for water temperature, dissolved oxygen and black disc measurements as normally recorded in the past.

Discussions with NIWA, Hamilton staff have determined that annual inter-laboratory comparisons will continue to be performed on <u>one</u> sample collected at one of the three NIWA sites (by TRC personnel) and <u>split on site for analysis</u> by each of the two laboratories, alongside the sample collected in the routine manner by NIWA field party staff.