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 and 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.

In the year under review, surveys continued to be performed regularly in the second week of every month from July 2011 to June 2012, under a narrower range of flow conditions than typical, ranging through smaller floods, moderate freshes, to low late summer-autumn flows. This year was characterised by significantly higher median flows sampled by the programme in all rivers and streams, except the eastern hill country where median flow was very slightly lower. 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 2011-2012 monitoring year, spring flows sampled were higher than usual. In general terms, water quality was comparatively poorer in clarity, and to a lesser degree in BOD_5, turbidity, and suspended solids and in median enterococci bacteria numbers. Narrower temperature ranges, mainly due to lower maximum water temperatures, but similar median water temperatures, were measured in the 2011-2012 period compared with ranges and medians measured during the first sixteen years of the SEM programme. Median total phosphorus levels were elevated at two sites and lower at three sites, one of which was in the lower Waingongoro River downstream of the recent diversion of the Eltham WWTP discharge (by pipeline) out of the catchment. Median nitrate and total nitrogen species levels were lower at up to four sites, while median ammonia nitrogen levels were higher at three sites and lower at two sites.

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 1995-2012 period.

This report on the results of the 2011-2012 monitoring period also includes recommendations for the 2012-2013 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.

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 2012 are summarised and presented briefly in the current Annual Report.

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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) has also been published (TRC, 2009a) and includes trend reporting. 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 2011-2012 monitoring year, the seventeenth year of the programme. The previous years' results were presented in TRC Technical Reports 97-105, 98-19, 98-90, 99-91, 2000-52, 2001-85, 2002-41, 2003-56, 2004-54, 2005-68 , 2006-74 ,2007-69, 2008-100, 2009-54, 2010-15, and 2011-47.

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.

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).

Using data collected in the NWQN since 1989, NIWA scientists have analysed trends over time for a number of parameters at the Taranaki sites and have rated them relative to other New Zealand rivers (McBride, 1996, TRC, 2003 and TRC, 2009). Water quality has been relatively stable at the Waitara River site compared with national trends and, not surprisingly, water quality remains high at the upper/mid catchment Manganui River site. A deterioration in aspects of water quality has occurred at the site in the lower reaches of the Waingongoro River over time Trends in nutrient levels (nitrates and phosphorus) have been identified at both lower catchment sites. There has been a reduction in ammonia-N levels at the Waitara River site (between 1989 and 2007) over the longer period. Levels of all nutrient species increased at the Waingongoro River site (between 1989 and 2007), although phosphorus levels have stabilised since 1995, most likely due to a reduced loading from a major point source discharge in the mid reaches of the Waingongoro River catchment.

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 subcatchment 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.

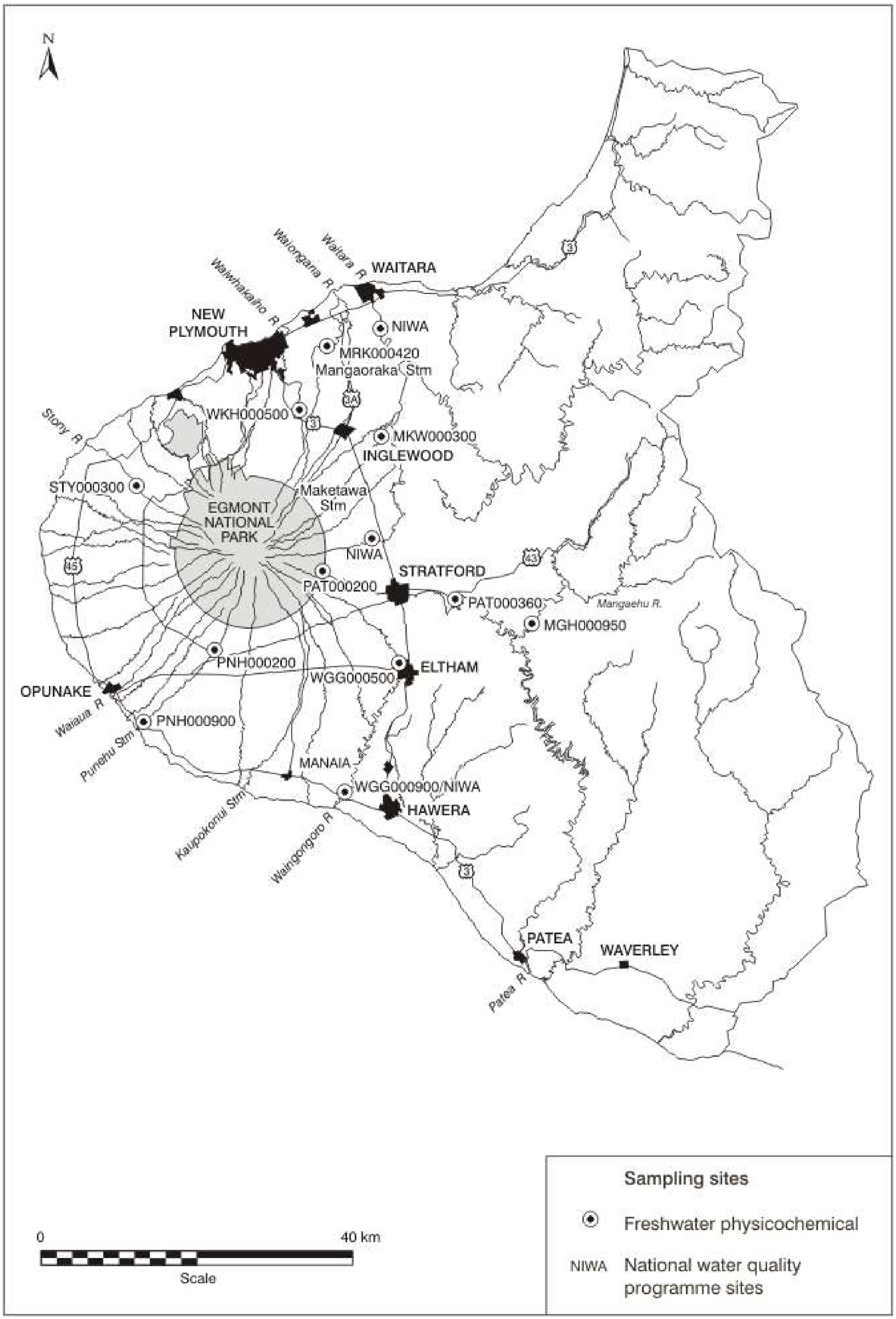

Figure 1 Freshwater physicochemical SEM sampling sites

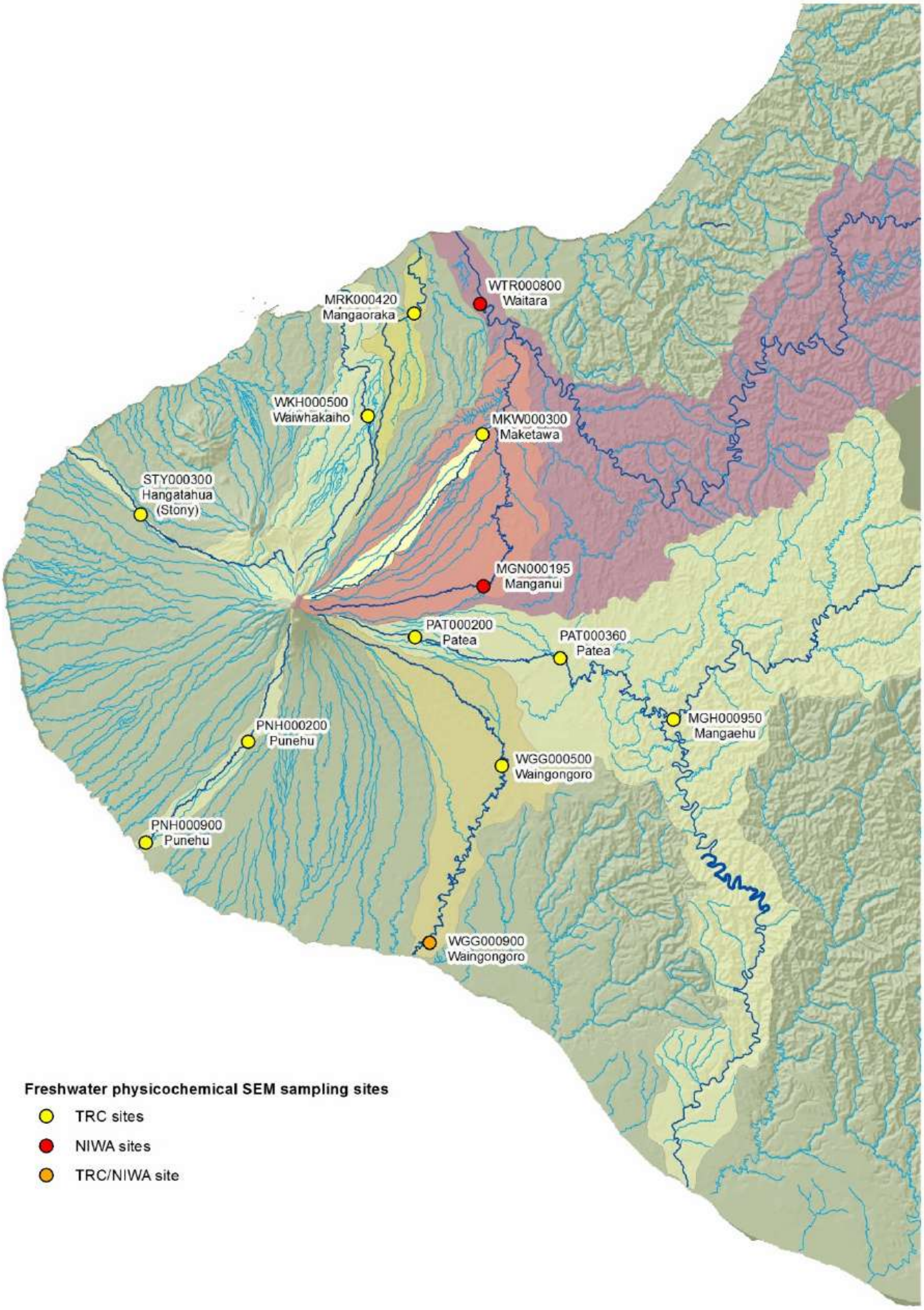

Figure 2 Freshwater physicochemical SEM sampling sites aerial map

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.

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 and more recently in the latter part of 2006 and during mid 2008 and mid 2009.

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 shutdown. 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 have been implemented at the lower reach site in 2011.

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 1996b).

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 followed by lab analysis
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 four sites where no permanent hydrological stations exist, 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 flow data stored in this database.

4. Water quality results

Water quality data accumulated for the period July 2011 to June 2012 are presented for each of the eleven sites. Statistical summaries of this data and the cumulative data for nine sites (July 1995 to June 2012), one site in the lower Waingongoro River (July 1998 to June 2012), and one site in the lower Maketawa Stream (July 2003 to June 2012) 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) $CaCO_3$)	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)
13 Jul 2011	0800	0.018	0.004	0.000	14	0.90	0.6	7.3	11.0	97	0.014	350	120
10 Aug 2011	0800	0.012	0.004	0.000	30	3.55	<0.5	8.6	11.4	98	0.017	96	11
14 Sep 2011	0800	0.038	0.008	0.000	15	0.21	1.6	6.5	11.5	100	0.030	5600	780
12 Oct 2011	0700	0.057	0.013	0.000	18	1.62	0.6	6.5	10.5	98	0.022	1900	300
08 Nov 2011	0700	0.013	0.003	0.000	27	3.14	<0.5	8.4	10.8	102	0.021	330	48
14 Dec 2011	0710	0.116	0.025	0.001	10	0.51	1.5	3.8	10.2	101	0.022	1800	520
11 Jan 2012	0705	0.066	0.013	0.000	17	1.94	0.7	5.8	9.8	99	0.022	830	190
08 Feb 2012	0705	0.016	0.004	0.000	29	3.76	0.7	8.3	9.9	100	0.018	300	92
14 Mar 2012	0700	0.019	0.004	0.000	29	3.32	<0.5	8.7	10.3	99	0.022	260	150
11 Apr 2012	0805	0.012	0.003	0.000	32	3.56	<0.5	9.0	10.3	100	0.020	96	90
09 May 2012	0805	0.017	0.004	0.000	31	3.03	0.7	8.8	10.3	97	0.020	310	430
13 Jun 2012	0800	0.002	0.001	0.000	29	4.18	<0.5	8.7	11.8	97	0.016	110	71

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)
13 Jul 2011	0800	350	6.733	0.031	0.002	0.528	7.3	5	9.1	0.21	0.74	0.035	1.8
10 Aug 2011	0800	96	1.610	0.012	0.001	0.209	7.6	<2	8.1	0.03	0.24	0.020	0.8
14 Sep 2011	0800	5700	16.807	0.035	0.003	0.137	7.4	55	8.1	0.24	0.38	0.142	14
12 Oct 2011	0700	1900	3.241	0.021	0.004	0.366	7.5	2	11.5	0.11	0.48	0.045	1.3
08 Nov 2011	0700	330	2.201	0.008	0.002	0.428	7.6	<2	12.0	0.01	0.44	0.027	0.6
14 Dec 2011	0710	1800	16.42	0.010	0.003	0.107	7.2	<2	13.8	0.34	0.45	0.100	4.4
11 Jan 2012	0705	870	3.212	0.009	0.003	0.287	7.5	<2	14.8	0.13	0.42	0.036	1.0
08 Feb 2012	0705	300	1.479	0.005	<0.001	0.049	7.7	<2	15.3	0.04	0.09	0.024	0.6
14 Mar 2012	0700	280	2.283	<0.003	0.001	0.399	7.6	<2	13.5	0.00	0.40	0.029	0.7
11 Apr 2012	0805	96	1.340	0.003	0.001	0.139	7.4	<2	13.1	0.02	0.16	0.030	0.6
09 May 2012	0805	320	1.693	0.003	0.001	0.029	7.7	2	11.8	0.09	0.12	0.023	0.6
13 Jun 2012	0800	110	1.824	<0.003	0.002	0.418	7.7	<2	6.4	0.08	0.50	0.030	0.7

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

Table 4 Statistical summary of data from July 2011 to June 2012: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.002	0.116	0.018	12	0.033
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.025	0.004	12	0.007
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity total	g/m³ $CaCO_3$	10	32	28	12	8
BLACK DISC	Black disc transparency	m	0.21	4.18	3.08	12	1.38
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	1.6	0.6	12	0.4
CONDY	Conductivity @ 20°C	mS/m	3.8	9.0	8.4	12	1.6
DO	Dissolved oxygen	g/m³	9.8	11.8	10.4	12	0.6
PERSAT	Dissolved oxygen saturation	%	97	102	99	12	0.2
DRP	Dissolved reactive phosphorus	g/m³P	0.014	0.030	0.020	12	0.004
ECOL	E. coli bacteria	nos/100 ml	96	5600	320	12	1580
ENT	Enterococci bacteria	nos/100 ml	11	780	135	12	233
FC	Faecal coliform bacteria	nos/100 ml	96	5700	325	12	1605
FLOW	Flow	m³/s	1.340	16.81	2.242	12	5.66
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.035	0.008	12	0.011
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.004	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m³N	0.03	0.53	0.25	12	0.168
pH	pH		7.2	7.7	7.6	12	0.2
SS	Suspended solids	g/m³	<2	55	<2	12	15
TEMP	Temperature	°C	6.4	15.3	11.9	12	2.9
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	0.34	0.08	12	0.11
TN	Total nitrogen	g/m³N	0.09	0.74	0.41	12	0.19
TP	Total phosphorus	g/m³P	0.020	0.142	0.030	12	0.037
TURB	Turbidity	NTU	0.6	14	0.8	12	3.9

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

Table 5 Statistical summary of data from July 2003 to June 2012: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.002	0.141	0.018	108	0.025
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.031	0.004	108	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	108	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	7	34	28	108	6
BLACK DISC	Black disc transparency	m	0.21	5.23	2.60	108	1.14
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	2.3	<0.5	108	0.4
CONDY	Conductivity @ 20°C	mS/m	3.2	12.6	8.5	108	1.3
DO	Dissolved oxygen	g/m³	9.0	12.5	10.5	108	0.8
PERSAT	Dissolved oxygen saturation	%	90	102	97	108	2
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.040	0.022	108	0.007
ECOL	E. coli bacteria	nos/100 ml	50	26000	305	108	2969
ENT	Enterococci bacteria	nos/100 ml	8	6300	145	108	1063
FC	Faecal coliform bacteria	nos/100 ml	50	26000	315	108	2978
FLOW	Flow	m³/s	0.846	17.20	1.958	108	2.887
NH_4	Ammoniacal nitrogen	g/m³N	0.003	0.087	0.009	108	0.015
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.009	0.002	108	0.002
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.92	0.25	108	0.215
pH	pH		6.8	7.9	7.6	108	0.2
SS	Suspended solids	g/m³	<2	55	<2	108	8
TEMP	Temperature	°C	4.8	17.6	11.6	108	3
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	0.52	0.07	108	0.1
TN	Total nitrogen	g/m³N	0.05	0.96	0.40	108	0.23
TP	Total phosphorus	g/m³P	0.018	0.180	0.032	108	0.026
TURB	Turbidity	NTU	0.5	14.0	0.8	108	2

Discussion

2011-2012 period

Good aesthetic water quality was indicated by a median black disc clarity of 3.08 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 4.18 m) was recorded in mid-winter under relatively low flow conditions (1.82 m^3/s). An elevation in turbidity (to 14 NTU) and in suspended solids concentration (55 g/m^3) under flood flow conditions (16.8 m^3/sec) was sampled in early spring 2011. Poorer water quality conditions apparent at the time of this flood flow were recorded with increases in bacterial number (5700 faecal coliforms/100ml), BOD_5 (1.6 g/m^3), and some nutrients (e.g. TP [0.142 g/m^3]) recorded when black disc visibility decreased to 0.21 m.

pH was relatively stable (7.2 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 (ie: prior to 0810 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: 0.6 g/m^3). Bacteriological quality was below average, but typical of the lower reaches of developed ring plain catchments, subject to agricultural impacts, with median faecal coliform and enterococci numbers of 325 and 135 (per 100 mls) respectively. Water temperature varied over a moderate range of 8.9°C with a maximum late summer (early morning) river temperature of 15.3°C recorded in February 2012.

Brief comparison with the previous 2003-2011 (eight year) period

Generally, stream water quality at this site during the 2011-2012 period was relatively similar in appearance/clarity (higher median black disc clarity [by 0.48m], equivalent median turbidity, and no difference in median suspended solids level). Bacterial water quality was also relatively similar, with a very small increase in median faecal coliform number of 10 per 100 mls and decrease in median enterococci number of 10 per 100 mls. Median water temperature was slightly higher (by 0.3°C), while the maximum water temperature (15.3°C) was 2.3°C lower than the previous maximum recorded. Other physicochemical aspects of water quality were very similar for the two periods. Moderately wide ranges for parameters such as suspended solids, turbidity, pH and total phosphorus reflected the two moderate flood events sampled during the 2011-2012 period. Median flow sampled during 2011-2012 was higher (by about 280 L/sec) than the median of flows sampled over the previous eight-year period due in part to much higher base flow conditions sampled during the latest period.(i.e. the lowest flow in the 2011-2012 period was about 500 L/sec higher than the historical minimum flow sampled to date). Median pH values were identical and the maximum pH value was within 0.2 unit of that of the past eight-year record. All nutrient species showed minimal differences in median values during the monitoring year in comparison with the previous eight-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)	BOD_5 (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/100ml)	ENT (Nos/100ml)
13 Jul 2011	0835	0.021	0.004	0.000	25	0.71	0.9	11.7	10.4	96	0.008	380	250
10 Aug 2011	0835	0.022	0.004	0.000	46	2.03	0.6	15.9	11.0	98	0.006	360	280
14 Sep 2011	0830	0.038	0.008	0.000	36	0.25	4.3	13.2	10.9	99	0.015	9100	3500
12 Oct 2011	0730	0.026	0.006	0.000	35	1.31	0.7	13.4	9.9	96	0.011	2200	2600
08 Nov 2011	0725	0.025	0.005	0.000	34	1.91	<0.5	13.1	10.4	101	0.010	570	91
14 Dec 2011	0735	0.039	0.008	0.000	34	1.47	1.3	11.8	9.6	98	0.028	2200	1100
11 Jan 2012	0745	0.049	0.009	0.000	36	1.51	1.1	12.5	-	-	0.012	3800	2400
08 Feb 2012	0735	0.034	0.007	0.000	51	2.43	1.1	15.8	9.8	101	0.005	510	540
14 Mar 2012	0730	0.032	0.006	0.000	39	1.65	0.6	13.6	10.0	97	0.010	570	500
11 Apr 2012	0830	0.022	0.004	0.000	53	2.62	<0.5	16.6	9.8	98	0.003	420	230
09 May 2012	0835	0.032	0.007	0.000	66	1.35	1.0	20.4	9.6	93	0.005	3200	1800
13 Jun 2012	0830	0.021	0.004	0.000	39	2.21	<0.5	13.9	11.5	96	<0.003	560	330
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)**
13 Jul 2011	0835	380	6.280	0.062	0.006	1.294	7.3	11	11.5	0.51	1.81	0.053	3.1
10 Aug 2011	0835	360	0.855	0.064	0.006	1.014	7.7	<2	9.9	0.22	1.24	0.018	1.6
14 Sep 2011	0830	9100	2.929	0.070	0.011	0.739	7.6	40	10.1	0.64	1.39	0.116	13
12 Oct 2011	0730	2300	1.825	0.063	0.007	1.073	7.5	3	13.8	0.24	1.32	0.033	1.5
08 Nov 2011	0725	580	1.897	0.044	0.006	0.934	7.6	2	13.7	0.14	1.08	0.024	1.3
14 Dec 2011	0735	2300	2.698	0.054	0.014	0.826	7.6	12	16.3	0.17	1.01	0.052	1.6
11 Jan 2012	0745	3900	1.939	0.033	0.010	0.910	7.4	2	16.8	0.33	1.25	0.034	1.8
08 Feb 2012	0735	540	0.732	0.006	0.031	0.529	7.8	<2	16.5	0.14	0.70	0.015	1.2
14 Mar 2012	0730	570	1.598	0.012	0.003	0.837	7.6	2	14.7	0.08	0.92	0.019	1.2
11 Apr 2012	0830	420	0.692	0.013	0.003	0.697	7.7	<2	15.2	0.02	0.72	0.011	1.1
09 May 2012	0835	3200	0.575	0.024	0.009	0.701	7.7	2	13.4	0.23	0.94	0.026	1.7
13 Jun 2012	0830	580	1.271	0.009	0.003	0.867	7.7	2	8.1	0.20	1.07	0.019	1.4

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

Table 7 Statistical summary of data from July 2011 to June 2012: Mangaoraka Stream at Corbett Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.021	0.049	0.029	12	0.009
A440F	Absorbance @ 440nm filtered	/cm	0.004	0.009	0.006	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.000	0.000	12	0
ALKT	Alkalinity total	g/m³ $CaCO_3$	25	66	38	12	11
BLACK DISC	Black disc transparency	m	0.25	2.62	1.58	12	0.69
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	4.3	0.8	12	1
CONDY	Conductivity @ 20°C	mS/m	11.7	20.4	13.5	12	2.5
DO	Dissolved oxygen	g/m³	9.6	11.5	10.0	11	0.6
PERSAT	Dissolved oxygen saturation	%	93	101	98	11	2
DRP	Dissolved reactive phosphorus	g/m³P	0.003	0.028	0.009	12	0.007
ECOL	E. coli bacteria	nos/100 ml	360	9100	570	12	2547
ENT	Enterococci bacteria	nos/100 ml	91	3500	520	12	1153
FC	Faecal coliform bacteria	nos/100 ml	360	9100	580	12	2552
FLOW	Flow	m³/s	0.575	6.280	1.712	12	1.567
NH_4	Ammoniacal nitrogen	g/m³N	0.006	0.070	0.038	12	0.024
NO_2	Nitrite nitrogen	g/m³N	0.003	0.031	0.006	12	0.008
NO_3	Nitrate nitrogen	g/m³N	0.53	1.29	0.85	12	0.201
pH	pH		7.3	7.8	7.6	12	0.1
SS	Suspended solids	g/m³	<2	40	2	12	11
TEMP	Temperature	°C	8.1	16.8	13.8	12	2.9
TKN	Total kjeldahl nitrogen	g/m³N	0.02	0.64	0.21	12	0.18
TN	Total nitrogen	g/m³N	0.70	1.81	1.08	12	0.31
TP	Total phosphorus	g/m³P	0.011	0.116	0.025	12	0.029
TURB	Turbidity	NTU	1.1	13	1.6	12	3.3

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

Table 8 Statistical summary of data from July 1995 to June 2012: Mangaoraka Stream at Corbett Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.014	0.074	0.025	204	0.012
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.019	0.005	204	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	204	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	14	96	40	204	17
BLACK DISC	Black disc transparency	m	0.06	4.73	1.83	204	0.93
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	14.0	0.6	204	1.5
CONDY	Conductivity @ 20°C	mS/m	5.6	26.7	14.4	204	3.6
DO	Dissolved oxygen	g/m³	7.8	11.8	10.1	203	0.8
PERSAT	Dissolved oxygen saturation	%	83	107	96	203	4
DRP	Dissolved reactive phosphorus	g/m³P	<0.003	0.041	0.008	204	0.008
ECOL	E. coli bacteria	nos/100 ml	120	60000	740	180	7712
ENT	Enterococci bacteria	nos/100 ml	31	180000	345	204	14790
FC	Faecal coliform bacteria	nos/100 ml	120	60000	740	204	8347
FLOW	Flow	m³/s	0.160	34.100	1.182	204	3.252
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.308	0.022	204	0.05
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.039	0.005	204	0.006
NO_3	Nitrate nitrogen	g/m³N	0.05	1.73	0.84	204	0.312
pH	pH		6.9	8.1	7.6	204	0.2
SS	Suspended solids	g/m³	<2	310	2	204	29
TEMP	Temperature	°C	5.8	20.5	13.2	204	3
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	4.46	0.20	204	0.47
TN	Total nitrogen	g/m³N	0.28	5.18	1.12	204	0.54
TP	Total phosphorus	g/m³P	0.007	0.860	0.022	204	0.098
TURB	Turbidity	NTU	0.75	100	1.6	203	9.31

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.

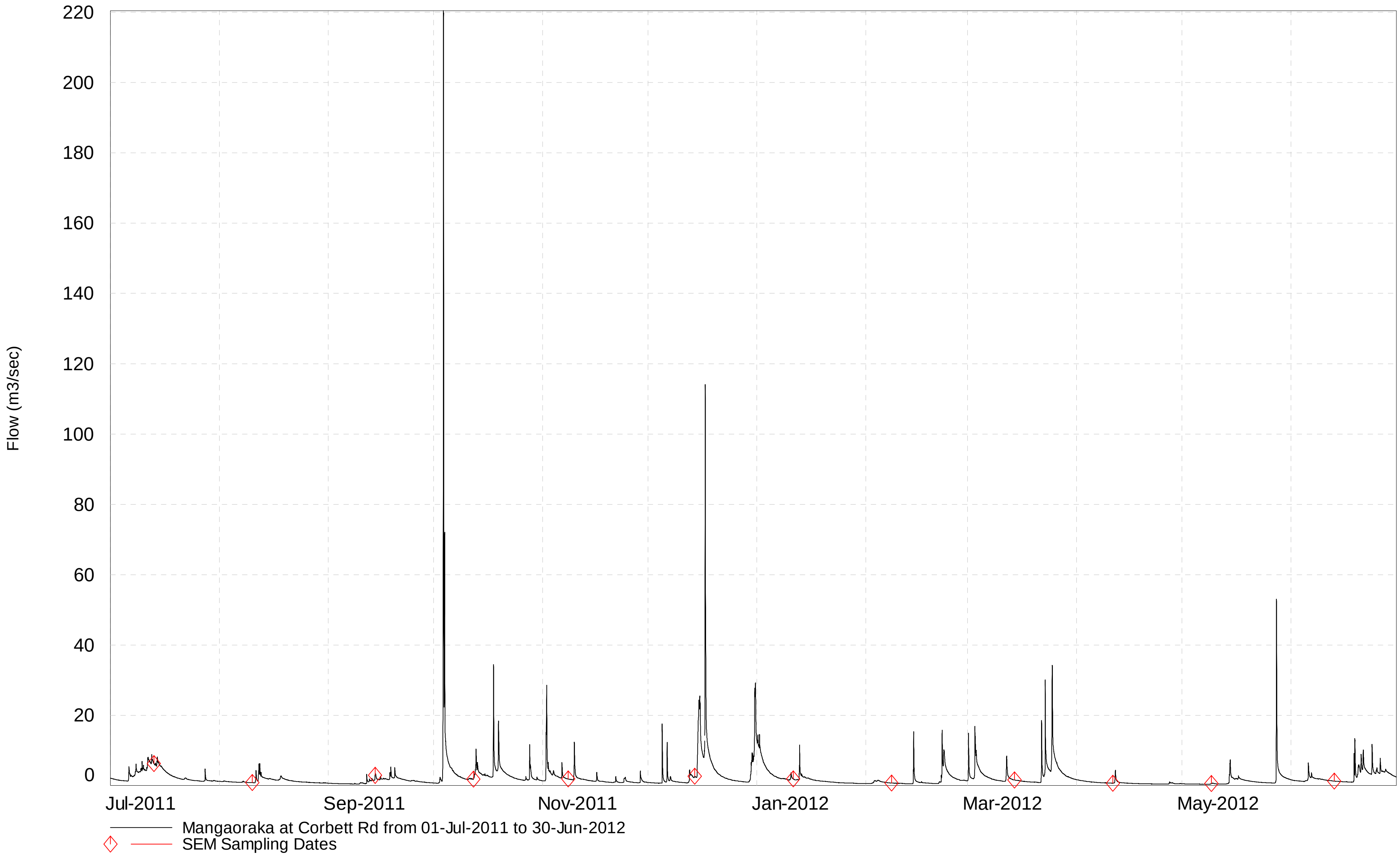

Figure 3 Flow record for the Mangaoraka Stream at Corbett Road

Discussion

2011-2012 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: 1.1 NTU; median: 1.6 NTU) than might be expected given the concentration of suspended solids (minimum: <2 g/m^3; median: 2 g/m^3). This is 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 relatively low maximum black disc value of 2.62 m coincided with late autumn, relatively low recession flow conditions, while the poorest turbidity conditions (13 NTU and 0.25 m black disc) were recorded during a fresh in early spring 2011 when a suspended sediment concentration of 40 g/m^3, BOD_5 of 4.3 g/m^3, and faecal coliform number of 9100 per 100 mls were measured. Most parameters indicated poorest water quality during this fresh, with elevated bacterial numbers and total phosphorus levels in particular.

Relatively few freshes during mid-summer to autumn coincided with slightly elevated pH values (up to 7.8) but these levels were not quite as high as have been recorded previously through late summer-autumn months. It should be noted all levels were recorded prior to mid-morning and were no indication of the higher pH levels that would be expected later in the day when algal photosynthetic activity might be expected to raise pH more significantly.

Generally, high dissolved oxygen concentrations, high percentage saturation, and low BOD_5 levels (< 1.0 g/m^3) were indicative of relatively good physicochemical water quality, but the very high median bacterial numbers (520 enterococci and 580 faecal coliforms per 100 ml), were 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. [Recent 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 8.7°C with a maximum (mid-morning) temperature of 16.8°C in January 2012 during moderately low flow conditions at that time. Dissolved oxygen saturation did not fall below 93% during the period.

Brief comparison with the previous 1995-2011 period

Aesthetic stream water quality at this site during the 2011-2012 period was slightly more turbid [lower median black disc clarity (by 0.27 m) although median suspended solids level and median turbidity remained the same]. Bacterial water quality improved as reflected in a decrease in median faecal coliform number of 165 per 100 mls but decreased in terms of the median enterococci number which increased by 180 per 100 mls. Median water temperature was 0.7˚C higher in the 2011-2012 period while the maximum water temperature (16.8°C) was 3.7°C lower than the previous maximum recorded. Median conductivity (and alkalinity) were slightly lower and probably reflected the proportionately greater incidence of higher flow conditions sampled during the latest period. This was reflected in the median flow sampled during 2011-2012 (1.71m^3 /sec) which was much higher (by 559 L/sec) than the median of flows sampled over the previous sixteen-year period. Moderate ranges for parameters such as suspended solids, turbidity, pH, and BOD_5 reflected the smaller flood events sampled on occasions during the 2011-2012 period (Figure 3), rather than high floods (or rising flows) occasionally sampled in the past.. Median pH values were identical but maximum pH was 0.3 unit lower than the past record. Most nutrient species had relatively similar or slightly lower median values during the monitoring year in comparison with the previous sixteen-year record with the exception of median ammoniacal nitrogen which for the second consecutive period was near twice the historical value.

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/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^{3}P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
13 Jul 2011	0915	0.016	0.003	0.000	17	1.32	<0.5	7.7	11.2	98	0.012	1000	110
10 Aug 2011	0905	0.010	0.002	0.000	52	3.66	<0.5	13.2	11.7	101	0.028	92	17
14 Sep 2011	0855	0.041	0.008	0.000	12	0.35	1.1	6.5	11.6	101	0.011	6200	1900
12 Oct 2011	0800	0.045	0.010	0.001	32	1.45	0.7	8.9	10.6	98	0.026	6200	6000
08 Nov 2011	0750	0.011	0.002	0.000	42	2.83	<0.5	11.2	11.1	104	0.022	260	13
14 Dec 2011	0810	0.085	0.019	0.001	9	0.78	0.9	3.4	10.3	100	0.007	930	250
11 Jan 2012	0820	0.052	0.011	0.000	30	1.76	0.8	7.7	9.9	101	0.024	1000	190
08 Feb 2012	0810	0.014	0.003	0.000	51	4.28	0.6	12.6	10.1	100	0.030	120	32
14 Mar 2012	0800	0.015	0.003	0.000	46	3.34	<0.5	11.8	10.7	102	0.025	180	64
11 Apr 2012	0905	0.009	0.002	0.000	64	4.66	<0.5	14.9	11.1	107	0.034	200	90
09 May 2012	0905	0.017	0.005	0.000	67	0.97	0.9	16.1	10.6	99	0.036	710	690
13 Jun 2012	0900	0.011	0.002	0.000	50	5.24	<0.5	12.6	12.1	99	0.019	69	<3

Date	Time (NZST)	FC (Nos/ 100ml)	Flow (m^3/s)	NH_4 (g/m^{3}N)	NO_2 (g/m^{3}N)	NO_3 (g/m^{3}N)	pH	SS (g/m^3)	Temp (°C)	TKN (g/m^{3}N)	TN (g/m^{3}N)	TP (g/m^{3}P)	Turb (NTU)
13 Jul 2011	0915	1100	13.201	0.032	0.002	0.258	7.5	2	8.8	0.15	0.41	0.030	1.1
10 Aug 2011	0905	92	2.970	0.004	0.001	0.099	7.9	<2	7.9	0.04	0.14	0.032	0.8
14 Sep 2011	0855	6200	28.999	0.019	0.002	0.068	7.3	23	7.8	0.25	0.32	0.063	5.5
12 Oct 2011	0800	6300	5.712	0.033	0.004	0.156	7.7	<2	11.1	0.14	0.30	0.047	1.2
08 Nov 2011	0750	260	4.424	0.013	0.001	0.139	7.9	<2	11.2	0.05	0.19	0.029	0.5
14 Dec 2011	0810	930	35.683	0.010	0.002	0.048	7.4	4	13.5	0.11	0.16	0.020	1.2
11 Jan 2012	0820	1000	6.039	0.013	0.003	0.087	7.8	<2	14.8	0.13	0.22	0.038	0.9
08 Feb 2012	0810	120	3.362	0.004	<0.001	0.059	8.0	<2	14.0	0.02	0.08	0.035	0.5
14 Mar 2012	0800	180	3.745	0.005	0.001	0.109	7.9	<2	13.0	0.01	0.12	0.027	0.5
11 Apr 2012	0905	200	2.279	<0.003	0.002	0.018	8.1	<2	12.9	0.03	<0.05	0.039	0.5
09 May 2012	0905	740	8.196	0.020	0.003	0.037	8.0	6	11.4	0.18	0.22	0.056	3.2
13 Jun 2012	0900	69	2.767	<0.003	0.001	0.179	7.9	<2	6.0	0.03	0.21	0.035	0.7

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

Table 10 Statistical summary of data from July 2011 to June 2012

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.009	0.085	0.016	12	0.024
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.019	0.003	12	0.005
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	9	67	44	12	19
BDISC	Black disc transparency	m	0.35	5.24	2.30	12	1.66
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.1	0.6	12	0.2
CONDY	Conductivity @ 20'C	mS/m	3.4	16.1	11.5	12	3.7
DO	Dissolved Oxygen	g/m^3	9.9	12.1	10.9	12	0.7
PERSAT	Dissolved Oxygen Saturation %	%	98	107	100	12	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.007	0.036	0.024	12	0.009
ECOL	E.coli bacteria	nos/100 ml	69	6200	485	12	2265
ENT	Enterococci bacteria	nos/100 ml	<3	6000	100	12	1730
FC	Faecal Coliforms	nos/100 ml	69	6300	500	12	2282
FLOW	Flow	m^3/s	2.279	35.683	5.068	12	11.05
NH4	Ammoniacal nitrogen	g/m^3N	0.003	0.033	0.012	12	0.011
NO2	Nitrite nitrogen	g/m^3N	0.001	0.004	0.002	12	0.001
NO3	Nitrate nitrogen	g/m^3N	0.02	0.26	0.09	12	0.069
PH	pH		7.3	8.1	7.9	12	0.3
SS	Suspended solids	g/m^3	<2	23	<2	12	6
TEMP	Temperature	°C	6.0	14.8	11.3	12	2.8
TKN	Total Kjeldahl nitrogen	g/m^3N	0.01	0.25	0.08	12	0.08
TN	Total nitrogen	g/m^3N	<0.05	0.41	0.20	12	0.1
TP	Total phosphorus	g/m^3P	0.020	0.063	0.035	12	0.012
TURB	Turbidity	NTU	0.4	5.5	0.8	12	1.5

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

Table 11 Statistical summary of data from July 1995 to June 2012: Waiwhakaiho River at SH3

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.006	0.095	0.015	204	0.019
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.022	0.004	204	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.007	0.000	204	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	8	72	48	204	17
BDISC	Black disc transparency	m	0.13	8.05	3.05	204	1.46
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	4.3	<0.5	204	0.5
CONDY	Conductivity @ 20'C	mS/m	3.4	16.6	12.2	204	3.3
DO	Dissolved Oxygen	g/m^3	9.1	12.8	10.8	204	0.7
PERSAT	Dissolved Oxygen Saturation %	%	91	108	100	204	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.108	0.024	204	0.011
ECOL	E.coli bacteria	nos/100 ml	23	56000	180	180	4669
ENT	Enterococci bacteria	nos/100 ml	1	28000	84	204	2124
FC	Faecal Coliforms	nos/100 ml	23	83000	200	204	7278
FLOW	Flow	m^3/s	1.718	83.440	3.746	204	9.596
NH4	Ammoniacal nitrogen	g/m^3N	<0.003	0.148	0.008	204	0.022
NO2	Nitrite nitrogen	g/m^3N	<0.001	0.010	0.002	204	0.001
NO3	Nitrate nitrogen	g/m^3N	<0.01	0.47	0.11	204	0.106
PH	pH		6.8	8.5	7.9	204	0.3
SS	Suspended solids	g/m^3	<2	89	<2	204	10
TEMP	Temperature	°C	4.8	18.3	11.2	204	2.9
TKN	Total Kjeldahl nitrogen	g/m^3N	<0.01	1.95	0.07	204	0.22
TN	Total nitrogen	g/m^3N	0.02	2.10	0.21	204	0.25
TP	Total phosphorus	g/m^3P	0.014	0.437	0.034	204	0.049
TURB	Turbidity	NTU	0.40	26	0.7	203	2.89

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.

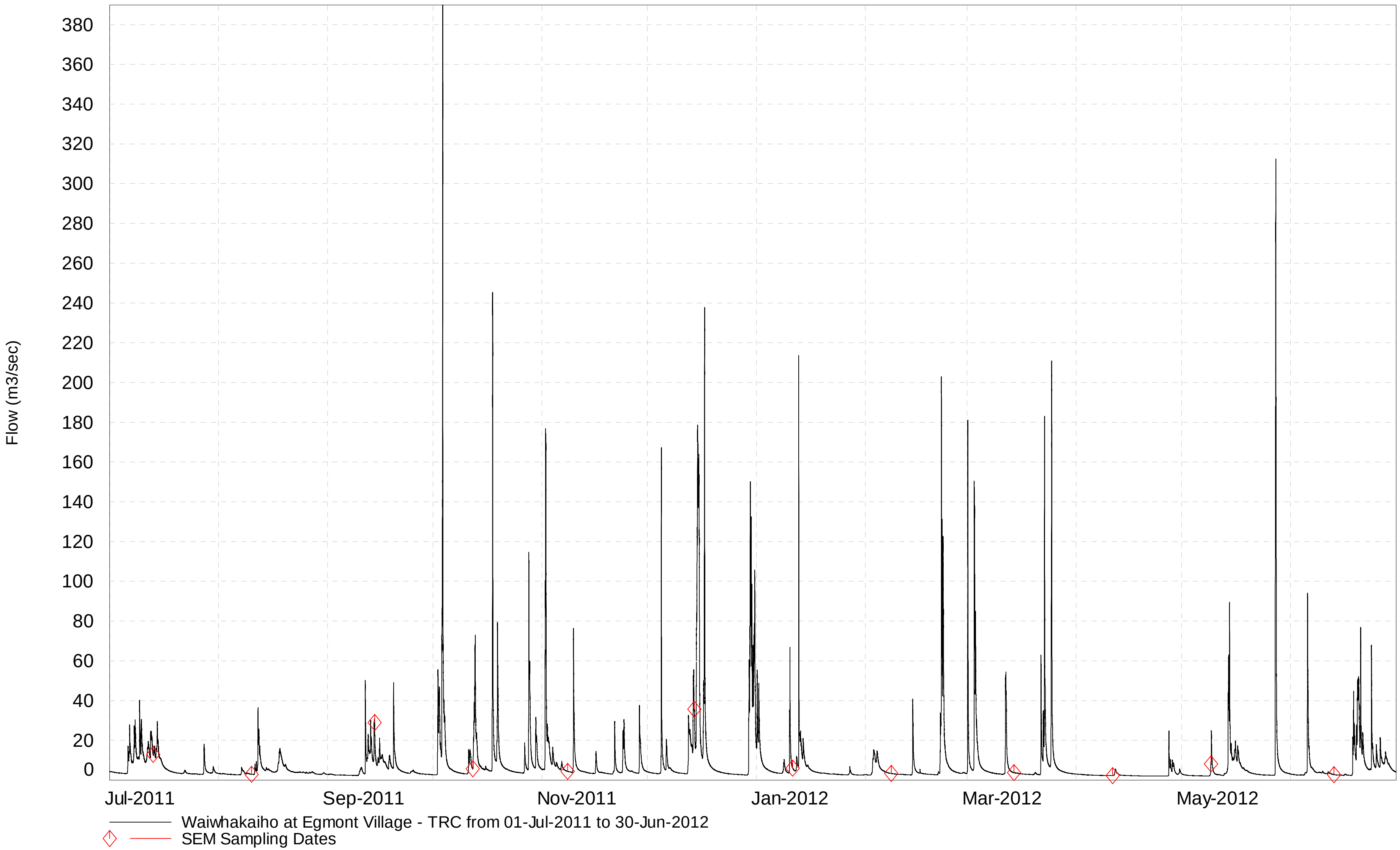

Figure 4 Flow record for the Waiwhakaiho River at SH3 Egmont Village

Discussion

2011-2012 period

Black disc clarity and turbidity results indicated a 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 2.30 m and 0.8 NTU respectively. The maximum black disc value (5.24 metres) was recorded in mid winter under relatively low flow conditions (2.77 m^3/sec) (Figure 4), with the worst conditions (black disc clarity of 0.35m) during a moderate fresh flow (29 m^3/sec) in September 2011 when the suspended solids concentration increased (23 g/m^3) and turbidity was 5.5 NTU. Generally, poorer water quality was recorded at the time of this fresh flow and in December 2011 (35.7 m^3/sec) (Figure 4) when elevated faecal coliform bacterial numbers (6,200 and 930 numbers/100 ml) and to a lesser extent colour, together with decreased clarity and conductivity, were recorded.

A maximum pH value of 8.1 was recorded under low flow conditions in late autumn during low 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 100%) and low BOD_5 levels (median of 0.6 g/m^3). Bacteriological quality was poor to moderate, with median faecal coliform and enterococci numbers (500 and 100 per 100 mls respectively) typically reflecting agricultural catchment influences and partly reflecting the increased frequency of freshes during, or immediately prior to, sampling surveys during 2011-2012.

River water temperatures recorded a moderate range of 8.8°C during the period with a maximum mid-morning water temperature of 14.8°C recorded in January 2012 during above median conditions.

Brief comparison with the previous 1995-2011 period

River water quality measured by the 2011-2012 survey in general was relatively similar to that recorded over the previous sixteen-year period. Median black disc clarity was poorer (by 0.76 m) with median turbidity greater by 0.1 NTU, but median suspended solids levels identical between periods. Bacteriological water quality was far worse in terms of median faecal coliform number (by 335 per 100 mls) and slightly worse for median enterococci number (by 18 per 100mls). A much narrower range of water temperatures (by 4.7˚C) was recorded in the most recent twelve-month period. Median water temperature was 0.2°C higher in the most recent period although the maximum temperature was 3.5°C lower than that recorded during the previous sixteen years.

Median sampled flow over the 2011-2012 period was much higher (by 1338 L/sec) than for the flows sampled in the previous sixteen-year period coincident with a increase in fresh events and particularly elevated flows between spring and mid-summer sampled during the latest period.

Median nutrient concentration for ammonia-N showed an increase over the most recent sampling period but all other median species' concentrations were relatively similar for both periods.

No significant differences were found in terms of the medians of BOD_5 and percentage dissolved oxygen between the two periods although the former rose by about 0.2 g/m^3 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)
13 Jul 2011	1010	0.008	0.002	0.000	16	0.61	<0.5	6.8	11.4	99	0.009	9	1
10 Aug 2011	1005	0.004	0.001	0.000	38	3.08	<0.5	9.8	11.6	98	0.017	24	1
14 Sep 2011	0955	0.018	0.004	0.000	14	0.27	<0.5	6.6	11.7	101	0.010	330	8
12 Oct 2011	0850	0.017	0.004	0.000	28	0.22	<0.5	7.6	10.6	98	0.019	31	33
08 Nov 2011	0845	0.006	0.001	0.000	34	1.03	<0.5	8.7	10.8	100	0.020	23	1
14 Dec 2011	0905	0.061	0.014	0.000	8	0.23	0.7	2.8	10.2	101	0.007	68	40
11 Jan 2012	0925	0.029	0.006	0.000	24	2.25	<0.5	6.2	9.8	100	0.015	11	8
08 Feb 2012	0915	0.007	0.001	0.000	45	4.15	<0.5	11.0	10.1	99	0.020	1	11
14 Mar 2012	0900	0.008	0.002	0.000	40	2.88	<0.5	10.2	10.6	100	0.020	<1	6
11 Apr 2012	1010	0.005	0.001	0.000	51	5.80	<0.5	11.9	10.5	101	0.022	4	20
09 May 2012	1015	0.010	0.003	0.000	12	<0.01	1.2	4.4	10.7	100	0.004	84	43
13 Jun 2012	1005	0.007	0.002	0.000	37	3.61	<0.5	9.2	11.7	99	0.006	8	<1

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)
13 Jul 2011	1010	9	14.568	0.006	<0.001	0.039	7.5	33	8.3	0.01	<0.05	0.061	4.9
10 Aug 2011	1005	24	3.588	<0.003	<0.001	0.019	7.8	<2	7.4	0.03	<0.05	0.019	0.7
14 Sep 2011	0955	330	13.784	<0.003	<0.001	0.009	7.4	87	7.9	0.04	<0.05	0.053	19
12 Oct 2011	0850	31	8.704	0.004	0.001	0.029	7.8	52	11.1	0.02	<0.05	0.115	15
08 Nov 2011	0845	23	4.366	<0.003	<0.001	0.029	7.8	10	10.7	0.02	<0.05	0.030	2.5
14 Dec 2011	0905	68	32.272	<0.003	0.001	0.009	7.4	110	14.0	0.07	0.08	0.185	22
11 Jan 2012	0925	12	6.398	<0.003	<0.001	0.009	7.8	<2	14.6	0.03	<0.04	0.028	1.2
08 Feb 2012	0915	1	2.981	<0.003	<0.001	0.009	8.0	<2	13.5	0.04	<0.05	0.023	0.6
14 Mar 2012	0900	<1	3.207	<0.003	<0.001	0.029	7.9	3	12.5	0.02	<0.05	0.024	0.9
11 Apr 2012	1010	5	2.496	<0.003	<0.001	0.009	8.0	<2	12.5	0.04	<0.05	0.023	0.5
09 May 2012	1015	100	18.1	0.003	<0.001	0.009	7.7	2500	11.5	1.62	1.63	3.38	700
13 Jun 2012	1005	8	3.484	<0.003	<0.001	0.049	7.9	<2	7.1	0.02	0.07	0.020	0.7

The statistical summary of this data is presented in Table 13

Table 13 Statistical summary of data from July 2011 to July 2012 Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.004	0.061	0.008	12	0.016
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.014	0.002	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.000	0.000	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	8	51	31	12	14
BDISC	Black disc transparency	m	0.01	5.80	1.64	12	1.9
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.2	<0.5	12	0.2
CONDY	Conductivity @ 20˚C	mS/m	2.8	11.9	8.2	12	2.7
DO	Dissolved oxygen	g/m^3	9.8	11.7	10.6	12	0.7
PERSAT	Dissolved oxygen saturation %	%	98	101	100	12	1
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.022	0.016	12	0.006
ECOL	E.coli bacteria	nos/100 ml	1	330	17	12	92
ENT	Enterococci bacteria	nos/100 ml	1	43	8	12	16
FC	Faecal coliforms	nos/100 ml	1	330	18	12	93
FLOW	Flow	m^3/s	2.496	32.272	5.382	12	8.921
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	0.05	0.01	12	0.014
pH	pH		7.4	8.0	7.8	12	0.2
SS	Suspended solids	g/m^3	<2	2500	6	12	715
TEMP	Temperature	°C	7.1	14.6	11.3	12	2.7
TKN	Total kjeldahl nitrogen	g/m^3N	0.01	1.62	0.03	12	0.46
TN	Total nitrogen	g/m^3N	<0.05	1.63	<0.05	12	0.46
TP	Total phosphorus	g/m^3P	0.019	3.380	0.029	12	0.962
TURB	Turbidity	NTU	0.4	700	1.8	12	200.4

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

Table 14 Statistical summary of data from July 1995 to June 2012: Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.003	0.077	0.009	204	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.028	0.002	204	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.007	0.000	204	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	5	54	38	204	12
BDISC	Black disc transparency	m	<0.01	13.12	3.40	204	2.83
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.6	<0.5	204	0.1
CONDY	Conductivity @ 20˚C	mS/m	2.8	12.7	9.6	204	2.4
DO	Dissolved oxygen	g/m^3	9.4	12.2	10.7	204	0.6
PERSAT	Dissolved oxygen saturation %	%	87	104	99	204	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.210	0.018	204	0.015
ECOL	E.coli bacteria	nos/100 ml	<1	950	8	180	93
ENT	Enterococci bacteria	nos/100 ml	<1	460	5	204	50
FC	Faecal coliforms	nos/100 ml	<1	1000	8	204	92
FLOW	Flow	m^3/s	2.050	55.504	3.609	204	7.559
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.019	<0.003	204	0.003
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.004	<0.001	204	0
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.11	0.02	204	0.018
pH	pH		7.0	8.2	7.8	204	0.2
SS	Suspended solids	g/m^3	<2	2500	<2	204	337
TEMP	Temperature	°C	5.7	16.6	10.8	204	2.5
TKN	Total kjeldahl nitrogen	g/m^3N	0.00	1.78	0.04	204	0.18
TN	Total nitrogen	g/m^3N	<0.05	1.82	0.06	204	0.18
TP	Total phosphorus	g/m^3P	0.008	3.380	0.024	204	0.329
TURB	Turbidity	NTU	0.2	700	0.8	203	72.6

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

2011-2012

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 in late May - early June 2011. Flood conditions in July and September, 2011 were reflected in black disc values of 0.61 m and 0.27 m respectively and turbidity values of 4.9 NTU and 15 NTU respectively with an elevation in suspended solids concentrations (33 g/m^3 and 87 g/m^3). Significant rainfall in mid December 2011 caused elevated turbidity (22 NTU), suspended solids (110 g/m^3), and total phosphorus (0.185 g/m3) and low black disc visibility (0.23 m). A further moderate fresh in May 2012 resulted in very elevated turbidity (700 NTU), suspended solids (2500 g/m^3), and total phosphorus (3.38 g/m^3) and a very marked deterioration in black disc clarity (<0.01 m). Three of these freshes resulted in moderate increases in bacterial levels (68 to 300 nos/100 mls) but not to the extent found in other ringplain streams following such freshes. The maximum black disc clarity of 5.80 m was measured in late autumn under low flow conditions coincident with the lowest suspended solids and turbidity (0. 5 NTU) levels.

Maximum mid-morning pH (8.0) and the median pH (7.8) were relatively similar to past years' results. Dissolved oxygen concentrations were consistently high with a minimum saturation of 98% and BOD_5 levels were below the detectable limit on all occasions except on two of the flood flow events; further indications of high water quality when not influenced by severe erosion events.

Bacteriological water quality was generally very high with median faecal coliform and enterococci numbers (18 and 8 per 100 mls respectively) indicative of minimal impact of upstream developed farmland at this site near mid-catchment.

River water temperatures varied over a moderate range of 7.5°C during the period, with a maximum mid-morning temperature of 14.6°C recorded in January 2012 under moderate flow conditions.

Nutrient levels were generally very low in terms of median ammoniacal nitrogen, nitrate-N, and dissolved reactive phosphorus concentrations (all less than 0.02 g/m^3). Total nitrogen and total phosphorus concentrations were relatively low throughout the year, with the exception of elevations in TP and TN during the December 2011 and May 2012 flood events coincident with much higher sediment loads.

Brief comparison with the previous 1995-2011 period

Water quality measured during the 2011-2012 survey period, in comparison with the previous sixteen years' survey results, was poorer aesthetically in terms of median black disc clarity (which was significantly lower by 1.92 m), median turbidity (higher by 1.1 NTU), and median suspended solids level (which was higher by 4 g/m^3).

Median bacteriological water quality was relatively similar for the two periods, with both periods illustrating very high quality, although the 2011-2012 median faecal coliform count was 10 per 100 mls higher than the historical median.

Water temperature range was narrower (by 3.4°C) due mainly to a lower maximum temperature during 2011-2012, but the median was slightly higher (0.6°C warmer) in the 2011-2012 period to that in the earlier sixteen-year period. All median nutrient species were relatively similar to the previous longer period medians.

Median sampled flow during the 2011-2012 period was higher (by 1.78 m^3/sec) than the median of flows sampled over the previous sixteen-year period, with several freshes and flood events (in excess of 5 m^3/sec) and fewer relatively low flow events sampled in 2011-2012. This was reflected in the lower median conductivity (by 1.5 mS/m @ 20˚C) over the 2011-2012 period.

Punehu Stream at Wiremu Road (site: PNH000200)

Analytical data are presented in Table 15 from the monthly samples. Indicative stream flow patterns may be obtained from the flow record at the Pihama (near SH45) site (Figure 5).

Table 15 Analytical results from the monthly samples: Punehu Stream at Wiremu 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)
13 Jul 2011	1045	0.041	0.009	0.000	11	1.27	<0.5	8.1	10.9	97	0.009	63	8
10 Aug 2011	1040	0.030	0.007	0.000	21	1.42	<0.5	8.8	11.7	100	0.020	4	<1
14 Sep 2011	1030	0.046	0.010	0.000	9	1.46	<0.5	6.4	11.4	101	0.012	27	1
12 Oct 2011	0925	0.033	0.007	0.000	21	1.34	<0.5	8.1	10.4	99	0.020	120	33
08 Nov 2011	0920	0.031	0.006	0.000	24	1.07	<0.5	8.5	10.3	101	0.023	440	230
14 Dec 2011	0945	0.034	0.007	0.001	26	2.15	0.6	8.7	9.7	102	0.030	740	220
11 Jan 2012	1005	0.049	0.009	0.000	18	1.50	0.5	7.9	9.3	99	0.019	200	11
08 Feb 2012	0950	0.032	0.006	0.000	26	2.24	<0.5	8.8	9.8	100	0.028	82	27
14 Mar 2012	0930	0.031	0.006	0.000	26	2.12	<0.5	8.9	10.7	103	0.025	720	36
11 Apr 2012	1050	0.023	0.005	0.000	25	2.71	<0.5	8.9	10.5	103	0.030	630	27
09 May 2012	1050	0.024	0.006	0.000	25	2.70	0.5	9.0	10.9	104	0.031	160	32
13 Jun 2012	1045	0.033	0.008	0.001	22	2.11	<0.5	9.1	11.8	100	0.010	21	<1
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)**
13 Jul 2011	1045	63	1.661	0.029	0.001	0.129	7.2	3	8.9	0.14	0.27	0.025	1.8
10 Aug 2011	1040	4	0.488	0.009	0.001	0.069	7.7	<2	7.1	0.09	0.16	0.024	2.5
14 Sep 2011	1030	27	1.117	0.005	0.001	0.009	7.2	4	8.4	0.05	0.06	0.023	1.8
12 Oct 2011	0925	120	0.535	0.009	0.002	0.038	7.5	2	11.7	0.07	0.11	0.033	2.4
08 Nov 2011	0920	450	0.424	0.006	<0.001	0.009	7.7	<2	12.8	0.07	0.08	0.030	2.4
14 Dec 2011	0945	740	0.348	0.005	<0.001	0.009	7.7	<2	16.1	0.07	0.08	0.043	1.7
11 Jan 2012	1005	200	0.702	0.005	0.002	0.048	7.7	<2	16.1	0.10	0.15	0.027	1.7
08 Feb 2012	0950	82	0.288	<0.003	<0.001	0.009	7.8	<2	15.1	0.04	<0.05	0.034	1.7
14 Mar 2012	0930	720	0.307	0.008	<0.001	0.009	7.8	<2	12.9	0.04	<0.05	0.032	1.6
11 Apr 2012	1050	640	0.269	<0.003	0.001	0.009	7.8	<2	13.1	0.04	<0.05	0.039	1.4
09 May 2012	1050	160	0.282	0.005	0.001	0.019	7.8	2	11.6	0.13	0.15	0.055	1.8
13 Jun 2012	1045	21	0.484	0.006	0.002	0.068	7.7	<2	6.7	0.10	0.17	0.026	2.5

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

Table 16 Statistical summary of data from July 2011 to June 2012 Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.023	0.049	0.032	12	0.008
A440F	Absorbance @ 440nm filtered	/cm	0.005	0.010	0.007	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	9	26	23	12	6
BDISC	Black disc transparency	m	1.07	2.71	1.80	12	0.56
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	0.6	<0.5	12	0
CONDY	Conductivity @ 20˚C	mS/m	6.4	9.1	8.8	12	0.7
DO	Dissolved oxygen	g/m³	9.3	11.8	10.6	12	0.8
PERSAT	Dissolved oxygen saturation %	%	97	104	100	12	2
DRP	Dissolved reactive phosphorus	g/m³P	0.009	0.031	0.022	12	0.008
ECOL	E.coli bacteria	nos/100 ml	4	740	140	12	285
ENT	Enterococci bacteria	nos/100 ml	<1	230	27	12	82
FC	Faecal coliforms	nos/100 ml	4	740	140	12	286
FLOW	Flow	m³/s	0.269	1.661	0.454	12	0.417
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.029	0.006	12	0.007
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.002	0.001	12	0
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.13	0.01	12	0.038
pH	pH		7.2	7.8	7.7	12	0.2
SS	Suspended solids	g/m³	<2	4	<2	12	1
TEMP	Temperature	°C	6.7	16.1	12.2	12	3.3
TKN	Total kjeldahl nitrogen	g/m³N	0.04	0.14	0.07	12	0.03
TN	Total nitrogen	g/m³N	<0.05	0.27	0.10	12	0.07
TP	Total phosphorus	g/m³P	0.023	0.055	0.031	12	0.009
TURB	Turbidity	NTU	1.4	2.5	1.8	12	0.4

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

Table 17 Statistical summary of data from July 1995 to July 2011: Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.017	0.144	0.033	204	0.024
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.032	0.007	204	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.005	0.000	204	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	6	27	22	204	5
BDISC	Black disc transparency	m	0.08	4.53	1.84	204	0.9
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	3.0	<0.5	204	0.3
CONDY	Conductivity @ 20˚C	mS/m	4.0	10.9	8.6	204	1.2
DO	Dissolved oxygen	g/m³	8.9	12.5	10.4	203	0.8
PERSAT	Dissolved oxygen saturation %	%	87	106	99	203	3
DRP	Dissolved reactive phosphorus	g/m³P	0.007	0.389	0.022	204	0.027
ECOL	E.coli bacteria	nos/100 ml	3	6100	120	180	889
ENT	Enterococci bacteria	nos/100 ml	<1	1200	36	204	163
FC	Faecal coliforms	nos/100 ml	3	6100	130	204	898
FLOW	Flow	m³/s	0.180	12.380	0.431	204	1.178
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.078	0.006	204	0.009
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.014	0.001	204	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.18	0.03	204	0.04
pH	pH		6.9	8.3	7.7	204	0.2
SS	Suspended solids	g/m³	<2	160	2	204	13
TEMP	Temperature	°C	5.0	19.2	12.0	204	3.3
TKN	Total kjeldahl nitrogen	g/m³N	0.01	0.85	0.10	204	0.13
TN	Total nitrogen	g/m³N	<0.05	0.87	0.14	204	0.14
TP	Total phosphorus	g/m³P	0.016	0.413	0.033	204	0.042
TURB	Turbidity	NTU	0.5	29	1.7	203	3.38

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

2011-2012

Although black disc clarity and turbidity results were indicative of relatively good water quality in terms of aesthetic appearance, these values continued to be lower than might be anticipated for the upper reaches of a ring plain stream, i.e. medians of 1.80 m (black disc) and 1.8 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 (1.07 m) occurred during moderate flow conditions in November 2011 following several freshes in the preceding month (Figure 5) but coincided with no measurable increase in suspended solids concentration (<2 g/m^3) and only a small increase in turbidity (2.4 NTU). A small increase in total phosphorus concentration occurred at this time, but some increase in faecal coliform bacteria number was recorded. Higher faecal coliform numbers (640-720 per 100 mls) were recorded later in the period under lower flow conditions. A maximum black disc value of 2.71 m was measured under relatively low flow conditions in April, 2012.

A maximum pH (7.8) was recorded (in mid morning) on four consecutive occasions during the period throughout summer to autumn, under low flow conditions.

Dissolved oxygen concentrations were consistently high (above 96% saturation for all 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.

A relatively poor median faecal coliform bacterial count for the upper reaches of a ring plain stream (140 per 100 mls) indicated some impacts of upstream farmland run-off (and possible stock access) on stream water quality at this site, and represented deterioration below the National Park boundary in this aspect of water quality. Surface runoff from surrounding farmland has been a common feature in this reach of the stream, with several moderate freshes sampled during the 2011-2012 period compared with previous periods.

Water temperatures varied over a relatively wide range (9.4°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 16.1°C was recorded on two consecutive occasions in mid summer, relatively high for the upper reaches of a ring plain stream at this time of the day (0945 and 1005 hrs).

Brief comparison with the previous 1995-2011 period

Stream water quality measured during the 2011-2012 period, was similar in terms of median turbidity and median black disc clarity (which decreased by 0.04 m) to the overall record. Median suspended solids concentration remained low and was very similar in the recent year in comparison with the previous sixteen-year period. Median dissolved oxygen percentage saturation levels were very similar (within 1%) for both periods.

Bacteriological water quality deteriorated slightly in terms of median faecal coliform number (by 10 per 100 ml) while median numbers of enterococci improved, reflecting the several freshes sampled in 2011-2012. Most median nutrient species' concentrations were similar between periods, but certain nitrogen species' medians tended to be slightly lower in the recent year.

The water temperature range was narrower (by 4.8°C) compared with surveys prior to the latest twelve-month period; with the median flow sampled being slightly higher (by 23 L/sec) in the 2011-2012 period. The narrower temperature range was caused mainly by a lower maximum temperature in 2011-2012 than the previous maximum recorded.

Median pH value was identical during the latest sampling period but the maximum pH was 0.5 unit lower than the maximum recorded in the previous sixteen-year period.

Punehu Stream at SH45 (site: PNH000900)

Analytical data are presented in Table 18 from the monthly samples. The flow record for the stream for the twelve month period is presented in Figure 5 while the flow data in Table 18 presents actual flows at the site at the time of sampling.

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)
13 Jul 2011	1110	0.036	0.007	0.000	22	0.47	2.0	16.4	10.9	98	0.029	620	670
10 Aug 2011	1110	0.032	0.007	0.000	33	1.29	1.0	18.0	11.5	98	0.042	230	38
14 Sep 2011	1050	0.024	0.007	0.000	26	0.55	1.7	12.5	10.8	98	0.044	1000	220
12 Oct 2011	0955	0.040	0.008	0.000	31	0.97	2.4	15.8	9.9	97	0.072	1800	1200
08 Nov 2011	0945	0.036	0.008	0.000	38	1.02	1.4	17.3	10.3	100	0.071	400	160
14 Dec 2011	1015	0.045	0.009	0.001	46	1.42	1.1	16.6	9.3	100	0.080	900	1400
11 Jan 2012	1030	0.040	0.007	0.000	32	1.62	1.1	15.9	9.2	99	0.059	510	330
08 Feb 2012	1020	0.039	0.007	0.000	41	2.42	1.0	16.6	9.6	99	0.073	310	600
14 Mar 2012	0955	0.042	0.008	0.000	40	2.03	0.7	15.5	10.2	98	0.079	520	800
11 Apr 2012	1120	0.027	0.005	0.000	41	2.74	0.7	16.0	10.1	103	0.086	440	610
09 May 2012	1120	0.043	0.010	0.000	40	1.77	0.9	15.6	10.5	100	0.090	790	820
13 Jun 2012	1110	0.033	0.007	0.001	32	1.76	0.5	16.3	11.9	99	0.020	100	57

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)
13 Jul 2011	1110	620	4.917	0.128	0.018	2.842	7.4	16	10.3	1.04	3.90	0.136	5.2
10 Aug 2011	1110	230	1.143	0.067	0.023	1.867	7.6	2	8.4	0.31	2.20	0.059	2.5
14 Sep 2011	1050	1000	2.076	0.040	0.015	0.585	7.6	11	10.2	0.06	0.66	0.086	4.6
12 Oct 2011	0955	1800	1.143	0.112	0.052	1.438	7.6	5	14.6	0.47	1.96	0.144	2.4
08 Nov 2011	0945	400	1.116	0.036	0.025	1.355	7.8	3	13.9	0.32	1.70	0.096	2.2
14 Dec 2011	1015	900	0.524	0.019	0.007	1.063	7.8	<2	19.0	0.33	1.40	0.112	1.7
11 Jan 2012	1030	510	1.588	0.034	0.018	1.162	7.6	2	17.7	0.36	1.54	0.091	1.7
08 Feb 2012	1020	330	0.535	0.015	0.005	0.745	7.8	<2	16.4	0.23	0.98	0.096	1.7
14 Mar 2012	0955	530	0.496	0.018	0.005	0.625	7.7	<2	14.4	0.17	0.80	0.109	1.6
11 Apr 2012	1120	440	0.439	0.017	0.008	0.672	7.7	<2	16.1	0.10	0.78	0.118	1.6
09 May 2012	1120	800	0.444	0.032	0.009	0.601	7.7	2	12.9	0.14	0.75	0.119	1.8
13 Jun 2012	1110	100	0.924	0.016	0.006	1.024	7.8	<2	7.3	0.21	1.24	0.044	1.8

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

Table 19 Statistical summary of data from July 2011 to June 2012 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.024	0.045	0.038	12	0.006
A440F	Absorbance @ 440nm Filtered	/cm	0.005	0.010	0.007	12	0.001
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	22	46	36	12	7
BDISC	Black disc transparency	m	0.47	2.74	1.52	12	0.7
BOD_5	Biochemical oxygen demand 5day	g/m^3	0.5	2.4	1.0	12	0.6
CONDY	Conductivity @ 20'C	mS/m	12.5	18.0	16.2	12	1.3
DO	Dissolved Oxygen	g/m^3	9.2	11.9	10.2	12	0.8
PERSAT	Dissolved Oxygen Saturation %	%	97	103	99	12	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.020	0.090	0.072	12	0.023
ECOL	E.coli bacteria	nos/100 ml	100	1800	515	12	454
ENT	Enterococci bacteria	nos/100 ml	38	1400	605	12	438
FC	Faecal Coliforms	nos/100 ml	100	1800	520	12	452
FLOW	Flow	m^3/s	0.439	4.917	1.020	12	1.254
NH_4	Ammoniacal nitrogen	g/m^3N	0.015	0.128	0.033	12	0.038
NO_2	Nitrite nitrogen	g/m^3N	0.005	0.052	0.012	12	0.013
NO_3	Nitrate nitrogen	g/m^3N	0.59	2.84	1.04	12	0.661
PH	pH		7.4	7.8	7.7	12	0.1
SS	Suspended solids	g/m^3	<2	16	2	12	5
TEMP	Temperature	°C	7.3	19.0	14.2	12	3.7
TKN	Total Kjeldahl nitrogen	g/m^3N	0.06	1.04	0.27	12	0.26
TN	Total nitrogen	g/m^3N	0.66	3.90	1.32	12	0.91
TP	Total phosphorus	g/m^3P	0.044	0.144	0.102	12	0.029
TURB	Turbidity	NTU	1.6	5.2	1.8	12	1.2

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

Table 20 Statistical summary of data from July 1995 to June 2012 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.015	0.115	0.040	204	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.027	0.008	204	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.006	0.000	204	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	10	46	34	204	7
BDISC	Black disc transparency	m	0.06	3.57	1.51	204	0.68
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	8.1	1.0	204	0.9
CONDY	Conductivity @ 20'C	mS/m	5.8	21.8	16.1	204	2.3
DO	Dissolved Oxygen	g/m^3	8.6	12.8	10.4	204	0.8
PERSAT	Dissolved Oxygen Saturation %	%	90	114	99	204	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.013	0.212	0.042	204	0.028
ECOL	E.coli bacteria	nos/100 ml	48	20000	475	178	2343
ENT	Enterococci bacteria	nos/100 ml	15	9300	300	203	1033
FC	Faecal Coliforms	nos/100 ml	51	20000	510	204	2688
FLOW	Flow	m^3/s	0.242	12.300	0.775	204	1.581
NH_4	Ammoniacal nitrogen	g/m^3N	0.004	0.376	0.040	204	0.064
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.110	0.014	204	0.015
NO_3	Nitrate nitrogen	g/m^3N	0.07	3.13	0.91	204	0.634
PH	pH		7.1	8.6	7.7	204	0.2
SS	Suspended solids	g/m^3	<2	220	3	204	22
TEMP	Temperature	°C	5.0	21.0	13.5	204	3.6
TKN	Total Kjeldahl nitrogen	g/m^3N	0.04	1.99	0.32	204	0.27
TN	Total nitrogen	g/m^3N	0.29	3.96	1.35	204	0.74
TP	Total phosphorus	g/m^3P	0.026	0.531	0.078	204	0.063
TURB	Turbidity	NTU	0.8	50	1.8	203	5.1

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.

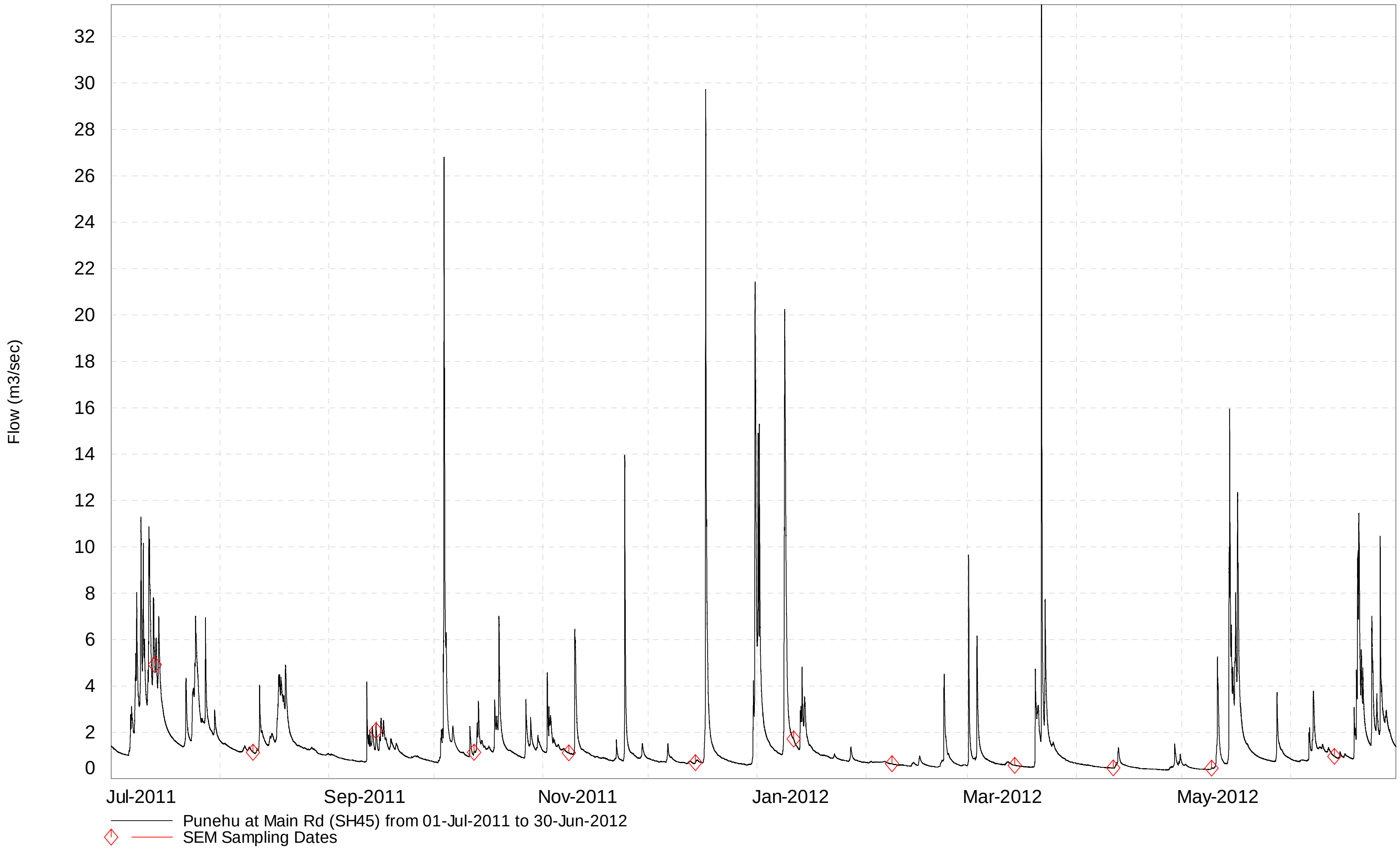

Figure 5 Flow record for the Punehu Stream at SH45

Discussion

2011-2012 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.52 m, this clarity being typical of the lower reaches of developed ringplain catchments. A median suspended solids concentration of 2 g/m^3 and turbidity of 1.8 NTU were also typical of the lower reaches of a ring plain catchment. Minimum clarity (black disc clarities of 0.47 and 0.55 m, turbidities of 5.2 and 4.6 NTU, and suspended solids concentrations of 16 and 11 g/m^3) were recorded during freshes in July and September 2011. Some deterioration in other water quality parameters under these conditions was shown by elevations in bacterial numbers and small increases in BOD_5.

pH peaked at 7.8 (in late spring – mid summer) but this was recorded in late morning and would be expected to have reached higher levels later in the day. This was 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 occasionally indicated low levels of organic enrichment (ie $\geq$1 g/m^3), particularly under lower flow conditions in the spring-summer period.

The high median bacteriological numbers (605 enterococci and 520 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 faecal coliform numbers found during summer-autumn lower flow conditions (330 to 900 per 100 ml) were indicative of point source discharges of pond system treated dairy sheds' wastes and/or stock access (TRC, 2011). Relatively high median nutrient levels were consistent with such impacts.

Water temperature varied over a moderate range of 11.7˚C with a maximum summer (late morning) temperature of 19.0°C recorded in December 2011 and the lowest temperature (7.3°C) recorded in June 2012; the former 2.2°C below the previous annual maximum temperature and the latter 2.3˚C above the previous annual minimal temperature.

Brief comparison of upper and lower sites during the 2011-2012 period

Deterioration in certain aspects of water quality in the lower stream reaches was emphasised by a very significant increase in median bacteriological numbers (380 faecal coliforms per 100 mls and 578 enterococci per 100 mls), and median nutrient concentrations (particularly nitrogen species) with total nitrogen and total phosphorus increasing by factors of about 13 and 3 times respectively. Similar median turbidity levels and suspended solids concentrations were found, but a decrease in median black disc clarity (16% reduction) occurred between sites. 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 125% in the lower reaches of the stream). The downstream water temperature range increased by 2.3°C while the median increased by only 2.2°C. The median pH did not change 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 1995-2011 period

Minimal change in aesthetic water quality was indicated by very similar median turbidity and median black disc clarity (0.01 m improvement) recorded during the more recent twelve-month survey period, and there was a small decrease in median suspended solids concentration (of 1 g/m^3).

In the more recent survey period a small deterioration was recorded in median faecal coliform bacterial number (by 20 per 100 mls) and a more significant deterioration in median enterococci bacteria number (by 215 per 100 mls). Small improvements in median nutrient species concentrations were recorded for ammoniacal nitrogen and total nitrogen which decreased by about 25% and 2 % of the long term medians respectively, with increases of 14% in nitrate N, 71% in dissolved reactive phosphorus, and 34% for total phosphorus.

Median dissolved oxygen saturation levels were identical and median BOD_5 levels were very similar (within 0.1 g/m^3) in the two periods.

There was no difference in median pH for the 2011-2012 period although the maximum pH was 0.8 unit lower in comparison with the previous sixteen-year period.

Water temperature range was much narrower (by 4.3°C); this decrease due to higher minimum and lower maximum water temperatures (both by about 2˚C) over the recent survey period, with the 2011-2012 median water temperature 0.8˚C higher than the median sixteen year temperature.

Median sampled flow over the 2011-2012 period was 247 L/sec higher than the median sampled flow for the previous sixteen-year period.

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 6.

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

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	(NZST)	(/cm)	(/cm)	(/cm)	(g/m^3 $CaCO_3$)	(m)	(g/m^3)	(mS/m)	(g/m^3)	(%)	(g/m^3P)	(Nos/ 100ml)	(Nos/ 100ml)
13 Jul 2011	1240	0.017	0.004	0.000	22	0.93	0.8	9.9	10.8	98	0.015	100	37
10 Aug 2011	1235	0.011	0.004	0.000	30	1.44	<0.5	11.7	11.5	102	0.010	16	23
14 Sep 2011	1200	0.029	0.007	0.000	19	0.72	1.0	8.1	11.4	103	0.012	1200	1400
12 Oct 2011	1115	0.027	0.006	0.000	24	0.82	1.2	9.9	10.2	99	0.022	2700	1200
08 Nov 2011	1105	0.009	0.002	0.000	30	1.43	0.7	11.5	10.4	102	0.028	140	20
14 Dec 2011	1125	0.030	0.007	0.000	21	0.73	2.1	6.6	9.7	100	0.014	2100	1400
11 Jan 2012	1145	0.023	0.004	0.000	23	1.20	0.9	9.5	9.5	101	0.023	110	31
08 Feb 2012	1135	0.017	0.004	0.000	36	1.99	0.8	12.6	10.1	105	0.019	84	35
14 Mar 2012	1115	0.020	0.004	0.000	30	2.25	0.6	11.2	10.6	103	0.024	100	44
11 Apr 2012	1250	0.017	0.004	0.000	34	1.93	<0.5	12.2	10.6	106	0.019	120	56
09 May 2012	1240	0.021	0.006	0.000	34	0.81	1.9	11.5	11	106	0.018	240	98
13 Jun 2012	1210	0.012	0.003	0.000	29	1.81	0.7	11.5	11.6	99	0.004	54	6

Date	Time	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
	(NZST)	(Nos/ 100ml)	(m^3/s)	(g/m^3N)	(g/m^3N)	(g/m^3N)		(g/m^3)	(°C)	(g/m^3N)	(g/m^3N)	(g/m^3P)	(NTU)
13 Jul 2011	1240	100	7.243	0.037	0.008	1.552	7.5	9	10.0	0.33	1.89	0.059	2.6
10 Aug 2011	1235	16	1.589	0.009	0.004	1.736	7.8	2	9.2	0.07	1.81	0.018	1.6
14 Sep 2011	1200	1200	3.531	0.028	0.006	0.624	7.6	7	9.6	0.20	0.83	0.045	2.2
12 Oct 2011	1115	2800	4.231	0.070	0.011	1.389	7.6	7	12.9	0.38	1.78	0.073	2.6
08 Nov 2011	1105	140	2.455	0.022	0.008	1.652	7.7	3	13.1	0.12	1.78	0.040	1.5
14 Dec 2011	1125	2200	5.558	0.011	0.003	0.267	7.6	13	16.0	0.28	0.55	0.088	3.0
11 Jan 2012	1145	110	4.194	0.035	0.010	1.350	7.7	3	16.3	0.24	1.60	0.047	1.5
08 Feb 2012	1135	84	0.975	0.003	0.004	1.246	7.9	2	16.3	0.13	1.38	0.030	1.2
14 Mar 2012	1115	110	1.589	0.020	0.007	1.333	7.8	2	13.9	0.10	1.44	0.039	1.2
11 Apr 2012	1250	120	1.206	0.007	0.008	1.382	8.0	<2	13.9	0.14	1.53	0.036	1.2
09 May 2012	1240	250	1.524	0.017	0.008	0.972	8.0	15	12.1	0.34	1.32	0.109	2.8
13 Jun 2012	1210	54	2.283	0.007	0.006	1.154	7.7	5	7.7	1.13	2.29	0.039	1.9

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

Table 22 Statistical summary of data from July 2011 to June 2012: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.009	0.030	0.018	12	0.007
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.007	0.004	12	0.002
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.000	0.000	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	19	36	30	12	6
BDISC	Black disc transparency	m	0.72	2.25	1.32	12	0.55
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	2.1	0.8	12	0.5
CONDY	Conductivity @ 20'C	mS/m	6.6	12.6	11.4	12	1.8
DO	Dissolved Oxygen	g/m³	9.5	11.6	10.6	12	0.7
PERSAT	Dissolved Oxygen Saturation %	%	98	106	102	12	3
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.028	0.018	12	0.007
ECOL	E.coli bacteria	nos/100 ml	16	2700	115	12	916
ENT	Enterococci bacteria	nos/100 ml	6	1400	40	12	588
FC	Faecal Coliforms	nos/100 ml	16	2800	115	12	952
FLOW	Flow	m³/s	0.975	7.243	2.369	12	1.955
NH_4	Ammoniacal nitrogen	g/m³N	0.003	0.070	0.018	12	0.019
NO_2	Nitrite nitrogen	g/m³N	0.003	0.011	0.008	12	0.002
NO_3	Nitrate nitrogen	g/m³N	0.27	1.74	1.34	12	0.424
PH	pH		7.5	8.0	7.7	12	0.2
SS	Suspended solids	g/m³	<2	15	4	12	5
TEMP	Temperature	°C	7.7	16.3	13.0	12	2.9
TKN	Total Kjeldahl nitrogen	g/m³N	0.07	1.13	0.22	12	0.28
TN	Total nitrogen	g/m³N	0.55	2.29	1.56	12	0.47
TP	Total phosphorus	g/m³P	0.018	0.109	0.042	12	0.026
TURB	Turbidity	NTU	1.2	3.0	1.8	12	0.7

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

Table 23 Statistical summary of data from July 1995 to June 2012: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.009	0.100	0.020	204	0.014
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.024	0.005	204	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.003	0.000	204	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	11	45	30	204	6
BDISC	Black disc transparency	m	0.10	4.39	1.71	204	0.83
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	7.3	0.7	204	0.9
CONDY	Conductivity @ 20'C	mS/m	4.6	13.4	11.2	204	1.6
DO	Dissolved Oxygen	g/m³	9.2	13.0	10.6	204	0.7
PERSAT	Dissolved Oxygen Saturation %	%	92	121	102	204	5
DRP	Dissolved reactive phosphorus	g/m³P	0.003	0.081	0.018	204	0.011
ECOL	E.coli bacteria	nos/100 ml	6	59000	160	180	4539
ENT	Enterococci bacteria	nos/100 ml	3	5700	100	204	847
FC	Faecal Coliforms	nos/100 ml	6	100000	180	204	8234
FLOW	Flow	m³/s	0.356	28.797	1.628	204	3.544
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.265	0.018	204	0.039
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.033	0.007	204	0.006
NO_3	Nitrate nitrogen	g/m³N	0.14	2.31	1.14	204	0.483
PH	pH		7.1	8.6	7.8	204	0.3
SS	Suspended solids	g/m³	<2	180	3	204	19
TEMP	Temperature	°C	5.6	20.8	12.4	204	3.2
TKN	Total Kjeldahl nitrogen	g/m³N	<0.01	2.15	0.20	204	0.28
TN	Total nitrogen	g/m³N	0.27	2.91	1.44	204	0.51
TP	Total phosphorus	g/m³P	0.013	0.829	0.036	204	0.079
TURB	Turbidity	NTU	0.70	36	1.5	203	4.19

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.

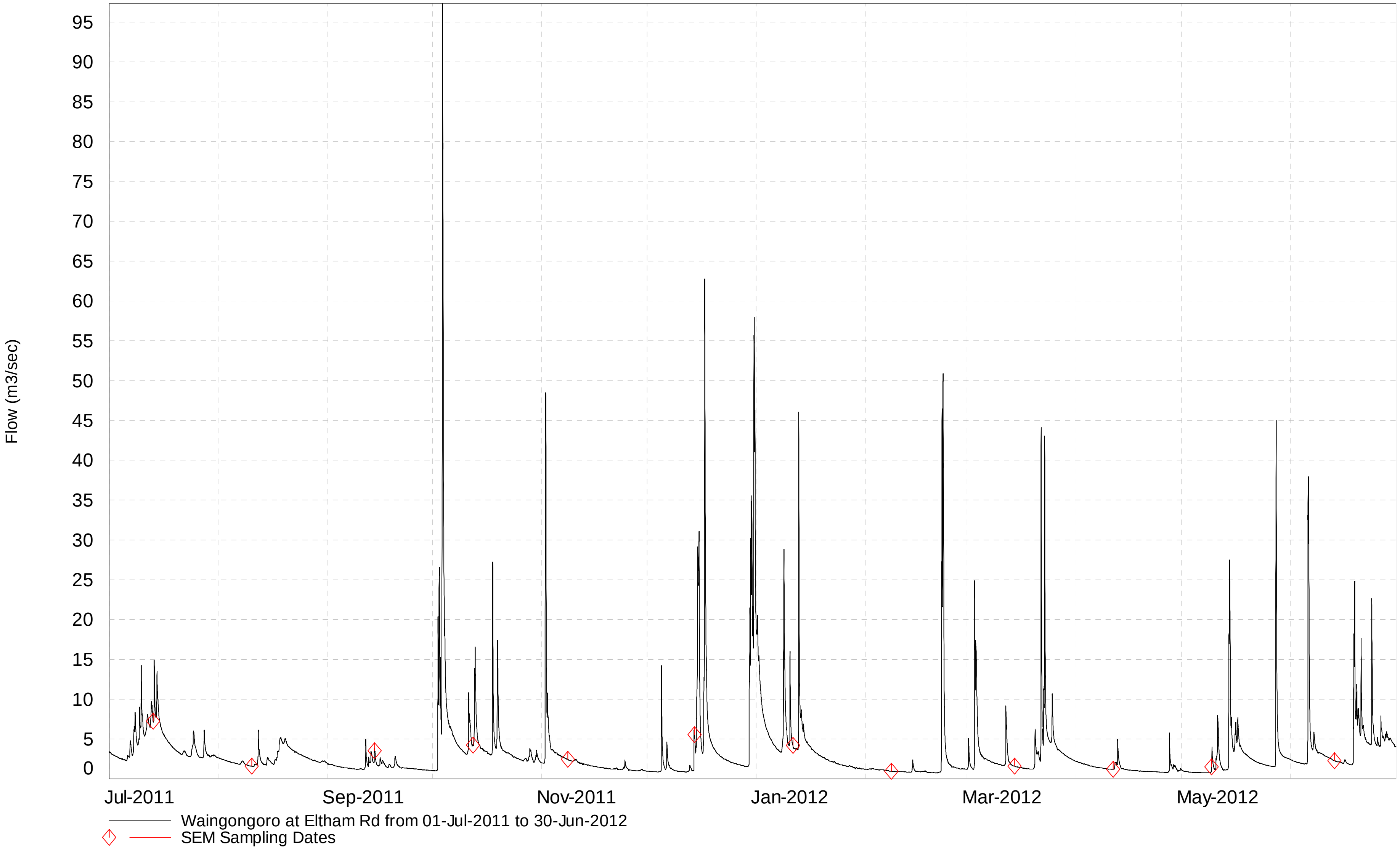

Figure 6 Flow record for the Waingongoro River at Eltham Road

Discussion

2011-2012

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.32 m and median turbidity of 1.8 NTU, in the mid-reaches of the longest ring-plain river in Taranaki. The relatively low maximum clarity (black disc value of 2.25 m), 2.14 m lower than the historical maximum, was recorded in early autumn during moderately low flow conditions (1.59 m^3/s), while worst black disc clarities (0.72 and 0.73 m) occurred during freshes in early spring and summer coincident with turbidities of 2.2 and 3.0 NTU and suspended solids concentrations of 7 and 13 g/m^3 sampled in September and December 2011 (Figure 6). Generally, poorer water quality conditions monitored during freshes (elevated bacterial numbers, some elevated nutrients, discolouration, and decreased clarity) were apparent on at least four occasions during the 2011-2012 period.

pH reached a maximum of 8.0 in autumn coincident with supersaturation (106%) of dissolved oxygen, although it would be expected that pH would have risen further later in the day, particularly in late summer, than at the time of sampling (near midday).

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 98% saturation recorded in mid winter) and low BOD_5 levels (median: 0.8 g/m^3). Bacteriological quality was better than that usually typical of the mid reaches of developed ring plain catchments, subject to agricultural impacts, with median faecal coliform and enterococci numbers of 115 and 40 (per 100 mls) respectively. Water temperature varied over a moderate range of 8.6°C with a maximum summer (late morning) river temperature of 16.3°C recorded in January 2012 under moderate flow conditions (Figure 6).

Brief comparison with previous 1995-2011 period

The latest twelve-month period sampled a narrower range of flow conditions, while median sampled flow was higher (by 746 L/sec) than the median of flows sampled in the previous sixteen-year period. Aesthetic river water quality was poorer in terms of median black disc clarity (which decreased by 0.41 m), median suspended solids level (which increased by 1 g/m^3), and median turbidity level (which increased by 0.4 NTU) during the 2011-2012 period, reflecting an increase in frequency of fresh flows sampled.

In general, an improvement in bacteriological water quality was recorded in the 2011-2012 period with much lower median faecal coliform number (by 70 per 100 mls) and median enterococci number (by 65 per 100 mls). Very minor differences between periods were indicated in most median nutrient species' concentrations over the 2011-2012 period with the exception of total nitrogen and nitrate which rose by about 16 to 24% respectively.

The range in water temperature was much narrower (by 6.6°C) over the 2011-2012 period mainly due to a much cooler (by 4.5˚C) maximum water temperature although the median water temperature was 0.6˚C higher in the 2011-2012 period.

Median pH values were very similar but the maximum pH previously recorded was 0.6 unit higher than that measured in the 2011-2012 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 7.

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

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)
13 Jul 2011	1200	0.030	0.007	0.000	29	0.30	2.6	14.3	10.8	98	0.030	900	190
10 Aug 2011	1150	0.023	0.008	0.000	40	1.02	1.7	18.4	11.5	105	0.038	77	20
14 Sep 2011	1130	0.030	0.007	0.000	37	0.74	2.1	16.6	10.9	101	0.034	740	140
12 Oct 2011	1030	0.036	0.008	0.001	30	0.72	1.8	13.1	10.1	98	0.036	870	600
08 Nov 2011	1030	0.022	0.005	0.000	38	1.01	1.1	15.8	10.1	101	0.042	250	33
14 Dec 2011	1045	0.042	0.009	0.001	47	1.22	1.8	18.5	9.5	102	0.085	270	85
11 Jan 2012	1110	0.042	0.008	0.000	32	1.04	1.7	12.7	9.4	99	0.046	1000	290
08 Feb 2012	1055	0.030	0.006	0.000	47	1.52	0.9	19.2	9.7	103	0.035	80	90
14 Mar 2012	1040	0.034	0.007	0.000	39	1.39	0.7	15.5	10.4	104	0.037	220	440
11 Apr 2012	1200	0.024	0.005	0.000	44	1.53	0.8	16.9	10.2	103	0.040	120	150
09 May 2012	1205	0.034	0.008	0.000	46	2.04	0.9	18.0	11.2	99	0.046	150	90
13 Jun 2012	1145	0.023	0.006	0.001	36	1.32	1.1	14.8	11.6	99	0.015	120	51

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)
13 Jul 2011	1200	900	25.301	0.060	0.025	2.155	7.5	34	10.6	0.80	2.98	0.154	8.8
10 Aug 2011	1150	77	6.828	0.040	0.039	2.981	7.8	7	10.9	0.29	3.31	0.055	3.1
14 Sep 2011	1130	740	6.776	0.050	0.038	2.062	7.8	14	11.3	0.44	2.54	0.072	3.7
12 Oct 2011	1030	910	11.445	0.066	0.023	1.767	7.6	10	13.9	0.39	2.18	0.092	3.1
08 Nov 2011	1030	250	7.476	0.036	0.019	2.051	7.8	6	15.1	0.33	2.40	0.069	2.4
14 Dec 2011	1045	290	3.049	0.043	0.038	1.702	7.9	9	19.0	0.90	2.64	0.123	2.5
11 Jan 2012	1110	1100	15.023	0.063	0.025	1.545	7.6	6	17.7	0.62	2.19	0.102	3.6
08 Feb 2012	1055	80	4.147	0.018	0.008	2.072	7.9	4	17.8	0.22	2.30	0.055	2.1
14 Mar 2012	1040	220	5.174	0.022	0.008	1.762	7.9	4	15.8	0.22	1.99	0.058	1.9
11 Apr 2012	1200	120	4.057	0.038	0.010	1.890	7.8	3	15.3	0.30	2.20	0.071	2.1
09 May 2012	1205	170	2.475	0.025	0.010	1.910	7.8	3	12.0	0.20	2.12	0.069	2.0
13 Jun 2012	1145	120	7.606	0.008	0.009	2.031	7.9	6	8.6	0.64	2.68	0.059	2.8

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

Table 25 Statistical summary of data from July 2011 to June 2012: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.022	0.042	0.030	12	0.007
A440F	Absorbance @ 440nm Filtered	/cm	0.005	0.009	0.007	12	0.001
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m3 CaCO3	29	47	38	12	6
BDISC	Black disc transparency	m	0.30	2.04	1.13	12	0.46
BOD_5	Biochemical oxygen demand 5day	g/m3	0.7	2.6	1.4	12	0.6
CONDY	Conductivity @ 20'C	mS/m	12.7	19.2	16.2	12	2.2
DO	Dissolved Oxygen	g/m3	9.4	11.6	10.3	12	0.8
PERSAT	Dissolved Oxygen Saturation %	%	98	105	101	12	2
DRP	Dissolved reactive phosphorus	g/m3P	0.015	0.085	0.038	12	0.016
ECOL	E.coli bacteria	nos/100 ml	77	1000	235	12	362
ENT	Enterococci bacteria	nos/100 ml	20	600	115	12	178
FC	Faecal Coliforms	nos/100 ml	77	1100	235	12	381
FLOW	Flow	m3/s	2.475	25.301	6.802	12	6.441
NH4	Ammoniacal nitrogen	g/m3N	0.008	0.066	0.039	12	0.019
NO2	Nitrite nitrogen	g/m3N	0.008	0.039	0.021	12	0.012
NO3	Nitrate nitrogen	g/m3N	1.55	2.98	1.97	12	0.36
PH	pH		7.5	7.9	7.8	12	0.1
SS	Suspended solids	g/m3	3	34	6	12	9
TEMP	Temperature	°C	8.6	19.0	14.5	12	3.3
TKN	Total Kjeldahl nitrogen	g/m3N	0.20	0.90	0.36	12	0.24
TN	Total nitrogen	g/m3N	1.99	3.31	2.35	12	0.39
TP	Total phosphorus	g/m3P	0.055	0.154	0.070	12	0.031
TURB	Turbidity	NTU	1.9	8.8	2.6	12	1.9

As this was the fourteenth year of state of the environment data collection by the Taranaki Regional Council for this site, only the fourteen years of Taranaki Regional Council data are provided in Table 26 for reference or comparative purposes at this stage.

Table 26 Statistical summary of data from July 1998 to June 2012: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.078	0.032	168	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.019	0.007	168	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	168	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	21	62	39	168	9
BDISC	Black disc transparency	m	0.12	4.34	1.18	168	0.6
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	6.7	1.0	168	0.9
CONDY	Conductivity @ 20˚C	mS/m	9.8	21.1	16.4	168	2.2
DO	Dissolved oxygen	g/m^3	8.4	12.9	10.5	168	0.8
PERSAT	Dissolved oxygen saturation %	%	89	141	101	168	7
DRP	Dissolved reactive phosphorus	g/m^3P	0.015	0.223	0.060	168	0.036
ECOL	E.coli bacteria	nos/100 ml	3	41000	220	167	3599
ENT	Enterococci bacteria	nos/100 ml	11	4200	150	168	514
FC	Faecal coliforms	nos/100 ml	3	41000	220	168	3590
FLOW	Flow	m^3/s	1.010	50.341	4.802	168	7.181
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.305	0.032	168	0.041
NO_2	Nitrite nitrogen	g/m^3N	0.003	0.132	0.022	168	0.019
NO_3	Nitrate nitrogen	g/m^3N	0.75	2.98	1.90	168	0.507
pH	pH		7.3	9.1	7.8	168	0.3
SS	Suspended solids	g/m^3	<2	120	5	168	17
TEMP	Temperature	°C	5.4	22.0	13.7	168	3.8
TKN	Total kjeldahl nitrogen	g/m^3N	0.02	1.51	0.41	168	0.25
TN	Total nitrogen	g/m^3N	1.03	3.59	2.44	168	0.55
TP	Total phosphorus	g/m^3P	0.042	0.325	0.101	168	0.052
TURB	Turbidity	NTU	1.3	36	2.4	167	4.4

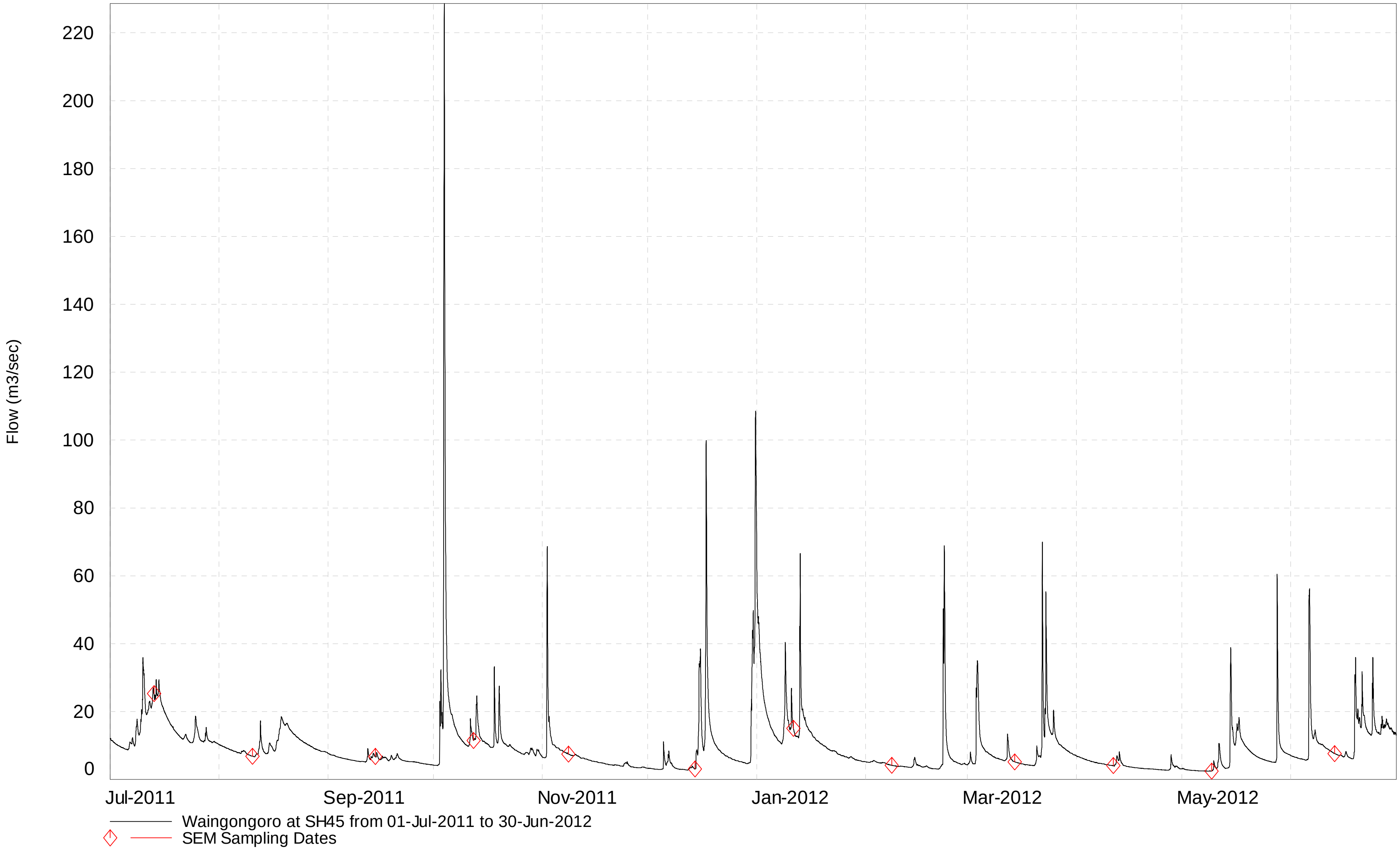

Figure 7 Flow record for the Waingongoro River at SH45

Discussion

2011-2012 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.13 m and median turbidity of 2.6 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 2.04 m) was recorded in early winter during low flow conditions (2.48 m^3/s). The lowest black disc clarity of 0.30 m and highest turbidity of 8.8 NTU were sampled during a moderate fresh in July 2011. Poorest water quality conditions were apparent at times of fresh flows (Figure 7) when elevated bacterial numbers, nutrients, and/or discolouration, and decreased clarity were typical (e.g. July 2011, September 2011, October 2011 and January 2012).

pH reached 7.9 in mid to late summer under relatively low flow conditions coincidental with highest dissolved oxygen saturation level (104%), although it would be expected that pH would have risen further during summer/autumn later in the day (i.e. after 1055 NZST), than at those particular sampling times.

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 98% saturation recorded in mid winter and spring 2011 under high flow conditions) and moderately low BOD_5 levels (median: 1.4 g/m^3). Bacteriological quality was typical for this site with numbers typical of those characteristic of the lower reaches of developed ring plain catchments, subject to agricultural impacts; with median faecal coliform and enterococci numbers of 235 and 115 (per 100 mls) respectively. These numbers reflected, to some degree, more frequent significant river freshes occurring immediately prior to or at the time of sampling surveys during the period. Median nutrient levels were relatively high and typical of the lower reaches of ring plain rivers receiving agricultural and municipal point-source discharges. Water temperatures varied over a moderate range of 10.4°C with a maximum summer (late morning) river temperature of 19.0°C recorded in December 2011.

Brief comparison of upper and lower sites during the 2011-2012 period

Downstream deterioration in aspects of water quality in the lower reaches of the river was emphasised by slightly more turbid conditions (lower median black disc clarity by 0.19 m (14% decrease), increased median turbidity level of 0.8 NTU, and a very small increase in median suspended solids concentration of 2 g/m^3). Bacteriological quality, in terms of the median faecal coliform count, deteriorated to a significant degree by 120 per 100 mls at the lower river site whereas the median enterococci count typically deteriorated by 75 per 100 mls (compared with an historical median deterioration of 45 per 100 ml). The lower river site's pH range was atypically narrower (by 0.1 unit) but the median pH level increased, but only by 0.1 unit at the lower site. Maximum pH recorded was 0.1 unit lower at the lower site, which was atypical of downstream trends in ringplain streams.

Median BOD_5 was higher by 0.6 g/m^3 at the SH45 site where nearly all median nutrient species' concentrations also showed significant increases (by up to nearly three times upstream concentrations).

Water temperature range was wider (by 1.8°C) at the lower site with median water temperature 1.5°C warmer at this site in the lower reach of the river in comparison with the mid reach site.

Brief comparison with the previous 1998-2011 period

The most recent twelve-month period sampled a much narrower (lower) range of flow conditions but the median sampled flow was far higher by 2,101 L/sec than that sampled over the previous thirteen-year period. This was due in part to the frequent freshes, particularly in spring-early summer 2011, and winter 2012 periods sampled in the 2011-2012 year.

Water clarity was slightly worse with the medians for suspended solids higher by 1 g/m^3, turbidity higher by 0.3 NTU, and black disc clarity lower by 0.05 m in the 2011-2012 period.

Median faecal coliform bacterial number showed a slight deterioration of 15 per 100 ml but enterococci improved by 35 per 100 ml. While pH median values were identical, a much narrower range (by 1.4 units) was recorded in the recent twelve-month period due to the absence of elevated summer pH values which had been recorded at times in the previous thirteen-year period. Dissolved oxygen saturation median values were identical while all median phosphorus species nutrient levels were lower in the recent one year period, (DRP by nearly 42%), but median nitrogen nutrient species' levels were slightly higher in the recent year.

The range in water temperatures was much narrower (by 6.2°C) mainly due to a much lower maximum temperature (by 3.0˚C) while the median was 0.8°C higher in the 2011-2012 sampling period to that recorded in the previous thirteen-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 $CaCO_3$)	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)
13 Jul 2011	1330	0.020	0.005	0.000	8	1.34	<0.5	4.7	11.1	97	0.007	110	60
10 Aug 2011	1310	0.010	0.004	0.000	23	4.04	<0.5	6.6	11.5	99	0.020	42	11
14 Sep 2011	1230	0.043	0.009	0.000	8	1.57	<0.5	4.6	11.2	99	0.008	13	19
12 Oct 2011	1140	0.045	0.010	0.000	10	1.81	<0.5	4.0	10.6	99	0.011	440	520
08 Nov 2011	1135	0.009	0.002	0.000	21	6.46	<0.5	6.1	10.6	99	0.024	35	23
14 Dec 2011	1200	0.104	0.021	0.001	6	1.31	0.7	2.8	10.2	100	0.007	23	31
11 Jan 2012	1220	0.036	0.007	0.000	11	2.83	0.5	3.8	9.6	99	0.012	23	16
08 Feb 2012	1200	0.013	0.003	0.000	27	4.23	0.5	7.3	10.1	99	0.032	24	42
14 Mar 2012	1145	0.018	0.004	0.000	20	4.34	<0.5	5.9	10.5	99	0.017	20	16
11 Apr 2012	1320	0.012	0.003	0.000	27	4.54	<0.5	7.3	10.6	100	0.027	37	160
09 May 2012	1305	0.083	0.020	0.000	8	0.87	0.8	3.4	10.6	99	0.012	160	28
13 Jun 2012	1240	0.012	0.003	0.000	23	6.66	<0.5	6.1	11.6	98	0.004	17	1
Date		**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)**
13 Jul 2011	1330	110	1.728	0.006	<0.001	0.029	7.1	<2	7.1	0.03	0.06	0.015	0.65
10 Aug 2011	1310	42	0.168	0.003	0.001	0.039	7.6	<2	6.3	0.01	<0.05	0.022	0.80
14 Sep 2011	1230	13	0.716	<0.003	<0.001	0.009	7.2	<2	7.0	0.05	0.06	0.013	0.65
12 Oct 2011	1140	580	1.219	0.006	0.001	0.009	7.4	<2	9.5	0.06	0.07	0.021	0.65
08 Nov 2011	1135	35	0.199	0.007	<0.001	0.019	7.5	<2	9.8	0.03	<0.05	0.024	0.40
14 Dec 2011	1200	23	1.900	<0.003	0.001	0.009	7.2	<2	12.2	0.12	0.13	0.019	0.75
11 Jan 2012	1220	23	0.480	<0.003	<0.001	0.009	7.4	<2	13.2	0.05	0.06	0.017	0.50
08 Feb 2012	1200	24	0.132	<0.003	<0.001	0.009	7.7	<2	12.0	0.04	<0.05	0.032	0.45
14 Mar 2012	1145	20	0.224	<0.003	<0.001	0.009	7.5	<2	10.6	0.04	<0.05	0.023	0.40
11 Apr 2012	1320	37	0.151	<0.003	0.001	0.019	7.7	<2	9.9	0.03	<0.05	0.030	0.45
09 May 2012	1305	160	1.220	0.007	0.002	0.008	7.3	4	9.4	0.18	0.19	0.033	1.5
13 Jun 2012	1240	17	0.188	<0.003	<0.001	0.039	7.6	<2	5.8	0.05	0.09	0.021	0.50

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

Table 28 Statistical summary of data from July 2011 to June 2012: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.104	0.019	12	0.031
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.021	0.004	12	0.007
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	6	27	16	12	8
BDISC	Black disc transparency	m	0.87	6.66	3.44	12	2.01
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	0.8	<0.5	12	0.1
CONDY	Conductivity @ 20˚C	mS/m	2.8	7.3	5.3	12	1.5
DO	Dissolved oxygen	g/m^3	9.6	11.6	10.6	12	0.6
PERSAT	Dissolved oxygen saturation %	%	97	100	99	12	1
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.032	0.012	12	0.009
ECOL	E.coli bacteria	nos/100 ml	13	440	30	12	122
ENT	Enterococci bacteria	nos/100 ml	1	520	26	12	146
FC	Faecal coliforms	nos/100 ml	13	580	30	12	160
FLOW	Flow	m^3/s	0.132	1.900	0.352	12	0.656
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.007	<0.003	12	0.002
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.002	<0.001	12	0
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.04	<0.01	12	0.012
pH	pH		7.1	7.7	7.4	12	0.2
SS	Suspended solids	g/m^3	<2	4	<2	12	1
TEMP	Temperature	°C	5.8	13.2	9.6	12	2.4
TKN	Total kjeldahl nitrogen	g/m^3N	0.01	0.18	0.04	12	0.05
TN	Total nitrogen	g/m^3N	<0.05	0.19	0.06	12	0.04
TP	Total phosphorus	g/m^3P	0.013	0.033	0.022	12	0.006
TURB	Turbidity	NTU	0.4	1.5	0.6	12	0.3

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

Table 29 Statistical summary of data from July 1995 to June 2012: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.006	0.112	0.016	204	0.023
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.024	0.004	204	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	204	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	3	31	22	203	7
BDISC	Black disc transparency	m	0.09	9.10	4.34	203	1.83
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	3.7	<0.5	204	0.3
CONDY	Conductivity @ 20˚C	mS/m	2.5	8.2	6.2	204	1.4
DO	Dissolved oxygen	g/m^3	9.1	12.4	10.6	204	0.7
PERSAT	Dissolved oxygen saturation %	%	90	103	98	204	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.038	0.018	204	0.008
ECOL	E.coli bacteria	nos/100 ml	<1	10000	21	180	811
ENT	Enterococci bacteria	nos/100 ml	<1	2200	9	204	187
FC	Faecal coliforms	nos/100 ml	<1	10000	21	204	764
FLOW	Flow	m^3/s	0.084	18.000	0.216	204	1.655
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.057	<0.003	204	0.005
NO_2	Nitrite nitrogen	g/m^3N	<0.01	0.003	0.001	204	0
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.14	0.02	204	0.017
pH	pH		6.5	8.0	7.5	204	0.2
SS	Suspended solids	g/m^3	<2	160	<2	204	12
TEMP	Temperature	°C	3.7	14.7	9.2	204	2.5
TKN	Total kjeldahl nitrogen	g/m^3N	<0.01	2.70	0.05	204	0.22
TN	Total nitrogen	g/m^3N	<0.05	2.72	0.08	204	0.22
TP	Total phosphorus	g/m^3P	0.010	0.281	0.024	204	0.024
TURB	Turbidity	NTU	0.3	31	0.5	203	2.39

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

2011-2012 period

Aesthetic water quality was very high, as emphasised by median black disc and turbidity values of 3.44 m and 0.6 NTU respectively, and a maximum black disc clarity of 6.66 m measured under mid winter low flow conditions. The lowest black disc clarity (0.87 m) was recorded in May 2012, coincident with a moderate fresh (1.220 m^3/s) in the river, with an increase in colour, and very small increases in BOD_5 and turbidity also recorded.

Maximum pH (7.7) at this shaded site was measured in late summer and autumn under low flow conditions. pH range however was relatively narrow under all flow conditions (varying by only 0.6 unit) over the period.

Dissolved oxygen concentrations were consistently high with a minimum saturation of 97% 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.

Bacterial water quality was relatively high (median faecal coliform and enterococci numbers of 30 and 26 per 100 mls respectively). There was minimal 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 (7.4°C) at this relatively shaded site during the period. A maximum mid-day temperature of 13.2°C was recorded under elevated flow conditions in January 2012.

Brief comparison with the previous 1995-2011 period

A much narrower range but a higher median of river flows was sampled during the 2011-2012 period, with one small and four larger freshes sampled, in comparison with the previous sixteen-year period. Median flow for the 2011-2012 sampling occasions was 137 L/sec higher than the median of sampled flows over the previous sixteen-year period. Aesthetic river water quality was similar (within 0.1 NTU) in terms of median turbidity although median black disc clarity was lower (by 0.91m) during the 2011-2012 period. Median suspended solids concentrations were very low and identical for both periods.

Median nutrient species levels were comparatively similar between the two periods, although there were small decreases in median dissolved reactive phosphorus, nitrate, and total nitrogen over the latest twelve-month sampling period.

Median faecal coliform bacterial number increased (by 10 per 100 mls) while enterococci increased (by 18 per 100 mls) over the recent sampling period. Median pH values were within 0.2 pH unit for the two periods while the maximum pH value was only 0.3 unit lower in the 2011-2012 period.

Median water temperature over the past twelve-month period was only 0.4°C higher than the median for the previous sixteen-year period but the maximum temperature was 1.5 °C lower in the latest period than previously recorded. A narrower range of temperatures (by 3.6°C) was recorded in this 2011-2012 period due mainly to a higher minimum temperature in this 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 8.

Table 30 Analytical results from monthly samples: Patea River at Skinner 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)
13 Jul 2011	1415	0.017	0.004	0.000	18	1.28	0.8	8.8	10.6	98	0.020	740	370
10 Aug 2011	1410	0.014	0.006	0.000	26	1.05	0.8	10.4	12.1	109	0.025	34	28
14 Sep 2011	1315	0.036	0.008	0.000	22	0.95	2.1	8.8	11.4	105	0.039	740	250
12 Oct 2011	1240	0.029	0.007	0.000	22	0.48	2.0	8.3	10.1	99	0.023	15000	1600
08 Nov 2011	1225	0.015	0.003	0.000	26	1.64	0.7	9.8	10.3	103	0.032	180	37
14 Dec 2011	1250	0.067	0.015	0.001	18	0.85	2.4	6.6	9.8	100	0.034	2200	2800
11 Jan 2012	1250	0.026	0.005	0.000	23	1.48	0.8	8.1	9.5	103	0.027	180	63
08 Feb 2012	1305	0.024	0.005	0.000	34	1.17	1.2	11.7	10.9	119	0.040	170	27
14 Mar 2012	1240	0.021	0.004	0.000	26	1.81	0.7	9.6	10.8	108	0.028	150	150
11 Apr 2012	1410	0.019	0.004	0.000	31	2.28	0.8	10.5	11.2	113	0.030	57	99
09 May 2012	1355	0.028	0.008	0.001	32	1.41	2.3	10.6	11.4	107	0.060	200	300
13 Jun 2012	1330	0.015	0.004	0.000	28	2.32	0.6	10.0	11.4	99	0.018	57	26
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)**
13 Jul 2011	1415	740	12.686	0.085	0.011	1.049	7.3	5	10.8	0.25	1.31	0.051	2.1
10 Aug 2011	1410	40	2.172	0.041	0.016	1.084	7.9	<2	9.6	0.14	1.24	0.034	1.4
14 Sep 2011	1315	760	4.343	0.086	0.013	0.627	7.8	8	10.0	0.18	0.82	0.074	2.8
12 Oct 2011	1240	15000	8.937	0.116	0.012	0.818	7.4	9	13.2	0.40	1.23	0.092	4.1
08 Nov 2011	1225	190	4.056	0.060	0.013	1.017	7.7	<2	13.6	0.08	1.11	0.043	1.2
14 Dec 2011	1250	2400	6.935	0.080	0.010	0.410	7.5	8	15.3	0.35	0.77	0.090	2.6
11 Jan 2012	1250	180	6.799	0.050	0.014	0.816	7.5	<2	17.2	0.21	1.04	0.050	1.3
08 Feb 2012	1305	170	1.327	0.010	<0.001	0.719	8.5	2	18.0	0.24	0.96	0.067	1.4
14 Mar 2012	1240	150	3.148	0.017	0.009	0.821	7.8	<2	14.9	0.11	0.94	0.043	1.2
11 Apr 2012	1410	57	1.843	0.003	0.013	0.847	7.6	<2	14.4	0.01	0.87	0.044	1.3
09 May 2012	1355	210	1.727	0.041	0.019	0.941	7.9	3	12.2	0.12	1.08	0.080	1.6
13 Jun 2012	1330	60	3.565	0.047	0.011	1.159	7.8	<2	7.8	0.13	1.30	0.041	1.2

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

Table 31 Statistical summary of data from July 2011 to June 2012: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.014	0.067	0.022	12	0.015
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.015	0.005	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	18	34	26	12	5
BDISC	Black disc transparency	m	0.48	2.32	1.34	12	0.56
BOD_5	Biochemical oxygen demand 5day	g/m³	0.6	2.4	0.8	12	0.7
CONDY	Conductivity @ 20˚C	mS/m	6.6	11.7	9.7	12	1.4
DO	Dissolved oxygen	g/m³	9.5	12.1	10.8	12	0.8
PERSAT	Dissolved oxygen saturation %	%	98	119	104	12	6
DRP	Dissolved reactive phosphorus	g/m³P	0.018	0.060	0.029	12	0.011
ECOL	E.coli bacteria	nos/100 ml	34	15000	180	142502	4250
ENT	Enterococci bacteria	nos/100 ml	26	2800	124	12	851
FC	Faecal coliforms	nos/100 ml	40	15000	185	12	4252
FLOW	Flow	m³/s	1.327	12.686	3.810	12	3.438
NH_4	Ammoniacal nitrogen	g/m³N	0.003	0.116	0.048	12	0.034
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.019	0.012	12	0.004
NO_3	Nitrate nitrogen	g/m³N	0.41	1.16	0.83	12	0.211
pH	pH		7.3	8.5	7.8	12	0.3
SS	Suspended solids	g/m³	<2	9	2	12	3
TEMP	Temperature	°C	7.8	18.0	13.4	12	3.1
TKN	Total kjeldahl nitrogen	g/m³N	0.01	0.40	0.16	12	0.11
TN	Total nitrogen	g/m³N	0.77	1.31	1.06	12	0.19
TP	Total phosphorus	g/m³P	0.034	0.092	0.050	12	0.02
TURB	Turbidity	NTU	1.2	4.1	1.4	12	0.9

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

Table 32 Statistical summary of data from July 1995 to June 2012: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.095	0.023	204	0.015
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.023	0.005	204	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	204	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	10	57	27	204	6
BDISC	Black disc transparency	m	0.05	4.68	1.83	204	0.88
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	16	0.9	204	1.6
CONDY	Conductivity @ 20˚C	mS/m	5.0	14.3	9.9	204	1.5
DO	Dissolved oxygen	g/m³	8.9	12.9	10.6	204	0.7
PERSAT	Dissolved oxygen saturation %	%	87	121	102	204	6
DRP	Dissolved reactive phosphorus	g/m³P	0.010	0.160	0.038	204	0.032
ECOL	E.coli bacteria	nos/100 ml	2	25000	200	180	3489
ENT	Enterococci bacteria	nos/100 ml	4	19000	115	204	1623
FC	Faecal coliforms	nos/100 ml	2	63000	220	204	5561
FLOW	Flow	m³/s	0.680	77.530	2.940	204	8.158
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.329	0.052	204	0.053
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.051	0.017	204	0.008
NO_3	Nitrate nitrogen	g/m³N	0.21	1.54	0.94	204	0.219
pH	pH		7.0	8.8	7.8	204	0.4
SS	Suspended solids	g/m³	<2	360	2	204	30
TEMP	Temperature	°C	5.3	21.8	12.8	204	3.4
TKN	Total kjeldahl nitrogen	g/m³N	0.01	4.07	0.24	204	0.39
TN	Total nitrogen	g/m³N	0.74	4.50	1.23	204	0.36
TP	Total phosphorus	g/m³P	0.022	1.390	0.068	204	0.119
TURB	Turbidity	NTU	0.2	80	1.5	203	7.6

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.

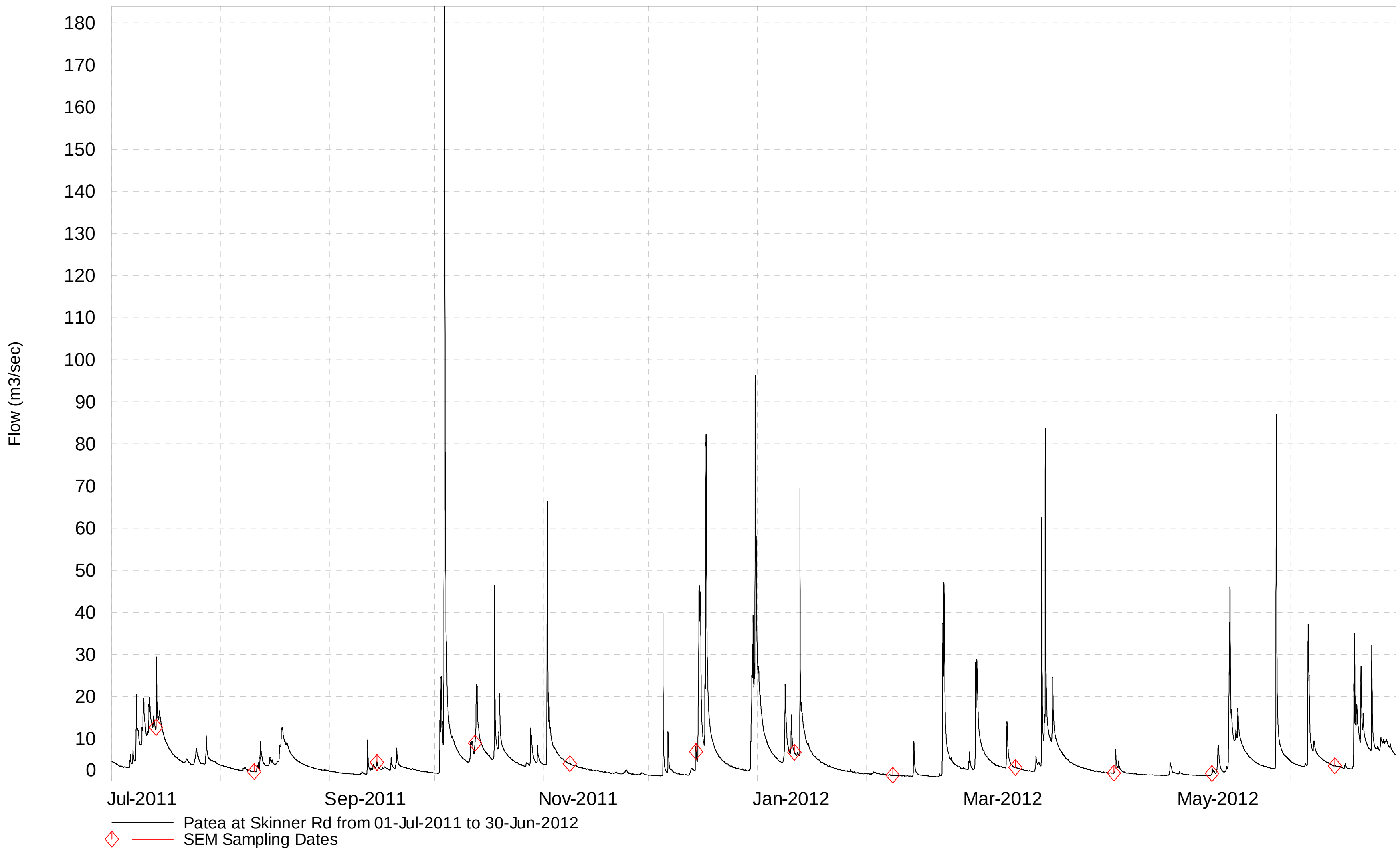

Figure 8 Flow record for the Patea River at Skinner Road

Discussion

2011-2012 period

Moderate median black disc clarity (1.34 metres) and median turbidity (1.4 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 0.48 m, turbidity of 4.1 NTU) and a small increase in suspended solids concentration (9 g/m^3) were recorded during a fresh event sampled in October 2011 (Figure 8). A deterioration in other water quality parameters during this event was also illustrated by a very high faecal coliform bacterial number, slightly elevated BOD_5 and total phosphorus, and a slight reduction in dissolved oxygen saturation.

Early afternoon pH levels reached a maximum of 8.5 units in late summer coincidental with a dissolved oxygen saturation peaking at 119%. Dissolved oxygen levels were consistently high (98% or higher saturation) with supersaturation recorded particularly during mid summer to autumn low flow conditions coincident with more extensive algal cover and elevated pH levels (7.6 to 8.5 units). BOD_5 concentrations under normal to low recession flow conditions were generally indicative of moderately low organic contamination (i.e. up to 2.3 g/m^3 on these occasions).

The moderate median bacteriological numbers (124 enterococci and 185 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 relatively wide range of faecal coliform numbers recorded under lower river flow conditions probably reflected the seasonal variability in the recently upgraded municipal oxidation pond performance due to the relative proximity of this discharge, more than to other point source or non-point source discharges.

Water temperatures varied over a moderately wide range of 10.2°C with a maximum (early afternoon) summer temperature of 18.0°C recorded in February 2012 (coincident with a pH of 8.5 and 119% dissolved oxygen saturation).

Brief comparison of upper and mid catchment sites during the 2011-2012 period

Some deterioration in 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 (5 to 6-fold increases) and increases in median nutrient species concentrations (2 to 80 fold). The pH range increased by 0.6 unit at the Skinner Road site with a maximum pH 0.8 unit higher than at the upstream site. A moderate increase in median turbidity levels (0.8 NTU) was measured in mid catchment while median BOD_5 increased by about 0.3 g/m^3 although maximum BOD_5 was 1.6 g/m^3 higher downstream. A deterioration in black disc clarity (median clarity decreased significantly by 2.10 m and maximum clarity to a larger degree by 4.33 m) was recorded, as a result of increased turbidity from run-off and point source discharges within the developed reaches of the river between the two sites.

Water temperature range increased (by 2.8°C) at the Skinner Road site where median water temperature was higher (by 3.8°C) and maximum water temperature was higher (by 4.8°C) than at the Barclay Road site.

Brief comparison with the previous 1995-2011 period

The median of sampled flows in the recent twelve-month period was a significant 960 L/sec higher than the median of flows sampled over the 1995-2011 period but despite more frequent freshes sampled in the 2011-2012 year, the range of river flows sampled was very much narrower. Aesthetic water quality was poorer than historical conditions with median black disc clarity lower by 0.51 m although there 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 0.6 pH unit) and lower maximum pH (by 0.3 pH unit) during the 2011-2012 period. Dissolved oxygen percentage saturation median was higher by an insignificant 2% in the 2011-2012 period.

Bacterial water quality improved for faecal coliform bacteria but was relatively similar for enterococci during the more recent sampling period, with the median faecal coliform number decreasing by 45 (per 100 mls) and the enterococci number increasing by 9 (per 100 mls). Seasonal variability in municipal oxidation ponds' system performance and dairy shed wastes disposal partly contributed to the variability in bacterial quality between periods.

Water temperature range was much narrower (by 6.3°C) during the more recent sampling period with the median water temperature slightly higher (by 0.6˚C) than the longer term median. The maximum water temperature recorded was 3.8°C lower than previously recorded but the minimum water temperature was higher (by 2.5°C) in the latest twelve-month period.

Median BOD_5 was very similar in the latest period with all median nutrient species showing decreases (ranging from 9% to 36%) during the more recent twelve-month sampling 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 9.

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

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³) $CaCO_3$)	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)
13 Jul 2011	1450	0.038	0.008	0.000	14	0.13	1.1	6.6	10.4	93	0.004	350	92
10 Aug 2011	1446	0.039	0.010	0.000	36	1.16	<0.5	10.1	11.4	100	0.004	34	9
14 Sep 2011	1355	0.077	0.015	0.001	28	0.29	0.9	8.6	10.8	99	0.004	1100	240
12 Oct 2011	1315	0.035	0.007	0.000	37	0.45	0.6	9.7	10.0	99	0.014	1200	310
08 Nov 2011	1300	0.042	0.008	0.000	33	1.05	<0.5	8.6	10.3	101	0.009	260	48
14 Dec 2011	1327	0.056	0.012	0.000	45	0.61	1.4	10.5	9.8	105	0.004	340	130
11 Jan 2012	1335	0.062	0.012	0.000	34	0.54	0.7	8.5	9.2	103	0.007	320	130
08 Feb 2012	1345	0.056	0.011	0.000	46	1.38	0.7	11.5	10	111	0.003	96	42
14 Mar 2012	1320	0.058	0.012	0.000	38	1.00	0.5	9.7	10.2	105	0.004	340	62
11 Apr 2012	1445	0.052	0.011	0.000	55	2.18	<0.5	12.5	10.7	109	<0.003	83	16
09 May 2012	1430	0.055	0.015	0.001	54	1.43	<0.5	13.0	11.5	106	0.006	80	15
13 Jun 2012	1405	0.044	0.009	0.001	36	1.17	<0.5	9.7	11.5	102	<0.003	54	6
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)**
13 Jul 2011	1450	350	53.486	0.021	0.001	0.359	7.2	98	9.9	0.29	0.65	0.139	30
10 Aug 2011	1446	34	6.798	0.014	0.002	0.168	7.8	2	9.1	0.11	0.28	0.012	3.2
14 Sep 2011	1355	1100	13.167	0.015	0.002	0.088	7.6	33	10.8	0.20	0.29	0.048	18
12 Oct 2011	1315	1200	13.621	0.014	0.002	0.128	7.7	17	14.3	0.16	0.29	0.141	6.7
08 Nov 2011	1300	270	9.865	0.010	0.002	0.118	7.7	4	13.8	0.10	0.22	0.018	3.1
14 Dec 2011	1327	340	5.046	0.008	0.003	0.017	8.0	3	18.1	0.11	0.13	0.014	3.1
11 Jan 2012	1335	320	8.852	0.004	0.001	0.069	7.6	4	19.4	0.20	0.27	0.020	4.6
08 Feb 2012	1345	96	4.098	<0.003	<0.001	0.009	8.3	<2	19.8	0.06	0.07	0.014	2.2
14 Mar 2012	1320	340	6.271	0.010	0.001	0.049	7.9	4	16.8	0.13	0.18	0.017	3.3
11 Apr 2012	1445	83	3.736	<0.003	0.002	0.038	7.8	<2	15.3	0.04	0.08	0.012	2.9
09 May 2012	1430	80	3.496	0.007	0.003	0.027	8.0	<2	11.0	0.13	0.16	0.009	2.7
13 Jun 2012	1405	54	6.290	0.006	0.003	0.157	7.9	<2	8.8	0.17	0.33	0.013	2.3

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

Table 34 Statistical summary of data from July 2011 to June 2012: Mangaehu River at Raupuha Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.035	0.077	0.054	12	0.012
A440F	Absorbance @ 440nm filtered	/cm	0.007	0.015	0.011	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0	0.001	0	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	14	55	36	12	11
BDISC	Black disc transparency	m	0.13	2.18	1.02	12	0.58
BOD_5	Biochemical oxygen demand 5day	g/m³	0.5	1.4	0.6	12	0.3
CONDY	Conductivity @ 20˚C	mS/m	6.6	13	9.7	12	1.8
DO	Dissolved oxygen	g/m³	9.2	11.5	10.4	12	0.7
PERSAT	Dissolved oxygen saturation %	%	93	111	102	12	5
DRP	Dissolved reactive phosphorus	g/m³P	<0.003	0.014	0.004	12	0.003
ECOL	E.coli bacteria	nos/100 ml	34	1200	290	12	392
ENT	Enterococci bacteria	nos/100 ml	6	310	55	12	97
FC	Faecal coliforms	nos/100 ml	34	1200	295	12	392
FLOW	Flow	m³/s	3.496	53.486	6.544	12	13.739
NH_4	Ammoniacal nitrogen	g/m³N	0.003	0.021	0.009	12	0.006
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.003	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.36	0.08	12	0.097
pH	pH		7.2	8.3	7.8	12	0.3
SS	Suspended solids	g/m³	2	98	4	12	28
TEMP	Temperature	°C	8.8	19.8	14	12	4
TKN	Total kjeldahl nitrogen	g/m³N	0.04	0.29	0.13	12	0.07
TN	Total nitrogen	g/m³N	0.07	0.65	0.24	12	0.15
TP	Total phosphorus	g/m³P	0.009	0.141	0.016	12	0.049
TURB	Turbidity	NTU	2.2	30	3.1	12	8

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

Table 35 Statistical summary of data from July 1995 to June 2012: Mangaehu River at Raupuha Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.027	0.181	0.054	204	0.019
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.056	0.011	204	0.006
A770F	Absorbance @ 770nm filtered	/cm	0	0.025	0	204	0.003
ALKT	Alkalinity Total	g/m³ $CaCO_3$	9	79	38	204	13
BDISC	Black disc transparency	m	<0.01	4.04	0.82	204	0.74
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	5.6	0.6	204	0.6
CONDY	Conductivity @ 20˚C	mS/m	4.3	15.6	9.8	204	2.2
DO	Dissolved oxygen	g/m³	7.7	12.9	10	204	0.9
PERSAT	Dissolved oxygen saturation %	%	83	118	100	204	6
DRP	Dissolved reactive phosphorus	g/m³P	0.003	0.026	0.006	204	0.004
ECOL	E.coli bacteria	nos/100 ml	6	16000	220	180	2048
ENT	Enterococci bacteria	nos/100 ml	1	6000	68	204	792
FC	Faecal coliforms	nos/100 ml	6	16000	245	204	2164
FLOW	Flow	m³/s	1.658	111.87	6.952	204	16.37
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.081	0.012	204	0.012
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.016	0.002	204	0.002
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.36	0.10	204	0.088
pH	pH		6.9	8.4	7.7	204	0.3
SS	Suspended solids	g/m³	<2	1300	4	204	128
TEMP	Temperature	°C	4.3	24	13.7	204	4.3
TKN	Total kjeldahl nitrogen	g/m³N	0.02	1.9	0.18	204	0.27
TN	Total nitrogen	g/m³N	0.07	2.1	0.3	204	0.3
TP	Total phosphorus	g/m³P	0.003	0.786	0.02	204	0.105
TURB	Turbidity	NTU	1.7	850	3.5	203	67.5

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.

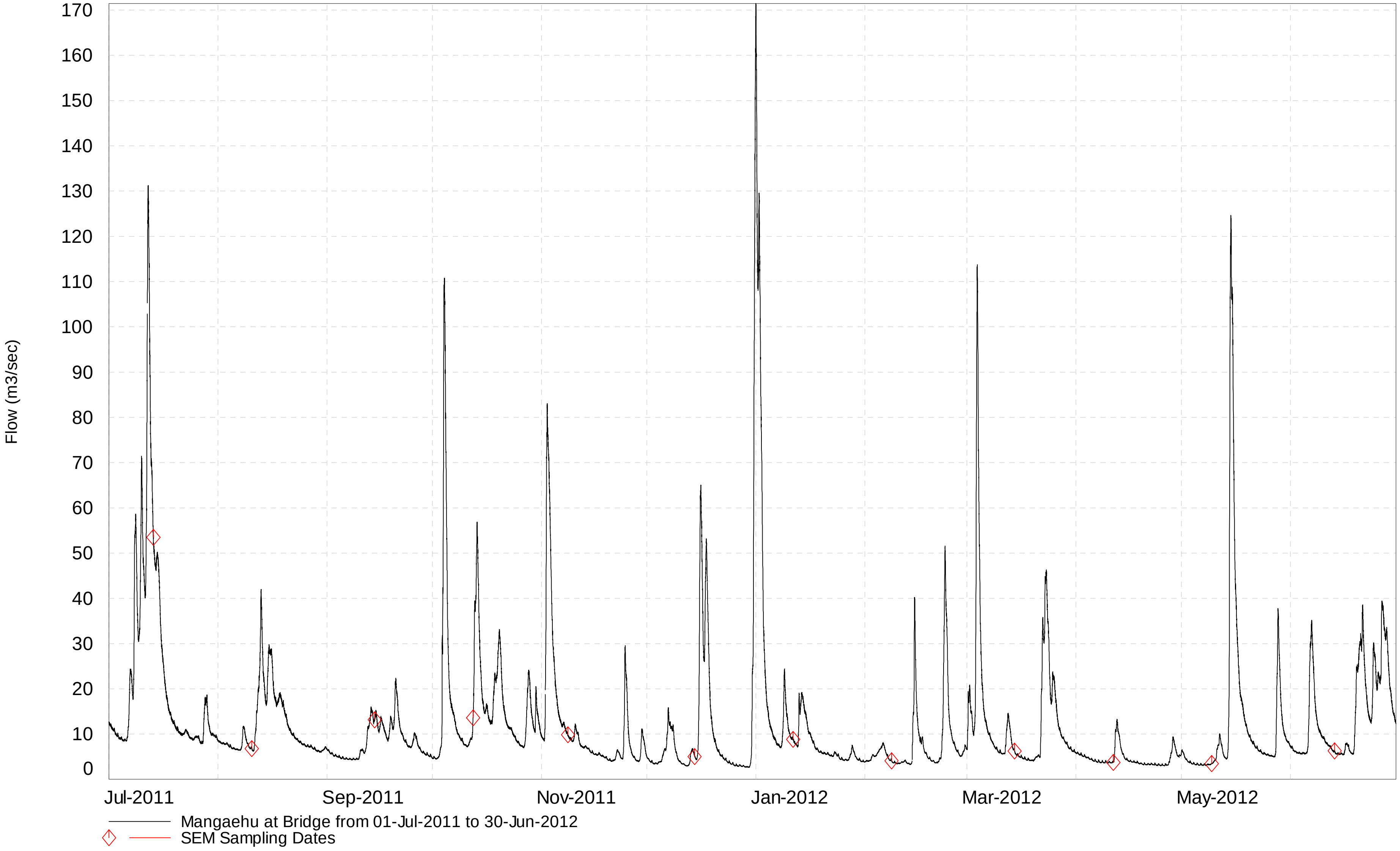

Figure 9 Flow record for the Mangaehu River at Raupuha Road

Discussion

2011-2012 period

The relatively poor visual appearance which characterises this eastern hill-country catchment river and particularly its lower reaches was emphasised by a low median black disc clarity of 1.02 metre with a maximum of 2.18 metres measured under low flow conditions in April 2012, some three weeks since a fresh. Clarity was frequently less than 1.2 metres (on nine occasions) due to the presence of very fine, colloidal suspended particles. However, the median suspended solids concentration was 4 g/m^3 which was typical for this river, although several fresh or flood events were sampled during the period. Absorbances (at 340 and 440 nm) were also relatively high (in excess of 0.034/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 (0.13 and 0.29 m black disc values) were coincident with turbidity levels of 30 and 18 NTU and suspended solids concentrations of 98 and 33 g/m^3, during flood flows of 53 and 13.1 m^3/s recorded in July and September 2011 respectively. Fresh flows (in excess of 10 m^3/s) were usually coincident with a general deterioration in water quality as emphasised by elevated turbidity, suspended solids, some nutrient species' levels and bacterial counts (e.g. in July, September, and October 2011, Figure 9).

Maximum mid-afternoon pH values in the mid summer to late autumn period (8.0 to 8.3) 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.

Dissolved oxygen concentrations however, were consistently high (median of 10.4 g/m^3) and the median saturation level was 102%. On most occasions BOD_5 concentrations were indicative of relatively low organic content (i.e. less than 1.0 g/m^3). The median bacteriological numbers (55 enterococci and 295 faecal coliforms per 100 ml) were more typical 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 moderate range of 11.0°C with a maximum (early afternoon) summer temperature of 19.8° C recorded in February 2012 during low flow conditions, at which time dissolved oxygen saturation was 112% and pH was 8.4.

Brief comparison with the previous 1995-2011 period

The range of flows sampled during the 2011-2012 period was narrower than the range sampled over the previous sixteen-year period mainly due to the smaller flood sampled during the latest period. However, the median sampled flow in the 2011-2012 period was lower (by 518 L/sec) than that sampled over the longer term. Median black disc clarity was better by 0.34 m and median turbidity was lower by 0.5 NTU in the most recent period, while the median suspended solids concentration was unchanged.

All nutrient species' median concentrations decreased slightly in the latest period, compared to the median for the previous sixteen-year period with total phosphorus

(24%), ammoniacal nitrogen (25%), and total nitrogen (27%) showing the principal decreases. Median bacterial numbers were slightly lower for enterococci (by 15 per 100 mls) but increased for faecal coliforms (by 60 per 100 ml) in the 2011-2012 period.

Median dissolved oxygen saturation level was very similar (2% higher) in the 2011-2012 period while median pH levels were within 0.1 unit between periods. Maximum pH was 0.1 unit lower than previously recorded.

The range of water temperatures was significantly narrower (by 8.7°C) in the latest twelve-month period than in the previous sixteen-year period while median water temperature was 0.3°C higher during 2011-2012, due to a much lower maximum temperature (by 4.2°C) and higher minimum temperature (by 4.5°C) recorded in the 2011-2012 sampling year.

4.2 Comparative water quality for the seventeen-year (1995-2012) period

4.2.1 TRC data

In addition to the site descriptions of water quality measured during the 2011-2012 monthly sampling programme, a general comparison between the eleven sites of the programme may be made for the seventeen-year sampling period to date (1995-2012) 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 seventeen year record are discussed within groupings of parameters as follows.

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

The water quality at all but two of the sites has been clean and clear with very low suspended solids concentrations (median: 3 g/m^3 or lower) and low turbidity levels (median: less than 2 NTU) except during flood flow conditions. The exceptions are 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 shows 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 1.5 metres. Due to the elevated turbidity of the Mangaehu River, the median clarity in the lower reaches of the river was only 0.82 metre while the site in the lower reaches of the Waingongoro River also had a relatively low median black disc value of 1.18 metres. Greatest variability was found at the Stony River site which has been the subject of several severe upper catchment erosion events during the seventeen year period.

Table 36 Some comparative water quality data for the eleven TRC SEM sites for the seventeen-year period July 1995 to June 2012 (n = 204 samples)

Site / Unit	Black disc (m)		BOD_5 (g/m^3)	Conductivity @ 20°C (mS/m)	Faecal coliform bacteria (nos per 100 ml)		Nutrients: Ammonia (g/m^3N)	Nutrients: Nitrate (g/m^3N)	Nutrients: Total N (g/m^3N)	Nutrients: DRP (g/m^3P)	Nutrients: Total P (g/m^3P)	pH		Dissolved oxygen saturation (%)			Suspended solids (g/m^3)	Temperature (°C)			Turbidity (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	2.60	<0.5	8.5	50	315	0.009	0.25	0.40	0.022	0.032	7.9	7.6	90	97	12	<2	17.6	11.6	12.8	0.8
Mangaoraka Stream at Corbett Road	4.73	1.83	0.6	14.4	120	740	0.022	0.84	1.12	0.008	0.022	8.1	7.6	83	96	24	2	20.5	13.2	14.7	1.6
Waiwhakaiho River at SH3	8.05	3.05	<0.5	12.2	23	200	0.008	0.11	0.21	0.024	0.034	8.5	7.9	91	100	17	<2	18.3	11.2	13.5	0.7
Stony River at Mangatete Road	13.1	3.40	<0.5	9.6	<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	1.84	<0.5	8.6	3	130	0.006	0.03	0.14	0.022	0.033	8.3	7.7	87	99	19	2	19.2	12.0	14.2	1.7
Punehu Stream at SH45	3.57	1.51	1.0	16.1	51	510	0.040	0.91	1.35	0.042	0.078	8.6	7.7	90	99	24	3	21.0	13.5	16.0	1.8
Waingongoro River at Eltham Road	4.39	1.71	0.7	11.2	6	180	0.018	1.14	1.44	0.018	0.036	8.6	7.8	92	102	29	3	20.8	12.4	15.2	1.5
Waingongoro River at SH45 **	4.34	1.18	1.0	16.4	3	220	0.032	1.90	2.44	0.060	0.101	9.1	7.8	89	101	52	5	22.0	13.7	16.6	2.4
Patea River at Barclay Road	9.10	4.34	<0.5	6.2	<1	21	<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	220	0.052	0.94	1.23	0.038	0.068	8.8	7.8	87	102	34	2	21.8	12.8	16.5	1.5
Mangaehu River at Raupuha Road	4.04	0.82	0.6	9.8	6	245	0.012	0.10	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 2012 (n = 108 samples); ** for the period July 1998 to June 2012 (n = 168 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, 13.5°C, and 12.8°C) and widest ranges (19.7°C, 16.6°C, 16.0°C and 16.5°C) respectively of water temperatures. Atypically, relatively high median (12.0°C), maximum (19.2°C) and a wide range (14.2°C) of water temperatures were 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 (above pH 7.0), i.e., medians ranging from 7.5 to 7.9 typical of ring plain rivers and streams.

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 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 (<15%) was found in the upper reaches of the Patea River, and the mid reaches of the Maketawa Stream with wider saturation ranges (>20%) recorded at mid and lower catchment sites, and the widest (52%) in the lower reaches of the longest ringplain river.

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 and good water quality 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 850% and 135% in median total nitrogen and total phosphorus respectively over the length of the Punehu Stream and 1440% and 180% respectively through the mid reaches of the Patea 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^3P) 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^3P) 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 740 per 100 mls) has been recorded at the sites in the lower reaches of the Punehu Stream, Waingongoro River, Mangaehu River, and the Mangaoraka Stream, and relatively poor bacteriological quality (medians from 180 to 220 per 100 mls) in the mid reaches of the Waiwhakaiho, Waingongoro and Patea Rivers, reflecting 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 these site's (Mangaoraka Stream) counts have continuously exceeded 120 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 21 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 130 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 seventeen 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.

Table 37 Some comparative water quality data for the three NIWA SEM sites for the seventeen-year period July 1995 to June 2012 (n = 204 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	0.49	0.7	8.8	0.011	0.31	0.57	0.006	0.033	8.6	7.7	102	23.2	13.7	16.7	8.5	29.5
Manganui River at SH3	7.7	4.13	<0.5	6.3	0.006	0.09	0.18	0.009	0.015	7.9	7.5	101	18.7	10.4	14.6	0.9	0.95
Waingongoro River at SH45	3.2	1.3	1.0	16.5	0.027	1.93	2.23	0.050	0.099	9.1	7.9	103	23.0	13.7	16.7	2.4	5.1
	(4.34)	(1.18)	(1.0)	(16.4)	(0.032)	(1.89)	(2.44)	(0.060)	(0.101)	(9.1)	(7.8)	(101)	(22.0)	(13.7)	(16.6)	(2.4)	(4.80)

[Notes ( ) = TRC data for the period July 1998 to June 2012 (n = 168 samples); NIWA data – BOD_5 (n = 85 samples)]

These data indicate more turbid (cloudier) appearance in the lower reach of the Waitara River (median black disc clarity of 0.49 metres and turbidity of 8.5 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 fourteen 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 seventeen 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 1995-2012 SEM (TRC and NIWA) sites' 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/m^3	<550/ 100mls	<3g/m^3	<0.03 g/m^{3}P	<0.03 g/m^{3}P •	<0.6 g/m^{3}N •	<1000/ 100mls	Median <100/100 mls	>0.8m	>80%	<0.4 g/m^{3}N	<0.9 g/m^{3}N	<25° C	<25 g/m^{3}N	<0.8 g/m^{3}P	<11.3 g/m^{3}N
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	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
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 SH 3	✓	✓✓	✓	✓✓	✓	✓	✓	✓	✓	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
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 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, 2012b), 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 failed to meet instantaneous guidelines ('Alert' and 'Action' modes (TRC, 2012b)) on occasions under spring-summer low flow conditions (refer to individual tables of 2011-2012 data).

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, 2012). 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, less grazing by macroinvertebrates, higher temperatures, and less dilution of discharges containing nutrients. The lower reaches of ring plain streams in southern and western Taranaki particularly can be prone to nuisance growths in the late 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 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 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 in stream 'health' trends over the seventeen years (1995 to 2012) to date (TRC, 2006c, Stark and Fowles, 2006 and TRC, 2012a).

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.

4.3 Trends in physicochemical water quality data from 1995 to 2012

4.3.1 Introduction

17 years of physicochemical water quality data has been collected up to 30 June 2012. This data has been analysed for trends since there has been 10 years of data available. Previous trend analysis has been reported in TRC (2006 and 2009a&b, 2010 and 2011).

This memo provides an update of the trends including data from the 2011-2012 monitoring year. It does not provide a detailed interpretation of the results. This will be provided at least prior to each 5 yearly State of the Environment Report (next due in 2014) if not before.

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).

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.

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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.

4.3.3 Results of trend analysis

Table 39 summarises the significant trends recorded for each water quality parameter at the 10 sites monitored in the Physicochemical State of the Environment Monitoring Programme where there is sufficient data.

Of the nutrients, DRP and to a lesser extent total phosphorus, have shown a significantly deteriorating trend at a number of sites, including sites in the mid catchments which would be less subject to anthropogenic pressures. The deterioration in total phosphorous appears to be concentrated in the mid/lower catchment sites, whereas DRP is deteriorating at 5 out of the 10 sites monitored, and throughout the upper, mid and lower catchments.

Nitrate also showed significant deteriorating trends at four sites mainly in mid-catchment areas. However, total nitrogen improved significantly at upper catchment sites, one mid catchment site (the Stony River) and also in the Waingongoro River at SH45 and Mangaehu River at Raupuha Rd sites which are situated at the lower catchment level. On the whole the rest of the sites remained stable. Ammonia-N showed generally stable trends throughout the catchment levels with the exception of the Waiwhakaiho River and the Mangaoraka Stream sites, where a significant trend of deterioration is apparent.

Generally, mid catchment sites appear to be showing the most deterioration in nutrients, and although the lower catchment sites show almost a similar number of deteriorations there is notable improvement in the Waingongoro SH45 site. This is a positive aspect in that lower catchments would be under the most pressure from landuse intensification and upstream influences. The Waiwhakaiho River at SH3, Waingongoro River at Eltham Road 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 Waiwhakaiho and three out of five for Waingongoro and four out of five for Punehu Stream at SH45 (Table 39).
In all three of these rivers phosphorus parameters seem to be increasing at a steady but slow rate (Figure 10). 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 (Table 40). 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). However the Punehu Stream at the SH45 site is showing the highest values for nitrate nitrogen towards more recent years (Figure 10). The Waingongoro River at SH45 is showing a very significant improving trend in dissolved reactive phosphorus, total phosphorus and total nitrogen and a significant trend in nitrate (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).

Faecal coliforms and enterococci bacteria generally showed little statistically significant change over the 17 year period, although three middle catchment sites (Patea River at Skinner Road and Waingongoro at Eltham Road and Stony River at Mangatete Road) indicated improving levels in faecal coliforms in these catchments. Enterococci levels did not show the same trend at these sites however. There is a very significant deteriorating trend in enterococci in the lower catchment site of the

Mangaoraka Stream at Corbett Road however this was not reflected in faecal coliform levels. There was also a deteriorating trend to a lower significance at the lower catchment site of Punehu stream at SH45 but again this was not reflected in faecal coliform levels.

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 17 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 1) 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 has also been deterioration in clarity at the Waingongoro SH45 site and Mangaehu at Raupuha Rd site although not to the same extent as the mentioned sites. Some significant trends in water temperature and pH have been noted (Table 40) 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 39 'Meaningful' trends in surface water quality at 10 State of the Environment Monitoring sites in Taranaki- 1995-2012 (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	12	0
Upper/ Middle	**Punehu Stream Wiremu Rd**	😐	😐	😐	😐	😃	😐	😐	😐	😐	😐	😐	😐	😐	1	12	0
Middle	**Stony River Mangatete Road**	😠	😠	😐	😐	😃	🙂	😐	😐	😠	😠	😐	😐	😐	2	7	4
Middle	**Patea River Skinner Rd**	😐	😐	😠	😐	😐	🙂	😐	😐	😐	😐	😐	😐	😐	1	11	1
Middle	**Waiwhakaiho SH3**	😠	😐	😠	😠	😐	😐	😐	😐	😠	😐	😐	😐	😐	0	9	4
Middle	**Waingongoro Eltham Rd**	😠	😠	😠	😐	😐	😃	😐	😐	😐	😐	😐	😐	😐	1	9	3
Lower	**Mangaoraka Stream Corbett Rd**	😠	🙁	😐	🙁	😐	😐	😠	😐	😠	😐	😐	😐	😐	0	8	5
Lower	**Waingongoro SH45***	😃	😃	😐	😐	😃	🙂	😐	😐	🙁	😐	😐	😠	😐	4	7	2
Lower	**Punehu Stream SH45**	😠	😠	😠	😐	🙁	😐	🙁	😐	😐	😐	😐	😐	😐	0	8	5
Lower	**Mangaehu River Raupuha Rd**	😐	😐	😐	😐	😃	😐	😐	😐	🙁	😐	😐	😐	😐	1	11	1
Total no. sites: Improvement 😃		1	1	0	0	5	4	0	0	0	0	0	0	0			
No change 😐		4	5	6	8	4	6	8	10	5	9	10	9	10			
Deterioration 😠		5	4	4	2	1	0	2	0	5	1	0	1	0			

Key:

*Waingongoro SH45: Data for this site only for the past 14 years: 1998 – 2012

😃 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 40 *p*-values (%) and trend slopes (% change per year) for flow and seasonally adjusted water quality variables at 10 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	2.24	0.94	73.02	-0.07	5.71	-0.33	55.21	-0.47	0.00	-5.25	11.38	-2.38	83.98	0.69
Upper/ Middle	Punehu Stream Wiremu Rd	59.26	0.16	41.19	-0.23	94.31	0.11	68.60	-0.38	0.00	-3.00	25.86	-1.53	46.82	-1.03
Middle	Stony River Mangatete Road	0.00	1.43	0.52	1.90	23.91	0.84	16.41	-0.33	0.00	-5.59	4.71	-3.32	66.00	-0.60
Middle	Patea River Skinner Rd	43.96	-0.39	24.87	-0.49	0.01	1.04	69.48	-0.31	14.36	0.39	2.62	-4.11	45.38	-0.93
Middle	Waiwhakaiho SH3	0.07	1.33	0.69	0.94	0.03	2.62	0.01	4.23	62.59	-0.19	10.33	1.60	95.26	-0.19
Middle	Waingongoro Eltham Rd	0.00	2.87	0.92	1.73	0.10	1.31	89.59	-0.22	0.75	0.94	0.14	-5.40	8.90	-2.67
Lower	Mangaoraka Stream Corbett Rd	0.10	2.82	4.20	1.66	67.73	-0.15	2.46	2.32	8.47	-0.53	30.09	1.25	0.01	6.01
Lower	Waingongoro SH45*	0.00	-2.79	0.03	-2.26	1.70	-0.98	15.96	1.62	0.76	-0.78	4.47	-3.28	83.72	-0.31
Lower	Punehu Stream SH45	0.00	3.12	0.14	1.76	0.02	2.13	83.98	-0.21	1.80	1.15	8.05	-1.92	4.06	2.98
Lower	Mangaehu River Raupuha Rd	15.71	1.03	27.92	-0.65	71.24	0.22	26.88	-0.95	0.28	-1.53	16.41	-2.04	82.13	-0.41
Total no. sites: Improvement ☺		1		1		0		0		5		4		0	
No change 😐		4		5		6		8		4		6		8	
Deterioration ☹		5		4		4		2		1		0		2	

Table 40 (cont) *p*-values (%) and trend slopes (% change per year) for flow and seasonally adjusted water quality variables at 10 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	28.99	-0.12	47.99	-0.25	69.46	0.01	6.53	-0.45	77.49	0.00	93.37	0.00
Upper/ Middle	Punehu Stream Wiremu Rd	0.04	0.28	11.38	-0.70	91.48	-0.01	3.14	-0.64	63.42	-0.06	0.01	-0.11
Middle	Stony River Mangatete Road	73.02	-0.04	0.00	-4.46	0.06	13.21	11.93	-0.34	8.34	0.00	0.56	-0.07
Middle	Patea River Skinner Rd	4.98	0.18	32.37	-0.54	56.01	-0.15	64.28	-0.13	25.86	0.81	4.20	-0.08
Middle	Waiwhakaiho SH3	0.31	-0.41	0.05	-1.67	18.69	0.09	1.68	-0.63	62.59	0.01	0.00	-0.12
Middle	Waingongoro Eltham Rd	46.82	0.12	62.59	-0.23	66.00	0.16	6.89	-0.37	74.82	0.18	5.26	-0.06
Lower	Mangaoraka Stream Corbett Rd	48.29	0.09	0.00	-2.77	7.26	1.24	21.18	-0.28	6.89	1.30	1.06	-0.06
Lower	Waingongoro SH45*	47.70	0.16	4.47	1.27	20.05	-0.87	6.45	-0.45	0.76	2.72	0.00	-0.19
Lower	Punehu Stream SH45	11.38	0.23	42.56	-0.40	8.68	-1.36	0.99	-0.54	67.73	0.16	0.00	-0.15
Lower	Mangaehu River Raupuha Rd	22.07	-0.17	3.14	-1.66	52.85	-0.48	3.97	-0.52	26.88	-0.61	37.25	0.03
	Total no. sites: Improvement ☺	0		0		0		0		0		0	
	No change 😐	10		5		9		10		9		10	
	Deterioration ☹	0		5		1		0		1		0	

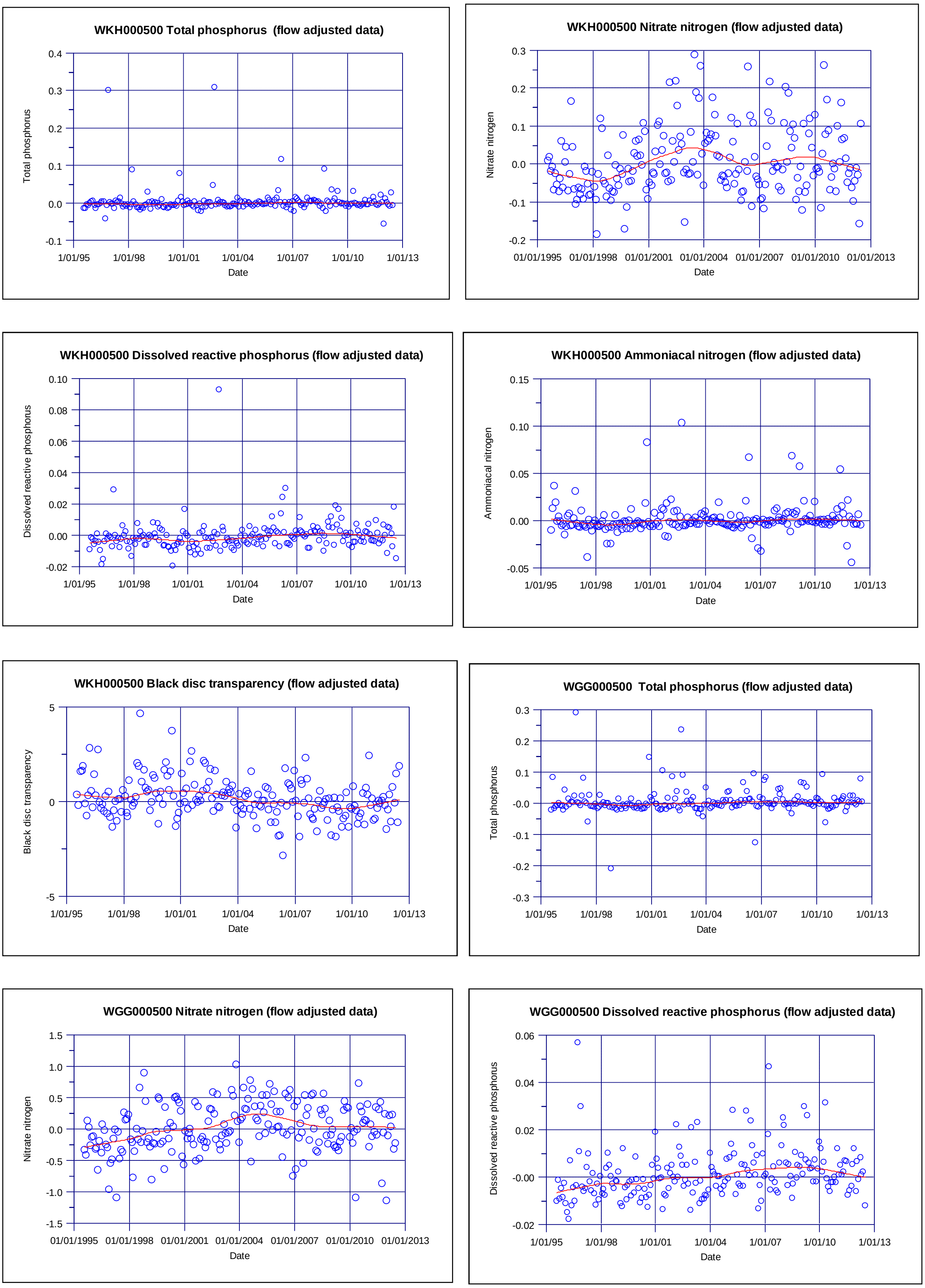


Figure 10 Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

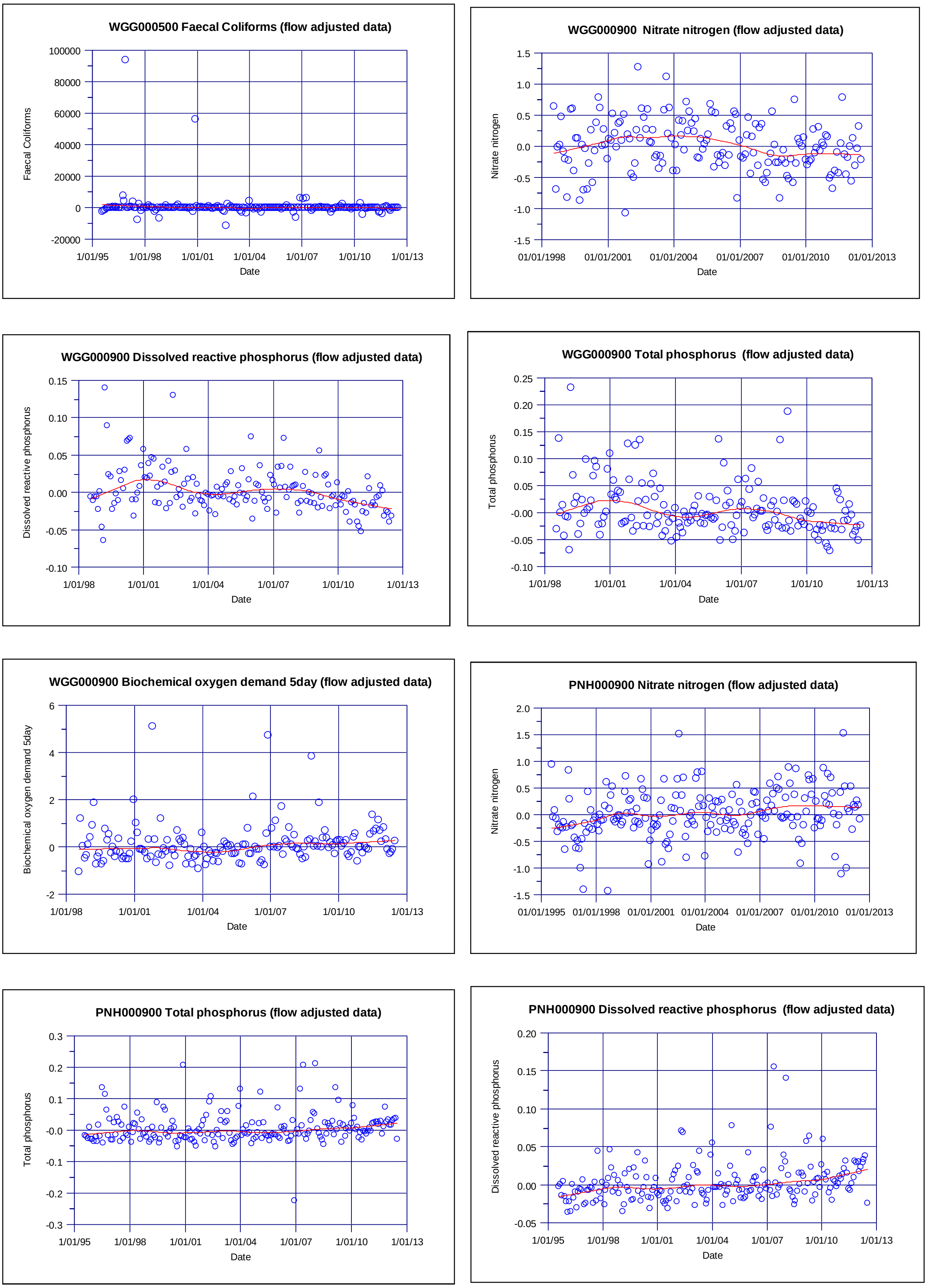
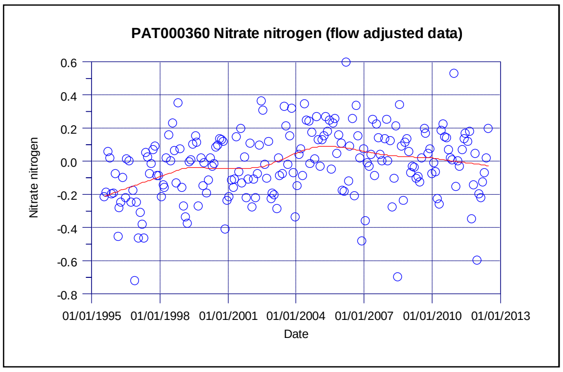
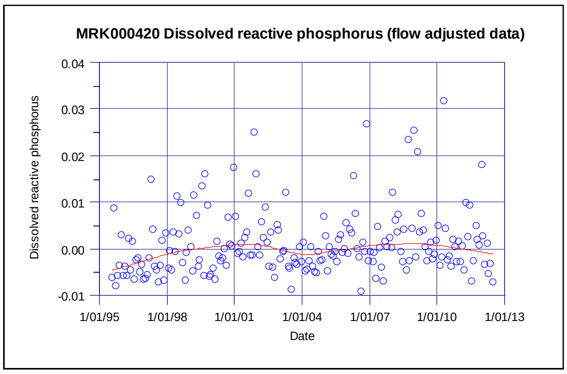
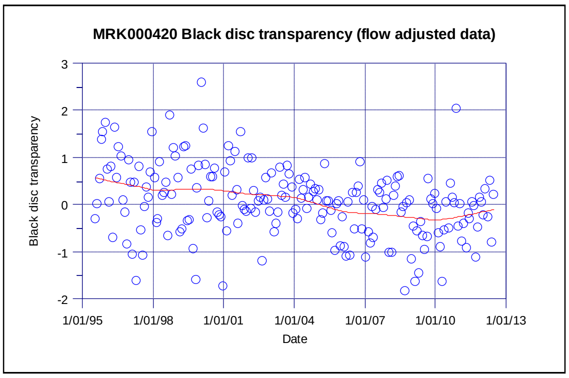
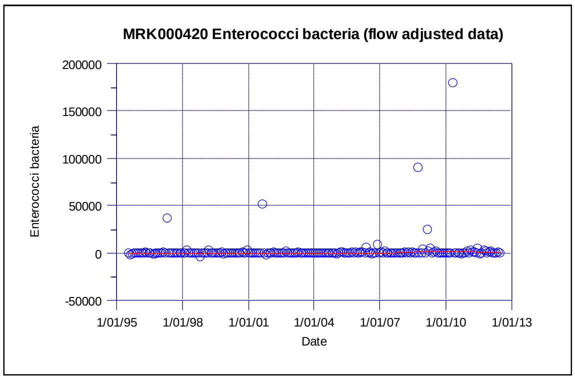


Figure 10 (Cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))









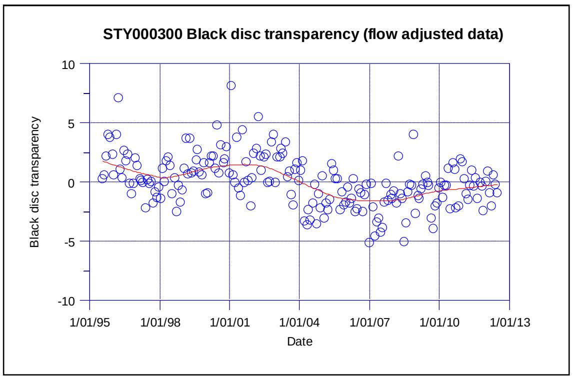


Figure 10 (Cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

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 2011 through to June 2012. 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 2011-2012 period, (in comparison with the previous sixteen year period), ranging from moderate freshes through to relatively low flow conditions but was characterised by more fresh events than typical during previous years. 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 16 years' data. It also provides an up-to-date statistical summary of the 17 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 mainly coincident with increased flows following 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 plating has been initiated in this reach.

During the 2011-2012 period, flows sampled were generally higher than typical of those sampled during the previous sixteen-year period for all but the Mangaehu catchment with median flows significantly higher over the latest period (by 6 to 64%), compared with the long-term sampled flow record. The eastern hill country catchment (Mangaehu River) median flow was slightly lower over the latest period (by 7%) compared with the long-term sampled flow record.

Table 41 Comparison of 2011-2012 water quality with previous long-term (1995-2011) 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	=	=	=	=	=	=	=	=	=	=	=	=	+320	17↑
Mangaoraka Stream at Corbett Road	=	=	x	✓	xx	xx	=	=	=	=	=	=	=	=	=	+559	49↑
Waiwhakaiho River at SH3	x	=	x	xx	x	xx	=	=	=	=	=	=	=	=	=	+1338	36↑
Stony River at Mangatete Road	xx	=	=	xx	xx	=	✓	✓	=	x	=	=	xx	=	xx	+1780	49↑
Punehu Stream at Wiremu Road	=	=	=	=	✓	=	✓✓	✓	=	=	=	=	=	=	=	+24	6↑
Punehu Stream at SH45	=	=	=	✓	xx	✓	=	=	xx	x	=	=	✓	=	=	+247	32↑
Waingongoro River at Eltham Road	x	=	x	✓	✓✓	=	x	=	=	=	=	=	x	=	x	+746	46↑
Waingongoro River at SH45	=	=	x	=	✓	x	=	=	✓	✓	=	=	=	=	=	+2101	45↑
Patea River at Barclay Road	x	=	=	xx	xx	=	✓✓	✓	✓	=	=	=	=	=	=	+137	64↑
Patea River at Skinner Road	x	=	=	=	=	=	=	=	✓	✓	=	=	=	=	=	+960	34↑
Mangaehu River at Raupuha Road	✓	=	=	x	✓	✓	=	✓	✓	✓	=	=	=	=	=	-518	7↓

[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 2011-2012 period (Table 41) showed poorer black disc clarity, but similar turbidity and suspended solids 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 lower maximum temperatures (in comparison with the longer period) during the 2011-2012 sampling period.

Median dissolved oxygen saturation and pH showed no significant differences in the latest period (Table 41), but BOD_5 concentrations rose slightly at five sites although they remained relatively low.

The majority of sites' median nutrient levels remained similar in the 2011-2012 period to these over the longer period, particularly the total nitrogen levels. A few improvements in median nutrient levels (dissolved reactive phosphorus at five sites (nitrate N at three sites, and total N at four sites)) were recorded. The Waingongoro River site in the lower reaches showed an improvement in two median nutrient levels coincident with the diversion of the major point source discharge (Eltham WWTP) out of the catchment. Limited deterioration was found in median total phosphorus (at two sites [Table 41]) and ammonia N (at three sites).

Bacteria numbers showed improvement at four sites in terms of median enterococci numbers although there was also some deterioration at five other sites during the 2011-2012 period. Three sites showed improvement in median faecal coliform bacteria numbers while four sites showed deterioration. This variable trend in bacteriological water quality during 2011-2012 probably reflected the more predominant sampling of freshes during the 2011-2012 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 although the Waingongoro River site in the lower reaches showed an improvement in two median nutrient levels coincident with the diversion of the major point source discharge (Eltham WWTP) out of the catchment.

A further trend assessment was performed upon ten TRC sites for the 1995-2012 period (including one site for the 1998-2012 period) and summarised in this Annual Report. This complements the reports prepared for the 1995 to 2008 period presented in TRC, 2009a and the period 1995 to 2009 presented in TRC, 2009. A significant improvement in aspects of temporal water quality (mainly nutrients) was found at the site in the lower Waingongoro River, subsequent to more recent reductions in waste loadings discharged to the river in mid catchment at Eltham.

6. Recommendations

1. THAT the freshwater physicochemical component of the SEM programme continue in a similar format for the 2012-2013 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 ten year (1995-2005) period (TRC, 2006a), the 1995-2009 period (TRC, 2009), and the 1995-2012 period (current report), be updated for the 1995-2013 period at the conclusion of the 2012-2013 year.

7. Acknowledgements

This programme's Job Manager is Chris Fowles (Scientific Officer) who was the principal author of the Annual Report. Statistical analyses were provided by Alex Connolly (Scientific Officer) with the majority of the field sample collection performed by Ray Harris and Amy Cameron (Technical Officers). All water quality analytical work was performed by the Taranaki Regional Council ISO-9000 accredited laboratory under the supervision of John Williams.

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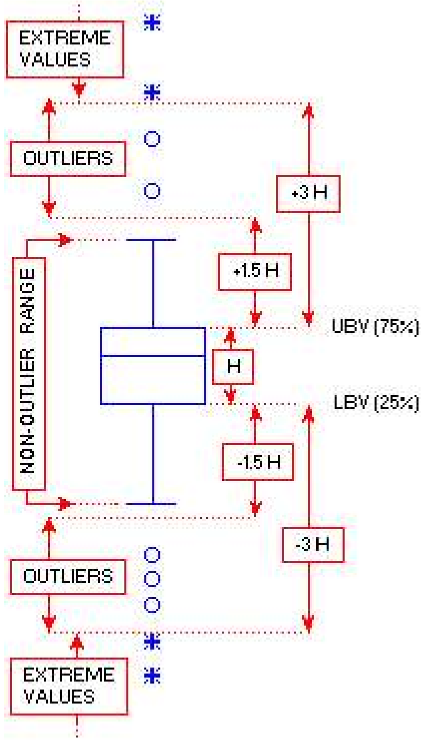
Appendix I

Statistical 'Box & Whisker' Plots of 1995-2012 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:

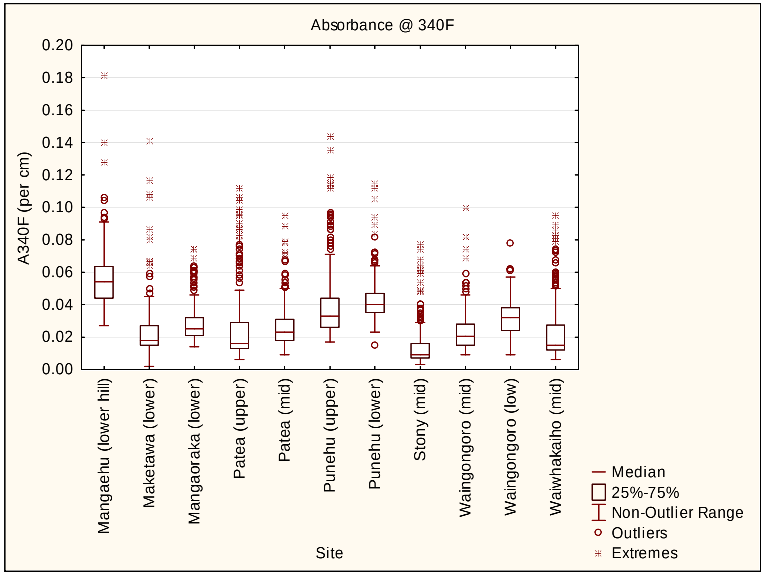
Lower fence = lower hinge - (3 x Hspread)
Upper fence = upper hinge + (3 x Hspread)

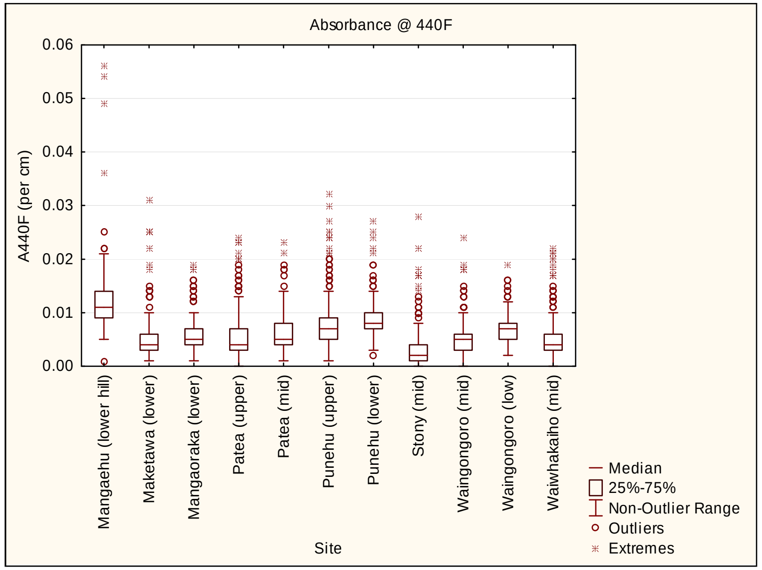
The whiskers show the range of values that lie within the inner fences. Values outside the inner fence are plotted as open circles (o). Values outside the outer fence are plotted as asterisks (*).

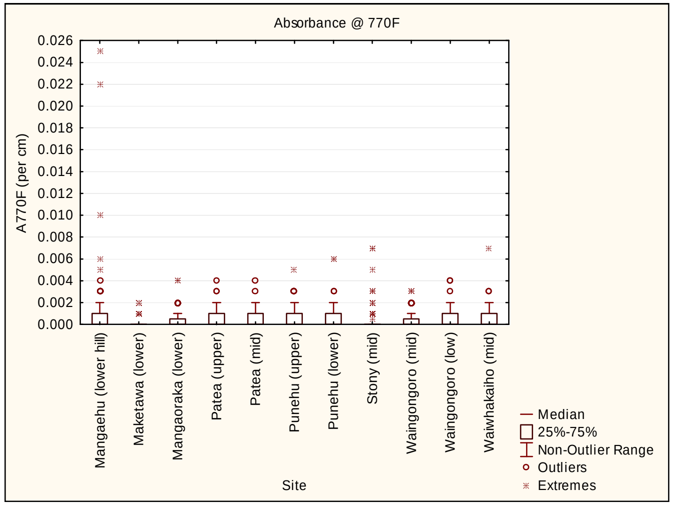
Site locations

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

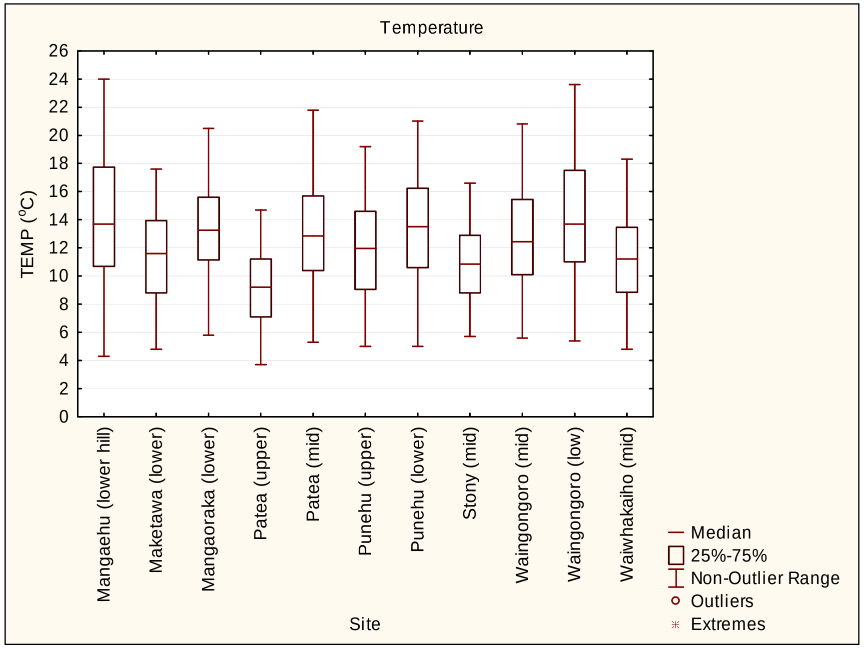
Absorbance (1 cm)

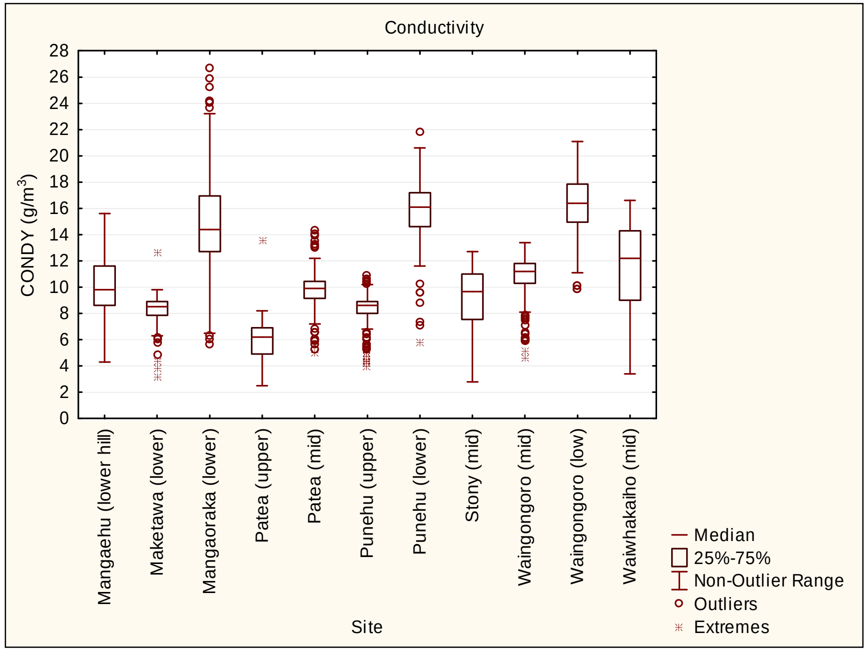


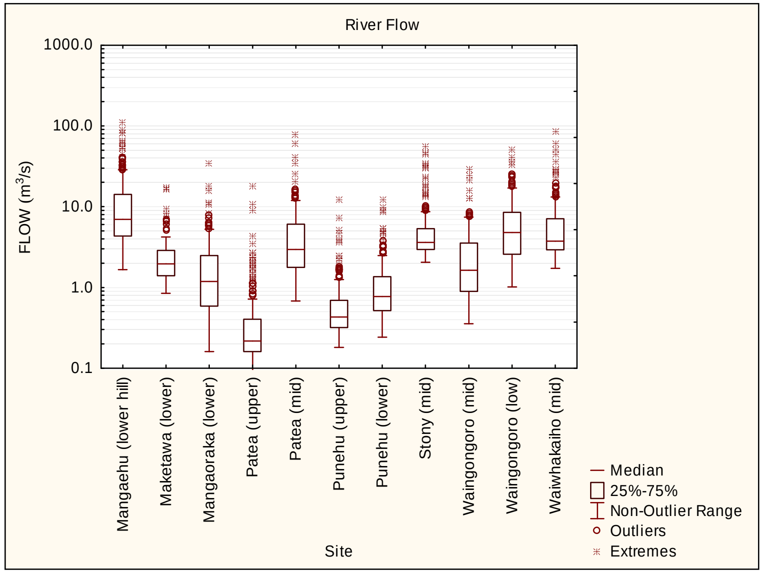


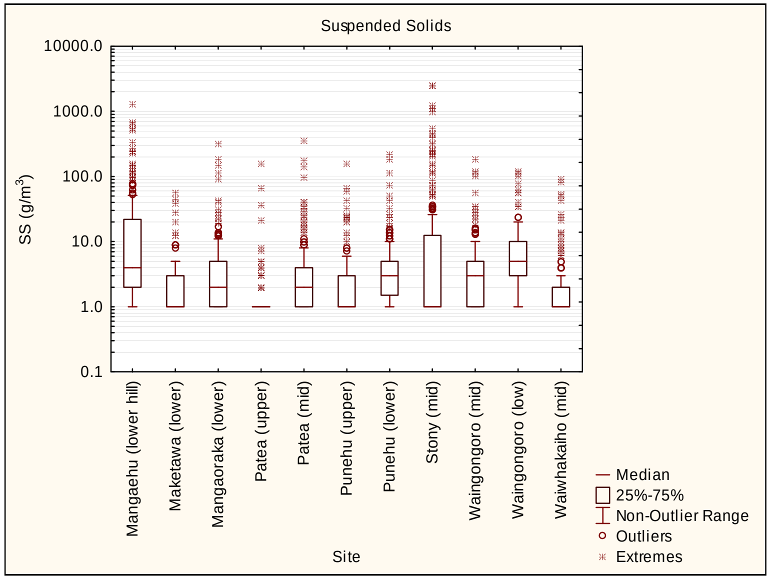


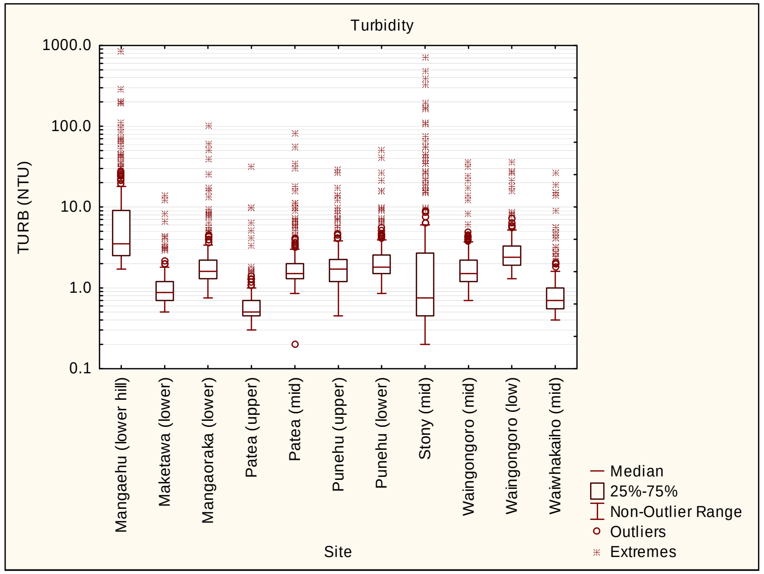
Physical Quality

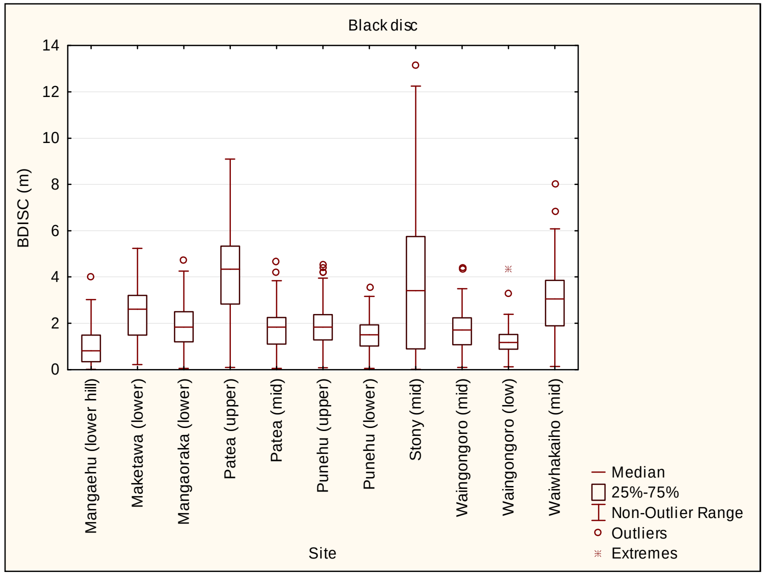


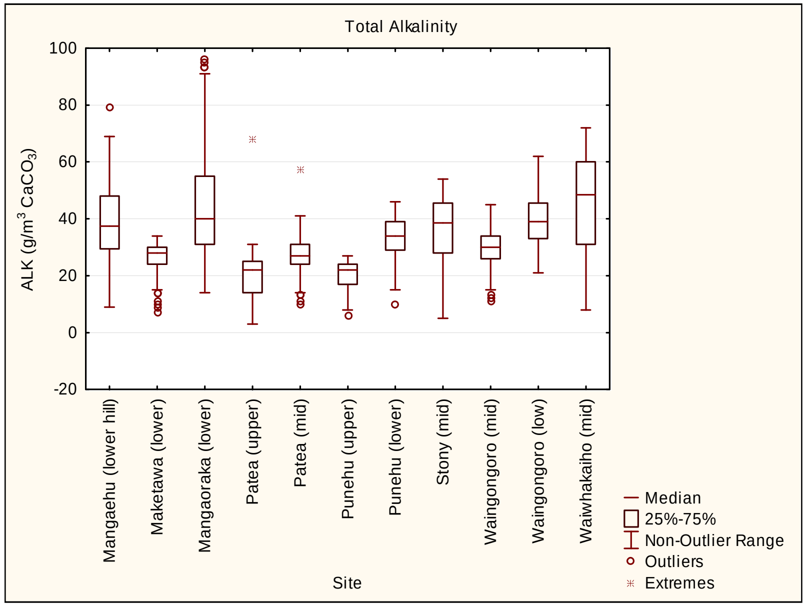


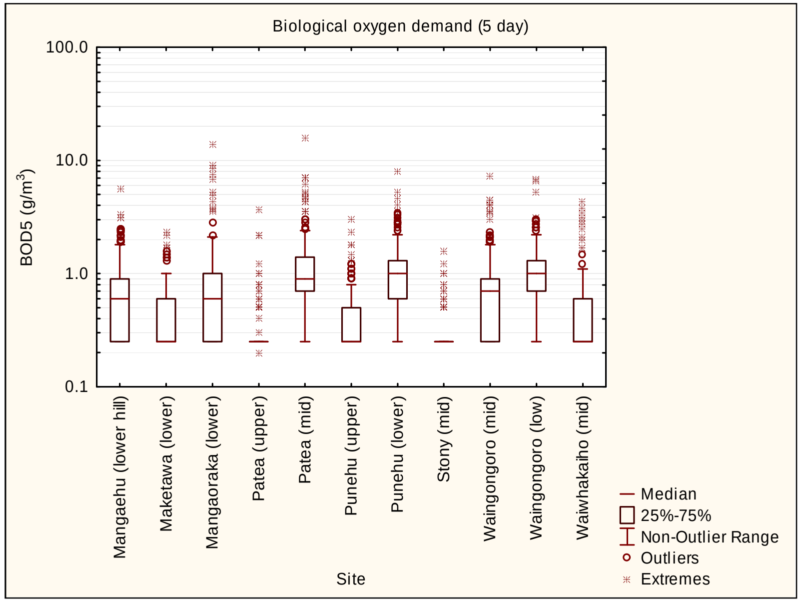

River Flow
FLOW (m3/s)
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

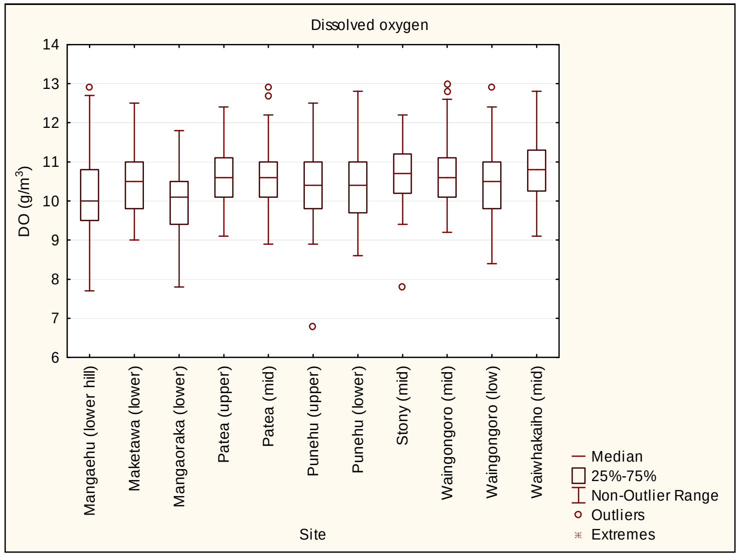

Suspended Solids
SS (g/m3)
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

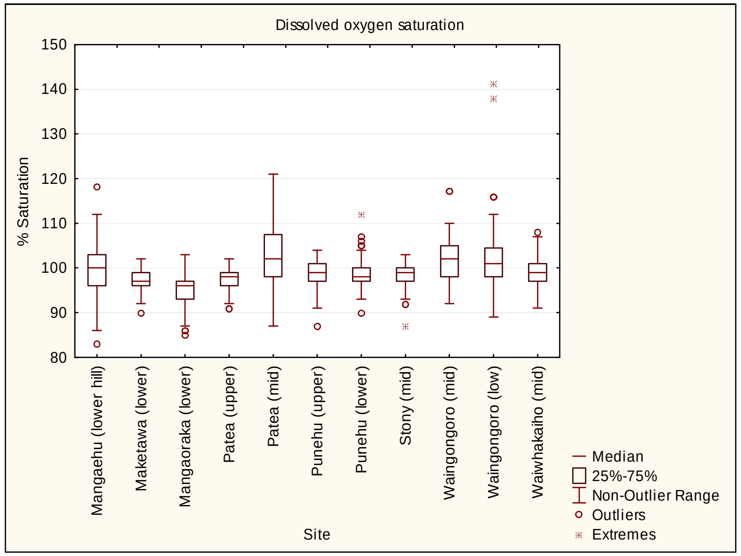

Turbidity
TURB (NTU)
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

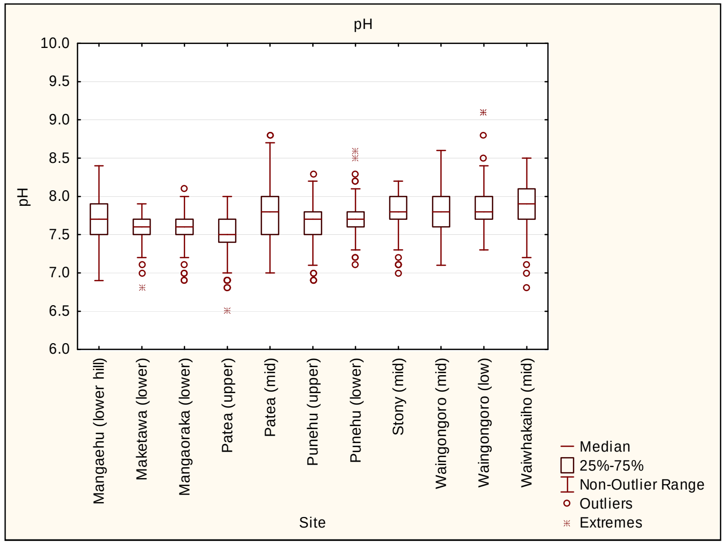

Black disc
BDISC (m)
14
12
10
8
6
4
2
0
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


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

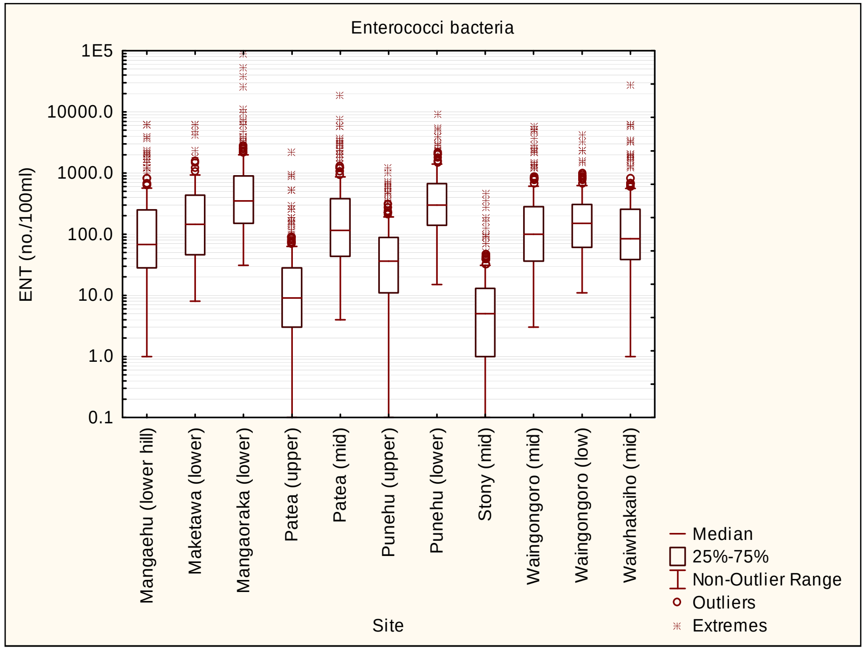

Biological oxygen demand (5 day)
BOD5 (g/m3)
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Wawhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Dissolved oxygen
DO (g/m3)
14
13
12
11
10
9
8
7
6
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

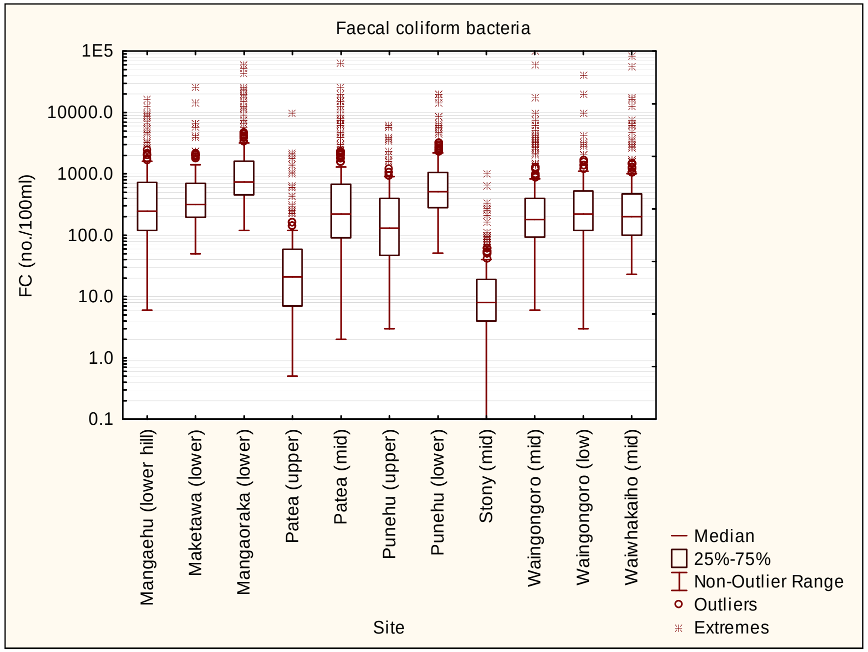

Dissolved oxygen saturation
% Saturation
150
140
130
120
110
100
90
80
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pH
pH
10.0
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

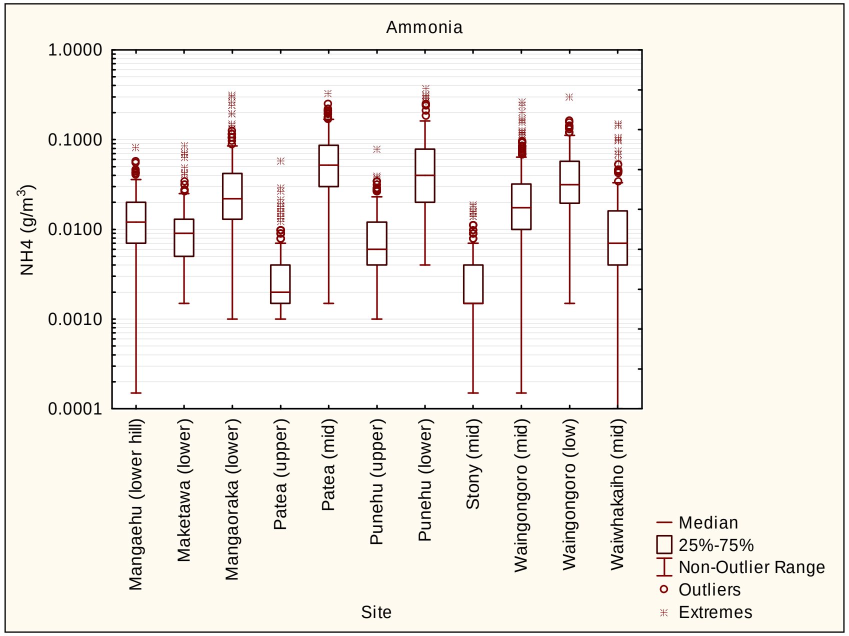


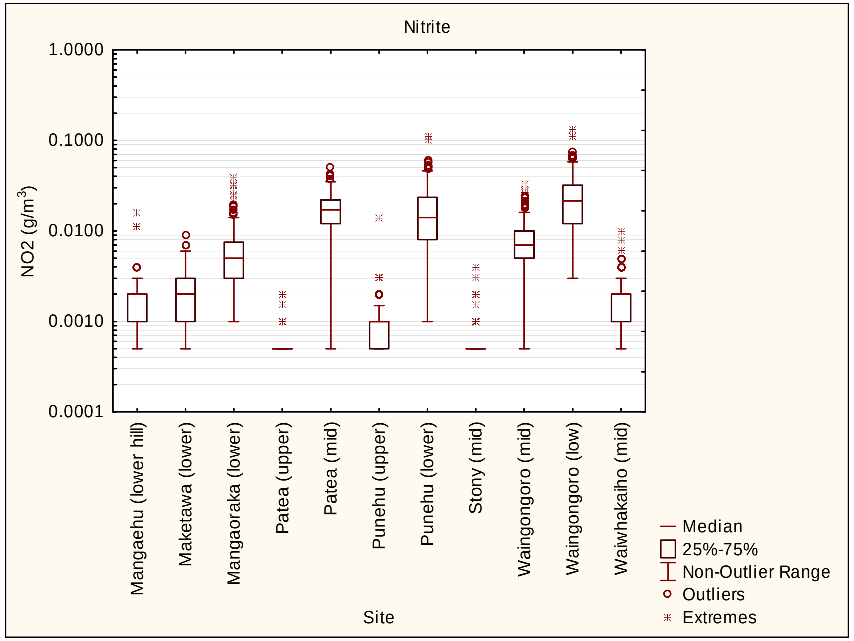
Enterococci bacteria
ENT (no./100ml)
1E5
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers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

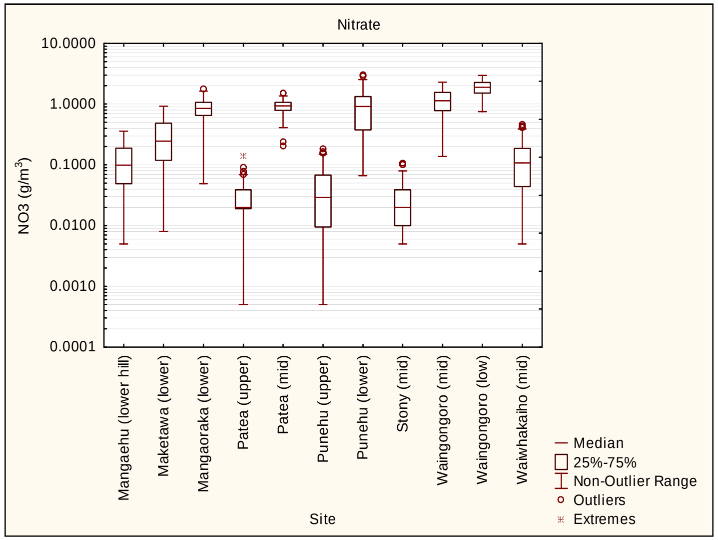


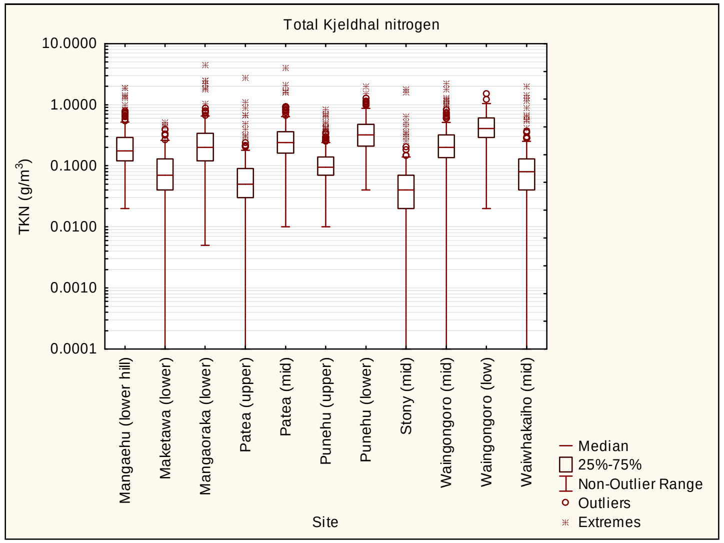
Faecal coliform bacteria
FC (no./100ml)
1E5
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers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

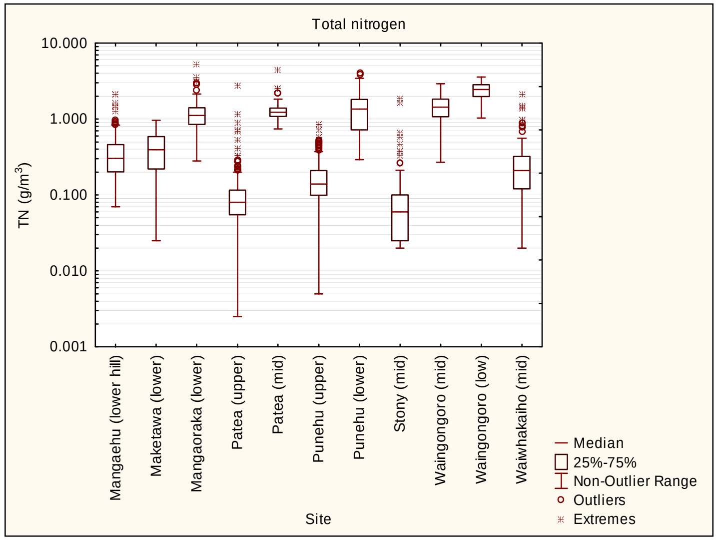
Nutrients

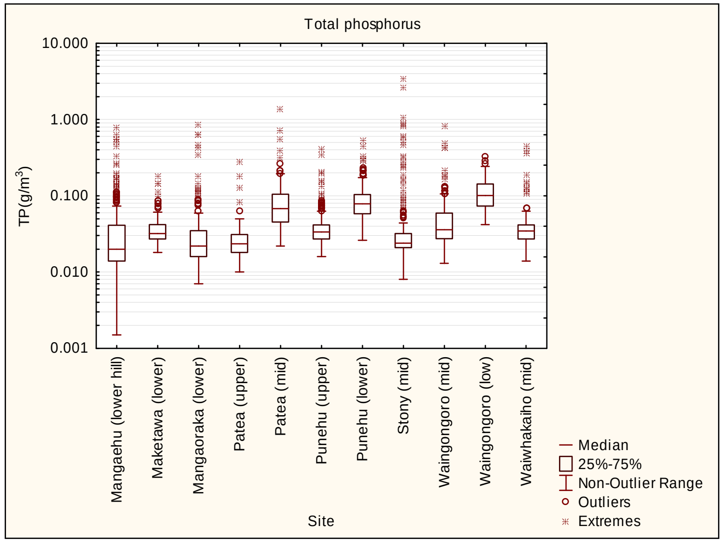

Ammonia
1.0000
0.1000
0.0100
0.0010
0.0001
NH4 (g/m3)
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

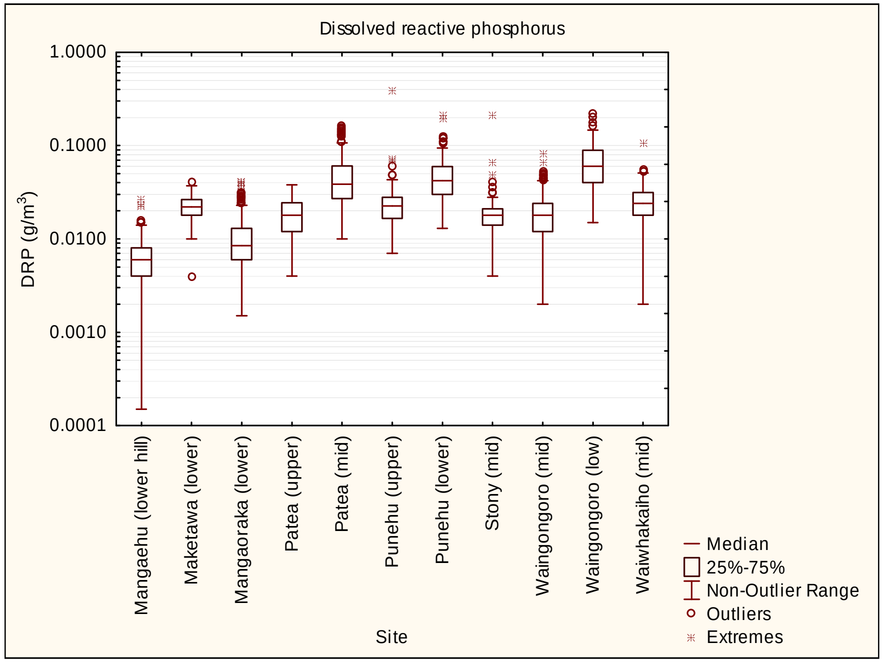

Nitrite
1.0000
0.1000
0.0100
0.0010
0.0001
NO2 (g/m3)
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


Nitrate
NO3 (g/m³)
10.0000
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)
10.0000
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 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 *ISSUE: 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

Policy One: 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.*

Policy Two: 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 2011-2012

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. The additional sample 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 2011-2012 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 2011 and June 2012.

First QC exercise

These split samples were collected from the Waingongoro River site at SH45 on 10 August 2011 under moderate low flow conditions (6.83 m^3/sec) and in fine weather conditions. Results are presented in Table 1.

Table 1 Results of SEM QC sampling on 10 August 2011

Site: WGG000900					
Date: 10 August 2011				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.023	0.022	2	✓
A440F	/cm	0.008	0.008	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	40	39	1	✓
BOD5	g/m^3	1.7	1.7	0	✓
CONDY	mS/m @ 20°C	18.4	18.4	0	✓
DO	g/m^3	11.5	11.4	<1	✓
DRP	g/m^3-P	0.038	0.036	3	✓
ENT	/100ml	20	20	0	✓
ECOL	/100ml	77	110	18	*
FC	/100ml	77	110	18	*
NH4	g/m^3-N	0.040	0.045	6	✓
NO2	g/m^3-N	0.09	0.039	0	✓
NO3	g/m^3-N	2.981	2.931	<1	✓
pH	pH	7.8	7.8	0	✓
SS	g/m^3	7	6	8	✓
TKN	g/m^3-N	0.29	0.36	11	*
TN	g/m^3-N	3.31	3.33	<1	✓
TP	g/m^3-P	0.055	0.056	<1	✓
TURB	NTU	3.1	3.1	0	✓

Comments:

The difference in TKN paired results was just outside the acceptable tolerance level for these samples. The differences between faecal coliform and *E.coli* bacterial counts for the paired samples were within acceptable tolerance levels for bacteriological samples (20%).

Overall results showed very good laboratory analytical precision performance, with 18 of 20 pairs of results being within the 10% guideline and 12 of these pairs showing < 1% difference in paired results.

Second QC exercise

These split samples were collected from the Punehu Stream site at SH45 on 8 November 2011 under moderate, slightly turbid flow (1.12 m^3/sec and fine overcast weather conditions. Results are presented in Table 2.

Table 2 Results of SEM QC sampling on 8 November 2011

Site: PNH000900					
Date: 8 November 2011				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.036	0.037	1	✓
A440F	/cm	0.008	0.008	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	38	38	0	✓
BOD5	g/m^3	1.4	1.4	0	✓
CONDY	mS/m @ 20°C	17.3	17.4	<1	✓
DO	g/m^3	10.3	10.3	0	✓
DRP	g/m^3-P	0.071	0.085	9	✓
ENT	/100ml	160	140	7	✓
ECOL	/100 ml	400	300	14	*
FC	/100ml	400	300	14	*
NH4	g/m^3-N	0.036	0.040	5	✓
NO2	g/m^3-N	0.025	0.025	0	✓
NO3	g/m^3-N	1.36	1.38	<1	✓
pH	pH	7.8	7.8	0	✓
SS	g/m^3	3	2	20	*
TKN	g/m^3-N	0.32	0.16	33	**
TN	g/m^3-N	1.70	1.56	4	✓
TP	g/m^3-P	0.096	0.102	3	✓
TURB	NTU	2.2	2.6	8	✓

Comments:

The differences in *E.coli* and faecal coliform bacterial counts were within acceptable tolerance levels for bacteriological samples (20%) but the TKN paired results were significantly different. None of these results were outliners in terms of the historical record for this site. The results for the paired suspended solids samples, although 20% different, were within 1 g/m^3, a very acceptable tolerance for this analytical method.

Otherwise, overall laboratory analytical precision performance was very good, with 16 of the 20 pairs of results recorded within the 10% guideline.

Third QC exercise

These split samples were collected from the site in the Waiwhakaiho River at SH3 on 8 February 2012 under clear, relatively low flow (3.36 m^3/sec), fine weather conditions. Results are presented in Table 3.

Table 3 Results of SEM QC sampling on 8 February 2012

Site: WKH000500					
Date: 8 February 2012				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.014	0.013	4	✓
A440F	/cm	0.003	0.003	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	51	52	<1	✓
BOD5	g/m^3	0.6	0.6	0	✓
CONDY	mS/m @ 20°C	12.6	12.9	1	✓
DRP	g/m^3-P	0.030	0.029	2	✓
ENT	/100ml	32	46	18	*
ECOL	/100ml	120	82	19	*
FC	/100ml	120	82	19	*
NH4	g/m^3-N	0.004	0.005	11	*
NO2	g/m^3-N	<0.001	<0.001	0	✓
NO3	g/m^3-N	0.06	0.06	0	✓
PH	pH	8.0	8.1	<1	✓
SS	g/m^3	<2	<2	0	✓
TKN	g/m^3-N	0.02	0.01	33	**
TN	g/m^3-N	0.08	0.07	7	✓
TP	g/m^3-P	0.035	0.034	1	✓
TURB	NTU	0.5	0.55	5	✓

Comments:

The differences in ammonia N and TKN paired results were outside the acceptable tolerance levels for samples which were very low in concentrations. The differences in all bacterial parameter counts were within acceptable tolerance levels for bacteriological samples (20%).

Otherwise 14 pairs of parameters analysed were within acceptable agreement, representing relatively good laboratory analytical precision for these samples.

Fourth QC exercise

These split samples were collected from the site in the Waingongoro River at SH45 on 9 May 2012 under slightly turbid, low flow (2.48 m^3/sec) but wet weather conditions. The results are presented in Table 4.

Table 4 Results of SEM QC sampling on 9 May 2012

Site: WGG000900					
Date: 9 May 2012				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.034	0.032	3	✓
A440F	/cm	0.008	0.008	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	46	46	0	✓
BOD5	g/m^3	0.9	0.9	0	✓
CONDY	mS/m @ 20°C	18.0	18.0	0	✓
DRP	g/m^3-P	0.046	0.044	2	✓
ENT	/100ml	90	92	1	✓
ECOL	/100ml	150	150	0	✓
FC	/100ml	170	150	6	✓
NH4	g/m^3-N	0.025	0.026	2	✓
NO2	g/m^3-N	0.010	0.010	0	✓
NO3	g/m^3-N	1.91	2.02	3	✓
PH	pH	7.9	7.8	<1	✓
SS	g/m^3	3	3	0	✓
TKN	g/m^3-N	0.20	0.07	48	**
TN	g/m^3-N	2.12	2.10	<1	✓
TP	g/m^3-P	0.069	0.068	<1	✓
TURB	NTU	2.0	2.1	2	✓

Comments:

The difference in TKN results (0.13 g/m^3 N) was statistically significant due to the difference between paired NO_3-N results (0.11 g/m^3) from which the TKN results were calculated.

Otherwise 18 of the 19 parameters' pairs of results were within the 10% guideline representing very good laboratory analytical precision.

Summary

Four split samples were collected and analysed during this one-year (2011-2012) 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	(93)	-	(7)	-	(0)	-	(0)
A440F	4	(70)	-	(19)	-	(7)	-	(3)
A770F	4	(76)	-	(0)	-	(10)	-	(13)
ALKT	4	(100)	-	(0)	-	(0)	-	(0)
BOD5	4	(87)	-	(12)	-	(0)	-	(1)
CONDY	4	(100)	-	(0)	-	(0)	-	(0)
DO	2	(100)	-	(0)	-	(0)	-	(0)
DRP	4	(93)	-	(6)	-	(0)	-	(1)
ENT	3	(48)	1	(21)	-	(25)	-	(6)
ECOL	1	(52)	3	(33)	-	(13)	-	(2)
FC	1	(52)	3	(31)	-	(13)	-	(3)
NH4	4	(81)	1	(10)	-	(6)	-	(3)
NO2	4	(96)	-	(3)	-	(1)	-	(0)
NO3	4	(85)	-	(6)	-	(7)	-	(2)
pH	4	(100)	-	(0)	-	(0)	-	(0)
SS	3	(88)	1	(9)	-	(3)	-	(0)
TKN	-	(45)	1	(23)	3	(26)	-	(6)
TN	4	(82)	1	(10)	-	(7)	-	(0)
TP	4	(84)	-	(7)	-	(6)	-	(3)
TURB	4	(97)	-	(2)	-	(2)	-	(0)

[NB: () = % of QC samples for 1995 to 2012 period]

This summary for the 2011-2012 period indicated:

- results from pairs of all three bacteriological species' samples were precise with no results falling outside the acceptable variability (20%) . This follows the historical trend for paired bacteriological analyses which have found at least 46% of the period's quality control samples within the 10% difference of the mean (for all three species), but 69% of samples within 20% of the mean for all species.
- TKN analytical variability greater than 10% was recorded on all occasions, 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 45% and 68% to date within 10% and 20% of the mean respectively.
- variability in split samples agreement for filtered absorbances at 340mm, 440mm, and 770 which had occurred occasionally, but almost entirely within equipment performance tolerance values, was not recorded over the 2011-2012 period.

In general, laboratory analytical performance has been acceptable, with very good precision of results shown for most 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 seventeen 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 intralab programme.

Appendix IV

SEM Physicochemical Programme
Inter-lab Quality Control Report 2011-2012

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.

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. Samples were collected from one of the three sites, on one occasion in the 2011-2012 year.

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 2011-2012 period on 21 February 2011. Sampling was performed during a low flow (10.3 m^3/sec), seven days after a flood flow (115 m^3/sec) in fine, overcast weather at the Waitara River site at Bertrand Road.

Results

2011-2012 exercise

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

Table 1 Results of SEM QC sampling by TRC & NIWA on 21 February 2012

WTR000800					
		Time: 0930		**Difference from mean (%)**	**Comments**
Parameter	Units	TRC	NIWA		
A340F	/cm	N/R	0.038	-	-
A440F	/cm	N/R	0.008	-	-
BDISC	m	1.45	1.09	13	*
CONDY	mS/m @ 20^{0}C	9.5	9.8	2	✓
DO	g/m^3	9.3	9.7	2	✓
DRP	g/m^3-P	0.009	0.005	29	**
ECOL	nos/100 ml	90	52	27	**
NH4	g/m^3-N	0.011	0.010	4	✓
NO3	g/m^3-N	0.21	0.22	2	✓
pH	pH	8.0	8.4	2	✓
TEMP	°C	20.6	20.5	<1	✓
TN	g/m^3-N	0.39	0.46	8	✓
TP	g/m^3-P	0.024	0.025	2	✓
TURB	NTU	1.60	2.05	12	*

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

Comments:

A significant difference in paired measurements between the two laboratories was recorded for turbidity, *E.coli,* and DRP. The difference in *E.coli* bacteria counts was also outside the acceptable variability (20%) for this parameter although the 95% confidence limit (72 per 100mls) of the NIWA count would have reduced this to an acceptable level (11%). Otherwise good analytical agreement was recorded for all other parameters.

Good operator field agreement was indicated by the similarity in the pairs of temperature and dissolved oxygen measurements, but a 13% difference in paired black disc measurements was larger than normally recorded and significant.

	Difference from mean of pairs of split samples							
Parameter ID	**<10%**		**10-20%**		**20-50%**		**>50%**	
A340F	-	(95)	-	(0)	-	(5)	-	(0)
A440F	-	(65)	-	(30)	-	(0)	-	(5)
CONDY	1	(91)	-	(4)	-	(0)	-	(4)
DO	1	(100)	-	(0)	-	(0)	-	(0)
DRP	-	(43)	-	(19)	1	(33)	-	(5)
ECOL	-	(0)	-	(50)	1	(50)	-	(0)
NH4	1	(32)	-	(23)	-	(18)	-	(27)
NO3	1	(91)	-	(9)	-	(0)	-	(0)
pH	1	(100)	-	(0)	-	(0)	-	(0)
TEMP	1	(100)	-	(0)	-	(0)	-	(0)
TN	1	(90)	-	(0)	-	(10)	-	(0)
TP	1	(55)	-	(30)	-	(15)	-	(0)
TURB	-	(41)	-	(45)	-	(14)	-	(0)

[NB: () - % of QC samples over the 1995 to 2012 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 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 was identified for DRP and further comparisons will be performed during future SEM programmes. Good field agreement was recorded for water temperature and dissolved oxygen measurements but the black disc measurements were not as precise as normally recorded in the past.

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