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 2010 to June 2011, under a narrower range of flow conditions ranging from moderate freshes to very low late spring and summer-autumn flows. This year was characterised by lower median flows sampled by the programme in all rivers and streams, except those southern catchments where median flows were up to 30% higher. 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 2010-2011 monitoring year, spring flows sampled were unseasonably lower than usual. In general terms, water quality was comparatively similar in clarity, turbidity, and suspended solids and improved particularly in median faecal coliform and also in enterococci bacteria numbers. Narrower temperature ranges, mainly due to lower maximum water temperatures, but similar median water temperatures, were measured in the 2010-2011 period compared with ranges and medians measured during the first fifteen years of the SEM programme. Median phosphorus species' levels were elevated at three sites and lower at two 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 nitrogen species levels were higher at up to five 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 1995-2011 period.

This report on the results of the 2010-2011 monitoring period also includes recommendations for the 2011-2012 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 2011 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 2009-2010 monitoring year, the fourteenth 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, and 2010-15.

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 landuses 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) during the 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.

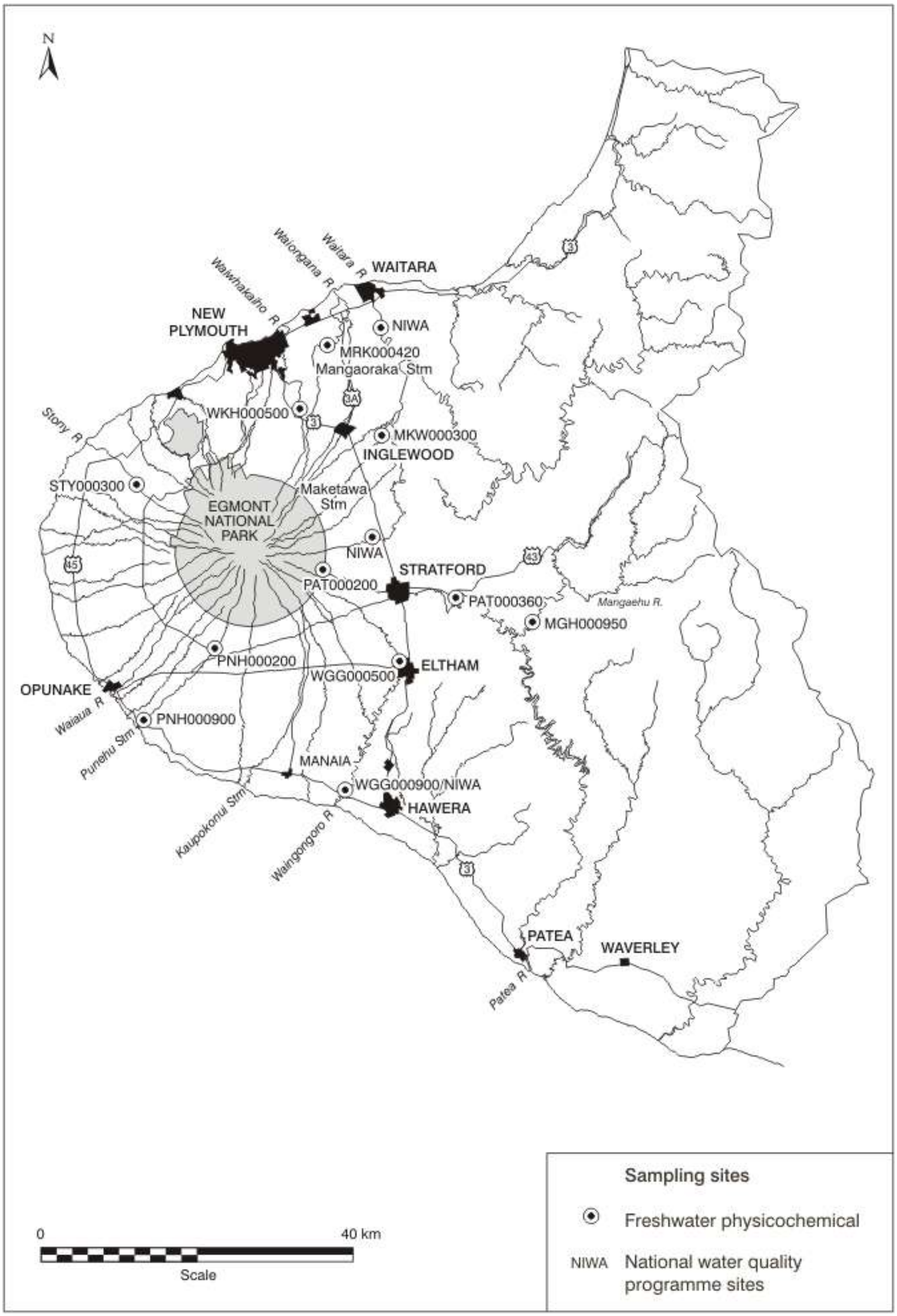

Figure 1 Freshwater physicochemical SEM sampling sites

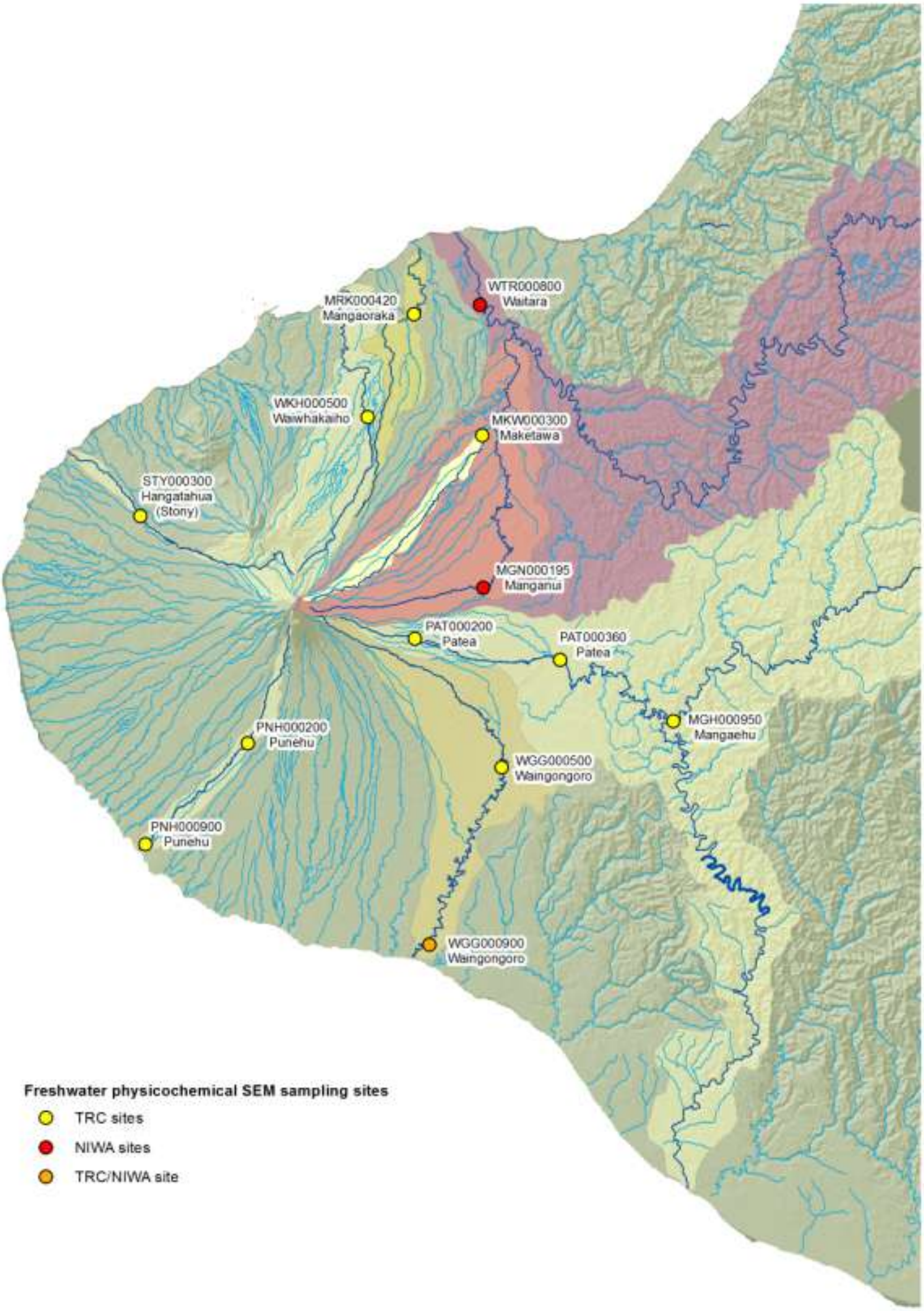

Figure 2 Freshwater physicochemical SEM sampling sites aerial map

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 particularly in the lower reaches of the catchment. 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 remains a NIWA hydrological recording station as a representative basin. 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.

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 LABSYS 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 2010 to June 2011 are presented for each of the eleven sites. Statistical summaries of this data and the cumulative data for nine sites (July 1995 to June 2011), one site in the lower Waingongoro River (July 1998 to June 2011), and one site in the lower Maketawa Stream (July 2003 to June 2011) are also presented on a site-by-site basis, together with a general discussion of water quality at each site. A comparison of water quality through the region is provided following the individual sites' discussions (Section 4.2).

4.1 Sites' water quality

Maketawa Stream at Tarata Road (site: MKW000300)

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

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

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ CaCO₃)	Black disc (m)	BOD_5 (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
14 July 10	0805	0.009	0.002	0.000	31	4.98	<0.5	9.0	12.5	99	0.023	120	23
11 Aug 10	0800	0.014	0.003	0.000	28	3.32	<0.5	8.9	11.8	100	0.019	230	27
8 Sept 10	0805	0.019	0.004	0.000	22	2.40	<0.5	7.7	11.1	99	0.016	300	120
13 Oct 10	0705	0.017	0.004	0.000	25	4.60	<0.5	7.6	11.6	100	0.020	300	31
10 Nov 10	0710	0.011	0.003	0.000	30	5.23	0.5	8.5	10.7	101	0.022	160	25
8 Dec 10	0700	0.017	0.004	0.001	32	3.21	0.5	8.8	9.8	98	0.037	190	110
12 Jan 11	0705	0.016	0.004	0.000	32	2.69	0.5	8.9	9.8	100	0.025	160	310
9 Feb 11	0700	0.067	0.014	0.001	23	1.56	0.6	7.3	9.7	98	0.019	620	1200
9 Mar 11	0700	0.020	0.005	0.000	27	2.11	<0.5	8.5	10.3	98	0.017	200	260
14 Apr 11	0805	0.018	0.003	0.000	32	2.10	0.5	9.3	10.3	100	0.022	410	470
13 May 11	0755	0.040	0.008	0.000	22	0.95	0.9	7.4	9.7	97	0.028	1100	300
8 June 11	0805	0.059	0.013	0.001	16	0.59	1.4	6.2	10.6	98	0.033	2400	1600

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)
14 July 10	0805	120	1.356	0.004	<0.001	0.299	7.6	<2	4.8	0.16	0.46	0.057	0.7
11 Aug 10	0800	230	2.372	0.010	0.002	0.538	7.6	<2	7.5	0.04	0.58	0.022	0.9
8 Sept 10	0805	320	4.222	0.018	0.002	0.638	7.5	<2	9.6	0.04	0.68	0.024	1.2
13 Oct 10	0705	300	2.421	0.004	0.002	0.248	7.6	<2	8.0	0.05	0.30	0.024	0.7
10 Nov 10	0710	160	1.359	0.005	<0.001	0.029	7.6	<2	12.0	0.04	0.07	0.026	0.5
8 Dec 10	0700	200	0.915	0.009	<0.001	0.019	7.7	<2	14.3	0.08	0.10	0.043	0.5
12 Jan 11	0705	170	1.219	0.005	0.002	0.118	7.4	<2	15.4	0.04	0.16	0.028	0.6
9 Feb 11	0700	640	2.133	0.010	0.002	0.198	7.6	<2	15.1	0.09	0.29	0.029	0.9
9 Mar 11	0700	200	2.068	0.011	0.002	0.358	7.7	4	12.4	0.02	0.38	0.034	1.1
14 Apr 11	0805	410	1.310	0.005	0.001	0.119	7.7	<2	13.2	0.07	0.19	0.036	0.8
13 May 11	0755	1100	5.295	0.068	0.009	0.65	7.3	12	14.3	0.23	0.89	0.086	2.9
8 June 11	0805	2400	6.595	0.087	0.007	0.49	7.3	14	11.2	0.43	0.93	0.086	4.2

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

Table 4 Statistical summary of data from July 2010 to June 2011: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.67	0.018	12	0.019
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.014	0.004	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m³ $CaCO_3$	16	32	28	12	5
BLACK DISC	Black disc transparency	m	0.59	5.23	2.55	12	1.52
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	1.4	0.5	12	0.3
CONDY	Conductivity @ 20°C	mS/m	6.2	9.3	8.5	12	0.9
DO	Dissolved oxygen	g/m³	9.7	12.5	10.5	12	0.92
PERSAT	Dissolved oxygen saturation	%	97	101	99	12	1.2
DRP	Dissolved reactive phosphorus	g/m³P	0.016	0.037	0.022	12	0.006
ECOL	E. coli bacteria	nos/100 ml	120	2400	265	12	654
ENT	Enterococci bacteria	nos/100 ml	23	1600	190	12	508
FC	Faecal coliform bacteria	nos/100 ml	120	2400	265	12	653
FLOW	Flow	m³/s	0.915	6.595	2.091	12	1.808
NH_4	Ammoniacal nitrogen	g/m³N	0.004	0.087	0.010	12	0.028
NO_2	Nitrite nitrogen	g/m³N	0.001	0.009	0.002	12	0.003
NO_3	Nitrate nitrogen	g/m³N	0.02	0.65	0.27	12	0.226
pH	pH		7.3	7.7	7.6	12	0.14
SS	Suspended solids	g/m³	<2	14	<2	12	4
TEMP	Temperature	°C	4.8	15.4	12.2	12	3.4
TKN	Total kjeldahl nitrogen	g/m³N	0.02	0.43	0.06	12	0.12
TN	Total nitrogen	g/m³N	0.07	0.93	0.34	12	0.295
TP	Total phosphorus	g/m³P	0.022	0.086	0.032	12	0.023
TURB	Turbidity	NTU	0.5	4.2	0.8	12	1.13

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

Table 5 Statistical summary of data from July 2003 to June 2011: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.141	0.018	96	0.024
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.031	0.004	96	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	96	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	7	34	28	96	6
BLACK DISC	Black disc transparency	m	0.23	5.23	2.58	96	1.11
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	2.3	<0.5	96	0.4
CONDY	Conductivity @ 20°C	mS/m	3.2	12.6	8.5	96	15
DO	Dissolved oxygen	g/m³	9.0	12.5	10.5	35	0.78
PERSAT	Dissolved oxygen saturation	%	90	102	97	96	2.3
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.040	0.022	96	0.007
ECOL	E. coli bacteria	nos/100 ml	50	26000	300	96	3105
ENT	Enterococci bacteria	nos/100 ml	8	6300	145	96	1122
FC	Faecal coliform bacteria	nos/100 ml	50	26000	305	96	3113
FLOW	Flow	m³/s	0.846	17.200	1.924	96	2.252
NH_4	Ammoniacal nitrogen	g/m³N	0.003	0.087	0.010	96	0.015
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.009	0.002	96	0.002
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.92	0.25	96	0.221
pH	pH		6.8	7.9	7.6	96	0.18
SS	Suspended solids	g/m³	<2	44	2	96	7
TEMP	Temperature	°C	4.8	17.6	11.4	96	3.30
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	0.52	0.07	96	0.10
TN	Total nitrogen	g/m³N	0.05	0.96	0.39	96	0.230
TP	Total phosphorus	g/m³P	0.018	0.180	0.032	96	0.025
TURB	Turbidity	NTU	0.5	12	0.9	96	1.63

Discussion

2010-2011 period

Good aesthetic water quality was indicated by a median black disc clarity of 2.55 metres, in the lower reaches of this ring-plain stream prior to its confluence with the Manganui River. The maximum clarity (black disc value of 5.23 m) was recorded in late spring under relatively low flow conditions (1.36 m^3/s). An elevation in turbidity (to 4.2 NTU) and in suspended solids concentration (14 g/m^3) under fresh flow conditions (6.6 m^3/sec) was sampled toward the end of the period. Poorer water quality conditions apparent at the time of this fresh flow were recorded with increases in bacterial number (2400 faecal coliforms/100ml) and BOD_5 (1.4 g/m^3) recorded in mid winter when black disc visibility decreased to 0.59 m.

pH was relatively stable (7.3 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: 0.5 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 265 and 190 (per 100 mls) respectively. Water temperature varied over a moderate range of 10.6°C with a maximum late summer (early morning) river temperature of 15.4°C recorded in January 2011.

Brief comparison with the previous 2003-2010 (seven year) period

Generally, stream water quality at this site during the 2010-2011 period was very similar in appearance/clarity (lower median black disc clarity (by only 0.03 m), lower median turbidity (by only 0.1 NTU), and no difference in median suspended solids level). Bacterial water quality was also relatively similar, with a moderate decrease in median faecal coliform number of 50 per 100 mls but an increase in median enterococci number of 45 per 100 mls. Median water temperature was higher (by 1.3°C), while the maximum water temperature (15.4°C) was 2.2°C lower than the previous maximum recorded. Other physicochemical aspects of water quality were very similar for the two periods. Moderate ranges for parameters such as suspended solids, turbidity, pH and total phosphorus reflected the smaller flood events sampled during the 2010-2011 period. Median flow sampled during 2010-2011 was higher (by about 200 L/sec) than the median of flows sampled over the previous seven-year period due in part to higher base conditions sampled during the latest period. Median pH values were identical and the maximum pH value was within 0.2 unit of that of the past seven-year record. With the exception of total nitrogen (TN), all other nutrient species showed minimal differences in median values during the monitoring year in comparison with the previous seven-year record. Median TN in 2010-2011 was 0.06 g/m^3 lower than the historical median.

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)
14 July 10	0835	0.021	0.004	0.000	44	1.53	<0.5	15.6	11.8	98	0.007	140	40
11 Aug 10	0830	0.019	0.004	0.000	33	1.92	<0.5	12.7	11.3	100	0.006	170	42
8 Sept 10	0835	0.023	0.005	0.000	26	1.02	0.5	11.4	11.2	103	0.015	690	200
13 Oct 10	0740	0.026	0.005	0.000	39	2.03	0.7	14.2	11.0	97	0.009	680	100
10 Nov 10	0740	0.025	0.005	0.000	66	4.26	1.1	20.4	10.7	103	0.005	930	200
8 Dec 10	0730	0.032	0.007	0.000	93	1.84	1.7	25.9	9.2	94	0.009	2400	2500
12 Jan 11	0735	0.025	0.006	0.000	63	2.23	0.8	18.6	9.5	98	0.005	730	620
9 Feb 11	0735	0.059	0.012	0.001	56	1.31	1.8	18.1	8.9	93	0.009	2300	3600
9 Mar 11	0730	0.021	0.005	0.000	41	1.60	0.9	14.4	9.9	96	0.004	1100	870
14 Apr 11	0835	0.025	0.005	0.000	59	1.26	1.0	18.3	9.5	93	0.018	1600	1400
13 May 11	0835	0.029	0.006	0.000	28	0.92	1.0	11.5	9.4	95	0.014	870	360
8 June 11	0845	0.039	0.008	0.000	27	0.46	2.8	11.1	10.1	96	0.023	4700	6100

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)
14 July 10	0835	140	0.965	0.041	0.003	1.097	7.6	2	7.1	0.08	1.18	0.019	1.6
11 Aug 10	0830	200	2.569	0.023	0.003	1.077	7.4	4	9.7	0.18	1.26	0.010	1.5
8 Sept 10	0835	710	5.229	0.042	0.004	1.116	7.4	8	11.2	0.24	1.36	0.026	2.5
13 Oct 10	0740	680	1.254	0.104	0.005	0.965	7.6	2	9.7	0.37	1.34	0.017	1.2
10 Nov 10	0740	930	0.380	0.104	0.017	0.583	7.8	2	13.4	0.31	0.91	0.015	1.3
8 Dec 10	0730	2400	0.181	0.085	0.039	0.541	7.8	<2	16.0	0.17	0.75	0.020	1.7
12 Jan 11	0735	740	0.408	0.028	0.011	0.469	7.9	<2	16.5	0.20	0.68	0.010	1.3
9 Feb 11	0735	2300	0.732	0.076	0.028	0.922	7.6	5	17.0	0.40	1.35	0.057	2.6
9 Mar 11	0730	1200	1.187	0.042	0.006	0.744	7.7	3	13.4	0.09	0.84	0.025	1.5
14 Apr 11	0835	1600	0.516	0.044	0.010	0.540	7.6	<2	14.0	0.14	0.69	0.030	1.4
13 May 11	0835	870	4.169	0.032	0.010	1.010	7.3	7	15.6	0.30	1.32	0.057	2.2
8 June 11	0845	5700	5.718	0.099	0.012	1.028	7.3	28	12.9	1.05	2.09	0.182	9.2

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

Table 7 Statistical summary of data from July 2010 to June 2011:Mangaoraka Stream at Corbett Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.019	0.059	0.025	12	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.004	0.012	0.005	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m³ $CaCO_3$	26	93	43	12	20
BLACK DISC	Black disc transparency	m	0.46	4.26	1.57	12	0.95
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	2.8	1.0	12	0.7
CONDY	Conductivity @ 20°C	mS/m	11.1	25.9	15.0	12	4.4
DO	Dissolved oxygen	g/m³	8.9	11.8	10.0	12	0.96
PERSAT	Dissolved oxygen saturation	%	93	103	97	12	3.4
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.023	0.009	12	0.006
ECOL	E. coli bacteria	nos/100 ml	140	4700	900	12	1275
ENT	Enterococci bacteria	nos/100 ml	40	6100	480	12	1867
FC	Faecal coliform bacteria	nos/100 ml	140	5700	900	12	1517
FLOW	Flow	m³/s	0.181	5.718	1.076	12	1.996
NH_4	Ammoniacal nitrogen	g/m³N	0.023	0.104	0.043	12	0.031
NO_2	Nitrite nitrogen	g/m³N	0.003	0.039	0.010	12	0.011
NO_3	Nitrate nitrogen	g/m³N	0.47	1.12	0.94	12	0.25
pH	pH		7.3	7.9	7.6	12	0.20
SS	Suspended solids	g/m³	<2	28	3	12	7
TEMP	Temperature	°C	7.1	17.0	13.4	12	3.1
TKN	Total kjeldahl nitrogen	g/m³N	0.08	1.05	0.22	12	0.26
TN	Total nitrogen	g/m³N	0.68	2.09	1.22	12	0.40
TP	Total phosphorus	g/m³P	0.010	0.182	0.023	12	0.048
TURB	Turbidity	NTU	1.2	9.2	1.6	12	2.21

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

Table 8 Statistical summary of data from July 1995 to June 2011: Mangaoraka Stream at Corbett Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.014	0.074	0.025	192	0.012
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.019	0.005	192	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	192	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	14	96	41	192	18
BLACK DISC	Black disc transparency	m	0.055	4.73	1.85	192	0.94
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	14.0	0.6	192	1.5
CONDY	Conductivity @ 20°C	mS/m	5.6	26.7	14.5	192	3.7
DO	Dissolved oxygen	g/m³	7.8	11.8	10.1	192	0.84
PERSAT	Dissolved oxygen saturation	%	83	107	96	192	3.8
DRP	Dissolved reactive phosphorus	g/m³P	<0.003	0.041	0.009	192	0.008
ECOL	E. coli bacteria	nos/100 ml	120	60000	755	168	7955
ENT	Enterococci bacteria	nos/100 ml	31	180000	340	192	15239
FC	Faecal coliform bacteria	nos/100 ml	120	60000	745	192	8579
FLOW	Flow	m³/s	0.160	34.100	1.152	192	3.331
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.308	0.021	192	0.051
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.039	0.005	192	0.006
NO_3	Nitrate nitrogen	g/m³N	0.05	1.73	0.85	192	0.32
pH	pH		6.9	8.1	7.6	192	0.21
SS	Suspended solids	g/m³	<2	310	2	192	30
TEMP	Temperature	°C	5.8	20.5	13.1	192	3.0
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	4.46	0.20	192	0.48
TN	Total nitrogen	g/m³N	0.28	5.18	1.12	192	0.56
TP	Total phosphorus	g/m³P	0.007	0.860	0.022	192	0.101
TURB	Turbidity	NTU	0.75	100	1.6	191	9.56

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.

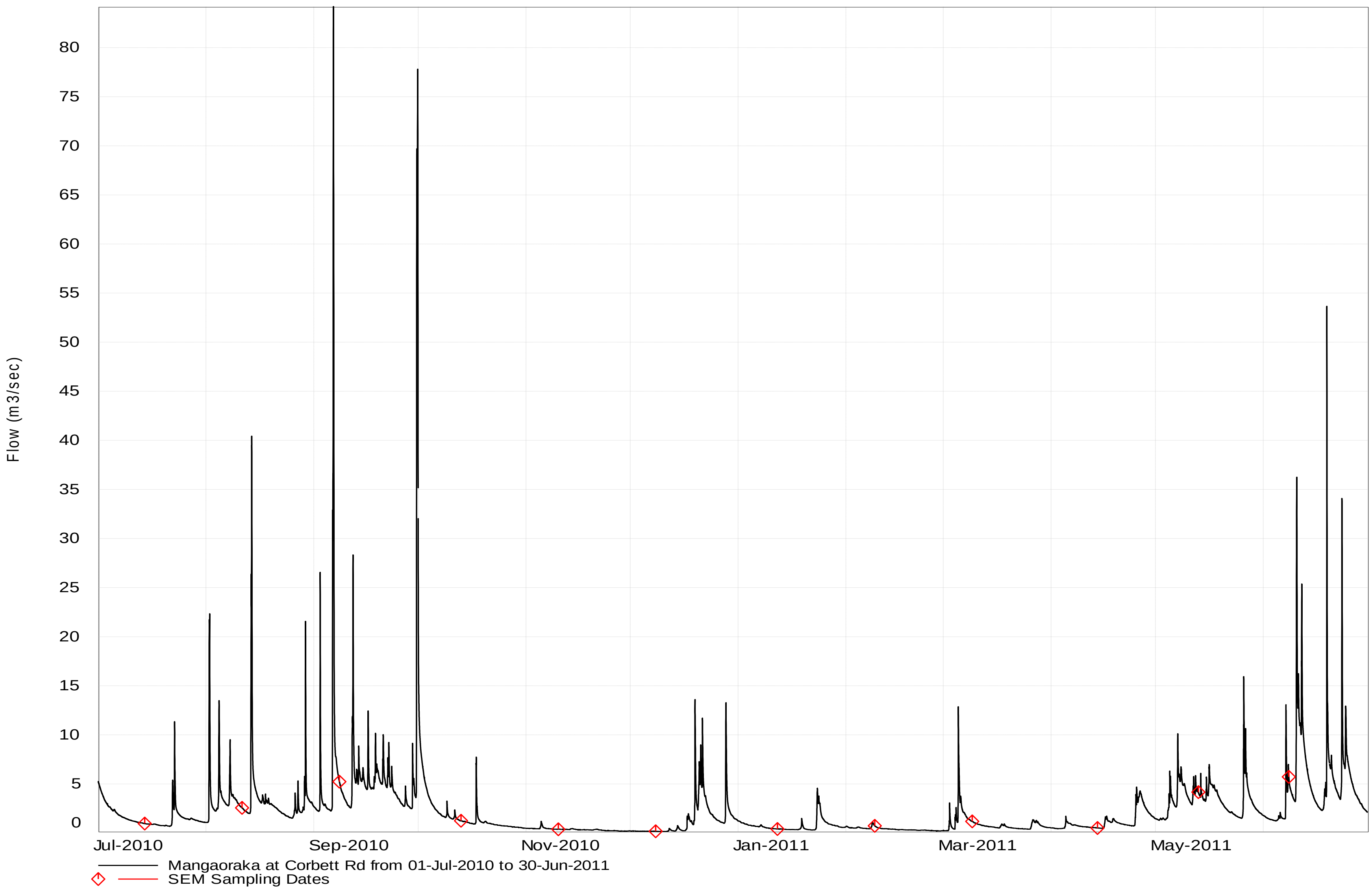

Figure 3 Flow record for the Mangaoraka Stream at Corbett Road

Discussion

2009-2011 period

Black disc clarity and turbidity results continued to indicate a reasonable standard of aesthetic water quality for the lower reaches of a developed, agricultural catchment although it is noted that turbidity levels were slightly higher (minimum: 1.2 NTU; median: 1.6 NTU) than might be expected given the concentration of suspended solids (minimum: <2 g/m^3; median: 3 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 moderate maximum black disc value of 4.26 m coincided with late spring, relatively low recession flow conditions, while the poorest turbidity conditions (9.2 NTU and 0.46 m black disc) were recorded during a fresh in June 2011 when a suspended sediment concentration of 28 g/m^3, BOD_5 of 2.8 g/m^3, and faecal coliform number of 5700 per 100 mls were measured. Most parameters indicated poorest water quality during this fresh, with elevated bacterial numbers and total phosphorus levels in particular. However, poor bacteriological water quality and an elevated BOD_5 concentration was also recorded in December 2010 when sampling coincided with very low flow conditions (Figure 3).

Relatively few freshes during mid-summer to autumn coincided with slightly elevated pH values (7.6 to 7.9) 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 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 (490 enterococci and 900 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 9.9°C with a maximum (mid-morning) temperature of 17.0°C in February 2011 (coincident with 93% dissolved oxygen saturation and pH of 7.6) during moderately low flow conditions at that time. Dissolved oxygen saturation did not fall below 90% during the period.

Brief comparison with the previous 1995-2010 period

Aesthetic stream water quality at this site during the 2010-2011 period was slightly more turbid [lower median black disc clarity (by 0.32 m) and higher median suspended solids level (by 1 g/m^3) although median turbidity remained the same]. Bacterial water quality was poorer as reflected in an increase in median faecal coliform number of 165 per 100 mls and an increase in the median enterococci number of 150 per 100 mls. Median water temperatures were similar while the maximum water temperature (17.0°C) was 3.5°C lower than the previous maximum recorded.

Median conductivity (and alkalinity) were slightly higher and probably reflected the proportionately higher incidence of low flow conditions sampled during the latest period. This was reflected in the median flow sampled during 2010-2011 which was slightly lower (by 76 L/sec) than the median of flows sampled over the previous fifteen-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 2010-2011 period (Figure 3), rather than high floods (or rising flows) occasionally sampled in the past.. Median pH values were identical but maximum pH was 0.2 unit lower than the past record. Most nutrient species had relatively similar or slightly higher median values during the monitoring year in comparison with the previous fifteen-year record with the exception of median ammoniacal nitrogen which was more than 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^3P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
14 July 10	0900	0.006	0.001	0.000	64	3.68	<0.5	15.3	12.8	102	0.036	26	16
11 Aug 10	0900	0.014	0.003	0.000	45	2.23	<0.5	11.8	12.1	102	0.023	73	15
8 Sept 10	0905	0.018	0.004	0.000	30	3.22	<0.5	8.8	11.1	98	0.014	230	74
13 Oct 10	0810	0.012	0.003	0.000	40	3.55	<0.5	10.4	11.8	101	0.024	210	52
10 Nov 10	0820	0.007	0.002	0.000	61	5.65	0.6	14.7	11.4	106	0.041	68	15
8 Dec 10	0800	0.013	0.003	0.000	68	2.84	<0.5	15.6	10.1	100	0.056	150	76
12 Jan 11	0805	0.009	0.003	0.000	63	3.34	<0.5	14.9	10.2	103	0.043	140	83
9 Feb 11	0805	0.044	0.010	0.000	35	2.19	0.6	9.5	10.0	101	0.018	260	360
9 Mar 11	0800	0.012	0.004	0.000	49	2.60	<0.5	13.1	10.6	99	0.022	100	110
14 Apr 11	0915	0.013	0.003	0.000	64	2.95	0.6	15.3	11.1	106	0.033	180	88
13 May 11	0905	0.033	0.007	0.000	28	1.73	0.7	8.0	9.8	97	0.027	490	140
8 June 11	0920	0.050	0.010	0.001	17	1.05	0.6	6.3	10.7	99	0.019	1100	270

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)
14 July 10	0900	26	2.345	<0.003	<0.001	0.129	8.0	<2	4.8	0.03	0.16	0.040	0.65
11 Aug 10	0900	74	3.723	0.007	<0.001	0.289	7.8	<2	7.0	0.01	0.30	0.027	0.6
8 Sept 10	0905	230	7.002	0.014	0.001	0.279	7.7	<2	9.1	0.03	0.31	0.018	0.7
13 Oct 10	0810	220	4.59	0.005	0.001	0.089	7.9	<2	7.7	0.07	0.16	0.024	0.5
10 Nov 10	0820	70	2.399	0.004	<0.001	0.019	8.1	<2	11.2	0.04	0.06	0.042	0.4
8 Dec 10	0800	150	1.718	0.009	0.001	0.019	8.1	<2	13.9	0.09	0.11	0.062	0.45
12 Jan 11	0805	150	2.164	0.004	0.001	0.029	8.1	<2	14.8	0.04	0.07	0.044	0.4
9 Feb 11	0805	280	4.68	0.011	0.002	0.088	7.8	<2	14.7	0.08	0.17	0.022	0.7
9 Mar 11	0800	100	3.432	0.020	0.002	0.208	8.0	<2	11.5	0.03	0.24	0.039	0.8
14 Apr 11	0915	180	2.554	0.008	0.004	0.066	8.0	<2	12.5	0.05	0.12	0.043	0.65
13 May 11	0905	490	10.067	0.070	0.008	0.352	7.5	2	13.9	0.14	0.50	0.045	1.2
8 June 11	0920	1100	14.563	0.044	0.003	0.257	7.4	3	10.9	0.11	0.37	0.041	1.5

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

Table 10 Statistical summary of data from July 2010 to June 2011

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.006	0.050	0.013	12	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.001	0.010	0.003	12	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	17	68	47	12	17
BDISC	Black disc transparency	m	1.05	5.65	2.90	12	1.156
BOD	Biochemical oxygen demand 5day	g/m^3	<0.5	0.7	<0.5	12	0.1
CONDY	Conductivity @ 20'C	mS/m	6.3	15.6	12.5	12	303
DO	Dissolved Oxygen	g/m^3	9.8	12.8	10.9	12	0.92
PERSAT	Dissolved Oxygen Saturation %	%	97	106	101	12	2.9
DRP	Dissolved reactive phosphorus	g/m^3P	0.014	0.056	0.026	12	0.012
ECOL	E.coli bacteria	nos/100 ml	26	1100	165	12	293
ENT	Enterococci bacteria	nos/100 ml	15	360	80	12	106
FC	Faecal Coliforms	nos/100 ml	26	1100	165	12	293
FLOW	Flow	m^3/s	1.718	14.563	3.57	12	3.862
NH4	Ammoniacal nitrogen	g/m^3N	0.003	0.070	0.009	12	0.020
NO2	Nitrite nitrogen	g/m^3N	<0.001	0.008	0.001	12	0.002
NO3	Nitrate nitrogen	g/m^3N	0.02	0.35	0.11	12	0.119
PH	pH		7.4	8.1	7.95	12	0.23
SS	Suspended solids	g/m^3	<2	3	<2	12	0
TEMP	Temperature	°C	4.8	14.8	11.4	12	3.3
TKN	Total Kjeldahl nitrogen	g/m^3N	0.01	0.14	0.05	12	0.04
TN	Total nitrogen	g/m^3N	0.06	0.50	0.17	12	0.13
TP	Total phosphorus	g/m^3P	0.018	0.62	0.041	12	0.012
TURB	Turbidity	NTU	0.4	1.5	0.7	12	0.33

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

Table 11 Statistical summary of data from July 1995 to June 2011: Waiwhakaiho River at SH3

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.006	0.095	0.015	192	0.019
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.022	0.004	192	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.007	0.000	192	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	8	72	49	192	17
BDISC	Black disc transparency	m	0.13	8.05	3.06	192	1.447
BOD	Biochemical oxygen demand 5day	g/m^3	<0.5	4.3	<0.5	192	0.6
CONDY	Conductivity @ 20'C	mS/m	3.4	16.6	12.5	192	3.2
DO	Dissolved Oxygen	g/m^3	9.1	12.8	10.8	192	0.74
PERSAT	Dissolved Oxygen Saturation %	%	91	108	100	192	3.2
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.108	0.024	192	0.011
ECOL	E.coli bacteria	nos/100 ml	23	56000	170	168	4798
ENT	Enterococci bacteria	nos/100 ml	1	28000	82	192	2149
FC	Faecal Coliforms	nos/100 ml	23	83000	180	192	7483
FLOW	Flow	m^3/s	1.718	83.440	3.730	192	9.51
NH4	Ammoniacal nitrogen	g/m^3N	<0.003	0.148	0.007	192	0.022
NO2	Nitrite nitrogen	g/m^3N	<0.001	0.010	0.002	192	0.001
NO3	Nitrate nitrogen	g/m^3N	<0.01	0.47	0.116	192	0.108
PH	pH		6.8	8.5	7.9	192	0.28
SS	Suspended solids	g/m^3	<2	89	<2	192	11
TEMP	Temperature	°C	4.8	18.3	11.1	192	2.9
TKN	Total Kjeldahl nitrogen	g/m^3N	<0.01	1.95	0.07	192	0.23
TN	Total nitrogen	g/m^3N	0.02	2.10	0.21	192	0.257
TP	Total phosphorus	g/m^3P	0.014	0.437	0.034	192	0.050
TURB	Turbidity	NTU	0.4	26	0.7	191	2.96

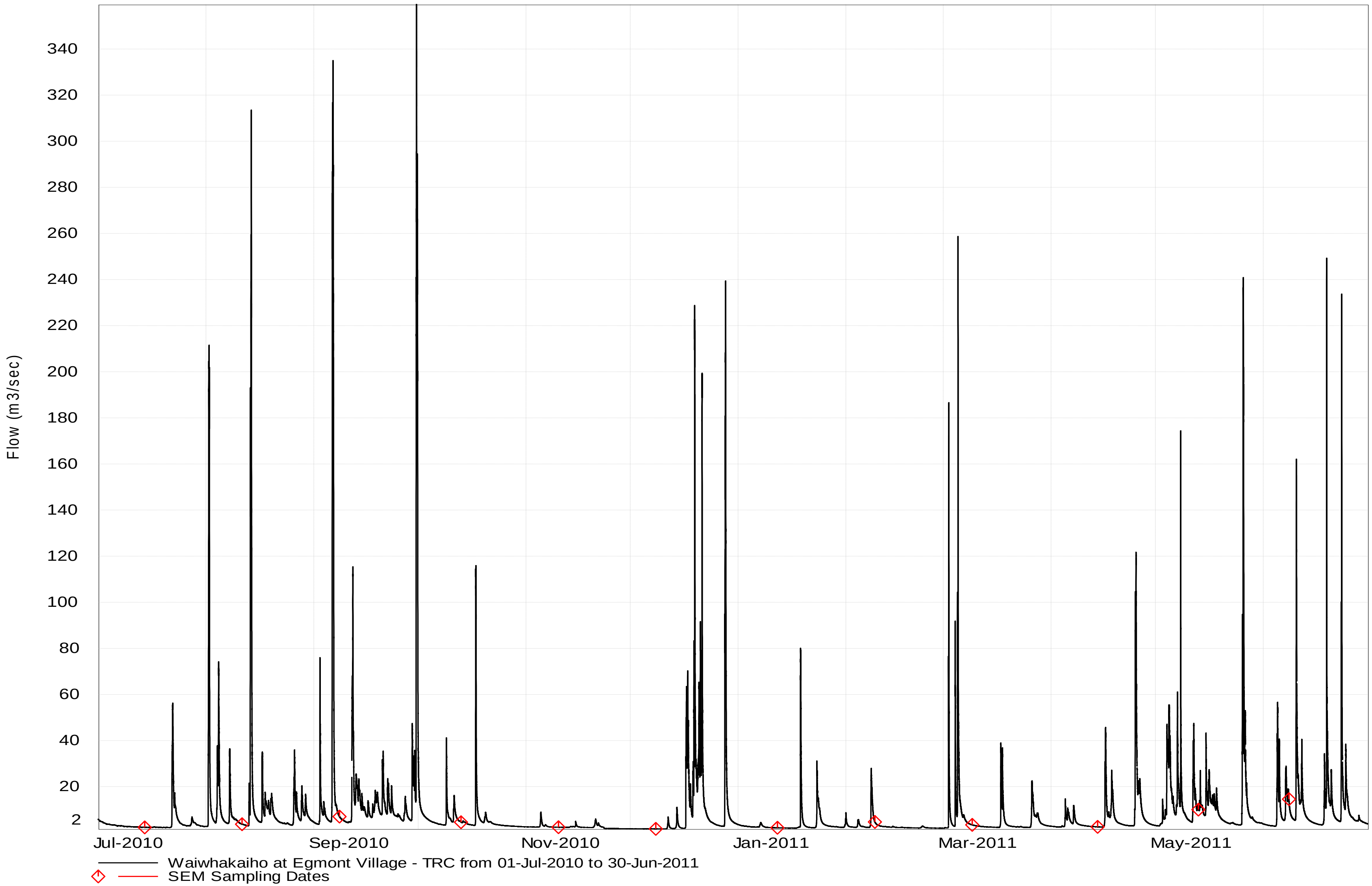

Figure 4 Flow record for the Waiwhakaiho River at SH3 Egmont Village

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

2010-2011 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 2.90 m and 0.65 NTU respectively. The maximum black disc value (5.65 metres) was recorded in late spring under relatively low flow conditions (2.40 m^3/sec) (Figure 4), with the worst conditions (black disc clarity of 1.05 m) during a moderate fresh flow (14.56 m^3/sec) in June 2011 when the suspended solids concentration remained low (3 g/m^3) and turbidity was 1.5 NTU. Generally, poorer water quality was recorded at the time of this fresh flow (Figure 4) when an elevation in faecal coliform bacterial numbers (1,100 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 spring to mid summer 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 0920 hrs.

Very good water quality was indicated by high dissolved oxygen concentrations (median saturation of 101%) and low BOD_5 levels (median of <0.5 g/m^3). Bacteriological quality was moderately good, with median faecal coliform and enterococci numbers (165 and 80 per 100 mls respectively) typically reflecting agricultural catchment influences and the relative infrequency of freshes during, or immediately prior to, sampling surveys.

River water temperatures recorded a moderate range of 10.0°C during the period with a maximum mid-morning water temperature of 14.8°C recorded in January 2011 under very low flow conditions.

Brief comparison with the previous 1995-2010 period

River water quality measured by the 2010-2011 survey in general was very similar to that recorded over the previous fifteen-year period. Median black disc clarity was slightly poorer (by 0.17m) although median turbidity and suspended solids levels remained identical between periods. Bacteriological water quality was slightly better in terms of median faecal coliform number (by 5 per 100 mls) and median enterococci number (by 3 per 100mls). A narrower range of water temperatures (by 3.1˚C) was recorded in the most recent twelve-month period. Median water temperature was 0.4°C higher in the most recent period although the maximum temperature was 3.5°C lower than that recorded during the previous fifteen years.

Median sampled flow over the 2010-2011 period was lower (by 165 L/sec) than for the flows sampled in the previous fifteen-year period coincident with a decrease in fresh events and some low flows in the late spring to mid-summer period sampled during the latest period.

Median nutrient concentration for total phosphorus showed an increase over the most recent sampling period but median nitrogen 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.

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/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)
14 July 10	1000	0.003	0.000	0.000	51	6.88	<0.5	12.0	12.2	99	0.022	13	<1
11 Aug 10	1005	0.009	0.002	0.000	40	6.13	<0.5	9.9	12.0	102	0.018	<1	<1
8 Sept 10	1010	0.015	0.005	0.001	28	0.29	<0.5	7.5	11.2	99	0.018	1	1
13 Oct 10	0900	0.008	0.002	0.000	34	2.40	<0.5	8.8	11.3	99	0.023	4	3
10 Nov 10	0930	0.003	0.001	0.000	48	7.06	<0.5	11.7	10.8	101	0.024	3	<1
8 Dec 10	0905	0.009	0.001	0.000	51	6.86	<0.5	12.2	10.2	101	0.026	4	8
12 Jan 11	0910	0.005	0.002	0.000	48	5.26	<0.5	11.7	9.9	100	0.026	3	8
9 Feb 11	0910	0.020	0.004	0.000	30	1.59	<0.5	8.0	9.9	99	0.005	21	42
9 Mar 11	0905	0.011	0.003	0.000	41	3.56	<0.5	10.3	10.6	99	0.011	7	4
14 Apr 11	1025	0.006	0.001	0.000	50	5.07	<0.5	12.3	10.5	100	0.021	8	4
13 May 11	0955	0.018	0.004	0.000	26	1.90	<0.5	6.4	10.2	99	0.014	1	4
8 June 11	1020	0.038	0.010	0.001	20	0.09	<0.5	5.7	10.9	99	0.048	8	4

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)
14 July 10	1000	13	2.410	0.003	<0.001	0.049	8.0	<2	5.8	<0.01	0.05	0.024	1.8
11 Aug 10	1005	<1	2.972	0.005	<0.001	0.049	7.8	<2	7.5	0.02	0.07	0.018	0.5
8 Sept 10	1010	1	5.08	0.003	<0.001	0.039	7.7	36	9.2	0.04	0.08	0.056	15
13 Oct 10	0900	4	3.597	0.005	<0.001	0.029	7.8	4	8.7	0.02	<0.05	0.023	1.1
10 Nov 10	0930	3	2.744	<0.003	<0.001	0.009	8.0	<2	11.6	0.04	<0.05	0.024	0.35
8 Dec 10	0905	4	2.647	<0.003	<0.001	0.009	8.0	<2	13.8	0.04	<0.05	0.026	0.45
12 Jan 11	0910	13	3.053	0.003	<0.001	0.019	8.0	<2	14.8	0.03	<0.05	0.026	0.45
9 Feb 11	0910	21	4.969	<0.003	<0.001	0.019	7.8	2	14.5	0.03	<0.05	0.008	0.95
9 Mar 11	0905	7	2.987	<0.003	<0.001	0.039	7.9	<2	11.6	0.03	0.07	0.026	0.81
14 Apr 11	1025	8	2.326	<0.003	<0.001	0.019	8.0	<2	12.4	0.03	<0.05	0.027	0.4
13 May 11	0955	1	7.5	<0.003	<0.001	0.009	7.6	5	13.1	0.04	<0.05	0.042	1.5
8 June 11	1020	8	10.287	0.006	0.001	0.019	7.5	530	10.3	0.10	0.12	0.613	105

The statistical summary of this data is presented in Table 13

Table 13 Statistical summary of data from July 2010 to July 2011 Stony River at Mangatete Road

Parrameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.003	0.038	0.009	12	0.010
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.010	0.002	12	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m³ $CaCO_3$	20	51	41	12	11
BDISC	Black disc transparency	m	0.09	7.06	4.32	12	2.612
BOD	Biochemical oxygen demand 5day	g/m³	<0.5	<0.5	<0.5	12	0.0
CONDY	Conductivity @ 20'C	mS/m	5.7	12.3	10.1	12	2.4
DO	Dissolved Oxygen	g/m³	9.9	12.2	10.7	12	0.76
PERSAT	Dissolved Oxygen Saturation %	%	99	102	99	12	1.1
DRP	Dissolved reactive phosphorus	g/m³P	0.005	0.048	0.022	12	0.011
ECOL	E.coli bacteria	nos/100 ml	<1	21	4	12	6
ENT	Enterococci bacteria	nos/100 ml	<1	42	4	12	11
FC	Faecal Coliforms	nos/100 ml	<1	21	6	12	6
FLOW	Flow	m³/s	2.326	10.287	3.020	12	2.435
NH4	Ammoniacal nitrogen	g/m³N	<0.003	0.006	<0.003	12	0.001
NO2	Nitrite nitrogen	g/m³N	<0.001	0.001	<0.001	12	0.000
NO3	Nitrate nitrogen	g/m³N	<0.01	0.05	0.02	12	0.015
PH	pH		7.5	8.0	7.85	12	0.17
SS	Suspended solids	g/m³	<2	530	<2	12	152
TEMP	Temperature	°C	5.8	14.8	11.6	12	2.9
TKN	Total Kjeldahl nitrogen	g/m³N	<0.01	0.10	0.03	12	0.02
TN	Total nitrogen	g/m³N	0.05	0.12	0.05	12	0.021
TP	Total phosphorus	g/m³P	0.008	0.613	0.026	12	0.169
TURB	Turbidity	NTU	0.35	105	0.9	12	29.98

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

Table 14 Statistical summary of data from July 1995 to June 2011: Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.003	0.077	0.009	192	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.028	0.002	192	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.007	0.000	192	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	5	54	39	192	11
BLACK DISC	Black disc transparency	m	<0.01	13.12	3.56	192	2.851
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	1.6	<0.5	192	0.1
CONDY	Conductivity @ 20°C	mS/m	3.0	12.7	9.7	192	2.4
DO	Dissolved oxygen	g/m³	9.4	12.2	10.7	192	0.64
PERSAT	Dissolved oxygen saturation	%	87	104	99	192	2.2
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.210	0.018	192	0.015
ECOL	E. coli bacteria	nos/100 ml	<1	950	7	168	94
ENT	Enterococci bacteria	nos/100 ml	<1	460	5	192	51
FC	Faecal coliform bacteria	nos/100 ml	<1	1000	8	192	92
FLOW	Flow	m³/s	2.050	55.504	3.602	192	7.444
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.019	<0.003	192	0.003
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.004	<0.001	192	0.000
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.11	0.02	192	0.018
pH	pH		7.0	8.2	7.85	192	0.22
SS	Suspended solids	g/m³	<2	2500	<2	192	300
TEMP	Temperature	°C	5.7	16.6	10.7	192	2.5
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	1.78	0.04	192	0.15
TN	Total nitrogen	g/m³N	0.02	1.82	0.06	192	0.149
TP	Total phosphorus	g/m³P	0.008	2.660	0.024	192	0.241
TURB	Turbidity	NTU	0.2	480	0.7	191	55.98

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

2010-2011

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 flood conditions in August -September, 2010 were reflected in black disc and turbidity values of 0.29 m and 15 NTU respectively with an elevation in suspended solids concentration (36 g/m^3). Significant rainfall in late May - early June 2011 caused headwater erosion resulting in elevated turbidity (105 NTU), suspended solids (530 g/m^3), and total phosphorus (0.613 g/m3) and very low black disc visibility (0.09 m). The maximum black disc clarity of 7.06 m was measured in late spring under low flow conditions coincident with the lowest suspended solids and turbidity (0.35 NTU) levels.

Maximum mid-morning pH (8.0) and the median pH (7.9) were relatively similar to past years' results.

Dissolved oxygen concentrations were consistently high with a minimum saturation of 99% and BOD_5 levels were below the detectable limit on all occasions including the largest flood flow event; 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 (6 and 4 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 9.0°C during the period, with a maximum mid-morning temperature of 14.8°C recorded in January 2011 under low flow conditions.

Nutrient levels were generally very low in terms of median ammoniacal nitrogen, nitrate-N and dissolved reactive phosphorus concentrations (all less than 0.03 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 June flood event coincident with a much higher sediment load.

Brief comparison with the previous 1995-2010 period

Water quality measured during the 2010-2011 survey period, in comparison with the previous fifteen years' survey results, was better aesthetically in terms of median black disc clarity (which was higher by 0.82 m), although median turbidity was slightly higher and suspended solids level was very similar to historical medians.

Median bacteriological water quality was very similar for the two periods, with both periods illustrating very high quality.

Water temperature range was narrower (by 1.9°C) due mainly to a lower maximum temperature during 2010-2011, but the median was higher (1.0°C warmer) in the 2010-2011 period to that in the earlier fifteen-year period. All median nutrient species were very similar to the previous longer period medians.

Median sampled flow during the 2010-2011 period was lower (by 0.60 m^3/sec) than the median of flows sampled over the previous fifteen-year period, with few significant flood events (in excess of 5 m^3/sec) and several relatively low flow events sampled in 2010-2011.

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)
14 July 10	1030	0.022	0.005	0.000	24	1.85	<0.5	9.3	12.5	101	0.022	5	9
11 Aug 10	1045	0.034	0.007	0.001	23	1.71	<0.5	9.2	11.8	102	0.020	13	1
8 Sept 10	1050	0.052	0.012	0.001	17	1.62	<0.5	7.9	10.8	100	0.014	17	5
13 Oct 10	0950	0.034	0.007	0.000	20	2.10	<0.5	8.2	11.3	100	0.019	120	7
10 Nov 10	1005	0.017	0.003	0.000	24	4.53	0.5	8.7	10.2	101	0.032	28	4
8 Dec 10	0945	0.020	0.004	0.000	26	3.10	<0.5	8.7	9.8	102	0.038	60	310
12 Jan 11	0945	0.026	0.006	0.000	25	2.02	<0.5	8.6	9.7	102	0.040	380	42
9 Feb 11	0940	0.060	0.012	0.000	18	1.19	0.6	9.0	9.7	99	0.014	600	330
9 Mar 11	0945	0.036	0.008	0.001	23	1.93	<0.5	9.4	10.3	100	0.010	420	50
14 Apr 11	1100	0.025	0.005	0.000	24	1.71	<0.5	9.2	10.5	104	0.025	43	43
13 May 11	1040	0.055	0.011	0.000	17	1.40	<0.5	8.1	10.1	99	0.017	84	60
8 June 11	1105	0.086	0.017	0.001	11	0.90	0.6	6.4	10.6	99	0.017	88	88

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)
14 July 10	1030	5	0.412	0.006	0.001	0.089	7.6	<2	5.0	0.05	0.14	0.033	2.8
11 Aug 10	1045	13	0.515	0.008	0.001	0.159	7.6	<2	7.8	0.01	0.17	0.023	2.6
8 Sept 10	1050	17	0.751	0.017	0.001	0.129	7.4	2	10.3	0.15	0.28	0.023	1.7
13 Oct 10	0950	140	0.556	0.004	0.001	0.029	7.6	<2	8.6	0.09	0.12	0.026	1.6
10 Nov 10	1005	28	0.283	0.004	<0.001	0.009	7.7	4	13.6	0.08	0.09	0.034	1.0
8 Dec 10	0945	60	0.228	0.006	<0.001	0.009	7.8	<2	15.6	0.05	0.06	0.041	0.9
12 Jan 11	0945	400	0.257	0.005	0.001	0.009	7.9	<2	16.1	0.12	0.13	0.046	1.2
9 Feb 11	0940	610	0.686	0.007	<0.001	0.019	7.5	<2	14.8	0.19	0.21	0.024	1.7
9 Mar 11	0945	420	0.423	0.005	<0.001	0.079	7.6	<2	12.5	0.08	0.16	0.026	1.6
14 Apr 11	1100	43	0.330	0.005	0.001	0.019	7.9	<2	13.4	0.07	0.09	0.036	1.7
13 May 11	1040	84	0.760	0.010	<0.001	0.099	7.4	2	12.9	0.08	0.18	0.032	2.2
8 June 11	1105	92	1.352	0.013	0.002	0.048	7.3	6	10.7	0.27	0.32	0.044	3.2

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

Table 16 Statistical summary of data from July 2010 to June 2011 Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.017	0.086	0.034	12	0.021
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.017	0.007	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m³ $CaCO_3$	11	26	23	12	4
BLACK DISC	Black disc transparency	m	0.90	4.53	1.78	12	0.962
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	0.6	<0.5	12	0.0
CONDY	Conductivity @ 20°C	mS/m	6.4	9.4	8.7	12	0.8
DO	Dissolved oxygen	g/m³	9.7	12.5	10.4	12	0.87
PERSAT	Dissolved oxygen saturation	%	99	104	101	12	1.5
DRP	Dissolved reactive phosphorus	g/m³P	0.010	0.040	0.020	12	0.010
ECOL	E. coli bacteria	nos/100 ml	5	600	72	12	197
ENT	Enterococci bacteria	nos/100 ml	1	330	43	12	116
FC	Faecal coliform bacteria	nos/100 ml	5	610	72	12	201
FLOW	Flow	m³/s	0.228	1.352	0.469	12	0.315
NH_4	Ammoniacal nitrogen	g/m³N	0.004	0.017	0.006	12	0.004
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.002	0.001	12	0.000
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.16	0.04	12	0.05
pH	pH		7.3	7.9	7.6	12	0.19
SS	Suspended solids	g/m³	<2	6	<2	12	1
TEMP	Temperature	°C	5.0	16.1	12.7	12	3.4
TKN	Total kjeldahl nitrogen	g/m³N	0.01	0.27	0.08	12	0.07
TN	Total nitrogen	g/m³N	0.06	0.32	0.15	12	0.077
TP	Total phosphorus	g/m³P	0.023	0.046	0.033	12	0.008
TURB	Turbidity	NTU	0.9	3.2	1.7	12	0.72

A statistical summary of the sixteen 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	192	0.024
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.032	0.007	192	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.005	0.000	192	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	6	27	22	192	5
BLACK DISC	Black disc transparency	m	0.08	4.53	1.84	192	0.92
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	3.0	<0.5	192	0.3
CONDY	Conductivity @ 20°C	mS/m	4.0	10.9	8.5	192	1.2
DO	Dissolved oxygen	g/m³	8.9	12.5	10.4	191	0.76
PERSAT	Dissolved oxygen saturation	%	87	106	99	191	2.9
DRP	Dissolved reactive phosphorus	g/m³P	0.007	0.389	0.023	192	0.028
ECOL	E. coli bacteria	nos/100 ml	3	6100	115	168	917
ENT	Enterococci bacteria	nos/100 ml	<1	1200	40	192	167
FC	Faecal coliform bacteria	nos/100 ml	3	6100	130	192	922
FLOW	Flow	m³/s	0.180	12.380	0.431	192	1.209
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.078	0.006	192	0.009
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.014	0.001	192	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.18	0.03	192	0.041
pH	pH		6.9	8.3	7.7	192	0.24
SS	Suspended solids	g/m³	<2	160	2	192	14
TEMP	Temperature	°C	5.0	19.2	12.0	192	3.3
TKN	Total kjeldahl nitrogen	g/m³N	0.01	0.85	0.10	192	0.13
TN	Total nitrogen	g/m³N	<0.05	0.87	0.15	192	0.141
TP	Total phosphorus	g/m³P	0.016	0.413	0.034	192	0.043
TURB	Turbidity	NTU	0.45	29	1.6	191	3.48

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

2010-2011

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 1.78 m (black disc) and 1.7 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 has also been subject to stock access in the past (see photos in TRC 2000 and Photo 1) although in recent years the banks have been fenced and planted in the immediate vicinity of the site.

Photo 1 Stock access immediately downstream of Wiremu Road, May 2011

Minimum black disc clarity (0.90 m) occurred during a small stream fresh in June 2011 (Figure 5) and coincided with a small increase in suspended solids concentration (6 g/m^3). Increases in total nitrogen and phosphorus concentrations and colour occurred at this time, but a minimal increase in faecal coliform bacteria number was recorded, during this event, with much higher faecal coliform numbers (460-610 per 100 mls) recorded earlier in the period under low flow conditions.

A maximum black disc value of 4.53 m was measured under relatively low flow conditions in November, 2010 representing the highest visibility (by 0.14 m) recorded at this site over the sixteen year period to date.

A maximum pH (7.9) was recorded (in mid morning) on two occasions during the period in mid summer and autumn, under low flow conditions.

Dissolved oxygen concentrations were consistently high (above 98% 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 moderate median faecal coliform bacterial count for the upper reaches of a ring plain stream (72 per 100 mls) indicated some impacts of upstream farmland run-off (and possible stock access) on stream water quality at this site, and represented some deterioration below the National Park boundary in this aspect of water quality. Surface runoff from surrounding farmland has been a common feature in this reach of the stream, although few freshes were sampled during the 2010-2011 period compared with previous periods.

Water temperatures varied over a relatively wide range (11.1°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 in January 2011, relatively high for the upper reaches of a ring plain stream at this time of the day (0945 hrs).

Brief comparison with the previous 1995-2010 period

Stream water quality measured during the 2010-2011 period, was very similar in terms of median turbidity and median black disc clarity (which decreased by 0.06 m) to the overall record. Median suspended solids concentration remained low and was very similar in the recent year in comparison with the previous fifteen-year period. Median dissolved oxygen percentage saturation levels were very similar (within 2%) for both periods.

Bacteriological water quality improved in terms of median faecal coliform number (by 58 per 100 ml) while median numbers of enterococci were very similar, reflecting in part only occasional freshes sampled in 2010-2011. All median nutrient species' concentrations were similar between periods.

The water temperature range was narrower (by 3.1°C) compared with surveys prior to the latest twelve-month period; with the median flow sampled being slightly higher (by 35 L/sec) in the 2010-2011 period. The narrower temperature range was caused mainly by a lower maximum temperature in 2010-2011 than the previous maximum recorded.

Median pH value was very similar (0.1 pH unit lower) during the latest sampling period but the maximum pH was 0.4 unit lower than the maximum recorded in the previous fifteen-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)
14 July 10	1055	0.027	0.005	0.000	34	1.47	0.6	18.2	12.3	100	0.028	390	16
11 Aug 10	1115	0.033	0.007	0.001	33	1.35	1.0	18.5	11.6	100	0.048	680	50
8 Sept 10	1115	0.039	0.009	0.001	29	0.78	1.0	19.1	11.0	100	0.040	1800	100
13 Oct 10	1020	0.031	0.006	0.000	34	1.73	1.9	18.0	11.3	100	0.040	700	180
10 Nov 10	1030	0.033	0.006	0.000	40	3.16	1.6	18.0	11.3	112	0.053	340	380
8 Dec 10	1010	0.041	0.008	0.000	42	2.12	1.0	16.2	9.9	101	0.070	350	670
12 Jan 11	1015	0.051	0.010	0.001	40	2.15	0.6	14.7	9.4	99	0.069	570	1200
9 Feb 11	1010	0.072	0.015	0.000	26	1.23	1.3	13.7	9.5	98	0.056	670	2900
9 Mar 11	1015	0.042	0.009	0.001	30	1.67	0.8	15.5	10.1	98	0.071	310	900
14 Apr 11	1225	0.036	0.007	0.000	32	1.80	0.8	14.7	10.2	102	0.081	310	600
13 May 11	1110	0.048	0.010	0.000	27	1.50	1.2	15.5	9.8	97	0.057	320	430
8 June 11	1130	0.071	0.014	0.001	18	0.45	1.4	9.6	10.9	99	0.029	730	2100

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)
14 July 10	1055	400	0.769	0.040	0.008	1.282	7.7	2	6.4	0.21	1.50	0.046	2.1
11 Aug 10	1115	680	1.097	0.120	0.017	1.493	7.6	3	8.8	0.53	2.04	0.069	2.8
8 Sept 10	1115	1800	2.656	0.152	0.012	2.388	7.5	12	11.1	0.64	3.04	0.083	3.8
13 Oct 10	1020	710	1.26	0.077	0.025	1.535	7.6	2	9.8	0.44	2.00	0.061	1.6
10 Nov 10	1030	340	0.444	0.016	0.033	1.117	8.0	2	15.0	0.22	1.37	0.079	1.5
8 Dec 10	1010	380	0.338	0.022	0.009	0.701	7.8	<2	16.3	0.14	0.85	0.096	1.7
12 Jan 11	1015	600	0.305	0.020	0.006	0.264	7.8	<2	17.7	0.27	0.54	0.088	1.4
9 Feb 11	1010	700	1.033	0.029	0.008	0.422	7.6	2	16.7	0.29	0.72	0.094	1.8
9 Mar 11	1015	320	0.732	0.044	0.013	0.697	7.7	3	13.9	0.16	0.87	0.102	1.6
14 Apr 11	1225	310	0.493	0.019	0.006	0.464	7.9	<2	15.2	0.18	0.65	0.104	1.5
13 May 11	1110	320	1.576	0.054	0.018	1.852	7.4	4	14.6	0.39	2.26	0.102	2.0
8 June 11	1130	730	2.478	0.025	0.005	0.505	7.4	24	11.1	0.43	0.94	0.103	7.0

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

Table 19 Statistical summary of data from July 2010 to June 2011 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.027	0.072	0.040	12	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.005	0.015	0.009	12	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	18	42	33	12	7
BDISC	Black disc transparency	m	0.45	3.16	1.59	12	0.693
BOD	Biochemical oxygen demand 5day	g/m^3	0.6	1.9	1.0	12	0.4
CONDY	Conductivity @ 20'C	mS/m	9.6	19.1	15.9	12	2.7
DO	Dissolved Oxygen	g/m^3	9.4	12.3	10.6	12	0.92
PERSAT	Dissolved Oxygen Saturation %	%	97	112	100	12	3.9
DRP	Dissolved reactive phosphorus	g/m^3P	0.028	0.081	0.055	12	0.017
ECOL	E.coli bacteria	nos/100 ml	310	1800	480	12	416
ENT	Enterococci bacteria	nos/100 ml	16	2900	515	12	889
FC	Faecal Coliforms	nos/100 ml	310	1800	600	12	414
FLOW	Flow	m^3/s	0.305	2.656	0.901	12	0.788
NH4	Ammoniacal nitrogen	g/m^3N	0.016	0.152	0.035	12	0.044
NO2	Nitrite nitrogen	g/m^3N	0.005	0.033	0.011	12	0.009
NO3	Nitrate nitrogen	g/m^3N	0.26	2.39	0.91	12	0.622
PH	pH		7.4	8.0	7.7	12	0.19
SS	Suspended solids	g/m^3	<2	24	2	12	7
TEMP	Temperature	°C	6.4	17.7	14.3	12	3.5
TKN	Total Kjeldahl nitrogen	g/m^3N	0.14	0.64	0.28	12	0.16
TN	Total nitrogen	g/m^3N	0.54	3.04	1.16	12	0.784
TP	Total phosphorus	g/m^3P	0.046	0.104	0.091	12	0.019
TURB	Turbidity	NTU	1.4	7.0	1.75	12	1.60

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

Table 20 Statistical summary of data from July 1995 to June 2011 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.015	0.115	0.040	192	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.027	0.008	192	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.006	0.000	192	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	10	46	34	192	7
BDISC	Black disc transparency	m	0.055	3.57	1.51	192	0.679
BOD	Biochemical oxygen demand 5day	g/m^3	<0.5	8.1	0.9	192	0.9
CONDY	Conductivity @ 20'C	mS/m	5.8	21.8	16.1	192	2.4
DO	Dissolved Oxygen	g/m^3	8.6	12.8	10.4	192	0.83
PERSAT	Dissolved Oxygen Saturation %	%	90	114	99	192	3.5
DRP	Dissolved reactive phosphorus	g/m^3P	0.013	0.212	0.042	192	0.028
ECOL	E.coli bacteria	nos/100 ml	48	20000	465	166	2420
ENT	Enterococci bacteria	nos/100 ml	15	9300	300	191	1060
FC	Faecal Coliforms	nos/100 ml	51	20000	500	192	2764
FLOW	Flow	m^3/s	0.242	12.300	0.773	192	1.601
NH4	Ammoniacal nitrogen	g/m^3N	0.004	0.376	0.044	192	0.065
NO2	Nitrite nitrogen	g/m^3N	<0.001	0.110	0.014	192	0.015
NO3	Nitrate nitrogen	g/m^3N	0.07	3.13	0.91	192	0.632
PH	pH		7.1	8.6	7.7	192	0.22
SS	Suspended solids	g/m^3	<2	220	3	192	23
TEMP	Temperature	°C	5.0	21.0	13.4	192	3.6
TKN	Total Kjeldahl nitrogen	g/m^3N	0.04	1.99	0.33	192	0.28
TN	Total nitrogen	g/m^3N	0.29	3.96	1.35	192	0.733
TP	Total phosphorus	g/m^3P	0.026	0.531	0.076	192	0.065
TURB	Turbidity	NTU	0.85	50	1.8	191	5.27

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.

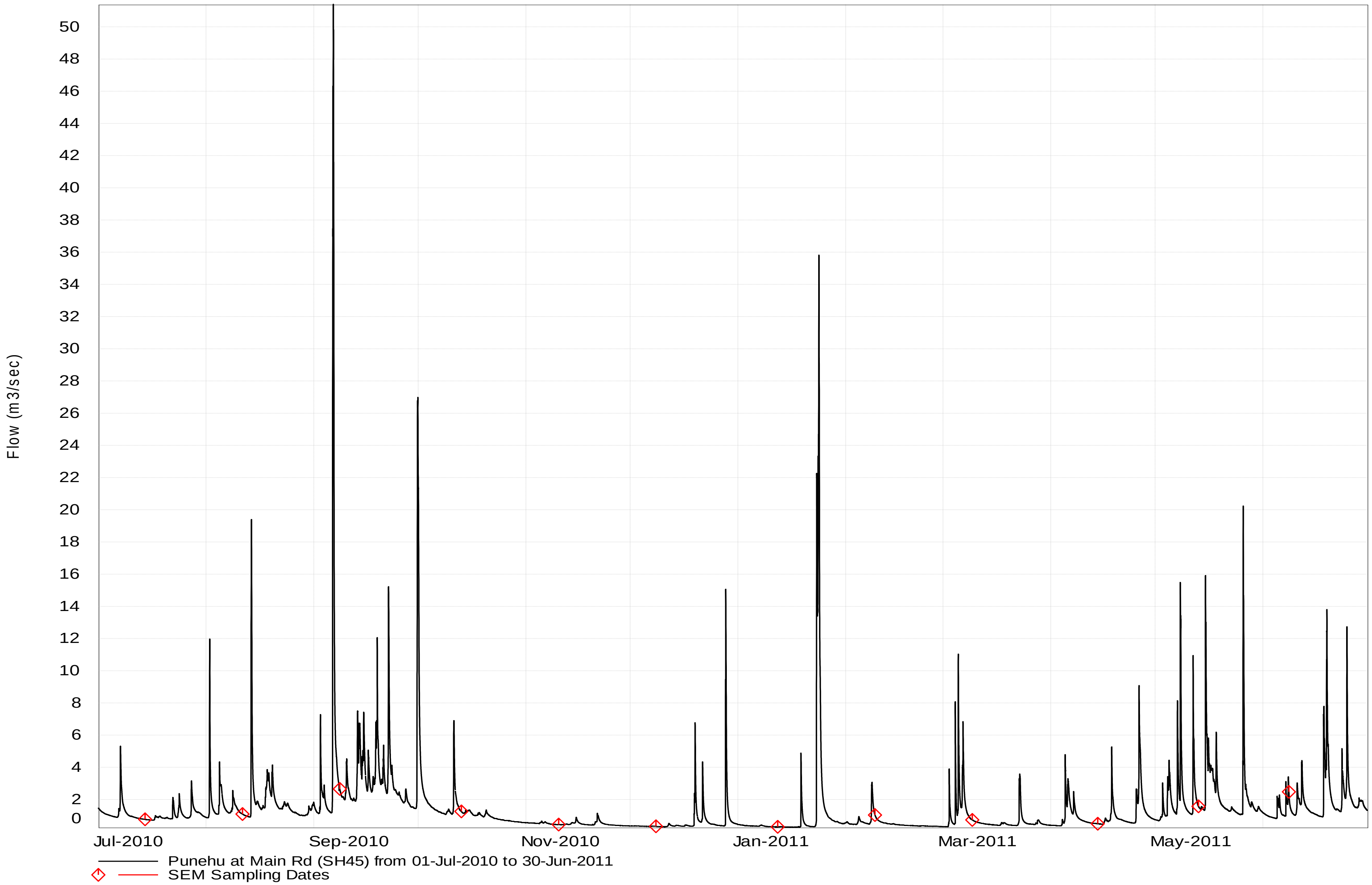

Figure 5 Flow record for the Punehu Stream at SH45

Discussion

2010-2011 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.59 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 clarity of 0.45 m, turbidity of 7 NTU, and suspended solids concentration of 24 g/m^3) was recorded during a small fresh in June 2010. Some deterioration in other water quality parameters under these conditions was shown by an elevation in bacterial numbers and a small increase in BOD_5.

pH peaked at 8.0 (in late spring) but this was recorded in late morning and would be expected to have reached higher levels later in the day. This was 0.6 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 (515 enterococci and 500 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 (310 to 700 per 100 ml) were indicative of point source discharges of pond system treated dairy sheds' wastes and/or stock access. [Note: Compliance monitoring of specific dairy pond systems in the Mangatawa Stream (a tributary stream a short distance upstream of this site) during the 2010-2011 season found significant non-compliance and cumulative impacts on receiving water quality (TRC, 2011), particularly in terms of nutrients, bacteria and BOD_5]. Relatively high median nutrient levels were consistent with such impacts.

Water temperature varied over a moderate range of 11.3˚C with a maximum summer (late morning) temperature of 17.7°C recorded in January 2011 and the lowest temperature (6.4°C) recorded in July 2010; the former 3.5°C below the previous annual maximum temperature and the latter 1.4˚C above the previous annual minimal temperature.

Brief comparison of upper and lower sites during the 2010-2011 period

Deterioration in certain aspects of water quality in the lower stream reaches was emphasised by a very significant increase in median bacteriological numbers (428 faecal coliforms per 100 mls and 472 enterococci per 100 mls), and median nutrient concentrations (particularly nitrogen species) with total nitrogen and total phosphorus increasing by factors of about 8 and 3 times respectively. Very small deteriorations in median turbidity levels and suspended solids concentrations and a larger decrease in median black disc clarity (11% 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 92% in the lower reaches of the stream).

The downstream water temperature range increased by only 0.2°C while the median increased by only 1.6°C. The median pH increased by only 0.1 unit in the lower reaches.

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

Brief comparison with the previous 1995-2010 period

Minimal change in aesthetic water quality was indicated by a significant change in median turbidity and median black disc clarity (0.09 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 deterioration was recorded in median faecal coliform bacterial number (by 100 per 100 mls) and a more significant deterioration in median enterococci bacteria number (by 235 per 100 mls). Small decreases in median nutrient species concentrations were recorded for ammoniacal nitrogen and total nitrogen which increased by about 20% and 11 % of the long term medians respectively, with an increase of 34% in dissolved reactive phosphorus and 21% for total phosphorus.

Median dissolved oxygen saturation levels were very similar (within 1%) as were median BOD_5 levels (within 0.1 g/m^3) in the two periods.

There was no difference in median pH for the 2010-2011 period although the maximum pH was 0.6 unit lower in comparison with the previous fifteen-year period.

Water temperature range was much narrower (by 4.7°C); this decrease due to higher minimum and lower maximum water temperatures over the recent survey period, with the 2010-2011 median water temperature 0.9˚C higher than the median fifteen year temperature.

Median sampled flow over the 2010-2011 period was 128 L/sec higher than the median sampled flow for the previous fifteen-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 (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)
14 July 10	1205	0.011	0.003	0.000	32	1.86	<0.5	12.1	12.3	101	0.010	84	7
11 Aug 10	1230	0.013	0.003	0.000	28	1.85	0.5	11.5	11.4	101	0.013	46	8
8 Sept 10	1225	0.017	0.004	0.001	26	1.52	0.5	10.6	10.8	102	0.014	1400	68
13 Oct 10	1140	0.014	0.003	0.000	27	2.71	<0.5	10.9	11.1	103	0.016	17	8
10 Nov 10	1150	0.014	0.003	0.000	33	4.37	0.7	12.2	11.0	110	0.018	52	39
8 Dec 10	1130	0.025	0.006	0.000	42	1.55	0.9	13.4	10.0	105	0.032	120	36
12 Jan 11	1135	0.026	0.005	0.000	33	2.83	<0.5	11.7	10.3	108	0.017	140	95
9 Feb 11	1115	0.024	0.005	0.000	33	1.50	0.7	12.6	9.9	103	0.021	400	690
9 Mar 11	1135	0.017	0.005	0.000	27	1.94	0.6	10.8	10.2	99	0.017	120	130
14 Apr 11	1240	0.015	0.003	0.000	32	1.44	0.8	11.8	10.7	106	0.018	88	80
13 May 11	1230	0.022	0.005	0.000	26	1.07	1.2	10.3	9.7	97	0.028	200	310
8 June 11	1245	0.027	0.005	0.000	24	0.96	1.2	9.4	10.6	100	0.025	220	170

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)
14 July 10	1205	84	1.440	0.007	0.003	1.637	7.7	<2	6.0	0.16	1.80	0.020	1.4
11 Aug 10	1230	46	3.110	0.011	0.003	1.797	7.7	4	9.2	0.06	1.86	0.018	1.5
8 Sept 10	1225	1400	4.047	0.020	0.005	1.555	7.6	4	11.6	0.31	1.87	0.029	1.8
13 Oct 10	1140	17	2.361	0.015	0.006	1.534	7.7	2	10.8	0.20	1.74	0.026	0.9
10 Nov 10	1150	52	0.958	0.012	0.006	1.154	8.2	<2	14.3	0.08	1.24	0.024	1.0
8 Dec 10	1130	140	0.525	0.029	0.012	1.038	7.9	5	16.7	0.13	1.18	0.051	1.9
12 Jan 11	1135	140	1.419	0.006	0.004	0.976	8.4	<2	16.5	0.33	1.31	0.023	1.0
9 Feb 11	1115	420	1.988	0.027	0.011	1.399	7.9	2	16.0	0.15	1.56	0.036	1.5
9 Mar 11	1135	130	2.206	0.026	0.008	1.252	7.7	3	12.8	0.04	1.30	0.039	1.2
14 Apr 11	1240	88	1.478	0.008	0.007	1.243	8.0	2	13.8	0.19	1.44	0.038	1.4
13 May 11	1230	200	6.131	0.050	0.016	1.704	7.5	8	14.2	0.32	2.04	0.085	2.6
8 June 11	1245	220	4.834	0.026	0.009	1.341	7.5	8	11.6	0.35	1.70	0.078	2.6

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

Table 22 Statistical summary of data from July 2010 to June 2011: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.011	0.027	0.017	12	0.006
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.006	0.005	12	0.001
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m³ $CaCO_3$	24	42	30	12	5
BLACK DISC	Black disc transparency	m	0.96	4.37	1.70	12	0.943
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	1.2	0.7	12	0.3
CONDY	Conductivity @ 20°C	mS/m	9.4	13.4	11.6	12	1.1
DO	Dissolved oxygen	g/m³	9.7	12.3	10.7	12	0.70
PERSAT	Dissolved oxygen saturation	%	97	110	103	12	3.8
DRP	Dissolved reactive phosphorus	g/m³P	0.010	0.032	0.018	12	0.006
ECOL	E. coli bacteria	nos/100 ml	17	1400	120	12	379
ENT	Enterococci bacteria	nos/100 ml	7	690	74	12	195
FC	Faecal coliform bacteria	nos/100 ml	17	1400	135	12	379
FLOW	Flow	m³/s	0.525	6.131	2.097	12	1.688
NH_4	Ammoniacal nitrogen	g/m³N	0.006	0.050	0.018	12	0.013
NO_2	Nitrite nitrogen	g/m³N	0.003	0.016	0.007	12	0.004
NO_3	Nitrate nitrogen	g/m³N	0.98	1.80	1.37	12	0.264
pH	pH		7.5	8.4	7.7	12	0.28
SS	Suspended solids	g/m³	<2	8	3	12	2
TEMP	Temperature	°C	6.0	16.7	13.3	12	3.2
TKN	Total kjeldahl nitrogen	g/m³N	0.04	0.35	0.18	12	0.11
TN	Total nitrogen	g/m³N	1.18	2.04	1.63	12	0.287
TP	Total phosphorus	g/m³P	0.018	0.085	0.033	12	0.022
TURB	Turbidity	NTU	0.9	2.6	1.5	12	0.57

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

Table 23 Statistical summary of data from July 1995 to June 2011: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.100	0.021	192	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.024	0.005	192	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.003	0.000	192	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	11	45	30	192	6
BLACK DISC	Black disc transparency	m	0.10	4.39	1.73	192	0.842
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	7.3	0.6	192	0.9
CONDY	Conductivity @ 20°C	mS/m	4.6	13.4	11.2	192	1.6
DO	Dissolved oxygen	g/m³	9.2	13	10.6	192	0.75
PERSAT	Dissolved oxygen saturation	%	92	121	102	192	5.2
DRP	Dissolved reactive phosphorus	g/m³P	0.003	0.081	0.018	192	0.011
ECOL	E. coli bacteria	nos/100 ml	6	59000	160	168	4693
ENT	Enterococci bacteria	nos/100 ml	3	5700	105	192	862
FC	Faecal coliform bacteria	nos/100 ml	6	100000	185	192	8482
FLOW	Flow	m³/s	0.356	28.797	1.623	192	3.623
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.265	0.018	192	0.040
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.033	0.007	192	0.006
NO_3	Nitrate nitrogen	g/m³N	0.14	2.31	1.11	192	0.487
pH	pH		7.1	8.6	7.8	192	0.28
SS	Suspended solids	g/m³	<2	180	3	192	19
TEMP	Temperature	°C	5.6	20.8	12.4	192	3.2
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	2.15	0.20	192	0.28
TN	Total nitrogen	g/m³N	0.27	2.91	1.41	192	0.513
TP	Total phosphorus	g/m³P	0.013	0.829	0.036	192	0.081
TURB	Turbidity	NTU	0.7	36	1.4	191	4.31

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.

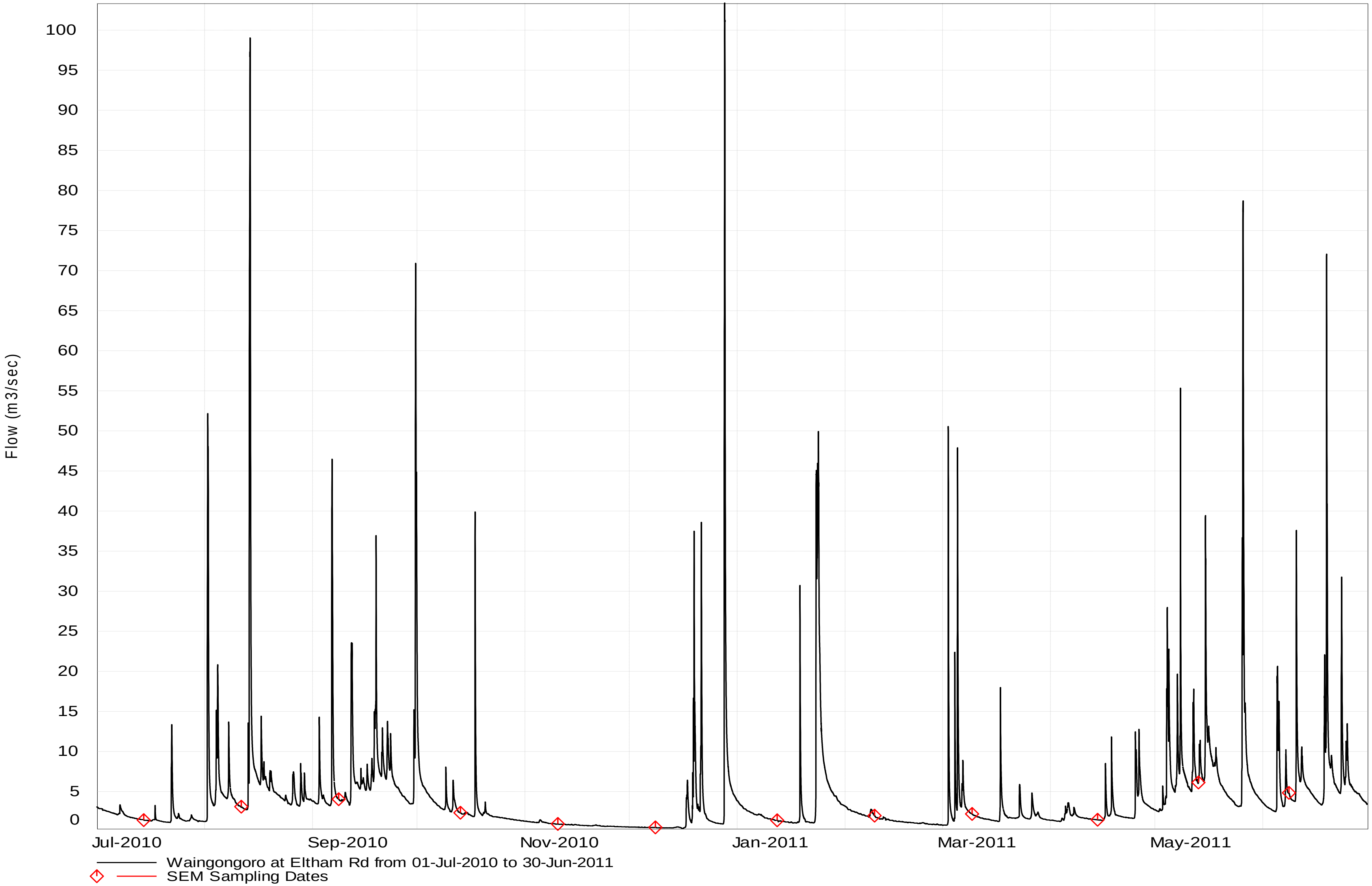

Figure 6 Flow record for the Waingongoro River at Eltham Road

Discussion

2010-2011

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.70 m and median turbidity of 1.5 NTU, in the mid-reaches of the longest ring-plain river in Taranaki. The maximum clarity (black disc value of 4.37 m), within 0.02 m of the historical maximum, was recorded in late spring during low flow conditions (0.96 m^3/s), while worst black disc clarity (0.96 m) occurred during a small fresh in winter coincident with a turbidity of 2.6 NTU and suspended solids concentration of 8 g/m^3 sampled in June 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 three occasions during the 2010-2011 period.

pH reached a maximum of 8.4 in mid summer coincident with supersaturation (108%) 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 97% saturation recorded in late autumn) and low BOD_5 levels (median: 0.7 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 135 and 74 (per 100 mls) respectively. Water temperature varied over a moderate range of 10.7°C with a maximum summer (late morning) river temperature of 16.7° C recorded in December 2010 under very low flow conditions (Figure 6).

Brief comparison with previous 1995-2010 period

The latest twelve-month period sampled a narrower range of flow conditions while median sampled flow was higher (by 481 L/sec) than the median of flows sampled in the previous fifteen-year period. Aesthetic river water quality was very similar in terms of median black disc clarity (which decreased by 0.03 m), median suspended solids level (which was identical), and median turbidity level (which increased very slightly by 0.1 NTU) during the 2010-2011 period.

In general, an improvement in bacteriological water quality was recorded in the 2010-2011 period with much lower median faecal coliform number (by 60 per 100 mls) and median enterococci number (by 36 per 100 mls). Very minor differences between periods were indicated in most median nutrient species' concentrations over the 2010-2011 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 4.5°C) over the 2010-2011 period mainly due to a much cooler (by 4.1˚C) maximum water temperature although the median water temperature was 1.0˚C higher in the 2010-2011 period.

Median pH values were very similar and the maximum pH previously recorded was only 0.2 unit higher than that measured in the 2010-2011 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/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)
14 July 10	1135	0.019	0.004	0.000	38	1.84	0.8	17.4	12.3	100	0.021	100	20
11 Aug 10	1150	0.020	0.004	0.000	33	0.96	1.3	15.6	11.7	102	0.030	80	11
8 Sept 10	1150	0.028	0.006	0.001	32	1.04	1.7	14.9	10.5	98	0.031	180	27
13 Oct 10	1100	0.026	0.005	0.000	36	1.29	<0.5	16.7	11.2	103	0.029	150	48
10 Nov 10	1110	0.025	0.005	0.000	46	4.34	1.0	18.7	10.4	105	0.032	46	12
8 Dec 10	1050	0.034	0.007	0.000	55	1.49	1.0	20.8	9.8	105	0.051	92	32
12 Jan 11	1055	0.033	0.007	0.000	43	2.12	0.7	15.6	10.4	111	0.028	42	54
9 Feb 11	1045	0.037	0.008	0.000	41	1.05	1.0	16.9	9.7	103	0.037	1100	990
9 Mar 11	1050	0.025	0.006	0.000	32	3.30	0.9	13.9	10.2	100	0.039	200	200
14 Apr 11	1200	0.024	0.005	0.000	40	1.66	0.9	15.7	10.8	106	0.038	170	180
13 May 11	1155	0.034	0.007	0.000	31	0.81	2.0	13.7	9.6	96	0.066	380	300
8 June 11	1210	0.037	0.007	0.001	30	0.42	2.6	13.1	10.4	98	0.048	600	700

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)
14 July 10	1135	100	5.488	0.014	0.007	2.393	7.7	5	6.4	0.30	2.70	0.042	2.2
11 Aug 10	1150	84	9.386	0.048	0.023	2.167	7.5	8	9.2	0.36	2.55	0.060	2.9
8 Sept 10	1150	180	11.187	0.061	0.028	2.272	7.6	18	12.1	0.36	2.66	0.057	4.0
13 Oct 10	1100	150	7.997	0.027	0.015	2.255	7.8	5	11.2	0.51	2.78	0.057	2.2
10 Nov 10	1110	46	3.442	0.017	0.011	1.969	8.0	3	15.6	0.30	2.28	0.046	1.5
8 Dec 10	1050	92	1.848	0.027	0.014	1.626	8.0	3	18.2	0.20	1.84	0.071	2.0
12 Jan 11	1055	42	2.725	0.009	0.007	1.113	8.3	<2	18.3	0.33	1.45	0.043	1.3
9 Feb 11	1045	1100	4.786	0.036	0.014	1.586	7.8	4	17.8	0.34	1.94	0.064	2.5
9 Mar 11	1050	200	6.512	0.026	0.015	1.495	7.7	4	14.1	0.20	1.71	0.069	1.9
14 Apr 11	1200	180	4.213	0.014	0.009	1.561	7.9	3	14.1	0.33	1.90	0.066	1.9
13 May 11	1155	380	16.987	0.135	0.053	2.007	7.5	13	14.9	0.46	2.52	0.152	4.2
8 June 11	1210	600	13.084	0.043	0.038	1.742	7.6	17	12.6	0.76	2.54	0.135	5.9

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

Table 25 Statistical summary of data from July 2010 to June 2011: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.019	0.037	0.027	12	0.006
A440F	Absorbance @ 440nm filtered	/cm	0.004	0.008	0.006	12	0.001
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m^3 $CaCO_3$	30	55	37	12	7
BLACK DISC	Black disc transparency	m	0.42	4.34	1.39	12	1.119
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	2.6	1.0	12	0.6
CONDY	Conductivity @ 20°C	mS/m	13.1	20.8	15.7	12	2.2
DO	Dissolved oxygen	g/m^3	9.6	12.3	10.4	12	0.81
PERSAT	Dissolved oxygen saturation	%	96	111	103	12	4.2
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.021	0.066	0.035	12	0.012
ECOL	E. coli bacteria	nos/100 ml	42	1100	160	12	308
ENT	Enterococci bacteria	nos/100 ml	11	990	51	12	315
FC	Faecal coliform bacteria	nos/100 ml	42	1100	165	12	308
FLOW	Flow	m^3/s	1.848	16.987	6.000	12	4.649
NH_4	Ammoniacal nitrogen	g/m^{3}N	0.009	0.135	0.027	12	0.034
NO_2	Nitrite nitrogen	g/m^{3}N	0.007	0.053	0.015	12	0.014
NO_3	Nitrate nitrogen	g/m^{3}N	1.11	2.39	1.86	12	0.389
pH	pH		7.5	8.3	7.8	12	0.24
SS	Suspended solids	g/m^3	<2	18	5	12	6
TEMP	Temperature	°C	6.4	18.3	14.1	12	3.7
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.20	0.76	0.34	12	0.15
TN	Total nitrogen	g/m^{3}N	1.45	2.78	2.40	12	0.45
TP	Total phosphorus	g/m^{3}P	0.042	0.152	0.062	12	0.035
TURB	Turbidity	NTU	1.3	5.9	2.2	12	1.35

As this was the thirteenth year of state of the environment data collection by the Taranaki Regional Council for this site, only the thirteen 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 2011: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.078	0.032	156	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.019	0.007	156	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	156	0.001
ALKT	Alkalinity total	g/m^3 $CaCO_3$	21	62	39	156	9
BLACK DISC	Black disc transparency	m	0.12	4.34	1.18	156	0.608
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	6.7	1.0	156	0.9
CONDY	Conductivity @ 20°C	mS/m	9.8	21.1	16.4	156	2.2
DO	Dissolved oxygen	g/m^3	8.4	12.9	10.5	156	0.82
PERSAT	Dissolved oxygen saturation	%	89	141	101	156	6.7
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.021	0.223	0.065	156	0.037
ECOL	E. coli bacteria	nos/100 ml	3	41000	210	155	3733
ENT	Enterococci bacteria	nos/100 ml	11	4200	150	156	531
FC	Faecal coliform bacteria	nos/100 ml	3	41000	220	156	3722
FLOW	Flow	m^3/s	1.010	50.341	4.701	156	7.245
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.305	0.031	156	0.042
NO_2	Nitrite nitrogen	g/m^{3}N	0.003	0.132	0.022	156	0.019
NO_3	Nitrate nitrogen	g/m^{3}N	0.75	2.98	1.89	156	0.517
pH	pH		7.3	9.1	7.8	156	0.28
SS	Suspended solids	g/m^3	<2	120	5	156	18
TEMP	Temperature	°C	5.4	22.0	13.7	156	3.8
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.02	1.51	0.41	156	0.25
TN	Total nitrogen	g/m^{3}N	1.03	3.59	2.47	156	0.559
TP	Total phosphorus	g/m^{3}P	0.042	0.325	0.104	156	0.053
TURB	Turbidity	NTU	1.3	36	2.3	155	4.54

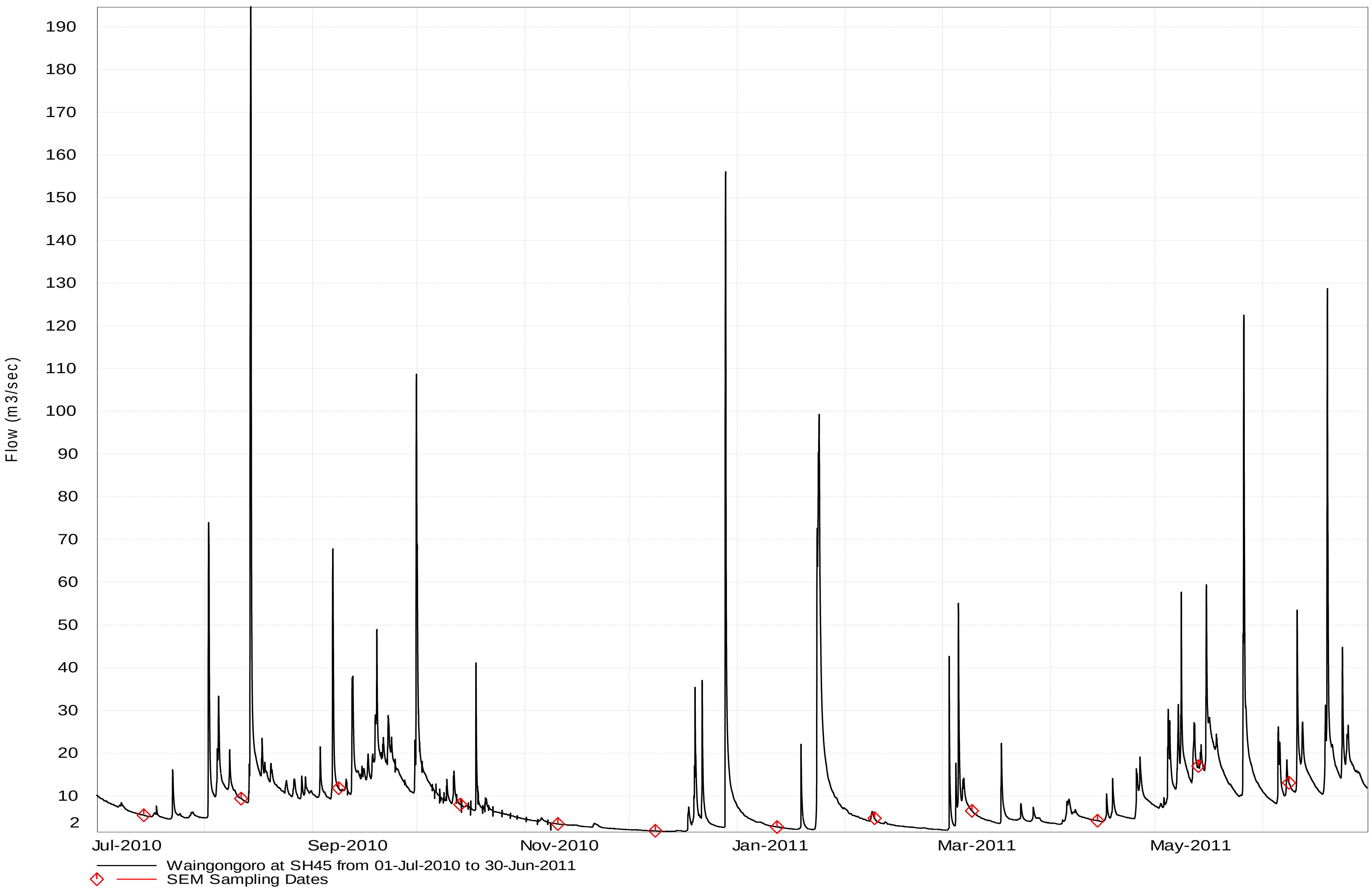

Figure 7 Flow record for the Waingongoro River at SH45

Discussion

2010-2011 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.39 m and median turbidity of 2.2 NTU, in the lower reaches of the longest ring-plain confined river or stream in Taranaki. The maximum clarity (black disc value of 4.34 m) was recorded in late spring during low flow conditions (3.44 m^3/s) and was the highest clarity measured to date (by 1.95 m). The lowest black disc clarity of 0.42 m and highest turbidity of 5.9 NTU were sampled during a small fresh in June 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. September 2010, May 2011, and June 2011) although more frequent preceding freshes may have reduced the impact of runoff on bacterial numbers on the first occasion.

pH reached 8.3 in mid summer under low flow conditions coincidental with highest dissolved oxygen saturation level (111%), although it would be expected that pH would have risen further during summer/autumn later in the day than at typical sampling times (i.e. after 1055 NZST).

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 96% saturation recorded in early winter 2011 under high flow conditions) and moderately low BOD_5 levels (median: 1.0 g/m^3). Bacteriological quality was typical for this site although numbers were slightly below those characteristic of the lower reaches of developed ring plain catchments, subject to agricultural impacts; with median faecal coliform and enterococci numbers of 165 and 51 (per 100 mls) respectively. These numbers reflected, to some degree, infrequent 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 11.9°C with a maximum summer (late morning) river temperature of 18.3°C recorded in January 2011.

Brief comparison of upper and lower sites during the 2010-2011 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 0.31 m (18% decrease) and increased median turbidity level of 0.7 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 relatively small degree by 30 per 100 mls at the lower river site whereas the median enterococci count atypically improved by 23 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 0.3 g/m^3 at the SH45 site where nearly all median nutrient species’ concentrations also showed significant increases (by up to two times upstream concentrations).

Water temperature range was wider (by 1.2°C) at the lower site with median water temperature 0.8°C warmer at this site in the lower reach of the river in comparison with the mid reach site.

Brief comparison with the previous 1998-2010 period

The most recent twelve-month period sampled a far narrower (lower) range of flow conditions but the median sampled flow was higher by 1,352 L/sec than that sampled over the previous twelve-year period. This was due in part to the wet late winter-early spring 2010 and winter 2011 periods sampled in the 2010-2011 year.

Water clarity was slightly better with the medians for suspended solids identical, turbidities very similar, and black disc clarity higher by 0.23 m in the 2010-2011 period.

Median faecal coliform bacterial number showed a marked improvement of 65 per 100 ml while enterococci also significantly improved by 114 per 100 ml. While pH median values were identical, a much narrower range (by 1.0 unit) was recorded in the recent twelve-month period due to the absence of very elevated summer pH values recorded at times in the previous twelve-year period. Dissolved oxygen saturation median values were almost identical (within 2%) while nearly all median nutrient levels were lower in the recent one year period, some by nearly 50%.

The range in water temperatures was much narrower (by 4.7°C) mainly due to a much lower maximum temperature (by 3.7˚C) while the median was 0.4°C higher in the 2010-2011 sampling period to that recorded in the previous twelve-year period.

Patea River at Barclay Road (site: PAT000200)

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

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

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ CaCO₃)	Black disc (m)	BOD_5 (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
14 July 10	1240	0.008	0.001	0.000	24	4.79	<0.5	6.7	12.3	99	0.021	<1	<1
11 Aug 10	1305	0.015	0.003	0.000	19	5.45	<0.5	5.8	12.0	102	0.016	60	4
8 Sept 10	1300	0.020	0.005	0.001	15	4.74	<0.5	4.8	11.2	100	0.012	3	3
13 Oct 10	1220	0.015	0.003	0.000	16	4.28	<0.5	5.2	11.0	97	0.016	33	<1
10 Nov 10	1225	0.010	0.002	0.000	26	6.22	<0.5	7.3	10.9	101	0.030	27	11
8 Dec 10	1210	0.015	0.003	0.001	30	3.55	<0.5	7.9	10.2	100	0.038	19	17
12 Jan 11	1210	0.018	0.004	0.000	27	6.29	<0.5	7.2	9.8	98	0.033	84	36
9 Feb 11	1150	0.025	0.005	0.000	23	2.83	<0.5	6.5	9.8	99	0.015	230	160
9 Mar 11	1205	0.017	0.005	0.000	19	6.24	<0.5	5.8	10.4	98	0.005	46	23
14 Apr 11	1315	0.012	0.003	0.000	25	2.91	<0.5	6.9	10.6	100	0.022	3	7
13 May 11	1305	0.049	0.011	0.000	9	2.20	0.5	3.4	9.9	98	0.011	140	42
8 June 11	1325	0.046	0.008	0.000	9	3.52	<0.5	3.6	10.6	98	0.011	9	5

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)
14 July 10	1240	<1	0.155	0.003	<0.001	0.039	7.5	<2	3.7	0.08	0.12	0.026	0.60
11 Aug 10	1305	60	0.287	<0.003	<0.001	0.039	7.5	<2	6.0	0.05	0.09	0.016	0.50
8 Sept 10	1300	3	0.316	0.004	<0.001	0.029	7.5	<2	7.9	0.06	0.09	0.013	0.65
13 Oct 10	1220	33	0.280	<0.003	<0.001	0.009	7.5	<2	7.4	0.04	0.05	0.018	0.45
10 Nov 10	1225	27	0.125	0.003	<0.001	0.009	7.7	<2	9.2	0.04	<0.05	0.030	0.60
8 Dec 10	1210	19	0.084	<0.003	<0.001	0.009	7.8	<2	11.6	0.05	0.06	0.044	0.45
12 Jan 11	1210	93	0.103	0.004	0.001	0.029	7.7	3	12.5	0.08	0.11	0.033	0.65
9 Feb 11	1150	230	0.163	0.003	<0.001	0.009	7.7	<2	13.0	0.40	0.41	0.018	0.50
9 Mar 11	1205	46	0.217	<0.003	<0.001	0.029	7.5	<2	9.9	0.06	0.09	0.020	0.55
14 Apr 11	1315	3	0.160	<0.003	<0.001	0.019	7.7	<2	10.0	0.03	<0.05	0.026	0.50
13 May 11	1305	140	1.191	0.003	<0.001	0.009	7.3	<2	12.0	0.04	<0.05	0.020	0.70
8 June 11	1325	9	0.683	0.003	<0.001	0.019	7.4	<2	9.4	0.08	0.10	0.016	0.45

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

Table 28 Statistical summary of data from July 2010 to June 2011: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.008	0.049	0.016	12	0.013
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.011	0.004	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m³ $CaCO_3$	9	30	21	12	7
BLACK DISC	Black disc transparency	m	2.20	6.29	4.51	12	1.436
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	0.5	<0.5	12	0.0
CONDY	Conductivity @ 20°C	mS/m	3.4	7.9	6.2	12	1.4
DO	Dissolved oxygen	g/m³	9.8	12.3	10.6	12	0.81
PERSAT	Dissolved oxygen saturation	%	97	102	99	12	1.5
DRP	Dissolved reactive phosphorus	g/m³P	0.005	0.038	0.016	12	0.010
ECOL	E. coli bacteria	nos/100 ml	<1	230	30	12	69
ENT	Enterococci bacteria	nos/100 ml	<1	160	9	12	44
FC	Faecal coliform bacteria	nos/100 ml	<1	230	30	12	69
FLOW	Flow	m³/s	0.084	1.191	0.190	12	0.319
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.004	0.003	12	0.000
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.001	<0.001	12	0.000
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.04	0.02	12	0.012
pH	pH		7.3	7.8	7.5	12	0.15
SS	Suspended solids	g/m³	<2	3	<2	12	0
TEMP	Temperature	°C	3.7	13.0	9.7	12	2.8
TKN	Total kjeldahl nitrogen	g/m³N	0.03	0.40	0.06	12	0.10
TN	Total nitrogen	g/m³N	<0.05	0.41	0.09	12	0.099
TP	Total phosphorus	g/m³P	0.013	0.044	0.020	12	0.009
TURB	Turbidity	NTU	0.45	0.7	0.5	12	0.09

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

Table 29 Statistical summary of data from July 1995 to June 2011: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.006	0.112	0.016	192	0.022
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.024	0.004	192	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	192	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	3	31	22	191	7
BLACK DISC	Black disc transparency	m	0.09	9.10	4.35	191	1.808
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	3.7	<0.5	192	0.3
CONDY	Conductivity @ 20°C	mS/m	2.5	8.2	6.2	192	1.4
DO	Dissolved oxygen	g/m³	9.1	12.4	10.6	192	0.67
PERSAT	Dissolved oxygen saturation	%	90	103	98	192	2.4
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.038	0.018	192	0.008
ECOL	E. coli bacteria	nos/100 ml	<1	10000	20	168	838
ENT	Enterococci bacteria	nos/100 ml	<1	2200	8	192	189
FC	Faecal coliform bacteria	nos/100 ml	<1	10000	20	192	787
FLOW	Flow	m³/s	0.084	18.000	0.215	192	1.698
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.057	<0.003	192	0.005
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.003	0.001	192	0.000
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.14	0.02	192	0.017
pH	pH		6.5	8.0	7.6	192	0.23
SS	Suspended solids	g/m³	<2	160	<2	192	13
TEMP	Temperature	°C	3.7	14.7	9.2	192	2.5
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	2.70	0.05	192	0.23
TN	Total nitrogen	g/m³N	<0.05	2.72	0.08	192	0.229
TP	Total phosphorus	g/m³P	0.010	0.281	0.024	192	0.025
TURB	Turbidity	NTU	0.3	31	0.5	191	2.46

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

2010-2011 period

Aesthetic water quality was very high, as emphasised by median black disc and turbidity values of 4.51 m and 0.5 NTU respectively, and a maximum black disc clarity of 6.29 m measured under mid summer low flow conditions. The lowest black disc clarity (2.20 m) was recorded in May 2011, coincident with a moderate fresh (1.191 m^3/s) in the river, with small increases in colour, and very small increases in BOD_5 and turbidity also recorded.

Maximum pH (7.8) at this shaded site was measured in early summer under low flow conditions. pH range however was relatively narrow under all flow conditions (varying by only 0.5 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 throughout 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 9 per 100 mls respectively) although counts were higher than usual during the 2010-2011 period. The slightly elevated counts found in summer-autumn during periods of stable flow conditions, may have been due to stock access upstream of the site, some evidence of which has been noted previously in this short reach of the river below the National Park boundary.

River water temperatures varied over a moderate range (9.3°C) at this relatively shaded site during the period. A maximum mid-day temperature of 13.0°C was recorded under low flow conditions in February 2011.

Brief comparison with the previous 1995-2010 period

A much narrower range and a slightly lower median of river flows were sampled during the 2010-2011 period, with few small and one larger fresh sampled, in comparison with the previous fifteen-year period. Median flow for the 2010-2011 sampling occasions was 25 L/sec lower than the median of sampled flows over the previous fifteen-year period. Aesthetic river water quality was similar in terms of median turbidity although median black disc clarity was slightly higher (by 0.16 m) during the 2010-2011 period. Median suspended solids concentrations were very low and identical for both periods.

Most median nutrient species levels were comparatively similar between the two periods, although there was a small decrease in median dissolved reactive phosphorus over the latest twelve-month sampling period.

Median faecal coliform bacterial number increased (by 10 per 100 mls) while enterococci increased (by 1 per 100 mls) over the recent sampling period. Median pH values were within 0.1 pH unit for the two periods while the maximum pH value was only 0.2 unit lower in the 2010-2011 period.

Median water temperature over the past twelve-month period was only 0.6°C lower than the median for the previous fifteen-year period but the maximum temperature was 1.7 °C lower in the latest period than previously recorded. A slightly narrower range of temperatures (by 1.7°C) was recorded in this 2010-2011 period due mainly to a lower maximum 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/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)
14 July 10	1340	0.012	0.003	0.000	28	2.63	0.5	10.1	12.7	104	0.027	28	12
11 Aug 10	1420	0.015	0.004	0.000	26	1.89	0.6	9.8	11.4	102	0.025	76	17
8 Sept 10	1345	0.020	0.005	0.001	24	1.91	0.8	9.2	10.5	100	0.022	120	25
13 Oct 10	1305	0.017	0.004	0.000	28	2.76	0.7	9.1	11.3	106	0.027	76	13
10 Nov 10	1315	0.019	0.004	0.000	31	3.52	1.1	10.9	11.8	120	0.057	37	4
8 Dec 10	1255	0.031	0.007	0.001	36	1.65	0.6	13.9	10.7	115	0.111	42	16
12 Jan 11	1305	0.027	0.006	0.000	30	2.21	0.9	11.0	11.0	119	0.031	110	60
9 Feb 11	1245	0.034	0.008	0.000	30	1.63	1.0	10.8	9.8	105	0.036	400	500
9 Mar 11	1305	0.020	0.005	0.001	26	2.63	0.9	9.5	10.1	101	0.035	150	220
14 Apr 11	1410	0.018	0.004	0.000	29	1.76	1.4	10.3	10.8	108	0.043	180	160
13 May 11	1355	0.024	0.005	0.000	24	0.78	1.5	8.7	9.7	98	0.026	1400	500
8 June 11	1420	0.026	0.005	0.000	22	1.01	1.3	8.4	10.4	100	0.030	730	92
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)**
14 July 10	1340	28	2.313	0.076	0.015	1.055	7.7	<2	5.8	0.18	1.25	0.035	1.3
11 Aug 10	1420	80	5.182	0.070	0.010	1.120	7.6	2	9.2	0.11	1.24	0.033	1.3
8 Sept 10	1345	130	7.791	0.066	0.010	1.050	7.5	3	11.8	0.33	1.39	0.037	1.5
13 Oct 10	1305	80	3.211	0.061	0.012	0.968	7.7	<2	11.1	0.12	1.10	0.036	1.1
10 Nov 10	1315	37	1.231	0.032	0.030	0.950	8.6	2	14.7	0.20	1.18	0.071	1.3
8 Dec 10	1255	52	0.694	0.033	0.040	1.490	7.8	<2	17.6	0.29	1.82	0.135	1.4
12 Jan 11	1305	110	1.929	0.009	0.011	0.759	8.6	2	17.9	0.16	0.93	0.047	1.5
9 Feb 11	1245	400	2.084	0.035	0.021	0.909	7.9	2	17.5	0.18	1.11	0.059	1.7
9 Mar 11	1305	150	4.493	0.105	0.016	0.944	7.7	<2	14.2	0.11	1.07	0.059	1.3
14 Apr 11	1410	190	2.126	0.032	0.026	0.974	7.6	2	14.2	0.20	1.20	0.064	1.6
13 May 11	1355	1600	11.607	0.070	0.018	1.062	7.4	6	14.6	0.26	1.34	0.070	2.3
8 June 11	1420	770	11.237	0.090	0.015	1.095	7.3	6	12.3	0.39	1.50	0.064	2.3

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

Table 31 Statistical summary of data from July 2010 to June 2011: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.012	0.034	0.020	12	0.007
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.008	0.005	12	0.001
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m³ $CaCO_3$	22	36	28	12	4
BLACK DISC	Black disc transparency	m	0.78	3.52	1.90	12	0.77
BOD_5	Biochemical oxygen demand 5 day	g/m³	0.5	1.5	0.9	12	0.3
CONDY	Conductivity @ 20°C	mS/m	8.4	13.9	10.0	12	1.5
DO	Dissolved oxygen	g/m³	9.7	12.7	10.8	12	0.86
PERSAT	Dissolved oxygen saturation	%	98	120	105	12	7.6
DRP	Dissolved reactive phosphorus	g/m³P	0.022	0.111	0.031	12	0.025
ECOL	E. coli bacteria	nos/100 ml	28	1400	115	12	406
ENT	Enterococci bacteria	nos/100 ml	4	500	43	12	183
FC	Faecal coliform bacteria	nos/100 ml	28	1600	120	12	459
FLOW	Flow	m³/s	0.694	11.607	2.762	12	3.777
NH_4	Ammoniacal nitrogen	g/m³N	0.009	0.105	0.064	12	0.028
NO_2	Nitrite nitrogen	g/m³N	0.010	0.040	0.016	12	0.009
NO_3	Nitrate nitrogen	g/m³N	0.76	1.49	1.01	12	0.174
pH	pH		7.3	8.6	7.7	12	0.42
SS	Suspended solids	g/m³	<2	6	2	12	2
TEMP	Temperature	°C	5.8	17.9	14.2	12	3.6
TKN	Total kjeldahl nitrogen	g/m³N	0.11	0.39	0.19	12	0.09
TN	Total nitrogen	g/m³N	0.93	1.82	1.22	12	0.233
TP	Total phosphorus	g/m³P	0.033	0.135	0.059	12	0.028
TURB	Turbidity	NTU	1.1	2.3	1.5	12	0.38

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

Table 32 Statistical summary of data from July 1995 to June 2011: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.095	0.023	192	0.015
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.023	0.005	192	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	192	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	10	57	28	192	6
BLACK DISC	Black disc transparency	m	0.05	4.68	1.85	192	0.889
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	16.0	0.9	192	1.6
CONDY	Conductivity @ 20°C	mS/m	5.0	14.3	9.9	192	1.5
DO	Dissolved oxygen	g/m³	8.9	12.9	10.6	192	0.74
PERSAT	Dissolved oxygen saturation	%	87	121	102	192	6.2
DRP	Dissolved reactive phosphorus	g/m³P	0.010	0.160	0.041	192	0.033
ECOL	E. coli bacteria	nos/100 ml	2	25000	200	168	3442
ENT	Enterococci bacteria	nos/100 ml	4	19000	115	192	1661
FC	Faecal coliform bacteria	nos/100 ml	2	63000	230	192	5641
FLOW	Flow	m³/s	0.680	77.530	2.850	192	8.368
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.329	0.053	192	0.054
NO_2	Nitrite nitrogen	g/m³N	0.003	0.051	0.017	192	0.008
NO_3	Nitrate nitrogen	g/m³N	0.21	1.54	0.94	192	0.220
pH	pH		7.0	8.8	7.8	192	0.37
SS	Suspended solids	g/m³	<2	360	2	192	31
TEMP	Temperature	°C	5.3	21.8	12.8	192	3.4
TKN	Total kjeldahl nitrogen	g/m³N	0.02	4.07	0.25	192	0.39
TN	Total nitrogen	g/m³N	0.74	4.50	1.24	192	0.359
TP	Total phosphorus	g/m³P	0.022	1.390	0.069	192	0.122
TURB	Turbidity	NTU	0.2	80	1.5	191	7.79

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.

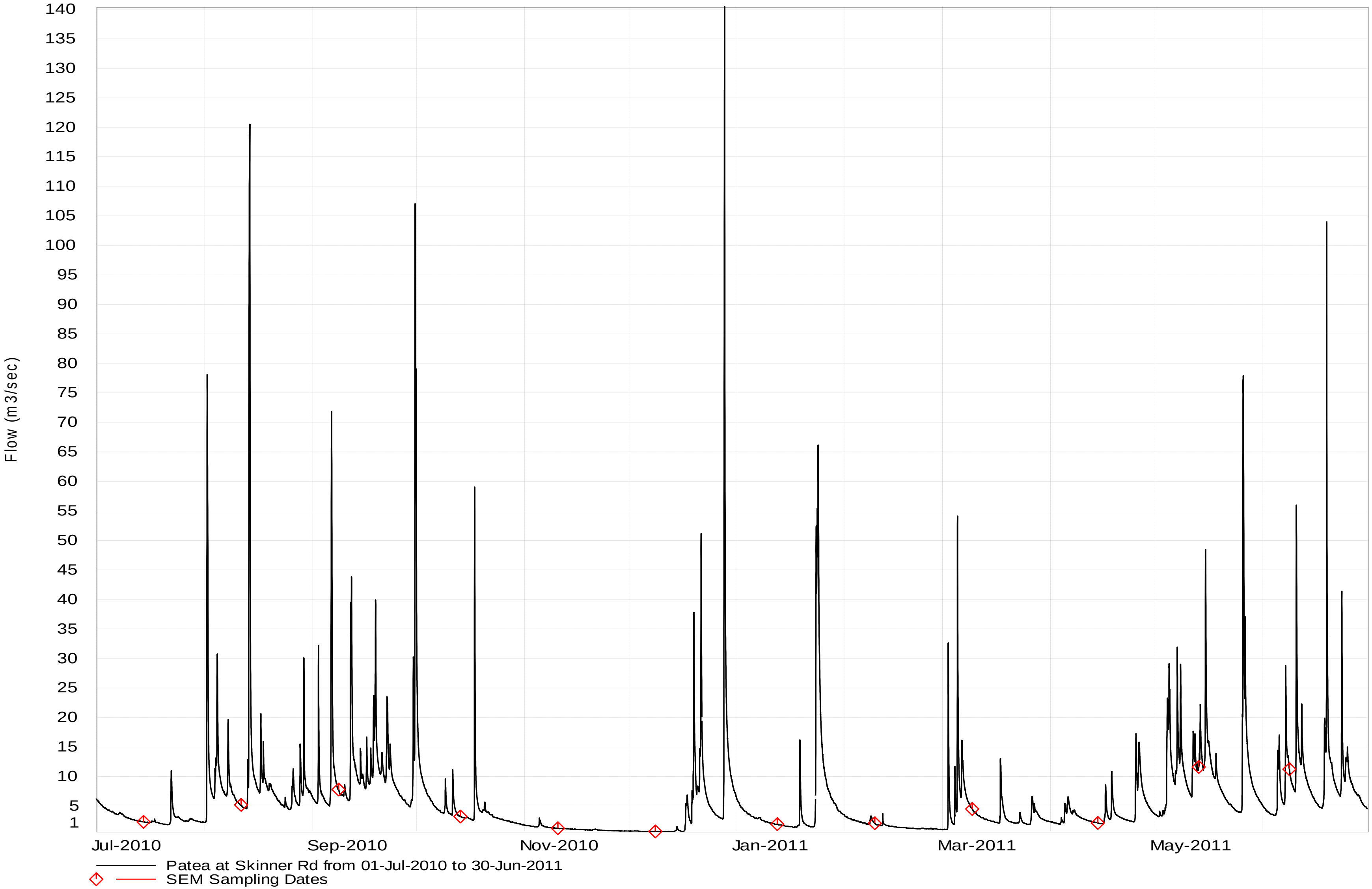

Figure 8 Flow record for the Patea River at Skinner Road

Discussion

2010-2011 period

Moderate median black disc clarity (1.90 metres) and median turbidity (1.5 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 0.78 m, turbidity of 2.3 NTU) and a small increase in suspended solids concentration (6 g/m^3) were recorded during a fresh event sampled in May 2011 (Figure 8). A deterioration in other water quality parameters during this event was also illustrated by a high faecal coliform bacterial number, slightly elevated BOD_5, and slight reduction in dissolved oxygen saturation.

Early afternoon pH levels reached a maximum of 8.6 units in early and mid-summer while dissolved oxygen levels were consistently high (98% or higher saturation) with supersaturation recorded particularly during early summer to autumn low flow conditions coincident with more extensive algal cover and elevated pH levels (7.8 to 8.6 units). BOD_5 concentrations under normal to low recession flow conditions were generally indicative of moderately low organic contamination (i.e. up to 1.4 g/m^3 on these occasions).

The moderate median bacteriological numbers (43 enterococci and 120 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, although low counts during spring-early summer were coincident with a relatively dry period and a reduction in dairy shed pond systems' discharge rates (see TRC, 2011a).

Water temperatures varied over a moderately wide range of 12.1°C with a maximum (early afternoon) summer temperature of 17.9°C recorded in January 2011 (coincident with a pH of 8.6 and 119% dissolved oxygen saturation).

Brief comparison of upper and mid catchment sites during the 2010-2011 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 (4 to 5-fold increases) and increases in median nutrient species concentrations (2 to 50 fold). The pH range increased by 0.8 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 (1.0 NTU) was measured in mid catchment while median BOD_5 increased by about 0.5 g/m^3 although maximum BOD_5 was 1 g/m^3 higher downstream. A deterioration in black disc clarity (median clarity decreased significantly by 2.61 m and maximum clarity by 2.77 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 markedly higher (by 4.5°C) and maximum water temperature was higher (by 4.9°C) than at the Barclay Road site.

Brief comparison with the previous 1995-2010 period

The median of sampled flows in the recent twelve-month period was 88 L/sec lower than the median of flows sampled over the 1995-2010 period but the range of river flows sampled was very much narrower. Aesthetic water quality was very similar to historical conditions with recent median turbidity identical and median black disc clarity higher by 0.05 m. There was no difference in the median suspended solids concentrations for the two periods.

There was a narrower pH range (by 0.5 pH unit) and lower maximum pH (by 0.2 pH unit) during the 2010-2011 period. Dissolved oxygen percentage saturation median was higher by an insignificant 3% in the 2010-2011 period.

Bacterial water quality improved markedly for faecal coliform bacteria and also for enterococci during the more recent sampling period, with median faecal coliform and enterococci numbers decreasing by 130 and 77 (per 100 mls) respectively. Seasonal variability in municipal oxidation ponds' system performance and dairy shed wastes disposal contributed to these improvements in bacterial quality during 2010-2011 (TRC, 2011a).

Water temperature range was narrower (by 4.4°C) during the more recent sampling period with the median water temperature higher (by 1.5˚C) than the longer term median. The maximum water temperature recorded was 3.9°C lower than previously recorded but the minimum water temperature was higher (by 2.0°C) in the latest twelve-month period.

Median BOD_5 was identical in the latest period with median ammonia and nitrate nitrogen of the nutrient species showing increases. There was a decrease in median dissolved reactive and total phosphorus species 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/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)
14 July 10	1410	0.045	0.010	0.000	46	1.62	<0.5	11.2	12.7	101	0.006	40	8
11 Aug 10	1455	0.044	0.009	0.001	28	0.61	<0.5	8.1	11.6	101	0.004	80	15
8 Sept 10	1425	0.049	0.011	0.001	17	0.19	0.7	6.3	10.1	96	0.004	330	37
13 Oct 10	1340	0.046	0.009	0.000	34	0.51	<0.5	9.2	11.2	106	0.006	110	17
10 Nov 10	1350	0.043	0.009	0.000	51	4.04	0.6	12.4	10.3	109	0.005	63	17
8 Dec 10	1335	0.039	0.008	0.000	68	1.62	1.1	15.0	9.3	105	0.005	86	66
12 Jan 11	1345	0.062	0.013	0.000	59	1.62	0.6	13.7	9.6	112	0.006	140	70
9 Feb 11	1225	0.064	0.014	0.000	50	0.65	0.7	12.9	9.4	104	<0.003	730	390
9 Mar 11	1345	0.060	0.013	0.001	31	0.62	0.5	9.0	9.6	99	<0.003	590	310
14 Apr 11	1450	0.049	0.010	0.000	42	1.25	0.6	10.9	10.3	103	0.009	280	86
13 May 11	1430	0.128	0.054	0.022	21	0.11	0.9	6.4	9.3	93	0.006	1000	490
8 June 11	1455	0.080	0.016	0.001	16	0.09	1.6	6.5	9.9	94	0.011	3300	1500

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)
14 July 10	1410	43	5.005	0.027	0.002	0.208	7.7	2	5.0	0.09	0.30	0.014	2.7
11 Aug 10	1455	80	11.623	0.016	0.001	0.289	7.5	8	8.5	0.05	0.34	0.021	4.2
8 Sept 10	1425	340	30.544	0.019	0.002	0.288	7.2	63	12.2	0.33	0.62	0.083	24
13 Oct 10	1340	120	8.316	0.010	0.002	0.128	7.7	5	12.1	0.14	0.27	0.018	3.7
10 Nov 10	1350	63	3.315	0.004	0.002	0.018	8.2	<2	17.5	0.11	0.13	0.012	2.2
8 Dec 10	1335	94	2.111	0.014	0.002	0.018	8.0	<2	20.5	0.21	0.23	0.032	1.8
12 Jan 11	1345	150	2.214	0.006	0.002	0.018	8.4	<2	22.4	0.17	0.19	0.012	2.4
9 Feb 11	1225	730	6.887	0.009	0.002	0.048	8.0	2	19.7	0.17	0.22	0.009	4.7
9 Mar 11	1345	610	7.211	0.011	0.001	0.149	7.7	4	16.1	0.14	0.29	0.015	4.2
14 Apr 11	1450	280	4.299	0.016	0.002	0.078	7.6	<2	14.9	0.13	0.21	0.017	2.5
13 May 11	1430	1000	45.371	0.016	0.011	0.189	7.2	120	14.7	0.45	0.65	0.199	40
8 June 11	1455	3300	64.97	0.022	0.002	0.258	7.1	270	12.4	1.00	1.26	0.249	72

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

Table 34 Statistical summary of data from July 2010 to June 2011: Mangaehu River at Raupuha Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.039	0.128	0.049	12	0.025
A440F	Absorbance @ 440nm filtered	/cm	0.008	0.054	0.011	12	0.013
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.022	0.000	12	0.006
ALKT	Alkalinity total	g/m^3 $CaCO_3$	16	68	38	12	17
BLACK DISC	Black disc transparency	m	0.09	4.04	0.64	12	1.10
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	1.6	0.6	12	0.3
CONDY	Conductivity @ 20°C	mS/m	6.3	15.0	10.1	12	3.0
DO	Dissolved oxygen	g/m^3	9.3	12.7	10.0	12	1.05
PERSAT	Dissolved oxygen saturation	%	93	112	102	12	5.8
DRP	Dissolved reactive phosphorus	g/m^3P	<0.003	0.011	0.006	12	0.002
ECOL	E. coli bacteria	nos/100 ml	40	3300	210	12	915
ENT	Enterococci bacteria	nos/100 ml	8	1500	68	12	427
FC	Faecal coliform bacteria	nos/100 ml	43	3300	215	12	914
FLOW	Flow	m^3/s	2.111	64.970	7.049	12	20.254
NH_4	Ammoniacal nitrogen	g/m^3N	0.004	0.027	0.015	12	0.007
NO_2	Nitrite nitrogen	g/m^3N	0.001	0.011	0.002	12	0.003
NO_3	Nitrate nitrogen	g/m^3N	0.02	0.29	0.14	12	0.105
pH	pH		7.1	8.4	7.7	12	0.41
SS	Suspended solids	g/m^3	<2	270	3	12	81
TEMP	Temperature	°C	5.0	22.4	14.8	12	5.0
TKN	Total kjeldahl nitrogen	g/m^3N	0.05	1.00	0.16	12	0.26
TN	Total nitrogen	g/m^3N	0.13	1.26	0.28	12	0.317
TP	Total phosphorus	g/m^3P	0.009	0.249	0.018	12	0.081
TURB	Turbidity	NTU	1.8	72	3.95	12	21.76

A statistical summary of the sixteen years' data collected since 1 July 1995 is presented in Table 34.

Table 35 Statistical summary of data from July 1995 to June 2011: Mangaehu River at Raupuha Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.027	0.181	0.054	192	0.019
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.056	0.011	192	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.025	0.000	192	0.003
ALKT	Alkalinity total	g/m^3 $CaCO_3$	9	79	38	192	13
BLACK DISC	Black disc transparency	m	<0.01	4.04	0.78	192	0.755
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	5.6	0.6	192	0.7
CONDY	Conductivity @ 20°C	mS/m	4.3	15.6	9.9	192	2.3
DO	Dissolved oxygen	g/m^3	7.7	12.9	10.0	192	0.95
PERSAT	Dissolved oxygen saturation	%	83	118	100	192	5.6
DRP	Dissolved reactive phosphorus	g/m^3P	<0.003	0.026	0.006	192	0.004
ECOL	E. coli bacteria	nos/100 ml	6	16000	220	168	2113
ENT	Enterococci bacteria	nos/100 ml	1	6000	70	192	814
FC	Faecal coliform bacteria	nos/100 ml	6	16000	235	192	2223
FLOW	Flow	m^3/s	1.658	111.87	7.062	192	16.545
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.081	0.012	192	0.012
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.016	0.002	192	0.002
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.36	0.10	192	0.088
pH	pH		6.9	8.4	7.7	192	0.31
SS	Suspended solids	g/m^3	<2	1300	4	192	131
TEMP	Temperature	°C	4.3	24.0	13.7	192	4.4
TKN	Total kjeldahl nitrogen	g/m^3N	0.02	1.90	0.18	192	0.28
TN	Total nitrogen	g/m^3N	0.09	2.10	0.33	192	0.302
TP	Total phosphorus	g/m^3P	0.003	0.786	0.021	192	0.108
TURB	Turbidity	NTU	1.7	850	3.6	191	69.5

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.

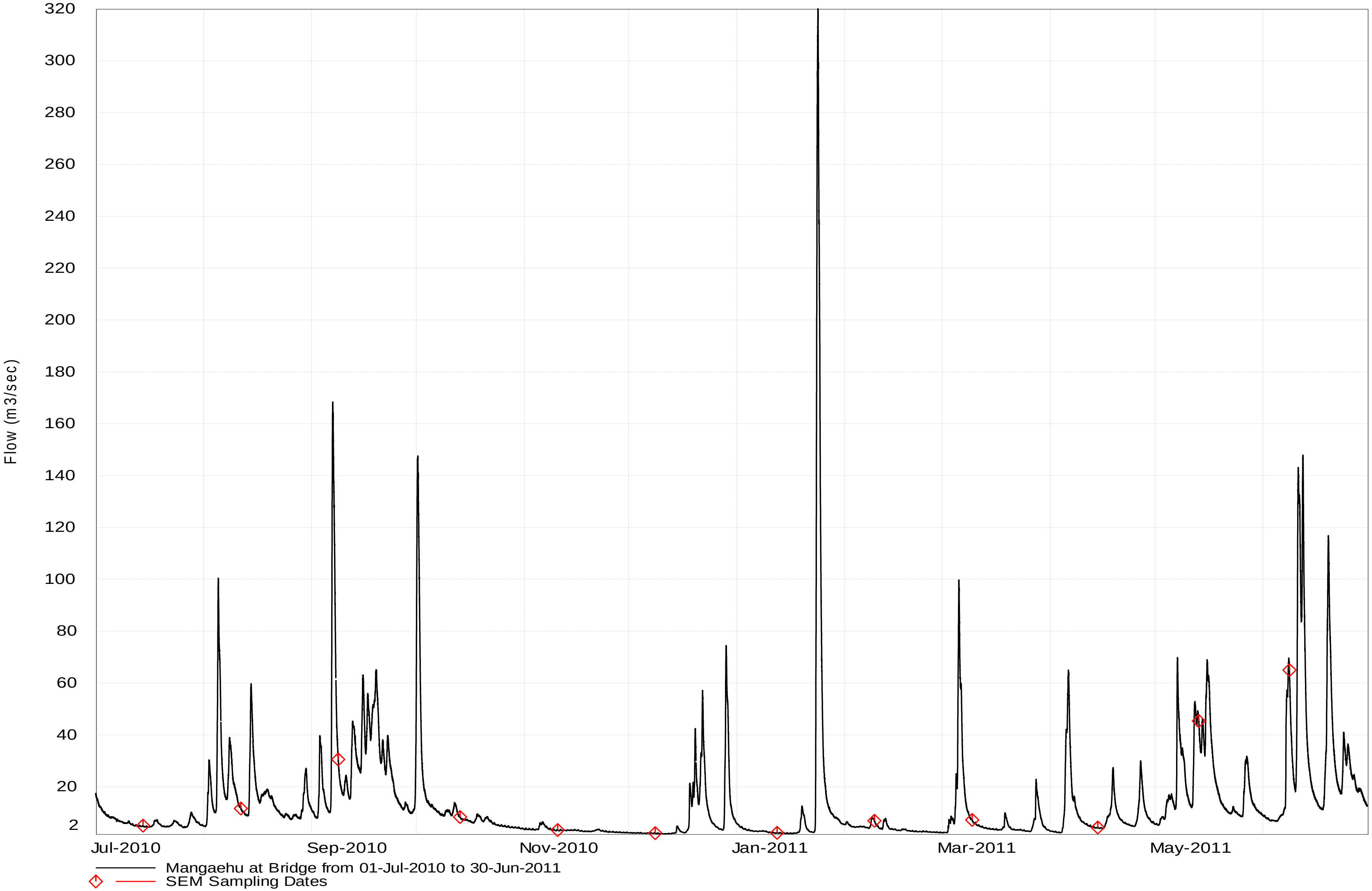

Figure 9 Flow record for the Mangaehu River at Raupuha Road

Discussion

2010-2011 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 0.64 metre although a maximum of 4.04 metres was measured after an unseasonably dry spring period, 1.01 metres greater than previously recorded. Clarity was frequently less than 1 metre (on seven occasions) due to the presence of very fine, colloidal suspended particles. However, the median suspended solids concentration was 3 g/m^3 which was lower than typical for this river, in part due to the few flood events sampled during the period. Absorbances (at 340 and 440 nm) were also relatively high (in excess of 0.038/cm and 0.007/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 clarity (0.09 and 0.11 m black disc values) was coincident with turbidity levels of 72 and 40 NTU and suspended solids concentrations of 270 and 120 g/m^3, during flood flows of 65 and 45.4 m^3/s recorded in May and June 2011 respectively. Fresh flows (in excess of 20 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 September 2010 and May and June 2011, Figure 9).

Maximum mid-afternoon pH values in the late spring to late summer period (8.0 to 8.4) 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 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 10.0 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 (68 enterococci and 215 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 relatively wide range of 17.4°C with a maximum (early afternoon) summer temperature of 22.4° C recorded in January 2011 during low flow conditions, at which time dissolved oxygen saturation was 112% and pH was 8.4.

Brief comparison with the previous 1995-2010 period

The range of flows sampled during the 2010-2011 period was much narrower than the range sampled over the previous fifteen-year period mainly due to the smaller principal fresh sampled during the latest period. However, the median sampled flow in the 2010-2011 period was only slightly lower (by 13 L/sec) than that sampled over the longer term. Median black disc clarity was poorer by 0.18 m and median turbidity was higher by 0.4 NTU in the most recent period, while the median suspended solids concentration decreased by 2 g/m^3.

There were no significant differences in most nutrient species' median concentrations, with the exception of nitrate and total nitrogen which increased slightly in the latest period, compared to the median for the previous fifteen-year period. Median bacterial numbers were very similar for enterococci but decreased slightly for faecal coliforms (by 20 per 100 ml) in the 2010-2011 period.

Median dissolved oxygen saturation level was very similar (3% higher) in the 2010-2011 period while median pH levels were equivalent between periods. Maximum pH was 0.1 unit higher than previously recorded.

The range of water temperatures was significantly narrower (by 2.3°C) in the latest twelve-month period than in the previous fifteen-year period while median water temperature was 1.1°C higher during 2010-2011, with a lower maximum temperature (by 1.6°C) and higher minimum temperature (by 0.7°C) recorded in the 2010-2011 sampling year.

4.2 Comparative water quality for the sixteen-year (1995-2011) period

4.2.1 TRC data

In addition to the site descriptions of water quality measured during the 2010-2011 monthly sampling programme, a general comparison between the eleven sites of the programme may be made for the sixteen-year sampling period to date (1995-2011) 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 sixteen 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 (3.6 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 0.78 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 sixteen year period.

Table 36 Some comparative water quality data for the eleven TRC SEM sites for the sixteen-year period July 1995 to June 2011 (n = 192 samples)

Site	Black disc		BOD_5	Conductivity @ 20°C	Faecal coliform bacteria		Nutrients: Ammonia	Nutrients: Nitrate	Nutrients: Total N	Nutrients: DRP	Nutrients: Total P	pH		Dissolved oxygen saturation (%)			Suspended solids	Temperature			Turbidity
Unit	(m)		(g/m^3)	(mS/m)	(nos per 100 ml)		(g/m^3N)	(g/m^3N)	(g/m^3N)	(g/m^3P)	(g/m^3P)						(g/m^3)	(°C)			(NTU)
	Maximum	Median	Median	Median	Minimum	Median	Median	Median	Median	Median	Median	Maximum	Median	Min	Med	Range	Median	Maximum	Median	Range	Median
Maketawa Stream at Tarata Road*	5.23	2.58	<0.5	8.5	50	305	0.010	0.25	0.39	0.022	0.032	7.9	7.6	90	97	12	<2	17.6	11.4	12.8	0.9
Mangaoraka Stream at Corbett Road	4.73	1.85	0.6	14.5	120	745	0.021	0.85	1.12	0.009	0.022	8.1	7.6	83	96	24	2	20.5	13.1	14.7	1.6
Waiwhakaiho River at SH3	8.05	3.06	<0.5	12.2	23	180	0.007	0.11	0.21	0.024	0.034	8.5	7.9	91	100	17	<2	18.3	11.1	13.5	0.7
Stony River at Mangatete Road	13.12	3.56	<0.5	9.7	<1	8	<0.003	0.02	0.06	0.018	0.024	8.2	7.9	87	99	17	<2	16.6	10.7	10.9	0.7
Punehu Stream at Wiremu Road	4.53	1.84	<0.5	8.5	3	130	0.006	0.03	0.15	0.023	0.034	8.3	7.7	87	99	19	2	19.2	12.0	14.2	1.6
Punehu Stream at SH45	3.57	1.51	0.9	16.1	51	500	0.044	0.91	1.35	0.042	0.076	8.6	7.7	90	99	24	3	21.0	13.4	16.0	1.8
Waingongoro River at Eltham Road	4.39	1.73	0.6	11.2	6	185	0.018	1.11	1.41	0.018	0.036	8.6	7.8	92	102	29	3	20.8	12.4	15.2	1.4
Waingongoro River at SH45 **	4.34	1.18	1.0	16.4	3	220	0.031	1.89	2.47	0.065	0.104	9.1	7.8	89	101	52	5	22.0	13.7	16.6	2.3
Patea River at Barclay Road	9.10	4.35	<0.5	6.2	<1	20	<0.003	0.02	0.08	0.018	0.024	8.0	7.6	90	98	13	<2	14.7	9.2	11.0	0.5
Patea River at Skinner Road	4.68	1.85	0.9	9.9	2	230	0.053	0.94	1.24	0.041	0.069	8.8	7.8	87	102	34	2	21.8	12.8	16.5	1.5
Mangaehu River at Raupuha Road	4.04	0.78	0.6	9.9	6	220	0.012	0.10	0.33	0.006	0.021	8.4	7.7	83	100	35	4	24.0	13.7	19.7	3.6

[Notes: * for the period July 2003 to June 2011 (n = 102 samples); ** for the period July 1998 to June 2011 (n = 156 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, 13.4°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) were 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 7.6 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, 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 (0.9 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 800% and 125% in median total nitrogen and total phosphorus respectively over the length of the Punehu Stream and 1450% and 185% 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^3) 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 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 745 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 230 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. 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 had comparatively good bacteriological water quality on occasions. The sites in the Patea River's upper reaches (at Barclay Road) and the Stony River in mid-reach (at Mangatete Road) generally recorded very high bacteriological water quality with median faecal coliform numbers of 20 and 8 per 100 mls respectively. The upper site in the Punehu Stream (at Wiremu Road) however 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 sixteen 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 sixteen-year period July 1995 to June 2011 (n = 192 samples)

Site Unit	Black disc (m)		BOD_5 (g/m^3)	Conductivity @ 20°C (mS/m)	Nutrients					pH		Dissolved oxygen saturation %	Temperature (°C)			Turbidity (NTU)	Flow (m^3/sec)
					Amm-N (g/m^3N)	Nitrate (g/m^3N)	Total N (g/m^3N)	DRP (g/m^3P)	TP (g/m^3P)								
	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	0.30	0.55	0.006	0.034	8.6	7.7	102	23.2	13.7	16.7	8.5	28.5
Manganui River at SH3	7.7	4.14	<0.5	6.2	0.006	0.09	0.18	0.009	0.015	7.9	7.5	101	18.7	10.4	14.1	0.9	0.93
Waingongoro River at SH45	2.9 (4.34)	1.3 (1.18)	1.0 (1.0)	16.5 (16.4)	0.027 (0.031)	1.93 (1.89)	2.26 (2.47)	0.053 (0.065)	0.102 (0.104)	9.1 (9.1)	7.9 (7.8)	104 (101)	23.0 (22.0)	13.8 (13.7)	16.7 (16.6)	2.4 (2.3)	4.9 (4.70)

[Notes ( ) = TRC data for the period July 1998 to June 2011 (n = 156 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 thirteen 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 sixteen 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 1995-2011 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/m³	<550/ 100mls	<3g/m³	<0.03 g/m³P	<0.03 g/m³P •	<0.6 g/m³N •	<1000/ 100mls	Median <100/100 mls	>0.8m	>80%	<0.4 g/m³N	<0.9 g/m³N	<25° C	<25 g/m³N	<0.8 g/m³P	<11.3 g/m³N
Reference	1,2	2,3	2,3	2	1,2	1	1	1,2	1			1,2	1	2	1	1	1,2
Site																	
Maketawa Stream at Tarata Road	✓	✓✓	✓	✓✓	✓	✓	✓	✓	x	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
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	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, 2011), 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, 2011)) on occasions under spring-summer low flow conditions (refer to individual tables of 2010-2011 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 (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 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 six 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. 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 sixteen years (1995 to 2011) to date (TRC, 2006c, Stark and Fowles, 2006 and TRC, 2011a).

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 2011

4.3.1 Comments

Sixteen years of physicochemical water quality data have been collected up to 30 June 2011. These data have been analysed for trends following the availability of 10 years of data, and previous trends have been reported in TRC, 2006a, TRC, 2008 and TRC, 2009a.

An update of the trends which includes data from the 2010-2011 monitoring year is reported here. It does not provide a detailed interpretation of the results which will be provided prior to each five yearly State of the Environment Report (next due in 2014).

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 sofware[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 of RSKSE indicates a positive (increasing) trend, and a negative SKSE or RSKSE indicates a negative or decreasing trend. The RSKSE allows comparisons in the slope between parameters and sites and is used in the tables below.

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

4.3.3 Results of trend analysis

Table 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 a long term data record (the Maketawa Stream at Tarata Road does not yet have 10 years of data).

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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.

Table 39 'Meaningful' trends in surface water quality at 10 State of the Environment Monitoring sites in Taranaki - 1995-2011 (p<5% and RSKSE (%change/yr) >%)

		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	**Improvement** 😃	**No change** 😐	**Deterioration** 😠
Upper	**Patea River Barclay Rd**	🙁	😐	😐	😐	😃	😐	😐	😐	😐	😐	😐	😐	😐	1	11	1
Upper/ Middle	**Punehu Stream Wiremu Rd**	😐	😐	😐	😐	😃	😐	😐	😐	😐	😐	😐	😐	😐	1	12	0
Middle	**Stony River Mangatete Road**	😠	😠	😐	😐	😃	😐	😐	😐	😠	😐	😐	😐	😐	1	9	3
Middle	**Patea River Skinner Rd**	😐	😐	😠	😐	😐	🙂	😐	😐	😐	😐	😐	😐	😐	1	11	1
Middle	**Waiwhakaiho SH3**	😠	🙁	😠	😠	😐	😐	😐	😐	😠	😐	😐	😐	😐	0	8	5
Middle	**Waingongoro Eltham Rd**	😠	🙁	😠	😐	😐	😃	😐	😐	😐	😐	😐	😐	😐	1	9	3
Lower	**Mangaoraka Stream Corbett Rd**	😠	🙁	😐	🙁	😐	😐	😠	😐	😠	😐	😐	😐	😐	0	8	5
Lower	**Waingongoro SH45***	😃	😃	🙂	😐	🙂	😐	😐	😐	😐	😐	😐	🙁	😐	4	8	1
Lower	**Punehu Stream SH45**	😠	🙁	😠	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	0	10	3
Lower	**Mangaehu River Raupuha Rd**	🙁	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	😐	0	12	1
	Total no. sites: Improvement 😃	1	1	1	0	4	2	0	0	0	0	0	0	0			
	No change 😐	2	4	5	8	6	8	9	10	7	10	10	9	10			
	Deterioration 😠	7	5	4	2	0	0	1	0	3	0	0	1	0			

Key:

*Waingongoro SH45: Data for this site only for the past 13 years: 1998 – 2011

😃 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**

Of the nutrients, DRP and to a lesser extent total phosphorus, have shown a significantly deteriorating trend at a number of sites, when taken across the entire (16 year) record, including sites in the upper and mid catchments which would be less subject to anthropogenic pressures. The deterioration in total phosphorus appears to be concentrated in the mid-catchment sites, whereas DRP is deteriorating at 7 out of the 10 sites monitored and at sites located 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 site which is situated at the lower catchment level. Overall 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. The lower catchment sites also show a number of deteriorations although 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, the Mangaoraka Stream, and the Punehu Stream at SH45 have the greatest number of deteriorating trends in relation to nutrients[(four out of five nutrients are deteriorating significantly for Waiwhakaiho and three out of five for Waingongoro, Mangaoraka and Punehu Stream at SH45 (Table 39)].

In all four 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 and 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). The Waingongoro River at SH45 for the first time since these trends have been performed is showing a very significant improving trend in dissolved reactive phosphorus, total phosphorus and a significant trend in nitrogen (Figure 10). It is probable that this is due to the more recent reduction in meatworks' discharges to the river at Eltham and the elimination of all Eltham WWTP municipal discharges in the catchment (since mid-2010).

Faecal coliforms and enterococci bacteria generally showed no statistically significant change over the 16 year period, although two middle catchment sites (Patea River at Skinner Road and Waingongoro at Eltham 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 at the lower catchment site of the Mangaoraka Stream at Corbett Road although 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 16 year period. However, the Stony River shows deterioration in clarity as a result of the significant erosion events that have occurred in the headwaters of this catchment from time to time in recent years and trending 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 1). 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.

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 (PAT000200)	1.562	1.850	94.82	0.32	45.092	0.000	42.03	0	0.000	-6.248	18.07	-1.04	66.8	0.00
Upper/ Middle	Punehu Stream Wiremu Rd (PNH000200)	34.274	1.111	63.060	-0.421	40.548	0.000	93.784	-1.233	0.019	-3.453	30.454	-2.316	88.632	-1.803
Middle	Stony River Mangatete Road (STY000300)	0.000	2.772	0.039	1.667	10.425	0.000	63.060	0.000	0.007	-5.506	7.933	-2.084	78.490	0.000
Middle	Patea River Skinner Rd (PAT000360)	94.819	0.706	42.789	0.194	0.000	1.554	98.963	-0.604	0.771	0.808	1.620	-1.988	29.246	0.000
Middle	Waiwhakaiho SH3 (WKH000500)	0.016	2.608	1.213	1.632	0.002	1.701	0.001	1.586	36.983	-0.873	15.658	-0.872	70.624	0.328
Middle	Waingongoro Eltham Rd (WGG000500)	0.000	3.556	2.455	1.408	0.010	1.776	84.543	0.000	0.133	0.838	0.714	-4.499	6.309	-2.379
Lower	Mangaoraka Stream Corbett Rd (MRK000420)	0.101	2.953	3.413	1.518	84.543	-0.178	2.997	3.167	17.236	-0.669	19.820	1.066	0.005	4.406
Lower	Waingongoro SH45* (WGG000900)	0.077	-2.186	0.410	-2.671	2.105	-1.395	12.547	0.000	1.179	-1.114	5.059	-3.099	98.595	-0.267
Lower	Punehu Stream SH45 (PNH000900)	0.013	2.870	4.396	1.701	0.190	1.972	94.819	-0.325	3.878	0.755	10.991	-3.671	12.240	1.667
Lower	Mangaehu River Raupuha Rd (MGH000950)	4.675	1.850	36.983	0.000	19.820	0.000	57.625	0.000	7.933	-0.700	30.454	-1.923	86.583	0.249
Total no. sites: Improvement ☺		1		1		1		0		4		2		0	
No change 😐		2		4		5		8		6		8		9	
Deterioration ☹		7		5		4		2		0		0		1	

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 *p*-value (%)	Conductivity % change per yr	Black Disc *p*-value (%)	Black Disc % change per yr	Suspended Solids *p*-value (%)	Suspended Solids % change per yr	Temp˚C *p*-value (%)	Temp˚C % change per yr	Biochemical O_2 Demand *p*-value (%)	Biochemical O_2 Demand % change per yr	pH *p*-value (%)	pH % change per yr
Upper	Patea River Barclay Rd (PAT000200)	30.45	0.32	85.46	0.51	34.25	0.00	3.199	-0.43	0.983	0.00	88.63	0.00
Upper/ Middle	Punehu Stream Wiremu Rd (PNH000200)	0.047	0.44	8.388	0.76	63.05	0.00	3.199	-0.46	73.53	0.00	0.00	0.00
Middle	Stony River Mangatete Road (STY000300)	76.5	0.41	0	-4.16	0.008	0.00	4.675	-0.15	24.92	0.00	0.06	0.00
Middle	Patea River Skinner Rd (PAT000360)	1.403	0.34	100	-0.23	66.8	0.00	45.88	0.00	41.29	0.00	3.64	0.00
Middle	Waiwhakaiho SH3 (WKH000500)	0.66	0.39	0.043	-1.98	8.865	0.00	0.159	-0.45	70.62	0.00	0.00	0.00
Middle	Waingongoro Eltham Rd (WGG000500)	44.32	0.11	86.58	-0.21	86.58	0.00	2.806	-0.20	66.8	0.00	3.20	0.00
Lower	Mangaoraka Stream Corbett Rd (MRK000420)	98.96	0.23	0.00	-3.03	2	0.00	5.28	-0.38	12.84	0.00	0.38	0.00
Lower	Waingongoro SH45* (WGG000900)	49.22	0.33	5.059	2.47	31.54	0.00	0.41	-0.49	2.77	2.36	0.00	-0.21
Lower	Punehu Stream SH45 (PNH000900)	20.74	0.35	35.61	0.03	24.21	0.00	0.714	-0.43	98.96	0.00	0.00	-0.14
Lower	Mangaehu River Raupuha Rd (MGH000950)	10.42	0.51	1.739	-0.85	98.96	0.00	2.997	-0.09	24.74	0.00	84.54	0.00
Total no. sites: Improvement ☺		0		0		0		0		0		0	
No change 😐		10		7		10		10		9		10	
Deterioration ☹		0		3		0		0		1		0	

Figure 10 shows the trends graphically for a selected number of sites and parameters where significant trends were recorded and commented on in this report.

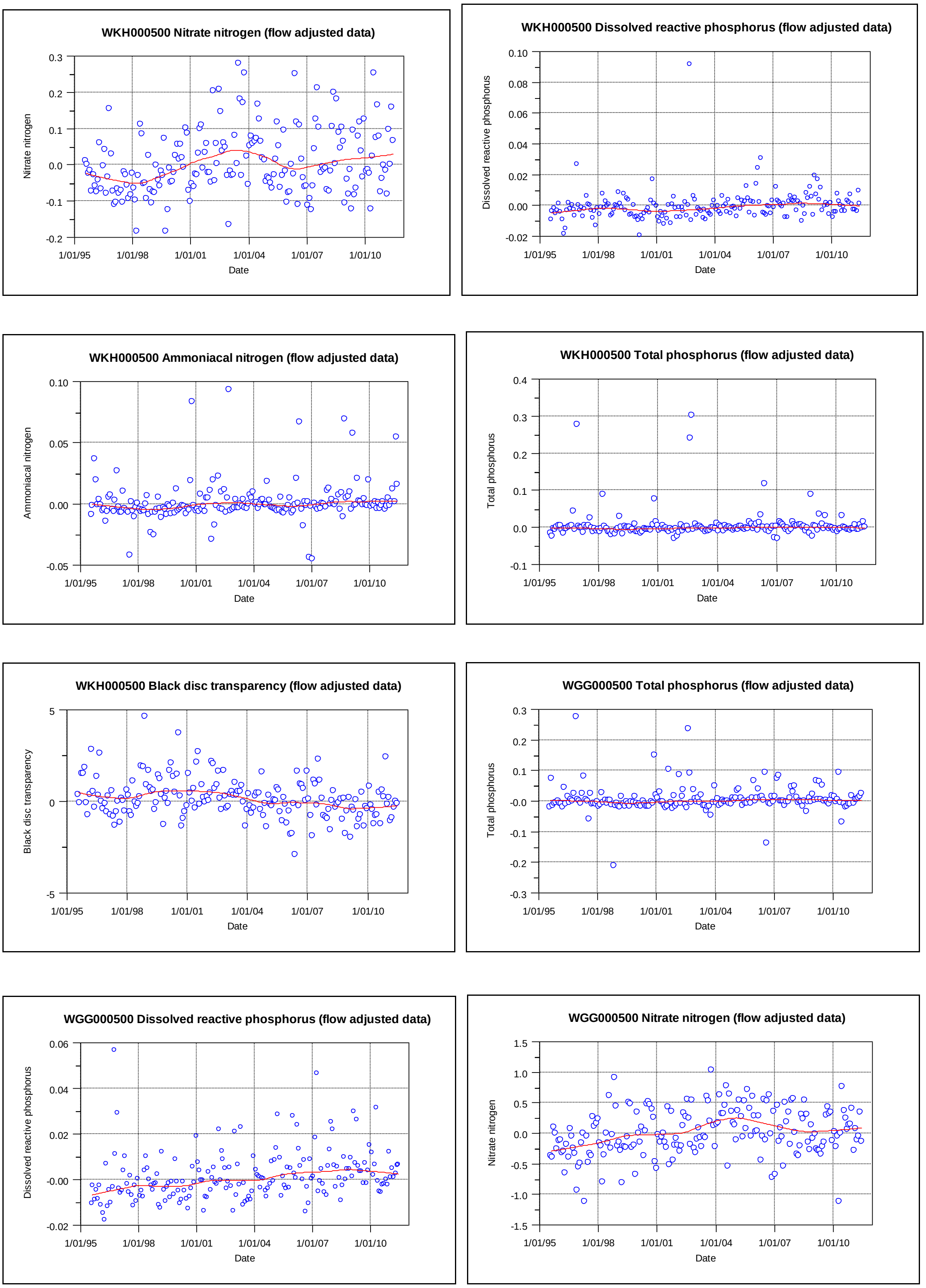

Figure 10 Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

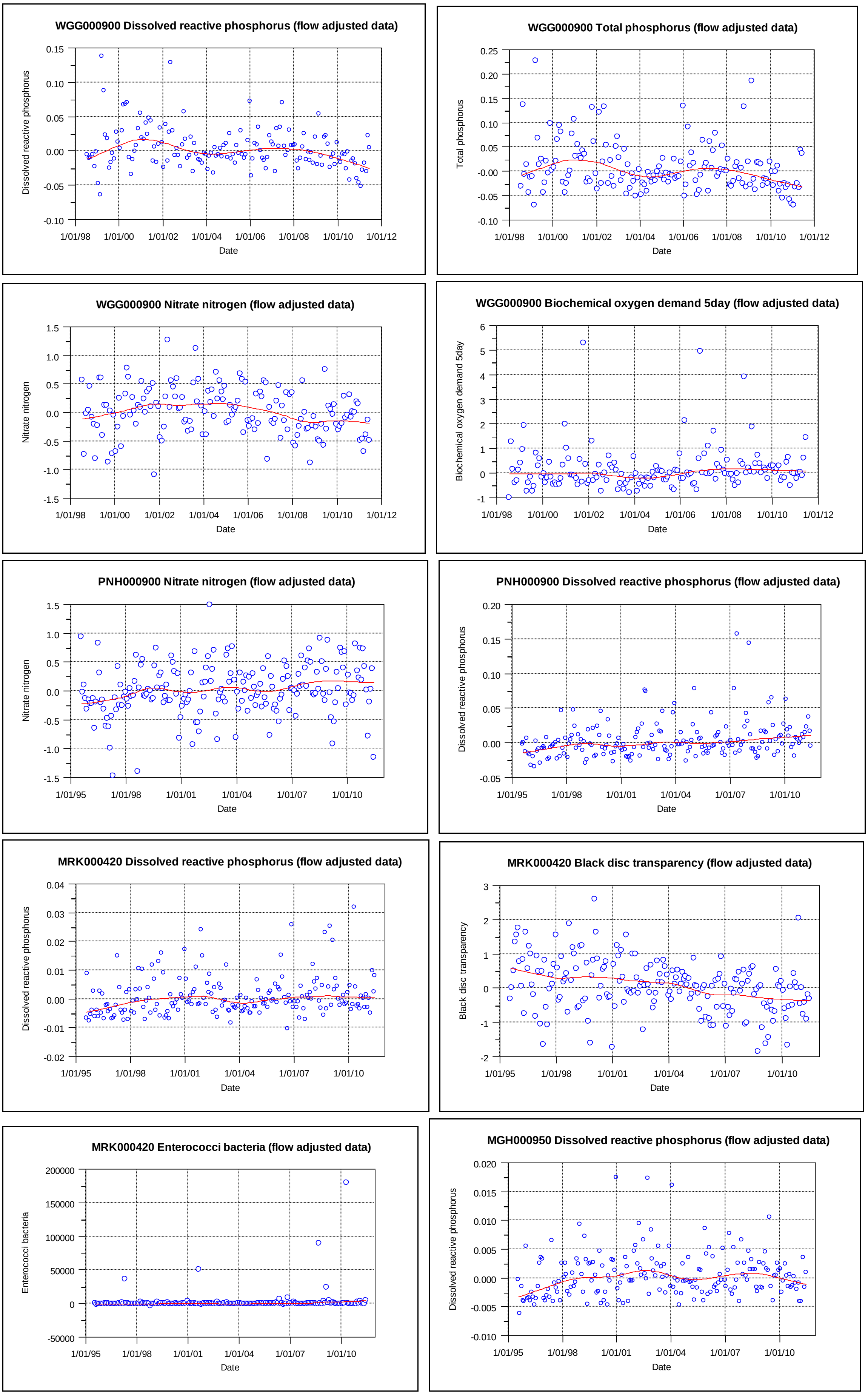

Figure 10 **(cont)** Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

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 2010 through to June 2011. 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 2010-2011 period, (in comparison with the previous fifteen year period), ranging from moderate freshes through to low flow conditions and was characterised by fewer significant flood events than 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 15 years' data. It also provides an up-to-date statistical summary of the 16 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 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 illustrated. 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.

During the 2010-2011 period, flows sampled were generally lower than typical of those sampled during the previous fifteen-year period for all but the southern catchments with median flows lower over the latest period (by 1 to 17%), compared with the long-term sampled flow record. Southern catchments (Punehu Stream and Waingongoro River) and the Maketawa Stream median flows were higher over the latest period (by 9 to 30%) compared with the long-term sampled flow record.

Table 41 Comparison of 2010-2011 water quality with previous long-term (1995-2010) 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	=	=	=	=	=	=	=	=	=	=	+200	11↑
Mangaoraka Stream at Corbett Road	=	=	xx	x	x	xx	=	=	=	=	=	=	x	=	=	-76	7↓
Waiwhakaiho River at SH3	=	=	=	=	=	x	=	=	=	x	=	=	=	=	=	-165	4↓
Stony River at Mangatete Road	✓	=	=	✓	✓	=	=	✓	x	=	=	=	=	=	x	-602	17↓
Punehu Stream at Wiremu Road	=	=	=	✓	=	=	x	=	=	=	=	=	=	=	=	+38	9↑
Punehu Stream at SH45	=	=	=	=	xx	✓	=	=	x	=	=	=	✓	=	=	+228	30↑
Waingongoro River at Eltham Road	=	=	=	✓	✓	=	x	=	=	=	=	=	=	=	=	+481	30↑
Waingongoro River at SH45	=	=	=	✓	✓✓	=	=	=	✓	✓	=	=	=	=	=	+1352	29↑
Patea River at Barclay Road	=	=	=	x	=	=	=	=	=	=	=	=	=	=	=	-25	12↓
Patea River at Skinner Road	=	=	=	✓✓	✓✓	=	=	=	✓	✓	=	=	=	=	=	-88	3↓
Mangaehu River at Raupuha Road	x	=	=	=	=	x	x	=	=	=	=	=	✓	=	=	-13	<1↓

[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 2010-2011 period (Table 41) showed very similar black disc clarity, 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 2010-2011 sampling period.

Median dissolved oxygen saturation, BOD_5, and pH showed no significant differences in the latest period (Table 41), and BOD_5 concentrations remained relatively low.

The majority of sites' median nutrient levels remained similar in the 2010-2011 period to these over the longer period, particularly the total nitrogen and total phosphorus levels. Minimal improvements in median nutrient levels (dissolved reactive phosphorus at two sites) were recorded 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. Limited deterioration was found in median dissolved reactive 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 three sites during the 2010-2011 period. Five sites showed improvement in median faecal coliform bacteria numbers while only two sites showed deterioration. This general trend toward better bacteriological water quality during 2010-2011 was not as marked as found in the previous year.

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 1995-2011 period (including one site for the 1998-2011 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 2011-2012 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 1995-2011 period (current report), be updated for the 1995-2012 period at the conclusion of the 2011-2012 year.

7. Acknowledgements

This programme's Job Manager was 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.

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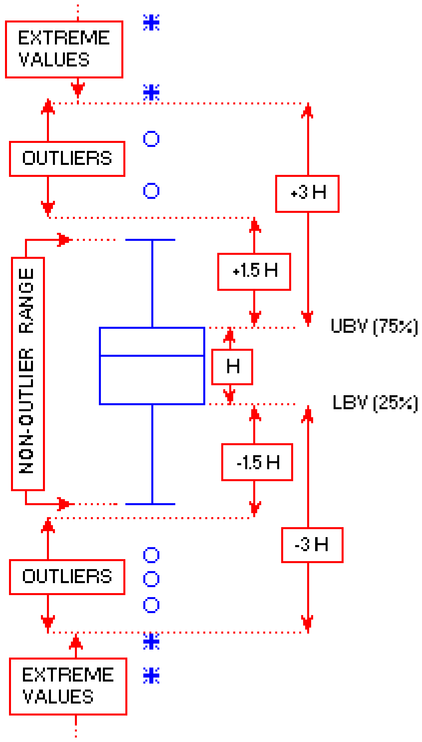
Appendix I

Statistical ‘Box & Whisker’ Plots of 1995-2011 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:

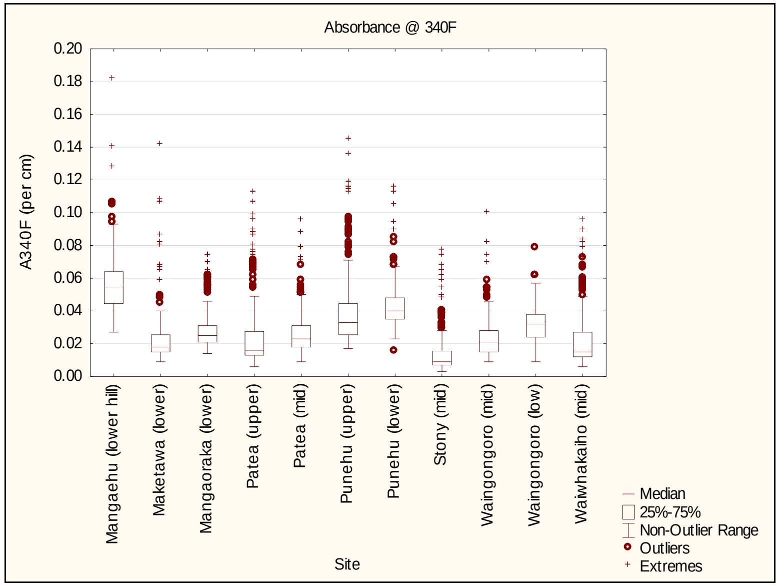
Lower fence = lower hinge - (3 x Hspread)
Upper fence = upper hinge + (3 x Hspread)

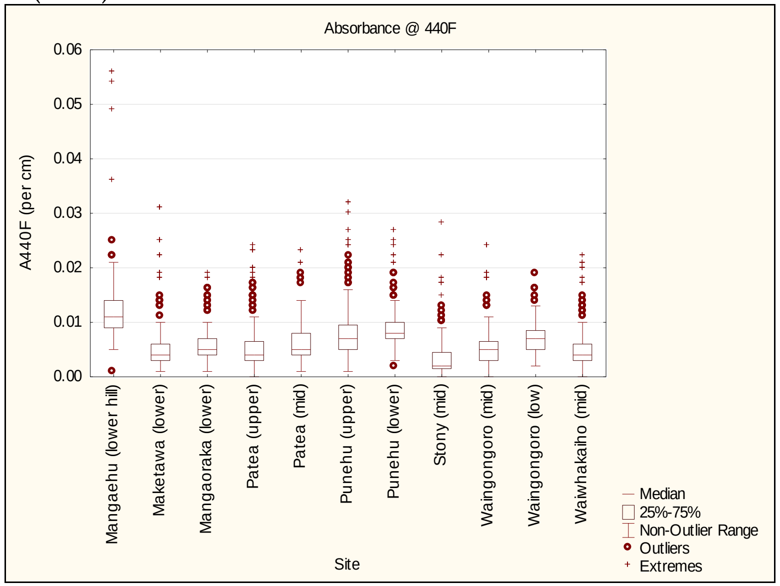
The whiskers show the range of values that lie within the inner fences. Values outside the inner fence are plotted as open circles (o). Values outside the outer fence are plotted as asterisks (*).

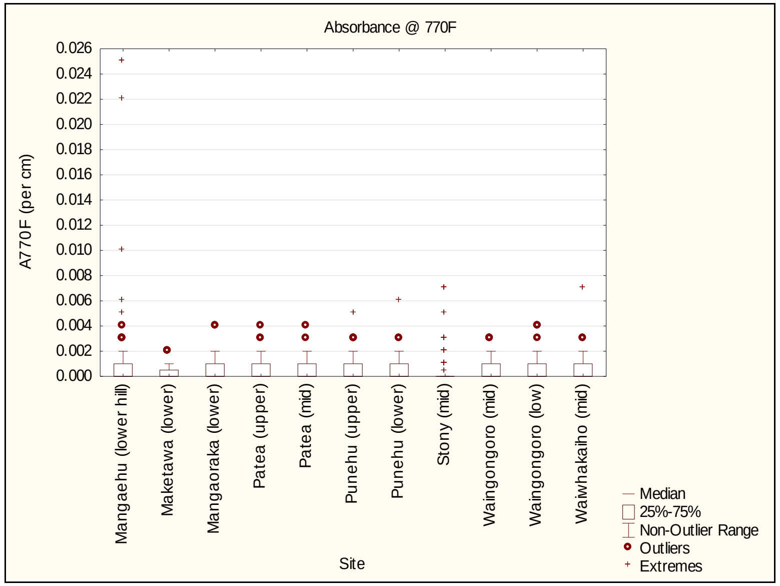
Site locations

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

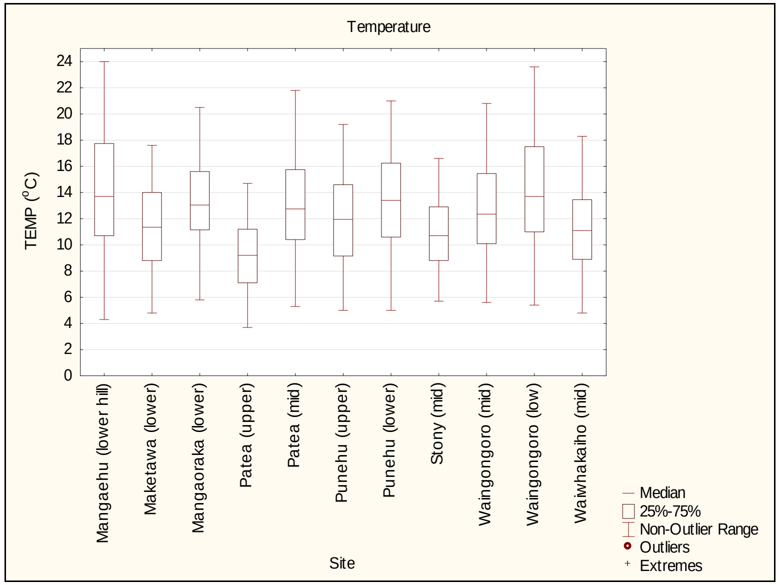
Absorbance (1 cm)

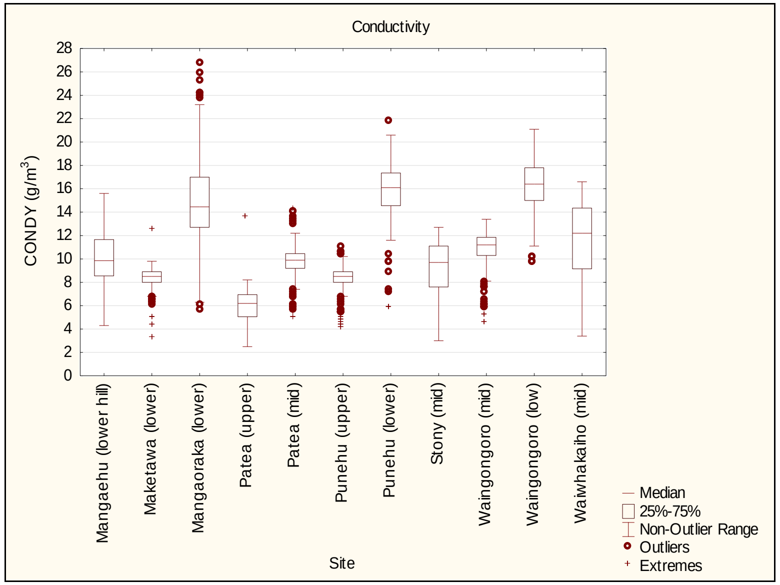


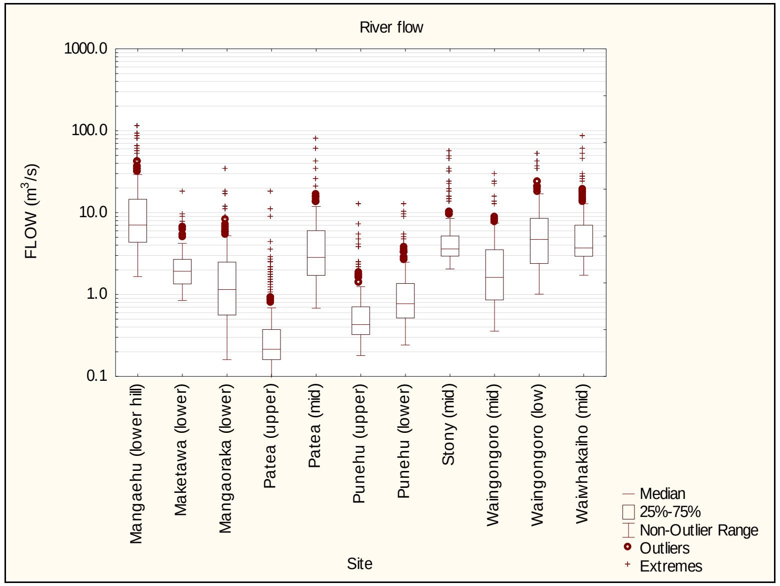


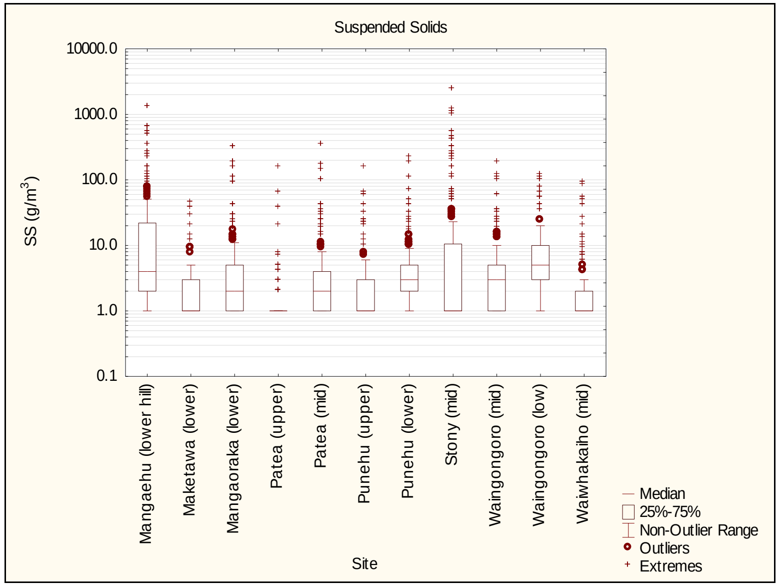


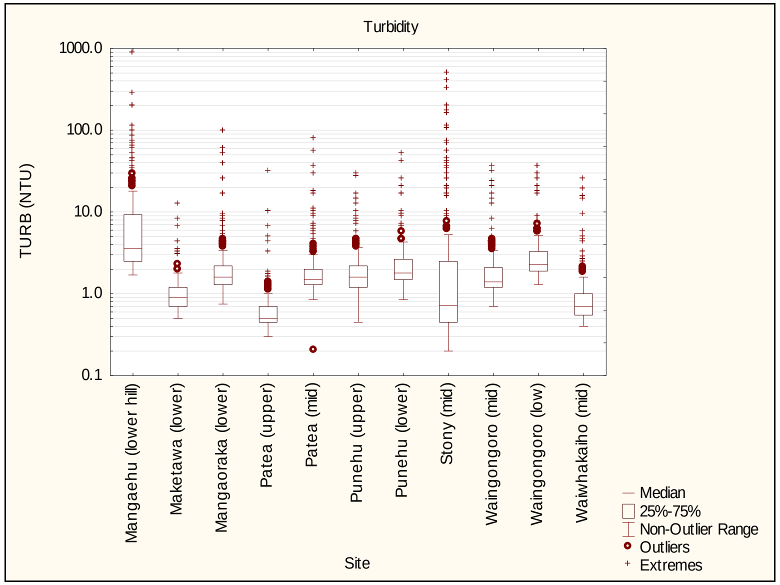
Physical Quality

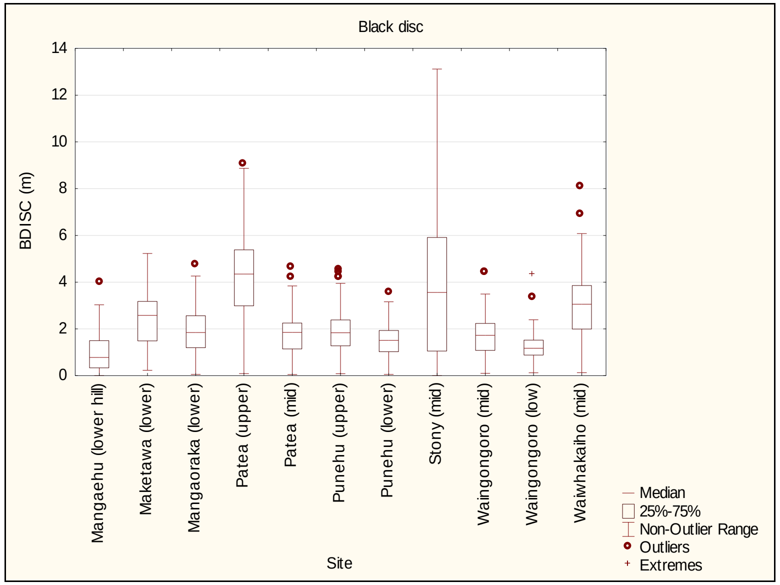


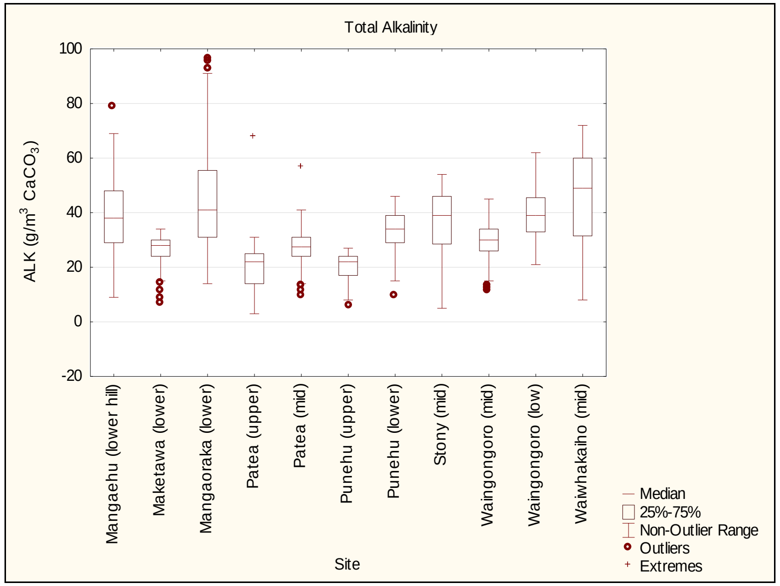


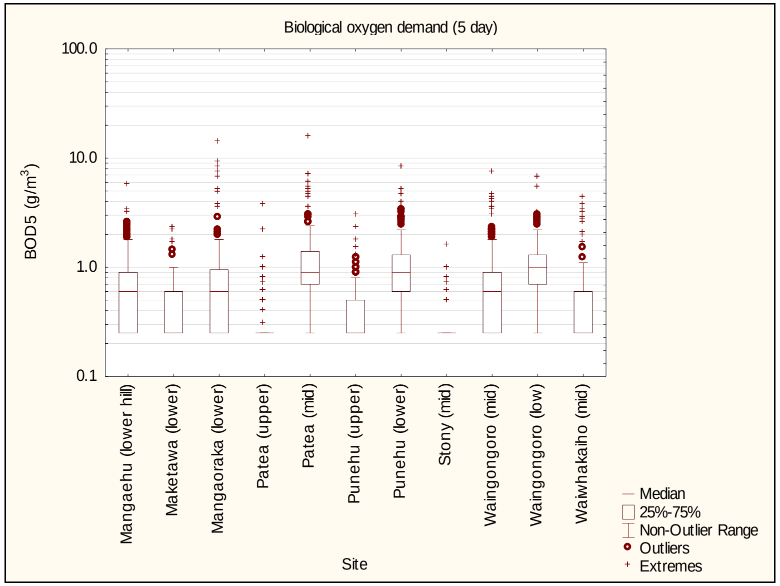

River flow
FLOW (m3/s)
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Wawhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

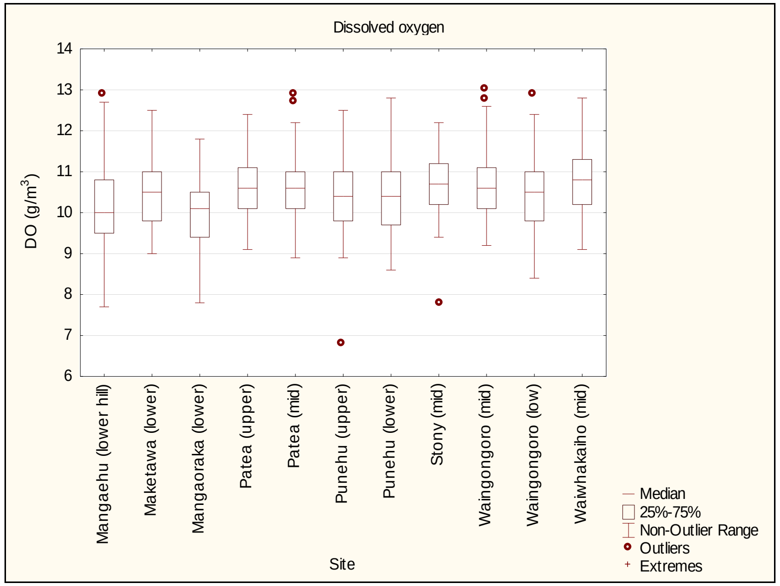

Suspended Solids
SS (g/m3)
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Wawhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


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)
Wawhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

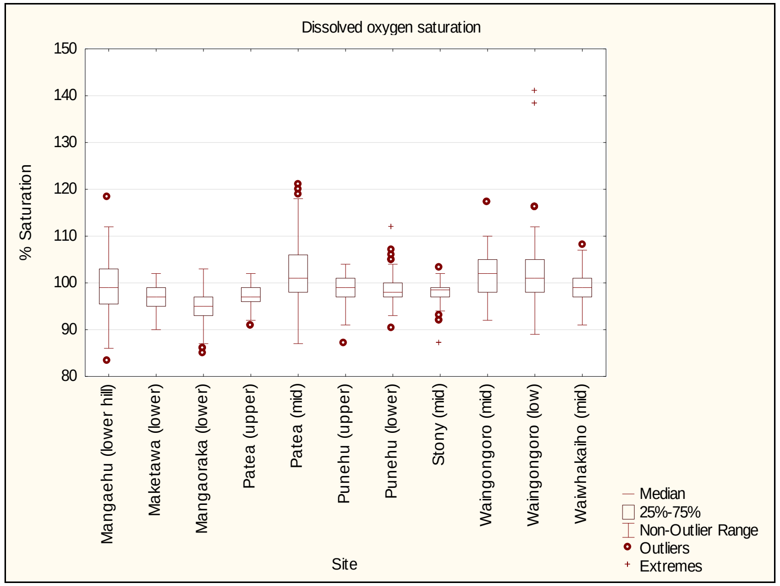

Black disc
BDISC (m)
14
12
10
8
6
4
2
0
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Wawhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


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)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

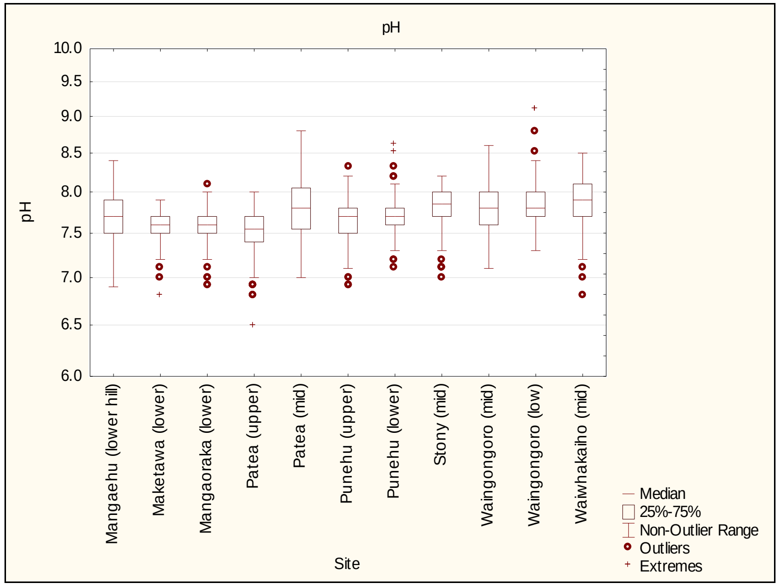

Biological oxygen demand (5 day)
BOD5 (g/m³)
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



Dissolved oxygen
DO (g/m^3)
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

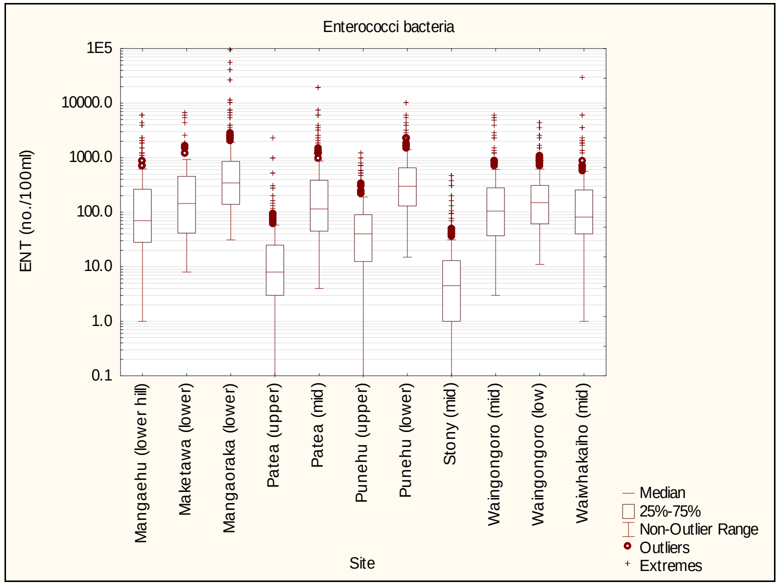


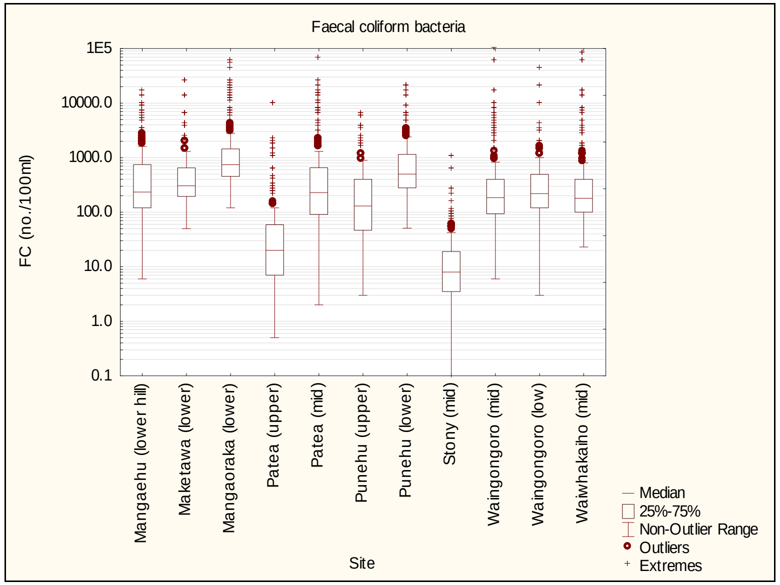
Dissolved oxygen saturation
% Saturation
150
140
130
120
110
100
90
80
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



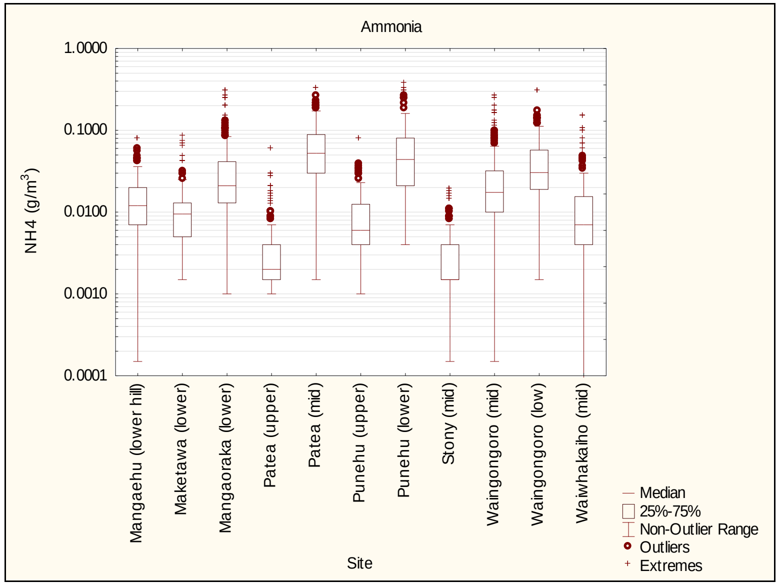
pH
pH
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

Bacteria

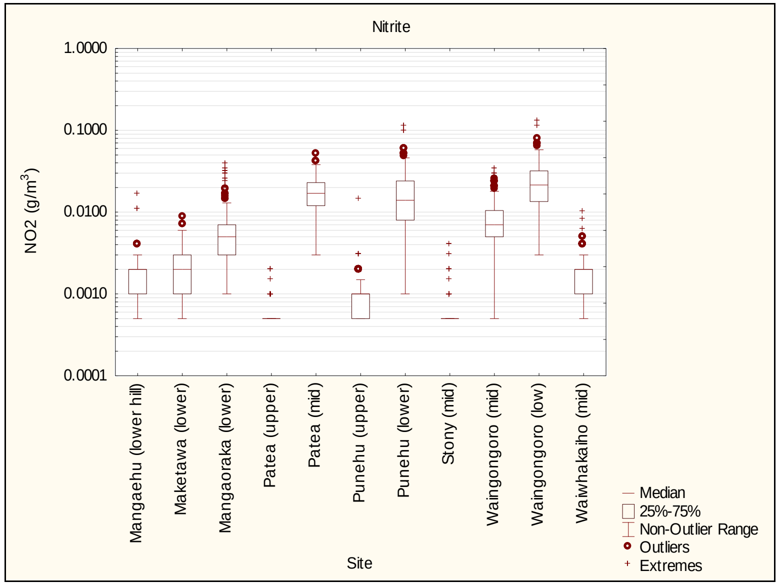

Enterococci bacteria
ENT (no./100ml)
1E5
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers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

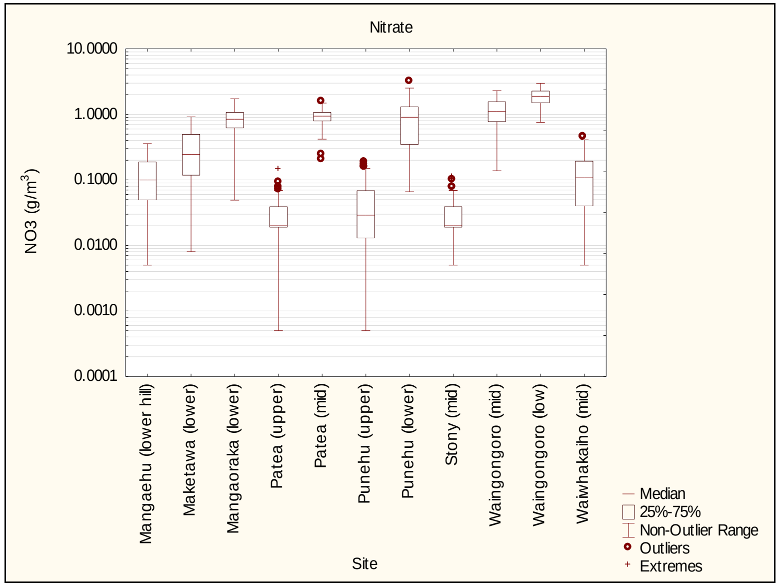
Nutrients



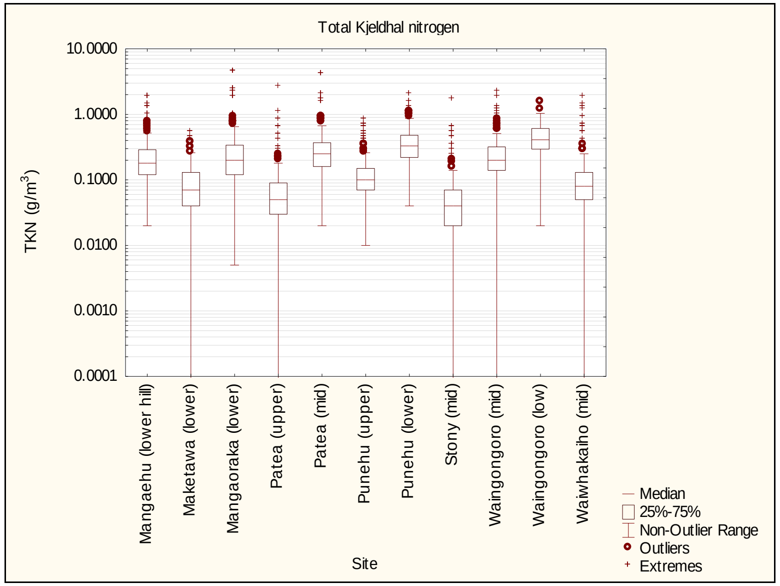
Ammonia
NH4 (g/m3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



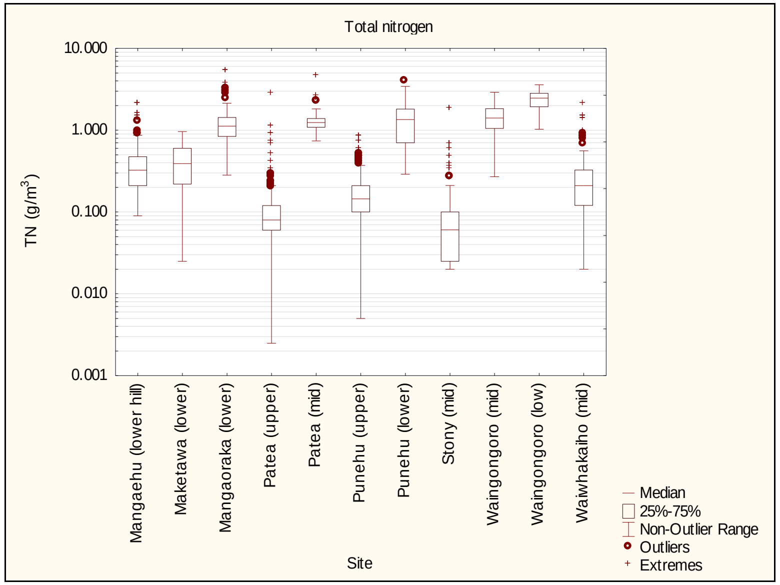
Nitrite
NO2 (g/m3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



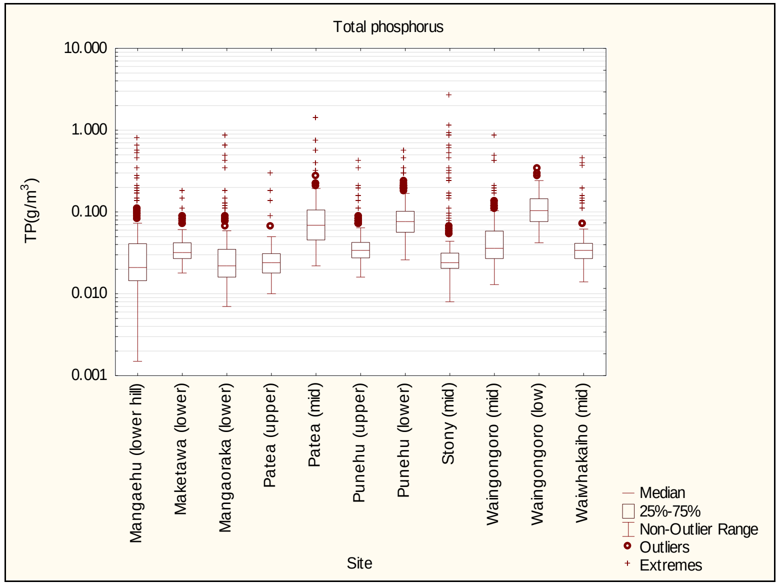
Nitrate
NO3 (g/m3)
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



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

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 2010-2011

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 2010-2011 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 2010 and June 2011.

First QC exercise

These split samples were collected from the Stony River site at Mangatete Road on 11 August 2010 under relatively low flow conditions (2.97 m^3/sec) and in fine weather conditions. Results are presented in Table 1.

Table 1 Results of SEM QC sampling on 11 August 2010

Site: STY000200					
Date: 11 August 2010				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.009	0.010	5	✓
A440F	/cm	0.002	0.002	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	40	40	0	✓
BOD5	g/m^3	<0.5	<0.5	0	✓
CONDY	mS/m @ 20°C	9.9	9.8	<1	✓
DO	g/m^3	12.0	12.0	0	✓
DRP	g/m^3-P	0.018	0.018	0	✓
ENT	/100ml	<1	<1	0	✓
ECOL	/100ml	<1	1	N/A	✓
FC	/100ml	<1	1	N/A	✓
NH4	g/m^3-N	0.005	<0.003	42	**
NO2	g/m^3-N	<0.001	<0.001	0	✓
NO3	g/m^3-N	0.049	0.049	0	✓
pH	pH	7.8	7.9	<1	✓
SS	g/m^3	<2	<2	0	✓
TKN	g/m^3-N	0.02	0.02	0	✓
TN	g/m^3-N	0.07	0.07	0	✓
TP	g/m^3-P	0.018	0.018	0	✓
TURB	NTU	0.5	0.55	5	✓

Comments:

The difference in ammonia N paired results was outside the acceptable tolerance level for samples which were extremely low in concentrations. Faecal coliform and *E.coli* bacterial counts were extremely low and paired samples were within 1 per 100 mls for both species.

Overall results showed very good laboratory analytical precision performance, with 19 of 20 pairs of results being within the 10% guideline and 15 of these pairs showing < 1% difference in paired results.

Second QC exercise

These split samples were collected from the Waingongoro River site at Eltham Road on 10 November 2010 under very low, clear flow (0.96 m^3/S and fine weather conditions. Results are presented in Table 2.

Table 2 Results of SEM QC sampling on 10 November 2010

Site: WGG000500					
Date: 10 November 2010				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.014	0.014	0	✓
A440F	/cm	0.003	0.003	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	33	33	0	✓
BOD5	g/m^3	0.7	0.8	7	✓
CONDY	mS/m @ 20°C	12.2	12.2	0	✓
DO	g/m^3	11.0	10.9	<1	✓
DRP	g/m^3-P	0.018	<0.003	>80	***
ENT	/100ml	39	32	<10	✓
ECOL	/100 ml	52	39	14	*
FC	/100ml	52	39	14	*
NH4	g/m^3-N	0.012	0.012	0	✓
NO2	g/m^3-N	0.006	0.006	0	✓
NO3	g/m^3-N	1.15	1.14	<1	✓
pH	pH	8.2	8.2	0	✓
SS	g/m^3	<2	<2	0	✓
TKN	g/m^3-N	0.08	0.09	6	✓
TN	g/m^3-N	1.24	1.23	<1	✓
TP	g/m^3-P	0.024	0.022	4	✓
TURB	NTU	1.0	1.0	0	✓

Comments:

The differences in *E.coli* and faecal coliform bacterial counts were within acceptable tolerance levels for bacteriological samples (20%) but the DRP paired results were significantly different and after re-checking laboratory analytical worksheets, no explanations were found. The result for the routine sample was within expected levels and consistent with the TP concentration whereas the QC sample result was an outlier and not consistent with the TP result.

Otherwise, overall laboratory analytical precision performance was very good, with 17 of the 20 pairs of results recorded within the 10% guideline.

Third QC exercise

These split samples were collected from the site in the Punehu Stream at SH45 on 9 February 2011under slightly turbid, moderate flow (1.03 m^3/sec), fine weather conditions. Results are presented in Table 3.

Table 3 Results of SEM QC sampling on 9 February 2011

Site: PNH000900					
Date: 9 February 2011				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.072	0.090	11	*
A440F	/cm	0.015	0.017	6	✓
A770F	/cm	0.000	0.001	100	***
ALKT	g/m^3 $CaCO_3$	26	26	0	✓
BOD5	g/m^3	1.3	1.2	4	✓
CONDY	mS/m @ 20°C	13.7	13.6	<1	✓
DO	g/m^3	9.5	9.5	0	✓
DRP	g/m^3-P	0.056	0.067	9	✓
ENT	/100ml	2900	2400	9	✓
ECOL	/100ml	670	620	4	✓
FC	/100ml	700	640	4	✓
NH4	g/m^3-N	0.029	0.027	4	✓
NO2	g/m^3-N	0.008	0.009	6	✓
NO3	g/m^3-N	0.42	0.42	0	✓
PH	pH	7.6	7.7	<1	✓
SS	g/m^3	2	2	0	✓
TKN	g/m^3-N	0.29	0.45	22	**
TN	g/m^3-N	0.72	0.88	10	✓
TP	g/m^3-P	0.094	0.102	4	✓
TURB	NTU	1.8	1.8	0	✓

Comments:

The difference of 0.001 units in filtered absorbance readings at 770mm was not significant as it was within acceptable equipment performance tolerance. However, the difference in readings at 340mm was just significantly different as were those for TKN. None of these results were outliers for this site in terms of the historical record.

Otherwise 18 pairs of parameters analysed were within acceptable agreement, representing relatively good laboratory analytical precision for these samples collected under moderate flow conditions.

Fourth QC exercise

These split samples were collected from the site in the Mangaoraka Stream at Corbett Road on 8 June 2011 under turbid, high flow (5.72 m^3/s) but fine weather conditions. The results are presented in Table 4.

Table 4 Results of SEM QC sampling on 8 June 2011

Site: MRK000420					
Date: 8 June 2011				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.039	0.044	6	✓
A440F	/cm	0.008	0.010	11	✓
A770F	/cm	0.000	0.001	100	✓
ALKT	g/m^3 $CaCO_3$	27	26	2	✓
BOD5	g/m^3	2.8	3.1	5	✓
CONDY	mS/m @ 20°C	11.1	11.1	0	✓
DO	g/m^3	10.1	10.2	<1	✓
DRP	g/m^3-P	0.023	0.022	2	✓
ENT	/100ml	6100	5400	6	✓
ECOL	/100ml	4700	4300	4	✓
FC	/100ml	5700	6000	3	✓
NH4	g/m^3-N	0.099	0.097	1	✓
NO2	g/m^3-N	0.012	0.013	4	✓
NO3	g/m^3-N	1.03	1.01	1	✓
PH	pH	7.3	7.3	0	✓
SS	g/m^3	28	29	2	✓
TKN	g/m^3-N	1.05	1.13	4	✓
TN	g/m^3-N	2.09	2.15	1	✓
TP	g/m^3-P	0.182	0.178	1	✓
TURB	NTU	9.2	9.2	0	✓

Comments:

The difference of 0.001 units in filtered absorbance readings at 770mm was not significant as it was within acceptable equipment performance tolerance. However, the difference of 0.002 units at 440mm bordered on significant, although after allowing for the correction factor (at 770mm), corrected absorbances pairs would not have been significantly different.

Otherwise 19 of the 20 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 (2009-2010) 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	3	(92)	1	(8)	-	(0)	-	(0)
A440F	3	(68)	1	(21)	-	(8)	-	(3)
A770F	2	(75)	-	(0)	-	(11)	2	(14)
ALKT	4	(100)	-	(0)	-	(0)	-	(0)
BOD5	4	(85)	-	(13)	-	(0)	-	(2)
CONDY	4	(100)	-	(0)	-	(0)	-	(0)
DO	4	(100)	-	(0)	-	(0)	-	(0)
DRP	3	(92)	-	(7)	-	(0)	1	(2)
ENT	4	(46)	-	(21)	-	(27)	-	(6)
ECOL	3	(55)	1	(29)	-	(14)	-	(2)
FC	3	(54)	1	(29)	-	(14)	-	(3)
NH4	3	(81)	1	(10)	-	(6)	-	(3)
NO2	4	(95)	-	(3)	-	(2)	-	(0)
NO3	4	(84)	-	(6)	-	(8)	-	(2)
pH	4	(100)	-	(0)	-	(0)	-	(0)
SS	4	(89)	-	(8)	-	(3)	-	(0)
TKN	3	(48)	-	(23)	1	(23)	-	(6)
TN	3	(81)	1	(11)	-	(8)	-	(0)
TP	4	(83)	-	(8)	-	(6)	-	(3)
TURB	4	(96)	-	(2)	-	(2)	-	(0)

[NB: () = % of QC samples for 1995 to 2011 period]

This summary for the 2010-2011 period indicated:

- results from pairs of two bacteriological species' samples were very 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 67% of samples within 20% of the mean for all species.
- TKN analytical variability greater than 10% was recorded on one occasion, due to reliance on calculations from another nitrogen species which, however, was within acceptable precision tolerance. TKN duplicates have traditionally shown this variability with only 48% and 71% to date within 10% and 20% of the mean respectively.
- variability in spilt samples agreement for filtered absorbances at 340mm, 440mm, and 770 occurred occasionally, but almost entirely within equipment performance tolerance values.

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 sixteen year historical database for all sites in the programme.

Appendix IV

SEM Physicochemical Programme
Inter-lab Quality Control Report 2010-2011

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 2009-2010 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 2010-2011 period on 21 June 2011. Sampling was performed during a recession flow (18.7 m^3/sec), two days after a flood flow (129 m^3/sec) in fine, overcast weather at the Waingongoro River site at SH45.

Results

2010-2011 exercise

Comparisons of the individual sample's analytical results for the Waingongoro River (at SH45) site are presented in Table 1.

Table 1 Results of SEM QC sampling by TRC & NIWA on 21 June 2011

WGG000900					
		Time: 1205		**Difference from mean (%)**	**Comments**
Parameter	Units	TRC	NIWA		
A340F	/cm	0.020	0.021	2	✓
A440F	/cm	0.004	0.004	0	✓
BDISC	m	0.66	0.65	<1	✓
CONDY	mS/m @ 20^{0}C	13.8	14.2	1	✓
DO	g/m^3	10.4	10.4	0	✓
DRP	g/m^3-P	0.049	0.041	9	✓
ECOL	nos/100 ml	250	185	15	*
NH4	g/m^3-N	0.085	0.086	<1	✓
NO3	g/m^3-N	2.20	2.27	2	✓
pH	pH	7.5	7.6	<1	✓
TEMP	°C	11.9	12.3	2	✓
TN	g/m^3-N	3.04	2.55	9	✓
TP	g/m^3-P	0.110	0.099	5	✓
TURB	NTU	4.5	6.7	20	*

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

Comments:

A significant difference in paired measurements between the two laboratories was recorded for turbidity. The difference in *E.coli* bacteria counts were within the acceptable variability (20%) for this parameter as also illustrated by the 95% confidence limit (256 per 100mls) of the NIWA count. Otherwise good analytical agreement was recorded for all other parameters.

Good operator field agreement was indicated by the similarity in the pairs of temperature, black disc clarity, and dissolved oxygen measurements, although a 0.4˚C difference in paired temperature measurements was larger than normally recorded.

	Difference from mean of pairs of split samples							
Parameter ID	**<10%**		**10-20%**		**20-50%**		**>50%**	
A340F	1	(95)	-	(0)	-	(5)	-	(0)
A440F	1	(65)	-	(30)	-	(0)	-	(5)
CONDY	1	(90)	-	(5)	-	(0)	-	(5)
DO	1	(100)	-	(0)	-	(0)	-	(0)
DRP	1	(45)	-	(20)	1	(30)	-	(5)
ECOL	-	(0)	1	(60)	-	(40)	-	(0)
NH4	1	(29)	-	(23)	-	(19)	-	(29)
NO3	1	(90)	-	(10)	-	(0)	-	(0)
pH	1	(100)	-	(0)	-	(0)	-	(0)
TEMP	1	(100)	-	(0)	-	(0)	-	(0)
TN	1	(89)	-	(0)	-	(11)	-	(0)
TP	1	(52)	-	(32)	-	(16)	-	(0)
TURB	-	(43)	-	(43)	-	(14)	-	(0)

[NB: () - % of QC samples over the 1995 to 2011 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, black disc clarity, and dissolved oxygen measurements although the water temperature measurements were not as precise as 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.