Freshwater Physicochemical Programme
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Taranaki Regional Council
Private Bag 713
STRATFORD

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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. Surveys continued to be performed regularly in the second week of every month from July 2009 to June 2010, under a narrower range of flow conditions ranging from small freshes to very low late summer-autumn flows. This year was characterised by lower median flows sampled by the programme. 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 2009-2010 monitoring year the median of flows sampled was lower than over the previous fourteen year period as a result of fewer freshes sampled and a lower flow period over late summer-autumn. Water quality was comparatively similar in clarity, turbidity, and suspended solids and improved in median faecal coliform and enterococci bacteria numbers. Narrower temperature ranges, mainly due to lower maximum water temperatures, but similar median water temperatures, were measured in the 2009-2010 period compared with those measured during 1995-2009, over the first fourteen years of the SEM programme. Median phosphorus species' levels were elevated at four sites whereas median total nitrogen was lower at four sites. The three other nutrient species' median levels were similar for the majority of sites between periods.

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 1995-2010 collection period.

This report on the results of the 2009-2010 monitoring period also includes recommendations for the 2010-2011 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, whereas data for the period 1995 to 2009 were summarised and presented in the previous Annual Report. Trending will next be undertaken for the 1995 to 2011 period for presentation in the appropriate 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, and 2009-54.

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 8 of the 69 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 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. 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. Levels of all nutrient species increased at the Waingongoro River site between 1989 and 2007 although phosphorus levels have stabilised between 1995 and 2010 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 designed for robust trend detection purposes.

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.

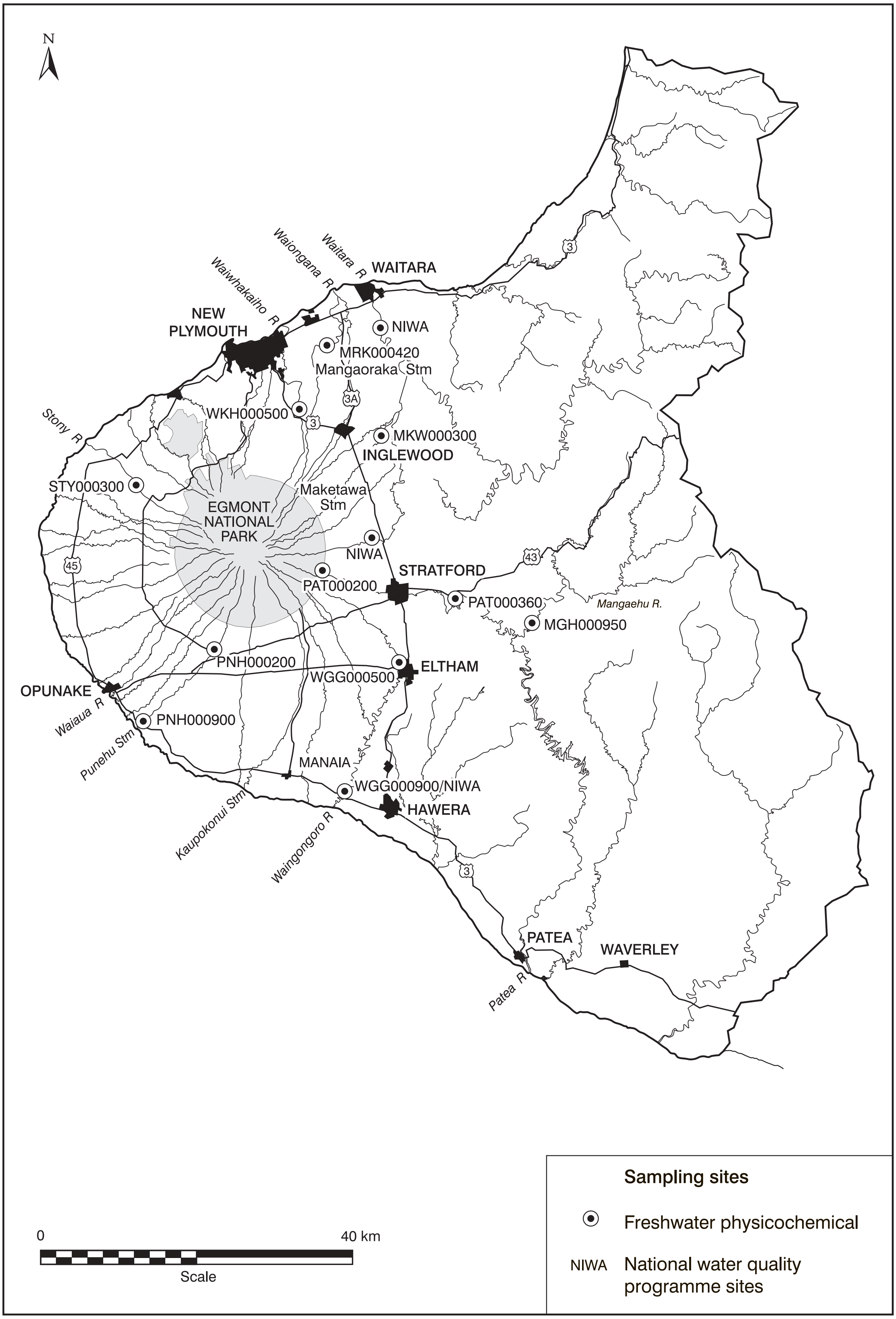

Figure 1 Freshwater physicochemical SEM sampling sites

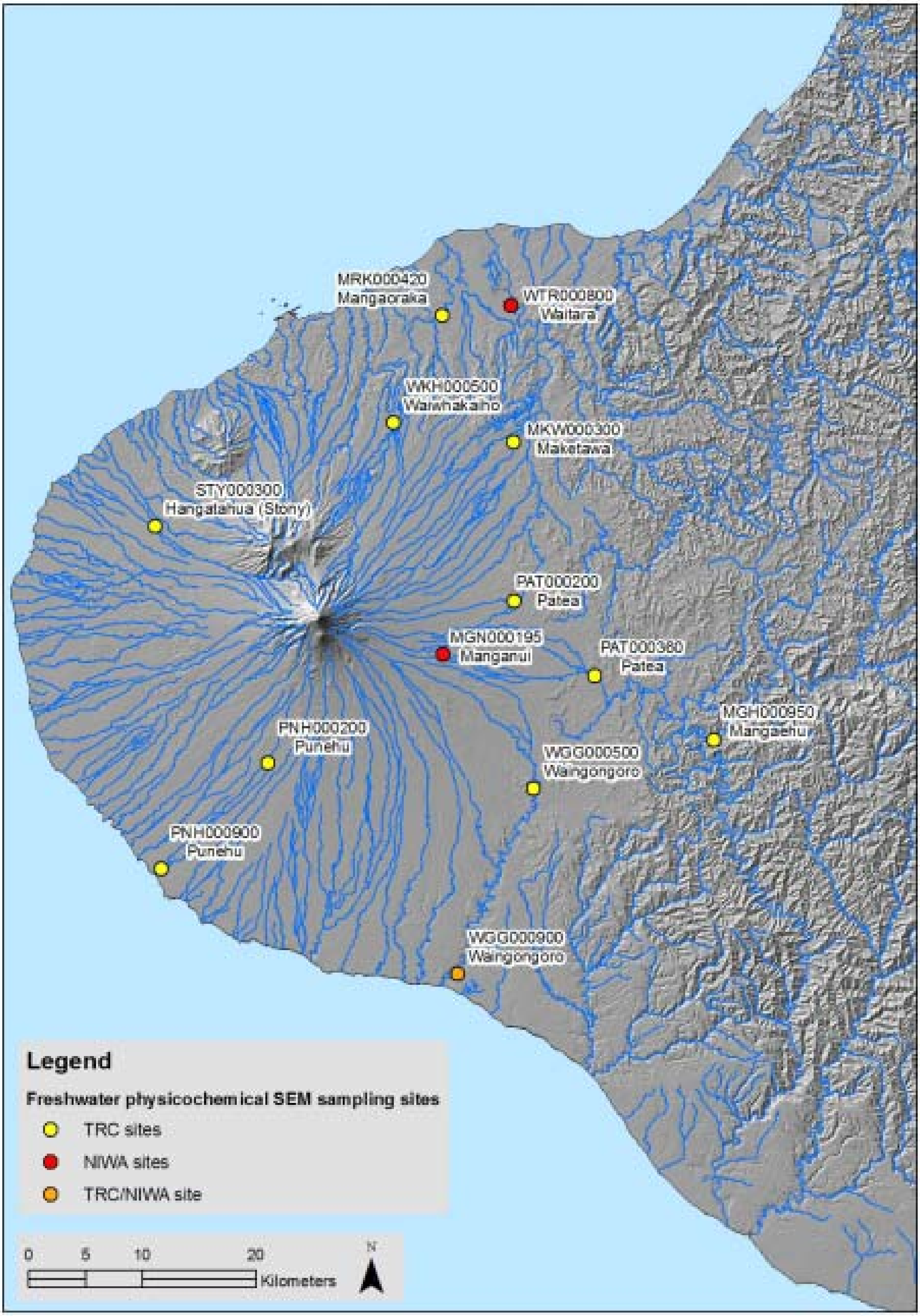

Figure 2 Freshwater physicochemical SEM sampling sites aerial map

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. 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 is due for diversion 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 2009 to June 2010 are presented for each of the eleven sites. Statistical summaries of this data and the cumulative data for nine sites (July 1995 to June 2010), one site in the lower Waingongoro River (July 1998 to June 2010) and one site in the lower Maketawa Stream (1 July 2003 to June 2010) are also presented on a site-by-site basis, together with a general discussion of results. A comparison of water quality through the region is provided following the individual sites' discussions.

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/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)
8 July 09	0805	0.030	0.006	0.000	25	0.70	0.7	8.1	11.0	96	0.017	2000	200
12 Aug 09	0800	0.018	0.003	0.000	28	1.42	<0.5	9.0	11.3	99	0.022	150	25
9 Sept 09	0810	0.014	0.004	0.000	28	3.88	<0.5	8.9	11.6	99	0.004	120	21
14 Oct 09	0715	0.018	0.003	0.000	26	2.44	<0.5	8.7	10.2	94	0.016	260	31
11 Nov 09	0705	0.013	0.003	0.000	29	2.04	0.5	8.5	10.7	102	0.018	310	24
9 Dec 09	0710	0.020	0.005	0.000	28	2.69	0.8	8.9	10.3	101	0.024	200	40
13 Jan 10	0700	0.023	0.006	0.001	27	3.33	0.6	9.6	10.2	98	0.033	510	290
10 Feb 10	0705	0.016	0.004	0.000	30	3.43	1.4	8.9	9.0	93	0.030	330	1500
10 Mar 10	0705	0.015	0.003	0.000	31	3.33	<0.5	9.2	9.5	95	0.026	390	470
14 April 10	0800	0.141	0.031	0.002	9	0.24	2.3	4.3	10.2	97	0.021	6300	6300
12 May 10	0805	0.016	0.004	0.000	32	3.68	<0.5	8.9	10.8	98	0.030	180	230
10 June 10	0810	0.017	0.004	0.001	24	2.46	<0.5	8.5	11.1	98	0.014	490	15

Date	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)
8 July 09	2000	3.814	0.026	0.002	0.378	7.3	5	8.7	0.22	0.60	0.050	3.4
12 Aug 09	150	1.480	0.010	0.002	0.358	7.4	2	8.6	0.03	0.39	0.030	0.95
9 Sept 09	120	1.759	0.011	0.002	0.458	7.4	5	7.6	0.11	0.57	0.060	1.1
14 Oct 09	260	2.490	0.005	0.002	0.498	7.4	4	10.9	<0.01	0.50	0.032	0.90
11 Nov 09	310	1.264	<0.003	<0.001	0.059	7.6	<2	12.2	0.07	0.13	0.024	0.65
9 Dec 09	220	2.448	0.010	0.003	0.497	7.4	<2	13.5	0.11	0.61	0.035	0.90
13 Jan 10	510	1.327	0.009	<0.001	0.109	7.4	3	12.9	0.07	0.18	0.038	0.95
10 Feb 10	340	0.914	0.008	<0.001	0.019	7.6	9	16.1	0.12	0.14	0.041	2.2
10 Mar 10	390	0.846	0.006	<0.001	0.059	7.6	<2	14.5	0.06	0.12	0.034	0.65
14 April 10	6500	7.4	0.010	0.003	0.137	7.0	28	12.5	0.52	0.66	0.180	12
12 May 10	180	1.208	0.004	<0.001	0.079	7.5	<2	10.4	0.06	0.14	0.036	0.70
10 June 10	490	3.652	0.011	0.005	0.695	7.7	<2	8.9	0.03	0.73	0.026	1.0

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

Table 4 Statistical summary of data from July 2009 to June 2010: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.013	0.141	0.018	12	0.036
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.031	0.004	12	0.008
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	12	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	9	32	28	12	6
BLACK DISC	Black disc transparency	m	0.24	3.88	2.58	12	1.179
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	2.3	0.5	12	0.5
CONDY	Conductivity @ 20°C	mS/m	4.3	9.6	8.9	12	1.4
DO	Dissolved oxygen	g/m³	9.0	11.6	10.5	12	0.75
PERSAT	Dissolved oxygen saturation	%	93	102	98	12	3
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.033	0.022	12	0.008
ECOL	E. coli bacteria	nos/100 ml	120	6300	320	12	1763
ENT	Enterococci bacteria	nos/100 ml	15	6300	120	12	1793
FC	Faecal coliform bacteria	nos/100 ml	120	6500	325	12	1817
FLOW	Flow	m³/s	0.846	7.400	1.620	12	1.866
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.026	0.010	12	0.006
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.005	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m³N	0.019	0.70	0.25	12	0.228
pH	pH		7.0	7.7	7.4	12	0.18
SS	Suspended solids	g/m³	<2	28	3	12	7
TEMP	Temperature	°C	7.6	16.1	11.6	12	2.7
TKN	Total kjeldahl nitrogen	g/m³N	<0.001	0.52	0.07	12	0.14
TN	Total nitrogen	g/m³N	0.12	0.73	0.45	12	0.240
TP	Total phosphorus	g/m³P	0.024	0.180	0.036	12	0.042
TURB	Turbidity	NTU	0.65	12.0	0.95	12	3.21

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

Table 5 Statistical summary of data from July 2003 to June 2010: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.010	0.141	0.018	84	0.024
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.031	0.004	84	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	84	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	7	34	28	84	6
BLACK DISC	Black disc transparency	m	0.23	4.24	2.58	84	1.039
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	2.3	<0.5	84	0.4
CONDY	Conductivity @ 20°C	mS/m	3.2	12.6	8.5	84	1.3
DO	Dissolved oxygen	g/m³	9.0	11.9	10.5	84	0.75
PERSAT	Dissolved oxygen saturation	%	90	102	97	84	2
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.040	0.022	84	0.007
ECOL	E. coli bacteria	nos/100 ml	50	26000	310	84	3305
ENT	Enterococci bacteria	nos/100 ml	8	6300	145	84	1184
FC	Faecal coliform bacteria	nos/100 ml	50	26000	315	84	3313
FLOW	Flow	m³/s	0.846	17.200	1.891	84	2.318
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.073	0.010	84	0.013
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.007	0.002	84	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.92	0.24	84	0.221
pH	pH		6.8	7.9	7.6	84	0.18
SS	Suspended solids	g/m³	<2	44	<2	84	7
TEMP	Temperature	°C	6.4	17.6	10.9	84	3.0
TKN	Total kjeldahl nitrogen	g/m³N	<0.001	0.52	0.07	84	0.10
TN	Total nitrogen	g/m³N	0.05	0.96	0.40	84	0.221
TP	Total phosphorus	g/m³P	0.018	0.180	0.032	84	0.025
TURB	Turbidity	NTU	0.5	12	0.9	84	1.69

Discussion

2009-2010 period

Good aesthetic water quality was indicated by a median black disc clarity of 2.58 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 3.88 m) was recorded in early spring under moderately low flow conditions (1.76 m^3/s). Elevations in turbidity (to 12NTU) and in suspended solids concentration (28 g/m^3) under fresh flow conditions (7.4 m^3/sec) were sampled during this period. Poorer water quality conditions apparent at the time of this fresh flow were recorded with increases in bacterial number (6500 faecal coliforms/100ml) and BOD_5 (2.3 g/m^3) recorded in late autumn.

pH was relatively stable (7.0 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 93% saturation recorded mainly under late summer low flow conditions) 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 325 and 120 (per 100 mls) respectively. Water temperature varied over a moderate range of 8.5°C with a maximum late summer (early morning) river temperature of 16.1°C recorded in February 2010.

Brief comparison with the previous 2003-2009 (six year) period

Generally, stream water quality at this site during the 2009-2010 period was very similar in appearance/clarity (lower median black disc clarity (by 0.07 m), higher median turbidity (by 0.1 NTU), and minimal increase in median suspended solids level (of 1 g/m^3)). Bacterial water quality was also very similar, with a small increase in median faecal coliform number of 15 per 100 mls and decrease in median enterococci number of 25 per 100 mls. Median water temperature was slightly higher (0.7°C higher), while the maximum water temperature (16.1°C) was 1.5°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 few and smaller flood events sampled during the 2009-2010 period. Median flow sampled during 2009-2010 was lower (by about 300 L/sec) than the median of flows sampled over the previous six-year period due in part to fewer fresh flow conditions sampled during the latest period. Median pH values were similar and the maximum pH value was within 0.2 unit of that of the past six-year record. All nutrient species showed minimal changes in median values during the monitoring year in comparison with the previous six-year record.

Mangaoraka Stream at Corbett Road (site: MRK000420)

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

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

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/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)
8 July 09	0835	0.038	0.008	0.000	28	0.27	1.5	11.6	10.8	97	0.008	1800	2000
12 Aug 09	0830	0.023	0.004	0.000	40	1.35	<0.5	14.5	10.8	97	0.008	150	630
9 Sept 09	0835	0.019	0.004	0.000	37	2.57	<0.5	14.2	11.2	99	0.010	670	92
14 Oct 09	0745	0.020	0.004	0.000	33	1.85	<0.5	13.2	10.4	99	0.007	290	84
11 Nov 09	0745	0.028	0.006	0.001	52	2.15	0.6	17.0	10.2	100	0.007	850	340
9 Dec 09	0740	0.030	0.007	0.001	31	1.56	0.5	12.8	10.1	100	0.012	2200	130
13 Jan 10	0730	0.038	0.008	0.000	51	2.07	0.9	16.9	9.9	97	0.013	1100	430
10 Feb 10	0735	0.038	0.008	0.000	86	1.68	1.0	23.7	8.2	88	0.004	830	590
10 Mar 10	0735	0.028	0.006	0.000	63	1.31	0.7	17.5	9.4	95	0.006	770	630
14 April 10	0830	0.063	0.015	0.001	62	0.10	14	19.3	9.6	95	0.041	17000	180000
12 May 10	0835	0.029	0.007	0.001	80	1.72	0.6	21.3	10.0	93	0.012	1100	460
10 June 10	0840	0.022	0.005	0.001	29	1.16	<0.5	12.1	10.5	96	0.009	300	350

Date	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)
8 July 09	1800	3.631	0.090	0.008	0.842	7.2	19	10.2	0.65	1.50	0.074	8.3
12 Aug 09	150	1.057	0.030	0.003	0.887	7.5	3	10.1	0.10	0.99	0.023	1.7
9 Sept 09	750	1.178	0.026	0.003	0.987	7.3	2	9.4	0.11	1.10	0.022	1.5
14 Oct 09	290	1.918	0.014	0.003	1.067	7.4	2	12.7	0.08	1.15	0.020	1.4
11 Nov 09	860	0.635	0.026	0.003	0.827	7.6	<2	14.0	0.03	0.86	0.016	1.6
9 Dec 09	2200	3.095	0.017	0.004	1.046	7.3	4	14.4	0.12	1.17	0.024	1.5
13 Jan 10	1100	0.569	0.025	0.005	0.855	7.6	<2	14.2	0.16	1.02	0.028	1.6
10 Feb 10	830	0.248	0.026	0.009	0.301	7.8	<2	18.5	0.33	0.64	0.014	2.1
10 Mar 10	770	0.426	0.018	0.002	0.378	7.8	12	15.4	0.20	0.58	0.015	2.2
14 April 10	17000	1.929	0.298	0.025	1.145	7.5	93	14.6	2.42	3.59	0.423	25
12 May 10	1100	0.291	0.017	0.006	0.654	7.7	<2	12.0	0.08	0.74	0.023	1.7
10 June 10	300	4.122	0.020	0.006	0.874	7.5	6	11.2	0.32	1.20	0.028	1.9

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

Table 7 Statistical summary of data from July 2009 to June 2010: Mangaoraka Stream at Corbett Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.019	0.063	0.029	12	0.012
A440F	Absorbance @ 440nm filtered	/cm	0.004	0.015	0.007	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.001
ALKT	Alkalinity total	g/m^3 $CaCO_3$	28	86	46	12	20
BLACK DISC	Black disc transparency	m	0.10	2.57	1.62	12	0.723
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	14	0.6	12	3.8
CONDY	Conductivity @ 20°C	mS/m	11.6	23.7	15.7	12	3.8
DO	Dissolved oxygen	g/m^3	8.2	11.2	10.2	12	0.79
PERSAT	Dissolved oxygen saturation	%	88	100	97	12	3
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.004	0.014	0.009	12	0.010
ECOL	E. coli bacteria	nos/100 ml	150	17000	840	12	4682
ENT	Enterococci bacteria	nos/100 ml	84	180000	445	12	51813
FC	Faecal coliform bacteria	nos/100 ml	150	17000	845	12	4679
FLOW	Flow	m^3/s	0.248	4.122	1.118	12	1.359
NH_4	Ammoniacal nitrogen	g/m^{3}N	0.014	0.298	0.026	12	0.080
NO_2	Nitrite nitrogen	g/m^{3}N	0.002	0.025	0.005	12	0.006
NO_3	Nitrate nitrogen	g/m^{3}N	0.30	1.15	0.87	12	0.261
pH	pH		7.2	7.8	7.5	12	0.19
SS	Suspended solids	g/m^3	<2	93	3	12	26
TEMP	Temperature	°C	9.4	18.5	13.4	12	2.6
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.03	2.42	0.14	12	0.66
TN	Total nitrogen	g/m^{3}N	0.58	3.59	1.06	12	0.793
TP	Total phosphorus	g/m^{3}P	0.014	0.423	0.023	12	0.116
TURB	Turbidity	NTU	1.4	25	1.7	12	6.82

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

Table 8 Statistical summary of data from July 1995 to June 2010: Mangaoraka Stream at Corbett Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.014	0.074	0.024	180	0.012
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.019	0.005	180	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	180	0.001
ALKT	Alkalinity total	g/m^3 $CaCO_3$	14	96	41	180	17
BLACK DISC	Black disc transparency	m	0.055	4.73	1.89	180	0.941
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	14	0.6	180	1.6
CONDY	Conductivity @ 20°C	mS/m	5.6	26.7	14.5	180	3.6
DO	Dissolved oxygen	g/m^3	7.8	11.8	10.1	180	0.83
PERSAT	Dissolved oxygen saturation	%	83	107	96	180	4
DRP	Dissolved reactive phosphorus	g/m^{3}P	<0.003	0.041	0.008	180	0.008
ECOL	E. coli bacteria	nos/100 ml	120	60000	735	156	8239
ENT	Enterococci bacteria	nos/100 ml	31	180000	340	180	15730
FC	Faecal coliform bacteria	nos/100 ml	120	60000	735	180	8842
FLOW	Flow	m^3/s	0.160	34.100	1.152	180	3.405
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.308	0.020	180	0.051
NO_2	Nitrite nitrogen	g/m^{3}N	0.001	0.033	0.005	180	0.005
NO_3	Nitrate nitrogen	g/m^{3}N	0.05	1.73	0.84	180	0.322
pH	pH		6.9	8.1	7.6	180	0.21
SS	Suspended solids	g/m^3	<2	310	2	180	30
TEMP	Temperature	°C	5.8	20.5	13.0	180	3.0
TKN	Total kjeldahl nitrogen	g/m^{3}N	<0.01	4.46	0.20	180	0.50
TN	Total nitrogen	g/m^{3}N	0.28	5.18	1.12	180	0.566
TP	Total phosphorus	g/m^{3}P	0.007	0.860	0.022	180	0.103
TURB	Turbidity	NTU	0.75	100	1.6	179	9.86

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.

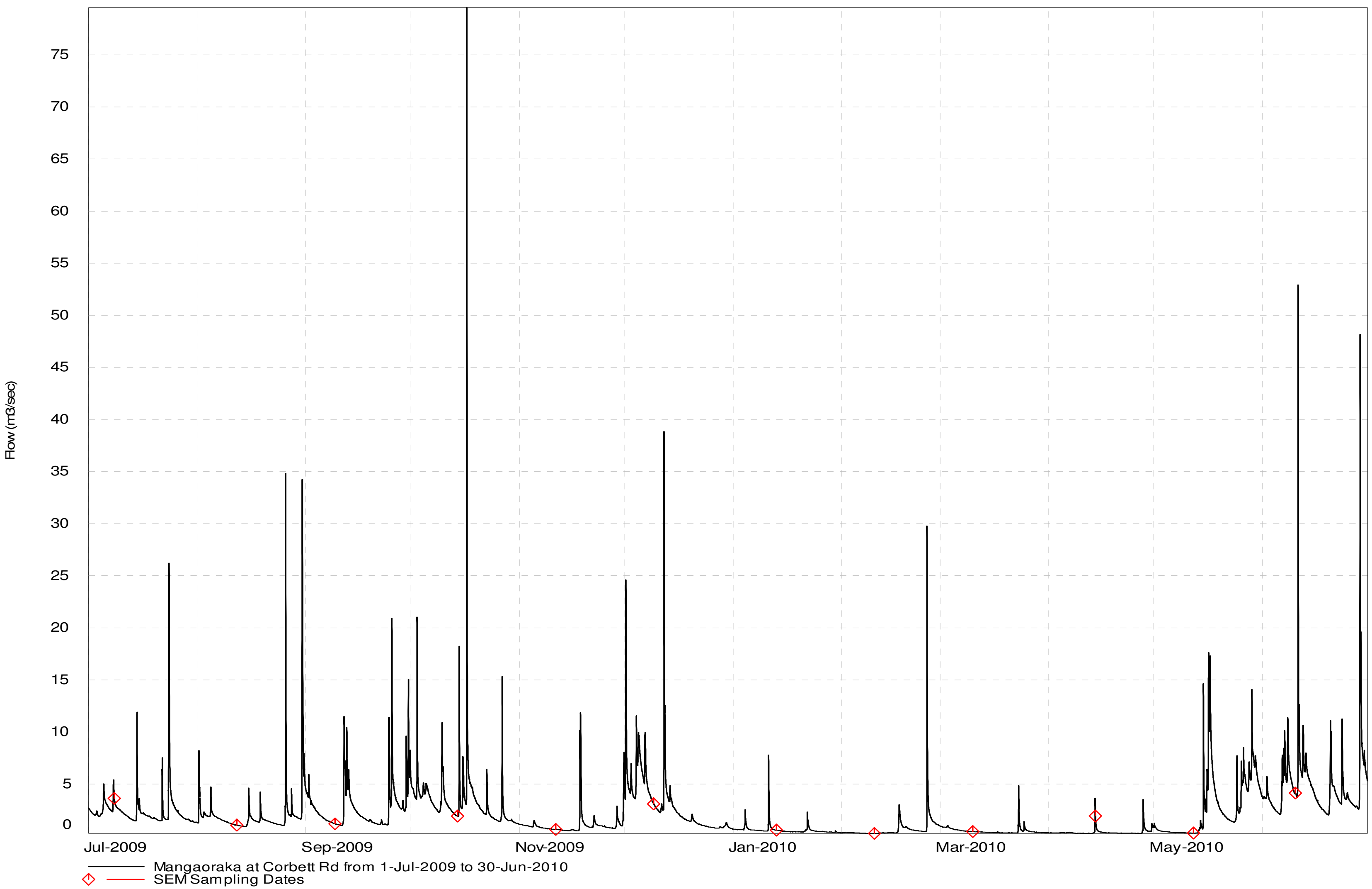

Figure 3 Flow record for the Mangaoraka Stream at Corbett Road

Discussion

2009-2010 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: 1.4 NTU; median: 1.7 NTU) than might be expected given the concentration of suspended solids (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 relatively low maximum black disc value of 2.57 m coincided with early spring, relatively low recession flow conditions, while the poorest turbidity conditions (25 NTU and 0.10 m black disc) were on the rising stage in April 2010 when a suspended sediment concentration of 93 g/m^3, BOD_5 of 14 g/m^3, and faecal coliform number of 17000 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 elevated BOD_5 concentrations were also recorded in July and December 2009 when sampling coincided with other small freshes (Figure 3).

Relatively few freshes during mid-summer to autumn coincided with slightly elevated pH values (7.6 to 7.8) but these levels were not quite as high as have been recorded previously through late summer-autumn months. It should be noted all levels were recorded prior to mid morning and were no indication of the higher pH levels expected later in the day when algal photosynthetic activity might be expected to raise pH significantly.

Generally, high dissolved oxygen concentrations, high percentage saturation and low BOD_5 levels (< 1.0 g/m^3) were indicative of good physicochemical water quality. The high median bacterial numbers (445 enterococci and 845 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]. Water temperatures varied over a moderate range of 9.1°C with a maximum (mid-morning) temperature of 18.5°C in February 2010 (coincident with 88% dissolved oxygen saturation and pH of 7.8) during low flow conditions at that time. Dissolved oxygen saturation fell below 90% on only this one occasion in early morning.

Brief comparison with the previous 1995-2009 period

Aesthetic stream water quality at this site during the 2009-2010 period was slightly more turbid (lower median black disc clarity (by 0.29 m), higher median turbidity (by 0.1 NTU) and higher median suspended solids level (by 1 g/m^3)). Bacterial water quality was poorer in terms of an increase in median faecal coliform number of 145 per 100 mls and an increase in the median enterococci number of 120 per 100 mls. Median water temperatures were very similar while the maximum water temperature (18.5°C) was 2.0°C lower than the previous maximum recorded. Median conductivity (and alkalinity) were slightly higher and probably reflected the increase in low flow conditions sampled during the latest period. This was reflected in the median flow sampled during 2009-2010 which was slightly lower (by about 18 L/sec) than the median of flows sampled over the previous fourteen-year period. Moderately wide ranges for parameters such as suspended solids, turbidity, pH, and BOD_5 reflected the presence of flood events sampled on occasions during the 2009-2010 period. Median pH was within 0.1 unit but maximum pH was 0.3 units lower than the past record. Most nutrient species had relatively similar median values during the monitoring year in comparison with the previous fourteen-year record.

Waiwhakaiho River at SH 3 (site: WKH000500)

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

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

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m^3 CaCO$_3$)	Black disc (m)	BOD$_5$ (g/m^3)	Cond @ 20 °C (mS/m)	DO (g/m^3)	DO Sat (%)	DRP (g/m^{3}P)	E.coli (Nos/ 100ml)	ENT (Nos/ 100ml)
8 July 09	0900	0.040	0.009	0.000	27	1.04	0.5	7.7	11.4	98	0.014	580	180
12 Aug 09	0900	0.012	0.003	0.000	55	2.64	<0.5	14.0	11.5	100	0.032	46	28
9 Sept 09	0905	0.010	0.002	0.000	54	3.85	<0.5	13.8	12.0	102	0.034	120	21
14 Oct 09	0815	0.011	0.002	0.000	46	2.02	<0.5	12.0	11.1	102	0.023	140	16
11 Nov 09	0815	0.009	0.003	0.000	59	2.91	0.6	14.4	10.8	102	0.034	140	15
9 Dec 09	0810	0.016	0.005	0.001	42	3.02	<0.5	11.6	10.7	104	0.025	200	7
13 Jan 10	0810	0.016	0.004	0.000	50	4.10	0.6	13.3	10.9	104	0.029	170	74
10 Feb 10	0815	0.011	0.003	0.000	66	2.82	0.5	15.8	9.8	101	0.044	71	110
10 Mar 10	0800	0.010	0.002	0.000	65	2.72	<0.5	15.1	10.5	103	0.037	140	93
14 April 10	0900	0.095	0.021	0.001	15	0.62	1.7	5.2	10.3	99	0.025	2900	5900
12 May 10	0905	0.011	0.003	0.000	69	2.36	0.6	15.5	11.1	102	0.045	100	66
10 June 10	0905	0.015	0.004	0.001	37	2.45	<0.5	10.6	11.2	99	0.020	100	31

Date	FC (Nos/ 100ml)	Flow (m^3/s)	NH$_4$ (g/m^{3}N)	NO$_2$ (g/m^{3}N)	NO$_3$ (g/m^{3}N)	pH	SS (g/m^3)	Temp (°C)	TKN (g/m^{3}N)	TN (g/m^{3}N)	TP (g/m^{3}P)	Turb (NTU)
8 July 09	580	8.67	0.015	0.003	0.137	7.4	2	7.7	0.10	0.24	0.032	1.6
12 Aug 09	46	2.86	0.006	0.001	0.159	7.9	<2	8.3	0.05	0.21	0.037	0.90
9 Sept 09	120	2.85	0.011	0.002	0.198	7.6	<2	7.3	0.06	0.26	0.040	0.65
14 Oct 09	140	4.063	0.008	0.002	0.178	7.6	<2	10.5	0.03	0.21	0.028	0.70
11 Nov 09	140	2.34	0.004	<0.001	0.019	8.3	<2	11.8	0.05	0.07	0.038	0.55
9 Dec 09	200	3.895	0.028	0.003	0.257	8.0	<2	12.9	0.04	0.30	0.028	0.60
13 Jan 10	170	2.576	0.004	<0.001	0.049	8.0	<2	12.1	0.05	0.10	0.032	0.55
10 Feb 10	71	1.77	0.004	<0.001	0.009	8.2	<2	15.6	0.09	0.10	0.048	0.65
10 Mar 10	140	2.25	0.004	0.005	0.025	8.0	<2	13.4	0.05	0.08	0.045	0.55
14 April 10	3,000	9.421	0.016	0.002	0.078	7.5	8	12.5	0.29	0.37	0.061	2.7
12 May 10	100	2.188	<0.003	0.001	0.069	7.9	7	10.5	0.02	0.09	0.048	1.1
10 June 10	100	5.049	0.011	0.004	0.436	7.7	4	8.9	0.01	0.45	0.024	0.70

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

Table 10 Statistical summary of data from July 2009 to June 2010

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.009	0.095	0.012	12	0.025
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.021	0.003	12	0.005
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	15	69	52	12	16
BDISC	Black disc transparency	m	0.62	4.10	2.68	12	0.995
BOD	Biochemical oxygen demand 5day	g/m³	<0.5	1.7	0.5	12	0.3
CONDY	Conductivity @ 20'C	mS/m	5.2	15.8	13.6	12	3.2
DO	Dissolved Oxygen	g/m³	9.8	12.0	11.0	12	0.58
PERSAT	Dissolved Oxygen Saturation %	%	98	104	102	12	2
DRP	Dissolved reactive phosphorus	g/m³P	0.014	0.045	0.031	12	0.009
ECOL	E.coli bacteria	nos/100 ml	46	2900	140	12	802
ENT	Enterococci bacteria	nos/100 ml	7	5900	49	12	1687
FC	Faecal Coliforms	nos/100 ml	46	3000	140	12	830
FLOW	Flow	m³/s	1.770	9.421	2.855	12	2.541
NH4	Ammoniacal nitrogen	g/m³N	<0.003	0.028	0.007	12	0.007
NO2	Nitrite nitrogen	g/m³N	<0.001	0.005	0.002	12	0.001
NO3	Nitrate nitrogen	g/m³N	<0.01	0.44	0.11	12	0.124
PH	pH		7.4	8.3	7.9	12	0.28
SS	Suspended solids	g/m³	<2	8	<2	12	2
TEMP	Temperature	°C	7.3	15.6	11.2	12	2.5
TKN	Total Kjeldahl nitrogen	g/m³N	0.01	0.29	0.05	12	0.07
TN	Total nitrogen	g/m³N	0.07	0.45	0.21	12	0.124
TP	Total phosphorus	g/m³P	0.024	0.061	0.038	12	0.011
TURB	Turbidity	NTU	0.55	2.7	0.7	12	0.63

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

Table 11 Statistical summary of data from July 1995 to June 2010: Waiwhakaiho River at SH3

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.007	0.095	0.015	180	0.019
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.022	0.004	180	0.005
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.007	0.000	180	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	8	72	49	180	17
BDISC	Black disc transparency	m	0.13	8.05	3.07	180	1.466
BOD	Biochemical oxygen demand 5day	g/m³	<0.5	4.3	<0.5	180	0.6
CONDY	Conductivity @ 20'C	mS/m	3.4	16.6	12.2	180	3.2
DO	Dissolved Oxygen	g/m³	9.1	12.4	10.8	180	0.72
PERSAT	Dissolved Oxygen Saturation %	%	91	108	100	180	3
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.108	0.024	180	0.011
ECOL	E.coli bacteria	nos/100 ml	23	56000	170	156	4974
ENT	Enterococci bacteria	nos/100 ml	1	28000	83	180	2217
FC	Faecal Coliforms	nos/100 ml	23	83000	190	180	7722
FLOW	Flow	m³/s	1.770	83.440	3.743	180	9.758
NH4	Ammoniacal nitrogen	g/m³N	<0.003	0.148	0.007	180	0.023
NO2	Nitrite nitrogen	g/m³N	<0.001	0.010	0.002	180	0.001
NO3	Nitrate nitrogen	g/m³N	<0.01	0.47	0.11	180	0.107
PH	pH		6.8	8.5	7.9	180	0.29
SS	Suspended solids	g/m³	<2	89	<2	180	11
TEMP	Temperature	°C	5.2	18.3	11.0	180	2.9
TKN	Total Kjeldahl nitrogen	g/m³N	<0.01	1.95	0.08	180	0.24
TN	Total nitrogen	g/m³N	0.02	2.10	0.21	180	0.253
TP	Total phosphorus	g/m³P	0.014	0.437	0.034	180	0.052
TURB	Turbidity	NTU	0.4	26	0.7	179	3.05

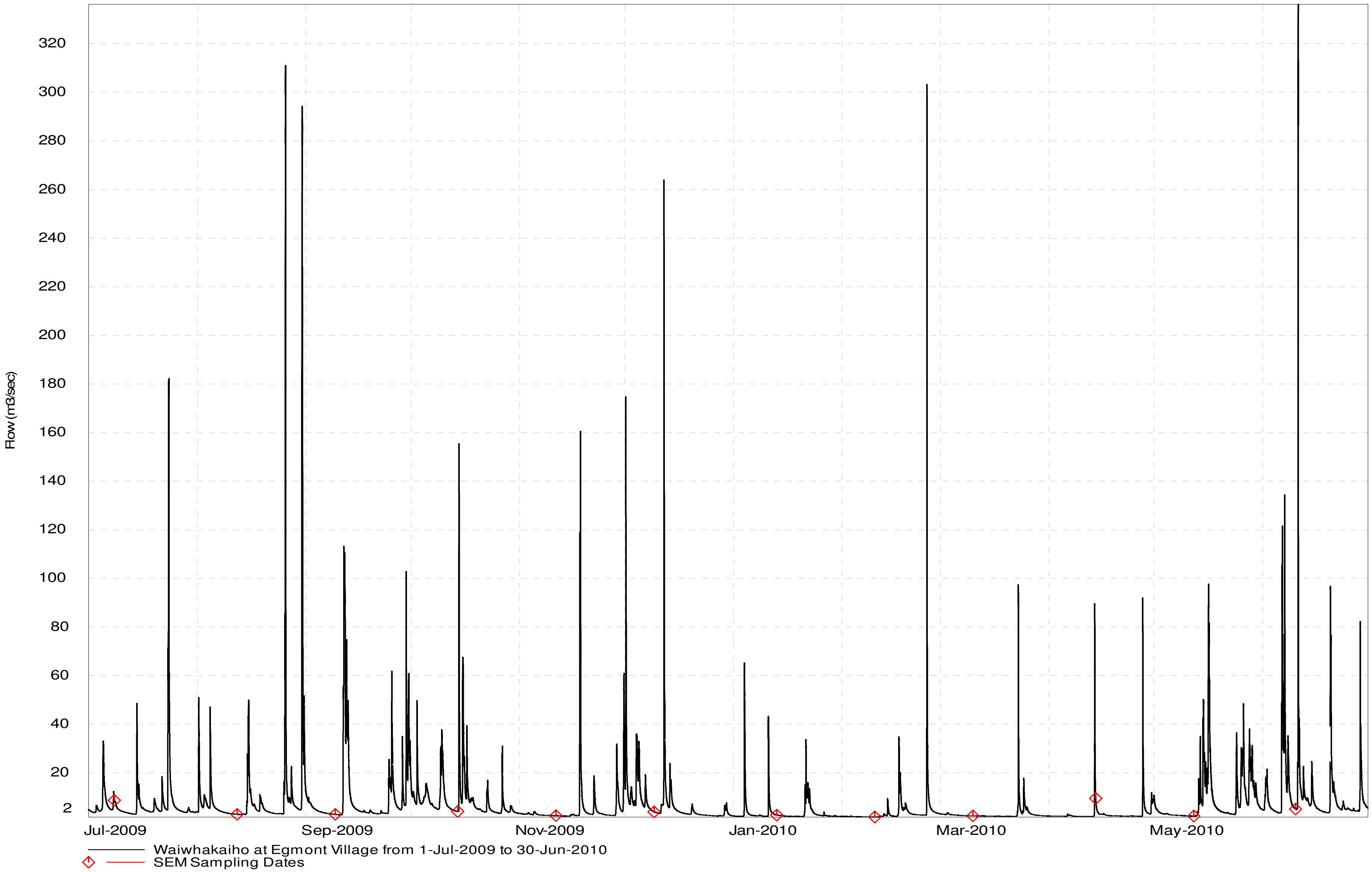

Figure 4 Flow record for the Waiwhakaiho River at SH3 Egmont Village

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

2009-2010 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 2.68 m and 0.7 NTU respectively. The maximum black disc value (4.10 metres) was recorded in mid summer under relatively low flow conditions (2.58 m^3/sec) (Figure 4), with the worst conditions (black disc clarity of 0.62 m) during a moderate fresh flow (9.42 m^3/sec) in April 2010 when the suspended solids concentration was slightly elevated (8 g/m^3) and turbidity was 2.7 NTU. Generally, poorer water quality was recorded at the time of this fresh flow (Figure 4) when an elevation in faecal coliform bacterial numbers (3,000 numbers/100 ml) and to a lesser extent BOD_5 (1.7g/m^3) and colour, together with decreased clarity were recorded.

A maximum pH value of 8.3 was recorded under low flow conditions in early 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 0905 hrs.

Very good water quality was indicated by high dissolved oxygen concentrations [104% saturation at times and median saturation of 102%] and low BOD_5 levels (median of 0.5 g/m^3). Bacteriological quality was moderately good, with median faecal coliform and enterococci numbers (140 and 49 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 exhibited a moderate range of 8.3°C during the period with a maximum mid-morning water temperature of 15.6°C recorded in February 2010 under very low flow conditions.

Brief comparison with the previous 1995-2009 period

River water quality measured by the 2009-2010 survey in general improved slightly in comparison with that recorded over the previous fourteen-year period. Median black disc clarity was poorer (by 0.46m) although median turbidity and suspended solids levels remained identical between periods. Bacteriological water quality was better in terms of median faecal coliform number (by 70 per 100 mls) and median enterococci number (by 34 per 100mls). A narrower range of water temperatures (by 4.8˚C) was recorded in the most recent twelve-month period. Median water temperature was 0.2°C higher in the most recent period although the maximum temperature was 2.7°C lower than that recorded at any time over the previous fourteen years.

Median sampled flow over the 2009-2010 period was lower (by 843 L/sec) than for the flows sampled in the previous fourteen-year period coincident with a decrease in fresh events and the very low flow summer-autumn period sampled during the latest period.

Median nutrient concentrations for phosphorus species showed increases over the most recent sampling period but median nitrogen species' concentrations were 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)
8 July 09	1000	0.038	0.008	0.000	26	1.62	<0.5	6.8	11.7	98	0.010	9	4
12 Aug 09	1000	0.007	0.001	0.000	46	2.21	<0.5	11.5	11.4	99	0.022	<3	3
9 Sept 09	1015	0.007	0.002	0.000	44	1.05	<0.5	11.1	11.7	102	0.025	5	3
14 Oct 09	0915	0.006	0.001	0.000	39	2.63	<0.5	10.2	11.1	101	0.020	8	1
11 Nov 09	0915	0.006	0.002	0.000	43	3.11	<0.5	11.0	10.8	99	0.020	9	<1
9 Dec 09	0920	0.009	0.002	0.000	38	4.14	<0.5	9.7	10.3	100	0.021	9	1
13 Jan 10	0910	0.010	0.002	0.000	40	4.90	<0.5	10.4	10.4	99	0.020	4	1
10 Feb 10	0910	0.006	0.001	0.000	50	3.95	<0.5	12.3	10.0	99	0.021	9	4
10 Mar 10	0910	0.005	0.001	0.000	49	5.00	<0.5	11.9	10.6	102	0.019	4	11
14 April 10	1000	0.040	0.009	0.001	20	0.37	0.6	5.5	10.5	100	0.014	54	70
12 May 10	1005	0.006	0.001	0.000	52	6.48	<0.5	12.0	10.7	100	0.023	21	11
10 June 10	1005	0.009	0.002	0.001	37	2.19	<0.5	9.2	11.4	99	0.018	4	<1

Date	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)
8 July 09	9	5.638	0.003	0.001	0.019	7.5	3	6.8	0.03	0.05	0.019	1.4
12 Aug 09	<3	2.415	0.003	<0.001	0.039	7.9	<2	8.4	<0.01	0.04	0.028	0.55
9 Sept 09	5	3.152	<0.003	<0.001	0.059	7.5	8	8.4	0.02	0.08	0.036	2.7
14 Oct 09	8	3.376	<0.003	<0.001	0.039	7.7	2	10.3	0.01	<0.05	0.023	0.65
11 Nov 09	9	3.164	<0.003	<0.001	0.009	7.9	<2	10.8	0.04	<0.05	0.021	0.55
9 Dec 09	9	3.398	<0.003	<0.001	0.039	7.8	<2	13.3	0.01	<0.05	0.021	0.7
13 Jan 10	4	3.163	<0.003	<0.001	0.019	7.8	<2	12.3	0.04	0.06	0.020	0.8
10 Feb 10	9	2.385	<0.003	<0.001	0.039	8.0	2	14.1	0.01	<0.05	0.024	1.0
10 Mar 10	4	2.331	<0.003	0.002	0.008	8.0	<2	12.9	0.04	<0.05	0.024	0.55
14 April 10	54	8.4	<0.003	<0.001	0.009	7.4	49	12.1	0.09	0.10	0.082	7.5
12 May 10	21	2.248	<0.003	<0.001	0.009	8.0	<2	11.6	0.04	<0.05	0.026	0.5
10 June 10	4	3.606	<0.003	0.001	0.059	7.8	2	8.5	<0.01	0.06	0.023	1.2

The statistical summary of this data is presented in Table 13

Table 13 Statistical summary of data from July 2009 to July 2010 Stony River at Mangatete Road

Parrameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.005	0.040	0.007	12	0.013
A440F	Absorbance @ 440nm Filtered	/cm	0.001	0.009	0.002	12	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	20	52	42	12	10
BDISC	Black disc transparency	m	0.37	6.48	2.87	12	1.803
BOD	Biochemical oxygen demand 5day	g/m³	<0.5	0.6	<0.5	12	0
CONDY	Conductivity @ 20'C	mS/m	5.5	12.3	10.7	12	2.1
DO	Dissolved Oxygen	g/m³	10.0	11.7	10.8	12	0.57
PERSAT	Dissolved Oxygen Saturation %	%	98	102	100	12	1
DRP	Dissolved reactive phosphorus	g/m³P	0.010	0.025	0.020	12	0.004
ECOL	E.coli bacteria	nos/100 ml	<3	54	9	12	14
ENT	Enterococci bacteria	nos/100 ml	<1	70	3	12	19
FC	Faecal Coliforms	nos/100 ml	<3	54	9	12	14
FLOW	Flow	m³/s	2.248	8.400	3.164	12	1.763
NH4	Ammoniacal nitrogen	g/m³N	<0.003	0.003	<0.003	12	0.000
NO2	Nitrite nitrogen	g/m³N	<0.001	0.002	<0.001	12	0.000
NO3	Nitrate nitrogen	g/m³N	<0.01	0.06	0.03	12	0.019
PH	pH		7.4	8.0	7.8	12	0.21
SS	Suspended solids	g/m³	<2	49	2	12	13
TEMP	Temperature	°C	6.8	14.1	11.2	12	2.3
TKN	Total Kjeldahl nitrogen	g/m³N	<0.01	0.09	0.03	12	0.03
TN	Total nitrogen	g/m³N	0.04	0.10	<0.05	12	0.017
TP	Total phosphorus	g/m³P	0.019	0.082	0.024	12	0.017
TURB	Turbidity	NTU	0.5	7.5	0.8	12	1.99

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

Table 14 Statistical summary of data from July 1995 to June 2010: Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.003	0.077	0.009	180	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.028	0.002	180	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.007	0.000	180	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	5	54	39	180	11
BLACK DISC	Black disc transparency	m	<0.01	13.12	3.50	180	2.872
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	1.6	<0.5	180	0.1
CONDY	Conductivity @ 20°C	mS/m	3.0	12.7	9.7	180	2.4
DO	Dissolved oxygen	g/m³	9.4	12.2	10.7	180	0.63
PERSAT	Dissolved oxygen saturation	%	87	104	99	182	2
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.210	0.018	180	0.016
ECOL	E. coli bacteria	nos/100 ml	<1	950	7	156	97
ENT	Enterococci bacteria	nos/100 ml	<1	460	5	180	53
FC	Faecal coliform bacteria	nos/100 ml	<1	1000	8	180	94
FLOW	Flow	m³/s	2.050	55.504	3.622	180	7.651
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.019	<0.003	180	0.003
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.004	<0.001	180	0.000
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.11	0.02	180	0.018
pH	pH		7.0	8.2	7.9	180	0.23
SS	Suspended solids	g/m³	<2	2500	<2	180	308
TEMP	Temperature	°C	5.7	16.6	10.6	180	2.5
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	1.78	0.04	180	0.15
TN	Total nitrogen	g/m³N	<0.02	1.82	0.07	180	0.154
TP	Total phosphorus	g/m³P	0.013	2.660	0.024	180	0.245
TURB	Turbidity	NTU	0.2	480	0.7	179	57.34

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

2009-2010

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 April, 2010 were reflected in black disc and turbidity values of 0.37 m and 7.5 NTU respectively with an elevation in suspended solids concentration (49 g/m^3) and faecal coliform bacteria numbers (54 per 100 mls). The maximum black disc clarity of 6.48 m was measured in late autumn under low flow conditions coincident with the lowest suspended solids and turbidity levels.

Maximum mid-morning pH (8.0) and the median pH (7.8) were relatively similar to past years' results.

Dissolved oxygen concentrations were consistently high with a minimum saturation of 98% on one occasion (under fresh flow conditions) and BOD_5 levels were below the detectable limit on all but the largest flood flow occasion; 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 (9 and 3 per 100 mls respectively) indicative of minimal impact of upstream developed farmland at this site near mid-catchment.

River water temperatures varied over a moderate range of 7.3°C during the period, with a maximum mid-morning temperature of 14.1°C recorded in February 2010 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 April flood event and a higher sediment load.

Brief comparison with the previous 1995-2009 period

Water quality measured during the 2009-2010 survey period, in comparison with the previous fourteen years' survey results, was poorer aesthetically in terms of median black disc clarity (which was lower by 0.72m), although median turbidity and suspended solids levels were very similar to historical medians.

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

Water temperature range was narrower (by 3.6°C) due mainly to a lower maximum temperature during 2009-2010, but the median was relatively similar (0.6°C warmer) in the 2009-2010 period to that in the earlier fourteen-year period. All median nutrient species were relatively similar to the previous longer period medians.

Median sampled flow during the 2009-2010 period was lower (by 0.55 m^3/sec) than the median of flows sampled over the previous fourteen-year period, with few significant flood events (in excess of 5 m^3/sec) and several relatively low flow events sampled.

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/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)
8 July 09	1030	0.078	0.016	0.001	15	0.22	0.8	7.7	11.4	98	0.014	320	140
12 Aug 09	1030	0.024	0.005	0.000	23	2.32	<0.5	9.2	11.8	100	0.022	11	1
9 Sept 09	1050	0.020	0.004	0.000	21	2.69	<0.5	8.9	11.6	102	0.023	4	1
14 Oct 09	0945	0.023	0.005	0.000	20	2.12	<0.5	8.9	10.7	99	0.016	50	<1
11 Nov 09	0945	0.024	0.005	0.000	23	1.94	<0.5	8.9	10.4	99	0.030	480	31
9 Dec 09	0955	0.036	0.008	0.000	23	1.96	<0.5	9.0	9.6	101	0.061	200	5
13 Jan 10	0950	0.033	0.007	0.000	24	3.07	0.5	8.8	10.0	99	0.026	270	28
10 Feb 10	0950	0.028	0.006	0.000	25	2.65	<0.5	9.1	9.7	100	0.026	130	100
10 Mar 10	0945	0.022	0.004	0.000	25	2.39	<0.5	8.8	10.4	104	0.031	190	56
14 April 10	1030	0.029	0.007	0.001	24	1.56	<0.5	8.5	10.2	101	0.036	62	110
12 May 10	1045	0.023	0.006	0.001	25	2.12	<0.5	9.0	10.8	101	0.036	84	92
10 June 10	1040	0.040	0.008	0.001	17	1.87	<0.5	9.0	11.1	98	0.013	33	7

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)
8 July 09	320	1.212	0.028	0.002	0.098	7.2	22	7.5	0.41	0.51	0.104	14
12 Aug 09	11	0.357	0.008	<0.001	0.069	7.4	<2	6.7	0.04	0.11	0.028	2.4
9 Sept 09	4	0.335	0.005	<0.001	0.079	7.4	<2	8.2	0.06	0.14	0.028	1.9
14 Oct 09	50	0.426	0.003	<0.001	0.039	7.4	3	10.5	0.07	0.11	0.024	1.8
11 Nov 09	480	0.293	0.006	<0.001	0.009	7.5	<2	11.9	0.07	0.08	0.033	1.5
9 Dec 09	200	0.403	0.004	<0.001	0.019	7.5	<2	16.1	0.09	0.11	0.068	1.8
13 Jan 10	280	0.277	<0.003	<0.001	0.009	7.5	<2	13.5	0.08	0.09	0.032	1.1
10 Feb 10	140	0.260	0.006	<0.001	0.009	7.8	<2	15.3	0.07	0.08	0.031	1.4
10 Mar 10	190	0.226	0.005	<0.001	0.009	7.8	<2	14.1	0.05	0.06	0.040	1.2
14 April 10	62	0.337	<0.003	<0.001	0.009	7.6	2	13.5	0.08	0.09	0.047	2.1
12 May 10	88	0.239	0.003	<0.001	0.029	7.7	2	11.1	0.07	0.10	0.045	1.8
10 June 10	33	0.675	0.012	0.003	0.157	7.7	<2	8.5	0.07	0.23	0.022	1.9

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

Table 16 Statistical summary of data from July 2009 to June 2010 Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.020	0.078	0.026	12	0.016
A440F	Absorbance @ 440nm filtered	/cm	0.004	0.016	0.006	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m³ $CaCO_3$	15	25	23	12	3
BLACK DISC	Black disc transparency	m	0.22	3.07	2.12	12	0.716
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	0.8	<0.5	12	0.1
CONDY	Conductivity @ 20°C	mS/m	7.7	9.2	8.9	12	0.4
DO	Dissolved oxygen	g/m³	9.6	11.8	10.6	12	0.72
PERSAT	Dissolved oxygen saturation	%	98	104	100	12	2
DRP	Dissolved reactive phosphorus	g/m³P	0.013	0.061	0.026	12	0.013
ECOL	E. coli bacteria	nos/100 ml	4	480	107	12	146
ENT	Enterococci bacteria	nos/100 ml	<1	140	30	12	50
FC	Faecal coliform bacteria	nos/100 ml	4	480	114	12	146
FLOW	Flow	m³/s	0.226	1.212	0.336	12	0.2768
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.028	0.005	12	0.007
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.003	<0.001	12	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.16	0.02	12	0.047
pH	pH		7.2	7.8	7.5	12	0.18
SS	Suspended solids	g/m³	<2	22	<2	12	6
TEMP	Temperature	°C	6.7	16.1	11.5	12	3.2
TKN	Total kjeldahl nitrogen	g/m³N	0.04	0.41	0.07	12	0.10
TN	Total nitrogen	g/m³N	0.06	0.51	0.11	12	0.124
TP	Total phosphorus	g/m³P	0.022	0.104	0.033	12	0.023
TURB	Turbidity	NTU	1.1	14	1.8	12	3.56

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

Table 17 Statistical summary of data from July 1995 to July 2010: Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.019	0.144	0.033	180	0.025
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.032	0.007	180	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.005	0.000	180	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	6	27	22	180	5
BLACK DISC	Black disc transparency	m	0.08	4.39	1.84	180	0.914
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	3.0	<0.5	180	0.3
CONDY	Conductivity @ 20°C	mS/m	4.0	10.9	8.5	180	1.2
DO	Dissolved oxygen	g/m³	8.9	12.4	10.4	179	0.75
PERSAT	Dissolved oxygen saturation	%	87	106	99	179	3
DRP	Dissolved reactive phosphorus	g/m³P	0.007	0.389	0.023	180	0.029
ECOL	E. coli bacteria	nos/100 ml	3	6100	120	156	948
ENT	Enterococci bacteria	nos/100 ml	<1	1200	40	180	170
FC	Faecal coliform bacteria	nos/100 ml	3	6100	130	180	948
FLOW	Flow	m³/s	0.180	12.380	0.431	180	1.2452
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.078	0.006	180	0.009
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.014	0.001	180	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.18	0.03	180	0.040
pH	pH		6.9	8.3	7.7	180	0.24
SS	Suspended solids	g/m³	<2	160	2	180	14
TEMP	Temperature	°C	5.0	19.2	11.9	180	3.3
TKN	Total kjeldahl nitrogen	g/m³N	0.01	0.85	0.10	180	0.13
TN	Total nitrogen	g/m³N	<0.05	0.87	0.15	180	0.144
TP	Total phosphorus	g/m³P	0.016	0.413	0.034	180	0.044
TURB	Turbidity	NTU	0.45	29	1.6	179	3.59

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

2009-2010

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 2.12 m (black disc) and 1.8 NTU (turbidity). This was related to the open nature of the reaches of both the stream and the upstream tributary draining developed farmland catchment immediately downstream of the National Park through the 2 km reach upstream of this site. This area has also been subject to stock access in the past (see photos in TRC 2000) although in recent years the banks have been fenced and planted in the immediate vicinity of the site. Minimum black disc clarity (0.22 m) occurred during a small stream fresh in July 2009 (Figure 5) and coincided with a moderate increase in suspended solids concentration (22 g/m^3). Increases in total nitrogen and phosphorus concentrations and colour occurred at this time, and also in faecal coliform bacteria number (320 per 100mls) although a higher faecal coliform number (480 per 100 mls) was recorded later in the period under lower flow conditions.

A maximum pH (7.8) was recorded (in mid morning) on two occasions during the period in late summer-autumn, under low flow conditions.

Dissolved oxygen concentrations were consistently high (above 97% saturation for all the period) and BOD_5 levels were very low, 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 (114 per 100 mls) indicated 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 seepage from surrounding farmland has been a common feature in this reach of the stream, but few freshes were sampled during the 2009-2010 period compared with previous periods.

Water temperatures varied over a moderately wide range (9.4°C) for the upper reaches of a ring plain stream, reflecting the bouldery, open nature of the reach below the National Park. A maximum mid morning water temperature of 16.1°C was recorded in December 2009, relatively high for the upper reaches of a ring plain stream at this time of the day (0955 hrs).

Brief comparison with the previous 1995-2009 period

Stream water quality measured during the 2009-2010 period, was slightly poorer in terms of median turbidity (by 0.2 NTU) although median black disc clarity increased by 0.33 m. Median suspended solids concentration remained low and was very similar in the recent year in comparison with the previous fourteen-year period. Median dissolved oxygen percentage saturation levels were very similar for both periods.

Bacteriological water quality improved slightly in terms of median faecal coliform number (by 16 per 100 ml) and median number of enterococci (by 10 per 100 ml), reflecting in part only occasional freshes sampled in 2009-2010. Median total nitrogen decreased slightly during this period compared with the previous fourteen-year period, whereas all other median nutrient species were similar between periods.

The water temperature range was narrower (by 3.8°C) compared with surveys prior to the latest twelve-month period; with the median flow sampled being lower (by 101 L/sec) in the 2009-2010 period. The narrower temperature range was caused mainly by a lower maximum temperature in 2009-2010 than previously recorded.

Median pH value was very similar (0.2 pH unit lower) during the latest sampling period but maximum pH was 0.5 unit lower than the maximum recorded in the previous fourteen-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 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)
8 July 09	1055	0.053	0.010	0.000	24	0.37	1.5	16.5	11.4	98	0.039	1800	630
12 Aug 09	1050	0.031	0.007	0.000	35	1.91	0.6	18.5	11.5	99	0.035	180	20
9 Sept 09	1120	0.026	0.005	0.000	30	2.40	0.7	18.9	11.6	101	0.054	140	120
14 Oct 09	1015	0.030	0.006	0.000	34	1.35	0.8	19.5	10.6	99	0.050	400	160
11 Nov 09	1010	0.037	0.008	0.001	40	1.43	1.2	19.3	10.2	98	0.047	640	320
9 Dec 09	1020	0.040	0.008	0.000	37	1.68	1.1	17.7	9.5	97	0.069	260	80
13 Jan 10	1015	0.046	0.010	0.000	38	1.65	1.2	16.9	9.5	98	0.110	550	500
10 Feb 10	1015	0.048	0.010	0.000	41	1.29	1.1	15.7	9.1	97	0.063	1200	3800
10 Mar 10	1010	0.045	0.008	0.000	40	1.57	0.7	14.1	9.9	101	0.063	270	1400
14 April 10	1100	0.045	0.009	0.001	40	1.43	1.0	13.6	10.0	100	0.066	670	2200
12 May 10	1110	0.039	0.008	0.001	40	2.67	<0.5	13.8	10.6	98	0.044	500	630
10 June 10	1105	0.033	0.007	0.001	25	1.45	0.7	19.6	10.9	97	0.032	270	77

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)
8 July 09	1900	2.817	0.129	0.017	1.663	7.3	15	8.8	0.80	2.48	0.109	10
12 Aug 09	180	0.767	0.056	0.015	1.665	7.5	2	8.7	0.08	1.76	0.059	1.9
9 Sept 09	150	0.842	0.102	0.026	1.674	7.3	2	9.1	0.38	2.08	0.081	1.8
14 Oct 09	400	1.206	0.076	0.028	1.732	7.4	3	12.3	0.23	1.99	0.077	2.0
11 Nov 09	650	0.688	0.042	0.021	1.499	7.6	2	13.6	0.22	1.74	0.076	2.0
9 Dec 09	260	0.999	0.044	0.030	0.930	7.7	<2	16.3	0.38	1.34	0.094	1.8
13 Jan 10	570	0.621	0.045	0.027	0.963	7.6	2	16.7	0.23	1.22	0.157	2.0
10 Feb 10	1200	0.494	0.263	0.014	0.406	7.7	<2	18.4	0.46	0.88	0.117	2.2
10 Mar 10	280	0.380	0.017	0.003	0.277	7.7	<2	16.1	0.18	0.46	0.087	1.9
14 April 10	700	0.488	0.013	0.005	0.265	7.6	<2	15.2	0.11	0.38	0.088	1.8
12 May 10	520	0.411	0.018	0.003	0.267	7.6	<2	11.9	0.08	0.35	0.060	1.6
10 June 10	280	1.905	0.053	0.013	2.427	7.6	3	10.1	0.72	3.16	0.068	1.6

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

Table 19 Statistical summary of data from July 2009 to June 2010 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.026	0.053	0.040	12	0.008
A440F	Absorbance @ 440nm Filtered	/cm	0.005	0.010	0.008	12	0.002
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m³ $CaCO_3$	24	41	38	12	6
BDISC	Black disc transparency	m	0.37	2.67	1.51	12	0.575
BOD	Biochemical oxygen demand 5day	g/m³	<0.5	1.5	0.9	12	0.3
CONDY	Conductivity @ 20'C	mS/m	13.6	19.6	17.3	12	2.3
DO	Dissolved Oxygen	g/m³	9.1	11.6	10.4	12	0.84
PERSAT	Dissolved Oxygen Saturation %	%	97	101	98	12	1
DRP	Dissolved reactive phosphorus	g/m³P	0.032	0.110	0.052	12	0.021
ECOL	E.coli bacteria	nos/100 ml	140	1800	450	12	484
ENT	Enterococci bacteria	nos/100 ml	20	3800	410	12	1137
FC	Faecal Coliforms	nos/100 ml	150	1900	460	12	505
FLOW	Flow	m³/s	0.38	2.817	0.728	12	0.721
NH4	Ammoniacal nitrogen	g/m³N	0.013	0.263	0.049	12	0.069
NO2	Nitrite nitrogen	g/m³N	0.003	0.030	0.016	12	0.010
NO3	Nitrate nitrogen	g/m³N	0.27	2.43	1.23	12	0.73
PH	pH		7.3	7.7	7.6	12	0.14
SS	Suspended solids	g/m³	<2	15	2	12	4
TEMP	Temperature	°C	8.7	18.4	13.0	12	3.4
TKN	Total Kjeldahl nitrogen	g/m³N	0.08	0.80	0.23	12	0.24
TN	Total nitrogen	g/m³N	0.35	3.16	1.54	12	0.882
TP	Total phosphorus	g/m³P	0.059	0.157	0.084	12	0.028
TURB	Turbidity	NTU	1.6	10	1.9	12	2.35

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

Table 20 Statistical summary of data from July 1995 to June 2010 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.015	0.115	0.040	180	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.027	0.008	180	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.006	0.000	180	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	10	46	35	180	7
BDISC	Black disc transparency	m	0.055	3.57	1.50	180	0.679
BOD	Biochemical oxygen demand 5day	g/m³	<0.5	8.1	0.9	180	0.9
CONDY	Conductivity @ 20'C	mS/m	5.8	21.8	16.1	180	2.4
DO	Dissolved Oxygen	g/m³	8.6	12.8	10.4	180	0.83
PERSAT	Dissolved Oxygen Saturation %	%	90	114	99	180	3
DRP	Dissolved reactive phosphorus	g/m³P	0.013	0.212	0.041	180	0.028
ECOL	E.coli bacteria	nos/100 ml	48	20000	465	154	2506
ENT	Enterococci bacteria	nos/100 ml	15	9300	280	179	1072
FC	Faecal Coliforms	nos/100 ml	51	20000	500	180	2847
FLOW	Flow	m³/s	0.242	12.300	0.773	180	1.642
NH4	Ammoniacal nitrogen	g/m³N	0.004	0.376	0.044	180	0.066
NO2	Nitrite nitrogen	g/m³N	<0.001	0.11	0.015	180	0.016
NO3	Nitrate nitrogen	g/m³N	0.07	3.13	0.91	180	0.631
PH	pH		7.1	8.6	7.7	180	0.22
SS	Suspended solids	g/m³	<2	220	3	180	23
TEMP	Temperature	°C	5.0	21.0	13.4	180	3.6
TKN	Total Kjeldahl nitrogen	g/m³N	0.04	1.99	0.34	180	0.28
TN	Total nitrogen	g/m³N	0.29	3.96	1.35	180	0.732
TP	Total phosphorus	g/m³P	0.026	0.531	0.075	180	0.067
TURB	Turbidity	NTU	0.85	50	1.8	179	5.43

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.

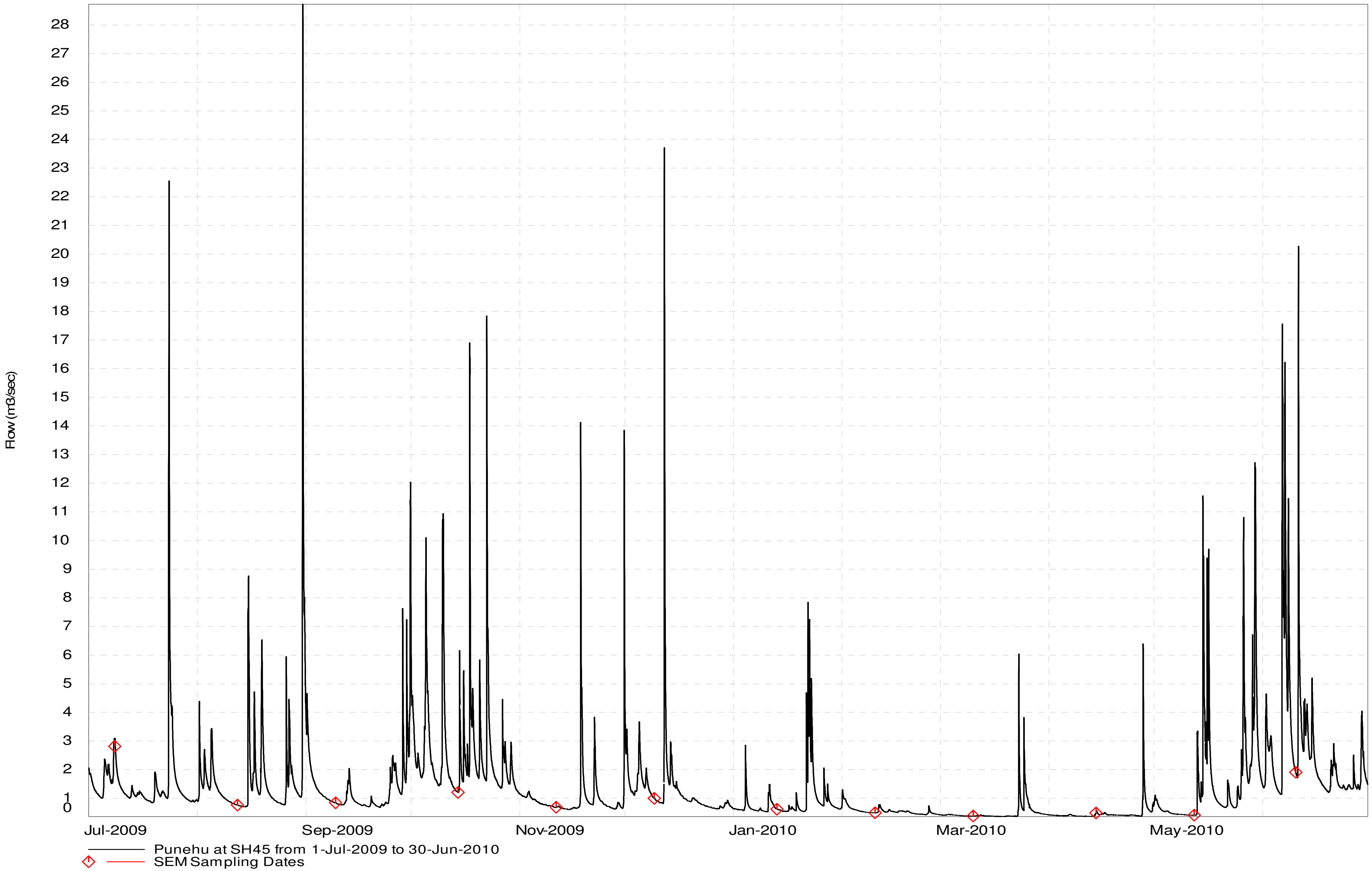

Figure 5 Flow record for the Punehu Stream at SH45

Discussion

2009-2010 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.51 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 1.9 NTU were also typical of the lower reaches of a ring plain catchment. Minimum clarity (black disc clarity of 0.37 m, turbidity of 10 NTU, and suspended solids concentration of 15 g/m^3) was recorded during a small fresh in July 2009. Some deterioration in other water quality parameters under these conditions was shown by an elevation in bacterial numbers, and increases in BOD_5 and certain nutrient species (eg, total phosphorus, total nitrogen, and ammoniacal nitrogen).

pH peaked at 7.7 (over summer) but this was recorded in late morning and would be expected to have reached higher levels later in the day. This was 0.9 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 late spring-summer period.

The relatively high median bacteriological numbers (410 enterococci and 460 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 (260 to 1200 per 100 ml) were indicative of point source discharges of pond system treated dairy sheds' wastes and/or stock access. Relatively high median nutrient levels were consistent with such impacts.

Water temperature varied over a moderate range of 9.7˚C with a maximum summer (late morning) temperature of 18.4°C recorded in February 2010 and the lowest temperature (8.7°C) recorded in August 2009; the former 2.8°C below the previous annual maximum temperature and the latter 3.7˚C above the previous annual minimal temperature.

Brief comparison of upper and lower sites during the 2009-2010 period

Deterioration in certain aspects of water quality in the lower stream reaches was emphasised by a very significant increase in median bacteriological numbers (343 faecal coliforms per 100 mls and 380 enterococci per 100 mls), and median nutrient concentrations (particularly nitrogen species) with total nitrogen and total phosphorus increasing by factors of about 14 and 3 times respectively. Small deteriorations in median turbidity levels, suspended solids concentrations and median black disc clarity (29% 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 117% in the lower reaches of the stream). The downstream water temperature range increased by only 0.3°C while the median increased by only 1.5°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 1995-2009 period

Minimal change in aesthetic water quality was indicated by a small increase in median turbidity (of 0.10 NTU) and very similar median black disc clarity (0.01 m improvement) recorded during the more recent twelve-month survey period, and there was a small decrease in median suspended solids concentration (of 1g/m^3).

In the more recent survey period a small improvement was recorded in median faecal coliform bacterial number (by 40 per 100 mls) but a deterioration in median enterococci bacteria number (by 130 per 100 mls). Small increases in most median nutrient species concentrations were recorded, particularly dissolved reactive phosphorus, nitrate nitrogen, and total nitrogen which increased by about 27%, 38%, and 15% of the long term medians respectively.

Median dissolved oxygen saturation levels were very similar (within 1%) as were median BOD_5 levels which were identical in the two periods.

The difference in median pH was minimal (0.1 unit lower) for the 2009-2010 period although the maximum pH was 0.9 unit lower in comparison with the previous fourteen-year period.

Water temperature range was much narrower (by 6.3°C); this decrease due to higher minimum and lower maximum water temperatures over the recent survey period, with the 2009-2010 median water temperature 0.4˚C lower than the median fourteen year temperature.

Median sampled flow over the 2009-2010 period was 47 L/sec lower than the median sampled flow for the previous fourteen-year period, partly due to few higher flood flow conditions sampled during the latest 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)
8 July 09	1205	0.016	0.004	0.000	26	0.90	0.5	10.8	11.2	99	0.019	150	46
12 Aug 09	1200	0.012	0.002	0.000	29	1.98	<0.5	11.7	11.3	101	0.014	34	8
9 Sept 09	1235	0.010	0.002	0.000	28	1.56	<0.5	12.1	11.2	102	0.023	19	7
14 Oct 09	1130	0.010	0.001	0.000	27	1.73	<0.5	11.6	10.8	102	0.014	120	5
11 Nov 09	1130	0.017	0.005	0.001	32	2.14	0.8	12.2	11.1	107	0.020	140	13
9 Dec 09	1130	0.024	0.006	0.000	31	1.59	0.7	10.8	10.1	105	0.034	71	5
13 Jan 10	1140	0.029	0.008	0.001	36	2.37	0.9	12.0	10.5	106	0.032	120	82
10 Feb 10	1225	0.025	0.006	0.000	37	2.05	0.7	11.3	10.1	110	0.022	260	240
10 Mar 10	1125	0.024	0.005	0.000	39	1.63	1.2	12.1	10.6	110	0.026	180	190
14 April 10	1215	0.100	0.024	0.002	16	0.48	4.1	6.2	10.2	99	0.047	3100	5700
12 May 10	1225	0.023	0.005	0.000	37	2.55	0.6	11.2	12.6	117	0.019	110	28
10 June 10	1210	0.014	0.003	0.000	26	1.18	0.6	11.8	10.7	98	0.020	77	38

Date	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)
8 July 09	150	3.126	0.023	0.007	1.393	7.5	6	9.1	0.44	1.84	0.037	2.5
12 Aug 09	34	1.701	0.013	0.004	1.606	7.5	3	9.5	0.23	1.84	0.034	1.7
9 Sept 09	19	2.813	0.024	0.004	1.916	7.4	4	10.1	0.26	2.18	0.033	1.6
14 Oct 09	120	3.744	0.013	0.005	1.825	7.6	3	11.7	0.08	1.91	0.033	1.4
11 Nov 09	140	1.389	0.018	0.007	1.583	8.0	<2	12.8	0.03	1.62	0.033	1.3
9 Dec 09	74	1.099	0.073	0.012	0.968	7.8	<2	16.2	0.15	1.13	0.051	1.3
13 Jan 10	120	0.656	0.017	0.006	0.774	7.8	<2	14.7	0.10	0.88	0.050	1.4
10 Feb 10	260	0.590	0.015	0.004	0.476	8.2	<2	18.5	0.09	0.57	0.032	1.5
10 Mar 10	190	0.444	0.016	0.002	0.518	7.9	4	15.9	0.11	0.63	0.039	1.3
14 April 10	3100	3.223	0.095	0.009	0.421	7.3	16	12.8	0.61	1.04	0.133	4.4
12 May 10	110	0.454	0.004	0.002	0.568	8.3	<2	10.9	0.01	0.58	0.029	1.2
10 June 10	77	8.028	0.044	0.008	1.892	7.6	7	10.4	0.20	2.10	0.033	2.0

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

Table 22 Statistical summary of data from July 2009 to June 2010: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.010	0.100	0.020	12	0.024
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.024	0.005	12	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	12	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	16	39	30	12	6
BLACK DISC	Black disc transparency	m	0.48	2.55	1.68	12	0.603
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	4.1	0.7	12	1.0
CONDY	Conductivity @ 20°C	mS/m	6.2	12.2	11.7	12	1.6
DO	Dissolved oxygen	g/m³	10.1	12.6	10.8	12	0.70
PERSAT	Dissolved oxygen saturation	%	98	117	104	12	6
DRP	Dissolved reactive phosphorus	g/m³P	0.014	0.047	0.021	12	0.009
ECOL	E. coli bacteria	nos/100 ml	19	3100	120	12	864
ENT	Enterococci bacteria	nos/100 ml	5	5700	33	12	1630
FC	Faecal coliform bacteria	nos/100 ml	19	3100	120	12	863
FLOW	Flow	m³/s	0.444	8.028	1.545	12	2.170
NH_4	Ammoniacal nitrogen	g/m³N	0.004	0.095	0.018	12	0.028
NO_2	Nitrite nitrogen	g/m³N	0.002	0.012	0.006	12	0.003
NO_3	Nitrate nitrogen	g/m³N	0.42	1.92	1.18	12	0.60
pH	pH		7.3	8.3	7.7	12	0.31
SS	Suspended solids	g/m³	<2	16	3	12	4
TEMP	Temperature	°C	9.1	18.5	12.3	12	3.0
TKN	Total kjeldahl nitrogen	g/m³N	0.01	0.61	0.13	12	0.18
TN	Total nitrogen	g/m³N	0.57	2.18	1.38	12	0.618
TP	Total phosphorus	g/m³P	0.029	0.133	0.034	12	0.029
TURB	Turbidity	NTU	1.2	4.4	1.5	12	0.90

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

Table 23 Statistical summary of data from July 1995 to June 2010: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.100	0.021	180	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.024	0.005	180	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.003	0.000	180	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	11	45	30	180	7
BLACK DISC	Black disc transparency	m	0.10	4.39	1.73	180	0.835
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	7.3	0.6	180	0.9
CONDY	Conductivity @ 20°C	mS/m	4.6	13.4	11.2	180	1.6
DO	Dissolved oxygen	g/m³	9.2	13.0	10.6	180	0.76
PERSAT	Dissolved oxygen saturation	%	92	121	102	181	5
DRP	Dissolved reactive phosphorus	g/m³P	0.003	0.081	0.018	180	0.012
ECOL	E. coli bacteria	nos/100 ml	6	59000	170	156	4866
ENT	Enterococci bacteria	nos/100 ml	3	5700	110	180	887
FC	Faecal coliform bacteria	nos/100 ml	6	100000	195	180	8755
FLOW	Flow	m³/s	0.356	28.797	1.616	180	3.719
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.265	0.018	180	0.041
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.033	0.007	180	0.006
NO_3	Nitrate nitrogen	g/m³N	0.14	2.31	1.10	180	0.496
pH	pH		7.1	8.6	7.8	180	0.28
SS	Suspended solids	g/m³	<2	180	3	180	20
TEMP	Temperature	°C	5.6	20.8	12.3	180	3.3
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	2.15	0.20	180	0.28
TN	Total nitrogen	g/m³N	0.27	2.91	1.40	180	0.524
TP	Total phosphorus	g/m³P	0.013	0.829	0.036	180	0.084
TURB	Turbidity	NTU	0.7	36	1.4	179	4.45

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.

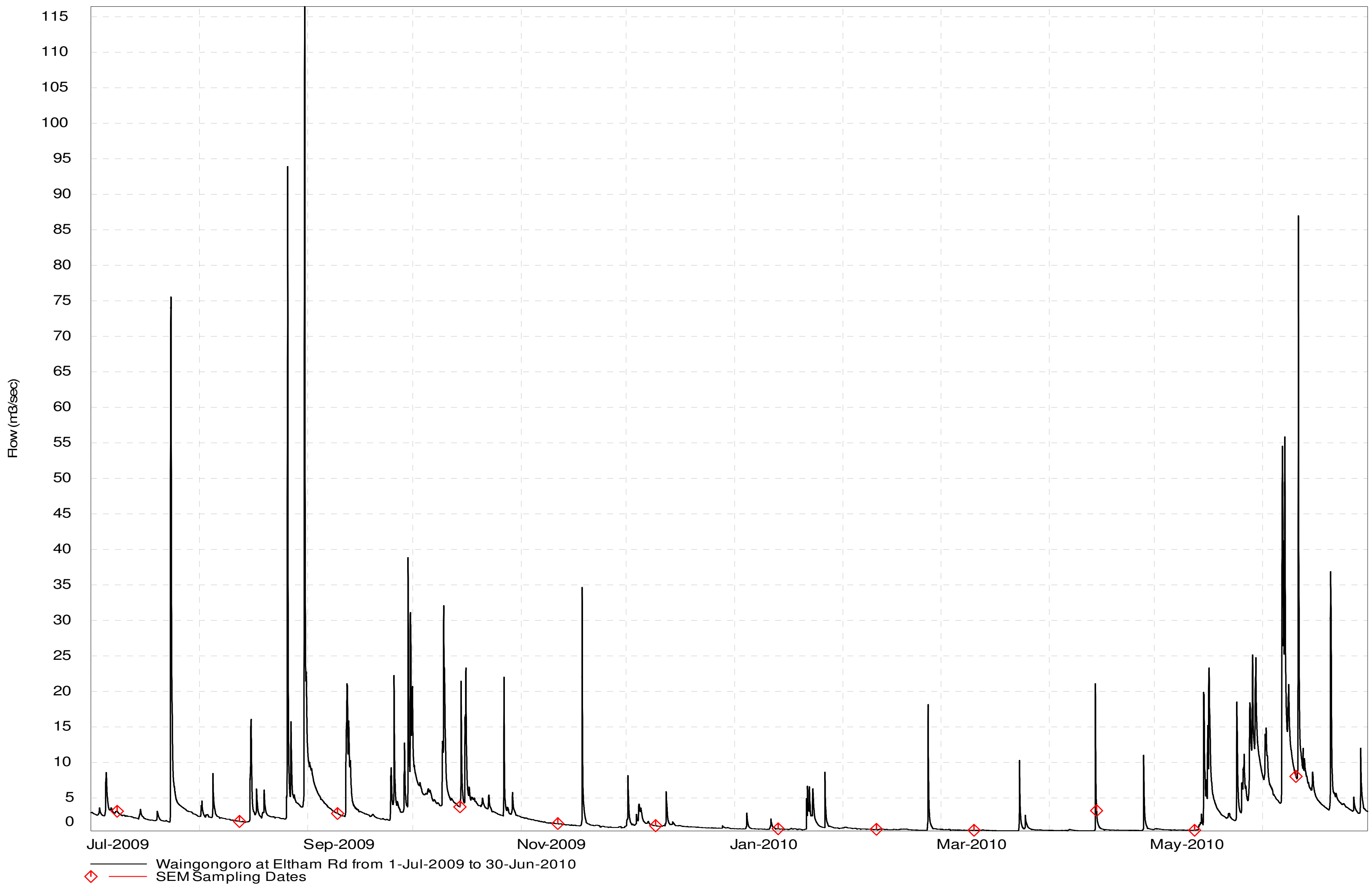

Figure 6 Flow record for the Waingongoro River at Eltham Road

Discussion

2009-2010

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.68 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 2.55 m) was recorded in late autumn during very low flow conditions (0.45 m^3/s), while worst black disc clarity (0.48 m) occurred during a fresh in early autumn coincident with a turbidity of 4.4 NTU and suspended solids concentration of 16 g/m^3 sampled in April 2010 (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 two occasions during the 2009-2010 period.

pH reached a maximum of 8.0 in late autumn coincident with supersaturation (117%) of dissolved oxygen, although it would be expected that pH would have risen further later in the day, particularly in late summer, than at the time of sampling (near midday).

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 98% saturation recorded in mid winter) and low BOD_5 levels (median: 0.7 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 120 and 33 (per 100 mls) respectively. Water temperature varied over a moderate range of 9.4°C with a maximum summer (late morning) river temperature of 18.5° C recorded in February 2010 under very low flow conditions (Figure 6).

Brief comparison with previous 1995-2009 period

The latest twelve-month period sampled a narrower range of flow conditions while median sampled flow was slightly lower (by 71 L/sec) than the median of flows sampled in the previous fourteen-year period. Aesthetic river water quality was very similar in terms of median black disc clarity (which decreased by 0.05 m), median suspended solids level (which was identical), and median turbidity level (which increased very slightly by 0.1 NTU) during the 2009-2010 period.

In general, an improvement in bacteriological water quality was recorded in the 2009-2010 period with much lower median faecal coliform number (by 80 per 100 mls) and median enterococci number (by 77 per 100 mls). Minor differences between periods were indicated in median nutrient species' concentrations over the 2009-2010 period.

The range in water temperature was much narrower (by 5.8°C) over the 2009-2010 period mainly due to a much warmer (by 3.5˚C) minimum water temperature although median water temperatures were identical for the two periods.

Median pH values were very similar although the maximum pH previously recorded was 0.3 unit higher than that measured in the 2009-2010 period.

Waingongoro River at SH45 (site: WGG000900)

Analytical data are presented in Table 24 from the monthly sampling programme. The river flow recorded at this site for the twelve-month period at this SH45 site is presented in Figure 7.

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

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/m³ CaCO₃)	Black disc (m)	BOD₅ (g/m³)	Cond @ 20 °C (mS/m)	DO (g/m³)	DO Sat (%)	DRP (g/m³P)	E.coli (Nos/100ml)	ENT (Nos/100ml)
8 July 09	1130	0.033	0.005	0.000	32	0.42	0.9	16.3	11.4	100	0.054	1100	330
12 Aug 09	1130	0.022	0.004	0.000	37	1.36	1.2	16.4	11.6	103	0.040	46	13
9 Sept 09	1155	0.017	0.003	0.000	34	1.76	0.9	15.8	11.4	103	0.040	150	16
14 Oct 09	1045	0.017	0.003	0.000	34	1.15	0.8	16.4	10.6	100	0.039	150	19
11 Nov 09	1045	0.027	0.006	0.000	42	1.51	1.2	18.3	10.4	103	0.045	68	13
9 Dec 09	1050	0.037	0.008	0.000	44	1.32	1.3	18.0	9.7	103	0.084	100	31
13 Jan 10	1055	0.043	0.010	0.001	50	1.44	1.3	19.4	10.0	104	0.086	130	74
10 Feb 10	1055	0.040	0.008	0.000	52	1.72	1.0	18.8	9.6	107	0.081	160	150
10 Mar 10	1055	0.038	0.008	0.000	54	1.43	1.1	19.0	10.6	111	0.095	110	120
14 April 10	1140	0.043	0.009	0.001	55	1.39	1.2	19.4	10.9	109	0.094	98	220
12 May 10	1140	0.036	0.007	0.001	51	1.91	0.6	17.6	11.3	104	0.073	260	150
10 June 10	1140	0.021	0.004	0.000	28	1.10	1.3	14.8	10.8	97	0.045	180	62

Date	FC (Nos/100ml)	Flow (m³/s)	NH₄ (g/m³N)	NO₂ (g/m³N)	NO₃ (g/m³N)	pH	SS (g/m³)	Temp (°C)	TKN (g/m³N)	TN (g/m³N)	TP (g/m³P)	Turb (NTU)
8 July 09	1100	9.838	0.053	0.027	1.953	7.5	14	9.4	0.52	2.50	0.101	5.0
12 Aug 09	46	5.141	0.021	0.014	2.186	7.6	3	9.7	0.04	2.24	0.068	2.1
9 Sept 09	160	7.613	0.080	0.031	2.299	7.4	4	10.6	0.50	2.83	0.072	2.1
14 Oct 09	150	11.322	0.032	0.025	2.215	7.5	5	12.3	0.39	2.63	0.073	2.2
11 Nov 09	68	4.817	0.020	0.010	2.190	7.8	4	14.5	0.42	2.62	0.071	2.1
9 Dec 09	100	3.557	0.031	0.018	1.602	7.9	4	18.0	0.64	2.26	0.123	2.4
13 Jan 10	130	2.009	0.096	0.022	1.218	7.8	3	16.8	0.57	1.81	0.135	2.4
10 Feb 10	170	1.642	0.023	0.011	1.159	8.1	4	20.3	0.09	1.26	0.107	2.4
10 Mar 10	110	1.353	0.021	0.009	1.091	8.1	7	17.3	0.39	1.49	0.134	1.8
14 April 10	100	1.307	0.025	0.013	1.557	8.0	2	15.2	0.19	1.76	0.145	2.4
12 May 10	280	1.333	0.017	0.008	1.182	7.8	2	11.4	0.21	1.40	0.094	1.9
10 June 10	180	20.851	0.102	0.040	2.130	7.6	10	10.4	0.55	2.72	0.084	3.4

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

Table 25 Statistical summary of data from July 2009 to June 2010: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.017	0.043	0.035	12	0.010
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.010	0.007	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m³ $CaCO_3$	28	55	43	12	10
BLACK DISC	Black disc transparency	m	0.42	1.91	1.41	12	0.384
BOD_5	Biochemical oxygen demand 5 day	g/m³	0.6	1.3	1.2	12	0.2
CONDY	Conductivity @ 20°C	mS/m	14.8	19.4	17.8	12	1.5
DO	Dissolved oxygen	g/m³	9.6	11.6	10.7	12	0.67
PERSAT	Dissolved oxygen saturation	%	97	111	103	12	4
DRP	Dissolved reactive phosphorus	g/m³P	0.039	0.095	0.064	12	0.023
ECOL	E. coli bacteria	nos/100 ml	46	1100	140	12	285
ENT	Enterococci bacteria	nos/100 ml	13	330	68	12	99
FC	Faecal coliform bacteria	nos/100 ml	46	1100	140	12	285
FLOW	Flow	m³/s	1.307	20.851	4.187	12	5.835
NH_4	Ammoniacal nitrogen	g/m³N	0.017	0.102	0.028	12	0.032
NO_2	Nitrite nitrogen	g/m³N	0.008	0.040	0.016	12	0.010
NO_3	Nitrate nitrogen	g/m³N	1.09	2.30	1.78	12	0.480
pH	pH		7.4	8.1	7.8	12	0.24
SS	Suspended solids	g/m³	2	14	4	12	4
TEMP	Temperature	°C	9.4	20.3	13.4	12	3.7
TKN	Total kjeldahl nitrogen	g/m³N	0.04	0.64	0.41	12	0.20
TN	Total nitrogen	g/m³N	1.26	2.83	2.25	12	0.559
TP	Total phosphorus	g/m³P	0.068	0.145	0.098	12	0.028
TURB	Turbidity	NTU	1.8	5.0	2.3	12	0.88

As this was the twelfth year of state of the environment data collection by the Taranaki Regional Council for this site, only the twelve years of Taranaki Regional Council data are provided in Table 25 for reference or comparative purposes at this stage.

Table 26 Statistical summary of data from July 1998 to June 2010: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.078	0.033	144	0.012
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.019	0.007	144	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	144	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	21	62	40	144	9
BLACK DISC	Black disc transparency	m	0.12	2.39	1.16	144	0.533
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	6.7	1.0	144	0.9
CONDY	Conductivity @ 20°C	mS/m	9.8	21.1	16.4	144	2.2
DO	Dissolved oxygen	g/m³	8.46	12.9	10.5	144	0.83
PERSAT	Dissolved oxygen saturation	%	89	141	101	144	7
DRP	Dissolved reactive phosphorus	g/m³P	0.021	0.223	0.067	144	0.037
ECOL	E. coli bacteria	nos/100 ml	3	41000	220	143	3882
ENT	Enterococci bacteria	nos/100 ml	13	4200	165	144	545
FC	Faecal coliform bacteria	nos/100 ml	3	41000	230	144	3870
FLOW	Flow	m³/s	1.010	50.341	4.648	144	7.431
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.305	0.031	144	0.043
NO_2	Nitrite nitrogen	g/m³N	0.003	0.132	0.022	144	0.019
NO_3	Nitrate nitrogen	g/m³N	0.75	2.98	1.89	144	0.527
pH	pH		7.3	9.1	7.8	144	0.028
SS	Suspended solids	g/m³	<2	120	5	144	18
TEMP	Temperature	°C	5.4	22.0	13.7	144	3.9
TKN	Total kjeldahl nitrogen	g/m³N	0.02	1.51	0.42	144	0.25
TN	Total nitrogen	g/m³N	1.03	3.59	2.47	144	0.567
TP	Total phosphorus	g/m³P	0.043	0.325	0.106	144	0.053
TURB	Turbidity	NTU	1.3	36	2.3	143	4.71

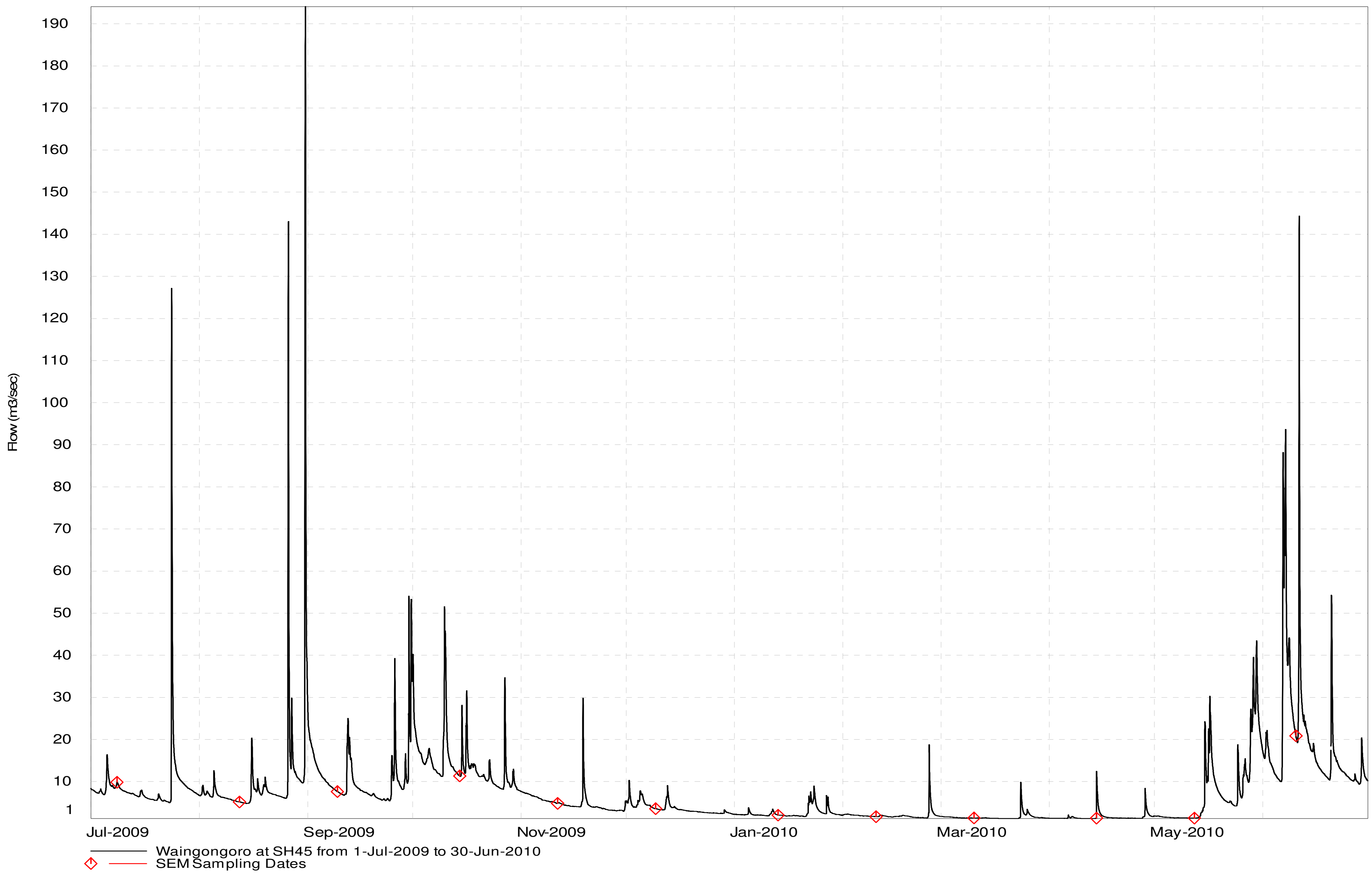

Figure 7 Flow record for the Waingongoro River at SH45

Discussion

2009-2010 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.41 m and median turbidity of 2.3 NTU, in the lower reaches of the longest ring-plain confined river or stream in Taranaki. The maximum clarity (black disc value of 1.91 m) was recorded in late autumn during very low flow conditions (1.33 m^3/s), while the lowest black disc clarity of 0.42 m and highest turbidity of 5.0 NTU were sampled during a small fresh in July 2009. 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 (eg July 2009 and June 2010) although more frequent preceding freshes may have reduced the impact of runoff on bacterial numbers on the latter occasion.

pH reached 8.1 in late summer-early autumn under very low flow conditions coincidental with highest dissolved oxygen saturation levels (107 to 111%), although it would be expected that pH would have risen further during summer/autumn later in the day than at typical sampling times (ie, after 1155 NZST).

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 97% saturation recorded in mid winter 2010 under high flow conditions) and moderately low BOD_5 levels (median: 1.2 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 140 and 68 (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 10.9°C with a maximum summer (late morning) river temperature of 20.3°C recorded in February 2010.

Brief comparison of upper and lower sites during the 2009-2010 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 0.27 m and increased median turbidity level of 0.8 NTU, and a very small increase in median suspended solids concentration of 1 g/m^3). Bacteriological quality, in terms of median faecal coliform and enterococci counts, deteriorated to a relatively small degree by 20 and 35 per 100 mls respectively at the lower river site. The lower river site's pH range was atypically narrower (by 0.3 unit) but the median pH level increased, but only by 0.1 unit at the lower site. Maximum pH recorded was 0.2 unit lower at the lower site, which was atypical of downstream trends in ringplain streams

Median BOD_5 was higher by 0.5 g/m^3 at the SH45 site where nearly all median nutrient species' concentrations also showed significant increases (by up to three times upstream concentrations). Water temperature range was wider (by 1.5°C) at the lower site with median water temperature 1.1°C warmer at this site in the lower reach of the river in comparison with the mid reach site.

Brief comparison with the previous 1998-2009 period

The most recent twelve-month period sampled a far narrower (lower) range of flow conditions and the median sampled flow was lower by 461 L/sec than that sampled over the previous eleven-year period. This was due in part to the absence of large freshes and the very low flow period sampled in the 2009-2010 year.

Water clarity was slightly better with the medians for suspended solids 1 g/m^3 lower, turbidities similar, and black disc clarity higher by 0.29 m in the 2009-2010 period.

Median faecal coliform bacterial number showed a marked improvement of 120 per 100 ml while enterococci also improved by 112 per 100 ml. While pH median values were within 0.1 unit, a much narrower range (by 1.1 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 eleven-year period. Dissolved oxygen saturation median values were almost identical (within 2%) while nearly all median nutrient levels were slightly lower in the recent one year period.

The range in water temperatures was much narrower (by 5.7°C) mainly due to a much higher minimum temperature (by 4.0˚C) while the median was 0.3°C lower in the 2009-2010 sampling period to that recorded in the previous eleven-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)
8 July 09	1240	0.027	0.006	0.000	19	2.42	<0.5	4.9	11.5	99	0.013	4	<1
12 Aug 09	1230	0.014	0.003	0.000	23	5.45	<0.5	6.7	11.4	99	0.020	<3	<1
9 Sept 09	1310	0.006	0.002	0.000	23	7.33	<0.5	6.5	12.1	102	0.022	3	<1
14 Oct 09	1205	0.008	0.003	0.000	18	3.05	<0.5	5.7	11.1	99	0.018	5	1
11 Nov 09	1200	0.012	0.003	0.001	26	4.40	<0.5	7.1	10.7	98	0.027	15	3
9 Dec 09	1200	0.016	0.004	0.001	21	5.42	<0.5	6.1	10.2	99	0.021	7	1
13 Jan 10	1220	0.020	0.005	0.001	24	4.69	<0.5	7.1	10.5	99	0.026	19	12
10 Feb 10	1205	0.015	0.003	0.000	26	3.36	<0.5	8.2	10.0	99	0.029	92	24
10 Mar 10	1205	0.012	0.003	0.000	28	5.46	<0.5	7.8	10.5	100	0.028	620	23
14 April 10	1255	0.080	0.017	0.001	9	1.92	<0.5	4.0	10.5	100	0.015	12	20
12 May 10	1300	0.014	0.003	0.000	29	3.72	<0.5	7.4	11.1	101	0.029	8	12
10 June 10	1240	0.018	0.004	0.000	14	3.83	<0.5	5.0	11.5	98	0.010	8	<1

Date	FC (Nos/ 100ml)	Flow (m³/s)	NH_4 (g/m³N)	NO_2 (g/m³N)	NO_3 (g/m³N)	pH	SS (g/m³)	Temp (°C)	TKN (g/m³N)	TN (g/m³N)	TP (g/m³P)	Turb (NTU)
8 July 09	4	0.415	0.003	<0.001	0.019	7.2	<2	6.2	0.03	0.05	0.016	0.65
12 Aug 09	<3	0.146	0.004	<0.001	0.029	7.4	<2	6.8	0.01	<0.05	0.027	0.65
9 Sept 09	3	0.135	<0.003	<0.001	0.039	7.3	4	5.6	0.06	0.10	0.026	0.70
14 Oct 09	5	0.217	<0.003	<0.001	0.019	7.4	<2	7.8	0.03	<0.05	0.021	0.70
11 Nov 09	15	0.145	0.003	<0.001	0.019	7.4	<2	9.0	0.03	<0.05	0.027	0.50
9 Dec 09	7	0.185	0.004	<0.001	0.019	7.3	<2	11.2	0.03	<0.05	0.023	0.40
13 Jan 10	19	0.125	<0.003	<0.001	0.019	7.4	<2	10.0	0.03	0.05	0.027	0.45
10 Feb 10	93	0.154	0.004	<0.001	0.019	7.7	<2	12.0	0.04	0.06	0.032	0.80
10 Mar 10	620	0.118	0.005	<0.001	0.029	7.5	3	10.6	0.05	0.08	0.040	0.80
14 April 10	12	0.337	<0.003	<0.001	0.009	7.3	<2	10.5	0.13	0.14	0.022	1.1
12 May 10	8	0.153	<0.003	<0.001	0.029	7.6	<2	8.5	0.04	0.07	0.042	0.70
10 June 10	8	0.283	0.003	0.001	0.039	7.5	<2	6.0	0.01	<0.05	0.014	0.40

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

Table 28 Statistical summary of data from July 2009 to June 2010: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.006	0.080	0.015	12	0.020
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.017	0.003	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m³ $CaCO_3$	9	29	23	12	6
BLACK DISC	Black disc transparency	m	1.92	7.33	4.12	12	1.521
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	0.5	<0.5	12	0.0
CONDY	Conductivity @ 20°C	mS/m	4.0	8.2	6.6	12	1.3
DO	Dissolved oxygen	g/m³	10.0	12.1	10.9	12	0.63
PERSAT	Dissolved oxygen saturation	%	98	102	99	12	1
DRP	Dissolved reactive phosphorus	g/m³P	0.010	0.029	0.022	12	0.007
ECOL	E. coli bacteria	nos/100 ml	<3	620	8	12	176
ENT	Enterococci bacteria	nos/100 ml	<1	24	2	12	9
FC	Faecal coliform bacteria	nos/100 ml	<3	620	8	12	176
FLOW	Flow	m³/s	0.118	0.415	0.154	12	0.095
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.005	0.003	12	0.001
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	0.009
pH	pH		7.2	7.7	7.4	12	0.14
SS	Suspended solids	g/m³	<2	4	<2	12	1
TEMP	Temperature	°C	5.6	12.0	8.8	12	2.2
TKN	Total kjeldahl nitrogen	g/m³N	0.01	0.13	0.03	12	0.03
TN	Total nitrogen	g/m³N	<0.05	0.14	0.05	12	0.029
TP	Total phosphorus	g/m³P	0.014	0.042	0.027	12	0.008
TURB	Turbidity	NTU	0.4	1.1	0.7	12	0.20

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

Table 29 Statistical summary of data from July 1995 to June 2010: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.006	0.002	0.016	180	0.022
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.024	0.004	180	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	180	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	3	31	22	179	7
BLACK DISC	Black disc transparency	m	0.09	9.10	4.35	179	1.832
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	3.7	<0.5	180	0.3
CONDY	Conductivity @ 20°C	mS/m	2.5	8.2	6.2	180	1.4
DO	Dissolved oxygen	g/m³	9.1	12.4	10.6	180	0.66
PERSAT	Dissolved oxygen saturation	%	90	103	98	180	2
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.038	0.018	179	0.008
ECOL	E. coli bacteria	nos/100 ml	<1	10000	20	155	872
ENT	Enterococci bacteria	nos/100 ml	<1	2200	8	179	196
FC	Faecal coliform bacteria	nos/100 ml	<1	10000	20	179	814
FLOW	Flow	m³/s	0.118	18.000	0.215	180	1.751
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.057	<0.003	179	0.006
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.003	<0.001	179	0.000
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.14	0.02	179	0.018
pH	pH		6.5	8.0	7.6	179	0.23
SS	Suspended solids	g/m³	<2	160	<2	179	13
TEMP	Temperature	°C	3.7	14.7	9.1	180	2.5
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	1.12	0.05	179	0.13
TN	Total nitrogen	g/m³N	<0.05	1.13	0.08	179	0.133
TP	Total phosphorus	g/m³P	0.010	0.281	0.024	180	0.025
TURB	Turbidity	NTU	0.3	31	0.5	179	2.54

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

2009-2010 period

Aesthetic water quality was very high, as emphasised by median black disc and turbidity values of 4.12 m and 0.7 NTU respectively, and a maximum black disc clarity of 7.33 m measured under early spring relatively low flow conditions. The lowest black disc clarity (1.92 m) was recorded in April 2010, coincident with recession (0.34 m^3/s) from a fresh in the catchment, with small increases in colour, BOD_5, and turbidity also recorded.

Maximum pH (7.7) at this shaded site was measured in late 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 98% 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 very high (median faecal coliform and enterococci numbers of 8 and 2 per 100 mls respectively) although slightly elevated counts found occasionally, 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 relatively narrow range (6.4°C) at this relatively shaded site during the period. A maximum mid-day temperature of 12.0°C was recorded under low flow conditions in February 2010.

Brief comparison with the previous 1995-2009 period

A much narrower range and a lower median of river flows were sampled during the 2009-2010 period, with few small freshes sampled, in comparison with the previous fourteen-year period. Median flow for the 2009-2010 sampling occasions was 68 L/sec lower than the median of sampled flows over the previous fourteen-year period. Aesthetic river water quality similar in terms of median turbidity although median black disc clarity was slightly lower (by 0.23 m) during the 2009-2010 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 increase in median dissolved reactive phosphorus and small decrease in median total nitrogen over the latest twelve-month sampling period.

Median faecal coliform bacterial number decreased (by 13 per 100 mls) while enterococci decreased (by 6 per 100 mls) over the recent sampling period. Median pH values were within 0.2 pH unit for the two periods while the maximum pH value was 0.3 unit lower in the 2009-2010 period.

Median water temperature over the past twelve-month period was only 0.4°C lower than the median for the previous fourteen-year period but the maximum temperature was 2.7 °C lower in the latest period than previously recorded. A slightly narrower range of temperatures (by 4.6°C) was recorded in this 2009-2010 period due mainly to a lower minimum temperature in this period.

Patea River at Skinner Road (site: PAT000360)

Analytical data are presented in Table 30 from the monthly sampling programme and the flow illustrated in Figure 8.

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

Date	Time (NZST)	A340F (/cm)	A440F (/cm)	A770F (/cm)	ALKT (g/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)
8 July 09	1330	0.017	0.004	0.000	23	0.85	0.7	9.3	11.3	102	0.029	340	150
12 Aug 09	1320	0.020	0.005	0.000	26	2.02	0.7	10.3	11.4	103	0.028	46	28
9 Sept 09	1400	0.012	0.002	0.000	26	2.51	<0.5	10.2	11.2	102	0.022	15	24
14 Oct 09	1255	0.020	0.002	0.000	24	2.11	0.6	9.6	10.6	100	0.018	280	120
11 Nov 09	1355	0.020	0.005	0.000	29	2.48	1.0	10.3	10.8	105	0.035	140	450
9 Dec 09	1300	0.028	0.009	0.002	28	1.93	0.9	9.8	10.0	105	0.045	1900	120
13 Jan 10	1305	0.040	0.011	0.002	29	2.28	1.3	10.9	10.5	106	0.078	140	56
10 Feb 10	1305	0.033	0.008	0.001	32	1.62	1.2	12.2	10.9	118	0.081	420	670
10 Mar 10	1300	0.028	0.006	0.000	34	1.70	1.3	11.6	11.0	115	0.085	88	180
14 April 10	1350	0.095	0.023	0.002	16	0.30	7.1	7.2	10.0	99	0.079	6000	5700
12 May 10	1400	0.023	0.005	0.001	32	1.61	1.4	10.5	11.6	108	0.084	170	120
10 June 10	1340	0.015	0.003	0.000	23	1.96	0.6	9.7	10.9	101	0.025	250	110

Date	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)
8 July 09	340	6.276	0.090	0.017	1.023	7.4	3	9.4	0.30	1.34	0.051	2.5
12 Aug 09	46	2.754	0.073	0.016	1.124	7.8	<2	9.6	0.08	1.22	0.042	1.4
9 Sept 09	15	3.937	0.062	0.011	1.139	7.4	<2	10.1	0.17	1.32	0.036	1.3
14 Oct 09	280	5.873	0.054	0.012	1.038	7.5	2	11.5	0.12	1.17	0.034	1.2
11 Nov 09	140	2.069	0.037	0.018	0.982	8.0	<2	12.9	0.04	1.04	0.050	1.3
9 Dec 09	1900	3.587	0.046	0.017	0.893	7.6	5	16.5	0.08	0.99	0.064	1.6
13 Jan 10	140	1.381	0.039	0.034	0.926	7.8	<2	14.5	0.26	1.22	0.100	1.7
10 Feb 10	480	1.068	0.020	0.018	0.882	8.5	<2	17.7	0.22	1.12	0.103	1.9
10 Mar 10	88	0.984	0.018	0.017	0.723	8.1	<2	15.9	0.19	0.93	0.106	1.6
14 April 10	6200	5.037	0.253	0.022	0.718	7.3	16	13.5	0.94	1.68	0.217	6.6
12 May 10	170	1.381	0.039	0.021	1.119	8.1	<2	10.8	0.20	1.34	0.117	1.6
10 June 10	270	9.781	0.068	0.013	1.177	7.3	4	10.5	0.29	1.48	0.041	1.3

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

Table 31 Statistical summary of data from July 2009 to June 2010: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.012	0.095	0.022	12	0.022
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.023	0.005	12	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	12	0.001
ALKT	Alkalinity total	g/m^3 $CaCO_3$	16	34	27	12	5
BLACK DISC	Black disc transparency	m	0.30	2.51	1.95	12	0.647
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	7.1	1.0	12	1.8
CONDY	Conductivity @ 20°C	mS/m	7.2	12.2	10.3	12	1.2
DO	Dissolved oxygen	g/m^3	10.0	11.6	10.9	12	0.51
PERSAT	Dissolved oxygen saturation	%	99	118	104	12	6
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.018	0.085	0.040	12	0.028
ECOL	E. coli bacteria	nos/100 ml	15	6000	210	12	1709
ENT	Enterococci bacteria	nos/100 ml	24	5700	120	12	1603
FC	Faecal coliform bacteria	nos/100 ml	15	6200	220	12	1763
FLOW	Flow	m^3/s	0.984	9.781	3.171	12	2.677
NH_4	Ammoniacal nitrogen	g/m^{3}N	0.018	0.253	0.050	12	0.062
NO_2	Nitrite nitrogen	g/m^{3}N	0.011	0.034	0.017	12	0.006
NO_3	Nitrate nitrogen	g/m^{3}N	0.72	1.18	1.00	12	0.155
pH	pH		7.3	8.5	7.7	12	0.38
SS	Suspended solids	g/m^3	<2	16	<2	12	4
TEMP	Temperature	°C	9.4	17.7	12.2	12	2.9
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.04	0.94	0.20	12	0.24
TN	Total nitrogen	g/m^{3}N	0.93	1.68	1.22	12	0.212
TP	Total phosphorus	g/m^{3}P	0.034	0.217	0.058	12	0.053
TURB	Turbidity	NTU	1.2	6.6	1.6	12	1.49

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

Table 32 Statistical summary of data from July 1995 to June 2010: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.095	0.023	180	0.015
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.023	0.005	180	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	180	0.001
ALKT	Alkalinity total	g/m^3 $CaCO_3$	10	57	27	180	6
BLACK DISC	Black disc transparency	m	0.05	4.68	1.85	180	0.896
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	16.0	0.9	180	1.6
CONDY	Conductivity @ 20°C	mS/m	5.0	14.3	9.9	180	1.5
DO	Dissolved oxygen	g/m^3	8.9	12.9	10.6	180	0.72
PERSAT	Dissolved oxygen saturation	%	87	121	102	180	6
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.010	0.160	0.042	180	0.033
ECOL	E. coli bacteria	nos/100 ml	2	25000	210	156	3560
ENT	Enterococci bacteria	nos/100 ml	9	19000	120	180	1711
FC	Faecal coliform bacteria	nos/100 ml	2	63000	250	180	5814
FLOW	Flow	m^3/s	0.680	77.530	2.850	180	8.590
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.329	0.052	180	0.055
NO_2	Nitrite nitrogen	g/m^{3}N	0.003	0.051	0.018	180	0.008
NO_3	Nitrate nitrogen	g/m^{3}N	0.21	1.54	0.93	180	0.221
pH	pH		7.0	8.8	7.8	180	0.37
SS	Suspended solids	g/m^3	<2	360	2	180	32
TEMP	Temperature	°C	5.3	21.8	12.7	180	3.4
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.02	4.07	0.26	180	0.41
TN	Total nitrogen	g/m^{3}N	0.74	4.50	1.24	180	0.367
TP	Total phosphorus	g/m^{3}P	0.022	1.390	0.075	180	0.126
TURB	Turbidity	NTU	0.2	80	1.5	179	8.03

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.

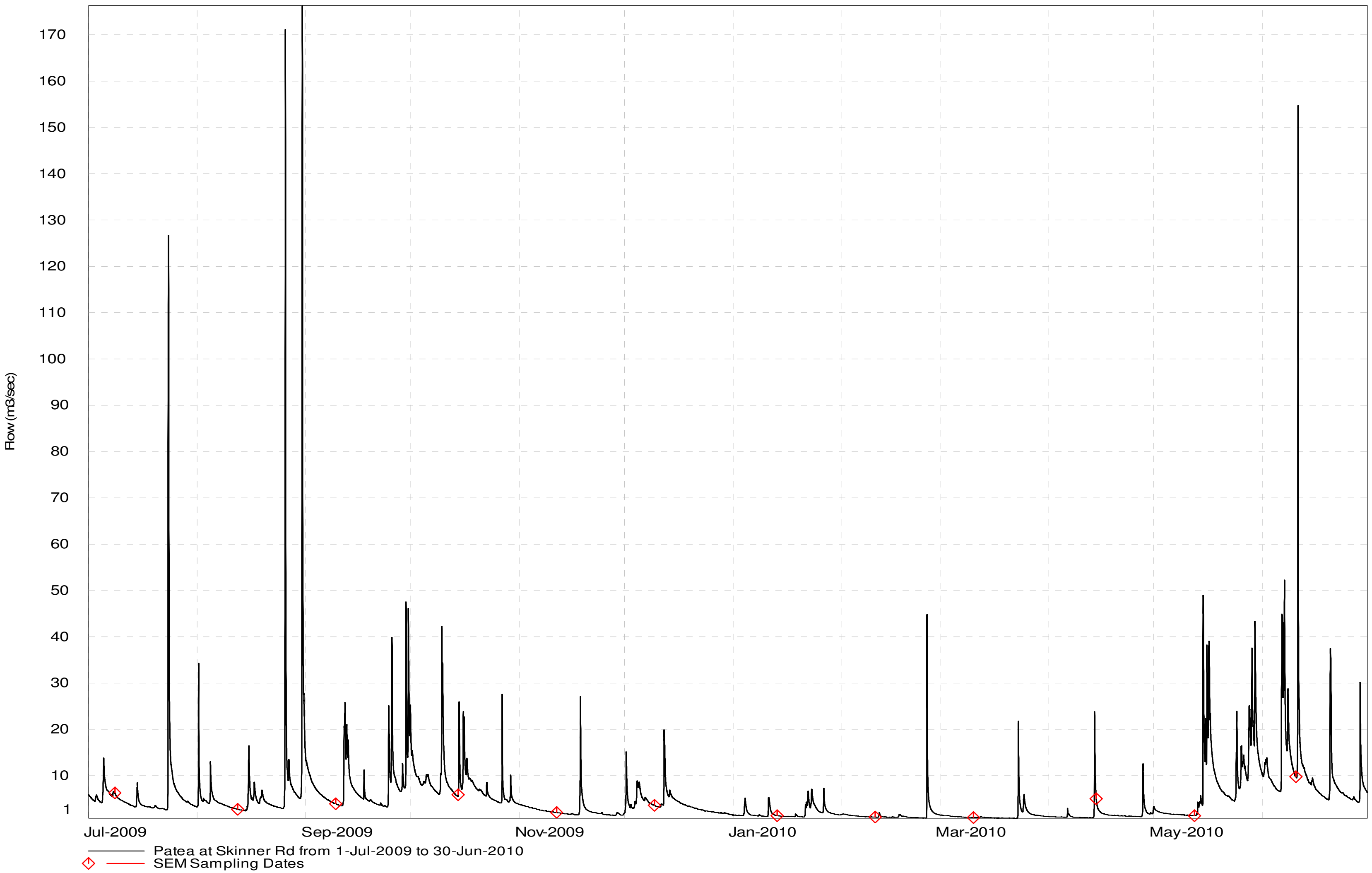

Figure 8 Flow record for the Patea River at Skinner Road

Discussion

2009-2010 period

Moderate median black disc clarity (1.95 metres) and median turbidity (1.6 NTU) were slightly lower than typical of the mid reaches of a ring plain river draining a developed catchment and receiving various point source discharges. However, this clarity and a low median suspended solids concentration (<2 g/m^3), were indicative of moderate aesthetic water quality at this site. Minimal clarity (black disc of 0.30 m, turbidity of 6.6 NTU) and an increase in suspended solids concentration (16 g/m^3) were recorded during a fresh event sampled in April 2010 (Figure 8). A deterioration in other water quality parameters during this event was also illustrated by a high faecal coliform bacterial number, elevated BOD_5 (7.1 g/m^3), increased total phosphorus concentration, and increased absorbance levels.

Early afternoon pH levels reached a maximum of 8.5 units in late summer while dissolved oxygen levels were consistently high (99% or higher saturation) with supersaturation recorded particularly during late-summer to autumn low flow conditions coincident with more extensive algal cover and elevated pH levels (8.1 to 8.5 units). BOD_5 concentrations under normal to low recession flow conditions were generally indicative of moderately low organic contamination (i.e: up to 1.4 g/m^3 on these occasions).

The moderately high median bacteriological numbers (120 enterococci and 220 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 municipal oxidation pond performance due to the relative proximity of this discharge, more than to other point source or non-point source discharges.

Water temperatures varied over a moderate range of 8.3°C with a maximum (early afternoon) summer temperature of 17.7°C recorded in February 2010 (coincident with a pH of 8.5 and 118% dissolved oxygen saturation).

Brief comparison of upper and mid catchment sites during the 2009-2010 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 (25 to 60-fold increases) and increases in median nutrient species concentrations (2 to 50 fold). The pH range increased by 0.7 unit at the Skinner Road site with a maximum pH 0.8 unit higher than at the upstream site. A moderate increase in median turbidity levels (0.9 NTU) was measured in mid catchment while median BOD_5 increased by about 0.5 g/m^3 and maximum BOD_5 was 6 g/m^3 higher downstream. A deterioration in black disc clarity (median clarity decreased significantly by 2.17 m and maximum clarity by 4.82 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 1.9°C) at the Skinner Road site where median water temperature was higher (by 1.1°C) and maximum water temperature was higher (by 5.7°C) than at the Barclay Road site.

Brief comparison with the previous 1995-2009 period

The median of sampled flows in the recent twelve-month period was 321 L/sec higher than the median of flows sampled over the 1995-2009 period but the range of river flows sampled was very much narrower. Aesthetic water quality was similar with recent median turbidity slightly higher by 0.10 NTU and median black disc clarity higher by 0.11 m. There was minimal difference in the median suspended solids concentrations for the two periods.

There was a narrower pH range (by 0.6 pH unit) and lower maximum pH (by 0.3 pH unit) during the 2009-2010 period. Dissolved oxygen percentage saturation median was higher by an insignificant 2% in the 2009-2010 period.

Bacterial water quality improved slightly for faecal coliform bacteria and was similar for enterococci during the more recent sampling period, with median faecal coliform and enterococci numbers decreasing by 30 and increasing by 5 (per 100 mls) respectively. Seasonal variability in municipal oxidation ponds' system performance and dairy shed wastes disposal contributed to this during 2009-2010.

Water temperature range was much narrower (by 8.2°C) during the more recent sampling period but the median water temperature was similar (within 0.5˚C) to the longer term median. The maximum water temperature recorded was 4.1°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 very similar (higher by 0.1 g/m^3) in the latest period with median nitrate nitrogen of the nutrient species the only nutrient showing an increase. There was a decrease in median total phosphorus 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)
8 July 09	1400	0.046	0.008	0.000	29	0.16	0.6	8.7	11.1	96	0.004	740	210
12 Aug 09	1350	0.040	0.008	0.000	36	1.75	<0.5	9.9	11.6	101	<0.003	23	6
9 Sept 09	1435	0.030	0.006	0.000	35	1.72	<0.5	9.7	11.2	102	0.006	46	8
14 Oct 09	1335	0.043	0.007	0.000	30	0.95	<0.5	8.6	10.3	99	0.006	220	24
11 Nov 09	1330	0.051	0.011	0.000	48	1.42	0.6	11.6	10.1	101	0.008	100	40
9 Dec 09	1330	0.068	0.017	0.003	31	1.05	<0.5	8.2	9.8	103	0.007	280	60
13 Jan 10	1340	0.091	0.022	0.003	34	1.11	1.0	9.2	9.5	99	0.007	870	350
10 Feb 10	1345	0.060	0.012	0.000	58	0.91	0.7	12.8	9.0	103	0.004	140	190
10 Mar 10	1330	0.064	0.013	0.000	53	0.83	<0.5	13.0	9.8	109	0.006	92	43
14 April 10	1420	0.053	0.011	0.001	79	1.27	0.6	13.5	10.8	107	0.008	140	64
12 May 10	1435	0.052	0.011	0.001	56	1.39	<0.5	13.2	11.4	107	0.007	120	48
10 June 10	1410	0.050	0.010	0.001	22	0.32	<0.5	7.2	10.8	95	0.005	140	38

Date	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)
8 July 09	760	29.211	0.022	0.003	0.177	7.3	72	8.5	0.28	0.46	0.058	28
12 Aug 09	23	6.587	0.018	0.002	0.178	7.6	2	8.7	0.10	0.28	0.012	2.4
9 Sept 09	46	7.106	0.019	0.002	0.198	7.4	3	10.7	0.13	0.33	0.033	2.7
14 Oct 09	220	11.297	0.010	<0.001	0.199	7.4	11	12.7	0.09	0.29	0.026	4.5
11 Nov 09	100	4.990	0.010	0.002	0.088	7.8	<2	14.6	0.06	0.15	0.014	2.4
9 Dec 09	280	8.746	0.009	0.002	0.068	7.5	2	16.9	0.11	0.18	0.018	2.8
13 Jan 10	880	4.881	0.008	0.002	0.028	7.7	3	16.8	0.22	0.25	0.026	4.6
10 Feb 10	140	2.655	0.011	0.002	0.018	8.2	2	21.4	0.20	0.22	0.011	3.0
10 Mar 10	92	2.621	0.008	<0.001	0.009	8.1	3	19.6	0.17	0.18	0.016	2.5
14 April 10	140	4.384	<0.003	0.001	0.009	8.1	3	14.4	0.11	0.12	0.017	3.5
12 May 10	120	2.464	0.005	0.002	0.058	7.8	<2	11.9	0.11	0.17	0.014	3.0
10 June 10	150	20.565	0.018	0.003	0.327	7.4	35	9.3	0.15	0.48	0.040	8.5

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

Table 34 Statistical summary of data from July 2009 to June 2010: Mangaehu River at Raupuha Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.030	0.091	0.052	12	0.016
A440F	Absorbance @ 440nm filtered	/cm	0.006	0.022	0.011	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.003	0.000	12	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	22	79	36	12	16
BLACK DISC	Black disc transparency	m	0.16	1.75	1.08	12	0.490
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	1.0	<0.5	12	0.1
CONDY	Conductivity @ 20°C	mS/m	7.2	13.5	9.8	12	2.2
DO	Dissolved oxygen	g/m³	9.0	11.6	10.6	12	0.82
PERSAT	Dissolved oxygen saturation	%	95	109	102	12	4
DRP	Dissolved reactive phosphorus	g/m³P	<0.003	0.008	0.006	12	0.002
ECOL	E. coli bacteria	nos/100 ml	23	870	140	12	273
ENT	Enterococci bacteria	nos/100 ml	6	350	46	12	105
FC	Faecal coliform bacteria	nos/100 ml	23	880	140	12	278
FLOW	Flow	m³/s	2.464	29.211	5.789	12	8.171
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.022	0.010	12	0.006
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.003	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.33	0.08	12	0.101
pH	pH		7.3	8.2	7.7	12	0.31
SS	Suspended solids	g/m³	<2	72	3	12	21
TEMP	Temperature	°C	8.5	21.4	13.6	12	4.3
TKN	Total kjeldahl nitrogen	g/m³N	0.06	0.28	0.12	12	0.06
TN	Total nitrogen	g/m³N	0.12	0.48	0.24	12	0.116
TP	Total phosphorus	g/m³P	0.011	0.058	0.018	12	0.014
TURB	Turbidity	NTU	2.4	28	3.0	12	7.24

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

Table 35 Statistical summary of data from July 1995 to June 2010: Mangaehu River at Raupuha Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.027	0.181	0.054	180	0.019
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.056	0.011	180	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.025	0.000	180	0.002
ALKT	Alkalinity total	g/m³ $CaCO_3$	9	79	38	180	13
BLACK DISC	Black disc transparency	m	<0.01	3.03	0.82	180	0.730
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	5.6	0.6	180	0.7
CONDY	Conductivity @ 20°C	mS/m	4.3	15.6	9.9	180	2.2
DO	Dissolved oxygen	g/m³	7.7	12.9	10.0	180	0.94
PERSAT	Dissolved oxygen saturation	%	83	118	99	180	6
DRP	Dissolved reactive phosphorus	g/m³P	<0.003	0.026	0.006	180	0.004
ECOL	E. coli bacteria	nos/100 ml	6	16000	220	156	2178
ENT	Enterococci bacteria	nos/100 ml	1	6000	71	180	833
FC	Faecal coliform bacteria	nos/100 ml	6	16000	235	180	2282
FLOW	Flow	m³/s	1.658	111.87	7.062	180	16.318
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.081	0.012	180	0.012
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.016	0.002	180	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.36	0.10	180	0.087
pH	pH		6.9	8.3	7.7	180	0.30
SS	Suspended solids	g/m³	<2	1300	5	180	134
TEMP	Temperature	°C	4.3	24.0	13.7	180	4.3
TKN	Total kjeldahl nitrogen	g/m³N	0.02	1.90	0.18	180	0.28
TN	Total nitrogen	g/m³N	0.09	2.10	0.33	180	0.302
TP	Total phosphorus	g/m³P	0.003	0.786	0.021	180	0.110
TURB	Turbidity	NTU	1.7	850	3.6	179	71.59

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.

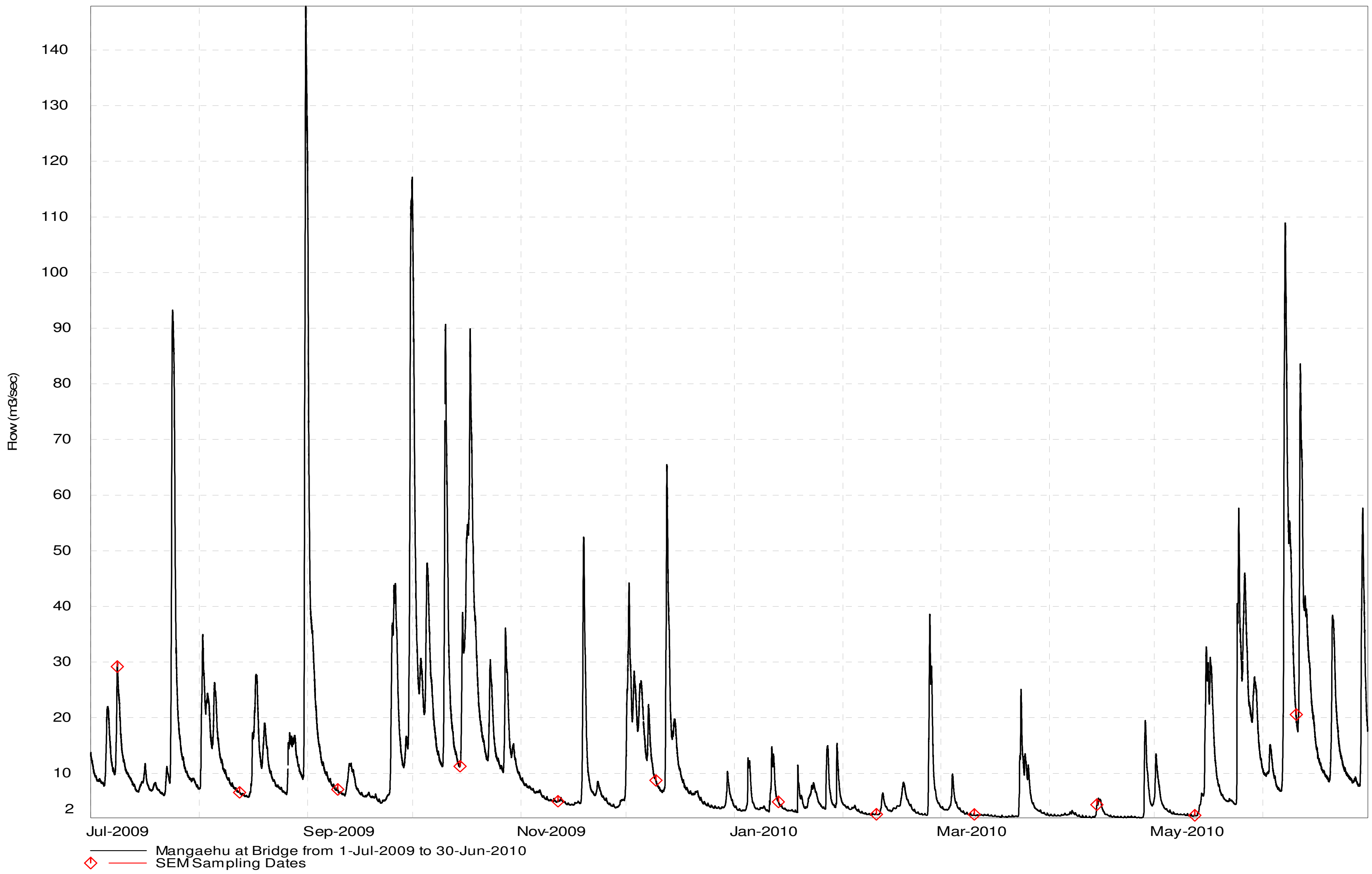

Figure 9 Flow record for the Mangaehu River at Raupuha Road

Discussion

2009-2010 period

The relatively poor visual appearance which characterises this eastern hill-country catchment river and particularly its lower reaches was emphasised by a relatively low median black disc clarity of 1.08 metres and a maximum of 1.75 metres. Clarity was frequently less than 1 metre (on five occasions) due to the presence of very fine, colloidal suspended particles. 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 0.029/cm and 0.005/cm) 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 (0.16 m black disc value) was coincident with a turbidity level of 28 NTU and suspended solids concentration of 72 g/m^3, during a flood flow of 29 m^3/sec recorded in July 2009. Fresh flows (in excess of 10 m^3/s) were usually coincident with a general deterioration in water quality as emphasised by elevated turbidity, suspended solids, some nutrient species' levels and bacterial counts (e.g. in July and October 2009 and June 2010, Figure 9).

Maximum mid-afternoon pH values in the late summer to autumn period (8.1 to 8.2) 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 10.6 g/m^3), and the median saturation level was 102%. On all occasions BOD_5 concentrations were indicative of relatively low organic content (ie less than 1.1 g/m^3). The median bacteriological numbers (46 enterococci and 140 faecal coliforms per 100 ml) were below those typical of the impacts of developed farmland run-off, and possibly some point source treated dairy shed effluent discharges, as well as stock access to the lower reaches of this eastern hill country river.

Water temperatures varied over a moderate range of 12.9°C with a maximum (early afternoon) summer temperature of 21.4° C recorded in February 2010 during low flow conditions (Figure 9), at which time dissolved oxygen saturation was 103% and pH was 8.2.

Brief comparison with the previous 1995-2009 period

The range of flows sampled during the 2009-2010 period was much narrower than the range sampled over the previous fourteen-year period due to the smaller freshes sampled during the latest period. Median sampled flow in the 2009-2010 period was also lower (by 1352 L/sec) than that sampled over the longer term. Median black disc clarity improved by 0.35 m and median turbidity was lower by 0.6 NTU in the most recent period, while 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 total nitrogen which decreased markedly in the latest period, compared to the median for the previous fourteen-year period. Median bacterial numbers decreased for enterococci (by 31 per 100 ml) and more significantly for faecal coliforms (by 125 per 100 ml) in the 2009-2010 period.

Median dissolved oxygen saturation level was very similar (3% higher) in the 2009-2010 period while median pH levels were equivalent between periods. Maximum pH was 0.1 unit lower than previously recorded.

The range of water temperatures was significantly narrower (by 6.8°C) in the latest twelve-month period than in the previous fourteen-year period while median water temperature was only 0.1°C lower during 2009-2010, with a lower maximum temperature (by 2.6°C) and higher minimum temperature (by 4.2°C) recorded in the 2009-2010 sampling year.

4.2 Comparative water quality for the fifteen-year (1995-2010) period

4.2.1 TRC data

In addition to the site descriptions of water quality measured during the 2009-2010 monthly sampling programme, a general comparison between the eleven sites of the programme may be made for the fifteen-year sampling period to date (1995-2010) using statistical (tabular and graphical) data summaries. These have been provided 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 comparisons 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 was 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 were at 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 (5 g/m^3) has been recorded at this site, but median turbidity level (3.6 NTU) was significantly higher for this river than at any other site. The site in the lower reaches of the longest ringplain river (Waingongoro) also had elevated median suspended solids concentration (5 g/m^3) and turbidity (2.3 NTU). The site in the mid-reaches of the Stony River showed marked variability, with erosion events in the headwaters the major contributing factor.

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

Black disc clarity showed 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 mid reaches of the Stony River (when not impacted by upper catchment erosion events) and Waiwhakaiho River with these sites' median clarities greater than 3.0 metres and all but two other sites achieving a median black disc clarity equal to, or in excess of 1.5 metres. Due to the elevated turbidity of the Mangaehu River, the median clarity in the lower reaches of the river was only 0.82 metres while the site in the lower reaches of the Waingongoro River had a relatively low median black disc value of 1.16 metres. Greatest variability was found at the Stony River site which has been the subject of several upper catchment erosion events during the fifteen year period.

Table 36 Some comparative water quality data for the eleven TRC SEM sites for the fifteen-year period July 1995 to June 2010 (n = 180 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*	4.24	2.58	<0.5	8.5	50	315	0.010	0.24	0.40	0.022	0.032	7.9	7.6	90	97	12	<2	17.6	10.9	11.2	0.9
Mangaoraka Stream at Corbett Road	4.73	1.89	0.6	14.5	120	735	0.020	0.84	1.12	0.008	0.022	8.1	7.6	83	96	24	2	20.5	13.0	14.7	1.6
Waiwhakaiho River at SH3	8.05	3.07	<0.5	12.2	23	190	0.007	0.11	0.21	0.024	0.034	8.5	7.9	91	100	17	<2	18.3	11.0	13.1	0.7
Stony River at Mangatete Road	13.12	3.50	<0.5	9.7	<1	8	<0.003	0.02	0.07	0.018	0.024	8.2	7.9	87	99	17	<2	16.6	10.6	10.9	0.7
Punehu Stream at Wiremu Road	4.39	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	11.9	14.2	1.6
Punehu Stream at SH45	3.57	1.50	0.9	16.1	51	500	0.044	0.91	1.35	0.041	0.075	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	170	0.018	1.10	1.40	0.018	0.036	8.6	7.8	92	102	29	3	20.8	12.3	15.2	1.4
Waingongoro River at SH45 **	2.39	1.16	1.0	16.4	3	230	0.031	1.89	2.47	0.067	0.106	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	9.1	11.0	0.5
Patea River at Skinner Road	4.68	1.85	0.9	9.9	2	250	0.052	0.93	1.24	0.042	0.075	8.8	7.8	87	102	34	2	21.8	12.7	16.5	1.5
Mangaehu River at Raupuha Road	3.03	0.82	0.6	9.9	6	235	0.012	0.10	0.33	0.006	0.021	8.3	7.7	83	99	35	5	24.0	13.7	19.7	3.6

[Notes: * for the period July 2003 to June 2010 (n = 90 samples); ** for the period July 1998 to June 2010 (n = 144 samples)]

Absorbances (at 340 nm /cm) were generally relatively low. They were 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 not due to the scattering effects of small colloidal particles.

Water temperature, pH, and conductivity

Coldest median water temperature (9.1°C) was 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), 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 exhibiting the highest medians (13.7°C, 13.7°C, 13.4°C and 12.7°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 (11.9°C) and 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.

Highest pH values (8.5 to 9.1) were recorded at the mid and lower river and stream sites due to algal photosynthetic effects coincidental with more extensive substrate algal cover under warmer, late summer, low flow conditions. pH values at all sites were slightly alkaline, 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 extensive algal substrate cover, resulted in supersaturation on occasions at various sites in the mid to lower reaches of streams and rivers. Wider saturation ranges (>20%) were recorded at mid and lower catchment sites with 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 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 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 120% in median total nitrogen and total phosphorus respectively over the length of the Punehu Stream and 1450% and 210% respectively through the mid reaches of the Patea River. Elevated nitrate concentrations often reflect high groundwater inputs, particularly after very wet weather 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, 2009). 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 230 to 735 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 170 to 250 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. 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 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 fifteen 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 fifteen-year period July 1995 to June 2010 (n = 180 samples)

Site Unit	Black disc (m)		BOD_5 (g/m^3)	Conductivity @ 20°C (mS/m)	Nutrients Amm-N (g/m^3N)	Nitrate (g/m^3N)	Total N (g/m^3N)	DRP (g/m^3P)	TP (g/m^3P)	pH		Dissolved oxygen saturation %	Temperature (°C)			Turbidity (NTU)	Flow (m/sec)
	Maximum	Median	Median	Median	Median	Median	Median	Median	Median	Maximum	Median	Median	Maximum	Median	Range	Median	Median
Waitara River at Bertrand Road	3.2	0.50	0.7	8.8	0.010	0.30	0.55	0.006	0.033	8.6	7.7	102	23.2	13.8	16.7	8.5	28.4
Manganui River at SH3	7.7	4.20	<0.5	6.2	0.006	0.09	0.18	0.010	0.015	7.9	7.5	101	18.7	10.4	14.6	0.8	0.90
Waingongoro River at SH45	(2.9) (2.39)	(1.3) (1.16)	(1.0) (1.0)	(16.7) (16.4)	(0.027) (0.031)	(1.95) (1.89)	(2.26) (2.47)	(0.053) (0.067)	(0.102) (0.106)	(9.1) (9.1)	(7.9) (7.8)	(104) (101)	(23.0) (22.0)	(13.8) (13.7)	(16.7) (16.6)	(2.3) (2.3)	(4.9) (4.65)

[Notes ( ) = TRC and NIWA data for the period July 1998 to June 2010 (n = 144 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 0.50 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. 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 eleven 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 fifteen 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 1995-2010 SEM (TRC and NIWA) sites' water quality with guideline values for various usages

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

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

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

4.2.3.1 Aesthetics

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

4.2.3.2 Contact recreation

The Council's and NIWA's programmes do not necessarily collect samples representative of water quality typical of conditions at times when contact recreation is likely, as is stipulated in the MfE guidelines, and therefore care should be taken when comparing results against the guideline. It should also be noted that most of the SEM sites in the programme are not contact recreational sites; the streams are too shallow, cold and/or small at these locations. A specific recreational water quality SEM programme is structured around the requirements of the MfE guidelines and reported separately (TRC, 2010), 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, 2010)) from time-to-time under spring-summer low flow conditions (refer to individual tables of 2009-2010 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). 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 25^{th} 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 fifteen years (1995 to 2010) to date (TRC, 2006c, Stark and Fowles, 2006 and TRC, 2010a).

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 2010

4.3.1 Comments

Fifteen years of physicochemical water quality data have been collected up to 30 June 2010 at ten of the eleven sites. The majority of this data have been analysed for trends following the availability of a minimum of 10 years of data, and previous trends have been reported in TRC, 2006a, TRC, 2008, and TRC, 2009a.

An update of the trends to include data from the 2008-2009 monitoring year was reported in the previous Annual Report (TRC, 2009). It did not provide a detailed interpretation of the results which will be provided in each five yearly State of the Environment Report (next due in 2014). The next updated trend reporting will be performed on date for the period to mid 2011 and presented in the appropriate Annual Report.

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 2009 through to June 2010. 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 coincided randomly with a narrower range of flow conditions in the 2009-2010 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 14 years' data. It also provides an up-to-date statistical summary of the 15 years' data 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 was shown on aspects of water quality. 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 2009-2010 period, flows sampled were generally lower than typical of those sampled during the previous fourteen-year period with all but one of the median flows lower over the latest period (by 3 to 31%), compared with the long-term sampled flow record.

Table 39 Comparison of 2009-2010 water quality with previous long-term (1995-2009) 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	=	=	=	=	=	=	=	=	=	=	=	=	xx	=	=	-344	16↓
Mangaoraka Stream at Corbett Road	=	=	=	x	x	x	=	=	=	=	=	=	x	=	=	-34	3↓
Waiwhakaiho River at SH3	=	=	=	✓	✓	=	=	=	x	=	=	=	=	=	=	-843	23↓
Stony River at Mangatete Road	=	=	=	=	✓	=	x	✓	=	=	=	=	=	=	=	-553	15↓
Punehu Stream at Wiremu Road	=	=	=	=	✓	=	✓	✓	=	=	=	=	=	=	=	-101	23↓
Punehu Stream at SH45	=	=	=	=	x	=	x	=	x	=	=	=	✓	=	=	-27	3↓
Waingongoro River at Eltham Road	=	=	=	✓	✓✓	=	=	=	x	=	=	=	=	=	=	-71	4↓
Waingongoro River at SH45	✓	=	=	✓	✓✓	=	=	=	=	=	=	=	=	=	=	-461	10↓
Patea River at Barclay Road	=	=	=	✓✓	✓✓	=	=	✓✓	x	=	=	=	=	=	x	-68	31↓
Patea River at Skinner Road	=	=	=	=	=	=	=	=	=	✓	=	=	=	=	=	+321	11↑
Mangaehu River at Raupuha Road	✓	=	=	✓	✓	=	=	✓	=	=	=	=	✓	=	=	-1352	19↓
Regional summary of tendency for 2007-08	=	=	=	=→✓	=→✓✓	=	x→=	=←✓	x→=	=	=	=	=	=	=	(N/A)	↓

[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 2009-2010 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 2009-2010 sampling period.

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

The majority of sites' median nutrient levels remained similar in the 2009-2010 period to these over the longer period, particularly the ammonia N and total phosphorus levels. Few improvements in median nutrient levels (mainly total nitrogen) were recorded while limited deterioration was found in median dissolved reactive phosphorus (at four sites (Table 41)).

Bacteria numbers showed improvement at seven sites in terms of median enterococci numbers although there was some deterioration at two sites during the 2009-2010 period. Six sites showed decreases in median faecal coliform bacteria numbers while only one site showed deterioration. This trend toward better bacteriological water quality during 2009-2010 reversed the trend found during the four previous years.

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

A further trend assessment will be performed upon ten TRC sites for the 1995-2011 period (including one site for the 1998-2011 period) and summarised in the appropriate Annual Report. This will complement the reports prepared for the 1995 to 2008 and 1995 to 2009 periods and more fully presented in TRC, 2009a.

6. Recommendations

1. THAT the freshwater physicochemical component of the SEM programme continue in a similar format for the 2010-2011 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) and for the 1995-2009 period (TRC, 2009), be updated for the 1995-2011 period.

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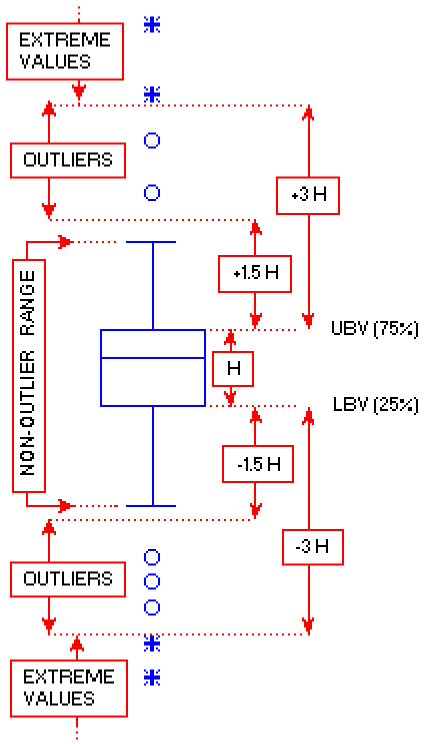
Appendix I

Statistical ‘Box & Whisker’ Plots of 1995-2010 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)

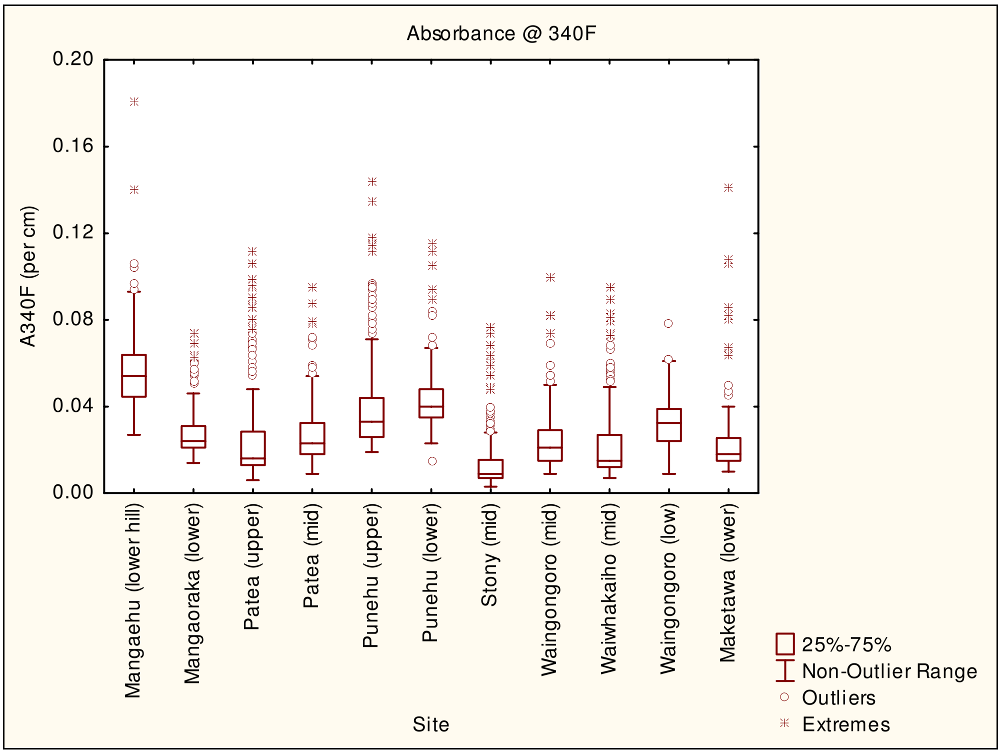
The outer fences (outside whiskers) are defined as follows:

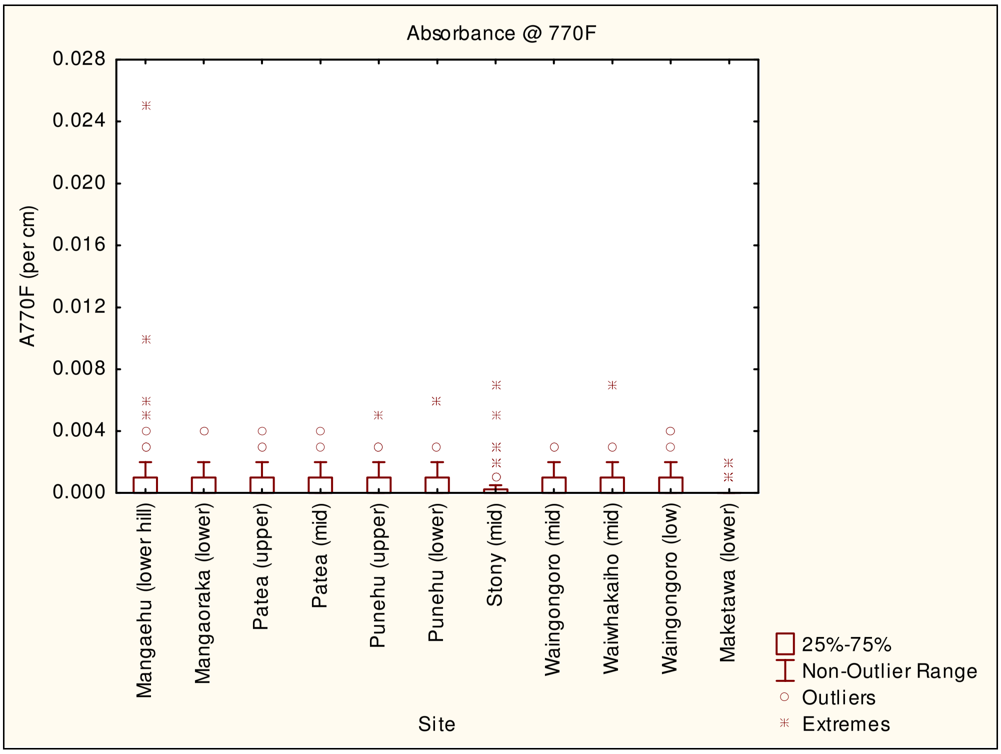
Lower fence = lower hinge - (3 x Hspread)
Upper fence = upper hinge + (3 x Hspread)

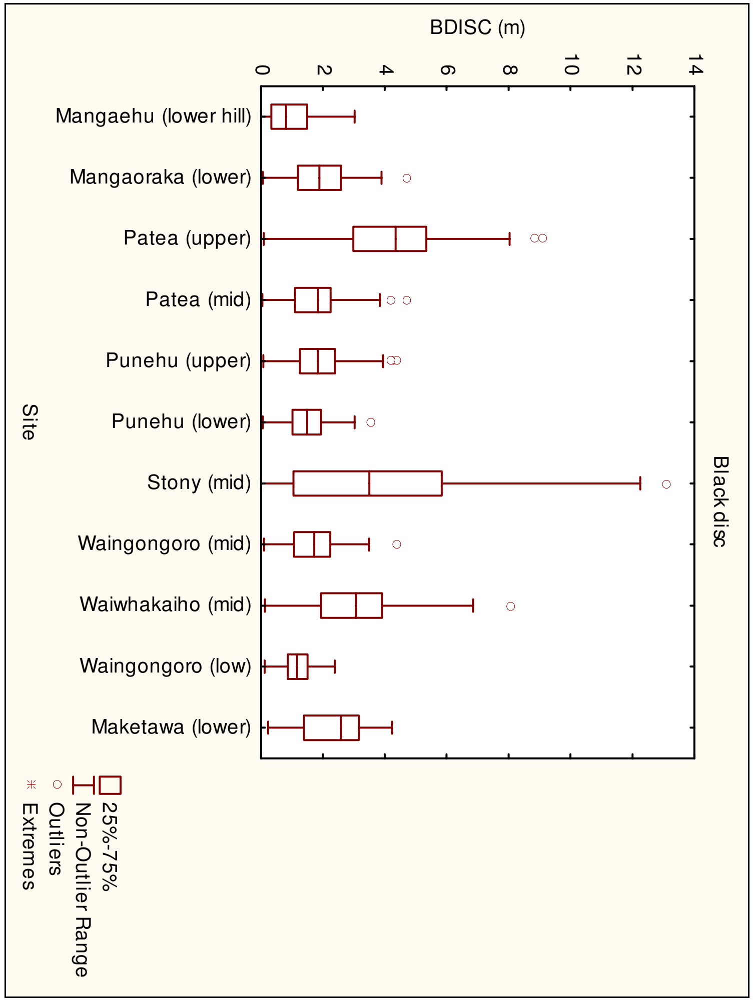
The whiskers show the range of values that lie within the inner fences. Values outside the inner fence are plotted as open circles (o). Values outside the outer fence are plotted as asterisks (*).

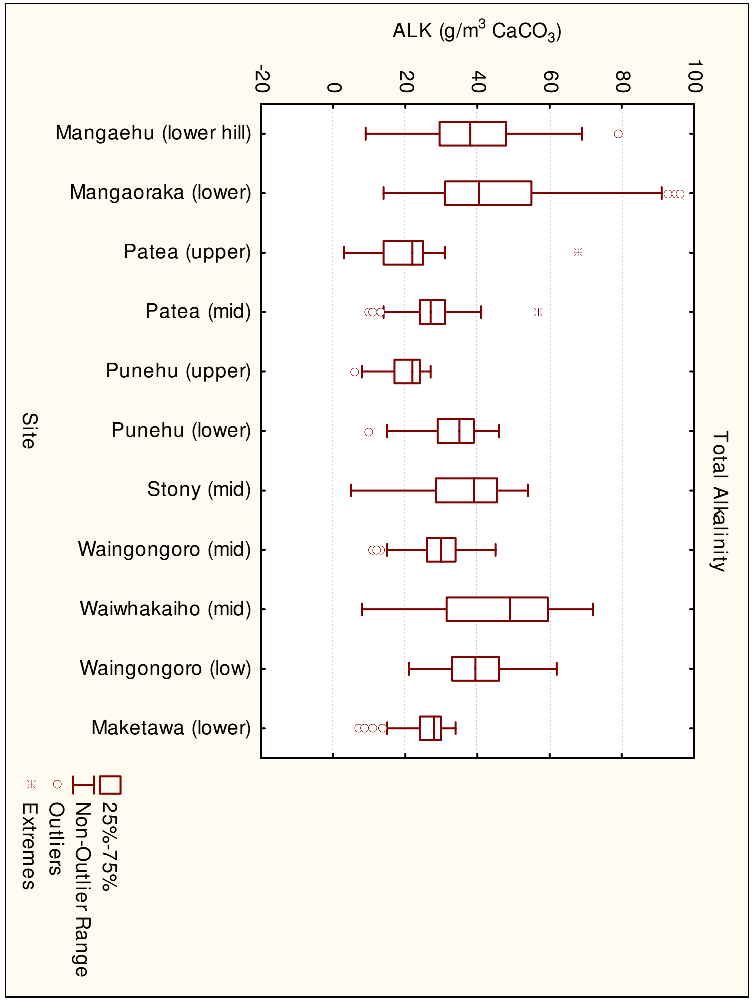
Site locations

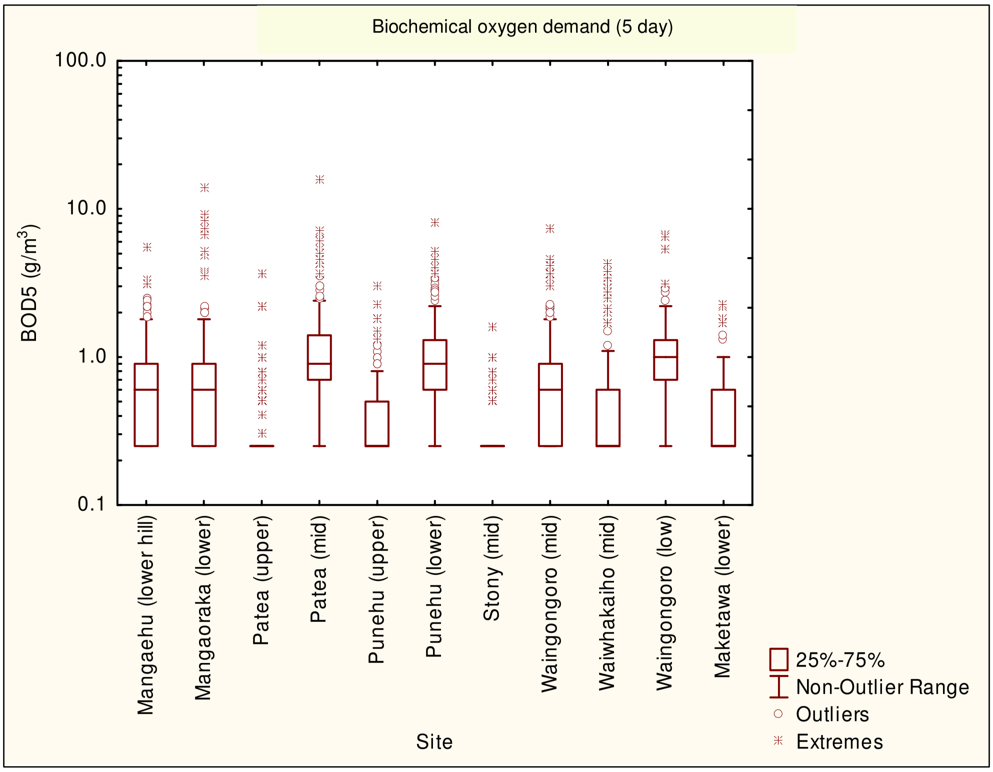
Stream	Location
Maketawa Stream	at Tarata Road
Mangaehu River	at Raupuha Road
Mangaoraka Stream	at Corbett Road
Patea River	at Barclay Road
Patea River	at Skinner Road
Punehu Stream	at Wiremu Road
Punehu Stream	at SH45
Stony River	at Mangatete Road
Waingongoro River	at Eltham Road
Waingongoro River	at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

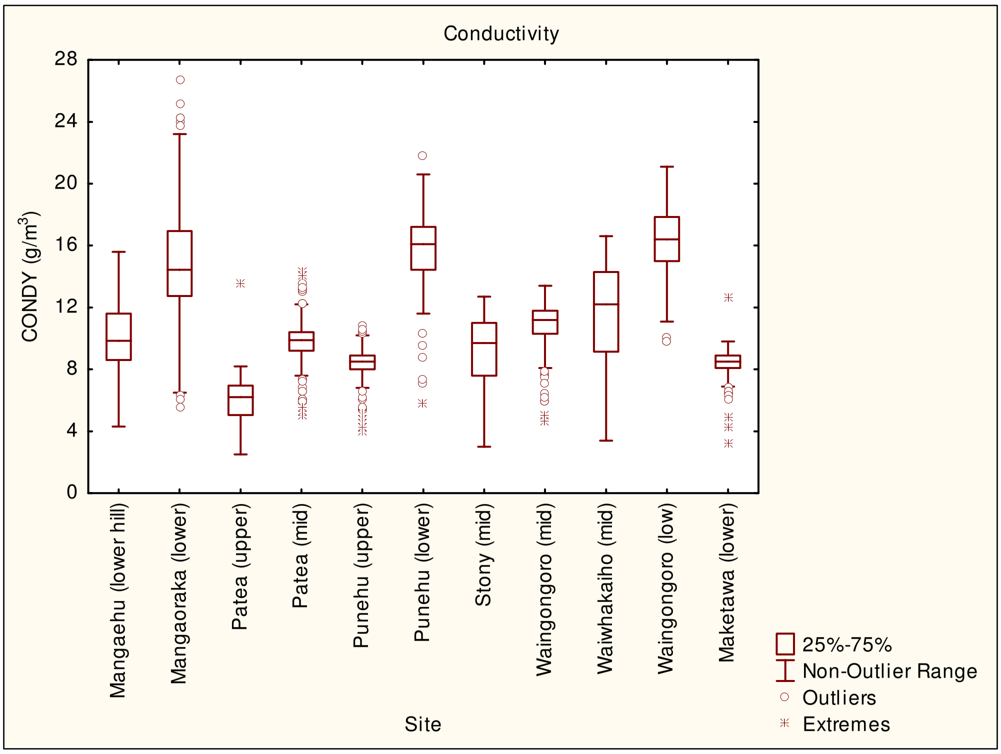

Absorbance @ 340F
A340F (per cm)
0.00
0.04
0.08
0.12
0.16
0.20
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
Site
25%-75%
Non-Outlier Range
Outliers
Extremes

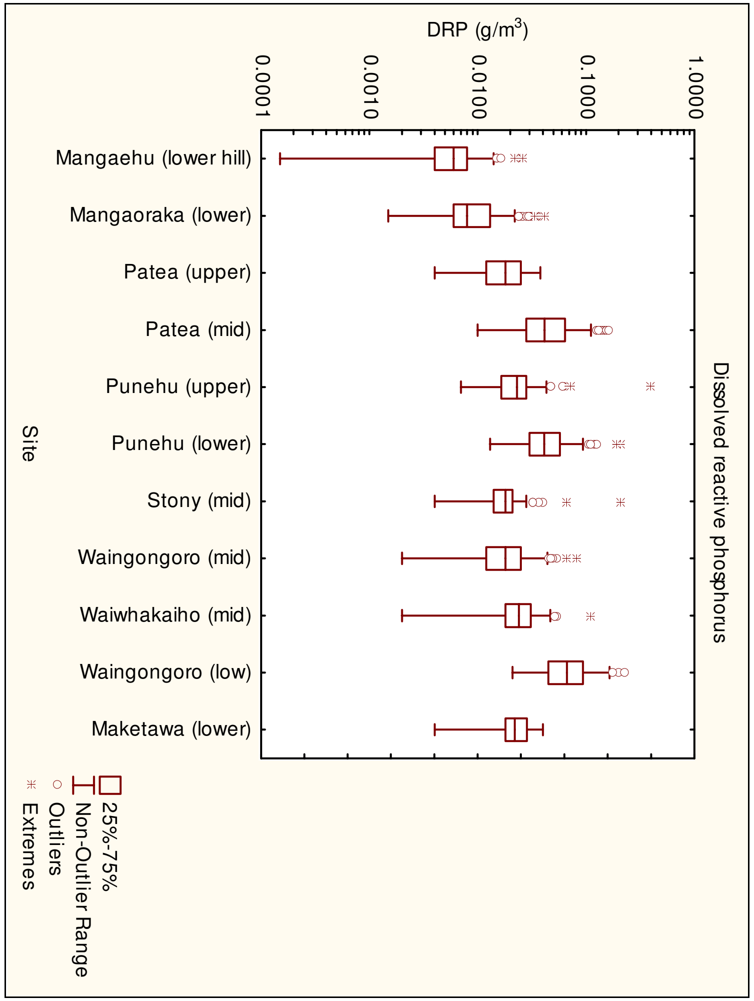

Absorbance @ 770F
A770F (per cm)
0.000
0.004
0.008
0.012
0.016
0.020
0.024
0.028
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
Site
25%-75%
Non-Outlier Range
Outliers
Extremes


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

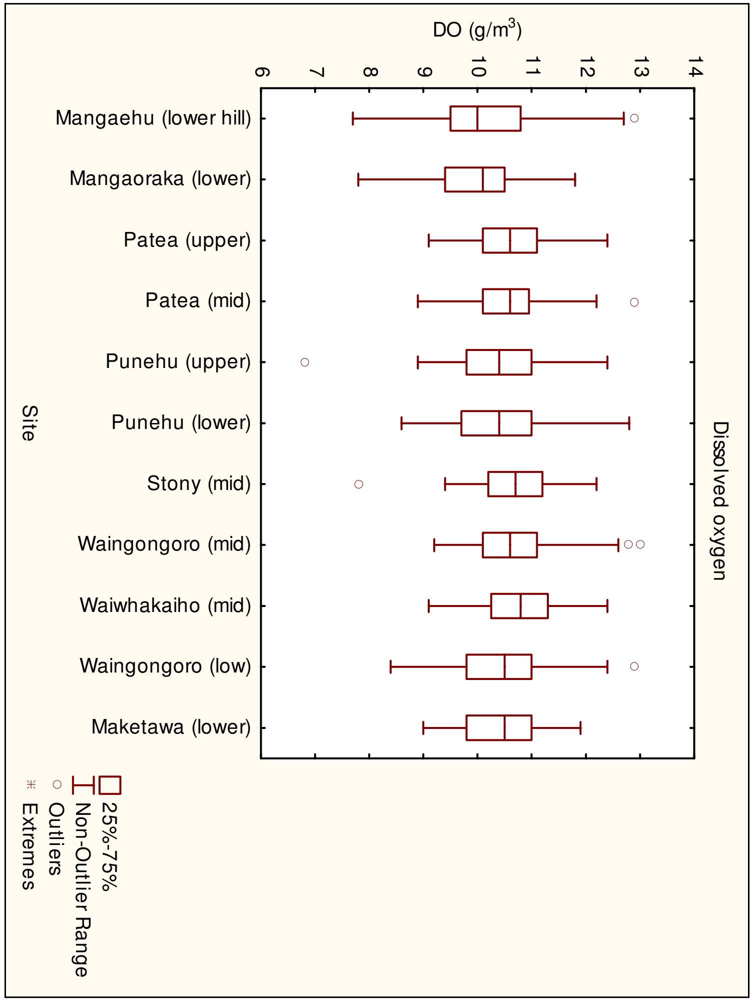

Total Alkalinity
ALK (g/m3 CaCO3)
-20
0
20
40
60
80
100
Site
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
25%-75%
Non-Outlier Range
Outliers
Extremes


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

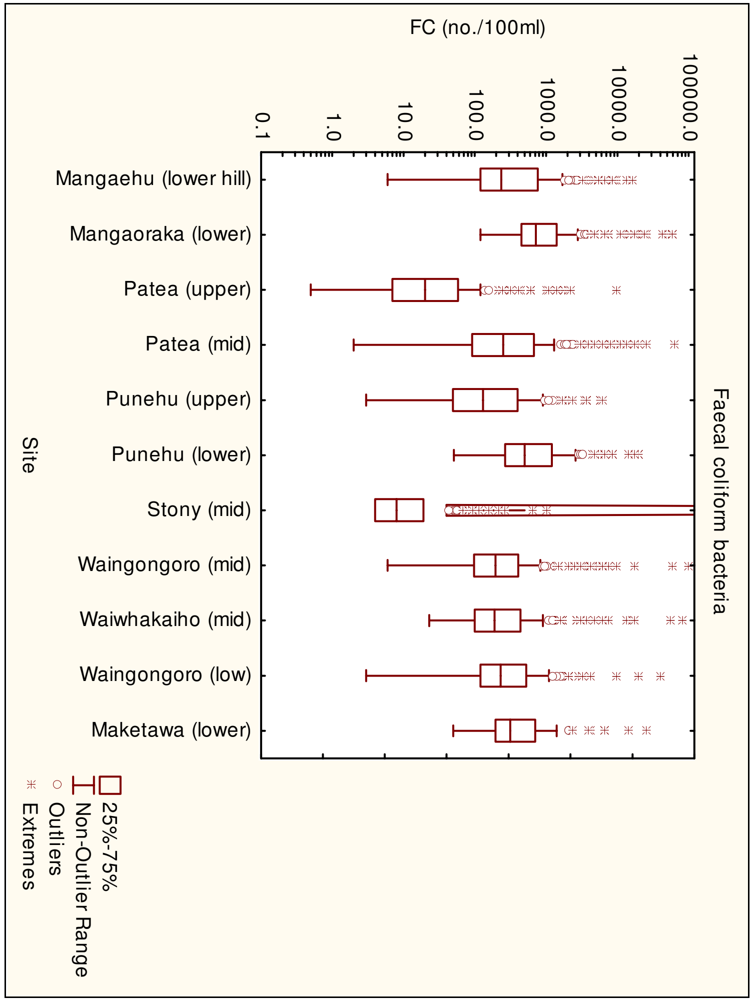

Conductivity
CONDY (g/m3)
28
24
20
16
12
8
4
0
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
Site
25%-75%
Non-Outlier Range
Outliers
Extremes



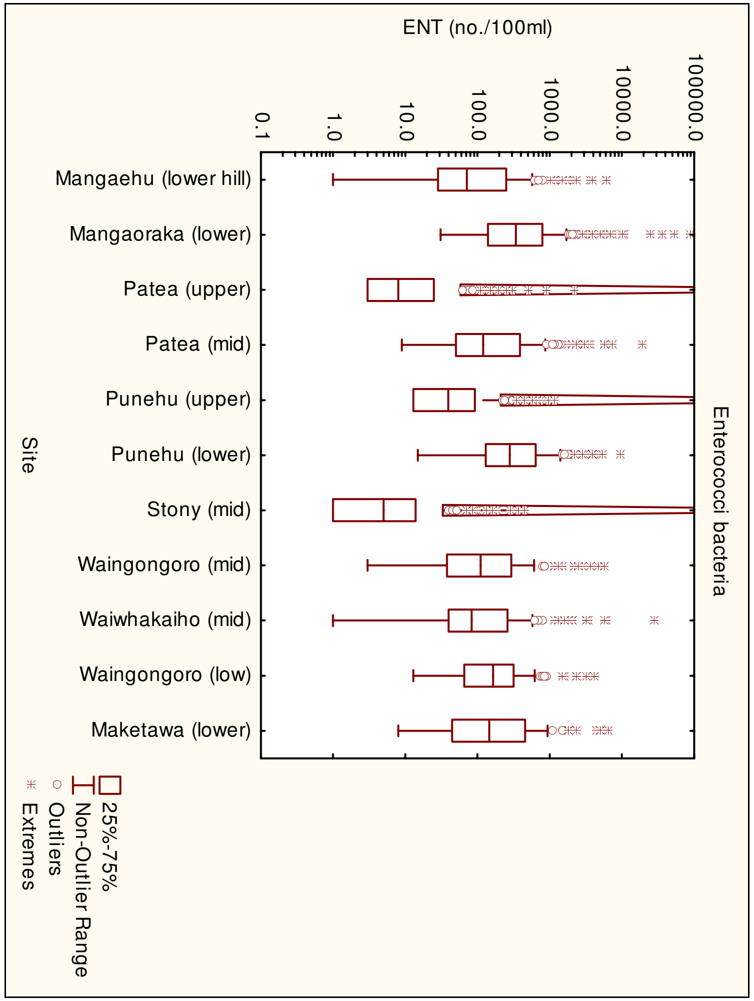
Dissolved reactive phosphorus
DRP (g/m3)
0.0001
0.0010
0.0100
0.1000
1.0000
Site
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
25%-75%
Non-Outlier Range
Outliers
Extremes



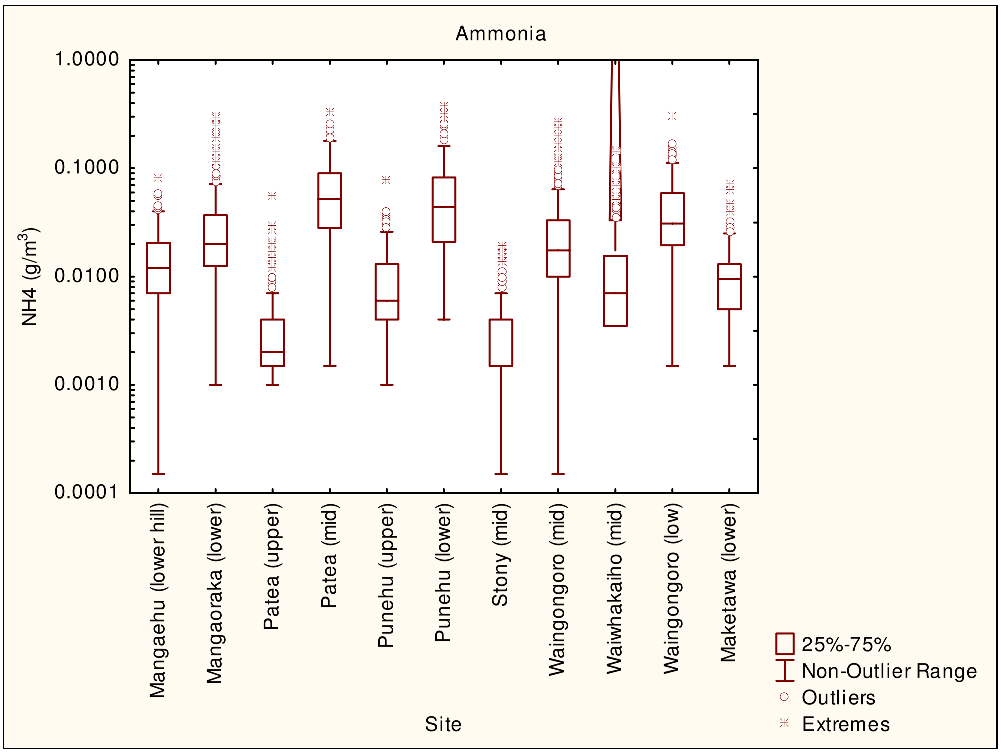
Dissolved oxygen
DO (g/m3)
6
7
8
9
10
11
12
13
14
Site
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
25%-75%
Non-Outlier Range
Outliers
Extremes



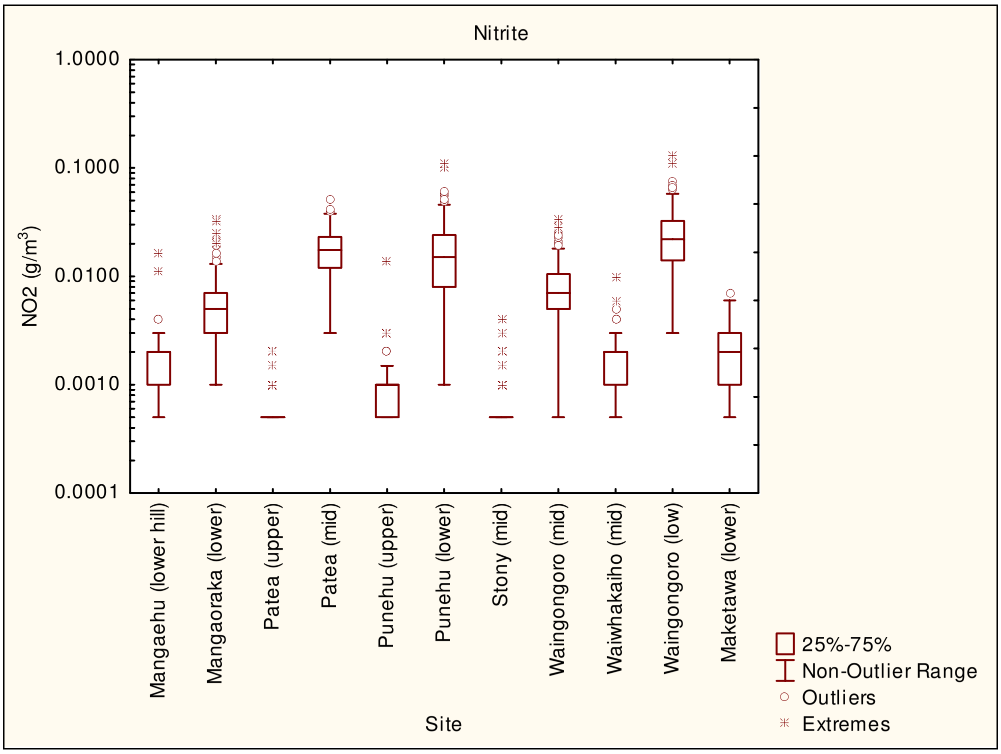
FC (no./100ml)
0.1
1.0
10.0
100.0
1000.0
10000.0
100000.0
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
Site
Faecal coliform bacteria
25%-75%
Non-Outlier Range
Outliers
Extremes



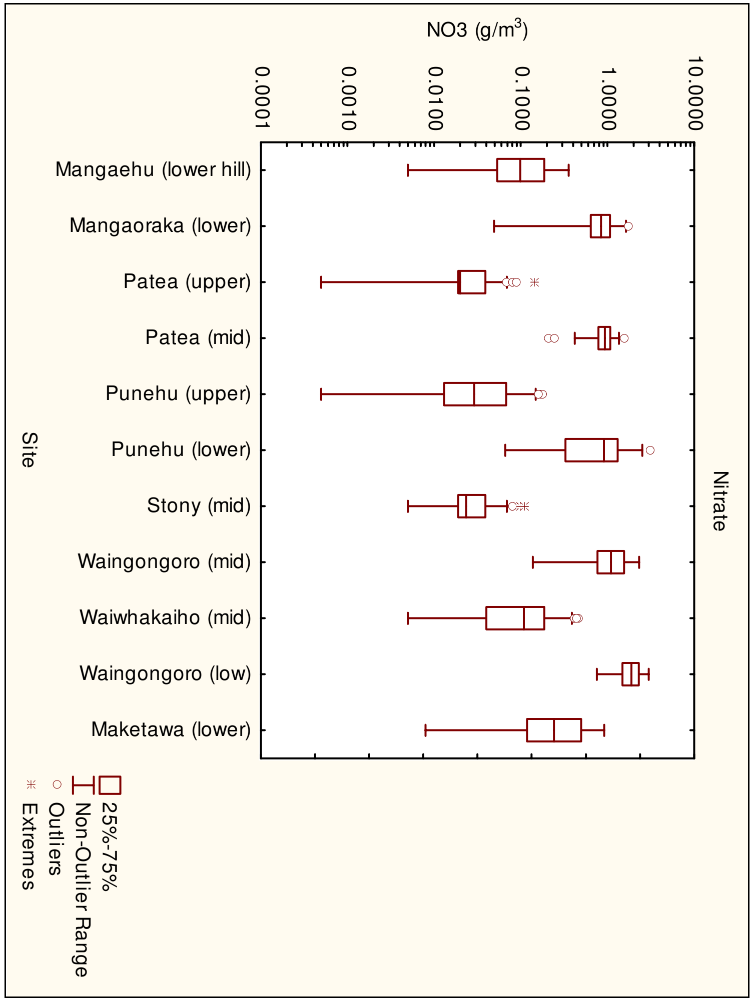
ENT (no./100ml)
0.1
1.0
10.0
100.0
1000.0
10000.0
100000.0
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
Site
Enterococci bacteria
25%-75%
Non-Outlier Range
Outliers
Extremes

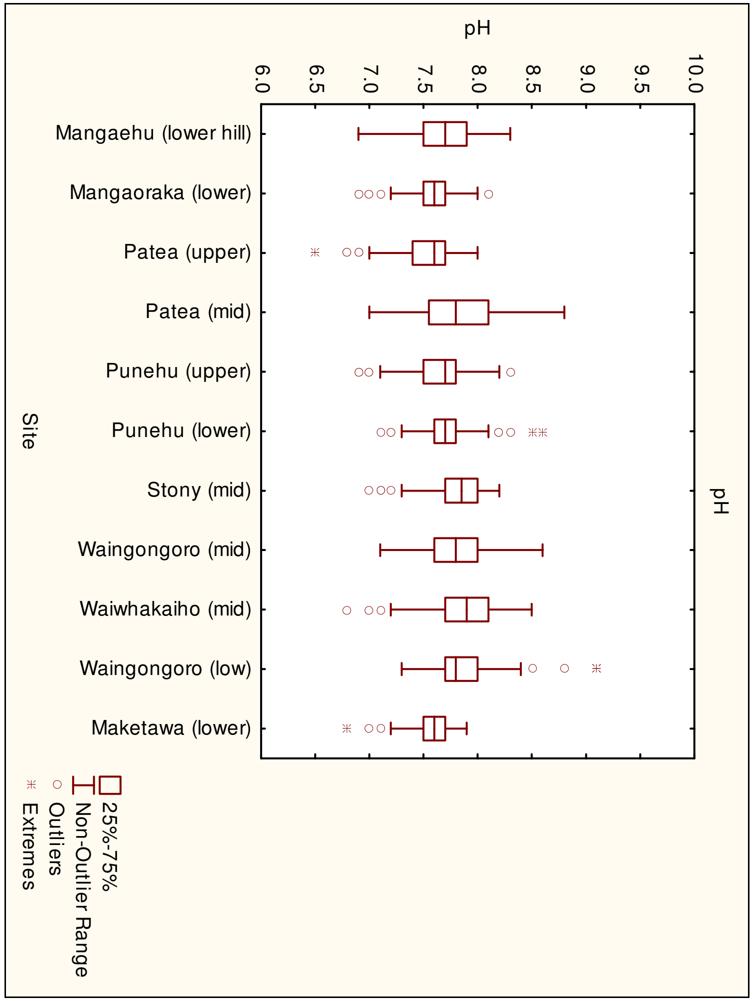


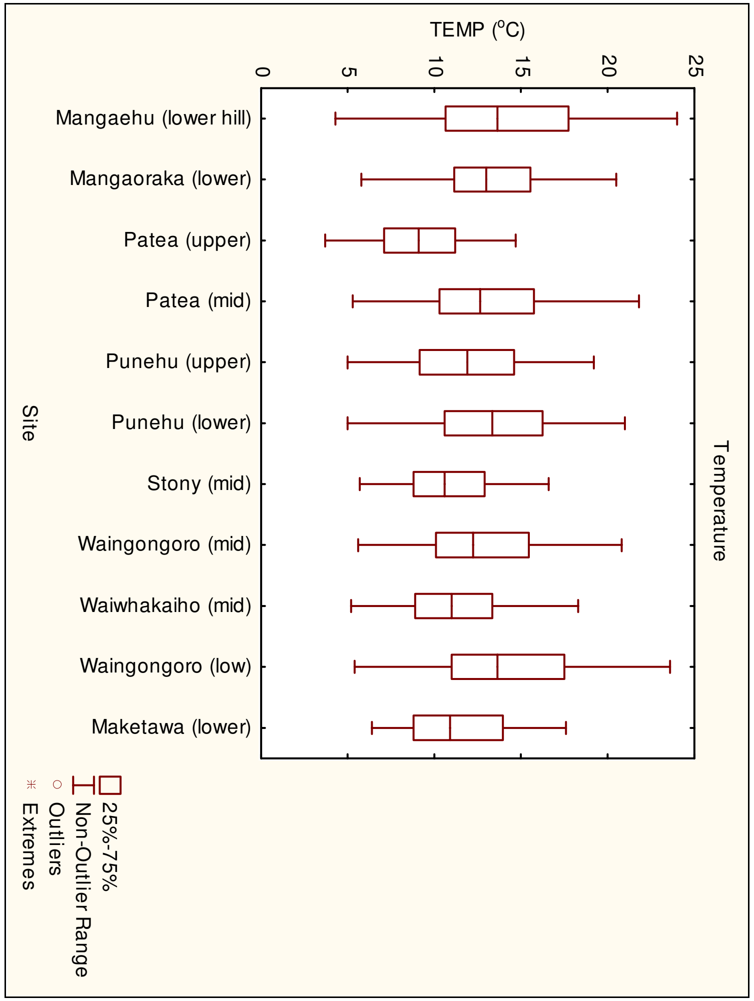
Ammonia
NH4 (g/m3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
Site
25%-75%
Non-Outlier Range
Outliers
Extremes



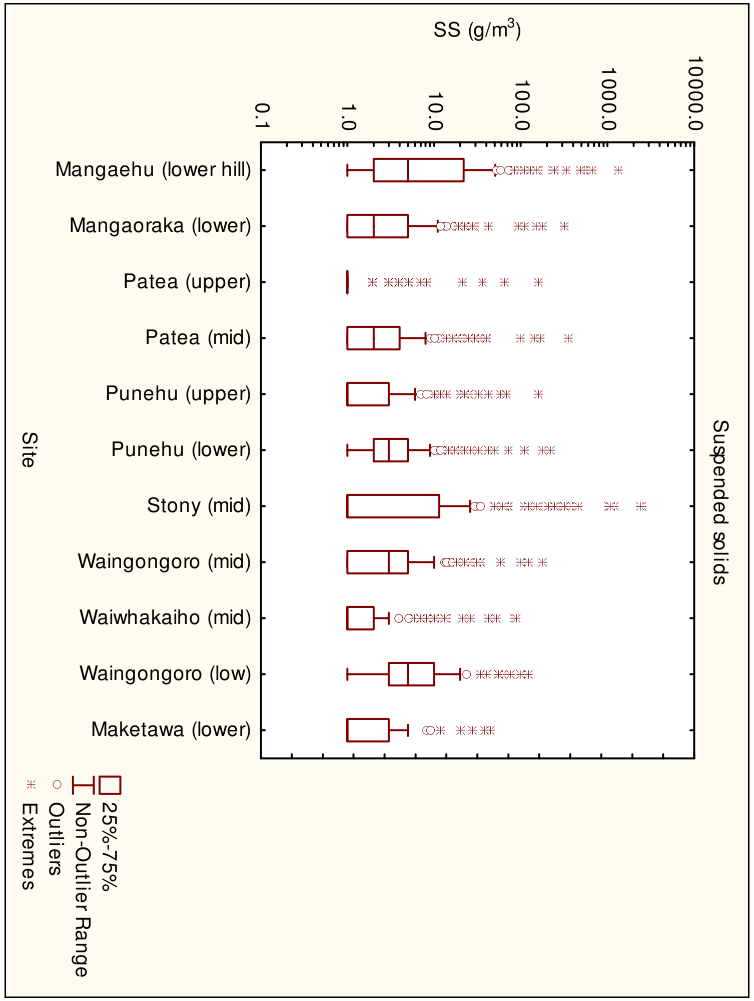
Nitrite
NO2 (g/m3)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
Site
25%-75%
Non-Outlier Range
Outliers
Extremes


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

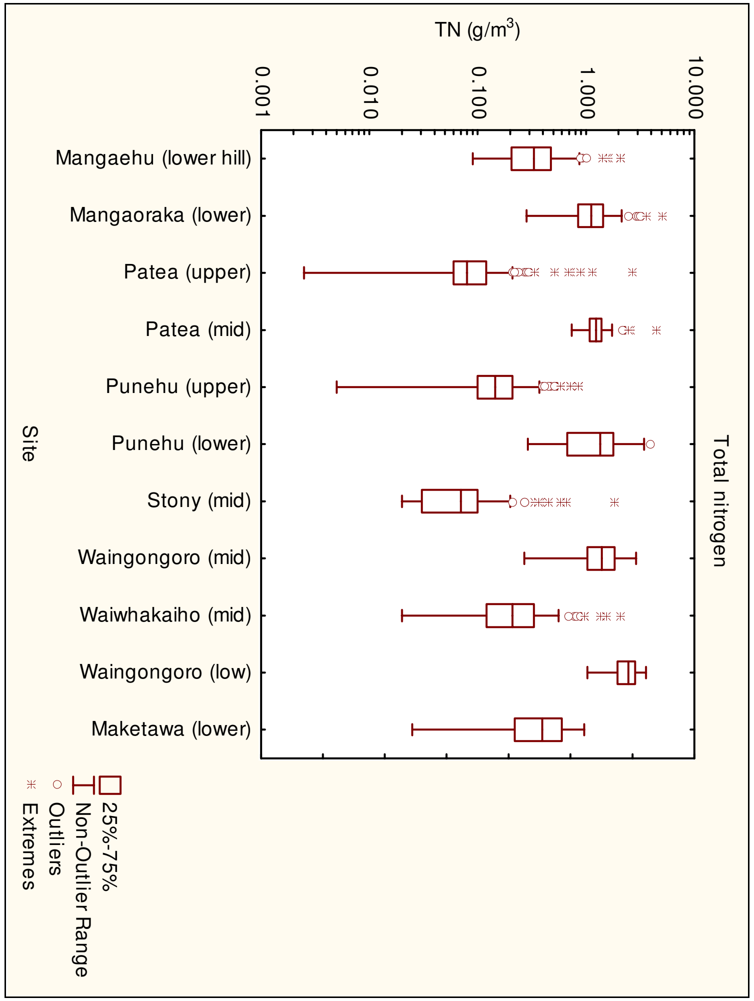

pH
pH
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
Site
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
25%-75%
Non-Outlier Range
Outliers
Extremes

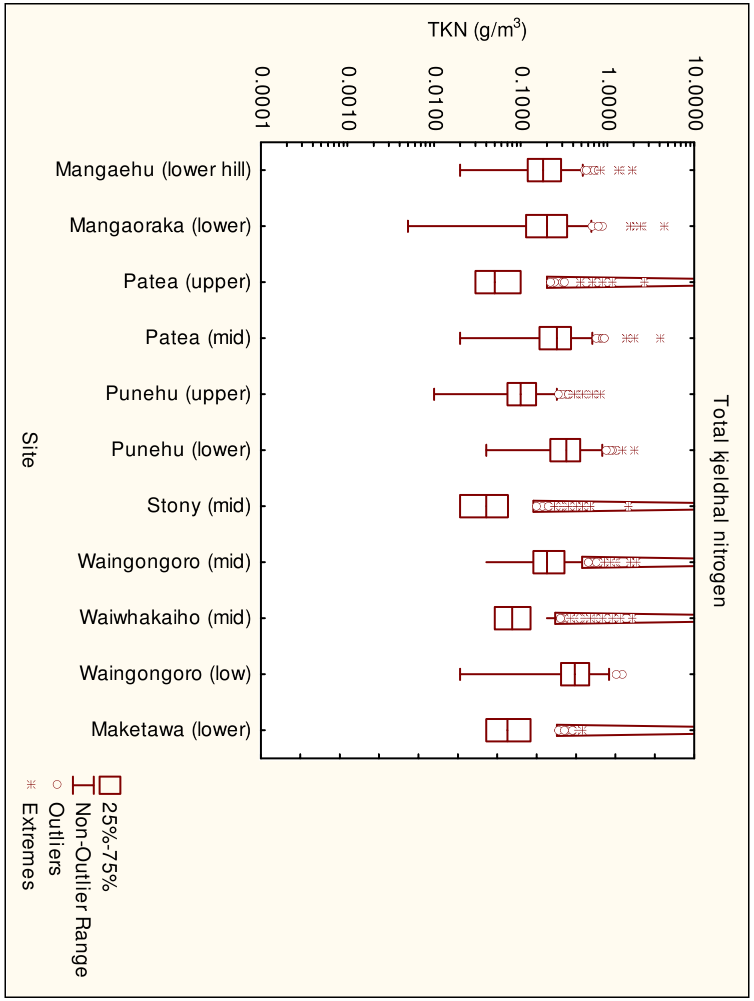


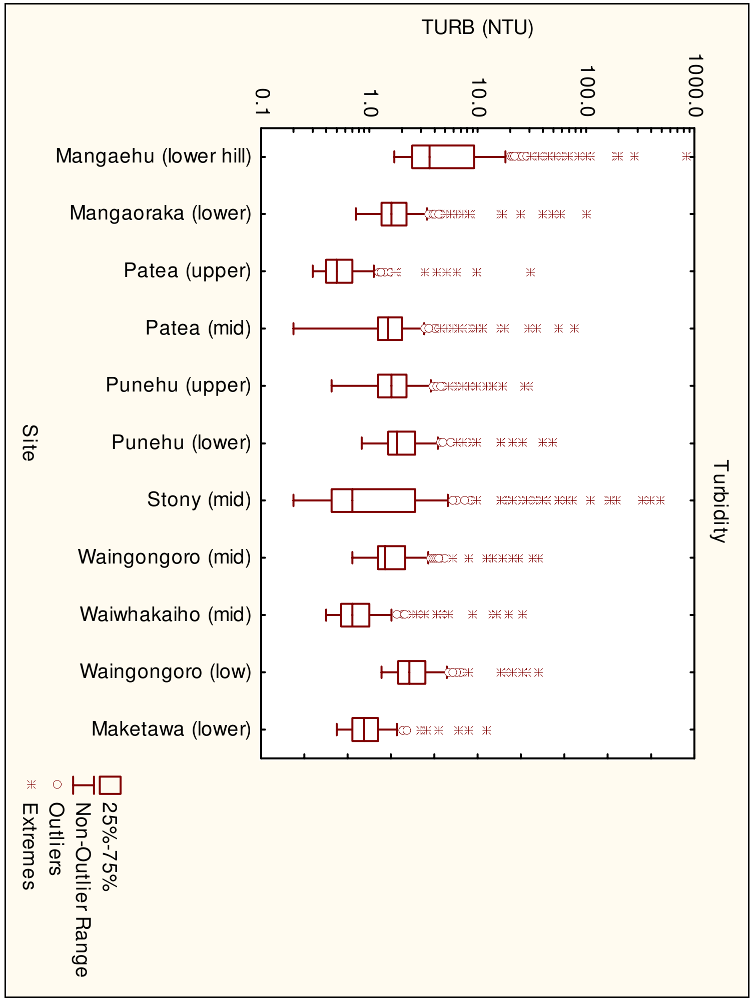
TEMP (°C)
Temperature
Site
0
5
10
15
20
25
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
25%-75%
Non-Outlier Range
Outliers
Extremes

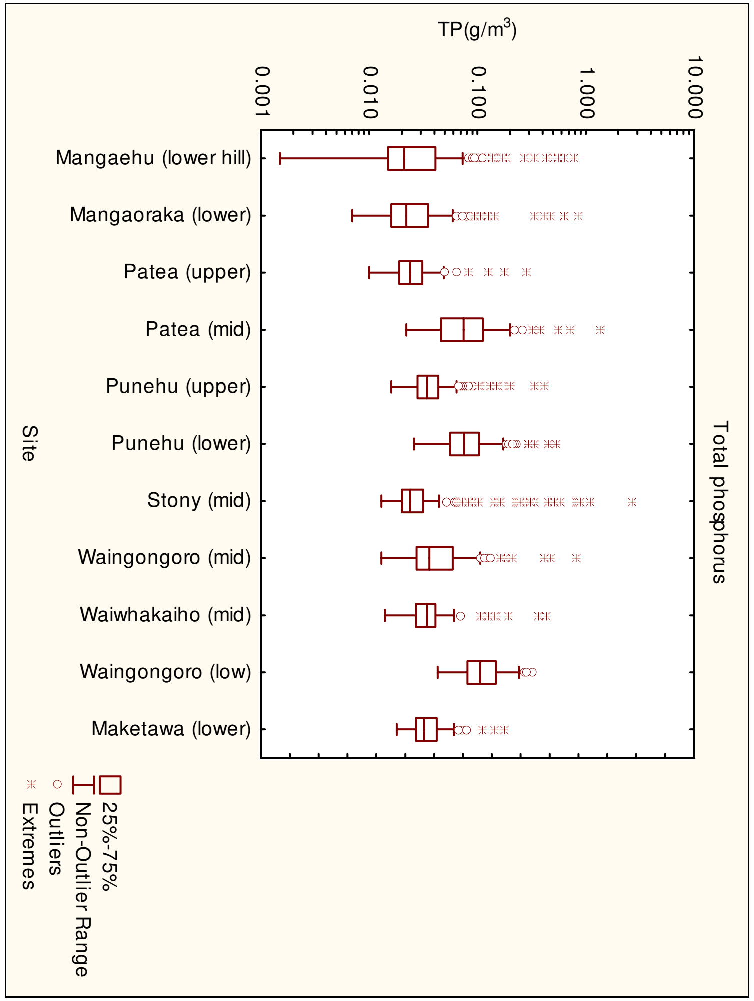


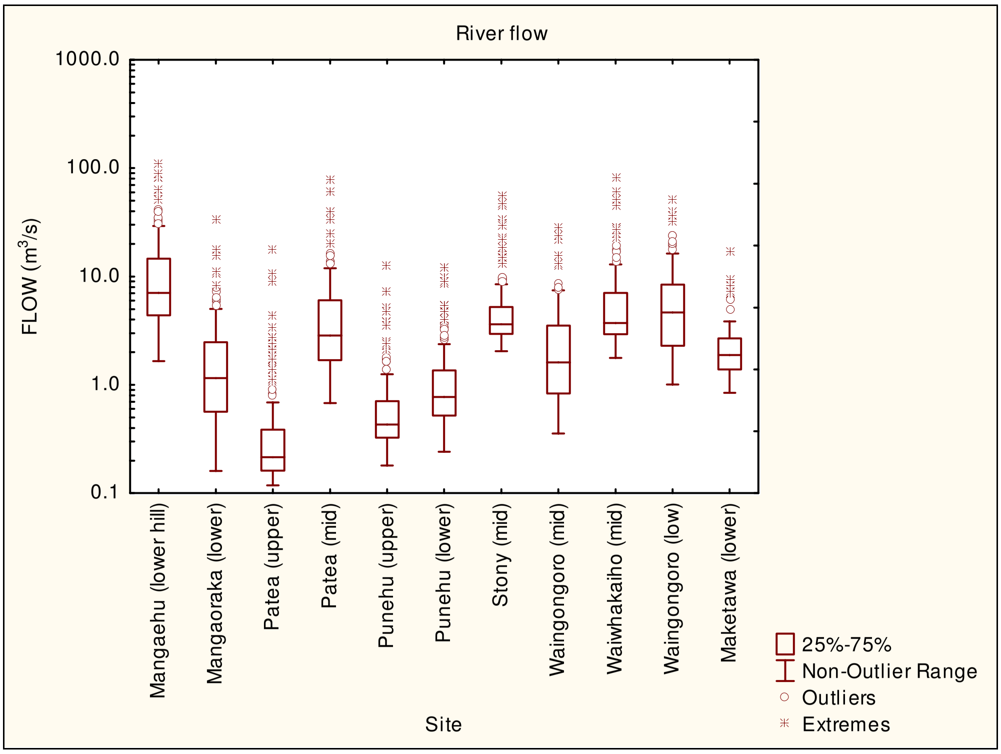
SS (g/m3)
Suspended solids
Site
0.1
1.0
10.0
100.0
1000.0
10000.0
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
25%-75%
Non-Outlier Range
Outliers
Extremes

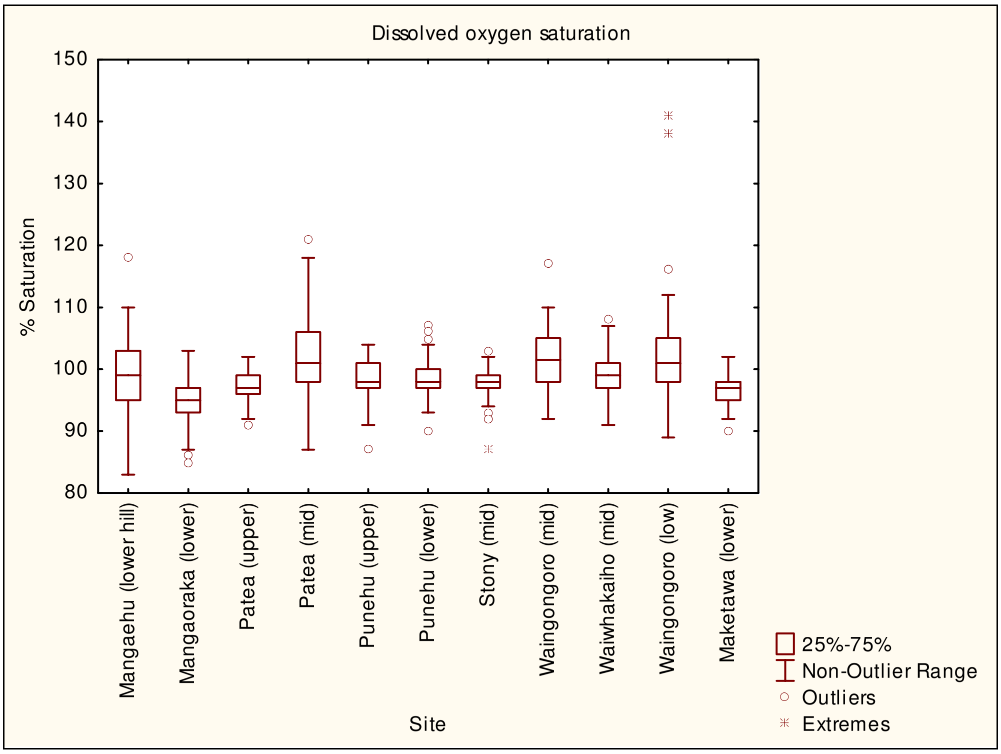

TN (g/m3)
0.001
0.010
0.100
1.000
10.000
Total nitrogen
Site
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
25%-75%
Non-Outlier Range
Outliers
Extremes

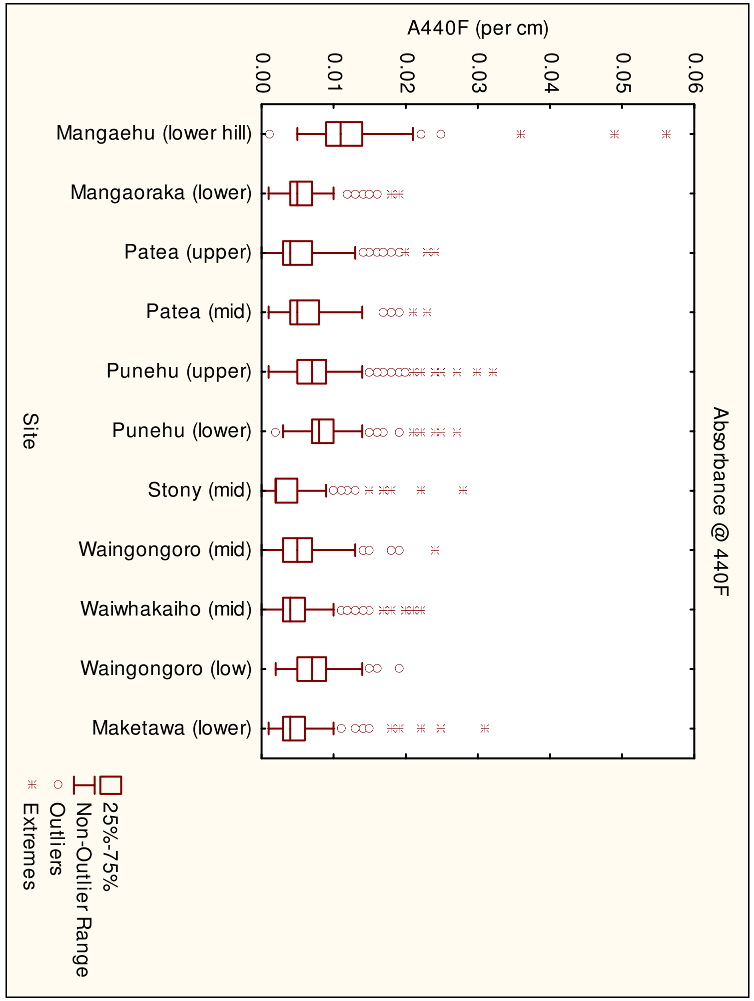

TKN (g/m3)
0.0001
0.0010
0.0100
0.1000
1.0000
10.0000
Total kjeldhal nitrogen
Site
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
25%-75%
Non-Outlier Range
Outliers
Extremes


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


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


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


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



Absorbance @ 440F
A440F (per cm)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
Mangaehu (lower hill)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waiwhakaiho (mid)
Waingongoro (low)
Maketawa (lower)
Site
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 2009-2010

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 2009-2010 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 2009 and June 2010.

First QC exercise

These split samples were collected from the Waiwhakaiho River site at SH3 on 12 August 2009 under relatively low flow conditions (2.86 m^3/sec) and in fine weather conditions. Results are presented in Table 1.

Table 1 Results of SEM QC sampling on 12 August 2009

Site: WKH000500					
Date: 12 August 2009				**Difference from mean(%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.012	0.014	7	✓
A440F	/cm	0.003	0.003	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	55	55	0	✓
BOD5	g/m^3	<0.5	<0.5	0	✓
CONDY	mS/m @ 20°C	14.0	14.0	0	✓
DO	g/m^3	11.5	11.5	0	✓
DRP	g/m^3-P	0.032	0.032	0	✓
ENT	/100ml	28	13	37	**
ECOL	/100ml	46	42	5	✓
FC	/100ml	46	44	2	✓
NH4	g/m^3-N	0.006	0.006	0	✓
NO2	g/m^3-N	0.001	0.001	0	✓
NO3	g/m^3-N	0.16	0.16	0	✓
pH	pH	7.9	7.9	0	✓
SS	g/m^3	<2	<2	0	✓
TKN	g/m^3-N	0.05	0.06	9	✓
TN	g/m^3-N	0.21	0.22	2	✓
TP	g/m^3-P	0.037	0.039	3	✓
TURB	NTU	0.9	0.7	13	*

Comments:

The difference in enterococci counts was outside the acceptable tolerance level for bacteriological samples (20%) but counts were both low for this parameter. Turbidity readings were within 0.2NTU despite the 13% variation.

Overall results showed good laboratory analytical precision performance, with 18 of 20 pairs of results being within the 10% guideline.

Second QC exercise

These split samples were collected from the Maketawa Stream site at Tarata Road on 11 November 2009 under low, clear flow and fine weather conditions. Results are presented in Table 2.

Table 2 Results of SEM QC sampling on 11 November 2009

Site: MKW000300					
Date: 11 November 2009				**Difference from mean(%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.013	0.013	0	✓
A440F	/cm	0.003	0.003	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	29	30	2	✓
BOD5	g/m^3	0.5	0.6	9	✓
CONDY	mS/m @ 20°C	8.5	8.6	1	✓
DO	g/m^3	10.7	10.7	0	✓
DRP	g/m^3-P	0.018	0.018	0	✓
ENT	/100ml	24	8	50	**
ECOL	/100 ml	310	260	9	✓
FC	/100ml	310	260	9	✓
NH4	g/m^3-N	<0.003	0.003	<10	✓
NO2	g/m^3-N	<0.001	<0.001	0	✓
NO3	g/m^3-N	0.06	0.05	9	✓
pH	pH	7.6	7.6	0	✓
SS	g/m^3	<2	<2	0	✓
TKN	g/m^3-N	0.07	0.07	0	✓
TN	g/m^3-N	0.13	0.12	4	✓
TP	g/m^3-P	0.024	0.022	4	✓
TURB	NTU	0.7	0.7	0	✓

Comments:

The difference in *enterococci* bacterial counts was outside of acceptable tolerance levels for bacteriological samples (20%).

Overall laboratory analytical precision performance was very good, with 19 of the 20 pairs of results recorded within the 10% guideline.

Third QC exercise

These split samples were collected from the site in the Waiwhakaiho River at SH3 on 11 February 2010 under clear, very low flow (1.77 m^3/sec), but showery weather conditions. Results are presented in Table 3.

Table 3 Results of SEM QC sampling on 10 February 2010

Site: WKH000500					
Date: 10 February 2010				**Difference from mean(%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.011	0.011	0	✓
A440F	/cm	0.003	0.003	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	66	66	0	✓
BOD5	g/m^3	0.5	0.7	17	*
CONDY	mS/m @ 20°C	15.8	15.8	0	✓
DO	g/m^3	9.8	9.9	<1	✓
DRP	g/m^3-P	0.044	0.044	0	✓
ENT	/100ml	110	80	16	*
ECOL	/100ml	71	80	6	✓
FC	/100ml	71	80	6	✓
NH4	g/m^3-N	0.004	0.005	11	**
NO2	g/m^3-N	<0.001	<0.001	0	✓
NO3	g/m^3-N	0.01	0.02	33	**
PH	pH	8.2	8.2	0	✓
SS	g/m^3	<2	<2	0	✓
TKN	g/m^3-N	0.09	0.11	10	✓
TN	g/m^3-N	0.10	0.13	13	*
TP	g/m^3-P	0.048	0.048	0	✓
TURB	NTU	0.65	0.6	4	✓

Comments:

Most nitrogen species paired results were statistically significantly different, although nitrate N concentrations were low. After re-checking laboratory analytical worksheets, no explanations were found. However no individual results were 'outliers' in the context of this site's historical dataset. BOD_5 results were also >10% different, but at very low concentrations. The variations in enterococci counts were inside the acceptable tolerance level of 20% for bacteriological samples.

Otherwise 14 pairs of parameters analysed were within acceptable agreement, representing relatively good laboratory analytical precision for these samples colleted under very low flow conditions.

Fourth QC exercise

These split samples were collected from the site in the Patea River at Barclay Road on 12 May 2010 under clear, low flow, and fine weather conditions. The results are presented in Table 4.

Table 4 Results of SEM QC sampling on 12 May 2010

Site: PAT000200					
Date: 12 May 2010				**Difference from mean(%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.014	0.012	8	✓
A440F	/cm	0.003	0.003	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m^3 $CaCO_3$	29	28	2	✓
BOD5	g/m^3	<0.5	<0.5	0	✓
CONDY	mS/m @ 20°C	7.4	7.4	0	✓
DO	g/m^3	11.1	11.0	5	✓
DRP	g/m^3-P	0.029	0.029	0	✓
ENT	/100ml	12	3	60	***
ECOL	/100ml	8	7	7	✓
FC	/100ml	8	8	0	✓
NH4	g/m^3-N	<0.003	0.003	<10	✓
NO2	g/m^3-N	<0.001	<0.001	0	✓
NO3	g/m^3-N	0.03	0.03	0	✓
PH	pH	7.6	7.5	<1	✓
SS	g/m^3	<2	<2	0	✓
TKN	g/m^3-N	0.04	0.04	0	✓
TN	g/m^3-N	0.07	0.07	0	✓
TP	g/m^3-P	0.042	0.040	2	✓
TURB	NTU	0.7	0.7	0	✓

Comments:

The difference in enterococci counts, although outside the 20% variability normally considered acceptable for such bacteria counts, was relatively small (9 per 100mls) at this low count.

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	4	(93)	-	(7)	-	(0)	-	(0)
A440F	4	(68)	-	(21)	-	(8)	-	(3)
A770F	4	(76)	-	(0)	-	(12)	-	(12)
ALKT	4	(100)	-	(0)	-	(0)	-	(0)
BOD5	3	(84)	1	(14)	-	(0)	-	(2)
CONDY	4	(100)	-	(0)	-	(0)	-	(0)
DO	4	(100)	-	(0)	-	(0)	-	(0)
DRP	4	(93)	-	(7)	-	(0)	-	(0)
ENT	-	(42)	1	(22)	2	(29)	1	(7)
ECOL	4	(53)	-	(29)	-	(15)	-	(2)
FC	4	(53)	-	(29)	-	(16)	-	(3)
NH4	3	(81)	1	(8)	-	(7)	-	(4)
NO2	4	(95)	-	(3)	-	(2)	-	(0)
NO3	3	(83)	-	(7)	1	(8)	-	(2)
pH	4	(100)	-	(0)	-	(0)	-	(0)
SS	4	(88)	-	(8)	-	(4)	-	(0)
TKN	3	(47)	1	(24)	-	(22)	-	(7)
TN	3	(81)	1	(10)	1	(8)	-	(0)
TP	4	(81)	-	(8)	-	(7)	-	(4)
TURB	3	(96)	1	(2)	-	(2)	-	(0)

[NB: () = % of QC samples for 1995 to 2010 period]

This summary for the 2009-2010 period indicated:

- while results from pairs of two bacteriological species' samples were very precise
- enterococci results fell outside the acceptable variability (20%) on three occasions This follows the historical trend for paired bacteriological analyses which have found slightly fewer than 55% of the period's quality control samples within the 10% difference of the mean (for all three species), but 64% of samples within 20% of the mean for enterococci.
- TKN analytical variability greater than 10% was recorded on one occasion, due to reliance on calculations from another nitrogen species which, on one occasion, was outside acceptable precision tolerances. TKN duplicates have traditionally shown this variability with only 47% and 69% to date within 10% and 20% of the mean respectively.

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 fifteen year historical database for all sites in the programme.

Appendix IV

SEM Physicochemical Programme
Inter-lab Quality Control Report 2009-2010

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 2009-2010 period on 22 June 2010. Sampling was performed during the recession from a moderate flow (1.2 m^3/sec), two days after a flood flow (26 m^3/sec) in fine weather at the Manganui River site at SH 3.

Results

2009-2010 exercise

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

Table 1 Results of SEM QC sampling by TRC & NIWA on 22 June 2010

MGN000195					
		Time: 1020		**Difference from mean(%)**	**Comments**
Parameter	Units	TRC	NIWA		
A340F	/cm	0.016	0.016	0	✓
A440F	/cm	0.003	0.003	0	✓
BDISC	m	4.53	5.09	6	✓
CONDY	mS/m @ 20^{0}C	5.5	5.6	1	✓
DO	g/m^3	11.4	11.5	<1	✓
DRP	g/m^3-P	0.011	0.007	22	**
ECOL	nos/100 ml	27	36	14	*
NH4	g/m^3-N	0.008	0.007	7	✓
NO3	g/m^3-N	0.21	0.20	2	✓
pH	pH	7.3	7.4	<1	✓
TEMP	°C	7.9	8.0	<1	✓
TN	g/m^3-N	0.22	0.25	6	✓
TP	g/m^3-P	0.013	0.012	4	✓
TURB	NTU	0.85	0.79	4	✓

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

Comments:

Significant differences in paired measurements between the two laboratories was recorded for DRP. *E. coli* bacteriological counts differences were within the acceptable variability (20%) for this parameter. 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.

	Difference from mean of pairs of split samples							
Parameter ID	**<10%**		**10-20%**		**20-50%**		**>50%**	
A340F	1	(95)	-	(0)	-	(5)	-	(0)
A440F	1	(63)	-	(32)	-	(0)	-	(5)
CONDY	1	(90)	-	(5)	-	(0)	-	(5)
DO	1	(100)	-	(0)	-	(0)	-	(0)
DRP	-	(42)	-	(21)	1	(32)	-	(5)
NH4	1	(25)	-	(25)	-	(20)	-	(30)
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	(50)	-	(33)	-	(17)	-	(0)
TURB	1	(45)	-	(40)	-	(15)	-	(0)

[NB: () - % of QC samples over the 1995 to 2010 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 analyses have showed greatest variability between laboratories.

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 measurement.

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.