Freshwater Physicochemical Programme
State of the Environment Monitoring
Annual Report
2015-2016

Technical Report 2016-27

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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 were used as the basis for the first five-year SEM report published in 2003, for trending purposes over the ten year period, 1995 to 2005 and the thirteen year period 1995 to 2008 as presented in the third SEM report published in 2009, and the nineteen year period 1995-2014 as presented in the fourth SEM report (TRC, 2015a)

In the year under review, surveys continued to be performed regularly in the second week of every month from July 2015 to June 2016, under a narrower range of flow conditions than typical, ranging through some moderate freshes to very low late summer-autumn flows. This year was characterised by lower median flows sampled by the programme in all rivers and streams. Each sampling run measured up to 22 physical and chemical water quality parameters at thirteen sites representing eight selected ring plain catchments and three eastern hill-country catchments. Two of the sites were newly included, to increase representation of the eastern hill-country, in anticipation of the government's requirement that the Council must establish Freshwater Management Units and have representative monitoring across the entire region.

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 two 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, Whenuakura and Waitara Rivers sites in these rivers' lower reaches.

Over the 2015-2016 monitoring year, flows at times of sampling were much lower than usual, with no flood flows sampled. In general terms, water quality was comparatively better in clarity and suspended solids concentrations, and similar in bacteria numbers and nutrient levels, to past quality. Wider temperature ranges, mainly due to higher maximum temperatures that included record high values at five eastern sites, and higher median water temperatures, were measured in the 2015-2016 period compared with ranges and medians measured during the first 20 years of the SEM programme. The 2015-2016 median dissolved reactive and/or total phosphorus levels were higher at five sites and lower at two sites. Median nitrate and/or total nitrogen species' levels were lower at four sites and higher at two sites, while median ammonia nitrogen levels were lower at three sites and higher at five sites.

The report also provides an assessment of each site's statistical water quality in terms of appropriate guidelines and standards for various usages based upon a summary of the record for the complete 1995-2016 period.

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

The Resource Management Act requires that particular regard be given to the *'maintenance and enhancement of the quality of the environment'*. Therefore a key determinant for the Council is to identify where trends in water quality show no change ('*maintenance*') and/or improvement ('*enhancement*'), or alternatively show decline. With the availability of a suitable period (minimum of ten years) of robust data and access to appropriate statistical software, temporal trend analyses were performed for state of the environment reporting purposes and reported elsewhere during 2006. Regular updates of these temporal trends subsequently have been prepared at appropriate intervals and reported separately, and data for the period 1995 to 2016 are summarised and presented for all eleven sites briefly in the current Annual Report.

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

Long term (21-year) physicochemical trends have shown some significant deterioration in some aspects of water quality (particularly phosphorus) in many of the middle and lower catchments (e.g. the Mangaoraka Stream at Corbett Road, Punehu Stream at SH 45, and Waiwhakaiho River at SH3). On the other hand, there has been a significant long term improvement in total nitrogen at three of the eleven sites monitored, with no site that is showing deterioration in this measure. Long term trends for faecal coliforms and enterococci bacteria showed statistically significant changes over the 21-year period for one or other species at four sites, out of eleven, with improvement at one site (Punehu Stream at Wiremu Road) and deterioration at three sites (Waiwhakaiho River at SH3, Mangaoraka Stream at Corbett Road and Punehu Stream at SH45). Significant deteriorations in black disc clarity were recorded at three sites, two of which reflected historical erosion events in the headwaters.

The most improvement in long term water quality has been illustrated in the Waingongoro River at SH 45, with significantly improving trends in DRP and total phosphorus, and with reduction in nitrate and total nitrogen by slightly less than the rate defined as significant. This improvement has been coincident with land-irrigation of a major industrial (meatworks) discharge and the diversion of Eltham's WWTP discharge out of the river in recent years. Most long term deterioration in aspects of water quality have been found in the mid reaches of the Waiwhakaiho River, where five parameters have deteriorated significantly (dissolved phosphorus, nitrate, ammonia, faecal coliforms and black disc), and in the lower reaches of the Mangaoraka Stream, where five parameters have significantly deteriorated (both phosphorus species, both bacteriological species and black disc) and no parameters show significant long term improvement. More recent data for these sites indicate the deterioration has ceased, except for bacteriological species in the Waiwhakaiho River.

Analysis of recent trends indicates a better direction in water quality, although the latest seven-year trends do not show the same wide-spread improvements that have been evident in recent years. The latest rolling seven-year trend is more positive than the long-term trend, with fewer sites and measures showing significant deterioration, particularly in nutrient concentrations. Other measures (bacteria, organics, aesthetics) show no regional pattern of change in either direction.

This report on the results of the 2015-2016 monitoring period also includes recommendations for the 2016-2017 period and the results of internal and external laboratory quality control exercises, which, with relatively few exceptions, resulted in good inter and intra-laboratory precision.

Recommendations provide for the continuation of this programme.

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

Annual SEM reports act as 'building blocks' towards the preparation of the regional state of the environment report every five years. The Council's first, or baseline, state of the environment report was prepared in 1996 (TRC, 1996b), summarising the region's progress in improving environmental quality in Taranaki over the past two decades. The second report (for the period 1995-2000) was published in 2003 (TRC, 2003). Data spanning the ten year period 1995 to 2005 have been used in the preparation of a trend report (TRC, 2006). The third State of the Environment report (for the period 1995 to 2007) was published (TRC, 2009a) and included trend reporting and the fourth report (for the 1995 to 2014 period) has been published (TRC, 2015a). The provision of appropriate computer software statistical procedures 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 2015-2016 monitoring year, the twenty-first year of the programme. Previous years' results have been presented in the TRC Technical Reports listed in the References section.

A network of nine freshwater sites was established in mid-1995 for physicochemical monitoring on a long-term basis to provide information on trends in the state of Taranaki's regional surface water quality and this network was maintained with the addition (for various purposes) of one site during the 1998-99 period, another site in the 2003-2004 period, and two more sites in the 2015-2016 period. The latter change was brought about because of the direction within the Government's '*National Policy*

Statement for Freshwater Management 2014', that all freshwater within each region must be included within a 'Freshwater Management Unit' (FMU), for each of which the regional council is obliged to set objectives and limits (bottom lines for quality measures that are related to community values for that water body), and to undertake representative monitoring that demonstrates progress towards the objectives for that FMU.

The Taranaki Regional Council's SEM programme also includes a freshwater biological component encompassing the same thirteen sites plus forty-six additional sites, which is reported separately (see TRC, 2016a).

The physicochemical programme has been designed to provide a general picture of water quality for nine 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 nine of the sixty-nine catchments in the Taranaki region and 44% of the total area of the region (Figures 1 and 2). Given that a number of the largest catchments in the region are included in the network, it provides a relatively representative indication of the state of surface water in the region.

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

The existing programme also meshes with a national programme, which has been operated by the National Institute of Water and Atmospheric Research (NIWA) since January 1989. This National Rivers Water Quality Network (NRWQN) 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). Until recently, the programme included 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 SH45). Data from these sites are presented within this report (sections 4.2.2 and 4.4) and previous reports.

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

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

Physicochemical water quality monitoring is performed to obtain an understanding of the physical and chemical characteristics of water by means of statistical sampling (Ward & McBride, 1986). It requires repetitive measurements of such characteristics through time. The complex variations of those characteristics in the natural, and more especially the modified environment, make 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 (Figure 1).

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
Whenuakura River	at Nicholson Road	WNR000450
Waitara River	at Autawa Road	WTR000540

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 LAB water quality computer and Taradise GIS databases.

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

Site Maketawa Stream at Tarata Road

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

Site Mangaoraka Stream at Corbett Road

This site is representative of a northern Taranaki ringplain stream, (but with its source outside the National Park), draining an intensive 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.

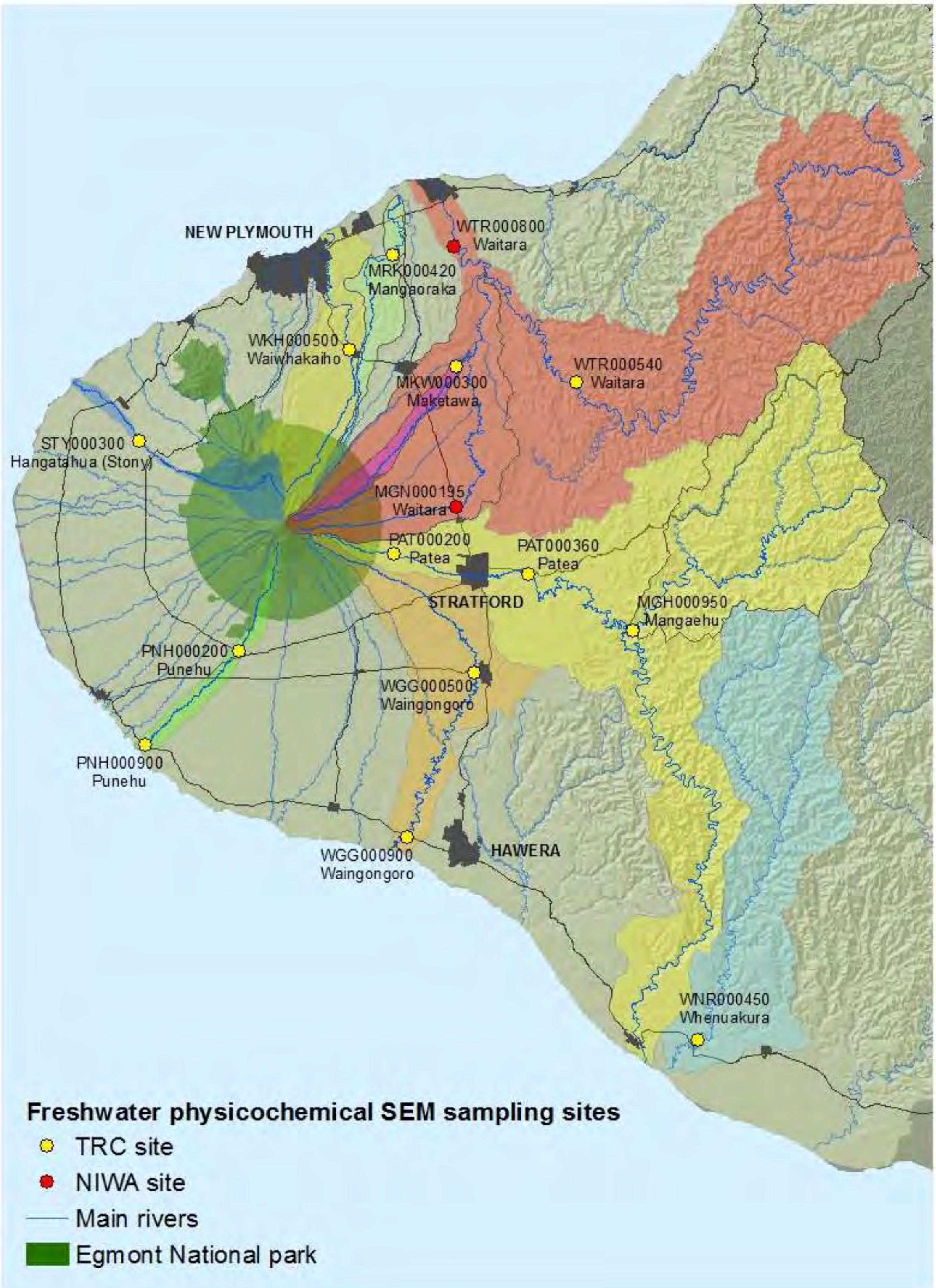


Figure 1 Freshwater physicochemical SEM sampling sites

Site Waiwhakaiho River at SH3

This site is an existing hydrological recording station and was included in the Taranaki ring plain survey (TRC 1984). It is representative of the mid catchment of a

National Park-sourced river draining developed farmland and is immediately upstream of the major diversion site for the New Plymouth water supply and the Mangorei HEP scheme. This site has also been integrated into compliance monitoring programmes related to the diversion consent. The lower river is markedly influenced by HEP generation releases and industrial impacts and is further monitored by way of a site specific monitoring programme. Occasional natural headwater erosion events may affect water quality from time to time (including iron-oxide release from tributary streams).

Site Hangatahua (Stony) River at Mangatete Road

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

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

This stream is representative of a south-western Taranaki catchment subjected primarily to intensive agricultural land use with water quality potentially affected by diffuse source run-off and point source discharges from dairy shed treatment pond systems in the lower reaches of the catchment and Mangatawa Stream sub-catchment in particular. No industrial discharges in the catchment are known to occur. Both sites were included in the Taranaki ring plain survey and the lower site near the coast remained a NIWA hydrological recording station for a national representative basin from 1970 until 2011, when the station was closed. The upstream site (located approximately 2 km from the National Park boundary) is representative of relatively unimpacted stream water quality although this reach is in open farmland, and requires regular flow rating. Flow gaugings at this site are therefore necessary on each sampling occasion and flow gaugings were implemented at the lower reach site in 2011 after hydro station closure by NIWA.

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

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

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

This site was part of the NIWA (NZ rivers) survey network from January 1989 to December 2015, and has been monitored by the Council since July 1998.

Sites Patea River catchment: Patea River at Barclay Road and at 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.

Sites Waitara River at Autawa Road (1) and at Bertrand Road (2, NIWA)

The Autawa Road site, in the mid reaches of the eastern hill country part of the Waitara catchment, is representative of a combination of upland agricultural development and native forest. It is 6.1 km above the hydrological recording station that was established in 1970 at Tarata for a national representative basin, with the discharge from the Motukawa power station in between, and has been monitored by the Council for physico-chemical water quality since July 2015.

The Bertrand Road 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 are utilised for this site.

Site Manganui River at SH3

This site was a Taranaki ring plain survey site and is currently one of the two Taranaki sites in the NIWA (NZ rivers) survey network in conjunction with the hydrological recording station that was established for a national representative basin in 1971. 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 are utilised for this site.

Site Whenuakura River at Nicholson Road

This site is in the lower reaches of an eastern hill county catchment in the southern part of the region that has largely been developed for agriculture, with some production forestry and native forest. It is an established hydrological recording station 10.7 km from the coast in the upper section of tidal river, above the saline influence, and has been monitored by the Council for physico-chemical water quality since July 2015.

3. Sampling procedure and analytical parameters

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

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

Table 2 SEM physicochemical parameters and site of measurement

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

The instrument used for turbidity measurement was changed in January 2016, from a Hach 2100A to a WTW Cyberscan turbidimeter. All the water samples collected monthly since June 2006, a period of almost ten years, had been tested with both instruments, providing data for comparative analysis on performance of the two meters, and for turbidity trend analysis using the replacement meter.

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 three months). These samples were unidentified for laboratory processing purposes and included with the other samples in the normal manner for laboratory analysis. Comparative results have been stored in the appropriate database and a separate internal report prepared for quality control purposes (see Appendix III).

Stream flow gaugings have been performed at the five sites where no permanent hydrological stations exist and/or the rating is unstable, in conjunction with each monthly sampling survey run. The Whenuakura River site was gauged over eight months from July 2015 while the rating curve was re-established following a flood that destroyed the station the previous month**.**

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

4. Water quality results

Water quality data accumulated for the period July 2015 to June 2016 are presented for each of the thirteen sites. Statistical summaries of these data and the cumulative data for nine sites (July 1995 to June 2016), one site in the lower Waingongoro River (July 1998 to June 2016), and one site in the lower Maketawa Stream (July 2003 to June 2016) are also presented on a site-by-site basis, together with a general discussion of water quality at each site. A comparison of water quality through the region is provided following the individual sites' discussions (Section 4.2).

4.1. Sites' water quality

Maketawa Stream at Tarata Road (site: MKW000300)

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

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

Date	Time NZST	A340F /cm	A440F /cm	A770F /cm	ALKT g/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 cfu/100mL	ENT cfu/100mL
08 Jul 2015	0805	0.022	0.004	0.000	24	2.39	<0.5	8.0	10.5	100	0.027	200	46
12 Aug 2015	0800	0.012	0.002	0.000	25	3.70	<0.5	8.7	12.2	101	0.016	140	12
09 Sep 2015	0800	0.012	0.002	0.000	26	3.94	<0.5	8.8	11.7	101	0.018	380	190
14 Oct 2015	0700	0.018	0.004	0.000	28	2.02	<0.6	8.3	10.9	100	0.029	3400	560
11 Nov 2015	0705	0.015	0.004	0.000	32	2.71	0.6	9.0	10.0	99	0.035	480	110
09 Dec 2015	0705	0.015	0.003	0.000	31	3.72	<0.5	8.9	10.5	100	0.031	410	780
11 Jan 2016	0705	0.016	0.004	0.000	29	5.12	0.8	8.1	9.9	100	0.043	320	300
10 Feb 2016	0700	0.013	0.004	0.000	34	3.75	<0.5	8.8	9.2	99	0.035	470	880
10 Mar 2016	0710	0.014	0.004	0.000	32	2.31	<0.5	8.9	9.9	99	0.032	510	680
13 Apr 2016	0815	0.078	0.017	0.001	20	0.82	1.1	6.9	10.0	100	0.055	1100	1200
11 May 2016	0800	0.017	0.004	0.000	32	3.08	1.1	8.9	9.9	98	0.040	350	430
8 Jun 2016	0800	0.011	0.002	0.000	30	3.72	<0.5	9.0	11.7	100	0.024	310	80
Date	**Time NZST**	**FC cfu/ 100mL**	**Flow m^3/s**	**NH_4 g/m^3N**	**NO_2 g/m^3N**	**NO_3 g/m^3N**	**pH pH**	**SS g/m^3**	**Temp °C**	**TKN g/m^3N**	**TN g/m^3N**	**TP g/m^3P**	**Turb NTU**
08 Jul 2015	0805	200	2.470	0.017	0.002	0.41	7.5	3	7.9	0.09	0.50	0.036	1.6
12 Aug 2015	0800	140	2.819	0.011	0.001	0.63	6.9	<2	6.9	0.05	0.68	0.025	0.8
09 Sep 2015	0800	380	2.484	0.007	0.002	0.50	7.6	<2	8.5	0.06	0.56	0.025	0.8
14 Oct 2015	0700	3400	2.157	0.013	0.003	0.22	7.7	<2	10.9	0.12	0.34	0.042	1.3
11 Nov 2015	0705	480	1.552	0.016	0.002	0.27	7.8	<2	14.2	0.10	0.37	0.046	0.9
09 Dec 2015	0705	410	1.576	0.005	0.001	0.17	7.7	<2	12.2	0.05	0.22	0.049	0.9
11 Jan 2016	0705	330	1.411	0.007	<0.001	0.14	7.7	<2	15.2	0.03	0.17	0.048	0.5
10 Feb 2016	0700	470	1.024	0.005	<0.001	0.02	7.7	<2	18.0	0.03	0.05	0.048	0.5
10 Mar 2016	0710	520	0.996	0.006	<0.001	0.04	7.6	<2	15.0	0.09	0.13	0.048	0.4
13 Apr 2016	0815	1200	2.788	0.061	0.012	0.48	7.6	4	13.8	0.25	0.74	0.100	2.4
11 May 2016	0800	350	1.392	0.011	0.002	0.21	7.6	<2	13.3	0.01	0.22	0.045	0.8
8 Jun 2016	0800	310	1.729	0.017	0.001	0.47	7.6	<2	8.0	0.00	0.47	0.026	0.8

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

Table 4 Statistical summary of data from July 2015 to June 2016: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.011	0.078	0.015	12	0.018
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.017	0.004	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity total	g/m^3 $CaCO_3$	20	34	30	12	4
BLACK DISC	Black disc transparency	m	0.82	5.12	3.39	12	1.13
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	1.1	<0.5	12	0.2
CONDY	Conductivity @ 20°C	mS/m	6.9	9.0	8.8	12	0.6
DO	Dissolved oxygen	g/m^3	9.2	12.2	10.2	12	0.9
PERSAT	Dissolved oxygen saturation	%	98	101	100	12	1
DRP	Dissolved reactive phosphorus	g/m^3P	0.016	0.055	0.032	12	0.011
ECOL	E. coli bacteria	cfu/100 mL	140	3400	395	12	892
ENT	Enterococci bacteria	cfu/100 mL	12	1200	365	12	384
FC	Faecal coliform bacteria	cfu/100 mL	140	3400	395	12	896
FLOW	Flow	m^3/s	0.996	2.819	1.652	12	0.653
NH_4	Ammoniacal nitrogen	g/m^3N	0.005	0.061	0.011	12	0.015
NO_2	Nitrite nitrogen	g/m^3N	0.001	0.012	0.002	12	0.003
NO_3	Nitrate nitrogen	g/m^3N	0.02	0.63	0.24	12	0.20
pH	pH		6.9	7.8	7.6	12	0.2
SS	Suspended solids	g/m^3	<2	4	<2	12	<2
TEMP	Temperature	°C	6.9	18.0	12.8	12	3.5
TKN	Total kjeldahl nitrogen	g/m^3N	0.00	0.25	0.06	12	0.07
TN	Total nitrogen	g/m^3N	<0.05	0.74	0.36	12	0.22
TP	Total phosphorus	g/m^3P	0.025	0.100	0.046	12	0.020
TURBY	Turbidity	NTU	0.4	2.4	0.8	12	0.6

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

Table 5 Statistical summary of data from July 2003 to June 2016: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.002	0.141	0.017	156	0.022
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.031	0.004	156	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	156	0.000
ALKT	Alkalinity total	g/m^3 $CaCO_3$	7	34	28	156	6
BLACK DISC	Black disc transparency	m	0.21	5.23	2.60	156	1.13
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.5	2.3	<0.5	156	<0.5
CONDY	Conductivity @ 20°C	mS/m	3.2	12.6	8.6	156	1.2
DO	Dissolved oxygen	g/m^3	9.0	12.5	10.5	156	0.8
PERSAT	Dissolved oxygen saturation	%	90	103	98	156	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.004	0.055	0.024	156	0.008
ECOL	E. coli bacteria	cfu/100 mL	50	26000	320	156	2605
ENT	Enterococci bacteria	cfu/100 mL	6	9700	175	156	1333
FC	Faecal coliform bacteria	cfu/100 mL	50	26000	330	156	2614
FLOW	Flow	m^3/s	0.838	17.2	1.924	156	2.499
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.093	0.009	156	0.016
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.012	0.002	156	0.002
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.92	0.25	156	0.21
pH	pH		6.8	7.9	7.6	156	0.2
SS	Suspended solids	g/m^3	2	55	<2	156	7
TEMP	Temperature	°C	4.8	18.0	11.5	156	3
TKN	Total kjeldahl nitrogen	g/m^3N	-0.01	0.52	0.07	156	0.10
TN	Total nitrogen	g/m^3N	<0.05	0.96	0.38	156	0.23
TP	Total phosphorus	g/m^3P	0.018	0.180	0.034	156	0.025
TURB	Turbidity (Hach 2100A)	NTU	0.5	14	0.9	156	1.8
TURBY	Turbidity (Cyberscan WTW)	NTU	0.4	30	1.2	133	4.1

Discussion

2015-2016 period

Good aesthetic water quality was indicated by a median black disc clarity of 3.39 metres, in the lower reaches of this ring-plain stream near to its confluence with the Manganui River. The maximum clarity (black disc value of 5.12 m) was recorded in mid-summer under moderate low flow conditions (1.41 m^3/s). No significant floods, but some small freshes, were sampled during the year, with moderate elevations in turbidity (1.3 to 2.4 NTU) and in suspended solids concentrations (4 g/m^3) under fresh flow conditions (2.22 to 2.79 m^3/sec) sampled in winter and spring 2015 and autumn 2016. Slightly poorer water quality conditions apparent at the time these fresh flows were recorded with increases in bacterial number (3,400 faecal coliforms/100mL), BOD_5 (1.1 g/m^3), and some nutrients (e.g. TN [0.74 g/m^3] and TP [0.10 g/m^3]) recorded when black disc visibility decreased to 0.82 m.

pH was relatively stable (6.9 to 7.8), although it would be expected that pH would have reached a higher maximum later in the day than at the usual times of sampling (i.e. prior to 0805 NZST), particularly during summer low flow conditions.

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 97% saturation) and low BOD_5 levels (median: < 0.5 g/m^3). Bacteriological quality was typical of the lower reaches of developed ring plain catchments subject to agricultural impacts, with median faecal coliform and enterococci numbers of 395 and 365 (per 100 mLs) respectively. Water temperature varied over a moderate range of 11.1 °C with a maximum late summer (early morning) river temperature of 18.0 °C recorded in February 2016.

Brief comparison with the previous 2003-2015 (twelve year) period

Generally, stream water quality at this site during the 2015-2016 period was significantly improved in appearance/clarity (higher median black disc clarity [by 0.84 m], lower median turbidity [by 0.4 NTU], but no difference in median suspended solids level). Bacterial water quality was poorer, with a higher median faecal coliform number by 35 cfu/100 mL and a higher median enterococci number by 210 cfu/100 mL. Median water temperature was higher [by 1.3°C] while the maximum water temperature was higher [by 0.4°C] than the maximum previously recorded. Other physicochemical aspects of water quality were very similar for the two periods. The flow range during 2015-2016 was the narrowest recorded. Median flow sampled was significantly lower (by 306/sec) than the median of flows sampled over the previous twelve-year period. Relatively narrow ranges for parameters such as suspended solids, conductivity, turbidity, pH and total phosphorus reflected the lack of significant flood events sampled. Median pH values were identical and the maximum and minimum pH values were within 0.1 unit of those of the past twelve-year record. For nutrients, nitrogen species had similar median values, whereas total and dissolved phosphorus were significantly higher (by 35 and 45%, respectively) during the monitoring year in comparison with the medians of the previous twelve 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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100 mL	cfu/100mL
08-Jul-2015	0845	0.023	0.004	0.000	35	2.66	0.5	13.7	11.1	99	0.010	500	270
12-Aug-2015	0830	0.017	0.004	0.000	29	2.32	0.5	12.8	11.6	100	0.004	440	37
09-Sep-2015	0835	0.020	0.003	0.000	32	2.50	0.5	13.5	11.1	101	0.006	680	120
14-Oct-2015	0735	0.027	0.006	0.000	53	1.19	1.6	17.1	10.5	99	0.010	9200	6800
11-Nov-2015	0735	0.025	0.005	0.000	46	2.63	0.7	15.3	10.0	100	0.016	1100	150
09-Dec-2015	0735	0.025	0.005	0.000	56	2.36	0.6	17.1	10.9	105	0.008	570	320
13-Jan-2016	0740	0.024	0.006	0.000	62	2.86	0.7	17.7	9.6	101	0.018	670	610
10-Feb-2016	0740	0.032	0.007	0.000	90	2.10	0.9	23.8	8.0	88	<0.003	1100	920
10-Mar-2016	0745	0.025	0.006	0.000	86	1.43	0.6	23.4	8.9	91	0.007	1200	800
13-Apr-2016	0845	0.040	0.008	0.000	47	0.80	1.2	15.6	9.7	100	0.026	5300	18000
11-May-2016	0825	0.030	0.006	0.000	64	2.02	0.7	17.8	9.5	95	0.024	2000	8400
08-Jun-2016	0830	0.021	0.004	0.000	38	2.30	0.5	14.9	11.2	99	0.007	410	210

Date	Time	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
	NZST	cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
08-Jul-2015	0845	500	1.931	0.026	0.004	1.12	7.5	5	9.6	0.34	1.46	0.028	2.7
12-Aug-2015	0830	440	2.906	0.024	0.003	1.44	7.0	4	9.1	0.06	1.50	0.023	2.4
09-Sep-2015	0835	680	1.995	0.026	0.004	1.28	7.5	2	11.0	0.02	1.30	0.018	1.5
14-Oct-2015	0735	9200	0.969	0.049	0.008	0.84	7.8	2	12.9	0.25	1.10	0.024	2.8
11-Nov-2015	0735	1100	0.776	0.015	0.004	0.83	7.8	<2	14.9	0.14	0.97	0.026	1.5
09-Dec-2015	0735	700	0.466	0.010	0.002	0.57	7.9	<2	13.2	0.10	0.67	0.021	1.0
13-Jan-2016	0740	670	0.287	0.017	0.003	0.44	7.9	<2	17.3	0.02	0.46	0.031	0.8
10-Feb-2016	0740	1100	0.176	0.011	0.003	0.23	7.7	<2	19.4	0.04	0.27	0.017	0.8
10-Mar-2016	0745	1200	0.183	0.008	0.002	0.38	7.7	<2	16.5	0.16	0.54	0.013	0.6
13-Apr-2016	0845	5300	1.082	0.019	0.009	0.87	7.8	5	15.6	0.28	1.16	0.060	4.5
11-May-2016	0825	2100	0.422	0.029	0.004	0.73	7.7	<2	14.7	0.04	0.77	0.033	1.3
08-Jun-2016	0830	410	1.267	0.036	0.004	1.00	7.6	<2	10.4	0.10	1.10	0.014	1.7

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

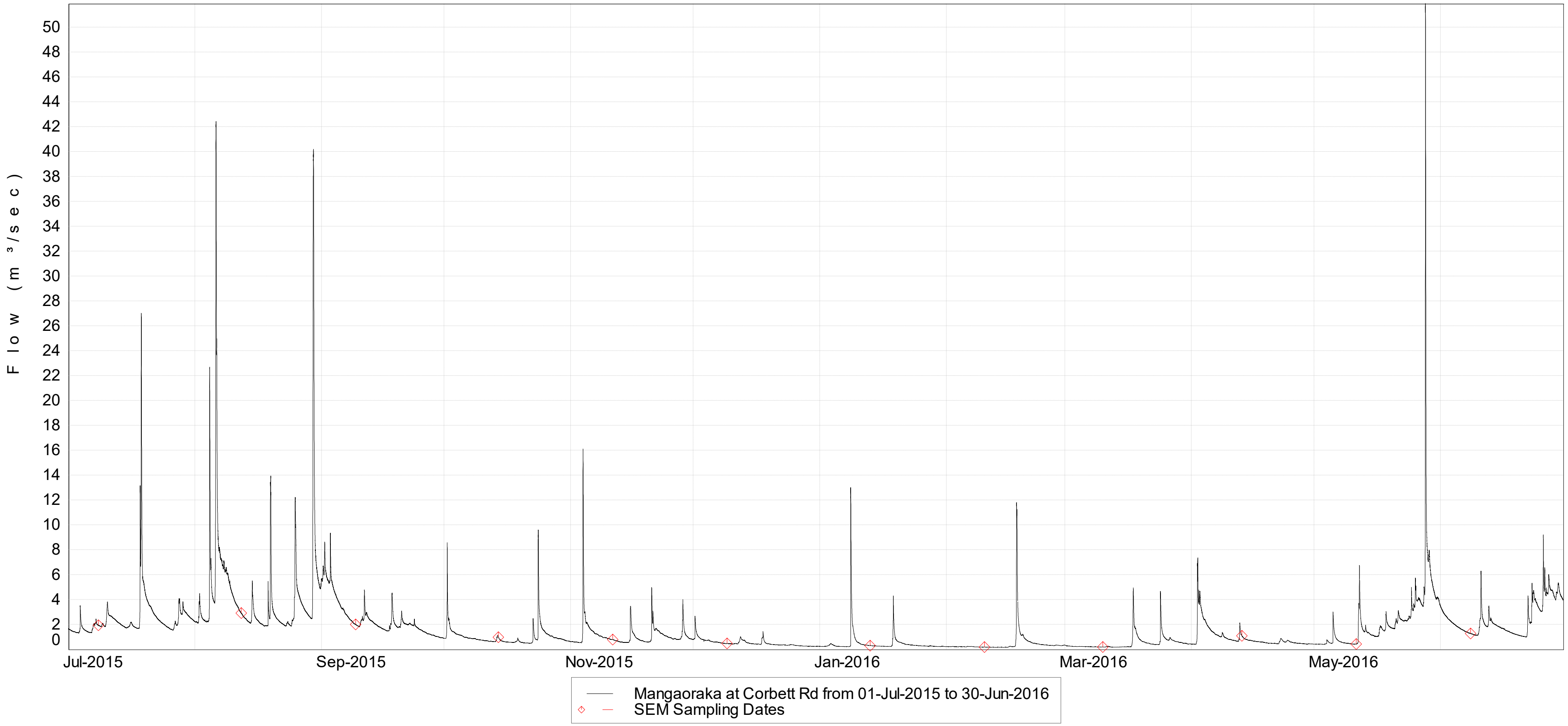


Figure 2 Flow record for the Mangaoraka Stream at Corbett Road

Table 7 Statistical summary of data from July 2015 to June 2016: Mangaoraka Stream at Corbett Road

Parameter		Units	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.017	0.040	0.025	12	0.006
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.008	0.006	12	0.001
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.000	0.000	12	0.000
ALKT	Alkalinity total	g/m³ CaCO³	29	90	50	12	20
BLACKDISC	Black disc transparency	m	0.80	2.86	2.31	12	0.64
BOD_5	Biochemical oxygen demand 5 day	g/m³	<0.5	1.6	0.6	12	0.3
CONDY	Conductivity @ 20°C	mS/m@20C	12.8	23.8	16.4	12	3.5
DO	Dissolved oxygen	g/m³	8.0	11.6	10.2	12	1.1
PERSAT	Dissolved oxygen saturation	%	88	105	100	12	5
DRP	Dissolved reactive phosphorus	g/m³ P	<0.003	0.026	0.009	12	0.008
ECOL	E. coli bacteria	cfu/100mL	410	9200	890	12	2658
ENT	Enterococci bacteria	cfu/100mL	37	18000	465	12	5486
FC	Faecal coliform bacteria	cfu/100mL	410	9200	900	12	2652
FLOW	Flow	m³/s	0.176	2.906	0.872	12	0.857
NH_4	Ammoniacal nitrogen	g/m³ N	0.008	0.049	0.022	12	0.012
NO_2	Nitrite nitrogen	g/m³ N	0.002	0.009	0.004	12	0.002
NO_3	Nitrate nitrogen	g/m³ N	0.23	1.44	0.83	12	0.37
PH	pH	pH	7.0	7.9	7.7	12	0.2
SS	Suspended solids	g/m³	<2	5	<2	12	1
TEMP	Temperature	˚C	9.1	19.4	14.0	12	3.3
TKN	Total kjeldahl nitrogen	g/m³ N	0.02	0.34	0.10	12	0.11
TN	Total nitrogen	g/m³ N	0.27	1.50	1.04	12	0.4
TP	Total phosphorus	g/m³ P	0.013	0.060	0.024	12	0.013
TURBY	Turbidity	NTU	0.6	4.5	1.5	12	1.1

A statistical summary of the 21 years' data collected since 1 July 1995 is presented in Table 8.

Table 8 Statistical summary of data from July 1995 to June 2016: Mangaoraka Stream at Corbett Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.014	0.074	0.025	252	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.019	0.005	252	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	252	0.001
ALKT	Alkalinity total	g/m³ $CaCO_3$	14	108	41	252	18
BLACK DISC	Black disc transparency	m	0.055	4.73	1.85	252	0.89
BOD_5	Biochemical oxygen demand 5 day	g/m³	0.5	14	0.7	252	1.4
CONDY	Conductivity @ 20°C	mS/m	5.6	28.7	14.5	252	3.8
DO	Dissolved oxygen	g/m³	7.8	11.8	10.1	251	0.8
PERSAT	Dissolved oxygen saturation	%	83	107	97	251	4
DRP	Dissolved reactive phosphorus	g/m³P	<0.003	0.074	0.009	252	0.008
ECOL	E. coli bacteria	cfu/100 mL	80	60000	785	228	6982
ENT	Enterococci bacteria	cfu/100 mL	31	180000	375	252	13461
FC	Faecal coliform bacteria	cfu/100 mL	84	60000	790	252	7621
FLOW	Flow	m³/s	0.160	34.1	1.152	252	2.989
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.308	0.021	252	0.047
NO_2	Nitrite nitrogen	g/m³N	0.001	0.039	0.005	252	0.005
NO_3	Nitrate nitrogen	g/m³N	0.05	1.73	0.84	252	0.31
pH	pH		6.9	8.1	7.6	252	0.2
SS	Suspended solids	g/m³	<2	310	2	252	26
TEMP	Temperature	°C	5.8	20.5	13.0	252	2.9
TKN	Total kjeldahl nitrogen	g/m³N	<0.01	4.46	0.2	252	0.44
TN	Total nitrogen	g/m³N	0.27	5.18	1.1	252	0.522
TP	Total phosphorus	g/m³P	0.007	0.860	0.023	252	0.09
TURB	Turbidity (Hach 2100A)	NTU	0.8	100	1.6	245	8.6
TURBY	Turbidity (Cyberscan WTW)	NTU	0.6	59	2.1	133	7.2

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

2015-2016 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 (median: 1.5 NTU) than might be expected given the concentration of suspended solids (median: <2 g/m^3). This was due to the very fine, colloidal nature of suspended material in the stream at this site partly due to the headwaters being situated below the National Park. The moderate maximum black disc value of 2.86 m coincided with mid summer, low flow conditions, while the poorest turbidity conditions (4.5 NTU and 0.80 m black disc) were recorded during a small fresh in mid autumn 2016, with some increase in suspended sediment, BOD_5 and faecal coliform number. Some nutrient species indicated poorest water quality during this fresh, particularly phosphorus levels, although higher bacteria numbers were recorded on a similar occasion in spring.

The relative absence of freshes near the sampling occasions in spring, summer and autumn contributed to the slightly elevated pH values (7.7 to 7.9), though these levels were similar to those recorded previously. It should be noted all levels were recorded prior to mid-morning and were not representative of higher pH levels that might be expected later in the day when algal photosynthetic activity would be likely to raise pH more significantly.

Generally, high dissolved oxygen concentrations, high percentage saturation, and low BOD_5 levels (< 1.7 g/m^3) were indicative of relatively good physicochemical water quality, but the very high median bacterial numbers (465 enterococci and 900 faecal coliforms cfu/100 mL), although lower than in the 2014-2015 period, were much higher than typical of the lower reaches of a stream draining an intensively developed catchment, although the Mangaoraka Stream is essentially a lowland catchment as its headwaters do not extend as far towards the upper slopes of Mt Taranaki as most ring plain rivers and streams. [Investigative work in the lower catchment has identified stock access to streams as a probable primary contributor to these elevated numbers although the cumulative impacts of consented dairy pond discharges also contribute, particularly under lower flow conditions]. Water temperatures varied over a moderate range of 10.3 °C with a maximum (mid-morning) temperature of 19.4 °C in February 2016 during a period of very low flow conditions. Dissolved oxygen saturation did not fall below 88% during the period, with this minimum recorded during a period of lengthy, very low flow conditions (Figure 3).

Brief comparison with the previous 1995-2015 period

Aesthetic stream water quality at this site during the 2015-2016 period was improved [median black disc clarity higher by 0.46 m, median suspended solids level lower, and median turbidities significantly lower, by 0.6 NTU]. Bacterial water quality deteriorated as reflected in higher median faecal coliform number by 110 cfu/100 mL and median enterococci number by 90 cfu/100 mL. Median water temperature was 1.0 °C higher in the 2015-2016 period although the maximum water temperature (19.4 °C) was 1.1 °C lower than the previous maximum recorded. Median conductivity was higher and reflected the absence of very high flow conditions and the lengthy low flow periods sampled during the latest period. The median flow sampled during 2015-2016 (0.872 m^3/sec) was significantly lower (by 280 L/s) than the median of flows sampled over the previous 20-year period. Moderate ranges for parameters such as suspended solids, turbidity, pH, and BOD_5 reflected the few smaller freshes sampled on occasions during the 2015-2016 period (Figure 3), rather than high floods occasionally sampled in the past. Median pH value was 0.1 unit higher and maximum pH was 0.2 unit lower than the past record. All nitrogen and phosphorus nutrient species had very similar median values during the monitoring year in comparison with the previous 20-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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m³ $CaCO_3$	m	g/m³	mS/m	g/m³	%	g/m³P	cfu/100 mL	cfu/100 mL
08-Jul-2015	0915	0.021	0.004	0.000	32	3.14	<0.5	9.2	11.8	101	0.020	96	46
12-Aug-2015	0900	0.006	0.001	0.000	44	5.65	<0.5	11.5	12.7	103	0.018	160	15
09-Sep-2015	0900	0.010	0.002	0.000	44	4.77	<0.5	11.5	11.9	104	0.020	100	21
14-Oct-2015	0805	0.045	0.010	0.000	28	1.14	0.8	7.7	11.4	103	0.019	2500	1000
11-Nov-2015	0805	0.013	0.004	0.000	60	2.26	0.6	14.5	10.5	102	0.050	360	120
09-Dec-2015	0805	0.011	0.003	0.000	55	3.52	<0.5	13.6	10.7	102	0.030	62	38
13-Jan-2016	0810	0.010	0.003	0.000	59	4.68	<0.5	13.5	10.5	105	0.036	1200	74
10-Feb-2016	0815	0.013	0.003	0.000	72	3.11	<0.5	16.2	9.6	104	0.046	200	270
10-Mar-2016	0820	0.009	0.003	0.000	71	2.17	0.5	16.3	10.5	105	0.051	180	190
13-Apr-2016	0920	0.052	0.013	0.001	39	0.96	0.7	10.4	10.4	104	0.042	1900	730
11-May-2016	0855	0.013	0.003	0.000	64	3.25	<0.5	15.2	10.1	99	0.046	280	280
08-Jun-2016	0915	0.008	0.002	0.000	59	4.4	<0.5	14.6	11.9	102	0.031	120	17
Date	**Time**	**FC**	**Flow**	**NH_4**	**NO_2**	**NO_3**	**pH**	**SS**	**Temp**	**TKN**	**TN**	**TP**	**Turb**
	NZST	cfu/ 100mL	m³/s	g/m³N	g/m³N	g/m³N	pH	g/m³	°C	g/m³N	g/m³N	g/m³P	NTU
08-Jul-2015	0915	96	6.178	0.009	0.001	0.17	7.6	4	7.7	0.03	0.20	0.027	0.5
12-Aug-2015	0900	160	4.627	0.004	<0.001	0.23	7.4	<2	5.9	0.00	0.22	0.033	0.5
09-Sep-2015	0900	100	4.042	0.004	0.002	0.15	7.8	<2	8.8	0.03	0.18	0.026	0.4
14-Oct-2015	0805	2500	5.630	0.013	0.002	0.06	7.8	3	10.0	0.19	0.25	0.037	1.7
11-Nov-2015	0805	360	2.574	0.066	0.006	0.17	8.1	<2	12.9	0.13	0.31	0.060	1.3
09-Dec-2015	0805	62	2.740	0.011	0.001	0.06	8.0	<2	12.0	0.05	0.11	0.038	0.5
13-Jan-2016	0810	1200	2.599	<0.003	<0.001	0.07	8.2	<2	14.5	0.01	0.08	0.040	0.4
10-Feb-2016	0815	210	1.919	<0.003	<0.001	0.01	8.2	<2	17.7	0.04	<0.05	0.057	0.4
10-Mar-2016	0820	190	2.489	0.014	0.003	0.06	8.2	<2	14.9	0.07	0.13	0.058	0.3
13-Apr-2016	0920	2000	5.454	0.030	0.010	0.19	7.6	<2	13.6	0.07	0.27	0.058	1.0
11-May-2016	0855	280	3.169	0.021	0.003	0.12	8.0	<2	13.2	0.02	0.14	0.050	0.5
08-Jun-2016	0915	120	2.874	0.007	<0.001	0.18	8.0	<2	8.2	0.02	0.20	0.033	0.5

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

Table 10 Statistical summary of data from July 2015 to June 2016

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.006	0.052	0.012	12	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.001	0.013	0.003	12	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	28	72	57	12	15
BDISC	Black disc transparency	m	0.96	5.65	3.2	12	1.46
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	0.8	<0.5	12	<0.5
CONDY	Conductivity @ 20'C	mS/m	7.7	16.3	13.6	12	2.8
DO	Dissolved Oxygen	g/m^3	9.6	12.7	10.6	12	0.9
PERSAT	Dissolved Oxygen Saturation %	%	99	105	103	12	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.018	0.051	0.034	12	0.013
ECOL	E.coli bacteria	cfu/100 mL	62	2500	190	12	819
ENT	Enterococci bacteria	cfu/100 mL	15	1000	97	12	315
FC	Faecal Coliforms	cfu/100 mL	62	2500	200	12	833
FLOW	Flow	m^3/s	1.919	6.178	3.022	12	1.444
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.066	0.010	12	0.018
NO_2	Nitrite nitrogen	g/m^3N	0.001	0.010	0.002	12	0.003
NO_3	Nitrate nitrogen	g/m^3N	0.01	0.22	0.13	12	0.14
PH	pH	pH	7.4	8.2	8.0	12	0.3
SS	Suspended solids	g/m^3	<2	4	<2	12	<2
TEMP	Temperature	°C	5.9	17.7	12.4	12	3.5
TKN	Total Kjeldahl nitrogen	g/m^3N	0.00	0.19	0.04	12	0.06
TN	Total nitrogen	g/m^3N	<0.05	0.31	0.20	12	0.08
TP	Total phosphorus	g/m^3P	0.026	0.060	0.039	12	0.013
TURBY	Turbidity	NTU	0.3	1.7	0.5	12	0.4

A statistical summary of the 21 years' data collected since 1 July 1995 is presented in Table 11.

Table 11 Statistical summary of data from July 1995 to June 2016: Waiwhakaiho River at SH3

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.005	0.095	0.014	252	0.018
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.022	0.003	252	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.007	0.000	252	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	8	76	49	252	17
BDISC	Black disc transparency	m	0.13	8.05	3.08	252	1.419
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	5.0	<0.5	252	0.6
CONDY	Conductivity @ 20'C	mS/m	3.4	17.4	12.2	252	3.3
DO	Dissolved Oxygen	g/m^3	9.1	12.8	10.8	252	0.7
PERSAT	Dissolved Oxygen Saturation %	%	91	110	100	252	3
DRP	Dissolved reactive phosphorus	g/m^3P	<0.004	0.108	0.024	252	0.012
ECOL	E.coli bacteria	cfu/100 mL	23	56000	200	228	4508
ENT	Enterococci bacteria	cfu/100 mL	<1	33000	97	252	2807
FC	Faecal Coliforms	cfu/100 mL	23	83000	210	252	6760
FLOW	Flow	m^3/s	1.705	83.44	3.741	252	9.901
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.148	0.008	252	0.02
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.010	0.002	252	0.001
NO_3	Nitrate nitrogen	g/m^3N	0.01	0.47	0.11	252	0.11
PH	pH	pH	6.8	8.5	7.9	252	0.3
SS	Suspended solids	g/m^3	<2	89	<2	252	10
TEMP	Temperature	°C	4.8	18.3	11.1	252	2.9
TKN	Total Kjeldahl nitrogen	g/m^3N	0.00	1.95	0.07	251	0.207
TN	Total nitrogen	g/m^3N	0.02	2.10	0.2	251	0.235
TP	Total phosphorus	g/m^3P	0.014	0.437	0.035	252	0.044
TURB	Turbidity (Hach 2100A)	NTU	0.4	26	0.7	245	2.8
TURBY	Turbidity (Cyberscan WTW)	NTU	0.3	35	0.7	133	3.8

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.

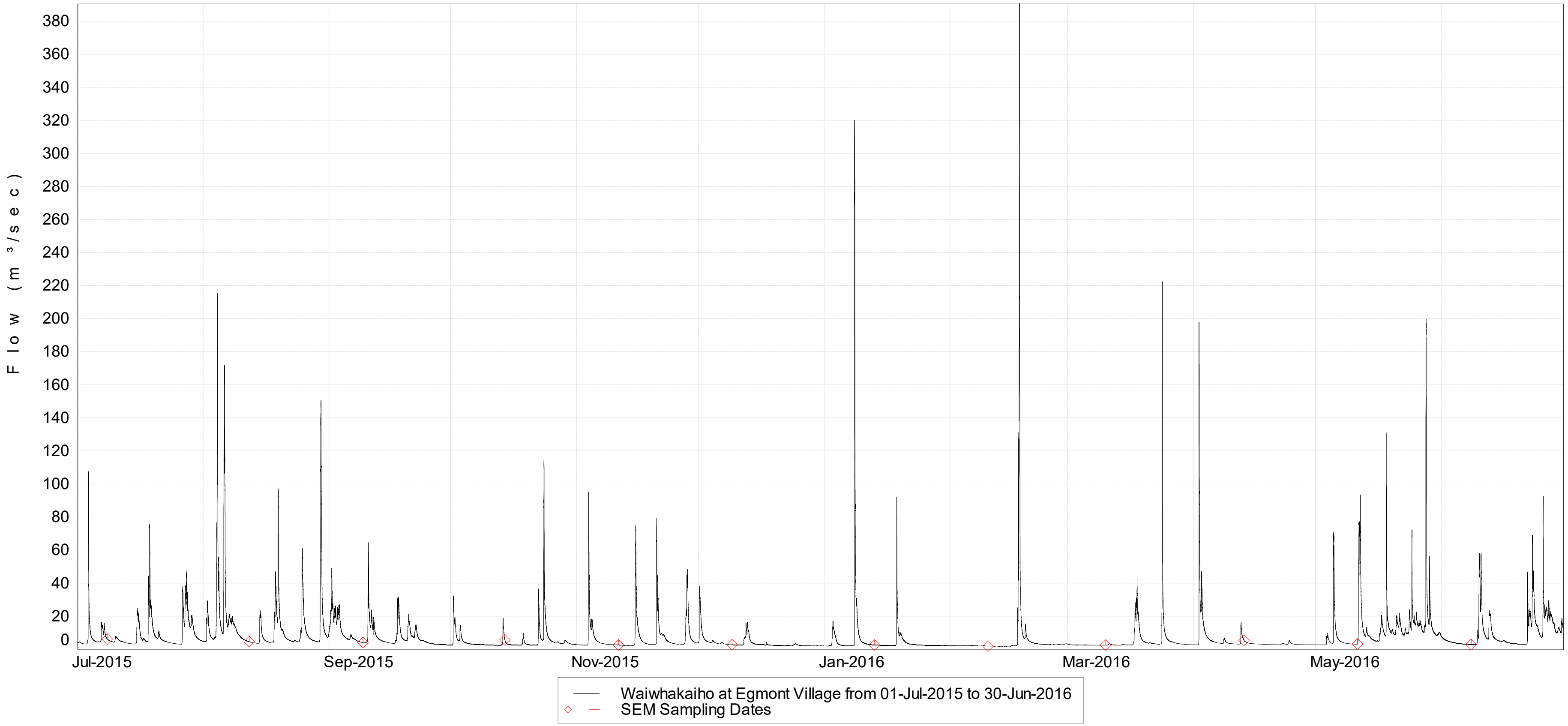


Figure 3 Flow record for the Waiwhakaiho River at SH3 Egmont Village

Discussion

2015-2016 period

During the 2015-2016 period there was no re-occurrence of the severe orange discolouration of the river which occurred in November 2013 when an iron-oxide laden seepage discharge from the Kokowai Stream entered the main river within the National Park. Discolouration had extended downstream beyond the mid reaches, but the river cleared within a few days of this event (TRC, 2014.) [Note: Similar events had occurred in the past (e.g. 1975) but none had been recorded since the inception of the SEM programme in mid-1995].

During the 2015-2016 period, black disc clarity and turbidity results indicated relatively good water quality in terms of appearance, particularly for the mid reaches of a developed ringplain agricultural catchment. This was emphasised by median black disc and turbidity values of 3.20 m and 0.5 NTU respectively. The maximum black disc value (5.65 m) was recorded in late winter moderate flow conditions (4.63 m^3/sec) (Figure 4), with the worst conditions (black disc clarity of 0.96 m) during a fresh in April 2016 when the turbidity increased noticeably (1.0 NTU) with negligible change in suspended solids concentration (<2 g/m^3). Generally, poorer water quality was recorded at the time of this fresh flow and in October 2015 when elevated faecal coliform bacterial numbers (1,900 and 2,500 cfu/100 mL, respectively) and increased colour (absorbances @ 340 nm and 440 nm), together with decreased clarity and conductivity, were recorded.

A maximum pH value of 8.2 was recorded under low flow conditions in mid summer, with values of ≥7.8 units on eight occasions throughout 2015-2016. pH values could be expected to have risen further later in the day, as all sampling at this site was undertaken no later than 0920 hrs.

Very good water quality was indicated by high dissolved oxygen concentrations (median saturation of 103%) and low BOD_5 levels (median of < 0.5 g/m^3). Bacteriological quality was moderate, with median faecal coliform and enterococci numbers (200 and 97 per 100 mLs, respectively) typically reflecting agricultural catchment influences in the relative infrequency of freshes during, or immediately prior to, sampling surveys during 2015-2016.

River water temperatures recorded a moderate range of 11.8 °C during the period with a maximum mid-morning water temperature of 17.7 °C recorded in February 2016 during a lengthy period of low flow conditions.

Brief comparison with the previous 1995-2015 period

River water quality measured by the 2015-2016 survey in many aspects was generally better than that recorded over the previous 20-year period. Median black disc clarity was higher (by 0.12 m) with median turbidity lower by 0.2 NTU, but median suspended solids levels were identical between periods. Bacteriological water quality was the same in terms of both median faecal coliform and enterococci numbers. A moderate range of water temperatures (11.8 °C) was recorded in the most recent twelve-month period. Median water temperature was 1.4 °C higher in the most recent period while the maximum temperature was 0.6 °C lower than that recorded during the previous twenty years.

Median sampled flow over the 2015-2016 period was significantly lower (by 724 L/s, or 19%) than for the flows sampled in the previous 20-year period, with an absence of samplings near floods and one sampling at less than mean annual low flow.

Median concentrations for nitrogen nutrient species were slightly higher or similar in the 2015-2016 period to those in the longer period while there were small increases in the median phosphorus species in the more recent period.

No significant differences were recorded in terms of the medians of BOD_5 and percentage dissolved oxygen between the two periods although the latter was higher by 3% over the most recent period.

Stony River at Mangatete Road (site: STY000300)

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

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

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m³ $CaCO_3$	m	g/m³	mS/m	g/m³	%	g/m³P	cfu/100mL	cfu/100mL
08-Jul-2015	1015	0.010	0.002	0.000	28	0.71	<0.5	7.9	11.9	101	0.018	12	5
12-Aug-2015	1015	0.013	0.003	0.000	38	1.01	<0.5	9.9	12.3	102	0.020	1	<1
09-Sep-2015	1005	0.007	0.001	0.000	37	6.03	<0.5	9.5	11.5	101	0.019	1	1
14-Oct-2015	0905	0.020	0.004	0.000	26	2.03	<0.5	7.0	11.4	102	0.014	9	4
11-Nov-2015	0900	0.006	0.001	0.000	45	4.96	0.2	11.3	10.6	102	0.026	20	3
09-Dec-2015	0900	0.007	0.001	0.000	42	4.94	<0.5	10.7	10.3	99	0.019	1	8
13-Jan-2016	0915	0.007	0.001	0.000	49	7.15	<0.5	10.8	10.5	106	0.024	4	5
10-Feb-2016	0940	0.006	0.001	0.000	54	5.36	0.6	12.6	9.6	100	0.022	23	160
10-Mar-2016	0930	0.004	0.001	0.000	49	1.01	<0.5	11.6	10.4	101	0.026	12	25
13-Apr-2016	1020	0.023	0.007	0.001	32	0.24	<0.5	8.3	10.3	101	0.028	12	17
11-May-2016	1010	0.008	0.001	0.000	50	1.93	<0.5	11.9	10.3	101	0.028	80	83
08-Jun-2016	1030	0.006	0.002	0.000	47	1.26	<0.5	11.7	11.2	99	0.022	5	1
Date	**Time**	**FC**	**Flow**	**NH_4**	**NO_2**	**NO_3**	**pH**	**SS**	**Temp**	**TKN**	**TN**	**TP**	**Turb**
	NZST	cfu/ 100mL	m³/s	g/m³N	g/m³N	g/m³N	pH	g/m³	°C	g/m³N	g/m³N	g/m³P	NTU
08-Jul-2015	1015	12	5.740	0.004	<0.001	0.05	7.6	24	7.3	0.00	0.05	0.029	11
12-Aug-2015	1015	1	4.251	<0.003	<0.001	0.06	7.4	14	6.8	0.02	0.08	0.079	7.7
09-Sep-2015	1005	3	4.379	<0.003	<0.001	0.04	7.7	<2	9.2	0.03	0.07	0.022	0.8
14-Oct-2015	0905	9	6.569	0.003	<0.001	<0.01	7.7	2	9.7	0.06	0.07	0.018	2.0
11-Nov-2015	0900	20	3.009	0.003	<0.001	0.03	8.0	<2	12.2	0.04	0.07	0.027	0.4
09-Dec-2015	0900	1	3.630	0.007	<0.001	0.02	7.9	<2	12.4	0.07	0.09	0.024	0.5
13-Jan-2016	0915	4	2.939	<0.003	<0.001	0.03	8.0	<2	14.4	0.02	<0.05	0.024	0.4
10-Feb-2016	0940	23	2.078	0.011	<0.001	<0.01	8.0	<2	16.5	0.04	<0.05	0.029	1.5
10-Mar-2016	0930	12	2.563	0.003	<0.001	0.04	8.0	5	13.8	0.01	<0.05	0.031	2.0
13-Apr-2016	1020	12	4.181	<0.003	0.001	0.02	7.8	250	12.8	0.04	0.06	0.277	76
11-May-2016	1010	83	2.930	0.007	<0.001	0.04	7.9	6	13.3	0.01	<0.05	0.040	3.3
08-Jun-2016	1030	5	2.359	0.004	<0.001	0.06	8.0	6	9.6	0.05	0.11	0.027	5.6

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

Table 13 Statistical summary of data from July 2015 to July 2016 Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.004	0.023	0.007	12	0.006
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.007	0.001	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m³ $CaCO_3$	26	54	44	12	9.0
BDISC	Black disc transparency	m	0.24	7.15	1.98	12	2.44
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	0.6	<0.5	12	<0.5
CONDY	Conductivity @ 20˚C	mS/m	7.0	12.6	10.8	12	1.8
DO	Dissolved oxygen	g/m³	9.6	12.3	10.6	12	0.8
PERSAT	Dissolved oxygen saturation %	%	99	106	101	12	2
DRP	Dissolved reactive phosphorus	g/m³P	0.014	0.028	0.022	12	0.004
ECOL	E.coli bacteria	cfu/100 mL	1	80	10	12	22
ENT	Enterococci bacteria	cfu/100 mL	<1	160	5	12	48
FC	Faecal coliforms	cfu/100 mL	1	83	10	12	22
FLOW	Flow	m³/s	2.078	6.569	3.320	12	1.374
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.011	0.003	12	0.003
NO_2	Nitrite nitrogen	g/m³N	<0.001	<0.001	<0.000	12	0.000
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.06	0.03	12	0.02
pH	pH		7.4	8.0	7.9	12	0.2
SS	Suspended solids	g/m³	<2	250	4	12	71
TEMP	Temperature	°C	6.8	16.5	12.3	12	3
TKN	Total kjeldahl nitrogen	g/m³N	0.00	0.07	0.04	12	0.02
TN	Total nitrogen	g/m³N	0.05	0.11	0.06	12	0.02
TP	Total phosphorus	g/m³P	0.018	0.277	0.028	12	0.073
TURB	Turbidity	NTU	0.4	76	2.0	12	21

A statistical summary of the 21 years' data collected since 1 July 1995 is presented in Table 14.

Table 14 Statistical summary of data from July 1995 to June 2016: Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.000	0.077	0.008	252	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.028	0.002	252	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.007	0.000	252	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	5	57	39	252	12
BDISC	Black disc transparency	m	<0.01	13.12	3.24	252	2.72
BOD_5	Biochemical oxygen demand 5day	g/m³	0.2	1.8	0.2	252	0.1
CONDY	Conductivity @ 20˚C	mS/m	2.8	13.3	9.7	252	2.4
DO	Dissolved oxygen	g/m³	9.4	12.3	10.7	252	0.6
PERSAT	Dissolved oxygen saturation %	%	87	106	99	252	2
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.210	0.018	228	0.014
ECOL	E.coli bacteria	cfu/100 mL	<1	950	8	252	103
ENT	Enterococci bacteria	cfu/100 mL	<1	870	5	252	73
FC	Faecal coliforms	cfu/100 mL	<1	1000	8	252	105
FLOW	Flow	m³/s	1.988	55.504	3.592	252	7.568
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.020	0.003	252	0.003
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.004	<0.001	252	0
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.11	0.02	254	0.02
pH	pH		7.0	8.2	7.8	252	0.2
SS	Suspended solids	g/m³	<2	2500	<2	252	305
TEMP	Temperature	°C	5.7	16.6	10.8	252	2.5
TKN	Total kjeldahl nitrogen	g/m³N	0.00	1.78	0.04	252	0.16
TN	Total nitrogen	g/m³N	0.02	1.82	0.06	252	0.16
TP	Total phosphorus	g/m³P	0.008	3.38	0.024	252	0.297
TURB	Turbidity (Hach 2100A)	NTU	0.2	700	0.75	245	66
TURBY	Turbidity (Cyberscan WTW)	NTU	0.24	1400	1.5	133	170

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

2015-2016

Black disc clarity and turbidity results, which more often in the past have indicated generally good river water quality in terms of appearance for the mid-reaches of a Taranaki ring plain river, have also showed significant deterioration in aesthetic quality from time to time as a result of severe erosion in the headwaters of this river during winter and spring floods in 1998-1999 and again following an intensive, prolonged wet period in February 2004. Some improvement occurred in 2004-2005 and continued through most of the 2005-2006 period but conditions deteriorated markedly following the very wet spring conditions in 2006, near mid winter 2008, and in mid winter 2009. No significant headwater erosion events were identified over the 2009-2010 period, but headwater erosion was recorded again in late May - early June 2011. Further erosion events in the headwaters were recorded during a dry period in February 2014 (see Photo 3, TRC 2014). Some headwater erosion was indicated after a flood event on 17/18 February 2016, for the remainder of the monitoring period. The minimum black disc value (0.24) and maximum turbidity (76 NTU) and suspended solids (250 g/m^3) values were recorded during a subsequent relatively small fresh (4.2 m^3/sec) in April 2016. Generally, wet weather and fresh flow conditions did not result in changes in nutrient or bacterial levels to the extent found in other monitored ringplain streams, with the exception of total phosphorus, which increased to a greater degree in particulate form (maximum of 0.28 g/m^3P). The maximum black disc clarity of 7.15 m was measured in mid-summer under low flow conditions coincident with the very low suspended solids and turbidity (0.4 NTU) levels.

Maximum mid-morning pH (8.0) occurred under spring and summer relatively low flow conditions while the median pH (7.8) was equivalent with the median of past years' results. Dissolved oxygen concentrations were consistently high with a minimum saturation of 99%, and BOD_5 levels were below the detectable limit on all but one occasion (0.6 g/m^3); a further indication of high water quality when not influenced by severe erosion events.

Bacteriological water quality was very high, with median faecal coliform and enterococci numbers (10 and 5 cfu/100 mL, respectively) indicative of minimal impact of upstream developed farmland at this site near mid-catchment.

River water temperatures varied over a moderate range of 9.7 °C during the period, with a maximum mid-morning temperature of 16.5 °C recorded in late summer (February 2016) under low flow conditions.

Nutrient levels were generally very low in terms of median ammoniacal nitrogen, nitrate-N, and dissolved reactive phosphorus concentrations. Total nitrogen and total phosphorus concentrations were also relatively low throughout the year, with the exception of elevation in TP at the time of the April 2016 fresh event coincident with increased suspended solids concentrations.

Brief comparison with the previous 1995-2015 period

Water quality measured during the 2015-2016 survey period, in comparison with the previous 20 years' survey results, was poorer aesthetically in terms of median black disc clarity (which was lower by 1.27 m), median turbidity (higher by 0.8 NTU), and suspended solids level which was higher (by >2 g/m^3) than the historical median.

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

Water temperature range was narrower (by 1.2 °C), mainly due to a higher minimum temperature during 2015-2016, with the median value higher (by 1.5 °C) in the 2015-2016 period than that in the earlier 20-year period. For nutrient species, nitrate was higher than the previous longer period median (by 70%), though still relatively low at 0.06 g/m^3; TN was the same; and DRP and TP were higher (by 22 and 17%, respectively).

Median sampled flow during the 2015-2016 period was lower (by 0.27 m^3/sec, or 8%) than the median of flows sampled over the previous 20-year period, with a few freshes and no flood events and a relatively lengthy mid-summer early autumn low flow period sampled in 2015-2016. The lower median flows surveyed in 2015-2016 were reflected in the higher median conductivity value (by 11%).

Punehu Stream at Wiremu Road (site: PNH000200)

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

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

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD$_5$	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^{3}P	cfu/100mL	cfu/100mL
08-Jul-2015	1050	0.041	0.008	0.000	15	1.45	<0.5	8.7	11.8	101	0.014	90	17
12-Aug-2015	1055	0.031	0.007	0.001	17	2.07	<0.5	9.0	12.1	102	0.012	8	3
09-Sep-2015	1045	0.032	0.007	0.000	21	2.36	<0.5	8.6	11.2	101	0.016	11	1
14-Oct-2015	0950	0.049	0.013	0.001	16	1.53	<0.5	7.3	11.0	102	0.018	88	19
11-Nov-2015	0930	0.027	0.006	0.000	25	2.29	0.5	9.1	10.2	102	0.024	54	7
09-Dec-2015	0940	0.023	0.005	0.000	26	2.29	0.6	9.0	10.2	100	0.028	56	4
13-Jan-2016	0955	0.020	0.005	0.000	26	3.02	<0.5	8.4	9.6	102	0.032	70	11
10-Feb-2016	1015	0.018	0.004	0.000	26	3.92	<0.5	8.6	9.4	103	0.035	90	380
10-Mar-2016	1005	0.015	0.003	0.000	25	2.28	<0.5	8.2	9.9	102	0.04	260	170
13-Apr-2016	1055	0.072	0.015	0.001	10	1.14	<0.5	9.7	9.9	100	0.014	130	130
11-May-2016	1050	0.020	0.004	0.000	25	2.68	<0.5	9.1	10.4	105	0.032	23	43
08-Jun-2016	1100	0.021	0.005	0.000	19	1.46	<0.5	10.0	11.7	100	0.016	12	70

Date	Time	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
	NZST	cfu/ 100mL	m^3/s	g/m^{3}N	g/m^{3}N	g/m^{3}N	pH	g/m^3	°C	g/m^{3}N	g/m^{3}N	g/m^{3}P	NTU
08-Jul-2015	1050	90	0.94	0.034	0.002	0.11	7.3	4	7.2	0.17	0.28	0.032	4.3
12-Aug-2015	1055	8	0.514	0.019	<0.001	0.15	7.2	<2	7.0	0.02	0.17	0.028	3.0
09-Sep-2015	1045	11	0.503	0.013	0.001	0.07	7.5	<2	9.8	0.07	0.14	0.024	2.8
14-Oct-2015	0950	88	0.540	0.004	<0.001	<0.01	7.6	<2	10.7	0.11	0.12	0.021	1.9
11-Nov-2015	0930	54	0.398	0.012	<0.001	0.02	7.7	<2	13.9	0.03	<0.05	0.028	2.0
09-Dec-2015	0940	88	0.327	0.010	<0.001	0.01	7.7	<2	12.8	0.09	0.10	0.050	3.8
13-Jan-2016	0955	76	0.228	0.006	<0.001	<0.01	7.8	<2	16.8	0.06	0.07	0.045	1.2
10-Feb-2016	1015	91	0.230	0.007	<0.001	<0.01	7.9	<2	18.3	0.04	<0.05	0.048	1.6
10-Mar-2016	1005	260	0.192	0.005	<0.001	<0.01	7.8	<2	16.0	0.04	<0.05	0.046	0.7
13-Apr-2016	1055	130	1.042	0.028	0.004	0.28	7.3	2	13.7	0.09	0.37	0.035	2.4
11-May-2016	1050	28	0.223	0.008	<0.001	0.02	7.9	<2	13.9	0.03	<0.05	0.034	1.2
08-Jun-2016	1100	12	0.384	0.017	<0.001	0.10	7.6	<2	7.4	0.05	0.15	0.021	3.7

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

Table 16 Statistical summary of data from July 2015 to June 2016 Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.015	0.072	0.025	12	0.016
A440F	Absorbance @ 440nm filtered	/cm	0.003	0.015	0.006	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	10	26	23	12	5
BDISC	Black disc transparency	m	1.14	3.92	2.28	12	0.78
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	0.6	<0.5	12	<0.5
CONDY	Conductivity @ 20˚C	mS/m	7.3	10.0	8.8	12	0.7
DO	Dissolved oxygen	g/m^3	9.4	12.1	10.3	12	0.9
PERSAT	Dissolved oxygen saturation %	%	100	105	102	12	1
DRP	Dissolved reactive phosphorus	g/m^3P	0.012	0.040	0.021	12	0.010
ECOL	E.coli bacteria	cfu/100 mL	8	260	63	12	70
ENT	Enterococci bacteria	cfu/100 mL	1	380	18	12	112
FC	Faecal coliforms	cfu/100 mL	8	260	82	12	70
FLOW	Flow	m^3/s	0.192	1.042	0.391	12	0.277
NH_4	Ammoniacal nitrogen	g/m^3N	0.004	0.034	0.011	12	0.009
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.004	<0.001	12	0.001
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.28	0.02	12	0.08
pH	pH		7.2	7.9	7.6	12	0.2
SS	Suspended solids	g/m^3	<2	4	<2	12	1
TEMP	Temperature	°C	7.0	18.3	13.2	12	3.9
TKN	Total kjeldahl nitrogen	g/m^3N	0.02	0.17	0.06	12	0.04
TN	Total nitrogen	g/m^3N	<0.05	0.37	0.11	12	0.10
TP	Total phosphorus	g/m^3P	0.021	0.050	0.033	12	0.011
TURBY	Turbidity	NTU	0.7	4.3	2.2	12	1.2

A statistical summary of the 21 years' data collected since 1 July 1995, is presented in Table 17.

Table 17 Statistical summary of data from July 1995 to July 2016: Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.015	0.144	0.032	252	0.023
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.032	0.007	252	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.005	0.000	252	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	6	27	22	252	5
BDISC	Black disc transparency	m	0.08	4.53	1.825	252	0.869
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	3.0	<0.5	252	0.3
CONDY	Conductivity @ 20˚C	mS/m	4.0	10.9	8.6	252	1.2
DO	Dissolved oxygen	g/m^3	8.9	12.5	10.4	251	0.8
PERSAT	Dissolved oxygen saturation %	%	87	106	100	251	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.007	0.389	0.023	252	0.025
ECOL	E.coli bacteria	cfu/100 mL	3	6100	100	228	810
ENT	Enterococci bacteria	cfu/100 mL	<1	1200	33	252	159
FC	Faecal coliforms	cfu/100 mL	3	6100	120	252	827
FLOW	Flow	m^3/s	0.18	12.38	0.436	252	1.096
NH_4	Ammoniacal nitrogen	g/m^3N	0.002	0.078	0.006	252	0.01
NO_2	Nitrite nitrogen	g/m^3N	0.001	0.014	0.001	252	0.001
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.28	0.03	252	0.04
pH	pH		6.9	8.3	7.6	252	0.2
SS	Suspended solids	g/m^3	<2	160	<2	252	12
TEMP	Temperature	°C	5.0	19.2	11.8	252	3.3
TKN	Total kjeldahl nitrogen	g/m^3N	0.01	0.85	0.09	252	0.122
TN	Total nitrogen	g/m^3N	<0.05	0.87	0.145	252	0.135
TP	Total phosphorus	g/m^3P	0.015	0.413	0.034	252	0.038
TURB	Turbidity (Hach 2100A)	NTU	0.45	29	1.7	245	3.1
TURBY	Turbidity (Cyberscan WTW)	NTU	0.46	28	2.4	133	3.8

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

2015-2016

Although black disc clarity and turbidity results were indicative of relatively good water quality in terms of aesthetic appearance, these values continued to be poorer than might be anticipated for the upper reaches of a ring plain stream, i.e. medians of 2.28 m (black disc) and 2.2 NTU (turbidity). This was related to the open nature of the reaches of both the stream and the upstream tributary draining developed farmland catchment immediately downstream of the National Park through the 2 km reach upstream of this site. This area had also been subject to stock access in the past (see photos in TRC 2000 and 2011) although in recent years the banks have been fenced and planted in the immediate vicinity of the site.

Minimum black disc clarity (1.14 m) was recorded during a flood recession in April 2016, coincidental with a minor increase in suspended solids concentration (2 g/m^3) and increase in turbidity (2.4 NTU). The highest recorded nitrate concentration (0.28 g/m^3N) occurred during this event. A maximum black disc value of 3.92 m was measured under low flow conditions in late summer (February 2016).

The maximum pH (7.9) was also recorded (in mid morning) in late summer, under low flow conditions (230 L/s).

Dissolved oxygen concentrations were consistently high (100 to 105% saturation for the period) and BOD_5 levels were very low and less than 0.5 g/m^3 on the majority of occasions, with a maximum of 0.6 g/m^3; further indications of generally high water quality.

A moderate median faecal coliform bacterial count for the upper reaches of a ring plain stream (63 cfu/100 mL) indicated some impacts of upstream farmland run-off (and possible stock access) on stream water quality at this site, and represented some deterioration below the National Park boundary in this aspect of water quality. Surface runoff from surrounding farmland has been a common feature in the past in this reach of the stream and two moderate freshes and a flood were sampled during the 2015-2016 period, similar to many previous periods, resulting in a relatively typical median for the latest period.

Water temperatures varied over a relatively wide range (11.3 °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 18.3 °C was recorded in February 2016, relatively high for the upper reaches of a ring plain stream at this time of the day (1015 hrs).

Brief comparison with the previous 1995-2015 period

Stream water quality measured during the 2015-2016 period was marginally better or similar in terms of median turbidity (which was lower by 0.2 NTU) and median black disc clarity (which was higher by 0.47 m) than the previous overall record. Median suspended solids concentration remained low and in the recent year was equivalent with the median of the previous 20-year period. Median dissolved oxygen percentage saturation levels were very similar (within 2%) for the two periods.

Bacteriological water quality was better over the most recent period in terms of median faecal coliform number (by 19 cfu/100 mL) and median number of enterococci (by 10 cfu/100 mL). The relative median nitrogen species concentrations varied between the periods, recent nitrate and total nitrogen values being lower, and recent ammonia higher. Total and dissolved phosphorus median values in the recent year were similar to those for the long-term record.

The water temperature range was narrower (by 2.9 °C) compared with surveys prior to the latest twelve-month period; with the median flow sampled lower by 46 L/s, or 11%, in the 2015-2016 period.

Median pH values were within 0.1 unit during the two sampling periods but the maximum pH was 0.4 unit lower than the maximum recorded in the previous 20-year period.

Punehu Stream at SH45 (site: PNH000900)

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

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

Date	Time NZST	A340F /cm	A440F /cm	A770F /cm	ALKT g/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 cfu/100mL	ENT cfu/100mL
08-Jul-2015	1115	0.033	0.006	0.000	28	0.93	1.1	20.0	11.5	100	0.028	340	190
12-Aug-2015	1120	0.029	0.005	0.000	34	1.81	<0.5	22.9	11.9	101	0.025	360	37
09-Sep-2015	1110	0.028	0.005	0.000	34	2.11	<0.5	19.6	11.1	101	0.032	450	54
14-Oct-2015	1015	0.039	0.008	0.000	29	1.6	2.0	14.8	10.9	102	0.039	610	1000
11-Nov-2015	0955	0.033	0.007	0.000	38	1.88	2.0	17.9	10.1	100	0.070	560	110
09-Dec-2015	1015	0.032	0.007	0.000	40	1.98	0.5	17.1	10.1	100	0.053	200	120
13-Jan-2016	1025	0.038	0.008	0.000	39	2.32	0.9	14.8	9.4	99	0.065	700	1200
10-Feb-2016	1030	0.041	0.008	0.000	41	3.65	0.7	14.3	9.1	101	0.054	730	3000
10-Mar-2016	1030	0.039	0.008	0.000	39	1.92	0.6	13.8	9.7	102	0.052	1000	4400
13-Apr-2016	1135	0.082	0.017	0.001	14	0.60	0.8	11.3	9.9	100	0.026	760	2100
11-May-2016	1115	0.033	0.006	0.000	37	2.56	<0.5	13.8	10.2	103	0.031	1100	2700
08-Jun-2016	1130	0.025	0.005	0.000	29	1.84	<0.5	17.7	12.0	100	0.028	230	120

Date	Time NZST	FC cfu/100mL	Flow m^3/s	NH_4 g/m^3N	NO_2 g/m^3N	NO_3 g/m^3N	pH pH	SS g/m^3	Temp °C	TKN g/m^3N	TN g/m^3N	TP g/m^3P	Turb NTU
08-Jul-2015	1115	340	2.573	0.078	0.016	2.98	7.4	10	9.0	0.13	3.13	0.054	4.8
12-Aug-2015	1120	380	1.818	0.106	0.013	3.79	7.2	3	8.5	0.50	4.30	0.054	3.0
09-Sep-2015	1110	450	1.321	0.064	0.020	2.48	7.6	2	11.1	0.37	2.87	0.048	2.0
14-Oct-2015	1015	610	1.245	0.102	0.044	1.28	7.6	3	12.4	0.47	1.79	0.072	4.7
11-Nov-2015	0955	560	0.754	0.058	0.034	1.22	7.8	<2	14.9	0.51	1.76	0.095	1.9
09-Dec-2015	1015	200	0.535	0.022	0.012	0.90	7.8	<2	14.8	0.20	1.11	0.071	1.4
13-Jan-2016	1025	720	0.342	0.032	0.011	0.62	7.8	<2	17.8	0.03	0.66	0.088	1.4
10-Feb-2016	1030	730	0.287	0.006	0.003	0.24	7.8	<2	20.1	0.11	0.35	0.078	1.7
10-Mar-2016	1030	1000	0.257	0.014	0.002	0.23	7.7	2	17.9	0.10	0.33	0.063	1.4
13-Apr-2016	1135	760	1.550	0.032	0.005	0.45	7.3	5	14.7	0.22	0.68	0.059	3.8
11-May-2016	1115	1100	0.306	0.015	0.002	0.14	7.8	<2	15.5	0.07	0.21	0.039	0.9
08-Jun-2016	1130	230	0.709	0.031	0.005	1.68	7.6	2	7.8	0.07	1.76	0.038	1.8

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

Table 19 Statistical summary of data from July 2015 to June 2016 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.025	0.082	0.033	12	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.005	0.017	0.007	12	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	14	41	36	12	8
BDISC	Black disc transparency	m	0.60	3.65	1.90	12	0.77
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	2.0	0.6	12	0.6
CONDY	Conductivity @ 20'C	mS/m	11.3	22.9	16.0	12	3.3
DO	Dissolved Oxygen	g/m^3	9.1	12.0	10.2	12	1.0
PERSAT	Dissolved Oxygen Saturation %	%	99	103	100	12	1
DRP	Dissolved reactive phosphorus	g/m^3P	0.025	0.070	0.036	12	0.016
ECOL	E.coli bacteria	cfu/100 mL	200	1100	585	12	287
ENT	Enterococci bacteria	cfu/100 mL	37	4400	595	12	1469
FC	Faecal Coliforms	cfu/100 mL	200	1100	585	12	286
FLOW	Flow	m^3/s	0.257	2.573	0.732	12	0.735
NH_4	Ammoniacal nitrogen	g/m^3N	0.006	0.106	0.032	12	0.034
NO_2	Nitrite nitrogen	g/m^3N	0.002	0.044	0.012	12	0.013
NO_3	Nitrate nitrogen	g/m^3N	0.14	3.79	1.06	12	1.19
PH	pH		7.2	7.8	7.6	12	0.2
SS	Suspended solids	g/m^3	<2	10	2	12	2
TEMP	Temperature	°C	7.8	20.1	14.8	12	4
TKN	Total Kjeldahl nitrogen	g/m^3N	0.03	0.51	0.16	12	0.18
TN	Total nitrogen	g/m^3N	0.21	4.30	1.44	12	1.29
TP	Total phosphorus	g/m^3P	0.038	0.095	0.061	12	0.018
TURBY	Turbidity	NTU	0.9	4.8	1.85	12	1.3

A statistical summary of the 21 years' data collected since 1 July 1995, is presented in Table 20.

Table 20 Statistical summary of data from July 1995 to June 2016 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.015	0.115	0.039	252	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.027	0.008	252	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.006	0.000	252	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	10	46	34	252	7
BDISC	Black disc transparency	m	0.055	3.65	1.54	252	0.694
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	8.1	1	252	0.9
CONDY	Conductivity @ 20'C	mS/m	5.8	22.9	16	252	2.4
DO	Dissolved Oxygen	g/m^3	8.6	12.8	10.4	252	0.8
PERSAT	Dissolved Oxygen Saturation %	%	90	114	99	252	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.013	0.212	0.044	252	0.027
ECOL	E.coli bacteria	cfu/100 mL	48	21000	495	226	2498
ENT	Enterococci bacteria	cfu/100 mL	15	14000	320	251	1525
FC	Faecal Coliforms	cfu/100 mL	51	21000	520	252	2752
FLOW	Flow	m^3/s	0.242	12.3	0.798	252	1.527
NH_4	Ammoniacal nitrogen	g/m^3N	0.004	0.376	0.04	252	0.06
NO_2	Nitrite nitrogen	g/m^3N	0.001	0.110	0.014	252	0.015
NO_3	Nitrate nitrogen	g/m^3N	0.07	3.79	0.93	252	0.71
PH	pH		7.1	8.6	7.7	252	0.2
SS	Suspended solids	g/m^3	<2	220	3	252	20
TEMP	Temperature	°C	5.0	21.0	13.3	252	3.5
TKN	Total Kjeldahl nitrogen	g/m^3N	0.03	1.99	0.32	252	0.27
TN	Total nitrogen	g/m^3N	0.21	4.30	1.38	252	0.80
TP	Total phosphorus	g/m^3P	0.026	0.531	0.078	252	0.06
TURB	Turbidity (Hach 2100A)	NTU	0.8	50	1.9	245	4.9
TURB	Turbidity (Cyberscan WTW)	NTU	0.8	49	2.3	133	6.3

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

2015-2016 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.90 m, this clarity being typical of the lower reaches of developed ringplain catchments. A median suspended solids concentration of 2 g/m^3 and turbidity of 1.8 NTU was also more typical of the lower reaches of a ring plain catchment. Minimum clarities (black disc values of 0.93 and 0.60 m, turbidities of 4.8 and 3.8 NTU, and suspended solids concentrations of 10 and 5 g/m^3) were recorded during freshes in July 2015 and April 2016.

Nitrate concentration and conductivity were elevated in winter and early spring, to the highest levels recorded (3.8 $g/m^3 NO_3$-N; 22.9 mS/m at 20°C) whereas the highest phosphorus concentrations occurred in late spring and summer under lower flows.

pH range was narrow, with the maximum value of 7.8 recorded on five occasions between November and May under low flow conditions, but these values were recorded in late morning and would be expected to have reached a higher level later in the day. These values were up to 0.8 unit lower than the maximum recorded previously at a similar time of the day.

Although dissolved oxygen concentrations remained consistently high (minimum of 99% saturation), BOD_5 concentrations often indicated low levels of organic enrichment (ie $\geq$1 g/m^3).

The high median bacteriological numbers (595 enterococci and 585 faecal coliform cfu/100 mL) were further indicative of the impacts of developed farmland run-off and point source discharges on the water quality of the lower reaches of a ring plain catchment. The wide range of faecal coliform numbers (200 to 1,100 cfu/100 mL) found during spring to autumn lower flow conditions was indicative of point source discharges of pond system treated dairy sheds' wastes and/or stock access (see TRC, 2011). Relatively high median nutrient levels were consistent with such impacts.

Water temperature varied over a moderate range of 12.3 ˚C with a maximum summer (late morning) temperature of 20.1 ˚C recorded in February 2016 and the lowest temperature (7.8 ˚C) recorded in June 2016; the former 0.9 ˚C below the previous maximum temperature and the latter 2.8˚C above the previous minimum temperature.

Brief comparison of upper and lower Punehu Stream sites during the 2015-2016 period

Downstream deterioration in certain aspects of water quality in the lower stream reaches was emphasised by a very significant increase in median bacteriological numbers (503 faecal coliforms cfu/100 mL and 577 enterococci cfu/100 mL), and median nutrient concentrations (particularly nitrogen species), with nitrate, total nitrogen, and total phosphorus increasing by factors of about 56, 13, and 1.8 times respectively. These downstream spatial trends may be compared with median 21-year historical data which indicate bacterial increases of 400 cfu/100 mL (faecal coliforms) and 287 cfu/100 mL (enterococci) and increases in nitrate, total nitrogen, and total phosphorus of 32, 10, and 2 times respectively. Relatively similar median (2015-2016) turbidity levels were found, with a significant increase in suspended solids and decrease in median black disc clarity (32% reduction) between sites compared with the historical median turbidity decrease of only 0.1 NTU and decrease in median black disc clarity of 0.28 m. Some of these changes are more apparent when mass loadings are calculated, taking into account the increased flow at the lower site (e.g. median flow increased by 84% in the lower reaches of the stream). The downstream water temperature range increased by only 1.8 ˚C while the median increased by only 1.5 ˚C. The long term median pH increased by only 0.1 unit in the lower reaches.

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

Brief comparison with the previous 1995-2015 period

Improved aesthetic water quality was indicated with a decrease in median turbidity (of 0.45 NTU) recorded during the more recent twelve-month survey period, increase in median black disc clarity (of 0.40 m), and reduction in median suspended solids concentration.

In the more recent survey period, a slight deterioration was recorded in median faecal coliform bacterial number (of 70 cfu/100 mL) and a larger increase in median enterococci bacteria number (by 275 cfu/100 mL). For nutrients, a slight deterioration in median concentrations was recorded in all nitrogen species, with ammonia, nitrate N and total nitrogen, increasing by 20%, 14 %, and 4 % of the long term medians, respectively. There was an improvement in phosphorus levels, with lower levels of both the dissolved reactive form (by 18 %) and total phosphorus (by 24 %).

Median dissolved oxygen saturation levels were within 1%, while median BOD_5 level was significantly lower, by 40%, for the most recent period.

There was minimal difference in median pH for 2015-2016, the recent period being 0.1 unit lower, and the maximum pH was 0.8 unit lower in comparison with the previous 20-year period.

Water temperature range was narrower (by 2.7 ˚C); this decrease due to both higher minimum and lower maximum water temperatures (by 2.8 and 0.9˚C) over the recent survey period, with the 2015-2016 median water temperature 1.6 ˚C higher than the median 20-year temperature.

Median sampled flow over the 2015-2016 period was below the median sampled (by 71 L/s) flow for the previous 20-year period.

Waingongoro River at Eltham Road (site: WGG000500)

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

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

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m³ $CaCO_3$	m	g/m³	mS/m	g/m³	%	g/m³P	cfu/100m	cfu/100m
08-Jul-2015	1240	0.013	0.002	0.000	29	1.95	0.5	11.4	11.5	102	0.019	140	37
12-Aug-2015	1245	0.013	0.002	0.000	28	1.30	<0.5	11.6	11.6	103	0.013	66	12
09-Sep-2015	1230	0.012	0.002	0.000	28	2.06	<0.5	11.5	11.3	104	0.015	40	4
14-Oct-2015	1135	0.015	0.003	0.000	33	1.64	0.6	11.7	11.5	111	0.020	68	20
11-Nov-2015	1115	0.020	0.005	0.000	38	1.60	1.1	12.0	10.3	105	0.036	57	12
09-Dec-2015	1130	0.021	0.005	0.000	39	2.09	0.7	11.9	10.4	105	0.036	190	21
13-Jan-2016	1150	0.022	0.006	0.000	37	3.36	0.7	10.5	10.2	108	0.037	230	120
10-Feb-2016	1205	0.027	0.007	0.000	45	2.01	1.3	12.1	10.4	120	0.020	280	250
10-Mar-2016	1145	0.021	0.005	0.000	39	2.08	0.8	11.1	10.0	106	0.017	510	410
13-Apr-2016	1250	0.036	0.008	0.001	29	1.22	1.1	10.2	10.1	102	0.064	930	7600
11-May-2016	1250	0.025	0.005	0.000	40	1.88	0.6	11.9	10.7	107	0.035	170	430
08-Jun-2016	1250	0.013	0.003	0.000	29	2.02	0.6	11.9	11.3	101	0.021	110	43

Date	Time	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
	NZST	cfu/ 100mL	m³/s	g/m³N	g/m³N	g/m³N	pH	g/m³	°C	g/m³N	g/m³N	g/m³P	NTU
08-Jul-2015	1240	140	2.277	0.011	0.005	1.68	7.6	3	8.9	0.30	1.98	0.040	2.1
12-Aug-2015	1245	68	4.101	0.014	0.004	2.21	7.4	5	9.4	0.07	2.28	0.045	3.3
09-Sep-2015	1230	40	2.977	0.013	0.006	1.85	7.7	4	11.0	0.24	2.10	0.029	2.0
14-Oct-2015	1135	68	1.309	0.016	0.012	1.31	8.3	<2	12.7	0.13	1.45	0.035	1.4
11-Nov-2015	1115	57	0.670	0.027	0.009	0.97	8.0	2	14.8	0.31	1.29	0.053	1.5
09-Dec-2015	1130	190	0.471	0.016	0.004	0.69	8.0	2	14.4	0.16	0.85	0.055	1.4
13-Jan-2016	1150	230	0.431	0.012	0.003	0.38	8.1	<2	18.7	0.03	0.41	0.051	1.2
10-Feb-2016	1205	280	0.331	<0.003	0.002	0.13	8.6	<2	21.5	0.08	0.21	0.050	1.3
10-Mar-2016	1145	510	0.386	0.008	0.001	0.23	7.9	<2	17.5	0.12	0.35	0.029	0.7
13-Apr-2016	1250	1000	1.119	0.103	0.022	0.83	7.7	<2	14.0	0.37	1.22	0.105	2.0
11-May-2016	1250	170	0.509	0.009	0.003	0.72	8.0	<2	13.9	0.06	0.78	0.046	1.0
08-Jun-2016	1250	110	2.130	0.023	0.006	1.88	7.7	2	10.0	0.00	1.88	0.037	2.0

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

Table 22 Statistical summary of data from July 2015 to June 2016: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.012	0.036	0.020	12	0.007
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.008	0.005	12	0.002
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m³ $CaCO_3$	28	45	35	12	6
BDISC	Black disc transparency	m	1.22	3.36	1.98	12	0.54
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	1.3	0.6	12	<0.5
CONDY	Conductivity @ 20'C	mS/m	10.2	12.1	11.6	12	0.6
DO	Dissolved Oxygen	g/m³	10.0	11.6	10.6	12	0.6
PERSAT	Dissolved Oxygen Saturation %	%	101	120	105	12	5
DRP	Dissolved reactive phosphorus	g/m³P	0.013	0.064	0.020	12	0.015
ECOL	E.coli bacteria	cfu/100 mL	40	930	155	12	255
ENT	Enterococci bacteria	cfu/100 mL	4	7600	40	12	2164
FC	Faecal coliforms	cfu/100 mL	40	1000	155	12	273
FLOW	Flow	m³/s	0.331	4.101	0.894	12	1.224
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.103	0.014	12	0.027
NO_2	Nitrite nitrogen	g/m³N	0.001	0.022	0.004	12	0.006
NO_3	Nitrate nitrogen	g/m³N	0.13	2.21	0.90	12	0.70
PH	pH		7.4	8.6	8.0	12	0.3
SS	Suspended solids	g/m³	<2	5	<2	12	<2
TEMP	Temperature	°C	8.9	21.5	14	12	3.9
TKN	Total Kjeldahl nitrogen	g/m³N	0.00	0.37	0.12	12	0.12
TN	Total nitrogen	g/m³N	0.21	2.28	1.26	12	0.72
TP	Total phosphorus	g/m³P	0.029	0.105	0.046	12	0.020
TURBY	Turbidity	NTU	0.7	3.3	1.45	12	0.7

A statistical summary of the 21 years' data collected since 1 July 1995, is presented in Table 23.

Table 23 Statistical summary of data from July 1995 to June 2016: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.009	0.100	0.021	252	0.013
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.024	0.005	252	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.003	0.000	252	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	11	49	30	252	7
BDISC	Black disc transparency	m	0.10	4.39	1.705	252	0.803
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	7.3	0.7	252	0.8
CONDY	Conductivity @ 20'C	mS/m	4.6	14.7	11.2	252	1.6
DO	Dissolved Oxygen	g/m³	9.2	13.0	10.6	253	0.7
PERSAT	Dissolved Oxygen Saturation %	%	92	121	103	253	5
DRP	Dissolved reactive phosphorus	g/m³P	0.003	0.146	0.02	252	0.014
ECOL	E.coli bacteria	cfu/100 mL	6	59000	175	228	4060
ENT	Enterococci bacteria	cfu/100 mL	3	7700	100	252	1017
FC	Faecal coliforms	cfu/100 mL	6	100000	190	252	7428
FLOW	Flow	m³/s	0.326	28.797	1.628	252	3.272
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	1.72	0.017	252	0.113
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.033	0.007	252	0.005
NO_3	Nitrate nitrogen	g/m³N	0.13	2.31	1.11	252	0.49
PH	pH		7.1	8.6	7.8	252	0.3
SS	Suspended solids	g/m³	<2	180	3	252	17
TEMP	Temperature	°C	5.6	21.5	12.6	252	3.2
TKN	Total Kjeldahl nitrogen	g/m³N	0.00	2.41	0.2	252	0.29
TN	Total nitrogen	g/m³N	0.21	3.22	1.43	252	0.52
TP	Total phosphorus	g/m³P	0.013	0.829	0.039	252	0.075
TURB	Turbidity (Hach 2100A)	NTU	0.70	36	1.5	245	3.8
TURB	Turbidity (Cyberscan WTW)	NTU	0.62	18	2.0	133	3.1

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

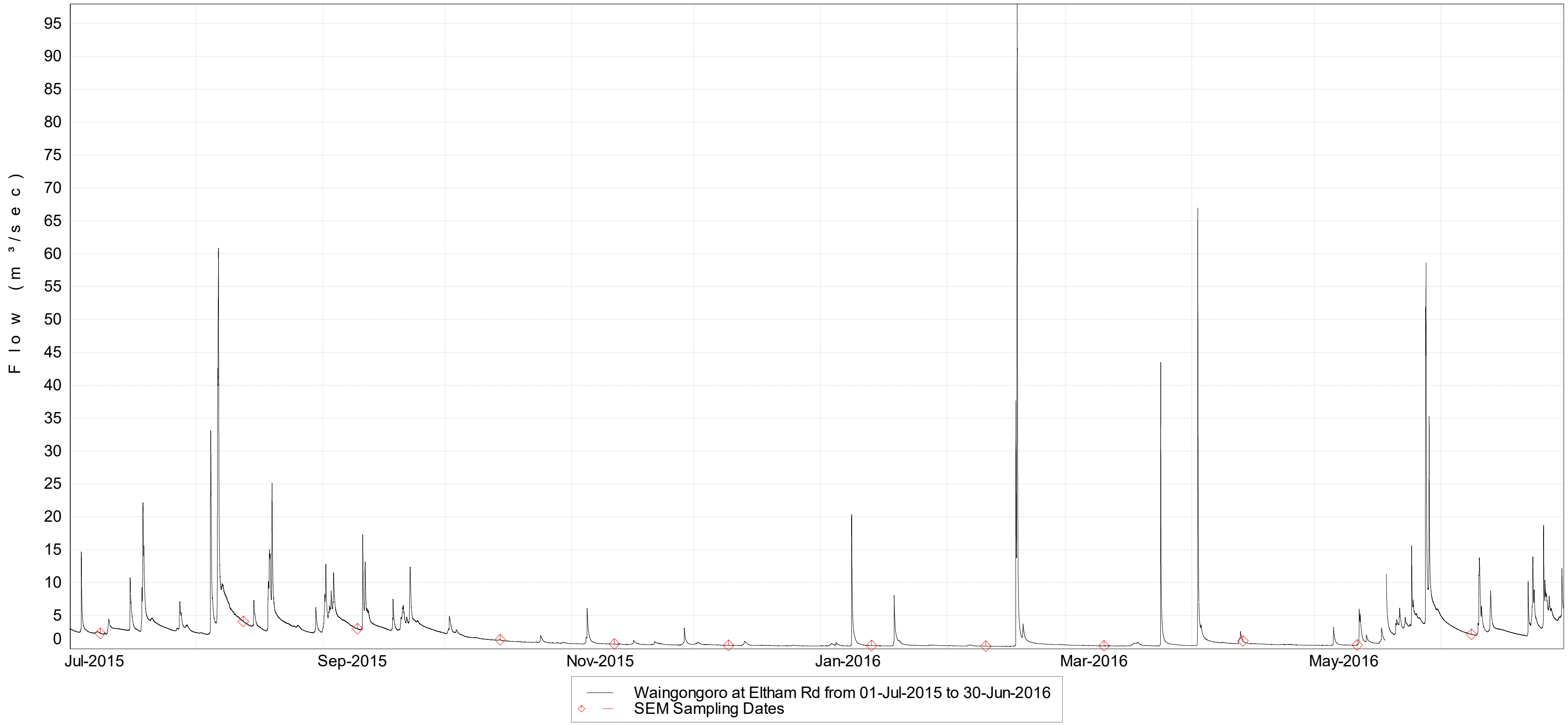


Figure 4 Flow record for the Waingongoro River at Eltham Road

Discussion

2015-2016

Moderate aesthetic water quality (more similar to lower ringplain reaches' aesthetic quality) was indicated by a median black disc clarity of 1.98 m and median turbidity of 1.4 NTU, in the mid-reaches of the longest ring-plain river in Taranaki but recognising that this site (altitude: 200 m asl) is 23 km from the National Park boundary. The maximum clarity (black disc of 3.36 m), 1.03 m lower than the historical maximum, was recorded in mid-summer during a period of very low flow conditions (0.43 m^3/s), while worst black disc clarities (1.22 and 1.30 m) occurred on the falling stages of small to moderate freshes coincident with turbidities of 3.3 and 2.0 NTU and suspended solids concentrations of 5 and <2 g/m^3 sampled in August 2015 and April 2016 (Figure 5). Generally, poorer water quality conditions monitored during freshes (elevated bacterial numbers, some elevated nutrients, discolouration, and decreased clarity) were apparent on one occasion during the 2015-2016 period with the April, 2016 event following a lengthy period of low flow conditions.

pH reached a maximum of 8.6 in mid-summer coincident with supersaturation (120%) of dissolved oxygen, although it would be expected that pH would have risen further later in the day, particularly in mid to late summer, than the value measured at the time of sampling (near midday).

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 101% saturation recorded in winter) and low BOD_5 levels (median: 0.8 g/m^3). Bacteriological quality was more typical of the mid reaches of developed ring plain catchments, subject to agricultural impacts, with median faecal coliform and enterococci numbers of 155 and 40 cfu/100 mL, respectively. Water temperature varied over a wide range of 12.4 ˚C with the highest yet maximum summer (late morning) river temperature of 21.5 ˚C recorded in February 2016 under very low flow conditions (Figure 5).

Brief comparison with previous 1995-2015 period

The latest twelve-month period sampled a narrower range of flow conditions with median sampled flow much lower (by 760 L/s. or 46%) than the median of flows sampled over the previous 20-year period. Aesthetic river water quality was better in terms of median black disc clarity (which was higher by 0.29 m), median suspended solids level (lower by >1 g/m^3), and median turbidity level (which decreased by 0.55 NTU) during the 2015-2016 period.

In general, some improvement in faecal coliform bacteriological water quality was recorded in the 2015-2016 period with a lower median number (by 25 cfu/100 mL) and in median enterococci number (by 60 cfu/100 mL). Reductions were indicated in median nitrogen species' concentrations over the 2015-2016 period, particularly ammoniacal nitrogen, nitrate N and total nitrogen, which fell by 22%, 20%and 11%, respectively. Median DRP value was similar, and total phosphorus rose by 21%. The differences between periods in median nutrient concentrations may be attributed to the relatively low flows sampled in 2015-2016, particularly in the warmer months when periphyton growth was greatest.

The range in water temperature was narrower (by 2.6 ˚C) over the 2015-2016 period mainly due to a warmer (by 2.3 ˚C) minimum water temperature. The maximum temperature in the 2015-2016 period was the highest recorded, by 0.7°C.

Median pH value was higher by 0.2 units, but the maximum pH previously recorded (over 20 years) was 0.4 unit higher than that measured in the 2015-2016 period.

Waingongoro River at SH45 (site: WGG000900)

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

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

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/ 100mL	cfu/100mL
08-Jul-2015	1200	0.025	0.004	0.000	36	1.04	2.1	18.2	11.2	100	0.050	280	290
12-Aug-2015	1200	0.021	0.004	0.000	33	0.99	0.8	16.7	11.7	102	0.028	100	23
09-Sep-2015	1155	0.019	0.003	0.000	36	1.52	1.1	16.4	11.1	103	0.028	110	23
14-Oct-2015	1100	0.024	0.005	0.000	44	1.33	0.9	18.9	10.9	105	0.029	220	70
11-Nov-2015	1040	0.032	0.006	0.000	51	1.32	1.1	20.1	10.2	105	0.051	84	37
09-Dec-2015	1100	0.033	0.007	0.000	57	2.10	0.8	20.3	10.2	107	0.047	57	33
13-Jan-2016	1110	0.045	0.010	0.000	50	2.22	1.0	17.7	9.8	108	0.057	120	72
10-Feb-2016	1125	0.044	0.009	0.000	61	2.60	0.9	19.4	10.3	117	0.048	250	320
10-Mar-2016	1120	0.035	0.007	0.000	54	2.10	1.0	17.2	10.4	111	0.033	190	540
13-Apr-2016	1220	0.054	0.012	0.001	38	0.69	1.6	15.2	9.7	100	0.083	1200	4700
11-May-2016	1155	0.038	0.007	0.000	51	0.82	0.7	17.6	11.2	112	0.052	360	640
08-Jun-2016	1200	0.017	0.003	0.000	33	2.10	0.6	15.2	11.8	101	0.029	80	150

Date	Time	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
	NZST	cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
08-Jul-2015	1200	280	9.470	0.104	0.054	2.58	7.6	8	10.1	0.99	3.62	0.086	4.5
12-Aug-2015	1200	100	17.096	0.078	0.025	2.88	7.3	10	9.3	0.40	3.31	0.079	5.9
09-Sep-2015	1155	110	10.879	0.032	0.028	2.68	7.7	6	11.7	0.33	3.04	0.065	2.1
14-Oct-2015	1100	220	5.128	0.034	0.014	2.44	7.9	3	13.7	0.21	2.66	0.056	3.1
11-Nov-2015	1040	84	2.607	0.040	0.016	1.99	8.0	3	16.7	0.71	2.72	0.072	2.7
09-Dec-2015	1100	57	1.619	0.029	0.010	1.42	8.0	3	17.3	0.37	1.80	0.072	2.1
13-Jan-2016	1110	130	1.201	0.028	0.010	1.11	8.0	<2	19.6	0.22	1.34	0.084	1.3
10-Feb-2016	1125	250	1.025	0.022	0.005	0.48	8.4	<2	21.5	0.07	0.55	0.066	1.0
10-Mar-2016	1120	190	1.127	0.010	0.004	0.51	8.1	<2	18.9	0.22	0.73	0.052	0.8
13-Apr-2016	1220	1200	4.279	0.022	0.015	1.22	7.8	7	15.8	0.67	1.90	0.150	5.4
11-May-2016	1155	360	1.402	0.010	0.006	1.26	8.2	6	15.0	0.09	1.36	0.080	6.0
08-Jun-2016	1200	80	5.838	0.032	0.011	2.03	7.7	<2	8.8	0.00	2.04	0.046	3.1

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

Table 25 Statistical summary of data from July 2015 to June 2016: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.017	0.054	0.032	12	0.012
A440F	Absorbance @ 440nm Filtered	/cm	0.003	0.012	0.006	12	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m3 CaCO3	33	61	47	12	10
BDISC	Black disc transparency	m	0.69	2.60	1.42	12	0.63
BOD_5	Biochemical oxygen demand 5day	g/m3	0.6	2.1	1.0	12	0.4
CONDY	Conductivity @ 20'C	mS/m	15.2	20.3	17.6	12	1.7
DO	Dissolved Oxygen	g/m3	9.7	11.8	10.6	12	0.7
PERSAT	Dissolved Oxygen Saturation %	%	100	117	105	12	5
DRP	Dissolved reactive phosphorus	g/m3P	0.028	0.083	0.048	12	0.016
ECOL	E.coli bacteria	cfu/100 mL	57	1200	155	12	312
ENT	Enterococci bacteria	cfu/100 mL	23	4700	111	12	1316
FC	Faecal Coliforms	cfu/100 mL	57	1200	160	12	312
FLOW	Flow	m3/s	1.025	17.096	3.443	12	5.02
NH_4	Ammoniacal nitrogen	g/m3N	0.010	0.104	0.030	12	0.027
NO_2	Nitrite nitrogen	g/m3N	0.004	0.054	0.012	12	0.014
NO_3	Nitrate nitrogen	g/m3N	0.48	2.88	1.71	12	0.83
PH	pH		7.3	8.4	8.0	12	0.3
SS	Suspended solids	g/m3	<2	10	3	12	3
TEMP	Temperature	°C	8.8	21.5	15.4	12	4.2
TKN	Total Kjeldahl nitrogen	g/m3N	0.00	0.99	0.28	12	0.30
TN	Total nitrogen	g/m3N	0.55	3.62	1.97	12	1.00
TP	Total phosphorus	g/m3P	0.046	0.150	0.072	12	0.027
TURBY	Turbidity	NTU	0.81	6.0	2.9	12	1.9

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

Table 26 Statistical summary of data from July 1998 to June 2016: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.078	0.032	216	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.019	0.007	216	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	216	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	21	62	39	216	9
BDISC	Black disc transparency	m	0.12	4.34	1.185	216	0.595
BOD_5	Biochemical oxygen demand 5day	g/m^3	0.5	6.7	1.0	216	0.8
CONDY	Conductivity @ 20°C	mS/m	9.8	23.2	16.4	216	2.2
DO	Dissolved oxygen	g/m^3	8.4	12.9	10.5	216	0.8
PERSAT	Dissolved oxygen saturation %	%	89	141	102	216	6
DRP	Dissolved reactive phosphorus	g/m^3P	0.015	0.223	0.054	215	0.034
ECOL	E.coli bacteria	cfu/100 mL	3	41000	220	216	3232
ENT	Enterococci bacteria	cfu/100 mL	6	5900	150	216	714
FC	Faecal coliforms	cfu/100 mL	3	41000	220	216	3226
FLOW	Flow	m^3/s	0.997	50.341	4.802	216	6.796
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.305	0.034	216	0.041
NO_2	Nitrite nitrogen	g/m^3N	0.003	0.132	0.02	216	0.019
NO_3	Nitrate nitrogen	g/m^3N	0.48	2.98	1.87	216	0.54
pH	pH		7.2	9.1	7.8	216	0.3
SS	Suspended solids	g/m^3	<2	120	5	216	15
TEMP	Temperature	°C	5.4	22.0	13.7	216	3.8
TKN	Total kjeldahl nitrogen	g/m^3N	0.00	1.51	0.39	216	0.25
TN	Total nitrogen	g/m^3N	0.55	3.62	2.4	216	0.60
TP	Total phosphorus	g/m^3P	0.042	0.325	0.097	216	0.049
TURB	Turbidity (Hach 2100A)	NTU	1.0	36	2.3	209	4.0
TURBY	Turbidity (Cyberscan WTW)	NTU	0.8	56	3.2	133	6.1

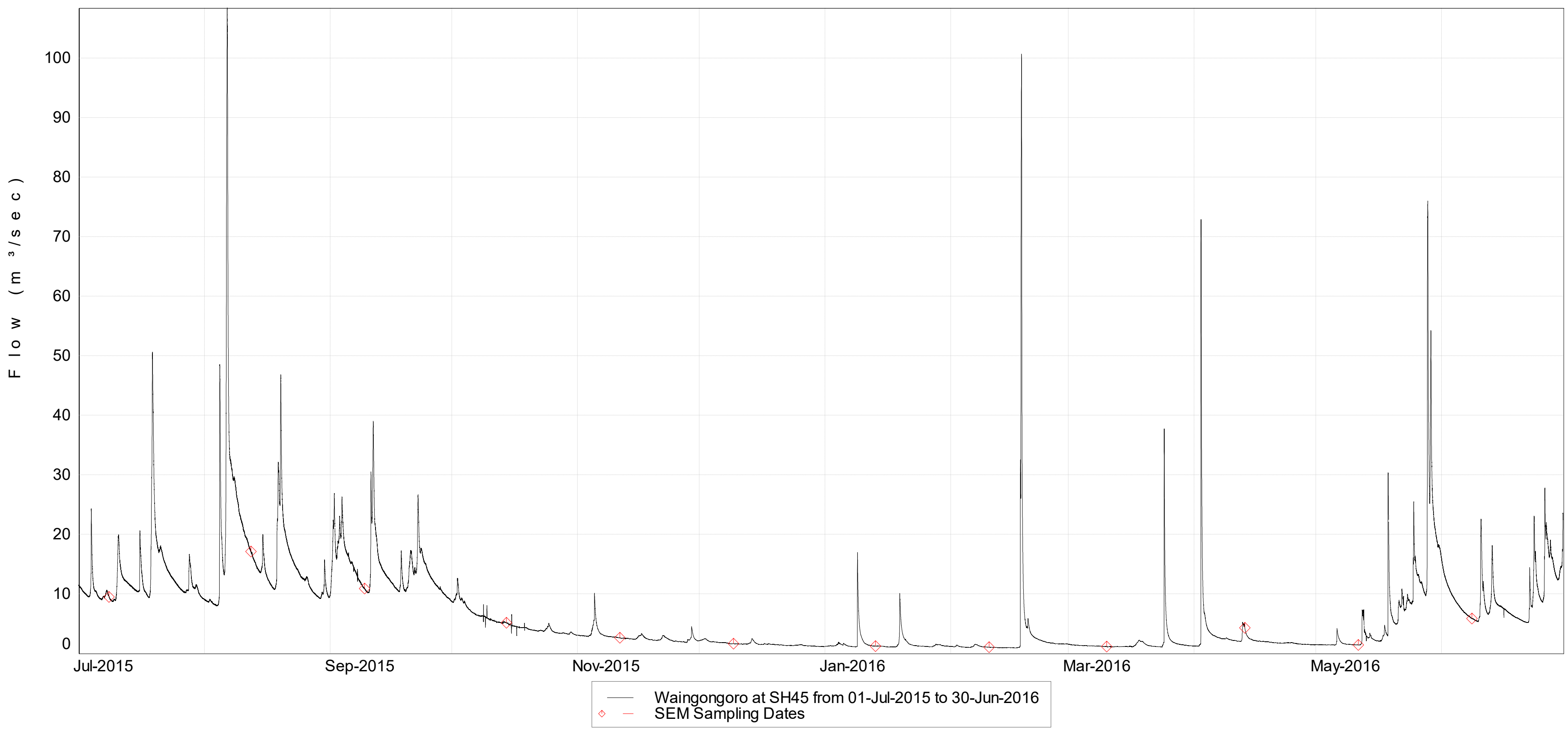


Figure 5 Flow record for the Waingongoro River at SH45

Discussion

2015-2016 period

Relatively poor aesthetic water quality was indicated by a median black disc clarity of 1.42 m and median turbidity of 2.9 NTU, in the lower reaches of the longest ring-plain confined river or stream in Taranaki. The moderately low maximum clarity (black disc value of 2.60 m) was recorded in late summer during very low flow conditions (1.02 m^3/s). The minimum clarity of 0.69 m was recorded in April 2016, coincident with the peak of a small fresh (Figure 5). Poorest water quality conditions were apparent at times of fresh flows, when elevated bacterial numbers, nutrients, and/or discolouration, and decreased clarity were typical.

pH reached 8.4 in late-summer under very low flow conditions coincidental with highest dissolved oxygen saturation levels (117 %), although it would be expected that pH would have risen further during summer/autumn later in the day (i.e. after 1125 NZST), than values recorded at the earlier sampling times.

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 100% saturation) and moderately low BOD_5 levels (median: 1.0 g/m^3). Bacteriological quality was relatively poor at this site, with numbers typical for the lower reaches of developed ring plain catchments, subject to agricultural impacts, with median faecal coliform and enterococci numbers of 160 and 111 (cfu/100 mL) respectively. These numbers reflected, to some degree, the relative lack of proximity of preceding river freshes on sampling survey occasions during the period. Median nutrient levels were relatively high and typical of the lower reaches of ring plain rivers receiving agricultural and industrial point-source discharges. Water temperatures varied over a moderate range of 12.7 ˚C with a maximum mid-summer (late morning) river temperature of 21.5 ˚C recorded in February 2016.

Brief comparison of upper and lower Waingongoro River sites during the 2015-2016 period

Downstream deterioration in aspects of water quality over the 40 km length between the mid reaches and the lower reaches of the river was emphasised by more turbid conditions [lower median black disc clarity by 0.56 m (28 % decrease), increased median turbidity level (by 1.4 NTU), and an increase in median suspended solids concentration of >1 g/m^3]. Bacteriological quality, in terms of the median faecal coliform count, remained poor (within 5 cfu/100 mL) at the lower river site whereas the median enterococci count deteriorated by 61 cfu/100 mL (compared with historical median deteriorations of 30 cfu/100 mL for faecal coliforms and 50 cfu/100 mL for enterococci). The lower river site's pH range was narrower (but only by 0.1 unit) over the 2015-2016 period but the median pH level was higher (by 0.1 unit) at the downstream site. However, maximum pH recorded was 0.2 unit lower at the downstream site which was atypical of downstream increases in pH in ringplain streams.

Median BOD_5 was higher by 0.4 g/m^3 at the SH45 site where all median nutrient species' concentrations also showed significant increases (by 36 % to 67%) compared with upstream concentrations. Historical (1998-2015) median data also indicate from 36% to 67% increases in nutrient species concentrations in a downstream direction.

Water temperature range was slightly larger (by 0.1 ˚C) at the lower site and median water temperature was 1.4 ˚C warmer at this site in the lower reach of the river in comparison with the mid reach site. Historical median temperatures have increased downstream by 1.1 ˚C and ranges have been wider by 1.4 ˚C. Median flow increased by 285 % at the lower reach site in the 2015-2016 period compared with 191% over the previous seventeen-year period.

Brief comparison with the previous 1998-2015 period

The most recent twelve-month period sampled a narrower range of flow conditions and the median sampled flow was lower by 1,375 L/s, or 26%, than that sampled over the previous seventeen-year period. This was due in part to sampling seldom coinciding with freshes, and long spring to autumn low flow periods in the 2015-2016 year.

Water clarity at the time of sampling was improved, with the medians for suspended solids lower by 2 g/m^3, turbidity lower by 0.3 NTU, and black disc clarity higher by 0.26 m in the 2015-2016 period.

Median faecal coliform bacterial number showed improvement, by 55 cfu/100 mL, and enterococci, by 39 cfu/100 mL. While pH median value increased by 0.2 unit, a much narrower range (by 0.8 unit) was recorded in the recent twelve-month period due to the absence of very elevated summer pH values which had been recorded at times in the previous seventeen-year period. Dissolved oxygen saturation median value was higher in the recent period, by 4%. Both median phosphorus species nutrient levels reduced (by 13 % to 28 %) in the recent one year period and all of the median nitrogen nutrient species' levels were also lower, by 10 to 12%.

The 2015-2016 range in water temperatures was much narrower (by 3.9 ˚C) due to a higher minimum temperature (by 3.4 ˚C) and lower maximum temperature (by 0.5 ˚C) while the median was 1.7 ˚C higher in the 2015-2016 sampling period than that recorded over the previous seventeen-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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100 mL	cfu/100 mL
08-Jul-2015	1315	0.014	0.002	0.000	18	5.78	<0.5	5.9	11.7	101	0.018	11	<1
12-Aug-2015	1315	0.013	0.002	0.000	17	10.14	<0.5	5.8	12.1	102	0.013	<1	<1
09-Sep-2015	1310	0.011	0.002	0.000	18	5.57	<0.5	6.0	11.7	101	0.016	1	1
14-Oct-2015	1230	0.012	0.002	0.000	25	4.8	<0.5	6.9	11.1	102	0.024	120	4
11-Nov-2015	1150	0.014	0.003	0.000	27	2.56	<0.5	7.2	10.5	101	0.032	1	<1
09-Dec-2015	1235	0.014	0.003	0.000	27	3.21	<0.5	7.4	10.4	100	0.028	60	16
13-Jan-2016	1220	0.014	0.004	0.000	28	5.19	<0.5	6.8	10.2	99	0.027	25	16
10-Feb-2016	1245	0.012	0.004	0.001	31	3.42	<0.5	7.7	9.6	101	0.034	58	120
10-Mar-2016	1230	0.011	0.002	0.000	29	4.03	<0.5	7.4	10.0	99	0.033	140	78
13-Apr-2016	1320	0.037	0.008	0.001	18	2.12	<0.5	5.5	10.2	100	0.023	54	62
11-May-2016	1320	0.033	0.008	0.000	26	1.61	<0.5	6.6	10.1	100	0.029	290	230
08-Jun-2016	1320	0.009	0.002	0.000	34	5.86	<0.5	6.5	11.5	100	0.018	830	3
Date	**Time**	**FC**	**Flow**	**NH_4**	**NO_2**	**NO_3**	**pH**	**SS**	**Temp**	**TKN**	**TN**	**TP**	**Turb**
	NZST	cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
08-Jul-2015	1315	11	0.267	<0.003	<0.001	0.04	7.4	<2	6.0	0.01	<0.05	0.027	0.5
12-Aug-2015	1315	<1	0.231	<0.003	<0.001	0.04	7.3	<2	5.6	0.01	<0.05	0.016	0.4
09-Sep-2015	1310	1	0.219	<0.003	<0.001	0.02	7.5	<2	6.8	0.03	<0.05	0.017	0.6
14-Oct-2015	1230	120	0.154	0.005	<0.001	<0.01	7.6	<2	9.4	0.11	0.12	0.027	1.0
11-Nov-2015	1150	1	0.117	0.004	<0.001	0.02	7.7	<2	10.5	0.06	0.08	0.032	0.7
09-Dec-2015	1235	60	0.194	0.009	<0.001	0.01	7.6	<2	10.5	0.13	0.14	0.036	0.6
13-Jan-2016	1220	25	0.178	0.006	<0.001	0.01	7.6	<2	11.8	0.04	0.05	0.029	0.5
10-Feb-2016	1245	60	0.140	<0.003	<0.001	0.01	7.7	<2	14.9	0.04	<0.05	0.043	0.7
10-Mar-2016	1230	140	0.111	0.008	<0.001	0.02	7.6	<2	12.8	0.03	<0.05	0.033	0.3
13-Apr-2016	1320	54	0.208	<0.003	0.001	0.01	7.1	<2	11.0	0.04	<0.05	0.027	0.4
11-May-2016	1320	290	0.238	0.003	<0.001	0.02	7.6	<2	11.3	0.04	0.06	0.036	1.1
08-Jun-2016	1320	830	0.148	0.014	<0.001	0.03	7.6	<2	7.4	0.00	<0.05	0.019	0.3

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

Table 28 Statistical summary of data from July 2015 to June 2016: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.037	0.014	12	0.009
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.008	0.002	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.001	0.000	12	0.000
ALKT	Alkalinity Total	g/m³ $CaCO_3$	17	34	26	12	6
BDISC	Black disc transparency	m	1.61	10.14	4.42	12	2.29
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	<0.5	<0.5	12	<0.5
CONDY	Conductivity @ 20°C	mS/m	5.5	7.7	6.7	12	0.7
DO	Dissolved oxygen	g/m³	9.6	12.1	10.4	12	0.8
PERSAT	Dissolved oxygen saturation %	%	99	102	100	12	1
DRP	Dissolved reactive phosphorus	g/m³P	0.013	0.034	0.026	12	0.007
ECOL	E.coli bacteria	cfu/100 mL	<1	830	56	12	235
ENT	Enterococci bacteria	cfu/100 mL	<1	230	10	12	70
FC	Faecal coliforms	cfu/100 mL	<1	830	57	12	235
FLOW	Flow	m³/s	0.111	0.267	0.186	12	0.05
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.014	0.004	12	0.003
NO_2	Nitrite nitrogen	g/m³N	<0.001	<0.001	<0.001	12	0
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.04	0.02	12	0.011
pH	pH		7.1	7.7	7.6	12	0.2
SS	Suspended solids	g/m³	<2	<2	<2	12	<2
TEMP	Temperature	°C	5.6	14.9	10.5	12	2.9
TKN	Total kjeldahl nitrogen	g/m³N	0.00	0.13	0.04	12	0.04
TN	Total nitrogen	g/m³N	<0.05	0.14	0.02	12	0.03
TP	Total phosphorus	g/m³P	0.016	0.043	0.028	12	0.008
TURBY	Turbidity	NTU	0.3	1.1	0.5	12	0.25

A statistical summary of the 21 years' data collected since 1 July 1995, is presented in Table 29.

Table 29 Statistical summary of data from July 1995 to June 2016: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.006	0.112	0.016	252	0.021
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.024	0.004	252	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	252	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	3	34	22	251	7.1
BDISC	Black disc transparency	m	0.09	10.14	4.38	251	1.829
BOD_5	Biochemical oxygen demand 5day	g/m³	0.2	3.7	0.2	252	0.3
CONDY	Conductivity @ 20°C	mS/m	2.5	8.2	6.2	252	1.4
DO	Dissolved oxygen	g/m³	9.1	12.4	10.6	252	0.7
PERSAT	Dissolved oxygen saturation %	%	90	103	99	252	2
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.042	0.018	252	0.008
ECOL	E.coli bacteria	cfu/100 mL	<1	10000	21	228	724
ENT	Enterococci bacteria	cfu/100 mL	1	2200	8	252	170
FC	Faecal coliforms	cfu/100 mL	1	10000	21	252	691
FLOW	Flow	m³/s	0.084	18	0.215	252	1.4975
NH_4	Ammoniacal nitrogen	g/m³N	0.002	0.057	0.002	252	0.006
NO_2	Nitrite nitrogen	g/m³N	<0.001	<0.003	<0.000	252	<0.000
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.14	0.02	252	0.02
pH	pH		6.5	8.0	7.5	252	0.2
SS	Suspended solids	g/m³	<2	160	1	252	11
TEMP	Temperature	°C	3.7	14.9	9.2	252	2.5
TKN	Total kjeldahl nitrogen	g/m³N	0.00	2.70	0.05	252	0.20
TN	Total nitrogen	g/m³N	<0.05	2.72	0.08	252	0.20
TP	Total phosphorus	g/m³P	0.008	0.281	0.024	252	0.022
TURB	Turbidity (Hach 2100A)	NTU	0.3	31	0.55	245	2.2
TURBY	Turbidity (Cyberscan WTW)	NTU	0.20	4.2	0.56	132	0.6

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

Discussion

2015-2016 period

Aesthetic water quality was very high, as emphasised by median black disc and turbidity values of 4.42 m and 0.2 NTU respectively, and a record high maximum black disc clarity of 10.14 m measured under late winter, low flow conditions (231 L/s). The lowest black disc clarity (1.61 m) and highest turbidity were recorded in May 2016, coincident with a small rainfall event. Suspended solids level was low (<2 g/m^3) on every sampling occasion.

Maximum pH (7.7) at this shaded site was measured under very low flow conditions on two occasions. pH range however was relatively narrow under all flow conditions (varying by only 0.6 unit) over the period, although measurements were confined to near midday.

Dissolved oxygen concentrations were consistently high with a minimum saturation of 99% 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. Dissolved reactive phosphorus levels were typical of National Park sourced rivers.

Bacterial water quality was relatively high (median faecal coliform and enterococci numbers of 57 and 10 cfu/100 mL respectively). There was some evidence of the slightly elevated counts found in past years in summer-autumn during periods of stable flow conditions, which may have been due to stock access upstream of the site noted previously in this short reach of the river below the National Park boundary. An unexplained elevated coliform count was returned for the June 2016 sampling.

River water temperatures varied over a moderate range (9.5 ˚C) at this relatively shaded site during the period. A maximum mid-day temperature of 14.9 ˚C was recorded under very low flow conditions in February 2016.

Brief comparison with the previous 1995-2015 period

A much narrower range and a lower median of river flows was sampled during the 2015-2016 period, with no significant fresh sampled, in comparison with the previous 20-year period. Median flow for the 2015-2016 sampling occasions was 31 L/s, or 14%, lower than the median of sampled flows over the previous 20-year period. Aesthetic river water quality was very similar in terms of median turbidity and median black disc clarity during the 2015-2016 period. Median suspended solids concentrations were very low (below 2 g/m^3) in both periods.

Median nutrient species levels were comparatively similar between the two periods, although there was an increase in median dissolved reactive phosphorus concentration (of 45%) over the latest twelve-month sampling period, possibly related to the lower flows.

Median faecal coliform bacterial number increased (by 37 cfu/100 mL) and median enterococci number increased (by 2 cfu/100 mL) over the recent sampling period. Median pH values were higher, by 0.2 unit, while the maximum pH value was only 0.3 unit lower in the 2015-2016 period.

Median water temperature over the past twelve-month period was 1.3 ˚C higher than the median for the previous 20-year period; the maximum temperature was 0.2˚C higher than any previously recorded, and the minimum temperature was 1.9 ˚C higher in the latest period. Therefore, a narrower range of temperatures (by 1.7 °C) was recorded in the 2015-2016 period.

Patea River at Skinner Road (site: PAT000360)

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

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

Date	Time NZST	A340F /cm	A440F /cm	A770F /cm	ALKT g/m³ $CaCO_3$	Black disc m	BOD_5 g/m³	Cond @ 20 °C mS/m	DO g/m³	DO Sat %	DRP g/m³P	E.coli cfu/100 mL	ENT cfu/100 mL
08-Jul-2015	1405	0.014	0.002	0.000	26	2.86	0.5	9.6	11.6	103	0.026	100	31
12-Aug-2015	1410	0.014	0.002	0.000	24	2.56	<0.5	9.7	11.6	103	0.015	210	85
09-Sep-2015	1400	0.013	0.002	0.000	25	2.76	<0.5	9.6	11.3	105	0.017	26	8
14-Oct-2015	1300	0.018	0.004	0.000	30	1.94	0.9	9.9	11.8	116	0.036	92	110
11-Nov-2015	1255	0.024	0.006	0.000	34	1.64	1.4	10.4	11.1	118	0.062	48	17
09-Dec-2015	1300	0.029	0.007	0.000	34	1.61	2.0	10.8	10.6	110	0.076	100	40
13-Jan-2016	1315	0.031	0.007	0.000	32	2.06	1.0	10.1	9.9	106	0.073	370	120
10-Feb-2016	1345	0.028	0.008	0.000	42	2.29	1.1	10.7	10.2	120	0.060	54	160
10-Mar-2016	1330	0.026	0.006	0.000	37	1.9	1.0	11.0	11.4	120	0.033	160	210
13-Apr-2016	1410	0.034	0.008	0.001	28	1.02	1.3	9.9	10.1	104	0.057	600	1000
11-May-2016	1415	0.028	0.006	0.000	34	1.51	1.5	10.6	10.3	104	0.052	620	870
08-Jun-2016	1400	0.013	0.002	0.000	28	2.77	<0.5	10.3	11.3	102	0.021	51	51

Date	Time NZST	FC cfu/ 100mL	Flow m³/s	NH_4 g/m³N	NO_2 g/m³N	NO_3 g/m³N	pH pH	SS g/m³	Temp °C	TKN g/m³N	TN g/m³N	TP g/m³P	Turb NTU
08-Jul-2015	1405	100	3.696	0.072	0.011	0.93	7.6	<2	8.7	0.5	1.44	0.043	1.7
12-Aug-2015	1410	220	6.402	0.055	0.007	1.32	6.9	2	9.2	0.07	1.4	0.028	1.6
09-Sep-2015	1400	26	4.941	0.028	0.009	1.21	7.7	<2	11.0	0.09	1.31	0.026	1.7
14-Oct-2015	1300	92	1.948	0.028	0.016	0.89	8.6	<2	13.6	0.1	1.01	0.054	1.7
11-Nov-2015	1255	48	1.082	0.031	0.023	0.81	8.5	<2	17.1	0.28	1.11	0.086	1.9
09-Dec-2015	1300	100	1.122	0.068	0.029	0.78	8.1	<2	16.5	0.3	1.11	0.114	2.6
13-Jan-2016	1315	370	1.235	0.047	0.018	0.63	8.0	<2	17.1	0.02	0.67	0.096	1.3
10-Feb-2016	1345	57	1.363	0.006	0.010	0.37	8.7	<2	22.3	0.03	0.41	0.094	1.4
10-Mar-2016	1330	160	1.142	0.005	0.003	0.47	8.5	<2	17.5	0.15	0.62	0.052	1.3
13-Apr-2016	1410	600	2.834	0.044	0.021	0.86	7.6	3	14.9	0.39	1.27	0.096	2.5
11-May-2016	1415	620	2.092	0.038	0.020	0.88	7.8	<2	14.0	0.12	1.02	0.076	2.6
08-Jun-2016	1400	57	3.535	0.052	0.012	1.13	7.6	<2	10.0	0.09	1.23	0.033	1.7

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

Table 31 Statistical summary of data from July 2015 to June 2016: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.013	0.034	0.025	12	0.008
A440F	Absorbance @ 440nm filtered	/cm	0.002	0.008	0.006	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	42	31	12	5
BDISC	Black disc transparency	m	1.02	2.86	2.00	12	0.58
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	2.0	1.0	12	<0.5
CONDY	Conductivity @ 20°C	mS/m	9.6	11.0	10.2	12	0.5
DO	Dissolved oxygen	g/m³	9.9	11.8	11.2	12	0.7
PERSAT	Dissolved oxygen saturation %	%	102	120	106	12	7
DRP	Dissolved reactive phosphorus	g/m³P	0.015	0.076	0.044	12	0.022
ECOL	E.coli bacteria	cfu/100 mL	26	620	100	12	212
ENT	Enterococci bacteria	cfu/100 mL	8	1000	98	12	338
FC	Faecal coliforms	cfu/100 mL	26	620	100	12	212
FLOW	Flow	m³/s	1.082	6.402	2.020	12	1.726
NH_4	Ammoniacal nitrogen	g/m³N	0.005	0.072	0.041	12	0.021
NO_2	Nitrite nitrogen	g/m³N	0.003	0.029	0.014	12	0.008
NO_3	Nitrate nitrogen	g/m³N	0.37	1.32	0.87	12	0.28
pH	pH		6.9	8.7	7.9	12	0.5
SS	Suspended solids	g/m³	<2	3	<2	12	<2
TEMP	Temperature	°C	8.7	22.3	14.4	12	4.1
TKN	Total kjeldahl nitrogen	g/m³N	0.02	0.50	0.11	12	0.15
TN	Total nitrogen	g/m³N	0.41	1.44	1.11	12	0.33
TP	Total phosphorus	g/m³P	0.026	0.114	0.065	12	0.031
TURB	Turbidity	NTU	1.3	2.6	1.7	12	0.5

A statistical summary of the 21 years' data collected since 1 July 1995 is presented in Table 32.

Table 32 Statistical summary of data from July 1995 to June 2016: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.095	0.023	252	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.023	0.005	252	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	252	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	10	57	28	252	6
BDISC	Black disc transparency	m	0.05	4.68	1.83	252	0.833
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.5	16	0.9	252	1.4
CONDY	Conductivity @ 20°C	mS/m	5.0	14.3	9.9	252	1.4
DO	Dissolved oxygen	g/m³	8.9	12.9	10.6	252	0.7
PERSAT	Dissolved oxygen saturation %	%	87	121	103	252	6
DRP	Dissolved reactive phosphorus	g/m³P	0.010	0.160	0.038	252	0.031
ECOL	E.coli bacteria	cfu/100 mL	2	25000	200	228	3140
ENT	Enterococci bacteria	cfu/100 mL	4	19000	110	252	1714
FC	Faecal coliforms	cfu/100 mL	2	63000	225	252	5036
FLOW	Flow	m³/s	0.65	77.53	2.893	252	7.474
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.329	0.052	252	0.05
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.051	0.016	252	0.008
NO_3	Nitrate nitrogen	g/m³N	0.21	1.54	0.91	252	0.22
pH	pH		6.9	8.8	7.8	252	0.4
SS	Suspended solids	g/m³	<2	360	<2	252	27
TEMP	Temperature	°C	5.3	22.3	12.9	252	3.4
TKN	Total kjeldahl nitrogen	g/m³N	0.01	4.07	0.24	252	0.36
TN	Total nitrogen	g/m³N	0.41	4.50	1.22	252	0.34
TP	Total phosphorus	g/m³P	0.022	1.39	0.066	252	0.109
TURB	Turbidity (Hach 2100A)	NTU	0.2	80	1.5	245	6.9
TURBY	Turbidity (Cyberscan WTW)	NTU	0.9	21	1.7	133	3.0

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.

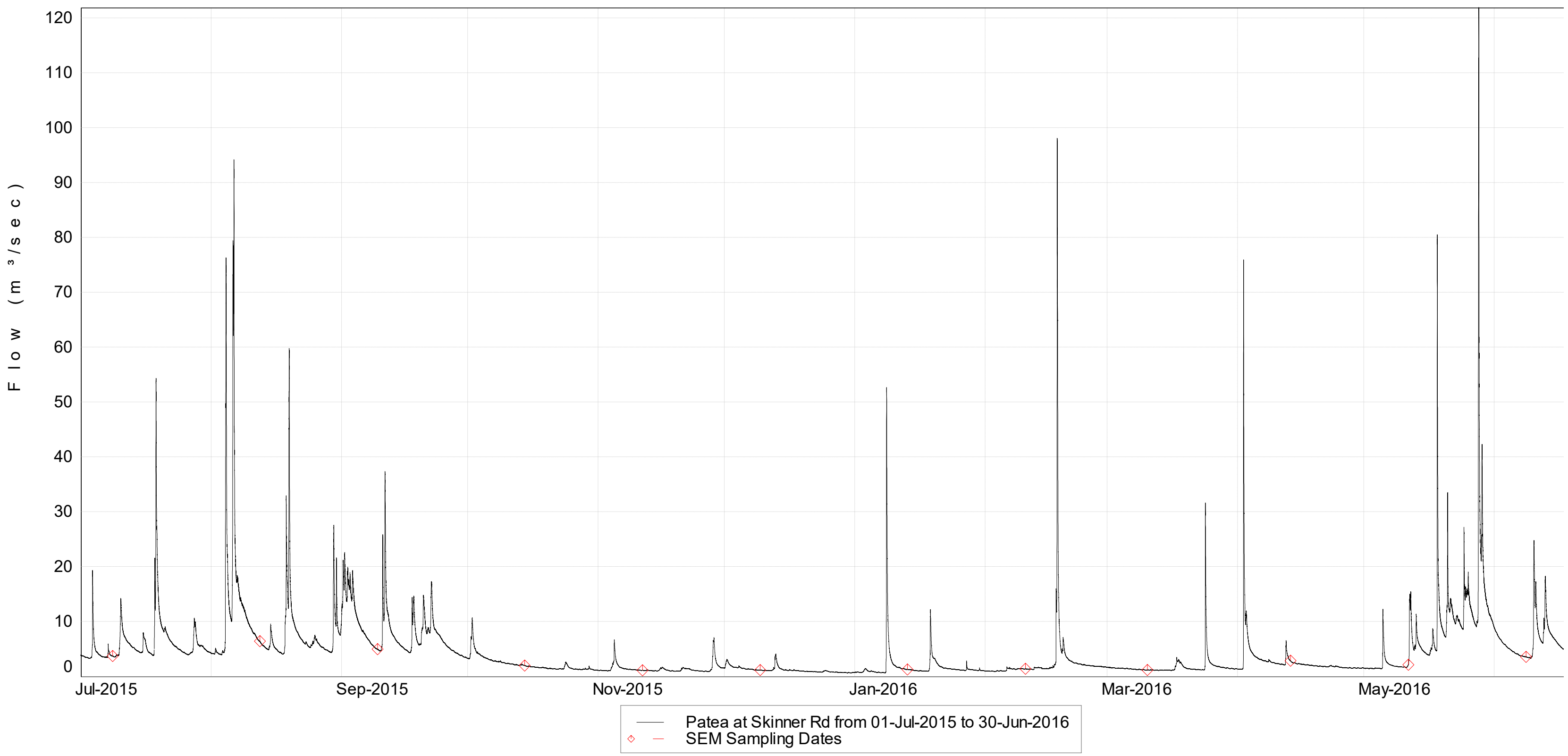


Figure 6 Flow record for the Patea River at Skinner Road

Discussion

2015-2016 period

Moderate median black disc clarity (2.00 m) and median turbidity (1.7 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. Minimum clarity (black disc of 1.02 m and turbidity of 2.5 NTU) and very small increase in suspended solids concentrations 3 g/m^3) were recorded on the falling stage of a small fresh sampled in April 2016 after a period of low flows (Figure 7). Deterioration in water quality during this event was also illustrated by high bacterial numbers.

Early afternoon pH levels reached a maximum of 8.7 units in late summer (after nearly a month with no freshes) coincident with dissolved oxygen saturation peaking at 120%. Dissolved oxygen levels were consistently high (102% or higher saturation) with supersaturation recorded particularly during mid-spring to early autumn low flow conditions coincident with more extensive algal cover and elevated pH levels (≥ 8.0 units). BOD_5 concentrations under normal to low recession flow conditions were generally indicative of moderately low organic contamination (i.e. up to 2.0 g/m^3).

The moderate median bacteriological numbers (100 faecal coliforms and 98 enterococci cfu/100 mL) 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 moderate range of faecal coliform numbers recorded under lower river flow conditions probably reflected some seasonal variability in the recently upgraded municipal oxidation pond performance due to the relative proximity of this discharge, together with other point source and non-point source discharges.

Water temperatures varied over a moderately wide range of 11.6 °C with a maximum (early afternoon) summer temperature of 22.3 ˚C recorded in February 2016 (coincident with a pH of 8.7 and 120% dissolved oxygen saturation).

Brief comparison of upper and mid Patea River catchment sites during the 2015-2016 period

Some deterioration from the high upstream water quality conditions measured at the Barclay Road site was apparent at the Skinner Road site nearly 19 km (river distance) below the National Park boundary. This was emphasised particularly by elevated median bacterial species' numbers (five to nine-fold increases) and increases in median nutrient species concentrations (0.7 to 52-fold) compared with historical (20-year) downstream increase in median bacterial numbers (10 to 13-fold) and nutrient species concentrations (2 to 47 fold). The pH range increased by 1.2 unit at the Skinner Road site with a maximum pH 1.0 unit higher than at the upstream site. A moderate increase in median turbidity levels (1.2 NTU) was measured in mid catchment, almost identical to the historical median increase. Median BOD_5 increased by about 0.5 g/m^3 although maximum BOD_5 was 0.7 g/m^3 higher downstream. A deterioration in black disc clarity (median clarity decreased significantly by 2.42 m and maximum clarity to a larger degree by 7.28 m) was recorded, as a result of increased turbidity from run-off and point source discharges within the developed catchment of the river between the two sites. This may be compared with a 20-year median black disc deterioration of 2.56 m and maximum clarity deterioration of 4.42 m.

Water temperature range increased (by 3.3 ˚C) at the Skinner Road site, where median water temperature was higher (by 3.9 ˚C) and maximum water temperature was higher (by 7.4 ˚C) than at the Barclay Road site. In comparison, the historical 20-year median and maximum water temperatures have shown downstream increases of 3.6 ˚C and 7.1 ˚C respectively.

Brief comparison with the previous 1995-2015 period

The median of sampled flows in the recent twelve-month period was 992 L/s, or 33%, lower than the median of flows sampled over the 1995-2015 period due largely to fewer and smaller freshes sampled in the 2015-2016 year, and the range of river flows sampled was much narrower in the most recent period. Aesthetic water quality was similar to historical conditions with median black disc clarity higher by 0.18 m, while and some reduction in the median suspended solids concentrations (<2 g/m^3) and minimal difference in turbidity (0.1 NTU) between periods.

There was an identical pH range and lower maximum pH (by 0.1 pH unit) during the 2015-2016 period. Median dissolved oxygen percentage saturation was higher by an insignificant 4% in the 2015-2016 period.

Bacterial water quality was improved for both faecal coliform and enterococci bacteria during the more recent sampling period, with the median numbers decreasing by 130 and 17 cfu/100 mL, respectively. Variability in municipal oxidation ponds' system performance and dairy shed wastes disposal would have been expected to have contributed to any differences in bacterial quality between periods, together with less sampling during or after freshes, when contamination from pasture run-off may occur, in the recent period.

Water temperature range was narrower (by 1.9 ˚C) during the more recent sampling period although the median water temperature was 1.6 ˚C higher than the longer term median. The maximum water temperature was the highest recorded (by 0.5 ˚C) and the minimum water temperature was higher (by 3.4 ˚C) in the latest twelve-month period.

Median BOD_5 was slightly higher during the more recent period (by 0.1 g/m^3), and all median nutrient species showed decreases (ranging from 5% to 22%), except dissolved phosphorus, which increased (by 16%).

Mangaehu River at Raupuha Road (site: MGH000950)

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

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

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100 mL	cfu/100 mL
08-Jul-2015	1445	0.067	0.018	0.002	23	0.04	1.4	7.6	10.8	97	0.008	1700	1900
12-Aug-2015	1445	0.031	0.005	0.000	29	0.25	<0.5	8.6	11.7	100	<0.003	140	32
09-Sep-2015	1440	0.035	0.006	0.000	34	0.32	<0.5	9.3	10.8	99	0.003	110	13
14-Oct-2015	1330	0.049	0.010	0.000	46	0.46	<0.5	11.3	10.4	103	0.005	240	98
11-Nov-2015	1325	0.053	0.010	0.000	48	1.58	0.6	11.3	9.7	105	0.007	60	20
09-Dec-2015	1330	0.057	0.011	0.000	47	0.91	0.5	10.8	10.0	103	0.006	260	68
13-Jan-2016	1355	0.078	0.016	0.001	47	1.06	0.5	11.0	9.3	105	0.005	84	98
10-Feb-2016	1415	0.050	0.011	0.000	64	1.96	0.5	13.9	9.0	110	<0.003	34	72
10-Mar-2016	1405	0.038	0.007	0.000	67	1.56	0.6	14.9	9.5	106	<0.003	100	57
13-Apr-2016	1440	0.080	0.018	0.001	39	0.12	1.9	10.4	9.1	94	0.007	5400	7200
11-May-2016	1450	0.064	0.013	0.000	59	1.2	<0.5	13.7	10.0	101	0.005	77	38
08-Jun-2016	1435	0.036	0.007	0.000	40	1.09	<0.5	10.8	11.9	100	0.004	88	20

Date	Time	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
	NZST	cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
08-Jul-2015	1445	1700	21.704	0.021	0.004	0.16	7.3	460	9.7	1.27	1.43	0.441	390
12-Aug-2015	1445	150	14.880	0.043	<0.001	0.34	7.0	37	8.0	0.15	0.49	0.072	30
09-Sep-2015	1440	110	9.847	0.022	0.002	0.25	7.6	19	11.2	2.47	2.72	0.040	17
14-Oct-2015	1330	240	8.202	0.017	0.002	0.11	7.9	10	14.5	0.14	0.25	0.023	13
11-Nov-2015	1325	60	4.400	0.012	0.002	0.08	8.0	2	18.3	0.12	0.20	0.015	3.3
09-Dec-2015	1330	260	4.724	0.009	0.002	0.05	7.9	2	15.9	0.15	0.20	0.027	7.8
13-Jan-2016	1355	84	3.335	0.010	0.002	0.03	8.0	5	20.8	0.14	0.17	0.018	4.3
10-Feb-2016	1415	34	2.353	<0.003	<0.001	<0.01	8.2	<2	24.9	0.04	<0.05	0.014	1.8
10-Mar-2016	1405	100	2.015	0.006	<0.001	<0.01	8.2	<2	20.4	0.12	0.13	0.009	1.9
13-Apr-2016	1440	5400	16.400	0.019	0.004	0.07	7.4	210	15.6	0.83	0.90	0.373	160
11-May-2016	1450	77	2.110	0.015	0.003	0.07	7.9	2	14.7	0.09	0.16	0.014	3.4
08-Jun-2016	1435	88	4.673	0.043	0.002	0.22	7.6	4	7.8	0.09	0.31	0.013	6.2

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

Table 34 Statistical summary of data from July 2015 to June 2016: Mangaehu River at Raupuha Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.031	0.080	0.052	12	0.017
A440F	Absorbance @ 440nm filtered	/cm	0.005	0.018	0.01	12	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	23	67	46	12	13
BDISC	Black disc transparency	m	0.04	1.96	0.98	12	0.64
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.9	0.5	12	0.5
CONDY	Conductivity @ 20˚C	mS/m	7.6	14.9	10.9	12	2.2
DO	Dissolved oxygen	g/m^3	9.0	11.9	10	12	1
PERSAT	Dissolved oxygen saturation %	%	94	110	102	12	4
DRP	Dissolved reactive phosphorus	g/m^3P	<0.003	0.008	0.005	12	0.002
ECOL	E.coli bacteria	cfu/100 mL	34	5400	105	12	1552
ENT	Enterococci bacteria	cfu/100 mL	13	7200	62	12	2084
FC	Faecal coliforms	cfu/100 mL	34	5400	105	12	1552
FLOW	Flow	m^3/s	2.015	21.704	4.698	12	6.522
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.043	0.016	12	0.013
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.004	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.34	0.07	12	0.10
pH	pH		7.0	8.2	7.9	12	0.4
SS	Suspended solids	g/m^3	2	460	4	12	138
TEMP	Temperature	°C	7.8	24.9	15.2	12	5.4
TKN	Total kjeldahl nitrogen	g/m^3N	0.04	2.47	0.14	12	0.73
TN	Total nitrogen	g/m^3N	<0.05	2.72	0.22	12	0.78
TP	Total phosphorus	g/m^3P	0.009	0.441	0.02	12	0.151
TURBY	Turbidity	NTU	1.8	390	7.0	12	114

A statistical summary of the 21 years' data collected since 1 July 1995 is presented in Table 35.

Table 35 Statistical summary of data from July 1995 to June 2016: Mangaehu River at Raupuha Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.027	0.181	0.054	252	0.018
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.056	0.011	252	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.025	0.000	252	0.002
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	9	79	38	252	13
BDISC	Black disc transparency	m	<0.01	4.04	0.855	252	0.748
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	5.6	0.6	252	0.6
CONDY	Conductivity @ 20˚C	mS/m	4.3	16.1	9.9	252	2.3
DO	Dissolved oxygen	g/m^3	7.7	12.9	10	252	0.9
PERSAT	Dissolved oxygen saturation %	%	83	118	100	252	6
DRP	Dissolved reactive phosphorus	g/m^3P	<0.003	0.026	0.006	252	0.004
ECOL	E.coli bacteria	cfu/100 mL	6	16000	220	228	1878
ENT	Enterococci bacteria	cfu/100 mL	1	7200	67	252	850
FC	Faecal coliforms	cfu/100 mL	6	16000	230	252	2000
FLOW	Flow	m^3/s	1.658	111.870	6.802	252	15.723
NH_4	Ammoniacal nitrogen	g/m^3N	0.003	0.081	0.012	252	0.011
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.016	0.002	252	0.001
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.43	0.09	252	0.09
pH	pH		6.8	8.4	7.7	252	0.3
SS	Suspended solids	g/m^3	<2	1300	4	252	119
TEMP	Temperature	°C	4.3	24.9	13.8	252	4.3
TKN	Total kjeldahl nitrogen	g/m^3N	0.02	2.47	0.17	252	0.230
TN	Total nitrogen	g/m^3N	<0.05	2.72	0.295	252	0.33
TP	Total phosphorus	g/m^3P	<0.003	0.786	0.020	252	0.102
TURB	Turbidity (Hach 2100A)	NTU	1.4	850	3.5	245	63
TURBY	Turbidity (Cyberscan WTW)	NTU	0.8	390	4.0	133	48

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

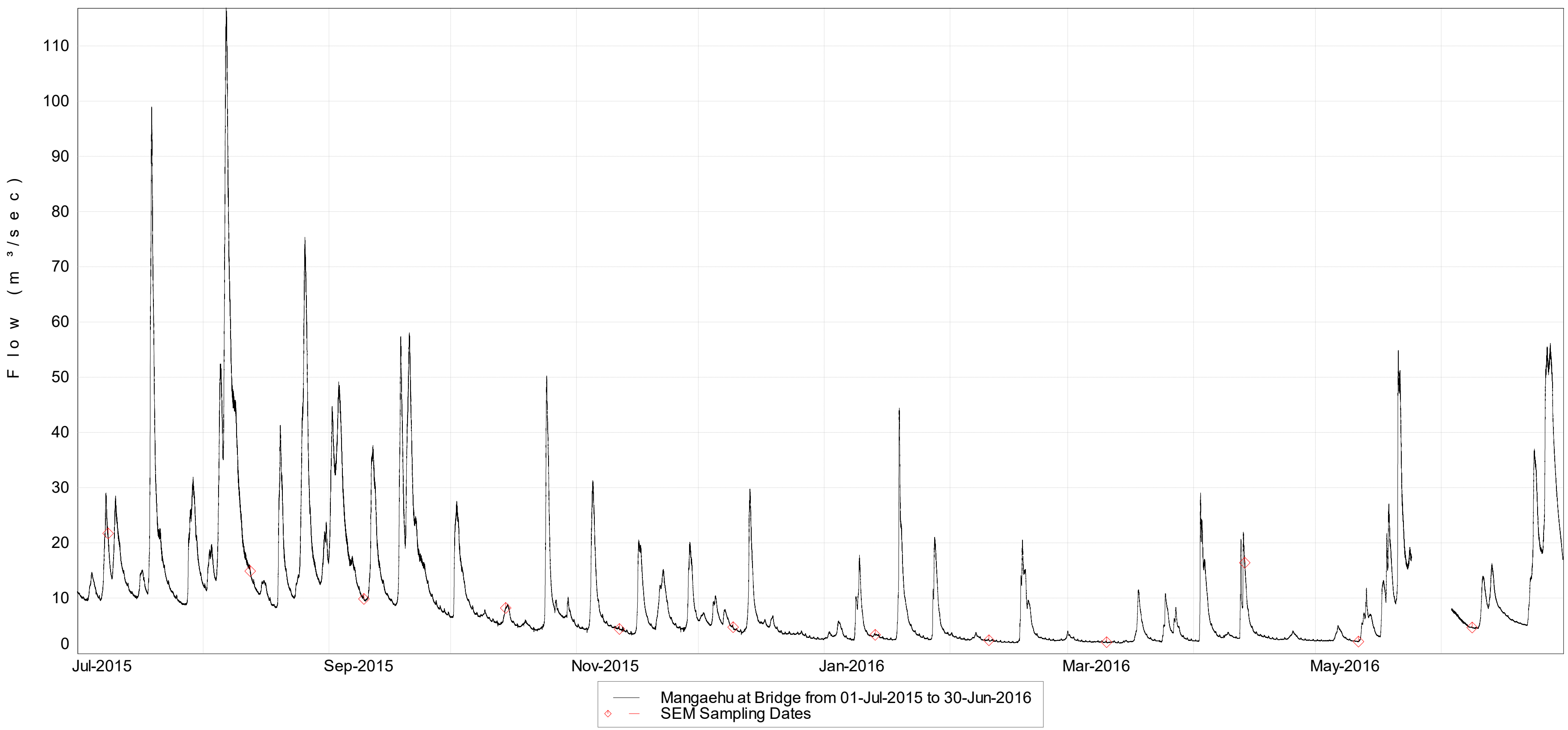


Figure 7 Flow record for the Mangaehu River at Raupuha Road

Discussion

2015-2016 period

The relatively poor visual appearance which characterises the mid and lower reaches of this eastern hill-country catchment river was emphasised by a low median black disc clarity of 0.98 metres with a maximum of 1.96 metres measured under a lengthy low flow period in February 2016. Clarity was infrequently more than 1.5 metres (on three occasions) due to the presence of very fine, colloidal, suspended particles. The median suspended solids concentration was 4 g/m^3 which was typical for this river. Absorbances (at 340 and 440 nm) were also relatively high (in excess of 0.080/cm and 0.018/cm respectively) at all times, indicative of slight dissolved colour in the river water (e.g. yellow-brown appearance) at this site in the lower reaches of the river. Minimum clarities (0.04 and 0.12 m black disc values) were coincident with turbidity levels of 390 and 160 NTU and suspended solids concentrations of 460 and 210 g/m^3, during flood flows of 21 and 16 m^3/s recorded in July 2015 and April 2016, respectively. Fresh flows (in excess of 8 m^3/s) were usually coincident with a general deterioration in water quality as emphasised by elevated turbidity, suspended solids, some nutrient species' (particularly total phosphorus) levels and bacterial counts (e.g. in July, August, September and October 2015 and April 2016; Figure 7).

Maximum mid-afternoon pH values in the mid to late summer period (8.0 to 8.2 units) were moderate for the lower reaches of a Taranaki river in early afternoon, an indication of the limited influence of algal photosynthetic activity on water quality (despite significant algal substrate cover) in this reach of the river system where more turbid conditions and silt deposition on the substrate have been typical of the site. A minimum pH (7.0 units) was found under flood conditions in August 2016.

Dissolved oxygen concentrations, were consistently high (median of 10.0 g/m^3) with a median saturation level of 102%. On the majority of occasions BOD_5 concentrations were indicative of relatively low organic content (i.e. less than 1.0 g/m^3). The median bacteriological numbers (62 enterococci and 105 faecal coliforms cfu/100 mL) were more reflective of the impacts of developed farmland run-off and possibly stock access to the lower reaches of this eastern hill country river.

Water temperatures varied over a wide range of 17.1 ˚C with a maximum (early afternoon) summer temperature of 24.9 ˚C recorded in February 2016 under low flow conditions, at which time dissolved oxygen saturation was 110% and pH was 8.2 units.

Brief comparison with the previous 1995-2015 period

The range of flows sampled during the 2015-2016 period was relatively wide but narrower than the range sampled over the previous 20-year period. The median sampled flow in the 2015-2016 period was lower (by 1,824 L/s, or 31%) than that sampled over the longer term. Median black disc clarity was slightly better (by 0.13 m) and median turbidity was higher (by 3.2 NTU) in the most recent period, while the median suspended solids concentrations were the same.

For nitrogen nutrient species, median concentrations of nitrate and total nitrogen were lower (by 31 and 27%, respectively) and ammonia higher (by 23%) in the latest period, while phosphorus species were similar to or lower compared to the medians for the previous 20-year period. Median bacterial numbers decreased slightly for enterococci (by 6 cfu/100 mL) whereas faecal coliforms were significantly lower (by 130 cfu/100 mL) in the 2015-2016 period.

Median dissolved oxygen saturation level was relatively similar (2% higher) in the 2015-2016 period while median pH level was 0.2 unit higher in the recent period. Maximum pH was 0.2 unit lower than the maximum previously recorded while minimum pH was 0.2 unit higher than the minimum recorded.

The range of water temperatures was narrower (by 2.6 °C) in the latest twelve-month period than over the previous 20-year period as, although the maximum temperature was the highest recorded (by 0.9 ˚C), the minimum temperature was higher (by 3.5 ˚C) in the 2015-2016 sampling year, while median water temperature was 1.5 ˚C higher during 2015-2016.

Whenuakura River at Nicholson Road (site: WNR000450)
Analytical data are presented in Table 36 from the monthly sampling programme. The flow record for the period is illustrated in Figure 8.

Table 36 Analytical results from monthly samples: Whenuakura River at Nicholson Road

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^{3}P	cfu/100 mL	cfu/100 mL
09-Jul-2015	1015	0.118	0.032	0.006	36		1.3	14.5	11.2	94	0.019	830	510
13-Aug-2015	1015	0.050	0.010	0.000	43		0.6	15.9	11.8	97	0.009	130	17
10-Sep-2015	1020	0.062	0.012	0.001	54		0.9	17.7	10.7	96	0.014	310	35
15-Oct-2015	0855	0.059	0.011	0.000	68		0.8	19.7	10.1	96	0.012	280	50
12-Nov-2015	0825	0.061	0.013	0.000	68		1.1	20.7	9.3	95	0.020	150	130
10-Dec-2015	0900	0.062	0.012	0.000	70		0.8	20.7	9.0	94	0.016	310	80
14-Jan-2016	0855	0.088	0.019	0.001	64		1.2	19.4	8.4	90	0.019	490	390
11-Feb-2016	0805	0.060	0.013	0.001	94		1.4	24.6	7.8	88	0.011	380	410
10-Mar-2016	0835	0.054	0.010	0.000	88	0.58	0.7	24.3	8.8	94	0.011	490	370
14-Apr-2016	0915	0.139	0.028	0.002	32	0.09	1.9	11.8	9.3	88	0.018	2200	1400
12-May-2016	0945	0.067	0.013	0.001	83	0.30	0.9	24.2	9.2	94	0.022	450	1300
09-Jun-2016	0945	0.062	0.012	0.000	64	0.44	0.5	19.9	11.6	97	0.016	100	42

Date	Time	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
	NZST	cfu/ 100mL	m^3/s	g/m^{3}N	g/m^{3}N	g/m^{3}N	pH	g/m^3	°C	g/m^{3}N	g/m^{3}N	g/m^{3}P	NTU
09-Jul-2015	1015	830	14.157	0.021	0.007	0.34	7.3	980	7.9	1.27	1.62	0.709	760
13-Aug-2015	1015	140	11.352	0.021	0.004	0.48	7.1	150	7.3	0.25	0.73	0.279	100
10-Sep-2015	1020	320	7.204	0.023	0.005	0.48	7.4	47	10.3	0.05	0.54	0.074	36
15-Oct-2015	0855	280	6.819	0.016	0.004	0.34	7.7	26	13.5	0.21	0.55	0.065	24
12-Nov-2015	0825	160	4.195	0.026	0.005	0.52	7.7	28	16.5	0.21	0.74	0.075	21
10-Dec-2015	0900	340	3.170	0.055	0.006	0.41	7.7	15	17.6	0.30	0.72	0.059	14
14-Jan-2016	0855	520	2.742	0.035	0.005	0.42	7.6	32	18.6	0.20	0.63	0.100	40
11-Feb-2016	0805	390	2.123	0.022	0.007	0.37	7.7	11	21.9	0.18	0.56	0.065	10
10-Mar-2016	0835	520	1.929	0.017	0.002	0.40	7.8	4	19.1	0.16	0.56	0.026	10
14-Apr-2016	0915	2300	6.299	0.052	0.006	0.27	7.2	400	13.8	0.92	1.20	0.042	340
12-May-2016	0945	450	2.42	0.028	0.005	0.52	7.9	33	15.9	0.15	0.68	0.082	32
09-Jun-2016	0945	100	3.137	0.043	0.004	0.43	7.7	20	7.3	0.01	0.44	0.043	19

The statistical summary of these data is presented in Table 37.

Table 37 Statistical summary of data from July 2015 to June 2016: Whenuakura River at Nicholson Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.050	0.139	0.062	12	0.028
A440F	Absorbance @ 440nm filtered	/cm	0.010	0.032	0.012	12	0.007
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.006	0.000	12	0.002
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	32	94	66	12	20
BDISC	Black disc transparency	m	0.09	0.58	0.37	4	0.21
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.9	0.9	12	0.4
CONDY	Conductivity @ 20°C	mS/m	11.8	24.6	19.8	12	4.0
DO	Dissolved oxygen	g/m^3	7.8	11.8	9.3	12	1.3
PERSAT	Dissolved oxygen saturation %	%	88	97	94	12	3
DRP	Dissolved reactive phosphorus	g/m^3P	0.009	0.022	0.016	12	0.004
ECOL	E.coli bacteria	nos/100 mL	100	2200	345	12	568
ENT	Enterococci bacteria	nos/100 mL	17	1400	250	12	479
FC	Faecal coliforms	nos/100 mL	100	2300	365	12	593
FLOW	Flow	m^3/s	1.929	14.157	3.682	12	3.913
NH_4	Ammoniacal nitrogen	g/m^3N	0.016	0.055	0.024	12	0.013
NO_2	Nitrite nitrogen	g/m^3N	0.002	0.007	0.005	12	0.001
NO_3	Nitrate nitrogen	g/m^3N	0.27	0.52	0.42	12	0.08
pH	pH	pH	7.1	7.9	7.7	12	0.3
SS	Suspended solids	g/m^3	4	980	30	12	285
TEMP	Temperature	°C	7.3	21.9	14.8	12	5
TKN	Total kjeldahl nitrogen	g/m^3N	0.01	1.27	0.2	12	0.38
TN	Total nitrogen	g/m^3N	0.44	1.62	0.66	12	0.33
TP	Total phosphorus	g/m^3P	0.026	0.709	0.070	12	0.192
TURBY	Turbidity	NTU	10	760	28	12	222

Discussion

2015-2016 period

The relatively poor visual appearance which characterises the mid and lower reaches of this eastern hill-country catchment river was indicated in the low black disc clarity (in the only four measurements taken, from March to June 2016) with a range of 0.09 to 0.57 metres, due to the presence of very fine, colloidal, suspended particles. The median suspended solids concentration over this first year of monitoring was high, at 30 g/m^3, with a maximum recorded value of 980 g/m^3 in July 2015, three values ≥150 g/m^3, and a minimum value of 4 g/m^3. Median turbidity level was correspondingly high, at 28 NTU with a range from 10 to 760 NTU. Absorbances (at 340 and 440 nm) were also relatively high (in excess of 0.050/cm and 0.010 /cm respectively) at all times, indicative of slight dissolved colour in the river water (e.g. brown appearance) at this site in the lower reaches of the river. Fresh flows (in excess of 6 m^3/s) were usually coincident with a general deterioration in water quality as emphasised by elevated turbidity, suspended solids, some nutrient species' (particularly total phosphorus) levels and bacterial counts (e.g. in July and August 2015; Figure 8).

Maximum early/mid-morning pH values in the autumn period (7.8 to 7.9 units) were moderate for the lower reaches of a Taranaki river, 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. A minimum pH (7.1 units) was found under flood conditions in August 2016.

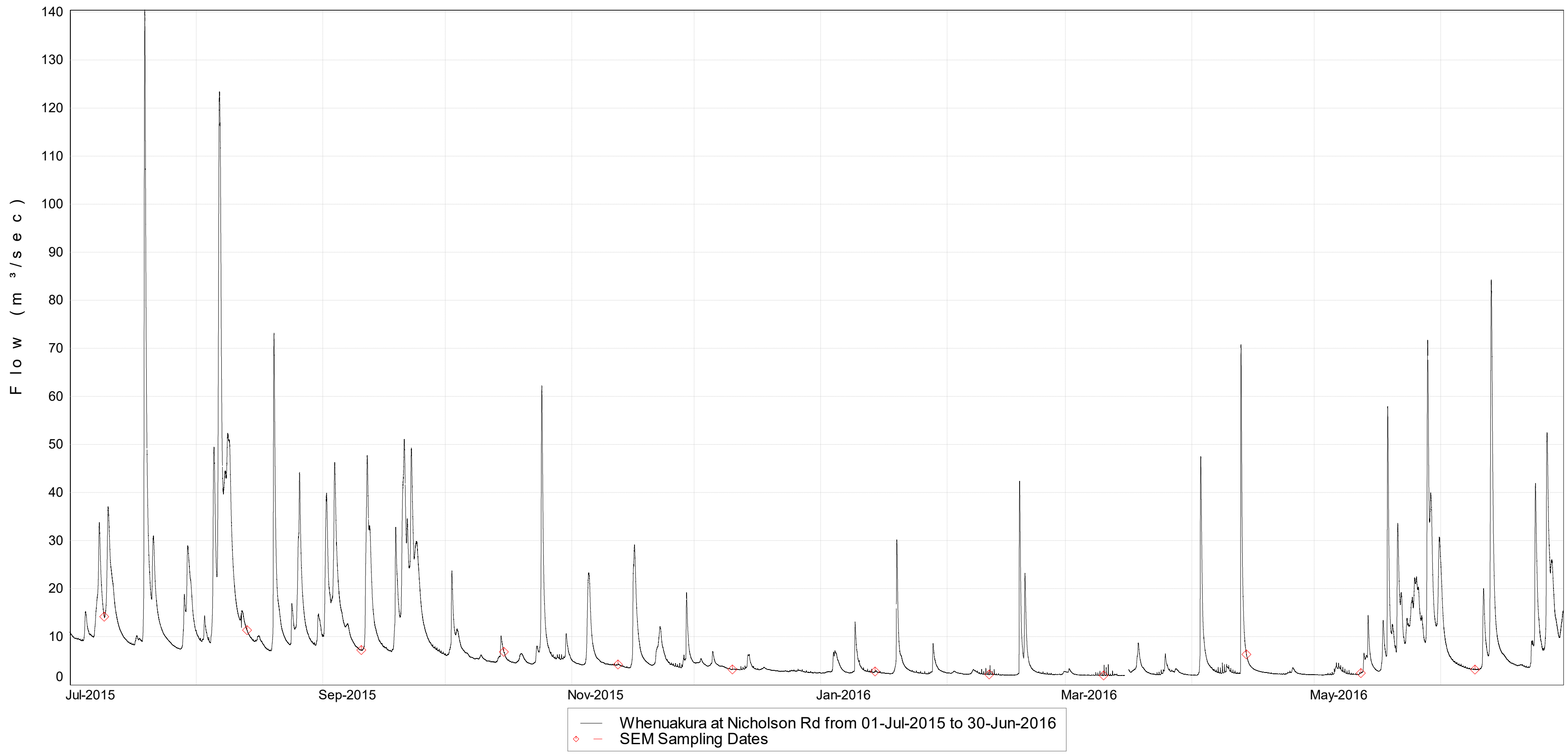


Figure 8 Flow record for the Whenuakura River at Nicholson Road

Dissolved oxygen concentrations (median 9.3 g/m^3) were consistently slightly below saturation level (range 88 to 97%). On the majority of occasions BOD_5 concentrations were indicative of relatively low organic content (i.e. less than 1.0 g/m^3), with values of up to 1.9 g/m^3 recorded. The median bacteriological numbers (365 faecal coliforms and 250 enterococci cfu/100 mL) were more reflective of the impacts of developed farmland run-off and possibly stock access to the lower reaches of this eastern hill country river. The high minimum faecal coliform number (100 cfu/100 mL) indicated a continuous or continual source upstream.

Water temperatures varied over a wide range of 14.6 ˚C with a maximum (early/mid- morning) summer temperature of 21.9 ˚C recorded in February 2016 under low flow conditions.

Waitara River at Tarata

Analytical data are presented in Table 38 from the monthly sampling programme. The flow record for the period is illustrated in Figure 9.

Table 38 Analytical results from monthly samples: Waitara River at Tarata

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD5	Cond @ 20 °C	DO	DO Sat	DRP	E.coli	ENT
	NZST	/cm	/cm	/cm	g/m^3 $CaCO_3$	m	g/m^3	mS/m	g/m^3	%	g/m^3P	cfu/100 mL	cfu/100 mL
09-Jul-2015	1335	0.076	0.019	0.002	15	0.07	0.7	7	11	96	0.010	930	160
13-Aug-2015	1335	0.026	0.006	0.001	19	0.29	<0.5	7.9	11.8	99	0.003	43	24
10-Sep-2015	1330	0.030	0.006	0.000	27	0.63	0.6	8.4	10.7	99	0.004	80	17
15-Oct-2015	1250	0.051	0.011	0.000	30	0.73	0.6	9	10.1	100	0.007	63	13
12-Nov-2015	1230	0.041	0.009	0.000	33	1.14	0.8	8.9	9.4	100	0.007	46	13
10-Dec-2015	1230	0.053	0.012	0.000	37	1.28	0.6	10.2	9.5	103	0.005	46	6
14-Jan-2016	1230	0.094	0.020	0.001	31	0.77	0.5	8.9	8.6	96	0.008	120	58
11-Feb-2016	1240	0.058	0.012	0.000	47	1.10	1.0	11.5	8.4	101	0.003	90	31
10-Mar-2016	1230	0.052	0.010	0.000	51	1.25	0.7	12.5	9.0	101	0.006	100	60
14-Apr-2016	1330	0.081	0.017	0.001	32	0.41	<0.5	10.2	9.4	94	0.008	540	250
12-May-2016	1330	0.076	0.016	0.001	42	0.54	0.6	11.6	9.5	97	0.006	400	600
09-Jun-2016	1315	0.033	0.006	0.000	30	0.68	<0.5	9.6	11.5	98	0.007	76	7

Date	Time	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
	NZST	cfu/ 100mL	m^3/s	g/m^3N	g/m^3N	g/m^3N	pH	g/m^3	°C	g/m^3N	g/m^3N	g/m^3P	NTU
09-Jul-2015	1335	930	38.519	0.027	0.003	0.21	7.3	320	8.6	0.43	0.64	0.021	300
13-Aug-2015	1335	43	28.909	0.018	0.002	0.47	7.2	25	7.8	0.09	0.56	0.055	22
10-Sep-2015	1330	84	24.113	0.013	0.002	0.36	7.4	8	10.9	0.07	0.43	0.022	11
15-Oct-2015	1250	63	20.901	0.008	0.002	0.13	7.6	6	14.8	0.15	0.28	0.021	8.6
12-Nov-2015	1230	68	11.38	0.011	0.002	0.16	7.7	4	18.2	0.1	0.26	0.020	5.3
10-Dec-2015	1230	46	7.226	0.036	0.002	0.01	7.8	3	18.7	0.21	0.30	0.023	3.7
14-Jan-2016	1230	120	9.985	0.018	0.002	0.01	7.5	7	20.7	0.16	0.26	0.029	8.3
11-Feb-2016	1240	93	5.72	0.007	<0.001	<0.01	7.8	5	24.5	0.08	0.09	0.020	4.2
10-Mar-2016	1230	100	4.625	0.012	0.001	0.02	7.9	2	21.1	0.16	0.18	0.023	3.7
14-Apr-2016	1330	560	21.389	0.017	0.003	0.11	7.4	19	15.6	0.44	0.55	0.043	18
12-May-2016	1330	410	25.587	0.011	0.003	0.14	7.7	15	15.4	0.17	0.31	0.034	11
09-Jun-2016	1315	76	10.485	0.036	0.002	0.34	7.6	6	7.8	0.04	0.38	0.019	9.1

A statistical summary of these data is presented in Table 39.

Table 39 Statistical summary of data from July 2015 to June 2016: Waitara River at Tarata

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.026	0.094	0.052	12	0.022
A440F	Absorbance @ 440nm filtered	/cm	0.006	0.020	0.012	12	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.002	0.000	12	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	15	51	32	12	10
BDISC	Black disc transparency	m	0.07	1.28	0.70	12	0.39
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.5	1.0	0.6	12	<0.5
CONDY	Conductivity @ 20˚C	mS/m	7.0	12.5	9.3	12	1.6
DO	Dissolved oxygen	g/m^3	8.4	11.8	9.5	12	1.1
PERSAT	Dissolved oxygen saturation %	%	94	103	99	12	3
DRP	Dissolved reactive phosphorus	g/m^3P	<0.003	0.010	0.006	12	<0.003
ECOL	E.coli bacteria	nos/100 mL	43	930	85	12	276
ENT	Enterococci bacteria	nos/100 mL	6	600	28	12	173
FC	Faecal coliforms	nos/100 mL	43	930	88	12	277
FLOW	Flow	m^3/s	4.625	38.519	16.14	12	10.706
NH_4	Ammoniacal nitrogen	g/m^3N	0.007	0.036	0.015	12	0.010
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.003	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m^3N	<0.01	0.47	0.13	12	0.14
pH	pH		7.2	7.9	7.6	12	0.2
SS	Suspended solids	g/m^3	2	320	6	12	90
TEMP	Temperature	°C	7.8	24.5	15.5	12	5.6
TKN	Total kjeldahl nitrogen	g/m^3N	0.04	0.44	0.15	11	0.14
TN	Total nitrogen	g/m^3N	0.09	0.64	0.30	12	0.16
TP	Total phosphorus	g/m^3P	0.019	0.055	0.022	12	0.011
TURB	Turbidity	NTU	3.7	300	8.8	12	84

Discussion

2015-2016 period

The relatively poor visual appearance which characterises the mid-reaches of this eastern hill-country catchment river was emphasised by a low median black disc clarity of 0.70 metres with a maximum of 1.28 metres measured under a lengthy low flow period in December 2015. Clarity was infrequently more than 1.2 metres (on two occasions) due to the presence of very fine, colloidal, suspended particles. The median suspended solids concentration was 6 g/m^3. Absorbances (at 340 and 440 nm) were also relatively high (in excess of 0.094/cm and 0.020/cm respectively) at all times, indicative of slight dissolved colour in the river water (e.g. yellow-brown appearance) at this site in the mid reaches of the river. Minimum clarity (0.07 m black disc value) was coincident with turbidity levels of 300 NTU and suspended solids concentration of 320 g/m^3, during flood flow of 39 m^3/s recorded in July 2015. Fresh flows (in excess of 20 m^3/s) were usually coincident with a general deterioration in water quality as emphasised by elevated turbidity, suspended solids, and bacterial counts (e.g. in July 2015, and April and May 2016; Figure 9).

Maximum mid-afternoon pH values in the mid to late summer period (7.8 to 7.9 units) were moderate for the mid reaches of a Taranaki river in early afternoon, an indication of the limited influence of algal photosynthetic activity on water quality. A minimum pH (7.0 units) was found under flood conditions in August 2016.

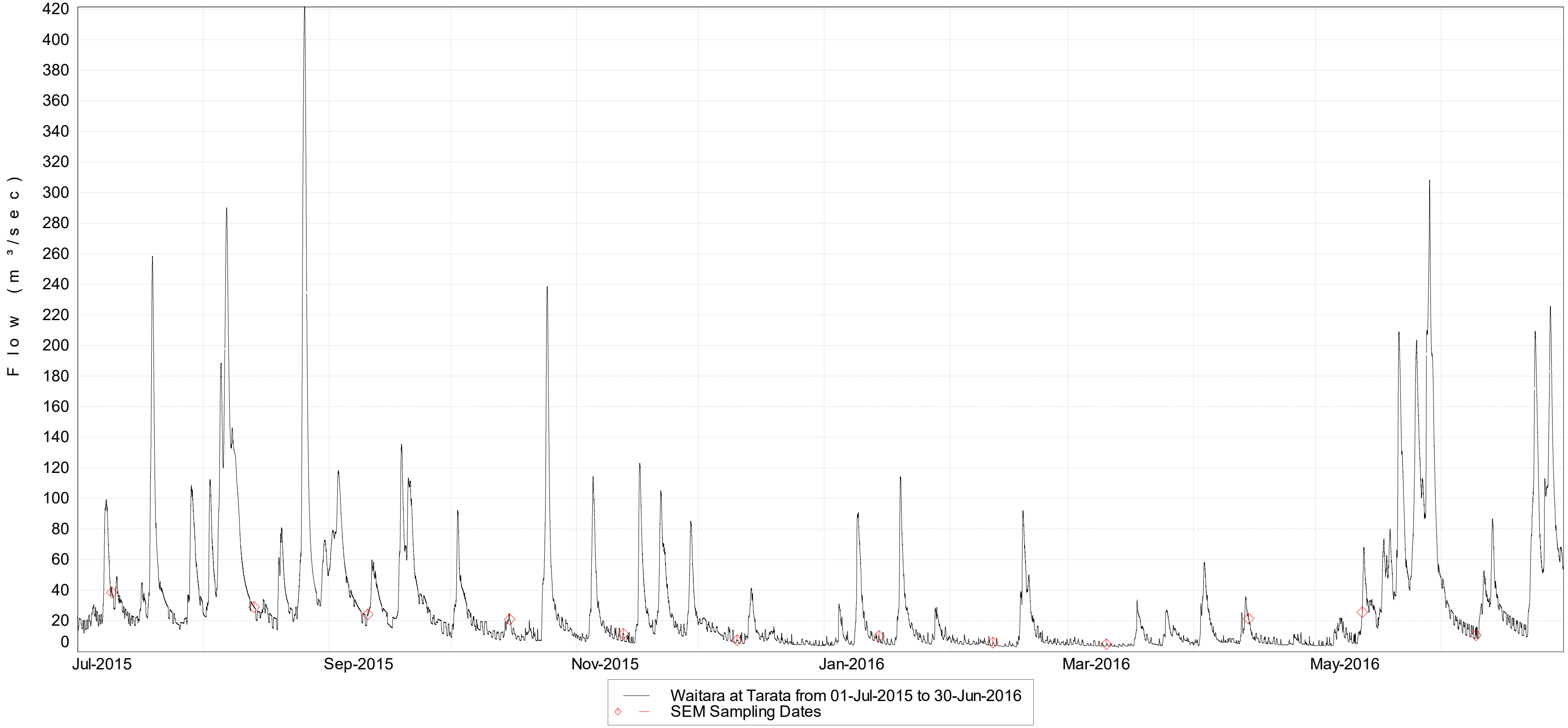


Figure 9 Flow record for the Waitara River at Tarata

Dissolved oxygen concentrations, were consistently high (median of 9.5 g/m^3) with a median saturation level of 99%. On the majority of occasions BOD_5 concentrations were indicative of relatively low organic content (i.e. less than 1.0 g/m^3). Moderate median bacteriological numbers (88 faecal coliforms and 28 enterococci cfu/100 mL) indicated some impacts of developed farmland run-off and possibly stock access to the lower reaches of this eastern hill country river. Nutrient species concentrations, both nitrogen and phosphorus, were relatively low, over narrow ranges.

Water temperatures varied over a wide range of 16.7 ˚C with a maximum (early afternoon) summer temperature of 24.5 ˚C recorded in February 2016 under low flow conditions, at which time dissolved oxygen saturation was 101% and pH was 7.8 units.

4.2. Comparative water quality for the twenty-year (1995-2016) period

4.2.1. TRC data

In addition to the site descriptions of water quality measured during the 2015-2016 monthly sampling programme, a general comparison between the thirteen sites of the programme may be made for the 21-year sampling period to date (1995-2016) using statistical (tabular and graphical) data summaries. These have been provided for each individual site in Tables 5, 8, 11, 14, 17, 20, 23, 26, 29, 32 and 35. Comparative statistics for selected parameters are provided in Table 40 and in the form of the 'box and whisker' plots of Appendix II.

These site comparisons for the summary data over the 21 year record are discussed within groupings of parameters, as follows.

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

The water quality at all but four of the sites has been clean and clear with very low median suspended solids concentrations (3 g/m^3 or lower) and low median turbidity levels (less than 2.5 NTU) except during flood flow conditions. The exceptions have been the three sites in the mid and lower reaches of eastern hill-country rivers and the lower reaches of the Waingongoro River. The eastern hill-country catchment rivers were typically slightly cloudy due to fine colloidal solids and yellow-brown in appearance under most flow conditions. An elevated median suspended solids concentration (30 g/m^3) has been recorded for the Whenuakura River, which was affected by widespread soil erosion after a major flood the month before the monitoring site was established in July 2015; median turbidity level (28 NTU, over one year) is significantly higher for this river than at any other site. The site in the lower reaches of the longest ring plain river (Waingongoro) also has elevated median suspended solids concentration (5 g/m^3) and turbidity (2.3 NTU). The site in the mid-reaches of the Stony River has shown marked variability, with erosion events in the headwaters the major contributing factor.

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

Black disc clarity has shown greater variation between sites although similar trends of decreasing clarity down catchments occurred. Highest clarity was found in the upper reaches of the Patea River and the mid reaches of the Stony River (when not impacted by upper catchment erosion events) and the Waiwhakaiho River, with these sites' median clarities greater than 3.0 metres and maxima in excess of 8 metres at times. All but four other sites have achieved a median black disc clarity in excess of 1.5 metres. Due to the elevated turbidity of the eastern hill country rivers, the median clarities in the mid and lower reaches of the rivers were all less than 0.9 metres, while the site in the lower reaches of the Waingongoro River also had a relatively low median black disc value of 1.18 metres. Greatest variability was found at the Stony River site which has been the subject of several severe upper catchment erosion events at irregular intervals during the 21 year period.

Table 40 Some comparative water quality data for the thirteen TRC SEM sites for the twenty one-year period July 1995 to June 2016 (n = 12 to 252 samples)

Site / Unit	Black disc (m)		BOD_5 (g/m^3)	Conductivity @ 20°C (mS/m)	Faecal coliform bacteria (cfu/100mL)		Nutrients: Ammonia (g/m^3N)	Nitrate (g/m^3N)	Total N (g/m^3N)	DRP (g/m^3P)	Total P (g/m^3P)	pH		Dissolved oxygen saturation (%)			Suspended solids (g/m^3)	Temperature (°C)			Turbidity (NTU)
	Maximum	Median	Median	Median	Minimum	Median	Median	Median	Median	Median	Median	Maximum	Median	Min	Med	Range	Median	Maximum	Median	Range	Median
Maketawa Stream at Tarata Road*	5.23	2.60	<0.5	8.6	50	320	0.009	0.25	0.38	0.024	0.034	7.9	7.6	90	98	13	<2	18.0	11.5	13.2	1.2
Mangaoraka Stream at Corbett Road	4.73	1.85	0.7	14.5	84	790	0.021	0.84	1.10	0.009	0.023	8.1	7.6	83	97	24	2	20.5	13.0	14.7	2.1
Waiwhakaiho River at SH3	8.05	3.08	<0.5	12.2	23	210	0.008	0.11	0.20	0.024	0.035	8.5	7.9	91	100	19	<2	18.3	11.1	13.5	0.7
Stony River at Mangatete Road	13.12	3.24	<0.5	9.7	<1	8	<0.003	0.02	0.06	0.018	0.024	8.2	7.8	87	99	19	<2	16.6	10.8	10.9	1.5
Punehu Stream at Wiremu Road	4.53	1.82	<0.5	8.6	3	120	0.006	0.03	0.14	0.023	0.034	8.3	7.6	87	100	19	<2	19.2	11.8	14.2	2.4
Punehu Stream at SH45	3.65	1.54	1.0	16.0	51	520	0.040	0.93	1.38	0.044	0.078	8.6	7.7	90	99	24	3	21.0	13.3	16.0	2.3
Waingongoro River at Eltham Road	4.39	1.70	0.7	11.2	6	190	0.017	1.11	1.43	0.020	0.039	8.6	7.8	92	103	29	3	21.5	12.6	15.9	2.0
Waingongoro River at SH45 **	4.34	1.18	1.0	16.4	3	220	0.034	1.87	2.40	0.054	0.097	9.1	7.8	89	102	52	5	22.0	13.7	16.6	3.2
Patea River at Barclay Road	10.14	4.38	<0.5	6.2	<1	21	<0.003	0.02	0.08	0.018	0.024	8.0	7.5	90	99	13	<2	14.9	9.2	11.2	0.6
Patea River at Skinner Road	4.68	1.83	0.9	9.9	2	225	0.052	0.91	1.22	0.038	0.066	8.8	7.8	87	103	34	2	22.3	12.9	17.0	1.7
Mangaehu River at Raupuha Road	4.04	0.86	0.6	9.9	6	230	0.012	0.09	0.30	0.006	0.020	8.4	7.7	83	100	35	4	24.9	13.8	20.6	4.0
Whenuakura River at Nicholson Road***			0.9	19.8	100	365	0.024	0.42	0.66	0.016	0.070	7.9	7.7	88	94	11	30	21.9	14.8	14.6	28
Waitara River at Tarata***	1.28	0.70	0.6	9.3	43	88	0.015	0.13	0.30	0.006	0.022	7.9	7.6	94	99	9	6	24.5	15.5	16.7	8.8

[Notes:* for the period July 2003 to June 2016 (n = 156 samples); ** for the period July 1998 to June 2016 (n = 216 samples); *** for the period July 2015 to June 2016 (n = 12 samples)]
Turbidity is for the period June 2005 to June 2016.

Absorbances (at 340 nm) have been generally relatively low. They are indicative of slight dissolved colour particularly at the eastern hill country sites, 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 were very low, indicating that any apparent dissolved colour was seldom due to the scattering effects of small colloidal particles.

Water temperature, pH, and conductivity

Coldest median water temperature (9.2 ˚C) has been measured at the upper site on the Patea River (altitude: 500 m asl) with increased median water temperatures in a downstream direction as might be expected. Highest maximum water temperatures have been recorded in the lower reaches of the Mangaehu River (24.9 ˚C), the Whenuakura River (24.5°C), the Waingongoro River (22.0 ˚C), and the smaller Punehu Stream (21.0 ˚C), and in the mid reaches of the Waitara River (24.5°C) and Patea River (22.3 ˚C); these six sites also exhibiting five of the six highest medians (13.8 ˚C, 14.8°C, 13.7 ˚C, 13.3 ˚C, 15.5°C and 12.9 ˚C, respectively) and widest ranges (20.6 ˚C, 14.6°C, 16.6 ˚C, 16.0 ˚C, 16.7°C and 17.0 ˚C, respectively) of water temperatures. Atypically, relatively high median (11.8 ˚C), maximum (19.2 ˚C) and a wide range (14.2 ˚C) of water temperatures have been recorded in the upper reach of the Punehu Stream at Wiremu Road, probably due to the open, bouldery nature of the 2 km reach between the National Park and the sampling site (altitude: 270 m asl).

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

Conductivity, a measure of the degree of mineralisation of the water, increased with distance downstream but median values were all indicative of relatively low total ionic content (i.e. <16.5 mS/m at 20 °C, except the new site in the lower reaches of the Whenuakura River, at 19.8 mS/m at 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 three eastern hill country sites. Ranges were relatively narrow at most sites (< 30% at ten sites) and median values were 94% saturation or higher at all sites. Summer-autumn lower flow conditions, coincident with more extensive algal substrate cover, resulted in supersaturation on occasions at various sites in the mid to lower reaches of streams and rivers. The narrowest saturation ranges (≤13%) were found in the upper reaches of the Patea River, mid reaches of the Maketawa Stream and Waitara River, and lower reaches of the Whenuakura River, with wider saturation ranges (≥19%) recorded at mid and lower catchment sites, and the widest (52%) in the lower reaches of the longest ring plain river where substrate periphyton cover often has been more extensive. (Note: Wider ranges may occur at all sites, but particularly lower reach sites, as the nature of the sampling regime does not provide for diurnal variability; rather sampling is confined to a narrow fixed time window for each site.)

Biochemical oxygen demand (BOD_5), a measure of the amount of biodegradable matter present, was generally less than 1 g/m^3 (i.e. no medians greater than 1.0 g/m^3), indicative of low organic enrichment at all sites. Median values were highest in the lower reaches of the Punehu Stream (1.0 g/m^3), Waingongoro River (1.0 g/m^3) and Whenuakura River (0.9 g/m^3), and the mid reaches of the Mangaoraka Stream and Waingongoro and Patea Rivers, all sites downstream of point and non-point source discharges. Elevated BOD_5 levels (>2 g/m^3) have been measured from time to time at most sites during fresh and flood flow conditions, reflecting the influence of non point source farmland and stormwater run-off, and have reached 2.4 g/m^3 under summer low flow conditions downstream of Stratford in the Patea River at the Skinner Road site.

Nutrients (nitrogen and phosphorus)

Nutrients such as nitrate, ammoniacal nitrogen and dissolved reactive phosphorus may readily be taken up by the flora of rivers and streams. An abundance of these nutrient forms may result in prolific and objectionable growths of attached filamentous algae (periphyton), particularly when in combination with low river flows, increased temperatures, and a plentiful supply of energy in the form of light (autotrophic growths) and/or organic matter (heterotrophic growths). Highest nutrient concentrations were recorded at the lower sites in the ring plain rivers and streams sampled, consistent with increased non-point source run-off and point source discharges through each ring plain catchment e.g., increases of 890% and 130% in median total nitrogen and total phosphorus respectively over the length of the Punehu Stream; 1425% and 175% respectively from the upper to the mid reaches of the Patea River; and 68% and 150% respectively through the mid to lower reaches of the Waingongoro River. Elevated nitrate concentrations often reflect high groundwater inputs, particularly after very wet weather (winter-spring) conditions when groundwater levels are higher and therefore contribute more proportionately to river/stream base flows. Highest median concentrations of dissolved reactive phosphorus (DRP), total phosphorus, ammoniacal, nitrate and total nitrogen were generally found at the lower Punehu Stream site, mid Patea River (Skinner Road) site, mid and lower Waingongoro River sites, and to a slightly lesser degree at the site in the Mangaoraka Stream. However, relatively low dissolved reactive phosphorus concentrations (median of <0.01 g/m^{3}P) in the Mangaoraka Stream reflect the source of this ring plain stream which rises outside of the National Park, compared with the documented natural sources of dissolved phosphorus from within the Park found in ring plain rivers and streams (TCC, 1984 and TRC, 2010). Relatively low dissolved reactive phosphorus (median of <0.01 g/m^{3}P) measured at the sites in the mid reaches of the Waitara River and lower reaches of the Mangaehu River reflect the rivers' eastern hill country catchment source. The high total phosphorus concentrations, largely in particulate form, measured for the lower reaches of the Whenuakura site (median of 0.07 g/m^{3}P) relate to the high sediment loads carried during the first year of monitoring.

Bacteria

Poor bacteriological water quality (median faecal coliform numbers from 220 to 790 per 100 mLs) has been recorded at the sites in the lower reaches of the Maketawa Stream, Punehu Stream, Waingongoro River, Mangaehu River, Whenuakura River and particularly the Mangaoraka Stream. Relatively poor bacteriological quality (medians from 190 to 225 per 100 mLs) in the mid reaches of the Waiwhakaiho, Waingongoro, and Patea Rivers, also reflect non-point source run-off and point source discharges (and possibly stock access) to these developed farmland river and streams. The cumulative impacts of several dairy pond treatment systems' discharges to the Mangatawa Stream have impacted upon Punehu Stream quality (TRC, 2011). One of the site's (Mangaoraka Stream) counts have continuously exceeded 80 faecal coliforms cfu/100 mL, indicative of consistently poor bacteriological quality, and the Whenuakura River minimum count of 100 cfu/100 mL was high in the first year of monitoring the lower reaches.

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

The sites in the Patea River's upper reaches (at Barclay Road) and the Stony River in mid-reach (at Mangatete Road) generally recorded very high bacteriological water quality, with median faecal coliform numbers of 21 and 8 cfu/100 mL respectively.

The upper site in the Punehu Stream (at Wiremu Road), however, has had an unexpectedly high median faecal coliform count of 120 cfu/100 mL, 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 21 years of data for the two Taranaki region sites included in the NIWA national network (see Figure 1) is presented in Table 41. (A third site, Waingongoro River at SH45, was monitored until December 2015. Refer to TRC 2015 for a summary of comparative data from this site).

Table 41 Some comparative water quality data for the two NIWA SEM sites for the 21-year period July 1995 to June 2016 (n = 252 samples)

Site Unit	Black disc (m)		BOD_5 (g/m^3)	Conductivity @ 20°C (mS/m)	Nutrients					pH		Dissolved oxygen saturation %	Temperature (°C)			Turbidity (NTU)	Flow (m^3/sec)
					Amm-N (g/m^3N)	Nitrate (g/m^3N)	Total N (g/m^3N)	DRP (g/m^3P)	TP (g/m^3P)								
	Maximum	Median	Median	Median	Median	Median	Median	Median	Median	Maximum	Median	Median	Maximum	Median	Range	Median	Median
Waitara River at Bertrand Road	3.14	0.49	0.7	8.8	0.013	0.33	0.58	0.006	0.037	8.6	7.7	102	23.1	13.8	16.7	8.6	29.5
Manganui River at SH3	7.7	4.03	<0.5	6.3	0.006	0.09	0.18	0.009	0.015	8.0	7.5	101	18.7	10.6	14.6	0.9	0.95

These data indicate more turbid (cloudier) appearance in the lower reach of the Waitara River (median black disc clarity of 0.49 metres and turbidity of 8.6 NTU) with very clear conditions toward the upper reach of the Manganui River. Lower Waitara River median clarity was the worst of all fifteen sites monitored in the region, reflecting the significant impact of the eastern hill country component of this large river's catchment. (Similar patterns are noted in the Mangaehu and Whenuakura Rivers [Table 40]). Median water temperatures were typical of those found at comparable sites elsewhere in the region (Table 40 and Table 41), 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).

4.2.3. Comparative water quality for the twenty-year (1995-2016) period

The 21 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 42.

Table 42 Comparison of 1995-2016 SEM (TRC and NIWA) sites' median water quality with guideline values for various usages

Usage	Aesthetics		Contact recreation		Prevention of undesirable growths			Stock water		Aquatic ecosystems					Irrigation	Drinking water	
Parameter	Black disc	BOD_5	*E.coli*	BOD_5	DRP	TP	TN	Faecal coliforms	Faecal coliforms	Black disc	DO Saturation	NO_3	NH_4	Temp	TN	TP	NO_3
Guideline	>1.6 m	<3g/m³	<550/ 100mLs	<3g/m³	<0.03 g/m³P	<0.03 g/m³P •	<0.6 g/m³N •	<1000/ 100mLs	Median <100/100 mLs	>0.8m	>80%	<0.4 g/m³N	<0.9 g/m³N	<25 ˚C	<25 g/m³N	<0.8 g/m³P	<11.3 g/m³N
Reference	1,2	2,3	2,3	2	1,2	1	1	1,2	1			1,2	1	2	1	1	1,2
Site																	
Maketawa Stream at Tarata Road	✓	✓✓	✓	✓✓	✓	x	✓	✓	x	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Mangaoraka Stream at Corbett Road	✓	✓	x	✓	✓	✓	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓	✓✓
Waiwhakaiho River at SH3	✓	✓	✓	✓	✓	x	✓	✓	x	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Stony River at Mangatete Road	✓	✓✓	✓	✓✓	✓	✓	✓	✓	✓	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓	✓✓
Punehu Stream at Wiremu Road	✓	✓	✓	✓	✓	x	✓	✓	x	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Punehu Stream at SH45	x	✓	✓	✓	x	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓✓	✓✓
Waingongoro River at Eltham Road	✓	✓	✓	✓	✓	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓	✓✓
Waingongoro River at SH45	x	✓	✓	✓	x	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓✓	✓✓
Patea River at Barclay Road	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Patea River at Skinner Road	✓	✓	✓	✓	x	x	x	✓	x	✓	✓✓*	x	✓✓	✓✓	✓✓	✓	✓✓
Mangaehu River at Raupuha Road	x	✓	✓	✓	✓✓	✓	✓	✓	x	✓	✓✓*	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Whenuakura River at Nicholson Road°	x	✓✓	✓	✓✓	✓✓	x	x	✓	x	x	✓✓*	x	✓✓	✓✓	✓✓	✓✓	✓✓
Waitara River at Autawa Road°	x	✓✓	✓	✓✓	✓✓	x	✓	✓✓	✓	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Manganui River at SH3	✓	✓✓	✓	✓✓	✓	✓	✓	✓	✓	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Waitara River at Bertrand Road	x	✓✓	✓	✓✓	✓	x	✓	✓	x	x	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Summary of sites (15) in compliance	9	15	14	15	12	5	9	15	4	13	15	9	15	15	15	15	15

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

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

[Note: ° Whenuakura River at Nicholson Road and Waitara River at Autawa Road data are for the period July 2015 to June 2016 (n = 12 samples).

4.2.3.1.Aesthetics

Most sites met the aesthetic quality guidelines, although the six sites which did not achieve the black disc clarity are all situated in the mid or lower reaches of catchments, three of which (Mangaehu, Waitara and Whenuakura 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 guidelines. 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, 2016), and on the Council's website (www.trc.govt.nz). However, the sites' data presented in Table 42 are indicative of bacteriological conditions likely to exist at contact recreational sites in the vicinity of the reaches of the streams/rivers monitored.

One site (in the lower reaches of the Mangaoraka Stream) consistently failed to meet the guideline, while most of the other sites have failed to meet instantaneous guidelines ('Alert' and 'Action' modes (TRC, 2016) occasionally under spring-summer low flow conditions (refer to individual tables of 2015-2016 data) and under flood flow conditions (when contact recreation suitability is not an issue).

4.2.3.3.Undesirable growths

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

In the lower reaches of most Taranaki catchments, elevated nutrient levels are high enough to promote algal growth under low flow conditions. Most lower river/stream sites illustrated exceedances of nutrient guideline values (Table 42). 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, TRC, 2014a and TRC, 2016b). In general, periphyton growths are more likely and more prolific in drier summers, when flows decrease and there is less scouring and disturbance of stream beds, more sunlight, higher temperatures, less grazing by macroinvertebrates, and less dilution of discharges containing nutrients. The lower reaches of ring plain streams in southern and western Taranaki particularly can experience nuisance growths particularly in the mid summer-early autumn period.

4.2.3.4. Stock water

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

The ANZECC (2000) water quality guideline stipulates a limit of 100 thermo-tolerant coliforms (which includes faecal coliforms) cfu/100 mL, 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 four of the nine sites shown in Table 42 as otherwise exceeding the bacteriological guidelines, the 25th percentile result (see Appendix I) satisfies the criterion. All sites complied with the nitrate-N guideline.

4.2.3.5. Aquatic ecosystems

While all sites complied with the ammonia-N and temperature guidelines, six sites (in the middle to lower reaches of catchments) had median values above the guideline for nitrate-N and two sites under the visibility guideline. The Council has a separate SEM programme that focuses specifically on the macroinvertebrate fauna of 59 sites in the region (including all of the thirteen sites in the physicochemical programme and the two NIWA sites) and none of these sites' communities has illustrated significant deterioration, while five (two middle and three lower reach) of the 13 sites in the physicochemical programme have shown significant improvements in stream 'health' trends over the 21 years (1995 to 2016) to date (TRC, 2006c, Stark and Fowles, 2006 and TRC, 2016a).

4.2.3.6. Irrigation

All sites met the relevant nutrient guidelines for irrigation water.

4.2.3.7. Drinking water

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

4.2.4. National Objectives Framework

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

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

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

Overall freshwater quality within a region must be maintained or improved. The national policy statement allows some variability in terms of freshwater quality, within each Freshwater Management Unit, as long as the overall freshwater quality is still maintained within that FMU.

In September 2015, Ministry for the Environment published a reference document on reporting and calculation NOF values called 'A Draft Guide to Attributes – in Appendix 2 of the NPS-FW, 2014. The purpose of the Guideline is to provide Council staff with guidance on the role and use of attributes involved in the implementation of the NPS-FM.

The NPS-FM identifies 13 national values and uses for freshwater. Two of these are compulsory values that apply to all water bodies: ecosystem health and human health for recreational objectives for freshwater, because it is moderately well correlated with *Campylobacter* bacteria and numeric health risk levels can be calculated (MfE, 2015).

Based on the guideline document, the recommended number of samples to determine the sample statistic for assessing progress towards freshwater objectives is at least 30 samples collected on a monthly basis over three years. Fewer samples can be used, but confidence in sample statistics will be lower. More samples will improve the confidence in estimates of sample statistics, however, the marginal improvements in confidence diminish beyond about 20-40 samples (McBride, 2014).

While the NOF documentation discusses an 'annual median' as the basis for determining compliance, the measure is rather the median of 3 years' worth of data, rather than just one. What that means in practice is that if the dataset encompasses one year of poor water quality and two years of relatively good quality, then the median of the full dataset will overall show a poorer quality than if the 3 individual annual medians were calculated and then the median of the annual medians used as the point of compliance determination.

SEM monitoring data from 2013 - 2016 were used to analyse the NOF attribute state (36 data points). The results for the 11 SEM sites where 3 years of data have been collected are summarised in Table 43 and illustrated in Figure 10.

Table 43 Summary result for water quality data from 2013-2016 against National Objective Framework attribute states (n=36 samples).

Value	Ecosystem health				Human health
Attribute	Nitrate-N (g/m3)		Ammoniacal-N		E.*coli*
	Annual median	Annual 95th percentile	Annual median	Annual 95th percentile	Annual median
Maketawa Stream at Tarata Rd	A	A	A	A	B
Mangaoraka Stream at Corbett Rd	A	A	A	B	D
Waiwhakaiho River at SH3	A	A	A	B	B
Stony River at Mangatete Rd	A	A	A	A	A
Punehu Stream at Wiremu Rd	A	A	A	A	A
Punehu Stream at SH45	B	B	A	B	C
Waingongoro River at Eltham Rd	B	B	A	B	A
Waingongoro River at SH45	B	B	A	B	A
Patea River at Barclay Rd	A	A	A	A	A
Patea River at Skinner Rd	A	A	B	B	A
Mangaehu River at Raupuha Rd	A	A	A	A	A

4.2.4.1.Ecosystem health

The national policy statement specifies attributes to manage long term exposure for two toxicants, nitrate and ammoniacal nitrogen. These toxicants can cause both lethal and sub-lethal (e.g. reducing growth rates or reproductive success) effects to aquatic species. It is recommended for councils to set freshwater objectives in the A or B attribute states when sensitive species are present that may be at risk of lethal effects.

All sites met the NOF standard set for toxicants nitrate and ammoniacal nitrogen. Almost half the sites (45%) achieved 'A' grade for both attributes, and all sites achieved either A or B grade.

4.2.4.2.Human health

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

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

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

All sites met the NOF attribute state for E.*coli* except Mangaoraka Stream at Corbett Rd. The "annual" median E.*coli* at this site exceeded the national bottom line limit of 1,000 E.*coli*/100mL. Investigative work on the Mangaoraka Stream in the past has attributed high E.*coli* and faecal coliform to direct stock access to streams and the cumulative impacts of consented dairy pond discharges, particularly under low flow conditions.

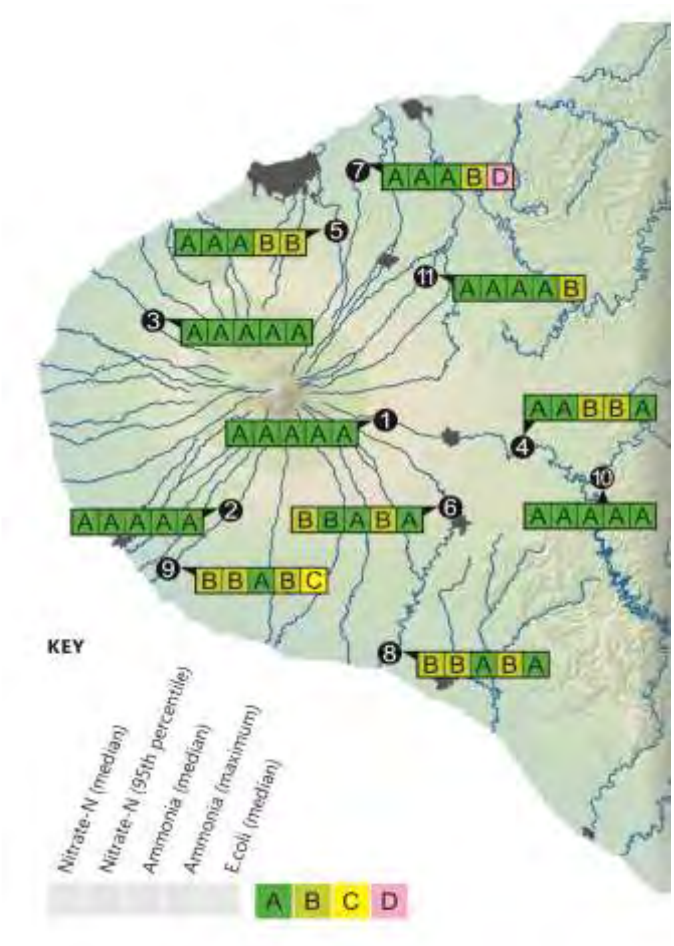


Figure 10 Results for NOF attribute states for 11 SEM sites in Taranaki

4.3. Trends in physicochemical water quality data from 1995 to 2016

4.3.1. Introduction

Twenty one years of physicochemical water quality data have been collected up to 30 June 2016. These data have been analysed for trends each year since 10 years of data became available. Previous trend analysis has been reported in TRC (2006, 2009, 2009a, 2010, 2011, 2012, 2013, 2014, 2015a and 2016).

An update of the trends including data from the 2015-2016 monitoring year is provided. It does not include a detailed interpretation of the results. This will be provided at least prior to each five-yearly State of the Environment Report, if not before.

4.3.2. Trend analysis methods

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

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

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

This analysis is based on two key measures:

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

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

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

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

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

4.3.3. Results of long term trend analysis

Table 44 summarises the significant trends recorded for each water quality parameter at the 11 sites monitored in the physicochemical state of the environment monitoring programme where there are sufficient data. Trend analysis will be performed on the two sites that were established in 2015-2016, on the Whenuakura River at Nicholson Road and the Waitara River at Tarata, when 10 years' of data have been gathered.

Of the nutrients, DRP, and to a lesser extent total phosphorus, have shown a significantly deteriorating trend (ie concentrations are increasing) at a number of sites, including the upper and middle catchments which would be less subject to anthropogenic pressures. Six out of eleven sites have shown a significant deterioration in DRP. When compared with other nutrients, the deterioration in total phosphorus is more limited to the middle and lower catchments where more land use intensification and urbanisation occurs.

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

Generally, where there is an increase in nutrient concentrations, this is occurring in mid (32% of measurements at such sites) or lower (28% of such measurements) catchment sites. There is notable improvement in the Waingongoro River at SH45 for DRP and total phosphorus. This is a positive aspect as the lower catchment would be under the most pressure from land use intensification and upstream influences. The Punehu Stream at SH45 has the greatest number of deteriorating trends in relation to nutrients (four out of five nutrients deteriorating significantly), followed by the Waiwhakaiho River at SH3 (three of five nutrients). All other sites had 2 or less of 5 nutrients increasing (Table 44).

Deterioration in phosphorus parameters appeared to be increasing at a steady but slow rate at the Maketawa Stream at Tarata Road, Waingongoro River at Eltham Road, Mangaoraka Stream at Corbett Rd and Punehu Stream at SH45 (Figure 12). The Patea River at Barclay Road and Waiwhakaiho River at SH3 also show an increasing DRP trend. The Punehu Stream at SH45 has recently shown very significant deteriorating trends in dissolved reactive phosphorus, nitrate, total nitrogen and, to a lesser extent, total phosphorus. Nitrogen parameters appear to have peaked between 2003 and 2005, and are still showing deteriorating trends in Waiwhakaiho River at SH3 and Punehu Stream at SH45 (Figure 12).

The Waingongoro River at SH45 is showing a very significant improving trend in dissolved reactive phosphorus and total phosphorus (Figure 12). It is probable that this is due to the more recent reduction in meatworks' discharges to the river at Eltham and the elimination of all Eltham WWTP municipal discharges in the catchment (since mid-2010). However, significant increasing trends were detected for ammonia-nitrogen and BOD at this site.

Summarizing across all measures of nutrients undertaken at all sites, variously between two-thirds and three-quarters of all nutrient trends either show no significant trend (ie 'maintenance') or show improvement ('enhancement').

Faecal coliforms and enterococci bacteria generally showed little statistically significant change over the 21 year period, although Mangaoraka Stream at Corbett Rd indicated a very significant deteriorating trend in faecal coliforms and enterococci. There is also a very significant increase in faecal coliforms at Waiwhakaiho River at SH3, and in enteroccoci at Punehu Stream at SH45. One site showed significant improvement in faecal coliforms: Punehu Stream at Wiremu Road, an upper catchment site.

Summarizing across all measures of trends in bacteriological quality at all sites. 82% of measures are showing either maintenance or enhancement over the long-term.

Traditional indicators of pollution, organic matter (BOD), suspended solids, clarity (black disc), conductivity (dissolved matter) generally show no apparent trends at most sites over the 21 year period. However, the Stony River shows deterioration in clarity and suspended solids as a result of the significant erosion events that have occurred in the headwaters of this catchment in recent years and the LOWESS curve (Figure 12) indicates periods of erosion and recovery over time. Deterioration in clarity has also been significant at Waiwhakaiho River (SH3) and the Mangaoraka Stream (Corbett Road), where steady declines throughout the period are apparent (Figure 12). There is no longer an improvement in clarity at the Waingongoro SH45 site, but a continued improvement in suspended solids at Punehu Stream SH 45. There has been a continued deterioration trend in BOD at Waingongoro SH45 since the 2014 year. Mangaoraka Stream at Corbett Road showed no significant deterioration in BOD in this year's analysis, being just less than the 1% per year criterion. Some significant trends in water temperature and pH have been noted (Table 44), with almost all sites showing a negative trend for both parameters. However, the rates of change per year in most of these cases are less than 1% and are not 'meaningful' changes.

Figure 12 shows the trends graphically for a selected number of sites and parameters where significant trends were recorded.

Table 44 'Meaningful' trends in surface water quality at 11 State of the Environment Monitoring sites in Taranaki- 1995-2016 (p<5% and RSKSE (%change/yr) >1%)

Catchment Level	Location	Dissolved Reactive P	Total Phosphorus	Nitrate	Ammonia-N	Total Nitrogen	Faecal coliforms	Enterococci	Conductivity	Black Disc	Suspended Solids	Temp°C	Biochemical O_2 Demand	pH	Total no. sites: Improvement	No change	Deterioration
Upper	Patea River Barclay Rd	● red	● grey	● grey	● grey	● dark green	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	1	11	1
Upper/ Middle	Punehu Stream Wiremu Rd	● grey	● grey	● grey	● red	● dark green	● green	● grey	● grey	● grey	● grey	● grey	● grey	● grey	2	10	1
Middle	Stony River Mangatete Road	● grey	● red	● grey	● grey	● dark green	● grey	● grey	● grey	● red	● red	● grey	● grey	● grey	1	9	3
Middle	Maketawa Stream Tarata Road*	● red	● orange	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	0	11	2
Middle	Patea River Skinner Rd	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	0	13	0
Middle	Waiwhakaiho R. SH3	● red	● grey	● red	● red	● grey	● red	● grey	● grey	● red	● grey	● grey	● grey	● grey	0	8	5
Middle	Waingongoro R. Eltham Rd	● red	● red	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	0	11	2
Lower	Mangaoraka Str. Corbett Rd	● red	● red	● grey	● grey	● grey	● red	● red	● grey	● red	● grey	● grey	● grey	● grey	0	8	5
Lower	Waingongoro R. SH45**	● dark green	● dark green	● grey	● red	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● red	● grey	2	9	2
Lower	Punehu Stream SH45	● red	● orange	● red	● grey	● red	● grey	● red	● grey	● grey	● green	● grey	● grey	● grey	1	7	5
Lower	Mangaehu River Raupuha Rd	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	● grey	0	13	0
Total no. sites: Improvement		1	1	0	0	3	1	0	0	0	1	0	0	0			
No change		4	5	9	8	7	8	9	11	8	9	11	10	11			
Deterioration		6	5	2	3	1	2	2	0	3	1	0	1	0			

Key:

*Maketawa Tarata Road: Data for this site only for the past 13 years: 2003-2016

**Waingongoro SH45: Data for this site only for the past 18 years: 1998 – 2016

● dark green statistically very significant **improvement** P<0.01 (1%)

● green statistically significant **improvement** P<0.05 (5%)

● grey no statistically significant change

● orange statistically significant **deterioration** P<0.05 (5%)

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

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

Table 45 *p*-values (%) and trend slopes (% change per year) for flow and seasonally adjusted water quality variables at 11 Taranaki sites. Significant deteriorations are shown in orange (*p*<5%) and red (*p*<1%) and significant improvements are shown in light green (p<5%) and dark green (p<1%). 'Real' trends (i.e., the change is ecologically significant) are highlighted (>1% change per

Catchment Level	Location	Water Quality Variable													
		Dissolved Reactive P		Total Phosphorus		Nitrate		Ammonia-N		Total Nitrogen		Faecal coliforms		Enterococci	
		p-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr
Upper	Patea River Barclay Rd	0.01	1.14	21.26	0.33	0.32	-0.54	77.36	0.07	0.00	-3.23	91.67	-0.08	8.59	2.55
Upper/ Middle	Punehu Stream Wiremu Rd	58.29	0.15	68.20	-0.12	11.26	1.13	0.40	2.88	0.00	-2.04	2.19	-2.05	80.04	-0.36
Middle	Stony River Mangatete Road	0.01	0.95	0.33	1.25	65.66	0.26	23.24	-0.15	0.00	-3.57	74.70	-0.54	9.94	1.57
Middle	Maketawa Stream Tarata Road	0.01	2.30	3.61	1.64	56.11	-0.55	6.44	2.27	5.95	-0.94	33.27	1.59	17.51	2.79
Middle	Patea River Skinner Rd	1.58	-0.84	4.05	-0.83	37.86	0.19	66.93	0.25	55.92	-0.10	17.11	-1.63	92.36	-0.11
Middle	Waiwhakaiho SH3	0.02	0.98	0.37	0.69	0.05	2.05	0.03	2.89	7.12	-0.72	0.11	3.06	13.15	1.48
Middle	Waingongoro Eltham Rd	0.00	3.74	0.00	2.54	1.82	0.68	35.10	0.72	18.23	0.39	14.07	-1.79	32.46	-1.26
Lower	Mangaoraka Stream Corbett Rd	0.01	2.49	0.23	1.56	36.00	-0.19	11.46	1.00	2.29	-0.51	0.26	2.54	0.00	6.16
Lower	Waingongoro SH45*	0.00	-2.91	0.00	-2.33	0.04	-0.95	0.43	2.08	0.01	-0.81	93.90	-0.08	92.16	-0.15
Lower	Punehu Stream SH45	0.00	1.96	1.24	1.01	0.00	2.15	96.52	-0.04	0.09	1.13	36.00	-0.75	0.01	4.37
Lower	Mangaehu River Raupuha Rd	68.20	0.19	45.87	0.43	53.60	0.24	89.60	0.04	4.05	-0.76	5.63	-1.78	66.93	0.74
Total no. sites: Improvement ☺		1		1		0		0		3		1		0	
No change ☹		4		5		9		8		7		8		9	
Deterioration ☹		6		5		2		3		1		2		2	

Table 45 (cont) *p*-values (%) and trend slopes (% change per year) for flow and seasonally adjusted water quality variables at 11 Taranaki sites. Significant deteriorations are shown in orange (*p*<5%) and red (*p*<1%) and significant improvements are shown in light green (p<5%) and dark green (p<1%). 'Real' trends (i.e., the change is ecologically significant) are highlighted [ ] (>1% change per year).

Catchment Level	Location	Conductivity *p*-value (%)	Conductivity % change per yr	Black Disc *p*-value (%)	Black Disc % change per yr	Suspended Solids *p*-value (%)	Suspended Solids % change per yr	Temp °C *p*-value (%)	Temp °C % change per yr	Biochemical O_2 *p*-value (%)	Biochemical O_2 % change per yr	pH *p*-value (%)	pH % change per yr
Upper	Patea River Barclay Rd	21.90	-0.09	88.15	-0.04	93.05	0.00	24.63	-0.22	70.24	0.00	43.78	-0.01
Upper/ Middle	Punehu Stream Wiremu Rd	0.00	0.30	38.81	-0.40	89.60	0.02	3.27	-0.41	30.36	-0.08	0.00	-0.09
Middle	Stony River Mangatete Road	76.03	0.03	0.00	-3.14	0.01	12.46	29.15	-0.14	30.28	0.00	2.74	-0.04
Middle	Maketawa Stream Tarata Road	56.11	0.04	79.16	-0.24	58.51	0.18	87.41	0.05	2.53	1.96	81.89	0.00
Middle	Patea River Skinner Rd	90.98	-0.01	32.46	-0.37	36.00	-0.17	89.60	-0.02	17.11	0.63	16.05	-0.04
Middle	Waiwhakaiho SH3	3.00	-0.19	0.25	-0.92	50.21	0.05	4.40	-0.36	11.87	0.47	0.00	-0.09
Middle	Waingongoro Eltham Rd	88.22	-0.02	14.07	-0.53	64.41	0.09	7.12	-0.24	13.15	0.78	0.30	-0.06
Lower	Mangaoraka Stream Corbett Rd	11.07	0.14	0.00	-1.73	28.75	0.63	11.07	-0.26	4.78	0.91	5.63	-0.03
Lower	Waingongoro SH45*	35.27	0.11	5.85	0.89	48.40	-0.42	9.43	-0.31	0.02	2.46	0.00	-0.14
Lower	Punehu Stream SH45	1.73	0.28	72.08	0.11	1.73	-1.47	4.40	-0.29	67.56	0.09	0.00	-0.11
Lower	Mangaehu River Raupuha Rd	32.46	-0.10	7.12	-0.88	57.09	0.21	1.06	-0.37	11.46	-0.40	68.20	0.01
	Total no. sites: Improvement ☺	0		0		1		0		0		0	
	No change 😐	11		8		9		11		9		11	
	Deterioration ☹	0		3		1		0		2		0	

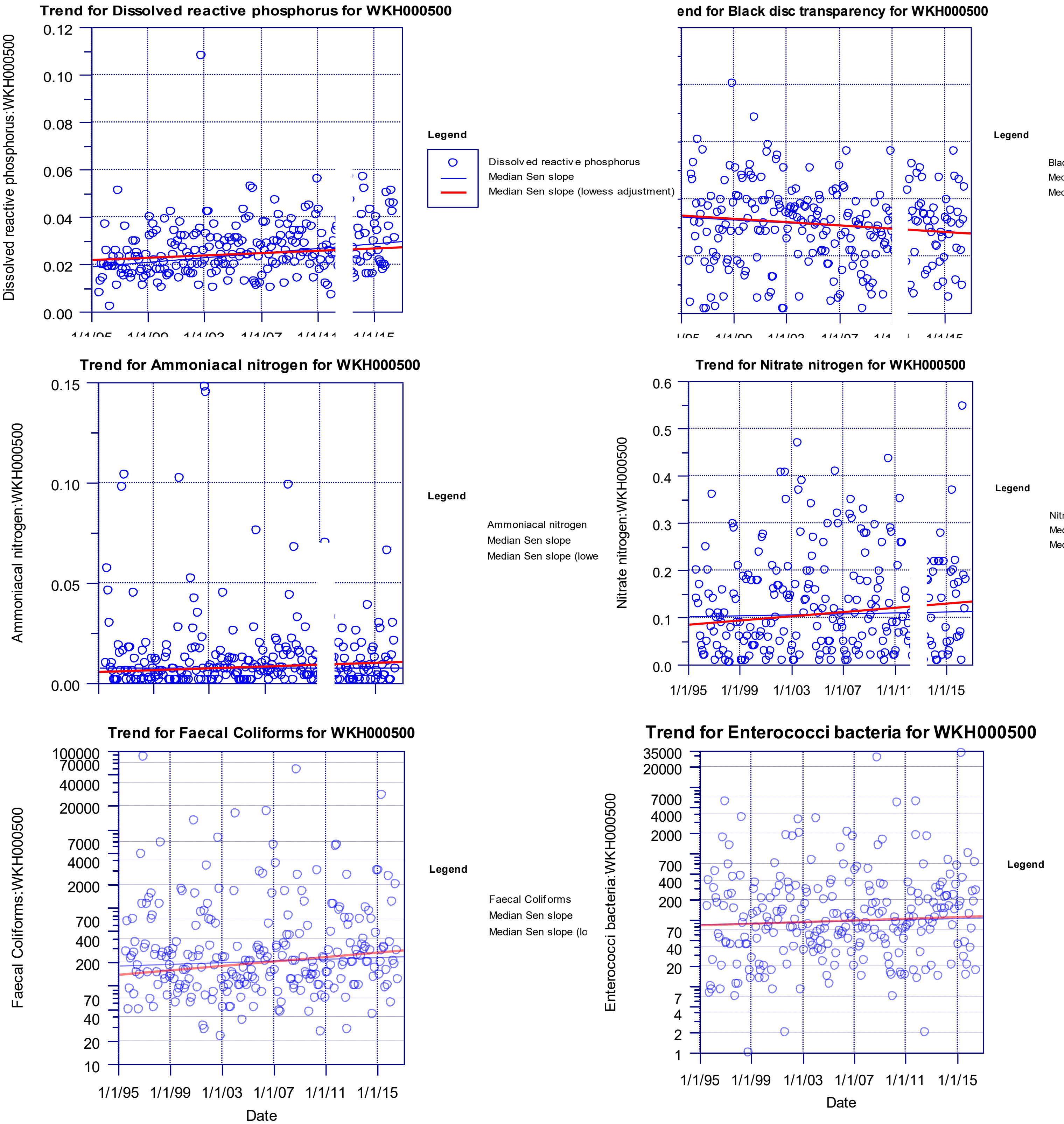


Figure 11 Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

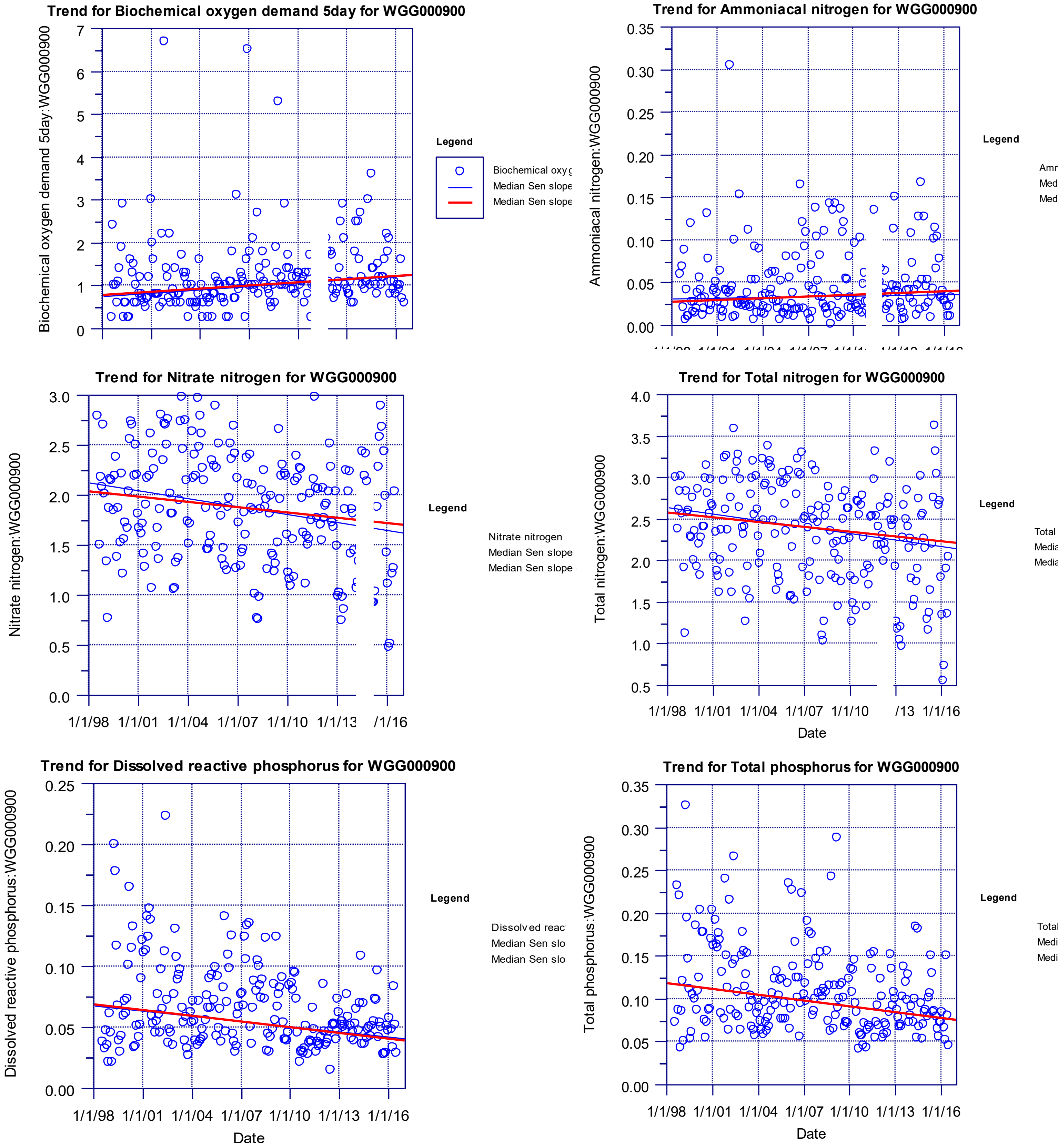


Figure 11 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

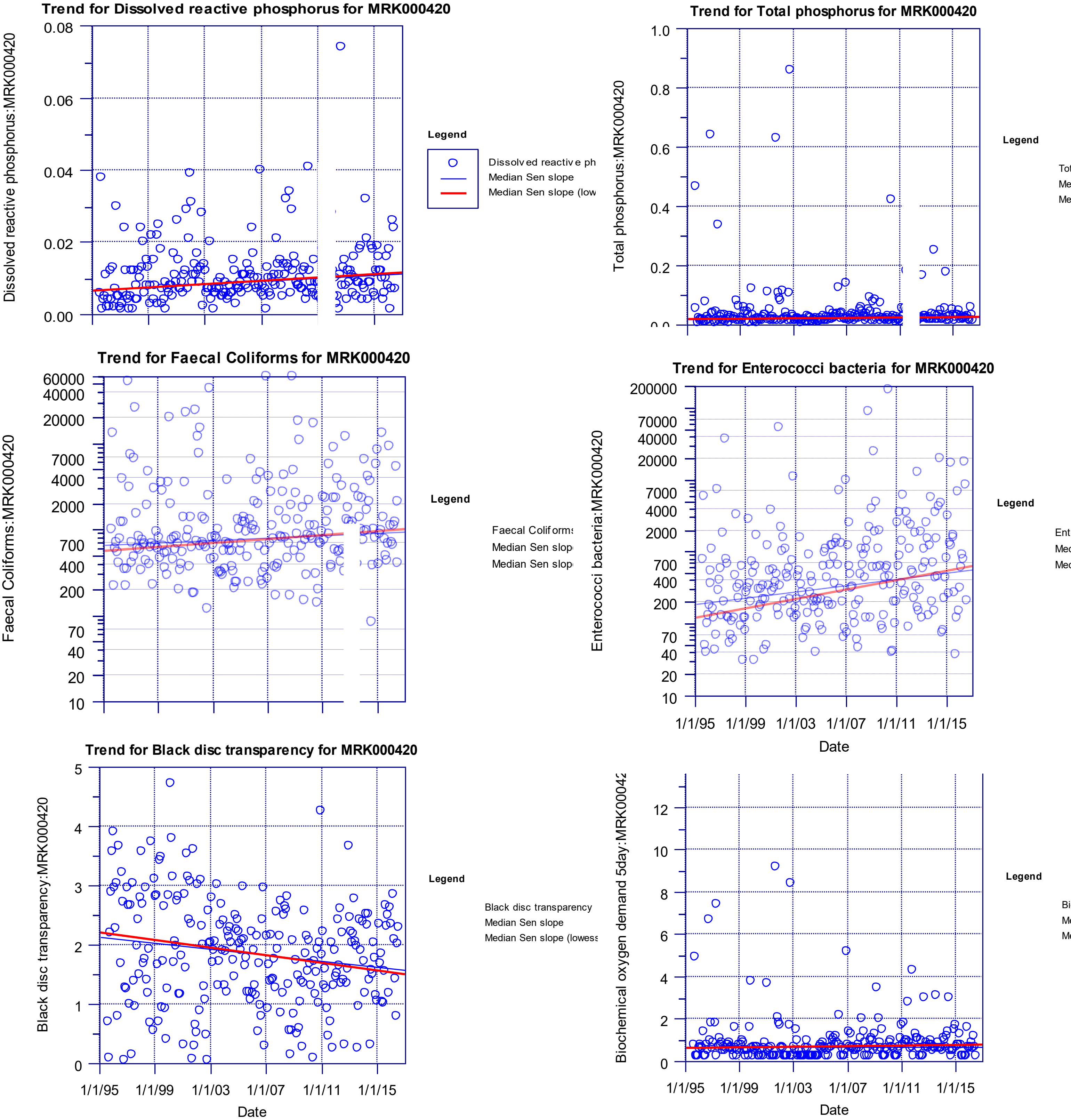


Figure 11 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

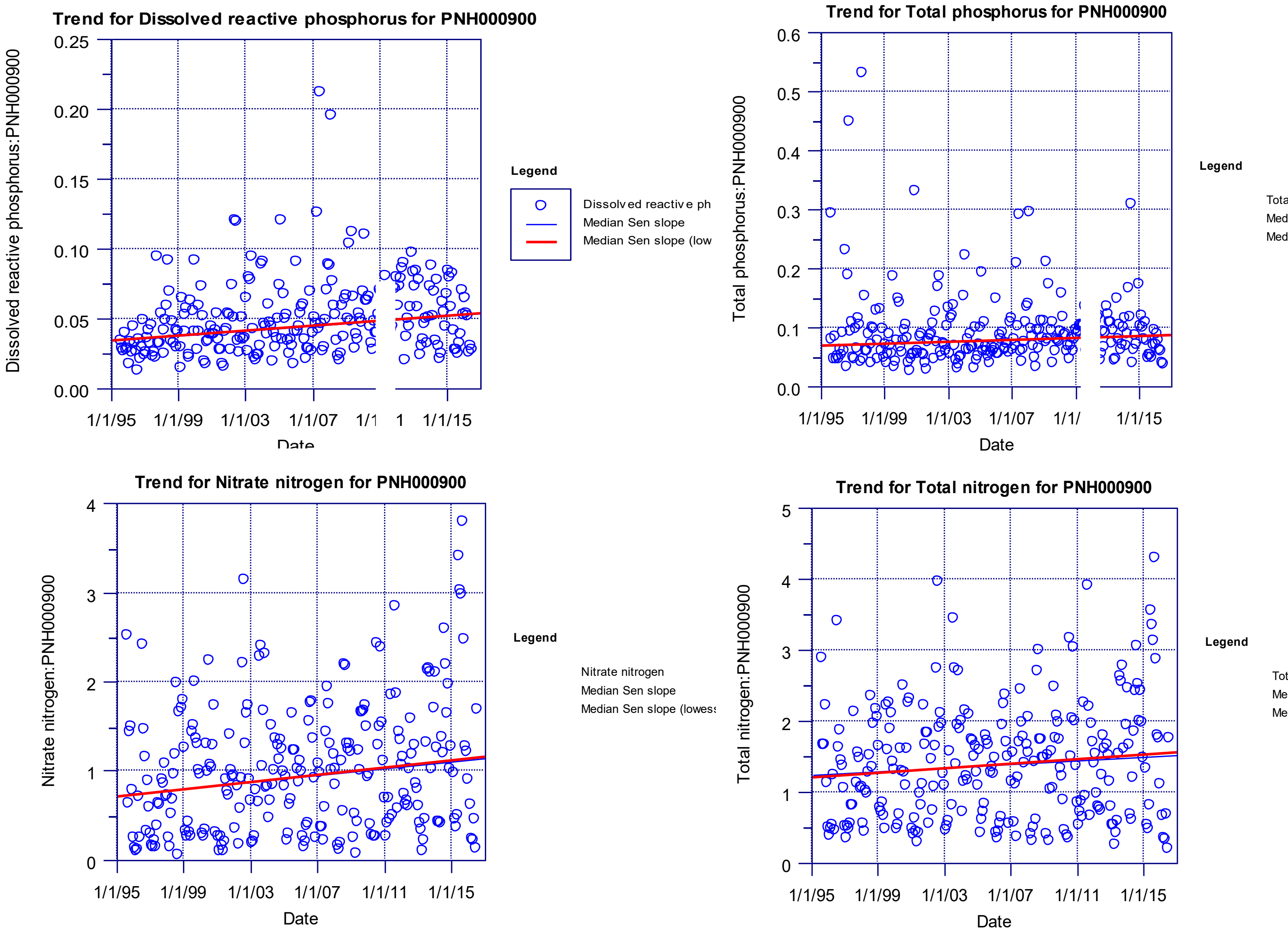


Figure 11 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

4.4. Trends in physicochemical water quality data from 2009 to 2016

4.4.1. Introduction

Data from State of the Environment physicochemical water quality monitoring programme (11 sites) for the most recent 7-year period (July 2009 – June 2016) were trended using the same methodology as for the full record (1995-2016, section 4.3.2) to observe if there were any changes in trends in recent years. The latter is the more meaningful feedback for effectiveness of current policies and interventions.

Physicochemical data from two NIWA sites were also assessed over a 7-year (July 2009 – June 2016) and the full record (January 1989 – June 2016). Starting from January 2016, Waingongoro site at SH45 is no longer monitored for water quality by NIWA. This is part of a NIWA plan to disestablish many of the pre-existing NRWQN sites and eventually replace with a lesser number of 'benchmark' sites that will include newly created sites and some selected NRWQN sites. Hence, there will be no further trending of NIWA information at this site and comparison with TRC data will not be discussed. (For previous analysis, refer to TRC, 2015)

Only significant 'real' trends are shown i.e., those significant trends where there was greater than 1% change per year for physicochemical parameters were considered 'real' trends with a change of a magnitude which could be ecologically significant as well.

An overall summary for the physicochemical water quality monitoring programme comparing the long term and short term trend is provided, together with a summary for each catchment.

4.4.2. Results of trend analysis

Overall, there were some differences between the long term and short term record, in the relative number of measures showing improvement, no significant change or deterioration (Table 46). There are more measures showing no significant trend in the short term record compared to the long term record. This is the result of fewer measures showing either improving or deteriorating trends in nutrients, organics and aesthetics, indicating wider stability in the recent trends. For bacteria, the number of measures showing deterioration is larger in the short term record, although the number of those trends that are very significant (p<0.01) is less.

Table 46 Summary of physicochemical trends between 21 years and 7 years of data

Statistical level	Total number of trends	
	21 years	7 years
Improvement (p<0.01)	5	0
Improvement (p<0.05)	2	1
Being maintained	77	93
Deterioration (p<0.05)	2	10
Deterioration (p<0.01)	24	6
Total	110	110

Comparison of long term trends 1995-2016 (21 years) and 2009-2016 (7 years) analysis.

Nutrients

- 38 of 55 measures of the nutrients (69%) showed maintenance (60%) or improvement (9%) in the long term trend.
- 46 of 55 measures of the nutrients (84%) showed maintenance (82%) or improvement (2%) in the recent 7 year trend.
- In particular, both nitrate and total nitrogen concentrations have shown no trend in the latest seven-year trend analysis, but dissolved reactive phosphorus is showing deterioration (ie increase) at 6 of eleven sites.

Bacteria

- 18 of 22 measures of bacterial levels (82%) showed maintenance (77%) or improvement (5%) in the long term trend.
- 15 of the 22 measures of the bacterial levels (68%) showed maintenance in the recent 7 year trend.
- The mid Waiwhakaiho River site and the upper Patea River site show deterioration in both faecal coliforms and enterococci.

Organics

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

Aesthetics

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

Specific changes in trends for nutrients, bacteria, organics and aesthetics are shown in Figure 12.

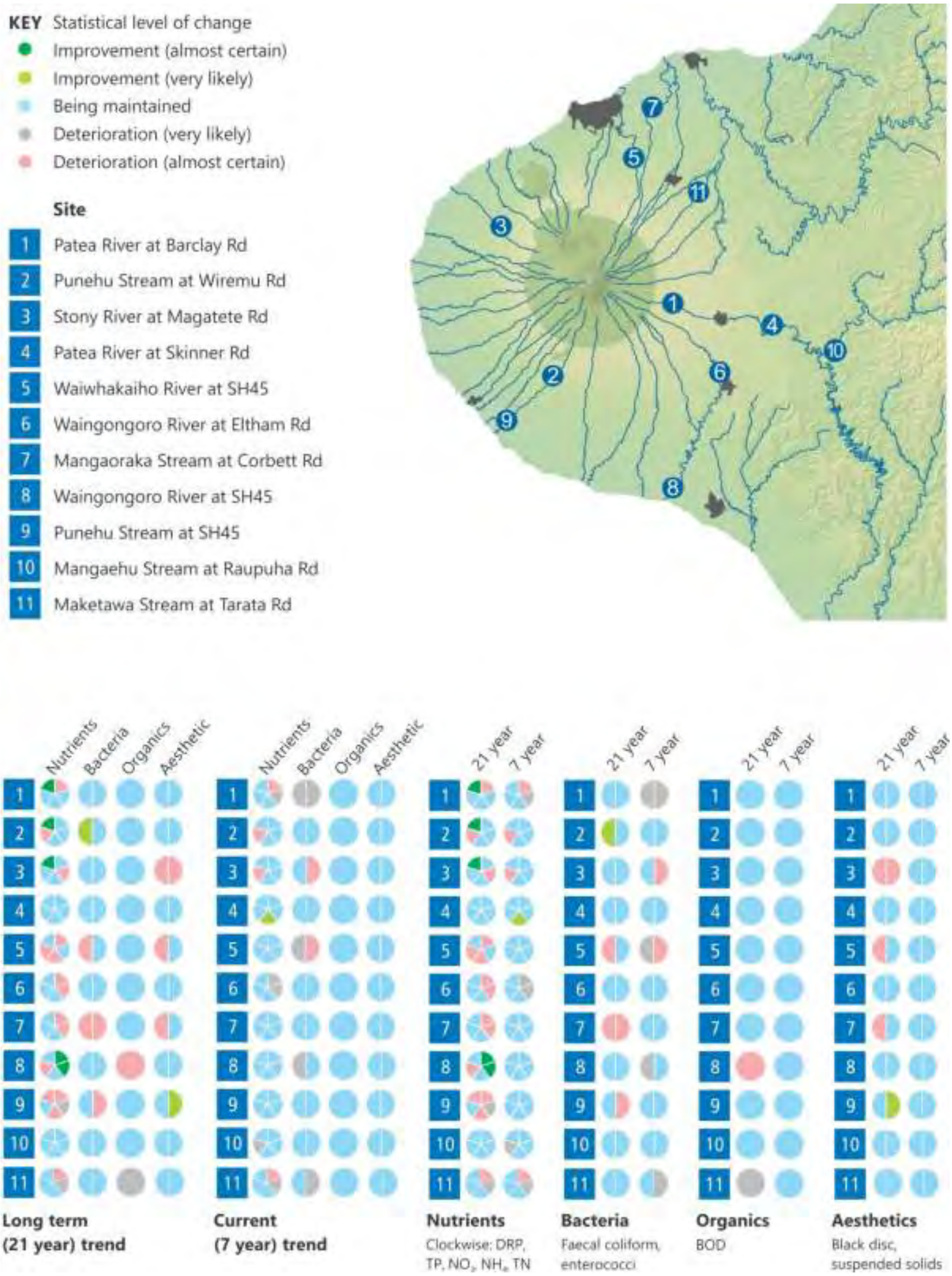


Figure 12 Specific changes in trend for nutrients, bacteria, organics and aesthetic parameters in the long term (21 years) and current (7 years) trend.

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

4.4.2.1.Patea River catchment

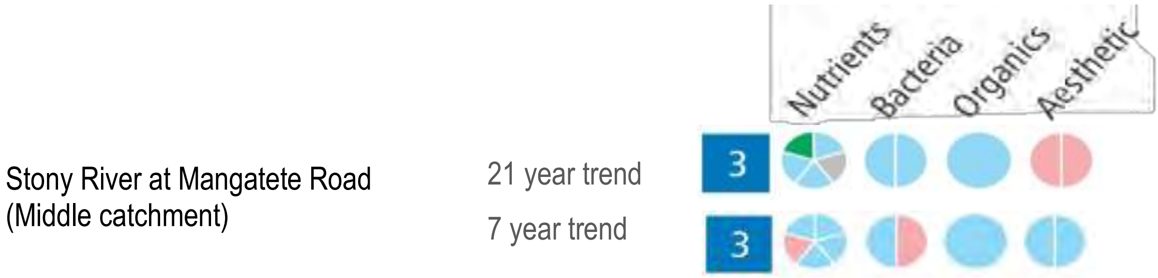
- At the upper site Barclay Road, significant long term deterioration in DRP continued in the 7 year trend. Significant improvement in TN has tapered off in the 7 year trend.
- At the middle site Skinner Road, NO_3 is showing significant improvement in the 7 year trend. Other parameters are not changing significantly.
- The Mangaehu River long term improvements in total nitrogen and faecal coliform have tapered off in the 7 year trend, with some deterioration in NH4.

4.4.2.2.Punehu Stream catchment

- At the upper site Wiremu Road, significant long term improvement in TN did not continue in the short term trends. NH4 deterioration showed in both the long and short tem trends. Other parameters are not changing significantly.
- At the lower site SH45, the long term deteriorating trends in DRP, TP, NO3 and TN have been tapered off in the 7 year trend. Significant long term improvement in suspended solids has also tapered off in the 7 year trend.

4.4.2.3.Stony River catchment

- Significant deterioration in TP, clarity and suspended solids was recorded in the long term trend. Significant improvement in TN has tapered off in the recent trend.
- The 7 year trend shows overall maintaining of water quality. NH4 and enterococci show significant deterioration in the 7 year trend.

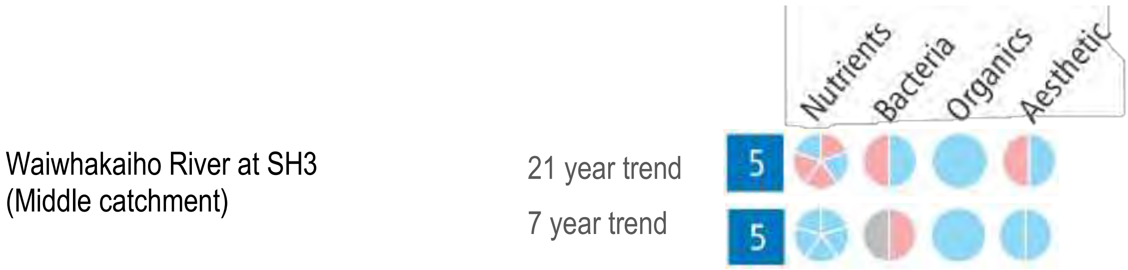


4.4.2.4.Maketawa River catchment

- Significant long term deterioration in DRP continued to show in the 7 year trend.

4.4.2.5.Waiwhakaiho River

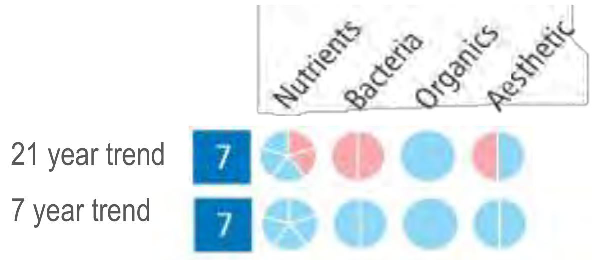
- Significant long term deterioration was recorded for DRP, NO3, NH_4, faecal coliforms and black disc at this mid catchment site.
- Deterioration for DRP, NO3 and NH4 tapered off in the recent 7 year trend. Faecal coliforms and enterococci continued to show a deteriorating trend. Other parameters are not changing significantly.



4.4.2.6.Mangaoraka Stream (Waiongana Stream catchment)

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

Mangaoraka Stream at Corbett Road
(Lower catchment)

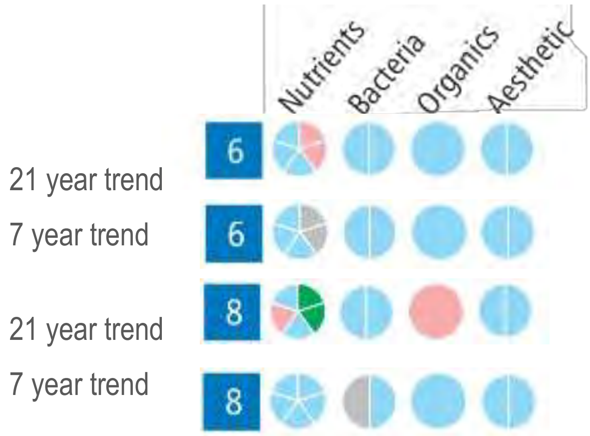


4.4.2.7.Waingongoro River catchment

- At the upper site Eltham Road, significant long term deterioration in DRP and TP continued in the 7 year trend. Other parameters are not changing significantly.
- At the lower site SH45, significant improvements in DRP and TP were recorded in the long-term trend. NH4 and BOD showed deterioration in the long-term trends. These trends tapered off in the recent 7 year trend, with only one deteriorating trend, for faecal coliforms.

Waingongoro River at Eltham Road
(Middle catchment)

Waingongoro River at State Highway 45
(Lower catchment)



4.4.3. NIWA State of the Environment sites

Physicochemical data from two NIWA sites in the Taranaki region were also assessed over a 7 year (July 2009 – June 2016) and the full record spanning from January 1989 to June 2016. In order to accurately compare the TRC and NIWA data, a 21-year trend has been compiled (TRC data spans from 1995).

Summary of trend results for NIWA sites is as follows:

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

Table 47 Meaningful' trends in surface water quality at NIWA's monitoring sites in Taranaki

Site	Record (years)	Dissolved Reactive P	Total Phosphorus	Nitrate	Ammonia-N	Total Nitrogen	Conductivity	Black Disc	Temp°C	pH	Total no. sites: Improvement	No change	Deterioration
Waitara River at Bertrand Rd Bridge	27	red	blue	red	blue	red	blue	blue	blue	blue	0	6	3
	21	blue	blue	red	red	red	blue	blue	blue	blue	0	6	3
	7	blue	blue	blue	blue	blue	blue	blue	blue	blue	0	9	0
Manganui River at SH3	27	blue	blue	blue	blue	blue	blue	blue	blue	blue	0	9	0
	21	blue	blue	blue	red	blue	blue	blue	blue	blue	0	8	1
	7	red	red	blue	grey	blue	grey	red	blue	blue	0	4	5

Key:

- (dark green) statistically significant improvement P<0.01
- (light green) statistically significant improvement P<0.05
- (blue) no statistically significant change
- (grey) statistically significant deterioration P<0.05
- (red) statistically significant deterioration P<0.01

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

The RMA requires [Section 35 (2)(a)] the Council to:

'*monitor the state of **the whole or any part of** the environment of its region…. .**to the extent that is appropriate** to enable the local authority to effectively carry out its functions under this Act;…*'.

The Council has had SEM monitoring of fresh water in place since 1995, through a number of specific programmes. These have been audited by the Office of the Auditor-General, as well as by other independent experts, and found each time to be fit for purpose. The programmes have targeted areas with the greatest pressures upon or changes in the water resources of the region, to determine how and why water quality might be changing and the effectiveness of the Council's interventions.

However, the NPS-FW now requires, in addition, that the Council *'identifies a site or sites at which monitoring will be undertaken that are **representative for each freshwater management unit'*** [Policy CB1 (b)]. All freshwater in every region must be incorporated into a Freshwater Management Unit (FMU) as defined within the NPS.

This Council has identified four FMUs for the Taranaki region: water bodies of outstanding value; the ring plain; the northern and southern coastal terraces; and the eastern hill country. In terms of the distribution of the current SEM sites for monitoring fresh water, Council staff determined that two more sites within the eastern hill country were needed for the purpose of representativeness of FMUs. Accordingly, since July 2015 Council staff have been undertaking sampling for water quality monitoring purposes at two new sites: Waitara River near Tarata in the northern hill country, and the Whenuakura River at SH 3, on the southern borders of the hill country. Results from these sites are reported for the first time herein.

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 2015 through to June 2016. 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. Sites in the mid reaches of the Waitara River and lower reaches of the Whenuakura River were added in July 2015, and thus 2015-2016 was the first full year of sampling. Sampling in the year under review coincided randomly with a lower range of flow conditions in the 2015-2016 period (in comparison with the previous 20 year period), ranging from moderate freshes through to a period of very low flow conditions but was characterised by a few fresh events. This report provides monthly data for up to 22 parameters and a statistical summary of the twelve months' data for each of the sites, and compares this period's water quality with the previous 20 years' data. It also provides an up-to-date statistical summary of the 21 years' data to date for all sites and discusses, in brief, comparative water quality at these sites.

River and stream waters were generally of moderate to good quality, particularly at sites in the upper reaches of ring plain catchments, with some deterioration in a downstream direction coincident with increased run-off, possible stock access and point source discharges. This was illustrated particularly by decreased clarity and increased nutrient levels and bacteriological numbers, and wider water temperature and pH ranges in a downstream direction. Aesthetic quality deterioration was also coincident with increased flows following, or during, the 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 sites in the mid and lower reaches were characterised by some dissolved colour, relatively high turbidity, poorer clarity, and slightly to moderately elevated suspended sediment concentrations.

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

Flows in 2015-2016

During the 2015-2016 period, median flows sampled were across all sites lower than typical of those sampled during the previous 20-year period, with median flows lower over the latest period (by 9 to 46%) compared with the long-term median of sampled flow records (Table 48).

Table 48 Comparison of 2015-2016 water quality with previous long-term (1995-2015) 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/s)	Flow (%)
						Ammonia -N	Nitrate-N	Total N	DRP	Total P							
Maketawa Stream at Tarata Road	✓	=	=	X	XX	X	=	=	X	X	=	=	=	=	✓	-306	16↓
Mangaoraka Stream at Corbett Road	✓	=	=	=	X	=	=	=	=	=	=	=	✓✓	=	✓	-310	26↓
Waiwhakaiho River at SH3	=	=	=	=	=	X	X	=	X	=	=	=	=	=	✓	-724	19↓
Stony River at Mangatete Road	X	=	=	X	=	=	XX	=	X	=	=	=	XX	=	XX	-272	8↓
Punehu Stream at Wiremu Road	✓	=	=	✓	✓	XX	✓	✓	=	=	=	=	=	=	=	-46	11↓
Punehu Stream at SH45	✓	=	✓	=	XX	=	=	=	=	✓	=	=	✓	=	✓	--71	9↓
Waingongoro River at Eltham Road	=	=	=	X	✓✓	✓	✓	=	=	X	=	=	✓	=	✓	-330	46↓
Waingongoro River at SH45	✓	=	=	✓	✓	✓	=	=	=	✓	=	=	✓	=	=	-1,375	29↓
Patea River at Barclay Road	=	=	=	XX	X	XX	=	✓✓	X	=	=	=	=	=	=	-31	14↓
Patea River at Skinner Road	=	=	=	✓✓	=	✓	=	=	=	=	=	=	✓✓	=	=	-1,992	33↓
Mangaehu River at Raupuha Road	=	=	=	✓✓	=	X	✓	✓	=	=	=	=	✓	=	XX	-2,132	31↓

[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]

Aesthetic and physical parameters in 2015-2016
Generally, water quality in the 2015-2016 period (Table 48) showed similar or improved **black disc clarity, suspended solids and turbidity** levels compared with the long-term monitoring record. By exception, the Stony River showed continuing deterioration in all three measures following a flood event in February 2016, and turbidity deteriorated at the eastern hill country site on the Mangaehu River (although suspended solids improved at the same site). Median water **temperatures** were higher at all of the eleven previously monitored sites in the year under review, and wider temperature ranges were measured, mainly due to higher maximum temperatures (in comparison with the longer period). The highest temperature recorded was measured at four sites in February 2016.

Median **dissolved oxygen saturation, BOD_5 concentration and pH** showed no significant differences in the latest period (Table 48).

Nutrients in 2015-2016
A majority of sites' median nutrient levels remained similar in the 2015-2016 period to those over the longer period. A few improvements in median nutrient species (nitrate N at three sites, total P at two sites, and total N at three sites) were recorded. Deterioration was found in median dissolved reactive phosphorus (at four sites), total phosphorus (at two sites) and ammonia N (at five sites) [Table 48]. On an overall view, total nitrogen levels showed more reductions, while dissolved reactive phosphorus and ammonia nitrogen showed more increases, and no clear pattern for either nitrate or total phosphorus.

Bacteria in 2015-2016
Overall there was no clear regional trend in bacteria, with the number of improving sites matching closely the number of sites showing deterioration. Bacteria numbers showed improvement at three sites in terms of median enterococci numbers but there was deterioration at four sites during the 2015-2016 period. Four sites showed improvement in median faecal coliform bacteria numbers while four sites showed deterioration. This variability in bacteriological water quality during 2015-2016 is typical of previous monitoring results.

Trends
This TRC programme is complemented by the two 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 trend assessment has been performed upon eleven TRC sites over the 1995-2016 period (including one site for the 1998-2016 period and one site for the 2003-2016 period) and summarised in this Annual Report. This complements earlier trend analyses.

In conclusion, long term (21-year) physicochemical trends have indicated significant deterioration for some parameters at some sites, especially for nutrients mainly in the middle and lower catchments, alongside stability in most measures and some improvements. Overall, between two-thirds and three-quarters (depending on the parameter) of results show either maintenance or improvement in water quality.

A significant improvement in aspects of temporal water quality (mainly nutrients) has been found at the site in the lower Waingongoro River, coincident with the relatively more recent reductions in waste loadings discharged by industry and/or the township to the river in mid catchment at Eltham (TRC, 2015a). Dissolved reactive phosphorus and total phosphorus have been the main nutrients showing significant deterioration in the Waingongoro River at Eltham Road and Punehu Stream at SH 45 where nitrate has also deteriorated. The Waiwhakaiho River site at SH3 has also recorded a significant deterioration in DRP, nitrate, and ammonia-N. The trends for these three sites have indicated that phosphorus level is increasing at a steady but slow rate. All three sites are situated in catchments with intensive agricultural land use. However there has been a significant improvement in total nitrogen at three of the eleven sites monitored, with the lower Punehu being the only site showing any degree of deterioration in total nitrogen over the long term (a trend which has disappeared in recent years).

One mid reach site, the Maketawa Stream at Tarata Road, has shown significant long term deterioration in BOD_5 although concentrations have remained consistently below the recognised criterion of $2g/m^3$ at this site.

Faecal coliforms and enterococci trends generally have not altered significantly over the 21-year period at the majority of sites. However, two sites of the eleven have shown significant deterioration, one in each of the lower or mid reaches, and one site in the upper reaches has shown improvement.

Fluctuating trends for black disc clarity and suspended solids reflect the historical erosion events in the headwaters of the Stony River. Significant deteriorations in black disc clarity were also recorded for the Waiwhakaiho River at SH3 and the Mangaoraka Stream at Corbett Road. All sites have had insignificant trends for conductivity, temperature, and pH.

Over the long term, the Waiwhakaiho River (mid catchment) and Mangaoraka Stream (lower catchment) show the greatest degree of deterioration; both sites show much less or no deterioration at all in recent years.

On a site specific basis comparing the 2015-2016 period with the previous 20-year historical record, the mid-reach sites on the Maketawa Stream and Waingongoro River showed the most variability in water quality, with seven of the fifteen parameters recording either lower or higher quality. Both sites, which are representative of developed farmland catchments, showed deterioration in bacteria numbers and TP, and improvement in clarity and turbidity. Another five sites had at least six parameters showing different from usual quality, which may be related to the lower flows sampled, and to the erosion event in the Stony River catchment. Main differences were found for ammoniacal nitrogen and bacterial species. Least differences in comparative water quality were found at the Patea River (mid-reach), Waiwhakaiho River (mid-reach) and Mangaoraka Stream (lower reach) sites, whereas the highest number of parameters that were better than usual were found at the Waingongoro River (mid and lower reaches) and Punehu Stream (mid and lower reaches) sites.

Overall, during the 2015-2016 period water quality parameters' medians differed by more than 20% from 20-year medians for 36% of comparisons (15% deterioration;

21% improvement), and by more than 50% from historical medians for 9% of comparisons (5.5% deterioration, 3.5% improvement). This was coincident with lower median flows (8 to 46%) sampled at all eleven sites over the 2015-2016 period.

6. Recommendations

1. THAT the existing freshwater physicochemical component of the SEM programme continue in a similar format for the 2016-2017 monitoring year.
2. THAT an additional (split) sample be collected on at least one occasion during the monitoring year, in conjunction with the intra-laboratory quality control programme, for analysis by an external, accredited laboratory.
3. THAT the appropriate trend analysis reported on the datasets for all Taranaki sites over the 1995-2016 period (provided in the current report), be updated for the 1995-2017 period at the conclusion of the 2016-2017 year.

7. Acknowledgements

This programme's Job Manager was James Kitto (Science Advisor) who was the principal author of the Annual Report. Statistical analyses were provided by Fiza Hafiz and Alex Connolly (Scientific Officers) with the majority of the field sample collection performed by Ray Harris, Rae West, David Olson and Katie Blakemore (Technical Officers). Hydrological data were provided by Fiona Jansma (Scientific Officer) with field gaugings performed by Andrew Cotter, Shane Sullivan, Warrick Johnston, Craig Pickford and Regan Diggelmann (Hydrology Officers). Graham Bryers and Mike Crump (NIWA) assisted with the provision of National network data for two Taranaki sites and with the inter-laboratory comparison exercise. All water quality analytical work was performed by the Taranaki Regional Council ISO-9000 accredited laboratory under the supervision of John Williams.

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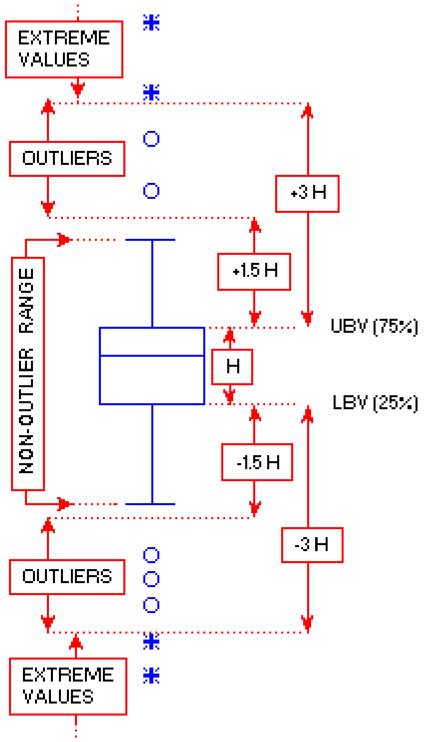
Appendix I

Statistical ‘Box & Whisker’ Plots of 1995-2016 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:

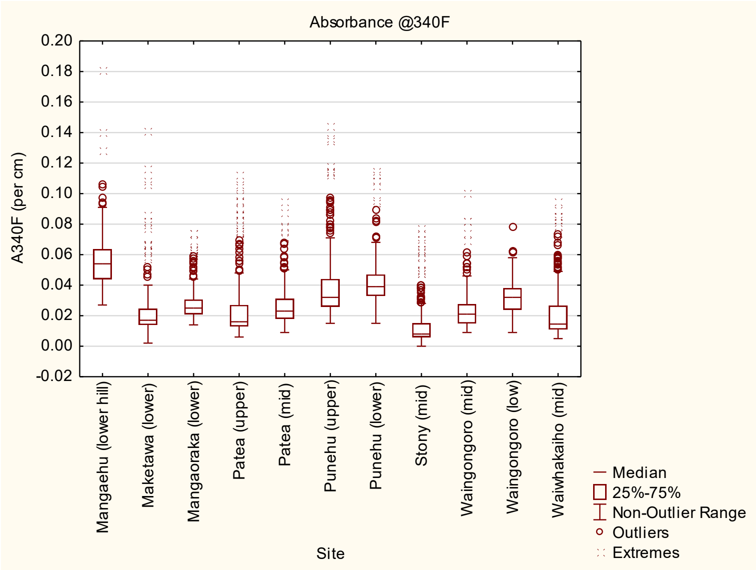
Lower fence = lower hinge – (3 x Hspread)
Upper fence = upper hinge + (3 x Hspread)

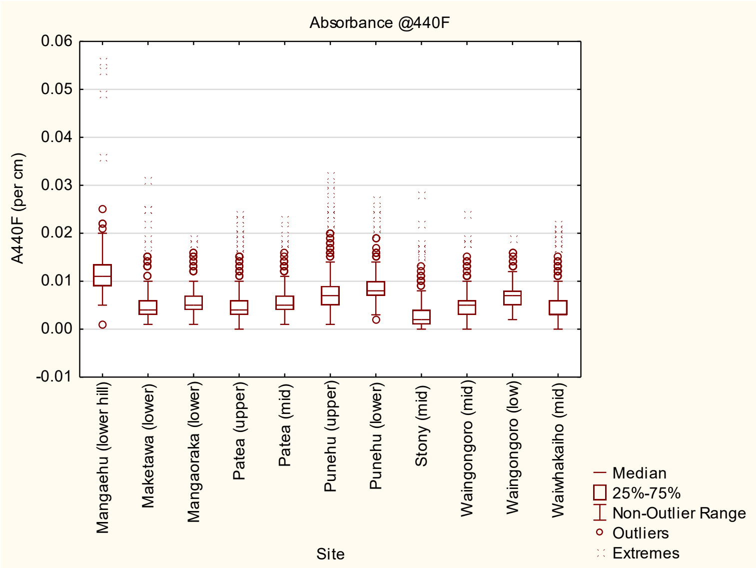
The whiskers show the range of values that lie within the inner fences. Values outside the inner fence are plotted as open circles (o). Values outside the outer fence are plotted as asterisks (*).

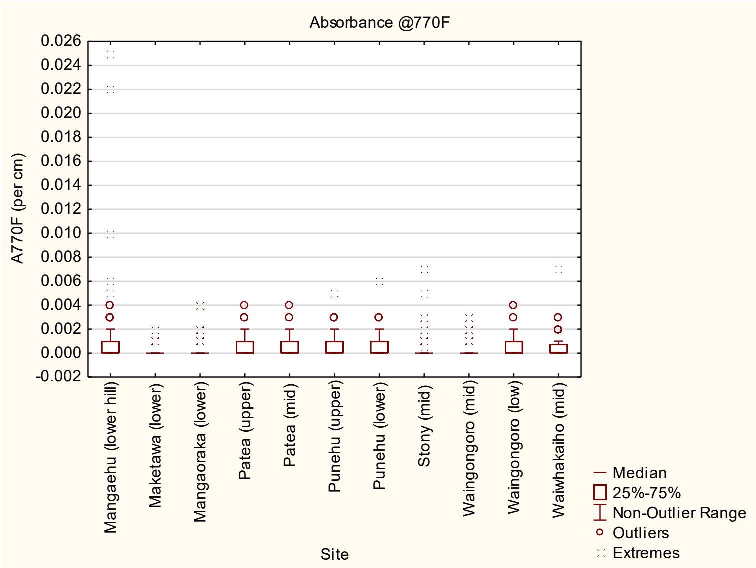
Site locations

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
Waitara River	at Tarata
Waiwhakaiho River	at SH3
Whenuakura River	at Nicholson Road

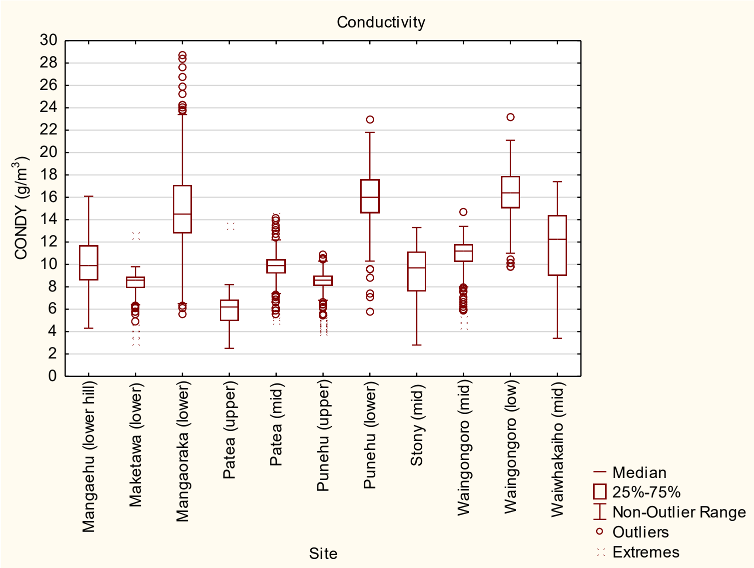
Absorbance (1cm)

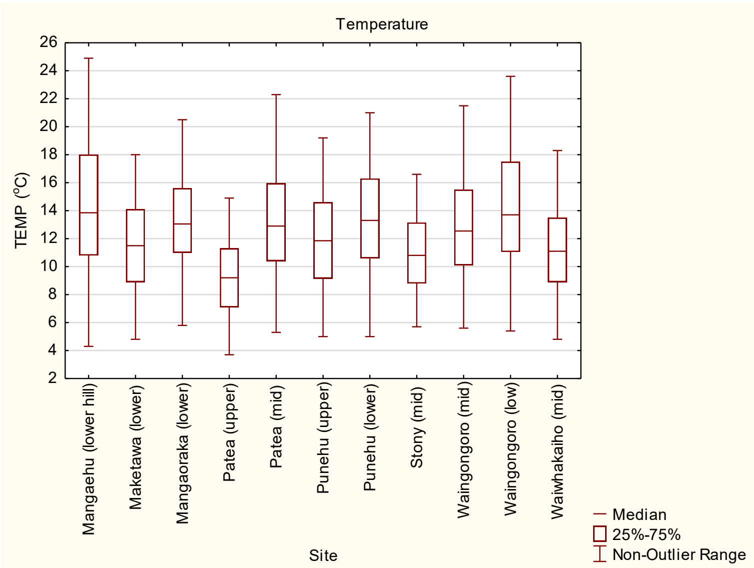


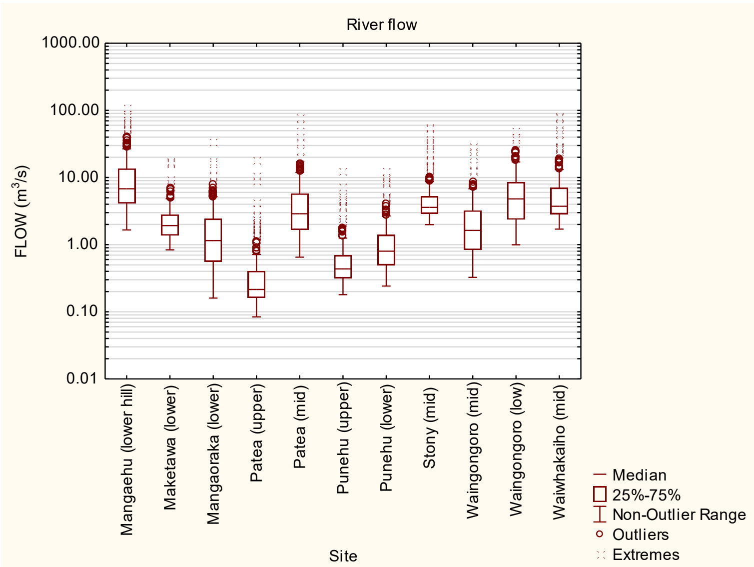


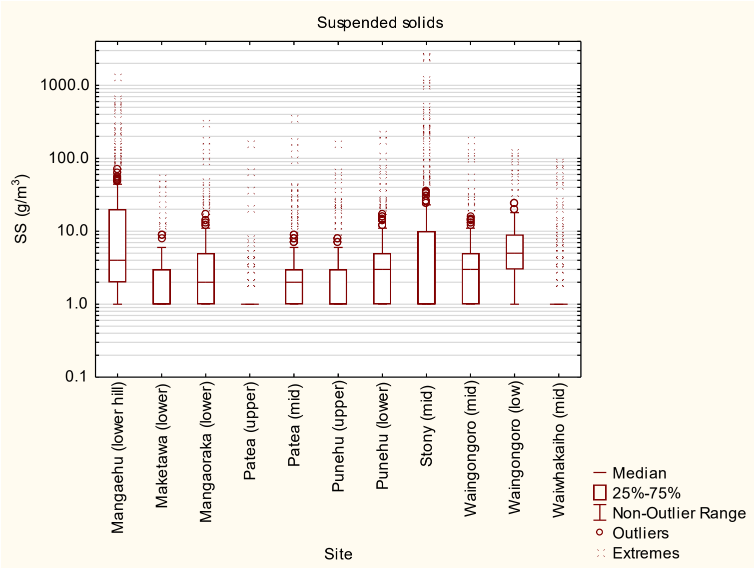


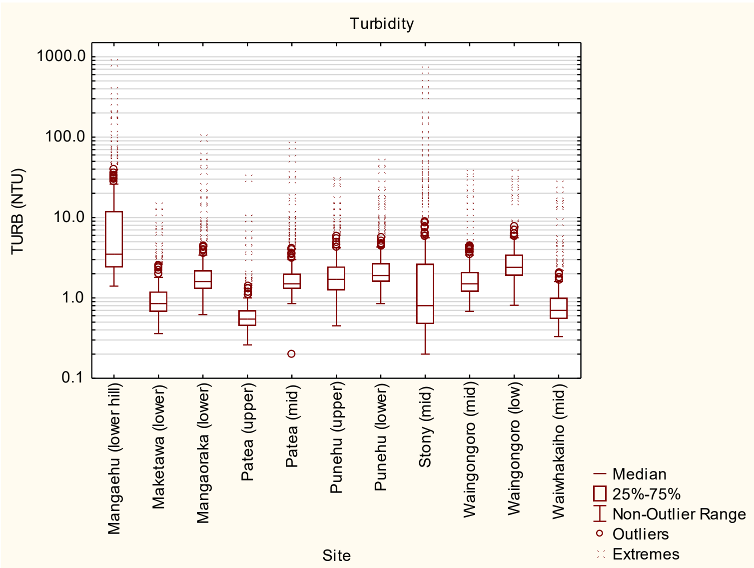
Physical Quality

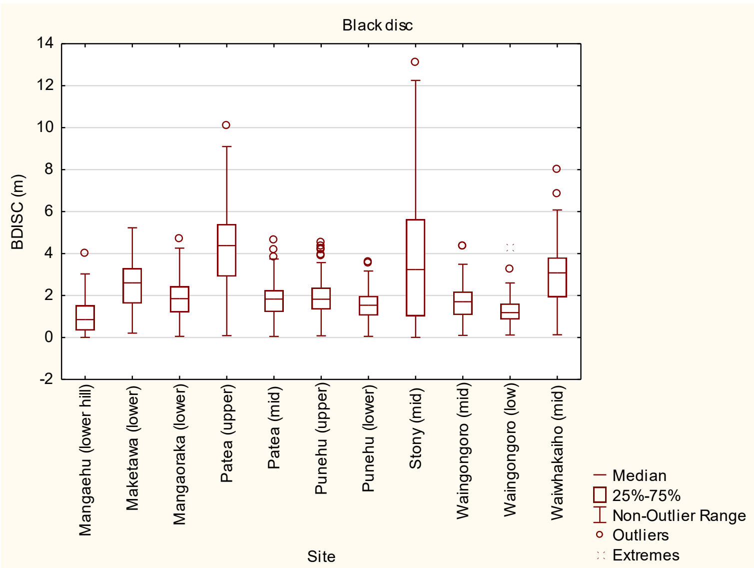


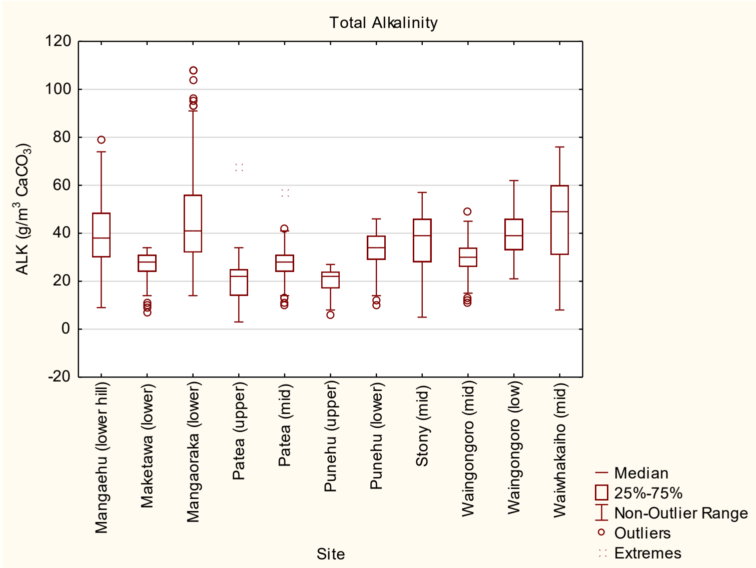




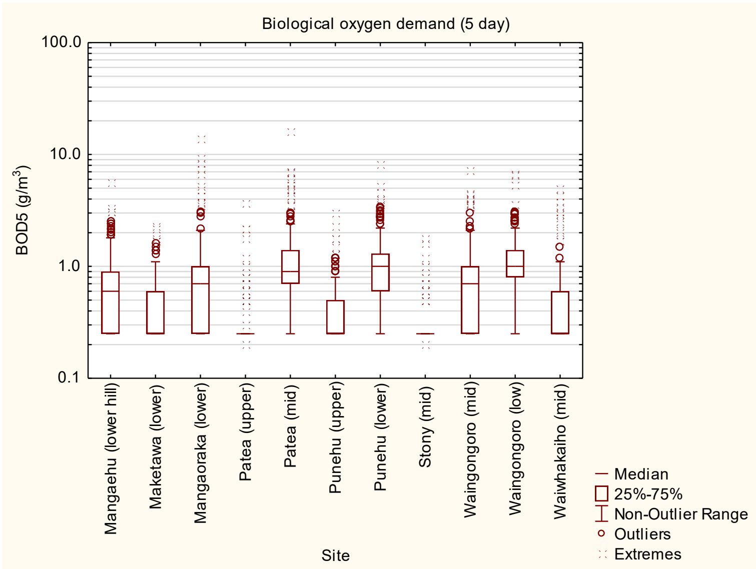

Suspended solids
SS (g/m3)
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


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

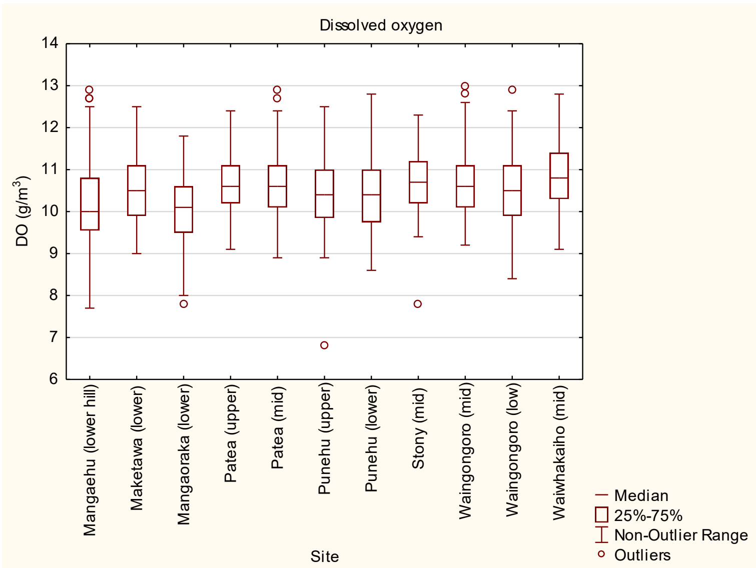

Black disc
BDISC (m)
14
12
10
8
6
4
2
0
-2
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



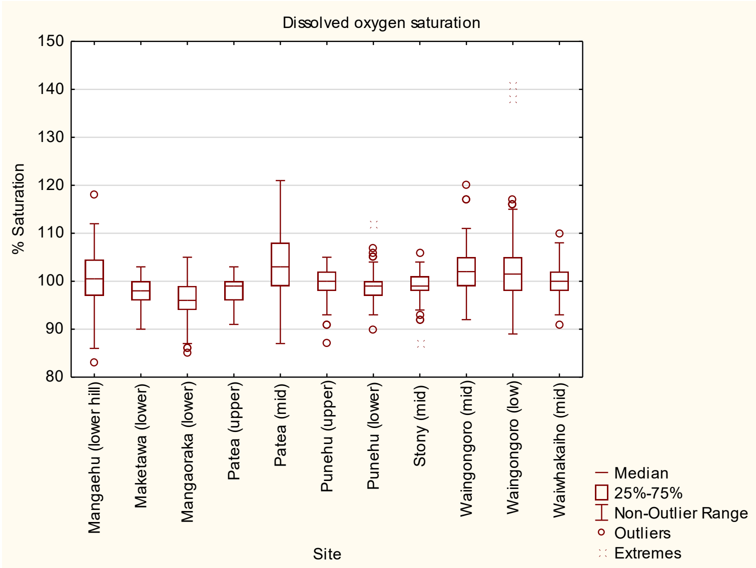
Total Alkalinity
ALK (g/m³ CaCO₃)
120
100
80
60
40
20
0
-20
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

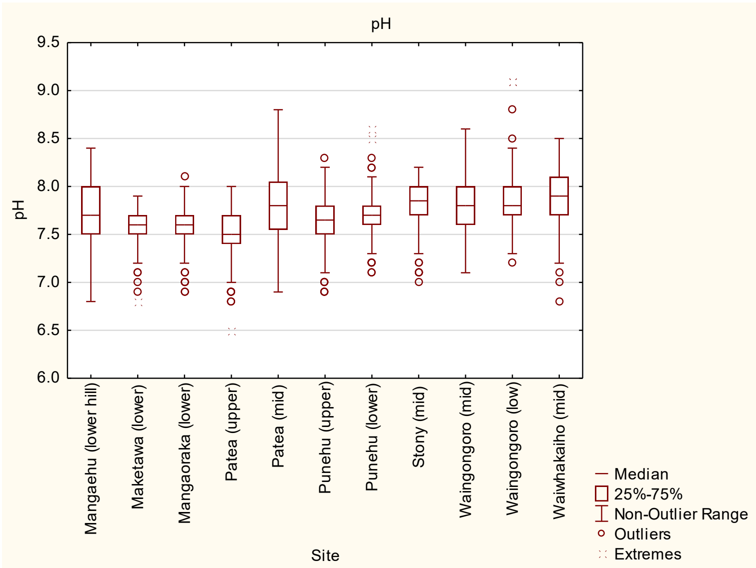


Biological oxygen demand (5 day)
BOD5 (g/m³)
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

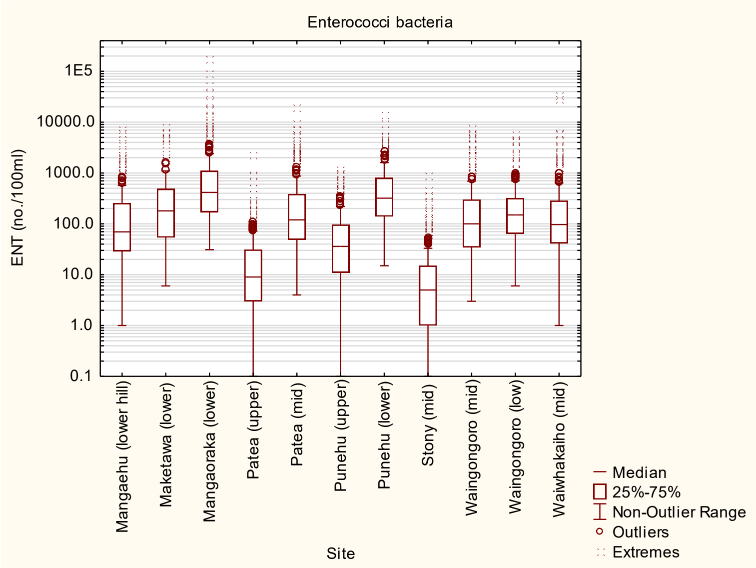


Dissolved oxygen
DO (g/m³)
14
13
12
11
10
9
8
7
6
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers

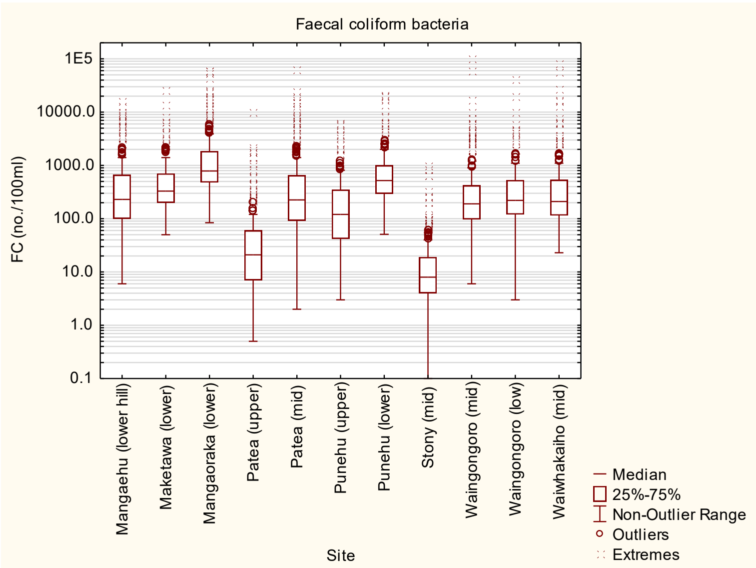

Dissolved oxygen saturation
% Saturation
150
140
130
120
110
100
90
80
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


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

Bacteria

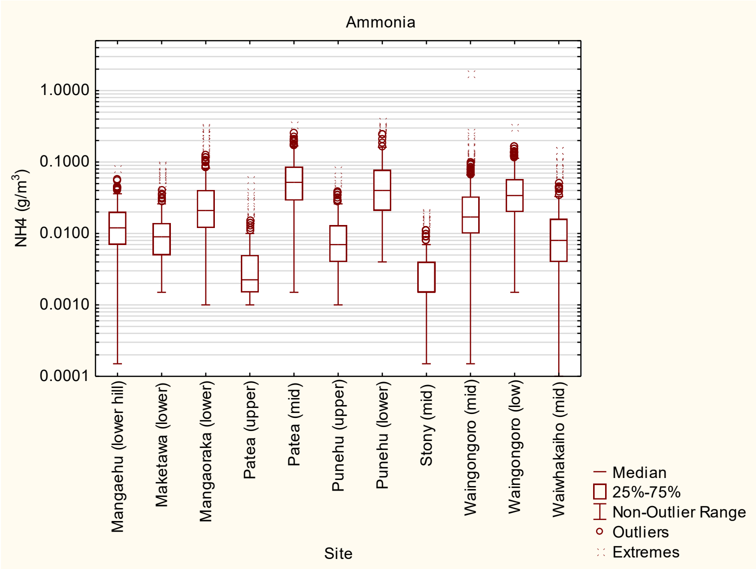


Enterococci bacteria
ENT (no./100ml)
1E5
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers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

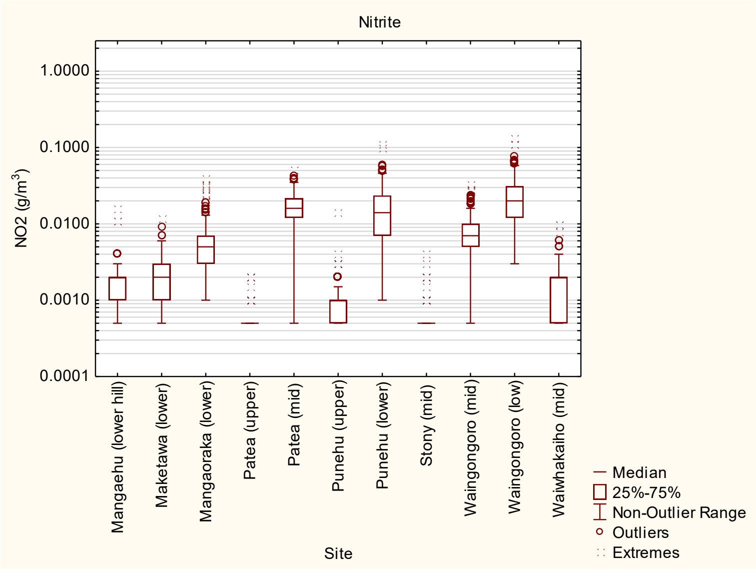


Faecal coliform bacteria
FC (no./100ml)
1E5
10000.0
1000.0
100.0
10.0
1.0
0.1
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers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

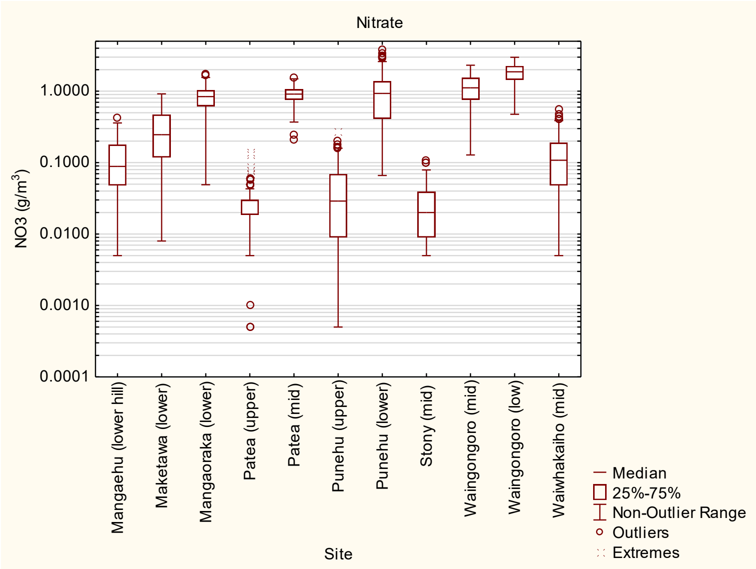
Nutrients



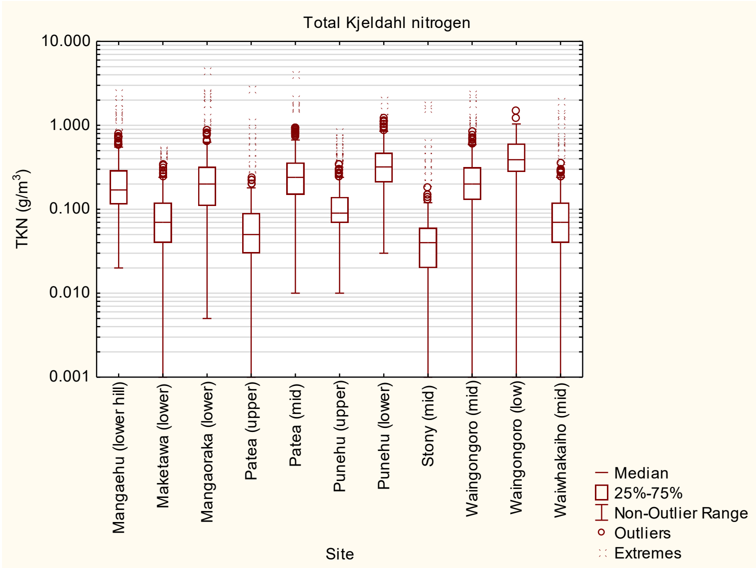
Ammonia
NH4 (g/m³)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

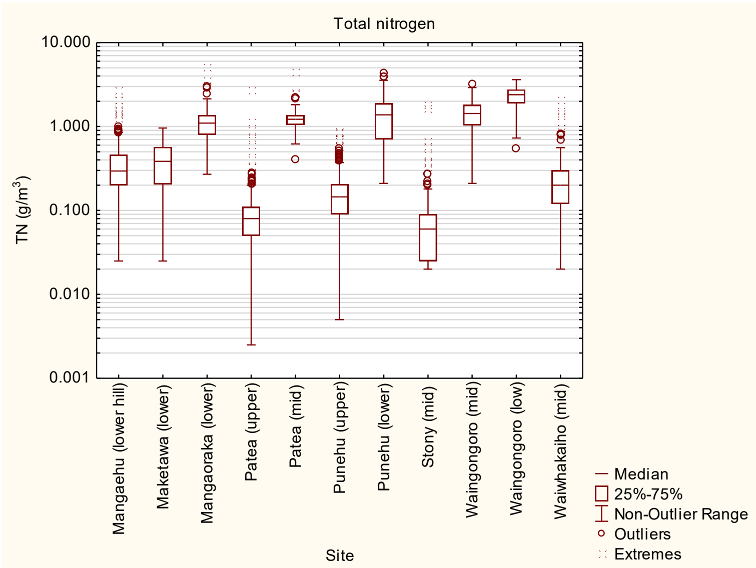


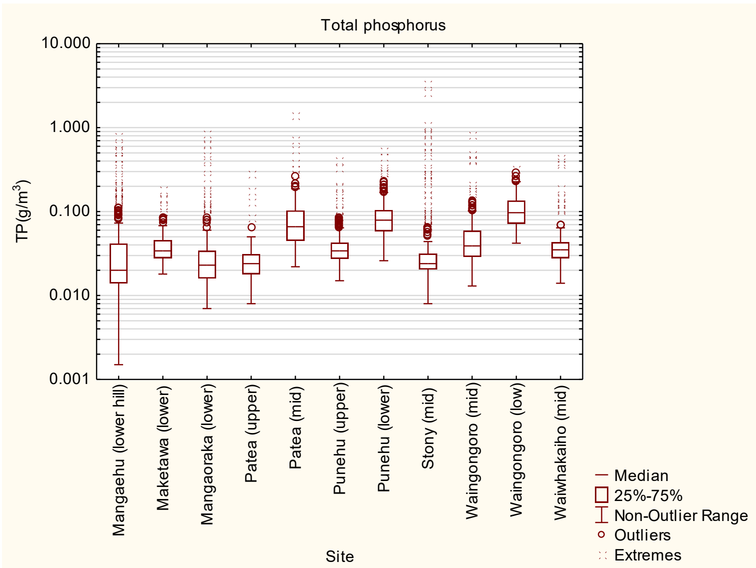
Nitrite
NO2 (g/m³)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

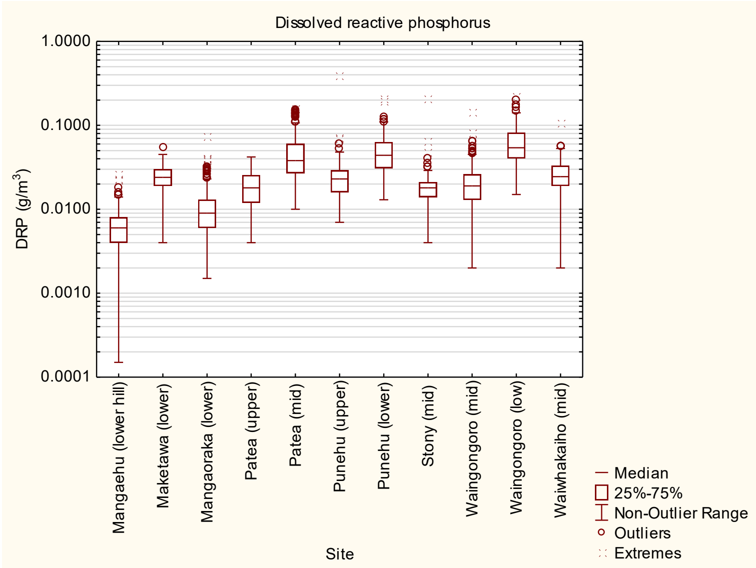


Nitrate
NO3 (g/m³)
1.0000
0.1000
0.0100
0.0010
0.0001
Mangaehu (lower hill)
Maketawa (lower)
Mangaoraka (lower)
Patea (upper)
Patea (mid)
Punehu (upper)
Punehu (lower)
Stony (mid)
Waingongoro (mid)
Waingongoro (low)
Waiwhakaiho (mid)
Site
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


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


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


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


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

Appendix II

Section 6.2 of the
Regional Policy Statement for Taranaki 2010

Maintaining and enhancing the quality of water in our rivers, streams, lakes, and wetlands

Background to the issue

Water use is important to economic growth and sustainability in the region. Use of water is a fundamental requirement of most rural based industry and agricultural activities and is appropriate where effects on water quality can be avoided, remedied or mitigated. Water quality refers to the physical, chemical and biological characteristics of water that affect its ability to sustain environmental values and uses. Good surface water quality is important, not only in terms of maintaining healthy rivers and streams but also in terms of water supply purposes, meeting the consumptive demands of Taranaki's agricultural and industrial sectors and protecting the natural character and amenity values associated with particular surface water bodies.

Taranaki's water bodies have generally good to excellent water quality on most physical, chemical and biological measures and comparisons. However, surface water quality is lost or reduced through land or water use activities resulting in point or diffuse source discharges of contaminants to surface water or onto land in circumstances where the discharge may enter water.

Point source discharges (ie: waste discharges from a pipe) commonly occur from a wide range of activities such as industries, urban wastewater treatment systems and farming operations etc. Most are treated and discharged in a manner that ensures that adverse effects on water quality are not significant or are no more than minor. However, multiple point source discharges to the same water body can have a cumulative adverse effect on water quality and point source discharges can contribute to the decline in water quality that occurs down the length of ring plain catchments.The Taranaki Regional Council closely monitors point source discharges and this will need to continue.

The cumulative effects of diffuse (widespread) or non-point source discharges to water, such as runoff from land of leachate of agricultural wastes, nutrients or sediments, are the principal cause of reduced water quality in most catchments in the region. Diffuse source contamination is often attributable to poor land use practices such as the excessive use of fertilisers and agrichemicals to land, grazing of river and stream margins, the direct entry of stock to water, and inappropriate land use on erosion prone land. The effects of diffuse source contamination are also exacerbated by the loss or modification of riparian vegetation along the banks of waterways. The adverse effects of point source discharges are not always significant and some are no more than minor.

The significant issues in relation to maintaining or enhancing surface water quality are:

WQU ISS 1 **Managing adverse effects on water quality arising from point source discharges to water bodies.**

WQU ISS 2 **Managing adverse effects on water quality arising from diffuse source discharges to water bodies**.

WQU ISS 3 **Managing the cumulative adverse effects on water quality arising from both multiple point source discharges and diffuse source discharges to water bodies**.

OBJECTIVE

WQU OBJECTIVE 1
To maintain and enhance surface water quality in Taranaki's rivers, streams, lakes and wetlands by avoiding, remedying or mitigating any adverse effects of point source and diffuse source discharges to water.

POLICIES

Sustainable land management practices

WQU POLICY 1
Sustainable land management practices and techniques that avoid, remedy or mitigate adverse effects on surface water quality will be encouraged, including:

(a) the retention and restoration of effective riparian buffer zones;
(b) the careful application of the correct types and quantity of fertiliser and agrichemicals;
(c) the careful application of the appropriate quantities of farm dairy effluent having regard to topography, land area, weather and soil conditions;
(d) the development, recontouring and restoration of disturbed land to reduce diffuse source discharges of contaminants to water;
(e) farm management practices that avoid, remedy or mitigate the effects of stock entry to rivers and streams, trampling and pugging by stock, overgrazing, and accelerated erosion from inappropriate land use on erosion prone land; and
(f) other land management practices, including the discharge of contaminants to land and the diversion of stormwater runoff to land, which avoid or reduce contamination of surface water.

Riparian management

WQU POLICY 2
The retirement and planting of riparian margins throughout the Taranaki region will be promoted, with a particular focus on ring plain catchments.

Protection of water quality in areas of high natural character

WQU POLICY 3
The water quality of the Stony (Hangatahua) River catchment and other rivers, streams, lakes and wetlands with high natural character, ecological and amenity values such as the Maketawa Stream catchment and parts of the Manganui River catchment will be maintained and enhanced as far as practicable.

Domestic and community water supplies

WQU POLICY 4
The importance of maintaining or enhancing water quality in catchments which are used for domestic and community water supplies will be recognised.

Point source discharges to surface water

WQU POLICY 5
Waste reduction and waste treatment and disposal practices, which avoid, remedy or mitigate the adverse environmental effects of the point source discharge of contaminants into water or onto or into land will be required. This includes the cumulative adverse effects of multiple point source discharges to the same waterbody.

In considering policies in regional plans or resource consent proposals to discharge contaminants or water to land or water, matters to be considered *by the Taranaki Regional Council will include:*

(a) the actual or potential effects of the discharge on the natural character, ecological and amenity values of the water body, including indigenous biodiversity values, fishery values and the habitat of trout;

(b) the relationship of tangata whenua with the water body;

(c) the use of water for domestic and community water supply purposes;

(d) the actual or potential risks to human and animal health from the discharge;

(e) the significance of any historic heritage values associated with the waterbody;

(f) the degree to which the needs of other resource users might be compromised;

(g) the allowance for reasonable mixing zones and sufficient dilution (determined in accordance with (a) to (o) of this Policy);

(h) the potential for cumulative effects;

(i) measures to reduce the volume and toxicity of the contaminant;

(j) off set mitigation of the effects of the contaminants;

(k) measures to reduce the risk of unintended discharges of contaminants;

(l) the necessity of the discharge and the use of the best practicable option for the treatment and disposal of contaminants;

(m) the availability and effectiveness of alternative means of disposing of the contaminant;

(n) relevant national guidelines and national environmental standards on catchment management; and

(o) the sensitivity of the receiving environment.

Restoration of water quality

WQU POLICY 6

Where the life-supporting capacity of rivers, streams, lakes or wetlands is under pressure as a result of point or diffuse discharges to surface water, improvements in the biological health and quality of water will be promoted.

For the purposes of this policy, in determining the desired life supporting capacity, the matters to be considered will include:

(a) the existing status of water quality according to a selection of chemical parameters and its consequences for life-supporting capacity;

(b) the existing habitat quality, including the need to maintain and enhance aquatic ecosystems and species;

(c) the degree to which cultural and spiritual values of or customary uses by tangata whenua are affected by existing water quality; and

(d) the natural character, ecological and amenity values of the water body, including indigenous biodiversity values, fishery values and the habitat of trout and the potential for enhancement of those values.

Explanation of the policies

Policy 1 outlines management practices to be encouraged that will contribute to maintaining and enhancing water quality by reducing diffuse source discharges of contaminants.

Policy 2 recognises the significant water quality benefits that can be achieved by maintaining and enhancing existing riparian vegetation and promoting the restoration of riparian margins. Riparian margins help mitigate adverse effects of diffuse source discharges of contaminants by providing buffering capacity and preventing direct entry of stock into waterways. Policy 2 applies throughout Taranaki. However, the focus will be on ring plain catchments, which includes Taranaki's most intensively farmed land and where pressures associated with diffuse source contamination are most significant.

Policy 3 recognises that some rivers, streams, lakes and wetlands are highly valued for their natural character, and ecological and amenity values. Through this policy, the Council seeks to maintain or enhance the quality of water in systems recognised as having high natural character and in-stream values (refer Appendix I).

Policy 4 recognises the importance to people and communities and their health and safety, of maintaining or enhancing water quality in catchments used for domestic or community water supplies. However, nutrients or other contaminants will always be present in water, either from natural sources or from the effects of land use or discharging activities, even if these activities are managed to best practice standards. Investment in appropriate water treatment systems and processes will therefore also be required to ensure the community has suitable potable water.

Policy *5* recognises that there are existing discharges to surface water and that discharges to surface water will be necessary in future. Policy 5 sets out a framework to assess proposals or policy on point source discharges to surface water. It requires waste reduction or treatment practices that avoid, remedy or mitigate adverse environmental effects arising from the discharge of contaminants to land or water from point sources. The policy also states the matters that will be considered by the Taranaki Regional Council including catchment specific values and uses, the degree to which other resource users (both consumptive and non-consumptive) may be affected, the adoption of measures to avoid, remedy or mitigate adverse effects, including off set mitigation measures such as riparian plantings, and any national guidelines.

Where multiple point source discharges occur to the same water body there may be cumulative adverse effects on water quality. These effects are also to be avoided, remedied or mitigated under Policy 5.

Policy *6* relating to life supporting capacity is to establish an overall policy intention to generally upgrade the receiving water environment in those waters in which the life supporting capacity is under pressure. Parameters that may be used to measure life supporting capacity include biological oxygen demand, suspended sediment, dissolved reactive phosphate, nitrate and ammonia levels, pH, temperature, macro-invertebrate community index, the presence of pathogenic micro-organisms, and nuisance algae. The necessity of the discharge itself will be considered under Policy 5.

Related policies

All policies relating to **Section 5.1** [Soil erosion]; Policy 1 of **Section 5.2** [Soil health], **Section 6.1** [Sustainable water allocation], **Section 6.2** [Surface water quality], **Section 6.4** [Wetlands], **Section 6.5** [Land drainage and other associated diversions], and **Section 6.6** [Use of river and lake beds]; Policy 1 of **Section 8.1** [Preservation of the natural character of the coastal environment]; all policies relating to **Section 9** [Indigenous biodiversity], **Section 10.1** [Outstanding natural features and landscapes]; **Section 10.3** [Amenity values]; and **Section 13** [Minerals]; Policy 1 of **Section 15.2** [Regionally significant infrastructure]; and all policies relating to **Section 16** [Issues of significance to iwi].

METHODS OF IMPLEMENTATION

The Taranaki Regional Council will:

WQU METH 1 Maintain a **regional plan or plans** with objectives, policies and methods of implementation to ensure that any adverse effects of point and diffuse source discharges to land and water are avoided, remedied, or mitigated, and that water quality is maintained and enhanced, particularly in water bodies that have high natural character, ecological and amenity values and in those that have relatively poor water quality.

WQU METH 2 Apply regional rules to allow, regulate, and in some instances prohibit the following point source discharges to land and water:

(a) point source discharges of water;
(b) point source discharges of stormwater;
(c) point source discharges from closed landfills;
(d) point source discharges from industrial and trade premises;
(e) point source agricultural discharges;
(f) point source discharges from hydrocarbon exploration; and
(g) other point source discharges.

WQU METH 3 Participate and support the dairy farming industry in the preparation and implementation of a regional action plan under the **Dairying and Clean Streams Accord** and include in that Plan targets for excluding stock from water bodies, farm dairy effluent discharge compliance with resource consents, the protection of regionally significant wetlands, and nutrient management.

WQU METH 4 Implement the **Sustainable Land Management Programme** to promote sustainable land use practices that will avoid, remedy or mitigate the adverse effects of diffuse source discharges.

WQU METH 5 Implement the **Riparian Management Programme** to promote the retirement and planting of riparian margins by:

(a) liaising and consulting with interested land users;
(b) preparing property plans in conjunction with landowners containing property-specific advice on riparian management actions and programmes; and
(c) providing on-going technical advice, information and other assistance to plan holders, promoting riparian management.

WQU METH 6 Consider the use of **financial incentives**, such as the provision of plant material at low cost to landowners, for riparian management purposes.

WQU METH 7 Provide **advice and information** including guidelines**,** to landowners, resource users and the public:

(a) to generally promote awareness of water quality issues;
(b) to encourage the adoption of riparian management principles and practices that avoid, remedy or mitigate adverse effects of diffuse source discharges on water quality; and
(c) on systems, siting, design, installation, operation and maintenance procedures for industrial and agricultural waste treatment and disposal systems.

(d) promote where appropriate the adoption of waste disposal systems that reduce the potential for cumulative adverse effects on water quality.

WQU METH 8 **Advocate**, as appropriate:

(a) to manufacturers and suppliers of agrichemicals, fertilisers and other agricultural compounds, the strengthening of the education and information provision role they play with a view to minimising the likelihood and potential effects of agrichemical and fertiliser application on water quality;

(b) to industrial and agricultural users to adopt waste minimisation or reduction practices and cleaner production technologies to reduce the quantity of contaminants being discharged to the environment;

(c) to industry to prepare and adopt codes of practice and guidelines aimed at reducing the effects of point and diffuse source discharges;

(d) to territorial authorities to construct and upgrade stormwater reticulation systems and wastewater treatment systems where urban developments make such an upgrade desirable; and

(e) to territorial authorities, the Department of Conservation, and other appropriate organisations such as the Queen Elizabeth II National Trust and the Taranaki Tree Trust, that they protect or retire riparian margins.

WQU METH 9 Promote the application and use of relevant **industry codes of practice.**

WQU METH 10 **Liaise or consult** as appropriate with territorial authorities regarding resource consent applications upstream of community water supply abstraction points.

WQU METH 11 Participate in the development and implementation of any **national environmental standards or national policy statements** on water quality or human drinking water standards.

WQU METH 12 **Support**, as and when appropriate, actions by the dairy industry under the Dairy Industry Strategy for Sustainable Environmental Management.

WQU METH 13 **Require** the preparation of **contingency plans** to reduce the risk of a spill that may have significant adverse effects on water quality.

WQU METH 14 **Monitor and gather information** on the state of water quality, pressures on water quality, and responses to management.

WQU METH 15 **Support**, as and when appropriate, **research and investigations** into water quality management including waste treatment options and the cumulative effects of point source discharges on water quality.

Territorial authorities may wish to consider the following methods:

WQU METH 16 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.

WQU METH 17 Include in **district plans** and **resource consents,** provisions or conditions for fencing and the retention or planting of riparian vegetation, including rules for the creation of esplanade reserves and esplanade strips when land is subdivided.

WQU METH 18 Consider the use of **financial incentives** such as land purchase or compensation, fencing grants, providing plants, rates relief and other funds.

WQU METH 19 **Plant**, where appropriate, riparian margins on land owned by the territorial authority.

Principal reasons for adopting the objective, policies and methods

The objective, policies and methods of implementation establish a policy framework for water quality issues in the Taranaki region. Their aim is to maintain Taranaki's generally high to excellent water quality and to enhance that water quality by addressing the effects of water contamination from diffuse and point sources.

The objective sets a broad direction for water quality management that seeks to maintain and enhance overall surface water quality in Taranaki's rivers, streams, lakes and wetlands. The objective states that this is to be done by avoiding, remedying or mitigating the adverse effects of point and diffuse source discharges to water through the policies and methods set out. The terms. 'maintain' and 'enhance' as used in the objective are not mutually exclusive terms that require both to be given effect to in all cases. The objective has been adopted to establish a broad region-wide goal but the extent to which surface water quality is maintained and enhanced will be determined on a case by case basis by reference to the policies and methods in the RPS. In some situations it will be appropriate that water quality be maintained and enhanced. In other situations for example where a new or increased discharge to water is proposed, it may not always be practicable to enhance water quality, but a range of matters and considerations have been set out in the Regional Policy Statement by which any adverse effects can be avoided, remedied or mitigated.

In respect of point source discharges of contaminants, the policies and methods focus on regulatory methods (complemented by a mix of non-regulatory methods). Regulation is a simple, efficient and effective method of controlling the adverse effects of these discharges, including their cumulative adverse effects on water quality.

Through rules and other provisions in a regional plan, appropriate levels of control are applied that address point source discharges to fresh water and which also protect water quality in rivers and streams that have high natural character, ecological and amenity values.

In respect of diffuse source discharges – the most significant source of contaminants entering waterways – non-regulatory methods such as advice and information and, in particular, the implementation of the Riparian Management Programme and the Sustainable Land Management Programme are considered appropriate. These programmes have proven to be successful to date in terms of public acceptance, the adoption of sustainable land management practices and the achievement of desired environmental outcomes. Other non-regulatory methods also contribute towards achieving the desired environmental outcomes. Financial incentives will aid in landowner acceptance and co-operation with regard to retiring land, particularly where these incentives support a voluntary approach to land use and management. The approaches for point and diffuse source discharges are considered appropriate having regard to their efficiency and effectiveness and their benefits and costs.

Environmental results anticipated

WQU ER 1

All significant point source discharges to surface water consented and monitored.

WQU ER 2

Any adverse environmental effects of point source discharges to surface water are avoided, remedied or mitigated.

WQU ER 3

Increased planting and fencing along the margins of rivers, streams lakes and wetlands with:

- *90% of dairy farms having riparian management plans by 2016; and*
- *90% of riparian management plans implemented by 2016.*

WQU ER 4

Maintain or enhance surface water quality and the life-supporting capacity of freshwater against a range of physical, chemical and biological measures.

The resource consents process and compliance monitoring

The Taranaki Regional Council's regulatory activities, particularly in the area of resource consent processing and administration and compliance monitoring, is one of the core activities of Council. The level of activity in this area fluctuates from year-to-year depending on the level of economic activity and other factors, but the Council anticipates it will process some 3,000 applications for resource consents (covering coastal, discharge, land use or water permits) over the next ten years.

In relation to water quality, all significant point source discharges to fresh water have a resource consent. Through the resource consents process, discharge activities that may have significant adverse effects on water quality are considered and only allowed subject to compliance with certain conditions (activities that have little or no adverse effects are permitted through rules in the *Regional Fresh Water Plan for Taranaki* – subject to compliance with conditions).

As at 1 April 2009, there were 1,479 discharge consents to surface water in the Taranaki region – 1,046 (or 71%) of which are agricultural discharges. Every discharge activity authorised by resource consent is monitored to ensure that the consent holder is complying with the conditions of that consent. The frequency and extent of that monitoring depends upon the size, scale and nature of discharge activity being monitored as well as the potential environmental impacts of the activity.

Over the last decade, there has been significant investment made by agriculture and industry in waste treatment and disposal systems and the overall level of compliance with consent conditions is high (generally around 95%). As a result, Taranaki rivers and streams show good to excellent water quality against most measures.

Riparian Management Programme

A major focus of the Taranaki Regional Council's land management work over the next ten years will be to continue to promote the retirement and planting of riparian margins along Taranaki rivers, streams, lakes and wetlands through the Riparian Management Programme.

The Riparian Management Programme, targets dairying land use on the ring plain, and includes the provision of a property planning service to land occupiers involving the preparation of riparian management plans and associated supply of low cost, high quality riparian plants.

Riparian management plans set out recommendations for the retirement or re-vegetation of land along the banks of rivers and streams. The retirement or revegetation of riparian margins forms an interface between the stream and land, preventing stock access, and decreases the amount of diffuse contaminants (in the form of animal excreta, sediment and fertiliser run-off) entering the stream and reducing water quality. Not only does this have major benefits for fresh water quality, it also has benefits for coastal waters into which rivers and streams ultimately flow.

As at 30 June 2009, the Taranaki Regional Council had prepared 2,255 riparian management plans, covering 12,212 kilometres of streambank. Some 93% of Taranaki dairy farms now have a riparian plan for their property. The programme has grown exponentially over time particularly since the implementation of the *Dairying and Clean Streams Accord – Regional Action Plan for Taranaki* has begun to be implemented. There continues to be strong demand for the property planning service and most plan recommendations are being implemented progressively. The Council's target as set out in the Regional Action Plan is to have 90% of [illegible] rec[illegible] im[illegible]

Appendix III

SEM Physicochemical Programme
TRC Intra-lab Quality Control
Report 2015-2016

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 and thirteen sites in the 2015-2016 period. Sampling is carried out on the second Wednesday of each month for the entire year at the first eleven sites, and on the next day for last two sites. The programme also meshes with a similar national programme operated by the National Institute of Water and Atmospheric Research (NIWA) since 1989, which included three sites in Taranaki until December 2015 and two sites thereafter.

As a quality control measure of the TRC laboratory precision for this programme, and as part of general quality assurance practices at the Council, a sample is collected from one of the eleven monitoring sites (chosen randomLy) every three to four months and split on site for duplicate analyses. For quality control purposes, this sample is unidentified and is analysed in exactly the same way and at the same time as other samples, and recorded on the Council's database. In conjunction with the sampling undertaken by NIWA, a sample from one of the three (now two) 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 2015-2016 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 2015 and June 2016.

First QC exercise

These split samples were collected from the Punehu Stream site at SH45 on 12 August 2015 under slightly turbid, recession flow conditions (0.514 m^3/sec), following a small fresh, and in fine conditions. Results are presented in Table 1.

Table 1 Results of SEM QC sampling on 12 August 2015

Site: PNU000200					
Date: 12 August 2015				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.031	0.032	2	✓
A440F	/cm	0.007	0.007	0	✓
A770F	/cm	0.001	0.000	100	***
ALKT	g/m^3 $CaCO_3$	17	17	0	✓
BOD5	g/m^3	< 0.5	< 0.5	0	✓
CONDY	mS/m @ 20°C	9.0	8.9	1	✓
DRP	g/m^3-P	0.012	0.013	3	✓
ENT	/100mL	3	1	50	**
ECOL	/100mL	8	8	0	✓
FC	/100mL	8	8	0	✓
NH4	g/m^3-N	0.019	0.018	3	✓
NO2	g/m^3-N	<0.001	<0.001	0	✓
NO3	g/m^3-N	0.15	0.16	3	✓
pH	pH	7.2	7.2	0	✓
SS	g/m^3	< 2	< 2	0	✓
TKN	g/m^3-N	0.02	0.03	20	*
TN	g/m^3-N	0.17	0.19	6	✓
TP	g/m^3-P	0.028	0.024	8	✓
TURBY	NTU	3.0	2.9	2	✓

Comments:

The difference of 0.001 units in filtered absorbance readings at 770 nm was not significant as it was within acceptable equipment performance tolerance. The difference between enterococci counts for the paired samples was not significant as the counts were below the lower range limit (20 cfu/100mL) for the test. The difference between paired TKN results was significant (at low concentrations) but neither result was an outlier in terms of the site's historical record.

Overall, results showed relatively good laboratory analytical precision performance, with 16 of 19 pairs of results being within the 10% guideline.

Second QC exercise

These split samples were collected from the Mangaoraka Stream site at Corbett Road on 11 November 2015 under slightly turbid, steady recession flow (0.776 m^3/sec), and fine, partly cloudy weather conditions. Results are presented in Table 2.

Table 2 Results of SEM QC sampling on 11 November 2015

Site: MRK000420					
Date: 11 November 2015				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.025	0.022	6	✓
A440F	/cm	0.005	0.004	11	*
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m³ $CaCO_3$	46	47	1	✓
BOD5	g/m³	0.7	0.7	0	✓
CONDY	mS/m @ 20°C	15.3	15.2	<1	✓
DRP	g/m³-P	0.016	0.014	7	✓
ENT	/100mL	150	180	9	✓
ECOL	/100 mL	1100	900	10	✓
FC	/100mL	1100	910	10	✓
NH4	g/m³-N	0.015	0.017	6	✓
NO2	g/m³-N	0.004	0.004	0	✓
NO3	g/m³-N	0.83	0.89	3	✓
pH	pH	7.8	7.8	0	✓
SS	g/m³	<2	<2	0	✓
TKN	g/m³-N	0.14	0.07	33	**
TN	g/m³-N	0.97	0.96	1	✓
TP	g/m³-P	0.026	0.027	2	✓
TURBY	NTU	1.5	1.3	7	✓

Comments:

The difference of 0.001 units in filtered absorbance readings at 440 nm was not significant as it was within acceptable equipment performance tolerance. The differences between the TKN paired results was significant at low concentration. None of the results were outliers in terms of the historical record for this site.

Otherwise, overall laboratory analytical precision performance was good, with 17 of the 19 pairs of results recorded within the 10% guideline.

Third QC exercise

These split samples were collected from the site in the Patea River at Barclay Road on 10 February 2016 under low, clear flow (0.140 m^3/sec), and fine, partially cloudy weather conditions. Results are presented in Table 3.

Table 3 Results of SEM QC sampling on 10 February 2016

Site: PAT000200					
Date: 10 February 2016				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.012	0.016	14	*
A440F	/cm	0.004	0.004	0	✓
A770F	/cm	0.001	0.001	0	✓
ALKT	g/m^3 $CaCO_3$	31	31	0	✓
BOD5	g/m^3	< 0.5	< 0.5	0	✓
CONDY	mS/m @ 20°C	7.7	7.7	0	✓
DRP	g/m^3-P	0.034	0.036	3	✓
ENT	/100mL	120	840	75	***
ECOL	/100mL	58	28	35	**
FC	/100mL	60	28	36	**
NH4	g/m^3-N	<0.003	<0.003	0	✓
NO2	g/m^3-N	< 0.001	< 0.001	0	✓
NO3	g/m^3-N	0.009	0.009	0	✓
PH	pH	7.7	7.7	0	✓
SS	g/m^3	< 2	< 2	0	✓
TKN	g/m^3-N	<0.04	<0.04	0	✓
TN	g/m^3-N	< 0.05	<0.05	0	✓
TP	g/m^3-P	0.043	0.043	0	✓
TURBY	NTU	0.7	0.8	7	✓

Comments:

The difference in readings of filtered absorbance at 340 nm was just significantly different. The differences between pairs of enterococci and faecal coliform counts were outside acceptable tolerance levels (20%) for bacteriological samples. None of these results were outliers in terms of the historical record for this site.

Otherwise 15 pairs of parameters analysed were well within acceptable agreement, representing good laboratory analytical precision for these samples.

Fourth QC exercise

These split samples were collected from the site in the Waingongoro River at SH3 on 11 May 2016 under slightly turbid, recession flow conditions (1.40 m^3/sec), and fine, partly cloudy weather. The results are presented in Table 4.

Table 4 Results of SEM QC sampling on 11 May 2016

Site: MKW000300					
Date: 11 May 2016				**Difference from mean (%)**	**Comments**
Parameter	**Units**	**Routine Sample**	**QC Sample**		
A340F	/cm	0.038	0.033	7	✓
A440F	/cm	0.007	0.007	0	✓
A770F	/cm	0.000	0.000	0	✓
ALKT	g/m³ $CaCO_3$	51	51	0	✓
BOD5	g/m³	0.7	0.7	0	✓
CONDY	mS/m @ 20°C	17.6	17.6	0	✓
DRP	g/m³-P	0.052	0.054	2	✓
ENT	/100mL	640	520	10	*
ECOL	/100mL	360	400	5	✓
FC	/100mL	360	410	6	✓
NH4	g/m³-N	0.010	0.008	11	*
NO2	g/m³-N	0.008	0.006	14	*
NO3	g/m³-N	1.26	1.06	9	✓
PH	pH	8.2	8.2	0	✓
SS	g/m³	6	6	0	✓
TKN	g/m³-N	0.09	0.32	56	***
TN	g/m³-N	1.36	1.39	1	✓
TP	g/m³-P	0.080	0.081	1	✓
TURBY	NTU	6.0	5.3	6	✓

Comments:

The difference between the pair of enterococci bacterial counts was within acceptable tolerance levels (20%) for bacteriological samples.

The differences in ammonia and nitrite results (both 0.002 g/m³) were relatively insignificant at the very low concentrations (<0.01 g/m³). The difference in TKN was significant at low concentration.

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

Summary

Four split samples were collected and analysed during this one-year (2015-2016) period for the assessment of internal laboratory analytical precision. The following table summarises the number of times each category of differences from the mean occurred for all analyses commonly performed on SEM samples.

	Difference from mean of pairs of split samples							
Parameter ID	<10%		10-20%		21-50%		>50%	
A340F	3	(93)	1	(7)	-	(0)	-	(0)
A440F	3	(72)	1	(19)	-	(6)	-	(2)
A770F	3	(77)	1	(0)	-	(9)	-	(15)
ALKT	4	(100)	-	(0)	-	(0)	-	(0)
BOD5	4	(86)	-	(12)	-	(1)	-	(1)
CONDY	4	(100)	-	(0)	-	(0)	-	(0)
DO*	-	(100)	-	(0)	-	(0)	-	(0)
DRP	3	(93)	1	(6)	-	(0)	-	(1)
ENT	1	(43)	1	(23)	1	(27)	1	(7)
ECOL	2	(48)	1	(34)	1	(16)	-	(2)
FC	2	(49)	1	(33)	1	(16)	-	(2)
NH4	3	(78)	1	(12)	-	(6)	-	(2)
NO2	3	(95)	1	(4)	-	(1)	-	(0)
NO3	4	(86)	-	(5)	-	(8)	-	(1)
pH	4	(100)	-	(0)	-	(0)	-	(0)
SS	4	(88)	-	(9)	-	(4)	-	(0)
TKN	3	(50)	-	(21)	-	(23)	1	(6)
TN	4	(82)	-	(11)	-	(7)	-	(0)
TP	4	(86)	-	(7)	-	(5)	-	(2)
TURB	4	(98)	-	(1)	-	(1)	-	(0)

[NB: () = % of QC samples for 1995 to 2016 period; * Winkler method to 2012]

This summary for the 2015-2016 period indicated:

- results from pairs of all three bacteriological species' samples varied in precision with one set of results falling outside the acceptable variability (20%). This follows the historical trend for paired bacteriological analyses which have found at least 43% of the period's quality control samples within the 10% difference of the mean (for all three species), and from 66% to 72% of samples within 20% of the mean for paired samples in all species.
- TKN analytical variability greater than 20% was recorded on one occasion, due to reliance on calculations from another nitrogen species which, however, was within acceptable precision tolerance. TKN duplicates have traditionally shown this variability with only 50% and 71% to date within 10% and 20% of the mean respectively.
- Ammonia and nitrite analytical variability of % was recorded on one occasion at very low concentrations and the difference of 0.3 g/m^3 was considered insignificant at this level.
- variability in split samples agreement for filtered absorbances at 340 nm, 440 nm, and 770 nm which had occurred occasionally, but almost entirely within equipment performance tolerance values, was only once recorded (at all three wavelengths on separate occasions) over the 2015-2016 period.

In general, laboratory analytical performance has been acceptable, with very good precision of results shown for the majority of parameters following the continuation of split-sampling field methodology to remove any sampling bias in the quality control programme. Some exceptions in analytical precision have been identified and these are being addressed by the laboratory. Additional inter-laboratory analyses are recommended as part of this process. No results from this exercise were statistical outliers in the context of the 21-year historical database for all sites in the programme. The dissolved oxygen measurement was undertaken by field meter during the year and therefore has been removed from the intra-laboratory programme.

Appendix IV

SEM Physicochemical Programme
Inter-lab Quality Control Report 2015-2016

Introduction

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

As a quality control measure for this programme, and as part of general quality assurance practices at the Council, a sample is collected randomLy from one of the eleven monitoring sites every three to four months and split for duplicate analyses (see Appendix III). The additional sample is analysed in exactly the same way and at exactly the same time as other samples, and recorded on the Council's database. In conjunction with the sampling undertaken by NIWA, the Council also shares a duplicate sub-sample from time to time as a quality control procedure to assess accuracy of laboratory analytical performance. Normally a single sample is collected from one of the three (now two) sites and then split for sub-samples' analyses by each of the laboratories. A sample was collected from one of the three (now two) sites, on one occasion in the 2015-2016 year for the inter-laboratory comparison exercise.

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

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

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

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

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

One quality control sampling run was performed with NIWA field staff during the 2015-2016 period on 17 May 2016. Sampling was performed at the Waitara River site at SH3 during the rising flow (47 m^3/s) of a small fresh in fine, overcast weather. The water appeared turbid brown, with a suspended solids concentration of 18 g/m^3 (TRC).

Results

2015-2016 exercise

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

Table 1 Results of SEM QC sampling by TRC & NIWA on 17 May 2016

WTR000800					
		Time:1005 (NZST)		**Difference from mean (%)**	**Comments**
Parameter	Units	TRC	NIWA		
A340F	/cm	0.056	0.059	3	✓
A440F	/cm	0.012	0.012	0	✓
BDISC	m	0.42	0.465	5	✓
CONDY	mS/m @ 20^{0}C	9.6	9.7	< 1	✓
DO	g/m^3	10.3	10.2	< 1	✓
DRP	g/m^3-P	0.018	0.016	6	✓
ECOL	nos/100 mL	1300	>2419	> 49	**
NH4	g/m^3-N	0.027	0.028	2	✓
NO3	g/m^3-N	0.61	0.582	2	✓
pH	pH	7.6	7.72	1	✓
TEMP	°C	14.5	14.2	1	✓
TN	g/m^3-N	0.85	0.910	3	✓
TP	g/m^3-P	0.079	0.054	18	*
TURBY	NTU	16	13.4	9	✓

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

Comments:

A significant difference in paired measurements between the two laboratories was recorded for *E. coli* and total phosphorus. Otherwise good analytical agreement was recorded for all other parameters, including dissolved phosphorus.

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

	Difference from mean of pairs of split samples							
Parameter ID	**<10%**		**10-20%**		**20-50%**		**>50%**	
A340F	1	(92)	-	(4)	-	(4)	-	(0)
A440F	1	(60)	-	(36)	-	(0)	-	(4)
CONDY	1	(93)	-	(4)	-	(0)	-	(4)
DO	1	(100)	-	(0)	-	(0)	-	(0)
DRP	1	(46)	-	(23)	-	(27)	-	(4)
ECOL		(27)	-	(36)	1	(33)	-	(0)
NH4	1	(41)	-	(19)	-	(19)	-	(22)
NO3	1	(89)	-	(7)	-	(4)	-	(0)
pH	1	(100)	-	(0)	-	(0)	-	(0)
TEMP	1	(100)	-	(0)	-	(0)	-	(0)
TN	1	(88)	-	(4)	-	(8)	-	(0)
TP	-	(60)	1	(28)	-	(12)	-	(0)
TURB	1	(37)	-	(44)	-	(19)	-	(0)

[NB: () - % of QC samples over the 1995 to 2016 period]

This summary indicates:

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

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

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

Discussions with NIWA, Hamilton staff have determined that annual inter-laboratory comparisons will continue to be performed on one sample collected at one of the two NIWA sites (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.