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State of the Environment Monitoring
Annual Report
2018-2019

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Taranaki Regional Council

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Executive summary

Section 35 of the *Resource Management Act* (RMA) requires local authorities to undertake monitoring of the region's environment, including land, air, and fresh and marine water quality. As set out in the *Regional Policy Statement for Taranaki (2010)*, the quality of the region's fresh water resources is of primary importance for the region's communities, including iwi, economic sectors, and social and cultural sectors. To inform the community of the state of, pressures upon, and trends in water quality in the region, a number of monitoring programmes have been put in place. The freshwater physicochemical component of the State of Environment Monitoring (SEM) programme for Taranaki was initiated by the Taranaki Regional Council in the 1995-1996 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 2018 to June 2019, under a narrower range of flow conditions than typical, ranging through moderate freshes to very low late summer flows. This year was characterised by much 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 established three years before, 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 Council's thirteen 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 2018-2019 monitoring year, flows at times of sampling were much lower than usual, with few freshes and several low flows sampled. Eleven of the thirteen sites recorded the lowest median sampled flow, and five recorded the lowest sampled flow. In general terms, for the eleven sites monitored for more than 10 years, water quality was comparatively better in clarity, suspended solids concentrations and nutrient levels, poorer in organics, and similar in bacteria numbers, to past quality. Narrower temperature ranges, mainly due to higher minimum temperatures, and similar median water temperatures, were measured in the 2018-2019 period compared with ranges and medians measured during the first 23 years of the SEM programme. The 2018-2019 median dissolved reactive and/or total phosphorus levels were higher at three sites and lower at four sites. Median nitrate and/or total nitrogen species' levels were higher at three sites and lower at two sites, while median ammoniacal nitrogen levels were lower at five and higher at one site.

The report also provides an assessment of each site's statistical water quality in terms of appropriate guidelines and standards for various usages based upon a summary of the record for the complete 1995-2019 period.

For the fifth 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-FM*). 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. During the 2017-2018 year, the Ministry for the Environment amended the NOF grading system so that the 4 grades, with the bottom grade being unacceptable, were removed from the NOF in respect of *E coli*. Instead, there is now a matrix of categorisation, with 4 separate criteria to each be considered and the overall grading being the worst of the four. There are now five grades, and no bottom line, for *E coli*. The Government has stated that as a whole, 80% of the country's waterways should be within the top 3 categories by 2030, and 90% by 2040. It should be noted that these percentages do not necessarily apply at the regional level. For the purpose of comparisons, this report uses the five-step categories, with rivers in either of the bottom two categories being deemed unacceptable for recreational purposes.

The RMA 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*'), in either case aligning with the objective of the RMA, 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 2019 are summarised and presented for all thirteen Council sites briefly in the current Annual Report. In addition, this report presents trend analysis for the two NIWA sites in Taranaki.

Also, for the fifth 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 (24-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, Waingongoro River at Eltham Road, and Maketawa Stream at Tarata Road). On the other hand, there has been a significant long term improvement in total nitrogen at three of the eleven sites monitored, with only one site that is showing deterioration in this measure. Long term trends for faecal coliforms and enterococci bacteria showed statistically significant changes over the 24-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 in mid and lower catchments. Significant deteriorations in black disc clarity were recorded at two sites, one 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 dissolved reactive 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 since 2001 and the diversion of Eltham's WWTP discharge out of the river since 2010. Most long term deterioration in aspects of water quality, where five parameters have significantly deteriorated, has been found in the mid-reaches of the Waiwhakaiho River (dissolved phosphorus, nitrate and ammonia nitrogen, and both bacteriological species), and in lower reaches of the Mangaoraka Stream (both phosphorus species, both bacteriological species and visual clarity), with no parameters showing significant long term improvement. More recent data indicate the deterioration has been arrested at both of these sites for all parameters monitored.

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 had 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. Every one of the 11 long-term sites is showing either an improvement or no trend, in both total and dissolved reactive phosphorus over the last 7 year period. There is no regional pattern in changes in ammonia (improving trends balance deteriorations), although it is noted that nitrate concentrations are increasing at a few, primarily upland sites. Other measures (bacteria, organics, aesthetics) show no regional pattern of change in either direction.

This report on the results of the 2018-2019 monitoring period also includes recommendations for the 2019-2020 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 (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 I.

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, 1996), 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 2018-2019 monitoring year, the twenty-fourth 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. It should be noted that FMUs allow for tailored approaches to management, and are not intended to represent clusters of catchments of like water quality. The primary driver of site selection across this programme as a whole, continues to be a focus on areas of active management. The Taranaki Regional Council is seeking to establish objectives and limits as appropriate for the Taranaki region through the current review of the Regional Fresh Water Plan for Taranaki.

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, 2019a).

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.

Notwithstanding the wide coverage of the region through the existing representative sites, in 2015-2016 the Council undertook an extended survey programme that involved regular sampling across a large number of additional catchments, to confirm (or otherwise) the degree of representation afforded by the current programme (TRC, 2017). In summary, for all physicochemical parameters, the range of values across the regular SEM sites encompassed the range found across the additional "comparative" sites. Under the range of conditions monitored seasonally over the full course of a year, the existing SEM sites were found to already represent the full range of baseline water quality in the Taranaki region. No site in either the existing network (11 catchments) or the five additional catchments gave anomalous results.

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 in 35 catchments around New Zealand (Smith, et al, 1989). Until December 2015, 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 December 2015 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 meant 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 reference system (ESAM) 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

This 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 hydroelectric power (HEP) scheme. Flow gauging is required on each sampling occasion for rating purposes. This site is located within the rohe of Pukerangiora Hapū and Te Kotahitanga o Te Atiawa Trust.

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. Located toward the lower catchment, it is the principal tributary of the lower Waiongana Stream. The Mangaoraka Stream is a trout fishery of local importance. This site is located within the rohe of Pukerangiora Hapū and Te Kotahitanga o Te Atiawa Trust.

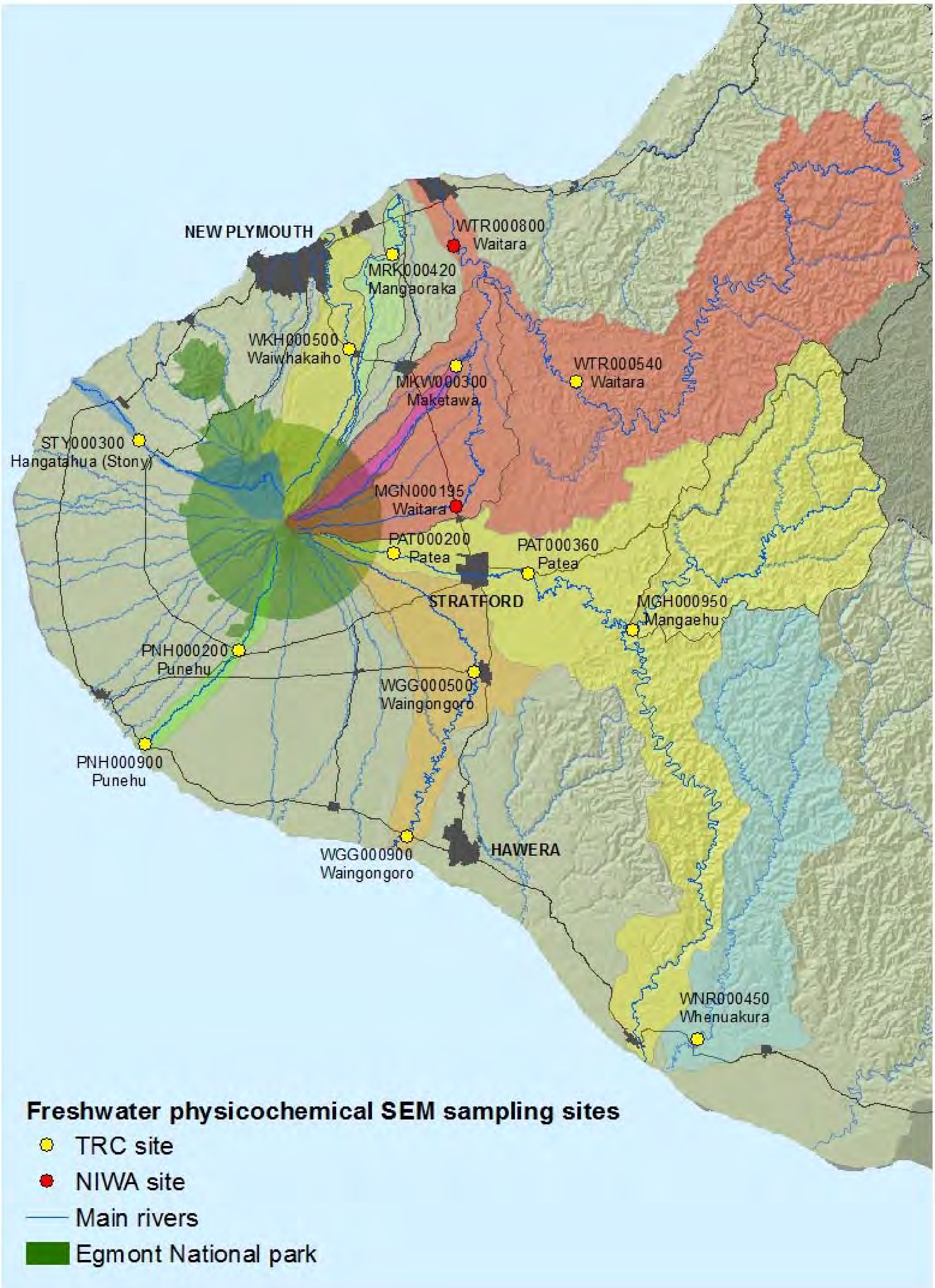


Figure 1 Freshwater physicochemical SEM sampling sites

Site Waiwhakaiho River at SH3

This site is an existing hydrological recording station and was included in the Taranaki ring plain survey (TCC 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). This site is located in the rohe of the local Ngāti Te Whiti, Ngāti Tawhirikura and Puketapu Hapū, and Te Kotahitanga o Te Atiawa Trust.

Site Hangatahua (Stony) River at Mangatete Road

This river is protected in its natural state by way of a Local Conservation Order. The 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 (TCC, 1984). This river is notoriously difficult to rate (hydrologically) and regular flow gauging is necessary, with a hydrological recording station now established. The river is periodically affected by significant natural erosion events in the headwaters. Several of these events have occurred since the SEM programme commenced, namely in the latter part of 2006, mid-2008, mid-2009, early 2014, mid-2016 and early/mid-2017. This site is in the rohe of Ngā Mahanga a Tairi Hapū and Te Kāhui o Taranaki Trust.

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. Water quality is potentially affected by diffuse source run-off and point source discharges from dairy shed treatment pond systems, in particular from the lower reaches of the catchment and Mangatawa Stream sub-catchment. No industrial discharges in the catchment are known to occur. Both sites were included in the Taranaki ring plain survey and the lower site near the coast 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. Both Punehu Stream sites are located in the rohe of Ngāti Titahi Hapū and Orimupiko Marae with the area also of interest for Te Korowai o Ngāruahine Trust and Te Kāhui o Taranaki Trust.

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

The Waingongoro River is the longest river which is confined to the ring plain. Both sites on the river were original Taranaki ring plain survey sites, and are existing hydrological recording stations. The sites are in the rohe of Okahu Inuawai and Araukūku Hapū, and are situated in an overlapping area of interest for Te Korowai o Ngāruahine and Te Runanga o Ngāti Ruanui Trusts.

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 have occurred in the vicinity of Eltham. The site is therefore also included in a consent compliance monitoring programme.

Site 2, in the lower reaches of what is a principal Taranaki trout fishery river, is representative of the combined impacts of industrial, municipal and agricultural point source discharges, and diffuse run-off. 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 November 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. The site is downstream of Stratford with associated urban run-off, closed landfill and up-graded (in 2009) oxidation pond discharges, and discharge from a gas-fired power station. It is also an established hydrological recorder station. Both sites lie in the rohe of Inuawai, Ngāti Tupaea and Ahitahi Hapū, and lie in an overlapping area of interest for Te Runanga o Ngāti Ruanui and Te Runanga o Ngati Maru Trusts. The Barclay Road site is also within an area of interest to Te Korowai o Ngāruahine Trust.

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. The site lies in an area of interest for Te Kaahui o Rauru, Te Runanga o Ngāti Ruanui and Te Runanga I Ngāti Maru Trusts.

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 section of the Waitara catchment, is representative of a combination of upland agricultural development and native forest. It is 6.1 km above the Tarata hydrological recording station, which was established as a national representative basin in 1970. The discharge from the Motukawa power station lies between, and has been monitored by the Council for physicochemical 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). The site is upstream of any tidal influence. NIWA data are utilised for this site.

Both Waitara River sites are in the rohe of Te Runanga o Ngāti Maru Trust, with the Bertrand road side also within the rohe of Pukerangiora Hapū.

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. The site lies in the rohe of Pukerangiora, Inuawai and Araukūku Hapū, and within an overlapping area of interest for Te Kotahitanga o Te Atiawa Trust, Te Runanga o Ngāti Maru, Te Runanga o Ngāti Ruanui Trust and Te Korowai o Ngāruahine Trust.

Site Whenuakura River at Nicholson Road

This site is in the lower reaches of an eastern hill country catchment that has largely been developed for agriculture, with some production forestry and native forest. It is an established hydrological recording station, located 10.7 km from the coast, in the upper section of tidal river but above the saline influence. The site lies in the rohe of Whenuakura Marae and Ngāti Hinewaiata Hapū, and within an overlapping area of interest for Te Kaahui o Rauru and Te Runanga o Ngāti Ruanui Trusts. The site has been monitored by the Council for physicochemical 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 Environmental Scientist and according to standard TRC field methodology outlined in an appropriate manual (TRC 2004a) which was last revised in 2012.

Analyses during the 2018-2019 monitoring period were performed by Hill Laboratories, an IANZ-registered facility, using standard methods. Previously, all analyses were carried out in the TRC IANZ-registered chemistry laboratory using equivalent standard methods, from 1995 until its closure in June 2018. 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. From July 2018 until June 2019, turbidity was measured with a Hach 2100N instrument.

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 (every month in 2018-2019). 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 TRC's Intra-lab Quality Control Report, Appendix II).

In conjunction with the sampling undertaken by NIWA for the NRWQN, samples from both Taranaki network sites are split in the field at least annually, as an inter-laboratory quality control procedure for analytical accuracy assessment. These comparisons between Hill Laboratories and NIWA results are reported in Appendix III.

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

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

4 Water quality results

Water quality data accumulated for the period July 2018 to June 2019 are presented for each of the thirteen sites. Statistical summaries of these data and the cumulative data for nine sites (July 1995 to June 2019), one site in the lower Waingongoro River (July 1998 to June 2019), one site in the lower Maketawa Stream (July 2003 to June 2019), and one site each in the lower Whenuakura River and mid Waitara River (July 2015 to June 2019) 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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 25 °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
11-Jul-2018	0805	0.014	<0.002	<0.002	22	2.08	<0.4	9.4	11.6	100	0.0146	60	20
08-Aug-2018	0800	0.014	0.003	<0.002	28	2.90	<0.4	10.0	10.7	99	0.0191	140	20
12-Sep-2018	0800	0.011	0.002	<0.002	29	4.44	0.8	9.8	11.7	101	0.020	120	10
10-Oct-2018	0700	0.017	0.006	0.005	32	3.35	0.9	10.3	10.9	100	0.031	1000	40
14-Nov-2018	0645	0.014	0.003	<0.002	31	3.52	<0.4	11.0	10.4	101	0.029	330	30
12-Dec-2018	0650	0.015	0.003	<0.002	32	2.30	0.7	10.8	9.8	100	0.032	300	40
09-Jan-2019	0710	0.014	0.002	<0.002	34	2.22	0.6	10.6	9.5	99	0.032	100	110
13-Feb-2019	0700	0.015	0.003	<0.002	34	2.66	0.8	10.8	9.2	100	0.046	140	270
13-Mar-2019	0705	0.028	0.007	0.002	30	0.49	1.6	10.1	9.6	100	0.055	10000	630
10-Apr-2019	0800	0.01	<0.002	<0.002	34	2.98	0.8	11.1	10.8	102	0.038	300	430
08-May-2019	0805	0.016	0.004	<0.002	35	4.19	0.7	11.2	10.9	101	0.022	600	260
12-Jun-2019	0810	0.012	<0.002	<0.002	30	2.96	<0.4	10.5	10.7	101	0.022	280	10

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		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
11-Jul-2018	0805	60	4.266	0.024	0.0035	0.78	7.3	<3	8.2	0.13	0.93	0.023	1.32
08-Aug-2018	0800	140	2.341	0.011	0.0026	0.54	7.5	<3	11.1	0.15	0.69	0.028	1.80
12-Sep-2018	0800	140	1.731	<0.005	0.0013	0.31	7.3	<3	8.3	<0.10	0.31	0.068	0.87
10-Oct-2018	0700	1000	1.237	0.008	0.0017	0.19	7.8	<3	10.9	0.14	0.26	0.040	1.20
14-Nov-2018	0645	400	2.110	0.010	0.0021	0.48	7.8	8	13.8	0.10	0.62	0.050	2.5
12-Dec-2018	0650	330	1.492	0.011	0.0023	0.29	7.6	<3	15.6	0.15	0.36	0.038	0.80
09-Jan-2019	0710	140	1.110	0.009	0.0011	0.06	7.7	<3	16.9	0.12	0.21	0.042	0.77
13-Feb-2019	0700	140	0.894	<0.005	0.0011	0.05	7.7	<3	17.2	0.14	0.15	0.060	0.50
13-Mar-2019	0705	11000	7.007	0.014	0.0031	0.15	7.6	36	16.3	0.26	0.58	0.130	7.6
10-Apr-2019	0800	500	1.164	<0.005	0.0011	0.18	8.0	<3	12.1	<0.10	0.25	0.044	0.49
08-May-2019	0805	700	1.510	<0.005	0.0019	0.34	7.6	<3	11.8	<0.10	0.44	0.026	0.65
12-Jun-2019	0810	340	2.378	<0.005	<0.002	0.47	7.4	<3	11.0	<0.10	0.54	0.026	0.78

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

Table 4 Statistical summary of data from July 2018 to June 2019: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.010	0.028	0.014	12	0.005
A440F	Absorbance @ 440nm filtered	/cm	<0.002	0.007	0.003	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	<0.002	0.005	<0.002	12	0.001
ALKT	Alkalinity total	g/m^3 $CaCO_3$	22	35	32	12	3.6
BLACK DISC	Black disc transparency	m	0.49	4.44	2.93	12	1.04
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.4	1.6	0.7	12	0.34
COND	Conductivity @ 25°C	mS/m	9.4	11.2	10.6	12	0.56
DO	Dissolved oxygen	g/m^3	9.2	11.7	10.7	12	0.80
PERSAT	Dissolved oxygen saturation	%	99	102	100	12	0.86
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.0146	0.055	0.030	12	0.012
ECOL	E. coli bacteria	cfu/100 mL	60	10000	290	12	2811
ENT	Enterococci bacteria	cfu/100 mL	10	630	40	12	202
FC	Faecal coliform bacteria	cfu/100 mL	60	11000	335	12	3086
FLOW	Flow	m^3/s	0.894	7.007	1.620	12	1.744
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.005	0.024	0.0085	12	0.006
NO_2	Nitrite nitrogen	g/m^{3}N	0.0011	0.0035	0.00195	12	0.001
NO_3	Nitrate nitrogen	g/m^{3}N	0.05	0.78	0.30	12	0.216
pH	pH		7.3	8.0	7.6	12	0.21
SS	Suspended solids	g/m^3	<3	36	<3	12	9.5
TEMP	Temperature	°C	8.2	17.2	11.95	12	3.16
TKN	Total kjeldahl nitrogen	g/m^{3}N	<0.10	0.26	0.125	12	0.045
TN	Total nitrogen	g/m^{3}N	0.15	0.93	0.40	12	0.232
TP	Total phosphorus	g/m^{3}P	0.023	0.130	0.041	12	0.029
TURBY	Turbidity (Hach 2100N)	NTU	0.49	7.6	0.84	12	1.976

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

Table 5 Statistical summary of data from July 2003 to June 2019: Maketawa Stream at Tarata Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.002	0.141	0.017	192	0.021
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.031	0.004	192	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.005	0.000	192	0.001
ALKT	Alkalinity total	g/m^3 $CaCO_3$	5	35	29	192	6
BLACK DISC	Black disc transparency	m	0.09	5.23	2.61	192	1.14
BOD_5	Biochemical oxygen demand 5 day	g/m^3	<0.4	5.4	<0.5	192	0.5
COND	Conductivity @ 25°C	mS/m	2.0	13.9	9.6	192	1.4
DO	Dissolved oxygen	g/m^3	8.6	12.6	10.6	192	0.8
PERSAT	Dissolved oxygen saturation	%	90	103	99	192	2
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.004	0.108	0.025	192	0.011
ECOL	E. coli bacteria	cfu/100 mL	50	62000	325	192	5065
ENT	Enterococci bacteria	cfu/100 mL	6	12000	170	192	1738
FC	Faecal coliform bacteria	cfu/100 mL	50	62000	335	192	5078
FLOW	Flow	m^3/s	0.838	101.989	1,983	192	7.867
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.252	0.010	192	0.025
NO_2	Nitrite nitrogen	g/m^{3}N	<0.001	0.012	0.002	192	0.002
NO_3	Nitrate nitrogen	g/m^{3}N	0.008	0.918	0.271	192	0.206
pH	pH		6.8	8.0	7.6	192	0.2
SS	Suspended solids	g/m^3	<2	130	<2	192	12
TEMP	Temperature	°C	4.8	19.1	11.6	192	3.1
TKN	Total kjeldahl nitrogen	g/m^{3}N	-0.01	2.0	0.07	192	0.2
TN	Total nitrogen	g/m^{3}N	<0.05	2.1	0.40	192	0.276
TP	Total phosphorus	g/m^{3}P	0.018	0.774	0.036	180	0.064
TURB	Turbidity (Hach 2100A)	NTU	0.5	14	0.9	150	1.8
TURBY	Turbidity (Cyberscan WTW)	NTU	0.4	75	1.2	157	7.6

Discussion

2018-2019 period

Good aesthetic water quality was indicated by a median black disc clarity of 2.93 metres, in the lower reaches of this ring-plain stream near to its confluence with the Manganui River. The maximum clarity (black disc value of 4.44 m) was recorded in early spring under moderate flow conditions (1.73 m^3/s). No significant floods, but a small fresh and one very low flow were sampled during the year, with some elevation in turbidity (7.6 NTU) and suspended solids concentration (38 g/m^3) and low black disc visibility (0.49 m) at the time of the March fresh. Poorest water quality conditions were recorded at the time of this fresh, in terms of bacterial number (11,000 faecal coliforms/100mL), BOD_5 (1.6 g/m^3) and some dissolved nutrients (DRP 0.055 g/m^3P).

pH was relatively stable (7.3 to 8.0), 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 0815 NZST), particularly during summer low flow conditions.

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 99% saturation) and low BOD_5 levels (median: 0.7 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 335 and 40 (per 100 mL) respectively. Water temperature varied over a moderate range of 9.0°C with a maximum mid-summer (early morning) river temperature of 17.2°C recorded in February 2019.

Brief comparison with the previous 2003-2018 (fifteen year) period

Generally, stream water quality was improved in appearance/clarity (higher median black disc clarity [by 0.32 m], and lower median turbidity [by 0.1 NTU] with no difference in median suspended solids level). Bacterial water quality was similar, with median numbers the same for faecal coliforms and lower for enterococci, by 130 cfu/100 mL. Median water temperature was slightly higher (by 0.5°C), while the maximum water temperature was lower (by 1.9°C) than the maximum previously recorded. Other physicochemical aspects of water quality were very similar for the two periods, in terms of median values. Relatively narrow ranges for parameters such as suspended solids, conductivity, turbidity, pH and total phosphorus reflected the lack of significant flood events sampled. Median flow sampled during 2018-2019 was lower (by 386 l/s) than over the previous fifteen-year period due in part to few fresh flow conditions sampled during the latest period. Median pH values were identical, and the maximum pH value was 0.1 unit higher than that of the past fifteen-year record. For nutrients, nitrogen species all had similar median values, and total and dissolved phosphorus were lower (by 18 and 32%, respectively) during the monitoring year in comparison with the medians of the previous fifteen 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 2.

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

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 25 °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
11 Jul 2018	0835	0.012	<0.002	<0.002	29	1.66	<0.4	14.2	11.0	99	0.0063	1100	120
08 Aug 2018	0835	0.018	0.003	<0.002	34	1.51	<0.4	14.9	10.4	99	0.0052	260	80
12 Sep 2018	0845	0.014	<0.002	<0.002	45	3.06	0.8	17.5	11.4	101	0.0129	900	120
10 Oct 2018	0730	0.023	0.005	<0.002	61	3.07	0.8	21.1	10.6	99	0.0122	700	240
14 Nov 2018	0730	0.023	0.006	<0.002	42	2.86	<0.4	16.2	10.2	101	0.0134	600	190
12 Dec 2018	0730	0.028	0.007	<0.002	57	1.88	0.5	19.4	9.6	101	0.0101	700	290
09 Jan 2019	0740	0.029	0.006	<0.002	84	2.00	0.9	26.6	9.2	96	0.0040	1200	370
13 Feb 2019	0735	0.031	0.006	<0.002	103	3.45	0.9	31.3	7.9	86	0.0037	510	400
13 Mar 2019	0745	0.038	0.008	0.002	79	1.55	0.9	26.2	8.6	91	0.0153	6000	880
10 Apr 2019	0845	0.021	<0.002	<0.002	64	2.34	1.0	22.3	10.4	100	0.0147	900	700
08 May 2019	0840	0.024	0.005	<0.002	48	3.24	0.8	18.4	10.7	101	0.0052	300	420
12 Jun 2019	0840	0.018	<0.002	<0.002	39	1.70	0.5	16.1	10.3	101	0.0101	480	140
Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		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
11 Jul 2018	0835	1100	4.115	0.019	0.0044	1.22	7.3	4	10.7	0.19	1.52	0.021	2.4
08 Aug 2018	0835	310	2.497	0.014	0.0034	1.11	7.5	<3	12.7	0.17	1.30	0.014	1.92
12 Sep 2018	0845	1100	0.948	<0.005	0.0025	0.92	7.6	<3	10.1	0.14	1.06	0.02	1.62
10 Oct 2018	0730	800	0.485	0.011	0.0043	0.80	7.8	5	12.2	0.26	1.00	0.034	2.8
14 Nov 2018	0730	600	1.210	0.009	0.0032	0.80	7.9	<3	15.0	0.18	1.03	0.028	1.61
12 Dec 2018	0730	800	0.585	<0.005	0.0037	0.49	7.7	<3	17.3	0.24	0.61	0.021	1.32
09 Jan 2019	0740	1400	0.243	0.011	0.0053	0.32	8.0	<3	17.2	0.25	0.59	0.022	1.82
13 Feb 2019	0735	810	0.156	0.019	0.0048	0.22	7.9	<3	19.0	0.28	0.45	0.023	1.05
13 Mar 2019	0745	7000	0.322	0.024	0.0060	0.49	7.8	3	18.2	0.26	0.80	0.040	1.37
10 Apr 2019	0845	1000	0.387	0.009	0.0031	0.55	7.8	<3	13.7	0.15	0.83	0.028	0.97
08 May 2019	0840	500	0.917	0.013	0.0032	0.75	7.6	<3	13.2	0.23	0.89	0.014	1.27
12 Jun 2019	0840	510	1.825	0.020	0.004	0.98	7.6	4	12.8	0.21	1.08	0.022	1.79

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

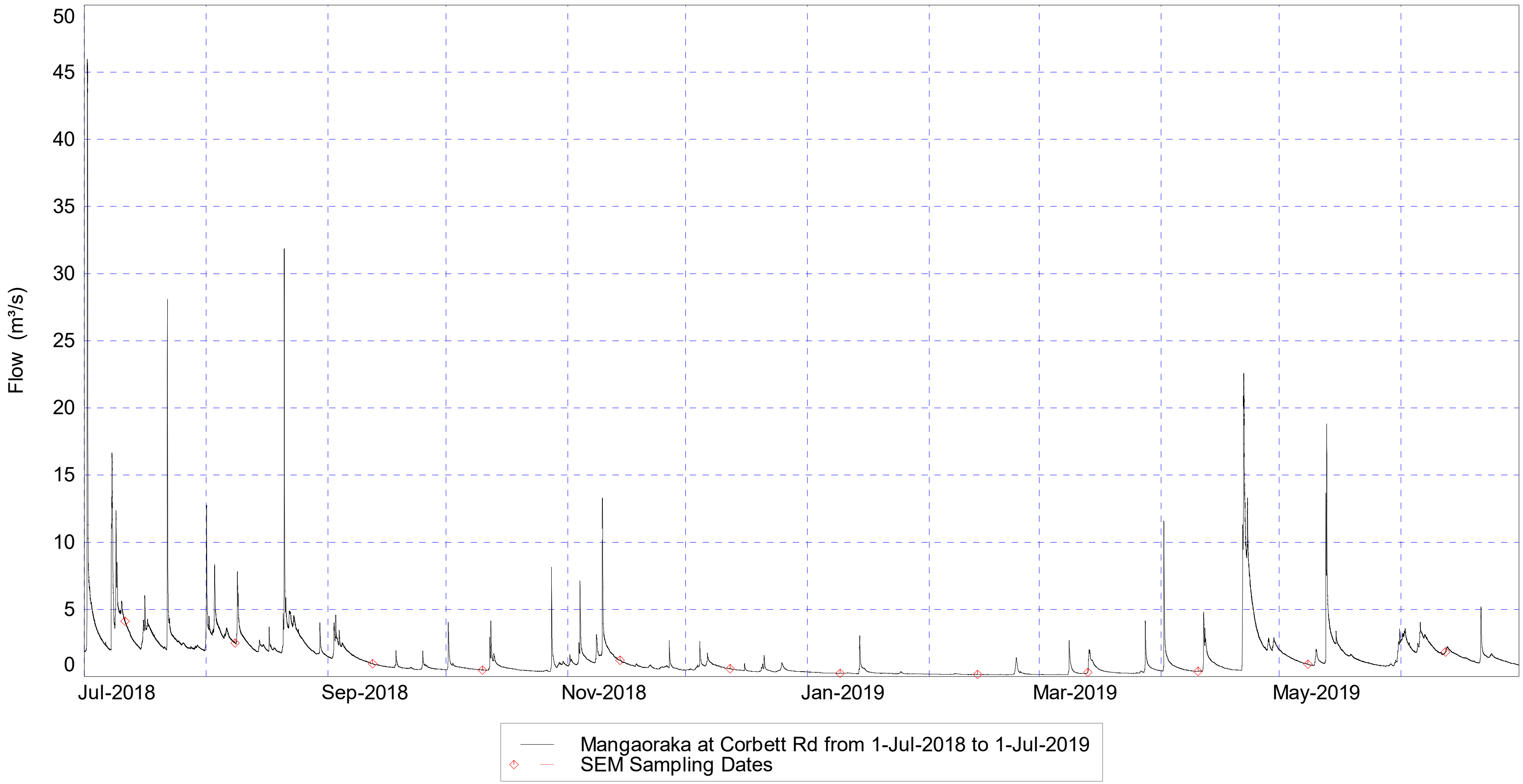


Figure 2 Flow record for the Mangaoraka Stream at Corbett Road

Table 7 Statistical summary of data from July 2018 to June 2019: Mangaoraka Stream at Corbett Road

Parameter		Units	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.012	0.038	0.023	12	0.007
A440F	Absorbance @ 440nm filtered	/cm	<0.002	0.008	0.005	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	<0.002	0.002	0.002	12	0
ALKT	Alkalinity total	g/m^3 CaCO^3	29	103	52	12	22
BLACKDISC	Black disc transparency	m	1.51	3.45	2.17	12	0.73
BOD$_5$	Biochemical oxygen demand 5 day	g/m^3	<0.4	1	0.8	12	0.2
COND	Conductivity @ 25°C	mS/m	14.2	31.3	18.9	12	5.3
DO	Dissolved oxygen	g/m^3	7.9	11.4	10.4	12	1
PERSAT	Dissolved oxygen saturation	%	86	101	100	12	5
DRP	Dissolved reactive phosphorus	g/m^3 P	0.004	0.015	0.010	12	0.004
ECOL	E. coli bacteria	cfu/100mL	260	6000	700	12	1559
ENT	Enterococci bacteria	cfu/100mL	80	880	265	12	247
FC	Faecal coliform bacteria	cfu/100mL	310	7000	805	12	1812
FLOW	Flow	m^3/s	0.156	4.115	0.751	12	1.168
NH$_4$	Ammoniacal nitrogen	g/m^3 N	<0.005	0.024	0.012	12	0.006
NO$_2$	Nitrite nitrogen	g/m^3 N	0.003	0.006	0.004	12	0.001
NO$_3$	Nitrate nitrogen	g/m^3 N	0.22	1.22	0.77	12	0.311
PH	pH	pH	7.3	8.0	7.8	12	0.2
SS	Suspended solids	g/m^3	<3	5	<3	12	1
TEMP	Temperature	˚C	10.1	19.0	13.4	12	3
TKN	Total kjeldahl nitrogen	g/m^3 N	0.14	0.28	0.22	12	0.05
TN	Total nitrogen	g/m^3 N	0.45	1.52	0.94	12	0.304
TP	Total phosphorus	g/m^3 P	0.014	0.040	0.022	12	0.008
TURBY	Turbidity (Hach 2100N)	NTU	1.0	2.8	1.6	12	0.5

A statistical summary of the 24 years' data collected since 1 July 1995 is presented in Table 8.

Table 8 Statistical summary of data from July 1995 to June 2019: Mangaoraka Stream at Corbett Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.012	0.074	0.025	288	0.011
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.019	0.005	288	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	288	0.001
ALKT	Alkalinity total	g/m^3 CaCO$_3$	12	108	41	288	18
BLACK DISC	Black disc transparency	m	0.055	4.73	1.85	288	0.89
BOD$_5$	Biochemical oxygen demand 5 day	g/m^3	<0.4	14	0.7	288	1.4
COND	Conductivity @ 25°C	mS/m	4.5	31.6	16.1	288	4.3
DO	Dissolved oxygen	g/m^3	7.8	11.8	10.1	287	0.8
PERSAT	Dissolved oxygen saturation	%	83	107	97	287	4
DRP	Dissolved reactive phosphorus	g/m^{3}P	<0.003	0.074	0.009	288	0.010
ECOL	E. coli bacteria	cfu/100 mL	80	60000	800	264	7677
ENT	Enterococci bacteria	cfu/100 mL	31	180000	400	288	14982
FC	Faecal coliform bacteria	cfu/100 mL	84	60000	800	288	8338
FLOW	Flow	m^3/s	0.156	70.243	1.171	288	4.954
NH$_4$	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.308	0.021	288	0.046
NO$_2$	Nitrite nitrogen	g/m^{3}N	0.001	0.039	0.005	288	0.005
NO$_3$	Nitrate nitrogen	g/m^{3}N	0.05	1.73	0.84	288	0.306
pH	pH		6.9	8.1	7.6	288	0.2
SS	Suspended solids	g/m^3	<2	310	2	288	27
TEMP	Temperature	°C	5.8	20.5	13.2	288	2.9
TKN	Total kjeldahl nitrogen	g/m^{3}N	<0.01	4.46	0.20	288	0.45
TN	Total nitrogen	g/m^{3}N	0.27	5.18	1.09	288	0.53
TP	Total phosphorus	g/m^{3}P	0.007	0.86	0.023	288	0.095
TURB	Turbidity (Hach 2100A)	NTU	0.8	100	1.6	245	8.6
TURBY	Turbidity (Cyberscan WTW)	NTU	0.6	81	2.1	157	9.8

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 IV.

Discussion

2018-2019 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: 1.6 NTU) than might be expected given the concentration of suspended solids (median: <3 g/m^3). This was due to the very fine, colloidal nature of suspended material in the stream at this site, partly as a consequence of the headwaters being situated below the National Park. The moderate maximum black disc value of 3.45 m coincided with late summer, low flow conditions (following no fresh events in the previous 30 days), while the poorest turbidity conditions (2.8 NTU) were recorded during a flow recession in spring 2018, with a small increase in suspended sediment. Poorest water quality, as indicated by elevated faecal bacteria number and phosphorus nutrient species, was recorded for the rising stage of a small fresh sampled in autumn.

The relative absence of freshes near the sampling occasions during spring and summer contributed to the slightly elevated pH values (up to 8.0), though 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 (<1.1 g/m^3) during moderate and lower flows were indicative of relatively good physicochemical water quality, but the high median bacterial numbers (265 enterococci and 805 faecal coliforms cfu/100 mL) were higher than typical of the lower reaches of a stream draining an intensively developed catchment, although the Mangaoraka Stream is essentially a lowland catchment as its headwaters do not extend as far towards the upper slopes of Mt Taranaki as most ring plain rivers and streams. [Investigative work in the lower catchment has identified stock access to streams as a probable primary contributor to these elevated numbers, although the cumulative impacts of consented dairy pond discharges also contribute, particularly under lower flow conditions]. Water temperatures varied over a moderate range of 8.9°C with a maximum (mid-morning) temperature of 19.0°C in February 2019 during a period of low flow conditions. Dissolved oxygen saturation did not fall below 86% during the period, with this minimum recorded during a period of low flow conditions (Figure 2).

Brief comparison with the previous 1995-2018 period

Aesthetic stream water quality at this site during the 2018-2019 period was clearer [median black disc clarity higher by 0.34 m, although median suspended solids level and median turbidity were about the same]. Bacterial water quality was similar as reflected in the same median faecal coliform number (800 cfu/100 mL) but lower median enterococci number by 155 cfu/100 mL. Median water temperature was 0.2°C higher in the 2018-2019 period although the maximum water temperature (19.0°C) was 1.5°C lower than the previous maximum recorded. Median conductivity was higher. The median flow sampled during 2018-2019 (0.751 m^3/s) was significantly lower (by 435 L/s, or 37%) than the median of flows sampled over the previous 23-year period, and the lowest flow yet was sampled (of 156 L/s) in February 2019. Relatively narrow ranges for parameters such as suspended solids, turbidity, pH, and BOD_5 reflected the lack of floods and the smaller and fewer fresh events sampled on occasions during the 2018-2019 period (Figure 2). Median pH value was the same and maximum pH was 0.1 unit lower than the past record. All nitrogen nutrient species had lower median values (ammonia, nitrate and total nitrogen by 43, 8 and 15%, respectively) during the monitoring year in comparison with the previous 23-year record, while phosphorus nutrient species had very similar median values over the 2018-2019 period.

Waiwhakaiho River at SH 3 (site: WKH000500)

Analytical data from the monthly samples are presented in Table 9 and the river flow record is illustrated in Figure 3.

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

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 25 °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
11-Jul-2018	0915	0.015	0.003	<0.002	29	2.76	0.6	10.5	11.6	101	0.0123	90	30
08-Aug-2018	0905	0.012	0.002	<0.002	44	2.94	<0.4	12.9	11	101	0.0187	130	10
12-Sep-2018	0915	0.007	<0.002	<0.002	55	4.11	1.0	15.6	12.1	104	0.029	210	90
10-Oct-2018	0800	0.008	<0.002	<0.002	62	3.92	0.7	17.1	11.7	106	0.039	180	80
14-Nov-2018	0800	0.013	0.004	0.002	53	3.37	<0.4	15.6	10.7	103	0.040	450	90
12-Dec-2018	0800	0.014	0.005	0.002	58	3.50	0.6	16.3	10.73	108	0.032	170	70
09-Jan-2019	0805	0.011	0.002	<0.002	70	3.21	0.4	18.7	10.4	108	0.046	120	80
13-Feb-2019	0810	0.011	0.002	<0.002	75	3.20	0.6	19.5	9.8	102	0.052	120	170
13-Mar-2019	0810	0.135	0.030	0.002	14	0.45	1.5	5.3	10	101	0.0129	1900	2300
10-Apr-2019	0915	0.005	<0.002	<0.002	67	3.28	<0.4	18.5	11.4	110	0.045	80	43
08-May-2019	0925	0.011	0.003	<0.002	70	4.00	0.8	18.2	11.8	109	0.033	130	80
12 Jun 2019	0910	0.016	0.003	<0.002	40	2.41	<0.4	12.4	10.96	102	0.020	270	140

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		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
11-Jul-2018	0915	90	8.234	0.009	0.0014	0.36	7.5	3	8.7	0.12	0.44	0.020	0.88
08-Aug-2018	0905	140	5.117	0.005	0.0014	0.23	7.7	<3	10.6	<0.10	0.29	0.022	0.84
12-Sep-2018	0915	220	3.019	0.01	0.0013	0.11	7.8	<3	8.1	<0.10	0.22	0.032	0.94
10-Oct-2018	0800	190	2.547	<0.005	0.0013	0.04	8.1	<3	10.3	<0.10	0.10	0.044	1.08
14-Nov-2018	0800	470	3.424	0.052	0.0030	0.18	8.1	<3	13.3	0.15	0.32	0.044	0.99
12-Dec-2018	0800	200	2.85	<0.005	0.0015	0.06	8.2	<3	14.6	0.15	0.15	0.037	0.61
09-Jan-2019	0805	150	2.091	<0.005	0.0011	0.01	8.2	<3	16.0	<0.10	0.11	0.051	0.82
13-Feb-2019	0810	160	1.973	<0.005	<0.0010	<0.01	8.2	<3	16.1	<0.10	0.10	0.056	0.65
13-Mar-2019	0810	2300	24.95	0.013	0.0034	0.04	7.3	17	15.1	0.37	0.53	0.074	6.7
10-Apr-2019	0915	80	2.244	0.008	0.0018	0.08	8.2	<3	12.7	<0.10	0.14	0.046	0.48
08-May-2019	0925	150	2.41	<0.005	0.0022	0.06	8.1	<3	11.6	<0.10	0.13	0.034	0.48
12 Jun 2019	0910	370	8.534	0.013	0.003	0.17	7.7	<3	10.7	<0.10	0.27	0.026	0.99

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

Table 10 Statistical summary of data from July 2018 to June 2019: Waiwhakaiho River at SH3

Paramete		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.005	0.135	0.012	12	0.036
A440F	Absorbance @ 440nm Filtered	/cm	<0.002	0.030	0.002	12	0.008
A770F	Absorbance @ 770nm Filtered	/cm	<0.002	0.002	<0.002	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	14	75	56	12	18
BDISC	Black disc transparency	m	0.45	4.11	3.24	12	0.97
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	1.5	0.6	12	0.3
COND	Conductivity @ 25'C	mS/m	5.3	19.5	15.9	12	4.1
DO	Dissolved Oxygen	g/m³	9.8	12.1	11.0	12	0.7
PERSAT	Dissolved Oxygen Saturation %	%	101	110	104	12	3
DRP	Dissolved reactive phosphorus	g/m³P	0.012	0.052	0.032	12	0.013
ECOL	E.coli bacteria	cfu/100 mL	80	1900	150	12	507
ENT	Enterococci bacteria	cfu/100 mL	10	2300	80	12	642
FC	Faecal Coliforms	cfu/100 mL	80	2300	175	12	616
FLOW	Flow	m³/s	1.973	24.95	2.934	12	6.504
NH_4	Ammoniacal nitrogen	g/m³N	0.005	0.052	0.007	12	0.013
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.003	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.36	0.072	12	0.104
PH	pH	pH	7.3	8.2	8.1	12	0.3
SS	Suspended solids	g/m³	<3	17	<3	12	4
TEMP	Temperature	°C	8.1	16.1	12.1	12	2.7
TKN	Total Kjeldahl nitrogen	g/m³N	<0.10	0.37	<0.10	12	0.08
TN	Total nitrogen	g/m³N	0.097	0.53	0.183	12	0.142
TP	Total phosphorus	g/m³P	0.020	0.074	0.040	12	0.015
TURBY	Turbidity (Hach 2100N)	NTU	0.48	6.7	0.86	12	1.7

A statistical summary of the 24 years' data collected since 1 July 1995 is presented in Table 11.

Table 11 Statistical summary of data from July 1995 to June 2019: Waiwhakaiho River at SH3

Paramete		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm Filtered	/cm	0.005	0.135	0.014	288	0.019
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.030	0.003	288	0.005
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.007	0.000	288	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	5	76	49	288	17
BDISC	Black disc transparency	m	0.12	8.05	3.08	288	1.41
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	5.0	<0.5	288	0.6
COND	Conductivity @ 25'C	mS/m	2.0	19.5	13.4	288	3.7
DO	Dissolved Oxygen	g/m³	9.1	12.8	10.8	288	0.7
PERSAT	Dissolved Oxygen Saturation %	%	91	110	101	288	3
DRP	Dissolved reactive phosphorus	g/m³P	<0.004	0.108	0.025	288	0.011
ECOL	E.coli bacteria	cfu/100 mL	23	57000	210	264	5495
ENT	Enterococci bacteria	cfu/100 mL	1	40000	100	288	3664
FC	Faecal Coliforms	cfu/100 mL	23	83000	220	288	7202
FLOW	Flow	m³/s	1.705	180	3.782	288	14.044
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.157	0.007	288	0.022
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.010	0.002	288	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.47	0.11	288	0.10
PH	pH	pH	6.8	8.5	7.9	288	0.3
SS	Suspended solids	g/m³	<2	280	<2	288	19
TEMP	Temperature	°C	4.8	18.3	11.2	288	2.9
TKN	Total Kjeldahl nitrogen	g/m³N	<0.01	1.95	0.07	288	0.21
TN	Total nitrogen	g/m³N	0.02	2.10	0.20	288	0.235
TP	Total phosphorus	g/m³P	0.014	0.437	0.035	288	0.046
TURB	Turbidity (Hach 2100A)	NTU	0.4	26	0.7	245	2.8
TURBY	Turbidity (Cyberscan WTW)	NTU	0.3	41	0.7	157	4.9

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 IV.

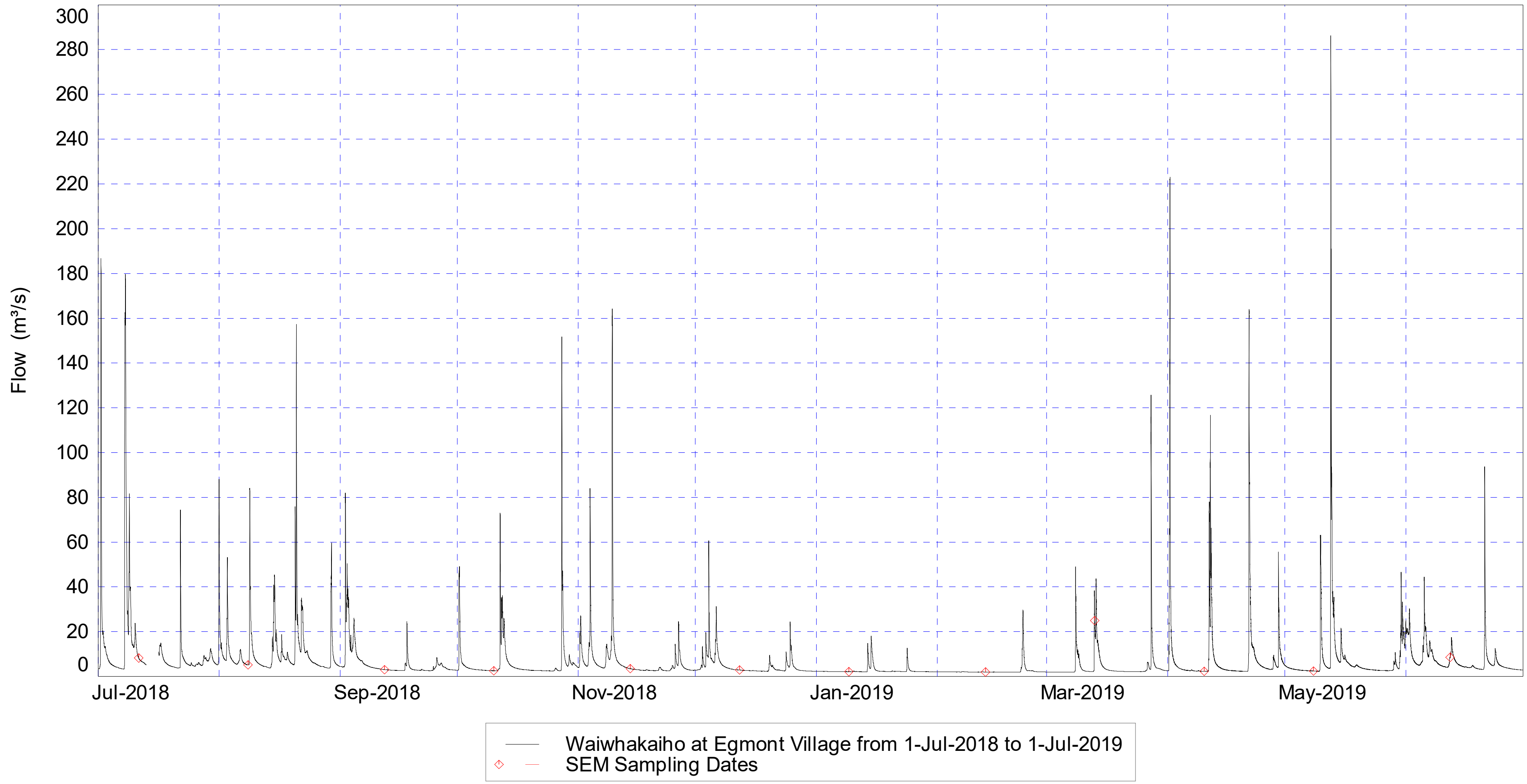


Figure 3 Flow record for the Waiwhakaiho River at SH3 Egmont Village

Discussion

2018-2019 period

During the 2018-2019 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 2018-2019 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 3.24 m and 0.9 NTU respectively. The maximum black disc value (4.11 m) was recorded in early spring moderate flow conditions (3.02 m^3/sec) (Figure 3) with the worst conditions (black disc clarity of 0.45 m) during a high in March 2019 when a turbidity of 6.7 NTU and suspended solids concentration of 17 g/m^3 were measured. Generally, poorer water quality was recorded at the time of this fresh flow when elevated faecal coliform bacterial numbers (2,300 cfu/100 mL) and increased colour (highest measured 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 on four occasions over summer and autumn, with values of $\geq$7.7 units on ten occasions throughout 2018-2019. pH values could be expected to have risen further later in the day, as all sampling at this site was undertaken no later than 0925 hrs.

Very good water quality was indicated by high dissolved oxygen concentrations (median saturation of 104%) and low BOD_5 levels (median of 0.6 g/m^3). Bacteriological quality was moderate, with median faecal coliform and enterococci numbers (175 and 80 per 100 mL, respectively) typically reflecting agricultural catchment influences and the relative infrequency of freshes during, or immediately prior to, sampling surveys during 2018-2019.

River water temperatures recorded a moderate range of 8.0°C during the period with a maximum mid-morning water temperature of 16.1°C recorded in February 2019 during a period of low flow conditions.

Brief comparison with the previous 1995-2018 period

River water quality measured by the 2018-2019 survey in many aspects was generally similar to that recorded over the previous 23-year period. Median black disc clarity was higher (by 0.18 m) with median turbidity higher by 0.2 NTU, and median suspended solids levels were the same between periods. Bacteriological water quality improved as reflected in decreases in median faecal coliform number of 50 cfu/100 mL and in enterococci number by 20 cfu/100 mL. Median water temperature was higher in the most recent period, while the maximum temperature was 2.2°C lower in the recent period than that recorded during the previous twenty-three years.

Median sampled flow over the 2018-2019 period was significantly lower (by 884 L/s, or 23%) than for the flows sampled in the previous 23-year period, coincident with a decrease in fresh events sampled. This was reflected in the higher median conductivity level found for the 2018-2019 period.

Median concentrations for all nitrogen nutrient species showed a decrease in the recent sampling period. The recent median phosphorus nutrient species concentrations showed a slight increase, compared to those of the longer period.

A slight increase was recorded in median BOD_5 in the recent period, and no significant difference in percentage dissolved oxygen between the two periods.

Stony River (Hangatahua) 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 @ 25 °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
11 Jul 2018	1015	0.007	<0.002	<0.002	28	1.1	<0.4	9.1	11.7	101	0.0132	3	2
08 Aug 2018	1005	0.008	<0.002	<0.002	35	2.4	<0.4	11.0	11.1	101	0.0175	<10	<10
12 Sep 2018	1020	0.006	<0.002	<0.002	45	4.8	0.8	12.7	11.5	101	0.0192	<10	<10
10 Oct 2018	0910	0.004	<0.002	<0.002	48	5.4	0.6	13.3	11.2	102	0.022	30	<10
14 Nov 2018	0905	0.008	0.003	<0.002	44	6.0	<0.4	12.8	10.5	101	0.022	2	3
12 Dec 2018	0900	0.007	0.002	<0.002	48	2.74	0.4	13.2	10.2	102	0.0191	10	10
09 Jan 2019	0910	0.004	<0.002	<0.002	53	5.0	<0.4	14.7	10.1	101	0.0187	10	<10
13 Feb 2019	0930	0.014	0.006	<0.002	56	0.17	0.8	14.8	10.0	102	0.0164	10	30
13 Mar 2019	0920	0.07	0.024	0.005	21	0.10	0.6	6.1	10.2	102	0.0070	100	110
10 Apr 2019	1030	0.003	<0.002	<0.002	50	0.61	<0.4	14.0	10.5	102	0.022	50	10
08 May 2019	1020	0.01	0.004	<0.002	54	4.8	0.5	13.9	10.3	103	0.021	40	20
12 Jun 2019	1015	0.009	<0.002	<0.002	28	0.7	<0.4	9.1	11.2	102	0.0128	40	15

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		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
11 Jul 2018	1015	3	5.546	<0.005	<0.0010	0.05	7.5	35	8.3	<0.10	0.07	0.022	4.2
08 Aug 2018	1005	<10	4.008	<0.005	<0.0010	0.06	7.7	<3	9.9	<0.10	0.05	0.020	1.36
12 Sep 2018	1020	<10	2.912	<0.005	<0.0010	0.04	7.7	<3	8.9	<0.10	0.05	0.020	0.49
10 Oct 2018	0910	30	2.736	<0.005	<0.0010	0.03	7.9	<3	10.2	<0.10	0.04	0.026	1.07
14 Nov 2018	0905	2	3.009	<0.005	<0.0010	0.04	8.0	<3	13.0	0.18	0.06	0.022	0.54
12 Dec 2018	0900	10	2.646	<0.005	<0.0010	0.01	8.0	<3	14.4	<0.10	0.02	0.019	0.43
09 Jan 2019	0910	10	2.204	<0.005	<0.0010	<0.01	8.1	<3	14.9	<0.10	0.03	0.021	0.38
13 Feb 2019	0930	10	2.055	<0.005	<0.0010	0.01	8.1	89	15.4	0.11	0.09	0.062	16.2
13 Mar 2019	0920	200	4.027	0.007	<0.0010	0.01	7.4	270	14.8	0.16	0.20	0.22	87
10 Apr 2019	1030	70	2.339	<0.005	<0.0010	0.05	7.9	15	13.5	<0.10	0.07	0.030	4.1
08 May 2019	1020	50	2.232	<0.005	<0.0010	0.04	7.9	<3	12.0	<0.10	0.06	0.022	0.52
12 Jun 2019	1015	40	6.204	0.006	<0.002	0.03	7.5	14	9.8	<0.10	0.05	0.016	4.6

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

Table 13 Statistical summary of data from July 2018 to July 2019 Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.003	0.07	0.007	12	0.018
A440F	Absorbance @ 440nm filtered	/cm	<0.002	0.024	<0.002	12	0.006
A770F	Absorbance @ 770nm filtered	/cm	<0.002	0.005	<0.002	12	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	21	56	46	12	12
BDISC	Black disc transparency	m	0.10	6.0	2.57	12	2.26
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	0.8	<0.4	12	0.2
COND	Conductivity @ 25°C	mS/m	6.1	14.8	13.0	12	2.7
DO	Dissolved oxygen	g/m³	10.0	11.7	10.5	12	0.6
PERSAT	Dissolved oxygen saturation %	%	101	103	102	12	1
DRP	Dissolved reactive phosphorus	g/m³P	0.007	0.022	0.019	12	0.005
ECOL	E.coli bacteria	cfu/100 mL	2	100	10	12	28
ENT	Enterococci bacteria	cfu/100 mL	2	110	10	12	29
FC	Faecal coliforms	cfu/100 mL	2	200	10	12	56
FLOW	Flow	m³/s	2.055	6.204	2.824	12	1.358
NH_4	Ammoniacal nitrogen	g/m³N	<0.005	0.007	<0.005	12	0.001
NO_2	Nitrite nitrogen	g/m³N	<0.0010	<0.002	<0.0010	12	0
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.056	0.034	12	0.018
pH	pH		7.4	8.1	7.9	12	0.2
SS	Suspended solids	g/m³	<3	270	<3	12	78
TEMP	Temperature	°C	8.3	15.4	12.5	12	2.6
TKN	Total kjeldahl nitrogen	g/m³N	<0.10	0.18	<0.10	12	0.03
TN	Total nitrogen	g/m³N	0.024	0.20	0.054	12	0.046
TP	Total phosphorus	g/m³P	0.016	0.22	0.022	12	0.057
TURBY	Turbidity (Hach 2100N)	NTU	0.38	87	1.2	12	24.6

A statistical summary of the 24 years' data collected since 1 July 1995 is presented in Table 14.

Table 14 Statistical summary of data from July 1995 to June 2019: Stony River at Mangatete Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.000	0.077	0.009	288	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.028	0.002	288	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.007	0.000	288	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	5	57	38	288	12
FBDISC	Black disc transparency	m	<0.01	13.12	3.10	288	2.69
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	1.8	<0.5	288	0.1
COND	Conductivity @ 25°C	mS/m	1.9	14.8	10.7	288	2.7
DO	Dissolved oxygen	g/m³	9.4	12.3	10.7	288	0.6
PERSAT	Dissolved oxygen saturation %	%	87	106	100	288	2
DRP	Dissolved reactive phosphorus	g/m³P	0.004	0.210	0.018	288	0.013
ECOL	E.coli bacteria	cfu/100 mL	<1	18000	8	264	1110
ENT	Enterococci bacteria	cfu/100 mL	<1	1900	6	288	130
FC	Faecal coliforms	cfu/100 mL	<1	18000	8	288	1063
FLOW	Flow	m³/s	1.988	80.237	3.593	288	8.426
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.021	<0.003	288	0.003
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.008	<0.001	288	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.11	0.02	288	0.02
pH	pH		7.0	8.2	7.8	288	0.2
SS	Suspended solids	g/m³	<2	2500	<2	288	307
TEMP	Temperature	°C	5.7	16.6	10.9	288	2.5
TKN	Total kjeldahl nitrogen	g/m³N	<0.010	1.78	0.04	288	0.15
TN	Total nitrogen	g/m³N	0.02	1.82	0.06	288	0.16
TP	Total phosphorus	g/m³P	0.008	3.38	0.025	288	0.325
TURB	Turbidity (Hach 2100A)	NTU	0.2	700	0.8	245	66
TURBY	Turbidity (Cyberscan WTW)	NTU	0.2	1400	1.6	157	164

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 IV.

Discussion

2018-2019

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 flood events in mid-February 2016, and early February 2017. Measured clarity improved from December 2017. Markedly reduced black disc (0.17 m) and elevated turbidity (16 NTU) and suspended solids (89 g/m^3) values were again recorded during a dry period in February 2019, which continued for two months. 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 0.22 g/m^3P). The maximum black disc clarity of 6.0 m was measured in late spring under low flow conditions, coincident with very low suspended solids and turbidity (0.5 NTU) levels.

Maximum mid-morning pH (8.1) occurred under summer low flow conditions, while the median pH (7.9) was 0.1 units higher than the median of past years' results. Dissolved oxygen concentrations were consistently high with a minimum saturation of 101%, and BOD_5 levels were below the detectable limit (0.4 g/m^3) on six occasions with a maximum of 0.8 g/m^3; a further indication of high water quality when not influenced by severe erosion events.

Bacteriological water quality was high, with median faecal coliform and enterococci numbers (both 10 cfu/100 mL) indicative of minimal impact of upstream developed farmland at this site near mid-catchment, although there was one instance of elevated counts under fresh flow conditions.

River water temperatures varied over a moderate range of 7.1°C during the period, with a maximum mid-morning temperature of 15.4°C recorded in late summer (February 2019) under low flow conditions.

Nutrient levels were generally very low in terms of median ammoniacal nitrogen, nitrate-nitrogen, and dissolved reactive phosphorus concentrations. Total nitrogen concentration was also relatively low throughout the year. Total phosphorus concentration varied relatively widely, coincident with suspended solids concentration, ranging from 0.016 to 0.22 g/m^3.

Brief comparison with the previous 1995-2018 period

Water quality measured during the 2018-2019 survey period, in comparison with the previous 23 years' survey results, was slightly poorer aesthetically in terms of median black disc clarity (which was lower by 0.02 m), median turbidity (higher by 0.4 NTU), and suspended solids level which was similar to the historical median.

Median bacteriological water quality was similar in the latest period, although both periods had high quality with all median faecal coliform and enterococci counts <30 cfu/100 mL.

Water temperature range was narrower (by 2.8°C) in the 2018-2019 period than that in the earlier 23-year period, with the median value higher (by 1.7°C) in the 2018-2019 period than in the earlier 23-year period. For nutrient species, median nitrate was higher than the previous longer period (by 70%), though still relatively low at 0.034 g/m^3; total nitrogen was similar and low; and median DRP and TP were both similar and moderate in the two periods.

Median sampled flow during the 2018-2019 period was lower (by 0.785 m^3/s, or 22%) than the median of flows sampled over the previous 23-year period, with one fresh event and eight relatively low flow periods sampled in 2018-2019. This was reflected in the higher median conductivity value (by 2.4 mS/m at 25°C) recorded in 2018-2019.

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 @ 25 °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
11 Jul 2018	1045	0.041	0.007	<0.002	13.4	2.02	1.0	9.8	11.4	100	0.0061	20	20
08 Aug 2018	1040	0.033	0.008	0.002	19.4	1.36	<0.4	10.1	11.1	101	0.0140	10	10
12 Sep 2018	1050	0.024	0.005	<0.002	21	1.82	0.9	10.2	11.2	101	0.0161	50	<10
10 Oct 2018	1000	0.017	0.003	<0.002	24	3.10	0.6	10.1	11.0	102	0.026	20	40
14 Nov 2018	0945	0.024	0.006	<0.002	24	1.94	0.5	10.8	10.0	101	0.028	900	<10
12 Dec 2018	0945	0.028	0.006	<0.002	24	1.86	0.8	10.6	9.8	103	0.026	80	20
09 Jan 2019	0940	0.021	0.004	<0.002	25	3.05	<0.4	10.2	9.6	103	0.028	30	20
13 Feb 2019	1015	0.019	0.004	<0.002	25	4.10	0.6	9.7	9.4	104	0.036	40	90
13 Mar 2019	0950	0.026	0.006	<0.002	24	1.19	0.7	10.0	9.5	100	0.036	7000	730
10 Apr 2019	1100	0.025	0.003	<0.002	20	1.42	0.5	12.1	10.3	103	0.023	70	90
08 May 2019	1100	0.026	0.007	<0.002	24	2.00	0.7	11.2	11.1	105	0.0199	390	20
12 Jun 2019	1050	0.022	0.004	<0.002	22	0.97	<0.4	11.5	10.9	101	0.0163	40	9
Date	Time NZST	FC	Flow	NH4	NO2	NO3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m3/s	g/m3N	g/m3N	g/m3N	pH	g/m3	°C	g/m3N	g/m3N	g/m3P	NTU
11 Jul 2018	1045	20	1.252	0.032	0.0019	0.25	7.3	<3	8.6	0.22	0.46	0.018	2.5
08 Aug 2018	1040	30	0.627	0.025	0.0019	0.10	7.3	<3	9.4	0.11	0.22	0.026	4.3
12 Sep 2018	1050	50	0.444	0.016	0.0010	0.07	7.1	<3	9.7	<0.10	0.19	0.021	3.4
10 Oct 2018	1000	20	0.311	0.007	<0.0010	0.03	7.7	<3	10.6	0.14	0.01	0.032	2.3
14 Nov 2018	0945	900	0.357	0.009	<0.0010	0.02	7.7	<3	14.9	0.21	0.11	0.036	2.8
12 Dec 2018	0945	100	0.32	0.010	<0.0010	0.02	7.7	<3	16.0	0.16	0.10	0.030	2.7
09 Jan 2019	0940	30	0.253	<0.005	<0.0010	0.01	7.6	<3	17.0	<0.10	0.08	0.032	1.66
13 Feb 2019	1015	40	0.190	0.007	<0.0010	<0.01	7.7	<3	18.5	<0.10	0.07	0.038	0.69
13 Mar 2019	0950	7000	0.25	0.008	<0.0010	0.03	7.5	4	16.9	0.11	0.14	0.047	1.89
10 Apr 2019	1100	90	0.392	0.009	0.0017	0.12	7.7	<3	14.0	<0.10	0.21	0.030	2.5
08 May 2019	1100	390	0.332	0.008	0.0015	0.07	7.5	<3	11.8	<0.10	0.16	0.026	2.5
12 Jun 2019	1050	40	0.452	0.018	<0.002	0.14	7.5	<3	10.0	0.11	0.29	0.020	3.6

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

Table 16 Statistical summary of data from July 2018 to June 2019 Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.017	0.041	0.024	12	0.006
A440F	Absorbance @ 440nm filtered	/cm	<0.003	0.008	0.005	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	<0.002	0.002	<0.002	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	13	25	24	12	3
BDISC	Black disc transparency	m	0.97	4.1	1.90	12	0.91
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.4	1.0	0.6	12	0.2
COND	Conductivity @ 25˚C	mS/m	9.7	12.1	10.2	12	0.7
DO	Dissolved oxygen	g/m^3	9.4	11.4	10.6	12	0.7
PERSAT	Dissolved oxygen saturation %	%	100	105	102	12	2
DRP	Dissolved reactive phosphorus	g/m^3P	0.006	0.036	0.024	12	0.009
ECOL	E.coli bacteria	cfu/100 mL	10	7000	45	12	1994
ENT	Enterococci bacteria	cfu/100 mL	<10	730	20	12	204
FC	Faecal coliforms	cfu/100 mL	20	7000	45	12	1992
FLOW	Flow	m^3/s	0.190	1.252	0.345	12	0.283
NH_4	Ammoniacal nitrogen	g/m^3N	<0.005	0.032	0.009	12	0.008
NO_2	Nitrite nitrogen	g/m^3N	<0.0010	0.0019	<0.001	12	0.001
NO_3	Nitrate nitrogen	g/m^3N	0.005	0.25	0.048	12	0.072
pH	pH		7.1	7.7	7.6	12	0.2
SS	Suspended solids	g/m^3	<3	4	<3	12	0
TEMP	Temperature	°C	8.6	18.5	12.9	12	3.5
TKN	Total kjeldahl nitrogen	g/m^3N	<0.10	0.22	0.11	12	0.04
TN	Total nitrogen	g/m^3N	0.07	0.46	0.15	12	0.111
TP	Total phosphorus	g/m^3P	0.018	0.047	0.030	12	0.008
TURBY	Turbidity (Hach 2100N)	NTU	0.7	4.3	2.5	12	0.9

A statistical summary of the 24 years' data collected since 1 July 1995, is presented in Table 17.

Table 17 Statistical summary of data from July 1995 to July 2019: Punehu Stream at Wiremu Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.015	0.144	0.032	288	0.023
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.032	0.007	288	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.005	0.000	288	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	6	27	22	288	5
BDISC	Black disc transparency	m	0.08	4.53	1.79	288	0.88
BOD5	Biochemical oxygen demand 5day	g/m3	<0.4	6.0	<0.5	288	0.4
COND	Conductivity @ 25˚C	mS/m	4.2	12.1	9.6	288	1.4
DO	Dissolved oxygen	g/m3	8.9	12.5	10.5	287	0.8
PERSAT	Dissolved oxygen saturation %	%	87	106	100	287	3
DRP	Dissolved reactive phosphorus	g/m3P	0.006	0.389	0.022	288	0.024
ECOL	E.coli bacteria	cfu/100 mL	3	7000	100	264	919
ENT	Enterococci bacteria	cfu/100 mL	<1	3000	34	288	235
FC	Faecal coliforms	cfu/100 mL	3	7000	115	288	930
FLOW	Flow	m3/s	0.180	12.380	0.434	288	1.119
NH4	Ammoniacal nitrogen	g/m3N	0.002	0.149	0.007	288	0.013
NO2	Nitrite nitrogen	g/m3N	<0.001	0.014	0.001	288	0.001
NO3	Nitrate nitrogen	g/m3N	<0.01	0.41	0.029	288	0.051
pH	pH		6.8	8.3	7.6	288	0.2
SS	Suspended solids	g/m3	<2	170	<2	288	15
TEMP	Temperature	°C	5.0	19.2	11.9	288	3.3
TKN	Total kjeldahl nitrogen	g/m3N	0.01	1.98	0.09	288	0.15
TN	Total nitrogen	g/m3N	<0.05	0.87	0.15	288	0.172
TP	Total phosphorus	g/m3P	0.015	0.639	0.033	288	0.051
TURB	Turbidity (Hach 2100A)	NTU	0.45	29	1.7	245	3.1
TURBY	Turbidity (Cyberscan WTW)	NTU	0.46	28	2.4	157	10.8

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 IV.

Discussion

2018-2019

Although black disc clarity and turbidity results were indicative of relatively good water quality in terms of aesthetic appearance, these values continued to be poorer than might be anticipated for the upper reaches of a ring plain stream, i.e. medians of 1.90 m (black disc) and 2.5 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 (0.97 m) was recorded during a flow recession in June 2019, coincidental with a low suspended solids concentration (<3 g/m^3) and a slight elevation in turbidity (3.6 NTU). A maximum black disc value of 4.10 m was measured under very low flow conditions in late summer (February 2019).

The maximum pH (7.7) was recorded (in mid-morning) on five occasions between spring and autumn, under low flow conditions (190 to 392 L/s).

Dissolved oxygen concentrations were consistently high (100 to 105% saturation for the period), and median BOD_5 level was 0.6 g/m^3; a further indication of generally high water quality.

A moderate median faecal coliform bacterial count for the upper reaches of a ring plain stream (45 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, but this did not occur near to sampling during the 2018-2019 period, unlike many previous periods, resulting in a relatively low median for the latest period. The high faecal bacteria counts (7,000 and 730 cfu/100 mL for faecal coliforms and enterococci, respectively) related to low flow in March 2019 just as water level started to rise in response to rainfall.

Water temperatures varied over a relatively wide range (9.9°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 18.5°C was recorded in February 2019, relatively high for the upper reaches of a ring plain stream at this time of the day (1015 hrs).

Brief comparison with the previous 1995-2018 period

Stream water quality measured during the 2018-2019 period was similar in terms of median turbidity (which was higher by 0.1 NTU) and median black disc clarity (which was higher by 0.13 m) than the previous overall record. Median suspended solids concentration (<3 g/m^3) remained low and in the recent year was equivalent with the median (<2 g/m^3) of the previous 23-year period. Median dissolved oxygen percentage saturation levels were similar for the two periods.

Bacteriological water quality was better over the most recent period in terms of median faecal coliform number (by 75 cfu/100 mL) and median number of enterococci (by 16 cfu/100 mL). The relative median nitrogen species concentrations varied between the periods, recent ammoniacal and nitrate nitrogen values being higher and total nitrogen being the same. 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 4.3°C) compared with surveys prior to the latest twelve-month period; with the median flow sampled lower, by 91 L/s, or 21%, in the 2018-2019 period.

Median pH values were the same during the two sampling periods, but the maximum pH was 0.4 unit lower than the maximum recorded in the previous 23-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	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 25°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
11 Jul 2018	1110	0.027	0.003	<0.002	23	0.95	0.9	21.6	11.3	101	0.021	400	190
08 Aug 2018	1105	0.026	0.004	<0.002	30	1.71	<0.4	21.8	10.9	101	0.022	210	40
12 Sep 2018	1120	0.022	0.002	<0.002	34	1.36	1.0	21.6	11.4	101	0.024	120	60
10 Oct 2018	1030	0.027	0.004	<0.002	39	3.33	1.0	20.2	10.9	103	0.047	500	110
14 Nov 2018	1015	0.034	0.008	<0.002	38	2.20	<0.4	18.4	9.9	101	0.035	290	240
12 Dec 2018	1015	0.036	0.009	<0.002	40	1.87	0.7	19.9	9.75	103	0.035	500	470
09 Jan 2019	1005	0.035	0.006	<0.002	44	3.18	0.5	20.0	9.7	104	0.035	1100	1400
13 Feb 2019	1035	0.039	0.007	<0.002	41	2.90	0.8	17.5	9.4	104	0.042	490	3500
13 Mar 2019	1015	0.044	0.009	<0.002	40	1.60	0.9	17.2	9.0	96	0.039	1500	5900
10 Apr 2019	1130	0.033	0.007	<0.002	30	1.34	0.6	16.8	10.2	102	0.033	400	1600
08 May 2019	1135	0.031	0.007	<0.002	37	2.31	0.7	19.5	11.0	102	0.021	800	440
12 Jun 2019	1120	0.023	0.003	<0.002	32	1.16	0.5	21.5	10.66	103	0.024	460	220
Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		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
11 Jul 2018	1110	400	3.860	0.043	0.0084	4.4	7.4	11	10.3	0.42	4.3	0.066	4.3
08 Aug 2018	1105	220	1.442	0.034	0.0117	2.79	7.5	3	11.3	0.24	3.2	0.038	2.4
12 Sep 2018	1120	120	1.082	0.040	0.0099	2.39	7.6	<3	10.2	0.24	2.6	0.038	2.6
10 Oct 2018	1030	600	0.556	0.036	0.024	1.46	7.7	<3	12.6	0.29	1.73	0.074	2.2
14 Nov 2018	1015	380	0.564	0.027	0.0080	0.69	7.8	<3	16.7	0.28	0.92	0.048	2.1
12 Dec 2018	1015	630	0.652	0.024	0.0072	0.96	7.8	<3	18.0	0.26	1.18	0.046	1.92
09 Jan 2019	1005	1300	0.457	0.014	0.0063	0.80	7.9	<3	18.7	0.27	1.08	0.051	1.82
13 Feb 2019	1035	630	0.335	0.009	0.0042	0.44	8.0	<3	20.3	0.24	0.66	0.055	1.36
13 Mar 2019	1015	1600	0.342	0.013	0.0037	0.36	7.6	<3	18.8	0.26	0.57	0.059	1.46
10 Apr 2019	1130	600	0.574	0.027	0.0031	0.44	7.8	<3	15.4	0.19	0.51	0.044	1.27
08 May 2019	1135	1000	0.568	0.019	0.0046	0.76	7.6	<3	12.7	0.18	1.01	0.080	1.41
12 Jun 2019	1120	520	1.035	0.032	0.005	1.70	7.6	11	11.9	0.20	1.95	0.046	2.5

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

Table 19 Statistical summary of data from July 2018 to June 2019 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.022	0.044	0.032	12	0.007
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.009	0.007	12	0.002
A770F	Absorbance @ 770nm Filtered	/cm	<0.002	<0.002	<0.002	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	23	44	38	12	6
BDISC	Black disc transparency	m	0.95	3.33	1.79	12	0.8
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	1	0.7	12	0.2
COND	Conductivity @ 25'C	mS/m	16.8	21.8	20.0	12	1.8
DO	Dissolved Oxygen	g/m³	9	11.4	10.4	12	0.8
PERSAT	Dissolved Oxygen Saturation %	%	96	104	102	12	2
DRP	Dissolved reactive phosphorus	g/m³P	0.021	0.047	0.034	12	0.009
ECOL	E.coli bacteria	cfu/100 mL	120	1500	475	12	393
ENT	Enterococci bacteria	cfu/100 mL	40	5900	340	12	1794
FC	Faecal Coliforms	cfu/100 mL	120	1600	600	12	434
FLOW	Flow	m³/s	0.335	3.86	0.571	12	0.973
NH_4	Ammoniacal nitrogen	g/m³N	0.009	0.043	0.027	12	0.011
NO_2	Nitrite nitrogen	g/m³N	0.003	0.024	0.007	12	0.006
NO_3	Nitrate nitrogen	g/m³N	0.356	4.4	0.883	12	1.22
PH	pH		7.4	8	7.7	12	0.2
SS	Suspended solids	g/m³	<3	11	<3	12	3
TEMP	Temperature	°C	10.2	20.3	14.1	12	3.7
TKN	Total Kjeldahl nitrogen	g/m³N	0.18	0.42	0.25	12	0.06
TN	Total nitrogen	g/m³N	0.51	4.3	1.13	12	1.182
TP	Total phosphorus	g/m³P	0.038	0.080	0.050	12	0.014
TURBY	Turbidity (Hach 2100N)	NTU	1.3	4.3	2.0	12	0.82

A statistical summary of the 24 years' data collected since 1 July 1995, is presented in Table 20.

Table 20 Statistical summary of data from July 1995 to June 2019 Punehu Stream at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.015	0.115	0.039	288	0.015
A440F	Absorbance @ 440nm Filtered	/cm	0.002	0.027	0.008	288	0.004
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.006	0.000	288	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	10	46	34	288	7
BDISC	Black disc transparency	m	0.055	3.65	1.50	288	0.72
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	11.0	0.9	288	1.0
COND	Conductivity @ 25'C	mS/m	6.4	25.2	17.7	288	2.7
DO	Dissolved Oxygen	g/m³	8.6	12.8	10.4	288	0.8
PERSAT	Dissolved Oxygen Saturation %	%	90	114	100	288	2.7
DRP	Dissolved reactive phosphorus	g/m³P	0.013	0.212	0.043	288	0.026
ECOL	E.coli bacteria	cfu/100 mL	48	34000	500	262	3132
ENT	Enterococci bacteria	cfu/100 mL	15	17000	320	287	1846
FC	Faecal Coliforms	cfu/100 mL	51	36000	565	266	3334
FLOW	Flow	m³/s	0.242	12.3	0.808	288	1.519
NH_4	Ammoniacal nitrogen	g/m³N	0.004	0.376	0.038	288	0.057
NO_2	Nitrite nitrogen	g/m³N	0.001	0.110	0.013	288	0.014
NO_3	Nitrate nitrogen	g/m³N	0.07	4.4	0.96	288	0.76
PH	pH		7.1	8.6	7.7	288	0.2
SS	Suspended solids	g/m³	<2	220	3	288	22
TEMP	Temperature	°C	5.0	21.0	13.4	288	3.6
TKN	Total Kjeldahl nitrogen	g/m³N	0.03	1.99	0.31	288	0.27
TN	Total nitrogen	g/m³N	0.21	4.3	1.40	288	0.84
TP	Total phosphorus	g/m³P	0.026	0.755	0.077	288	0.071
TURB	Turbidity (Hach 2100A)	NTU	0.9	50	1.9	245	4.9
TURB	Turbidity (Cyberscan WTW)	NTU	0.8	160	2.3	157	14.1

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 IV.

Discussion

2018-2019 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.79 m, this clarity being typical of the lower reaches of developed ringplain catchments. A median suspended solids concentration of 4 g/m^3 and turbidity of 2.0 NTU was also more typical of the lower reaches of a ring plain catchment. Minimum clarity (black disc value of 0.95 and turbidity of 4.3 NTU, and suspended solids concentration of 11 g/m^3) was recorded during a moderate fresh in July 2018.

Nitrate concentration and conductivity were elevated in winter and early spring, to the highest nitrate level recorded (4.4 g/m^{3}N, though total and kjeldahl nitrogen values of 4.3 and 0.42 g/m^3 imply a lower nitrate concentration of about 3.9 g/m^3), whereas highest phosphorus concentrations occurred in late spring and summer under lower flows.

pH range was moderate, with the maximum value of 8.0 recorded in February under low flow conditions, but this value was recorded in late morning and would be expected to have reached a higher level later in the day. This value was 0.6 unit lower than the maximum recorded previously at a similar time of the day.

Although dissolved oxygen concentrations remained consistently high (minimum of 96% saturation), BOD_5 concentrations occasionally indicated low levels of organic enrichment (ie 1 g/m^3).

The high median bacteriological numbers (600 faecal coliforms and 340 enterococci cfu/100 mL) were further indication 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 (380 to 1,600 cfu/100 mL) found during summer 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 10.1˚C with a maximum summer (late morning) temperature of 20.3˚C recorded in February 2019 and the lowest temperature (10.2˚C) recorded in September 2018; the former 0.7˚C below the previous maximum temperature and the latter 5.1˚C above the previous minimum temperature.

Brief comparison of upper and lower Punehu Stream sites during the 2018-2019 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 (555 faecal coliforms cfu/100 mL and 320 enterococci cfu/100 mL), and median nutrient concentrations (particularly nitrogen species), with nitrate and total nitrogen, and total phosphorus increasing by factors of about 18, 7.5 and 1.7 times, respectively. These downstream spatial trends may be compared with median 23-year historical data which indicate bacterial increases of 440 cfu/100 mL (faecal coliforms) and 284 cfu/100 mL (enterococci) and increases in nitrate and total nitrogen, and total phosphorus of 33, 9.3, and 2.3 times respectively. Relatively similar median (2018-2019) turbidity levels and suspended solids concentrations were found, with a small decrease in median black disc clarity (6% reduction) between sites, compared with the historical median turbidity decrease of only 0.1 NTU and decrease in median black disc clarity of 0.27 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 surveyed flow increased by 66% in the lower reaches of the stream). The downstream water temperature range increased by 0.2˚C while the median increased by 1.2˚C. The median pH increased by only 0.1 unit in the lower reaches.

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

Brief comparison with the previous 1995-2018 period

Similar aesthetic water quality was indicated with a small increase in median turbidity (of 0.1 NTU) recorded during the more recent, twelve-month survey period, minimal increase in median black disc clarity (of 0.02 m), and no measured change in median suspended solids concentration (of <3 g/m^3).

In the more recent survey period, a small deterioration was recorded in median faecal coliform bacterial number (of 40 cfu/100 mL) and increase in median enterococci bacteria number (by 20 cfu/100 mL). An improvement in median nitrogen nutrient species concentrations was recorded for the recent period, with ammonia, nitrate and total nitrogen values decreasing by 32, 8 and 19%, respectively. There was a large reduction in phosphorus levels, with lower levels of both the dissolved reactive form (by 23%) and total phosphorus (by 37%).

Median dissolved oxygen saturation levels were within 3%, while median BOD_5 level was lower, by 0.2 g/m^3 or 22%, for the most recent period.

There was no difference in median pH, and the maximum pH was 0.6 unit lower in comparison with the previous 23-year period.

Water temperature range was narrower (by 5.9˚C); this decrease due to both higher minimum and lower maximum water temperatures (by 5.2 and 0.7˚C) over the recent survey period, with the 2018-2019 median water temperature 0.7˚C higher than the median 23-year temperature.

Median sampled flow over the 2018-2019 period was significantly lower than the median sampled (by 249 L/s, or 30%) flow for the previous 23-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 4.

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

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 25°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
11 Jul 2018	1240	0.013	0.002	<0.002	24	1.56	0.5	12.1	11.1	101	0.0163	150	22
08 Aug 2018	1235	0.013	0.003	0.002	28	1.79	<0.4	12.3	11.0	103	0.0154	150	10
12 Sep 2018	1245	0.007	<0.002	<0.002	29	1.79	0.6	13.1	11.3	104	0.0145	120	20
10 Oct 2018	1200	0.015	0.003	<0.002	34	2.19	0.8	13.5	11.5	108	0.034	420	40
14 Nov 2018	1130	0.021	0.006	<0.002	35	1.72	0.7	13.3	10.2	105	0.033	210	30
12 Dec 2018	1130	0.026	0.008	0.005	35	1.91	0.9	12.8	10.0	107	0.044	170	170
09 Jan 2019	1130	0.022	0.004	<0.002	38	2.31	0.6	13.5	10.2	110	0.030	190	80
13 Feb 2019	1150	0.027	0.007	<0.002	44	2.76	1.0	14.2	9.8	109	0.029	370	170
13 Mar 2019	1140	0.032	0.007	<0.002	41	2.21	1.0	14.3	9.6	103	0.038	400	1400
10 Apr 2019	1255	0.017	<0.002	<0.002	36	2.47	<0.4	12.5	10.7	105	0.032	290	380
08 May 2019	1310	0.016	0.004	<0.002	34	2.33	0.6	13.6	11.1	107	0.020	190	90
12 Jun 2019	1250	0.01	<0.002	<0.002	30	1.14	<0.4	13.4	10.7	102	0.0181	290	60

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		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
11 Jul 2018	1240	170	4.692	0.015	0.0048	1.76	7.4	6	10.1	0.24	1.92	0.043	2.6
08 Aug 2018	1235	210	2.109	0.013	0.0042	1.52	7.3	<3	11.0	0.21	1.74	0.030	2.3
12 Sep 2018	1245	130	2.318	0.015	0.0046	1.86	7.6	6	10.7	0.14	2.1	0.028	2.7
10 Oct 2018	1200	440	1.032	0.040	0.0095	1.37	7.8	<3	11.6	0.29	1.67	0.058	1.73
14 Nov 2018	1130	270	0.948	0.021	0.0147	1.10	7.8	4	16.1	0.29	1.50	0.062	2.0
12 Dec 2018	1130	260	0.994	0.031	0.0146	0.92	8.0	4	17.8	0.48	1.33	0.066	2.4
09 Jan 2019	1130	270	0.599	0.011	0.0078	0.71	8.1	<3	18.2	0.19	0.94	0.044	1.56
13 Feb 2019	1150	440	0.346	0.006	0.0037	0.45	8.0	<3	19.5	0.21	0.68	0.049	1.03
13 Mar 2019	1140	500	0.451	<0.005	0.0086	0.54	7.8	<3	17.8	0.19	0.74	0.062	1.36
10 Apr 2019	1255	370	0.511	0.006	0.0025	0.53	7.7	<3	13.6	0.14	0.53	0.042	0.84
08 May 2019	1310	250	1.636	0.006	0.0071	1.41	7.7	5	12.8	0.13	1.84	0.034	1.63
12 Jun 2019	1250	400	2.574	0.012	0.004	1.94	7.6	3	11.7	0.16	2.0	0.032	1.46

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

Table 22 Statistical summary of data from July 2018 to June 2019: Waingongoro River at Eltham Rd

Paramete		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.007	0.032	0.016	12	0.007
A440F	Absorbance @ 440nm Filtered	/cm	<0.002	0.008	0.004	12	0.002
A770F	Absorbance @ 770nm Filtered	/cm	<0.002	0.005	<0.002	12	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	24	44	34	12	6
BDISC	Black disc transparency	m	1.14	2.76	2.05	12	0.45
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	1	0.6	12	0.2
COND	Conductivity @ 25'C	mS/m	12.1	14.3	13.4	12	0.7
DO	Dissolved Oxygen	g/m³	9.6	11.5	10.7	12	0.6
PERSAT	Dissolved Oxygen Saturation %	%	101	110	105	12	3
DRP	Dissolved reactive phosphorus	g/m³P	0.015	0.044	0.029	12	0.01
ECOL	E.coli bacteria	cfu/100 mL	120	420	200	12	105
ENT	Enterococci bacteria	cfu/100 mL	10	1400	70	12	390
FC	Faecal coliforms	cfu/100 mL	130	500	270	12	118
FLOW	Flow	m³/s	0.346	4.692	1.013	12	1.258
NH_4	Ammoniacal nitrogen	g/m³N	<0.005	0.04	0.013	12	0.011
NO_2	Nitrite nitrogen	g/m³N	0.003	0.029	0.007	12	0.007
NO_3	Nitrate nitrogen	g/m³N	0.446	1.94	1.238	12	0.543
PH	pH		7.3	8.1	7.8	12	0.2
SS	Suspended solids	g/m³	<3	7	<3	12	1
TEMP	Temperature	°C	10.1	19.5	13.2	12	3.4
TKN	Total Kjeldahl nitrogen	g/m³N	0.13	0.48	0.2	12	0.1
TN	Total nitrogen	g/m³N	0.53	2.1	1.585	12	0.559
TP	Total phosphorus	g/m³P	0.028	0.066	0.044	12	0.014
TURBY	Turbidity (Hach 2100N)	NTU	0.8	2.7	1.65	12	0.61

A statistical summary of the 24 years' data collected since 1 July 1995, is presented in Table 23.

Table 23 Statistical summary of data from July 1995 to June 2019: Waingongoro River at Eltham Rd

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.007	0.100	0.021	288	0.014
A440F	Absorbance @ 440nm Filtered	/cm	0.000	0.024	0.005	288	0.003
A770F	Absorbance @ 770nm Filtered	/cm	0.000	0.003	0.000	288	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	9	49	30	288	7
BDISC	Black disc transparency	m	0.10	4.39	1.71	288	0.79
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	7.3	0.7	288	0.9
COND	Conductivity @ 25'C	mS/m	4.5	16.2	12.3	288	1.8
DO	Dissolved Oxygen	g/m³	9.2	13.0	10.6	288	0.7
PERSAT	Dissolved Oxygen Saturation %	%	92	121	103	288	5
DRP	Dissolved reactive phosphorus	g/m³P	0.003	0.146	0.020	288	0.015
ECOL	E.coli bacteria	cfu/100 mL	6	59000	190	288	4026
ENT	Enterococci bacteria	cfu/100 mL	3	15300	100	288	1438
FC	Faecal coliforms	cfu/100 mL	6	100000	205	288	7073
FLOW	Flow	m³/s	0.326	46.451	1.639	288	4.092
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	1.72	0.017	288	0.107
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.033	0.007	288	0.005
NO_3	Nitrate nitrogen	g/m³N	0.13	2.31	1.13	288	0.49
PH	pH		7.1	8.6	7.8	288	0.3
SS	Suspended solids	g/m³	<2	180	3	288	19
TEMP	Temperature	°C	5.6	21.5	12.7	288	3.3
TKN	Total Kjeldahl nitrogen	g/m³N	0.00	2.78	0.19	288	0.32
TN	Total nitrogen	g/m³N	0.21	4.10	1.45	288	0.55
TP	Total phosphorus	g/m³P	0.013	0.829	0.040	288	0.086
TURB	Turbidity (Hach 2100A)	NTU	0.70	36	1.5	245	3.8
TURB	Turbidity (Cyberscan WTW)	NTU	0.62	18	2.0	157	7.8

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 IV.

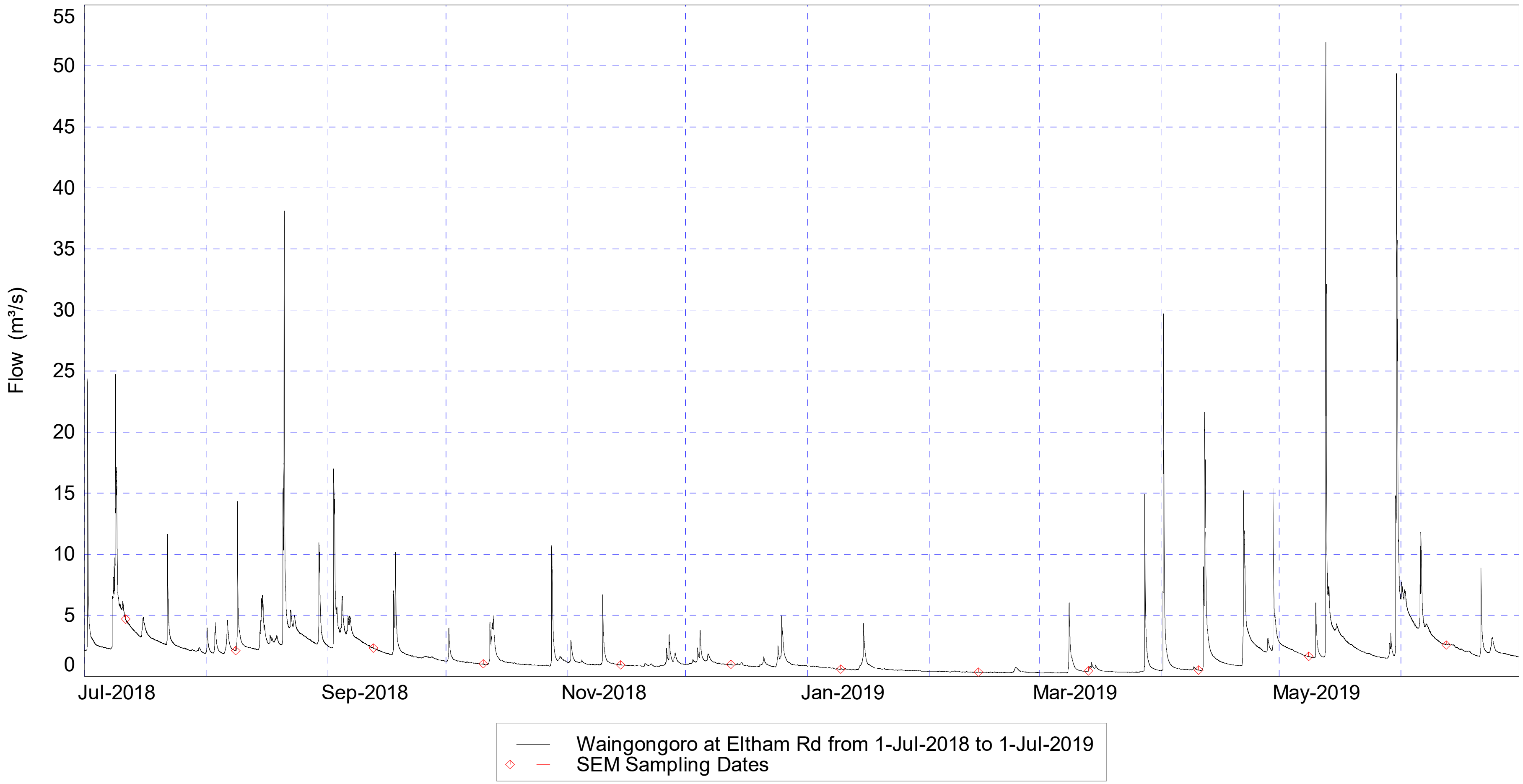


Figure 4 Flow record for the Waingongoro River at Eltham Road

Discussion

2018-2019

Moderate aesthetic water quality (more similar to lower ringplain reaches' aesthetic quality) was indicated by a median black disc clarity of 2.05 m and median turbidity of 1.6 NTU, in the mid-reaches of the longest ring-plain river in Taranaki but recognising that this site (altitude: 200 m asl) is 23 km from the National Park boundary. The maximum clarity (black disc of 2.76 m), 1.89 m lower than the historical maximum, was recorded in late-summer during five-year return period low flow conditions (0.346 m^3/s), while lowest black disc clarity (1.14 m) occurred on the late falling stages of a flood, coincident with a relatively high turbidity of 1.5 NTU and low suspended solids concentration of 3 g/m^3 sampled in June 2019 (Figure 4). Generally, the poorer water quality conditions monitored during freshes (elevated bacterial numbers, some elevated nutrients, discolouration, and decreased clarity) were apparent on fewer occasions than usual during the 2018-2019 period.

pH reached a maximum of 8.1 in mid-summer coincident with supersaturation (110%) of dissolved oxygen, although it would be expected that pH would have risen further later in the day, particularly in 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: 0.6 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 270 and 70 cfu/100 mL, respectively. Water temperature varied over a moderate range of 9.4˚C with the maximum summer (late morning) river temperature of 19.5˚C recorded in February 2019 under low flow conditions (Figure 4).

Brief comparison with previous 1995-2018 period

The latest twelve-month period sampled a narrower range of flow conditions with median sampled flow much lower (by 554 L/s. or 33%) than the median of flows sampled over the previous 23-year period. Aesthetic river water quality was higher in terms of median black disc clarity (which was higher by 0.32 m), though median turbidity level was slightly higher (by 0.2 NTU), with median suspended solids level slightly lower (by <1 g/m^3), during the 2018-2019 period.

In general, some deterioration in faecal coliform bacteriological water quality was recorded in the 2018-2019 period with a higher median number (by 70 cfu/100 mL) and in median enterococci number (by 90 cfu/100 mL). Some increases were indicated in median nutrient species' concentrations over the 2018-2019 period, particularly nitrate and total nitrogen, and dissolved and total phosphorus, which were the higher by 10%, 10%, 45% and 10%, respectively. Median ammonia nitrogen value fell by 24%.

The range in water temperature was narrower (by 6.5˚C) over the 2018-2019 period due to both warmer (by 4.5°C) minimum and cooler maximum (by 2.0°C) water temperatures.

Median pH value was the same, and the maximum pH previously recorded (over 23 years) was 0.5 unit higher than that measured in the 2018-2019 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 5.

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

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 25°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
11-Jul-2018	1145	0.022	0.004	<0.002	29	0.68	1.2	15.7	11.2	100	0.028	290	70
08-Aug-2018	1200	0.026	0.005	0.002	38	1.10	<0.4	19.1	10.7	99	0.038	150	40
12-Sep-2018	1215	0.017	0.002	<0.002	38	1.06	0.9	19.4	11.3	102	0.028	110	30
10-Oct-2018	1130	0.024	0.005	<0.002	46	2.26	0.7	21.1	11.0	105	0.037	190	60
14-Nov-2018	1100	0.03	0.007	<0.002	46	1.85	<0.4	19.7	9.8	102	0.046	170	30
12-Dec-2018	1050	0.03	0.006	<0.002	47	1.40	0.8	18.7	9.5	103	0.047	190	83
09-Jan-2019	1050	0.033	0.006	<0.002	52	1.54	0.7	19.9	10.0	111	0.040	140	90
13-Feb-2019	1115	0.035	0.007	<0.002	58	3.64	1.0	21.5	9.4	107	0.036	180	380
13-Mar-2019	1105	0.056	0.013	0.003	51	1.62	2.0	22.5	8.7	94	0.076	900	2500
10-Apr-2019	1215	0.036	0.004	<0.002	50	1.56	0.5	20.6	10.6	105	0.068	230	540
08-May-2019	1220	0.026	0.006	<0.002	40	2.60	1.3	17.6	11.1	105	0.034	140	240
12-Jun-2019	1210	0.016	<0.002	<0.002	36	0.96	0.6	17.2	10.7	102	0.052	280	130
Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		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
11-Jul-2018	1145	300	17.866	0.019	0.0123	2.2	7.5	13	10.1	0.42	2.7	0.079	5.8
08-Aug-2018	1200	150	8.681	0.030	0.035	2.6	7.5	9	11.5	0.34	3.1	0.076	6.0
12-Sep-2018	1215	140	9.428	0.009	0.029	2.9	7.6	7	11.1	0.29	3.1	0.048	4.0
10-Oct-2018	1130	210	3.860	0.019	0.0106	2.6	7.8	5	13.1	0.34	3.0	0.070	3.8
14-Nov-2018	1100	230	2.977	0.017	0.0079	1.86	7.9	<3	18.0	0.54	2.2	0.066	2.5
12-Dec-2018	1050	220	2.707	0.011	0.0076	1.30	7.8	3	18.9	0.31	1.61	0.069	2.4
09-Jan-2019	1050	160	1.875	0.013	0.0060	1.05	8.1	<3	20.5	0.23	1.37	0.061	1.69
13-Feb-2019	1115	220	1.151	0.017	0.0062	0.67	8.0	<3	21.4	0.38	1.08	0.058	0.83
13-Mar-2019	1105	900	1.218	<0.005	0.020	1.38	7.5	<3	19.3	0.47	1.92	0.120	1.33
10-Apr-2019	1215	380	1.552	0.021	0.0090	1.28	7.9	<3	15.0	0.3	1.46	0.090	1.22
08-May-2019	1220	240	4.545	0.011	0.0096	1.64	7.7	<3	13.0	0.22	2.2	0.060	1.92
12-Jun-2019	1210	350	8.998	0.096	0.050	2.4	7.6	6	11.8	0.24	2.6	0.072	2.3

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

Table 25 Statistical summary of data from July 2018 to June 2019: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev.
A340F	Absorbance @ 340nm Filtered	/cm	0.016	0.056	0.028	12	0.011
A440F	Absorbance @ 440nm Filtered	/cm	<0.002	0.013	0.005	12	0.003
A770F	Absorbance @ 770nm Filtered	/cm	<0.002	0.003	<0.002	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	29	58	46	12	8
BDISC	Black disc transparency	m	0.68	3.64	1.55	12	0.82
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.4	2.0	0.8	12	0.5
COND	Conductivity @ 25'C	mS/m	15.7	22.5	19.5	12	1.9
DO	Dissolved Oxygen	g/m^3	8.7	11.3	10.6	12	0.8
PERSAT	Dissolved Oxygen Saturation %	%	94	111	102	12	4
DRP	Dissolved reactive phosphorus	g/m^3P	0.028	0.076	0.039	12	0.015
ECOL	E.coli bacteria	cfu/100 mL	110	900	185	12	213
ENT	Enterococci bacteria	cfu/100 mL	30	2500	86	12	696
FC	Faecal Coliforms	cfu/100 mL	140	900	225	12	206
FLOW	Flow	m/s	1.151	17.866	3.418	12	4.994
NH_4	Ammoniacal nitrogen	g/m^3N	<0.005	0.096	0.017	12	0.024
NO_2	Nitrite nitrogen	g/m^3N	0.005	0.050	0.010	12	0.014
NO_3	Nitrate nitrogen	g/m^3N	0.674	2.871	1.746	12	0.702
PH	pH		7.5	8.1	7.8	12	0.2
SS	Suspended solids	g/m^3	<3	13	3	12	3
TEMP	Temperature	°C	10.1	21.4	14.1	12	4.1
TKN	Total Kjeldahl nitrogen	g/m^3N	0.22	0.54	0.32	12	0.1
TN	Total nitrogen	g/m^3N	1.08	3.1	2.2	12	0.713
TP	Total phosphorus	g/m^3P	0.048	0.12	0.070	12	0.019
TURBY	Turbidity (Hach 2100N)	NTU	0.8	6	2.35	12	1.73

This was the twenty-first 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 2019: Waingongoro River at SH45

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.078	0.032	252	0.011
A440F	Absorbance @ 440nm filtered	/cm	<0.002	0.019	0.007	252	0.003
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	252	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	17	62	39	252	9
BDISC	Black disc transparency	m	0.12	4.34	1.21	252	0.61
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.4	6.7	1.0	252	0.9
COND	Conductivity @ 25°C	mS/m	8.6	25.5	18.0	252	2.5
DO	Dissolved oxygen	g/m^3	8.4	12.9	10.5	252	0.8
PERSAT	Dissolved oxygen saturation %	%	89	141	102	252	6
DRP	Dissolved reactive phosphorus	g/m^3P	0.015	0.223	0.052	252	0.032
ECOL	E.coli bacteria	cfu/100 mL	3	41000	220	251	3103
ENT	Enterococci bacteria	cfu/100 mL	6	14700	150	252	1151
FC	Faecal coliforms	cfu/100 mL	3	41000	225	252	3107
FLOW	Flow	m^3/s	0.997	54.817	4.886	252	7.285
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.389	0.032	252	0.045
NO_2	Nitrite nitrogen	g/m^3N	0.003	0.132	0.019	252	0.019
NO_3	Nitrate nitrogen	g/m^3N	0.48	3.11	1.67	252	0.57
pH	pH		7.2	9.1	7.8	252	0.3
SS	Suspended solids	g/m^3	<2	170	5	252	19
TEMP	Temperature	°C	5.4	22.0	13.9	252	3.8
TKN	Total kjeldahl nitrogen	g/m^3N	0.00	1.51	0.38	252	0.26
TN	Total nitrogen	g/m^3N	0.55	3.78	2.39	252	0.63
TP	Total phosphorus	g/m^3P	0.042	0.553	0.090	252	0.063
TURB	Turbidity (Hach 2100A)	NTU	1.0	36	2.3	209	4.0
TURBY	Turbidity (Cyberscan WTW)	NTU	0.8	58	3.2	157	7.7

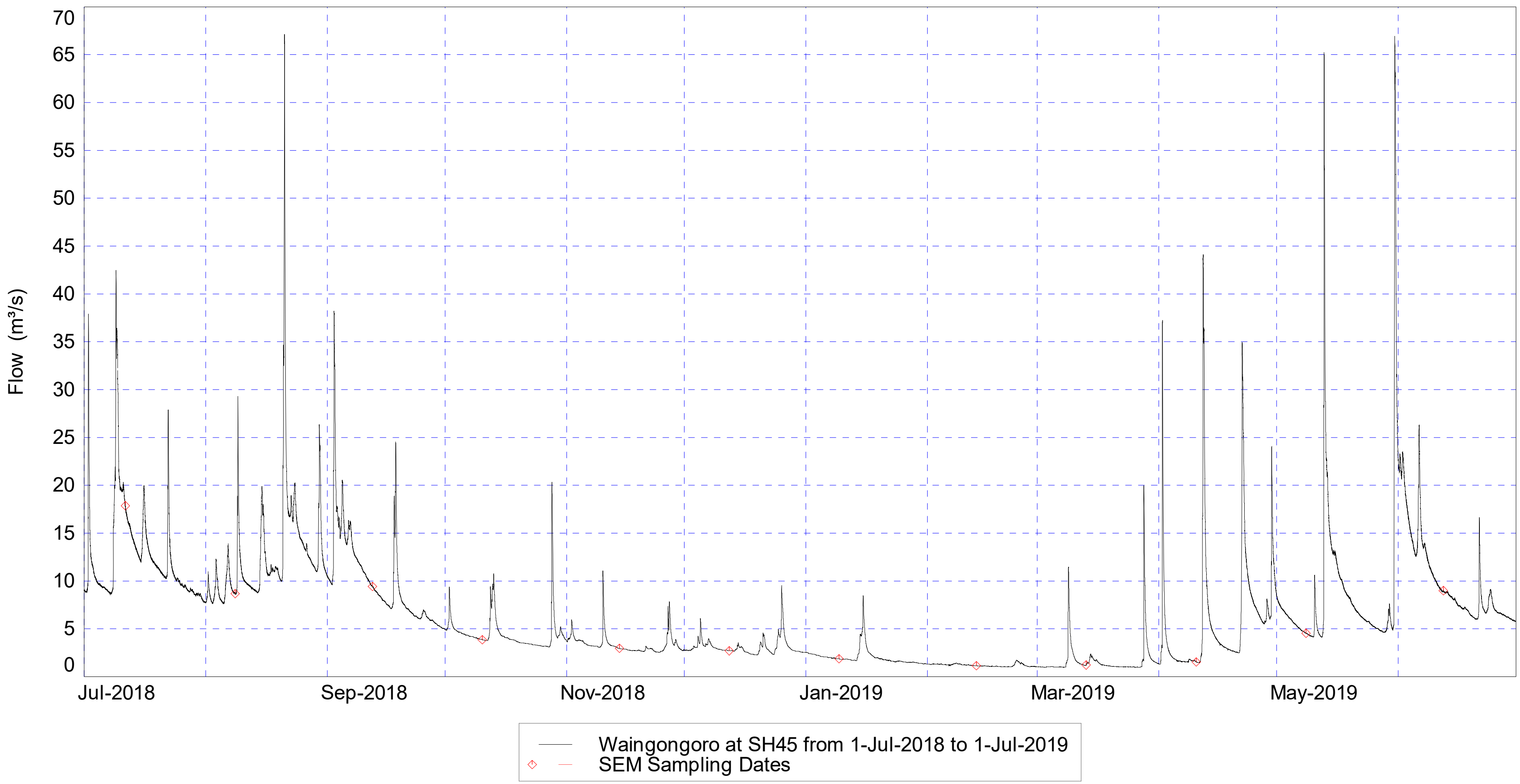


Figure 5 Flow record for the Waingongoro River at SH45

Discussion

2018-2019 period

Moderate aesthetic water quality was indicated by a median black disc clarity of 1.55 m and median turbidity of 1.7 NTU, in the lower reaches of the longest ringplain-confined river or stream in Taranaki. The moderately high maximum clarity (black disc value of 3.64 m) was recorded in late summer in very low flow conditions (1.16 m^3/s). The minimum clarity of 0.68 m was recorded during a large fresh in July 2018. Poorest water quality conditions were generally apparent at times of fresh flows, when elevated bacterial numbers, nutrients, and/or discolouration, and decreased clarity were typical, though the March 2019 sample, taken in drizzly weather during low flow conditions, returned elevated BOD, faecal bacteria and nutrient levels with some (brown) colour, yet had moderate clarity and low turbidity.

pH reached 8.1 in mid-summer under low flow conditions coincidental with highest dissolved oxygen saturation level (111%), although it would be expected that pH would have risen further during summer/autumn later in the day (i.e. after 1215 NZST) than values recorded at the earlier sampling times.

Good water quality was indicated by high dissolved oxygen concentrations (minimum of 94% saturation) and moderately low BOD_5 levels (median: 0.8 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 225 and 86 (cfu/100 mL) respectively. These numbers reflected, to some degree, the relative lack 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 11.3˚C with a maximum late-summer (late morning) river temperature of 21.4˚C recorded in February 2019.

Brief comparison of upper and lower Waingongoro River sites during the 2018-2019 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 0.50 m (24% decrease), increased median turbidity level (by 0.7 NTU), and no change in median suspended solids concentration of 3 g/m^3. Bacteriological quality, in terms of the median faecal coliform count, remained poor (higher by 20 cfu/100 mL) at the lower river site whereas the median enterococci count deteriorated by16 cfu/100 mL (compared with historical median deteriorations of 40 cfu/100 mL for faecal coliforms and 50 cfu/100 mL for enterococci). The lower river site's sampled pH range was narrower (by 0.2 unit) over the 2018-2019 period, but the median and maximum pH levels were the same.

Median BOD_5 was higher by 0.2 g/m^3 at the SH45 site where all median nutrient species' concentrations also showed significant increases (by 29% to 59%) compared with upstream concentrations. Historical (1998-2018) median data also indicate from 57% to 152% increases in nutrient species concentrations in a downstream direction.

Water temperature range was wider (by 1.9˚C) at the lower site and median water temperature was 0.9˚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 0.7˚C. Median flow increased by 237% at the lower reach site in the 2018-2019 period compared with 210% over the previous twenty-year period.

Brief comparison with the previous 1998-2018 period

The most recent twelve-month period sampled a much narrower (lower) range of flow conditions and the median sampled flow was lower by 1,589 L/s, or 32%, than that sampled over the previous twenty-year period. This was due in part to the few freshes sampled, particularly in spring, summer and autumn, in the 2018-2019 year.

Water clarity at the time of sampling was slightly better, with the medians for both suspended solids and turbidity the same, and black disc clarity higher by 0.36 m (31%) in the 2018-2019 period. The black disc visibility distance of 3.64 m measured on 13 February 2019 was the second highest recorded (after 4.34 m on 10 November 2010).

Median faecal coliform bacterial number was the same, with a decrease in enterococci, by 64 cfu/100 mL. While pH median values were the same, a much narrower range (by 1.3 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 twenty-year period. Dissolved oxygen saturation median value was the same between the periods. Both median phosphorus species nutrient levels reduced (each by 26%) in the recent one year period, and all of the median nitrogen nutrient species' levels were lower, by 8% to 200% (ammonia).

The 2018-2019 range in water temperatures was narrower (by 5.3˚C) due to a higher minimum temperature (by 4.7˚C) and lower maximum temperature (by 0.6˚C) while the median was 0.2˚C higher in the 2018-2019 sampling period than that recorded over the previous twenty-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 @ 25 °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
11 Jul 2018	1315	0.019	0.002	<0.002	13.3	2.88	0.8	5.4	11.4	100	0.0068	<1	<1
08 Aug 2018	1310	0.018	0.004	<0.002	19.0	3.00	<0.4	6.3	11.0	101	0.0146	50	<10
12 Sep 2018	1315	0.009	<0.002	<0.002	21	6.65	0.6	7.1	11.6	101	0.0163	10	<10
10 Oct 2018	1240	0.012	0.003	<0.002	26	7.50	0.8	8.0	11.5	102	0.025	10	20
14 Nov 2018	1205	0.014	0.004	<0.002	24	5.03	<0.4	7.7	10.5	100	0.021	18	12
12 Dec 2018	1215	0.017	0.004	0.003	25	4.24	0.7	7.8	10.2	102	0.023	10	<10
09 Jan 2019	1155	0.015	0.003	<0.002	29	4.89	<0.4	8.7	9.9	101	0.028	50	50
13 Feb 2019	1230	0.015	0.003	<0.002	31	4.48	<0.4	9.1	9.8	101	0.036	30	50
13 Mar 2019	1215	0.047	0.012	0.003	23	1.21	0.5	7.7	10.1	100	0.026	90	330
10 Apr 2019	1335	0.011	<0.002	<0.002	26	2.96	0.4	8.1	10.8	101	0.026	80	23
08 May 2019	1350	0.014	0.004	<0.002	27	5.28	0.5	8.0	11.1	102	0.022	60	11
12 Jun 2019	1330	0.012	<0.002	<0.002	21	3.20	0.6	7.2	11.0	97	0.0180	20	10
Date	Time NZST	FC	Flow	NH4	NO2	NO3	pH	SS	Temp	TKN	TN	TP	Turb
		cfu/ 100mL	m3/s	g/m3N	g/m3N	g/m3N	pH	g/m3	°C	g/m3N	g/m3N	g/m3P	NTU
11 Jul 2018	1315	<1	0.45	<0.005	<0.0010	0.03	7.2	<5	7.3	<0.10	0.08	0.009	0.73
08 Aug 2018	1310	50	0.278	<0.005	<0.0010	0.04	7.4	<3	8.4	<0.10	0.06	0.020	1.01
12 Sep 2018	1315	10	0.226	<0.005	<0.0010	0.04	7.2	<3	7.1	<0.10	0.06	0.019	0.67
10 Oct 2018	1240	10	0.135	0.009	<0.0010	0.03	7.4	<3	7.7	<0.10	0.20	0.028	1.37
14 Nov 2018	1205	23	0.181	0.008	<0.0010	0.02	7.6	<3	11.2	<0.10	0.05	0.024	0.70
12 Dec 2018	1215	10	0.173	<0.005	<0.0010	0.01	7.8	<3	12.5	<0.10	0.04	0.027	1.01
09 Jan 2019	1155	50	0.134	<0.005	<0.0010	0.01	7.7	<3	13.5	<0.10	0.06	0.033	0.70
13 Feb 2019	1230	60	0.09	0.008	<0.0010	0.01	7.7	<3	14.0	<0.10	0.06	0.041	0.66
13 Mar 2019	1215	100	0.213	0.006	<0.0010	0.01	7.5	<3	12.7	0.10	0.11	0.038	1.47
10 Apr 2019	1335	90	0.144	<0.005	<0.0010	0.03	7.9	<3	10.0	<0.10	0.06	0.026	0.43
08 May 2019	1350	70	0.162	<0.005	<0.0010	0.04	7.4	<3	9.6	<0.10	0.07	0.024	0.80
12 Jun 2019	1330	30	0.253	<0.005	<0.002	0.04	7.4	<3	8.4	<0.10	0.12	0.022	0.89

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

Table 28 Statistical summary of data from July 2018 to June 2019: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.047	0.014	12	0.01
A440F	Absorbance @ 440nm filtered	/cm	<0.002	0.012	0.003	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	<0.002	0.003	<0.002	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	13	31	24	12	5
BDISC	Black disc transparency	m	1.21	7.5	4.36	12	1.76
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.4	0.8	0.5	12	0.2
COND	Conductivity @ 25°C	mS/m	5.4	9.1	7.8	12	1
DO	Dissolved oxygen	g/m^3	9.8	11.6	10.9	12	0.6
PERSAT	Dissolved oxygen saturation %	%	97	102	101	12	1
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.007	0.036	0.022	12	0.007
ECOL	E.coli bacteria	cfu/100 mL	<1	90	25	12	30
ENT	Enterococci bacteria	cfu/100 mL	<1	330	12	12	91
FC	Faecal coliforms	cfu/100 mL	<1	100	40	12	33
FLOW	Flow	m^3/s	0.09	0.45	0.177	12	0.095
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.005	0.009	<0.005	12	0.002
NO_2	Nitrite nitrogen	g/m^{3}N	<0.001	0.002	<0.001	12	0
NO_3	Nitrate nitrogen	g/m^{3}N	0.01	0.038	0.03	12	0.012
pH	pH		7.2	7.9	7.4	12	0.2
SS	Suspended solids	g/m^3	<3	<5	<3	12	1
TEMP	Temperature	°C	7.1	14.0	9.8	12	2.5
TKN	Total kjeldahl nitrogen	g/m^{3}N	<0.1	0.1	<0.1	12	0
TN	Total nitrogen	g/m^{3}N	0.045	0.199	0.064	12	0.043
TP	Total phosphorus	g/m^{3}P	0.009	0.041	0.025	12	0.009
TURBY	Turbidity (Hach 2100N)	NTU	0.4	1.5	0.75	12	0.31

A statistical summary of the 24 years' data collected since 1 July 1995, is presented in Table 29.

Table 29 Statistical summary of data from July 1995 to June 2019: Patea River at Barclay Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.006	0.112	0.016	288	0.022
A440F	Absorbance @ 440nm filtered	/cm	0.000	0.024	0.004	288	0.005
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	288	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	2	34	22	287	7
BDISC	Black disc transparency	m	0.09	10.14	4.33	287	1.82
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.4	3.7	<0.5	288	0.3
COND	Conductivity @ 25°C	mS/m	1.9	9.1	6.8	288	1.5
DO	Dissolved oxygen	g/m^3	9.1	12.4	10.6	288	0.7
PERSAT	Dissolved oxygen saturation %	%	90	103	99	288	2
DRP	Dissolved reactive phosphorus	g/m^{3}P	0.004	0.042	0.019	288	0.008
ECOL	E.coli bacteria	cfu/100 mL	<1	10000	22	264	6982
ENT	Enterococci bacteria	cfu/100 mL	<1	2200	9	288	185
FC	Faecal coliforms	cfu/100 mL	<1	10000	23	288	657
FLOW	Flow	m^3/s	0.084	18.000	0.216	288	1.526
NH_4	Ammoniacal nitrogen	g/m^{3}N	<0.003	0.057	<0.003	288	0.006
NO_2	Nitrite nitrogen	g/m^{3}N	<0.001	<0.003	<0.001	288	<0.000
NO_3	Nitrate nitrogen	g/m^{3}N	<0.01	0.14	0.019	288	0.017
pH	pH		6.5	8.0	7.5	288	0.2
SS	Suspended solids	g/m^3	<2	160	<2	288	10
TEMP	Temperature	°C	3.7	14.9	9.4	288	2.5
TKN	Total kjeldahl nitrogen	g/m^{3}N	0.00	2.70	0.05	288	0.19
TN	Total nitrogen	g/m^{3}N	<0.05	2.72	0.07	288	0.19
TP	Total phosphorus	g/m^{3}P	0.008	0.281	0.025	288	0.021
TURB	Turbidity (Hach 2100A)	NTU	0.3	31	0.6	245	2.2
TURBY	Turbidity (Cyberscan WTW)	NTU	0.2	9.3	0.6	156	0.9

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 IV.

Discussion

2018-2019 period

Aesthetic water quality was high, as emphasised by median black disc and turbidity values of 4.36 m and 0.75 NTU respectively. The lowest black disc clarity (1.21 m) and highest turbidity were recorded in March 2019, coincident with a small rainfall event and increase in bacterial numbers, but minimal increases in BOD_5 and suspended solids levels.

Maximum pH (7.9) at this shaded site was measured under low flow conditions in mid-autumn. pH range, however was relatively narrow under all flow conditions (varying by 0.7 unit) over the period, although measurements were confined to near midday.

Dissolved oxygen concentrations were consistently high with a minimum saturation of 97% recorded. The high water quality was also emphasised by very low BOD_5 levels (≤0.5 g/m^3 for the majority of the period) and generally low nutrient concentrations under normal flow conditions. Dissolved reactive phosphorus levels were typical of National Park sourced rivers.

Bacterial water quality was relatively high (median faecal coliform and enterococci numbers of 40 and 12 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.

River water temperatures varied over a moderate range (6.9˚C) at this relatively shaded site during the period. A maximum mid-day temperature of 14.0˚C was recorded under low flow conditions in February 2019.

Brief comparison with the previous 1995-2018 period

A much narrower range and a lower median of river flows was sampled during the 2018-2019 period, with no significant fresh sampled, in comparison with the previous 23-year period. Median flow for the 2018-2019 sampling occasions was 177 L/s, or 19%, lower than the median of sampled flows over the previous 23-year period. Aesthetic river water quality was similar in terms of median black disc clarity and turbidity, during the two periods. Median suspended solids concentrations were very low (below 3 g/m^3) in both periods.

Median nutrient species levels were comparatively similar between the two periods, although there was a small increase in median dissolved reactive phosphorus concentration (of 0.003 g/m^{3}P, or 16%) over the latest sampling period, possibly related to the lower flows.

Median faecal coliform bacterial number increased (by 17 cfu/100 mL) and median enterococci number increased (by 4 cfu/100 mL) over the recent sampling period. Median pH value was lower by 0.1 unit, while the maximum pH value was 0.1 unit lower, in the 2018-2019 period.

Median water temperature over the past twelve-month period was 0.4˚C higher than the median for the previous 23-year period; the maximum temperature was 0.9˚C lower, and the minimum temperature was 3.4˚C higher in the latest period. Therefore, a narrower range of temperatures (by 4.3°C) was recorded in the 2018-2019 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 6.

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

Date	Time NZST	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 25 °C	DO	DO Sat	DRP	E.coli	ENT
		/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
11 Jul 2018	1405	0.011	<0.002	«0.002	23	1.75	1.0	10.7	11.0	101	0.021	1500	270
08 Aug 2018	1355	0.016	0.004	<0.002	26	1.55	<0.4	10.8	10.9	104	0.023	140	<10
12 Sep 2018	1355	0.014	0.003	<0.002	27	1.56	0.7	11.6	11.4	105	0.024	30	20
10 Oct 2018	1315	0.018	0.004	<0.002	31	2.30	0.8	11.8	11.5	109	0.067	300	250
14 Nov 2018	1255	0.024	0.007	<0.002	31	2.20	0.5	11.6	10.1	105	0.047	220	20
12 Dec 2018	1255	0.026	0.008	0.002	31	1.86	0.8	11.4	10.3	111	0.045	240	80
09 Jan 2019	1250	0.028	0.006	<0.002	35	2.31	0.7	14.4	10.6	116	0.051	130	20
13 Feb 2019	1300	0.030	0.006	<0.002	41	2.68	0.7	13.5	10.8	121	0.080	180	60
13 Mar 2019	1250	0.043	0.010	0.003	36	0.89	1.4	13.2	9.7	104	0.099	2700	390
10 Apr 2019	1415	0.024	0.003	<0.002	32	2.10	0.6	12.1	11.3	112	0.080	700	350
08 May 2019	1415	0.020	0.005	<0.002	31	2.30	1.0	13.1	11.3	109	0.022	280	380
12 Jun 2019	1405	0.013	<0.002	<0.002	27	1.95	0.5	11.5	10.8	103	0.0178	260	360

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		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
11 Jul 2018	1405	2200	9.724	0.104	0.0108	1.23	7.3	3	10.3	0.32	1.51	0.044	2.1
08 Aug 2018	1355	150	4.364	0.064	0.0127	1.01	7.3	<3	11.4	0.25	1.28	0.044	2.5
12 Sep 2018	1355	40	3.077	0.043	0.0103	1.08	7.6	<3	10.7	0.22	1.29	0.036	1.46
10 Oct 2018	1315	300	1.396	0.05	0.0187	0.93	7.5	<3	11.8	0.26	1.20	0.076	2.5
14 Nov 2018	1255	310	2.220	0.054	0.021	0.86	7.8	<3	16.4	0.2	1.18	0.066	1.72
12 Dec 2018	1255	280	2.251	0.023	0.0174	0.79	8.0	<3	17.7	0.22	1.07	0.062	2.0
09 Jan 2019	1250	150	0.990	0.008	0.0084	0.57	8.3	<3	18.9	0.2	0.84	0.071	1.48
13 Feb 2019	1300	190	0.589	0.007	0.0087	0.50	8.3	<3	19.5	0.24	0.82	0.103	1.01
13 Mar 2019	1250	3000	1.062	0.048	0.036	0.73	7.8	6	17.1	0.33	1.19	0.142	2.3
10 Apr 2019	1415	700	0.930	0.075	0.034	0.81	8	<3	13.8	0.22	1.00	0.093	1.15
08 May 2019	1415	330	2.375	0.031	0.0142	0.93	7.9	<3	12.9	0.18	1.30	0.030	1.35
12 Jun 2019	1405	340	4.346	0.051	0.009	1.07	7.4	<3	11.8	0.15	1.17	0.028	1.54

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

Table 31 Statistical summary of data from July 2018 to June 2019: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.011	0.043	0.022	12	0.009
A440F	Absorbance @ 440nm filtered	/cm	<0.002	0.010	0.005	12	0.002
A770F	Absorbance @ 770nm filtered	/cm	<0.002	0.003	<0.002	12	0
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	23	41	31	12	5
BDISC	Black disc transparency	m	0.89	2.68	2.02	12	0.47
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.4	1.4	0.7	12	0.3
COND	Conductivity @ 25˚C	mS/m	10.7	14.4	11.7	12	1.1
DO	Dissolved oxygen	g/m^3	9.7	11.5	10.9	12	0.6
PERSAT	Dissolved oxygen saturation %	%	101	121	107	12	6
DRP	Dissolved reactive phosphorus	g/m^3P	0.018	0.099	0.046	12	0.028
ECOL	E.coli bacteria	cfu/100 mL	30	2700	250	12	782
ENT	Enterococci bacteria	cfu/100 mL	10	390	165	12	162
FC	Faecal coliforms	cfu/100 mL	40	3000	305	12	933
FLOW	Flow	m^3/s	0.589	9.724	2.236	12	2.528
NH_4	Ammoniacal nitrogen	g/m^3N	0.007	0.104	0.049	12	0.028
NO_2	Nitrite nitrogen	g/m^3N	0.008	0.036	0.014	12	0.009
NO_3	Nitrate nitrogen	g/m^3N	0.501	1.23	0.893	12	0.212
pH	pH		7.3	8.3	7.8	12	0.4
SS	Suspended solids	g/m^3	<3	6	<3	12	1
TEMP	Temperature	°C	10.3	19.5	13.4	12	3.4
TKN	Total kjeldahl nitrogen	g/m^3N	0.15	0.33	0.22	12	0.05
TN	Total nitrogen	g/m^3N	0.82	1.51	1.185	12	0.197
TP	Total phosphorus	g/m^3P	0.028	0.142	0.064	12	0.034
TURB	Turbidity (Hach 2100N)	NTU	1.01	2.5	1.63	12	0.5

A statistical summary of the 24 years' data collected since 1 July 1995 is presented in Table 32.

Table 32 Statistical summary of data from July 1995 to June 2019: Patea River at Skinner Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.009	0.095	0.024	288	0.014
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.023	0.005	288	0.004
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.000	288	0.001
ALKT	Alkalinity Total	g/m^3 $CaCO_3$	10	57	28	288	6
BDISC	Black disc transparency	m	0.05	4.68	1.83	288	0.82
BOD_5	Biochemical oxygen demand 5day	g/m^3	<0.4	16	1.0	288	1.4
COND	Conductivity @ 25˚C	mS/m	4	15.7	10.9	288	1.6
DO	Dissolved oxygen	g/m^3	8.9	12.9	10.6	288	0.7
PERSAT	Dissolved oxygen saturation %	%	87	121	103	288	6
DRP	Dissolved reactive phosphorus	g/m^3P	0.010	0.160	0.038	288	0.030
ECOL	E.coli bacteria	cfu/100 mL	2	35000	210	264	3788
ENT	Enterococci bacteria	cfu/100 mL	4	19000	110	288	1769
FC	Faecal coliforms	cfu/100 mL	2	63000	240	288	5463
FLOW	Flow	m^3/s	0.589	77.53	3.012	288	8.231
NH_4	Ammoniacal nitrogen	g/m^3N	<0.003	0.329	0.052	288	0.050
NO_2	Nitrite nitrogen	g/m^3N	<0.001	0.051	0.016	288	0.008
NO_3	Nitrate nitrogen	g/m^3N	0.21	1.54	0.91	288	0.22
pH	pH		6.9	8.8	7.8	288	0.4
SS	Suspended solids	g/m^3	<2	360	<2	288	26
TEMP	Temperature	°C	5.3	22.3	12.9	288	3.4
TKN	Total kjeldahl nitrogen	g/m^3N	0.01	4.07	0.23	288	0.35
TN	Total nitrogen	g/m^3N	0.41	4.50	1.21	288	0.34
TP	Total phosphorus	g/m^3P	0.022	1.390	0.066	288	0.106
TURB	Turbidity (Hach 2100A)	NTU	0.2	80	1.5	245	6.9
TURBY	Turbidity (Cyberscan WTW)	NTU	0.9	45	1.7	157	5.2

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 IV.

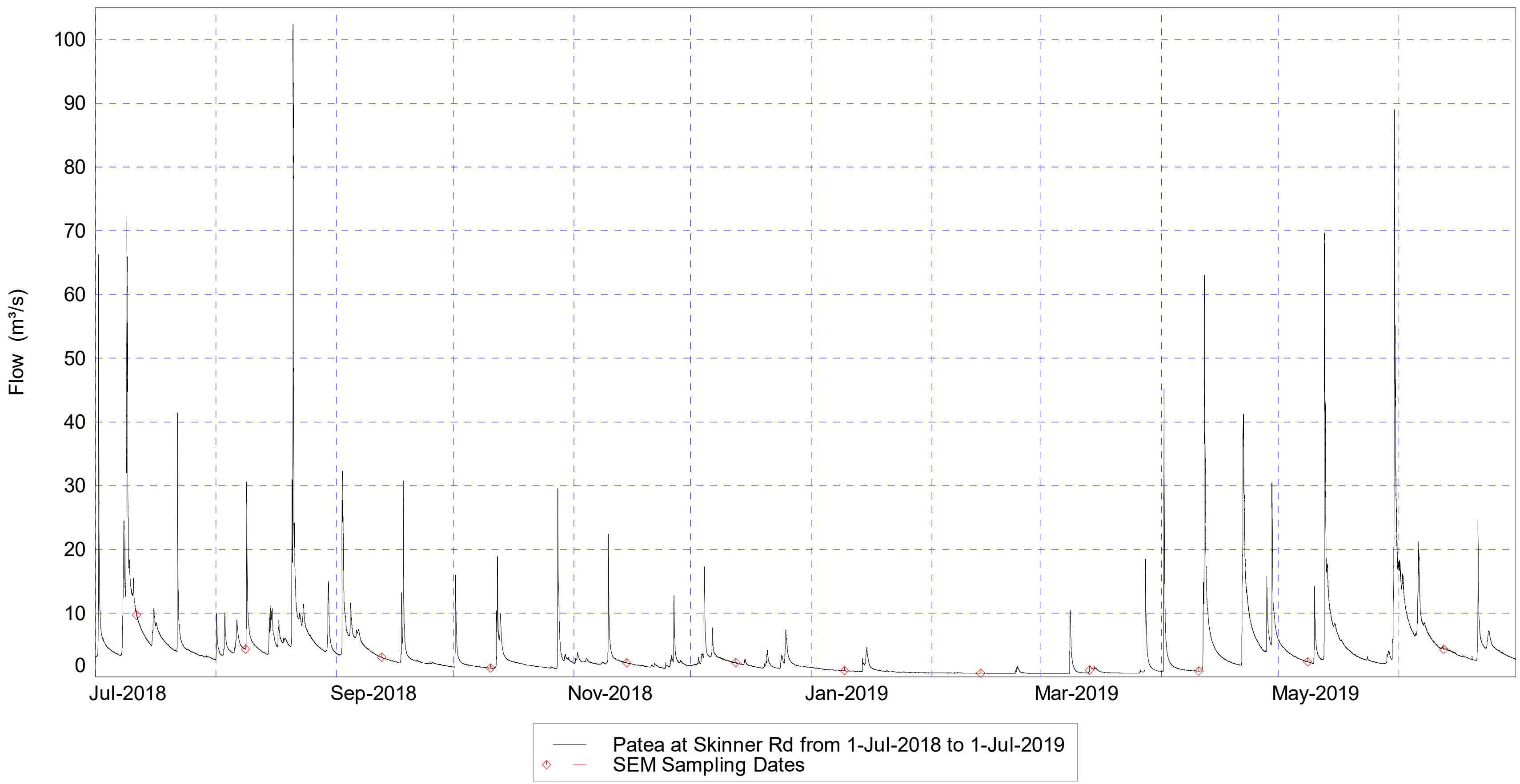


Figure 6 Flow record for the Patea River at Skinner Road

Discussion

2018-2019 period

Moderate median black disc clarity (2.02 m) was slightly lower and median turbidity (1.6 NTU) was slightly higher than typical of the mid reaches of a ring plain river draining a developed catchment and receiving various point source discharges. Overall, this clarity and a low median suspended solids concentration (<3 g/m^3), were indicative of moderate aesthetic water quality at this site. Minimum clarity (black disc of 0.89 m and turbidity of 2.3 NTU) and an increase in suspended solids concentrations (6 g/m^3) were recorded on the rising stage of a small fresh sampled in March 2019 (Figure 6). Deterioration in water quality during this event was also illustrated by high bacterial numbers and elevated BOD_5 and total phosphorus concentration. Another, much larger fresh was sampled in July 2018.

Early afternoon pH levels reached a maximum of 8.3 units in mid- and late summer, coincident with dissolved oxygen saturation peaking at 121%. Dissolved oxygen levels were consistently high (100% or higher saturation) with supersaturation recorded particularly during summer low flow conditions coincident with more extensive algal cover and elevated pH levels (≥ 8.0 units). BOD_5 concentrations under normal to low recession flow conditions were generally indicative of moderately low organic contamination (i.e. up to 1.0 g/m^3), with higher oxygen demand during the few freshes sampled (i.e. up to 1.4 g/m^3).

The moderately poor median bacteriological numbers (305 faecal coliforms and 165 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 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 moderate range of 9.2°C with a maximum (early afternoon) summer temperature of 19.5˚C recorded in February 2019 (coincident with a pH of 8.3 and 121% dissolved oxygen saturation).

Brief comparison of upper and mid Patea River catchment sites during the 2018-2019 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 (8.6 to 15-fold increases) and increases in median nutrient species concentrations (1.6 to 30-fold) compared with historical (23-year) downstream increase in median bacterial numbers (10 to 14-fold) and nutrient species concentrations (2.1 to 46 fold). The pH range increased by 0.3 unit at the Skinner Road site with a maximum pH 0.4 unit higher than at the upstream site. A moderate increase in median turbidity levels (0.85 NTU) was measured in mid catchment, almost identical to the historical median increase. Median BOD_5 increased by about 0.2 g/m^3 although maximum BOD_5 was 0.6 g/m^3 higher downstream. A deterioration in black disc clarity (median clarity decreased significantly by 2.34 m and maximum clarity to a larger degree by 4.8 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 23-year median black disc deterioration of 2.51 m and maximum clarity deterioration of 5.46 m.

Water temperature range increased (by 2.3˚C) at the Skinner Road site, where median water temperature was higher (by 3.6˚C) and maximum water temperature was higher (by 4.6˚C) than at the Barclay Road site. In comparison, the historical 23-year median and maximum water temperatures have shown downstream increases of 3.5˚C and 7.4˚C respectively.

Brief comparison with the previous 1995-2018 period

The median of sampled flows in the recent twelve-month period was 812 L/s, or 27%, lower than the median of flows sampled over the 1995-2018 period, due largely to fewer and smaller freshes sampled in the 2018-2019 year, and the range of river flow sampled was much narrower in the most recent period. Aesthetic water quality was similar to historical conditions, with median black disc clarity higher by 0.20 m, and negligible difference in median suspended solids concentrations and turbidities between periods.

There was a narrower pH range (by 0.9 pH unit) and lower maximum pH (by 0.5 unit) during the 2018-2019 period. Median dissolved oxygen percentage saturation was higher by an insignificant 4% during the later period.

Bacterial water quality deteriorated for both faecal coliform and enterococci bacteria during the more recent sampling period, with the median numbers increasing by 75 and 55 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.

Water temperature range was much narrower (by 7.8˚C) during the more recent sampling period, and the median water temperature was 0.5˚C higher than the longer term median. The maximum water temperature was 2.8°C lower than previously recorded and the minimum water temperature was higher (by 5.0˚C) in the latest twelve-month period.

Median BOD_5 was lower during the more recent period (by 0.3 g/m^3), with median nitrogen nutrient species concentrations decreasing slightly (range of -2 to -6%). There was an increase in median dissolved reactive phosphorus (by 21%) and negligible change in total phosphorus during the more recent twelve-month period.

Mangaehu River at Raupuha Road (site: MGH000950)

Analytical data are presented in Table 33 from the monthly sampling programme. The flow record for the period is illustrated in Figure 7.

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

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 25°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
11 Jul 2018	1450	0.039	0.007	<0.002	19.2	0.22	0.6	7.7	11.0	97	0.0010	160	30
08 Aug 2018	1430	0.050	0.010	<0.002	30	0.70	<0.4	9.3	11.0	101	0.0026	120	20
12 Sep 2018	1430	0.043	0.008	<0.002	41	1.50	0.8	12.0	11.1	102	0.0017	40	<10
10 Oct 2018	1400	0.052	0.011	<0.002	50	2.25	0.6	13.7	10.8	106	0.0024	90	<10
14 Nov 2018	1335	0.054	0.012	<0.002	40	1.77	<0.4	11.3	9.7	104	0.0028	170	30
12 Dec 2018	1330	0.065	0.016	0.004	50	1.88	0.8	13.2	9.6	108	0.0010	80	10
09 Jan 2019	1325	0.051	0.009	<0.002	59	2.79	0.6	15.2	9.0	107	0.0010	110	50
13 Feb 2019	1340	0.042	0.008	<0.002	68	3.03	0.7	17.3	9.1	106	0.0010	100	70
13 Mar 2019	1325	0.057	0.013	0.005	47	1.61	0.7	15.0	9.7	105	0.0013	60	160
10 Apr 2019	1450	0.057	0.008	<0.002	59	1.50	0.6	16.4	11.1	111	0.0027	30	10
08 May 2019	1450	0.058	0.014	<0.002	48	1.75	0.9	13.2	11.9	105	0.0011	130	60
12 Jun 2019	1445	0.043	0.011	0.002	37	0.98	0.4	11.4	11.0	103	0.0030	180	20

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		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
11 Jul 2018	1450	250	36.757	0.014	0.0015	0.33	7.3	73	9.5	0.33	0.58	0.072	38
08 Aug 2018	1430	180	12.037	0.020	0.0026	0.18	7.4	10	10.6	0.19	0.35	0.018	7.7
12 Sep 2018	1430	40	6.226	<0.005	0.0026	0.16	7.5	<3	11.4	0.12	0.26	0.010	3.2
10 Oct 2018	1400	100	3.991	<0.005	0.0022	0.07	7.6	<3	13.7	0.14	0.189	0.016	3.0
14 Nov 2018	1335	250	5.728	<0.005	0.0019	0.07	7.8	<3	18.8	0.28	0.24	0.014	3.2
12 Dec 2018	1330	120	4.101	<0.005	0.0020	0.02	7.9	<3	20.3	0.29	0.167	0.010	3.0
09 Jan 2019	1325	110	2.435	<0.005	0.0011	<0.01	8.1	<3	23.2	0.15	0.181	0.007	2.4
13 Feb 2019	1340	130	1.428	<0.005	<0.0010	<0.01	8.1	<3	22.0	0.19	0.176	0.010	1.52
13 Mar 2019	1325	80	2.186	<0.005	0.0016	0.01	7.9	<3	18.9	0.18	0.22	0.012	1.66
10 Apr 2019	1450	30	1.779	<0.005	0.0023	0.03	8.1	<3	14.9	0.15	0.197	0.006	2.2
08 May 2019	1450	140	3.313	0.012	0.0025	0.11	7.8	<3	12.6	0.14	0.28	0.008	2.7
12 Jun 2019	1445	220	7.174	0.016	0.002	0.19	7.6	<3	11.0	0.14	0.32	0.008	2.4

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

Table 34 Statistical summary of data from July 2018 to June 2019: Mangaehu River at Raupuha Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.039	0.065	0.052	12	0.008
A440F	Absorbance @ 440nm filtered	/cm	0.007	0.016	0.01	12	0.003
A770F	Absorbance @ 770nm filtered	/cm	<0.002	0.005	<0.002	12	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	19	68	48	12	13
BDISC	Black disc transparency	m	0.22	3.03	1.68	12	0.8
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	0.9	0.6	12	0.2
COND	Conductivity @ 25˚C	mS/m	7.7	17.3	13.2	12	2.8
DO	Dissolved oxygen	g/m³	9	11.9	10.9	12	0.9
PERSAT	Dissolved oxygen saturation %	%	97	111	105	12	4
DRP	Dissolved reactive phosphorus	g/m³P	0.001	0.003	0.002	12	0.001
ECOL	E.coli bacteria	cfu/100 mL	30	180	105	12	49
ENT	Enterococci bacteria	cfu/100 mL	<10	160	25	12	43
FC	Faecal coliforms	cfu/100 mL	30	250	125	12	74
FLOW	Flow	m³/s	1.428	36.757	4.046	12	9.75
NH_4	Ammoniacal nitrogen	g/m³N	<0.005	0.02	<0.005	12	0.005
NO_2	Nitrite nitrogen	g/m³N	0.001	0.003	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m³N	0	0.33	0.068	12	0.101
pH	pH		7.3	8.1	7.8	12	0.3
SS	Suspended solids	g/m³	<3	73	<3	12	20
TEMP	Temperature	°C	9.5	23.2	14.3	12	4.8
TKN	Total kjeldahl nitrogen	g/m³N	0.12	0.33	0.16	12	0.07
TN	Total nitrogen	g/m³N	0.167	0.58	0.23	12	0.116
TP	Total phosphorus	g/m³P	0.006	0.072	0.010	12	0.018
TURBY	Turbidity	NTU	1.5	38	2.85	12	10.23

A statistical summary of the 24 years' data collected since 1 July 1995 is presented in Table 35.

Table 35 Statistical summary of data from July 1995 to June 2019: Mangaehu River at Raupuha Road

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.027	0.181	0.054	288	0.018
A440F	Absorbance @ 440nm filtered	/cm	0.001	0.056	0.011	288	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.025	0.000	288	0.002
ALKT	Alkalinity Total	g/m³ $CaCO_3$	9	79	38	288	13
BDISC	Black disc transparency	m	<0.01	4.04	0.86	288	0.75
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	5.6	0.6	288	0.6
COND	Conductivity @ 25˚C	mS/m	4.7	17.7	11.0	288	2.6
DO	Dissolved oxygen	g/m³	7.7	12.9	10.0	288	0.9
PERSAT	Dissolved oxygen saturation %	%	83	118	100	288	5.4
DRP	Dissolved reactive phosphorus	g/m³P	<0.003	0.026	0.006	288	0.003
ECOL	E.coli bacteria	cfu/100 mL	6	16000	215	264	1858
ENT	Enterococci bacteria	cfu/100 mL	1	7200	67	288	879
FC	Faecal coliforms	cfu/100 mL	6	16000	230	288	1976
FLOW	Flow	m³/s	1.428	111.870	6.952	299	16.406
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.081	0.012	288	0.011
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.016	0.002	288	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.43	0.10	288	0.09
pH	pH		6.8	8.4	7.7	288	0.3
SS	Suspended solids	g/m³	<2	1300	4	288	121
TEMP	Temperature	°C	4.3	24.9	13.9	288	4.4
TKN	Total kjeldahl nitrogen	g/m³N	0.02	2.47	0.16	288	0.29
TN	Total nitrogen	g/m³N	<0.05	2.72	0.295	288	0.32
TP	Total phosphorus	g/m³P	<0.003	0.786	0.020	288	0.104
TURB	Turbidity (Hach 2100A)	NTU	1.4	850	3.5	245	63
TURBY	Turbidity (Cyberscan WTW)	NTU	0.8	390	4.4	157	51

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 IV.

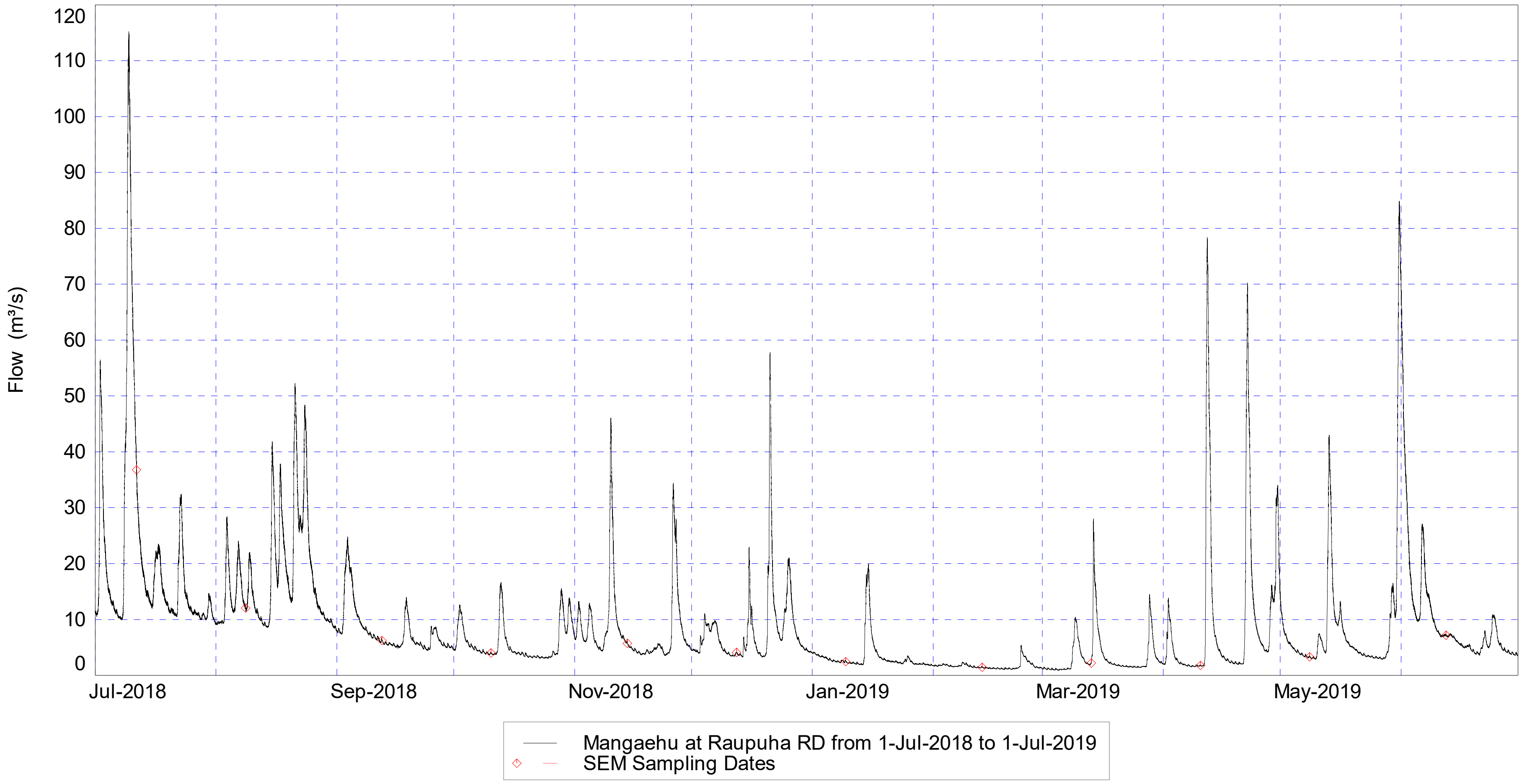


Figure 7 Flow record for the Mangaehu River at Raupuha Road

Discussion

2018-2019 period

The relatively poor visual appearance which characterises the mid and lower reaches of this eastern hill-country catchment river was indicated by a moderately low median black disc clarity of 1.68 metres with a maximum of 3.03 metres measured under a lengthy 30-day receding flow period in February 2019. Clarity was infrequently more than 2 metres (on three occasions) due to the presence of very fine, colloidal, suspended particles. The median suspended solids concentration was <3 g/m^3 which was lower than typical for this river. Absorbances (at 340 and 440 nm) were also relatively high (in excess of 0.039/cm and 0.007/cm respectively) at all times, indicative of slight dissolved colour in the river water (e.g. yellow-brown appearance) at this site in the lower reaches of the river. Minimum clarity (0.22 m black disc value) was coincident with a turbidity level of 38 NTU and suspended solids concentration of 73 g/m^3, during a flood flow of 37 m^3/s recorded in July 2018. Fresh flows (in excess of 10 m^3/s) were usually coincident with a general deterioration in water quality as emphasised by elevated turbidity, suspended solids, some nutrient species' (particularly total phosphorus) levels and bacterial counts (e.g. in July and August 2018, Figure 7).

Maximum mid-afternoon pH values in the summer to mid-autumn period (7.9 to 8.1 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 (7.3 units) was found under flood conditions in July 2018.

Dissolved oxygen concentrations were consistently high (median of 10.9 g/m^3) with a median saturation level of 106%. 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 (25 enterococci and 125 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 13.7˚C with a maximum (early afternoon) summer temperature of 23.2˚C recorded in January 2018 under low flow conditions, at which time dissolved oxygen saturation was 107% and pH was 8.1 units.

Brief comparison with the previous 1995-2018 period

The range of flows sampled during the 2018-2019 period was relatively wide but much narrower than the range sampled over the previous 23-year period due to the proportionately fewer and smaller floods sampled during the latest period. The median sampled flow in the 2018-2019 period was markedly lower (by 3,097 L/s, or 43%) than that sampled over the longer term; the flow on 13 February 2019 (of 1, 428 L/s) was the lowest yet sampled. Median black disc clarity was higher (by 0.84 m) and median turbidity was lower (by 0.7 NTU) in the most recent period, while the median suspended solids concentration was lower by >1 g/m^3.

For nitrogen nutrient species, median concentrations of ammoniacal, nitrate and total nitrogen were lower (by >58, 32 and 22%, respectively) in the latest period, Dissolved reactive and total phosphorus were significantly lower (by 67 and 50%, respectively) compared to the medians for the previous 23-year period, though there is some question as to the influence of a change in laboratory test methodology on the phosphorus species concentrations reported for Mangaehu River in 2018-2019. Median bacterial numbers decreased for enterococci (by 47 cfu/100 mL) and faecal coliforms (by 120 cfu/100 mL) in the 2018-2019 period.

Median dissolved oxygen saturation level was relatively similar (5% higher) in the 2018-2019 period while median pH level was 0.1 unit higher in the recent period. Maximum pH was 0.3 unit lower than the maximum previously recorded while minimum pH was 0.5 unit higher than the minimum recorded.

The range of water temperatures was narrower (by 6.9°C) in the latest twelve-month period than over the previous 23-year period due to a lower maximum temperature (by 1.7˚C) and higher minimum temperature (by 5.2˚C) in the 2018-2019 sampling year, while median water temperature was 0.4˚C higher during 2018-2019.

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^3P	cfu/100mL	cfu/100mL
12 Jul 2018	1040	0.091	0.022	<0.002	33	0.11	<0.4	15.1	11.3	96	0.0056	110	48
09 Aug 2018	1030	0.079	0.018	<0.002	46	0.19	1.2	18.4	10.9	97	0.0119	100	70
13 Sep 2018	1020	0.052	0.009	<0.002	58	0.41	0.6	20.8	10.7	97	0.0138	80	20
11 Oct 2018	0930	0.048	0.009	<0.002	69	0.86	0.7	23.6	10.2	99	0.024	270	70
15 Nov 2018	0945	0.063	0.013	<0.002	60	0.71	0.4	20.2	9.1	96	0.0186	500	110
13 Dec 2018	0840	0.062	0.010	<0.002	66	0.76	0.6	22.1	8.9	96	0.0177	240	58
10 Jan 2019	1000	0.047	0.008	<0.002	82	1.13	1.1	25.9	9.0	102	0.0094	130	80
14 Feb 2019	1000	0.043	0.008	<0.002	92	1.32	1.1	28.0	9.5	108	0.0068	100	80
14 Mar 2019	0920	0.117	0.025	<0.002	56	0.12	2.3	23.3	8.5	90	0.0140	5800	3400
11 Apr 2019	1020	0.078	0.016	0.003	71	0.57	0.7	26.1	9.6	97	0.028	600	350
09 May 2019	1015	0.061	0.011	<0.002	71	0.98	0.6	23.1	10.3	97	0.0176	130	40
13 Jun 2019	1015	0.050	0.011	<0.002	54	0.24	0.5	19.8	10.8	100	0.0183	260	170

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		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
12 Jul 2018	1040	150	13.641	0.019	0.0029	0.30	7.6	170	9.0	0.43	0.65	0.148	78
09 Aug 2018	1030	100	7.955	0.096	0.0057	0.45	7.4	44	10.3	0.43	0.85	0.070	35
13 Sep 2018	1020	80	5.147	0.034	0.0060	0.58	7.7	22	11.1	0.27	0.77	0.050	14.4
11 Oct 2018	0930	280	3.440	0.082	0.0126	0.64	7.9	11	13.7	0.31	0.93	0.062	8.3
15 Nov 2018	0945	540	3.654	0.014	0.0069	0.47	7.7	21	18.3	0.35	0.74	0.055	11.8
13 Dec 2018	0840	370	3.238	0.007	0.0046	0.46	7.7	16	19.4	0.24	0.64	0.052	10.2
10 Jan 2019	1000	180	2.237	<0.005	0.0028	0.39	8.0	6	21.6	0.24	0.6	0.027	4.6
14 Feb 2019	1000	100	1.730	<0.005	0.0041	0.35	8.1	5	21.7	0.24	0.55	0.030	3.6
14 Mar 2019	0920	7600	4.581	0.061	0.0088	0.48	7.5	144	18.7	1.00	1.29	0.23	82
11 Apr 2019	1020	900	2.280	0.062	0.0116	0.55	7.8	9	15.2	0.36	0.89	0.059	6.6
09 May 2019	1015	150	2.716	0.022	0.0049	0.50	7.7	9	13.0	0.24	0.69	0.036	7.3
13 Jun 2019	1015	300	5.530	0.034	0.006	0.46	7.6	42	11.4	0.32	0.67	0.050	17.8

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

Table 37 Statistical summary of data from July 2018 to June 2019: Whenuakura River at Nicholson Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.043	0.117	0.062	12	0.022
A440F	Absorbance @ 440nm filtered	/cm	0.008	0.025	0.011	12	0.006
A770F	Absorbance @ 770nm filtered	/cm	<0.002	0.003	<0.002	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	33	92	63	12	16
BDISC	Black disc transparency	m	0.11	1.32	0.64	12	0.41
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	2.3	0.6	12	0.5
COND	Conductivity @ 25°C	mS/m	15.1	28	22.6	12	3.6
DO	Dissolved oxygen	g/m³	8.5	11.3	9.9	12	0.9
PERSAT	Dissolved oxygen saturation %	%	90	108	97	12	4
DRP	Dissolved reactive phosphorus	g/m³P	0.006	0.028	0.016	12	0.007
ECOL	E.coli bacteria	nos/100 mL	80	5800	185	12	1617
ENT	Enterococci bacteria	nos/100 mL	20	3400	75	12	957
FC	Faecal coliforms	nos/100 mL	80	7600	230	12	2124
FLOW	Flow	m³/s	1.73	13.641	3.547	12	3.316
NH_4	Ammoniacal nitrogen	g/m³N	<0.005	0.096	0.028	12	0.031
NO_2	Nitrite nitrogen	g/m³N	0.003	0.013	0.006	12	0.003
NO_3	Nitrate nitrogen	g/m³N	0.3	0.637	0.469	12	0.095
pH	pH	pH	7.4	8.1	7.7	12	0.2
SS	Suspended solids	g/m³	5	170	18	12	56
TEMP	Temperature	°C	9	21.7	14.4	12	4.5
TKN	Total kjeldahl nitrogen	g/m³N	0.24	1	0.32	12	0.21
TN	Total nitrogen	g/m³N	0.55	1.29	0.715	12	0.201
TP	Total phosphorus	g/m³P	0.027	0.23	0.054	12	0.059
TURBY	Turbidity (Hach 2100N)	NTU	3.6	82	11	12	27.77

A statistical summary of the four years' data collected since 1 July 2015 is presented in Table 38.

Table 38 Statistical summary of data from July 2015 to June 2019: Whenuakura River at Nicholson Rd

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.043	0.151	0.062	48	0.026
A440F	Absorbance @ 440nm filtered	/cm	0.008	0.036	0.013	48	0.007
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.006	0.001	48	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	17	94	58	48	17
BDISC	Black disc transparency	m	0.04	1.32	0.30	40	0.32
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	2.3	0.8	48	0.4
COND	Conductivity @ 25°C	mS/m	10.5	28	20.7	48	4.2
DO	Dissolved oxygen	g/m³	7.8	12.1	9.6	48	1.1
PERSAT	Dissolved oxygen saturation %	%	88	108	96	48	3
DRP	Dissolved reactive phosphorus	g/m³P	0.006	0.039	0.017	48	0.006
ECOL	E.coli bacteria	nos/100 mL	23	5800	440	48	1124
ENT	Enterococci bacteria	nos/100 mL	17	3400	145	48	554
FC	Faecal coliforms	nos/100 mL	23	7600	440	48	1313
FLOW	Flow	m³/s	1.730	63.169	5.424	48	10.889
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.096	0.025	48	0.019
NO_2	Nitrite nitrogen	g/m³N	0.001	0.013	0.005	48	0.002
NO_3	Nitrate nitrogen	g/m³N	0.087	0.672	0.41	48	0.149
pH	pH	pH	7.1	8.1	7.6	48	0.2
SS	Suspended solids	g/m³	4	1100	39	48	256
TEMP	Temperature	°C	6.1	21.9	13.8	48	4.5
TKN	Total kjeldahl nitrogen	g/m³N	0.01	18.96	0.29	48	2.7
TN	Total nitrogen	g/m³N	0.32	19.40	0.68	48	2.71
TP	Total phosphorus	g/m³P	0.022	1.08	0.074	48	0.223
TURBY	Turbidity (Cyberscan WTW)	NTU	4.9	760	36	36	151

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 IV.

Discussion

2018-2019 period

The poor visual appearance which characterises the mid and lower reaches of this eastern hill-country catchment river was emphasised in the low black disc clarity with a range of 0.11 to 0.32 metres, due to the presence of very fine, colloidal, suspended particles. The median suspended solids concentration over this fourth year of monitoring was moderately high, at 18 g/m^3, with a maximum recorded value of 170 g/m^3 in July 2018, two values ≥100 g/m^3, and a minimum value of 5 g/m^3. Median turbidity level was correspondingly high, at 11 NTU with a range from 3.6 to 82 NTU. Absorbances (at 340 and 440 nm) were also relatively high (medians of 0.062/cm and 0.011/cm respectively), 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 7 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.

Maximum early/mid-morning pH value, in the late summer (8.1 units), was 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 (7.4 units) was found on the rising stage after a series of small freshes in August 2018.

Dissolved oxygen concentrations (median 9.9 g/m^3) were mostly slightly below saturation level (minimum of 90%), with a maximum super-saturation (of 108%) measured in February 2018 when the lowest sampled flow and highest clarity were recorded. BOD_5 concentrations were often indicative of a low level of organic enrichment (i.e. ≥ 1.0 g/m^3), with values of up to 2.3 g/m^3 recorded. The median bacteriological numbers (230 faecal coliforms and 75 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 faecal coliform number during spring recession flows indicated a continuous or continual source upstream.

Water temperatures varied over a wide range of 12.7˚C with a maximum (early/mid- morning) summer temperature of 21.7˚C recorded in February 2019 under very low flow conditions.

Brief comparison with the previous 2015-2018 period

The median of sampled flows in the recent twelve-month period was significantly lower (by 6,468 L/s, or 54%) than flows sampled over the previous three years, due to fewer and smaller freshes being sampled in the 2018-2019 year. The range of river flows sampled was narrower, with lower maximum (of 13.5 m^3/s), and minimum (1.48 m^3/s) flows sampled.

Median black disc clarity was significantly higher (by 0.38 m, or 146%) and median turbidity was lower (by 25 NTU, or 69%) in the more recent period, while the median suspended solids concentrations was lower by 38 g/m^3, or 83%.

For nitrogen nutrient species, median concentration of nitrate was significantly higher (by 29%), while ammoniacal and total nitrogen were slightly higher (by 12% and 5%, respectively) in the later period. Dissolved reactive phosphorus was slightly lower, while total phosphorus was significantly higher (by 6 and 39%), compared to the medians for the previous three-year period. Median bacterial numbers reduced markedly for enterococci (by 135 cfu/100 mL) and faecal colif6orms (by 290 cfu/100 mL) in the 2018-2019 period.

Median dissolved oxygen saturation level was relatively similar (2% higher) in the 2018-2019 period while median pH level was 0.1 unit higher during the more recent period. Maximum pH was 0.2 unit lower and minimum pH was 0.3 unit higher.

The range of water temperatures was narrower (by 3.1°C) in the later twelve-month period than over the previous three-year period due to a lower maximum temperature (by 0.2˚C) and lower minimum temperature (by 2,9˚C) in the 2018-2019 sampling year, while median water temperature was 0.8˚C higher during 2018-2019.

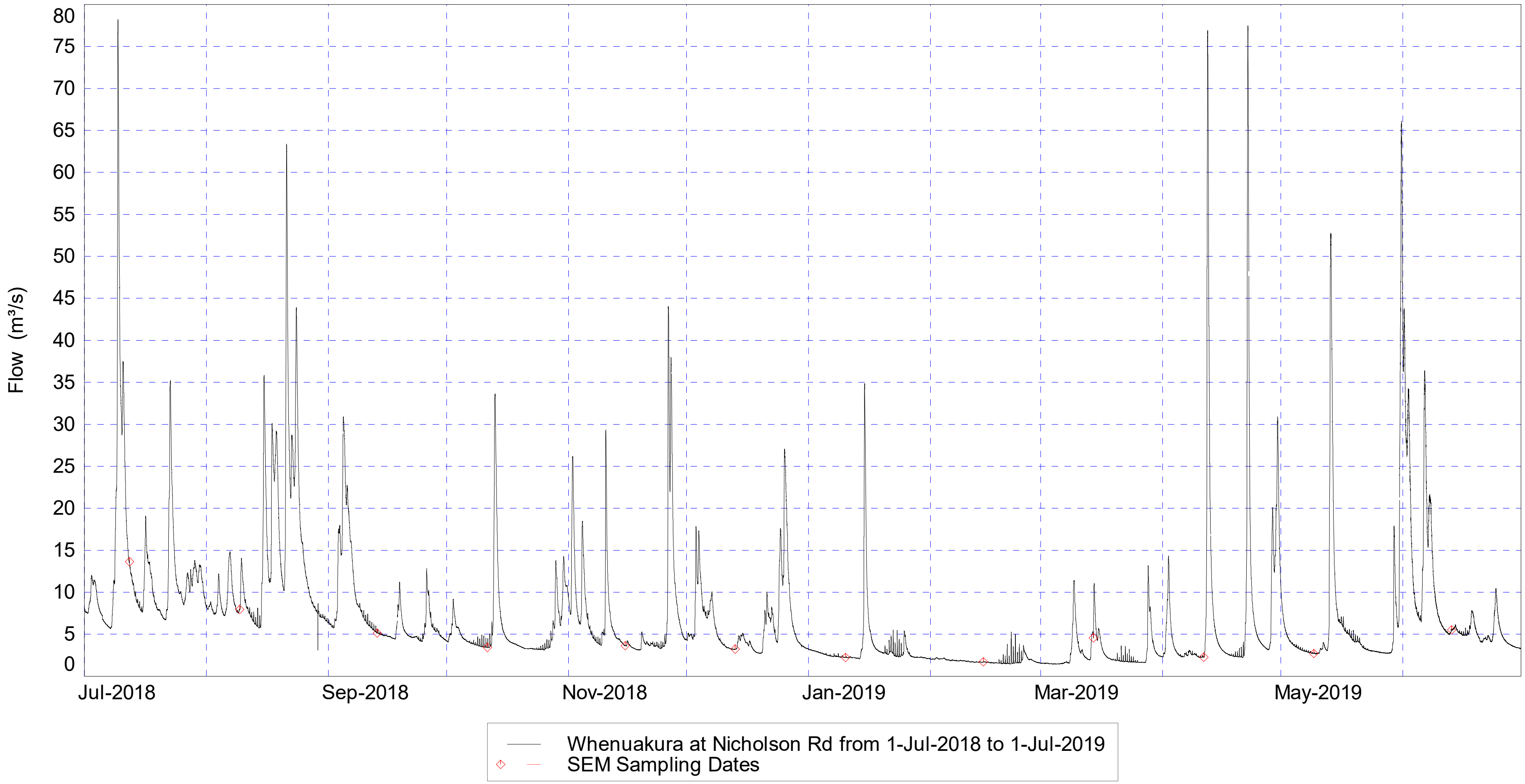


Figure 8 Flow record for the Whenuakura River at Nicholson Road

Waitara River at Tarata

Analytical data are presented in Table 39 from the monthly sampling programme. The flow record for the period is illustrated in Figure 9.

Table 39 Analytical results from monthly samples: Waitara River at Tarata

Date	Time	A340F	A440F	A770F	ALKT	Black disc	BOD_5	Cond @ 25°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
12 Jul 2018	1345	0.039	0.011	<0.002	16.8	0.14	<0.4	7.7	11.2	97	0.0021	140	25
09 Aug 2018	1335	0.052	0.012	<0.002	20	0.24	0.6	8.1	10.7	98	0.0011	330	130
13 Sep 2018	1330	0.037	0.008	<0.002	32	1.50	<0.4	10.3	10.8	99	0.0025	10	10
11 Oct 2018	1235	0.047	0.009	<0.002	37	1.46	0.6	11.4	10.3	101	0.0039	10	71
15 Nov 2018	1240	0.046	0.009	<0.002	28	0.95	<0.4	9.5	9.3	98	0.0030	140	20
13 Dec 2018	1230	0.055	0.009	<0.002	35	0.88	0.5	11.1	9.0	101	0.0029	60	12
10 Jan 2019	1300	0.050	0.009	<0.002	51	0.85	1.4	13.8	8.7	104	0.0017	60	19
14 Feb 2019	1230	0.040	0.007	<0.002	58	1.37	1.1	15.7	8.2	98	<0.0010	60	20
14 Mar 2019	1230	0.122	0.032	<0.003	16	0.02	2.1	11.2	8.3	87	0.0051	14000	3800
11 Apr 2019	1315	0.067	0.015	0.002	36	0.38	1.4	12.2	9.8	98	0.0053	2900	4700
09 May 2019	1325	0.040	0.008	0.002	34	0.9	0.6	11.3	10.5	99	0.0025	80	30
13 Jun 2019	1320	0.033	0.007	<0.002	26	0.8	<0.4	10.1	10.7	100	0.0035	220	50

Date	Time NZST	FC	Flow	NH_4	NO_2	NO_3	pH	SS	Temp	TKN	TN	TP	Turb
		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
12 Jul 2018	1345	150	53.933	0.011	0.0016	0.44	7.8	86	9.4	0.32	0.64	0.070	51
09 Aug 2018	1335	340	61.090	<0.005	0.0024	0.27	7.0	67	10.7	0.33	0.48	0.074	44
13 Sep 2018	1330	30	14.368	0.006	0.0023	0.32	7.8	5	11.6	0.10	0.38	0.015	5.4
11 Oct 2018	1235	20	8.520	0.007	0.0023	0.120	7.8	4	13.9	0.19	0.35	0.020	4.6
15 Nov 2018	1240	140	16.403	0.006	0.0022	0.18	7.5	7	18.1	0.19	0.35	0.019	7.8
13 Dec 2018	1230	60	11.758	0.009	0.0026	0.12	7.5	7	20.4	0.27	0.28	0.022	7.8
10 Jan 2019	1300	60	4.989	<0.005	0.0022	0.02	8.0	7	24.0	0.27	0.27	0.018	6.7
14 Feb 2019	1230	60	3.139	<0.005	<0.0010	<0.01	8.0	<3	23.8	0.22	0.19	0.010	2.0
14 Mar 2019	1230	19000	79.166	0.052	0.0043	0.23	7.6	720	17.9	0.62	0.88	0.63	1030
11 Apr 2019	1315	3700	5.107	0.014	0.0032	0.18	7.4	28	14.6	0.28	0.49	0.051	17.4
09 May 2019	1325	110	8.26	0.015	0.0026	0.28	7.5	4	12.7	0.15	0.43	0.016	4.9
13 Jun 2019	1320	240	21.272	0.012	<0.002	0.29	7.4	7	11.2	0.26	0.42	0.012	6.5

A statistical summary of these data is presented in Table 40.

Table 40 Statistical summary of data from July 2018 to June 2019: Waitara River at Tarata

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.033	0.122	0.046	12	0.024
A440F	Absorbance @ 440nm filtered	/cm	0.007	0.032	0.009	12	0.007
A770F	Absorbance @ 770nm filtered	/cm	<0.002	0.003	<0.002	12	0
ALKT	Alkalinity Total	g/m³ $CaCO_3$	16	58	33	12	13
BDISC	Black disc transparency	m	0.02	1.50	0.86	12	0.51
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	2.1	0.6	12	0.6
COND	Conductivity @ 25˚C	mS/m	7.7	15.7	11.1	12	2.2
DO	Dissolved oxygen	g/m³	8.2	11.2	10.1	12	1.1
PERSAT	Dissolved oxygen saturation %	%	87	104	98	12	4
DRP	Dissolved reactive phosphorus	g/m³P	0.001	0.005	0.003	12	0.001
ECOL	E.coli bacteria	nos/100 mL	10	14000	110	12	4018
ENT	Enterococci bacteria	nos/100 mL	<10	4700	28	12	1651
FC	Faecal coliforms	nos/100 mL	20	19000	125	12	5455
FLOW	Flow	m³/s	3.139	79.166	13.063	12	25.697
NH_4	Ammoniacal nitrogen	g/m³N	<0.005	0.052	0.008	12	0.013
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.004	0.002	12	0.001
NO_3	Nitrate nitrogen	g/m³N	<0.01	0.44	0.21	12	0.125
pH	pH		7	8	7.6	12	0.3
SS	Suspended solids	g/m³	<3	720	7	12	204
TEMP	Temperature	°C	9.4	24	14.2	12	5.1
TKN	Total kjeldahl nitrogen	g/m³N	0.1	0.62	0.26	12	0.13
TN	Total nitrogen	g/m³N	0.19	0.88	0.40	12	0.184
TP	Total phosphorus	g/m³P	0.010	0.63	0.020	12	0.175
TURBY	Turbidity	NTU	2	1030	7.25	12	293.63

A statistical summary of the four years' data collected since 1 July 2015 is presented in Table 41.

Table 41 Statistical summary of data from July 2015 to June 2019: Waitara River at Tarata

Parameter		Unit	Min	Max	Median	N	Std Dev
A340F	Absorbance @ 340nm filtered	/cm	0.026	0.122	0.052	48	0.022
A440F	Absorbance @ 440nm filtered	/cm	0.006	0.032	0.011	48	0.006
A770F	Absorbance @ 770nm filtered	/cm	0.000	0.004	0.001	48	0.001
ALKT	Alkalinity Total	g/m³ $CaCO_3$	11	58	29	48	10
BDISC	Black disc transparency	m	0.02	1.50	0.37	48	0.44
BOD_5	Biochemical oxygen demand 5day	g/m³	<0.4	2.2	0.6	48	0.4
COND	Conductivity @ 25˚C	mS/m	4.7	15.7	9.9	48	2.1
DO	Dissolved oxygen	g/m³	7.9	11.8	9.8	48	1.0
PERSAT	Dissolved oxygen saturation %	%	87	104	98	48	3
DRP	Dissolved reactive phosphorus	g/m³P	<0.003	0.115	0.007	48	0.016
ECOL	E.coli bacteria	nos/100 mL	10	14000	295	48	2792
ENT	Enterococci bacteria	nos/100 mL	6	4700	64	48	922
FC	Faecal coliforms	nos/100 mL	20	19000	305	48	3415
FLOW	Flow	m³/s	3.139	271.437	21.331	48	43.488
NH_4	Ammoniacal nitrogen	g/m³N	<0.003	0.073	0.017	48	0.014
NO_2	Nitrite nitrogen	g/m³N	<0.001	0.005	0.002	48	0.001
NO_3	Nitrate nitrogen	g/m³N	0.009	0.488	0.188	48	0.119
pH	pH		7.0	8.0	7.4	48	0.2
SS	Suspended solids	g/m³	2	1200	18	48	290
TEMP	Temperature	°C	7.5	24.5	14.9	48	4.9
TKN	Total kjeldahl nitrogen	g/m³N	0.04	9.81	0.21	48	1.39
TN	Total nitrogen	g/m³N	0.09	10.2	0.42	48	1.42
TP	Total phosphorus	g/m³P	0.010	1.52	0.046	48	0.256
TURBY	Turbidity (Cyberscan WTW)	NTU	3.7	900	22	36	206

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 IV.

Discussion

2018-2019 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 0.86 metres with a maximum of 1.50 metres measured during a recession low flow period in September 2018. Clarity was infrequently more than 1.0 metres (on three occasions) due to the presence of very fine, colloidal, suspended particles. The median suspended solids concentration was 7 g/m^3. Absorbances (at 340 and 440 nm) were also relatively high (medians of 0.046/cm and 0.009/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 (0.02 m black disc value) was coincident with a turbidity level of 1030 NTU and suspended solids concentration of 720 g/m^3, during a flood flow of 79m^3/s recorded in March 2019. Fresh flows (in excess of 50 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 and August 2018, and March 2019 (Figure 9). The initial, rising stage of a fresh in April 2019 also showed such deterioration.

Maximum mid-afternoon pH value in mid-late summer (8.0 units) was 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 2018.

Dissolved oxygen concentrations, were generally high (median of 10.1 g/m^3) and slightly below saturation with a median saturation level of 98%, with a minimum level of 87% measured during a flood in March 2019. BOD_5 concentrations were indicative of relatively low organic content (i.e. less than 1.0 g/m^3), with a low level of organic enrichment between January and April 2019 during the lowest flows sampled and the March flood. Moderate median bacteriological numbers (115 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 14.6˚C with a maximum (early afternoon) summer temperature of 24.0˚C recorded in January 2019 under low flow conditions, at which time dissolved oxygen saturation was 104% and pH was 8.0 units.

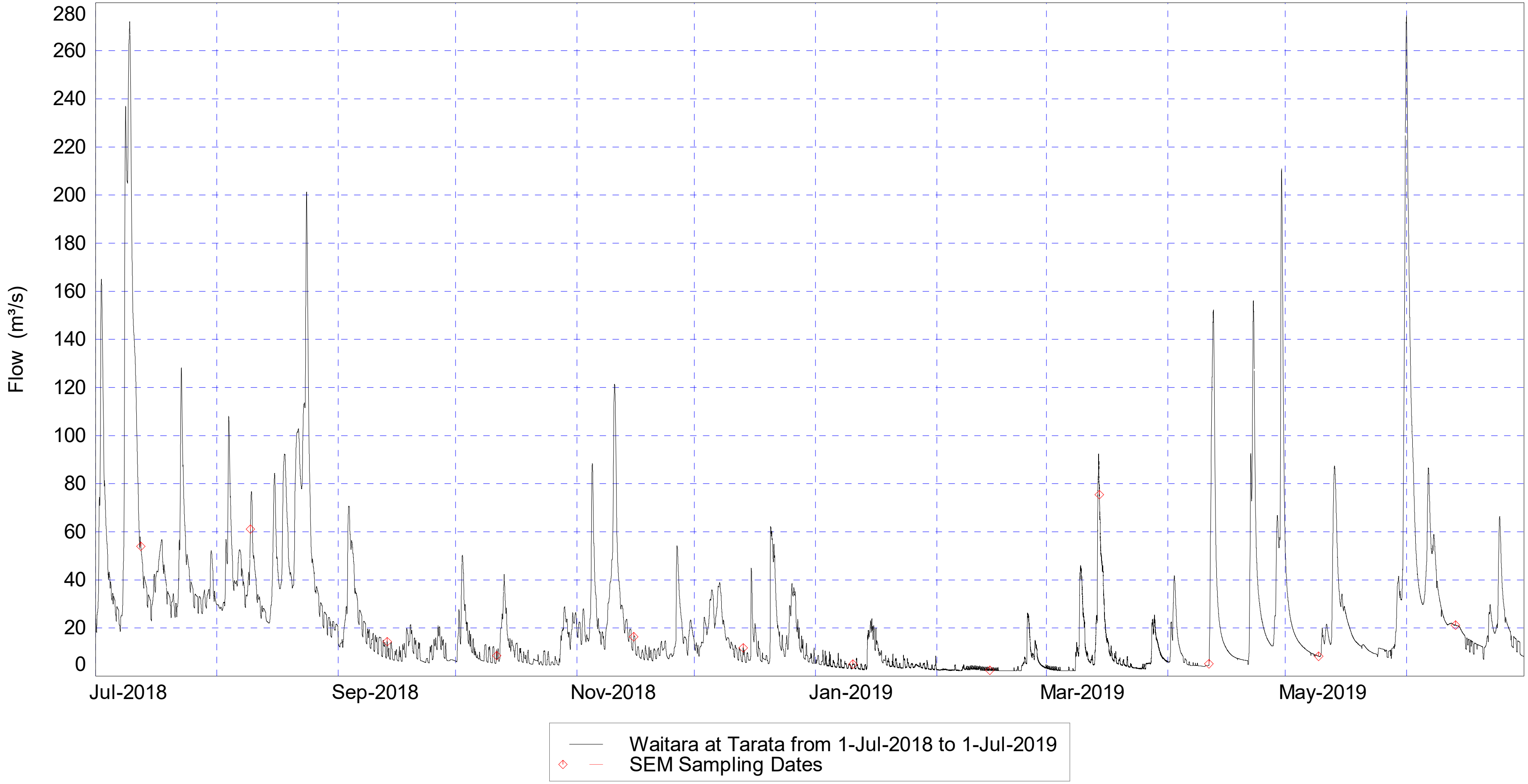


Figure 9 Flow record for the Waitara River at Tarata

Brief comparison with the previous 2015-2018 period

The median of sampled flows in the recent twelve-month period was significantly lower (by 12,524 L/s, or 49%) than flows sampled over the previous three years, due to fewer and smaller freshes being sampled in the 2018-2019 year. The range of river flows sampled was narrower in 2018-2019, due to both lower maximum (79.2 m^3/s) and minimum (3.14 m^3/s) flows. The relatively low number of fresh flows sampled were usually coincident with a general deterioration in water quality, as emphasised by elevated turbidity, suspended solids, all nutrient species (particularly total phosphorus) and bacterial counts.

Median black disc clarity was significantly higher (by 0.54 m, or 169%) and median turbidity was lower (by 15 NTU, or 67%) in the more recent period, while the median suspended solids concentrations was lower by 13 g/m^3, or 65%.

For nitrogen nutrient species, median concentrations of nitrate was higher (by 18%), and median concentrations of ammoniacal and total nitrogen lower (by 56 and 9%, respectively) in the later period, while dissolved reactive and total phosphorus were lower (by 62 and 39%) compared to the medians for the previous three-year period, though there is some question as to the influence of a change in laboratory test methodology on the phosphorus species concentrations reported for Waitara River at Autawa Road in 2018-2019. Median bacterial numbers decreased for enterococci (by 56 cfu/100 mL) and for faecal coliforms (by 245 cfu/100 mL) in the 2018-2019 period.

Median dissolved oxygen saturation level was relatively similar (1% lower) in the 2018-2019 period while median pH level was the same for the two periods. Maximum pH was 0.2 unit higher and minimum pH was the same in comparison with the respective previously recorded values.

The range of water temperatures was narrower (by 2.4°C) in the later twelve-month period due to a lower maximum temperature (by 0.5˚C) and higher minimum temperature (by 1.9˚C) in the 2018-2019 sampling year, while median water temperature was 1.0˚C lower during 2018-2019.

4.2 Comparative water quality for the twenty four-year (1995-2019) period

4.2.1 TRC data

In addition to the site descriptions of water quality measured during the 2018-2019 monthly sampling programme, a general comparison between the thirteen sites of the Council's programme and also including the two NIWA sites may be made for the 24-year sampling period to date (1995-2019) 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, 35, 38 and 41. Comparative statistics for selected parameters are provided in Table 42 and in the form of the 'box and whisker' plots of Appendix IV.

These site comparisons for the summary data over the 24 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 (39 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 (33 NTU, over four years) 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 (3.2 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 1.2 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 24 year period.

Table 42 Some comparative water quality data for the thirteen TRC SEM sites for the twenty four-year period July 1995 to June 2019 (n = 48 to 288 samples)

Site Unit	Black disc m		BOD_5 g/m^3	Conductivity @ 25°C mS/m	Faecal coliform bacteria cfu/100mL		Nutrients: Ammonia g/m^3N	Nutrients: Nitrate g/m^3N	Nutrients: Total N g/m^3N	Nutrients: DRP g/m^3P	Nutrients: Total P g/m^3P	pH		Dissolved oxygen saturation %			Suspended solids g/m^3	Temperature °C			Turbidity NTU
	Maximum	Median	Median	Median	Minimum	Median	Median	Median	Median	Median	Median	Maximum	Median	Min	Med	Range	Median	Maximum	Median	Range	Median
Maketawa Stream at Tarata Road*	5.23	2.61	<0.5	9.6	50	335	0.010	0.27	0.40	0.025	0.036	8.0	7.6	90	99	13	<2	19.1	11.6	14.3	1.2
Mangaoraka Stream at Corbett Road	4.73	1.85	0.7	16.1	84	800	0.021	0.84	1.08	0.009	0.023	8.1	7.6	83	97	24	2	20.5	13.2	14.7	2.1
Waiwhakaiho River at SH3	8.05	3.08	<0.5	13.4	23	220	0.007	0.11	0.20	0.025	0.035	8.5	7.9	91	101	19	<2	18.3	11.2	13.5	0.7
Stony River at Mangatete Road	13.12	3.10	<0.5	10.7	<1	8	<0.003	0.02	0.06	0.018	0.025	8.2	7.8	87	100	19	<2	16.6	10.9	10.9	1.6
Punehu Stream at Wiremu Road	4.53	1.79	<0.5	9.6	3	115	0.007	0.03	0.15	0.022	0.033	8.3	7.6	87	100	19	<2	19.2	11.9	14.2	2.4
Punehu Stream at SH45	3.65	1.50	0.9	17.7	51	565	0.038	0.96	1.40	0.043	0.077	8.6	7.7	90	100	24	3	21.0	13.4	16.0	2.3
Waingongoro River at Eltham Road	4.39	1.71	0.7	12.3	6	205	0.017	1.13	1.45	0.020	0.040	8.6	7.8	92	103	29	3	21.5	12.7	15.9	2.0
Waingongoro River at SH45 **	4.34	1.21	1.0	18.0	3	225	0.032	1.67	2.39	0.052	0.090	9.1	7.8	89	102	52	5	22.0	13.9	16.6	3.2
Patea River at Barclay Road	10.14	4.33	<0.5	6.8	<1	23	<0.003	0.02	0.07	0.019	0.025	8.0	7.5	90	99	13	<2	14.9	9.4	11.2	0.6
Patea River at Skinner Road	4.68	1.83	1.0	10.9	2	240	0.052	0.91	1.21	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	11.0	6	230	0.012	0.10	0.30	0.006	0.020	8.4	7.7	83	100	35	4	24.9	13.9	20.6	4.4
Whenuakura River at Nicholson Road***	1.32	0.30	0.8	20.7	23	440	0.025	0.41	0.68	0.017	0.074	8.1	7.6	88	96	20	39	21.9	13.8	15.8	33
Waitara River at Tarata***	1.50	0.37	0.6	9.9	20	305	0.017	0.19	0.42	0.007	0.046	8.0	7.4	87	98	17	18	24.5	14.9	17.0	19

[Notes: * for the period July 2003 to June 2019 (n = 192 samples);
** for the period July 1998 to June 2019 (n = 252 samples);
*** for the period July 2015 to June 2019 (n = 48 samples)
Turbidity is for the period June 2005 to June 2018, except July.2015 to June 2019 at Whenuakura and Waitara rivers sites]

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 (9.4˚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 exhibit five of the six highest medians (13.9˚C, 13.8°C, 13.9˚C, 13.4˚C, 14.9°C and 12.9˚C, respectively) and the widest ranges (20.6˚C, 15.8°C, 16.6˚C, 16.0˚C, 17.0°C and 17.0˚C, respectively) of water temperatures. Atypically, relatively high median (11.9˚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 in the ring plain rivers and streams, and from 7.4 to 7.7 in eastern hill-country rivers. (Note: diurnal temperature and pH variability is limited by the sampling regime for each site – see Note in the section 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. ≤18.0 mS/m at 25°C, except the new site in the lower reaches of the Whenuakura River, at 20.7 mS/m at 25°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 96% saturation or higher at all sites. Summer-autumn lower flow conditions, coincident with more extensive algal substrate cover, resulted in supersaturation on occasions at various sites in the mid to lower reaches of streams and rivers. The narrowest saturation ranges (≤17%) 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 Waingongoro River (1.0 g/m^3), Punehu Stream (0.9 g/m^3) and Whenuakura River (0.8 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. This is consistent with the non-point-source run-off and point-source discharges that are present through each ring plain catchment. As an example, increases in median total nitrogen and total phosphorus levels of 1.25 and 0.044 g/m3, respectively, were recorded over the length of the Punehu Stream. Similarly, increases of 1.14 and 0.041 g/m3 have been recorded between the upper and the mid reaches of the Patea River, while 0.94 and 0.05 g/m3 increases have been recorded in total nitrogen and total phosphorous, 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^3P) in the Mangaoraka Stream reflect the source of this ring plain stream which rises outside of the National Park, compared with the documented natural sources of dissolved phosphorus from within the Park found in ring plain rivers and streams (TCC, 1984 and TRC, 2010). Relatively low dissolved reactive phosphorus (median of <0.01 g/m^3P) 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 0.074 g/m^3P) relate to the high sediment loads carried during the first four years of monitoring.

Bacteria

Poor bacteriological water quality (median faecal coliform numbers from 225 to 800 per 100 mL) 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 205 to 370 per 100 mL) in the mid reaches of the Waiwhakaiho, Waingongoro, Patea and Waitara 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 sites' (Mangaoraka Stream) counts have continuously exceeded 80 faecal coliforms cfu/100 mL, indicative of consistently poor bacteriological quality.

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 23 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 115 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 24 years of data for the two Taranaki region sites included in the NIWA national network (see Figure 1) is presented in Table 43. (A third site, Waingongoro River at SH45, was monitored until November 2015. Refer to TRC 2015 for a summary of comparative data from this site). The Manganui River system draining from Mt Taranaki is a sub-catchment of the Waitara River basin, and thus provides an 'upstream' comparison with the Bertrand Rd site on the lower Waitara River. The Waitara River itself flows from the highly erodible eastern hill country.

Table 43 Some comparative water quality data for the two NIWA SEM sites for the 24-year period July 1995 to June 2019 (n = 287 samples)

Site Unit	Black disc (m)		BOD_5 (g/m^3)	Conductivity @ 25°C (mS/m)	Nutrients					pH		Dissolved oxygen saturation %	Temperature (°C)			Turbidity (NTU)	Flow (m^3/sec)
					Amm-N (g/m^3N)	Nitrate (g/m^3N)	Total N (g/m^3N)	DRP (g/m^3P)	TP (g/m^3P)								
	Maximum	Median	Median	Median	Median	Median	Median	Median	Median	Maximum	Median	Median	Maximum	Median	Range	Median	Median
Waitara River at Bertrand Road	3.2	0.44	0.7	9.7	0.012	0.31	0.58	0.006	0.037	8.6	7.7	102	24.8	13.8	18.3	9.8	29.5
Manganui River at SH3	7.7	3.9	<0.5	7.0	0.006	0.09	0.18	0.009	0.015	8.0	7.5	100	18.7	10.6	14.6	1.0	0.91

These data indicate more turbid (cloudier) appearance in the lower reach of the Waitara River (median black disc clarity of 0.44 metres and turbidity of 9.8 NTU) with very clear conditions toward the upper reach of the Manganui River. Lower Waitara River median clarity was the third to 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. (Lower clarities are noted in the Mangaehu and Whenuakura Rivers (Table 42), which drain entirely from the eastern hill country). Median water temperatures were typical of those found at comparable sites elsewhere in the region (Table 42 and Table 43), 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 four-year (1995-2019) period

The 24 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 44.

Table 44 Comparison of 1995-2019 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/m³ N•	<1000/ 100mL	Median <100/100 mL	>0.8m	>80%	<0.4 g/m³N	<0.9 g/m³N	<25 °C	<25 g/m³N	<0.8 g/m³ P	<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	✓	✓	x	x	✓✓*	✓	✓✓	✓✓	✓✓	✓	✓✓
Manganui River at SH 3	✓	✓✓	✓	✓✓	✓	✓	✓	✓	✓	✓	✓✓*	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Waitara River at Bertrand Road	x	✓✓	✓	✓✓	✓	x	✓	✓	x	x	✓✓*	✓	✓✓	✓✓	✓✓	✓	✓✓
Summary of sites (15) in compliance	9	15	14	15	12	5	9	15	3	12	15	9	14	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 2019 (n = 48 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 for monitoring recreational bathing, 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, 2019), and on the Council's website (www.trc.govt.nz). However, the sites' data presented in Table 44 are indicative of bacteriological conditions likely to exist at contact recreational sites in the vicinity of the reaches of the streams/rivers monitored, from a year-round, all-flows perspective. The Government's NOF standards apply to data gathered all year round, and are applied to the SEM data further in section 4.2.4.2 below.

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, 2019) occasionally under spring-summer low flow conditions (refer to individual tables of 2018-2019 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 44). This is true particularly of total nitrogen and total phosphorus species which generally increased in concentration downstream. Dissolved reactive phosphorus levels were more variable with levels decreasing or remaining relatively stable downstream of the National Park boundary (where dissolved reactive phosphorus is present from natural sources).

The Council has a separate SEM programme that focuses specifically on nuisance growths at various freshwater indicator locations in the region (TRC, 2006b and TRC, 2018). 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 three of the nine sites shown in Table 44 as otherwise exceeding the bacteriological guidelines, the 25th percentile result (see Appendix IV) satisfies the criterion. All sites complied with the nitrate-N guideline.

4.2.3.5 Aquatic ecosystems

While all sites complied with the ammoniacal nitrogen 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 communities where monitoring has taken place for more than 10 years has illustrated significant deterioration, while seven (one upper, three middle and three lower reach) of the 11 sites in the physicochemical programmes have shown significant improvements in stream 'health' trends over the 24 years (1995 to 2018) to date (TRC, 2006c, Stark and Fowles, 2006 and TRC, 2019a).

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-FM)' 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) that specifies nationally applicable standards for particular water quality parameters, 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 of NOF values called 'A Draft Guide to Attributes – in Appendix 2 of the NPS-FM, 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 recreation. For ecosystem health, the NPS-FM specifies attributes to manage long-term exposure to two toxicants, nitrate (NO_3N) and ammoniacal nitrogen (NH_4N). *E. coli* is the attribute used for specifying 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).

For nitrate and ammoniacal nitrogen attributes, 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).

In March 2018, MfE published an updated document: 'A Draft Guide to Attributes in Appendix 2 of the NPS-FM 2014 (as amended 2017)' focussing on new attribute state recommendations for *E. coli* and planktonic cyanobacteria. A background document for the proposed new changes to *E. coli* was produced earlier (December 2017), titled 'A Draft Guide to Swimming, E. coli and National Targets under the NPS-FM 2014 (as amended 2017)', which provided an overview of 'primary contact' objectives, policies, approach to monitoring and reporting for regional councils to follow.

A major change for *E. coli* was presented, with five attribute states A, B, C, D and E (previously four: A, B, C and D) and four criteria or 'statistical tests' to satisfy each attribute state. The overall grading to be assigned to a river is to be the worst of the four. The rigorous criteria were developed to determine the infection risk profiles relating to *E. coli* levels and the proportion of population at risk of *Campylobacter* infection for activities likely to involve full immersion such as swimming or white water rafting (McBride, 2014; Ministry for the Environment and Ministry of Health, 2003). Additionally, the attribute state for *E. coli* is determined by using a minimum of 60 samples over a maximum of five years, collected on a regular basis regardless of weather and flow condition.

Thus, there are now five grades, but no 'bottom line', for *E coli*. The Government has stated that, as a whole, 80% of the country's waterways should be within the top 3 categories by 2030, and 90% by 2040. It should be noted that these percentages do not necessarily apply at the regional level. For the purpose of comparisons, this report uses the five-step categories, with rivers in either of the bottom two categories being deemed unacceptable for recreational purposes.

The following sections present the results of the NOF analysis at 13 sites monitored as part of the Taranaki physico-chemical programme. This includes Whenuakura River at Nicholson Road and Waitara River at Autawa Road, that were added to the programme in July 2015 (48 samples were collected and available for the analysis). Two of NIWA's national monitoring sites were also included in the analysis, i.e., Waitara River and Bertrand Road and Manganui River at State Highway 3.

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 (Figure 10, Table 45). Almost three-quarters of the sites (73%) achieved ‘A’ grade for both attributes in terms of their annual medians.

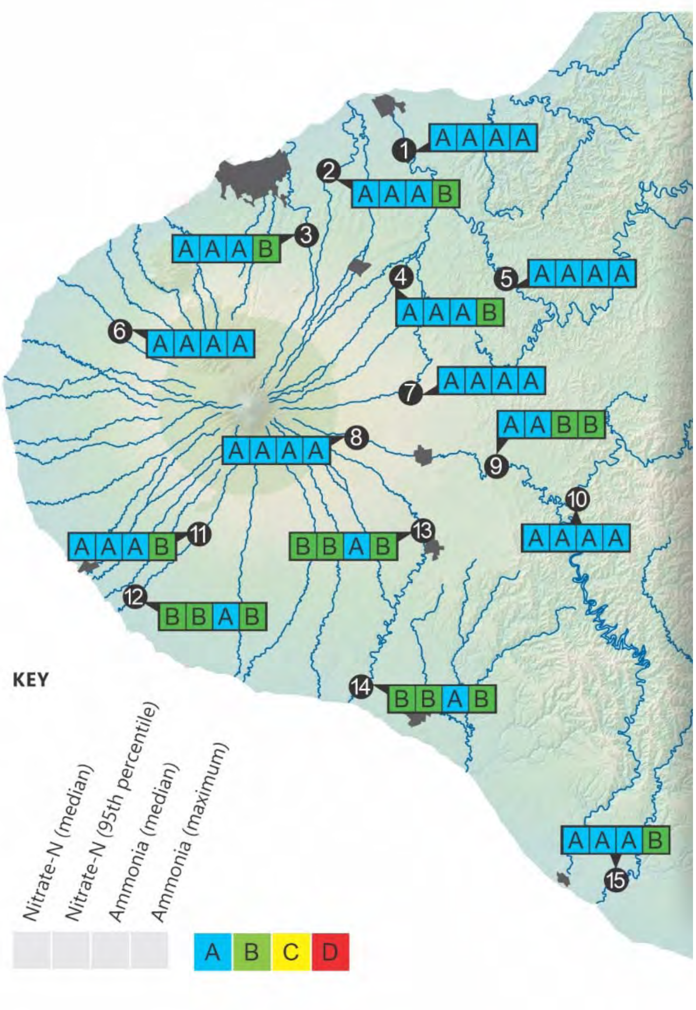


Figure 10 NOF results for ecosystem health at 13 SEM sites and two NIWA sites in Taranaki

Table 45 Summary result for water quality data from 2016-2019 for ecosystem health (n=36 samples).

Site No	Value	Ecosystem health			
	Attribute	Nitrate-N (g/m^{3})		Ammoniacal-N	
		Annual median	Annual 95th percentile	Annual median	Annual maximum
1	Waitara River at Bertrand Rd	A	A	A	A
2	Mangaoraka Stream at Corbett Rd	A	A	A	B
3	Waiwhakaiho River at SH3	A	A	A	B
4	Maketawa Stream at Tarata Rd	A	A	A	B
5	Waitara River at Autawa Rd	A	A	A	A
6	Stony River at Mangatete Rd	A	A	A	A
7	Manganui River at SH3	A	A	A	A
8	Patea River at Barclay Rd	A	A	A	A
9	Patea River at Skinner Rd	A	A	B	B
10	Mangaehu River at Raupuha Rd	A	A	A	A
11	Punehu Stream at Wiremu Rd	A	A	A	B
12	Punehu Stream at SH45	B	B	A	B
13	Waingongoro River at Eltham Rd	B	B	A	B
14	Waingongoro River at SH45	B	B	A	B
15	Whenuakura River at Nicholson Rd	A	A	A	B

4.2.4.2 Human health

The definition of primary contact sites in the Freshwater NPS is:

a. Any part of specified river or lake that a regional council considers is used, or would be used but for existing freshwater quality, for primary contact; and
b. Any other site in any other river or lake that regional council has determined should be managed for primary contact.

According to the updated Draft Guide to Attributes (as amended 2017), the *E. coli* attribute describes different statistical measures of the distribution of *E. coli* concentrations, and the associated risk of *Campylobacter* infection through ingestion of water during recreation activities (McBride, 2012; Ministry for the Environment and Ministry of Health, 2003). The four individual statistical measures are:

- Percentage of exceedances greater than 540 cfu/100 mL: this measure indicates how often the level of *E. coli* exceeds the acceptable threshold for swimming
- Percentage of exceedances greater than 260 cfu/100 mL: This measure indicates how often the level of *E. coli* exceeds the point where additional monitoring is required
- Median: the mid-point of *E. coli* levels
- 95th percentile: an indication of the top range of *E. coli* levels within the distribution.

All four criteria are necessary to establish an attribute state. If one or more criteria can't be satisfied, a lower attribute state must apply. Higher attribute states provide lower levels of infection risk for each activity type.

Overall, two sites (13%) met all four of the new NOF standards set for *E. coli* (Figure 11, Table 46), if compliance is assumed to require at least a 'C' grade. The sites located in the upper river catchments showed better results compared to the sites in the middle and lower catchments, i.e. Patea River at Barclay Road and Stony River at Mangatete Road (grade A).

The majority of the sites (87%) received 'D' grade for the 95th percentile criterion, and hence fail to satisfy the Government's target.

Four sites met the requirement of acceptable threshold for swimming (less than 20% of the time recording exceedances greater than 540 cfu/100 mL), the national threshold applied within the summer recreational bathing survey. However, it is important to note that 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.

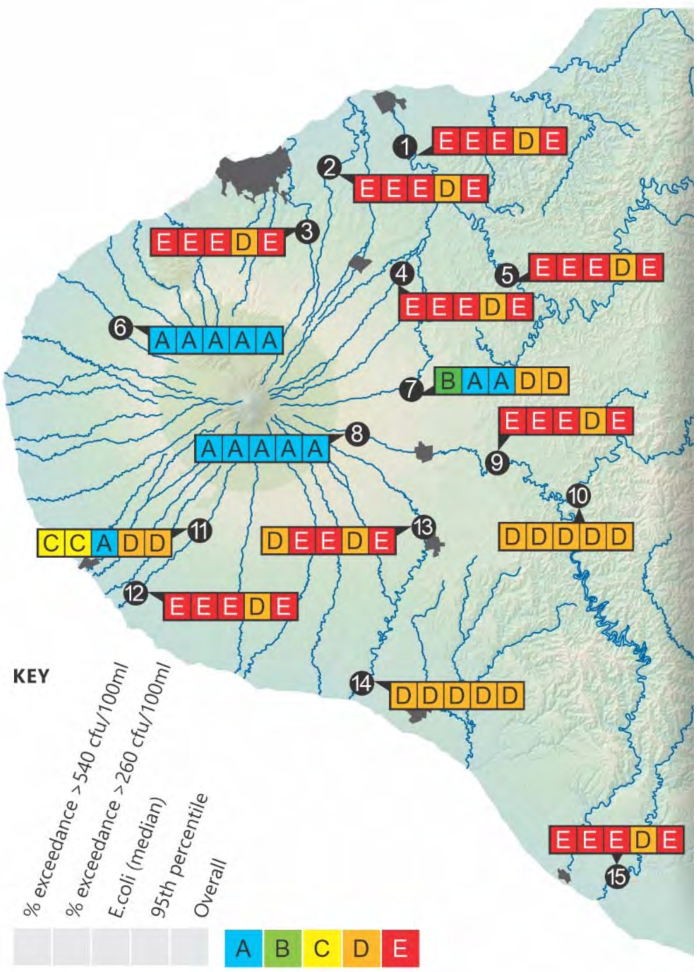


Figure 11 NOF results for human health for recreation at 13 SEM sites and two NIWA sites in Taranaki

Table 46 Results for NOF attribute states for 13 SEM and two NIWA sites in Taranaki

Site No	Value / Attribute	Human health for recreation: Escherichia coli (*E.coli*/100mL) % exceedances over 540 cfu/100 mL	% exceedances over 260 cfu/100 mL	Median concentration cfu/100 mL	95th percentile of *E. coli*/100 mL	Overall
1	Waitara River at Bertrand Rd	E	E	E	D	E
2	Mangaoraka Stream at Corbett Rd	E	E	E	D	E
3	Waiwhakaiho River at SH3	E	E	E	D	E
4	Maketawa Stream at Tarata Rd	E	E	E	D	E
5	Waitara River at Autawa Rd	E	E	E	D	E
6	Stony River at Mangatete Rd	A	A	A	A	A
7	Manganui River at SH3	B	A	A	D	D
8	Patea River at Barclay Rd	B	A	A	A	A
9	Patea River at Skinner Rd	E	E	E	D	E
10	Mangaehu River at Raupuha Rd	D	D	D	D	D
11	Punehu Stream at Wiremu Rd	C	C	A	D	D
12	Punehu Stream at SH45	E	E	E	D	E
13	Waingongoro River at Eltham Rd	D	E	E	D	E
14	Waingongoro River at SH45	D	D	D	D	D
15	Whenuakura River at Nicholson Rd	E	E	E	D	E

4.3 Trends in physicochemical water quality data from 1995 to 2019

4.3.1 Introduction

Twenty four years of physicochemical water quality data have been collected up to 30 June 2019. 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, 2015, 2015a, 2016, 2017 and 2018).

An update of the trends including data from the 2018-2019 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

[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.

value of flow (adjusted value = raw value – smoothed value + median value (where the smoothed value is that predicted from the flow using LOWESS)).

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

This analysis is based on two key measures:

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

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

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

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

4.3.3 Results of long term trend analysis

Table 47 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 (i.e. concentrations are increasing) at a number of sites in the middle and lower catchments, which would be more subject to anthropogenic pressures. Five and three out of eleven sites have shown a significant deterioration in DRP and total phosphorus, respectively; another two sites come close to the significant trend definition for deterioration in dissolved phosphorus, and two for total phosphorus. On the other hand, the lower Waingongoro River site shows significant reductions in both forms of phosphorus, and another site comes close to the significant trend definition for improvement.

Total nitrogen improved significantly at three of the eleven sites monitored, deteriorated significantly at one site, and otherwise generally showed no significant trend. The improvements are in the upper (Patea River at Barclay Road and Punehu Stream at Wiremu Road), and middle (Stony River at Mangatete Road) catchment, and the deterioration in the lower (Punehu at SH45) catchment. Nitrate showed significant deteriorating trends at three of the eleven sites, in the upper-middle (Punehu Stream at Wiremu Road), middle (Waiwhakaiho at SH3) and lower (Punehu Stream at SH45) catchments where more land use intensification occurs. While ammoniacal nitrogen showed generally stable trends throughout all catchment levels, with the exception of the Punehu Stream at Wiremu Road (upper catchment), Maketawa Stream at Tarata Road, and Waiwhakaiho River at SH3 (both mid catchment), where significant trends of deterioration are apparent.

Generally, mid catchment and lower catchment sites appear to be showing the most deterioration in nutrients. 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, Waiwhakaiho River at SH3 and Maketawa at Tarata Road have the greatest number of deteriorating trends in relation to nutrients (three of five nutrients). All other sites had 2 or less of 5 nutrients increasing (Table 47).

The Waingongoro River at SH45 is showing a very significant improving trend in dissolved reactive phosphorus and total phosphorus (Figure 12), with two other parameters, nitrate and total nitrogen, improving at slightly less than the rate defined as a significant trend. It is probable that this is due to the reduction in meatworks' discharges to the river at Eltham (between 2001 and 2008) and the elimination of all Eltham WWTP municipal discharges in the catchment (since mid-2010). However, a significant increasing trend was detected for BOD at this site.

Faecal coliforms and enterococci bacteria generally showed little statistically significant change over the 24 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 a significant increase for enterococci), and in enterococci at Punehu Stream at SH45 (but not for faecal coliforms). One site showed significant improvement in faecal coliforms: Punehu Stream at Wiremu Road, an upper catchment site.

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 24 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 indicates periods of erosion and recovery over time. Deterioration in clarity has also been significant at the Mangaoraka Stream (Corbett Road), where steady declines throughout the period are apparent (Figure 12), with Waiwhakaiho River (SH3) slightly outside the defined significantly changing definition. There was a significant 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, and at Maketawa Stream at Tarata Road since the 2016 year. Conversely, the trends in both clarity and suspended solids for the Waingongoro at SH45 came close to the definition of significant improvement. Some significant trends in water temperature and pH have been noted (Table 48), all being negative, however, the rates of change per year in all 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 47 'Meaningful' trends in surface water quality at 11 State of the Environment Monitoring sites in Taranaki- 1995-2019 (p<5% and RSKSE (%change/yr) >1%)

		Water Quality Variable															
															Total no. sites		
Catch-ment Level	Location	Dissolved Reactive P	Total Phosphorus	Nitrate	Ammonia-N	Total Nitrogen	Faecal coliforms	Enterococci	Conductivity	Black Disc	Suspended Solids	Temp°C	Biochemical O_2 Demand	pH	Improvement	No change	deterioration
Upper	Patea River Barclay Rd	⚪	⚪	⚪	⚪	🟢	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	1	12	0
Upper/ Middle	Punehu Stream Wiremu Rd	⚪	⚪	🔴	🔴	🟢	🟢	⚪	⚪	⚪	⚪	⚪	⚪	⚪	2	9	2
Middle	Stony River Mangatete Road	⚪	⚪	⚪	⚪	🟢	⚪	⚪	⚪	🔴	🔴	⚪	⚪	⚪	1	10	2
Middle	Maketawa Stream Tarata Road*	🔴	🔴	⚪	🟠	⚪	⚪	⚪	⚪	⚪	⚪	⚪	🔴	⚪	0	9	4
Middle	Patea River Skinner Rd	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	0	13	0
Middle	Waiwhakaiho R. SH3	🔴	⚪	🔴	🔴	⚪	🔴	🟠	⚪	⚪	⚪	⚪	⚪	⚪	0	8	5
Middle	Waingongoro R. Eltham Rd	🔴	🔴	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	0	11	2
Lower	Mangaoraka Stream Corbett Rd	🔴	🔴	⚪	⚪	⚪	🔴	🔴	⚪	🔴	⚪	⚪	⚪	⚪	0	8	5
Lower	Waingongoro R. SH45**	🟢	🟢	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	🔴	⚪	2	10	1
Lower	Punehu Stream SH45	🔴	⚪	🔴	🟩	🔴	⚪	🔴	⚪	⚪	🟢	⚪	⚪	⚪	2	7	4
Lower	Mangaehu River Raupuha Rd	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	⚪	0	13	0
Total no. sites:	Improvement	1	1	0	1	3	1	0	0	0	1	0	0	0			
	No change	5	7	8	7	7	8	8	11	9	9	11	9	11			
	Deterioration	5	3	3	3	1	2	3	0	2	1	0	2	0			

Key:

*Maketawa Tarata Road: Data for this site only for the past 16 years: 2003-2019
**Waingongoro SH45: Data for this site only for the past 21 years: 1998 – 2019

- 🟢 statistically very significant **improvement** P<0.01 (1%)
- 🟩 statistically significant **improvement** P<0.05 (5%)
- ⚪ no statistically significant change
- 🟠 statistically significant **deterioration** P<0.05 (5%)
- 🔴 statistically very significant **deterioration** P<0.01 (less than 1% probability that the trend is due to natural variability and doesn't represent an actual change)

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

Table 48 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	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	6.57	0.63	55.23	-0.17	5.23	-1.64	53.80	0.98	0.00	-3.76	49.18	1.01	10.56	3.58
Upper/ Middle	Punehu Stream Wiremu Rd	67.27	0.12	24.90	-0.29	0.38	1.54	0.00	3.79	0.49	-1.15	0.12	-2.10	84.67	0.40
Middle	Stony River Mangatete Road	0.01	0.78	0.51	0.82	24.90	0.67	91.44	-0.01	0.00	-2.39	37.85	0.68	29.57	0.54
Middle	Maketawa Stream Tarata Road	0.00	2.55	0.00	1.97	54.13	0.39	2.14	1.72	88.63	0.11	7.93	1.97	44.32	0.81
Middle	Patea River Skinner Rd	3.47	-0.53	0.08	-0.84	64.16	0.08	100.00	0.00	15.01	-0.20	96.00	0.05	68.32	0.35
Middle	Waiwhakaiho SH3	0.00	1.19	0.01	0.78	0.16	1.61	0.14	2.32	26.71	-0.37	0.00	2.50	2.60	1.79
Middle	Waingongoro Eltham Rd	0.00	3.65	0.00	2.00	1.52	0.56	77.46	0.13	7.46	0.32	46.96	0.52	15.42	-0.78
Lower	Mangaoraka Stream Corbett Rd	0.00	2.50	0.07	1.56	55.23	-0.10	83.55	0.13	7.23	-0.29	0.13	1.99	0.00	3.96
Lower	Waingongoro SH45*	0.00	-2.66	0.00	-2.29	0.01	-0.79	86.85	0.11	0.01	-0.76	84.11	0.24	55.92	0.57
Lower	Punehu Stream SH45	0.23	1.03	40.22	0.30	0.00	1.95	3.59	-1.09	0.02	1.06	100.00	0.00	0.00	3.05
Lower	Mangaehu River Raupuha Rd	24.90	-0.42	82.43	-0.06	27.33	0.49	58.14	-0.33	0.36	-0.77	9.81	-1.00	70.43	0.33
	Total no. sites: Improvement	1		1		0		1		3		1		0	
	No change	5		7		8		7		7		8		8	
	Deterioration	5		3		3		3		1		2		3	

Table 48 (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 geen (p<5%) and dark green (p<1%). 'Real' trends (i.e., the change is ecologically significant) are highlighted (>1% change per year).

Catchment Level	Location	Water Quality Variable											
		Conductivity		Black Disc		Suspended Solids		Temp °C		Biochemical O_2		pH	
		p-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr	*p*-value (%)	% change per yr
Upper	Patea River Barclay Rd	22.90	-0.08	37.22	-0.21	9.23	0.34	92.58	0.03	22.88	0.10	2.23	-0.03
Upper/ Middle	Punehu Stream Wiremu Rd	0.00	0.37	66.23	-0.16	88.61	0.01	77.46	-0.05	17.42	0.00	0.00	-0.10
Middle	Stony River Mangatete Road	7.01	0.12	0.00	-3.05	0.00	3.42	52.39	0.07	42.91	0.00	1.61	-0.03
Middle	Maketawa Stream Tarata Road	0.02	0.38	41.29	0.57	47.45	0.19	7.93	0.40	0.48	3.38	70.62	0.00
Middle	Patea River Skinner Rd	27.33	0.07	55.23	-0.20	41.03	-0.17	45.21	0.12	92.58	-0.03	11.03	-0.03
Middle	Waiwhakaiho SH3	44.36	0.06	0.67	-0.66	8.57	0.00	88.05	-0.03	66.21	-0.01	0.47	-0.05
Middle	Waingongoro Eltham Rd	92.58	0.01	24.90	-0.27	55.23	0.16	94.86	0.01	34.09	0.44	0.04	-0.06
Lower	Mangaoraka Stream Corbett Rd	0.00	0.22	0.00	-1.51	26.09	0.34	96.00	-0.01	6.79	0.70	5.50	-0.02
Lower	Waingongoro SH45*	31.61	0.11	0.30	0.90	4.05	-0.91	70.78	0.06	0.89	1.39	0.00	-0.10
Lower	Punehu Stream SH45	0.06	0.34	24.90	0.37	0.49	-1.49	65.19	0.06	6.68	-0.67	0.00	-0.09
Lower	Mangaehu River Raupuha Rd	71.50	0.04	40.22	-0.31	97.71	0.00	48.73	-0.10	4.50	-0.52	80.21	0.00
Total no. sites: Improvement		0		0		1		0		0		0	
No change		11		9		9		11		9		11	
Deterioration		0		2		1		0		2		0	

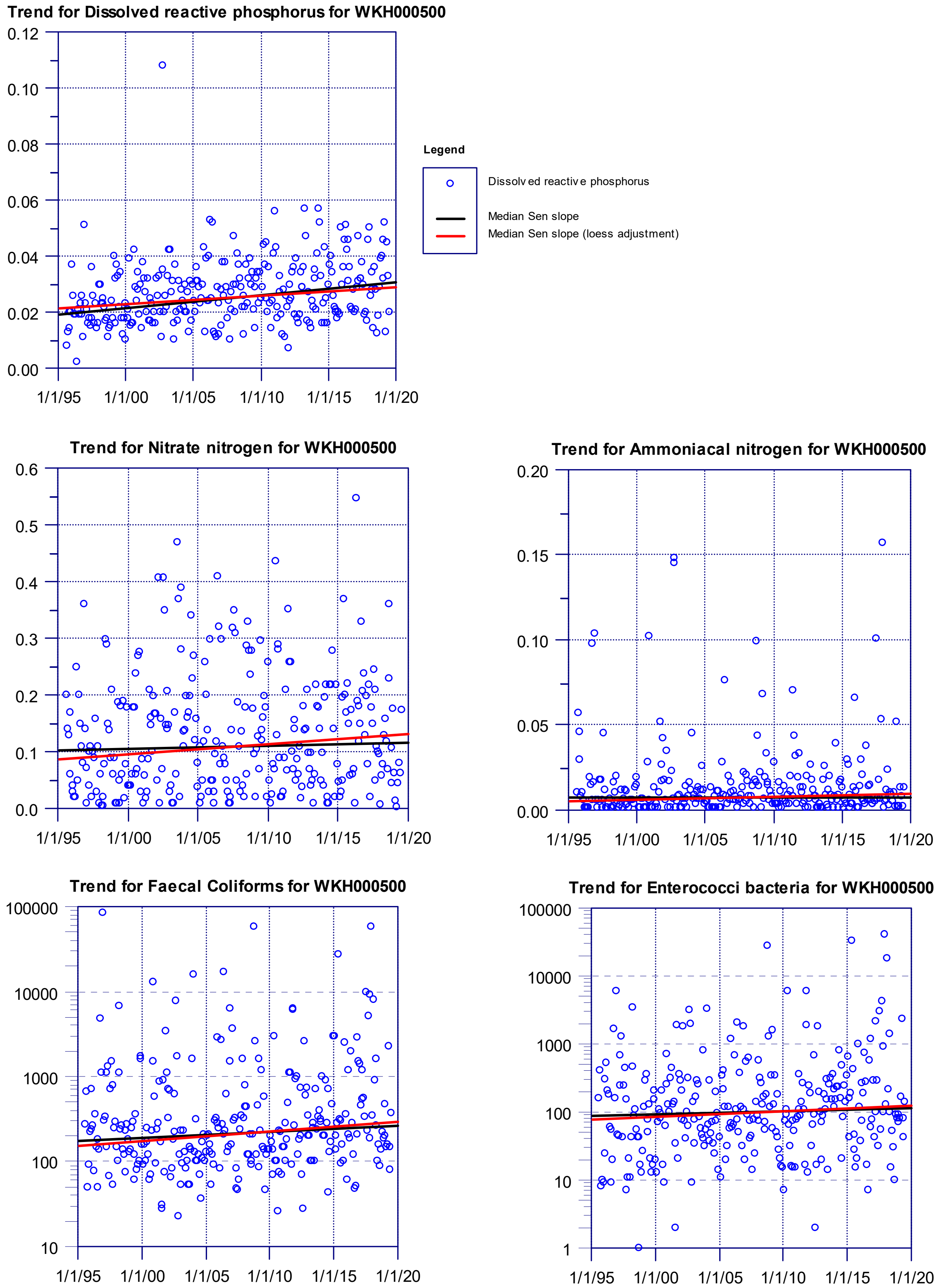


Figure 12 Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

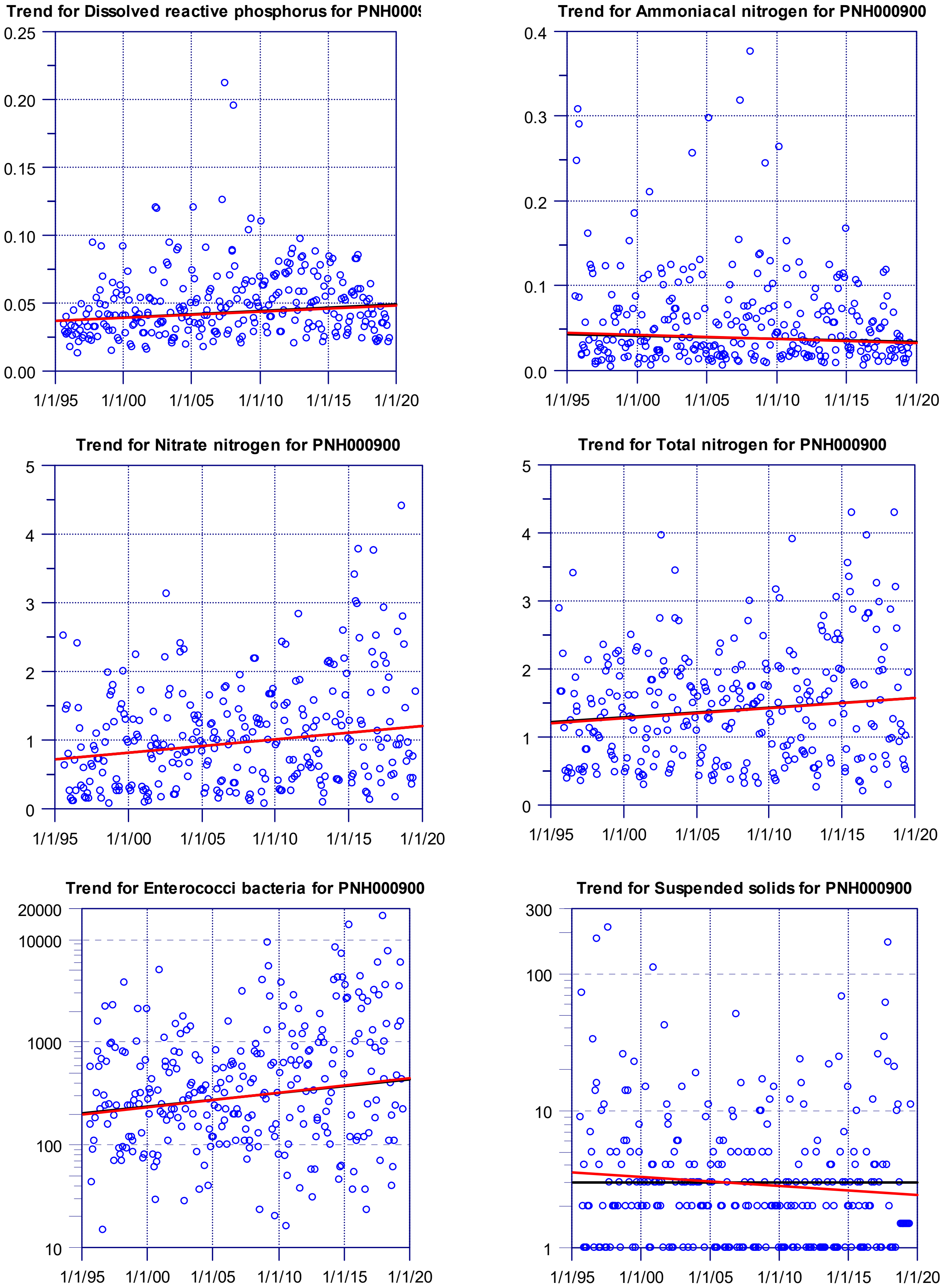


Figure 12 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

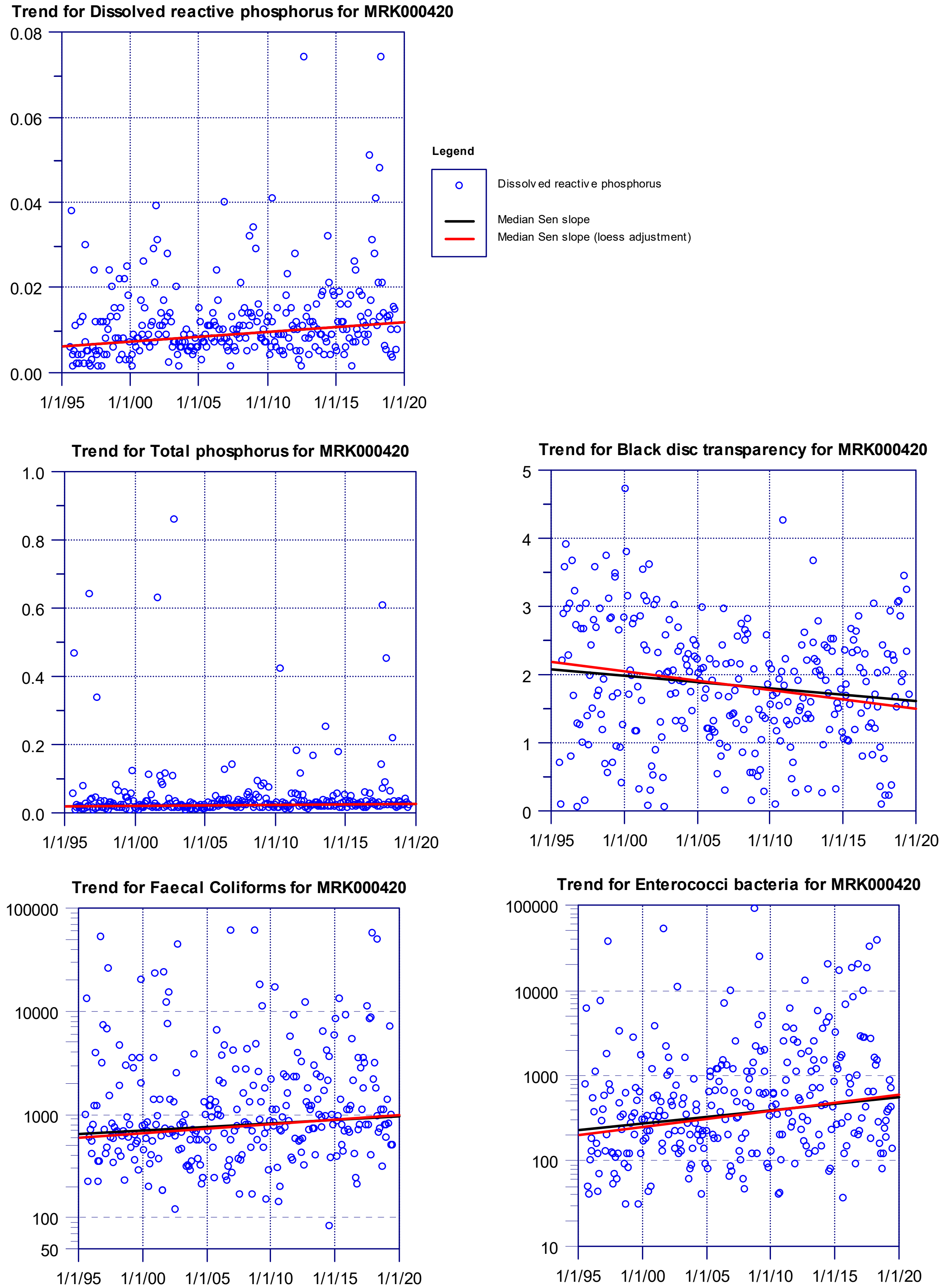


Figure 12 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

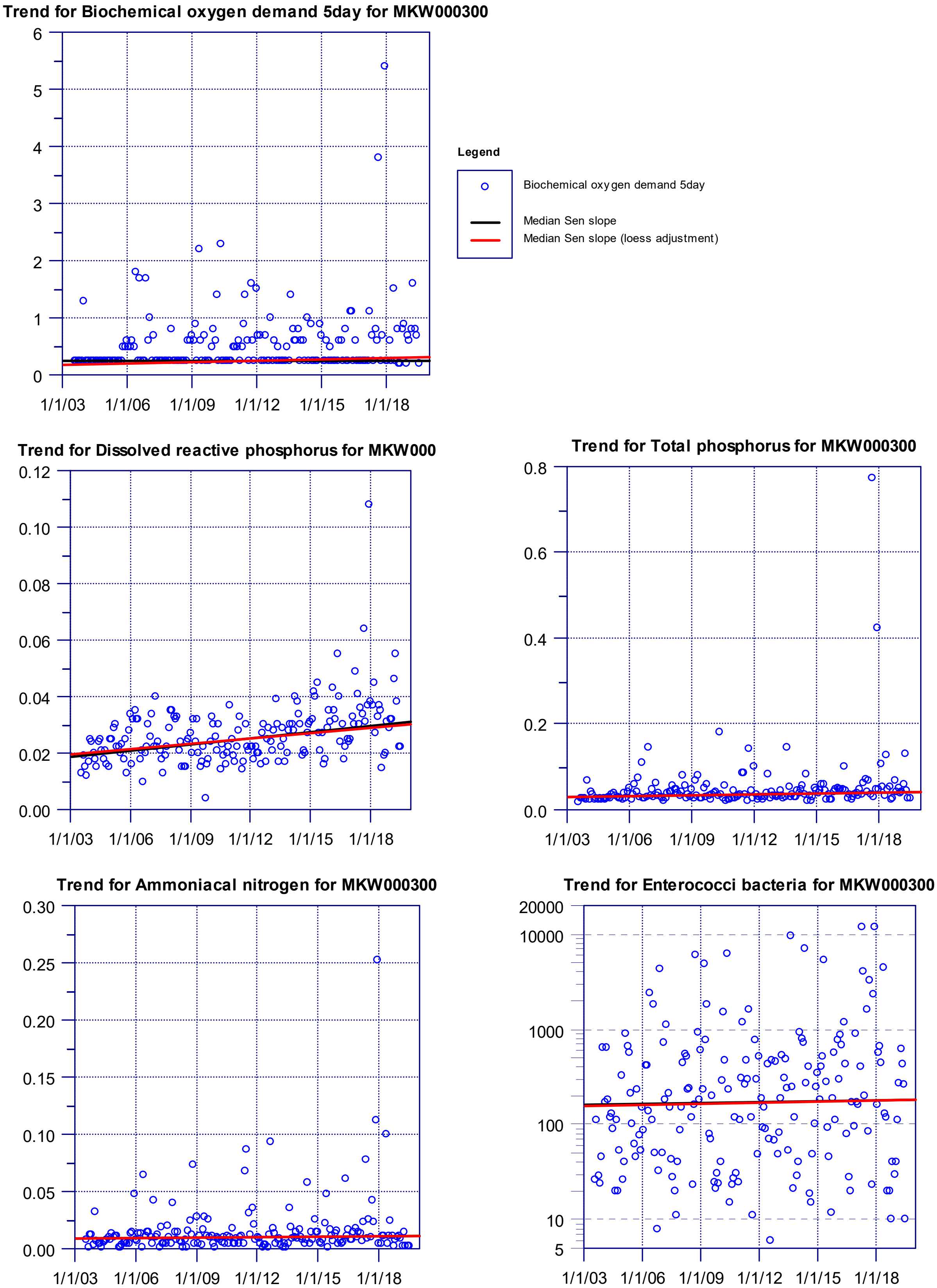


Figure 12 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

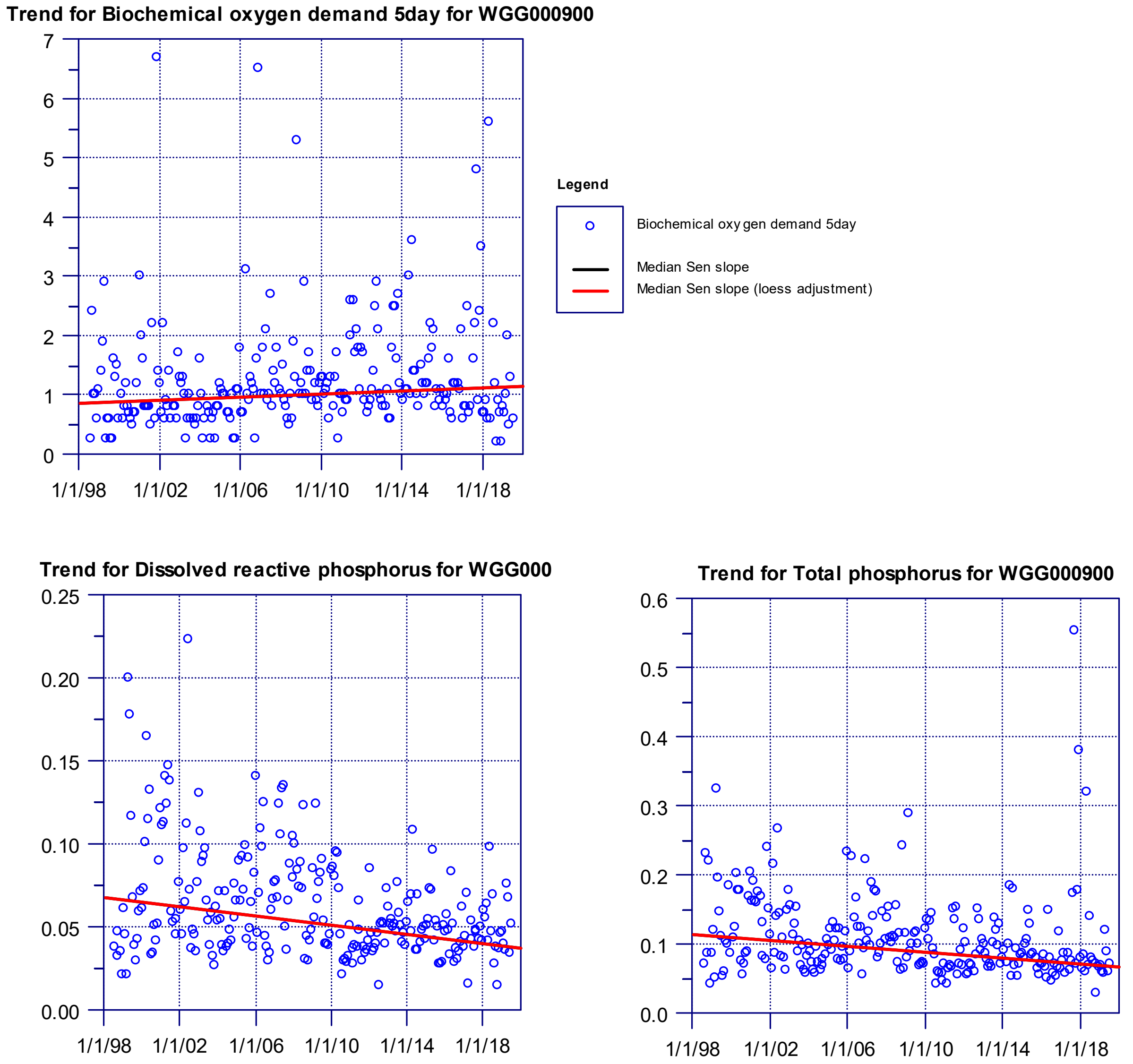


Figure 12 (cont) Scatterplots of selected parameters for selected sites where significant trends have been reported (flow adjusted data and LOWESS trend line (span 30%))

4.4 Trends in physicochemical water quality data from 2012 to 2019

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 2012- June 2019) were trended using the same methodology as for the full record (1995-2019, 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 2012-June 2019) and the full record (January 1989-June 2019). Starting from December 2015, 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 49). 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.

Table 49 Summary of physicochemical trends between 24 years and 7 years of data

Statistical level	Total number of trends	
	24 years	7 years
Improvement ($p<0.01$)	7	6
Improvement ($p<0.05$)	1	6
Being maintained	77	81
Deterioration ($p<0.05$)	2	10
Deterioration ($p<0.01$)	23	7
Total	110	110

Comparison of long term trends 1995-2019 (24 years) and 2012-2019 (7 years) analysis.

Nutrients

- 40 of 55 measures of the nutrients (73%) showed maintenance (62%) or improvement (11%) in the long term trend.
- 45 of 55 measures of the nutrients (82%) showed maintenance (73%) or improvement (9%) in the recent 7 year trend.

Bacteria

- 17 of 22 measures of bacterial levels (77%) showed maintenance (72%) or improvement (5%) in the long term trend.
- 22 of the 22 measures of the bacterial levels (100%) showed maintenance in the recent 7 year trend.

Organics

- 9 of 11 measures (82%) of organics contamination showed maintenance in the long term trend.
- 10 of 11 measures of organics (90%) showed maintenance (72%) or improvement (18%) in the recent 7 year trend.

Aesthetics

- 19 of 22 measures (86%) of aesthetics showed maintenance (81%) or improvement (5%) in the long-term trend.
- 16 of 22 measures of the aesthetics (73%) showed maintenance (68%) or improvement (5%) in the recent 7 year trend.

Specific changes in trends for nutrients, bacteria, organics and aesthetics are shown in Figure 13.

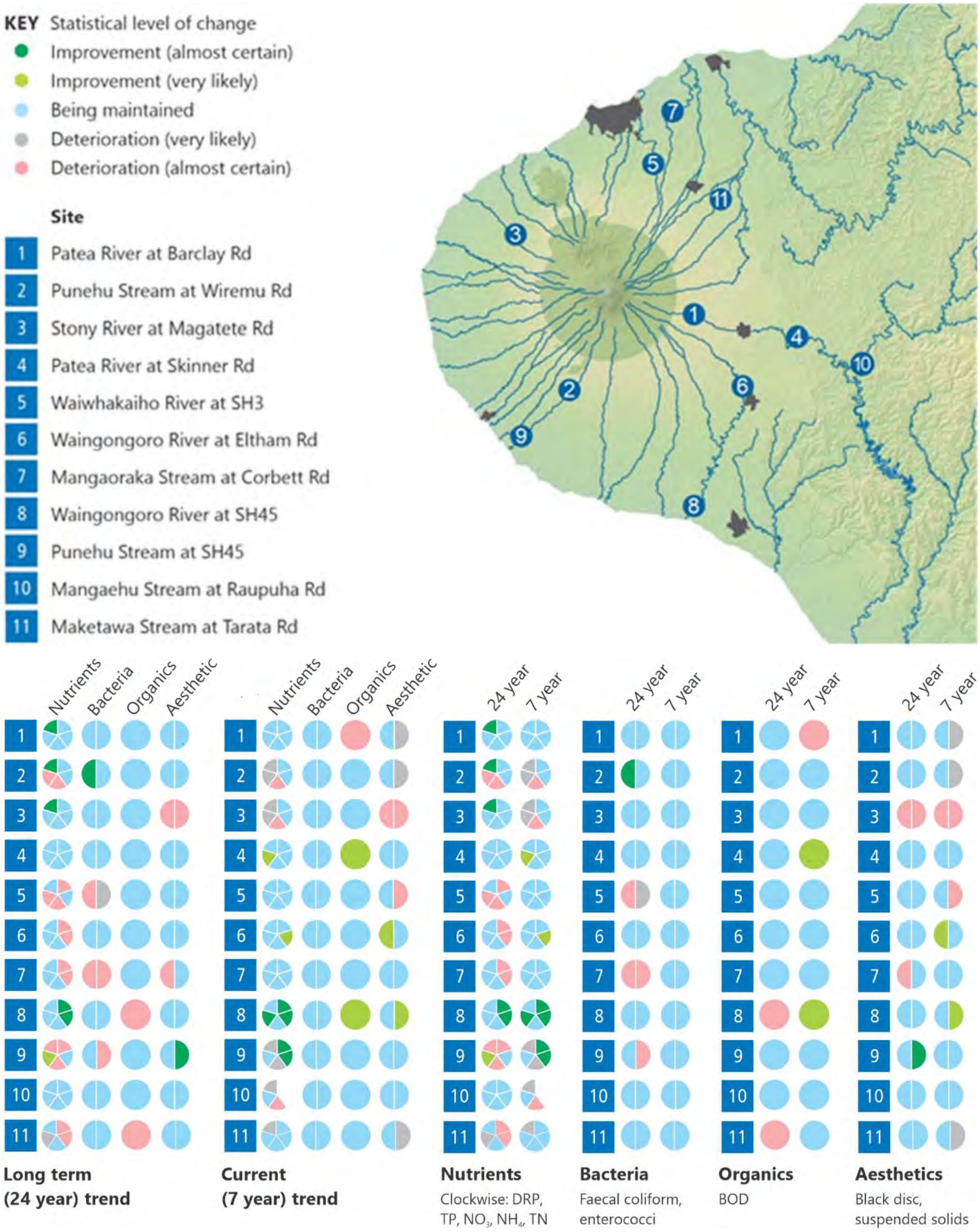
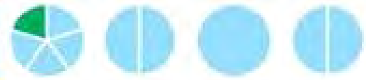
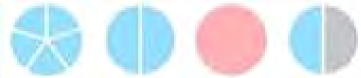
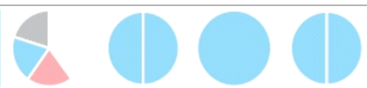


Figure 13 Specific changes in trend for nutrients, bacteria, organics and aesthetic parameters in the long term (24 years) and current (7 years) trend

Note: current (7-years) trends for DRP and TP are not reported for site 10 as data for these variables had to be excluded due to change in test laboratory

4.4.2.1 Patea River catchment

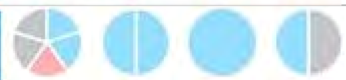
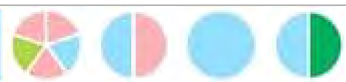
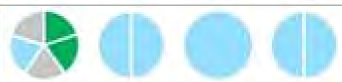
- At the upper site Barclay Road, significant long term deterioration in TN has tapered off in the 7 year trend. Deterioration in BOD and suspended solids has appeared in the short term trend. Other parameters are not changing significantly.
- At the middle site Skinner Road, long term and recent trends are not changing significantly for all parameters measured. NH_4 and BOD have improved in the short term.
- The Mangaehu River has shown deterioration over the short term for NO_3 and TN.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Patea River at Barclay Road (upper catchment)	24 year trend	1 
	7 year trend	1 
Patea River at Skinner Road (middle catchment)	24 year trend	4 
	7 year trend	4 
Mangaehu River at Raupuha Road (lower catchment)	24 year trend	10 
	7 year trend	10 

Key: Nutrients: Clockwise: DRP, TP, NO_3, NH_4, TN
Bacteria: Faecal coliform, enterococci
Organics: Biological oxygen demand
Aesthetics: Black disc, suspended solids

4.4.2.2 Punehu Stream catchment

- At the upper site Wiremu Road, significant long term improvement in TN and faecal coliforms did not continue in the short term trend, with TN deteriorating. Significant deterioration in NO_3 and NH_4 recorded in the long term trend continued in the 7 year trend. Suspended solids has deteriorated in the short term. Other parameters are not changing significantly.
- At the lower site SH45, the long term deteriorating trends in NO_3, and TN, but not in enterococci, continued in the 7 year trend, with DRP reversing and the TP trend changing to show improvement. Long term improvement in suspended solids was not recorded in the short term.

• Sites	Records	Nutrients Bacteria Organics Aesthetic
Punehu Stream at Wiremu Road (upper catchment)	24 year trend	2 
	7 year trend	2 
Punehu Stream at SH 45 (lower catchment)	24 year trend	9 
	7 year trend	9 

4.4.2.3 Stony River catchment

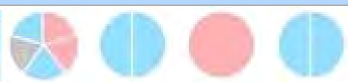
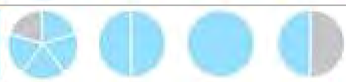
- Significant improvement recorded in the long term trend for TN had reversed in the recent 7 year period, with significant deterioration recorded. Significant deterioration in clarity and suspended solids recorded in the long term trend has continued in the recent trend.
- NO_3, and NH_4 show significant deterioration in the recent 7 year trend.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Stony River at Mangatete Road (middle catchment)	24 year trend	3 
	7 year trend	3 

Key: Nutrients: Clockwise: DRP, TP, NO_3, NH_4, TN
Bacteria: Faecal coliform, enterococci
Organics: Biological oxygen demand
Aesthetics: Black disc, suspended solids

4.4.2.4 Maketawa River catchment

- Significant long term deterioration in DRP, TP, NH_4 and BOD did not continue in the 7 year trend.
- The 7-year trend showed deterioration in TN and suspended solids.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Maketawa River at Tarata Road (middle catchment)	24 year trend	11 
	7 year trend	11 

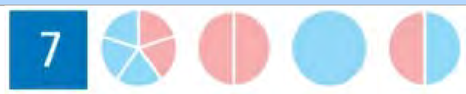
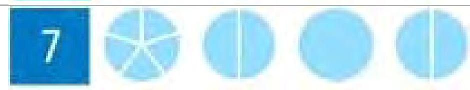
4.4.2.5 Waiwhakaiho River

- Significant long term deterioration was recorded for DRP, NO3, NH_4 and faecal coliforms at this mid catchment site, with enterococci also deteriorating.
- These trends had tapered off in the 7 year trend. Other parameters are not changing significantly, except suspended solids which showed a deteriorating trend in the short term.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Waiwhakaiho River at SH3 (middle catchment)	24 year trend	5 
	7 year trend	5 

4.4.2.6 Mangaoraka Stream (Waiongana Stream catchment)

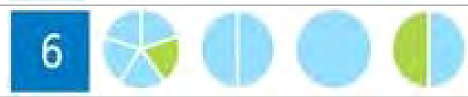
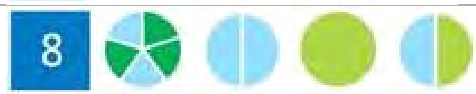
- Significant long term deteriorations were recorded for DRP, TP, faecal coliforms, enterococci and black disc. These trends had tapered off in the 7 year trend, except for DRP.
- These trends had all tapered off in the 7 year trend.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Mangaoraka Stream at Corbett Road	24 year trend	
	7 year trend	

Key: Nutrients: Clockwise: DRP, TP, NO_3, NH_4, TN
Bacteria: Faecal coliform, enterococci
Organics: Biological oxygen demand
Aesthetics: Black disc, suspended solids

4.4.2.7 Waingongoro River catchment

- At the upper site Eltham Road, significant long term deterioration in DRP and TP has tapered off in the 7 year trend, with reversal of the trend in DRP. Other parameters are not changing significantly, except for improvement in clarity.
- At the lower site SH45, significant improvements in DRP and TP were recorded in the long-term trend continued in the short term trend, along with NH_4. BOD showed significant deterioration to significant improvement between the long and short-term trend. Suspended solids and NH_4 also showed improvement in the short term. Bacterial parameters are not changing significantly.

Sites	Records	Nutrients Bacteria Organics Aesthetic
Waingongoro River at River Road	23 year trend	
	7 year trend	
Waingongoro River at SH45	23 year trend	
	7 year trend	

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 2012-June 2019) and the full record spanning from January 1989 to June 2019 (Table 50). In order to accurately compare the TRC and NIWA data, a 24-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 is recorded for the nutrients DRP and all nitrogen species, with DRP and ammonia tapering off and appearing to be stable in the last 7 years. Conductivity has increased over the short term.
- In the Manganui River, no significant trend is recorded in either the 30-year long term or 7-year recent period.
- Note that suspended solids and BOD are not recorded by NIWA, and bacteria had been recorded only since 2005; as such these parameters are not included in the tables below.

Table 50 Meaningful' trends in surface water quality at NIWA's monitoring sites in Taranaki

Site	Record (years)	Dissolved Reactive P	Total Phosphorus	Nitrate	Ammoniacal-N	Total Nitrogen	Conductivity	Black Disc	Temp°C	pH	Total no sites:	Improvement	No change	Deterioration
Waitara River at Bertrand Rd Bridge	30	🔴	🔵	🔴	🔴	🔴	🔵	🔵	🔵	🔵		0	5	4
	24	🔵	🔵	🔴	🔴	🔴	🔵	🔵	🔵	🔵		0	6	3
	7	🔵	🔵	⚫	🔵	🔴	⚫	🔵	🔵	🔵		0	6	3
Manganui River at SH3	30	🔵	🔵	🔵	🔵	🔵	🔵	🔵	🔵	🔵		0	9	0
	24	🔵	🔵	🔵	🔴	🔵	🔵	🔴	🔵	🔵		0	7	2
	7	🔵	🔵	🔵	🔵	🔵	🔵	🔵	🔵	🔵		0	9	0

Key
- statistically significant **improvement** $P<0.01$
- statistically significant improvement $P<0.05$
- no statistically significant change
- statistically significant **deterioration** $P<0.05$
- statistically significant **deterioration** $P<0.01$

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 2018 through to June 2019. 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 2018-2019 was the fourth full year of sampling. Sampling in the year under review coincided randomly with a narrower range of flow conditions in the 2018-2019 period (in comparison with the previous 23 year period), ranging from moderate freshes through to very low flow conditions and was characterised by fewer fresh events than typical during previous years. This report provides monthly data for up to 22 parameters and a statistical summary of the twelve months' data for each of the sites, and compares this period's water quality with the previous 23 years' data. It also provides an up-to-date statistical summary of the 24 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 2018-2019

During the 2018-2019 period, median flows sampled were all much lower than typical of those sampled during the previous 23-year period. For nine of the eleven sites monitored over at least 10 years, median flows were lowest over the latest period (by 19 to 43%), compared with the long-term median of sampled flow records (Table 51), the exceptions being Waingongoro River at Eltham and Patea River at Skinner Road in 2016-2017.

Table 51 Comparison of 2018-2019 water quality with previous long-term (1995-2018) 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	=	=	XX	=	✓✓	=	=	=	=	=	=	=	=	=	=	-386	19↓
Mangaoraka Stream at Corbett Road	=	=	X	=	✓	✓	=	=	=	=	=	=	=	=	=	-435	37↓
Waiwhakaiho River at SH3	=	=	XX	✓	=	=	✓	=	✓	=	=	=	=	=	X	-884	23↓
Stony River at Mangatete Road	=	=	=	=	XX	=	XX	=	=	=	=	=	=	=	X	-785	22↓
Punehu Stream at Wiremu Road	=	=	XX	✓✓	✓	X	X	=	=	=	=	=	=	=	X	-91	21↓
Punehu Stream at SH45	=	=	✓	=	=	✓	=	✓	✓	✓	=	=	✓	=	=	-249	30↓
Waingongoro River at Eltham Road	=	=	=	X	✓	✓	=	=	X	=	=	=	✓	=	=	-654	39↓
Waingongoro River at SH45	✓	=	=	=	✓	✓✓	=	=	✓	✓	=	=	✓	=	=	-1,589	32↓
Patea River at Barclay Road	=	=	XX	XX	XX	=	XX	=	X	=	=	=	=	=	X	-41	19↓
Patea River at Skinner Road	=	=	✓	X	X	=	=	=	X	=	=	=	=	=	=	-812	27↓
Mangaehu River at Raupuha Road	✓✓	=	=	✓✓	✓✓	✓✓	✓	✓	(✓✓)	(✓)	=	=	✓✓	=	✓	-3,095	43↓
Whenuakura River at Nicholson Road	✓✓	=	✓	✓✓	✓✓	=	X	=	=	✓	=	=	✓✓	=	✓✓	-2,657	43↓
Waitara River at Autawa Road	✓✓	=	=	✓✓	✓✓	✓✓	X	=	(✓✓)	(✓✓)	=	=	✓✓	=	✓✓	-12,524	49↓

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

[Notes: Whenuakura River and Waitara River data collection commenced in mid 2015; Maketawa Stream data collection commenced in mid 2003; Waingongoro River at SH45 data collection commenced in mid 1998]. Phosphorus species results for Mangaehu and Waitara Rivers possibly affected by change in analytical testing

Aesthetic and physical parameters in 2018-2019

Generally, for the sites monitored at least 10 years, water quality in the 2018-2019 period (Table 51) showed similar or better **black disc clarity** and **suspended solids** levels, and varying turbidity levels, compared with the long-term monitoring record. (Turbidity values possibly were affected by the different test instrument used for measurement throughout 2018-2019, as the three sites with lowest turbidity showed deterioration whereas the site with highest turbidity showed improvement). Ten of the eleven sites showed no significant change in visual clarity, with improvement at the only (Mangaehu River) hill country site. Median water **temperatures** were similar in the year under review, and narrower temperature ranges were measured, mainly due to higher minimum temperatures (in comparison with the longer period).

Median **dissolved oxygen saturation** and **pH** showed no significant differences in the latest period (Table 51). **BOD_5 concentration** increased at two upper (Patea and Punehu), two mid (Maketawa and Waiwhakaiho) and one lower (Mangaoraka) catchment site and was similar for the other sites, between the two periods.

Nutrients in 2018-2019

A majority of sites' median nutrient levels remained similar in the 2018-2019 period to those over the longer period. A few improvements in median nutrient species (ammonia-nitrogen at five sites, nitrate nitrogen at two sites and total nitrogen at two sites) were recorded. Deterioration was found in median nitrate nitrogen (at three of eleven sites, two by more than 50%), ammoniacal nitrogen (at one site), and dissolved reactive phosphorus (at three sites) (Table 51). On an overall view, total nitrogen and total phosphorus levels showed no increases and some decreases, with dissolved nitrogen and phosphorus species showing a few increases and decreases. This is consistent with the low proportion of fresh events sampled.

Bacteria in 2018-2019

Overall, there was an improvement in bacteriological water quality, with the number of improving sites exceeding the number of sites showing deterioration. Bacteria numbers showed improvement at six sites in terms of median enterococci numbers, although there was also some deterioration at three sites during the 2018-2019 period. Four sites showed improvement in median faecal coliform bacteria numbers, while three sites showed deterioration. This variable general trend of improvement in bacteriological water quality during 2018-2019 probably reflected the lesser frequency of sampling of freshes during the 2018-2019 period compared with that over the longer period.

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 1995-2019 period (including one site for the 1998-2019 period and one site for the 2003-2019 period) and summarised in this Annual Report. Trend analysis has also been performed on the two NIWA sites. This complements earlier trend analyses.

In conclusion, long term (24-year) flow-adjusted 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 55% and 91% (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 reductions between 2001 and 2010 in waste loadings discharged by industry and 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 (upstream) at Eltham Road, Mangaoraka Stream at Corbett Road, and in Maketawa Stream at Tarata Road where ammonia has also deteriorated. The Waiwhakaiho River site at SH3 in mid-catchment and Punehu Stream site at SH45 in lower catchment also have recorded a significant deterioration in DRP and nitrate, with ammoniacal nitrogen improving at the former and deteriorating at the latter. The trends for these four sites have indicated that phosphorus level is increasing at a steady but slow rate. All four 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.

One mid-reach site, the Maketawa Stream at Tarata Road, and one lower reach site, the Waingongoro River at SH45, have shown significant long term deterioration in BOD_5 although concentrations have remained consistently below the recognised criterion of 2 g/m^3 at these sites.

Faecal coliforms and enterococci trends generally have not altered significantly over the 24-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 an upper reach, 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 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 2018-2019 period with the previous 23-year historical record, the lower reach site on the Mangaehu River showed the most variability in water quality in the recent period, recording ten of the fifteen parameters as having higher quality, with no instance of any reduced quality. This site, which is representative of eastern hill country catchments, showed improvement in visual clarity, turbidity, suspended solids, both bacterial species and all nutrient species. Another two lower reach sites, on Punehu Stream and Waingongoro River, which are representative of developed farmland catchments, had at least six parameters all showing improvement from usual quality, with ammoniacal nitrogen, phosphorus species and suspended solids in common. These improvements may be related to the greater proportion of lower flows sampled in 2018-2019. Two other, upper reach sites, on Patea River at Barclay Road and Punehu Stream at Wiremu Road, also had at least six parameters showing difference from usual quality, mainly deterioration in turbidity, BOD and nitrate, with variations in bacterial species, ammonia and dissolved phosphorus, all at low levels. Least differences in comparative water quality were found at Maketawa River at Tarata Road (mid-reach), Stony River at Mangatete Road (mid-reach) and Mangaoraka Stream at Corbett Road (lower reach).

Overall, during the 2018-2019 period water quality parameters' medians differed by more than 20% from 23-year medians for 51% of comparisons (20% deterioration; 31% improvement), and by more than 50% from historical medians for 16% of comparisons (8% deterioration, 8% improvement). This was coincident with lower median flows (by 19 to 43%) sampled at all of the eleven long-term monitored sites over the 2018-2019 period.

6 Recommendations

1. THAT the existing freshwater physicochemical component of the SEM programme continue in a similar format for the 2019-2020 monitoring year.
2. THAT additional (split) samples 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 1995-2019 period (provided in the current report), be updated for the 1995-2020 period at the conclusion of the 2019-2020 year.

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Appendix I

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 dairy farms covered by riparian plans by 2010 and to have 90% implemented by 2015.

Appendix II

SEM Physicochemical Programme Hill Laboratories Intra-lab Quality Control Report 2018-2019

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 1998-1999 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 11 sites, and on the next day for the 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 November 2015 and two sites thereafter.

Introduction

Quality assurance is an essential aspect of any laboratory and monitoring programme. As a quality control (QC) measure of the precision and accuracy of the Hill Laboratories practices undertaken for this programme, each month of the 2018-2019 monitoring year, a dual sample is collected from one of the thirteen monitoring sites. The QC sample is then sent as an unidentified sample to Hill Laboratories and analysed in exactly the same way and at the same time as the monitoring run's other SEM samples (Intra-lab Quality Control Report Appendix II). In conjunction with the sampling undertaken by NIWA, samples from both Taranaki network sites are split in the field at least annually, as an inter-laboratory quality control procedure for analytical accuracy assessment. These comparisons between Hill Laboratories and NIWA results are reported in Appendix III.

This report (Appendix II) presents the results from the twelve intra-lab control tests undertaken in the 2018-2019 monitoring year. The laboratory results for matched SEM and QC samples are compared to assess the precision of laboratory results over the 19 different parameters measured. In this report, the difference between the individual QC and SEM measurements and the mean of the two measurements is used to assess measurement precision and accuracy. In order to compare with previous intra-laboratory quality reports for the TRC laboratory (which was used for physicochemical sample analysis up to June 2018), the difference between measurement and mean is presented as a percentage of the mean, with levels of these differences expressed broadly as:

Difference from mean (%)
<10%
10-20%
21-50%
>50%

The acceptability of the precision of pairs of analyses varies from parameter to parameter, with the bands defined above only being 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 matched samples. Given that the amount of variation in results can differ from type of analysis to another, 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.

There are various reasons why sub-sample results may differ, including discrepancies in laboratory equipment, techniques, or sample variation. For the 2018-2019 monitoring year, the variation between QC and SEM measurements may be expected to be higher than in previous years due to sampling technique. For this year, dual QC and SEM samples were taken simultaneously on site, in two separate bottles, with all practical steps taken to keep them as identical as possible. This is in contrast to previous years of the SEM physicochemical programme, where only a single sample has been collected, with splitting into duplicate samples in the field. The change was brought about with the switch from analysing samples internally at the TRC laboratory, to sending samples for external analysis at Hill Laboratories. A return to the sample splitting technique is recommended for the next monitoring year, to ensure the robustness of intra-laboratory quality control.

Results

For the 2018-19 monitoring season, 225 paired QC-SEM measurements were analysed for intra-laboratory quality control. Of these, 192 paired measurements placed in the top general band of agreeance, varying less than 10% from the mean of the matched measurements. Of the 33 paired measurements that exceeded the 10% difference-from-mean threshold, 22 fell in the 10-20% difference band, while the remaining 11 varied 20-50% from the mean. No paired measurements fell into the lowest quality band of >50% difference-from-mean. A summary of results for each sampling run is given in Figure 1, showing that 6 of the 12 sampling runs had only 1-2 matched measurements exceeding the 10% difference threshold, while no run had more than 5 of the 19 matched measurements outside of the top band of agreeance.

A comparison of matched QC and SEM measurements, split by parameter, is given for the entire monitoring year in Figure 2. It can be seen that the significant majority of paired measurements fall either within the 10% difference-from-mean thresholds, or very close to the limit. There are only a handful of measurements that fall significantly outside the 10% acceptance band, and these are discussed further below. It must be noted, however, that for some parameters, the line of 10% difference is not the best indicator for measurement precision. In the case of pH, for example, a better measure is whether the QC and SEM measurements agree within 0.2 units; which is the case for all 12 paired measurements taken in this monitoring period. Similarly, 4% is a better guide for the agreeance of Total Alkalinity (ALKT) measurements; a threshold which all 12 paired measurements met this period.

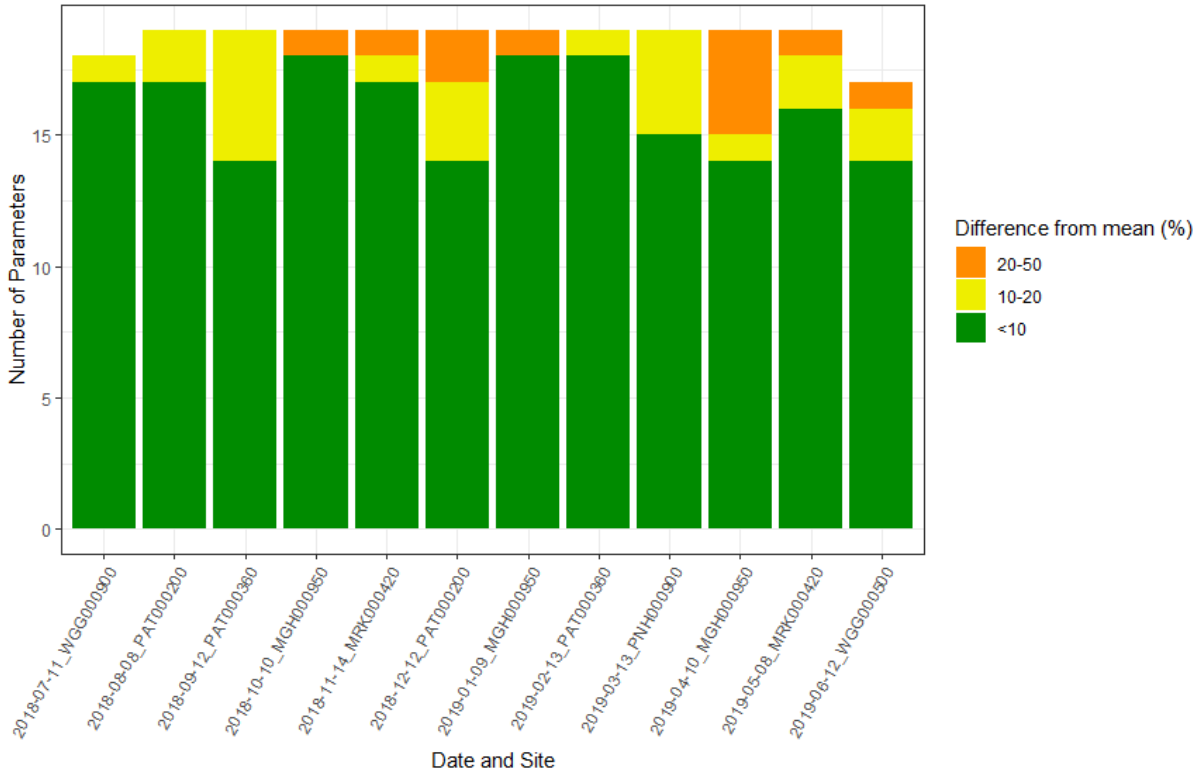


Figure 1: Number of paired measurements falling into measure of agreeance bands, for each sampling run of the 2018-19 monitoring season.

Note: Only 18 and 17 parameters, out of the usual 19, were measured for the QC sample in the July 2018 and June 2019 runs, respectively.

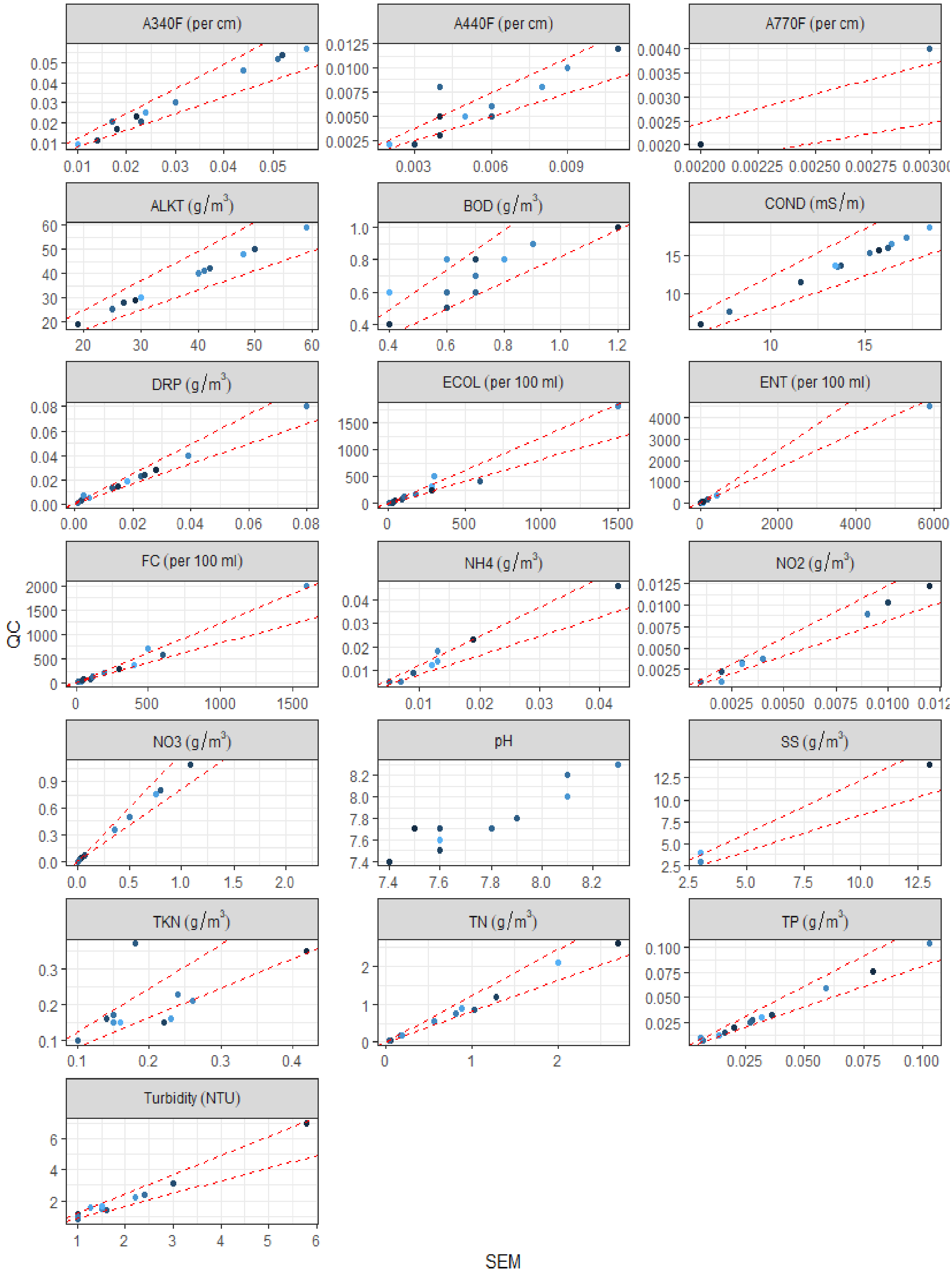


Figure 2: Comparison of matched SEM and QC sample results. Red dashed lines represent the base-line limit of acceptance of 10% from mean measurement.

A summary of the paired SEM-QC results which did not meet the 10% agreeance threshold is given in Table 1. On inspection, the majority of the exceedances fall into two main groups: those where greater variability is expected due to the nature of the parameter, such as bacteriological parameters, and those where the measured levels are low enough that a small variation in results has led to a large percentage difference. Between them, all but one of the exceedances can be accounted for by either or both of these reasons.

The exception is the discrepancy seen between the QC and SEM measurements of TKN on 14/11/2018. On closer inspection of the nitrogen species measurements taken in this run, it appears that there may have been an error in the analysis process of the SEM sample, with TN not being roughly equal to the sum of the nitrogen species results.

Table 1: Matched SEM-QC sample results from the 2018-2019 monitoring year exceeding the 10% from mean acceptance threshold.

Sampling Date	Parameter	QC result	SEM result	% from Mean	Sample Site
11/07/2018	A440F	0.005	0.004	11.1	WGG000900
08/08/2018	A440F	0.003	0.004	14.3	PAT000200
08/08/2018	FC	70	50	16.7	PAT000200
12/09/2018	A340F	0.011	0.014	12.0	PAT000360
12/09/2018	A440F	0.002	0.003	20.0	PAT000360
12/09/2018	ECOL	20	30	20.0	PAT000360
12/09/2018	FC	50	40	11.1	PAT000360
12/09/2018	TKN	0.15	0.22	18.9	PAT000360
10/10/2018	DRP	0.0031	0.002	21.6	MGH000950
14/11/2018	ECOL	410	600	18.8	MRK000420
14/11/2018	TKN	0.37	0.18	34.5	MRK000420
12/12/2018	A340F	0.021	0.017	10.5	PAT000200
12/12/2018	A440F	0.008	0.004	33.3	PAT000200
12/12/2018	A770F	0.004	0.003	14.3	PAT000200
12/12/2018	FC	20	10	33.3	PAT000200
12/12/2018	Turbidity	0.8	1	11.1	PAT000200
09/01/2019	ENT	80	50	23.1	MGH000950
13/02/2019	NH4	0.005	0.007	16.7	PAT000360
13/03/2019	ENT	4500	5900	13.5	PNH000900
13/03/2019	FC	2000	1600	11.1	PNH000900
13/03/2019	NH4	0.018	0.013	16.1	PNH000900
13/03/2019	TKN	0.21	0.26	10.6	PNH000900
10/04/2019	BOD	0.8	0.6	14.3	MGH000950
10/04/2019	DRP	0.0075	0.0030	42.9	MGH000950
10/04/2019	ENT	21	10	35.5	MGH000950
10/04/2019	NO2	0.001	0.002	33.3	MGH000950
10/04/2019	TP	0.010	0.006	25.0	MGH000950
08/05/2019	ECOL	500	300	25.0	MRK000420
08/05/2019	FC	700	500	16.7	MRK000420
08/05/2019	TKN	0.16	0.23	17.9	MRK000420
12/06/2019	BOD	0.6	0.4	20.0	WGG000500
12/06/2019	ENT	20	60	50.0	WGG000500
12/06/2019	SS	4	3	14.3	WGG000500

Table 2 shows that the intra-laboratory QC results obtained for Hills laboratory in the 2018-19 monitoring year are, in general, on par with that obtained for the TRC laboratory between 1995-2018.

Table: 2 Comparison of the percentage of intra-laboratory quality assurance results falling into each band of agreeance for analyses undertaken by Hills laboratory and TRC laboratory (in parenthesis).

	Difference from mean of pairs of split samples							
Parameter ID	**<10%**		**10-20%**		**21-50%**		**>50%**	
A340F	83	(93)	17	(7)	0	(0)	0	(0)
A440F	67	(75)	25	(18)	8	(5)	0	(2)
A770F	92	(78)	8	(0)	0	(9)	0	(13)
ALKT	100	(100)	0	(0)	0	(0)	0	(0)
BOD5	83	(86)	17	(11)	0	(2)	0	(1)
CONDY	100	(100)	0	(0)	0	(0)	0	(0)
DRP	83	(93)	0	(6)	17	(0)	0	(1)
ECOL	75	(49)	17	(31)	8	(19)	0	(1)
ENT	67	(42)	8	(24)	25	(27)	0	(7)
FC	58	(49)	33	(31)	8	(18)	0	(2)
NH4	83	(78)	17	(13)	0	(5)	0	(3)
NO2	91	(92)	0	(3)	9	(3)	0	(1)
NO3	100	(86)	0	(4)	0	(9)	0	(1)
pH	100	(100)	0	(0)	0	(0)	0	(0)
SS	92	(87)	8	(10)	0	(3)	0	(0)
TKN	67	(50)	25	(19)	8	(22)	0	(9)
TN	100	(84)	0	(10)	0	(7)	0	(0)
TP	92	(87)	0	(7)	8	(4)	0	(2)
TURB	92	(98)	8	(1)	0	(1)	0	(0)

Summary

Twelve dual samples were collected and analysed during the 2018-19 monitoring period for the assessment of Hills laboratory analytical precision.

In general, laboratory analytical performance has been acceptable, with good precision of results shown for the majority of parameters. One particular exception in analytical precision has been identified; in the TN and TKN measurements from 14/11/2018. This highlights the importance of intra-laboratory quality control, the timely analysis of results, and the follow up of any identified discrepancies, such that samples can be reanalysed when necessary.

It is recommended that in the future, split samples are taken for QC purposes, rather than dual samples. In addition, intra-laboratory QC data should be analysed in a timely manner such that any discrepancies are picked up and samples reanalysed.

Appendix III

SEM Physicochemical Programme
Inter-lab Quality Control Report 2018-2019

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, another in the 2003-2004 period and two more in the 2015-2016 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 included 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 thirteen monitoring sites every three to four months and split for duplicate analyses (see Appendix II). 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 each of the (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 2018-2019 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 2018-2019 period, on 21 August 2018. Sampling was performed at the Waitara River site at Bertrand Road during steep recession flow (153 m^3/s), 14 hours after a large flood peak in fine, overcast weather. The water appeared turbid brown. The Manganui River site, upstream at SH3, was sampled lower in the recession during the same flood event (2.53 m^3/s). The water appeared slightly turbid and was coloured brown with tannins.

Results

Comparisons of the split samples' analytical results for the Waitara River (at Bertrand Road) site are presented in Table 1, with results for the Manganui River (at SH3) site presented in Table 2. In general, good analytical agreement was recorded over the suite of parameters, with a couple of notable exceptions. At both sites, significant differences were recorded in the pH measurements from the two laboratories. While 10% is used as a general guideline for analytical agreement, in the case of pH, a better guideline is 0.2 units. A difference of 0.7 and 0.8 units were recorded for the Waitara and Manganui samples, respectively, indicating an analytical discrepancy between the two laboratories. Although this difference was flagged as soon as the NIWA results became available, unfortunately due to delays, the Hill Laboratory samples had already been disposed of, before re-analysis could be undertaken.

Table 1 Results of SEM QC measurements from a split sample taken at WTR000800 on 21 August 2018, and analysed by Hill & NIWA Laboratories.

WTR0008000					
		Time: 1020 (NZST)		Difference from mean (%)	Comments
Parameter	Units	HILL	NIWA		
A340F	/cm	0.0540	0.0480	5.9	✓
A440F	/cm	0.0140	0.0105	14.3	*
COND	mS/m @ 25°C	6.6	7.17	4.1	✓
DRP	g/m^3	0.0044	0.0080	29	**
ECOL	cfu/100 mL	>2420	6488	-	-
NH4	g/m^3	0.039	0.048	9.8	✓
NO3+NO2	g/m^3	0.394	0.379	2.0	✓
pH	pH	7.10	7.79	5.5	
TN	g/m^3	1.15	1.06	4.1	✓
TP	g/m^3	0.220	0.205	3.6	✓
TURB	NTU	59.0	58.4	0.5	✓

Table 2: Results of SEM QC measurements from a split sample taken at MGN000195 on 21 August 2018, and analysed by Hills & NIWA Laboratories.

MGN000195					
		Time: 1020 (NZST)		Difference from mean (%)	Comments
Parameter	Units	HILL	NIWA		
A340F	/cm	0.0350	0.0363	1.8	✓
A440F	/cm	0.0080	0.0078	1.6	✓
COND	mS/m @ 25°C	54.0	55.7	1.5	✓
DRP	g/m^3	0.006	0.007	3.9	✓
ECOL	cfu/100 mL	167	145	7.1	✓
NH4	g/m^3	0.007	0.013	29.3	**
NO3+NO2	g/m^3	0.221	0.211	2.4	✓
pH	pH	7.00	7.79	5.3	
TN	g/m^3	0.360	0.348	1.6	✓
TP	g/m^3	0.022	0.020	4.6	✓
TURB	NTU	2.10	1.84	6.6	✓

Table 3: Results of the 2018-19 SEM Hill-NIWA QC measurements with historical TRC-NIWA QC measurements.

	Difference from mean of pairs of split samples							
Parameter ID	**<10%**		**10-20%**		**20-50%**		**>50%**	
A340F	2	(93)	-	(4)	-	(4)	-	(0)
A440F	1	(59)	1	(37)	-	(0)	-	(4)
COND	2	(93)	-	(4)	-	(0)	-	(3)
DRP	1	(43)	-	(25)	1	(29)	-	(4)
ECOL	1	(25)	-	(33)	-	(33)	-	(0)
NH4	1	(38)	-	(24)	1	(17)	-	(21)
NO3+NO2	2	(90)	-	(7)	-	(3)	-	(0)
pH	2	(100)	-	(0)	-	(0)	-	(0)
TN	2	(85)	-	(7)	-	(7)	-	(0)
TP	2	(59)	-	(26)	-	(15)	-	(0)
TURB	2	(34)	-	(48)	-	(17)	-	(0)

(NB: () - % of QC samples over the 1995 to 2018 period)

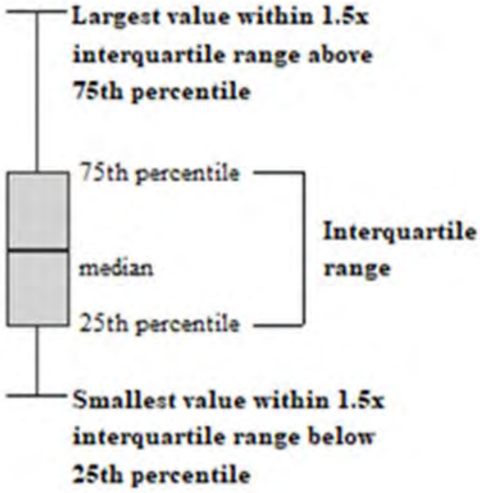
This summary indicates:

- Generally good inter-laboratory analytical performance for most parameters while taking into account variations in laboratory methods and equipment performance tolerances.
- pH levels showed the greatest variability between the two laboratories, however the Hill samples were disposed of before reanalysis could be undertaken. Ammoniacal nitrogen and dissolved reactive phosphorus nutrient analyses measurements also showed some notable variability between laboratories.

Appendix IV

Statistical 'Box & Whisker' Plots of 1995-2019 Water Quality Parameters for all SEM sites

HOW TO INTERPRET A BOXPLOT

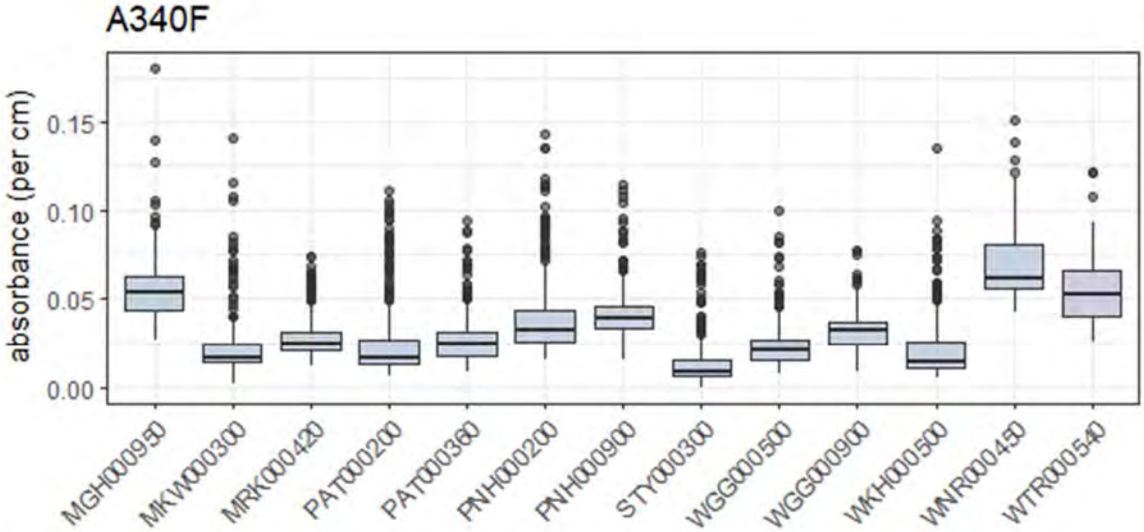


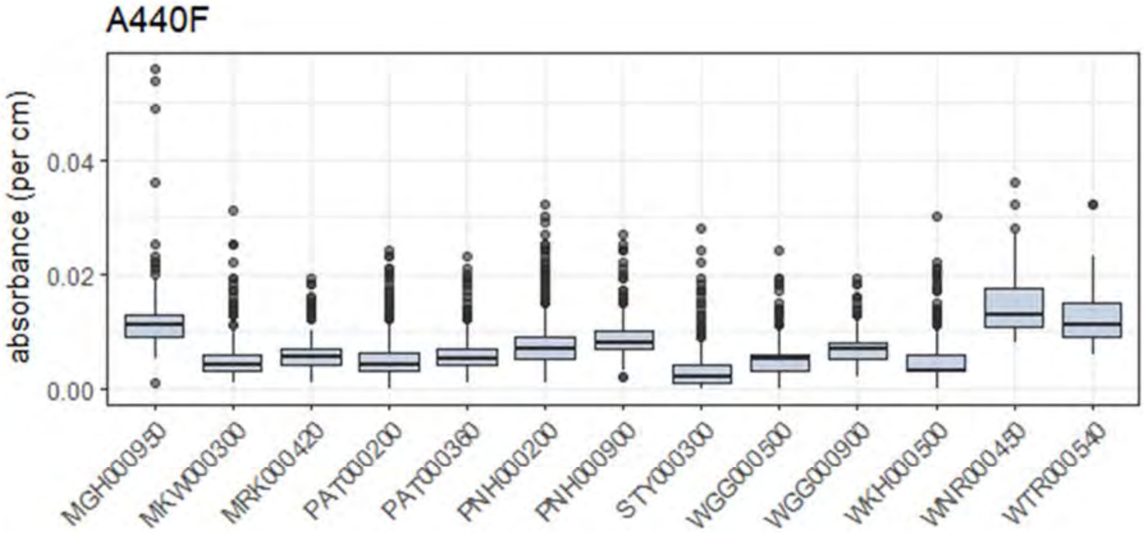
- **Outlier**-Value is >1.5x and <3x the interquartile range beyond either end of the box

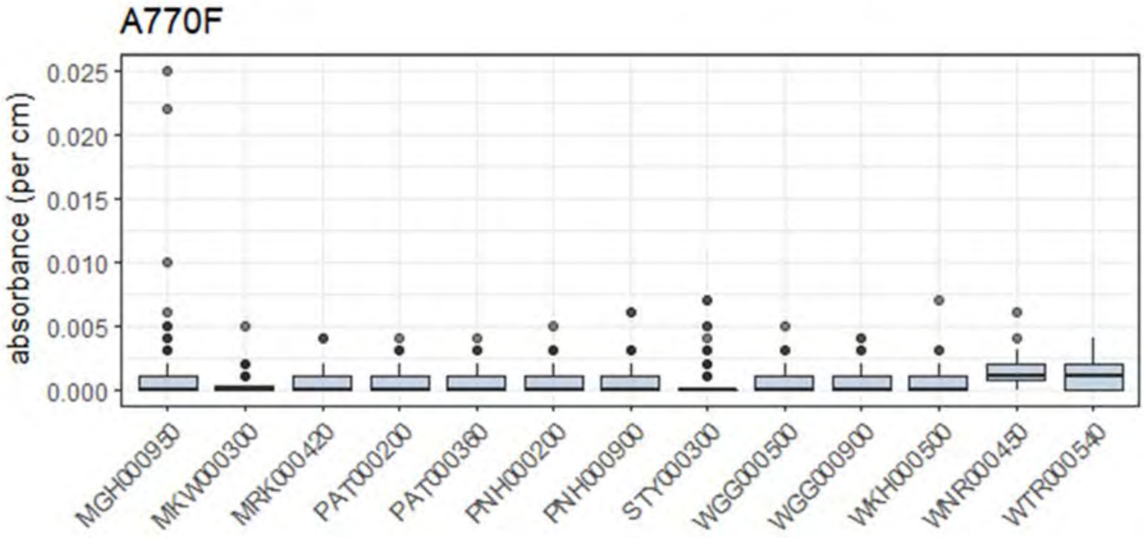
Site locations

Stream	Location	Site code
Maketawa Stream	at Tarata Road	MKW000300
Mangaehu River	at Raupuha Road	MGH000950
Mangaoraka Stream	at Corbett Road	MRK000420
Patea River	at Barclay Road	PAT000200
Patea River	at Skinner Road	PAT000360
Punehu Stream	at Wiremu Road	PNH000200
Punehu Stream	at SH45	PNH000900
Stony River	at Mangatete Road	STY000300
Waingongoro River	at Eltham Road	WGG000500
Waingongoro River	at SH45	WGG000900
Waitara River	at Tarata	WTR000540
Waiwhakaiho River	at SH3	WKH000500
Whenuakura River	at Nicholson Road	WNR000540

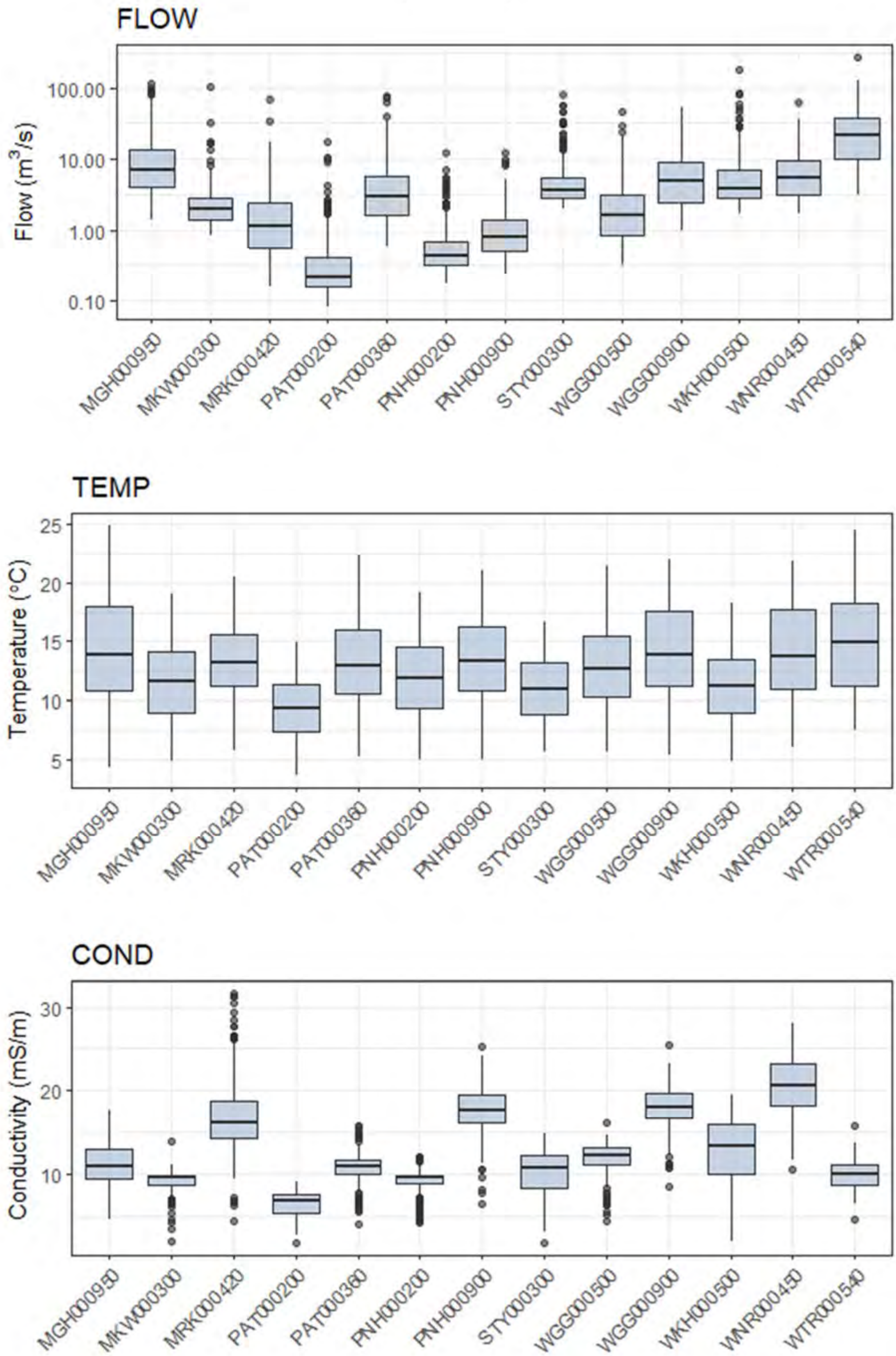
Absorbance (1cm)

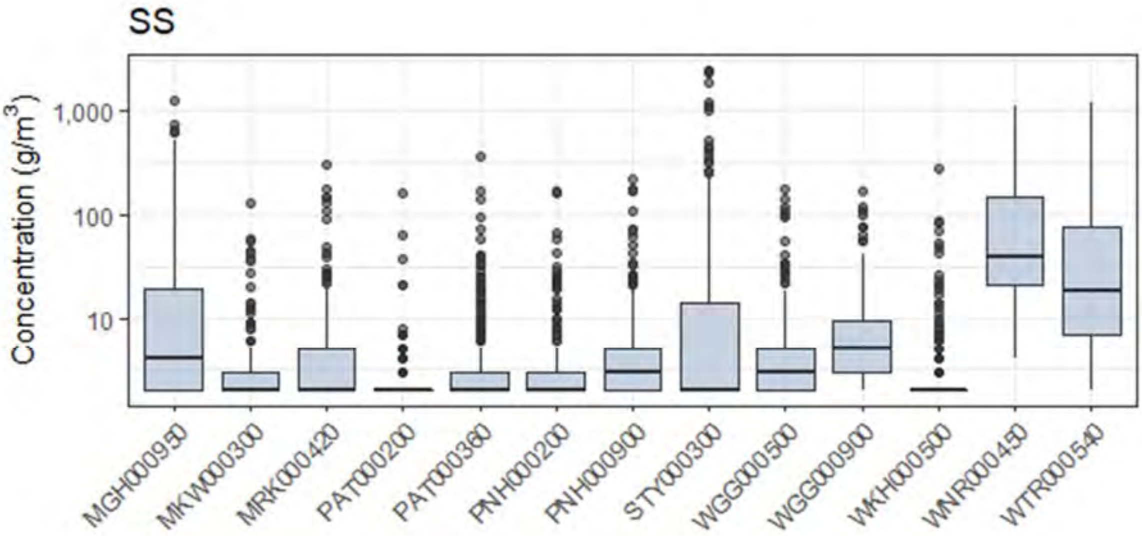






Physical Quality




SS
Concentration (g/m3)
1,000
100
10
MGH00950
MKW00300
MRK00420
PAT00200
PAT00360
PNH00200
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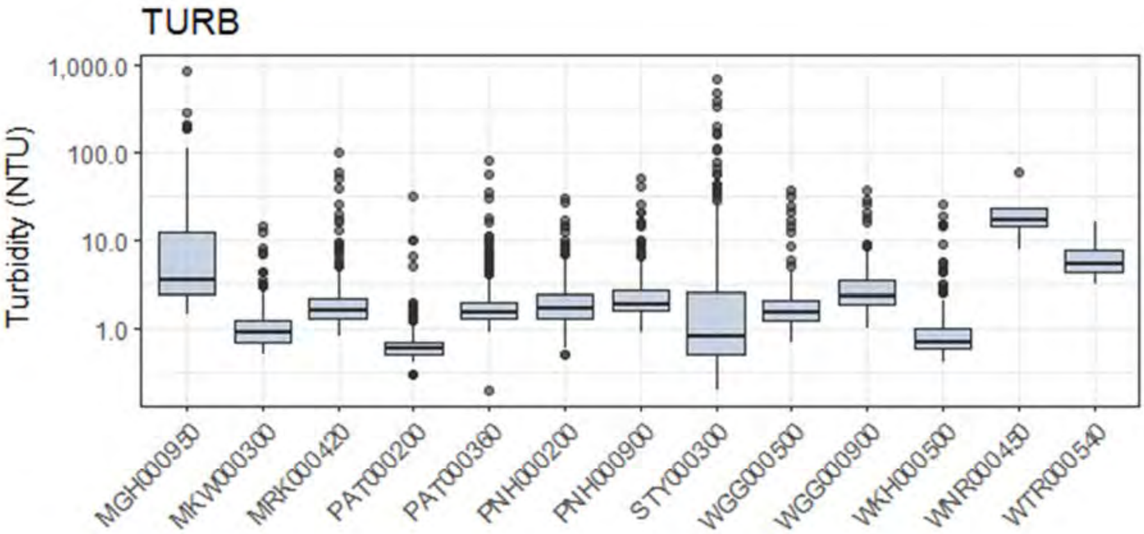
WGG00900
WKH00500
WNR00450
WTR00540


TURB
Turbidity (NTU)
1,000.0
100.0
10.0
1.0
MGH00950
MKW00300
MRK00420
PAT00200
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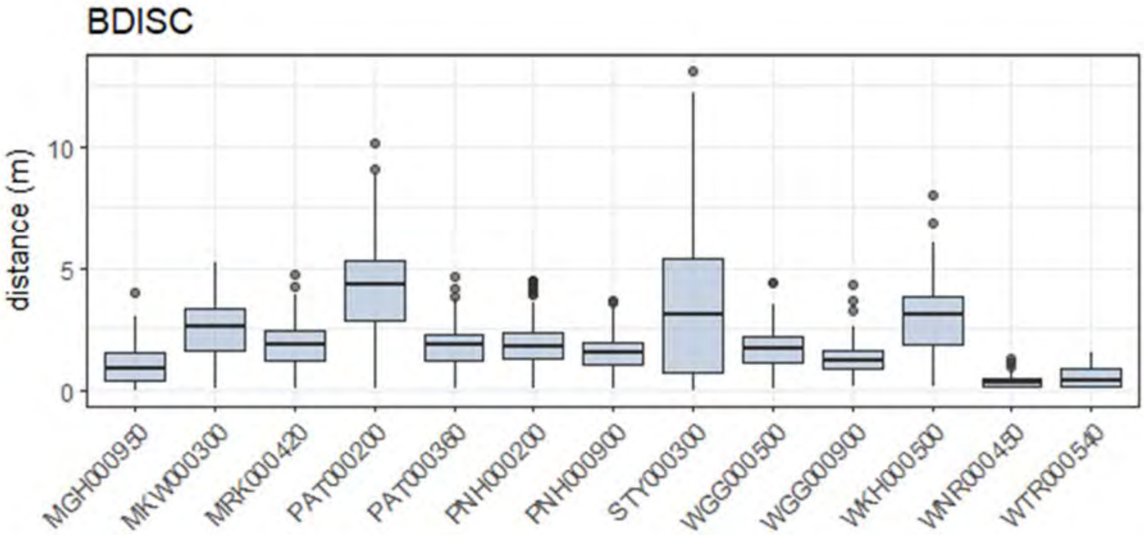
WKH00500
WNR00450
WTR00540


BDISC
distance (m)
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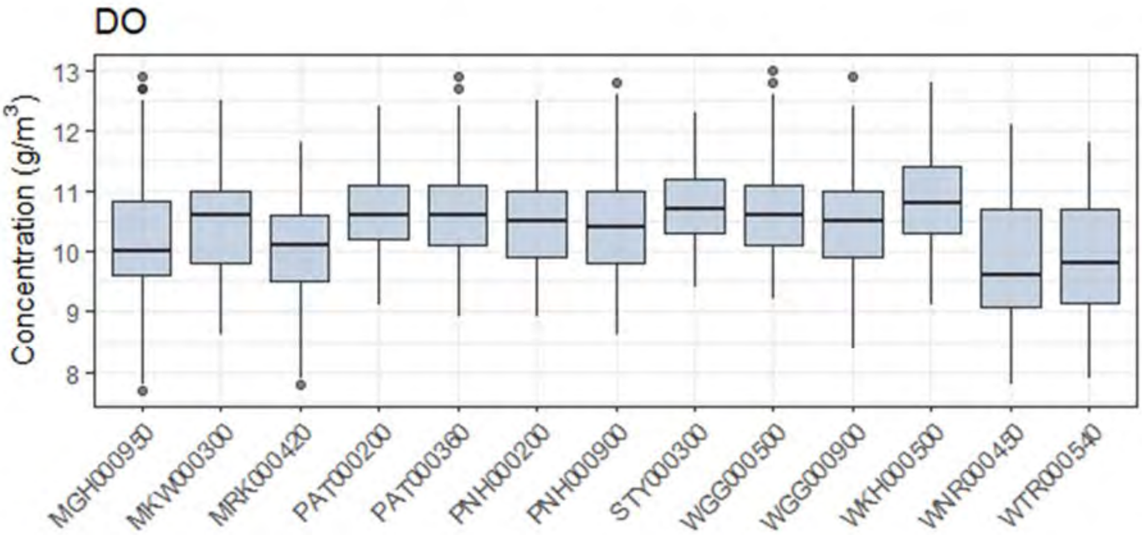
5
0
MGH00950
MKW00300
MRK00420
PAT00200
PAT00360
PNH00200
PNH00900
STY00300
WGG00500
WGG00900
WKH00500
WNR00450
WTR00540


DO
Concentration (g/m3)
13
12
11
10
9
8
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MKW000300
MRK000420
PAT000200
PAT000360
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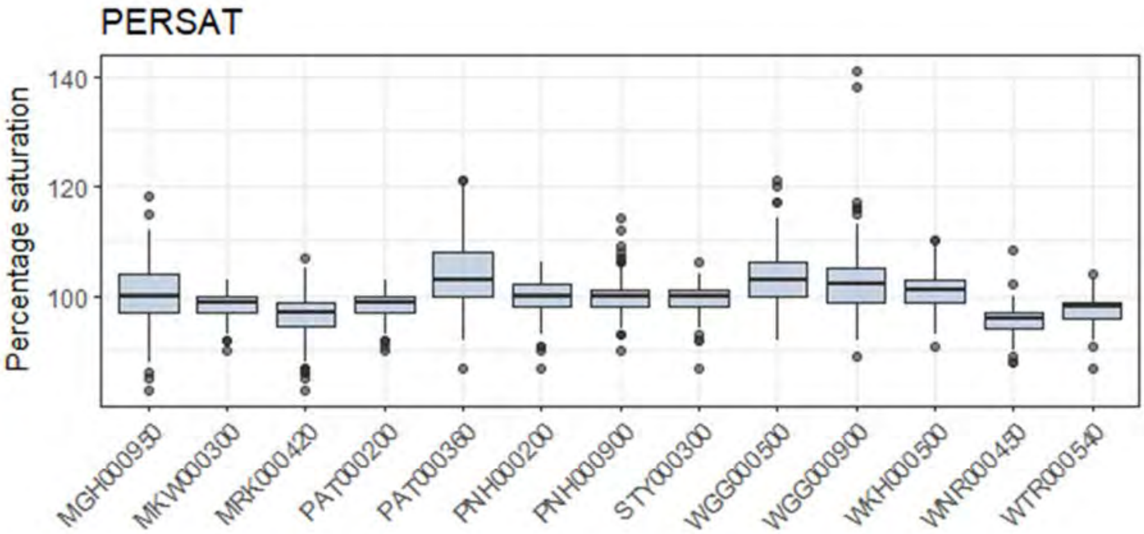
WKH000500
WNR000450
WTR000540


PERSAT
Percentage saturation
140
120
100
MGH000950
MKW000300
MRK000420
PAT000200
PAT000360
PNH000200
PNH000900
STY000300
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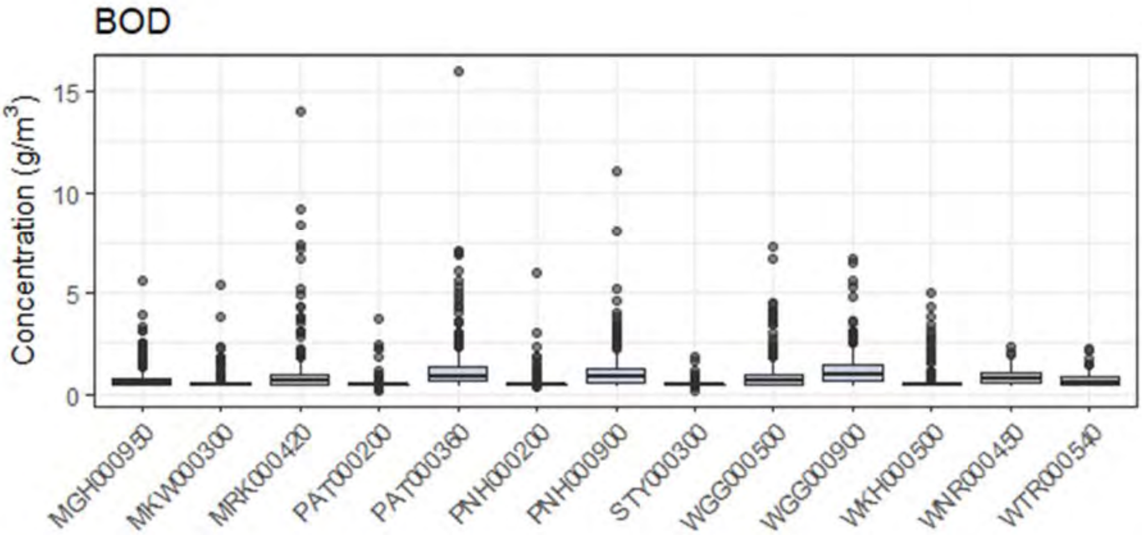
WKH000500
WNR000450
WTR000540


BOD
Concentration (g/m3)
15
10
5
0
MGH000950
MKW000300
MRK000420
PAT000200
PAT000360
PNH000200
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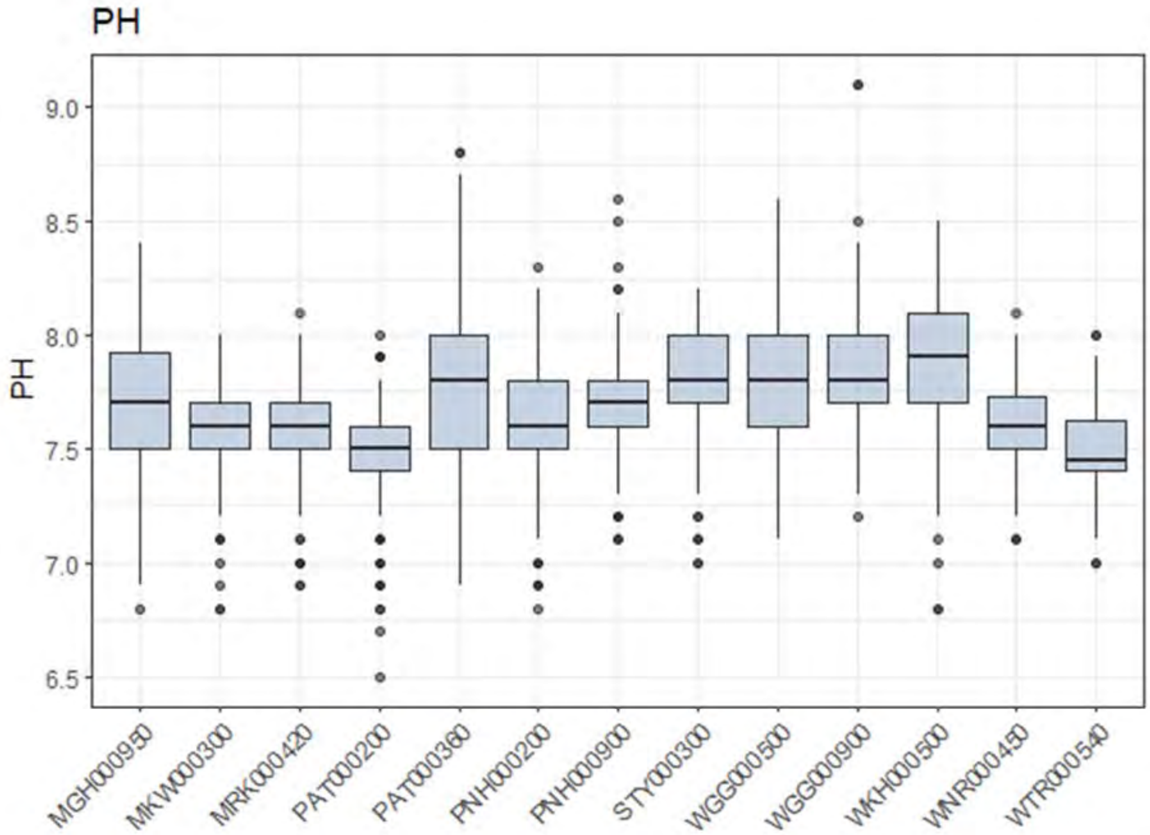
WKH000500
WNR000450
WTR000540


PH
PH
9.0
8.5
8.0
7.5
7.0
6.5
MGH000950
MKW000300
MRK000420
PAT000200
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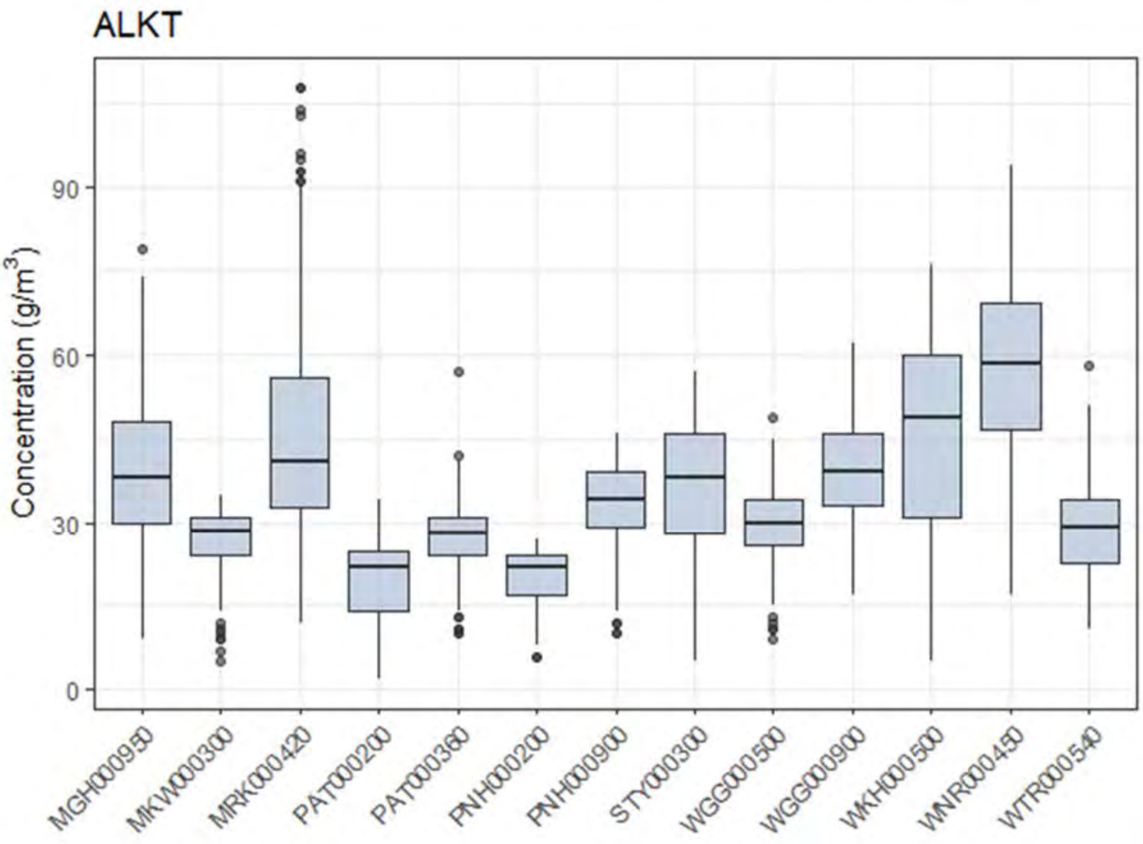
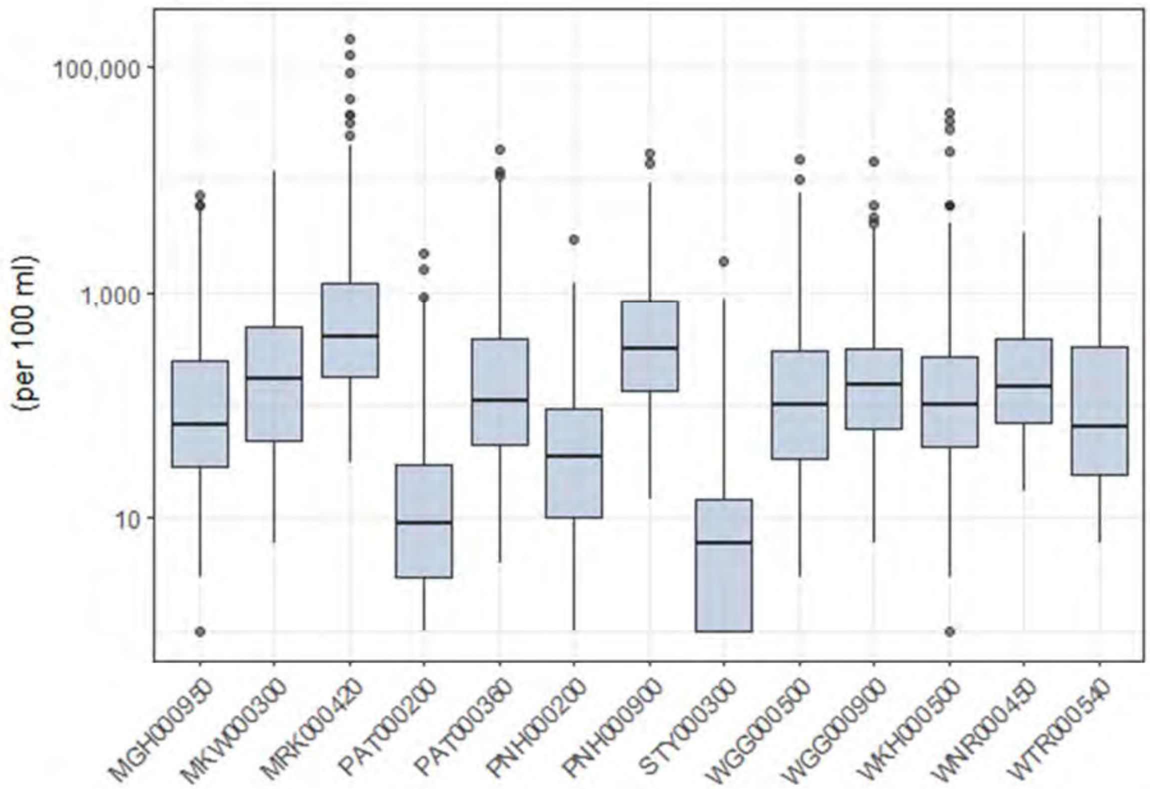
WKH000500
WNR000450
WTR000540

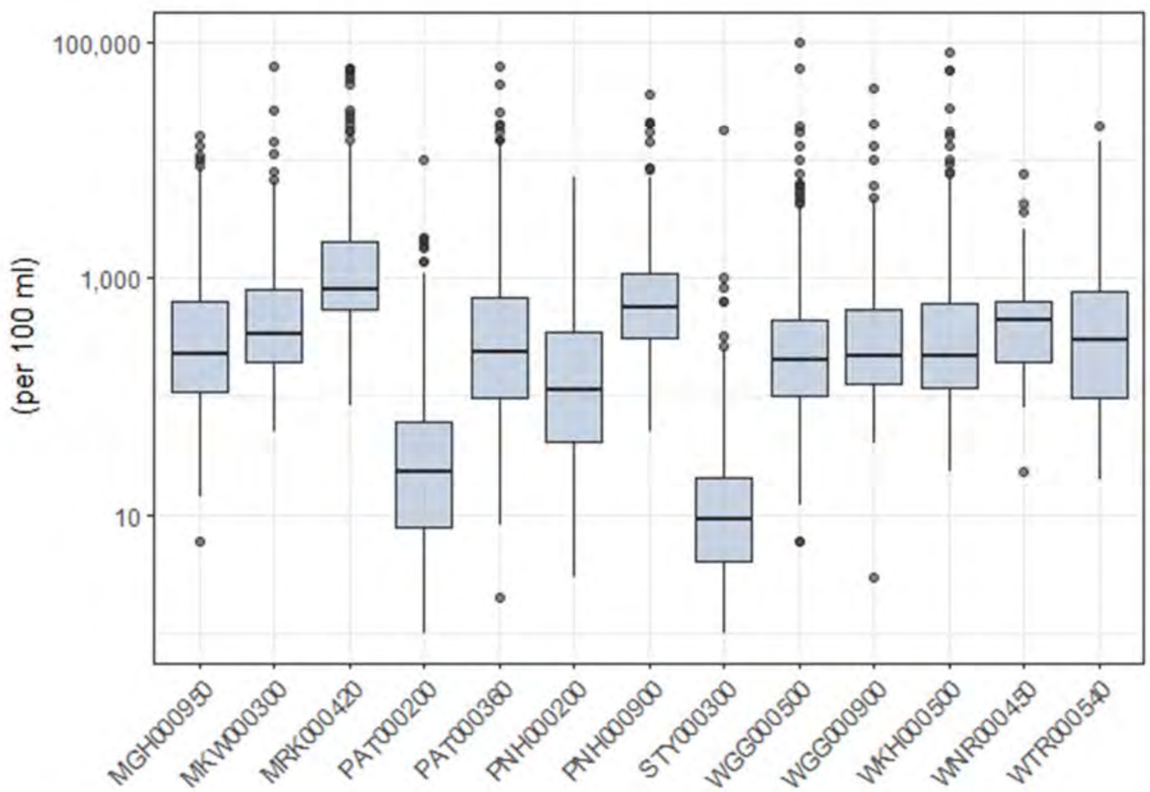

ALKT
Concentration (g/m3)
90
60
30
0
MGH000950
MKW000300
MRK000420
PAT000200
PAT000360
PNH000200
PNH000900
STY000300
WGG000500
WGG000900
WKH000500
WNR000450
WTR000540

Bacteria

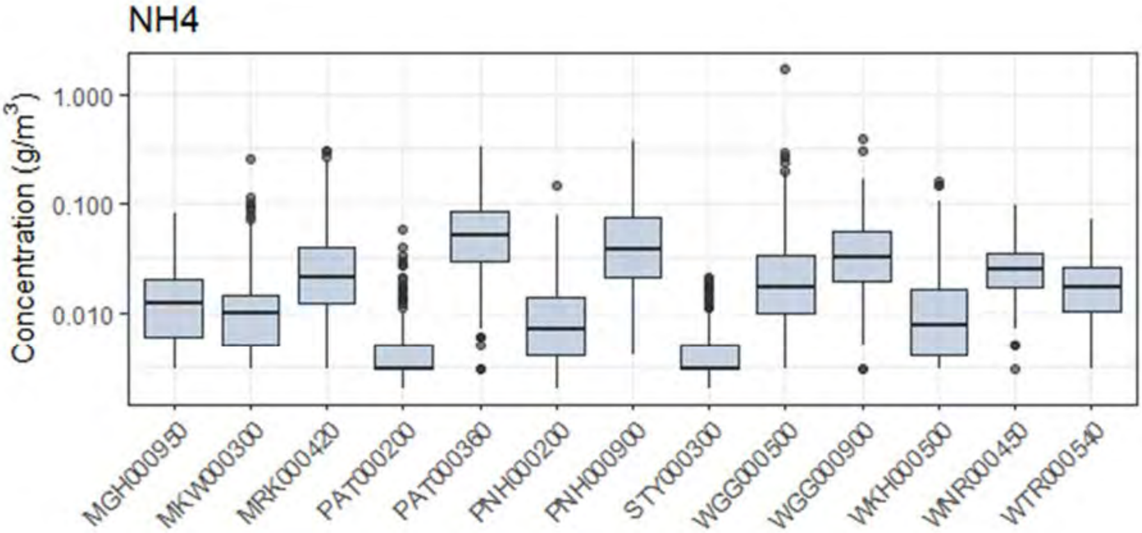
ENT



FC



Nutrients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Concentration (g/m^3)
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0.010
MGH000950
MKW000300
MRK000420
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PAT000360
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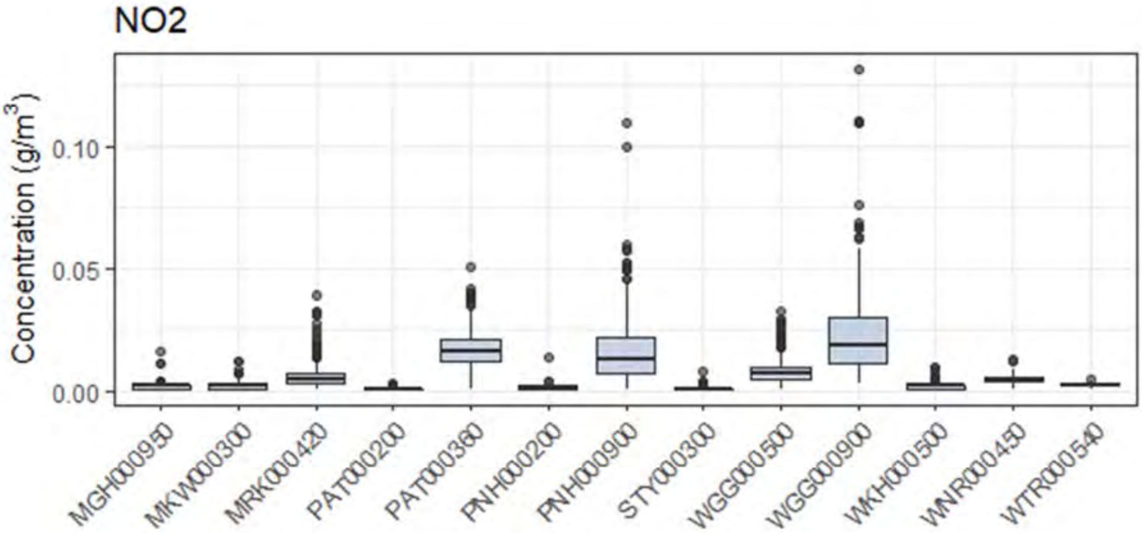
WKH000500
WNR000450
WTR000540


NO2
Concentration (g/m^3)
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0.05
0.00
MGH000950
MKW000300
MRK000420
PAT000200
PAT000360
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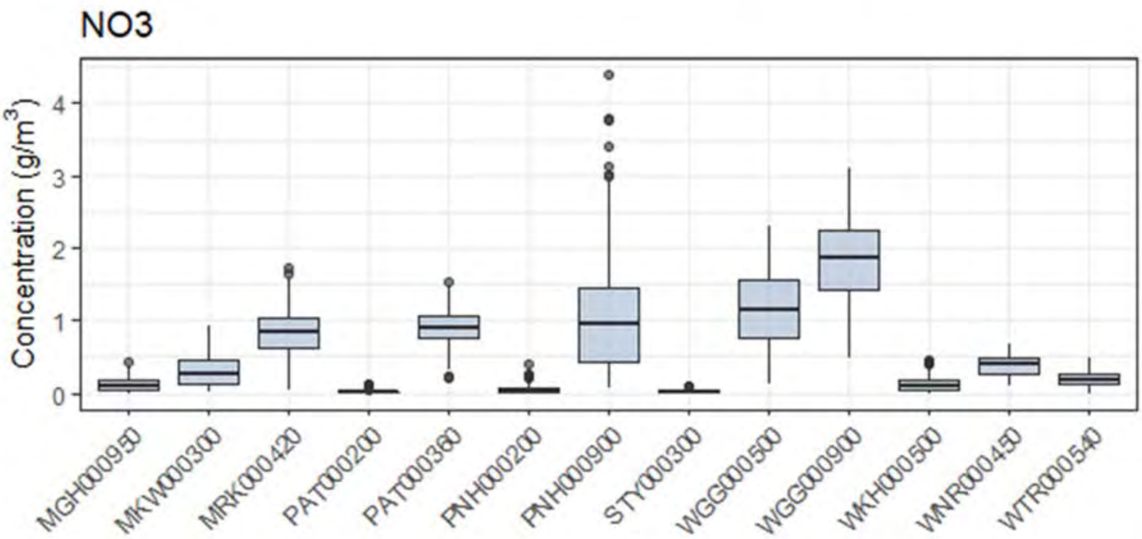
WKH000500
WNR000450
WTR000540


NO3
Concentration (g/m^3)
4
3
2
1
0
MGH000950
MKW000300
MRK000420
PAT000200
PAT000360
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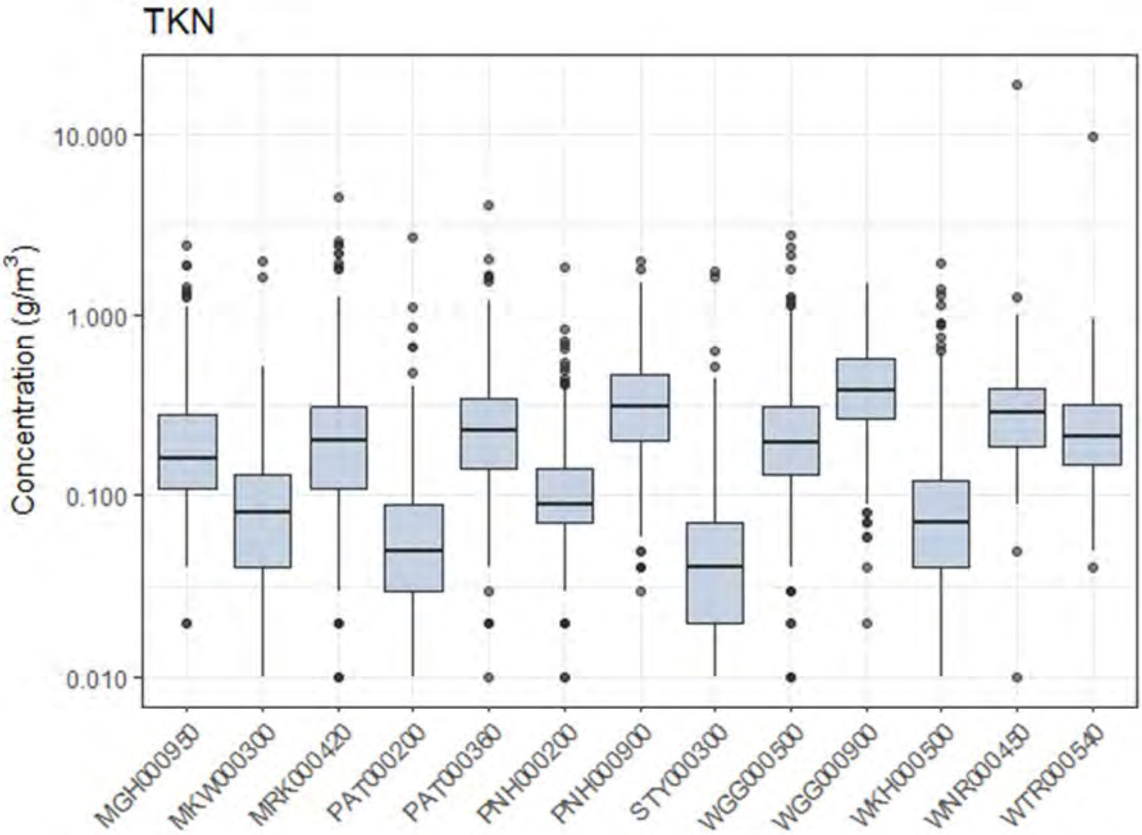
WKH000500
WNR000450
WTR000540


TKN
Concentration (g/m^3)
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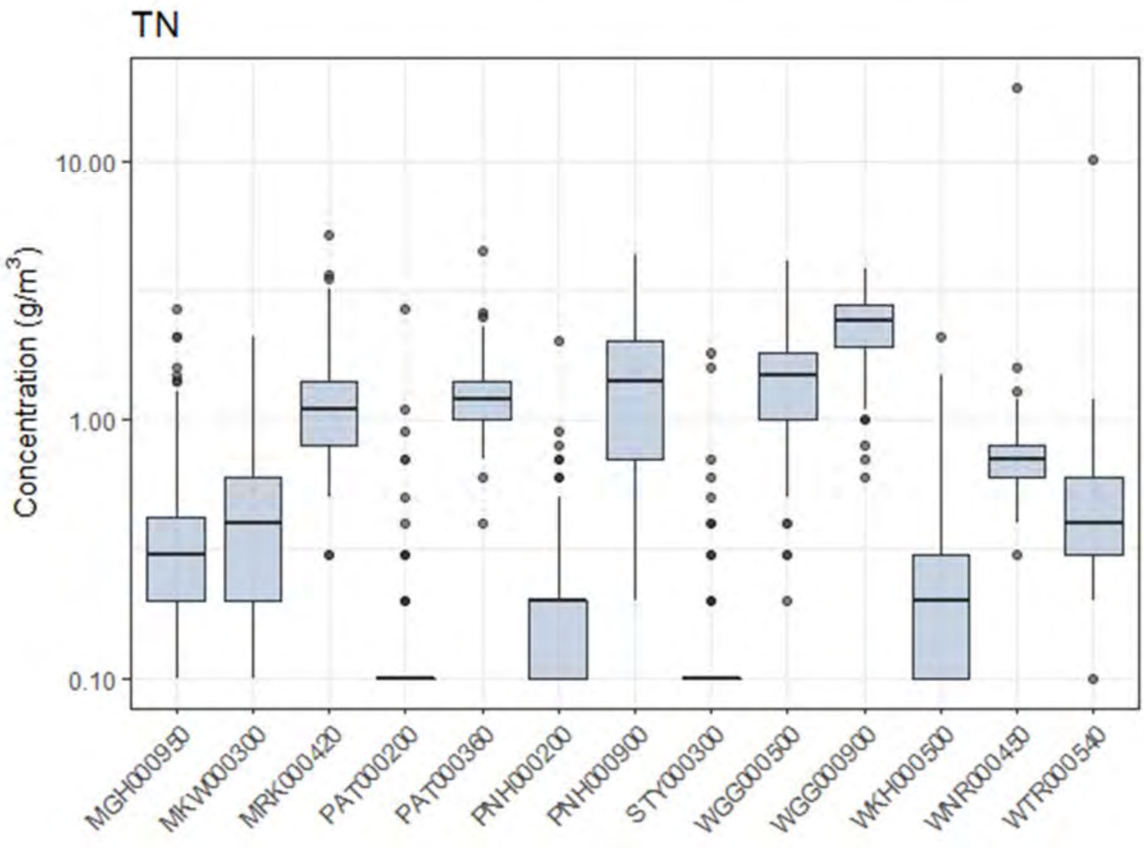
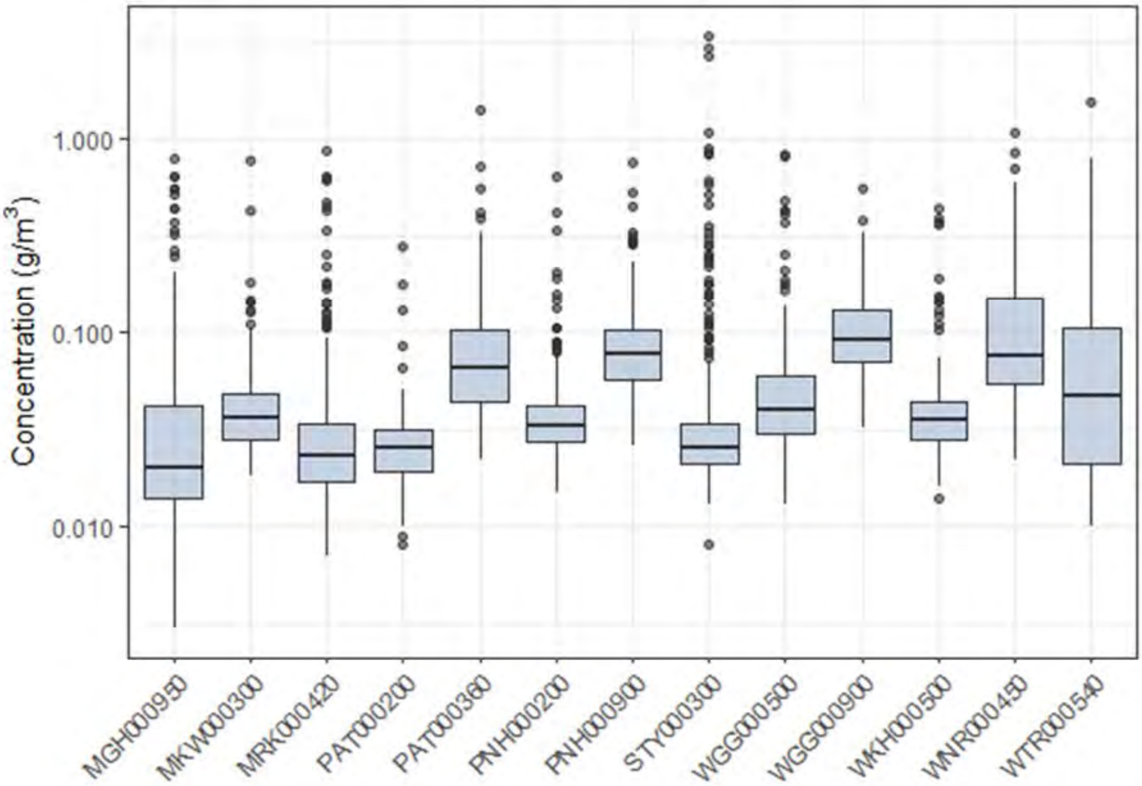
1.000
0.100
0.010
MGH00950
MKW000300
MRK000420
PAT000200
PAT000360
PNH000200
PNH000900
STY000300
WGG000500
WGG000900
WKH000500
WNR000450
WTR000540


TN
Concentration (g/m^3)
10.00
1.00
0.10
MGH00950
MKW000300
MRK000420
PAT000200
PAT000360
PNH000200
PNH000900
STY000300
WGG000500
WGG000900
WKH000500
WNR000450
WTR000540

TP


1.000
0.100
0.010
Concentration (g/m^3)
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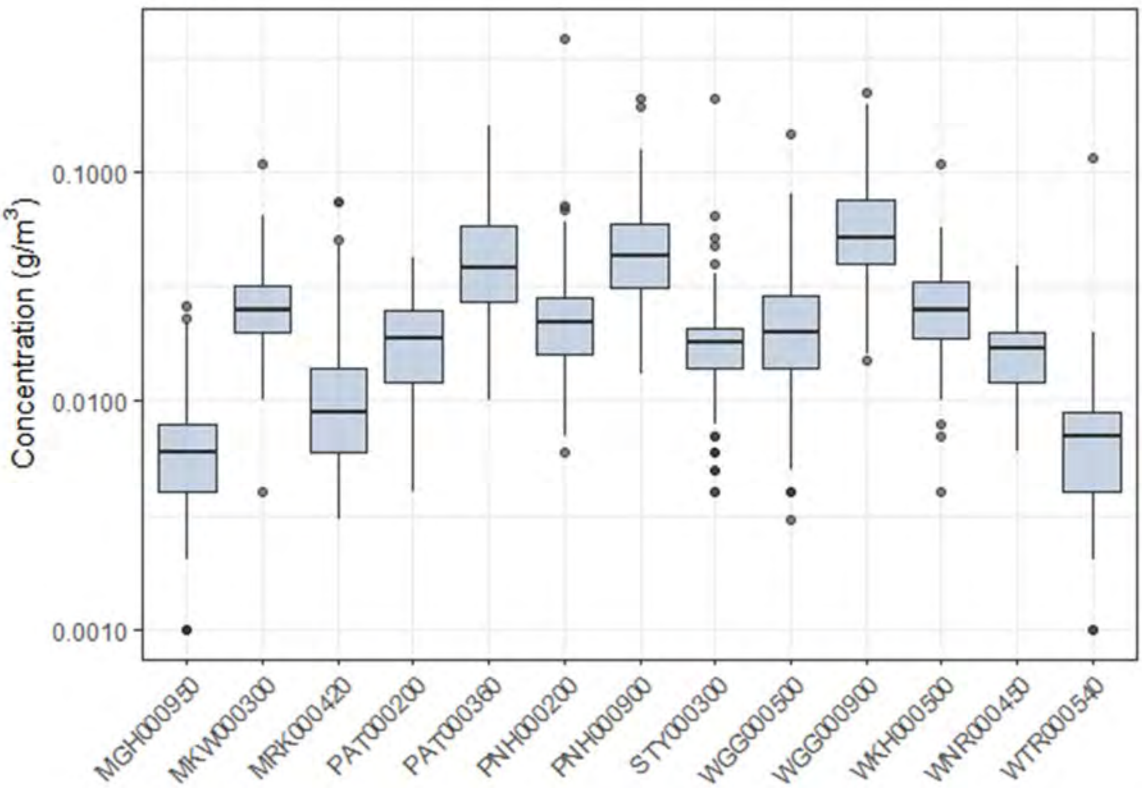
MKW00300
MRK00420
PAT00200
PAT00360
PNH00200
PNH00900
STY00300
WGG00500
WGG00900
WKH00500
WNR00450
WTR00540

DRP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0.0100
0.0010
Concentration (g/m^3)
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MKW00300
MRK00420
PAT00200
PAT00360
PNH00200
PNH00900
STY00300
WGG00500
WGG00900
WKH00500
WNR00450
WTR00540