Water Quality of Bay of Plenty Rivers 1989-2008

Prepared by Paul Scholes, Environmental Scientist and
John McIntosh, Environmental Consultant (Lochmoigh Ltd)

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Cover Photo: Motu River

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Thanks also to NIWA for making available the data for several of the National River Water Quality Network sites that are located in the Bay of Plenty.

Executive summary

Rivers and streams in the Bay of Plenty provide a range of economic benefits and have important ecological, recreational, aesthetic and cultural values. Uses of rivers and streams in the region include municipal and industrial water supply, waste disposal, irrigation, frost protection and hydro-generation. These uses and values can be adversely affected by degradation of water quality.

Management of the environmental quality of rivers and streams in the Bay of Plenty is guided primarily by the Regional Water and Land Plan (RWLP). Objectives, methods and policies in this plan, and in the Regional Plan for the Tarawera River Catchment, are intended to provide for the maintenance and enhancement of water quality and quantity. Water classifications are included in regional plans as a guide for issuing resource consents for activities that might impact on waterways.

Over 40 river and stream sites are included in the Bay of Plenty's Natural Environment Regional Monitoring Network (NERMN) water quality module and an additional seven sites are monitored by NIWA. The sampling sites are representative of a range of land uses and catchment land cover and include most of the regions major rivers and streams.

The purpose of this report is to summarise the results of trend analysis for water quality in the regions' rivers and streams. NERMN data from 1989 to 2008 has been used to examine trends in a number of parameters; dissolved oxygen, temperature, colour, pH, suspended solids, turbidity, visual clarity, five forms of nutrients and three forms of indicator bacteria.

While there are a number of significant improving trends, the key finding of the report is that the water quality of many rivers and streams is deteriorating. The main indicators of this are nutrients, bacteria and suspended solids/turbidity. A number of specific examples are summarised below:

- There were five sites with increasing trends in suspended solids and 10 with increasing turbidity. Some sites showed improvements in these parameters including the Tarawera River at Awakaponga (reduced loading for the pulp and paper mills) and the Nukuhou River (possible impact of catchment riparian works).

- There were 12 sites with significant increases in total nitrogen (TN) and oxides of nitrogen (TOx-N). Of these, eight sites had increases of greater than 1% per year for TN and 11 sites had increases of greater than 1% per year for TOx-N. Notably, these trends are in catchments dominated by pastoral agriculture. However, some stream sites influenced by pastoral activity have decreasing trends in TN (e.g. the Waimana and the Nukuhou).

- Trends in phosphorus varied throughout the region with two sites increasing and two decreasing for dissolved reactive phosphorus (DRP). Five increasing trends greater than 1% per year were also found for total phosphorus (TP) and seven decreasing trends at greater than 1% per year. The Waitao Stream showed decreasing trends in all nutrient species including phosphorus as did the Waipapa Stream (with the exception of ammonium-nitrogen). Other rivers show a similar pattern of increasing trends such as the Tarawera at Awakaponga and the Motu at Waitangirua.

- Ammonium-nitrogen concentrations are relatively low. Six sites had increasing ammonium-nitrogen and six were decreasing. Two sites on the Rangitaiki system had a decrease while two lower sites on the Tarawera River are increasing.

- Many of the Rotorua and Central Rivers group have elevated nitrogen and phosphorus levels compared to the ANZECC guidelines for nutrient contamination. The high rate of nitrate leaching on pumice soils and phosphorus leached from the underlying geology due to the length of time groundwater remains in subterranean systems is the cause of these phenomena. The overriding value given to each river is not compromised in any case. However the two streams entering Lake Rotorua carry nitrogen and phosphorus that leads to the lake failing to meet its classification.

- The greatest number of increasing trends (at 15 sites) was found for the indicator bacteria Escherichia coli. This indicates increasing faecal contamination and increased risk to people using these waterways for recreation or water supply.

- Just two decreasing trends were found for the bacterial indicators, these were meaningful decreasing trends for Enterococci and faecal coliforms in the Kaituna River at Te Matai.

The report concludes with a number of recommendations to improve the river and stream monitoring module of the NERMN.

Contents

Tables and Figures

Part 1: Introduction

Rivers and streams in the Bay of Plenty provide a range of economic benefits and have important ecological, recreational, aesthetic and cultural values. Uses of rivers and streams in the region include municipal and industrial water supply, waste disposal, irrigation, frost protection and hydro-generation. These uses and values can be adversely affected by degradation of water quality.

Management of the environmental quality of rivers and streams in the Bay of Plenty is guided primarily by the Regional Water and Land Plan (RWLP). Objectives, methods and policies in this plan, and in the Regional Plan for the Tarawera River Catchment, are intended to provide for the maintenance and enhancement of water quality and quantity. Water classifications are included in regional plans as a guide for issuing resource consents for activities that might impact on waterways.

Objective 13 of the RWLP states:

The water quality in rivers and streams is maintained or improved to meet the Water Quality Classifications set in the Water Quality Classification Map, and the following environmental outcomes:

(a) Natural State (Lake) Water Quality Classification - the natural quality of the water shall not change.

(b) Natural State (River) Water Quality Classification - the natural quality of the water shall not change.

(c) Managed State (Lake) Water Quality Classification - the water quality in the lake shall not deteriorate.

(d) Aquatic Ecosystem (Bay of Plenty) Water Quality Classification – water quality shall be sufficient to support diverse and healthy aquatic ecosystems.

(e) Contact Recreation Water Quality Classification - water quality shall be sufficient to allow contact recreational uses.

(f) Water Supply Water Quality Classification - water quality shall be sufficient to allow for municipal water supply purposes, while recognising water treatment may still be required.

(g) Drains with Ecological Values Water Quality Classification - water quality shall be sufficient to support aquatic ecosystems, while recognising that aquatic ecosystems in such areas are limited.

(h) Regional Baseline Water Quality Classification - water quality shall not deteriorate.

Routine monitoring of the water quality of the rivers and streams in the Bay of Plenty has been occurring since 1989 at a range of sites (Figure 1.1). This monitoring forms a module of the Natural Environmental Regional Monitoring Network (NERMN). The monitoring enables council to assess water quality trends and in turn assess the effectiveness of the Regional Policy Statement and regional plans. The objectives of this report are to:

- Summarise the water quality of the regions' rivers and streams.
- Detect water quality trends in the interests of maintaining and/or enhancing water quality.
- Identify specific water quality issues.
- Develop recommendations for future monitoring.

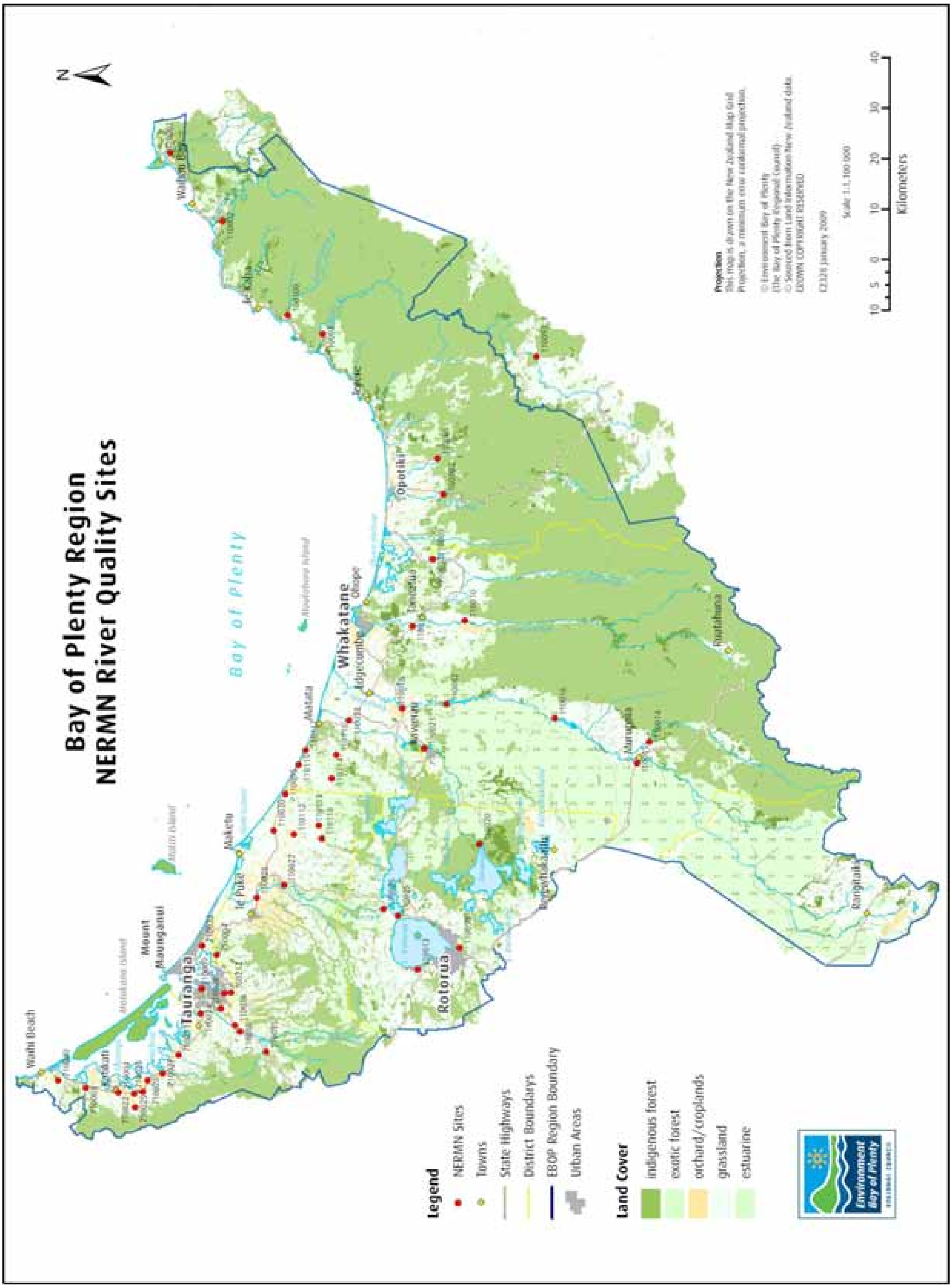


Figure 1.1 NERMN River and Stream Water Quality Monitoring Sites.

Part 2: Methods

2.1 Sampling and Analysis

Sampling and analyses where performed in accordance with established internal protocols. Most analyses were performed by the Environment Bay of Plenty laboratory (which holds IANZ accreditation) or Hills Laboratory, Hamilton.

Table 2.1 Methods used for chemical/biological analysis of water samples.

Parameter (abbreviation)	Method	Detection Limit/ Units
Ammonium Nitrogen (NH_4-N)	NWASCO Misc. Pub. No. 38, 1982. Phenolhypochlorite colorimetry	1 mg/m^3
Total Oxidised Nitrogen (TOx-N)	Flow injection analyser, APHA 4500 NO3-I	1 mg/m^3
Total Klejdahl Nitrogen[1] (TKN)	APHA Method 4500B NIWA mod., Oct 1990	90 mg/m^3
Total Phosphorus (TP)	NWASCO Misc. Pub. No. 38, 1982. Acid persulphate digestion.	8 mg/m^3
Dissolved Reactive Phosphorus (DRP)	NWASCO Misc. Pub. No. 38, 1982. Antimony – phosphate – molybdate.	4 mg/m^3
Water clarity - black disc	Black disc measured in metres (to 0.1m increments) with a viewing tube	0.1 m
Turbidity	APHA Method 2130B-HACH 2100N ratio and signal averaging on.	0.01 NTU
pH	APHA method 4500-H+ measurement at 25^{o}C	
Temperature	YSI or Hach DO Meter	0.1 deg C
Conductivity	APHA Method 2510B, EDTRE 387 Tx Meter	0.5 mS/m at 25 deg C
Suspended Solids (SS)	APHA Method 2540D	0.5 g/m^3
Colour Coefficient	Adsorption at 440nm measured by spectrophotometer using 1cm cell	Abs at 440nm/cm
Dissolved oxygen[2]	APHA Method 4500-0-G, YSI or Hach Meter	0.5 g/m^3
Biochemical Oxygen Demand (BOD_5)	APHA Method 5210B	0.5 g/m^3
Escherichia coli (E.coli) **Faecal coliform (FC)**	Membrane filtration, Standard Methods for the Examination of Water & Wastewaters (2005)	1 cfu/100ml
Enterococci (Ent)	Method No 1600, USEPA 1986 EPA-821-R-97-004	1 cfu/100ml
River Flow	Manual gauging or derived from stage-discharge rating curve	m^3/s

[1] Total nitrogen (TN) is derived from TKN and TOx-N.

[2] Dissolved oxygen saturation (DO%) has been calculated using: DO% = (100*(DO/(14.6-0.4027*T+0.007899*(T^2)-0.00007722*(T^3))), T = concurrent temperature (no altitudinal adjustment has been made).

Water quality analyses were completed using the methods in Table 2.1. All samples for chemical analysis were stored and returned within the time period stipulated by the methods.

2.1.1 Monitoring sites

Over 40 sites make up the NERMN water quality module for rivers and streams (see Figure 1.1). The sites characterise a range of land uses and catchment land cover and examine the state of most of the major rivers and streams in the Bay of Plenty.

Currently sites are divided into groups based on geographic location and are sampled monthly for a year every three years. Several sites are monitored monthly ever year as are sites sampled and analysed by the National Institute of Water and Atmospheric Research (NIWA). NIWA monitored sites are shown in Table 2.2.

Sampling runs are planned so that individual sites are sampled at a similar time to minimise changes due to diurnal fluctuations. A range of flow conditions are encountered during sampling.

Table 2.2 NERMN River Sites and RWLP Classifications.

Area	Rivers	Description	Site No	Grid No.	Classification
Western/ Rotorua	Ngongotaha	Town Bridge	BOP110013	U15:9190-4170	Aquatic ecosystem
	Puarenga	FRI	BOP110058	U16:9620-3340	Aquatic ecosystem
	Ohau	SH 33 Bridge	BOP110025	U15:0250-4560	Aquatic ecosystem
	Rotoiti o/lt	Control Gate	BOP110026	U15:0380-4850	Aquatic ecosystem
	Kaituna	Te Matai Rail Bridge	BOP110028	U14:0610-7365	Contact recreation
	Kaituna	Maungarangi Rd Br	BOP110027	U15:0860-6820	Aquatic ecosystem
	Pongakawa	SH 2 Bridge	BOP110030	V15:1943-7020	MWCEV
	Pongakawa	U/S Site	BOP110112	V15:1860-6620	Aquatic ecosystem
	Pongakawa	Johnston Rd	BOP110118	V15:1780-6070	Aquatic ecosystem
	Pikowai Stream	SH 2	BOP110115	V15:3240-6530	Aquatic ecosystem
	Mimiha Stream	SH 2	BOP110117	V15:3530-6390	Aquatic ecosystem
	Waitahanui Stream	SH2 Bridge	BOP110095	V15:2660-6790	Aquatic ecosystem
Tauranga Harbour	Waitao	Spensers farm	BOP710004	U14:9480-8150	Aquatic ecosystem
	Waimapu	Pukemapui Road	BOP160212	U14:8730-7870	Aquatic ecosystem
	Waimapu	Greerton Park	BOP160121	U14:8710-8000	Contact recreation
	Wairoa	d/s Powerstation	BOP110088	U14:7960-7680	Aquatic ecosystem
	Wairoa lwr	S.H 2 Bridge	BOP110034	U14:8310-8460	Aquatic ecosystem
	Ngamuwahine	Old Ngamuwahine Br.	BOP110035	U14:7560-7170	Aquatic ecosystem
	Omanawa	S.H 29 Bridge	BOP110036	U14:8080-7780	Aquatic ecosystem
	Waipapa	Old Highway Bridge	BOP710011	U14:7490-8900	Contact recreation
	Tuapiro	Surtees Rd.	BOP710003	T13:6840-0740	Aquatic ecosystem
	Kopurererua	S.H.2	BOP710009	U14:8810-8450	Aquatic ecosystem
	Kopurererua	S.H.29-Rec. house	BOP710008	U14:8420-8060	Aquatic ecosystem
	Te Mania Strm	S.H 2 bridge	BOP710022	T14:6730-9780	Aquatic ecosystem
	Wainui	S.H 2 bridge	BOP710027	U14:7130-9220	Aquatic ecosystem
	Waitekohe	S.H 2 bridge	BOP710023	T14:6770-9610	Aquatic ecosystem
	Waiau	Waiau Road Ford	BOP710040	T13:6990-1290	Aquatic ecosystem
	Te Rereatukahia Stream	SH2	BOP710025	T14:6460-9760	Aquatic ecosystem
	Aongatete	S.H 2 bridge	BOP710028	T14:6990-9520	Aquatic ecosystem
	Rocky Strm	Mangatawa Lane	BOP710032	U14:9660-8440	Regional baseline
	Uretara	Henry Rd. crossing	BOP210004	T13:6750-0092	Aquatic ecosystem

Area	Rivers	Description	Site No	Grid No.	Classification
Eastern	Whangaparaoa	S.H.35 Bridge	BOP110001	Y14:5340-9070	Aquatic ecosystem
	Raukokore	S.H.35 Bridge	BOP110002	Y14:3995-8045	Aquatic ecosystem
	Haparapara	SH35 Bridge	BOP160100	X15:2130-6740	Aquatic ecosystem
	Motu*	S.H.35 Bridge	BOP110003	X15:1760-6050	Natural state
	Motu*	Waitangirua	BOP110093	X16:1310-1825	Natural state
	Otara	Brown's Bridge	BOP110005	X16:9290-3780	Contact Recreation
	Waioeka	Pa Site	BOP160102	W16:8580-3660	Contact Recreation
	Nukuhou	Old Quarry	BOP110007	W16:7290-3870	Aquatic ecosystem
Whakatane	Waimana	Taneatua Bridge	BOP110009	W16:7290-3870	Water supply
	Whakatane	Ruatoki Bridge	BOP110010	W16:6080-3240	Aquatic ecosystem
	Whakatane	Pekatahi Bridge	BOP110011	W15:5970-4270	Water supply
Rangitaiki	Whirinaki*	Galatea Bridge	BOP110014	V17:3700-9590	Aquatic ecosystem
	Rangitaiki*	Old Bridge at Murupara	BOP110015	V17:3270-9830	Aquatic ecosystem
	Rangitaiki	Inlet to Canal	BOP110016	V16:4160-1460	Aquatic ecosystem
	Rangitaiki*	Te Teko Bridge	BOP110018	V15:4360-4480	Aquatic ecosystem
	Rangitaiki	Matahina Dam	BOP110082	V16:4440-3600	Aquatic ecosystem
Tarawera	Tarawera*	Lake Outlet	BOP110020	V16:1670-2950	Fish purposes UTR
	Tarawera	Boyce Park	BOP110021	V15:3570-4040	Fish purposes UTR
	Tarawera*	Awakaponga	BOP110052	V15:4120-5530	Fish purposes LTR

*NIWA co-monitored site.

2.2 Data Assessment

River water quality data sets have been assessed by temporal and comparative methods. Where available data allows, data sets have been assessed for trends using the methods described below. Changes to the frequency of sampling have occurred over the years leading to discontinuity in some data sets. The periods of data capture are listed in Part 4 of this report (Tables 4.2 to 4.4).

2.3 Trend Analysis

River water quality data sets have been assessed by temporal and comparative methods. Where available data allows, data sets have been assessed for trends using the methods described below.

Trend analysis has been undertaken on river sites with three or more years of data where the data offers reasonable continuity. Analysis is undertaken taking into account temporal and hydrological changes where appropriate. The approach to trend analysis follows the non-parametric methods of Helsel and Hirsch (1992) which have been utilised by Vant and Smith (2004), and more recently have been used to analyse New Zealand's National River Water Quality Network (Ballantine and Davies-Colley, 2009).

To accurately detect trends in water quality data it is necessary to look at the influence seasonal variability and flow variability has on the data. Seasonality affects many parameters such as temperature, or land use impacts on water quality may occur seasonally which in turn impact some water quality parameters. Likewise, flow adjustment may be necessary as many water quality parameters will change with increasing and decreasing volumes of water in a river. This dilution effect can obscure underlying trends and hence flow adjusting can decrease variability, increasing the power of trend detection.

Seasonality has been examined using the 'Time Trends' software[3] for each parameter at each site. If a seasonal pattern was identified then trend analysis was undertaken using the seasonal-Kendall test and if no seasonal pattern was readily identified then trend analysis was undertaken using the Mann-Kendall test.

Correlations were used to examine if there was a relationship between flow and other water quality parameters. Generally a flow relationship was established if Spearman R was greater than 0.3 (and p>0.05). Each parameter was also plotted against flow to check correlations.

Trend analysis involved computation of each parameter either with the seasonal-Kendall test or Mann-Kendall test using the Time Trends software. Flow adjustment can be performed for each test where necessary and where this was done adjustment utilised Locally Weighted Scatterplot Smoothing (LOWESS) with a 30% span.

The Sen Slope Estimator (SEN) is used to represent the direction and magnitude of trends in data. This approach involves computing slopes for all the pairs of ordinal time points and then using the median of these slopes as an estimate of the overall slope.

Positive slopes indicate an increase in the values of a water quality parameter and negative slopes indicate an overall decrease. For each trend slope the probability of the slope occurring due to chance is also calculated. The p-value indicates if the trend detected is statistically significant. Conventionally, p-values of 5% (or p<0.05) or less are regarded as statistically significant (i.e. the 95% confidence level, unlikely to occur due to chance).

Results for trend analysis over the relative dataset record have been described firstly by their p-value (i.e. are they statistically significant) and then by their trend slope. The trend slope is expressed by the relevant parameters units/year. For many water quality variables when expressed in units/year the numbers are very small. Trend slopes in units/year have therefore been reformatted by multiplying by 10^{-3}, thus avoiding using a large number of zeros.

Values of the SEN were also normalised by dividing through by the raw data median to give the *relative* SEN (RSEN). Expressed is a percentage change per year (%/year), this standardisation of the slopes allows for easier comparison between sites (and parameters). *Meaningful* trends have been categorised by Scarsbrook (2006) and Ballantine and Davies-Colley (2009) as being those with RSEN greater than 1% per year with the null hypothesis for the Kendall test rejected (p<0.05).

[3] http//www.niwa.co.nz/ncwr/tools

Part 3: Results

3.1 Introduction

Trend statistics for water quality at each of the monitoring sites are presented here along with basic statistics. Observed long-term trends over the period of analysis are described by p-values and trend slopes followed by the percentage annual change in slope (or *relative* Sen slope estimate, RSEN). Significant ($p<0.05$) or meaningful ($p<0.05$, RSEN>1.0) trends are highlighted by bold type.

Rivers and streams have been grouped into geographical locations. At the end of each section a summary is provided with box plots for five key parameters enabling comparison of sites within each geographical location (sub-region).

3.2 Eastern Bay of Plenty

The Eastern Bay of Plenty has a variety of rivers types. In the East Cape area the rivers emanate from the argillite and sandstone dominated Raukumara ranges which are dominated by indigenous vegetation (e.g. the Motu and Raukokore Rivers). Further west the rivers also have their origins in indigenous forest headwaters but quickly wind along extensive floodplains dominated by high intensity livestock agriculture (e.g. the Waimana and Whakatane Rivers).

3.2.1 Whangaparaoa River

The Whangaparaoa River is the largest of the East Cape rivers and has its headwaters in the Gisborne District. The upper catchment is dominated by pastoral hill country and a small floodplain at Matarau where the braided channel reaches over 120 metres in width. The river then winds its way through steep forested hill country before emerging at the coastal floodplain were it travels for approximately 5 kilometres before reaching the ocean.

Trend and water quality statistics are given in Table 3.1. Data capture has varied with monitoring occurring quarterly from 1990 to 1999 and then changing to monthly for 2003/2004 and 2006/2007. Most water quality data show no significant trends with the exception of *E.coli* which is increasing. This trend is driven by several high values in the summer of 2003/2004 and results have since improved.

Suspended solids and conductivity also have increasing trends although not significant. These trends may reflect the easily erodable nature of the landscape which also tends to generally lower the average water clarity and increase the average turbidity levels.

Table 3.1 Whangaparaoa River statistics for several water quality parameters, 1990 to 2007.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	-	-	34	1.52	1.39	0.19	4.89
DO%	71.8 (-93)	-0.09	56	104.6	103.9	87.3	140.8
Temperature (ºC)	73 (30)	0.18	58	15.4	16.3	8.0	23.8
Colour (absat440nm/cm)	49 (10)	1.4	45	0.77	0.69	0.00	1.92
Conductivity (mS/m)	14(-110)	-0.58	57	18.5	18.8	7.6	26.2
Suspended solids (g/m^3)	12 (30)	0.75	58	42.6	5.5	0.4	700.0
Turbidity (NTU)	58 (10)	0.28	56	24.8	4.3	0.4	295.0
pH	22.7 (-3)	0	57	7.7	7.7	7.4	8.5
DRP (g/m^3)	61.9 (<1)	0	56	0.015	0.015	0.002	0.038
Ammonium-N (g/m^3)	43 (<0.2)	2.5	56	0.009	0.008	0.001	0.025
TOx-N (g/m^3)	45 (<0.3)	1.43	55	0.059	0.022	0.001	0.287
Total Nitrogen (g/m^3)	18 (-2.6)	-1.64	57	0.186	0.159	0.003	0.912
Total Phosphorus (g/m^3)	58 (<-0.1)	-0.36	56	0.051	0.028	0.014	0.450
Escherichia coli (cfu/100mL)	**2 (39)**	**2.43**	54	98	52	1	770
Enterococci (cfu/100mL)	30.5 (22)	1.97	58	81	15	1	1000
Faecal coliforms (cfu/100mL)	40.6 (13)	0.68	58	230	92	7	3000
Flow (m^3/s)			53	4.03	3.43	1.00	14.76

3.2.2 Raukokore River

The headwaters of the Raukokore River are known as the Mangahaupapa Stream, which forms part of the regional boundary between the Bay of Plenty and Gisborne District. There are some pastoral lands in this area but the rugged and eroded terrain is predominantly vegetated with native bush. Large gully head erosion and slips are apparent in the upper catchment and these feed the braided system with abundant alluvium.

Once the river emerges from the hill country it travels less than three kilometres before meeting the ocean. Here the alluvial fan extends to a width of almost half a kilometre over the small floodplain.

While not significant there is a trend of increasing turbidity in the river and a decreasing trend in conductivity (Table 3.2). There may be a change in the colloidal input to the river that accounts for these trends and possibly also the significantly increasing trend in DRP. Increased input from the greywacke geology may be occurring.

Table 3.2 Raukokore River water quality statistics, 1990 to 2007.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	23.6 (25)	2.43	37	1.52	0.92	0.25	6.43
DO%	65.5 (41)	0.04	56	102.2	101.3	87.5	113.3
Temperature (ºC)	33.5 (-27)	-0.2	58	14.6	14.7	8.4	21.5
Colour (absat440nm/cm)	48 (10)	4.35	44	0.41	0.23	0.00	2.15
Conductivity (mS/m)	9.6 (-52)	-0.44	57	11.9	11.7	7.4	18.9
Suspended solids (g/m^3)	58.2 (131)	1.56	58	24.2	6.4	0.4	325.0
Turbidity (NTU)	10 (239)	3.51	56	13.6	5.5	0.5	170.0
pH	75.8 (-1)	-0.01	57	7.7	7.7	7.0	8.0
DRP (g/m^3)	**4 (0.3)**	**2.73**	57	0.011	0.011	0.001	0.032
Ammonium-N (g/m^3)	75 (<0.1)	0	57	0.006	0.003	0.001	0.067
TOx-N (g/m^3)	32 (0.3)	1.71	55	0.036	0.028	0.001	0.132
Total Nitrogen (g/m^3)	70.9 (-0.7)	-0.63	57	0.125	0.113	0.006	0.413
Total Phosphorus (g/m^3)	83 (<0.1)	0	56	0.028	0.020	0.008	0.168
Escherichia coli (cfu/100mL)	**2.1 (50)**	**4.72**	54	63	14	1	1000
Enterococci (cfu/100mL)	43.1 (2)	0.24	58	87	7	1	2700
Faecal coliforms (cfu/100mL)	92 (5)	0.34	57	209	30	1	6800
Flow (m^3/s)			45	13.03	9.20	2.94	48.62

3.2.3 Motu River

The Motu River catchment is the largest on the western side of the Raukumara Peninsula beginning its journey to the coast from inside the Gisborne District. From this rolling hill country dominated by pastoral agriculture the river moves into the steep hill country of the Raukumara Forest Park where the main channel twists through a widening alluvial fan. Braids form in the alluvium as the river reaches the coastal floodplain before entering the ocean.

Two sites are monitored by NIWA and Environment Bay of Plenty, one at Waitangirua in the Gisborne Region and the other on the lower river at Houpoto (SH35). Pasture dominates the landscape above the Waitangirua site which is predominantly low intensity livestock agriculture. Significant trends of increasing nutrients occur for the upper Motu River site. Both total nitrogen (TN) and total phosphorus (TP) have meaningful increasing trends of greater than 1 %/year (Table 3.3). The DRP concentrations have also been increasing as shown by the flow adjusted data in Figure 3.1. DRP is only a minor component of the increasing TP.

After seasonal and flow adjustment the water clarity trend for the lower Motu River site shows a meaningful increase in water clarity of 1.4 cm/year. The upper Motu River site (Waitangirua) did not correspond with this improving trend displaying a non-significant decreasing trend. Improving water clarity relates to decreasing trends in turbidity (Figure 3.2) and more recently suspended solids (SS). Turbidity in the lower river is on average four times higher than the upper river site indicating that much of the sediment input to the river emanates from the steeper hill country.

A trend was detected in dissolved oxygen saturation data in the lower Motu River, showing a slight but statistically significant decrease. Conductivity also displays a decreasing trend in the lower river (Table 3.4, Figure 3.2) and this may relate to significant decreases in nutrients TP, TOx-N and NH_4-N as well as SS.

The trend for NH_4-N is due to higher concentrations in 1995/1996. After this time there is no significant trend. TP is highly correlated with SS (Pearson r=0.93, $p<0.01$) indicating the main phosphorus input is via sediment.

Table 3.3 Motu River at Waitangirua water quality statistics, 1989 to 2008 (Ammonium-N 1995 to 2008).

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)	22.2 (-6)	-0.3	256	1.9	1.9	0.02	5.1
DO%	41.6 (-46)	-0.05	257	102.0	101.5	92.1	126.0
Temperature (ºC)	18.7 (36)	0.28	257	13.0	12.7	4.6	22.7
Colour (absat440nm/cm)	99.3 (<1)	0.0	256	4.2	4.0	0.0	15.4
Conductivity (mS/m)	71.7 (-19)	-0.02	256	80.1	79.6	32.4	112.7
Turbidity (NTU)	63.2 (5)	0.27	255	11.3	1.8	0.6	650.0
pH	29.2 (2)	0.02	255	7.7	7.7	6.6	8.9
DRP (g/m^3)	**<1 (<0.2)**	**2.25**	244	0.009	0.009	0.001	0.027
Ammonium-N (g/m^3)	23.7 (0.1)	1.64	179	0.008	0.007	0.000	0.038
TOx-N (g/m^3)	6 (1.1)	0.89	242	0.152	0.122	0.000	0.548
Total Nitrogen (g/m^3)	**<1 (3.1)**	**1.25**	255	0.318	0.247	0.085	3.050
Total Phosphorus (g/m^3)	**<1 (0.4)**	**1.75**	257	0.042	0.023	0.008	1.190
Flow (m^3/s)			257	12.1	6.6	0.6	261.0

Table 3.4 Motu River at State Highway 35 water quality statistics, 1989 to 2008 (Ammonium-N 1995 to 2008, SS from 2001 to 2008).

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)	**<1 (14)**	**2.46**	256	1.6	0.6	0.02	8.9
DO%	**<1 (-71)**	**-0.07**	256	100.4	99.8	90.5	113.2
Temperature (ºC)	11.3 (32)	0.24	256	13.8	13.4	5.8	25.5
Colour (absat440nm/cm)	17.3 (40)	0.77	251	7.4	5.2	0.0	50.6
Conductivity (mS/m)	**<1 (-287)**	**-0.31**	254	91.6	92.4	53.5	129.0
Suspended solids (g/m^3)	**<1 (-822)**	-8.43	127	51.3	7.2	0.4	900.0
Turbidity (NTU)	**<1 (-178)**	**-2.22**	256	46.0	7.8	0.0	630.0
pH	68.8 (-0.4)	-0.01	254	7.8	7.7	7.4	8.7
DRP (g/m^3)	5.7 (0.1)	0.91	255	0.011	0.011	0.004	0.031
Ammonium-N (g/m^3)	**1.7 (-0.1)**	**-4.76**	173	0.003	0.002	0.000	0.019
TOx-N (g/m^3)	**3.0 (-0.6)**	**-0.94**	254	0.066	0.062	0.000	0.212
Total Nitrogen (g/m^3)	53.2 (0.3)	0.25	243	0.139	0.120	0.000	0.658
Total Phosphorus (g/m^3)	**<1 (-0.3)**	**-1.26**	255	0.087	0.023	0.000	1.085
Flow (m^3/s)			256	84.9	51.6	12.5	632.1

Figure 3.1 Sen slope trend and residual data for DRP and TN, Motu River at Waitangirua.

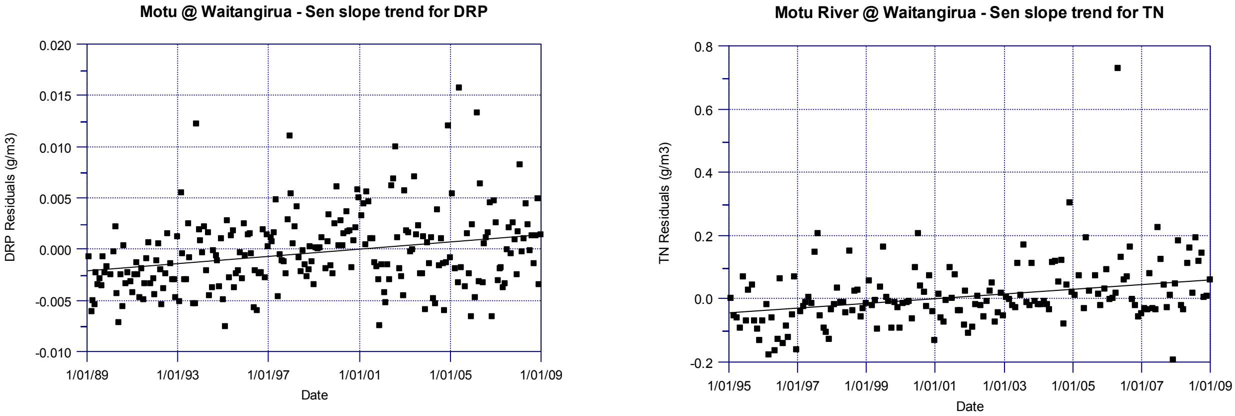
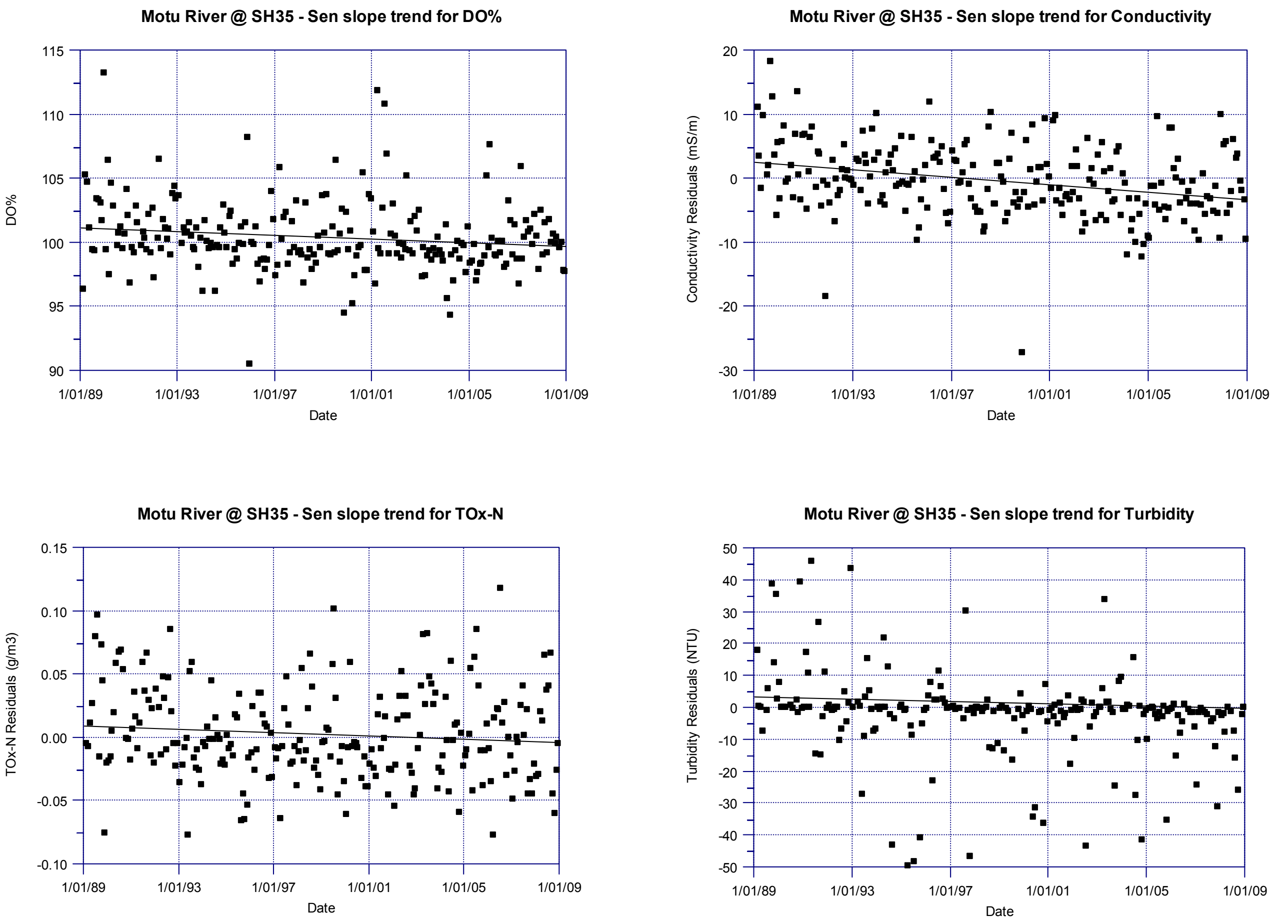


Figure 3.2 Sen slope trend and residual data for DO%, Conductivity, TOx-N, and Turbidity, Motu River at SH35.



3.2.4 Otara River

The Otara River is fed from the steep hill country of the Raukumara Ranges mainly by three streams: the Totaetoko; Te Waiiti and Pakahi Stream. The 350 km^2 catchment is predominantly forested ranges made up of Urewera Greywacke and Cretaceous conglomerates, sandstones and siltstones (Mitchel, 1977). The river then travels through Holocene deposits covered with pastoral agriculture and some horticulture. The Otara forms the eastern boundary of Opotiki before joining with the Waioeka River.

Table 3.5 Otara River at Browns Bridge water quality statistics, 1990 to 2007.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
DO%	87.2 (-48)	-0.05	64	101.5	101.1	89.5	120.5
Temperature (ºC)	48.3 (50)	0.36	66	14.3	14.6	6.8	22.4
Colour (absat440nm/cm)	77.7(-2)	-0.87	52	0.3	0.2	0.0	1.4
Conductivity (mS/m)	30.1 (-12)	-0.15	65	7.9	7.9	6.4	11.2
Suspended solids (g/m^3)	8.8 (63)	4.2	64	5.3	1.5	0.1	59.0
Turbidity (NTU)	**3.6 (52)**	**3.35**	63	3.7	1.6	0.1	28.0
pH	92.5 (<1)	0	65	7.4	7.4	6.6	8.1
DRP (g/m^3)	10.6 (0.3)	1.11	66	0.029	0.028	0.015	0.155
Ammonium-N (g/m^3)	16.5 (0.2)	4.26	66	0.007	0.005	0.001	0.051
TOx-N (g/m^3)	77.8 (-0.1)	-0.21	64	0.052	0.046	0.001	0.146
Total Nitrogen (g/m^3)	22.2 (1.6)	1.27	62	0.133	0.127	0.049	0.331
Total Phosphorus (g/m^3)	9.9 (0.4)	1.29	65	0.033	0.031	0.013	0.085
Escherichia coli (cfu/100mL)	5.8 (31)	2.98	63	68	12	1	1900
Enterococci (cfu/100mL)	41 (7)	0.82	66	17	6	1	190
Faecal coliforms (cfu/100mL)	73.7 (-9)	-0.61	66	87	30	1	2100
Flow (m^3/s)			66	7.5	5.9	1.6	27.1

The only significant trend detected over the 1990 to 2007 analysis period was one of increasing turbidity. The upper hill country is prone to slipping under saturated conditions and an increasing turbidity may indicate a greater number of slips occurring more recently.

Larger flood events sampled in the last decade may be partly the cause of this trend, but whether this is an artefact of sampling or indicates a period of more extreme weather has been occurring is not clear. The Interdecadal Pacific Oscillation (IPO) is a climate cycle affecting the majority of the Pacific. This cycle has an impact on flood frequency. The IPO cycle is strongly correlated to heavy rainfall and floods in the Bay of Plenty resulting in successive “benign” and “active”: phases. These phases persist for 20 to 30 years. The cycle shifted to a “benign” phase in the mid-1970’s and subsequently to an “active” phase around 1997-98 (Waugh, 2008).

E.coli concentrations are also showing an increasing trend just outside the significance test, although this trend is not shown by faecal coliforms.

3.2.5 Waioeka River

The Waioeka River flows through a well defined gorge in its upper reaches and has a catchment area of 825 km^2. The catchment is relatively steep with extensive bush cover. The lower reaches of the river meander across flood plains before being joined at Opotiki by the Otara and flowing out to sea. Intensive rainstorms occur in the catchment with associated flooding and gravel movement being difficult to control.

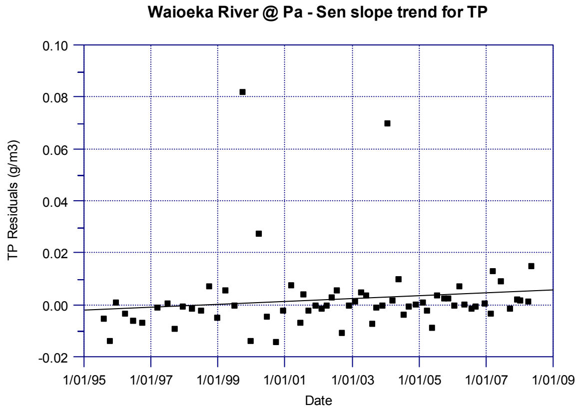
Table 3.6 Waioeka River at Pa water quality statistics, 1995 to 2008.

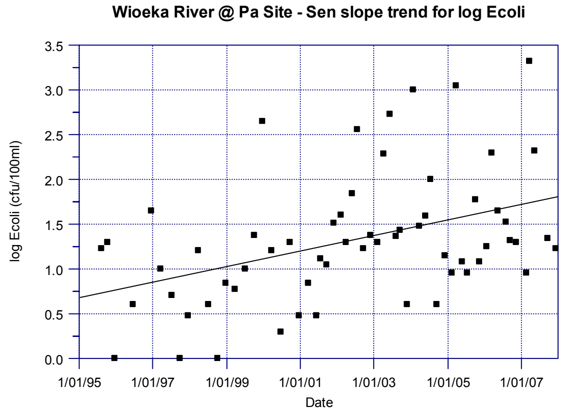
	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)	25.6 (-38)	-1.17	75	3.4	3.5	0.1	8.2
DO%	47.8 (-264)	-0.27	102	97.4	97.7	75.4	121.2
Temperature (ºC)	29.2 (-129)	-0.9	105	14.3	14.4	6.3	22.8
Colour (absat440nm/cm)	32.2 (<1)	1.89	98	0.5	0.5	0.0	2.1
Conductivity (mS/m)	56.8 (-4)	-0.06	105	7.7	7.7	6.1	12.1
Suspended solids (g/m^3)	**2.8 (104)**	**7.46**	104	9.3	1.5	0.1	284.0
Turbidity (NTU)	9 (60)	3.79	103	7.0	1.4	0.3	198.0
pH	12 (-8)	-0.11	105	7.4	7.4	6.1	8.4
DRP (g/m^3)	73.1 (0.1)	0.61	102	0.017	0.017	0.001	0.044
Ammonium-N (g/m^3)	**3.7 (0.2)**	**5**	103	0.009	0.005	0.001	0.111
TOx-N (g/m^3)	60.9 (0.3)	1.58	97	0.060	0.019	0.001	0.722
Total Nitrogen (g/m^3)	47.8 (2.9)	2.56	88	0.147	0.114	0.050	0.553
Total Phosphorus (g/m^3)	**<1 (0.5)**	**2.38**	86	0.029	0.020	0.008	0.272
Escherichia coli (cfu/100mL)	**<1 (76)**	**5.93**	103	132	21	1	2900
Enterococci (cfu/100mL)	**<1 (101)**	**10.53**	104	57	11	1	1400
Faecal coliforms (cfu/100mL)	**2.7 (46)**	**3.31**	105	179	28	1	4100
Level (m)			100	0.62	0.59	0.04	1.72

Like the Otara River, there are significantly meaningful trends of increasing SS (although not turbidity), as well as TP (Figure 3.3). SS and TP show some correlation (Spearman r=0.65, $p<0.05$) indicating most of the phosphorus is from sediment sources. Nitrogen also shows an increasing trend although only ammonium-nitrogen has a significant meaningful increasing trend. DIN concentrations are very low as are the indicator bacteria concentrations.

Indicator bacteria all have significant meaningful increasing trends, and like that for ammonium-nitrogen this may indicate increased agricultural activity or stock access to the river.

Figure 3.3 Waioeka River at Pa Sen slope trend and residual data for TP and E.coli.





3.2.6 Nukuhou River

Starting its journey in the Matahi Forest, the Nukuhou River winds its way across a wide stretch of intensely farmed pastoral lands. This expanse of floodplain is bounded by rolling hill country with a mixture of drystock, forestry and indigenous forest cover. The floodplain narrows as it moves north bounded to the west by the Kererutahi Forest before cutting its way through greywacke hills to enter the Ohiwa Harbour.

The Nukuhou River is the largest freshwater inflow to Ohiwa Harbour and has been noted to have high turbidity and indicator bacteria levels.

Table 3.7 Nukuhou River at Quarry water quality statistics, 1990 to 2008.

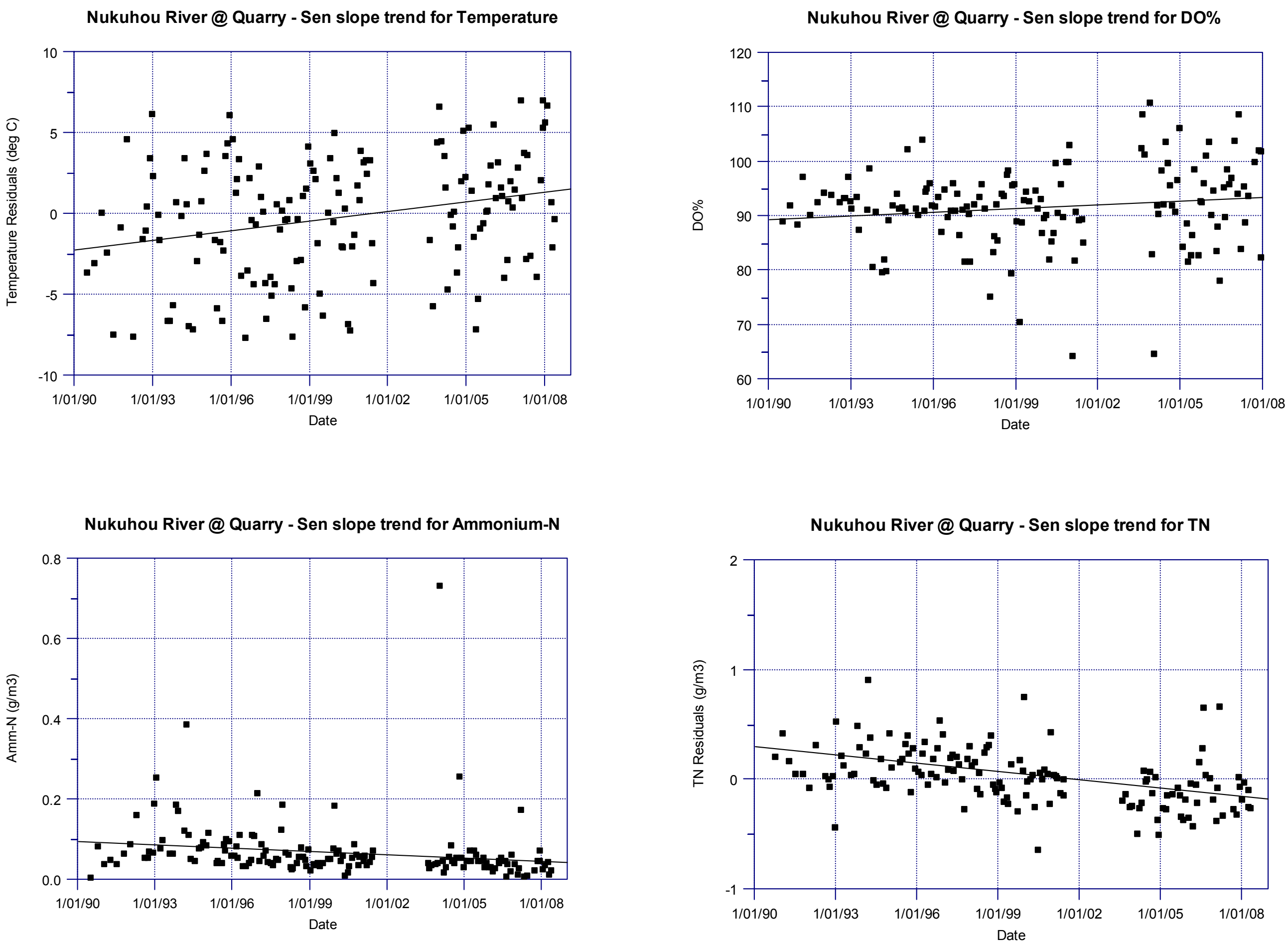
	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	14.2 (11)	2.02	123	0.9	0.9	0.1	4.1
DO%	**1.4 (292)**	**0.32**	153	91.7	91.8	64.1	115.6
Temperature (ºC)	**<1 (199)**	**1.33**	156	14.5	15.0	6.1	24.5
Colour (absat440nm/cm)	6.5 (25)	1.3	129	2.3	1.9	0.0	16.1
Conductivity (mS/m)	**<1 (29)**	**0.28**	154	10.3	10.2	7.7	18.9
Suspended solids (g/m^3)	**<1 (-471)**	**-3.92**	154	19.1	12.0	2.8	160.0
Turbidity (NTU)	63.1 (16)	0.23	151	9.8	6.9	3.2	66.0
pH	69.4 (-0.3)	0	154	7.1	7.1	6.0	7.8
DRP (g/m^3)	76.2 (-0.1)	-0.27	154	0.04	0.04	0.01	0.23
Ammonium-N (g/m^3)	**<1 (-2.6)**	**-5.36**	155	0.07	0.05	0.00	0.73
TOx-N (g/m^3)	**<1 (-10)**	**-1.97**	151	0.53	0.50	0.11	1.42
Total Nitrogen (g/m^3)	**<1 (-25)**	**-2.58**	150	1.02	0.98	0.32	5.13
Total Phosphorus (g/m^3)	**2 (-0.9)**	**-1.4**	154	0.08	0.07	0.01	0.29
Escherichia coli (cfu/100mL)	96.8 (<1)	0	144	2154	630	3	99000
Enterococci (cfu/100mL)	17.1 (-14)	-0.62	156	366	190	7	3900
Faecal coliforms (cfu/100mL)	7.2 (-11)	-0.39	156	2485	795	19	94000
Level (m)			155	1.6	1.1	0.2	25.2

Several significant trends are apparent since 1990. Temperature in the river has a meaningful increase (Table 3.7, Figure 3.4) with temperatures in summer reaching levels that are likely to be impacting fish and macroinvertebrate health. Even with an increasing temperature trend, dissolved oxygen saturation has been significantly improving. Dissolved oxygen seasonal minimums had until 2005 been declining, but this has recently improved.

Other trends in the Nukuhou River indicate some improvement in water quality. SS levels show a meaningful decrease, although turbidity data does not display the same trend which may be an influence of the high colour of the water. TN (Figure 3.4) and components of nitrogen all display meaningful decreasing trends (Table 3.7). TP also has a significantly decreasing trend although there is no obvious trend in DRP.

Thermotolerant bacteria (*E.coli* and faecal coliforms) are on average elevated over the early summer period and lowest in winter (June, July). Faecal coliforms do have a small decreasing non-significant trend (-0.39 %/year) as do enterococci (-0.52 %/year).

Figure 3.4 Nukuhou River Sen slope trend and residual data for several water quality parameters.



3.2.7 Waimana River

The Waimana River arises from the ranges in Te Urewera National Park before emerging into a narrow valley floor with a few areas of river flats in the upper 48 km. After leaving the main range the floor widens to an area of high intensity livestock agriculture and for the next 19.5 km the river channel is wide and braided. The final

13 km of the Waimana River are through a gorge with the exception of the last 1.6 km, where it empties out of the gorge on to the valley floor just upstream of the confluence with the Whakatane River. The Waimana catchment covers 440 km^2 extending 77 km from the confluence to the upper tributaries.

Little monitoring has occurred in recent years so a limited trend analysis has been done using as a covariant river level (rather than flow) as there is little flow gauging information. Hence trend information is only indicative and not absolute.

Observed trends include one of decreasing TN and TP, although *E.coli* show some increase.

Table 3.8 Waimana River at Taneatua water quality statistics, 1990 to 2004.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)	15.4 (61)	2.96	29	3.0	2.8	0.4	6.2
DO%	41.4 (214)	0.2	50	106.7	105.3	90.6	142.6
Temperature (ºC)	83 (-15)	-0.11	50	14.1	13.5	7.8	21.7
Colour (absat440nm/cm)	53.2 (8)	3.48	35	0.4	0.2	0.0	2.3
Conductivity (mS/m)	9.1 (46)	0.55	49	8.5	8.5	7.0	10.7
Suspended solids (g/m^3)	37.4 (-33)	-1.47	49	4.0	2.4	0.4	39.0
Turbidity (NTU)	76.8 (17)	1	45	2.4	1.7	0.2	23.0
pH	32.9 (6)	0.06	49	7.5	7.5	7.0	8.5
DRP (g/m^3)	6.2 (-0.3)	-1.62	50	0.019	0.019	0.007	0.073
Ammonium-N (g/m^3)	13.9 (-0.3)	-3.75	50	0.010	0.008	0.001	0.077
TOx-N (g/m^3)	10.5 (-3.9)	-2.86	50	0.142	0.137	0.003	0.386
Total Nitrogen (g/m^3)	**2.2 (-4.9)**	**-2.02**	48	0.255	0.242	0.050	0.521
Total Phosphorus (g/m^3)	**3.4 (-0.6)**	**-2.4**	49	0.026	0.025	0.009	0.077
Escherichia coli (cfu/100mL)	**0.7 (32)**	**1.97**	45	84	42	3	850
Enterococci (cfu/100mL)	63.6 (4)	0.33	49	70	19	1	1000
Faecal coliforms (cfu/100mL)	96.6 (1)	0.05	49	174	75	7	3100
Level (m)			50	0.957	0.961	0.719	1.26

3.2.8 Whakatane River

The Whakatane River flows along a graben that is located where the volcanic zone intersects the coast. The river itself broadly comprises two main branches; the Waimana River and the Whakatane River.

The catchment area above the Valley Road monitoring site covers approximately 1,100 km^2 and extends 112 km to its upper tributaries. Both catchments are relatively narrow and the tributaries are short and steep, draining extensive bush covered catchments. The two branches arise in the Huiarau and Ikawhenua Ranges and run due north along the Waimana and Whakatane fault lines until they converge at Taneatua. Below this point streams flowing from the foothill catchments augment the river. The main foothill streams are the Owhakatoro and the Waioho.

As the Whakatane River flows from the Huiarau Range it quickly drops into a deeply incised valley and with the exception of small areas of rolling hill country at Ruatahuna and Maungapōhatu. There are no significant river flats for the next 64 km until the river flows out of the main range at the upper Ruatoki Valley. At this point the valley floor widens out to an average width of 1,600 meters before widening out again at the limeworks. At the same time, the catchment cover changes from indigenous forest in the ranges (which incorporate Te Urewera National Park) to scrub and grasslands at the foothills.

Below this for the next 6.5 km the river has developed a wide meander belt with considerable areas of shingle bed and river flats. Below the Ruatoki Bridge, which is 32.6 km from the sea, the river is generally more confined until it reaches the confluence with the Waimana. Downstream of the confluence the river continues for another 3.5 km before it reaches the Pekatahi Bridge and below this the river is stop banked.

A limited trend analysis is presented in Table 3.9 for the Ruatoki site with data up to 2004. No covariant adjustment has taken place, only seasonality is taken into account for most parameters. No significant trends are apparent although TN is close to showing a significantly decreasing trend.

Table 3.9 Whakatane River at Ruatoki water quality statistics, 1990 to 2004.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)			28	3.0	2.5	0.5	6.8
DO%	34.8 (381)	0.38	46	102.2	100.7	90.7	120.7
Temperature (ºC)	10.6 (142)	1.11	47	13.5	13.0	7.3	20.8
Colour (absat440nm/cm)	44 (<1)	0	33	0.4	0.2	0.0	1.6
Conductivity (mS/m)	16.2 (102)	1.06	47	9.7	9.6	7.9	11.9
Suspended solids (g/m^3)	54.6 (-66)	-2.44	47	5.2	3.1	0.4	48.0
Turbidity (NTU)	32.4 (38)	2.17	43	3.1	1.7	0.4	26.0
pH	47 (<1)	0	47	7.6	7.5	7.2	8.1
DRP (g/m^3)	87 (<1)	0	47	0.022	0.023	0.005	0.068
Ammonium-N (g/m^3)	81.8 (<1)	0	47	0.004	0.004	0.001	0.026
TOx-N (g/m^3)	24.7 (-2)	-5.81	45	0.052	0.033	0.004	0.179
Total Nitrogen (g/m^3)	5.2 (-4.3)	-3.28	44	0.140	0.133	0.054	0.302
Total Phosphorus (g/m^3)	65.3 (-0.2)	-0.71	47	0.028	0.028	0.014	0.088
Escherichia coli (cfu/100mL)	49 (19)	1.9	43	28	13	1.0	330
Enterococci (cfu/100mL)	85 (<1)	0	47	33	9	1.0	430
Faecal coliforms (cfu/100mL)	72 (6)	0.45	47	52	21	0.5	520
Flow (m^3/s)			5	12.8	12.3	8.2	18.6

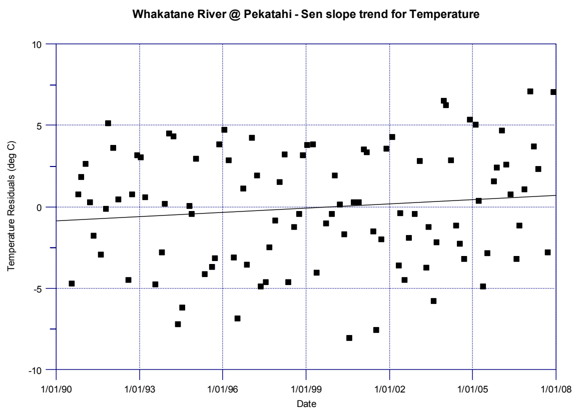
Table 3.10 Whakatane River at Pekatahi water quality statistics, 1990 to 2007.

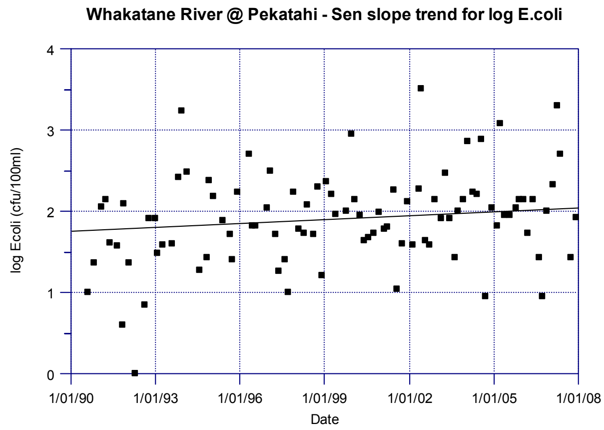
	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	22.2 (-41)	-2.27	124	1.8	1.8	0.2	5.4
DO%	33.8 (123)	0.12	175	101.1	99.9	82.7	129.7
Temperature (ºC)	5.4 (88)	0.64	178	14.4	14.0	6.5	24.1
Colour (absat440nm/cm)	8.1 (8)	1.74	142	0.5	0.5	-1.3	2.1
Conductivity (mS/m)	16.7 (13)	0.14	179	9.3	9.3	6.6	12.5
Suspended solids (g/m^3)	12.2 (107)	2.02	179	15.4	5.5	1.0	254.0
Turbidity (NTU)	6.2 (79)	2.32	172	8.7	3.3	0.3	153.0
pH	30.2 (-3)	-0.04	180	7.4	7.4	6.2	8.1
DRP (g/m^3)	83.6 (<1)	0	180	0.023	0.023	0.006	0.077
Ammonium-N (g/m^3)	44.9 (0.1)	1	181	0.011	0.010	0.001	0.060
TOx-N (g/m^3)	44.9 (0.7)	0.74	176	0.107	0.092	0.001	0.356
Total Nitrogen (g/m^3)	25.6 (-1.5)	-0.68	172	0.241	0.223	0.050	0.762
Total Phosphorus (g/m^3)	78.3 (<1)	0	177	0.039	0.032	0.012	0.201
Escherichia coli (cfu/100mL)	**3.6 (16)**	**0.83**	167	205	90	1	3200
Enterococci (cfu/100mL)	8.5 (16)	1.09	180	121	32	1	2800
Faecal coliforms (cfu/100mL)	55.2 (7)	0.34	179	312	130	9	7600
Flow (m^3/s)			182	42.4	33.4	7.7	212.6

Lower in the river at Pekatahi, the longer dataset (with seasonal and flow adjustment) also displays little in the way of significant trends. Temperature shows a non-significant increase, as it did at Ruatoki, and colour, SS and turbidity also appear to be increasing in the lower river. A closer look at the data suggests that temperature started increasing around 2005 and this may be due to some changes in the catchment since that time.

Indicator bacteria levels are increasing but only *E.coli* display a significant increase (Table 3.10, Figure 3.5).

Figure 3.5 Whakatane River at Pekatahi - Sen slope trend and residual data for Temperature and E.coli.





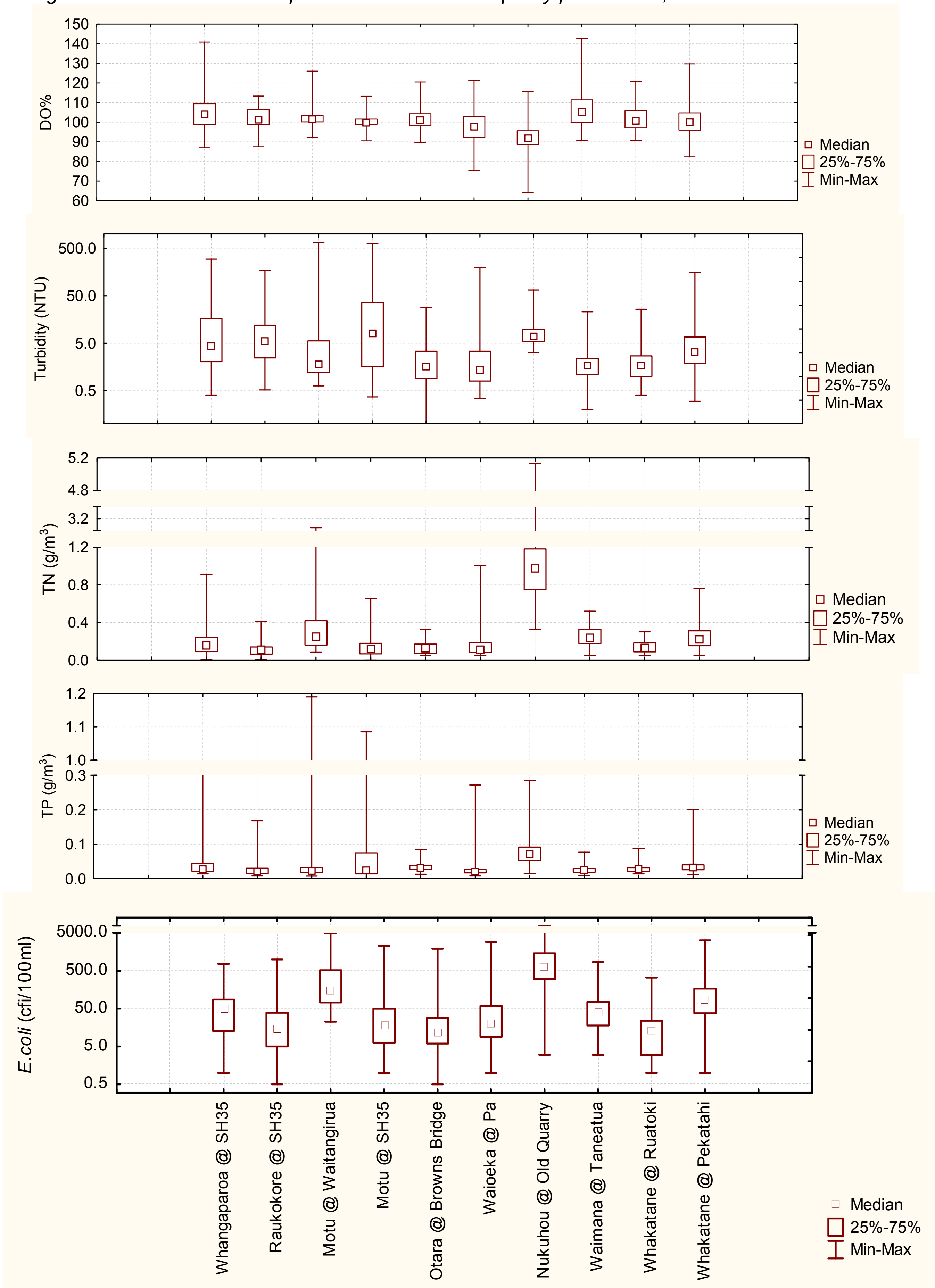
3.2.9 **Eastern Rivers Summary**

Dissolved oxygen levels are high in most of the eastern rivers. The Nukuhou River has the lowest dissolved oxygen on average and at times is below 80% of saturation. This river also has one of the highest median turbidity levels as does the lower Motu River (Figure 3.6). Both sites are often above the default ANZECC trigger value for turbidity 5.6 NTU (for slightly disturbed lowland rivers). Note that turbidity in Figure 3.6 is plotted with a logarithmic scale as high flow events in many of these systems can dramatically increase turbidity.

The Nukuhou River also has elevated TN and TP compared to the other eastern rivers. Median TN level are above the relevant ANZECC guideline while the other rivers are below this level. TP levels are also elevated in other rivers, for example the Whangaparaoa and the Motu. The average TP levels for these rivers are marginally greater than the ANZECC guideline, most probably due to the high suspended sediment load in these systems.

Most Eastern Bay rivers monitored have *E.coli* concentrations below 50 cfu/100ml, which is well below contact recreation guidelines. However, the Nukuhou River has a median *E.coli* concentration above the contact recreation guideline.

Figure 3.6 Box whisker plots for several water quality parameters, Eastern Rivers.



3.3 Central Eastern Bay of Plenty

3.3.1 Whirinaki River

Starting its life in steep greywacke and ignimbrite country, the Whirinaki forms an 11 km river valley at Minginui before winding its way again through steep hill country emerging onto the Galatea plains. The river then travels 7 km northwest to meet the Rangitaiki River.

One of the most significant trends shown in the analysis of data from 1989 to 2008 is the meaningful trends of decreasing water clarity (Figure 3.7) and increasing turbidity (Table 3.11). SS also show an increasing but not significant trend in recent years. This ties in with a significantly increasing trend in TP, which is highly correlated with turbidity (Pearson R=0.77, $p<0.05$) and SS (Pearson R=0.84, $n<0.05$).

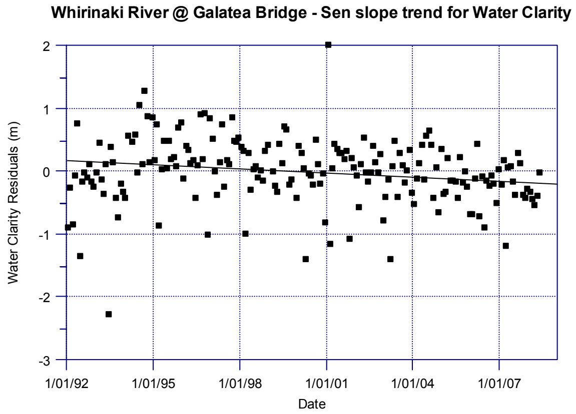
Nitrogen concentrations also show an increasing trend with the exception of ammonium-nitrogen which since 1995 has a meaningful decreasing trend. Conductivity and pH also show significant trends, and although the change over time is very small these are likely to be related to other observed trends.

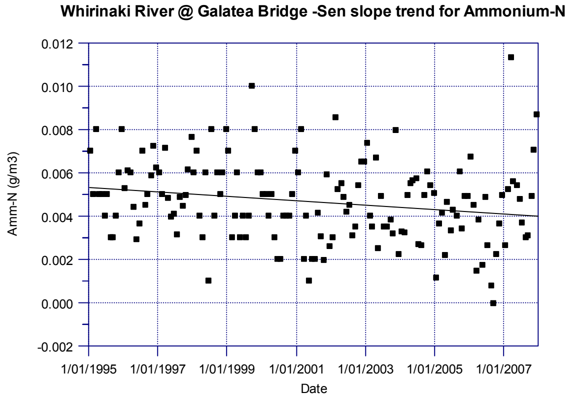
Faecal coliforms are the only indicator bacteria to display a trend since 2001, and this is a meaningful increase. Given that *E.coli* are highly correlated with faecal coliforms it seems unusual that a similar trend is not found in the *E.coli* data.

Table 3.11 Whirinaki River at Galatea Bridge water quality statistics, 1989 to 2008 (ammonium-N 1995 to 2008, SS and indicator bacteria data 2001 to 2008).

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)	**<1 (-22)**	**-1.16**	202	1.7	1.9	0.1	4.1
DO%	**<1 (-74)**	**-0.07**	244	103.0	102.4	93.8	118.0
Temperature (ºC)	15.5 (-31)	-0.26	245	12.5	12.0	5.2	21.3
Conductivity (mS/m)	**3.7 (6)**	**0.08**	245	8.0	8.0	5.0	11.0
Suspended solids (g/m^3)	7.8 (233)	5.13	85	12.2	4.4	1.1	104.0
Turbidity (NTU)	**<1 (26)**	**1.63**	245	4.0	1.7	0.6	76.0
pH	**3.1 (-3)**	**-0.04**	245	7.8	7.8	6.3	8.5
DRP (g/m^3)	35.8 (0)	0.00	230	0.021	0.021	0.011	0.035
Ammonium-N (g/m^3)	**<1 (-0.1)**	**-2.08**	156	0.005	0.005	0.000	0.011
TOx-N (g/m^3)	8 (<1)	0.01	225	0.121	0.120	0.007	0.285
Total Nitrogen (g/m^3)	6.9 (2)	0.80	222	0.227	0.217	0.070	0.801
Total Phosphorus (g/m^3)	**2.2 (<1)**	**0.33**	230	0.038	0.030	0.018	0.188
Escherichia coli (cfu/100mL)	65.2 (10)	0.64	89	70	40	1	430
Enterococci (cfu/100mL)	61 (5)	0.4	86	35	14	1	710
Faecal coliforms (cfu/100mL)	**3 (38)**	**2.24**	86	94	49	1	920
Flow (m^3/s)			229	14.7	11.1	3.3	100.2

Figure 3.7 Whirinaki River Sen slope trend and residual data for water clarity and ammonium-nitrogen.





3.3.2 Rangitaiki River

The Rangitaiki catchment covers an area of around 3,005 km^2. The river starts its journey from the Ahimanawa Ranges before travelling through broad flat pumice dominated geology used for pastoral agriculture and pine plantations. As the river travels northeast through the Kaingaroa Forest it is dominated to the east by the Ikuwhenua Ranges in Te Urewera National Park before emerging on the Galatea flood plain which is covered by dairy farms.

The river has three hydroelectric power schemes; at the Whaeo River, Aniwhenua and Matahina. Lake Aniwhenua is formed at the lower end of the Galatea Plains where the river is constricted by steep sided hills formed from ignimbrite in the west and greywacke in the east. A small flood plain is present downstream at Waiohau before the river is again dammed to form Lake Matahina. Much of the hilly landscape in this area is dominated by pine plantations before opening up to the Rangitaiki Plains.

The Rangitaiki Plains are dominated by pastoral agriculture established on what was previously wetland. Two small settlements are located near the river at Te Teko and Edgecumbe. At Edgecumbe Fonterra operates a large dairy factory and discharges waste products to land and the river.

Monitoring of the river occurs at Murupara, Aniwhenua outlet and Te Teko (see also the Whirinaki River which forms part of the Rangitaiki system).

Trends in the Rangitaiki at Murupara include meaningful increases in turbidity, nitrate-nitrogen and TN, and decreasing water clarity (Table 3.12). The increasing nitrogen has been occurring since 1998 and is likely to be due to increased land converted to dairy and more intensive dairy farming. Water clarity and turbidity are closely correlated and these trends may also reflect changing land use in the catchment.

Other significant trends at Murupara include increasing conductivity (Figure 3.8) and decreasing dissolved oxygen. These less significant trends do indicate a change in the chemistry at this site which could be related to increasing suspended sediment and nutrients and/or decreasing oxygen holding capability. No significant trends are obvious in the indicator bacteria but there is only data from 2001.

Table 3.12 Rangitaiki River at Murupara water quality statistics, 1989 to 2008 (ammonium-N 1995 to 2008, SS and indicator bacteria data 2001 to 2008).

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	**<1 (-30)**	**-1.5**	232	2.1	2.0	0.2	6.3
DO%	**2.6 (-57)**	**-0.05**	230	105	104	97	118
Temperature (ºC)	79 (<1)	0	232	13.2	13.2	7.7	18.9
Conductivity (mS/m)	**<1 (241)**	**0.29**	232	83.3	83.4	61.9	104.1
Suspended solids (g/m^3)	50.7 (85)	1.72	82	7.6	5.0	1.3	33.0
Turbidity (NTU)	**<1 (16)**	**1.33**	232	1.5	1.2	0.5	15.0
pH	23.3 (-2)	-0.02	230	7.8	7.7	7.3	8.4
DRP (g/m^3)	70.6 (<1)	0	227	0.022	0.021	0.012	0.052
Ammonium-N (g/m^3)	**9.3 (<1)**	**0**	156	0.006	0.006	0.001	0.020
TOx-N (g/m^3)	**<1 (10)**	**1.68**	227	0.599	0.596	0.302	0.971
Total Nitrogen (g/m^3)	**<1 (11)**	**1.65**	213	0.679	0.665	0.424	1.110
Total Phosphorus (g/m^3)	30.7 (<1)	0	226	0.032	0.030	0.022	0.088
Escherichia coli (cfu/100mL)	64 (14)	1.14	85	52	17	1	980
Enterococci (cfu/100mL)	79.4 (<1)	0	83	19	10	1	130
Faecal coliforms (cfu/100mL)	93 (<1)	0	83	54	21	1	590
Flow (m^3/s)			232	21.5	21.2	8.6	51.5

Figure 3.8 Rangitaiki River at Murupara, Sen slope trend and residual data for several water quality parameters.

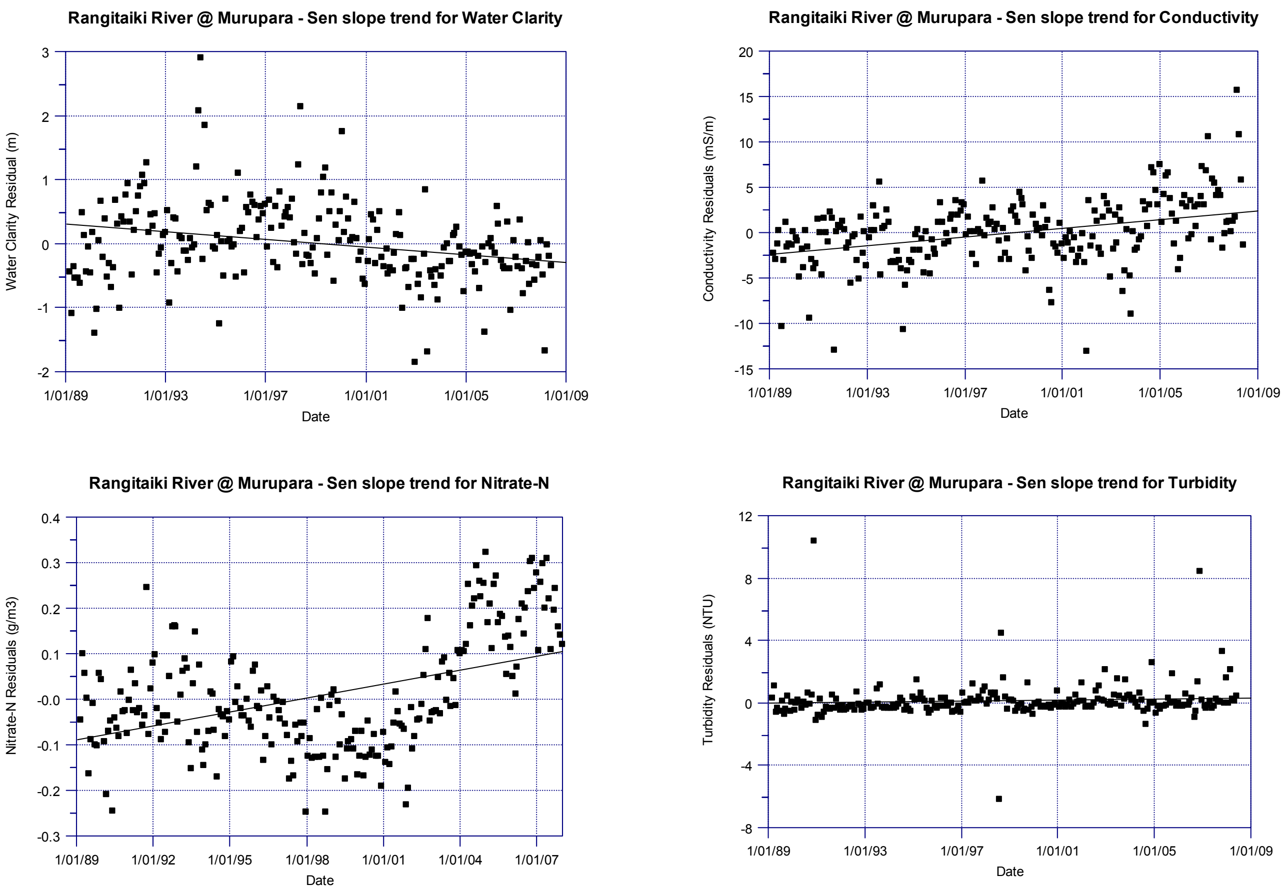
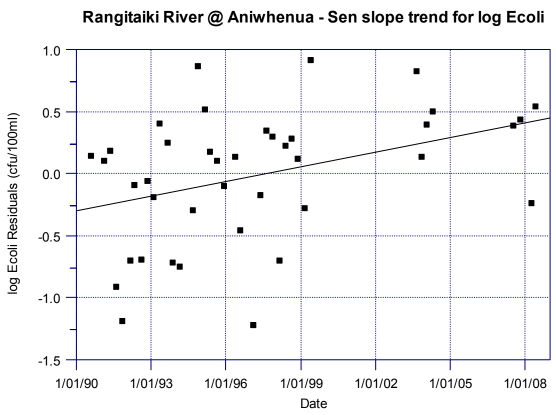


Table 3.13 Rangitaiki River at Aniwhenua water quality statistics, 1990 to 2008.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
DO%	49.5 (-140)	-0.14	53	97.6	96.2	67.2	135.8
Temperature (ºC)	43 (-37)	-0.27	54	14.0	13.8	9.1	21.0
Colour (absat440nm/cm)	25.3 (<1)	0	41	0.6	0.5	0.0	1.6
Conductivity (mS/m)	**<1 (58)**	**0.64**	53	9.0	9.0	6.3	10.4
Suspended solids (g/m^3)	90.4 (10)	0.45	55	3.6	2.4	0.3	19.8
Turbidity (NTU)	90 (4)	0.23	53	3.0	1.7	0.6	22.0
pH	**1.6 (-8)**	**-0.1**	55	7.2	7.2	6.8	7.5
DRP (g/m^3)	93.7 (<1)	0	53	0.035	0.035	0.015	0.068
Ammonium-N (g/m^3)	19.6 (<1)	-1.67	53	0.027	0.024	0.005	0.134
TOx-N (g/m^3)	8.4 (5)	1.22	51	0.372	0.377	0.071	0.536
Total Nitrogen (g/m^3)	71.7 (-3)	0.32	51	0.533	0.532	0.252	0.704
Total Phosphorus (g/m^3)	17.1 (<1)	-0.71	51	0.042	0.042	0.018	0.075
Escherichia coli (cfu/100mL)	**<1 (40)**	**3.32**	49	60	16	1	1500
Enterococci (cfu/100mL)	84 (3)	0.31	54	28	9	1	590
Faecal coliforms (cfu/100mL)	11.7 (14)	0.99	54	92	26	3	1700
Flow (m^3/s)			54	56.5	55.0	24.1	101.3

At Aniwhenua there is a significant increasing trend in *E.coli* over the longer 1990 to 2008 data set (Table 3.13, Figure 3.9), although the data set is much smaller. Lake Aniwhenua does have a moderating effect on river water quality as it provides a sink for sediment and nutrients. Nitrate-nitrogen continues to show a non-significant increasing trend at this site which is consistent with the trend identified at Murupara. Conductivity again shows a significant increasing trend (Table 3.13) indicating an increase in dissolved salts.

Figure 3.9 Rangitaiki River at Aniwhenua, Sen slope trend and residual data for several E.coli and conductivity.



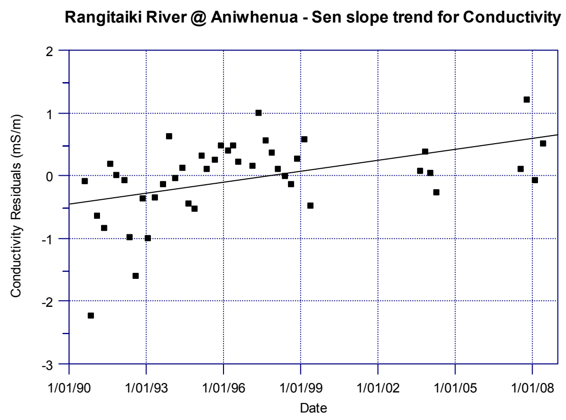
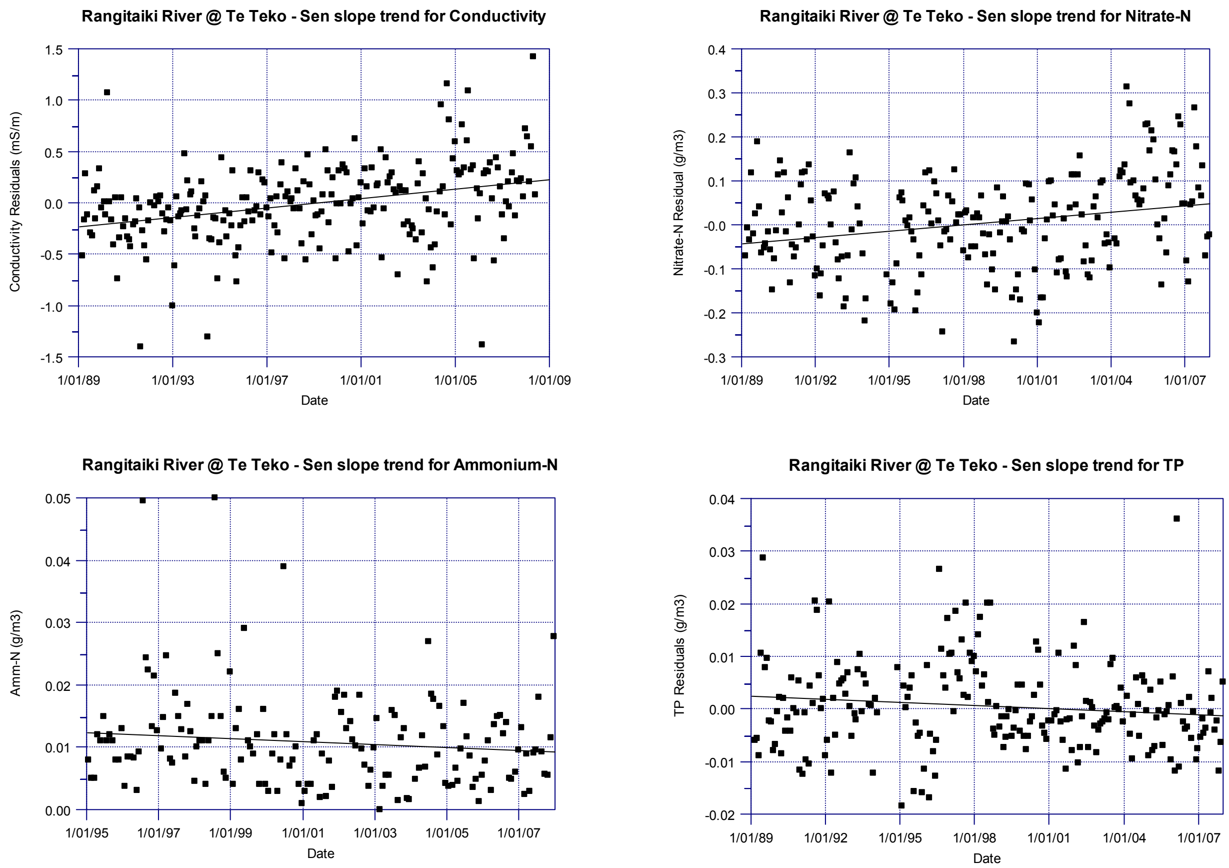


Table 3.14 Rangitaiki River at Te Teko water quality statistics, 1989 to 2008 (ammonium-N 1995 to 2008, SS and indicator bacteria data 2001 to 2008).

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)	58.8 (4)	0.29	196	1.4	1.2	0.0	3.7
DO%	13 (106)	0.1	233	106.0	104.4	85.8	138.5
Temperature (ºC)	77.6 (4)	0.03	234	15.0	14.9	8.9	21.9
Conductivity (mS/m)	**<1 (23)**	**0.25**	234	9.1	9.2	7.0	10.2
Suspended solids (g/m^3)	34.9 (167)	-3.47	101	8.5	5.4	1.0	44.0
Turbidity (NTU)	70.1 (4)	0.22	233	3.9	2.0	0.6	82.0
pH	9 (3)	0.04	233	7.1	7.1	6.5	7.6
DRP (g/m^3)	37 (-0.1)	-0.5	216	0.018	0.020	0.000	0.035
Ammonium-N (g/m^3)	**<1 (-0.2)**	**-2.06**	216	0.012	0.010	0.000	0.050
TOx-N (g/m^3)	**<1 (4.8)**	**1.43**	216	0.327	0.335	0.014	0.676
Total Nitrogen (g/m^3)	**<1 (5)**	**1.13**	212	0.447	0.442	0.160	0.757
Total Phosphorus (g/m^3)	**3.6 (-0.2)**	**-0.53**	226	0.040	0.038	0.020	0.126
Escherichia coli (cfu/100mL)	5.4 (22)	1.65	123	45	25	1	236
Enterococci (cfu/100mL)	6.2 (24)	2.44	124	25	10	1	530
Faecal coliforms (cfu/100mL)	78.9 (-4)	-0.29	124	62	33	1	440
Flow (m^3/s)			278	68.7	57.3	30.9	292.6

Figure 3.10 Rangitaiki River at Te Teko, Sen slope trend and residual data for several water quality parameters.



Lake Matahina also provides a moderating effect on the Te Teko site especially as there are few direct inflows to the Rangitaiki River between Matahina and Te Teko. However, the meaningful increasing trend in TN and nitrate-nitrogen (Table 3.14) continues in the lower river despite any moderating influences, although like the upper river the trend appears to be the result of more recent nitrogen increases (Figure 3.10). The other dissolved inorganic component of nitrogen, ammonium-nitrogen, has a meaningful decreasing trend since 1995.

Conductivity again displays a significant increasing trend consistent with the upstream sites. TP has a significant decreasing trend (Figure 3.10). Data indicates that changes occurred in TP concentrations after 1996.

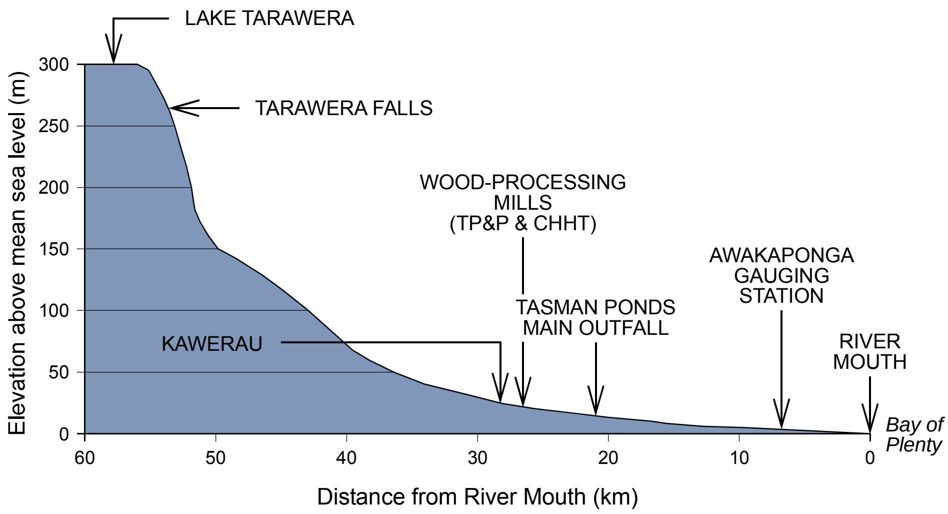
The changes in nutrient balance may have impacted periphyton (nuisance algae) growth as Te Teko shows an increasing trend in filamentous periphyton cover (1990 to 2006 data). Data over the same period indicate mat forming periphyton on average to be decreasing (Quinn and Raaphorst, 2009), although the mat forming species *Phormidium* has been prevalent since the summer of 2006/2007. Periphyton also had a higher cover at the Whirinaki site compared to Te Teko which may be largely a function of bed substrate (Quinn and Raaphorst, 2009).

3.3.3 Tarawera River

The Tarawera River catchment has an area of approximately 984 km^2. In the upper catchment six major lakes occur of which Lake Tarawera is the largest. The lakes sit in the Okataina Volcanic Centre which is an active complex system of features including faults, rhyolitic volcanoes and geothermal fields, all of which are geologically recent in origin.

The Tarawera Lakes catchments are a mixture of indigenous forest, pasture, and exotic forestry with some bare ground and scrub in and around Mount Tarawera. With the exception of the Lake Okataina catchment, there has been significant catchment modification in all of these catchments.

Figure 3.11 Tarawera River elevation and site locations (from the Regional Plan for the Tarawera River Catchment).



The Tarawera River begins at the outlet of Lake Tarawera and so the lake sets the initial river water quality. Flowing through a landscape composed of Kaharoa Ash, Tarawera Lapilli and Matahina ignimbrite, the upper reach of the river catchment is dominated by exotic production forestry. The river drops elevation rapidly as it exits from a subterranean chamber at Tarawera Falls (Figure 3.11) before descending a steep grade to the township of Kawerau.

The river then travels across the Rangitaiki Plains to the coast flanked by the Manawahe Hills to the west. After Kawerau the river passes the Tasman Industrial Complex where approximately 10% of its mean annual flow is abstracted before discharge as treated wastewater at Onepu. Dairy farming is dominant on the Rangitaiki Plains and Fonterra irrigates whey effluent from the dairy factory to an area between the Omeheu/Awaiti Canal system and Edgecumbe. Treated sewage from Edgecumbe is also discharged to this canal system.

The water quality of the river is monitored at the lake outlet, Kawerau (Boyce Park) and at Awakaponga.

Being a lake outlet, many of the water quality parameters measured at the Tarawera River outlet do not have a strong relationship with flow. Temperature is the main exception. There are significant decreasing trends for conductivity and pH but the magnitude of these is not large. Conductivity has been reducing by 0.43 %/year (Table 3.15, Figure 3.12).

Table 3.15 Tarawera River at Lake Outlet, water quality statistics, 1989 to 2008 (ammonium-N 1995 to 2008, SS and indicator bacteria data 2001 to 2008).

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)	45.8 (-15)	-0.27	196	5.7	5.7	2.3	10.7
DO%	76.5 (-12)	-0.01	230	106.8	107.1	91.5	123.5
Temperature (ºC)	9.9 (38)	0.24	231	15.9	15.8	10.4	23.0
Colour (absat440nm/cm)	5.1 (1)	1.17	233	0.1	0.1	0.0	1.2
Conductivity (mS/m)	**<1 (-229)**	**-0.43**	231	53.5	53.7	50.0	56.9
Suspended solids (g/m^3)	89.5 (<1)	0.00	97	1.4	1.0	0.2	6.6
Turbidity (NTU)	50.1 (<1)	0.16	231	0.5	0.5	0.2	2.0
pH	**3.4 (-3)**	**-0.04**	231	8.1	8.1	7.6	9.4
DRP (g/m^3)	<1 (<0.1)	0.00	220	0.002	0.002	0.001	0.008
Ammonium-N (g/m^3)	**<1 (-0.1)**	**-10**	210	0.002	0.002	0.000	0.011
TOx-N (g/m^3)	<1 (-0.1)	0.00	210	0.002	0.001	0.000	0.013
Total Nitrogen (g/m^3)	**3 (0.5)**	**0.57**	219	0.088	0.088	0.013	0.189
Total Phosphorus (g/m^3)	**<1 (0.1)**	**1.43**	221	0.007	0.007	0.000	0.015
Escherichia coli (cfu/100mL)	71.6 (<1)	0.0	96	6	2	1	110
Enterococci (cfu/100mL)	6.7 (-37)	-12.16	95	4	1	1	57
Faecal coliforms (cfu/100mL)	88.7 (<1)	0.0	94	16	2	1	740
Flow (m^3/s)			239	6.6	6.5	4.1	10.6

There is a meaningful trend of increasing TP (Figure 3.12) and a significant trend of increasing DRP (Table 3.15). A similar trend has been seen in lake water quality monitoring showing that the nutrient balance in the lake is fluctuating. Nitrogen parameters also display significant trends, although only ammonium-nitrogen displays a distinct change. Ammonium-nitrogen has a meaningful decreasing trend which is contrary to lake monitoring results.

A trend of decreasing conductivity also occurs at Kawerau and at Awakaponga (Tables 3.16, 3.17). Mean conductivity drops from the upper river at the lake outlet to Kawerau, and increases slightly at Awakaponga. At both of these sites conductivity is negatively correlated with flow.

Meaningful increasing ammonium-nitrogen trends occur at the downstream sites. Ammonium-nitrogen concentrations increase by a log order from the lake outlet to Kawerau and are five times greater at Awakaponga compared to Kawerau.

Nitrogen shows a significant increasing trend at all sites. TOx-N is a significant proportion of the TN and both TOx-N and TN increase downstream. Meaningful increasing trends in TOx-N occur at Awakaponga and Kawerau indicating nitrate-nitrogen increasing through forested and pastoral landscapes and at Awakaponga as a result of the mill wastewater discharges. Nitrogen fixation occurs in the Tasman effluent ponds and as a result there are elevated DIN and organic nitrogen levels in the wastewater discharge.

Figure 3.12 Tarawera River at Outlet, Sen slope trend and residual data for TP and conductivity.

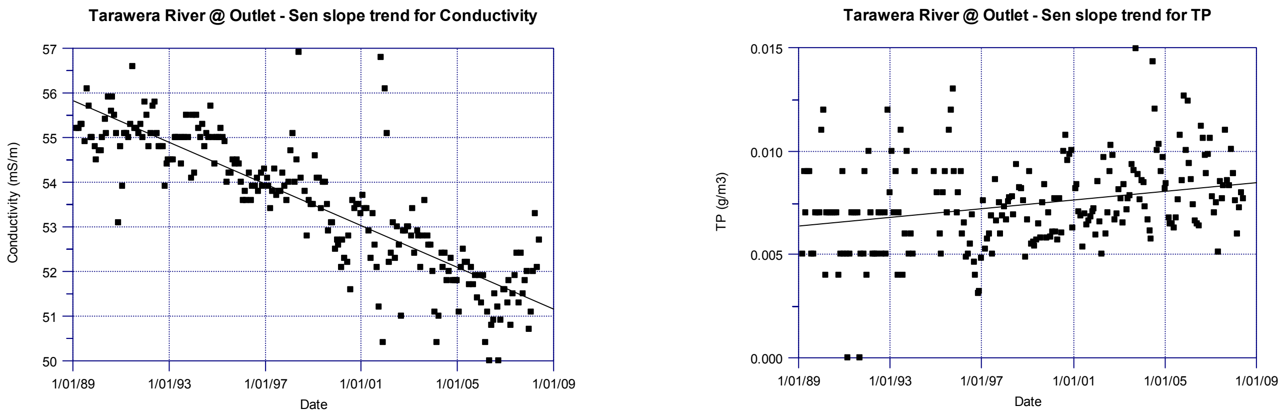
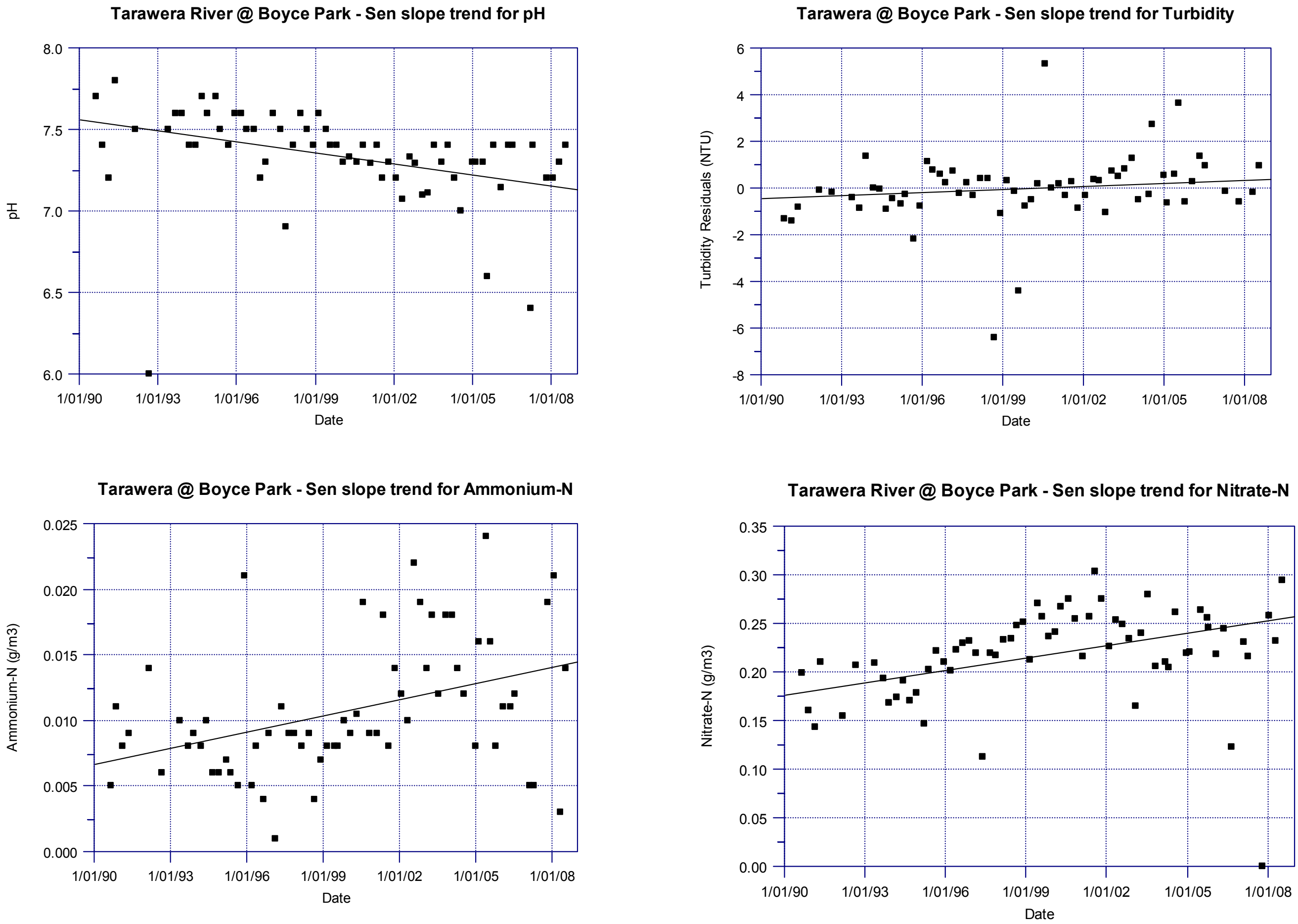


Table 3.16 Tarawera River at Kawerau, water quality statistics, 1990 to 2008.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	73.1 (6)	-0.32	86	1.9	1.9	0.7	3.2
DO%	16 (112)	0.11	121	97.7	97.7	87.4	112.9
Temperature (ºC)	43 (29)	0.2	121	14.7	14.7	11.0	19.4
Colour (absat440nm/cm)			111	0.2	0.2	-0.3	1.1
Conductivity (mS/m)	**<1 (-122)**	**-0.38**	119	31.8	31.9	23.9	36.0
Suspended solids (g/m^3)	**<1 (121)**	**2.28**	120	8.2	5.9	0.9	32.0
Turbidity (NTU)	**<1 (44)**	**1.68**	115	2.9	2.5	1.0	12.0
pH	**<1 (-22)**	**-0.3**	120	7.3	7.4	6.0	7.8
DRP (g/m^3)	50.1 (0.1)	0.21	118	0.048	0.048	0.005	0.140
Ammonium-N (g/m^3)	**<1 (0.4)**	**4.44**	118	0.011	0.010	0.001	0.037
TOx-N (g/m^3)	**<1 (4.3)**	**1.95**	111	0.228	0.234	0.001	0.308
Total Nitrogen (g/m^3)	**<1 (4)**	**1.19**	100	0.339	0.342	0.051	0.553
Total Phosphorus (g/m^3)	30 (0.1)	0.18	116	0.059	0.057	0.039	0.144
Escherichia coli (cfu/100mL)	26.9 (15)	0.8	115	136	77	2	1400
Enterococci (cfu/100mL)	14.1 (17)	1.23	117	51	23	1	1200
Faecal coliforms (cfu/100mL)	98.3 (<1)	0	118	176	110	15	2200
Flow (m^3/s)			110	22.0	21.4	15.5	32.9

Figure 3.13 Tarawera River at Kawerau, Sen slope trend and residual data for several water quality parameters.



Turbidity and SS both display meaningful increasing trends at Kawerau (Figure 3.13). At this site there is an approximate 6-fold increase in the SS concentration and turbidity compared to the lake outlet.

Lower in the river at Awakaponga SS has been increasing but with no significant trend. Turbidity at Awakaponga shows a significant decrease which correlates with improving water clarity (Table 3.17). This has occurred due to the improvements in the quality of wastewater discharged from the Tasman site. These improvements are also seen in the trend for colour, which has decreased by an average of 6.57 %/year and dissolved oxygen (increased by 0.83 %/year).

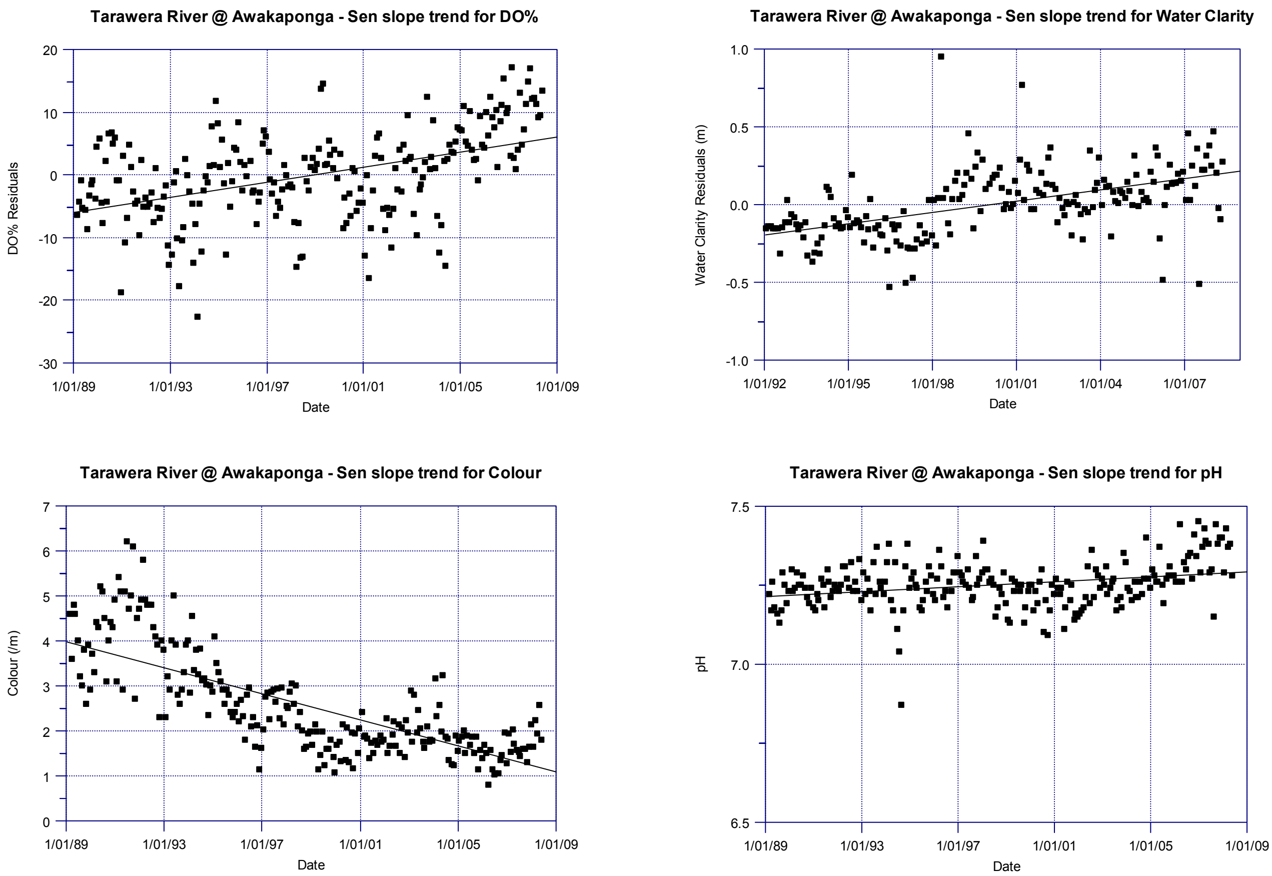
There is a significant declining trend in pH at the outlet and Kawerau sites, but pH is increasing at Awakaponga. The increase in pH has occurred since 2001 (Figure 3.14), a shift that has occurred in other parameters around the same time reflecting a change in wastewater discharged from the Tasman site.

However, while colour and oxygen levels have been improving (as mentioned above) nutrient levels are increasing, particularly the dissolved forms. These trends are likely to be due to a combination of catchment inputs and inputs from the industrial sites at Kawerau.

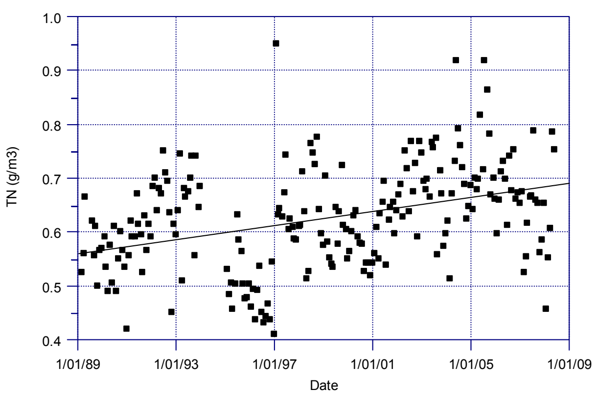
Table 3.17 Tarawera River at Awakaponga, water quality statistics, 1989 to 2008 (ammonium-N 1995 to 2008, SS and indicator bacteria data 2001 to 2008).

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	**<1 (24)**	**3.41**	195	0.7	0.7	0.2	1.7
DO%	**<1 (604)**	**0.83**	230	71.9	72.3	44.7	90.4
Temperature (ºC)	53.3 (-9)	-0.05	231	16.6	16.7	12.5	21.2
Colour (absat440nm/cm)	**<1 (-145)**	**-6.57**	232	2.6	2.2	0.8	6.2
Conductivity (mS/m)	**<1 (-316)**	**-0.83**	232	38.5	38.2	27.1	48.3
Suspended solids (g/m^3)	33.7 (242)	2.02	89	15.1	12.0	0.4	95.0
Turbidity (NTU)	**<1 (-57)**	**-1.72**	232	3.8	3.3	1.5	26.0
pH	**<1 (4)**	**0.05**	232	7.3	7.3	6.9	7.5
DRP (g/m^3)	**<1 (0.7)**	**1**	232	0.073	0.070	0.025	0.244
Ammonium-N (g/m^3)	**1.5 (0.6)**	**1.12**	220	0.053	0.053	0.007	0.122
TOx-N (g/m^3)	**<1 (5.1)**	**1.47**	232	0.350	0.347	0.163	0.512
Total Nitrogen (g/m^3)	**<1 (6.5)**	**1.04**	218	0.625	0.624	0.410	0.949
Total Phosphorus (g/m^3)	86.6 (0.1)	0.08	232	0.126	0.120	0.075	0.337
Escherichia coli (cfu/100mL)	37.8 (-25)	-1.17	112	413	250	3	3900
Enterococci (cfu/100mL)	86 (6)	0.37	113	81	63	1	560
Faecal coliforms (cfu/100mL)	19.7 (-24)	-1.06	114	719	315	10	5000
Flow (m^3/s)			235	27.8	26.9	17.0	60.3

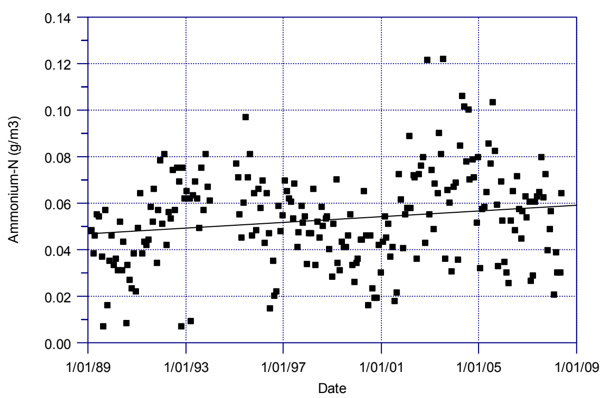
Figure 3.14 Tarawera River at Awakaponga, Sen slope trend and residual data for several water quality parameters.



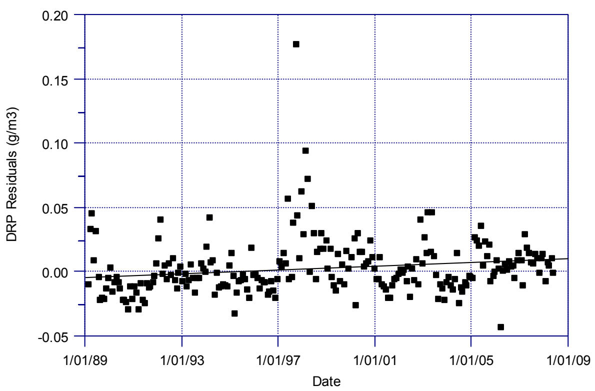
Tarawera River @ Awakaponga - Sen slope trend for TN



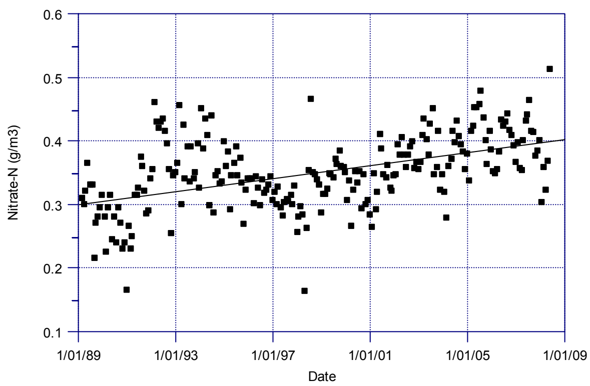
Tarawera River @ Awakaponga - Sen slope trend for Ammonium-N



Tarawera River @ Awakaponga - Sen slope trend for DRP



Tarawera River @ Awakaponga - Sen slope trend for Nitrate-N



3.3.4 Central Eastern Rivers Summary

Statistics for five key water quality variables are summarised for the Central Eastern sites in Figure 3.15.

Oxygen saturation is always above 80% for all sites except Awakaponga.

Turbidity in the Rangitaiki River does increase marginally downstream although there is little difference between the Whirinaki site and the Rangitaiki at Te Teko. Two dams between these sites are likely to moderate downstream turbidity to some extent.

In the Tarawera River turbidity can be seen to increase incrementally downstream from the Lake Outlet, reflecting the rivers transition to a lower gradient in a pastoral landscape and the presence of industrial discharges. Water quality at the Tarawera lake outlet is of much higher quality than in the other river sites due the impact of the lake on settling of suspended matter.

Total nitrogen (TN) is elevated in the upper Rangitaiki River at Murupara compared to both the downstream site and the Tarawera River sites. This nitrogen signature is influenced by the greater inputs from livestock agriculture compared to the Whirinaki site, although it is comparable to the lower Tarawera River. TN concentrations are moderated in the dams on the Rangitaiki River (due to plant uptake and sediment nutrient cycling) before reaching Te Teko

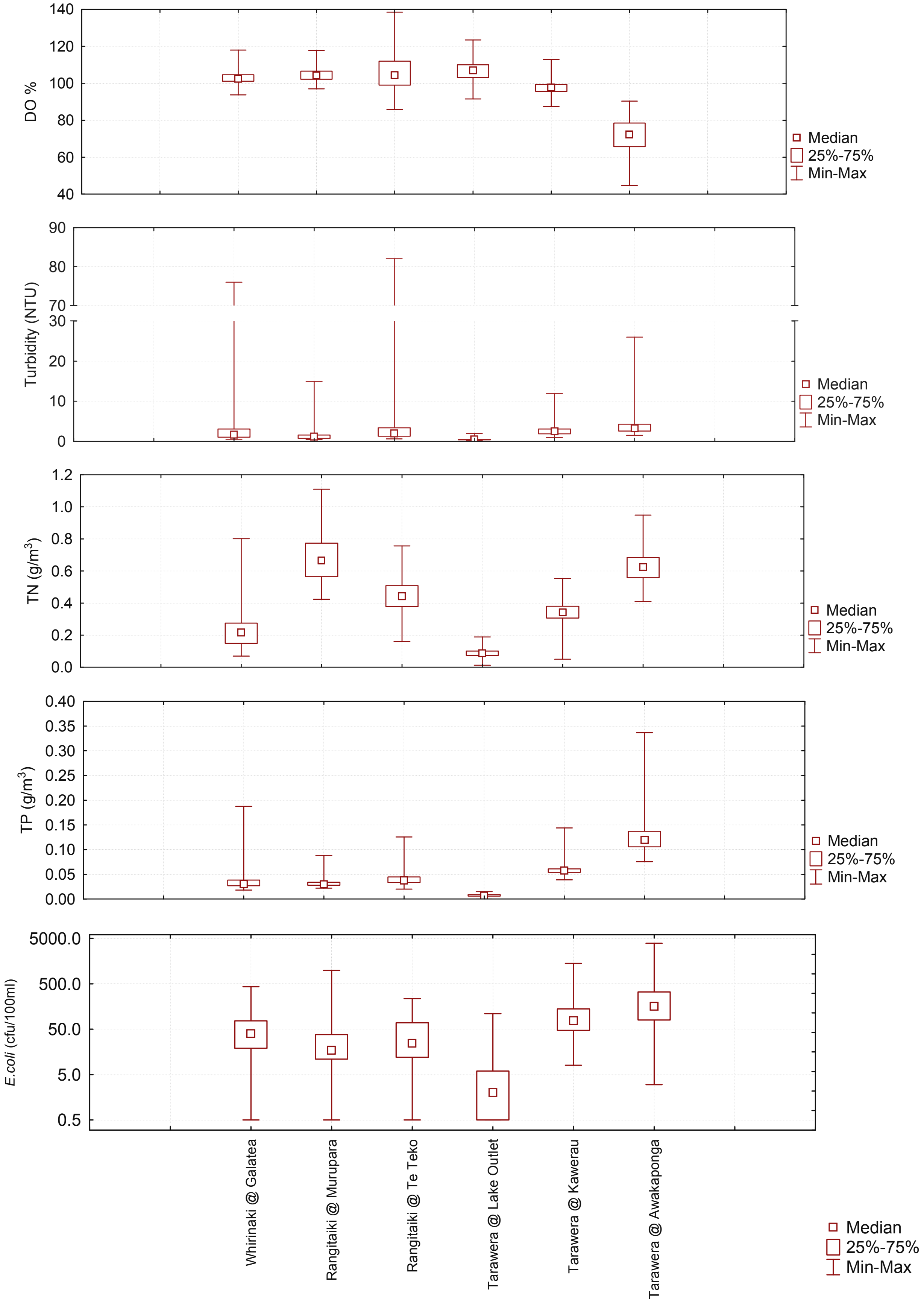


Figure 3.15 Box whisker plots for several water quality parameters, Central Eastern Bay Rivers (1989 to 2008 data, E.coli from 2001)

There is little change in TP in the Rangitaiki River over the three sites monitored. In contrast TP concentration in the Tarawera River increase markedly downstream being on average three times greater at the downstream site compared to the Rangitaiki at Te Teko. Such a contrast is a result of the differing geological inputs, the influence of dams, built urban areas and industrial inputs.

E.coli levels are fairly stable over the Rangitaiki sites. In the Tarawera River there is a marked increase in *E.coli* from the Lake Outlet to Kawerau, and a less marked increase to Awakaponga. At this site *E.coli* levels are often above guidelines for recreational use.

3.4 Central Bay of Plenty/Rotorua

3.4.1 Kaituna River Catchment

The Upper Kaituna Catchment encompasses Lakes Rotorua and Rotoiti and their tributaries. The catchment area is approximately 623 km^2, of which 114 km^2 is lake surface. The catchment includes rolling and steep hill country (including Mt Ngongotaha), the Mamaku Plateau and flat areas around the south of Lake Rotorua.

Lake Rotorua is situated in a caldera (a collapsed inverted volcano) formed during an ignimbrite eruption. As the magma surfaced from underground vents 220,000 years ago, the ignimbrite formed the Mamaku ranges and other landscape features. Lake Rotoiti lies within the Haroharo caldera and was formed following an eruption in the Okataina Volcanic Centre about 8,500 years ago. The lake was dammed by lava from that eruption.

Land cover in the upper catchment is a mixture of native and exotic forest, urban areas and pasture. Land use around the lakes has intensified considerably over the last 65 years. Sheep numbers increased from 117,000 in 1941 to a peak of 852,000 in 1967. This has since declined to 221,000 in 2001 as farms continued to intensify into dairy and deer farms. The large farms have intensified production and nutrient inputs and outputs. At the same time, subdivision of some rural properties into lifestyle blocks also became common. Approximately 62% of all rural properties within the Lake Rotorua catchment are under 5 ha in size (Proposed Lake Rotorua and Rotoiti Action Plan, 2007).

The catchment area of the Kaituna River below the outlet of Lake Rotoiti is approximately 620 km^2 – slightly less than half of the total catchment. The catchment geology is dominated by Mamaku Ignimbrite sloping from the Mamaku Plateau north towards the coast. Recent terrace and alluvium deposits are predominant at the coast.

The lower Kaituna River catchment just below the lakes is dominated by pasture and exotic forestry with some sub-catchments retaining extensive native forest cover. In recent years there has been some conversion of exotic forestry to dairy farms. Much of the mid section of this catchment has had suitable land converted to horticulture with kiwifruit being very popular. The lower regions of the catchment are predominantly productive river flat plains with extensive drainage schemes. The dominant land use again being dairy farming.

The water quality of Lakes Rotorua and Rotoiti has been degrading over many years and this is documented in several reports. Restoration measures have been in place since the 1970’s beginning with the Kaituna catchment control scheme which involved various land management initiatives such as riparian protection and land stabilisation measures. The latest project to restore water quality to Lake Rotoiti is the installation of the Ohau Channel diversion wall designed to reduce the impact of the nutrient load to Lake Rotoiti coming from Lake Rotorua via the Ohau Channel.

Trend analyses of Ohau Channel data are summarised in Table 3.18. Meaningful trends of increasing SS and turbidity are apparent over the 1995 to 2008 analysis period (Figure 3.16). Two mechanisms are likely to be responsible for this increase: increasing algal concentrations; and increased particulate matter generated by wind/wave action on the extensive shallow areas of Lake Rotorua just before entry to the channel.

Table 3.18 Ohau Channel at SH33, water quality statistics, 1995 to 2008.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)	72.7 (-12)	-0.74	135	1.6	1.6	0.4	3.8
DO%	**1.9 (289)**	**-0.31**	176	92.6	92.6	65.8	112.5
Temperature (ºC)	25.9 (-47)	-0.31	177	15.1	15.4	8.0	22.7
Colour (absat440nm/cm)	**<1 (<1)**	**0**	148	0.3	0.2	0.0	0.9
Conductivity (mS/m)	**4.4 (35)**	**0.17**	176	20.5	20.3	7.4	33.8
Suspended solids (g/m^3)	**<1 (230)**	**3.96**	173	7.5	5.6	0.7	57.2
Turbidity (NTU)	**1.1 (70)**	**2.63**	175	3.2	2.5	0.5	15.0
pH	**<1 (-17)**	**-0.24**	177	6.9	6.9	4.8	8.2
DRP (g/m^3)	38.2 (<0.1)	0	174	0.009	0.007	0.001	0.048
Ammonium-N (g/m^3)	18.6 (0.3)	2.5	174	0.026	0.012	0.001	0.506
TOx-N (g/m^3)	22.8 (-0.5)	-1.61	167	0.059	0.034	0.001	0.340
Total Nitrogen (g/m^3)	78.2 (-0.9)	-0.21	169	0.457	0.411	0.125	1.450
Total Phosphorus (g/m^3)	8.5 (0.6)	1.54	174	0.043	0.038	0.010	0.350
Escherichia coli (cfu/100mL)	**<1 (68)**	**6.84**	167	23	9	1	450
Enterococci (cfu/100mL)	**<1 (58)**	**7.39**	176	21	6	1	710
Faecal coliforms (cfu/100mL)	**<1 (63)**	**5.64**	175	28	12	1	500
Flow (m^3/s)			176	16.9	16.4	9.2	34.1

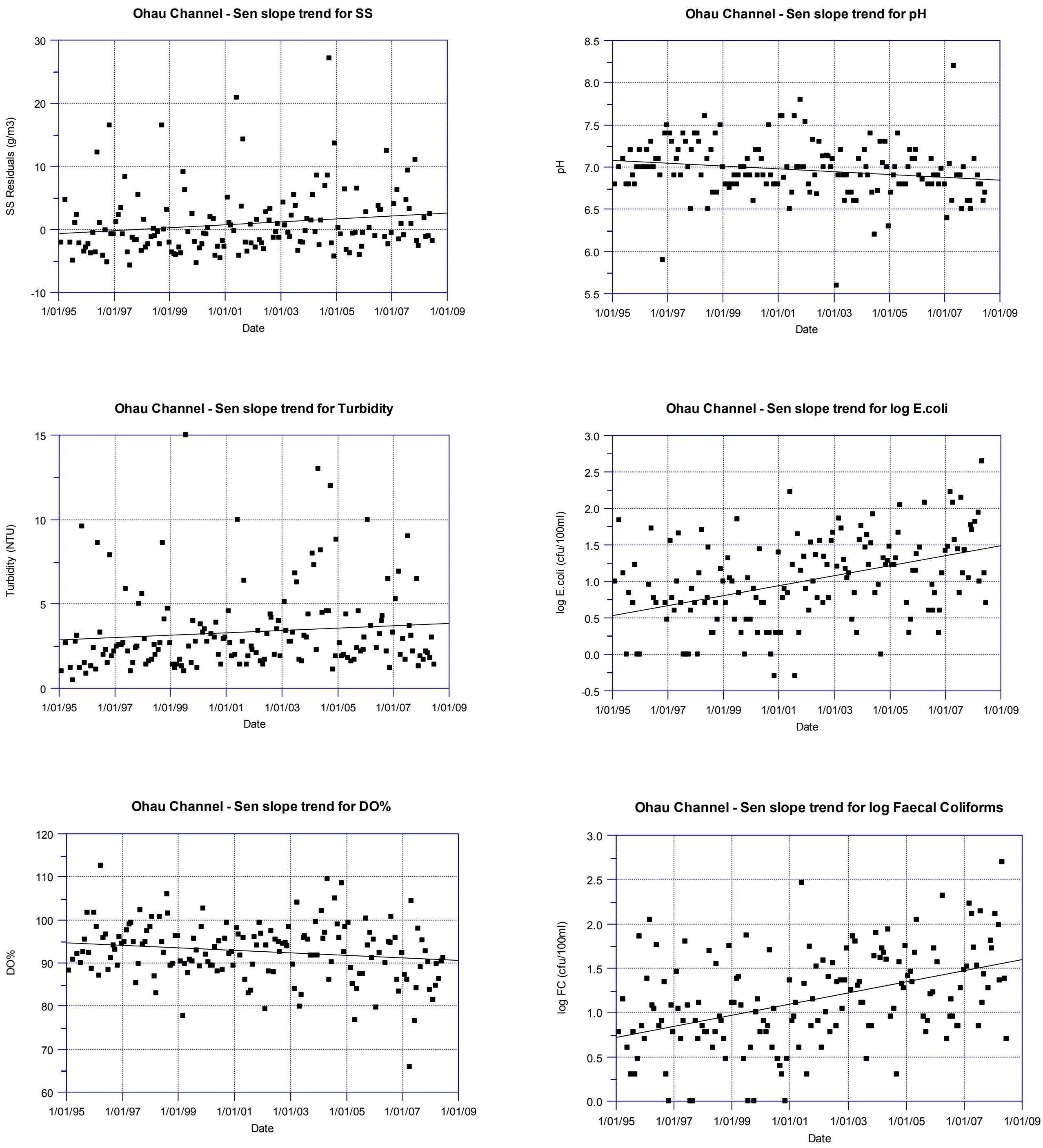
Meaningful increasing trends are seen in all of the faecal bacteria indicators (Table 3.18, Figure 3.16). The cause of this increase is unclear, but concentrations of these indicators are generally well under recreational water quality guidelines.

Significant trends also occur for DO%, pH and conductivity. A decreasing trend in dissolved oxygen saturation is likely to be occurring as increased biological activity results in changes to microbial and processes such as nitrification.

Changes in pH can occur with changes in algal biomass and species. Such changes have occurred within Lake Rotorua and the Ohau Channel and may explain a decreasing trend towards an acidic pH (e.g. some cyano-bacteria drive pH to an alkaline state). As algal detritus is deposited in the shallow shelf at the Ohau Channel entrance in Lake Rotorua, the increasing decomposing biomass is increasing carbon dioxide levels in the water, causing the pH to decrease. As this detritus is re-suspended we also see increases in SS and turbidity as well as impacts on dissolved oxygen due to the increased biochemical oxygen demand.

Other factors influencing this trend could be lake acidification through increased carbon dioxide adsorption and increased geothermal inputs. This latter point may explain the increase in conductivity.

Figure 3.16 Ohau Channel, Sen slope trend and residual data for several water quality parameters.



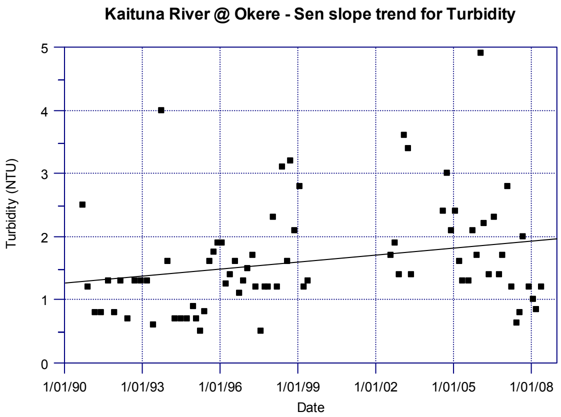
Like the Ohau Channel, a meaningful increasing trend in turbidity is seen in the Kaituna River at Okere (Figure 3.17). However, the data is showing a recent decline in turbidity and improvements in water clarity and algal biomass in Lake Rotoiti are likely to explain this.

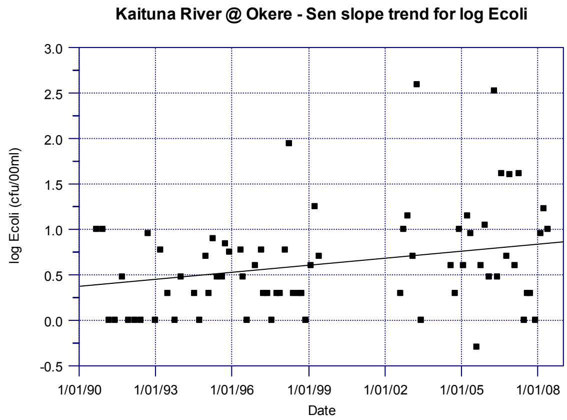
E.coli and enterococci both show meaningful increasing trends at Okere, although the mean and median levels are slightly lower than at the Ohau Channel.

Table 3.19 Kaituna River at Okere, water quality statistics, 1990 to 2008.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
DO%	100 (-2)	<1	127	95.9	95.2	79.8	115.1
Temperature (ºC)	83.6 (9)	0.06	128	15.6	15.3	9.3	24.0
Colour (absat440nm/cm)	26.2 (<1)	0	99	0.2	0.2	0.0	0.7
Conductivity (mS/m)	15.1 (-17)	-0.09	127	18.9	18.9	9.2	26.2
Suspended solids (g/m³)	11.8 (40)	1.58	125	3.2	2.8	0.4	20.0
Turbidity (NTU)	**<1 (36)**	**2.57**	129	1.6	1.4	0.3	4.9
pH	75.6 (<1)	-0.01	128	7.1	7.1	5.8	8.1
DRP (g/m³)	14.1 (<0.1)	0	124	0.006	0.005	0.001	0.063
Ammonium-N (g/m³)	26.2 (<0.2)	1.82	125	0.015	0.011	0.001	0.115
TOx-N (g/m³)	68.8 (-0.2)	-0.93	125	0.058	0.021	0.001	1.470
Total Nitrogen (g/m³)	51.1 (-1)	-0.31	120	0.351	0.327	0.037	1.740
Total Phosphorus (g/m³)	56.1 (<0.1)	0.38	125	0.028	0.026	0.007	0.145
Escherichia coli (cfu/100mL)	**1.1 (26)**	**4.78**	118	18	4	1	390
Enterococci (cfu/100mL)	**3.2 (13)**	**4.22**	127	15	2	1	430
Faecal coliforms (cfu/100mL)	12.7 (14)	2.06	125	29	6	1	600
Flow (m³/s)			129	21.3	20.4	8.6	43.1

Figure 3.17 Kaituna River at Okere, Sen slope trend and residual data for turbidity and log E.coli.





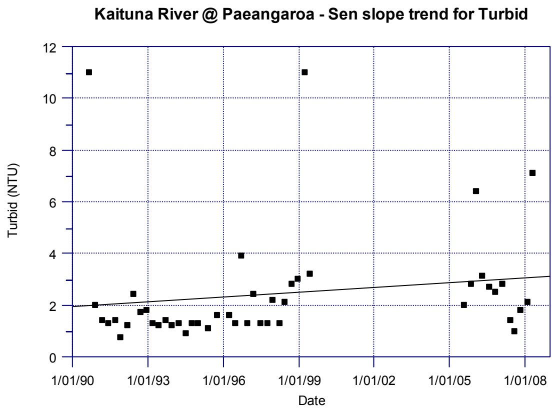
There is a large gap in the data set from 2000 to 2005 for the Kaituna River at Paengaroa and while this does compromise trend detection there are three clear trends (Figure 3.18). Turbidity again has the greatest meaningful trend and like the upper Kaituna sites displays an increasing trend overall but a decrease more recently.

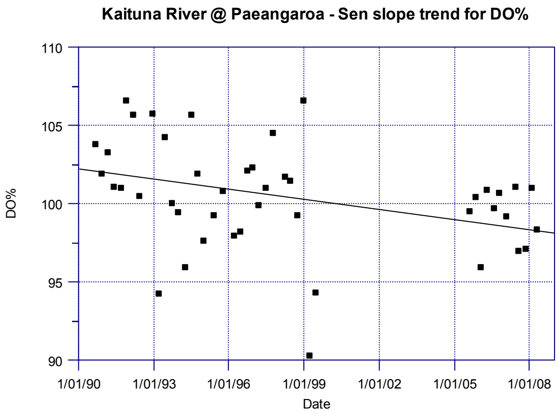
Dissolved oxygen saturation at Paengaroa has a significant decreasing trend although levels remain above 95%. Decreasing pH can also be seen at Paengaroa, and the lower river site, Te Matai (Table 3.21, Figure 19). However, changes are very small and on average pH is the same at Te Matai as at the Ohau Channel.

Table 3.20 Kaituna River at Paengaroa, water quality statistics, 1990 to 2008.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
DO%	**4.8 (-216)**	**-0.21**	68	100.0	100.4	90.1	109.4
Temperature (ºC)	25.9 (-82)	-0.53	70	15.6	16.1	10.2	21.0
Colour (absat440nm/cm)	**3 (<1)**	**0**	47	0.2	0.2	-0.1	0.9
Conductivity (mS/m)	18.9 (-37)	-0.21	68	17.1	17.1	14.8	19.0
Suspended solids (g/m^3)	22.7 (83)	1.47	69	9.2	5.9	1.8	47.0
Turbidity (NTU)	**<1 (61)**	**3.71**	69	2.7	1.8	0.8	16.0
pH	**<1 (-10)**	**-0.14**	70	7.0	7.0	6.0	7.4
DRP (g/m^3)	91.3 (<0.1)	0	70	0.019	0.017	0.002	0.039
Ammonium-N (g/m^3)	15.2 (0.3)	3.33	68	0.011	0.009	0.001	0.034
TOx-N (g/m^3)	27.8 (1.1)	0.59	66	0.201	0.189	0.118	0.308
Total Nitrogen (g/m^3)	91.1 (0.2)	0.04	68	0.466	0.452	0.150	0.739
Total Phosphorus (g/m^3)	79.9 (0.1)	0.26	69	0.038	0.038	0.021	0.061
Escherichia coli (cfu/100mL)	5.3 (34)	2.27	65	81	29	1	1600
Enterococci (cfu/100mL)	40.1 (14)	1.34	68	37	11	1	420
Faecal coliforms (cfu/100mL)	36.2 (10)	0.61	68	98	38	6	1600
Flow (m^3/s)			69	27.7	27.6	15.4	47.1

Figure 3.18 Kaituna River at Paengaroa, Sen slope trend and residual data for turbidity, DO% and pH.





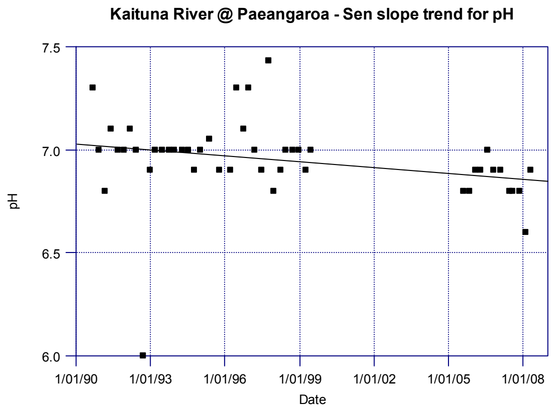


Table 3.21 Kaituna River at Te Matai, water quality statistics, 1990 to 2008.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
DO%	**4.9 (-163)**	**-0.17**	91	96.6	96.5	85.4	112.6
Temperature (ºC)	83.4 (-9)	-0.6	97	15.2	15.0	9.6	19.8
Colour (absat440nm/cm)	20.9 (<1)	0	75	0.3	0.2	-0.1	2.6
Conductivity (mS/m)	86.7 (-5)	-0.03	96	15.0	14.9	10.9	17.8
Suspended solids (g/m^3)	31.3 (100)	1.35	97	10.0	7.4	0.9	54.0
Turbidity (NTU)	**1.2 (35)**	**1.46**	96	2.9	2.3	0.6	14.0
pH	**<1 (-11)**	**-0.16**	98	6.9	6.9	6.1	7.8
DRP (g/m^3)	9.8 (-0.3)	-0.91	96	0.034	0.033	0.008	0.078
Ammonium-N (g/m^3)	8.2 (-1.2)	-1.76	96	0.073	0.070	0.005	0.248
TOx-N (g/m^3)	**<1 (8.3)**	**2.06**	94	0.431	0.412	0.191	1.380
Total Nitrogen (g/m^3)	17.8 (3.1)	0.43	91	0.750	0.734	0.491	1.610
Total Phosphorus (g/m^3)	**4.3 (-0.7)**	**-1.37**	98	0.053	0.051	0.029	0.140
Escherichia coli (cfu/100mL)	91.1 (-1)	-0.05	93	506	150	1	8400
Enterococci (cfu/100mL)	**1.2 (-27)**	**-1.62**	97	108	46	1	2900
Faecal coliforms (cfu/100mL)	**<1 (-57)**	**-2.26**	96	889	310	6	11000
Flow (m^3/s)			98	33.1	31.9	20.0	99.6

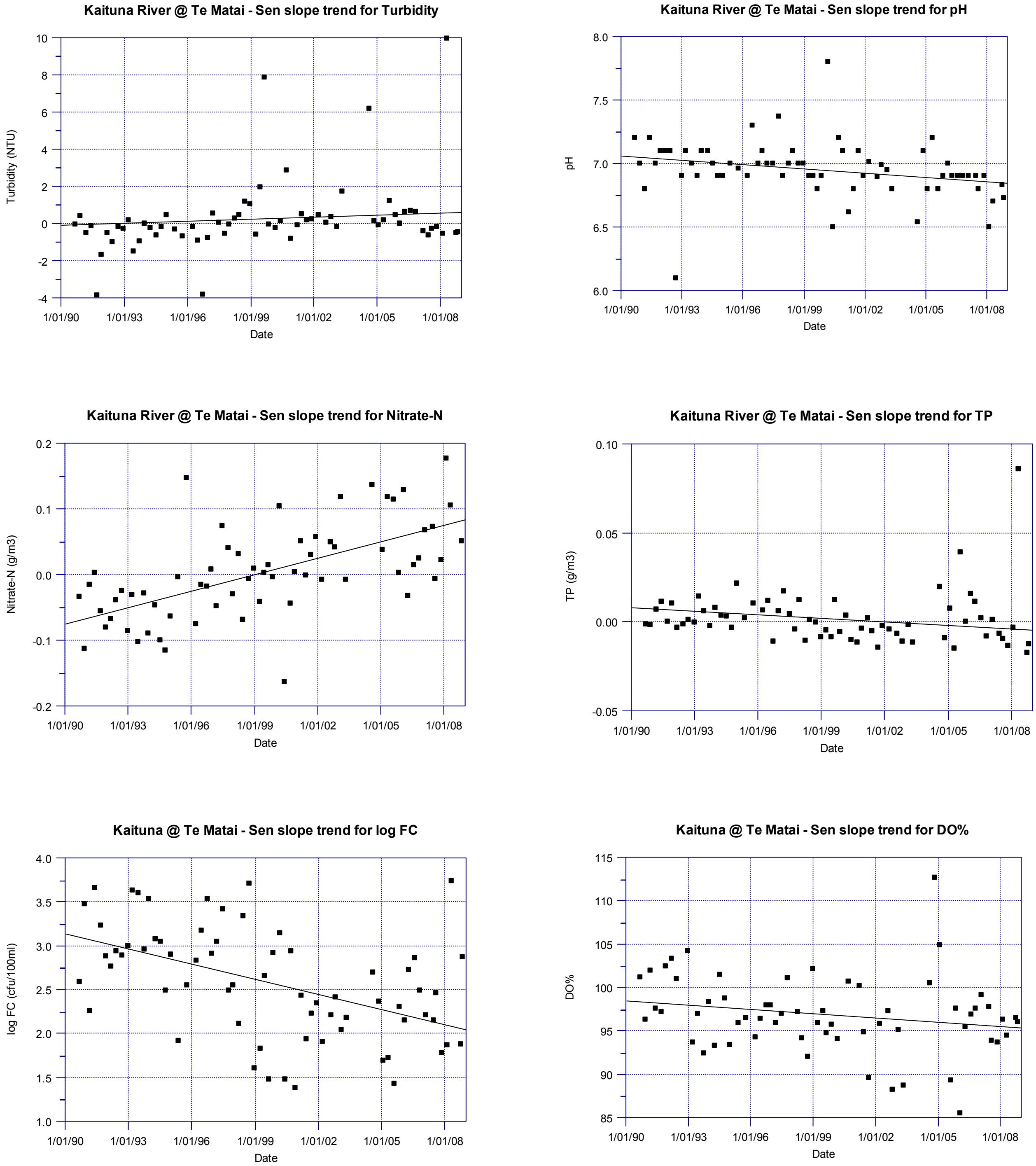
Turbidity continues to have a meaningful increasing trend in the Kaituna River at Te Matai, however this is influenced by the wastewater discharge from the AFFCO Rangiuru meat processing plant.Improvements in treatment have reduced contaminant inputs from this source since 2002 and reduction in turbidity can be seen after this time (Figure 3.19).

TOx-N also displays a meaningful increasing trend (Figure 3.19) with an average concentration almost double that at Paengaroa. Increases in nitrate-nitrogen (the major component of TOx-N) will come from the surrounding catchment primarily through agricultural inputs but also from AFFCO as ammonium-nitrogen in the effluent is converted to TOx-N.

A meaningful decrease in TP can be seen in Figure 3.20 (Table 3.21) with the dominant component being the dissolved form, DRP. It would appear that the AFFCO discharge does not affect phosphorus levels significantly as concentrations above the discharge are similar (see Scholes, 2008). Both DRP and TP are significantly correlated with ammonium-nitrogen (Pearson R=0.7 & 0.64 respectively, $p<0.05$), of which AFFCO contributes a significant amount to the river, but a similar correlation also occurs with flow.

The indicator bacteria faecal coliforms and enterococci both have significant decreasing trends over the analysis period (Table 3.21). Improvements to the quality of the AFFCO wastewater are likely to influence these trends although it is interesting that *E.coli*, a sub-group of the thermolerant indicator bacteria faecal coliforms, does not display this trend. Possibly this is because of inputs of *E.coli* bacteria from other sources. However, *E.coli* levels have improved and are generally within guidelines for recreational use.

Figure 3.19 Kaituna River at Te Matai, Sen slope trend and residual data for several water quality parameters.



3.4.2 Puarenga Stream

The Puarenga Stream has a catchment area of 81 km^2. The upper parts of the catchment are in pasture, exotic and indigenous forest. In the lower reaches the stream flows through the Whakarewarewa Village, before passing through industrial and reserve areas to the lake.

Tertiary treated effluent from the Rotorua wastewater treatment plant is spray irrigated into the Whakarewarewa forest which is within the Puarenga catchment. In the lower reaches there are significant geothermal inflows beginning near the Whakarewarewa Village. Because of the geothermal inputs this area of the stream is uninhabited by fish and has low biodiversity. The geothermal influences result in the stream being turbid at the Scion monitoring site.

Over the 1992 to 2008 analysis period the stream has shown a meaningful increasing trend for SS (Table 3.22). This may also explain the increasing trend in TP (Figure 3.20) as some of the phosphorus will be bound to suspended solids. Much of the TP is in a dissolved form, and the DRP also displays a significantly increasing trend.

Table 3.22 Puarenga Stream at Scion, water quality statistics, 1992 to 2008.

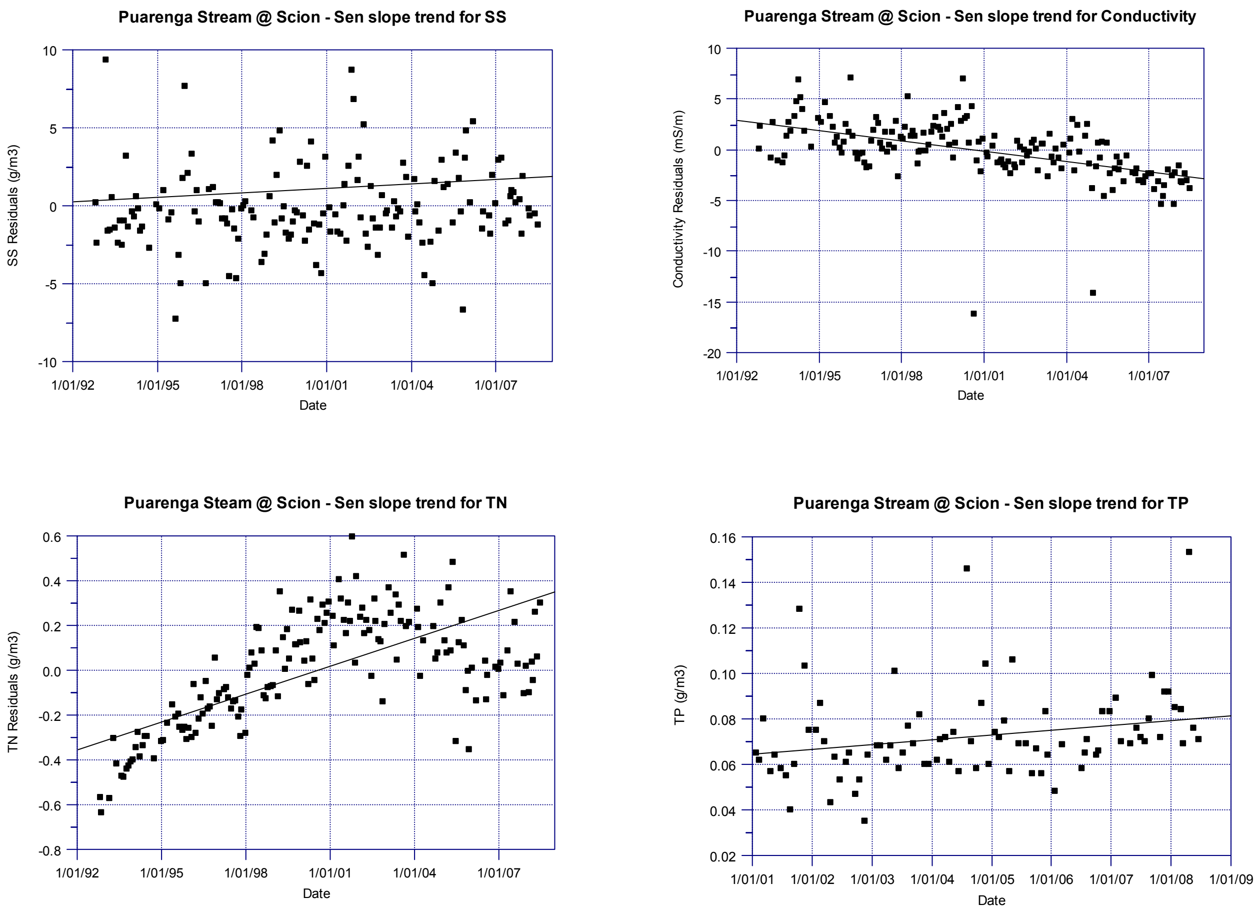
	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)	60.5 (-5)	-0.43	119	1.0	1.0	0.2	2.0
DO%	41.2 (106)	0.11	172	93.7	93.9	80.4	113.9
Temperature (ºC)	17.6 (-37)	-0.23	179	16.0	16.2	9.9	21.0
Colour (absat440nm/cm)	26 (10)	0.86	146	1.3	1.1	0.0	5.1
Conductivity (mS/m)	**<1 (-338)**	**-1.4**	176	24.1	24.1	6.4	33.4
Suspended solids (g/m^3)	**1.5 (100)**	**1.43**	176	10.7	7.0	2.7	147.0
Turbidity (NTU)	10.4 (48)	0.9	177	6.8	5.4	1.5	77.0
pH	8.9 (<1)	0	179	6.7	6.7	5.9	7.5
DRP (g/m^3)	**<1 (0.4)**	**0.85**	177	0.047	0.047	0.004	0.080
Ammonium-N (g/m^3)	6.2 (-0.5)	-0.72	177	0.070	0.069	0.002	0.176
TOx-N (g/m^3)	**<1 (40)**	**4.65**	174	0.811	0.863	0.001	1.280
Total Nitrogen (g/m^3)	**<1 (41)**	**3.55**	167	1.128	1.167	0.191	2.015
Total Phosphorus (g/m^3)	**<1 (2.1)**	**3.04**	176	0.069	0.065	0.035	0.193
Escherichia coli (cfu/100mL)	89.8 (<1)	0	165	377	140	1	16000
Enterococci (cfu/100mL)	44.5 (-15)	-0.87	176	178	49	2	4500
Faecal coliforms (cfu/100mL)	73.4 (4)	0.19	171	566	220	1	16000
Flow (m^3/s)			176	1.7	1.7	0.6	3.6

TN and TOx-N both have meaningful increasing trends (Table 3.22). Like TP, the TN is composed mostly of dissolved forms and therefore both species display very similar trends. While the overall trend is increasing for TN and TOx-N, since 2001 the trend has markedly changed to a meaningful decrease (TOx-$N_{2001\text{-}2008}$ p<0.001, RSEN= -3.5) (Figure 3.20).

One of the main potential nutrient loads to the stream comes from the irrigation of treated sewage in the catchment. The distinct change in trend in nitrogen comes from improvements made to the irrigation system around 2001. Although reductions in nitrogen are occurring, of concern is the increasing phosphorus load. Recent analysis of data from the Waipa Stream (a tributary of the Puarenga) and effluent characteristics suggest that the irrigation scheme is becoming overloaded with respect to phosphorus (*pers comm.* Stephen Park).

The Puarenga Stream has a relatively high conductivity compared to other streams due to the strong geothermal influence. There is a steady decreasing trend in total dissolved salts as indicated by the conductivity data however the cause of this is unexplained.

Figure 3.20 Puarenga Stream at Scion, Sen slope trend and residual data for several water quality parameters.



3.4.3 Ngongotahā Stream

The Ngongotaha Stream is spring fed with a catchment area of 78 km^2. The upper catchment is a mixture of forest and pasture that cover parts of the ignimbrite geology of the Mamaku plateau and the western slopes of the rhyolitic dome of Mount Ngongotaha. In the lower catchment the stream meanders through an urban landscape before flowing into the western side of Lake Rotorua.

The Ngongotaha Stream is monitored within 1 km of Lake Rotorua, in an area that is well frequented by anglers. The stream has a mobile bed load due to the volcanic geology. Forming part of the bed load, the SS concentrations (and turbidity) show a meaningful increasing trend over the 1990 to 2008 period (Table 3.23, Figure 3.21), which corresponds to a decreasing trend in water clarity of -1.61 %/year.

Oxides of nitrogen and TN show significant increasing trends (Table 3.23, Figure 3.21). Most of the increase has occurred over the 1990 to 1996 period, since this time nitrogen levels have remained stable.

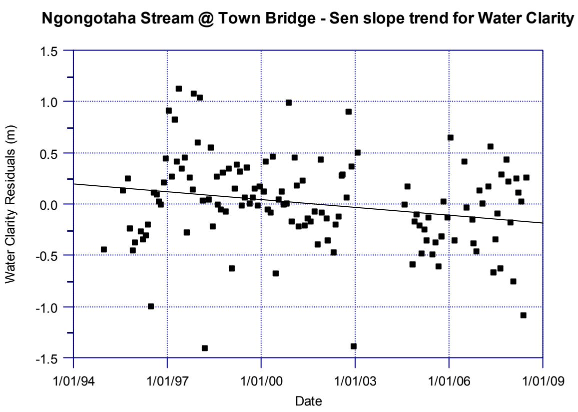
E.coli also show a significant increasing trend (Figure 3.21) with an RSEN of 0.73 %/year. Median *E.coli* levels are below the orange alert recreational guideline level, however individual samples are often above both the orange and red alert recreational guideline levels.

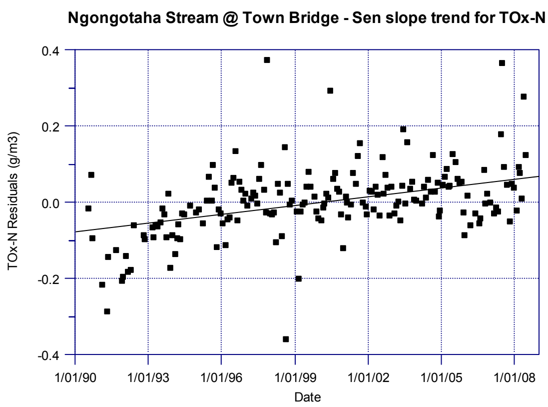
Table 3.23 Ngongotaha Stream at Town Bridge, water quality statistics, 1990 to 2008 (water clarity data from 1994 to 2008).

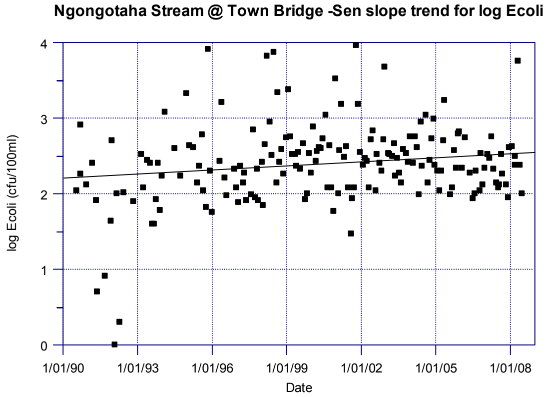
	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	**2.8 (-25)**	**-1.61**	129	1.5	1.5	0.2	2.8
DO%	61.2 (27)	0.03	190	92.0	91.8	76.1	111.1
Temperature (ºC)	23 (20)	0.17	195	12.0	12.0	7.3	16.4
Colour (absat440nm/cm)	18.5 (10)	1.94	146	0.7	0.5	0.0	4.6
Conductivity (mS/m)	**<1 (29)**	**0.44**	191	6.6	6.6	1.9	27.3
Suspended solids (g/m^3)	**<1 (240)**	**2.66**	189	12.0	9.0	2.0	123.0
Turbidity (NTU)	**<1 (89)**	**2.69**	189	4.5	3.3	0.5	49.0
pH	**<1 (6)**	**-0.08**	195	7.0	7.0	6.2	7.9
DRP (g/m^3)	11.3 (-0.2)	-0.54	191	0.037	0.037	0.005	0.127
Ammonium-N (g/m^3)	23.3 (-0.1)	-0.67	191	0.018	0.015	0.001	0.159
TOx-N (g/m^3)	**<1 (7.7)**	**1**	185	0.769	0.769	0.490	1.230
Total Nitrogen (g/m^3)	**<1 (6.5)**	**0.68**	183	0.972	0.955	0.189	1.975
Total Phosphorus (g/m^3)	27.4 (0.1)	0.22	191	0.052	0.047	0.016	0.257
Escherichia coli (cfu/100mL)	**1 (18)**	**0.73**	180	586	245	1	9200
Enterococci (cfu/100mL)	86.3 (<1)	0	191	321	90	11	12000
Faecal coliforms (cfu/100mL)	47.8 (3)	0.13	186	729	320	23	10000
Flow (m^3/s)			195	1.6	1.5	1.0	6.6

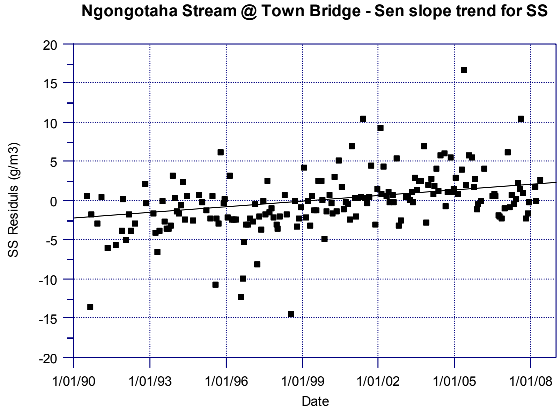
Conductivity has a significant increasing trend (Table 3.23), but there are phases of increasing and declining conductivity within the data, most noticeably with a change occurring in 2006. pH values show a minor but significant decreasing trend.

Figure 3.21 Ngongotaha Stream at Town Bridge, Sen slope trend and residual data for several water quality parameters.









3.4.4 Mimiha Stream

The Mimiha catchment is relatively short extending approximately 8.5 kilometres in length from the Manawahe Hills to the coast. The stream cuts through ignimbrite and volcanogenic sediments and dacite and rhyolite volcanics. The catchment is dominated by pasture with some exotic and native forest.

Few trends are obvious in the water quality data over the eight year monitoring period. Data is also limited as monitoring of this stream has occurred monthly for one year every three years. The only significant trends apparent in the data are increasing *E.coli* and faecal coliforms. Median *E.coli* levels are below the orange alert recreational guideline level however individual samples are often above both the orange and red alert recreational guidelines.

Table 3.24 Mimiha Stream at SH2, water quality statistics, 1999 to 2007.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
DO%	86.5 (134)	0.14	44	98.9	99.8	88.2	107.8
Temperature (ºC)	60 (121)	0.88	46	13.4	14.0	8.3	20.0
Colour (absat440nm/cm)	17.5 (89)	7.76	43	1.1	0.9	0.0	4.2
Conductivity (mS/m)	86.1 (-4)	-0.03	47	10.4	10.4	10.2	11.7
Suspended solids (g/m^3)	23.5 (<1)	0	46	15.7	10.5	3.2	68.0
Turbidity (NTU)	86.5 (<1)	0	47	7.3	4.8	1.2	43.0
pH	73 (<1)	0	47	7.2	7.2	6.5	7.7
DRP (g/m^3)	86.5 (-0.2)	-0.67	46	0.030	0.029	0.006	0.099
Ammonium-N (g/m^3)	33.9 (0.3)	3.33	46	0.010	0.009	0.003	0.022
TOx-N (g/m^3)	44.4 (-17)	-1.09	44	1.507	1.500	0.955	2.900
Total Nitrogen (g/m^3)	50 (-18)	-1.04	44	1.717	1.746	0.236	3.027
Total Phosphorus (g/m^3)	52.6 (0.8)	0.97	45	0.029	0.026	0.015	0.084
Escherichia coli (cfu/100mL)	**3.9 (39)**	**1.59**	47	529	270	37	3000
Enterococci (cfu/100mL)	39.6 (55)	2.9	47	285	120	10	3200
Faecal coliforms (cfu/100mL)	**2.7 (49)**	**1.96**	47	620	390	43	3100
Flow (m^3/s)			43	0.3	0.3	0.2	0.6

3.4.5 Pikowai Stream

The Pikowai catchment is long and narrow beginning near Lake Rotoma and running north-east to the coast. With a catchment area of approximately 30 km^2 it is only about three kilometres at its widest extent. The stream winds its way through ignimbrite and volcanogenic sediments. There is exotic and native forest dominant in the upper catchment and pastoral land-use is dominant in the lower catchment with patches of exotic and native forest.

No significant trends are apparent over the 1999 to 2007 period. The indicator bacteria all have non-significant increasing trends and this will be something to examine into the future given that median levels are close to exceeding contact recreation guidelines.

Table 3.25 Pikowai Stream at SH2, water quality statistics, 1999 to 2007.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
DO%	100 (48)	0.05	43	97.2	97.3	87.4	111.9
Temperature (ºC)	56 (100)	0.7	46	14.2	14.3	11.0	18.5
Colour (absat440nm/cm)	16.8 (40)	8.72	43	0.6	0.5	0.0	2.8
Conductivity (mS/m)	68.8 (<1)	0	46	9.9	10.0	8.1	10.4
Suspended solids (g/m^3)	65 (-1.46)	-5.83	46	25.3	21.0	6.8	126.0
Turbidity (NTU)	100 (-1)	-0.02	47	5.8	4.3	2.4	34.0
pH	86.1 (<1)	0	47	7.2	7.2	6.8	7.4
DRP (g/m^3)	88.3 (0.2)	0.27	47	0.074	0.076	0.029	0.093
Ammonium-N (g/m^3)	23.3 (0.3)	3.75	47	0.010	0.008	0.004	0.031
TOx-N (g/m^3)	52.4 (6.5)	-0.66	45	0.984	0.988	0.752	1.220
Total Nitrogen (g/m^3)	60.9 (-7.3)	0.38	41	1.170	1.176	0.869	1.400
Total Phosphorus (g/m^3)	100 (-0.2)	-0.24	45	0.083	0.082	0.054	0.114
Escherichia coli (cfu/100mL)	38.2 (52)	2.23	47	328	230	37	1200
Enterococci (cfu/100mL)	24.3 (50)	2.76	47	168	67	3	1400
Faecal coliforms (cfu/100mL)	38.2 (43)	1.77	47	402	270	37	1800
Flow (m^3/s)			40	1.2	1.2	0.9	1.5

3.4.6 Waitahanui Stream

The Waitahanui Stream arises north of Lakes Rotoehu and Rotoma and has a total catchment area of 155.4 km^2. The catchment is dominated by Rotoiti pyroclastics, smaller lenses of welded ignimbrite flows, and sediments of volcanic origins. Some smaller outcrops of greywacke appear near the coast, interlaced with Holocene aged sediments.

Much of the catchment is covered in exotic forestry with patches of native vegetation. Pastoral farming occurs closer to the coast and a pumice quarry is operated at Otamarakau.

The stream has a good correlation of flow versus conductivity indicating that it is predominantly spring fed (Spearman R = -0.69, p<0.01). This relationship was used to model missing flow data for the trend analysis for parameters where flow was considered an influencing factor. Being spring fed may also explain the relatively high DRP concentrations in these waters, due to the phosphorus being leached out of the underlying geology.

No significant trends are apparent in the water quality data (Table 3.26).

Table 3.26 Waitahanui Stream at SH2, water quality statistics, 1996 to 2007.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
DO%	75.2 (51.1)	0.54	22	97.7	94.9	85.0	135.1
Temperature (ºC)	7.3 (327)	2.31	22	14.3	14.2	11.0	18.6
Colour (absat440nm/cm)	21.9 (<1)	0	21	0.5	0.5	0.2	1.6
Conductivity (mS/m)	82.1 (-5)	-0.03	21	18.1	18.1	17.2	18.9
Suspended solids (g/m^3)	17.1 (-4.22)	-4.22	22	15.7	11.3	1.6	48.0
Turbidity (NTU)	91.6 (-24)	-0.74	22	3.9	3.3	1.0	12.0
pH	100 (<1)	0	22	7.5	7.4	7.0	8.4
DRP (g/m^3)	52.5 (-2)	-1.6	22	0.085	0.094	0.009	0.111
Ammonium-N (g/m^3)	91.4 (<1)	0	22	0.015	0.014	0.004	0.047
TOx-N (g/m^3)	20.3 (-3.7)	-0.57	22	0.661	0.648	0.354	1.185
Total Nitrogen (g/m^3)	91.6 (-6.3)	-0.77	22	0.834	0.822	0.514	1.281
Total Phosphorus (g/m^3)	82.1 (-0.6)	-0.56	21	0.109	0.107	0.095	0.130
Escherichia coli (cfu/100mL)	30.3 (22)	0.95	21	269	220	38	1500
Enterococci (cfu/100mL)	11.8 (37)	2.17	23	143	53	12	1400
Faecal coliforms (cfu/100mL)	52.6 (14)	0.58	23	334	250	49	1500
Flow (m^3/s)			22	5.5	5.4	4.7	6.6

3.4.7 Pongakawa Stream

The 132.5 km^2 Pongakawa stream catchment extends through Rotoiti pyroclastics into Pleistocene and Holocene sediments. In the upper catchment exotic and native forests are the predominant land cover, with some pastoral land. Pasture with low intensity livestock agriculture is prevalent in the mid-catchment, followed by high intensity pastoral and horticultural use in the lower catchment.

Monitoring has occurred at two sites; an upstream site located near the intersection of Old Coach Road and Rotoehu Road, and at SH2. Table 3.27 gives trend analyses information and statistics for the upstream site.

No significant trends are present over the 1999 to 2007 period. One near significant trend is that of decreasing ammonium-nitrogen concentrations. Downstream at the SH2 site ammonium-nitrogen displays a meaningful increasing trend over a longer analysis period (Table 3.28, Figure 3.22) as well as the shorter 1999 to 2007 period. This upstream-downstream difference in trends is likely to indicate the impacts of varying land use in the upper catchment versus the lower catchment. These differences are observed in a range of other parameters.

Both TOx-N and TN have meaningful increasing trends in the lower Pongakawa (Table 3.28, Figure 3.22), indicating that all nitrogen species are increasing in the lower catchment. TP displays the opposite trend, decreasing over the analysis period. The dissolved component of phosphorus (DRP) displays no trend meaning the TP trend in driven predominantly by particulate phosphorus. A non-significant trend of decreasing SS is likely also to be related to this observation.

E.coli are the only indicator bacteria to have a meaningful increasing trend at the SH2 site (Table 3.28, Figure 3.22) although median concentrations are very similar to those at the upstream site.

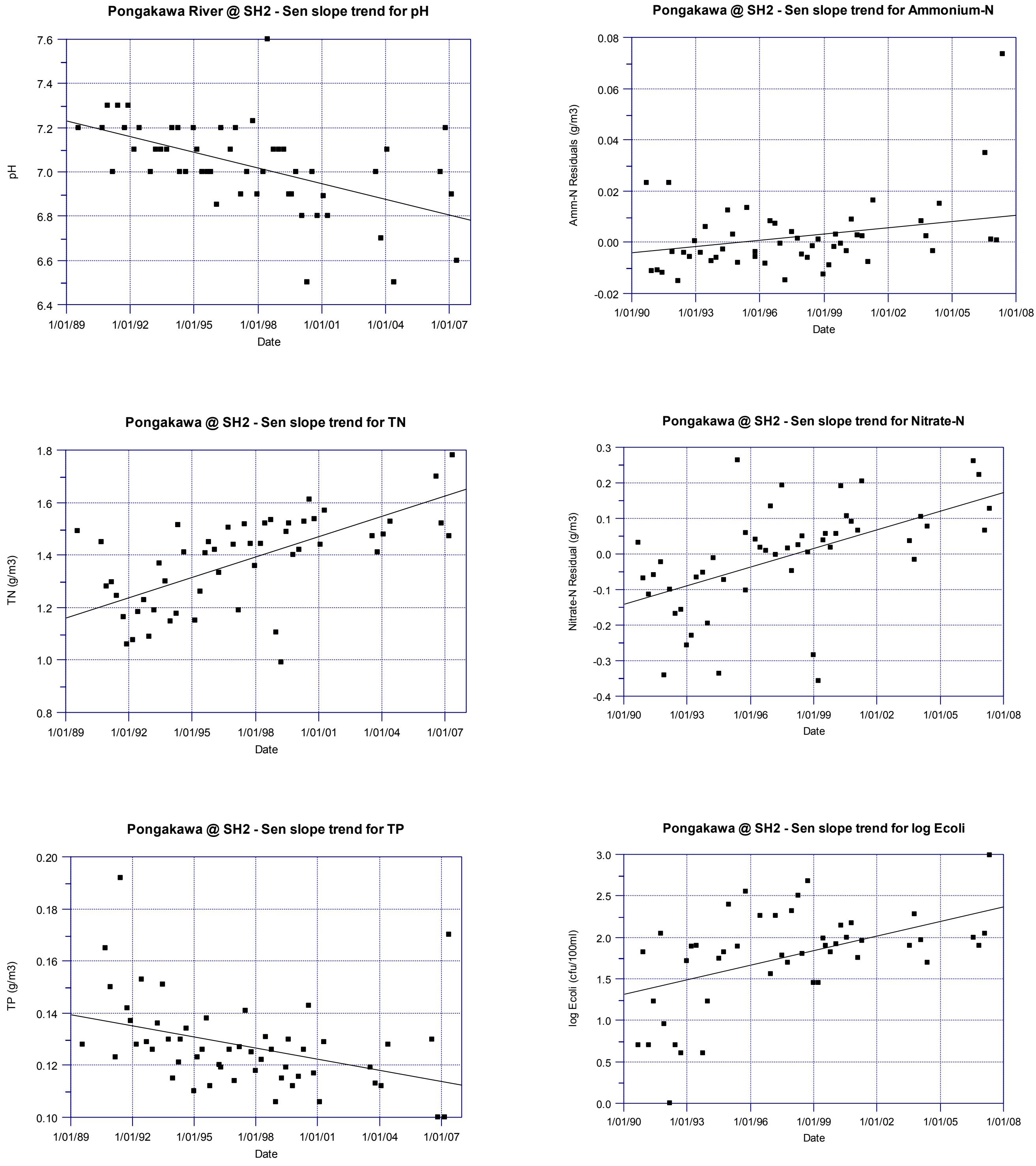
Table 3.27 Pongakawa Stream at Old Coach Road, water quality statistics, 1999 to 2007.

	p-value (trend slope 10^{-3} units/yr)	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
DO%	87.7 (-256)	-0.27	40	95.8	94.9	85.5	113.9
Temperature (ºC)	21.2 (119)	0.81	42	14.7	14.8	12.8	16.7
Colour (absat440nm/cm)			39	0.2	0.2	-0.2	1.4
Conductivity (mS/m)	88.4 (0)	0	42	10.9	10.8	10.0	11.7
Suspended solids (g/m^3)	64.3 (-404)	-4.04	42	14.9	10.5	0.1	37.0
Turbidity (NTU)	44 (-54)	-2.07	42	3.0	2.6	0.8	6.7
pH	86.6 (0)	0	42	6.9	6.8	6.5	7.9
DRP (g/m^3)	64.3 (0.2)	-0.17	42	0.116	0.119	0.058	0.138
Ammonium-N (g/m^3)	9 (-0.6)	-4.8	42	0.015	0.013	0.001	0.047
TOx-N (g/m^3)	86.8 (-3.3)	-0.24	40	1.315	1.360	0.002	1.640
Total Nitrogen (g/m^3)	74.2 (-1)	-0.07	40	1.453	1.487	0.192	1.780
Total Phosphorus (g/m^3)	75.5 (-0.3)	-0.25	42	0.118	0.120	0.059	0.150
Escherichia coli (cfu/100mL)	87.7 (-1)	-0.52	42	127	77	13	550
Enterococci (cfu/100mL)	100 (<1)	0	42	104	45	1	977
Faecal coliforms (cfu/100mL)	87.7 (-18)	-0.94	42	165	100	37	930
Flow (m^3/s)			40	4.7	4.7	4.0	5.2

Table 3.28 Pongakawa Stream at SH2, water quality statistics, 1990 to 2007.

	p-value (trend slope 10^{-3} units/yr)	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
DO%	28.6 (-246)	-0.26	89	95.1	94.9	78.7	120.1
Temperature (ºC)	92.5 (-4)	-0.03	92	14.7	14.8	9.9	18.0
Colour (absat440nm/cm)	1.8 (0)	0	67	0.3	0.2	0.0	1.6
Conductivity (mS/m)	11.4 (21)	0.19	85	11.5	11.2	9.8	28.0
Suspended solids (g/m^3)	54.3 (-109)	-1.04	92	14.7	10.1	0.4	74.0
Turbidity (NTU)	94.8 (3)	0.11	82	3.4	2.6	0.6	23.0
pH	**<1 (-24)**	**-0.34**	91	7.0	7.0	6.5	7.6
DRP (g/m^3)	96.9 (<0.1)	0	93	0.117	0.118	0.026	0.168
Ammonium-N (g/m^3)	**<1 (0.8)**	**4.71**	93	0.020	0.017	0.001	0.091
TOx-N (g/m^3)	**<1 (17.4)**	**1.38**	91	1.215	1.270	0.330	1.530
Total Nitrogen (g/m^3)	**<1 (26.6)**	**1.5**	90	1.396	1.432	0.519	1.780
Total Phosphorus (g/m^3)	**<1 (-1.4)**	**-1.11**	91	0.127	0.126	0.100	0.192
Escherichia coli (cfu/100mL)	**<1 (58)**	**3.09**	79	134	80	1	970
Enterococci (cfu/100mL)	15.1 (16)	1	91	105	40	1	2100
Faecal coliforms (cfu/100mL)	17.8 (17)	0.84	91	169	110	12	970
Flow (m^3/s)			83	4.7	4.6	3.9	5.7

Figure 3.22 Pongakawa Stream at SH2, Sen slope trend and residual data for several water quality parameters.



3.4.8 Central Bay of Plenty/Rotorua Rivers Summary

Median DO saturation values for all of the Rotorua and Central Bay of Plenty rivers and streams are well above 80% (Figure 3.23). The Ohau Channel occasionally dips below this level in late summer as a result of algal deposition and decomposition.

Turbidity is stable in the Kaituna River with the highest average turbidity measured at the Ohau Channel. At the Okere site turbidity is moderated by Lake Rotoiti and downstream from here little change occurs. The highest turbidity occurs in the Puarenga due to the geothermal influence. However the Mimiha also has a high median turbidity with an average of 7.8 NTU, over the ANZECC (2000) trigger value for lowland rivers with slightly disturbed ecosystems (5.6 NTU). The Mimiha catchment does have some significant gully head erosion which contributes to the elevated turbidity.

In the Kaituna River catchment TN is on average higher in the Ohau Channel than at Okere site primarily due to algal biomass and the moderating effect of Lake Rotoiti. From Okere TN increases in concentration downstream with TN concentrations at Te Matai on average almost twice those at Paengaroa. At the lowland sites the major component on TN is TOx-N compared with the upper sites which are predominantly organic nitrogen. The Puarenga Stream has a relatively high TN compared to the other rivers in part due to the impact of the Rotorua wastewater irrigation scheme.

Of these rivers and streams the Mimiha Stream has the highest median TN concentration. It is unclear why this stream is elevated compared to the Pikowai or Waitahanui, but these concentrations result from high TOx-N values as do those at the Pongakawa Stream sites. The high TOx-N levels of the Mimiha may result from greater grazing intensity, particularly in winter when TOx-N levels are greatest. Despite this the adverse effects of nitrogen leaching will be minimal in these streams at the current levels.

All of the coastal streams display a high proportion of phosphorus in the dissolved form reflecting that they are groundwater dominated (spring fed). The lower phosphorus level in the Mimiha Stream indicates a younger groundwater.

In the Kaituna River TP displays a similar pattern to TN. The highest TP concentrations are observed in the Pongakawa Stream with the downstream site having the highest median concentrations. Differences in geology, groundwater age, the effect of the lakes, as well as flow regimes are all likely to explain why the Pongakawa has a higher median TP concentration than adjacent catchments.

E.coli concentrations in the Kaituna River are generally low in the upper catchment, increasing further downstream. At its furthest downstream extent (Te Matai site) the median concentrations in the Kaituna River are similar to other streams of the Rotorua/Central Bay of Plenty group. The highest median concentration is in the Mimiha Stream and this is just above the recreational guideline orange alert level (260 *E.coli*/100ml).

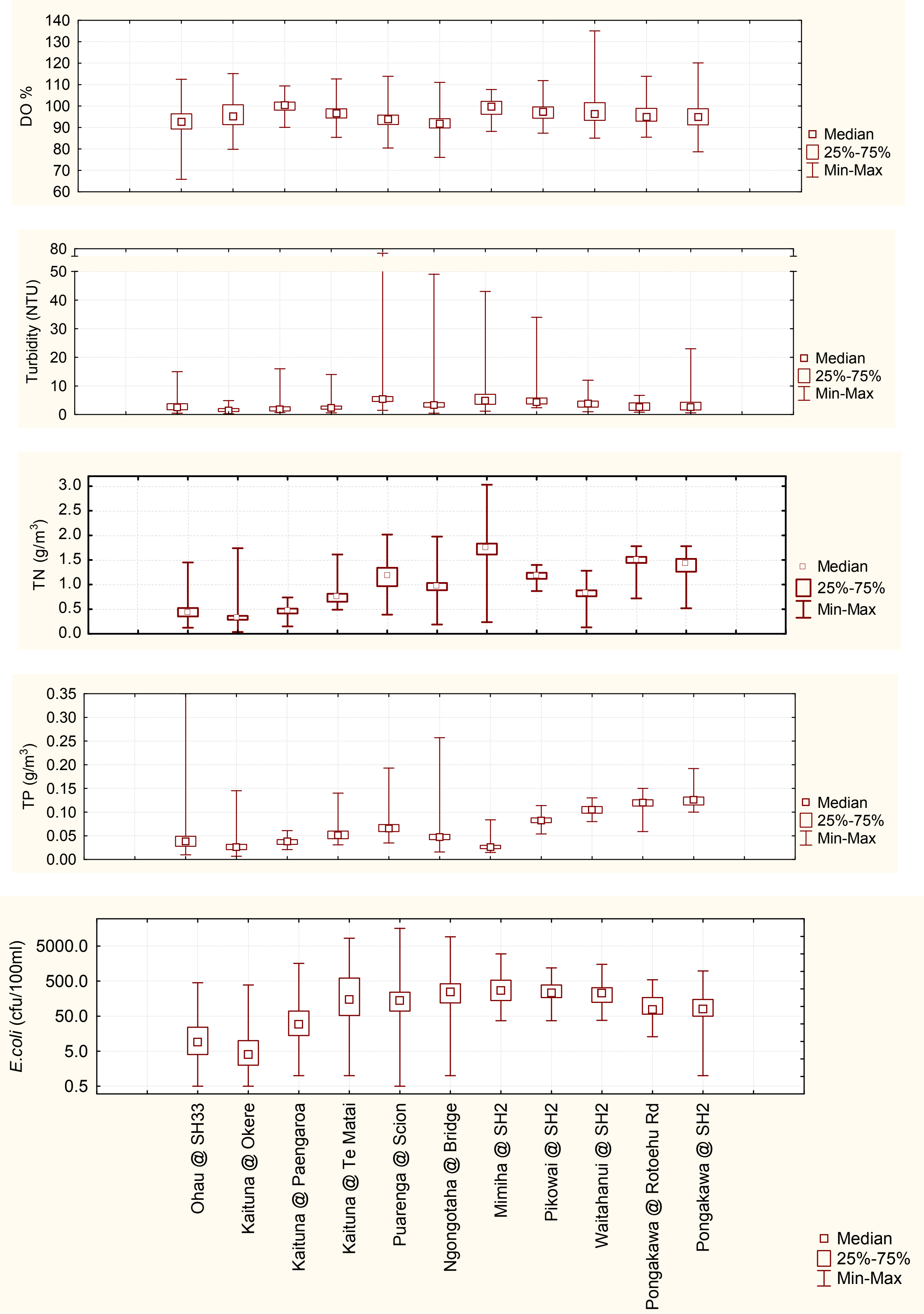


Figure 3.23 Box whisker plots for several water quality parameters, Rotorua/Central Bay of Plenty Rivers.

3.5 Tauranga Harbour Catchment

3.5.1 Rocky Stream

Rocky Stream is highly modified over much of its length. It begins in the northern Papamoa Hills in Papamoa ignimbrite, Minden rhyolite and associated fluvial deposits before flowing a few kilometres along SH2 through peat and fixed foredunes. The stream then turns west from SH2 and flows into the eastern extreme of Rangataua Bay in Tauranga Harbour.

Land use is a mixture of indigenous and exotic forest and pasture, with some horticulture. The Te Maunga Waste Water Treatment Plant is downstream of the Mangatawa Bridge monitoring site.

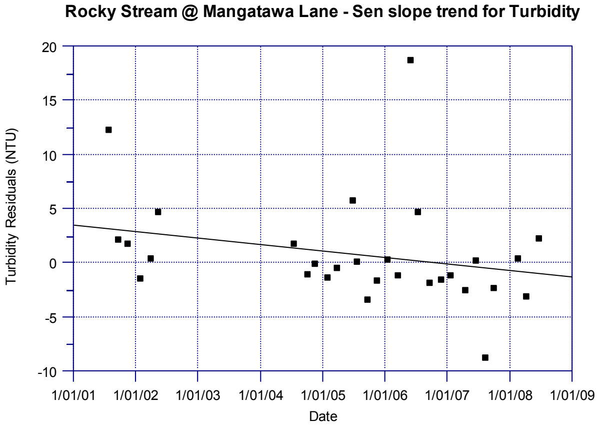
TN displays the greatest meaningful trend with a decrease of 9.42 %/year (Table 3.29). Other nitrogen species have a similar trend although most of the nitrogen is in the organic form suggesting a highly productive system. Various phases of urban and road construction earthworks are also likely to have influenced SS and turbidity.

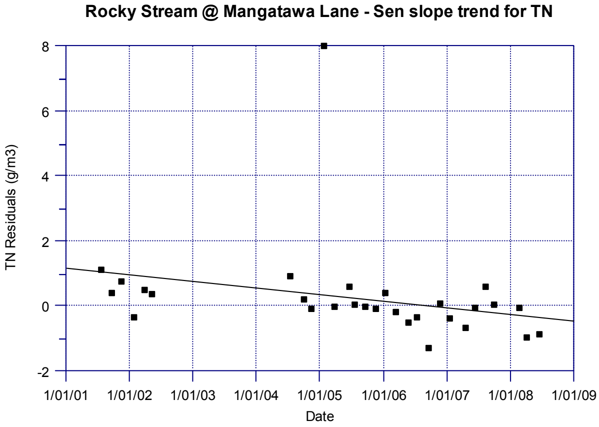
Table 3.29 Rocky Stream at Mangatawa Bridge, water quality statistics, 2001 to 2008.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
DO%	17.5 (-138)	-1.86	55	80.4	82.9	24.8	164.5
Temperature (ºC)	75.5 (-15.8)	-0.99	55	16.3	16.4	8.8	22.3
Colour (absat440nm/cm)	8.8 (-19.9)	-4.48	50	4.7	4.6	2.4	8.7
Conductivity (mS/m)	**<1 (-723)**	**-3.75**	55	19.0	19.5	9.1	23.2
Suspended solids (g/m^3)	61.2 (-117)	-2.93	56	7.5	4.0	0.4	49.0
Turbidity (NTU)	**3.4 (-598)**	**-6.8**	56	11.0	8.9	2.2	45.0
pH	42 (-9)	-0.13	56	6.8	6.7	6.2	7.4
DRP (g/m^3)	23.7 (-0.7)	-3.5	55	0.022	0.021	0.001	0.064
Ammonium-N (g/m^3)	7 (-12)	-10.43	55	0.177	0.120	0.002	0.541
TOx-N (g/m^3)	10.3 (-30)	-3.95	55	0.864	0.755	0.072	4.660
Total Nitrogen (g/m^3)	**<1 (-203)**	**-9.42**	54	2.316	2.175	0.597	9.922
Total Phosphorus (g/m^3)	17.5 (-1.8)	-4.86	55	0.043	0.039	0.018	0.144
Escherichia coli (cfu/100mL)	7.6 (50)	1.97	55	690	300	57	14000
Enterococci (cfu/100mL)	75.5 (7)	0.33	56	396	150	23	7400
Faecal coliforms (cfu/100mL)	13.4 (33)	1.25	56	740	355	84	14000
Flow (m^3/s)			50	0.2	0.2	0.0	0.8

Conductivity is the only other parameter to show a meaningful decreasing trend. Like colour, this trend may be a result of less dissolved salts being leached from local soils.

Figure 3.24 Rocky Stream at Mangatawa Bridge, Sen slope trend and residual data for turbidity and TN.





3.5.2 **Waitao Stream**

The Waitao Stream flows north through Minden rhyolite and the lavas of the andesitic Otawa volcanics. Some tributaries also pass through Papamoa ignimbrite before reaching recent fluvial terrace deposits where tributaries come together before reaching Rangataua Bay in Tauranga Harbour. The catchment area is approximately 3,732 ha with the upper reaches having predominantly indigenous vegetation cover with some exotic forestry. An active quarry occurs in the catchment.

At the end of 1999 the monitoring site on the Waitao Stream was moved from the Welcome Bay Road Bridge upstream (less than 0.5 km) to Spenser's farm to reduce the tidal influence. As a consequence some data has not been included in the trend analysis, most notably conductivity. Trend analyses have used data from both sites.

Table 3.30 and Figure 3.25 highlight several significant trends. All dissolved and total nutrients have decreasing trends. It is possible that this is a result of better rural practices, such as better effluent management, and an increase in lifestyle properties.

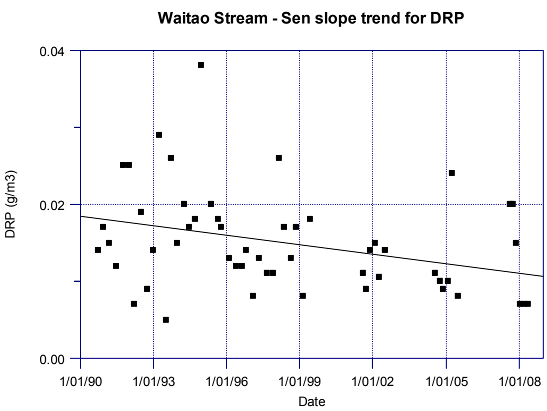
Colour has a significant increasing trend. There is a correlation of colour with indicator bacteria (Pearson R for *E.coli* = 0.45, $p<0.05$) which could suggest that stock are responsible for the colour increase. However, the indicator bacteria trends although increasing are not significant.

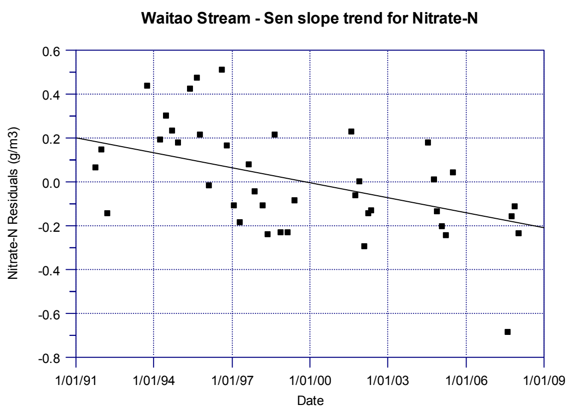
Table 3.30 Waitao Stream at Spensers Farm, water quality statistics, 1990 to 2008.

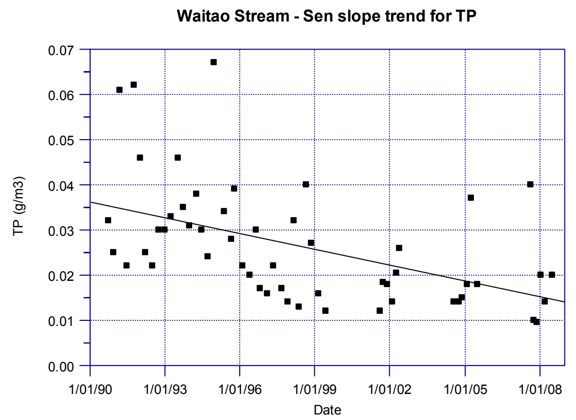
	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	58.2 (27)	1.78	43	1.6	1.6	0.3	2.7
DO%	50.2 (86)	0.09	70	92.9	92.7	76.2	107.4
Temperature (ºC)	100 (<1)	0	70	13.5	13.3	7.0	21.8
Colour (absat440nm/cm)	**2.6 (38)**	**4.13**	56	1.1	0.9	0.2	3.1
Conductivity (mS/m)			70	10.3	9.5	6.6	27.8
Suspended solids (g/m^3)	22.3 (102)	1.84	69	8.9	6.2	1.7	48.0
Turbidity (NTU)	33.6 (28)	0.78	68	4.9	3.4	1.8	35.0
pH	65.4 (-2)	-0.03	68	7.0	7.0	6.4	7.8
DRP (g/m^3)	**<1 (-0.4)**	**-2.86**	68	0.014	0.013	0.005	0.038
Ammonium-N (g/m^3)	**3.4 (-1.1)**	**-3.76**	68	0.040	0.029	0.009	0.330
TOx-N (g/m^3)	**<1 (-22.6)**	**-4.55**	68	0.536	0.483	0.004	1.200
Total Nitrogen (g/m^3)	**<1 (-27)**	**-3.52**	67	0.770	0.765	0.135	1.435
Total Phosphorus (g/m^3)	**<1 (-1.2)**	**-5.45**	68	0.024	0.021	0.006	0.067
Escherichia coli (cfu/100mL)	38.7 (13)	0.52	65	730	370	47	12000
Enterococci (cfu/100mL)	26 (19)	0.92	68	282	117	12	3800
Faecal coliforms (cfu/100mL)	74.9 (6)	0.21	67	835	480	57	12000
Flow (m^3/s)			50	0.7	0.6	0.2	2.5

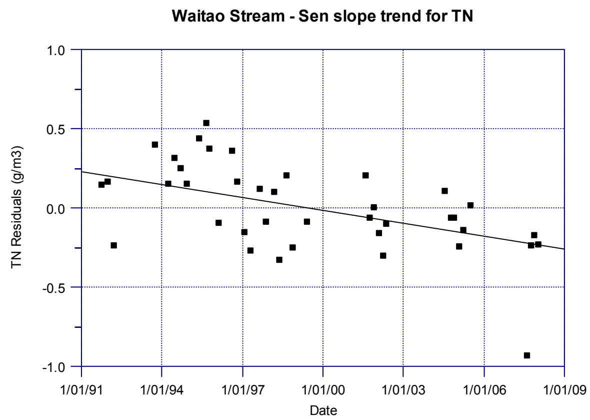
Indicator bacteria results are elevated and at times in excess of recreational water quality guidelines. Recent monitoring further up the catchment at Kaiate Falls also indicates poor recreational water quality with stock having ready access to the stream upstream of the falls.

Figure 3.25 Waitao Stream at Spenser Farm, Sen slope trend and residual data for several water quality parameters.









3.5.3 Waimapu Stream

The Waimapu Stream catchment covers 11,164 ha with approximately 50% of this in pasture (2001 land cover data). Over 30% of the catchment has indigenous vegetation cover, predominant at the head of the catchment. Less than 10% of the catchment is in exotic forestry and there is increasing urban development in the lower catchment.

The catchment geology is dominated by Mamaku and Waimakariri ignimbrites in the east and the older Waiteariki ignimbrite to the east. Some Minden rhyolite occurs at the head of the catchment.

Monitoring of the Waimapu occurs at the Pukemapui Bridge approximately 1.5 kilometres upstream of the Waimapu Estuary. Some tributaries enter further downstream from the monitoring site. More recently monitoring has also been occurring at Greerton but there is insufficient data at this site for trend analysis.

Declining pH is the only significant trend in this short data set (Table 3.31) and this has occurred since 2007.

Table 3.31 Waimapu Stream at Pukemapui, water quality statistics, 2001 to 2008.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	36.8 (-49)	-2.24	41	2.1	2.2	0.6	3.5
DO%	100 (-16)	-0.02	50	96.7	98.1	77.5	108.7
Temperature (ºC)	74.3 (22)	0.16	50	14.1	13.9	7.6	19.6
Colour (absat440nm/cm)	73.3 (<1)	0	47	1.0	0.9	0.2	3.8
Conductivity (mS/m)	44.5 (10)	0.14	50	6.8	6.9	5.2	7.7
Suspended solids (g/m^3)	100 (-19)	-0.53	50	5.9	3.6	1.2	60.0
Turbidity (NTU)	44.5 (79)	3.56	50	3.4	2.4	1.2	29.0
pH	**2.7 (-30)**	**-0.42**	49	7.1	7.1	6.6	7.4
DRP (g/m^3)	61.9 (0.1)	0.67	50	0.016	0.015	0.002	0.038
Ammonium-N (g/m^3)	100 (0.1)	0.83	50	0.016	0.012	0.002	0.086
TOx-N (g/m^3)	44.5 (-4.8)	0.85	45	0.585	0.572	0.005	1.040
Total Nitrogen (g/m^3)	50 (-19.4)	-2.66	43	0.789	0.765	0.195	1.263
Total Phosphorus (g/m^3)	64.9 (-0.5)	-2.78	47	0.030	0.019	0.012	0.200
Escherichia coli (cfu/100mL)	51.8 (34)	1.42	49	563	230	32	10000
Enterococci (cfu/100mL)	44 (-36)	-2.18	50	219	90	7	4300
Faecal coliforms (cfu/100mL)	64.9 (19)	0.81	50	597	255	69	10000
Flow (m^3/s)			50	1.8	1.5	0.7	6.7

3.5.4 Kopurererua Stream

The Kopurererua Stream catchment is long and narrow and covers an area of 7,405 ha. The stream extends north to south and emerges at the southern end of the Waikareao Estuary. In the northern end of the catchment fluvial sediments deposited by the stream are surrounded by Te Ranga ignimbrite. To the south the catchment geology is dominated by Mamaku and Waimakariri ignimbrite and older fluvial deposits. The Kopurererua Stream is characterised by relatively high suspended solids loads even at base flow.

Like the Waimapu catchment the dominant land use is pastoral at approximately 45% (based on 2001 data). Indigenous vegetation covers approximately 35% of the catchment with much of this near the stream tributaries particularly to the south. The urban component of the catchment is larger than the Waimapu and is has also grown in recent years. Exotic forestry is relatively small at around 6% of the catchment.

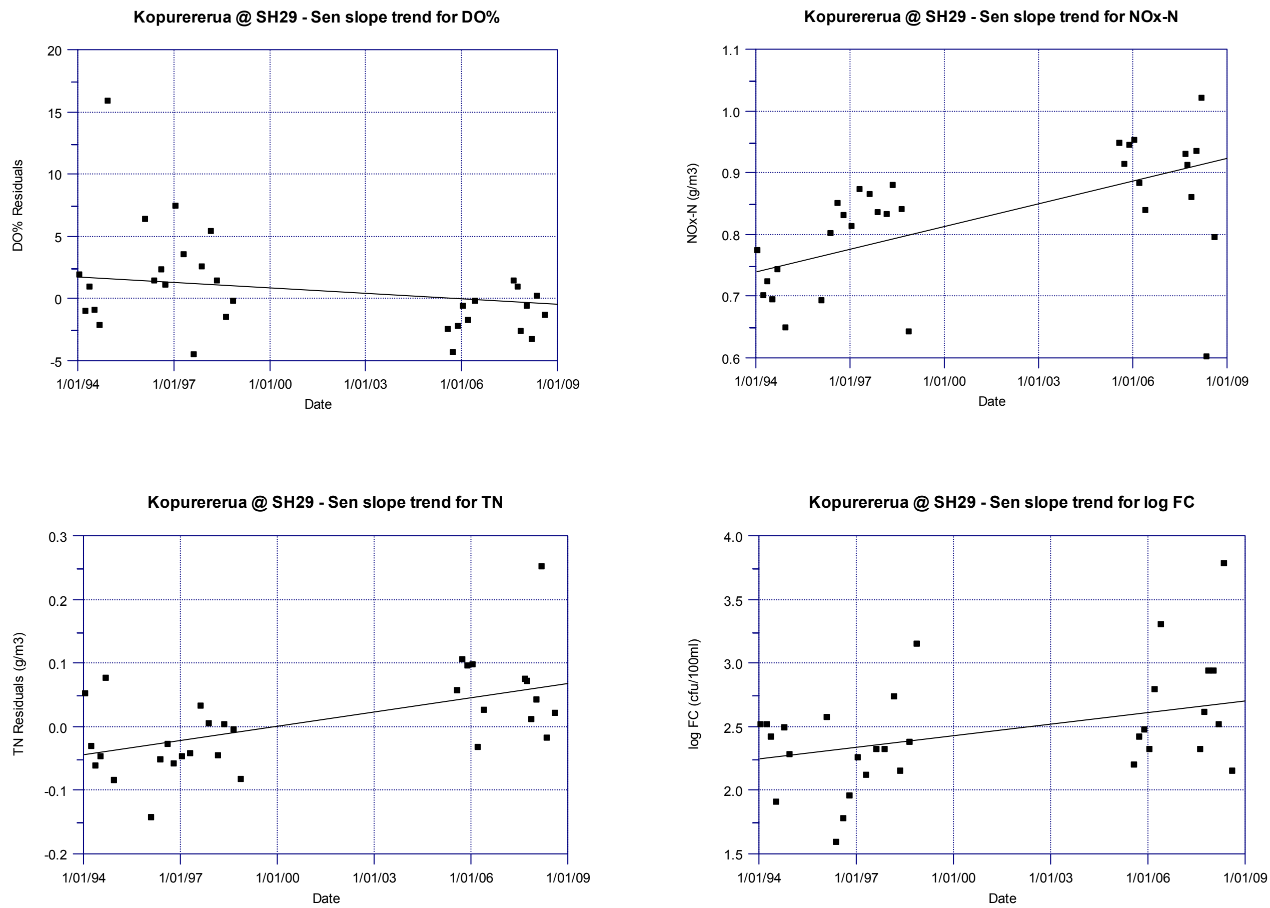
Monitoring has occurred at SH29 over the last 15 years although no monitoring occurred between 2000 and 2004. Table 3.32 shows trend analysis results for a range of water quality parameters with meaningful increasing trends occurring for enterococci and faecal coliforms (Figure 3.26). *E.coli* also show an increasing but non-significant trend. The median *E.coli* levels are below recreational water quality guidelines, but these guidelines are regularly exceeded usually during periods of higher flow.

TOx-N is the major component of TN in the Kopurererua Stream and both display significant increasing trends (Figure 3.26). This coupled with increasing trends in indicator bacteria potentially indicates that pastoral agriculture is having an increasing impact on the stream.

Table 3.32 Kopurererua Stream at SH29, water quality statistics, 1993 to 2008.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)			37	0.9	0.8	0.3	2.0
DO%	5.9 (-151)	-0.16	63	95.7	95.9	71.9	113.3
Temperature (ºC)	52.5 (27)	0.2	63	13.4	13.5	8.6	18.1
Colour (absat440nm/cm)	16.9 (21)	2.23	54	1.0	0.9	0.0	5.0
Conductivity (mS/m)	**<1 (26)**	**0.36**	63	7.1	7.1	5.8	8.4
Suspended solids (g/m^3)	65.3 (-161)	-0.76	63	36.4	21.0	6.3	685.0
Turbidity (NTU)	24.2 (150)	2.28	62	16.3	6.3	2.0	442.0
pH	8.7 (-13)	-0.18	63	7.0	7.1	6.5	7.4
DRP (g/m^3)	8.8 (-0.4)	-1.38	62	0.028	0.029	0.007	0.051
Ammonium-N (g/m^3)	41.7 (-0.2)	-1.43	62	0.018	0.015	0.004	0.062
TOx-N (g/m^3)	**<1 (12.2)**	**1.45**	59	0.799	0.830	0.510	1.020
Total Nitrogen (g/m^3)	**<1 (7.4)**	**0.72**	59	1.009	1.005	0.670	1.576
Total Phosphorus (g/m^3)	**3.2 (-0.3)**	**-0.86**	61	0.045	0.035	0.025	0.390
Escherichia coli (cfu/100mL)	15.7 (40)	1.7	55	458	220	22	5800
Enterococci (cfu/100mL)	**3.7 (41)**	**2.09**	60	293	88	1	5600
Faecal coliforms (cfu/100mL)	**3 (30)**	**1.25**	61	491	250	39	6000
Flow (m^3/s)			60	1.8	1.7	1.3	4.3

Figure 3.26 Kopurererua Stream at SH29, Sen slope trend and residual data for several water quality parameters.



There is a significant decreasing trend in TP (Table 3.32) that may be due to better control of surface run-off in the lower catchment. This may also explain why there is a non-significant decreasing trend in turbidity which correlates well with TP (Pearson R = 0.60, $p<0.05$).

An increase in organic matter in the stream may also explain the decreasing oxygen saturation levels (Figure 3.26) which on occasions is below 80%.

3.5.5 Ngamuwahine Stream

The Ngamuwahine catchment is located in the southern Kaimai Ranges in Waiteariki ignimbrite. On the true left of the stream is the Minden rhyolite dome known as Kaikaikaroro. The streams confluence is just beyond SH29 where it becomes the Mangakarengorengo Stream, part of the Wairoa River system.

Indigenous forest is the dominant land cover but with extensive pasture occurring in the Mangatotara catchment, a tributary of the Ngamuwahine.

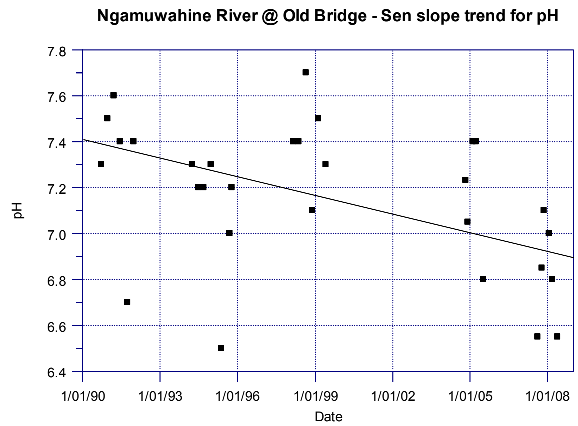
Trend analysis has been undertaken without any flow weighting as there is a lack of flow data for this stream. Three increasing trends occur over the 1990 to 2008 analysis period (Table 3.33, Figure 3.27)). Colour is increasing at 10.2 %/year, ammonium-nitrogen at 3.3 %/year and *E.coli* at 2.3 %/year. Colour is at moderate levels as are *E.coli* levels, although levels can exceed recreational guidelines at times.

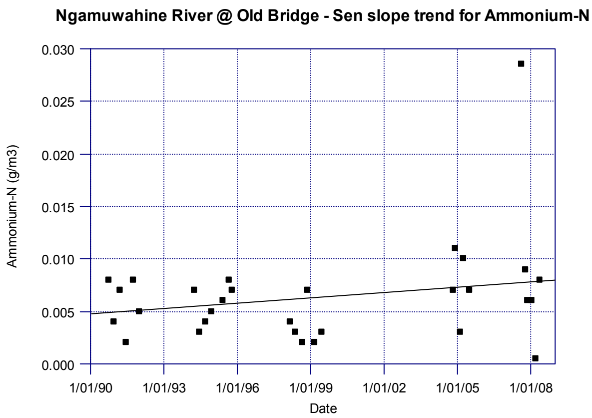
Ammonium-nitrogen is generally at low concentrations with a recent increase in concentrations occurring due to increased flow (ascertained with available flow data). It is likely, given the relationship between flow and ammonium-nitrogen, that there is no significant trend. This is also likely to be the case for pH, i.e. if flow adjusted the trend would be less significant.

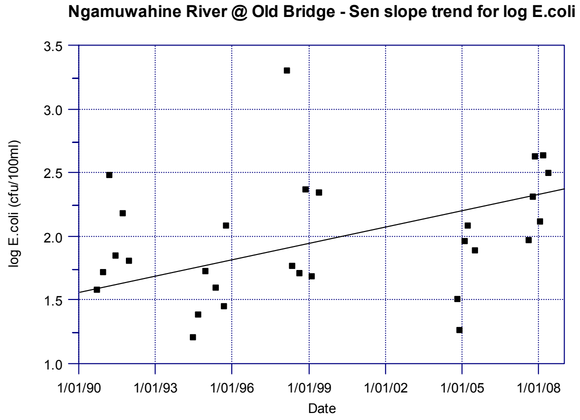
Table 3.33 Ngamuwahine Stream at Old Highway Bridge, water quality statistics, 1990 to 2008.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)			26	3.0	3.3	0.9	5.1
DO%	**1.5 (-166)**	**-0.17**	38	99.2	99.5	74.7	121.4
Temperature (°C)	23.9 (85)	0.68	38	13.3	13.1	6.5	19.1
Colour (absat440nm/cm)	**3 (94)**	**10.21**	27	1.4	0.9	0.2	6.1
Conductivity (mS/m)	9.6 (-42)	-0.92	38	4.6	4.6	2.9	5.8
Suspended solids (g/m^3)	35.7 (18)	1.41	37	1.5	1.4	0.2	5.9
Turbidity (NTU)	6.2 (24)	3.23	37	1.0	0.8	0.2	3.6
pH	**<1 (-27)**	**-0.37**	38	7.1	7.2	6.0	7.7
DRP (g/m^3)	82.9 (<0.1)	0	38	0.008	0.008	0.001	0.016
Ammonium-N (g/m^3)	**1.5 (0.2)**	**3.33**	38	0.008	0.006	0.001	0.044
TOx-N (g/m^3)	78.6 (-0.6)	-0.32	37	0.165	0.181	0.001	0.345
Total Nitrogen (g/m^3)	70.3 (1.9)	0.68	35	0.296	0.278	0.055	0.583
Total Phosphorus (g/m^3)	21 (-0.2)	-2.41	37	0.009	0.008	0.002	0.030
Escherichia coli (cfu/100mL)	**2.7 (43)**	**2.27**	37	250	73	15	2000
Enterococci (cfu/100mL)	23.2 (31)	2.26	37	78	29	1	910
Faecal coliforms (cfu/100mL)	19.1 (29)	1.39	36	493	122	22	5800
Flow (m^3/s)			24	1.3	1.1	0.4	3.0

Figure 3.27 Ngamuwahine Stream at Old Highway Bridge, Sen slope trend and residual data for several water quality parameters.







3.5.6 **Omanawa River**

The Omanawa catchment is small at approximately 59 km^2. Land use is a mixture of indigenous and exotic forest, pasture and horticulture.

To the south the catchment geology is dominated by Mamaku and Waimakariri ignimbrites and older fluvial deposits. Some Waiteariki ignimbrite has been uncovered by the eroding stream in the southern end of the catchment. Flow in this system seems to be dominated by springs which maintain a consistent flow with peaks over the winter period. Very few water quality parameters display a good relationship with flow.

Water clarity has shown a meaningful increasing trend (Table 3.34, Figure 3.28) over the 1990 to 2008 period. Correlation of water clarity is strongest with SS and turbidity but neither of these parameters displays a significant trend, suggesting other influences.

TN is composed mostly of TOx-N and both parameters have meaningful increasing trends (Figure 3.28). Agriculture is likely to be the cause of the increase in TOx-N and average concentrations found at this site are above the ANZECC guideline for lowland streams. These concentrations are high enough for nuisance periphyton growth to be problem.

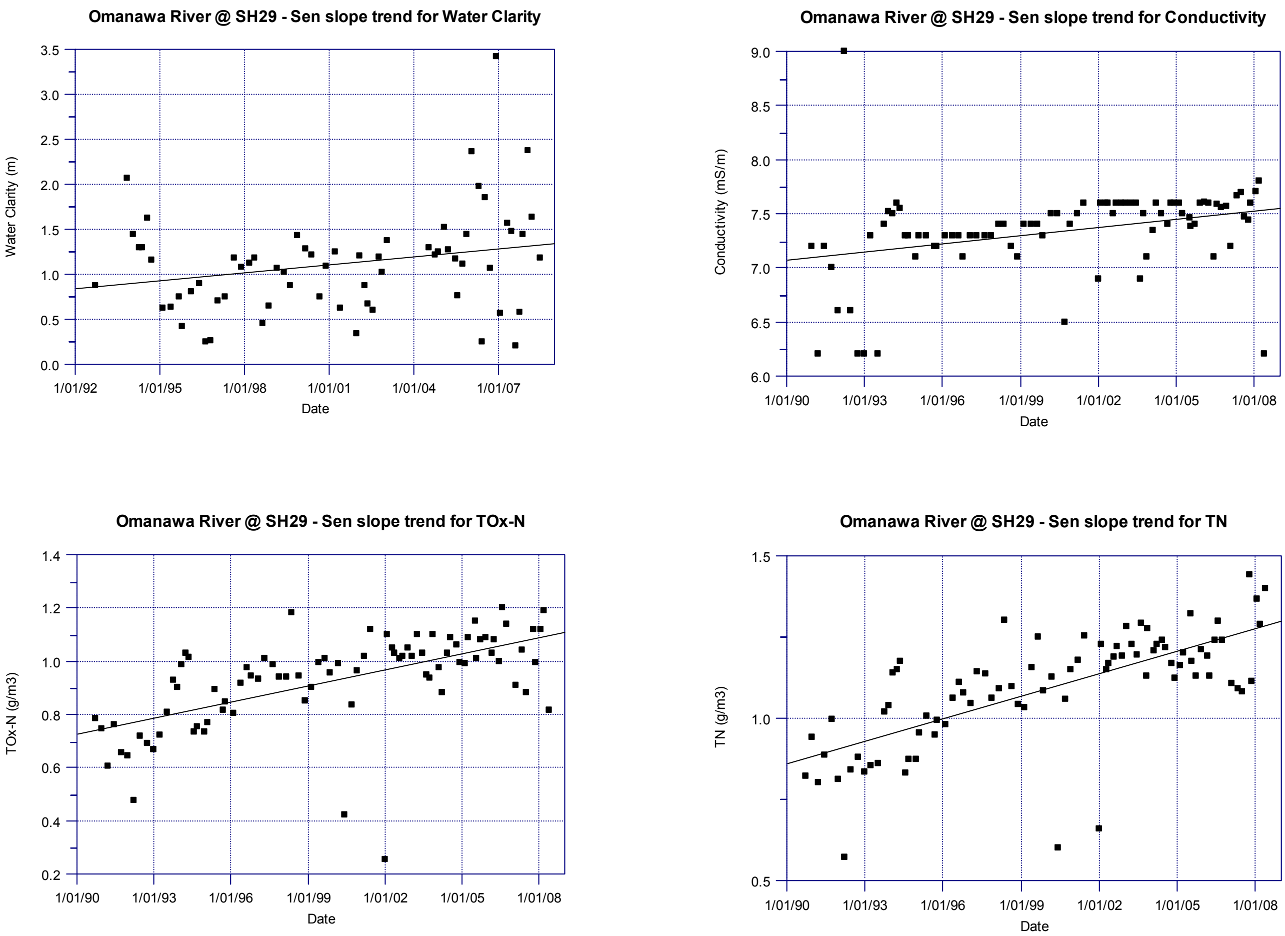
The three indicator bacteria species monitored also have meaningful increasing trends (Table 3.34, Figure 3.28) which may indicate increasing faecal contaminant loadings from livestock.

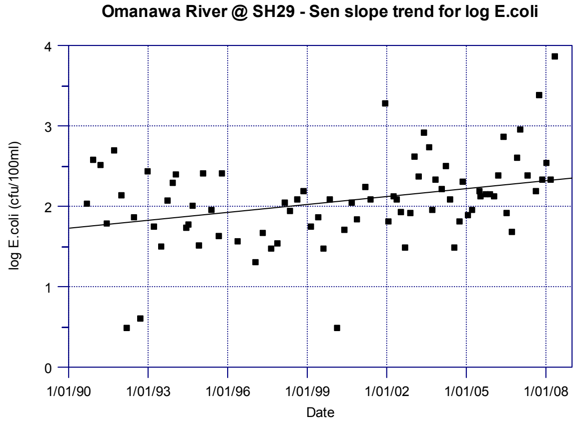
Conductivity and pH show significant trends. Conductivity is increasing at 0.34 %/year (Table 3.34) suggesting an increase in mineral salts and major ions. There is a strong correlation between conductivity and TOx-N (Pearson $R = 0.67$, $p<0.05$) suggesting that TOx-N may be the major cause of this change.

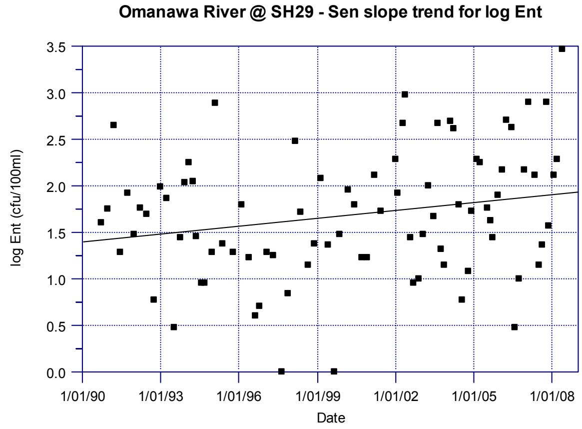
Table 3.34 Omanawa River at SH29, water quality statistics, 1990 to 2008.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)	**4.4 (30)**	**2.65**	89	1.2	1.2	0.1	3.4
DO%	37.4 (-9)	-0.09	129	98.0	97.9	73.8	129.2
Temperature (ºC)	34.9 (27)	0.19	130	14.0	13.9	8.7	19.6
Colour (absat440nm/cm)	40.1 (0)	0	108	0.6	0.5	0.0	4.6
Conductivity (mS/m)	**<1 (25)**	**0.34**	128	7.4	7.4	6.2	9.0
Suspended solids (g/m^3)	81.2 (39)	0.28	129	21.8	13.0	0.5	210.0
Turbidity (NTU)	84.5 (-9)	-0.19	125	7.6	4.6	1.0	84.0
pH	**1.6 (-5)**	**-0.07**	130	7.1	7.1	6.5	7.4
DRP (g/m^3)	49.9 (-0.1)	-0.37	127	0.027	0.027	0.002	0.045
Ammonium-N (g/m^3)	94.9 (0)	0	129	0.011	0.009	0.001	0.037
TOx-N (g/m^3)	**<1 (21)**	**2.1**	124	0.931	0.982	0.255	1.220
Total Nitrogen (g/m^3)	**<1 (23)**	**2.04**	123	1.094	1.130	0.570	1.440
Total Phosphorus (g/m^3)	14.1 (-0.2)	-0.67	128	0.032	0.030	0.014	0.098
Escherichia coli (cfu/100mL)	**<1 (32)**	**1.55**	122	291	125	3	7300
Enterococci (cfu/100mL)	**1 (28)**	**1.65**	127	144	53	1	2900
Faecal coliforms (cfu/100mL)	**<1 (30)**	**1.36**	125	350	150	20	9600
Flow (m^3/s)			118	1.4	1.4	1.0	1.9

Figure 3.28 Omanawa River at SH29, Sen slope trend and residual data for several water quality parameters.







3.5.7 Wairoa River

Monitoring of the Wairoa River occurs below the Ruahihi Powerhouse and includes the Ngamuwhine catchment (see above). The catchment is around 2,132 km^2 in area with 45% in pastoral land-use and 44% in indigenous vegetation (2001 data). Less than 10% of the catchment is in exotic forestry and less than 1% is urban.

The geology is dominated by Waiteariki ignimbrite punctured by Minden rhyolite and Ongatiti ignimbrite on the true left of the river, and Mamaku and Waimakariri ignimbrites and some older fluvial deposits on the true right. Recent fluvial deposits dominate in the lower catchment surrounding some older fluvial terraces with estuarine deposits.

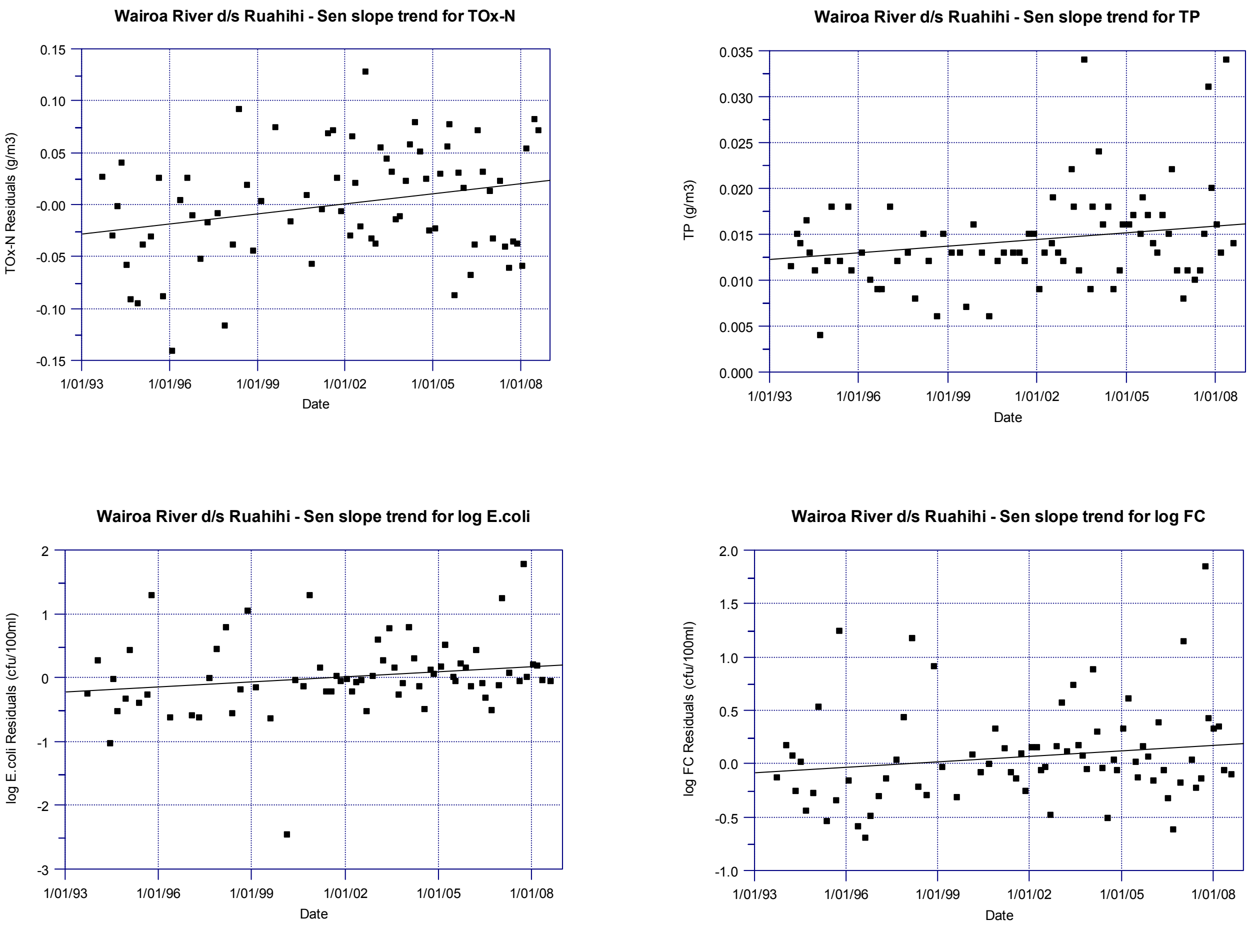
There is a meaningful increasing trend in colour over the analysis period (Table 3.35). Colour was also found to be increasing in the Ngamuwahine Stream. There is possibly a link with increasing turbidity (a non-significant increasing trend, see Table 3.35) as there is some correlation of colour with turbidity (Pearson R = 0.54, p<0.05). pH has a significant decreasing trend which is also consistent with trends found in the Ngamuwahine catchment.

A significant increasing trend in TOx-N is seen over the analysis period (Figure 3.29) and a similar trend also occurs for TN. TOx-N concentrations are at levels that may cause nuisance aquatic plant growth.

Table 3.35 Wairoa River below Ruahihi, water quality statistics, 1993 to 2008.

	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)	35 (-16)	-0.6	93	2.8	2.7	0.3	6.8
DO%	25.6 (-122)	-0.13	123	97.8	97.5	74.6	119.4
Temperature (ºC)	11.9 (55)	0.42	125	13.4	13.4	7.2	20.2
Colour (absat440nm/cm)	**3 (20)**	**2.84**	112	0.9	0.7	0.0	5.5
Conductivity (mS/m)	43.3 (5)	0.1	124	5.2	5.3	3.9	9.6
Suspended solids (g/m^3)	25 (44)	2.2	125	2.8	2.0	0.4	20.0
Turbidity (NTU)	9 (16)	1.22	122	1.6	1.3	0.5	8.1
pH	**3 (8)**	**-0.11**	125	7.0	7.0	6.2	7.5
DRP (g/m^3)	85.3 (<0.1)	0	123	0.014	0.014	0.001	0.063
Ammonium-N (g/m^3)	76.3 (<0.1)	0	123	0.011	0.010	0.001	0.040
TOx-N (g/m^3)	**2.5 (3.2)**	**0.95**	120	0.324	0.337	0.001	0.493
Total Nitrogen (g/m^3)	**2.9 (4.6)**	**0.97**	119	0.467	0.467	0.016	0.934
Total Phosphorus (g/m^3)	**2.5 (0.2)**	**1.54**	121	0.015	0.013	0.004	0.060
Escherichia coli (cfu/100mL)	**4.9 (26)**	**1.39**	117	309	82	1	6900
Enterococci (cfu/100mL)	9.9 (30)	1.93	123	111	31	1	2000
Faecal coliforms (cfu/100mL)	**3.7 (17)**	**0.84**	124	329	100	5	7000
Flow (m^3/s)			118	18.6	14.5	0.4	85.2

Figure 3.29 Wairoa River below Ruahihi, Sen slope trend and residual data for several water quality parameters.



TP displays a meaningful increasing trend of 1.54 %/year (Table 3.35, Figure 3.29). Elevated concentrations of TP have occurred since 2002.

E.coli and faecal coliforms both have meaningful increasing trends while enterococci have a non-significant increasing trend. Median *E.coli* levels are well within recreational guidelines but these are exceeded for some samples.

Increasing indicator bacteria coupled with increasing nitrogen trends suggest an increasing contaminant loading from agricultural sources.

3.5.8 Waipapa River

Extending from the Kaimai Ranges to Waipapa Estuary in Tauranga, the Waipapa catchment takes in a land area of 45 km^2. Over 50% of the land cover is pastoral with approximately 27% indigenous vegetation occurring mostly at the head of the catchment in the Kaimai Ranges. Over 12% of the land use is horticultural and around 7% is exotic vegetation.

The catchment geology is predominantly Waiteariki ignimbrite with recent fluvial deposits in the extreme lower catchment surrounding some older fluvial terraces with estuarine deposits.

Monitoring occurs at the Old Highway Bridge but for trend analysis flow adjusted data has been generated using flow data from upstream of the sampling site (Goodwins Road). This not only provides more flow data but also removes much of the impact of water takes between Goodwins Road and the Old Highway Bridge. Conductivity at the Old Highway Bridge is highly correlated with flow at Goodwins Road (Pearson R = -0.96, $p<0.05$) indicating a suitable relationship for trend analysis as this river is primarily spring fed.

Table 3.36 Waipapa River at Old Highway Bridge, water quality statistics, 1990 to 2008.

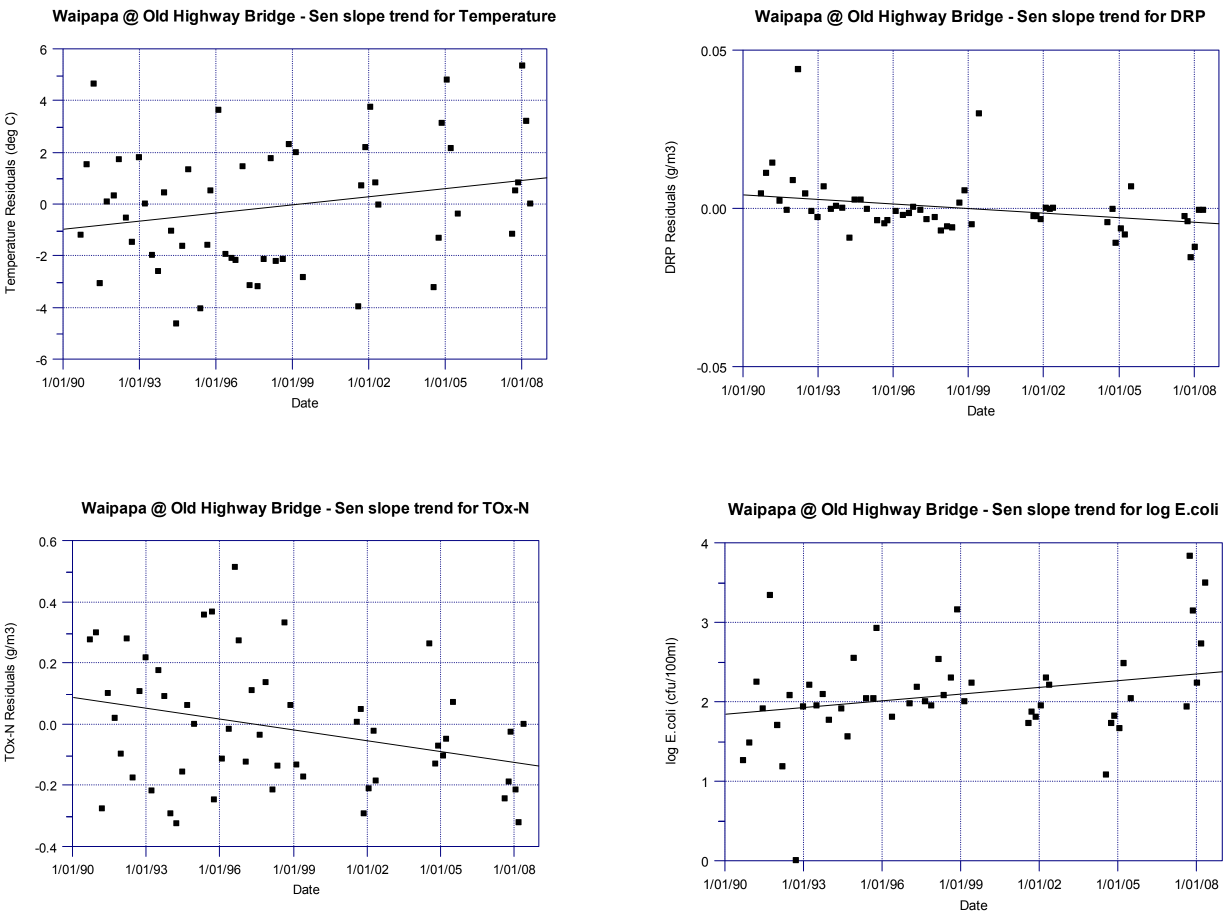
	***p*-value (trend slope 10^{-3} units/yr)**	**%/yr (RSEN)**	**n**	**Mean**	**Median**	**Minimum**	**Maximum**
Water Clarity (m)			38	3.4	3.3	1.1	6.3
DO%	93.3 (-5)	0	69	99.2	98.4	83.6	133.7
Temperature (ºC)	**2.9 (105)**	**0.7**	69	15.4	15.2	9.5	22.5
Colour (absat440nm/cm)	**3.3 (23)**	**5.02**	56	0.6	0.5	0.0	3.1
Conductivity (mS/m)	86.7 (-2)	-0.03	69	7.0	7.0	4.4	10.2
Suspended solids (g/m^3)	63.4 (13)	0.89	68	2.6	1.4	0.1	28.0
Turbidity (NTU)	63.5 (4)	0.4	68	1.4	1.0	0.6	8.0
pH	20.9 (-7)	-0.09	68	6.9	7.0	6.2	7.4
DRP (g/m^3)	**<1 (-0.5)**	**-3.13**	69	0.017	0.016	0.001	0.063
Ammonium-N (g/m^3)	**<1 (-0.6)**	**-4**	69	0.027	0.013	0.003	0.706
TOx-N (g/m^3)	**<1 (-12)**	**-2.32**	69	0.513	0.486	0.001	1.170
Total Nitrogen (g/m^3)	**1.2 (-16.6)**	**-2.54**	68	0.679	0.645	0.105	1.708
Total Phosphorus (g/m^3)	**<1 (-0.8)**	**-4.21**	69	0.022	0.018	0.006	0.099
Escherichia coli (cfu/100mL)	**<1 (28)**	**1.4**	65	391	100	1	6800
Enterococci (cfu/100mL)	**2 (24)**	**1.35**	68	169	65	4	4200
Faecal coliforms (cfu/100mL)	53.1 (6)	0.26	67	496	140	16	10000
Flow (m^3/s)			48	0.76	0.55	0.24	2.51

Increasing abstraction pressure and/or climate changes may explain the significant increasing trend in temperature (Table 3.36, Figure 3.30). Summer maximums have not exceeded 23 ºC, a temperature which can impact certain macroinvertebrate and fish species (Maxted *et al*, 2005).

All macro-nutrient species have meaningful decreasing trends (Table 3.36). TP is composed mostly of dissolved phosphorus (DRP) and this also shows a steady declining trend (Figure 3.30). Nitrogen displays a similar trend. Ammonium-nitrogen has been stable over the last ten years and TOx-N displays a distinct decrease (Figure 3.30).

The reduction in phosphorus may be a function of the geology but this and other nutrient reductions may also be related to abstraction and/or changes in land use. Further examination of the abstraction and water quality data may be warranted to determine future potential impacts.

Figure 3.30 Waipapa River at Old Highway Bridge, Sen slope trend and residual data for several water quality parameters.



3.5.9 Aongatete River

The Aongatete catchment covers 46 km^2 and the river flows north-east from the Kaimai Ranges to Tauranga Harbour. The catchment geology is dacite and Coromandel andesite in the Kaimai Ranges through Waiteariki ignimbrite and then recent and older fluvial terraces with estuarine deposits.

Land cover is 70% indigenous vegetation, 24% pasture with much of the remaining in horticulture (2001 data).

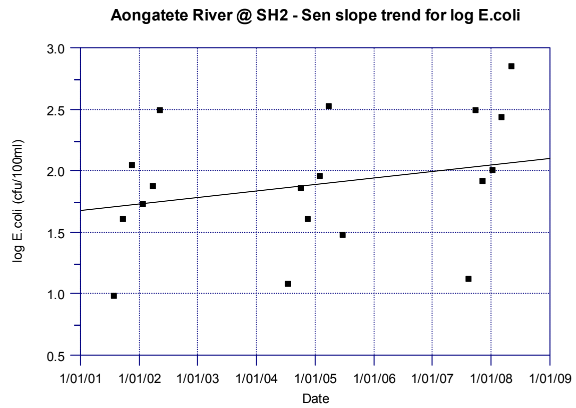
The Aongatete River is monitored at SH2 and has been included in the monitoring programme since 2001. No significant trends were found although water clarity, TOx-N and *E.coli* were close to being significant (Table 3.37).

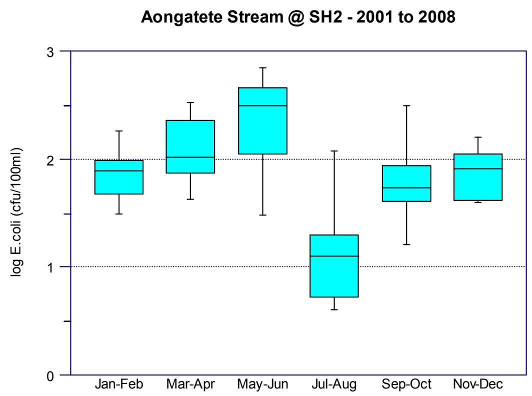
Increasing TOx-N is predominantly entering the stream through groundwater contributions as flow and TOx-N are highly correlated (Pearson R = 0.71, $p<0.05$).

Table 3.37 Aongatete River at SH2, water quality statistics, 2001 to 2008.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	6.8 (121)	3.49	24	3.3	3.3	1.5	5.4
DO%	28.6 (331)	0.32	33	103.3	101.4	89.3	120.7
Temperature (ºC)	52.2 (20.5)	1.34	34	15.7	15.2	9.5	24.8
Colour (absat440nm/cm)	100 (<1)	0	31	0.8	0.7	0.0	2.4
Conductivity (mS/m)	13.6 (-67)	-1.13	34	6.0	6.0	5.1	6.7
Suspended solids (g/m^3)	40.3 (84)	10.17	34	1.2	0.8	0.2	5.2
Turbidity (NTU)	70.5 (-22)	-2.53	34	1.5	0.8	0.4	9.8
pH	84.9 (-4)	-0.05	34	7.0	7.0	6.5	7.6
DRP (g/m^3)	100 (<0.1)	0	34	0.005	0.005	0.001	0.014
Ammonium-N (g/m^3)	25.1 (-0.2)	-2.67	34	0.008	0.008	0.002	0.018
TOx-N (g/m^3)	5.8 (-8)	-3.67	33	0.285	0.243	0.040	1.340
Total Nitrogen (g/m^3)	9.5 (-1.7)	-0.5	33	0.400	0.332	0.181	1.397
Total Phosphorus (g/m^3)	19 (-0.3)	-6.38	34	0.005	0.004	0.001	0.012
Escherichia coli (cfu/100mL)	5.5 (53)	2.78	34	125	75	4	700
Enterococci (cfu/100mL)	28.6 (23)	1.52	34	96	53	1	370
Faecal coliforms (cfu/100mL)	28.6 (67)	3.42	34	150	86	14	1000
Flow (m^3/s)			29	1.13	0.85	0.05	3.18

Figure 3.31 Aongatete River at SH2, Sen slope trend and data for E.coli and seasonal box plot (2001 to 2008).





Median *E.coli* levels are well within recreational guidelines but have an increasing trend as do other indicator bacteria. The recreational guidelines may be exceeded more commonly in the future if levels continue to increase. *E.coli* shows an interesting seasonal variation (Figure 3.31) with levels increasing steadily from winter to late autumn then rapidly decreasing. The decrease may be due to increased winter flows as well as a change in stock management at this time.

3.5.10 Te Mania Stream

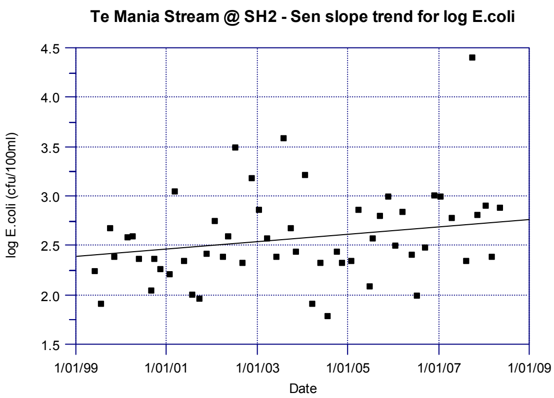
The Te Mania catchment is relatively small at 13.1 km^2. The headwaters of the stream arise predominantly from Coromandel andesite with a tributary in Waiteariki ignimbrite. The stream then moves through late to mid Pleistocene fluvial sediments before emerging into Tauranga Harbour south of Katikati.

The dominant land cover (2001 data) is pasture at 63% followed by indigenous forest and scrub at 21%. Indigenous cover occurs mainly in the headwaters and some of the higher catchment riparian areas. Almost 10% of the catchment is in horticulture which is spread amongst the converging tributaries and the lower catchment. There are a number of abstraction consents based mainly around horticultural activity. A timber products manufacturer operates on the true left of the lower catchment.

Monitoring has taken place at SH2 since 1990 but because of the intermittent nature of the monitoring from 1990 to 1997, and the lack of flow data for some periods, trend analyses have been confined to the 1999 to 2008 period. Other descriptive statistics are taken from the wider data set, 1990 to 2008 (Table 3.38).

Meaningful increasing trends over the 1999 to 2008 period were found for *E.coli* and faecal coliforms (Table 3.38, Figure 3.32). Median *E.coli* levels are near to exceeding amber alert recreational water quality guidelines. Given the dominant pasture cover and abstraction in this catchment, increases in faecal concentrations may occur with livestock intensification and/or increased water abstraction.

Figure 3.32 Te Mania Stream at SH2, Sen slope trend and data for E.coli and Faecal coliforms.



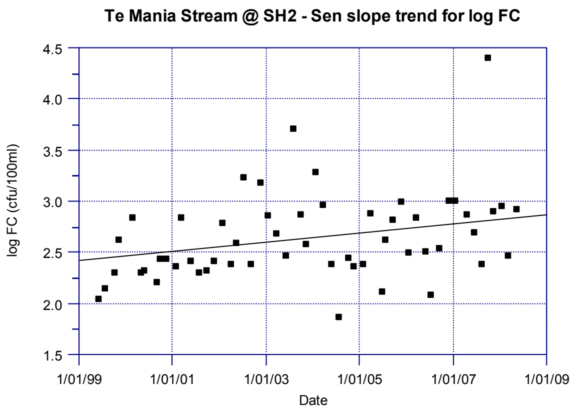


Table 3.38 Te Mania Stream at SH2, water quality statistics, trends statistics from 1999 to 2008, other statistics from 1990 to 2008.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)			66	1.30	1.24	0.10	5.13
DO%	51.3 (20.7)	0.22	134	94.4	94.1	70.3	111.1
Temperature (ºC)	93.4 (22)	0.15	138	14.91	14.65	7.8	22.0
Colour (absat440nm/cm)	96.4 (0)	0	116	1.31	1.30	0.10	3.53
Conductivity (mS/m)	56.3 (12)	0.16	138	7.62	7.50	5.71	11.90
Suspended solids (g/m^3)	68.4 (55)	0.83	139	15.01	6.60	0.90	360.0
Turbidity (NTU)	73.2 (24)	0.47	124	8.32	5.40	0.90	160.0
pH	56.3 (8)	0.12	134	6.89	6.90	6.00	7.80
DRP (g/m^3)	25.4 (0.2)	-2.38	139	0.010	0.009	0.001	0.044
Ammonium-N (g/m^3)	19 (-0.5)	2.22	139	0.027	0.021	0.001	0.245
TOx-N (g/m^3)	28.2 (-3.4)	-1.37	134	0.305	0.260	0.005	1.190
Total Nitrogen (g/m^3)	18.7 (-5.8)	-1.37	134	0.528	0.450	0.109	3.298
Total Phosphorus (g/m^3)	16.4 (0.4)	2.67	138	0.022	0.015	0.003	0.422
Escherichia coli (cfu/100mL)	**3.6 (38)**	**1.55**	124	707	275	1	25000
Enterococci (cfu/100mL)	70.9 (15)	0.66	138	310	120	2	3900
Faecal coliforms (cfu/100mL)	**<1 (45)**	**1.76**	124	791	355	1	25000
Flow (m^3/s)			109	0.33	0.21	0.05	2.50

3.5.11 **Uretara River**

The headwaters of the Uretara River are found in the Kaimai Ranges emanating from dacite and Coromandel andesite. The catchment area is 32.9 km^2 and the river moves from the headwaters over late Pleistocene fluvial sediments before passing through the township of Katikati. The river then flows into the Tauranga Harbour at a small estuarine embayment.

Indigenous vegetation covers almost half of the catchment with pasture at 30%, horticulture at 11% and exotic vegetation at less than 2% (2001 data). Monitoring occurs above Katikati at Henry Road to avoid tidal effects lower in the river.

No significant trends were detected over the 2001 to 2008 analysis period, however phosphorus and TOx-N display near significant decreasing trends. Such a decline may signal some land use or land management changes. There are several water abstractions from the stream.

TOx-N concentrations peak in the winter months. This is expected in pastoral catchments where nitrate-nitrogen is leached during saturated soil conditions in winter.

Table 3.39 Uretara River at Henry Crossing, water quality statistics from 2001 to 2008.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)	36.1 (46)	1.77	42	2.7	2.7	0.5	5.4
DO%	69.5 (714)	0.7	50	99.9	99.9	81.7	120.4
Temperature (ºC)	69.5 (153)	0.97	50	16.1	15.8	8.8	24.9
Colour (absat440nm/cm)	28.4 (-21)	-4.54	46	0.7	0.5	0.0	2.7
Conductivity (mS/m)	36.3 (18)	0.26	50	6.9	7.0	5.3	9.6
Suspended solids (g/m^3)	29.4 (-98)	6.14	50	2.9	1.6	0.4	16.0
Turbidity (NTU)	14.2 (-72)	-3.79	49	2.6	1.9	0.9	9.0
pH	83.3 (-3)	-0.04	49	7.1	7.1	6.4	7.6
DRP (g/m^3)	7.1 (-0.6)	-12	49	0.006	0.005	0.001	0.013
Ammonium-N (g/m^3)	97.2 (<1)	0	50	0.013	0.010	0.001	0.055
TOx-N (g/m^3)	9 (-20)	-13.89	49	0.186	0.161	0.001	0.532
Total Nitrogen (g/m^3)	15.1 (-22)	-9.69	48	0.282	0.265	0.105	0.748
Total Phosphorus (g/m^3)	8.3 (-0.4)	-8	50	0.007	0.005	0.001	0.029
Escherichia coli (cfu/100mL)	89.6 (-27)	-1.25	49	239	140	7	1700
Enterococci (cfu/100mL)	100 (-2)	-0.12	50	147	94	3	870
Faecal coliforms (cfu/100mL)	100 (-7)	-0.32	50	256	160	17	1700
Flow (m^3/s)			44	0.88	0.63	0.15	5.00

3.5.12 Waiau River

The Waiau River catchment area is 33.1 km^2 and extends from foothills beyond the Kaimai Ranges to the very north of Tauranga Harbour where it emerges through an extensive saltmarsh wetland. The upper catchment geology includes a rhyolite dome, Coromandel andesite and ignimbrite and much of this is covered with exotic forestry (34%) and indigenous vegetation (10%). Large tracts of pasture also occur to the north and west of the upper catchment and extend into the lower catchment to make up around 47% of the land cover (2001 data).

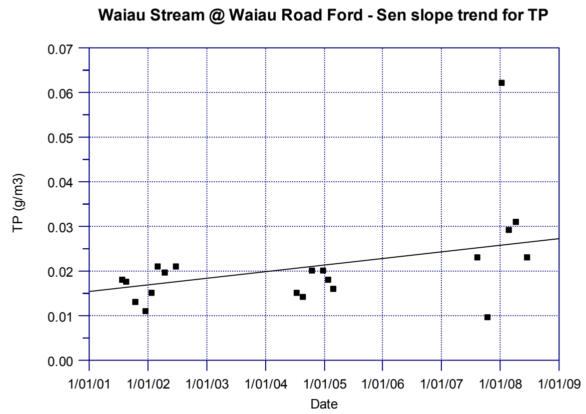
Andesite and ignimbrite geology make most of the hilly terrain with Holocene sediments composing the lower catchment flat areas. Monitoring occurs at Waiau Ford Road before the rivers descends to the flatter terrain.

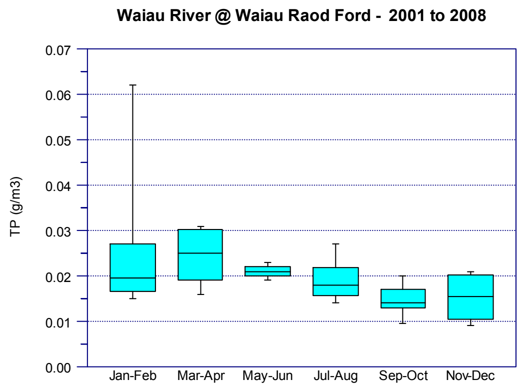
The only meaningful trend over the analysis period is for TP which is increasing (Table 3.40, Figure 3.33). DRP also displays a non-significant increasing trend but it may be particulate phosphorus that is driving the TP trend. DRP increases dramatically in April/May which also drives an increase in TP (Figure 3.33) at this time. Increased run-of from recently harvested forest may explain the increasing trend but does not explain the seasonal pattern. Other land uses may be contributing to a summer/autumn loading of TP.

Table 3.40 Waiau River at Waiau Road Ford, water quality statistics from 2001 to 2008.

	p-value (trend slope 10^{-3} units/yr)	%/yr (RSEN)	n	Mean	Median	Minimum	Maximum
Water Clarity (m)			20	2.1	2.0	1.2	3.6
DO%	51.3 (940)	0.98	29	97.2	97.0	86.6	111.4
Temperature (ºC)	32.6 (214)	1.34	29	15.6	15.5	9.3	22.7
Colour (absat440nm/cm)	33.4 (20)	2.9	27	0.8	0.7	0.2	2.1
Conductivity (mS/m)	11.4 (38)	0.41	28	9.1	9.2	8.1	10.0
Suspended solids (g/m^3)	86.8 (33)	0.98	29	5.0	3.4	0.6	29.0
Turbidity (NTU)	100 (17)	0.65	29	3.1	2.3	1.3	14.0
pH	77 (1)	0.02	28	7.0	7.1	6.3	7.4
DRP (g/m^3)	25.5 (0.5)	3.85	29	0.014	0.013	0.001	0.027
Ammonium-N (g/m^3)	19 (1.3)	12.75	29	0.013	0.010	0.004	0.051
TOx-N (g/m^3)	59.8 (-1)	-0.35	26	0.275	0.230	0.001	0.827
Total Nitrogen (g/m^3)	86 (-1.6)	-0.35	26	0.413	0.392	0.024	1.282
Total Phosphorus (g/m^3)	**2.9 (1.5)**	**8.02**	28	0.020	0.018	0.009	0.062
Escherichia coli (cfu/100mL)	51.3 (39)	1.67	29	320	220	21	1200
Enterococci (cfu/100mL)	51.3 (-31)	-1.55	29	211	97	9	1100
Faecal coliforms (cfu/100mL)	32.6 (26)	1.08	29	347	260	67	1200
Flow (m^3/s)			26	0.47	0.38	0.13	1.42

Figure 3.33 Waiau River at Waiau Road Ford, Sen slope trend and data for TP and seasonal box plot TP 2001 to 2008.





3.5.13 **Tauranga River Summary**

The average dissolved oxygen saturation levels at the Tauranga river and stream sites are above 80%. In Rocky Stream the dissolved oxygen levels are at times very low, particularly when compared to the other streams (Figure 3.34).

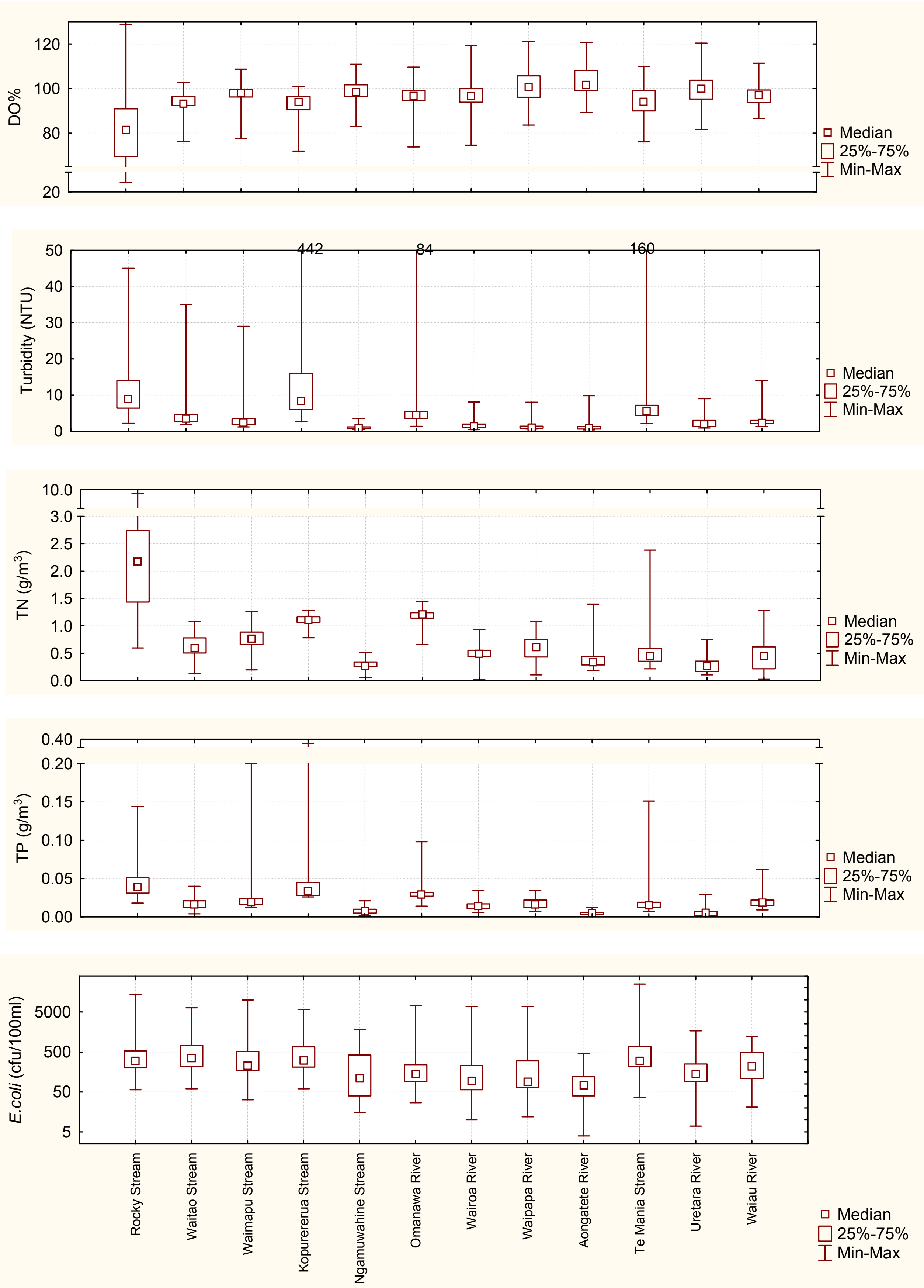
Turbidity levels are highest in the Kopurererua Stream followed by the Rocky and Te Mania Streams. These three streams and the Omanawa Stream all have turbidity levels over the ANZECC (2000) trigger value for lowland rivers with slightly disturbed ecosystems (5.6 NTU). They also have the lowest water clarity as measured by black disk.

Rocky Stream has elevated nitrogen concentration compared to the other Tauranga sites due to a high biomass in this slow moving stream. In the Wairoa system the Omanawa Stream has elevated TN compared to the Ngamuwahine Stream and the lower Wairoa River. The Kopurererua and Waimapu Streams also have higher TN levels on average than many other streams. Much of the TN is in the form of TOx-N which may indicate that livestock agriculture is the major source.

Phosphorus levels, like TN, are on average highest in the Rocky and Kopurererua Streams (Figure 3.34). Streams with higher TP levels tend to have a larger proportion of phosphorus in the particulate form which is often attributable to suspended solids loading in these streams.

The Waitao, Kopurererua and Te Mania Streams have the highest median *E.coli* levels of the Tauranga group. *E.coli* levels in these streams often exceed recreational water quality guidelines. The Aongatete River has the lowest *E.coli* levels and this may in part be due to the small percentage of area in pasture.

Figure 3.34 Box whisker plots for several water quality parameters, Tauranga Rivers (2001 to 2008).



Part 4: Trend Summary

The following tables provide summaries of the trend analyses presented in Part 3 of this report. Upward pointing arrows indicate increasing trends (▲) and downward decreasing trends (▼). Colour coding has also bean added to indicate if the trend is a meaningful or significant trend. A ‘meaningful’ trend shows the null hypothesis for the Kendall test was rejected (*p* < 0.05) and the magnitude of the trend was greater than 1% per year of the data median (i.e. RSEN > 1%/year). A ‘significant’ trend is the same as a ‘meaningful’ trend (i.e. is statistically significant) but the magnitude of the trend is less than 1% per year of the data median (i.e. RSEN < 1%/year).

Trends can be used as a general indicator of the health of rivers and streams and as a tool for examining what is happening in these river catchments. While an overall trend may be increasing or decreasing there may also be short term trends within the data. A trend that shows an overall increase may now be decreasing. Hence, visual examination of the data is warranted before making a full assessment of any waterway.

4.1 Regional summary

A summary of regional trends by water quality parameter is presented in Table 4.1.

While many of the sites did not have suitable data for trend analyses of water clarity, six sites did show meaningful trends with three showing increasing clarity and three decreasing. Dissolved oxygen saturation had no meaningful changes but 7 sites showed decreases. Only one site, the Nukuhou River, showed a significant increase in temperature.

Over 13 significant but not meaningful decreases in pH have been detected over the region. This tendency for rivers to become more acidic may be related to changes in dissolved chemical compounds.

Table 4.1 Number of significant water quality parameter trends for Bay of Plenty NERMN river sites.

	Water Clarity	DO%	Temperature	Colour	Conductivity	Suspended solids	Turbidity	pH	Ammonium	TOx-N	Total Nitrogen	DRP	Total Phosphorus	Escherichia coli	Enterococci	Faecal coliforms
Significant increasing trends	**3**	**2**	**1**	**2**	**9**	**7**	**10**	**1**	**6**	**12**	**12**	**4**	**6**	**15**	**5**	**8**
Meaningful increasing ▲	3		1	2		5	10		6	11	8	2	5	13	5	7
Significant but not meaningful ▲		2			9	2		1		1	4	2	1	2		1
Significant decreasing trends	**3**	**7**	**0**	**2**	**7**	**1**	**3**	**13**	**6**	**4**	**5**	**2**	**9**	**0**	**1**	**1**
Meaningful decreasing ▼	3			2	2	1	3		6	3	5	2	7		1	1
Significant but not meaningful ▼		7			5			13		1			2			

There were five meaningful increasing trends in suspended solids and 10 of increasing turbidity indicating decreasing water clarity and increased sediment loading. Three meaningful decreases in turbidity and one of suspended solids also show some improvements have occurred at sites such as the Tarawera River at Awakaponga (Table 4.2) and the Nukuhou River at the Old Quarry (Table 4.3).

Six rivers had meaningful increasing ammonium-nitrogen trends and six had meaningful decreasing trends. Two sites on the Rangitaiki system had a decrease while two lower sites on the Tarawera River are increasing (Table 4.2). However, concentrations are relatively low and trends are dependant upon a range of complex nitrogen interactions.

Table 4.2 Summary of water quality trends for Central Eastern/Rotorua, Bay of Plenty River sites.

River at site	Water Clarity	DO%	Temperature	Colour	Conductivity	Suspended solids	Turbidity	pH	Ammonium	TOx-N	Total Nitrogen	DRP	Total Phosphorus	Escherichia coli	Enterococci	Faecal coliforms	Analysis Period
Whirinaki	▼ (green)	▼ (blue)		na	▲ (yellow)		▲ (red)	▼ (blue)	▼ (green)				▲ (yellow)			▲ (red)	1989 - 2008*
Rangitaiki at Murapara	▼ (green)	▼ (blue)		na	▲ (yellow)		▲ (red)			▲ (red)	▲ (red)						1989 - 2008
Rangitaiki at Aniwhenua	na				▲ (yellow)			▼ (blue)						▲ (red)			1990 - 2008
Rangitaiki at Te Teko				na	▲ (yellow)				▼ (green)	▲ (red)	▲ (red)		▼ (blue)				1989 – 2008*
Tarawera at Outlet					▼ (blue)			▼ (blue)	▼ (green)		▲ (yellow)		▲ (red)				1989 - 2008
Tarawera at Boyce Park				na	▼ (blue)	▲ (red)	▲ (red)	▼ (blue)	▲ (red)	▲ (red)	▲ (red)						1990 - 2008
Tarawera at Awakaponga	▲ (red)	▲ (yellow)		▼ (green)	▼ (blue)		▼ (green)	▲ (yellow)	▲ (red)	▲ (red)	▲ (red)	▲ (yellow)					1989 - 2008
Kaituna at Okere	na						▲ (red)							▲ (red)	▲ (red)		1990-2008
Kaituna at Paeangaroa	na	▼ (blue)					▲ (red)	▼ (blue)									1990-2008
Kaituna at Te Matai	na	▼ (blue)					▲ (red)	▼ (blue)		▲ (red)			▼ (green)		▼ (green)	▼ (green)	1990-2008
Ngongotaha at Town Bridge	▼ (green)				▲ (yellow)	▲ (red)	▲ (red)	▼ (blue)		▲ (red)	▲ (yellow)			▲ (yellow)			1990-2008
Puarenga at Scion					▼ (green)	▲ (red)				▲ (red)	▲ (red)	▲ (yellow)	▲ (red)				1992-2008
Ohau Channel at SH33		▼ (blue)			▲ (yellow)	▲ (red)	▲ (red)	▼ (blue)						▲ (red)	▲ (red)	▲ (red)	1995-2008
Pongakawa at SH2	na							▼ (blue)	▲ (red)	▲ (red)	▲ (red)		▼ (green)	▲ (red)			1990-2007
Pongakawa at Upstream	na																1999-2007
Pikowai at SH2	na																1999-2007
Mimiha at SH2	na													▲ (red)		▲ (red)	1999-2007
Waitahanui at SH2	na																1996-2007

▲ (red) = meaningful increase; ▲ (yellow) = significant increase; ▼ (green) = meaningful decrease; ▼ (blue) = significant decrease; na = not analysed. * indicates some analyses are based on a shorter period – see Part 3.

Both total nitrogen (TN) and oxides of nitrogen (TOx-N) had 12 significant increasing sites with eight of these meaningful for TN and 11 for TOx-N. Notably, increasing trends are in catchments dominated by pastoral agriculture, although this is not always the case with rivers like the Waimana and the Nukuhou having meaningful decreasing trends in TN (Table 4.3).

Table 4.3 Summary of water quality trends for Eastern Bay of Plenty River sites.

River at site	Water Clarity	DO%	Temperature	Colour	Conductivity	Suspended solids	Turbidity	pH	Ammonium	TOx-N	Total Nitrogen	DRP	Total Phosphorus	Escherichia coli	Enterococci	Faecal coliforms	Analysis Period
Whangaparoa at SH35	na													▲ (red)			1990 - 2007
Raukokore at SH35												▲ (red)		▲ (red)			1990 - 2007
Motu at SH35	▲ (red)	▼ (blue)			▼ (blue)		▼ (green)		▼ (green)	▼ (blue)			▼ (green)	na	na	na	1989 - 2008
Motu at Waitangirua				▼ (green)		na			▲ (red)	▲ (red)	▲ (red)	▲ (red)	▲ (red)	na	na	na	1989 - 2008
Otara at Browns Bridge	na						▲ (red)										1990 - 2007
Waioeka at Pa						▲ (red)	▲ (red)		▲ (red)					▲ (red)	▲ (red)	▲ (red)	1995 - 2008
Nukuhou at Old Quarry		▲ (yellow)	▲ (red)		▲ (yellow)	▼ (green)			▼ (green)	▼ (green)	▼ (green)		▼ (green)				1990 - 2007
Whakatane at Ruatoki	na																1990 - 2004
Whakatane at Pekatahi														▲ (yellow)			1990 - 2007
Waimana at Taneatua											▼ (green)		▼ (green)	▲ (red)			1990 - 2004

▲ (red) = meaningful increase; ▲ (yellow) = significant increase; ▼ (green) = meaningful decrease; ▼ (blue) = significant decrease; na = not analysed.

Trends in phosphorus varied throughout the region with two meaningful increasing and two meaningful decreasing trends in dissolved reactive phosphorus (DRP). Five meaningful increasing trends were also found for total phosphorus (TP) as well as seven meaningful decreasing trends.

The Waitao Stream showed decreasing trends in all nutrient species (Table 4.4) including phosphorus as did the Waipapa Stream (with the exception of ammonium-nitrogen). Others show a similar pattern of increasing trends such as the Tarawera at Awakaponga and the Motu at Waitangirua.

Most of the meaningful increasing trends were found for the indicator bacteria *Escherichia coli* (Table 4.1). This indicates increasing faecal contamination and an increased risk to people using these waterways for recreation or water supply. Just two decreasing trends were found for the bacterial indicators, these were meaningful decreasing trends for *Enterococci* and faecal coliforms in the Kaituna River at Te Matai (Table 4.2).

Table 4.4 Summary of water quality trends for Tauranga, Bay of Plenty River sites.

River at site	Water Clarity	DO%	Temperature	Colour	Conductivity	Suspended solids	Turbidity	pH	Ammonium	TOx-N	Total Nitrogen	DRP	Total Phosphorus	Escherichia coli	Enterococci	Faecal coliforms	Analysis Period
Rocky at Mangatawa Lane	na				▼ (green)		▼ (green)				▼ (green)						2001 - 2008
Waitao at Spensers Farm				▲ (red)					▼ (green)	▼ (green)	▼ (green)	▼ (green)	▼ (green)				1990 - 2008
Waimapu at Pukemapui								▼ (blue)									2001 - 2008
Kopurererua at SH29	na	▼ (blue)			▲ (yellow)					▲ (red)	▲ (yellow)		▼ (blue)		▲ (red)	▲ (red)	1993 - 2008
Ngamuwahine at Old Bridge	na			▲ (red)				▼ (blue)	▲ (red)					▲ (red)			1990- 2008
Omanawa at SH29	▲ (red)				▲ (yellow)	▲ (yellow)		▼ (blue)		▲ (red)	▲ (red)			▲ (red)	▲ (red)	▲ (red)	1990 - 2008
Wairoa at d/s Ruahihi								▼ (blue)		▲ (yellow)	▲ (yellow)		▲ (red)	▲ (red)		▲ (yellow)	1993 - 2008
Waipapa at Old Highway Bridge	na				▼ (blue)	▲ (yellow)				▼ (green)	▼ (green)	▼ (green)	▼ (green)				1990 - 2008
Aongatete at SH2																	2001 - 2008
Te Mania at SH2	na													▲ (red)		▲ (red)	1999 - 2008
Uretara at Henry Crossing																	2001 - 2008
Waiau at Waiau Road Ford	na												▲ (red)				2001 - 2008

▲ (red) = meaningful increase; ▲ (yellow) = significant increase; ▼ (green) = meaningful decrease; ▼ (blue) = significant decrease; na = not analysed.

Part 5: Recommendations

Monitoring of the water quality of rivers and streams under the NERMN Programme has occurred for almost 20 years. Over that time the frequency and location of monitoring has changed for some sites. Continuity of monitoring does effect the interpretation of the data and the ability of resource managers to assess the state of the environment and the effectiveness of policies and plans.

Several recommendations are set out here with regards to the frequency of monitoring and continuation of sites to be monitored. In Table 5.1 the sites with the status ‘Regional’ are monitored the most frequently at once every month. Other rivers are monitored once a month for one year every three years.

Recommendations are:

- That the Otara River and Waioeka River sites be re-located and/or added to sites located lower in the catchment. These are currently located in the foothills and are not picking up what is happening on agriculturally dominated floodplains. This decision needs to take account of irrigation water takes in the area.

- That a stream with the classification ‘Natural State’ be added to the programme, e.g. the Ohora Stream (Whakatane River) or the Ohiaho Stream (Waiotahi River).

- Establish a site on the lower Waiotahi River. Currently neither the river nor the estuary is monitored apart from recreational surveillance monitoring.

- Establish monitoring sites in the Upper Rangitaiki catchment (Taupo District) to better understand the rising nitrogen trends found at Murupara. The suggested monitoring frequency is 3 monthly to coincide in with rain gauge servicing.

- Any sites monitored with tidal influences are strictly sampled at low tide within certain conductivity (or salinity) tolerances e.g. the Kopurererua Stream at SH2.

- Remove the Mimiha and Pikowai sites from the NERMN Programme. These sites are similar in character to the Waitahanui Stream. The Waitahanui will give a good representation of what is occurring in the general area and it is not subject to blockage at the fore-dunes (as occurs in the Pikowai Stream).

- Change the ‘Regional’ status of Rocky Stream and instead monitor the Waitao at an increased frequency. Change the status of Kopurererua at SH2 to normal rather than Regional as the SH29 site provides a good catchment overview and is not so influenced by tidal ingress. Also consider moving the Wainui stream site further away from tidal influence.

- Cease BOD (Biochemical Oxygen Demand) analysis except for the Tarawera and Kaituna Rivers (BOD monitoring is necessary for these to take account of the large industrial discharges). The concentrations of BOD are generally too low in rivers and streams to be useful for detecting trends.

- Include automated diurnal monitoring for Regional sites: parameters to examine include temperature, dissolved oxygen, turbidity and conductivity. Install flow recorders at all regional sites. Obtain pH and conductivity in-situ using multi-parameter probes.

- Investigate periphyton monitoring of selected rivers and streams.

Table 5.1 NERMN River Sites

Status	Rivers	Site	Site No	Flow Monitoring	Classification
	Whangaparaoa	S.H.35 Bridge	BOP110001	Gauge	Aquatic ecosystem
	Raukokore	S.H.35 Bridge	BOP110002	Gauge	Aquatic ecosystem
	Haparapara	SH35 Bridge	BOP160100	Gauge	Aquatic ecosystem
	Otara	Brown's Bridge	BOP110005	EBOP recorder	Contact Recreation
Regional	Waioeka	Pa Site	BOP160102	Gauge	Contact Recreation
Regional	Nukuhou	Old Quarry	BOP110007	EBOP recorder	Aquatic ecosystem
	Waimana	Taneatua Bridge	BOP110009	EBOP recorder (5km)	Water supply
	Whakatane	Ruatoki Bridge	BOP110010	Unable to gauge	Aquatic ecosystem
Regional	Whakatane	Pekatahi Bridge	BOP110011	EBOP recorder	Water supply
	Rangitaiki	Inlet to Canal	BOP110016	NIWA recorder	Aquatic ecosystem
	Rangitaiki	Matahina Dam	BOP110082	Dam flow?	Aquatic ecosystem
Regional	Tarawera	Boyce Park	BOP110021	Gauge	FSP UTR
	Tarawera	SH30	BOP110023	Use Awakaponga	FSP UTR
Regional	Ngongotaha	Town Bridge	BOP110013	NIWA recorder	Aquatic ecosystem
Regional	Puarenga	FRI	BOP110058	Gauge	Aquatic ecosystem
Regional	Ohau	SH 33 Bridge	BOP110025	Gauge	Aquatic ecosystem
	Rotoiti o/lt	Control Gate	BOP110026	EBOP recorder	Aquatic ecosystem
Regional	Kaituna	Te Matai Rail Bridge	BOP110028	Gauge	Contact recreation
	Kaituna	Maungarangi Rd Br	BOP110027	Use Te Matai	Aquatic ecosystem
	Pongakawa	SH 2 Bridge	BOP110030	Gauge	MWCEV
	Pongakawa	U/S Site	BOP110112	Gauge	Aquatic ecosystem
	Pongakawa	Johnston Rd	BOP110118	Gauge	Aquatic ecosystem
	Pikowai Stream	SH 2	BOP110115	Gauge	Aquatic ecosystem
	Mimiha Stream	SH 2	BOP110117	Gauge	Aquatic ecosystem
	Waitahanui Stream	SH2 Bridge	BOP110095	Gauge	Aquatic ecosystem
	Waitao	Spensers farm	BOP710004	Gauge	Aquatic ecosystem
	Waimapu	Pukemapui Road	BOP160212	EBOP recorder (McCarols)	Aquatic ecosystem
Regional	Waimapu	Greerton Park	BOP160121	As above	Contact recreation
	Wairoa	d/s Powerstation	BOP110088	EBOP recorder + P/Station flow	Aquatic ecosystem
Regional	Wairoa lwr	S.H 2 Bridge	BOP110034	As above	Aquatic ecosystem
	Ngamuwahine	Old Ngamuwahine Br.	BOP110035	Gauge	Aquatic ecosystem
	Omanawa	S.H 29 Bridge	BOP110036	Gauge	Aquatic ecosystem
	Waipapa	Old Highway Bridge	BOP710011	Gauge/ Goodwins Rd Recorder	Contact recreation
	Tuapiro	Surtees Rd.	BOP710003	Gauge (above ford)	Aquatic ecosystem
Regional	Kopurererua	S.H.2	BOP710009	EBOP recorder at SH29	Aquatic ecosystem
Regional	Kopurererua	S.H.29-Rec. house	BOP710008	EBOP recorder	Aquatic ecosystem
Regional	Te Mania Strm	S.H 2 bridge	BOP710022	Gauge	Aquatic ecosystem
	Wainui	S.H 2 bridge	BOP710027	Gauge	Aquatic ecosystem
	Waitekohe	S.H 2 bridge	BOP710023	Gauge	Aquatic ecosystem
	Waiau	Waiau Road Ford	BOP710040	Gauge	Aquatic ecosystem
	Te Rereatukahia Stream	SH2	BOP710025	Gauge	Aquatic ecosystem
	Aongatete	S.H 2 bridge	BOP710028	Gauge	Aquatic ecosystem
Regional	Rocky Strm	Mangatawa Lane	BOP710032	Gauge	Regional baseline
	Uretara	Henry Rd. crossing	BOP210004	Gauge	Aquatic ecosystem

Table 5.2 NIWA monitored sites.

Area	Rivers	Description	Site No	Grid No.	Classification
	Motu	S.H.35 Bridge	BOP110003	X15:1760-6050	Natural state
	Motu	Waitangirua	BOP110093	X16:1310-1825	Natural state
	Whirinaki	Galatea Bridge	BOP110014	V17:3700-9590	Aquatic ecosystem
	Rangitaiki	Old Bridge at Murupara	BOP110015	V17:3270-9830	Aquatic ecosystem
	Tarawera	Awakaponga	BOP110052	V15:4120-5530	Fish purposes LTR
	Tarawera	Lake Outlet	BOP110020	V16:1670-2950	Fish purposes UTR
	Rangitaiki	Te Teko Bridge	BOP110018	V15:4360-4480	Aquatic ecosystem

Part 6: References

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