Freshwater contact recreational water quality at selected Taranaki sites State of the Environment Monitoring Report 2010-2011 Technical Report 2011–01

ISSN: 0114-8184 (Print)
ISSN:1178-1467 (Online)
Document: 916026

Taranaki Regional Council
Private Bag 713
STRATFORD

September 2011

Executive summary

This survey of fifteen freshwater contact recreational sites in the Taranaki region was the fifteenth of an on-going programme designed to annually monitor the bacteriological quality of lakes, rivers and streams at popular contact recreational sites. It forms a component of the State of the Environment bathing beaches trend monitoring programme, which commenced in the 1995-1996 summer period. Two sites (at Lakes Ratapiko and Opunake) were monitored in this programme during this 2010-2011 period for the fifth time, partly as a component of the recently instituted cyanobacteria programme (covering four lakes and one river site) instigated after consultation with Taranaki Healthcare. An additional site in the lower Waitara River was added in the previous period at the joint request of Taranaki Healthcare and NPDC. The fifteen sites have been graded for recreational suitability according to MfE, 2003 guidelines, based upon the immediately preceding five seasons of monitoring data (where such data existed) although short-comings of this grading methodology are acknowledged. A sixteenth site (Lake Rotokare) has been monitored since 2007, principally for cyanobacteria.

The results of this 2010-2011 survey have continued to illustrate variability in bacteriological water quality, with the highest water quality achieved at the Urenui River estuary and lower Patea River sites where marked seawater intrusion is the norm (under high tide conditions), Lakes Ratapiko and Rotomanu, and Waiwhakaiho River (at Merrilands Domain). Impacts on bacteriological water quality at some sites, particularly the Waimoku Stream and Lake Opunake were due principally to resident wild fowl populations in the vicinity of recreational usage sites.

In terms of *E. coli*, bacteriological water quality showed significant improvement in the latest survey period in comparison with historical surveys, although only one site had its lowest median count on record. The total number of samples falling within the "Alert" or "Action" categories was almost half that of the previous season. Of note, very few high counts were recorded during the 2010-2011 season. Fewer exceedances of MfE guidelines ('Alert' and 'Action') modes were coincidental with drier early season conditions and a reduction in dairy shed pond systems treated wastes discharge rates noted from field inspections during that time.

One site (Waimoku Stream at Oakura beach) continued to record all of its single samples in the 'Action' mode of the MfE, 2003 guidelines. Previous investigative work in the catchment, together with DNA marker tracking, had confirmed the principal contribution to be the wildfowl populations. All sites in the freshwater contact recreational programme are monitored throughout every season. However, the Waimoku Stream site has been monitored primarily to provide background information in relation to nearby Oakura Beach coastal water quality. With sufficient data now available, this stream site will in future be monitored at three yearly intervals. Nine other sites exhibited occasional single sample entries into the 'Alert' or 'Action' modes of the 2003 guidelines at some time during the season. However, only four sites had counts which entered the 'Action' mode, a decrease in the number and frequency of exceedances in comparison with previous seasons' results. To a certain extent these exceedances were probably a feature common to the mid and lower reaches of rivers and streams draining developed (particularly agricultural) catchments throughout New Zealand. Birdlife contributed to exceedances from time to time particularly at one site where recreationalists often fed the birds. Limited follow-up sampling was performed when deemed necessary following exceedances of the 'Action' limit as in most cases bacteriological quality was found to have returned to typical levels within a short period. Permanent health warning signage has been erected at two sites by the New Plymouth District Council (on the direction of Taranaki District Health Board) following

past exceedances of 'Alert' levels (at Oakura and Waitara) but single sample 'Alert' level exceedances were not signposted.

DNA marker tracking investigations in the lower Waitara River found that the principal faecal contributions were sourced from ruminants with infrequent contributions from humans and bird life, but only one exceedance of the 'Action' mode was recorded during the season.

Temporal trends over the 1996-2011 period have been evaluated for the eleven sites with ten years or more data (and will continue to be assessed annually). Two sites (Oakura River and Waimoku Stream) have shown a statistically significant trend (increase) in median *E. coli counts* with median counts consistently in the 'Action' level for the Waimoku Stream but no median counts reaching 'Alert' or 'Action' levels in the Oakura River. No other sites have shown significant trends (positive or negative) in seasonal median *E. coli* counts although these counts have trended downward in the Waingongoro River at Ohawe Beach with marginal statistical significance.

Elevated enterococci to faecal coliform ratios typified ponded sites near the stream/river mouths possibly as a result of vegetative sources of enterococci and/or more prolonged survival in ponded freshwater environments, under high tidal conditions and often where saltwater penetration occurred.

Additional sampling (in accordance with the MfE, 2003 guidelines) at two principal usage sites (Lake Rotomanu and Waiwhakaiho River) coincided on only one occasion with wet weather conditions and resulted in very slight increases in the overall median bacteriological numbers at both sites. No additional exceedances of limits occurred at the river site and one exceedance occurred at the lake site where poorer bacteriological quality followed the wet weather event.

A cyanobacteria bloom was recorded again at Lake Rotokare from near mid-season with numbers peaking later in summer, necessitating a warning notice to avoid contact recreation on these waters through the mid December 2010 to mid February 2011 period but levels had fallen below recreational guidelines toward the end of the survey period. Numbers were well below those typical of the previous summer, however. Unlike the situation in the 2008-2009 season, no cyanobacteria were found in Lake Rotomanu during the season. This lake was lowered for weeding prior to the season for maintenance purposes.

Timely reporting of the results of bacteriological water quality and cyanobacteria presence/absence was undertaken by use of the Taranaki Regional Council website (www.trc.govt.nz) as well as liaison with territorial local authorities and the Health Protection Unit of Taranaki District Health Board (who also utilised its newly created website) throughout the survey season of 2010-2011.

It is recommended that bacteriological monitoring of selected freshwater sites be continued on an annual basis (in conjunction with the coastal bathing water programme) by use of a similar sampling format over a five month (November to March inclusive) contact recreational period to provide information for trend detection purposes. Cyanobacteria monitoring at up to five selected sites (including the four lakes) at a lesser frequency is also recommended to continue. A further recommendation involves appropriate scheduling of the annual round of dairy wastes disposal systems and advice provided in relation to stock access to watercourses to attempt to reduce the frequency of exceedances of recreational limits particularly in catchments where historical problems have been located.

Table of contents

List of tables

List of figures

List of photographs

1. Introduction

The microbiological water quality at bathing beaches along the Taranaki coast has been monitored by the Taranaki Regional Council (and its predecessors) since 1979, with systematic surveys undertaken since 1987. A more comprehensive annual bathing beach monitoring programme was implemented during the 1995-1996 summer as an ongoing component of the state of the environment monitoring (SEM) programme for the Taranaki region.

Freshwater bathing and recreational sites were added during the 1996-1997 summer and integrated within the bathing beach bacteriological water quality monitoring programme in order to maximise the efficiency of field sampling procedures and protocols. This format has been continued in the summer periods since this date with an additional component of cyanobacteria monitoring instituted at one river and three lake sites since the 2006-2007 summer and an additional lake site in 2007-2008.

The SEM bacteriological bathing water quality programme has three objectives:

- to characterise the bacteriological quality of principal recreation waters in the Taranaki area, and more specifically to determine their suitability for contact recreation;
- to identify changes in contact recreational water quality over time. Therefore the detection of trends is an important component in programme design; and
- to assess compliance with recreational water quality guidelines.

*[**Note**: Contact recreation concerns water-based activities involving a high probability of accidental water ingestion. This mainly applies to bathing, but may also include water- and jet-skiing, surfing, boardsailing etc. Bathing, kayaking, and water skiing are the principal freshwater contact recreational usages identified.]*

2. Contact recreation water quality standards and guidelines

Prior to 2003, the Council has used guidelines for the management of recreational and marine shellfish-gathering waters (MfE, 1998) which replaced the provisional guidelines (DOH, 1992). These guidelines were developed (by MfE and MoH) to assist water managers to implement the Resource Management Act (1991) and the Health Act (1956) for the purposes of shellfish-gathering and contact recreation (refer to previous annual reports for more information on these historical guidelines). Since 2003 new guidelines are now relevant to this programme. This guideline is detailed below.

2.1 Freshwater microbiological water quality guidelines (2003)

Guidelines have been prepared by Ministry for the Environment in conjunction with the Ministry of Health (MfE, 2003). Components of these guidelines include sanitary surveys/inspections together with assessments of historical microbiological data which, when combined, provide an overall suitability for recreation grade, which describes the general condition of a site based on both risk and indicator bacteria counts. Changes to the *E. coli* freshwater recreational guideline values have been made for the purpose of regularly assessing single sample compliance with suitability for recreation. The new freshwater guidelines are now more reflective of New Zealand conditions. 'Alert' and 'Action' guideline levels are used for surveillance throughout the bathing season. They may be summarised as follows (with the marine levels included as some of the Taranaki sites monitored are in the lower, tidal reaches of rivers and streams).

Mode	Acceptable (green)	Alert (amber)	Action (red)
Freshwater (*E. coli*/100mls)	≤260	261-550	>550
Marine (enterococci/100mls)	≤140	141-280	>280 (2 consecutive samples)

2.2 Suitability for recreation grading (SFRG) of sites

The 2003 Microbiological Water Quality Guidelines (MfE, 2003) provide for the grading of recreational water bodies utilising Microbiological Assessment Categories (using historical data) and Sanitary Inspection Categories which generate a measure of the susceptibility of water bodies to faecal contamination. The SFRG therefore describes the general condition of a site based on both risk and indicator bacteria water quality. A grade is established on the basis of the most recent five years' data and recalculation of a grade may be performed annually although grades should be reassessed on a five-yearly basis.

SFRGs are very good, good, fair, poor, and very poor. Sites graded very good, are those where it is believed they will almost always comply with the guideline values for recreation, and there are few sources of faecal contamination in the catchment. Consequently there is a low risk of illness from bathing. Sites graded very poor are in catchments with significant sources of faecal contamination, and it is considered that

they will rarely pass the guidelines. The risk of illness from bathing at these sites is deemed to be high, and swimming is not recommended. For the remaining beaches (good, fair and poor) it is recommended that weekly monitoring be carried out during the bathing season. The public will be informed when guideline values are exceeded and swimming is not recommended (MfE, 2003).

All of the eleven freshwater sites originally included in the bathing sites programme have been graded by the Council according to these criteria, using all historical SEM microbiological water quality data extending over the November 2005 to March 2010 period (i.e. the five years immediately preceding the current season as required by the Guidelines). The two new sites added to the programme in 2006-2007, the two sites added in 2007-2008, and the single site added in 2009-2010 have limited historical bacteriological data and only a maximum of four year's data have been collected in the recent five year period. The relevant information is provided in Appendix 1 and is summarised in Table 1.

Table 1 Suitability for recreation grade for freshwater sites for the period November 2005 to March 2010

Site	Sanitary Inspection Category	Microbiological assessment *E.coli* (nos/100ml)			SFR Grade	% of all samples in compliance (ie: <550 *E.coli*)
		95 %ile	Number of samples	Category		
L Rotomanu: western beach	High	3150	65	D	Very poor	87
Waiwhakaiho R: Merrilands domain	High	208	65	B	Poor	98
Patea R: King Edward Park	High	880	65	D	Very poor	83
Patea R. boatramp, Patea	High	87	52	A	Poor	100
Waingongoro R: Eltham camp	High	360	65	C	Poor	100
Waingongoro R: Ohawe beach	High	903	65	D	Very poor	92
Kaupokonui R: Beach domain	High	618	65	D	Very poor	95
L Opunake: adjacent boatramp	High	1242	52	D	Very poor	88
Timaru S: Lower Weld Road	High	565	65	D	Very poor	93
Waimoku S: Oakura	High	6050	65	D	Very poor	3
Oakura R: d/s SH45	High	428	65	C	Poor	96
Waitara R: Town wharf	High	-	13	-	-	92
Urenui R: estuary	High	26	65	A	Poor	100
Manganui R: Everett Park	High	390	65	C	Poor	98
L Ratapiko: boatramp	High	91	51	A	Poor	100
L Rotokare: adjacent boatramp	High	84	30	A	Very good	100

Although most of the sites' SFRGs indicate possible high risks associated with contact recreational usage, the gradings have been strongly influenced by the agricultural nature of nearly all catchments. The 5-year microbiological data however, indicate that all but one site (Waimoku Stream) would not have entered the 'Action' guideline (ie would have been out of compliance) on more than 17% of all sampling occasions, with twelve sites achieving compliance on 90% or more of occasions. The Eltham camp site in the mid reaches of the Waingongoro River, the Urenui River estuary site, the Patea River estuary site and the Lake Ratapiko site have not reached the 'Action' mode during the previous five seasons, under the

sampling protocols of SEM programme, and the Merrilands Domain site in the lower reaches of the Waiwhakaiho River, and Everett Park site in the Manganui River entered this 'Action' level on only one occasion. In general, these data indicate shortcomings in the grading system for these sites based upon landuse/perceived impacts and extremes (95 % confidence levels) in bacteriological quality data, rather than actual monitoring data measured throughout the bathing seasons. Council's contact recreational water quality programmes confirm that gradings do not reflect the recreational water quality experienced by recreational users. They show only susceptibility and predominantly reflect perceptions and suppositions about how some land uses might influence quality, as designated 'risk factors'. It is the view of the Council that when there is regular and systematic testing of the actual quality, those results reflect actual levels and are far more informative to recreational water users. Gradings should not be used to make any statement about how safe water actually is for recreational purposes. Rather, the Council emphasises the importance of results of systematic and on-going testing in terms of the reporting of actual contact recreational water quality.

2.3 Programme design

2.3.1 Trend detection

It should be noted that the existing programme was designed and implemented prior to the release of the 1998 and 2003 guidelines. Therefore, for trend detection monitoring purposes, consistency in programme design is essential and will be maintained where possible. Results are interpreted in this report with reference to the 2003 guidelines for the purposes of assessment of compliance with contact recreational guidelines.

The locations of the sixteen sites sampled in the 2010-2011 programme are shown in Figure 1 and summarised in Table 2.

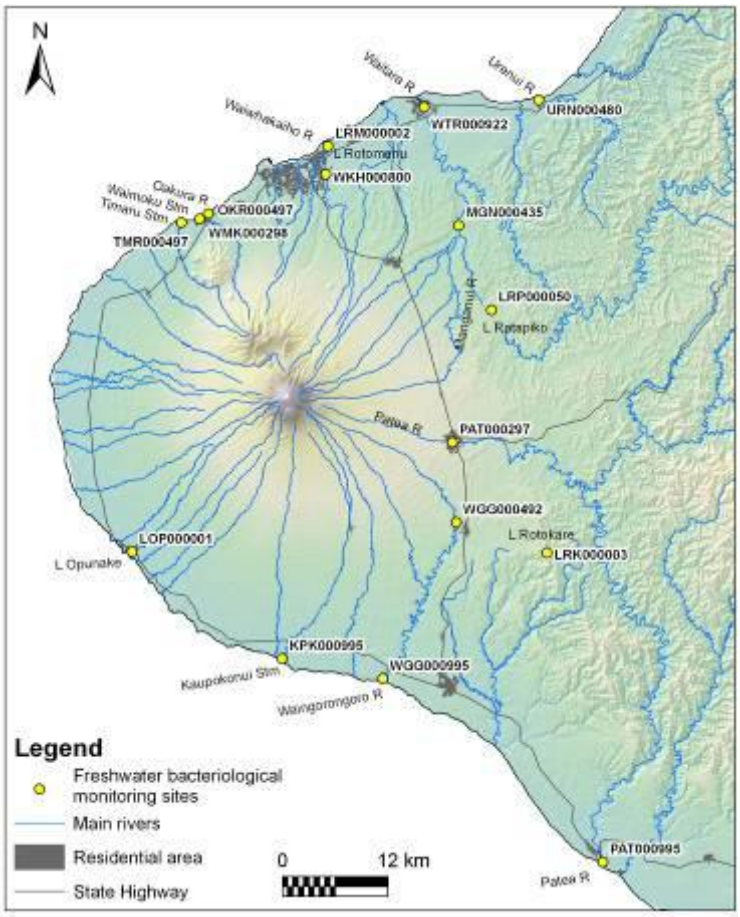


Figure 1 Location of freshwater contact recreation survey sites

For sampling convenience these sites were included with the (three) coastal bathing beaches runs undertaken over the same five month period from early November 2010 to mid April 2011. Eight sites, relatively close to stream mouths, were potentially affected by tidal influences (see conductivity data later in this report).

Table 2 Location of bathing water bacteriological sampling sites

Site	Location	GPS Location		Site code
Lake Rotomanu	Western beach	E 1696309	N 5678128	LRM000002
Waiwhakaiho River	Merrilands Domain	E 1696059	N 5674931	WKH000800
Patea River	King Edward Park, Stratford	E 1710433	N 5644464	PAT000297
Patea River	Boatramp, Patea	E 1727517	N 5596784	PAT000995
Waingongoro River	Eltham Presbyterian Camp	E 1710861	N 5635349	WGG000492
Waingongoro River	Ohawe Beach	E1702531	N 5617624	WGG000995
Kaupokonui River	Beach domain	E 1691110	N 5619893	KPK000995
Lake Opunake	adjacent to boatramp	E 1674029	N 5632022	LOP000001
Timaru Stream	end of Weld Road	E 1697622	N 5669438	TMR000497
Waimoku Stream	Oakura Beach	E 1681725	N 5669851	WMK000298
Oakura River	d/s SH45 bridge	E1682721	N 5670440	OKR000497
Waitara River	Town wharf	E 1707203	N 5682572	WTR000922
Urenui River	Urenui estuary	E 1720245	N 5683370	URN000480
Manganui River	Everett Park (d/s Kurapete S)	E1711149	N 5669127	MGN000435
Lake Ratapiko	Boatramp	E1714913	N 5659488	LRP000050
Lake Rotokare*	Adjacent to boatramp	E 1721182	N5631898	LRK000003

Sample collection, field measurements, transport and analyses were undertaken according to documented Taranaki Regional Council procedures. It was intended that on average, three samples would be collected from each of the sites in each month when hydrological flow conditions permitted, within two hours of high tide (due to the format of the coastal programme). However, spring wet weather affected the frequency of sample collection earlier in the period. Sampling commenced in early November 2010 with three of the sampling surveys performed prior to January 2011. The majority of the surveys were performed over the latter half of the summer period. Bathing water samples were normally taken between the hours of 0900 and 1800 hours (NZDST) with none collected within a three day period following significant river fresh conditions. [NB: regional differences in rainfall patterns have caused difficulties at various sites in the past as localised rainfall may impact on bacteriological quality on isolated occasions]. Where necessary, a 2 metre sampling pole was used for bacteriological sample collection immediately beneath the water surface and at a minimum of calf depth at the sites. Thirteen samples were collected from each site during the season.

Samples were analysed for enterococci, E. coli and faecal coliform bacteria, turbidity and conductivity. In addition, at each of the sites the following information was recorded; time, water temperature, weather, colour/appearance, percentage estimation of algal cover on the streambed, and number of bathers and other users. All sites' locations (map references and GPS) and descriptions are stored in the Council Taradise and laboratory (Labsys) computer database and all analytical results were stored in Labsys following standard sample registration procedures.

After consultation with Taranaki District Healthboard, cyanobacteria monitoring commenced at each of the three lake sites and the lower Waiwhakaiho River site in the 2006-2007 bathing season and continued in 2010-2011 and included an additional lake site. Cyanobacteria can produce toxicity in recreational waters which pose risks to humans and animals by contact or consumption during recreational activities. Visual checks for surface scums were made on each sampling occasion and samples were collected for microscopic analysis which was performed in the TRC biological laboratory.

Results were posted on the Taranaki Regional Council website (www.trc.govt.nz) for public and local health authority notification in particular, as soon as checking had been completed. Mapping of the results was also included on the recently established Taranaki District Health Board website (www.tdhb.org.nz) in the 2010-2011 season. Where results fell in the 'Action' mode, further investigations (e.g. sampling and inspections) were performed when considered necessary ie: where historical databases and staff expertise indicated this was warranted. Cyanobacteria information was included on the websites where appropriate.

2.3.2 Additional monitoring (MfE guidelines)

The revised guidelines (MfE, 2003) require weekly surveillance monitoring during the 5-month recreational period, with a minimum of 20 data points collected, regardless of weather conditions or state of the tide. Following consultation with the three territorial local authorities and Taranaki District Health Board, TRC undertook to add seven sampling occasions to the SEM protocol at two of the most popular freshwater recreational sites (Lake Rotomanu and Waiwhakaiho River at Merrilands Domain) in the 2003-04 period and this additional monitoring has continued annually since. These seven sampling occasions were systematically selected (one per week) in weeks not sampled by the SEM programme and were performed regardless of prior weather conditions or tides but adhering to all other SEM programme protocols and using documented sampling methods. Both sites were signposted advising the public of monitoring activity. Also, the additional data were included on the TRC website [Note: These data will not be used for future trend detection purposes as they do not comply with the format of the originally established SEM programme].

3. Results

3.1 Introduction

Sampling times in relation to tidal conditions (particularly for estuarine sites, see Appendix II), weather conditions and sites' usage information are contained in Appendix III and IV. Timing of sampling in relation to river flows is illustrated by Figures 7, 13, 18, 20 and 25. Those illustrate that the majority of the sampling occasions coincided with steady to low river recession flow conditions. Very occasionally sampling was affected by localised rainfall and/or a prior increase in river flows. However, where possible no sampling was undertaken within three days following significant river freshes. A total of 13 samples were collected at each site during the period from early November 2010 to mid April 2011.

Sampling was confined to weekdays during the period with no public holidays included due to sampling personnel and laboratory schedules' requirements. For these reasons, recreational usage of the waters was generally less intensive, often with no apparent usage at the time of sampling. However, all sites are known to be regularly utilised for bathing and other contact recreational activities, particularly at weekends, dependent on suitable weather conditions (see Appendix IV of TRC, 1999). The two additional sites included in the 2001-2002 programme (Patea River at Stratford and Waingongoro River at Eltham), and monitored annually since then, have been identified as used locally for bathing and other recreational purposes. The two lake sites (Ratapiko and Opunake) added to the 2006-2007 programme are also used for these purposes, while Lake Rotokare (added in the 2007-2008 season for cyanobacteria monitoring) is used extensively for recreational boating activities. The lower Patea River site (added in 2007-2008 year as a result of a Patea Wastewater Treatment Plant consent monitoring condition) is used principally for boating purposes. The lower Waitara River site (added in the 2009-2010) is used for boating and bathing purposes, more so recently with the construction of a new wharf in the town.

3.2 Presentation of results and discussion

All results are presented and discussed on a site-by-site basis for the sampling period, which extended from 9 November 2010 to 12 April 2011 and totalled thirteen sampling occasions at each site. The results for the sites with additional (seven) sampling occasions are also presented within the discussion for the two appropriate sites.

3.2.1 Lake Rotomanu

3.2.1.1 SEM programme

Bathing usage of the lake was minimal, although boating, water and jet-skiing and/or picnicking activities were recorded at the time of several of the sampling surveys as no signage warning of health risks associated with lake water quality was required over the period. Ducks (and occasionally, gulls) were present on the lake or in the vicinity of the lake edge throughout the period and were often attracted to the immediate vicinity of the sampling site by public feeding of the ducks. Lake levels were lowered early in the period for weed control purposes, in addition to biological (grass carp) control, and levels returned to normal by mid December 2010. In

addition, a wetland had been created recently at Peringa Park to improve the quality of stormwater runoff entering the lake.

The data for this site are presented in Table 3 and illustrated in Figure 2, with a statistical summary provided in Table 4.

Table 3 Analytical results for Lake Rotomanu

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	1150	15.8	150	130	150	21.4	3.3
24.11.10	1200	15.8	84	37	88	20.0	2.8
6.12.10	1110	15.9	140	37	140	25.0	2.5
6.01.11	1120	12.3	140	51	150	24.3	1.6
10.01.11	1355	12.7	26	8	34	24.2	4.8
3.02.11	1025	13.1	14	4	14	22.4	1.0
11.02.11	1140	12.9	54	210	57	23.3	1.1
18.02.11	1020	12.8	34	80	34	24.0	1.4
21.02.11	1120	13.1	37	400	66	24.6	1.0
10.03.11	1340	13.2	14	13	14	19.9	0.9
21.03.11	1110	13.2	6	4	6	21.3	1.4
25.03.11	1350	13.7	11	44	11	19.2	1.2
12.04.11	1610	13.3	20	25	20	19.1	0.6

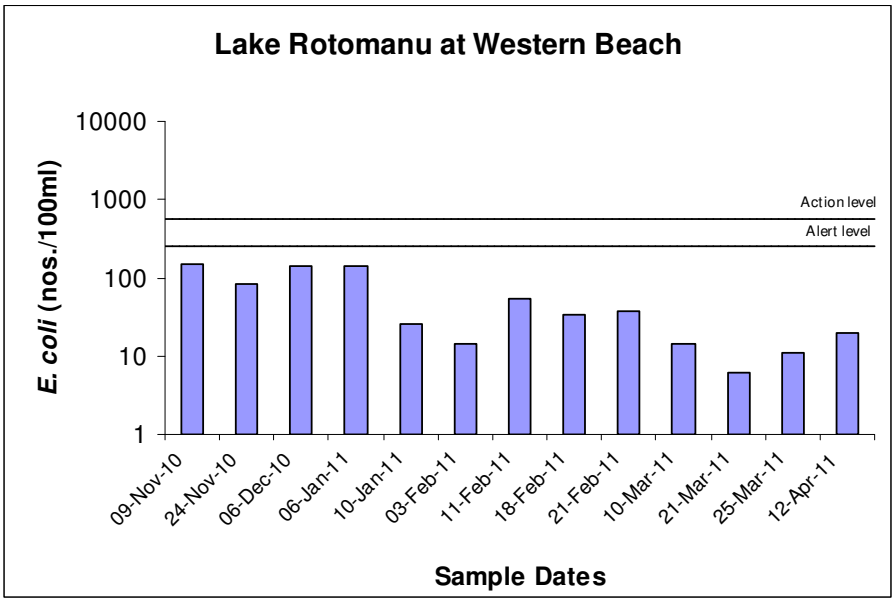


Figure 2 *E. coli* numbers for Lake Rotomanu during the regular season
(Note: Action limit >550/100 ml [single sample: Alert limit => 260 nos/100ml [single sample])

Table 4 Statistical results summary for Lake Rotomanu

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	12.3	15.9	13.2
E. coli	nos/100ml	13	6	150	34
Enterococci	nos/100ml	13	4	400	37
Faecal coliforms	nos/100ml	13	6	150	34
Temperature	°C	13	19.1	25.0	22.4
Turbidity	NTU	13	0.6	4.8	1.4

The lake, which is close to the coast, is replenished from time to time by inflow from the nearby Waiwhakaiho River. Water quality was relatively good with small variations in clarity (median turbidity: 1.4; range: 4.2 NTU) possibly as a result of some sediment disturbance shortly after weed harvesting and /or fluctuating concentrations of suspended algae. Water temperatures were relatively high (above 20°C) almost throughout the period with a high maximum of 25.0°C (in early December 2010) and a range of 5.9°C. Conductivity had a relatively narrow range through the season.

Generally bacteriological quality was relatively good considering that the inflow to the lake is from the lower reaches of a river draining a developed catchment. No elevated numbers of *E. coli* (in or near the 'Action' mode) were found on any occasion despite the wildfowl population and the number of ducks attracted to the main public recreational area. No bacterial counts approached the 'Alert' level and therefore NPDC signage discouraging lake usage was not required to be erected at the lake as had been the case in previous seasons.

3.2.1.1.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 5.

Table 5 Bacterial guidelines performance at Lake Rotomanu [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	0 [0]	0 [0]

(Designation: freshwater contact recreational area)

No single samples exceeded the 'Action' mode during the period, and no single sample was recorded within the 'Alert' mode.

3.2.1.1.2 Comparison with previous summers' surveys

A statistical comparison of each of the fifteen seasons' *E. coli* surveys data is presented graphically in Appendix V for all sites. These summer data for the Lake Rotomanu site are summarised in Table 6 and illustrated in Figure 3.

Table 6 Summary of *E. coli* bacteriological water quality data (nos/100ml) for all summer surveys at Lake Rotomanu to date

Summer	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11
Minimum	3	12	7	7	1	31	9	20	<3	6	7	54	51	23	6
Maximum	899	740	200	140	90	980	2200	5500	220	380	3000	1200	6000	3600	150
Median	32	46	79	25	14	110	92	120	11	68	72	180	220	100	34

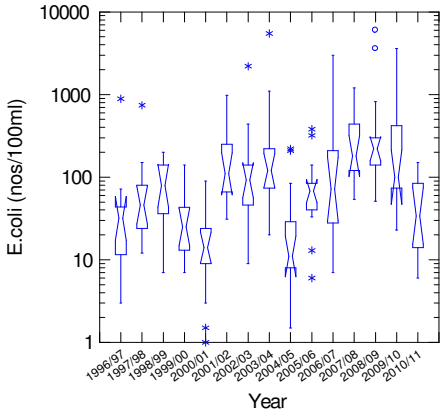
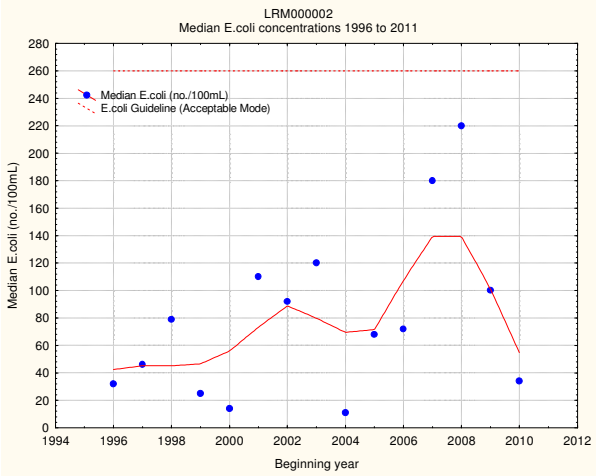


Figure 3 Box and whisker plots for all summer SEM surveys of *E coli* bacteria numbers at Lake Rotomanu

A recent trend of relatively high median *E. coli* numbers in recent years was not continued over the summer of 2010-2011 with a narrow range of counts recorded by this survey and a low median value, the fifth lowest to date. The maximum count was the third lowest to date. The median value remained well below the 'Alert' level of the 2003 MfE guidelines.

Trend analysis of these median *E. coli* numbers has been performed for the fifteen seasons of data by first applying a LOWESS fit (tension 0.4) to a time scatterplot of the median numbers (Figure 4) and testing the significance of any trend using the Mann-Kendall test at the 5% level followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.



N = 15
Kendall tau = +0.276
p level = 0.151 [>FDR, p = 0.454]
N/S at p < 0.05

Figure 4 LOWESS trend plot of median *E. coli* numbers (per 100ml) at Lake Rotomanu for the 1996-2011 period

A positive, but not statistically significant increase in median *E. coli* numbers has been found over the fifteen seasons of monitoring although median numbers have

trended downwards over the latest two seasons. None of these seasonal medians exceeded the 'Alert' or 'Action' modes.

3.2.1.2 MfE guidelines additional sampling

Seven additional samples were collected randomly under varying weather conditions during the survey season. Limited bathing and boating was noted on these occasions. Ducks were present in moderate numbers on the lake on all occasions and gulls and swan recorded infrequently. One survey occurred by chance soon after a significant rainfall event.

The data from these additional surveys are presented in Table 7, illustrated and statistically summarised (with the 13 SEM samples' data) in Figure 5 and Table 8 respectively.

Table 7 Lake Rotomanu additional seven water quality samples' results

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
16.11.10	0920	15.5	77	110	77	20.3	2.8
29.11.10	0950	15.7	120	86	130	21.9	3.1
14.12.10	0935	15.5	1200	600	1200	21.0	2.0
13.01.11	1000	12.9	37	11	37	21.9	1.9
27.01.11	0955	12.7	100	48	100	21.6	1.2
15.02.11	0940	13.2	40	29	40	24.4	1.1
16.03.11	0945	13.4	60	7	60	22.0	0.9

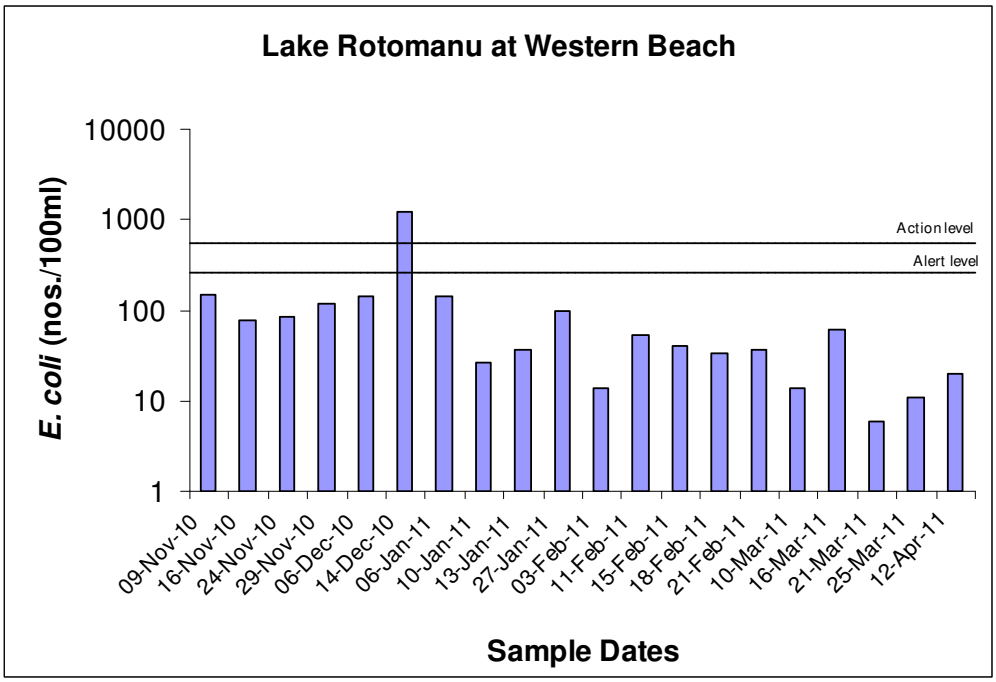


Figure 5 *E. coli* numbers for Lake Rotomanu for the 20 sample extended survey

Table 8 Summary statistics for SEM and additional samples at Lake Rotomanu

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	20	12.3	15.9	13.2
E. coli	nos/100ml	20	6	1200	47
Enterococci	nos/100ml	20	4	600	41
Faecal coliforms	nos/100ml	20	6	1200	59
Temperature	°C	20	19.1	25.0	21.9
Turbidity	NTU	20	0.6	4.8	1.4

The additional sampling resulted in a very small difference to the overall seasonal median bacteria numbers with an increase of 4 *E.coli* (per 100mls). These additional surveys' bacteria counts had a moderately wide range (6 to 1200 *E. coli* per 100mls), wider than the standard SEM sampling survey range, due to the proximity of wet weather to one of the sampling survey occasions.

3.2.1.2.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 9.

Table 9 Bacterial guidelines performance at Lake Rotomanu [% of 20 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Simgle sample 261-550/100ml	ACTION Single sample >550/100ml
E. coli	0[0]	1[5]

The number of exceedances of the single sample 'Alert' and 'Action' modes increased with the additional monitoring, as one additional exceedance of the 'Action' level but none of the 'Alert' level occurred; this one exceedance following wet weather conditions and elevated river flows in mid December 2010.

3.2.1.3 Cyanobacteria

No visual surface algal blooms were recorded during the season but slightly more turbid lake water quality, partly due to suspended algae, was noted in the early part of the season following lake refilling after maintenance work. Microscopic scans of samples found no cyanobacteria present in any of the samples analysed during the season. The results of this sampling are presented in Table 10.

Table 10 Cyanobacteria counts (cells/ml) for Lake Rotomanu [Health warning: >15,000 cells/ml]

Date	Cyanobacteria total cell count (cells/ml)	Principal species
16.11.10	nil	-
29.11.10	nil	-
14.12.10	nil	-
13.01.11	nil	-
27.01.11	nil	-
15.02.11	nil	-
16.03.11	nil	-

Therefore, no health warning signage was required at the lake as the cyanobacteria density remained well below the health warning high alert level of 15,000 cells/ml (TDHB, 2006) unlike during the 2008-2009 season when *Microcystis* dominated the lake (TRC, 2009). No toxin testing of the lake waters (by the Cawthron Nelson laboratory) was therefore required by the Taranaki Health Board. *Microcystis* had also been found in the lake during the previous (2009-2010) season when cyanobacteria numbers ranged from nil to 7600 cells/ml (TRC, 2010).

3.2.2 Waiwhakaiho River at Merrilands Domain

3.2.2.1 SEM programme

Limited usage of this site was recorded at the time of the sampling surveys, with minor bathing and more frequent walking or picnicking on the banks of the river noted.

The data for this site are presented in Table 11 and illustrated in Figure 7, with a statistical summary provided in Table 12. River flow information is illustrated in Figure 6.

Table 11 Analytical results for the Waiwhakaiho River at Merrilands Domain

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	0855	12.8	48	1	48	14.7	1.1
24.11.10	0930	12.8	13	1	15	16.8	1.0
6.12.10	1220	15.2	81	28	86	22.0	1.7
6.01.11	0820	12.1	34	36	34	20.5	0.6
10.01.11	1045	12.7	95	50	96	19.3	1.7
3.02.11	1135	12.5	46	40	46	19.4	0.5
11.02.11	1115	10.5	4	16	4	20.1	0.4
18.02.11	1100	13.9	60	42	60	19.7	0.7
21.02.11	0820	13.7	21	17	21	20.1	0.5
10.03.11	0950	11.3	54	100	54	14.4	0.4
21.03.11	0805	10.0	74	29	74	16.2	0.6
25.03.11	1050	13.5	200	100	210	16.4	0.7
12.04.11	1245	12.2	130	35	130	15.5	1.0

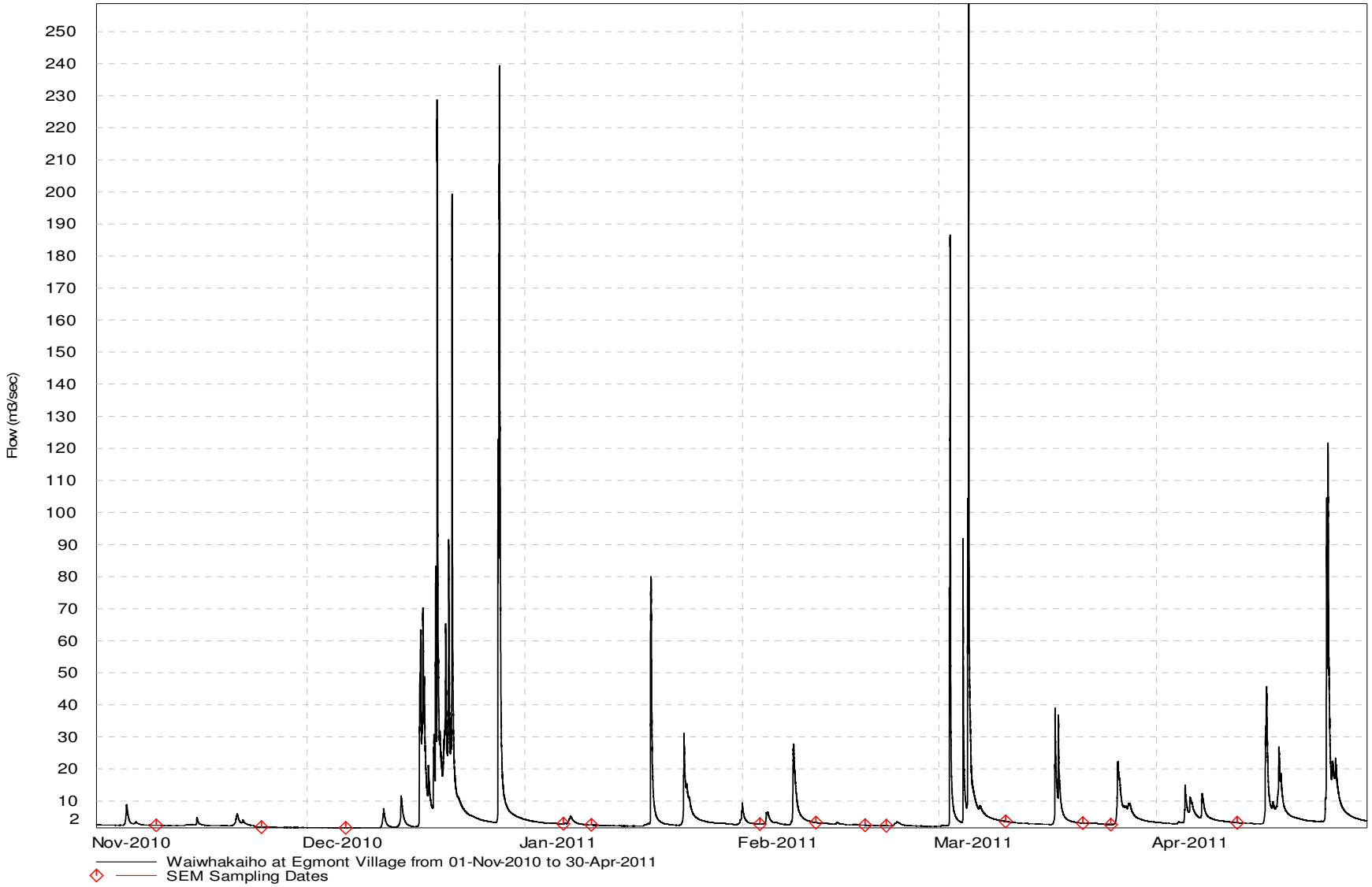


Figure 6 River flow in the Waiwhakaiho River during the survey period (NOTE: Waiwhakaiho at Egmont Village Flow is unaudited data)

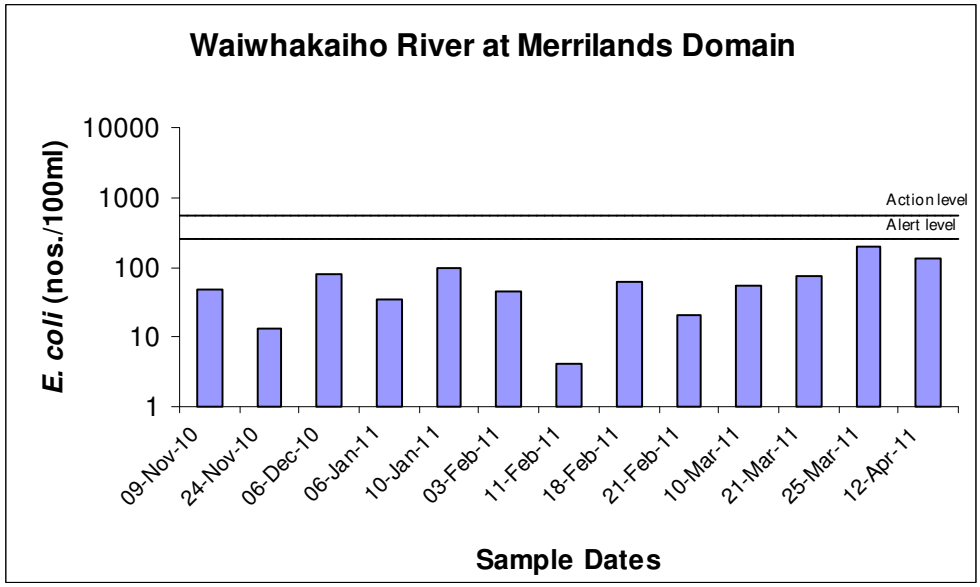


Figure 7 *E. coli* numbers for the Waiwhakaiho River at Merrilands Domain during the regular survey season

Table 12 Statistical results summary for the Waiwhakaiho River at Merrilands Domain

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	10.0	15.2	12.7
E. coli	nos/100ml	13	4	200	54
Enterococci	nos/100ml	13	1	100	35
Faecal coliforms	nos/100ml	13	4	210	54
Temperature	°C	13	14.4	22.0	19.3
Turbidity	NTU	13	0.4	1.7	0.7

This river drains an extensively developed farmland catchment prior to flowing through two kilometres of urban New Plymouth upstream of this popular domain and recreational area sited in the lower reaches of the river nearly 4 km from the sea.

Water temperatures varied over a moderate range of 7.6°C between early November and mid April, with a maximum of 22.0°C in early December 2010. Conductivity and turbidity results were indicative of very clean, clear, relatively high water quality but percentage algal cover was relatively high throughout most of the period.

Considering the influence of agricultural activities, particularly dairying in the catchment, bacteriological water quality was relatively high. Bacterial numbers were not excessive remaining within a relatively narrow range on all occasions through the season and no high counts were recorded. A good standard of compliance with on-site dairy wastes disposal practices was recorded by the season's annual inspection round in this catchment.

3.2.2.1.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 13.

Table 13 Bacterial guidelines performance at the Waiwhakaiho River Merrilands Domain site [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	0 [0]	0 [0]

(Designation: freshwater contact recreational area)

No single sample was recorded within the 'Action' mode and none in the 'Alert' mode during the season. Bacteriological water quality measured at this site was therefore within the acceptable standard for contact recreational usage for the entire survey period.

3.2.2.1.2 Comparison with previous summers' surveys

A statistical comparison of each of the fifteen summer's surveys data is presented graphically in Appendix V for all sites. These data for the Waiwhakaiho River site are summarised in Table 14 and illustrated in Figure 8.

Table 14 Summary of *E. coli* bacteriological water quality data (nos/100 ml) for all summer surveys in the Waiwhakaiho River at Merrilands domain to date

Summer	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11
Minimum	16	16	26	8	6	17	3	34	11	15	8	28	19	23	4
Maximum	970	1800	330	100	270	420	130	320	330	160	510	110	110	570	200
Median	42	84	69	39	23	60	29	77	54	34	48	48	46	110	54

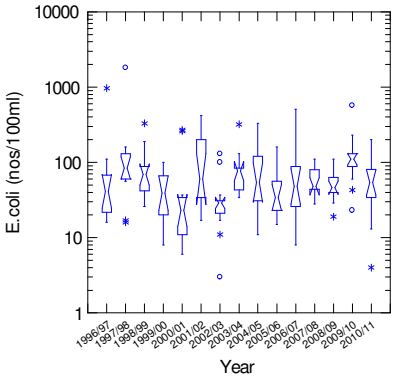
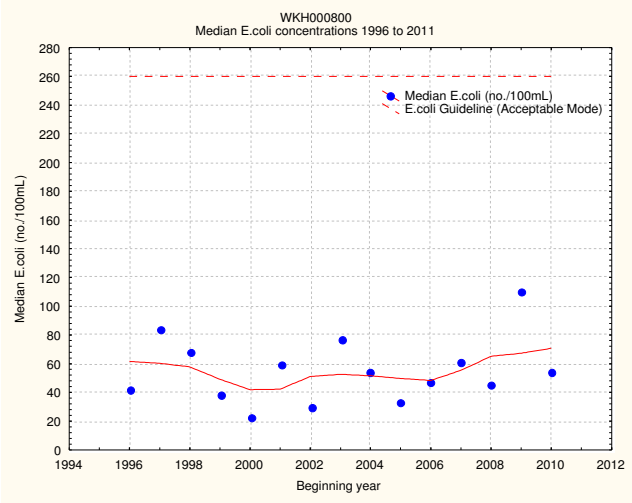


Figure 8 Box and whisker plots for all summer SEM surveys of *E.coli* bacteria numbers in the Waiwhakaiho River at Merrilands Domain

The median *E. coli* number in the 2010-2011 period was typical of most recorded to date and 56 per 100 mls below the maximum of the range of historical medians (Table 13 and Figure 8), all of which have been well below the 'Alert' level of the 2003 MfE guidelines.

Trend analysis these median *E.coli* numbers has been performed for the fifteen seasons of data by first applying a LOWESS fit (tension 0.4) to a time scatterplot of the median numbers (Figure 9) and testing the significance of any trend using the Mann-Kendall test at the 5% level followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.



N = 15
Kendall tau = +0.077
p level = 0.691 [>FDR, p = 0.784]
N/S at p <0.05

Figure 9 LOWESS trend plot of median *E.coli* numbers (per 100ml) at the Waiwhakaiho River, Merrilands Domain for the 1996 to 2011 period.

An insignificant temporal trend of slightly increasing median *E.coli* numbers was found over the fifteen seasons of monitoring. None of these seasonal medians exceeded the 'Alert' or 'Action' modes.

3.2.2.2 MfE guidelines additional sampling

Seven additional samples were collected randomly at irregular intervals and under varying weather conditions (one of which by chance was a wet weather event) during the survey season. Minimal recreational activities on these occasions included bathing and walking (sometimes with dogs present in the river).

The data from these additional surveys are presented in Table 15, illustrated in Figure 10, and statistically summarised (together with the 13 SEM samples' data) in Table 16.

Table 15 Waiwhakaiho River at Merrilands Domain additional seven water quality samples' results

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
16.11.10	0940	12.9	80	12	81	17.6	1.6
29.11.10	0930	14.1	250	230	250	20.4	1.1
14.12.10	0920	12.1	200	330	210	18.0	1.5
13.01.11	0940	13.4	21	21	23	18.3	0.7
27.01.11	0935	11.5	36	36	36	18.9	0.6
15.02.11	0920	13.0	46	42	46	20.3	0.4
16.03.11	0925	14.6	80	42	80	17.2	0.7

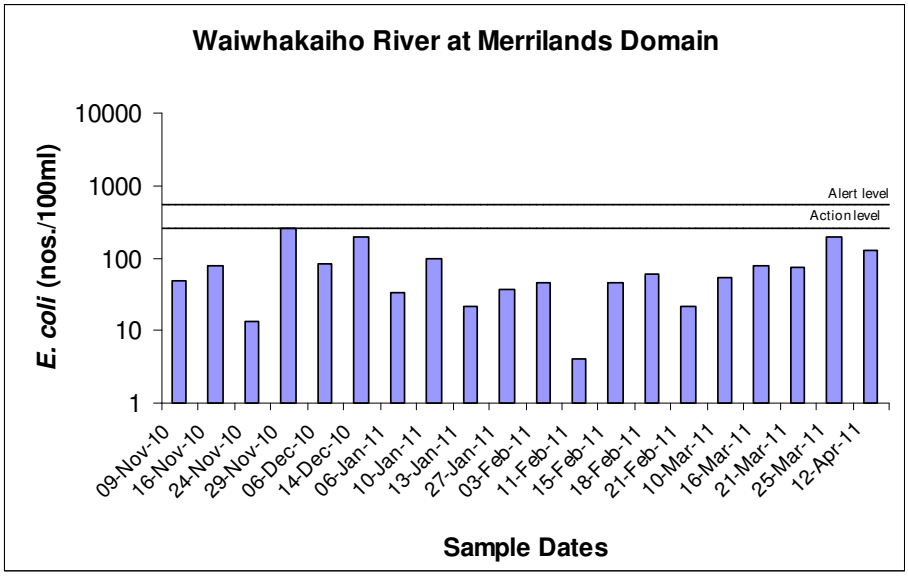


Figure 10 *E. coli* numbers for the Waiwhakaiho River at Merrilands Domain for the 20 sample extended survey

Table 16 Summary statistics for SEM and additional samples in the Waiwhakaiho River at Merrilands Domain

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	20	10.0	15.2	12.9
E. coli	nos/100ml	20	4	250	60
Enterococci	nos/100ml	20	1	330	36
Faecal coliforms	nos/100ml	20	4	250	60
Temperature	°C	20	14.4	22.0	19.1
Turbidity	NTU	20	0.4	1.7	0.7

These seven additional samples resulted in very small increases in the seasonal median bacterial numbers in comparison with the regular SEM programme results (Table 12). The ranges for all three bacteria species were wider due to elevated counts recorded in late November and mid December 2010, the latter under higher river flow conditions following a significant rainfall event, as also indicated by a decrease in conductivity level (Table 15).

3.2.2.2.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 17.

Table 17 Bacterial guidelines performance in the Waiwhakaiho River at Merrilands Domain [% of 20 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	0 [0]	0[0]

(Designation: freshwater contact recreational area)

No exceedances of the single sample 'Alert' mode occurred and no sample counts exceeded 550 *E. coli* per 100 mls ('Action' mode).

3.2.2.3 Cyanobacteria

No visual surface or river margin algal blooms were noted during the season. Microscopic scans of samples found no cyanobacteria species present in any of these samples during the period. The results of the sampling are presented in Table 18.

Table 18 Cyanobacteria counts (cells/ml) for the Waiwhakaiho River at Merrilands Domain [Health warning :>15,000 cells/ml]

Date	Cyanobacteria total cell count (cells/ml)
16.11.10	nil
29.11.10	nil
14.12.10	nil
13.01.11	nil
27.01.11	nil
15.02.11	nil
16.03.11	nil

Therefore no health warning signage was required to be displayed at this site during the period.

3.2.3 Patea River at King Edward Park, Stratford

Minimal bathing usage of this river site was recorded at the time of sampling surveys, most of which were in the morning or early afternoon. Picnickers and fishermen were noted on some occasions at this site, and following the release of trout into the river for the 'Take a Kid Fishing' promotion in February 2011.

Data from the site are presented in Table 19 and illustrated in Figure 11, with a statistical summary provided in Table 20. River flow records are illustrated in Figure 12.

Table 19 Analytical results for the Patea River at Kind Edward Park, Stratford

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	1305	9.3	54	29	54	13.7	0.5
24.11.10	1210	9.9	100	70	100	14.5	0.7
6.12.10	1120	9.9	220	250	220	15.9	0.9
6.01.11	1230	9.0	230	510	240	16.4	0.8
10.01.11	1015	9.4	180	420	210	13.5	0.6
3.02.11	1220	9.4	200	550	210	17.0	0.6
11.02.11	1150	9.4	120	140	120	14.7	0.7
18.02.11	1125	9.4	610	380	610	16.2	0.8
21.02.11	1315	9.7	88	220	88	18.0	1.2
10.03.11	1420	8.7	150	260	160	13.6	0.7
21.03.11	1200	8.6	180	260	180	12.9	0.7
25.03.11	1025	8.6	160	320	180	12.7	1.0
12.04.11	1205	8.9	160	160	180	11.4	1.0

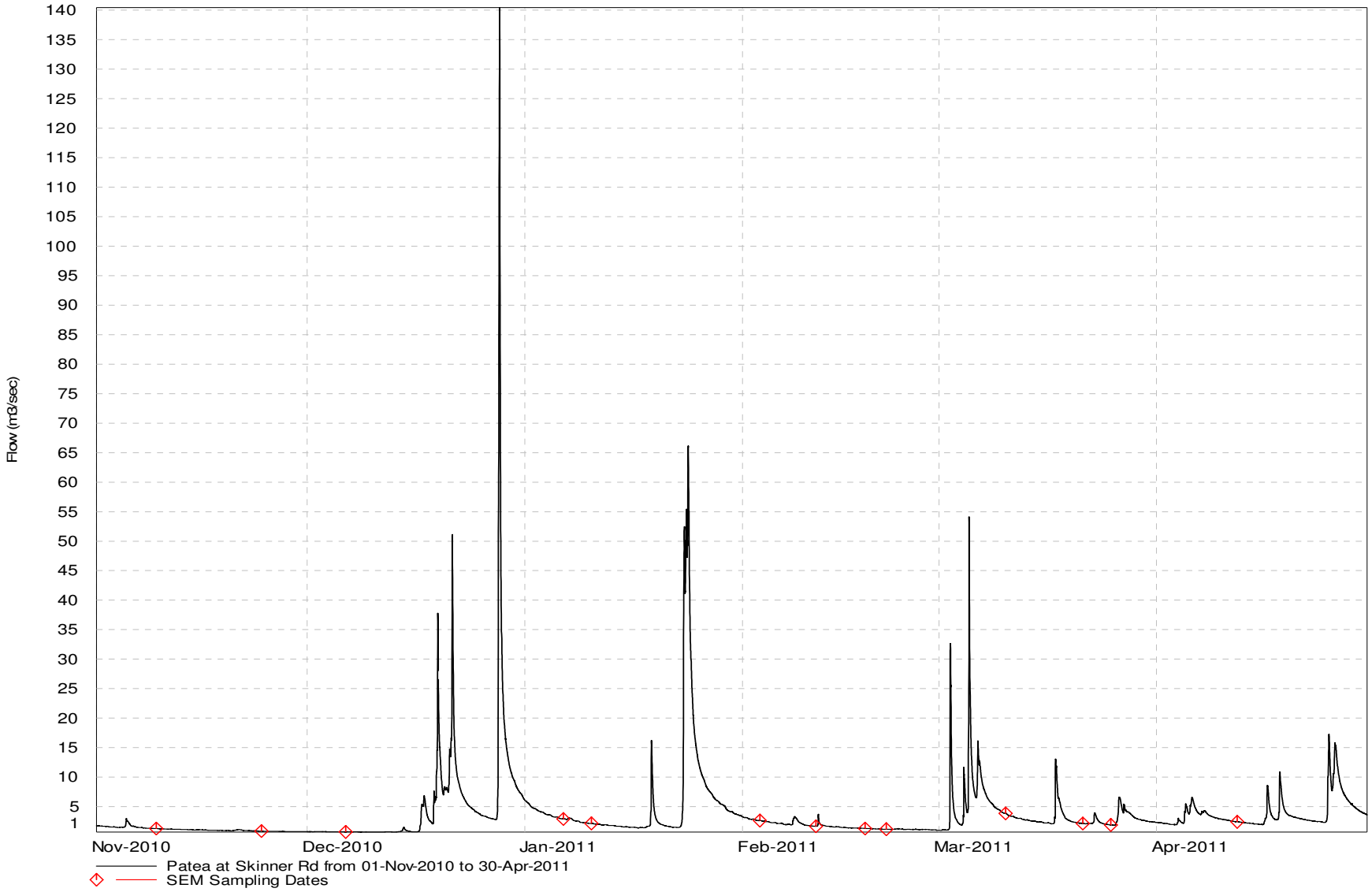


Figure 11 Flow in the Patea River during the survey period

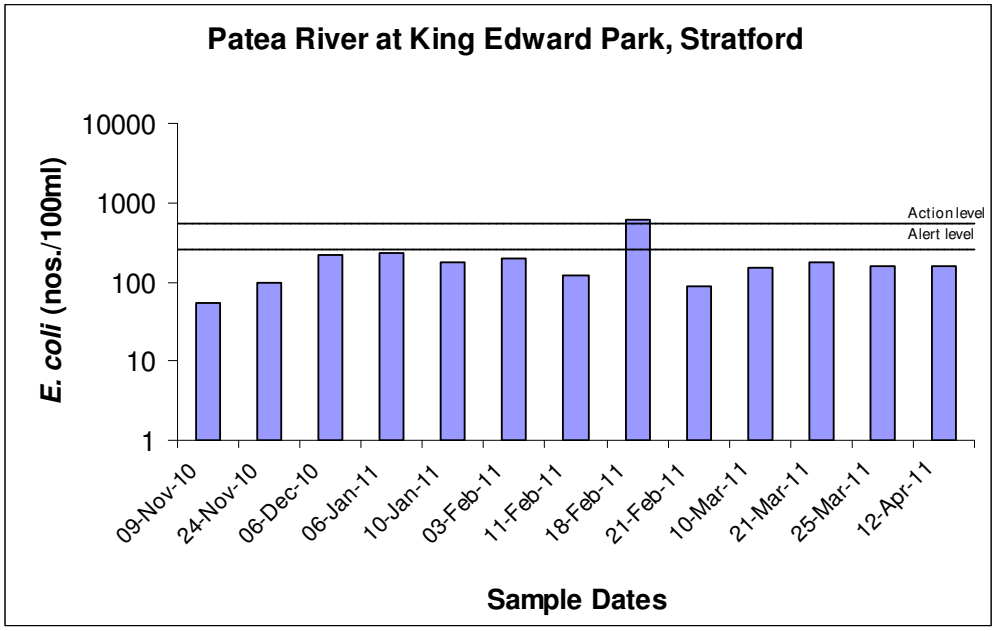


Figure 12 *E. coli* numbers for the Patea River at King Edward Park, Stratford during the survey season

Table 20 Statistical results summary for the Patea River at King Edward Park, Stratford

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	8.6	9.9	9.4
E. coli	nos/100ml	13	54	610	160
Enterococci	nos/100ml	13	29	550	260
Faecal coliforms	nos/100ml	13	54	610	180
Temperature	°C	13	11.4	18.0	14.5
Turbidity	NTU	13	0.5	1.2	0.7

This ring plain river drains a developed agricultural catchment. The survey site is situated within King Edward Park in Stratford township, approximately 11 km downstream of the National Park boundary, with several consented dairy ponds' treated wastes discharges in the catchment upstream of the site. River water was consistently clear and generally colourless with relatively low conductivity levels.

Water temperatures had a moderate range of 6.6°C for this site (at an elevation of 300 m asl, with a maximum of 18.0°C recorded at 1315 hrs in mid January 2011. All but one of the samples were collected before 1420 hours and therefore maximum river temperatures (which tend to occur later in the afternoon) were not recorded.

Bacteriological water quality was moderate for the mid reaches of this Taranaki ring plain river draining a predominantly agricultural catchment. A moderately high count was recorded on one occasion during the survey period (in mid February 2011), which did not necessitate further investigation as regular sampling followed three days later and found a much lower count (88 *E.coli* per 100 mls). This was a considerable improvement over most previous seasons' surveys when it had been necessary to re-inspect a number of dairy farms' disposal systems in smaller upstream catchments and on several occasions issue abatement notices for non-compliance with consented disposal requirements. One count exceeded the 'Action' level (in mid February 2011) but this short term incident was not considered to

warrant the placement of appropriate signage at the site by the Stratford District Council.

Future annual dairy farms inspections in this area of the upper Patea catchment should continue to be timed to ensure compliance with consent conditions prior to the start at the contact recreation period.

3.2.3.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 21.

Table 21 Bacterial guidelines performance at the Patea River at King Edward Park, Stratford site [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	0 [0]	1 [8]

(Designation: freshwater contact recreational area)

No single samples fell within the 'Alert' mode, and one sample fell in the 'Action' mode. The latter count occurred in mid February 2011 but did not require immediate follow-up sampling (see above). In terms of the guidelines for contact recreational usage, bacteriological water quality at this site was compliant with the acceptable level for almost the entire period, with no incursions into the 'Alert' level.

3.2.3.2 Comparison with previous summers' surveys

A statistical comparison of each of the fifteen summers' survey data is presented graphically in Appendix V for all sites. A shorter data period (ten years) exists for the Patea River (at King Edward Park, Stratford) site which was added in 2001-2002. These summer data for the Patea River at King Edward Park, Stratford site are summarised in Table 22 and illustrated in Figure 13.

Table 22 Summary *E. coli* bacteriological water quality data (nos/100 ml) all summer surveys in the Patea River at King Edward Park, Stratford

Summer	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11
Minimum	46	120	48	96	100	28	46	51	51	54
Maximum	640	780	580	760	840	1000	690	570	7400	610
Median	250	190	110	300	310	200	290	200	250	160

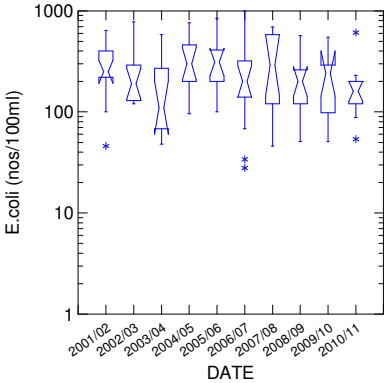
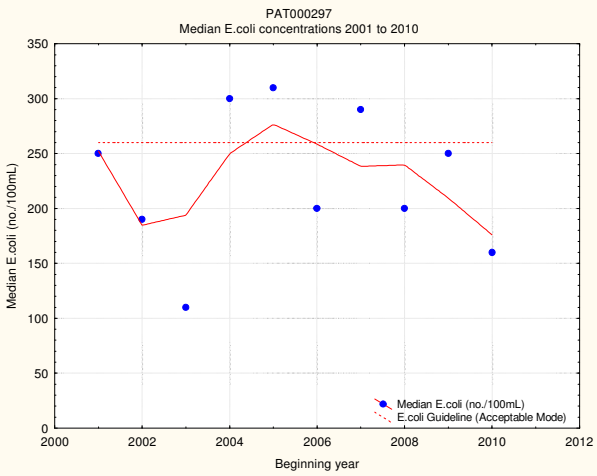


Figure 13 Box & whisker plots for all summer surveys of *E.* coli bacterial numbers for the Patea River at King Edward Park, Stratford

An improvement was indicated as the median *E. coli* bacterial count recorded for the 2009-2010 season was better than all but one of the historical median counts over the monitoring seasons. The 2009-2010 season recorded a narrower range of counts for this site compared with most of the ten monitoring seasons to date.

Trend analysis of these median *E.coli* numbers has been performed for the ten seasons of data by first applying LOWESS fit (tension 0.4) to a time scatterplot of the median numbers (Figure 14) and testing the significance of any trend using the Mann-Kendall test at the 5% level followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.



N = 10
Kendall tau = -0.068
p level = 0.784 [>FDR, p = 0.784]
N/S at p < 0.05

Figure 14 LOWESS trend plot of median *E.coli* numbers (per 100ml) at the Patea River, King Edward Park site, for the 2000-2011 period

An insignificant temporal trend of decreasing media *E.coli* numbers has been found over the ten monitoring seasons. Three of these seasonal medians exceeded the 'Alert' mode but none have exceeded the 'Action' modes.

3.2.4 Patea River at the boatramp, Patea

No bathing usage of this river site was recorded at the time of sampling surveys, the majority of which were in the morning. Boating and fishing were noted from time to time at this site with boating as the main activity as this was a popular launching site for fishermen, judging by the number of boat trailers often in the parking area and the recent provision of a boat jetty.

Data from the site are presented in Table 23 and illustrated in Figure 15, with a statistical summary provided in Table 24.

Table 23 Analytical results for the Patea River at the boatramp, Patea

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	0930	4650	<1	<1	<1	15.6	24
24.11.10	0915	4680	4	7	5	17.4	18
6.12.10	0805	4700	3	3	3	18.8	33
6.01.11	0840	4730	4	<1	4	20.2	22
10.01.11	1125	4680	<1	7	<1	19.8	16
3.02.11	0830	4580	33	24	33	19.7	13
11.02.11	1545	4680	<1	<1	<1	21.0	6.6
18.02.11	0800	4670	4	5	4	19.7	12
21.02.11	0955	4690	7	<1	7	20.9	6.4
10.03.11	1100	4630	15	3	16	19.1	17
21.03.11	0900	4590	4	7	4	19.0	18
25.03.11	1200	4570	3	3	3	18.1	31
12.04.11	1415	4700	6	2	6	17.6	35

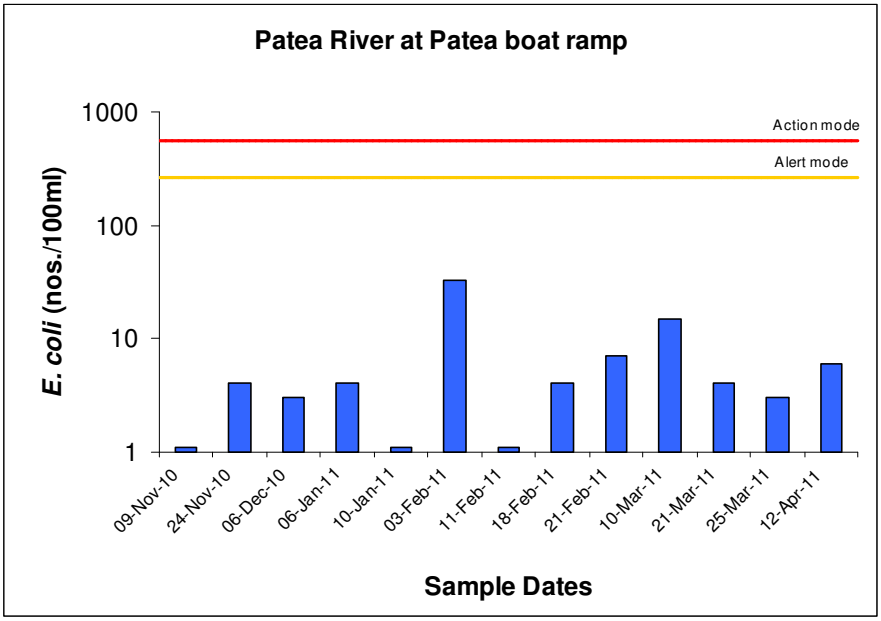


Figure 15 *E. coli* numbers for the Patea River at the boatramp, Patea during the survey season

Table 24 Statistical results summary for the Patea River at the boatramp, Patea

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	4570	4730	4680
E. coli	nos/100ml	13	<1	33	4
Enterococci	nos/100ml	13	<1	24	3
Faecal coliforms	nos/100ml	13	<1	33	4
Temperature	°C	13	15.6	21.0	19.1
Turbidity	NTU	13	6.4	35	18

This ring plain river drains an extensively developed agricultural catchment. The survey site is situated some 45km downstream of the Patea HEP dam, 300 metres upstream of the river mouth. There are consented dairy ponds' treated wastes discharges in the catchment upstream of the site and the consented upgraded Patea Wastewater Treatment Plant discharge 0.7km upstream of the boatramp. River water was usually slightly turbid in appearance with high conductivity levels typical of seawater ingress at high tide.

Water temperatures had a moderate range of 5.4˚C, a narrower than expected range as a result of the coastal seawater influence, with a maximum of 21.0˚C recorded in mid afternoon in mid February 2011 when the river was in normal flow. Most of the samples were collected before 1415 hours and therefore maximum river temperatures (which tend to occur later in the afternoon) were seldom sampled.

Bacteriological water quality was very good for the lower reaches of this Taranaki ring plain river draining a predominantly agricultural catchment principally as a result of the coastal seawater influence under high tide conditions (median: 4 *E.coli* per 100mls and 3 enterococci per 100mls). The existing recreational sampling programme was performed around higher tidal conditions for SEM trend purposes (due to its incorporation within the coastal sites programme) at times when public usage is likely to be more predominant at this site. Poorer bacteriological water quality could be expected under outflowing low tide conditions as emphasised by a consent monitoring programme undertaken at low tide at this site over the same recreational period when a median *E. coli* bacterial number of 105 per 100mls (with counts ranging from 53 to 320 per 100mls) was found with numbers tending to be higher when seawater intrusion was less apparent.

3.2.4.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 25.

Table 25 Bacterial guidelines performance at the Patea River at the boatramp, Patea site [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	0 [0]	0 [0]

(Designation: freshwater contact recreational area)
No single sample fell within the 'Alert' mode or within the 'Action' mode at any time during the monitoring period.

The bacteriological water quality at this site was within the acceptable guideline for contact recreational usage throughout the season recognising that all sampling occasions coincided with high tides and therefore a predominance of higher quality saline water mixing with poorer quality river water at this estuarine site. This was consistent with data for the nearby 'Mana' Bay coastal site adjacent to the river mouth monitored in the current season [median *E.coli*: 18 per 100 mls] for consent and SEM purposes.

3.2.4.2 Comparison with previous summers' surveys

Three previous SEM sampling seasons have been surveyed at this site. Otherwise prior sampling has been confined to consent monitoring surveys (TRC 2010b). A statistical comparison of each of the three summers' survey data is presented graphically in Appendix V for all sites. A much shorter data period exists for the Patea River (at Patea boat ramp) site which was added in 2007-2008. These data are summarised in Table 26 and illustrated in Figure 16.

Table 26 Summary *E. coli* bacteriological water quality data (nos/100ml) all summer surveys in the Patea River at the boat ramp, Patea

Summer	07/08	08/09	09/10	10/11
Minimum	1	1	1	<1
Maximum	190	87	82	33
Median	5	9	11	4

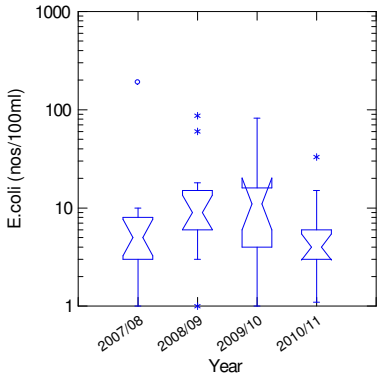


Figure 16 Box & whisker plots for all summer surveys of *E. coli* bacterial numbers for the Patea River at the boat ramp, Patea

Relatively similar (very low) median *E. coli* numbers have been found by these three seasons' surveys with a much narrower range of counts and the lowest maximum value found in the most recent season. Trend analysis of median *E. coli* numbers will not be performed until the sampling period has encompassed ten seasons of data collection at this site.

3.2.5 Waingongoro River at Eltham camp

No bathing usage of this river site was recorded at the time of sampling surveys but camp activities were recorded occasionally as the camp was occupied on several occasions. The site is used as part of the camp's activities. Sheep were present in the paddock adjacent to this unfenced site on occasions.

Data from the site are presented in Table 27 and illustrated in Figure 17 with a statistical summary provided in Table 28. River flow records are illustrated in Figure 18.

Table 27 Analytical results for the Waingongoro River at Eltham camp

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	1235	11.9	32	19	32	15.5	1.5
24.11.10	1150	12.5	76	17	88	15.6	1.4
6.12.10	1100	12.9	140	25	160	17.4	1.9
6.01.11	1205	11.2	180	530	180	17.6	2.0
10.01.11	1035	11.7	100	120	110	15.3	1.6
3.02.11	1145	12.6	210	560	220	17.8	1.7
11.02.11	1215	12.3	220	440	230	17.0	1.7
18.02.11	1105	12.5	150	180	150	17.0	1.3
21.02.11	1255	12.6	140	100	140	18.9	1.4
10.03.11	1400	11.0	110	82	120	15.2	1.8
21.03.11	1140	15.4	490	260	500	14.1	2.1
25.03.11	1045	11.0	240	210	240	13.9	2.7
12.04.11	1225	11.4	120	48	120	12.8	2.0

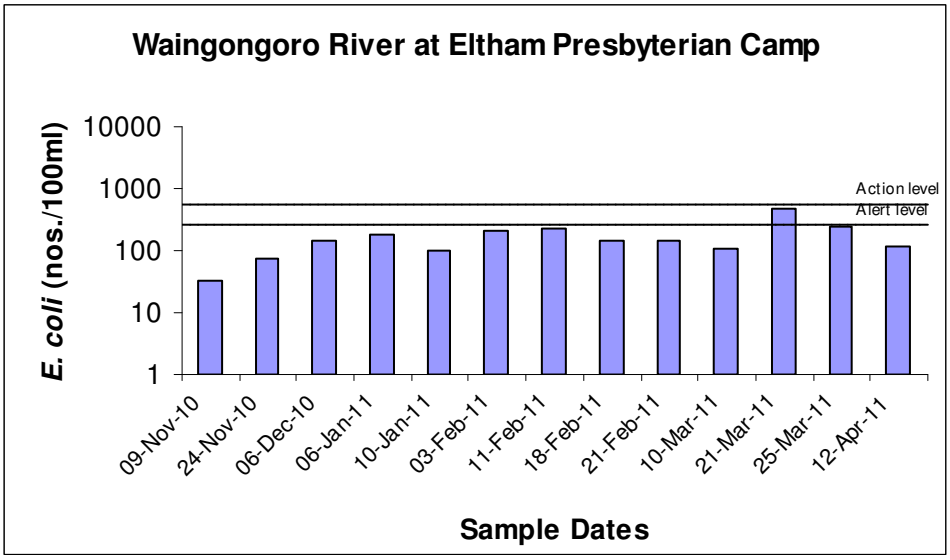


Figure 17 *E. coli* numbers for the Waingongoro River at Eltham Camp during the survey season

Table 28 Statistical results summary for the Waingongoro River at Eltham camp

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	11.0	15.4	12.3
E. coli	nos/100ml	13	32	490	140
Enterococci	nos/100ml	13	17	560	120
Faecal coliforms	nos/100ml	13	32	500	150
Temperature	°C	13	12.8	18.9	15.6
Turbidity	NTU	13	1.3	2.7	1.7

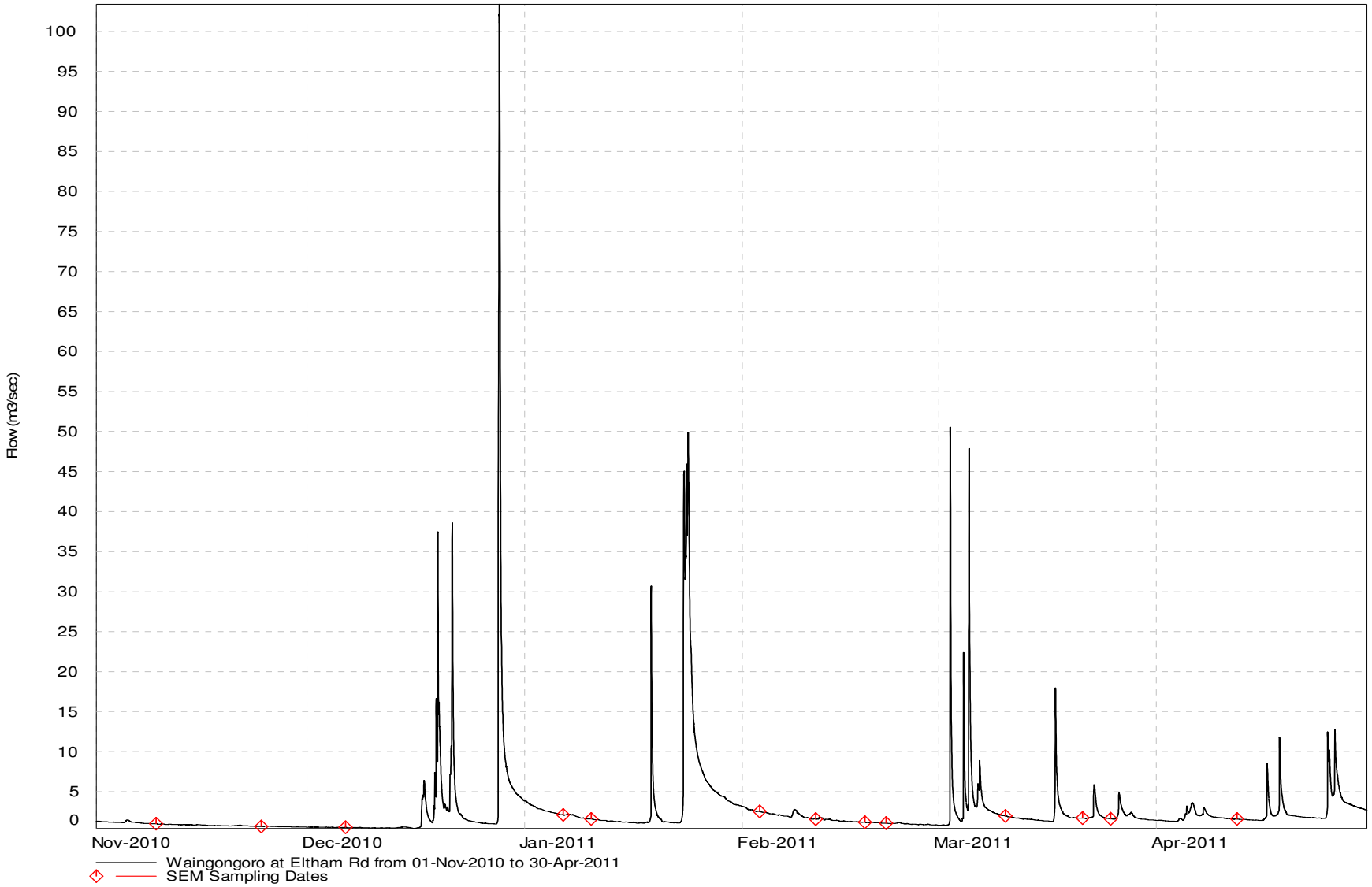


Figure 18 Waingongoro at Eltham Rd from 01 November 2007 to 15 April 2008 (NOTE: Waingongoro at Eltham Rd flow data from 8th Jan 2010 onwards is unaudited data)

This ring plain river drains an extensively developed agricultural catchment, with the survey site situated in Eltham some 21km below the National Park boundary. River water was consistently relatively clear in appearance with moderate conductivity levels. Water temperatures were within a moderate range of 6.1 ˚C and with a relatively typical maximum of 18.9 ˚C recorded at 1255 hours in mid February 2011. All samples were collected before 1405 hours and therefore higher river temperatures (which tend to occur later in the afternoon) were not recorded.

Bacteriological water quality was in the range typical of the mid reaches of the Taranaki ring plain river draining a predominantly agricultural catchment. This was also apparent in comparison with the nearby Eltham Road (state of the environment physicochemical monitoring) site where a median *E.coli* count of 160 per 100mls (range: 6 to 59000 per 100mls) has been recorded by monthly sampling since 1995. The highest counts in the current survey tended to occur later in the period under more variable flow conditions (Figures 17 and 18). A relatively good standard of compliance with dairy wastes disposal practices was found by the annual inspection round.

3.2.5.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 29.

Table 29 Bacterial guidelines performance at the Waingongoro River, Ohawe Beach [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	1 [8]	0 [0]

(Designation: freshwater contact recreational area)

Only one single sample fell within the 'Alert' mode and no samples reached the 'Action' mode. The highest sample count (in the 'Alert' mode) occurred toward the very end of the season in March 2011 during a moderately low flow period but a few days after the first river fresh for about 10 days. The count fell below the 'Alert' mode some four days later. In general these results were a small improvement on typical bacteriological counts obtained at the site just downstream at Eltham Road (by the longer term physicochemical SEM programme), although the latter programme samples more random river flows and variable climatological conditions.

In terms of contact recreational usage guidelines, bacteriological water quality at this site was within the acceptable level for almost the entire period and no warning signage was required during the period.

3.2.5.2 Comparison with previous summers' surveys

A statistical comparison of each of the fifteen summer's survey data is presented graphically in Appendix V for all sites. A shorter data period exists for the Waingongoro River (at Eltham camp) site which was added to the programme in

2001-2002. These data for the Waingongoro River site at Eltham camp are summarised in Table 30 and illustrated in Figure 19.

Table 30 Summary of *E. coli* bacteriological water quality data (nos/100 ml) for all summer surveys in the Waingongoro River at Eltham camp to date

Summer	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11
Minimum	31	63	23	51	54	23	57	77	57	32
Maximum	870	550	360	1700	430	290	420	500	270	490
Median	230	230	100	170	130	110	160	130	160	140

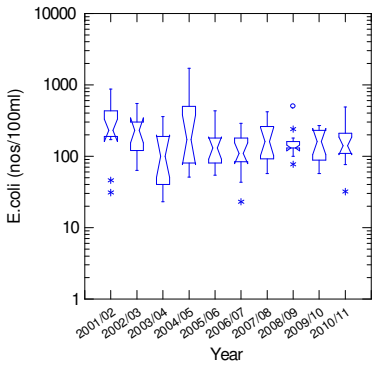
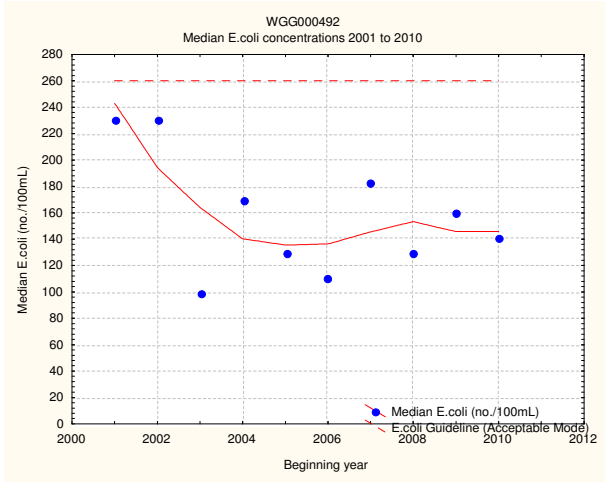


Figure 19 Box and whisker plots for all summer surveys of *E. coli* bacterial numbers of the Waingongoro River at Eltham Camp

Similar *E.coli* bacterial water quality was indicated by a median count within the mid range of those recorded by the nine preceding seasons (Figure 19). There was a relatively narrow range of counts over the 2010-2011 season in comparison with the nine other seasons monitored previously.

Trend analysis of these median *E.coli* numbers has been performed for the ten seasons of data by first applying a LOWESS fit (tension 0.4) to a time scatterplot of the median numbers (Figure 20) and testing the significance of any trend using the Mann-Kendall test at the 5% level followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.



N = 10
Kendall tau = - 0.205
p level = 0.410 [>FDR, p = 0.615]
N/S at p <0.05

Figure 20 LOWESS trend plot of median *E.coli* numbers (per 100ml) at the Waingongoro River, Eltham camp for the 2000 to 2011 period

An insignificant temporal trend of slightly increasing median *E.coli* numbers was found over the ten seasons of monitoring. None of these seasonal medians exceeded the 'Alert' or 'Action' modes although those of the first two seasons were relatively high.

3.2.6 Waingongoro River at Ohawe Beach

Some bathing usage of this site was recorded with the site used more frequently for whitebaiting (in season) and picnicking. Stock occasionally were present in the paddock upstream of the site but were not noted at the river's edge or in the river as had previously been the case on occasions in the past (TRC, 2010). The data for this site are presented in Table 31 and illustrated in Figure 21, with a statistical summary provided in Table 32. River flow records are illustrated in Figure 22.

Table 31 Analytical results for the Waingongoro River at Ohawe Beach

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	1030	19.3	28	20	32	14.8	2.3
24.11.10	1010	20.8	43	20	43	17.0	2.4
6.12.10	0855	21.8	96	130	98	19.2	2.4
6.01.11	0945	15.2	180	180	190	20.2	2.0
10.01.11	1225	15.5	8	28	8	20.0	2.0
3.02.11	0935	16.3	180	330	180	20.0	2.3
11.02.11	1445	17.0	34	66	34	20.6	1.9
18.02.11	0855	17.4	120	98	130	19.5	2.0
21.02.11	1055	17.9	100	98	120	20.5	1.5
10.03.11	1200	14.2	110	420	120	15.5	1.8
21.03.11	0955	17.7	160	430	200	15.4	2.6
25.03.11	1255	14.8	51	130	60	16.1	3.2
12.04.11	1515	15.7	110	91	110	15.4	2.6

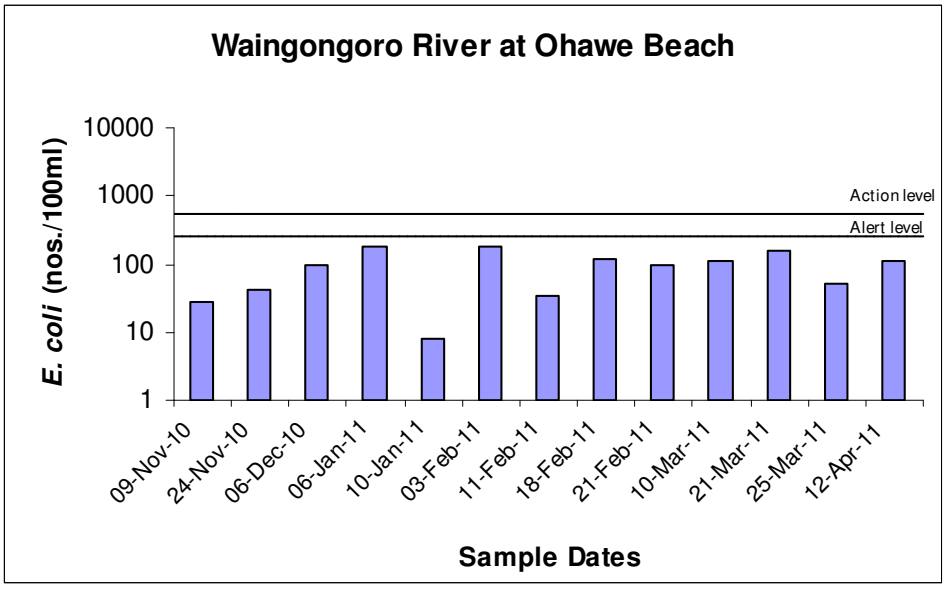


Figure 21 *E.coli* numbers for the Waingongoro River at Ohawe Beach during the survey season

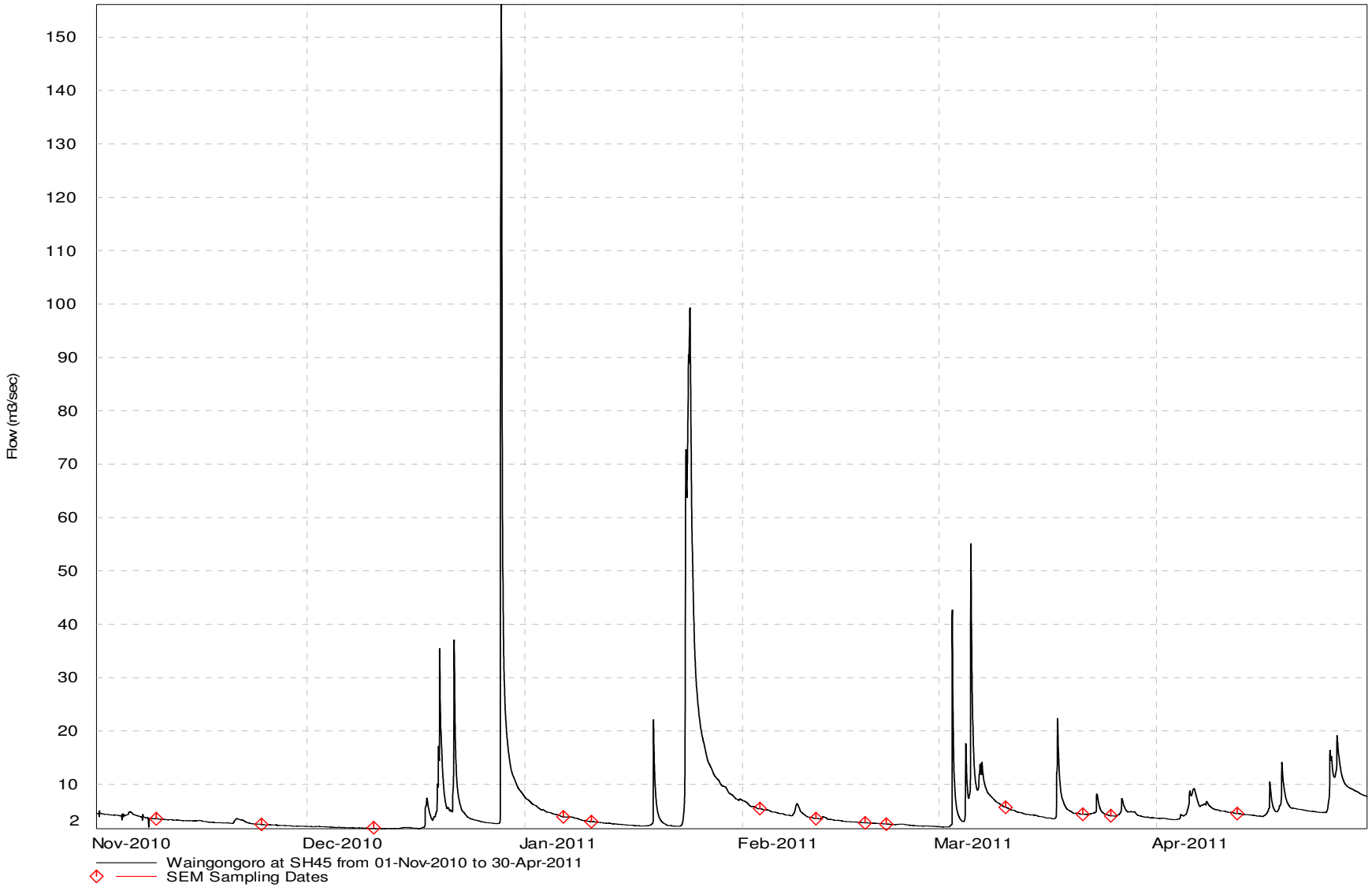


Figure 22 River flow in the Waingongoro River at SH45 during the survey period

Table 32 Statistical results summary for the Waingongoro River at Ohawe Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	14.2	21.8	17.0
E. coli	nos/100ml	13	8	180	100
Enterococci	nos/100ml	13	20	430	98
Faecal coliforms	nos/100ml	13	8	200	110
Temperature	°C	13	14.8	20.6	19.2
Turbidity	NTU	13	1.5	3.2	2.3

This river drains an extensively farmed catchment and receives point source industrial wastes (in its mid-reaches) and dairy pond wastes (more than 110 treatment systems) discharges. These industrial (meatworks) wastes are predominantly diverted out of the river (to land irrigation) during summer months while the Eltham WWTP municipal and industrial wastes discharge was diverted permanently out of the catchment in winter 2010. The site is in the lower reaches of the river immediately upstream of the mouth, but is generally not tidal, although occasional upstream surging in the ponded area has been noted during low river flow and higher tidal conditions during late summer. These conditions were less prevalent during the 2010-2011 season.

The range of water temperatures was relatively narrow (5.8°C) with a maximum of 20.6°C recorded in mid afternoon in mid February 2011. However, as most sampling was not performed before 1300 hrs at this site, this maximum could be expected to have been exceeded later in the day from time-to-time during the period of the survey. Conductivity values were typical of the lower reaches of a Taranaki ring plain and showed minimal salt water influence on any occasion despite sampling low flow conditions coincident with higher tides. Turbidity values were indicative of relatively clean water on most occasions and were consistent with the presence of some fine colloidal material in suspension (ie: 2 to 3 NTU on most occasions), typical of the lower reaches of a ring plain river.

Bacteriological water quality (Figure 21) was relatively good for the lower reaches of a Taranaki ring plain river receiving agricultural run-off and point source discharges in the catchment. This was also apparent in comparison with the nearby (state of the environment physicochemical monitoring) site at SH45 where monthly sampling since mid 1998 has recorded a median *E. coli* count of 200 per 100 mls. On-site monitoring of dairy farm wastes disposal systems indicated a generally good standard of compliance in the catchment during the survey period. Uncontrolled stock access to the river, particularly during low flow periods, was not as apparent during the current season as it had been historically.

3.2.6.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 33.

Table 33 Bacterial guidelines performance at the Waingongoro River, Ohawe Beach [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	0 [0]	0 [0]

(Designation: freshwater contact recreational area)

No single sample was recorded in the 'Alert' category or in the 'Action' mode. Counts were consistently between 100 and 200 *E.coli* per 100 mls under late summer lower flow conditions.

Bacteriological water quality at this site was within the acceptable guidelines for contact recreational usage for the entire survey period noting the diversion of the Eltham WWTP discharge out of the catchment and consistent with on-site monitoring of dairy wastes disposal systems having a relatively good compliance standard for this large catchment at the time of the summer contact recreation survey period.

3.2.6.2 Comparison with previous summers' surveys

A statistical comparison of each of the fifteen summer's survey data is presented graphically in Appendix V for all sites. These summer data for the Waingongoro River site at Ohawe Beach are summarised in Table 34 and illustrated in Figure 23.

Table 34 Summary of *E. coli* bacteriological water quality data (nos/100 ml) for all summer surveys in the Waingongoro River at Ohawe Beach to date

Summer	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11
Minimum	88	43	17	34	38	46	31	43	54	31	31	9	31	26	8
Maximum	310	650	300	240	850	660	14000	280	940	380	410	5000	870	1000	180
Median	185	130	80	180	170	160	110	110	130	96	100	100	120	96	100

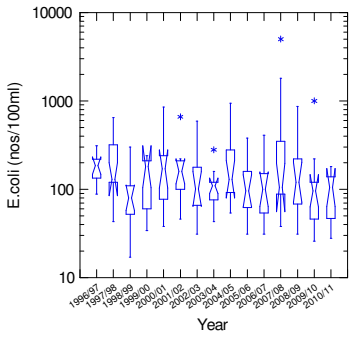
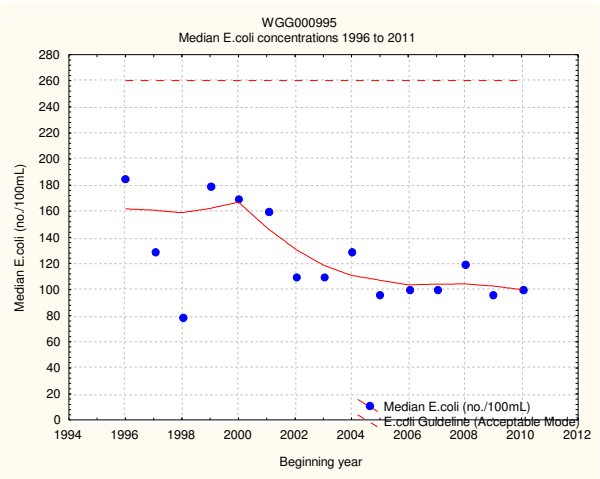


Figure 23 Box and whisker plots for all summer surveys of *E. coli* bacterial numbers in the Waingongoro River at Ohawe Beach

Median *E. coli* bacteria number for the 2010-2011 period was very similar to those found in the previous six seasons, maintaining the general trend of improvement in bacterial water quality recorded over the last nine seasons (Figure 23). The narrowest range of *E. coli* numbers was recorded in the recent 2010-2011 period in comparison with all past seasons' ranges to date, including the lowest seasonal maximum to date.

Trend analysis of these median *E.coli* numbers has been performed for the fifteen seasons of data by first applying a LOWESS fit (tension 0.4) to a time scatterplot of the median numbers (Figure 24) and testing the significance of any trend using the Mann-Kendall test at the 5% level followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.



N = 15
Kendall tau = - 0.461
p level = 0.017 [>FDR, p = 0.066]
Significant at p< 0.05,
not significant after FDR.

Figure 24 LOWESS trend plot of median *E.coli* numbers (per 100ml) for the 1996 to 2011 period at the Waingongoro River Ohawe beach site

A strongly decreasing trend in median *E.coli* number was found over the fifteen seasons of monitoring and this has been particularly apparent over the past six seasons. Although the trend was statistically significant at the p <0.05 level, it was not significant after FDR application. None of these seasonal medians exceeded the 'Alert' or 'Action' modes.

3.2.7 Kaupokonui River at Beach Domain

Limited usage at this site by bathers was recorded at the time of the sampling surveys while other recreational usage (mainly fishing (whitebaiting was common in early season) and picnicking) was occurring on a majority of survey occasions at this popular site. The site was characterised by the tidal ponded nature of this reach of the river, particularly under very high tide and low river flow conditions. No stock access was noted near the river's edge upstream of the domain during the current season. Data from this site are presented in Table 35 and illustrated in Figure 26, with a statistical summary provided in Table 36. River flow records are provided in Figure 25.

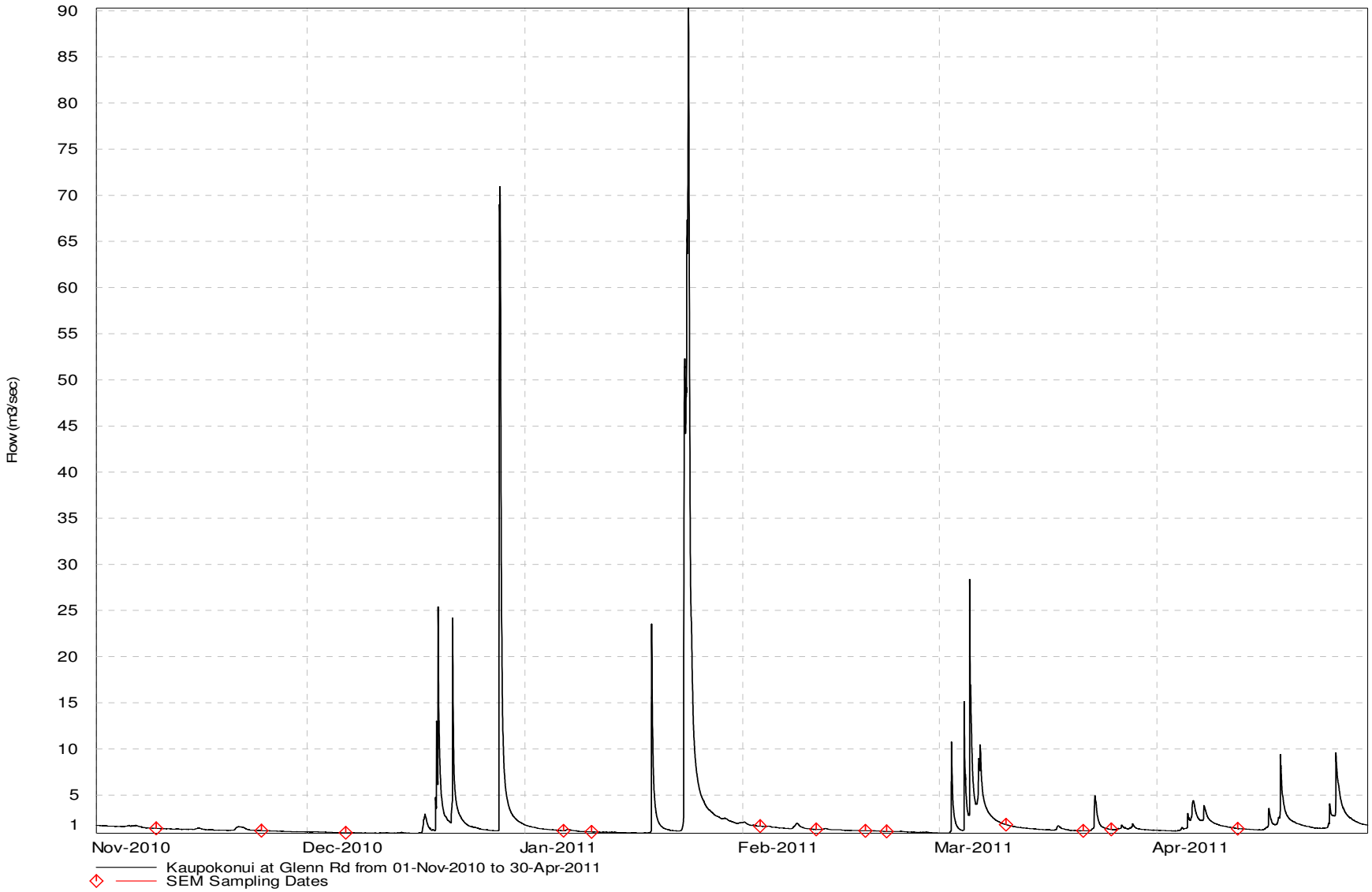


Figure 25 River flow in the Kaupokonui River during the survey period

Table 35 Analytical results for the Kaupokonui River at the beach domain

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	1100	18.1	42	16	42	17.8	1.2
24.11.10	1035	18.8	340	42	360	18.2	1.4
6.12.10	0930	18.4	76	60	86	19.1	1.3
6.01.11	1020	34.9	96	140	96	21.8	1.3
10.01.11	1310	15.6	43	73	43	22.4	1.3
3.02.11	1010	19.0	150	260	150	21.8	1.1
11.02.11	1410	16.2	20	52	20	21.6	1.0
18.02.11	0925	107	120	380	120	19.5	1.1
21.02.11	1120	127	37	120	37	22.4	1.7
10.03.11	1225	14.2	68	100	68	18.2	1.4
21.03.11	1015	3130	130	180	140	17.5	1.5
25.03.11	1320	15.1	110	120	120	17.0	1.9
12.04.11	1540	14.9	68	42	68	17.1	1.1

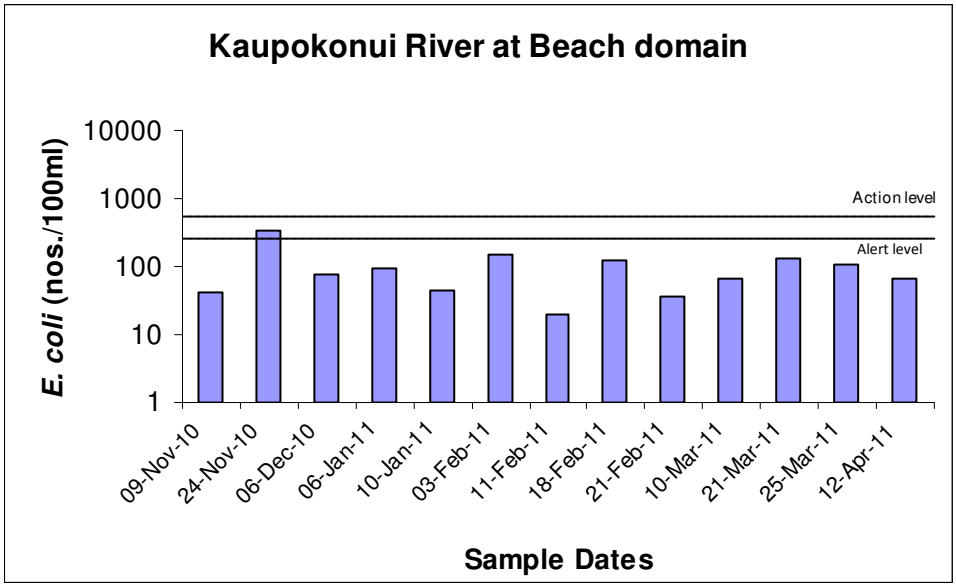


Figure 26 *E. coli* numbers for the Kaupokonui River at the beach domain during the survey season

Table 36 Statistical results summary for the Kaupokonui River at the beach domain

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	14.2	3130	18.4
E. coli	nos/100ml	13	20	340	76
Enterococci	nos/100ml	13	16	380	100
Faecal coliforms	nos/100ml	13	20	360	86
Temperature	°C	13	17.0	22.4	19.1
Turbidity	NTU	13	1.0	1.9	1.3

This river also drains an extensively farmed catchment and receives point source wastes discharges from dairy pond wastes treatment systems, and in its mid-reaches from Fonterra Kapuni Company (cooling waters) and the upgraded Kaponga township municipal wastewater treatment system.

The site is located in the lower reach of the river near the mouth and on six occasions was noted as tidal (incoming surges or ponded) in terms of flow conditions. However, elevated conductivity levels indicating some seawater influence were recorded only on three occasions later in summer 2011 at high tide and under low flow conditions (Figure 25). Otherwise these levels were relatively stable (14.2 to 19.0 mS/m at 20°C) and typical of the lower reaches of a Taranaki ring plain river.

Turbidity levels were typical of lower ring plain river reaches throughout the period with minimal impacts of suspended algal matter, unlike in many previous survey periods. Foaming was seldom noticeable in the ponded reach of the river and toward the edges, unlike in previous periods when foaming and suspended algal matter reduced the aesthetic quality of this reach from time to time. Water temperatures varied over a relatively narrow range of 5.4°C with a maximum of 22.4°C recorded in late February 2011 and the majority greater than 18˚C. This temperature was recorded in late morning and would be expected to have been exceeded later in the day, particularly as all but one of the surveys were performed before 1415 hrs at this site.

Bacteriological water quality was relatively good and very similar to that recorded in the lower reaches of the nearby Waingongoro River (see section 3.2.6), and better than typical of the lower reaches of a Taranaki ring plain river draining a predominantly agricultural catchment. On-site monitoring of dairy farm wastes disposal systems indicated a generally good standard of compliance during the summer bathing period.

Previous surveys have noted that bacteriological water quality deteriorated in this tidal pool reach of the river probably as a result of the ponding of the flow and 'accumulation' of slugs of poorer quality downstream flow. This may have been in response to upstream stock access, point source dairy effluent discharges and/or various other non-point source runoff, emphasising the importance of control and surveillance of dairy shed wastewater disposal practices, particularly in lower reaches of ring plain catchments utilised for bathing and recreational purposes. It has also been noted that lower faecal coliform to enterococci ratios than usual have been recorded at this (and other) tidal ponded sites, possibly as a result of vegetative enterococcal sources and/or better enterococci survival in tidal pool environments, particularly sites characterised by ebbing and flowing within the ponded river mouth reach. This again was apparent later in summer (Table 35) when enterococci numbers were often well in excess of *E. coli* numbers.

One 'Alert' level was recorded, toward the start of the season, but a much lower count was recorded by the following survey twelve days later. Previously, many flocks of ducks have been recorded upstream of this site.

Relatively poor aesthetic water quality has been noted from time-to-time at this site, mainly in the form of surface froth (particularly toward the river margins) and fragments of periphyton suspended in the water column. These aspects of physical water quality were not as apparent during the 2010-2011 season.

3.2.7.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 37.

Table 37 Bacterial guidelines performance at the Kaupokonui River beach domain site [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	1 [8]	0 [0]

(Designation: freshwater contact recreational area)

One individual sample was recorded in the 'Alert' mode during the season. Minimal rainfall preceded this count with numbers returning to typical levels by the time of the scheduled survey following this rise in count.

In summary, bacteriological water quality at this ponded lower river site was within guidelines for contact recreational usage for the majority of the survey period consistent with the generally good compliance standards found by on-site monitoring of dairy wastes disposal systems in the mid and lower reaches of this catchment.

3.2.7.2 Comparison with previous summers' surveys

A statistical comparison of each of the fifteen summer's survey data is presented graphically in Appendix V for all sites. These summer data for the Kaupokonui River site at the Beach Domain are summarised in Table 38 and illustrated in Figure 27.

Table 38 Summary of *E. coli* bacteriological water quality data (nos/100ml) for all summer surveys in the Kaupokonui River at the Beach Domain

Summer	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11
Minimum	26	31	3	7	17	46	46	<8	40	14	26	15	29	20	20
Maximum	360	2100	580	780	2000	400	630	200	880	280	2500	850	890	440	340
Median	110	360	130	80	120	110	130	77	92	160	140	77	210	100	76

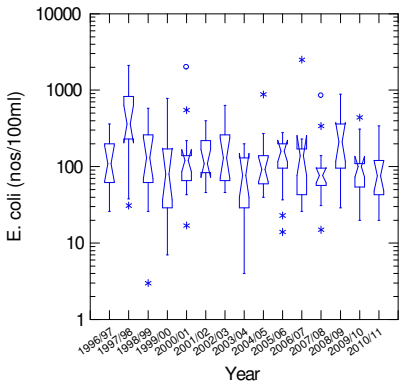
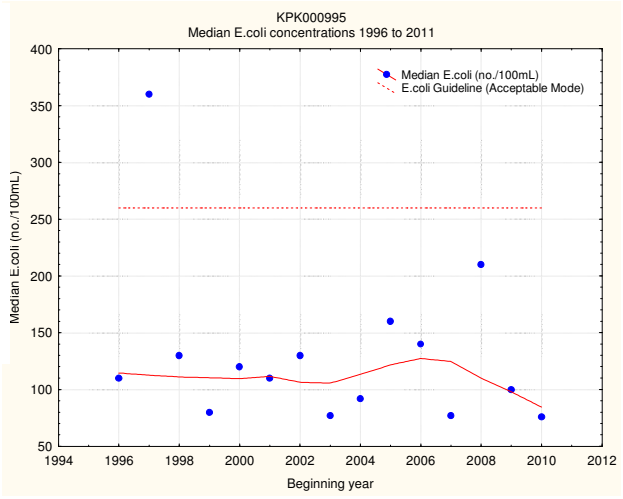


Figure 27 Box and whisker plots for all summer surveys of *E. coli* bacterial numbers in the Kaupokonui River at the Beach Domain

An improved *E. coli* bacterial water quality in terms of median number, and very similar to the lowest of the range found by most of the previous fourteen survey

seasons, was recorded over the 2010-2011 season (Figure 27). The median *E. coli* count was lower (by 1 *E.coli* per 100 mls) than all other season's medians to date (Table 38), and the seasonal maximum was the third lowest of the 15 years of record.

Trend analysis of these median *E. coli* numbers has been performed for the fifteen seasons of data by first applying a LOWESS fit (tension 0.4) to a time scatterplot of the median numbers (Figure 27) and testing the significance of any trend using the Mann-Kendall test at the 5% level followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.



N = 15
Kendall tau = -0.174
p level = 0.366 [>FDR p = 0.615]
N/S at p < 0.05

Figure 28 LOWESS trend plot of median *E. coli* numbers (per 100ml) at the Kapokonui River beach domain site for the 1996 to 2011 period

A slight, but not statistically significant, decreasing trend in median *E. coli* counts was found over the fifteen seasons of monitoring. One of these seasonal medians (1997-1998 season) exceeded the 'Alert' mode (early in the period), but none have exceeded the 'Action' mode.

3.2.8 Lake Opunake

No bathing usage of the lake was noted on any occasion, but picnicking, fishing and jet-skiing activities were recorded occasionally at the time of sampling surveys. Ducks were also noted regularly on the lake or in the vicinity of the lake edge and numbers were high on most occasions. These wildfowl were present frequently on the picnic area grass verge adjacent to the lake edge, attracted from time to time by food provided by picnickers. A thick unsightly, algal scum was prevalent on the lake surface for several weeks during mid to late summer (Photo 1).

Photo 1 Surface mats of algae, Lake Opunake; December 2010

Data from this site are presented in Table 39 and illustrated in Figure 29, with a statistical summary provided in Table 40.

Table 39 Analytical results for Lake Opunake

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	1155	14.1	42	20	42	18.2	1.0
24.11.10	1055	13.0	20	12	23	18.5	1.2
6.12.10	1000	14.4	52	21	66	20.1	1.6
6.01.11	1050	13.2	48	34	48	21.5	1.5
10.01.11	1340	13.6	17	20	20	21.9	1.0
3.02.11	1040	13.5	3800	700	3800	20.9	0.9
11.02.11	1250	-	570	180	830	18.9	230
18.02.11	1025	15.7	1000	54	1100	19.5	280
21.02.11	1155	14.5	8	390	8	22.7	4.9
10.03.11	1255	13.7	100	46	110	17.5	1.7
21.03.11	1045	13.9	200	78	220	16.6	0.9
25.03.11	1350	12.4	83	48	86	17.3	1.2
12.04.11	1605	13.6	80	48	84	16.8	1.0

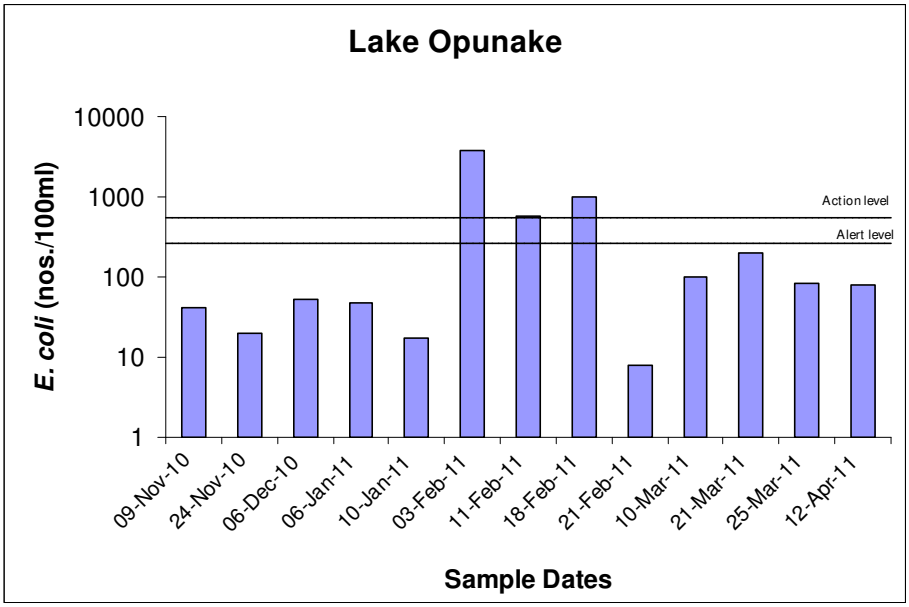


Figure 29 *E. coli* numbers for Lake Opunake during the survey season

Table 40 Statistical results summary for Lake Opunake

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	12	12.4	20.0	13.7
E. coli	nos/100ml	13	8	3800	80
Enterococci	nos/100ml	13	12	700	48
Faecal coliforms	nos/100ml	13	8	3800	84
Temperature	°C	13	16.6	22.7	18.9
Turbidity	NTU	13	0.9	280	1.2

The lake is formed by the diversion of water from the nearby Waiaua River (as a component of the Waiaua HEP scheme) and is close to the coast. Water clarity was generally relatively good (median turbidity: 1.2 NTU; range of turbidity: 270 NTU) as a result of minimal sediment disturbance or suspended algae in the water column with the exception of a period when an extensive surface algal scum was wind blown toward the sample site. Generally good water quality was due, in part, to the lake's short residence time, with regular replenishment as a result of local hydroelectric power scheme usage. Water temperatures were moderately high (above 17˚C) for the majority of the period with a maximum of 22.7˚C (in mid February 2011) and a moderate range of 6.1˚C. Conductivity varied over a narrow range (3.3. mS/m @ 20˚C) reflecting river flow conditions.

Generally bacteriological quality was moderate, influenced in part by the inflow to the lake originating from the lower reaches of a river draining a developed catchment. Elevated numbers, above 200 *E. coli* per 100 mls, were found in the latter half of the season co-incidental with higher wildfowl numbers in the immediate vicinity of the site. Marked fluctuations in counts were most likely associated with this bird population, particularly in instances where ducks had been attracted to the immediate vicinity of the monitoring site by picnickers feeding the birds.

3.2.8.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 41.

Table 41 Bacterial guidelines performance at Lake Opunake
[% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	0 [0]	3 [23]

(Designation: freshwater contact recreational area)

Three single sample exceedances of the 'Action' mode occurred during the period but no single samples were recorded within the 'Alert' mode. Sampling subsequent to the initial 'Alert' level in early February 2011 showed high *E. coli* numbers within eight to 15 days of this exceedance. These counts remained in the 'Alert' mode for about two weeks. No installation of 'health warning' signage by STDC was performed but publicity was given to the state of the lake by the local newspaper and on both relevant websites.

3.2.8.2 Comparison with previous summers' surveys

A statistical comparison of each of the summers' *E. coli* survey data is presented graphically in Appendix V for all sites. The five summers of data collection for the Lake Opunake site are summarised in Table 42 and illustrated in Figure 30.

Table 42 Summary of *E. coli* bacteriological water quality data to date (nos/100 ml) for all summer surveys at Lake Opunake to date

Summer	06/07	07/08	08/09	09/10	10/11
Minimum	33	26	54	64	8
Maximum	720	1300	2800	320	3800
Median	110	130	210	220	80

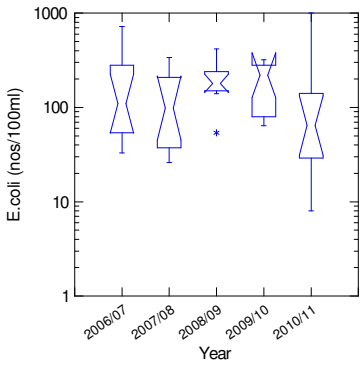


Figure 30 Box and whisker plots for the summer SEM survey of *E. coli* bacteria numbers at Lake Opunake

A lower median *E. coli* number was found in the latest season in comparison with those found by the four previous seasons' surveys but the widest range of counts was found during the latest season (Figure 30).

Trend analysis of median *E. coli* numbers will not be performed for this site until ten seasons' data are available.

3.2.8.3 Cyanobacteria

Microscopic scans of seven samples were performed for the presence and enumeration of cyanobacteria during the season. The results of these analyses are presented in Table 43.

Table 43 Cyanobacteria counts (cells/ml) for Lake Opunake [Health warning:>15,000 cells/ml]

Date	Cyanobacteria total cell count (cells/ml)
16.11.10	nil
29.11.10	nil
14.12.10	nil
13.01.11	nil
27.01.11	nil
15.02.11	nil
16.03.11	nil

No cyanobacteria were detected in any of these samples. No cyanobacteria had been found in this lake during the 2006-2007, 2008-2009 or 2009-2010 seasons, but their presence (in low numbers) on three occasions in the latter part of the 2007-2008 season followed a lengthy, extremely low flow period. However, these numbers did not reach levels requiring the issue of 'health warnings' during that season. The relatively short lake water residence time (due to hydroelectric power generation usage) may be a controlling factor in these populations.

3.2.9 Timaru Stream at Weld Road (near mouth)

Bathing usage was noted at this site on only one sampling occasion while minimal picnicking and fishing usage was recorded at the times of sampling surveys during the season. The site had been a popular camping area (until the camp was closed by NPDC during early 2005) and access point to the sea coast. The site, to a certain extent tidal, showed varying degrees of saltwater penetration, particularly in the latter half of the period under low flow recession conditions.

Data from this site are presented in Table 44 and illustrated in Figure 31, with a statistical summary provided in Table 45.

Table 44 Analytical results for the Timaru Stream at Weld Road

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	0935	74.6	31	33	31	14.2	0.8
24.11.10	0940	17.0	110	40	110	16.5	0.4
6.12.10	0815	215	350	120	350	19.0	2.5
6.01.11	0915	57.0	410	280	420	9.5	0.9
10.01.11	1140	16.1	28	83	28	19.5	0.5
3.02.11	0830	20.8	280	670	280	19.8	0.6
11.02.11	1310	9.2	84	140	88	18.3	0.5
18.02.11	0805	4220	280	450	280	18.0	3.2
21.02.11	0950	343	220	890	220	20.8	7.8
10.03.11	1055	12.8	170	150	170	15.4	0.5
21.03.11	0900	4090	240	260	250	16.1	0.8
25.03.11	1200	70.4	180	250	180	16.6	0.7
12.04.11	1415	13.0	96	76	96	16.8	0.5

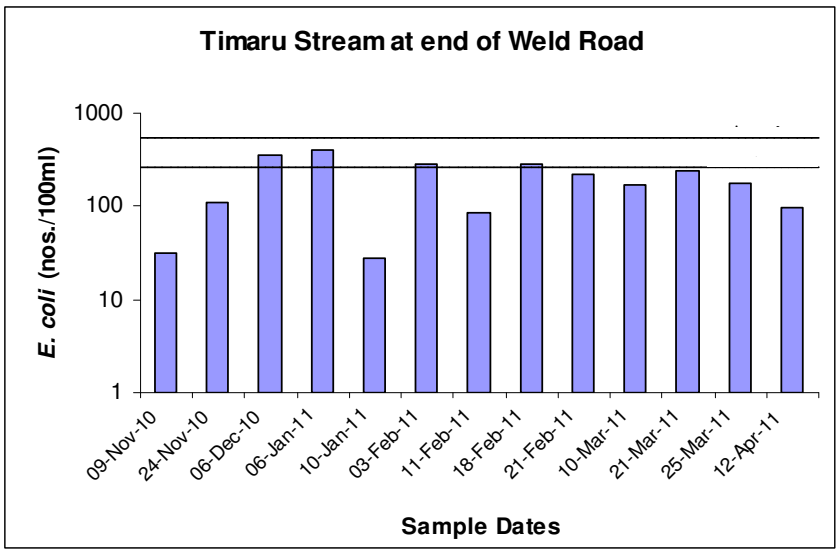


Figure 31 *E.coli* numbers for the Timaru Stream at Weld Road during the survey season

Table 45 Statistical results summary for the Timaru Stream at Weld Road

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	9.2	4220	57.0
E. coli	nos/100ml	13	28	410	180
Enterococci	nos/100ml	13	33	890	150
Faecal coliforms	nos/100ml	13	28	420	180
Temperature	°C	13	14.2	20.8	18.0
Turbidity	NTU	13	0.4	7.8	0.7

This river drains a moderately farmed catchment (five consented dairy farm discharges) receiving point and non-point source discharges from these dairy farms, although it is relatively short in length, rising partly in the nearby Kaitake range and the north-western area of Egmont National Park. Conductivity levels varied markedly in response to saltwater penetration at this site and were elevated on several occasions during the season and particularly in mid to late summer-autumn under low stream flow conditions. Turbidity levels generally were very low consistent with the clear appearance of the river. No algal cover was noted in association with the good aesthetic appearance of the river due to the sandy substrate at this deeper, ponded site. Water temperature varied over a moderate range of 6.6°C with a maximum water temperature of 20.8°C recorded in mid morning in mid February 2011. This maximum could have been expected to have been exceeded later in the day during summer as all of the sampling was undertaken before 1420 hrs.

Bacteriological water quality at this site was generally below average but more typical of the lower reaches of a smaller Taranaki ring plain stream draining an agricultural catchment. Elevated counts occurred sporadically, more particularly under low flow conditions in the mid to latter part of the sampling period. There was no installation of 'health warning' signage at the site by NPDC as there was no exceedance of the 'Action' level. No problems with wastes disposal practices were recorded by the annual dairy farms inspection round. Stock access to the lower stream (which was crossed to reach adjacent farmland at times) during the prolonged dry period of the 2007-2008 seasons (requiring remedial action after incidents were reported by the general public) was not repeated in the 2009-2010 or 2010-2011 season. Surveys in other rivers with tidal pool reaches have found that bacteriological water quality may deteriorate probably as a result of ponding of the flow and 'accumulation' of slugs of poorer quality downstream flow. It has also been noted at these tidal pool sites that lower faecal coliform to enterococci ratios than usual have been recorded possibly due to vegetative sources and/or better enterococci survival in pool environments characterised by the ebb and flow in the ponded river/stream mouth.

3.2.9.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 46.

Table 46 Bacterial guidelines performance at the Timaru Stream, Weld Road site [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	4 [31]	0 [0]

(Designation: freshwater contact recreational area)

Four single samples were recorded in the 'Alert' mode, but none were recorded in the 'Action' mode during the period. Poorer bacteriological water quality coincided with the localised rainfall events some two to three days prior to two surveys coincident with low stream flow and/or limited higher quality seawater intrusion at the site. No follow-up surveys were necessary on these occasions and the erection of health warning signage was not required.

In terms of the new contact recreation guidelines, the bacteriological water quality at the site was moderately good, although partly affected by the ponding caused by the site's proximity to the sea coast. Good compliance with dairy sheds' wastes disposal practices was monitored in this catchment during the season.

3.2.9.2 Comparison with previous summers' surveys

A statistical comparison of each of the summers' survey data is presented graphically in Appendix V for all sites. These summer data for the Timaru Stream site at the end of Weld Road (which has been monitored for twelve summers) are summarised in Table 47 and illustrated in Figure 32.

Table 47 Summary of *E. coli* bacteriological water quality data to date (nos/100ml) for all summer surveys in the Timaru Stream at lower Weld Road

Summer	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11
Minimum	40	23	31	77	31	140	77	84	38	43	46	92	46	28
Maximum	410	710	1400	540	660	1000	410	1000	460	480	930	440	560	410
Median	280	210	160	180	180	260	220	260	220	200	180	230	290	180

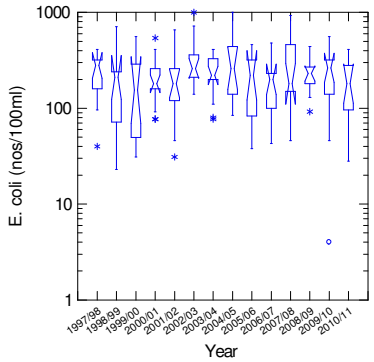
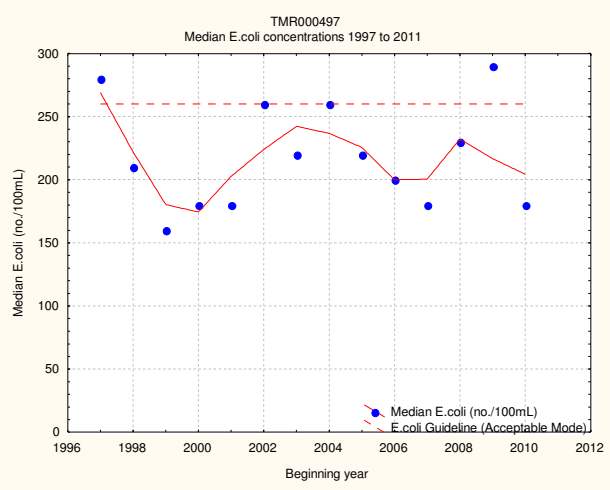


Figure 32 Box and whisker plots for all summer surveys of *E.coli* bacterial numbers in the Timaru Stream at lower Weld Road

The median *E. coli* count for the 2010-2011 season indicated some improvement in bacterial water quality (Table 47) in comparison with recent seasons and was lower than the majority of previous seasons' counts. Counts over the 2010-2011 season had a relatively narrow range (Figure 32), with no counts reaching the 'Action' mode, and the equal lowest seasonal maximum found over the 15 years of monitoring.

Trend analysis of these median *E. coli* numbers has been performed for the fourteen seasons of data by first applying a LOWESS fit (tension 0.4) to a time scatterplot of the median numbers (Figure 32) and testing the significance of any trend using the Mann-Kendall test at the 5% level followed by Benjamini-Hockberg False Discovery Rate (FDR) analysis.



N = 14
Kendall tau = +0.058
p level = 0.774 [>FDR, p = 0.784]
N/S at p < 0.05

Figure 33 LOWESS trend plot of median *E. coli* numbers (per 100ml) at Timaru Stream, lower Weld Road site for the 1997 to 2011 period

A very slight increasing trend in median *E. coli* numbers has been found over the fourteen seasons of monitoring. However, this trend has not been statistically significant. None of these seasonal medians exceeded the 'Action' mode, although the median for the initial and previous seasons entered the 'Alert' mode and two others have been very close to the 'Alert' mode.

3.2.10 Waimoku Stream at Oakura beach

The easy access to this small stream which flows and often ponds across Oakura beach, the most popular recreational beach in north Taranaki, provides a convenient contact recreational area for children in particular. Bacteriological monitoring and various investigation surveys have been performed at this site from time-to-time, particularly in relation to septic tank wastes disposal in Oakura, the interpretation of coastal bathing beach water quality and for assessment of the effectiveness of Council's water policies. Such a survey at the mouth and upstream of Oakura township during the 1998-1999 bathing period, and two more recent catchment surveys in the 2004-2005 (TRC, 2005) and 2009-2010 periods (TRC, 2010a) indicated that the relatively high bacterial counts found in the stream at the coast were also apparent in the Waimoku Stream upstream of the township, where some stock access and extensive wildfowl populations contributed to high bacterial numbers. This was particularly apparent in certain tributaries upstream of the coastal township and

therefore not attributable to domestic wastes disposal practices within Oakura township. Historical data have highlighted the poor bacteriological water quality regularly exhibited in this stream resulting in considerable publicity (see Appendix VI). More appropriate, permanent health warning signage was erected by NPDC in consultation with the Area Health Board early in the 2009-2010 season in positions of public prominence. As a consequence, bacteriological samples collected during the first half of the 2009-2010 programme were also analysed by Cawthron Institute, Nelson using faecal source DNA tracking marker techniques in association with high *E.coli* counts at this site. All samples were found to contain bacteria indicative of wildfowl (principally ducks and other species) origin, with minimal ruminant (cattle) sources and no indications of human origin. (Note: At that time there were no markers available for pukeko faecal identification). These results were consistent with the conclusions of the catchment survey reports referenced above. Planting of streamside vegetation as a component of a riparian management scheme (in cooperation with landowners) although contributing to aspects of bacteriological water quality improvement in the lower reaches of the stream may also provide habitat for wildfowl species. Management of dairy farm wastes in the catchment will also continue to be monitored in conjunction with bathing water quality as a long-term component of the SEM programme. The recent completion of a newly reticulated sewerage system (by NPDC in 2010), with Oakura domestic wastewater collected and pumped to the New Plymouth WWTP, will also ensure that surface water bacteriological water quality will not be compromised by septic tank effluent seepages in the township.

Very limited contact recreation (paddling) was observed at this very shallow stream site at the time of sampling visits. Although few people were present on the beach in the immediate vicinity of the stream mouth on most sampling occasions, this site is known to be popular with children and families during favourable weather conditions at holiday periods and weekends (see Appendix VI, TRC 2009a and TRC, 2010). The channel flowed directly across the beach until late in the season when the stream migrated northwards and ponded on the beachfront prior to entering the sea.

Data from the site are presented in Table 48 and illustrated in Figure 34, with a statistical summary provided in Table 49.

Table 48 Analytical results for the Waimoku Stream at Oakura beach

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	1000	16.8	1300	230	1300	13.2	2.2
24.11.10	1000	15.1	1800	350	2000	13.0	36
6.12.10	0840	15.5	2700	2200	2700	16.5	3.1
6.01.11	0930	14.5	3400	3100	3400	17.6	4.6
10.01.11	1205	15.0	13000	12000	13000	17.0	5.9
3.02.11	0855	15.6	2800	3500	2900	17.9	3.1
11.02.11	1330	14.5	1500	1800	1500	17.4	3.6
18.02.11	0830	14.8	3400	4100	3500	16.0	3.2
21.02.11	1010	15.4	2400	3800	17000	17.2	3.9
10.03.11	1120	15.2	2700	2500	2800	13.5	2.5
21.03.11	0930	15.2	1800	2200	1900	14.7	2.6
25.03.11	1230	16.4	1500	1900	1500	15.5	2.4
12.04.11	1445	15.6	6300	2300	6300	15.4	3.5

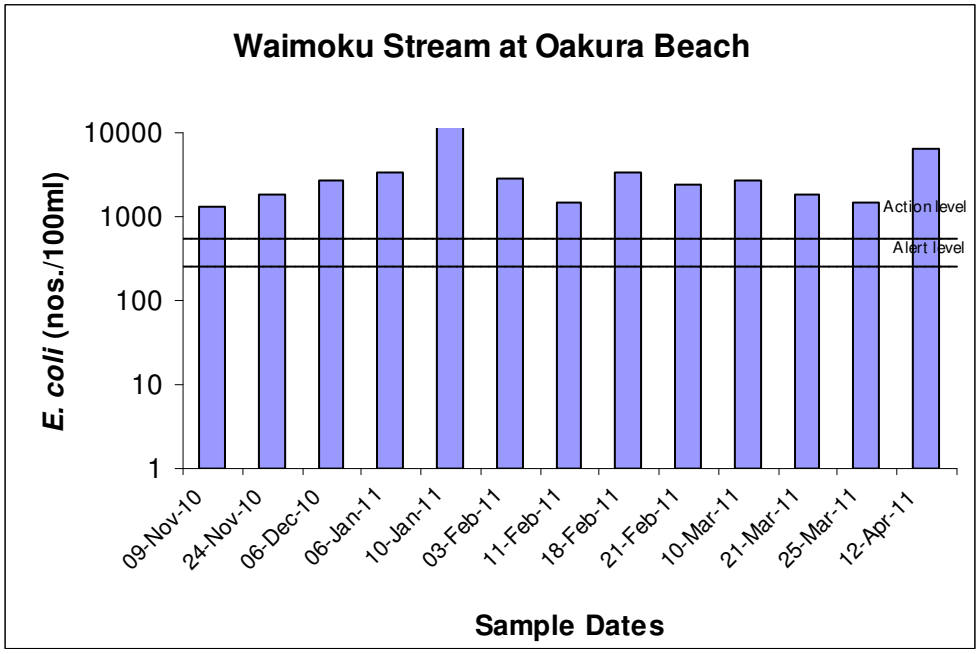


Figure 34 *E. coli* numbers for the Waimoku Stream at Oakura beach during the survey season

Table 49 Statistical results summary for the Waimoku Stream at Oakura beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	14.5	16.8	15.2
E. coli	nos/100ml	13	1300	13000	2700
Enterococci	nos/100ml	13	230	12000	2300
Faecal coliforms	nos/100ml	13	1300	17000	2800
Temperature	°C	13	13.0	17.9	16.0
Turbidity	NTU	13	2.2	36	3.2

This stream drains a catchment receiving very few dairy point source discharges together with non-point source run-off from these dairy farms over a relatively short distance from its source in the Kaitake Range to the sea. The stream flows for a short distance through Oakura township where sewage disposal was via septic tank or similar systems to ground soakage although a pumped reticulation system (transferring sewage to the New Plymouth Wastewater Treatment Plant) has been completed recently by NPDC although not all domestic wastes have been connected to this system. Wildfowl (ducks and pukekos in particular) are present in significant numbers on the stream or at the stream edges, particularly in some of the smaller tributaries (TRC, 2005 and TRC, 2010a), and have been confirmed as major sources of faecal contamination by recent DNA marker investigations.

Conductivity levels were relatively stable throughout the survey period with no salt water intrusion recorded. The stream was slightly turbid in appearance and the streambed had a cover (up to 100%) of periphyton growth (although not by thick mats). Water temperatures varied over a relatively narrow range of 4.9°C with a maximum water temperature of 17.9°C recorded in mid morning in early February 2011. Water temperatures later in the day could be anticipated to exceed the maximum recorded as nearly all sampling at this site was performed prior to 1335 hrs.

Bacteriological water quality was very poor throughout the survey period, and characterised by high enterococci, *E. coli* and faecal coliform counts. Although elevated counts were also found in other ponded tidal reaches of ringplain rivers and streams, counts in this small stream were comparatively much higher. On-site farm dairy waste disposal practices during the season indicated a good standard of compliance. However, the presence of ducks (and other wildfowl (particularly pukekos)) and some stock access to this small stream and tributaries upstream of the survey site could be expected to have contributed substantially to these elevated bacterial counts (see TRC, 2005 and TRC, 2010a).

3.2.10.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 50.

Table 50 Bacterial guidelines performance at the Waimoku Stream, Oakura beach [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	0 [0]	13 [100]

(Designation: freshwater contact recreational area)

No single samples were recorded in the 'Alert' mode with every one of the 13 single samples within the 'Action' mode.

In summary, bacterial water quality at this site at the mouth of this small stream consistently failed to achieve the guidelines for contact recreational usage throughout the survey period. However, the coastal bathing waters monitored

adjacent to the stream mouth (main Oakura beach) met the enterococci guidelines on 19 of 21 sampling occasions (median: 20 per 100ml) with two individual samples entering the 'Alert' or 'Action' modes but no occurrence (of two consecutive samples) entering the 'Alert' mode in these coastal waters. The proximity of this small inflow from the Waimoku Stream only slightly impacted on the main beach water quality as indicated by the median *E. coli* number (15 per 100 mls) for the SEM season (TRC, 2011).

3.2.10.2 Comparison with previous summers' surveys

A statistical comparison of each of the summers' survey data is presented graphically in Appendix V for all sites. Shorter data periods exist for the Waimoku Stream at Oakura beach which was first included in the programme in 1999-2000. These summer data for the Waimoku Stream site at Oakura beach are summarised in Table 51 and Figure 35.

Table 51 Summary of *E. coli* bacteriological water quality data (nos/100ml) for all summer surveys in the Waimoku Stream at Oakura beach to date

Summer	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11
Minimum	200	85	250	300	450	440	560	390	730	700	1400	1300
Maximum	1700	900	1800	1700	1700	2200	6300	3200	8100	4600	6200	13000
Median	480	400	730	770	710	900	830	930	2100	1600	2800	2700

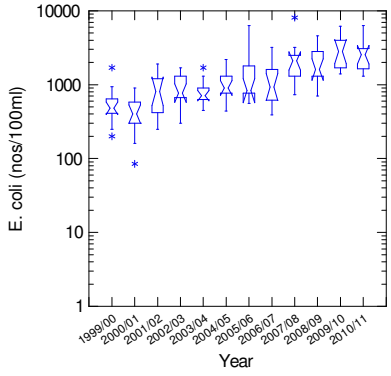
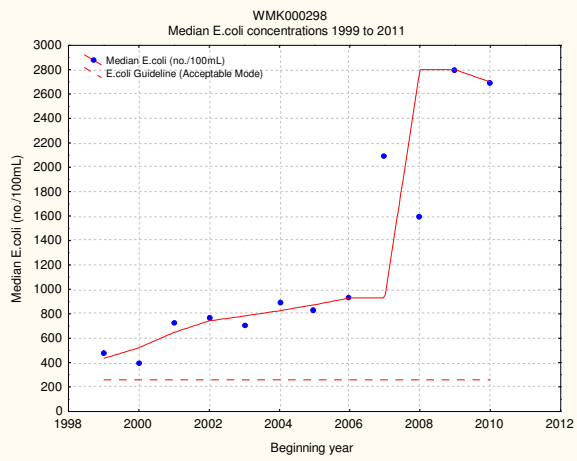


Figure 35 Box and whisker plots for all summer surveys of *E.coli* bacterial numbers in the Waimoku Stream at Oakura beach

The very high median *E. coli* count for the 2010-2011 season continued the more recent seasons' high median bacterial levels with the second highest median of the twelve seasons' surveys and the widest range of counts to date. The trend of relatively high minimum counts also continued with the second highest seasonal minimum count to date, indicative of poor bacterial water quality, long associated with this small predominantly agricultural catchment stream with high wildfowl numbers.

Trend analysis of median *E.coli* numbers has been performed for the twelve seasons of data by first applying a LOWESS fit (tension 0.4) to a time scatterplot of the median numbers (Figure 36) and testing the significance of any trend using the Mann-Kendall test at the 5% level followed by Benjamini-Hockberg False Discovery Rate (FDR) analysis.



N =12
Kendall tau = +0.818
p level = 0.0002 [>FDR, p = 0.0026]
Significant at p<0.05 and after FDR

Figure 36 LOWESS trend plot of median *E. coli* numbers (per 100ml) at Waimoku Stream, Oakura Beach site for the 1999 to 2011 period

A steady increase in median *E. coli* numbers has been found over the twelve seasons of monitoring with a marked increase over the past four seasons. This trend was statistically very significant. All of these seasonal medians exceeded the 'Alert' mode and the latest ten seasonal medians have all exceeded the 'Action' mode.

3.2.11 Oakura River below SH45

Some bathing usage, fishing, and whitebaiting (in season), were recorded at this site and often people were present on the riverbank at this very accessible tidal site where ponding and upstream surging frequently occurred under high tide conditions.

Data from the site are presented in Table 52 and illustrated in Figure 37, with a statistical summary provided in Table 53.

Table 52 Analytical results for the Oakura River below SH45

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	1020	23.8	19	5	19	16.9	0.4
24.11.10	1020	7.7	37	40	40	18.9	0.8
6.12.10	0900	58.8	100	46	110	19.0	0.4
6.01.11	1000	11.8	290	180	290	20.3	0.6
10.01.11	1220	8.6	34	69	34	21.0	1.0
3.02.11	0910	8.5	140	230	140	18.8	0.3
11.02.11	1250	7.0	71	96	77	19.0	0.3
18.02.11	0850	478	180	300	180	17.9	0.5
21.02.11	0915	113	150	210	150	20.5	0.6
10.03.11	1140	8.0	34	96	34	15.7	0.7
21.03.11	0945	325	160	210	160	16.1	0.5
25.03.11	1140	29.1	110	300	110	16.7	0.5
12.04.11	1340	8.4	26	58	26	16.6	0.4

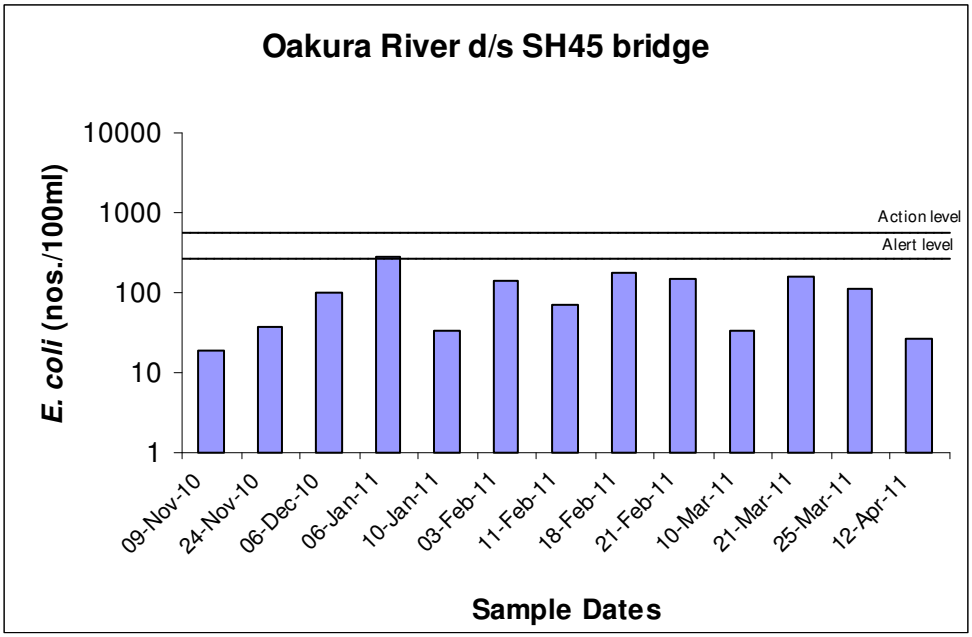


Figure 37 *E. coli* numbers for the Oakura River below SH45 during the survey season

Table 53 Statistical results summary for the Oakura River below SH45

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	7.0	478	11.8
E. coli	nos/100ml	13	19	290	100
Enterococci	nos/100ml	13	5	300	96
Faecal coliforms	nos/100ml	13	19	290	110
Temperature	°C	13	15.7	21.0	18.8
Turbidity	NTU	13	0.3	1.0	0.5

This river drains a mainly agricultural catchment (five consented dairy farm discharges) with the survey site established in the short tidal reach between SH45 and the mouth of the river. The river was noted as tidal with ponding or inflowing surges obvious on eleven sampling occasions. Conductivity levels indicated an influence of saltwater intrusion on at least six sampling occasions during the season, all with the more significant intrusion occurring during low flow conditions in the latter part of this season. On all occasions the river was clear in appearance with no algal substrate cover due to the sandy nature of much of the substrate. Water temperatures varied over a relatively narrow range (5.3°C) during the period reaching a maximum of 21.0°C near midday in mid January 2011, below the maximum water temperature which might be anticipated later in the day as all sampling at this site occurred before 1345 hrs.

Bacteriological water quality was above average, with the majority of *E. coli* counts below 185 per 100 mls. Bacteriological water quality was not dissimilar to that found elsewhere in ponded tidal reaches of ringplain rivers and streams, probably as a result of the occasional 'accumulation' of slugs of poorer quality downstream flow. This may have resulted from upstream stock access, agricultural non-point source runoff and/or point source discharges. Lower faecal coliform to enterococci ratios (than normally found at flowing river sites) were occasionally recorded possibly as a

result of vegetative sources of enterococci and/or better survival rates in tidal pool environments; sites which are characterised by ebbing and flowing within the ponded river mouth reach. An elevated count in early January 2011 was coincident with the presence of seagulls and no saltwater intrusion under low flow conditions. Regular sampling four days after this elevated count, found a very low *E. coli* count (34 per 100mls). A good standard of compliance with on-site dairy waste disposal practices was recorded during the season.

3.2.11.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 54.

Table 54 Bacterial guidelines performance at the Oakura River SH45 bridge site [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	1 [8]	0 [0]

(Designation: freshwater contact recreational area)

Only one single sample fell within the 'Alert' mode and no samples entered the 'Action' mode. This occurrence coincided with low flow conditions but a subsequent sample showed a return to lower than normal levels, well below the 'Alert' mode, within four days of the occurrence. No health warning signage was required to be displayed at this site by NPDC following the 'Alert' level exceedance.

However, generally bacteriological water quality was better than average for the lower reaches of a Taranaki ringplain river, and within the acceptable single sample guidelines for contact recreational usage for the majority of the sampling occasions.

3.2.11.2 Comparison with previous summers' surveys

A statistical comparison of each of the fifteen summers' survey data is presented graphically in Appendix V for all sites. These summer data for the Oakura River site below the SH45 bridge are summarised in Table 55 and illustrated in Figure 38.

Table 55 Summary of *E. coli* bacteriological water quality data (nos/100ml) for all summer surveys in the Oakura River downstream of SH45

Summer	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11
Minimum	7	28	42	24	23	31	26	43	11	46	23	31	34	60	19
Maximum	260	1100	240	540	310	580	420	1200	820	380	330	2400	450	2500	290
Median	34	110	100	77	80	120	120	120	140	160	220	140	180	150	100

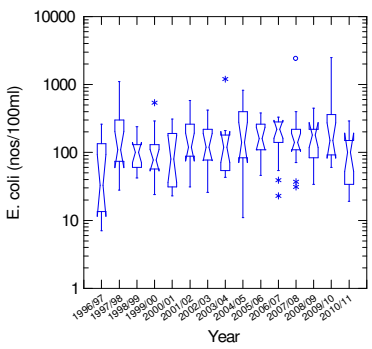
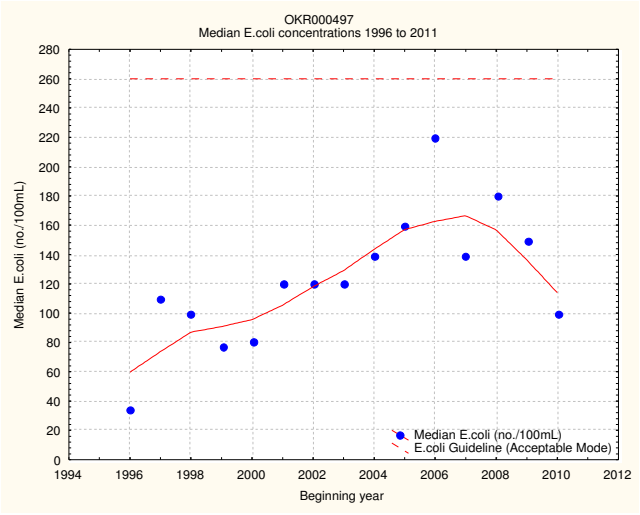


Figure 38 Box and whisker plots for all summer Oakura River downstream of SH45

The median *E. coli* count was the lowest since the 2000-2001 season (Figure 38). A narrow range of *E. coli* counts was recorded, one of the smallest over the fifteen year period, due to the absence of high counts. No median *E. coli* counts have exceeded the new guidelines for contact recreational usage over the fifteen seasons of monitoring.

Trend analysis of these median *E. coli* numbers has been performed for the fifteen seasons of data by first applying a LOWESS fit (tension 0.4) to a time scatterplot of the median numbers (Figure 39) and testing the significance of any trend using the Mann-Kendall test at 5% level followed by Benjamini-Hockberg False Discovery Rate (FDR) analysis.



N = 15
Kendall tau = + 0.566
p level = 0.0033 [>FDR, p = 0.020]
Significant at p < 0.05; not significant are p < 0.01 after FDR.

Figure 39 LOWESS trend plot of median *E.coli* numbers (per 100ml) at the Oakura River, SH 45 site for the 1996 to 2011 period

A strong increasing trend in median *E. coli* counts has been found over the fifteen seasons of monitoring. Although statistically significant at the p< 0.05 level, it was not significant at p< 0.01 after FDR application. However, none of these seasonal medians exceeded the 'Alert' or 'Action' modes. This increasing trend may warrant further investigation if it continues although it should be noted that there has been an improving trend in median *E.coli* counts over the past four year period.

3.2.12 Waitara River at the town wharf, Waitara

Minimal bathing usage of this river site at the new town wharf was recorded at the time of sampling surveys, the majority of which were in the morning. Whitebaiting, kayaking, rowing, and fishing were noted from time-to-time at this site with walking and picnicking as an additional activity.

Concerns relating to the source of faecal bacteria found at this site by past monitoring, led TRC to undertake additional microbial source tracing (MST) using DNA marker techniques (see Section 3.2.10) at four sites in the lower Waitara River. These sampling surveys were undertaken on five occasions (three under low flow, low tide conditions; one under low flow, high tide conditions and one following a river flood) between November 2010 and April 2011. The results of these investigations are presented in Appendix VII. In summary, faecal bacteria found at

this Town Wharf site were sourced predominantly from cattle (under all tidal and flow conditions) with some indication of human origin under high tide and flood conditions. Upstream (Bertrand Road site) faecal bacteria were totally of cattle origin whilst downstream (on both sides of the river mouth), faecal bacteria of cattle (all occasions), wildfowl and human (occasional) derivation were found.

Regular sampling data from the site are presented in Table 56 and illustrated in Figure 40 with a statistical summary provided in Table 57. River flow information is illustrated in Figure 41.

Table 56 Analytical results for the Waitara River at the town wharf, Waitara

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	1120	1020	32	40	32	17.3	1.2
24.11.10	1015	1930	74	31	74	18.0	2.1
6.12.10	0830	2340	76	33	76	19.6	3.2
6.01.11	1010	483	170	37	170	21.9	2.8
10.01.11	1300	347	19	9	20	22.7	2.0
3.02.11	1000	726	150	97	150	19.6	2.4
11.02.11	1345	182	23	9	23	23.2	1.6
18.02.11	0920	1390	420	230	430	21.8	2.1
21.02.11	1110	2260	56	39	58	22.9	2.6
10.03.11	1155	429	570	110	570	17.5	16
21.03.11	1020	1120	120	33	120	18.6	2.6
25.03.11	1215	775	66	42	66	17.9	2.6
12.04.11	1510	255	100	21	100	17.0	6.7

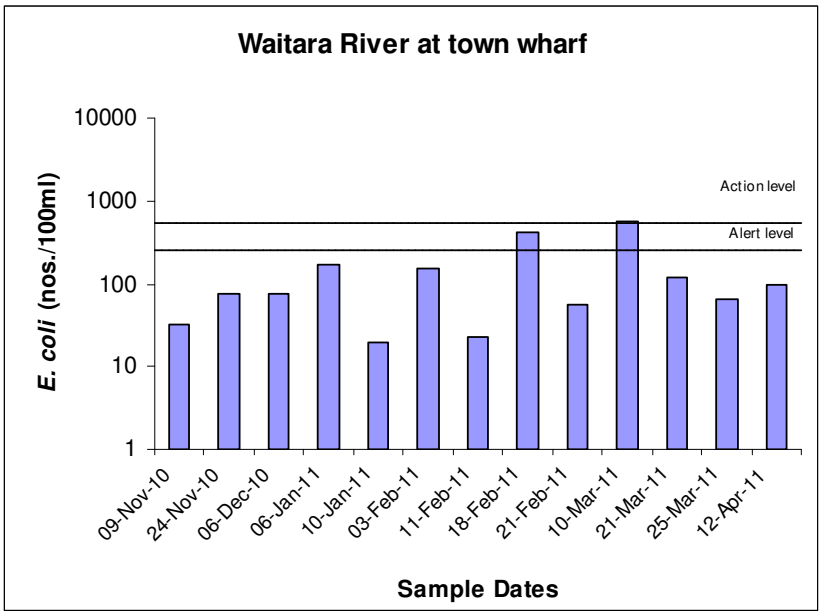


Figure 40 *E.coli* numbers for the Waitara River at the town wharf, Waitara during the survey season

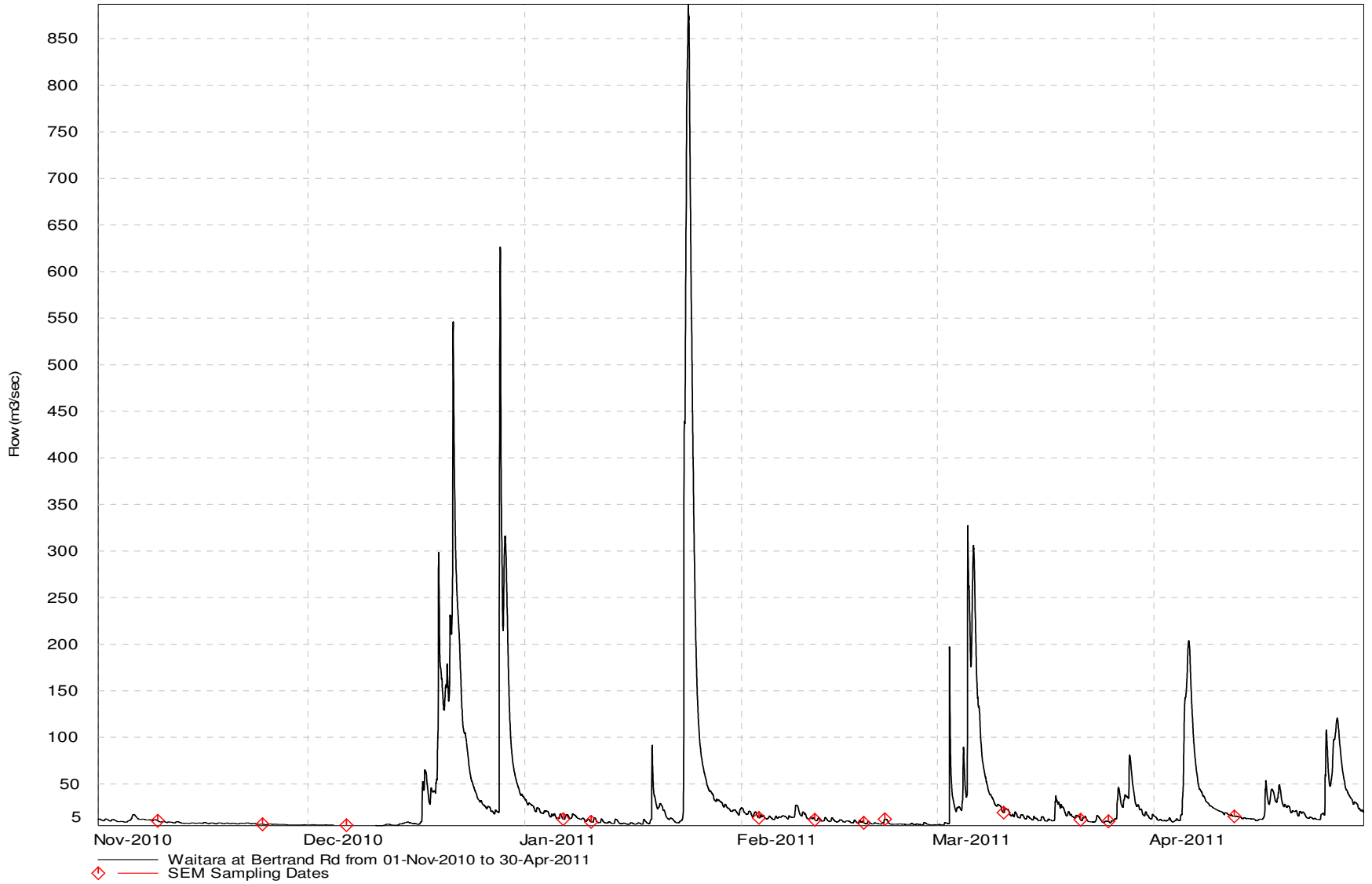


Figure 41 Flow in the Waitara River at Bertrand Road during the survey period

Table 57 Statistical results summary for the Waitara River at the town wharf, Waitara

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20° C	mS/m	13	182	2340	775
E. coli	nos/100ml	13	19	570	76
Enterococci	nos/100ml	13	9	230	37
Faecal coliforms	nos/100ml	13	20	570	76
Temperature	˚C	13	17.0	23.2	19.6
Turbidity	NTU	13	1.2	16	2.6

This ring plain and eastern hill country river drains an extensively developed agricultural catchment. The survey site is situated in the lower tidal reaches of this large river, some 2km upstream of the river mouth. There are consented dairy pond's treated wastes discharges in the catchment upstream of the site particularly in the Manganui River sub catchment (see 3.2.14). River water was generally slightly turbid and occasionally turbid in appearance with elevated conductivity levels typical of seawater ingress near high tide on all sampling occasions.

Water temperatures had a moderate range of 6.2˚C due to the coastal seawater influence, with a maximum of 23.2˚C recorded at 1345 hrs in mid February 2011. All but one of the samples were collected before 1350 hrs and therefore maximum river temperatures (which tend to occur later in the afternoon) were not sampled.

Bacteriological water quality was relatively good for the lower reaches of this large Taranaki eastern hill country and ring plain river draining a predominantly agricultural catchment despite some coastal seawater influence under high tide conditions (median 76 *E. coli* per 100mls and 37 enterococci per 100mls). The existing recreational sampling programme was performed around higher tidal conditions for SEM trend purposes (due to its incorporation within the coastal sites programme) at times when public usage is often more predominant at this site. Poorer bacteriological water quality might be expected under outflowing low tide conditions (see Appendix VII) although monitoring undertaken 6km further upstream (at the flow recorder site at Bertrand Road) over the same recreational period and base flow conditions found a median *E. coli* bacterial number of 66 per 100mls and a narrower range of *E. coli* numbers (21 to 360 per 100mls).

3.2.12.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 58.

Table 58 Bacterial guidelines performance at the Waitara River at the town wharf, Waitara [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	1 [8]	1 [8]

(Designation: freshwater contact recreational area)

One single sample fell within the 'Alert' mode and one within the 'Action' mode during the monitoring period. The 'Action' exceedance occurred about five to seven days following river freshes (Figure 41), coincident with more turbid river appearance indicative of the lag effects of rainfall run-off within this large catchment. The three-day post rainfall sampling protocols followed by the SEM programme for the other (ringplain) catchment sites are therefore not necessarily appropriate for this site near the mouth of this large predominantly eastern hill country catchment river. These issues were discussed with the Area Health Board and NPDC staff and appropriately worded health warning signage was permanently installed at the town wharf prior to the 2010-2011 season. Sampling a further 11 days later indicated that *E.coli* number had fallen below the 'Alert' level. Sampling 3 days after the 'Alert' level incident in mid February 2011 found that the *E.coli* number had returned to an acceptable level.

Generally, *E. coli* numbers were relatively good (i.e. < 170 per 100mls) for the majority of the sampling period and no exceedances of the guidelines were recorded during dry weather conditions (6 days or more after a river fresh).

3.2.12.2 Comparison with previous summers' surveys

One previous SEM sampling season has been monitored at this site. Therefore only a brief statistical comparison can be made with previous data. These data for the Waitara River at the town wharf, Waitara site are summarised in Table 59 and illustrated in Figure 42 for this, the second season of monitoring.

Table 59 Summary *E. coli* bacteriological water quality data (nos/100ml) for summer surveys in the Waitara River at the town wharf, Waitara

Summer	09/10	10/11
Minimum	92	19
Maximum	1700	570
Median	230	76

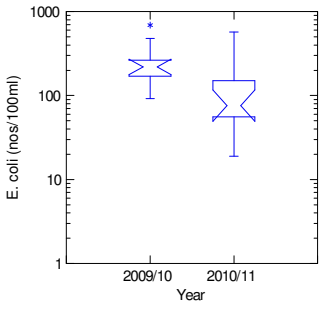


Figure 42 Box and whisker plots for all summer surveys of *E. coli* bacterial numbers for the Waitara River at the town wharf, Waitara

A relatively low median *E. coli* number was found by this second season's survey with a narrower range of counts found during the season due to fewer delayed effects of preceding freshes in this large, predominantly hill country catchment. Trend analysis of median *E. coli* numbers will not be performed until the sampling period has encompassed ten seasons of data collection at this site.

3.2.13 Urenui River at the estuary

Bathing usage of this site was moderate (on four of the sampling surveys) with some usage apparent for other activities (eg boating, fishing, and picnicking) at this tidal site. This is a very popular site during weekends and holiday periods (see TRC, 1999 and TRC, 2008a).

Data from the site are presented in Table 60 and enterococci counts (as the site is predominantly seawater) illustrated in Figure 43, with a statistical summary provided in Table 61.

Table 60 Analytical results for the Urenui River at the estuary

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	1015	4710	<1	<1	<1	16.2	3.7
24.11.10	0915	4720	<1	<1	<1	15.2	23
6.12.10	0935	4750	1	3	1	18.6	2.7
6.01.11	0905	4670	7	52	8	20.6	15
10.01.11	1140	4730	<1	1	<1	21.4	11
3.02.11	1050	4640	23	13	23	18.3	16
11.02.11	1250	4750	4	7	4	21.4	3.4
18.02.11	1010	4650	13	35	13	21.1	11
21.02.11	1005	4690	3	1	3	21.3	5.9
10.03.11	1045	4700	28	150	28	19.9	10
21.03.11	1130	4710	7	1	7	20.2	21
25.03.11	1120	4620	5	8	5	19.1	15
12.04.11	1415	4650	4	1	4	19.1	3.8

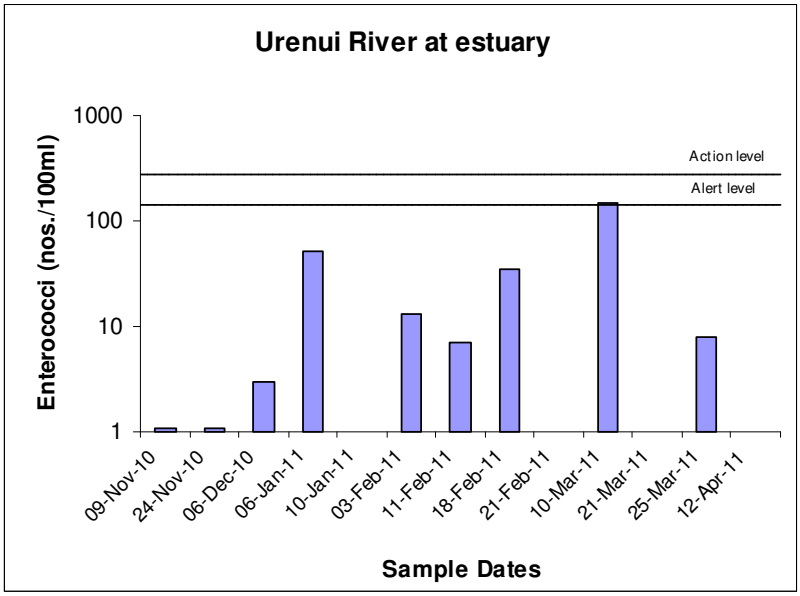


Figure 43 Enterococci numbers for the Urenui River at the estuary during the survey season

Table 61 Statistical results summary for the Urenui River at the estuary

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	4620	4750	4700
E. coli	nos/100ml	13	<1	28	4
Enterococci	nos/100ml	13	<1	150	3
Faecal coliforms	nos/100ml	13	<1	28	4
Temperature	°C	13	15.2	21.4	19.9
Turbidity	NTU	13	2.7	23	11

This hill country catchment river typically is turbid under low tide conditions in the tidal lower reaches of the estuary where it is extensively used by visitors and the holiday population based at the Urenui Beach settlement. High tide conditions resulted in marked aesthetic improvements within the estuary. Under high tide sampling conditions, the minimum (2.7 NTU) and median turbidity (11 NTU) levels were indicative of slightly to moderately turbid conditions typical of mixing of the more discoloured river flow with inflowing cleaner seawater. The river at this site was generally described as greenish in appearance and relatively clear to slightly turbid. Conductivity levels were characteristic of coastal saltwater on all occasions. Relatively high water temperatures (median of 19.9°C), more typical of coastal seawater temperatures, varied over a relatively narrow range of 6.2°C during the sampling period with a maximum of 21.4°C recorded in late morning in early January 2011. All sampling however, was undertaken prior to 1420 hrs when water temperatures could have been expected to have been cooler than later in the day, dependent upon the state of the tide.

Bacteriological water quality was generally very good as a result of the seawater tidal intrusion into the estuary. Poorer bacteriological river water quality might be expected under low outflowing tidal conditions as comparative sampling at the semi-tidal upstream SH3 bridge site to date has identified significantly higher numbers of all three bacteriological species (eg medians for *E. coli* [220 per 100 ml] and enterococci [150 per 100 ml]). The existing sampling programme was designed around higher tidal conditions (for SEM trend purposes and due to its incorporation within the coastal sites sampling programme) at times when bathing is more predominant at this site. One elevated enterococci count was recorded during the monitoring period.

No problems with dairy sheds' waste disposal practices were found during the season's annual inspection round.

3.2.13.1 Compliance with guidelines

Compliance with the 2003 guidelines for contact usage is summarised in Table 62 using the marine guidelines, which are considered to be more appropriate for this estuarine site.

Table 62 Bacterial guidelines performance at the Urenui River estuary site [% of 13 samples]

Parameter	Number of exceedances of enterococci guidelines	
	ALERT Single sample 141-280/100ml	ACTION 2 consecutive single samples >280/100 ml
E. coli	1 [8]	0 [0]

(Designation: coastal contact recreational area)

One single sample fell within the 'Alert' mode but none within the 'Action' mode at any time during the monitoring period. This occurred some five days after a series of river freshes.

The bacteriological water quality at this site was within the acceptable guideline for contact recreational usage throughout the season recognising that all sampling occasions coincided with high tides and therefore a predominance of high quality saline water mixing with poorer quality river water at this estuarine site. This was consistent with data for the nearby Urenui Beach coastal site (median enterococci: 5 per 100mls) monitored over six seasons to date.

3.2.13.2 Comparison with previous summers' surveys

A statistical comparison of each of the fifteen summers' survey data is presented graphically in Appendix V for all sites. These summer enterococci data for the Urenui River site at the estuary are summarised in Table 63 and illustrated in Figure 44.

Table 63 Summary of enterococci bacteriological water quality data (nos/100ml) for all summer surveys in the Urenui River estuary to date

Summer	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05-06	06/07	07/08	08/09	09/10	10/11
Minimum	<1	<1	<1	1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1
Maximum	40	69	82	220	160	27	19	72	640	30	9	36	120	190	150
Median	5	7	3	8	14	8	4	4	5	4	1	2	11	7	3

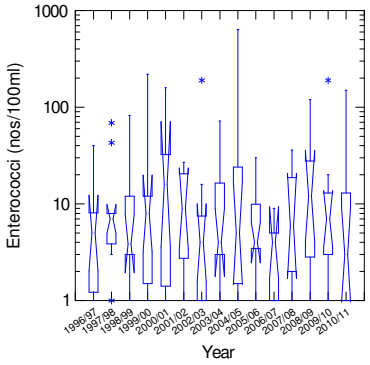
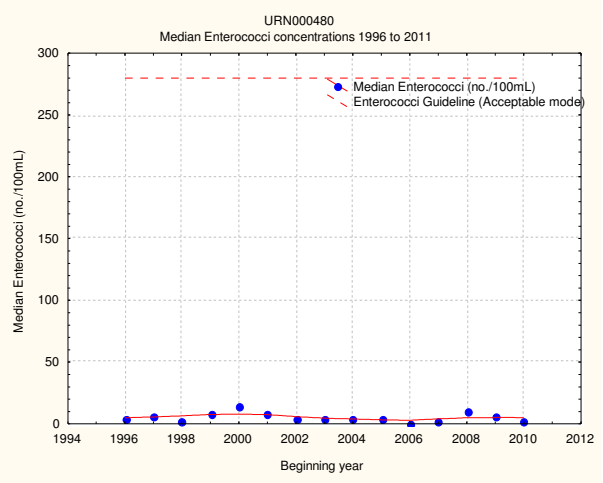


Figure 44 Box and whisker plots for all summer surveys of enterococci bacterial numbers in the Urenui River at the estuary

The high bacteriological water quality of the Urenui River estuary, during high tide conditions, was maintained during the 2010-2011 season (Figure 44) as emphasised by all seasonal median enterococci counts being less than 15 enterococci (per 100 mls). The range was moderate for enterococci during the 2010-2011 season as a result of one elevated single sample count during the period.

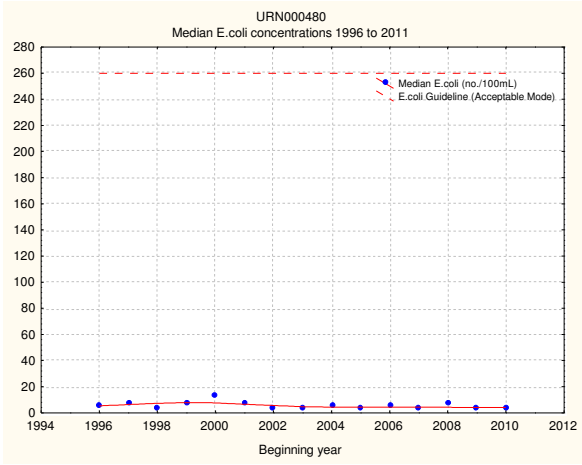
The high bacteriological quality of the coastal sea water intrusion was the major influence on the bacteriological water quality of the lower quality river water at this estuarine site during preferred recreational usage (ie, higher tide) conditions.

Trend analysis of median enterococci and *E. coli* numbers has been performed for the fifteen seasons of data by first applying a LOWESS fit (tension 0.4) to a time scatterplot of the median numbers (Figures 45 and 46) and testing the significance of any trend using the Mann-Kendall test at 5% level followed by Benjamini-Hockberg False Discovery Rate (FDR) analysis.



N = 15
Kendall tau = - 0.197
p level = 0.306 [>FDR, p = 0.611]
N/S at p < 0.05

Figure 45 LOWESS trend plot of median enterococci (per 100ml) at the Urenui River, estuary site for the 1996 to 2011 period



N = 15
Kendall tau = - 0.238
p level = 0.216 [>FDR, p = 0.519]
N/S at p < 0.05

Figure 46 LOWESS trend plot of median *E. coli* (per 100ml) at the Urenui River, estuary site for the 1996 to 2011 period

No statistically significant trend in median enterococci or *E. coli* counts has been found over the fifteen seasons of monitoring. None of these medians exceeded the 'Alert' or 'Action' modes for either marine or freshwater contact recreational usage.

3.2.14 Manganui River at Everett Park (downstream of Kurapete Stream)

No bathing and minimal other usage of this river site was noted at the time of sampling occasions during the survey period despite the proximity of the site to a nearby outdoor adventure camp.

Data from the site are presented in Table 64 and illustrated in Figure 47, with a statistical summary provided in Table 65. River flow records are illustrated in Figure 47.

Table 64 Analytical results for the Manganui River at Everett Park (downstream of the Kurapete Stream)

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	0920	9.8	160	44	160	14.3	0.6
24.11.10	0825	10.0	320	160	350	15.5	1.2
6.12.10	1020	10.1	170	23	170	19.7	2.0
6.01.11	0820	10.0	300	230	320	19.4	1.0
10.01.11	1045	10.3	130	88	130	17.7	0.9
3.02.11	1150	10.5	260	240	280	19.8	0.8
11.02.11	1145	9.8	200	84	200	18.4	0.8
18.02.11	1055	10.0	220	100	240	19.0	0.9
21.02.11	0920	10.2	160	63	160	19.2	0.8
10.03.11	0945	9.9	220	4	240	14.5	1.0
21.03.11	1220	9.4	100	88	110	16.2	0.8
25.03.11	1020	9.9	160	120	160	15.6	0.9
12.04.11	1300	10.4	110	87	110	14.3	0.9

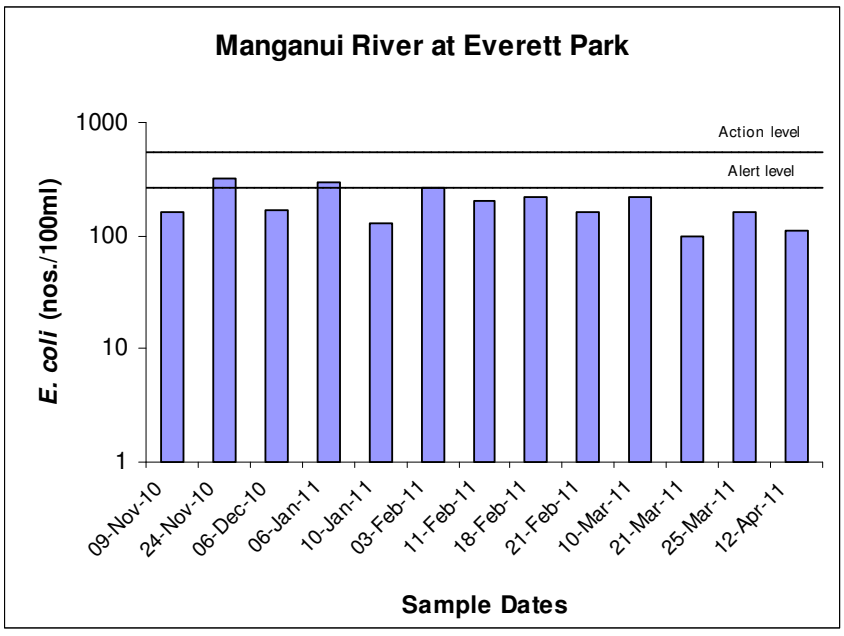


Figure 47 *E. coli* numbers for the Manganui River at Everett Park (downstream of the Kurapete Stream) during the survey season

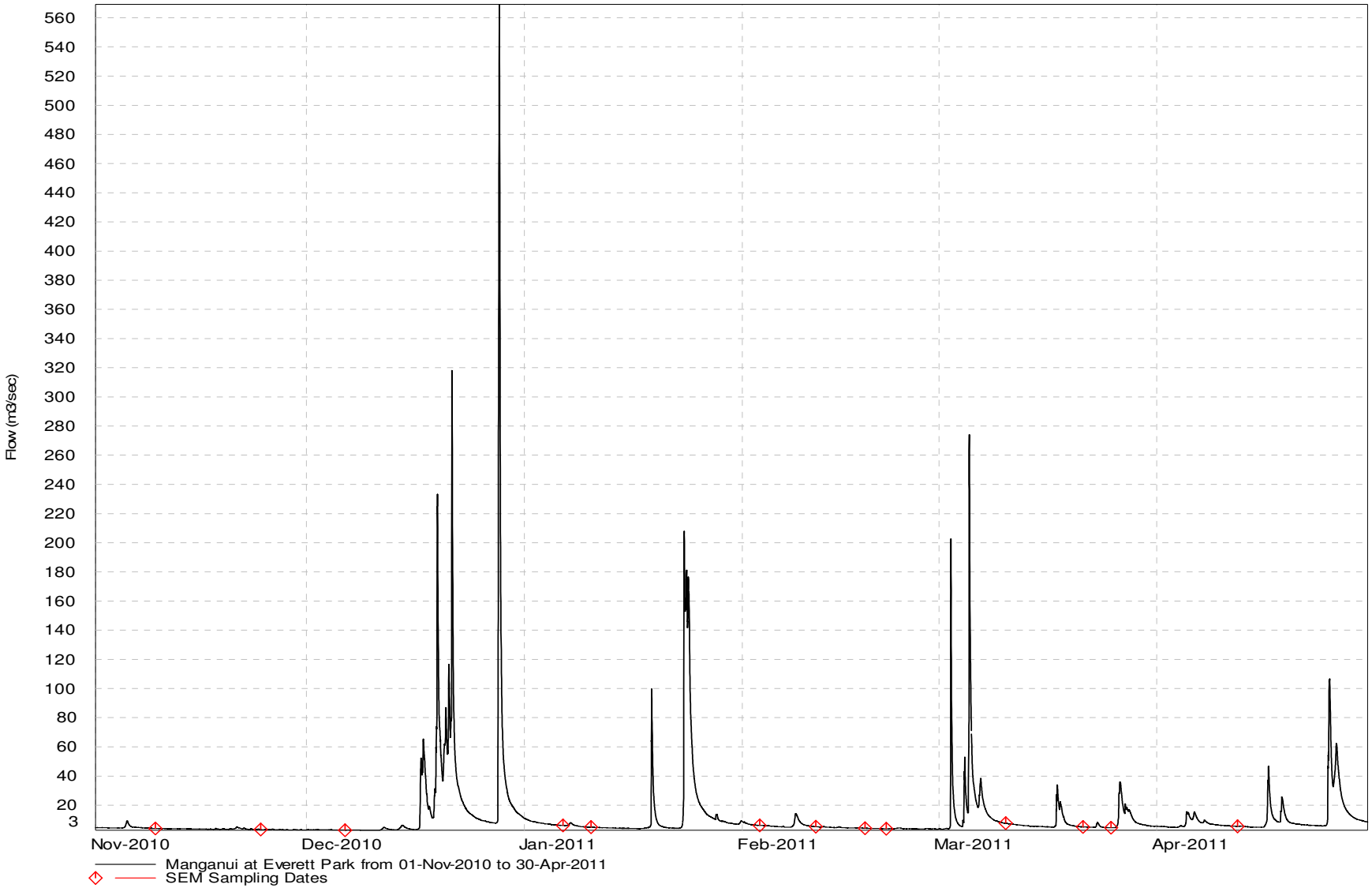


Figure 48 Flow in the Manganui River during the survey period (NOTE: This is all unaudited data from NIWA recorder site)

Table 65 Statistical results summary for the Manganui River at Everett Park (downstream of Kurapete Stream)

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	9.4	10.5	10.0
E. coli	nos/100ml	13	100	320	170
Enterococci	nos/100ml	13	4	240	88
Faecal coliforms	nos/100ml	13	110	350	170
Temperature	°C	13	14.3	19.8	17.7
Turbidity	NTU	13	0.6	2.0	0.9

This ring plain river drains an extensively developed agricultural catchment, the site surveyed being situated at Everett Park approximately 300 m downstream of the Kurapete Stream confluence, and about 500 m below another (less utilised) Manganui River recreational site, upstream of the Kurapete Stream. Since the 1999-2000 season's survey, discharges from the Inglewood municipal oxidation ponds' system (approximately 8 km upstream of the survey site) have been diverted out of the Kurapete Stream to the New Plymouth wastewater treatment plant.

The river was clear and green/brown at the time of the majority of the sampling surveys, with relatively low conductivity levels. Water temperatures varied over a relatively narrow range of 5.5°C with the maximum temperature (19.8°C) recorded in late morning in early February 2011. Higher temperatures could be expected later in the day as no sampling surveys were performed after 1300 hrs.

Bacteriological water quality was moderate for this site during the 2010-2011 survey period with all but one of the counts recorded during the period in excess of 100 *E. coli* per 100 mls (Figure 47). The elevated counts in November 2010, and January 2011, which entered the 'Alert' level, coincided with low flow conditions for the former, and followed a river fresh for the latter (Figure 48). Levels decreased below the 'Alert' level within one to two weeks under low flow conditions following each of these exceedances.

On-site dairy wastes disposal methods were generally satisfactory in the catchment above the site.

3.2.14.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 66.

Table 66 Bacterial guidelines performance at the Manganui River at Everett Park (upstream of Kurapete Stream) [% of 13 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	2 [15]	0 [0]

(Designation: freshwater contact recreational area)

Two single samples fell in the 'Alert' mode but none reached the 'Action' mode during the season. One of these elevated counts followed a relatively recent river fresh prior to the survey.

Bacteriological water quality at this site in terms of contact recreational usage was acceptable considering the impacts of farming activities, particularly in relation to the residual flow remaining in the river in mid-catchment downstream of the Motukawa HEP diversion (ie, significant abstraction of higher quality upper catchment water for hydroelectric power production purposes).

3.2.14.2 Comparison with previous summers' surveys

A statistical comparison of each of the fifteen summers' survey data is presented graphically in Appendix V for all sites. These summer data for the Manganui River site at Everett Park are summarised in Table 67 and illustrated in Figure 49.

Table 67 Summary of *E. coli* bacteriological water quality summary data (nos/100ml) for all summer surveys in the Manganui River at Everett Park to date

Summer	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11
Minimum	58	85	76	46	26	100	54	66	83	46	11	54	100	92	100
Maximum	690	2400	830	350	450	970	460	880	730	240	320	1200	480	370	320
Median	150	220	160	110	98	210	140	180	180	120	190	160	170	200	170

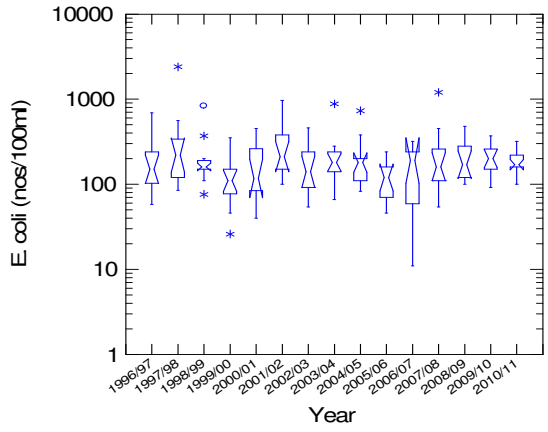
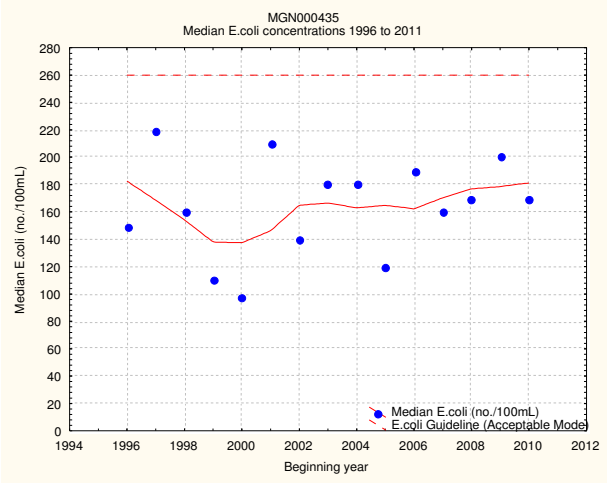


Figure 49 Box and whisker plots for all summer surveys of *E. coli* bacterial numbers in the Manganui River at Everett Park

The median *E. coli* count for the 2010-2011 season was within the range of the previous seasons' medians recorded within the fifteen seasons since the inception of the programme in 1996-97 (Figure 49). However the range of *E. coli* numbers was the narrowest recorded to date mainly due to a moderate maximum count of 320 per 100 mls; the second lowest seasonal maximum recorded to date at this site.

Trend analysis of these median *E. coli* numbers has been performed for the fifteen seasons of data by first applying a LOWESS fit (tension 0.4) to a time scatterplot of the median numbers (Figure 50) and testing the significance of any trend using the Mann-Kendall test at 5% level followed by Benjamini-Hockberg False Discovery Rate (FDR) analysis.



N = 15
Kendall tau = + 0.135
p level = 0.482 [>FDR, p= 0.643]
N/S at p< 0.05

Figure 50 LOWESS trend plot of median *E. coli* numbers (per 100ml) at the Manganui River, Everett Road site for the 1996 to 2011 period

A slight, but statistically insignificant, increase in median *E. coli* counts has been found over the fifteen seasons of monitoring. None of these seasonal medians exceeded the 'Alert' or 'Action' modes.

3.2.15 Lake Ratapiko

Bathing usage of the lake was noted on only one occasion, as was picnicking. No boating, waterskiing, kayaking, or fishing, activities were recorded at the time of any of the sampling surveys. However, the lake is commonly used for boating and fishing purposes, particularly at weekends and holidays. Ducks were present in moderate numbers on the lake as occasionally were shags. Stock had access to the lake margins and were present on at least three occasions. The lake was drawn down for maintenance purposes toward the end of the season (in early April, 2011).

The data for this site are presented in Table 68 and illustrated in Figure 51 with a statistical summary provided in Table 69.

Table 68 Analytical results for Lake Ratapiko

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
9.11.10	0850	8.0	13	4	13	15.6	2.5
24.11.10	0805	8.0	13	17	13	19.5	1.9
6.12.10	1045	8.3	27	35	27	22.2	2.5
6.01.11	0800	8.2	120	27	130	20.8	1.9
10.01.11	1025	8.3	13	1	13	20.8	1.5
3.02.11	1230	8.9	23	20	25	20.6	1.3
11.02.11	1120	8.2	87	15	89	20.4	3.2
18.02.11	1115	8.2	23	32	23	22.3	1.3
21.02.11	0855	8.5	15	5	28	21.9	1.7
10.03.11	0925	7.9	76	3	83	15.0	1.1
21.03.11	1235	6.7	84	20	84	18.5	1.7
25.03.11	1005	6.9	140	29	140	16.7	1.9
12.04.11	1240	-	-	-	-	-	-

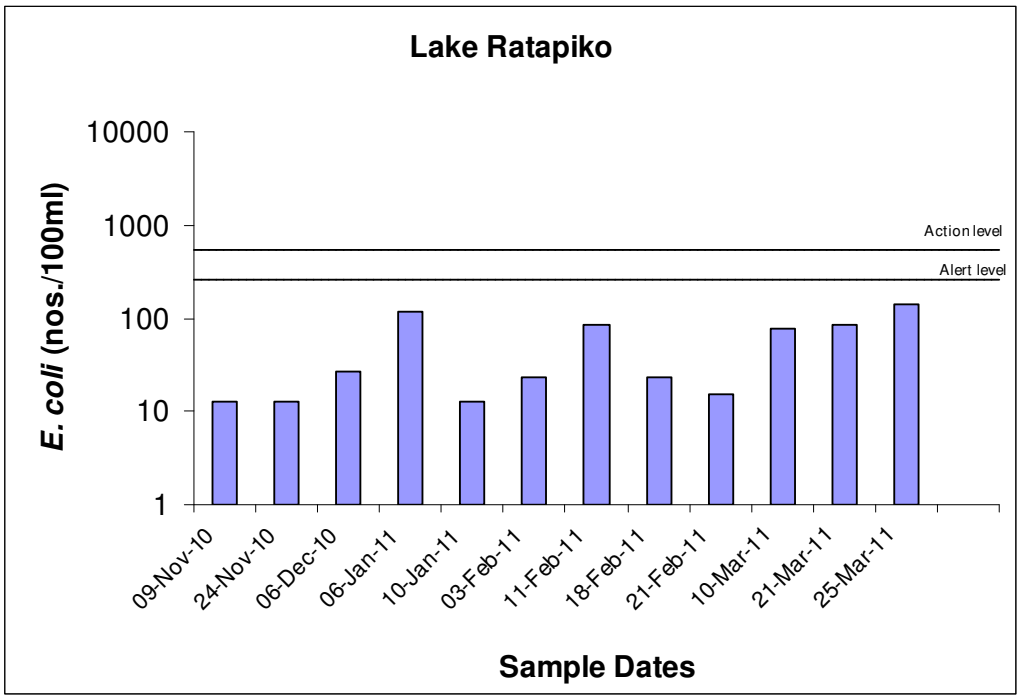


Figure 51 *E. coli* numbers for Lake Ratapiko during the survey season

Table 69 Statistical results summary for Lake Ratapiko

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	12	6.7	8.9	8.2
E. coli	nos/100ml	12	13	140	25
Enterococci	nos/100ml	12	1	35	19
Faecal coliforms	nos/100ml	12	13	140	28
Temperature	°C	12	15.0	22.3	20.5
Turbidity	NTU	12	1.1	3.2	1.8

The lake is replenished by diversion water flow from the mid reaches of the Manganui River via the Motukawa HEP scheme. Water quality was generally very good with minimal variation in clarity (median turbidity: 1.8 NTU; range of turbidity: 2.1 NTU) as a result of low suspended algae populations possibly due to short retention times. Water temperatures were moderate ranging over 7.3˚C for the period with a moderately high maximum of 22.3˚C (late morning in mid February 2011) although all measurements were recorded prior to 1240 hrs. Conductivity showed minimal variation during the period.

Generally bacteriological quality was very good considering that the inflow to the lake is from the mid reaches of a river draining a developed farmland catchment. No counts exceeded 140 *E. coli* per 100 mls despite the low summer-autumn flow conditions. No sampling was possible at the very end of the season coincident with the HEP scheme lake lowering for maintenance purposes.

3.2.15.1 Compliance with guidelines

Compliance with the 2003 guidelines for freshwater contact usage is summarised in Table 70.

Table 70 Bacterial guidelines performance at Lake Ratapiko [% of 12 samples]

Parameter	Number of exceedances of *E. coli* guidelines	
	ALERT Single sample 261-550/100ml	ACTION Single sample >550/100 ml
E. coli	0 [0]	0 [0]

(Designation: Freshwater contact recreational area)

No single sample exceedances of the 'Action' mode occurred and no samples were recorded within the 'Alert' mode during the entire period.

3.2.15.2 Comparison with previous summers' surveys

A statistical comparison of all sites' summers' *E. coli* survey data is presented graphically in Appendix V for all sites. Data from the five summer surveys for the Lake Ratapiko site are summarised in Table 71 and illustrated in Figure 52.

Table 71 Summary of *E.coli* bacteriological water quality data (nos/100ml) for all summer surveys at Lake Ratapiko to date

Summer	06/07	07/08	08/09	09/10	10/11
Minimum	1	1	5	4	13
Maximum	86	120	220	91	140
Median	21	16	35	16	25

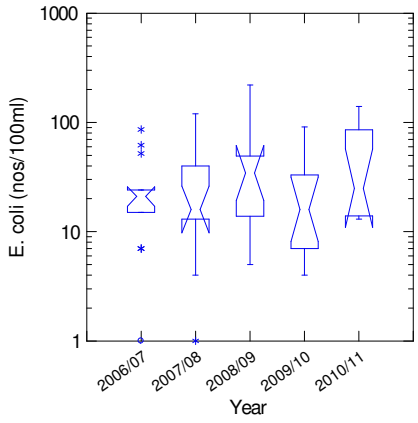


Figure 52 Box and whisker plots for all summer SEM surveys of *E.coli* bacteria numbers at Lake Ratapiko

A low median *E. coli* number was found by the latest season's survey and a relatively narrow range of counts was recorded. All seasonal medians have been low, however. Trend analysis of median *E. coli* numbers will not be performed for this site until ten seasons' data are available.

3.2.15.3 Cyanobacteria

There was no visual evidence of any nuisance algal blooms during the survey period. Microscopic scans of samples collected on seven sampling occasions were performed and found no cyanobacteria species present at any time of the season. Results of these analyses are presented in Table 72.

Table 72 Cyanobacteria counts (cells /ml) for Lake Ratapiko [Health warning: >15,000 cells /ml]

Date	Cyanobacteria total cell count (cells/ml)
16.11.10	nil
29.11.10	nil
14.12.10	nil
13.01.11	nil
27.01.11	nil
15.02.11	nil
16.03.11	nil

No cyanobacteria were detected in any of the samples. None had been found in this lake during the 2006-2007, 2008-2009, or 2009-2010 seasons, but low numbers of *Anabaena* had been present in the latter part of the 2007-2008 season following a lengthy, extremely low flow period. The relatively short lake water residence time (due to hydroelectric power generation usage) may be a factor in the control of these bacteria populations.

3.2.16 Lake Rotokare

Cyanobacteria monitoring of this lake was instigated in the 2007-2008 season in recognition of this small lake's recreational usage, particularly for boating activities. The boating season is restricted to the period from 1 December to 1 May by the STDC in recognition of the status of the Rotokare Scenic Reserve.

Some bacteriological water quality monitoring was also undertaken in conjunction with the cyanobacteria monitoring during the 2010-2011 season, with the lake visited on 14 occasions between mid November 2010 and mid April 2011. [Note: bacteriological monitoring is not a component of the SEM programme at this lake].

Usage of the lake included walkers (visitors) and picnicking throughout the season. There was no boating or jet-skiing recorded at the time of sampling visits despite the boat ramp remaining unlocked during a period of high cyanobacteria levels (see beneath) from mid December 2010 to mid February 2011 during which period public health warning signage was displayed at the lake and at the intersection of Rawhitiroa and Sangster Roads. A few ducks were noted from time to time on the lake which appeared murky to quite turbid, brownish throughout most of the period before improving toward relatively clear, pale greenish-brown toward mid March 2011.

The bacteriological water quality data for this site are presented in Table 73 with a statistical summary provided in Table 74.

Table 73 Analytical results for Lake Rotokare

Date	Time	Conductivity @ 20°C	Bacteria			Temperature	Turbidity
	(NZST)	(mS/m)	*E. coli* (nos/100ml)	Enterococci (nos/100ml)	Faecal coliforms (nos/100ml)	(°C)	(NTU)
15.11.10	1010	11.8	-	-	-	18.8	2.6
24.11.10	0810	11.8	37	1	39	19.3	1.9
30.11.10	0835	11.9	1	<1	1	20.8	5.0
15.12.10	0835	12.0	5	1	7	20.3	8.6
13.01.11	0800	11.8	3	16	3	21.6	5.9
31.01.11	1120	11.7	23	110	23	19.1	3.8
16.02.11	1425	12.1	23	28	23	23.7	2.1
28.02.11	1425	17.0	5	12	4	22.7	4.4
15.03.11	1050	18.8	15	36	15	20.4	4.8
30.03.11	0915	11.6	1	39	1	18.7	2.4
12.04.11	1150	11.8	-	-	-	17.8	1.0

Table 74 Statistical results summary for Lake Rotokare

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	11	11.6	18.8	11.8
E. coli	nos/100ml	9	1	37	5
Enterococci	nos/100ml	9	<1	110	16
Faecal coliforms	nos/100ml	9	1	39	7
Temperature	°C	11	17.8	23.7	20.3
Turbidity	NTU	11	1.0	8.6	3.8

In general, bacteriological water quality was very good, as might be expected for a small, bush clad lake with only small inflows and relatively low wild fowl numbers. Conductivity levels were relatively stable (7.2 mS/m range) through the period emphasising limited variation in inflow during the season, while water temperatures varied over a moderate range of 5.9°C with a maximum of 23.7°C recorded in mid February 2011. Turbidity was moderate (median: 3.8 NTU) with the range (7.6 NTU) reflecting the variability in abundances of suspended algae in the water column during the season. Maximum turbidity (8.6 NTU) was coincidental with a peak in cyanobacteria concentration in mid December 2010.

No bacterial counts approached or entered the 'Alert' or 'Action' levels on any occasion during the season although it should be noted that the overriding health warnings on both the Regional Council and Area Health Board's websites and on the sites at the lake and road access related to cyanobacteria level exceedances of guidelines (see below).

3.2.16.1 Cyanobacteria

Microscopic scans of 12 samples during the recreational monitoring period found a moderate cyanobacteria population in November 2010 but elevated concentrations present throughout the period from mid December 2010 to mid February 2011. However, these peak concentrations were far lower than maximum numbers found during the 2009-2010 period (by up to 177,000 cells per 100 mls). The results of these analyses are presented in Table 75 and illustrated in Figure 53.

Table 75 Cyanobacteria counts (cells/ml) for Lake Rotokare [Health warning: > 15,000 cells /ml]

Date	Cyanobacteria total cell count (cells/ml)	Principal species
15.11.10	8,800	*Anabaena*
24.11.10	7,500	*Anabaena*
30.11.10	12,600	*Anabaena*
15.12.10	33,000	*Anabaena*
23.12.10	25,500	*Anabaena*
13.01.11	33,000	*Anabaena*
31.01.11	16,500	*Anabaena*
15.02.11	18,200	*Anabaena*
28.02.11	10,200	*Anabaena*
08.03.11	6,100	*Anabaena*
15.03.11	10,400	*Anabaena*
12.04.11	815	*Anabaena*

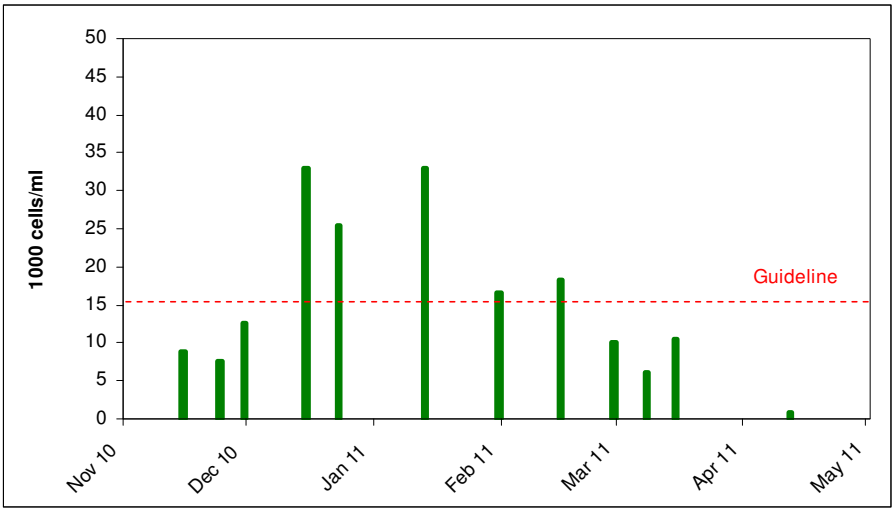


Figure 53 Cyanobacteria counts (cells/ml) at Lake Rotokare [Health warning: >15,000 cells/ml]

Moderate counts of *Anabaena* found in the lake in November 2010 did not necessitate installation of a blue-green algal hazard warning sign by the STDC upon advice from the Taranaki Area Health Board. Increasing counts exceeded the health guideline [15,000 cells/ml] by mid December 2010 at which time STDC erected signage at the lake and road access but the boatramp was not locked. *Anabaena* concentrations remained relatively high through summer peaking at about 33,000 cells/ ml in mid January 2011 before decreasing gradually through late January-March 2011 with no occurrence of the *Microcystis* bloom which had been found toward the end of the 2007-2008 season. However, low population of *Microcystis* were found in late February through to mid March 2011.

Warning signage was displayed adjacent to the boatramp from mid December 2010 until mid March 2011 but, although no primary contact recreational usage of the lake was recorded at the time of sampling surveys, recreational use of the lake was possible as the boat ramp remained unlocked. Potential water-based recreationalists were re-directed to Lake Rotorangi, some 10 km further to the east of Lake Rotokare.

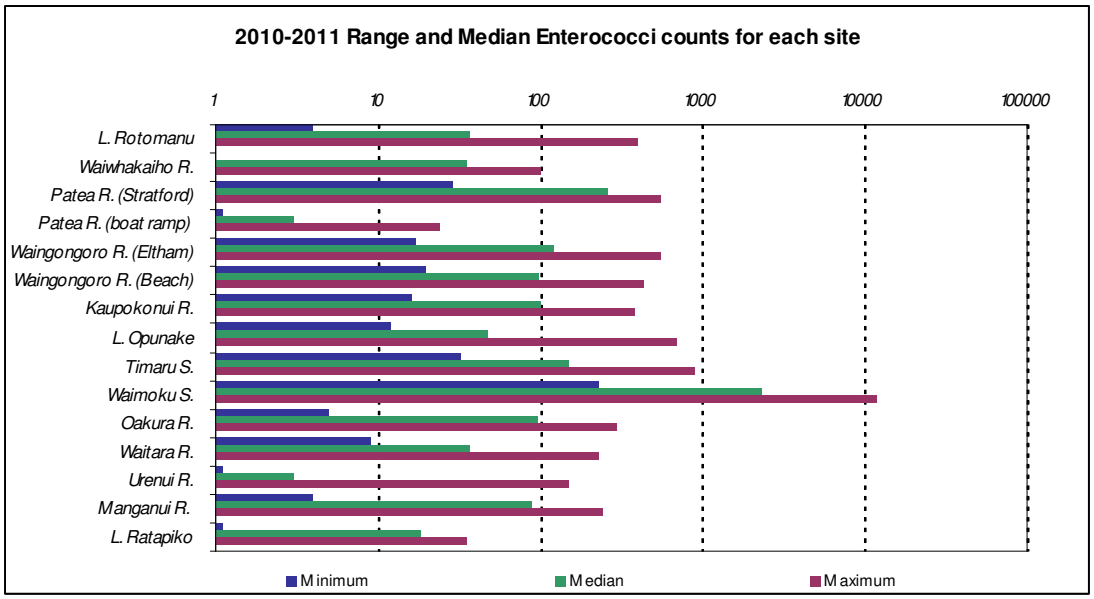
A late season survey in mid April 2011 found a significant decrease in counts to approximately 800 cells/ml, all of which were *Anabaena.*

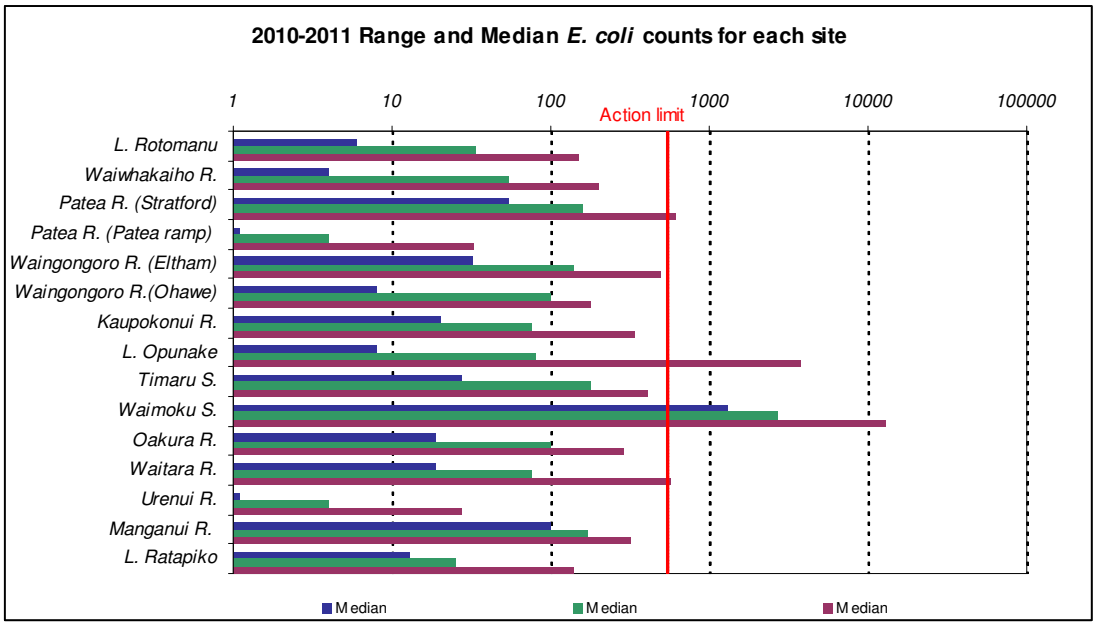
4. General data summary

A comparative summary of results of the fifteenth summer bacteriological quality freshwater survey involving fifteen contact recreational sites in the Taranaki region is provided in Table 76. Results are also illustrated in Figure 54 for each of the bacteriological species and a comparison of all sites' summer data is presented in Appendix V in the form of statistical 'box and whisker' plots.

Table 76 Statistical summary of results for the sites sampled in the SEM freshwater contact recreational water quality survey, 2010-2011

Site		Temperature (°C)	Conductivity @ 20°C (mS/m)	Faecal coliforms (nos/100 ml)	E. coli (nos/100 ml)	Enterococci (nos/100 ml)	Turbidity (NTU)
Lake Rotomanu	Median	22.4	13.2	34	34	37	1.4
	Minimum	19.1	12.3	6	6	4	0.6
	Maximum	25.0	15.9	150	150	400	4.8
	No. of samples	13	13	13	13	13	13
Waiwhakaiho River at Merrilands Domain	Median	12.3	12.7	54	54	35	0.7
	Minimum	14.4	10.0	4	4	1	0.4
	Maximum	22.0	15.2	210	200	100	1.7
	No. of samples	13	13	13	13	13	13
Patea River at King Edward Park, Stratford	Median	14.5	9.4	180	160	260	0.7
	Minimum	11.4	8.6	54	54	29	0.5
	Maximum	18.0	9.9	610	610	550	1.2
	No. of samples	13	13	13	13	13	13
Patea River at boatramp, Patea	Median	19.1	4680	4	4	3	18
	Minimum	15.6	4570	<1	<1	<1	6.4
	Maximum	21.0	4730	33	33	24	3.5
	No. of samples	13	13	13	13	13	13
Waingongoro River at Eltham camp	Median	15.6	12.3	150	140	120	1.7
	Minimum	12.8	11.0	32	32	17	1.3
	Maximum	18.9	15.4	500	490	560	2.7
	No. of samples	13	13	13	13	13	13
Waingongoro River at Ohawe Beach	Median	19.2	17.0	110	100	98	2.3
	Minimum	14.8	14.2	8	8	20	1.5
	Maximum	20.6	21.8	200	180	430	3.2
	No. of samples	13	13	13	13	13	13
Kaupokonui River at beach domain	Median	19.1	18.4	86	76	100	1.3
	Minimum	17.0	14.2	20	20	16	1.0
	Maximum	22.4	3130	360	340	380	1.9
	No. of samples	13	13	13	13	13	13
Lake Opunake adjacent to boat ramp	Median	18.9	13.7	84	80	48	1.2
	Minimum	16.6	12.4	8	8	12	0.9
	Maximum	22.7	20.0	3800	3800	700	280
	No. of samples	13	13	13	13	13	13
Timaru Stream at Weld Road (near mouth)	Median	18.0	57.0	180	180	150	0.7
	Minimum	14.2	9.2	28	28	33	0.4
	Maximum	20.8	4220	420	410	890	7.8
	No. of samples	13	13	13	13	13	13
Waimoku Stream at Oakura Beach	Median	16.0	15.2	2800	2700	2300	3.2
	Minimum	13.0	14.5	1300	1300	230	2.2
	Maximum	17.9	16.8	17000	13000	12000	36
	No. of samples	13	13	13	13	13	13
Oakura River d/s of SH45 bridge	Median	18.8	11.8	110	100	96	0.5
	Minimum	15.7	7.0	19	19	5	0.3
	Maximum	21.0	478	290	290	300	0.5
	No. of samples	13	13	13	13	13	13
Waitara River at town wharf,Waitara	Median	19.6	775	76	76	37	2.6
	Minimum	17.0	182	20	19	9	1.2
	Maximum	23.2	2340	570	570	230	16
	No. of samples	13	13	13	13	13	13
Urenui River at estuary	Median	19.9	4700	4	4	3	11
	Minimum	15.2	4620	<1	<1	<1	2.7
	Maximum	21.4	4750	28	28	150	23
	No. of samples	13	13	13	13	13	13
Manganui River d/s of Kurapete S. (Everett Park)	Median	17.7	10.0	170	170	88	0.9
	Minimum	14.3	9.4	110	100	4	0.6
	Maximum	19.8	10.5	350	320	240	2.0
	No. of samples	13	13	13	13	13	13
Lake Ratapiko at boat ramp	Median	20.5	8.2	28	25	19	1.8
	Minimum	15.0	6.7	13	13	1	1.1
	Maximum	22.3	8.9	140	140	35	3.2
	No. of samples	12	12	12	12	12	12





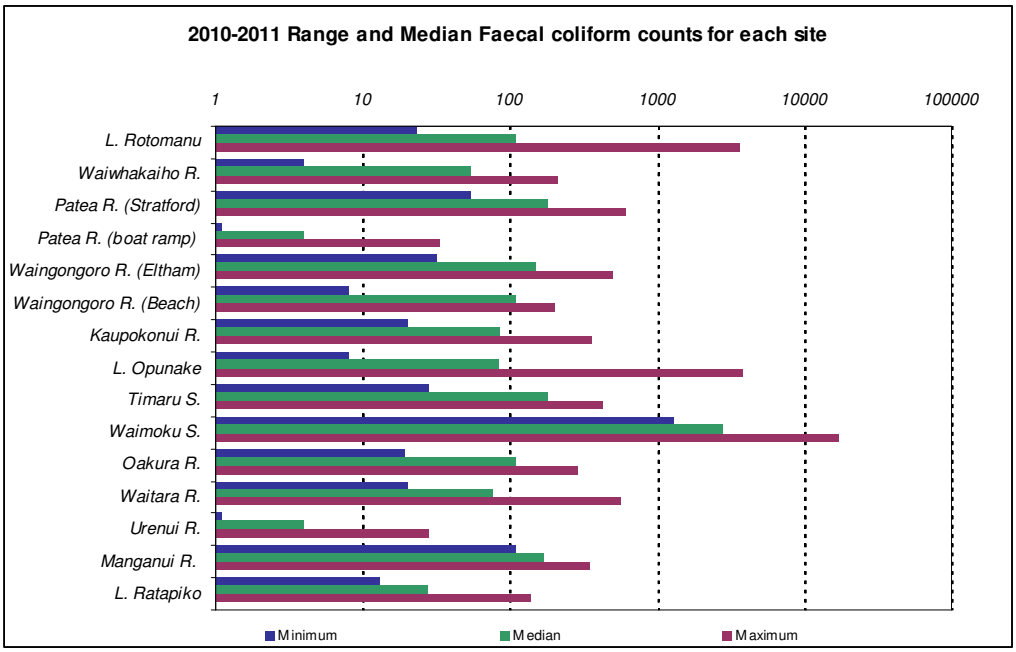


Figure 54 Ranges and medians of bacteria numbers recorded from all sites by the SEM programme over the 2010-2011 survey season

Compliance with the 2003 guidelines has varied at the fifteen freshwater contact recreational sites sampled during the survey period (Figure 53 and Table 77) but not to the same degree as recorded in previous seasons. In relation to the guidelines, only one site (Waimoku Stream at Oakura beach) regularly failed to meet the *E. coli* 'Action' guideline suitable for contact recreation. In terms of median *E. coli* counts, this was also the only site with the median count in the 'Action' (>550 *E. coli* per 100mls) mode, whereas no other sites had median counts in the 'Action' or 'Alert' modes.

Table 77 Number of occasions single sample *E.coli* counts entered the 'Alert' and 'Action' modes and percentage [%] of samples which fell below these modes (ie complied with guidelines). [Note: the latter is consistent with MfE reporting of national compliance with recreational guidelines (www.mfe.govt.nz/environmental-reporting)].

Site	'Alert' mode	'Action' mode
Lake Rotomanu at western beach	0 [100]	0 [100]
Waiwhakaiho River at Merrilands Domain	0 [100]	0 [100]
Patea River at King Edward Park, Stratford	0 [92]	1 [92]
Patea River at boatramp, Patea	0 [100]	0 [100]
Waingongoro River at Eltham Camp	0 [92]	1 [92]
Waingongoro River at Ohawe Beach	0 [100]	0 [100]
Kaupokonui River at beach domain	1 [92]	0 [100]
Lake Opunake at boat ramp	0 [77]	3 [77]
Timaru Stream at Weld Road	4 [69]	0 [100]
Waimoku Stream at Oakura Beach	0 [0]	13 [0]
Oakura River at SH45	1 [92]	0 [100]
Waitara River at town wharf, Waitara	1 [85]	1 [92]
Urenui River at estuary*	1 [92]	0 [100]
Manganui River at Everett Park	2 [85]	0 [100]
Lake Ratapiko at boat ramp	0 [100]	0 [100]

[Notes: N = 13 samples; * = enterococci count]

Five sites maintained counts below the 'Alert' mode at all times throughout the season (compared with two sites over the 2009-2010 season), while five other sites maintained counts below the 'Action' mode (Table 77) at all times. In terms of the overall monitoring season, ten 'Alert' levels (5% of counts) and nineteen 'Action' levels resulted over the period representing an overall 85% compliance with contact recreational guidelines (compared with 72% compliance in the 2009-2010 season).

Overall, a range from relatively good to good bacteriological water quality was measured at the fifteen sites. In terms of results to date, this represented an improvement influenced to some extent by a relatively dry spring period and a marked reduction in the volume and number of dairy shed ponds wastes discharged to natural surface water, particularly prior to mid-season. In terms of median *E. coli* counts, by far the best bacteriological quality was again found in the lower (estuarine) reach of the Patea River, Lake Ratapiko, and at the most estuarine site (Urenui River) which was strongly influenced by seawater penetration during high tide conditions. The programme focused on high tide periods due to its design and integration with the coastal bathing water quality monitoring programme. While future programmes' designs could give consideration to extending sampling to include low tide timing of sampling (at tidal sites), if this becomes necessary, it is essential that the high-tide format is retained for future trend monitoring purposes.

Based upon median *E. coli* bacterial numbers for the survey period, the following ranking of sites (in descending water quality) may be used to summarise results:

1. Urenui River at estuary
2. Patea River at boatramp, Patea
3. Lake Ratapiko
4. Lake Rotomanu
5. Waiwhakaiho River at Merrilands Domain
6. Waitara River at town wharf, Waitara
7. Kaupokonui River at beach domain
8. Lake Opunake at boat ramp
9. Oakura River d/s of SH 45 bridge
9. Waingongaro River at Ohawe Beach
11. Waingongoro River at Eltham camp
12. Patea River at King Edward Park, Stratford
13. Manganui River at Everett park (d/s of Kurapete Stream)
14. Timaru Stream at Weld Road (near mouth)
15. Waimoku Stream at Oakura beach

The biggest improvement in ranking, in comparison with the 2009-2010 season, occurred at the Waitara River and Lake Opunake sites while the two lowest rankings remained the same. Although, the Waingongoro River at Ohawe Beach slipped furthest down in the rankings (where it was ranked sixth lowest) in terms of seasonal median bacteriological water quality, there was minimal change in this median *E.coli* count between seasons (an increase of 4 *E.coli*/100 mls) reflecting the overall improvement in bacteriological water quality across the region's sites in 2010 – 2011.

4.1 Comparison with fourteen previous summers' surveys

A statistical comparison of each summer's survey *E. coli* data is presented graphically in Appendix V for all sites. Shorter data periods exist for the Waimoku Stream at Oakura beach which was included in the programme in 1999-2000 for the first time, Patea River (at King Edward Park, Stratford) and Waingongoro River (at Eltham camp) which were added in 2001-2002, two lakes' sites (Lakes Ratapiko and Opunake) which were added in 2006-2007, the site in the lower reaches of the Patea River which was added in the 2007-2008 season, and the site in the lower Waitara River which was added in the 2009-2010 season.

In general terms, *E. coli* bacteriological water quality remained within ranges generally narrower than those recorded over previous summer bathing seasons due to an absence of very high counts in most cases. There was some deterioration at one site and improvement at four sites in terms of median counts, in comparison with the previous summers' results. Variability in quality between bathing seasons at each site relates to a variety of reasons including hydrological conditions, stock access, wildlife presence and dairy farm wastes disposal practices in particular.

Trending of season's median *E.coli* counts at each site, with a minimum of ten years' data, was undertaken statistically for the period 1996 to 2011. Only three sites showed statistically significant ($p < 0.05$) trends in median *E.coli* counts and the two of these sites which were significant after FDR were:

- Oakura River below the SH45 bridge had a strong trend of increasing median *E.coli* numbers over the fifteen year period to date which was significant at p< 0.01 after FDR application.
- Waimoku Stream at Oakura beach had a strong trend of increasing median *E. coli* numbers over the twelve year period to date which was significant at p<0.01 after FDR application. This trend has been strongly influenced by higher counts since 2006 coincident with high numbers of wildfowl with access to surface water.

The Oakura River site's seasonal median *E.coli* counts did not approach contact recreational 'Alert' (or 'Action') guidelines whereas all seasonal median counts at the Waimoku Stream site were in the 'Action' mode. A ranking of the order of the significance of the temporal trends at those sites with a minimum of ten seasons' data (eleven sites) is provided in Table 78.

Table 78 Ranking of sites in terms of significant temporal trends in median *E.coli* counts over the period 1996 to 2010 [significant at p< 0.05 and p<0.01]

Site	Location	Valid N	p-level	FDR-corrected p value	Trend
Waimoku Stream	Oakura Beach	12	0.0002	0.0026	↑↑↑
Oakura River	d/s SH45 bridge	15	0.0033	0.020	↑↑↑
Waingongoro River	Ohawe Beach	15	0.017	0.066	↓↓
Lake Rotomanu	Western beach	15	0.151	0.454	↑
Urenui River	Urenui estuary	15	0.216	0.519	↓
Kaupokonui River	Beach Domain	15	0.366	0.615	↓
Waingongoro River	Eltham Camp	10	0.410	0.615	↓
Manganui River	Everett Park	15	0.482	0.643	↑
Waiwhakaiho River	Merrilands Domain	15	0.691	0.784	↑
Timaru Stream	End of Weld Road	14	0.774	0.784	↑
Patea River	King Edward Park	10	0.784	0.784	↓

In summary, two sites have shown a significant (increasing) temporal trend in seasonal median *E. coli* counts. The other insignificant trends indicate gradual improvement (five sites) or deterioration (four sites) in seasonal median *E. coli* counts. With the exception of one seasonal median count at each of the Timaru Stream and the Kaupokonui River sites (which both entered the 'Alert' mode in the 1996-1997 season), none of these seasonal median counts at the sites with insignificant temporal trends have reached 'Alert' or 'Action' modes at any time.

4.2 General

The Taranaki Regional Council will continue to ensure that attention is given to the appropriate timing of dairy shed wastes disposal inspections and repeat inspections when necessary in specific catchments, to ensure that river and stream bacteriological water quality is not compromised by inappropriate wastes disposal practices. There is also a need to encourage farmers to refrain from allowing direct stock access to natural surface waters and/or fording stock through streams particularly under summer-autumn low flow conditions.

It is intended that the improved liaison initiated over the 2000-2001 season with territorial local authorities and the Health Protection Unit of Taranaki Healthcare,

and maintained to date, will continue with particular regard to the frequency and immediacy of reporting bathing water quality and cyanobacteria results during the survey period and in particular by usage of the Regional Council's website. All sites' results were displayed on this website throughout the 2010-2011 survey period and every instance of exceedance of standards was advised to the appropriate authorities. Few follow-up investigations were necessary over the 2010-2011 season and there were few issues with dairy wastes disposal systems contributing to elevated counts in receiving waters. A noticeable reduction in dairy discharges to surface water over the earlier part of the season was coincidental with improved bacteriological water quality. In most cases, mainly at lakes, wildfowl contamination was responsible for elevation in counts, particularly where public feeding of ducks and geese encouraged large numbers of birds at recreational sites. Very few isolated instances were related to localised rainfall and on very few occasions, particularly during lengthy low flow periods, stock access problems and/or cumulative impacts of consented wastewater discharges may have contributed.

In particular sub-catchments, appropriate publicity and timing of the annual round of dairy inspections could assist with mitigation of these effects. Regular reviews of the sites' grading system will be performed and maintenance of the programme of increased sampling frequency (20 samples per season) will continue at the two principal freshwater contact recreation usage sites. Cyanobacteria monitoring will also continue at designated sites (at a slightly lesser frequency to the bacteriological monitoring).

Cyanobacteria were absent from the four designated monitoring sites with the exception of Lake Rotokare where, although numbers were lower than found in the previous three seasons, they exceeded public health levels for a two month period between mid December, 2010 and mid February, 2011.

5. Recommendations

As a result of the 2010-2011 summer freshwater contact recreation bacteriological survey it is recommended that:

1. THAT the 2011-2012 survey be performed at fourteen regular sites [Waimoku S. excluded] continuing with the existing sampling protocols during the season extending from 1 November to 31 March and (into April, if necessary).
2. THAT the 2011-2012 survey includes an additional seven samples collected at the two principal usage sites (Lake Rotomanu and Waiwhakaiho River at the Merrilands Domain) in accordance with MfE, 2003 guidelines.
3. THAT the 2011-2012 summer survey includes cyanobacteria monitoring at the three lake sites , the principal river usage site (Waiwhakaiho River at Merrilands Domain), and an additional lake (Rotokare) site.
4. THAT follow-up sampling be performed as deemed necessary by TRC staff.
5. THAT appropriate timing of the annual dairy farms inspection round be incorporated into the programme for catchments where issues relating to exceedances of contact recreational standards have been identified and advice and publicity be provided in relation to the prevention of stock access to natural water.
6. THAT reporting of results be performed as appropriate during the season, and in an Annual Report upon completion of the season's programme.
7. THAT the appropriate statistical trend detection procedures be applied to the data and reported in the Annual Report

Bibliography and References

Abbott, S.E; Caughley, B.P; Ionas, G; and Learmonth, J; 2006. Effect of water fowl on recreational water quality. Water 2006 International Conference, Auckland, NZ. 25pp.

APHA (2005). Standard methods for the examination of water and wastewater. American Public Health Association, American Water Works Association, and the Water Environment Federation.

Benjamini,Y and Hochberg, Y, 1995. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society B (57):289-300.*

Canterbury Regional Council, 1993: Bathing water quality in Canterbury: Recreational water quality survey results for 1992/93. Canterbury Regional Council Report 93(15).

Deely, J, Hodges, S, McIntosh, J, and Bassett, D, 1997: Enterococcal numbers measured in waters of marine, lake, and river swimming sites of the Bay of Plenty, New Zealand. NZ Jour. Mar F. W. Res. V31: 89-101.

Department of Health, 1992: Provisional microbiological water quality guidelines for recreational and shellfish gathering waters in New Zealand. Public Health Services, Department of Health, Wellington.

EPA (United States Environmental Protection Agency), 1986. Ambient water quality criteria for bacteria. EPA Report 440/5-84-002.

McBride, G B; Salmond, C E; Bandaranayake, D R; Turner, S J; Lewis, G D; Till, D G, 1998: Health Effects of Marine Bathing in New Zealand. International Journal of Environmental Health Research 8(3). In press.

MfE, 1998: Bacteriological water quality guidelines for marine and fresh water: Guidelines for the management of recreational and marine shellfish-gathering waters. Ministry for the Environment publication.

MfE, 2003: Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. Ministry for the Environment and Ministry of Health, Wellington.

MfE, 2008: Environment New Zealand 2007. Ministry for the Environment publication ME847.

Stark, JD and Fowles, CR 2006: An approach to the evaluation of temporal trends in Taranaki State of the Environment Macroinvertebrate Data. Cawthorn Institute Report No 1135. 88pp

Taranaki District Health Board, 2006: Proposed cyanobacteria incident plan for Taranaki. 24pp (draft).

Taranaki Regional Council, 1997: Freshwater bathing water quality of selected Taranaki sites. Survey results for summer 1996-97. Technical Report 97-4.

Taranaki Regional Council, 1998: Freshwater bathing water quality at selected Taranaki sites. State of the Environment Report. Summer 1997-98. Technical Report 98-20.

Taranaki Regional Council, 1999: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 1998-99. Technical Report 99-18.

Taranaki Regional Council, 2000: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 1999-2000. Technical Report 2000-06.

Taranaki Regional Council, 2001: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 2000-2001. Technical Report 2001-07.

Taranaki Regional Council, 2002: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 2001-2002. Technical Report 2002-01.

Taranaki Regional Council, 2002: State of the Environment Monitoring Report: Bathing Beach Water Quality 2000-2001 and 2001-2002. Technical Report 2002-45.

Taranaki Regional Council, 2003: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 2002-2003. Technical Report 2003-05.

Taranaki Regional Council, 2003: 'Taranaki – our place, our future' Report on the state of the environment of the Taranaki region – 2003'. TRC publication, 206pp.

Taranaki Regional Council, 2004: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 2003-2004. Technical Report 2004-19.

Taranaki Regional Council, 2005: Bacteriological water quality of the Waimoku catchment. TRC Technical Report 2004-21.

Taranaki Regional Council, 2005: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 2004-2005. Technical Report 2005-09.

Taranaki Regional Council, 2006: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 2005-2006. Technical Report 2006-32.

Taranaki Regional Council, 2007: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 2006-2007. Technical Report 2007-11.

Taranaki Regional Council, 2008a: Recreational use of coast, rivers and lakes in Taranaki 2007-2008. TRC Report.

Taranaki Regional Council, 2008b: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 2007-2008. Technical Report 2008-02.

Taranaki Regional Council, 2009: Taranaki Where We Stand. State of the Environment Report 2009. TRC, 284p.

Taranaki Regional Council, 2009a: Bathing beach water quality. State of the Environment Report. Summer 2008-2009. Technical Report 2009-11.

Taranaki Regional Council, 2009b: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report Summer 2008-2009 . Technical Report 2009-12.

Taranaki Regional Council, 2010: Bathing beach water quality. State of the Evironment monitoring report. Summer 2009-2010. Technical Report 2010-08.

Taranaki Regional Council, 2010a: A further [summer 2010] visual assessment of the Waimoku catchment in relation to bacteriological water quality issues. Internal report.

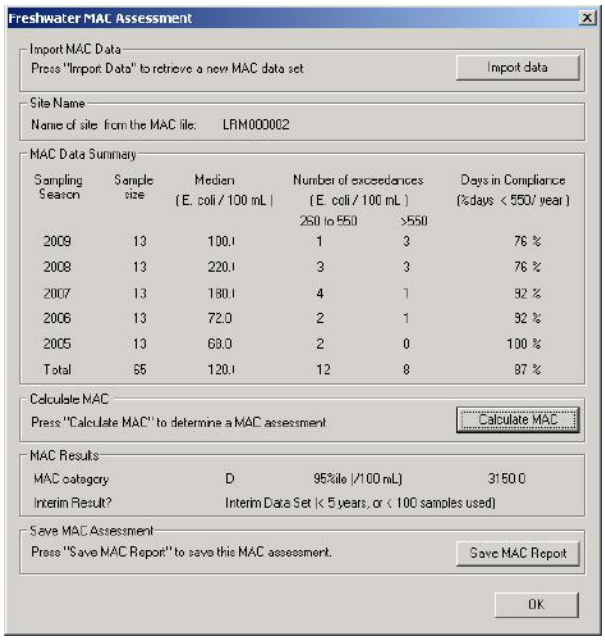
Taranaki Regional Council, 2010b: South Taranaki District Council Waverley, Kaponga, Manaia and Patea Municipal Oxidation Ponds Systems Monitoring Programmes Annual Report 2009-2010. Technical Report 2010-14.

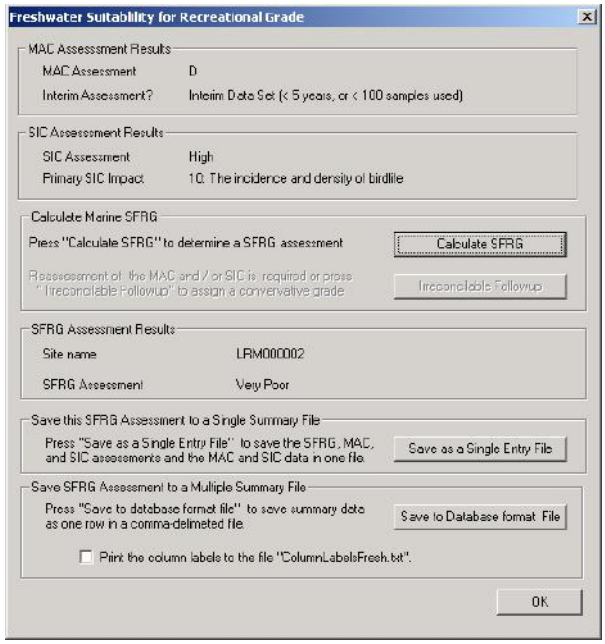
Taranaki Regional Council, 2010c: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report Summer 2009-2010 . Technical Report 2010-11.

Appendix I

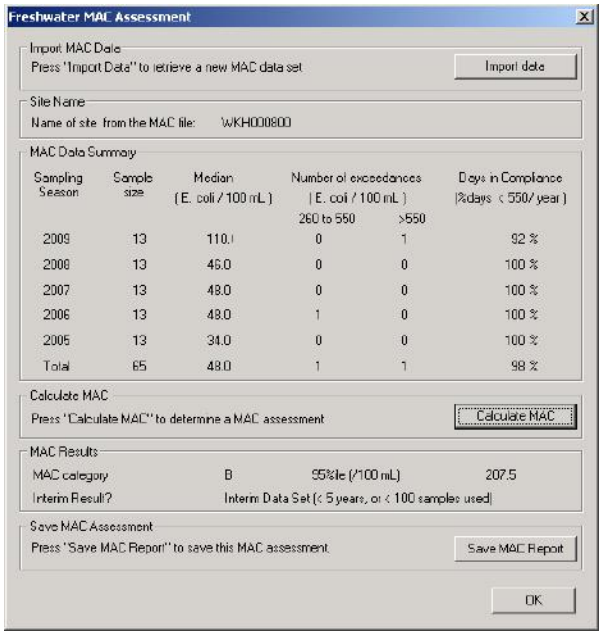
MAC assessments for all sites

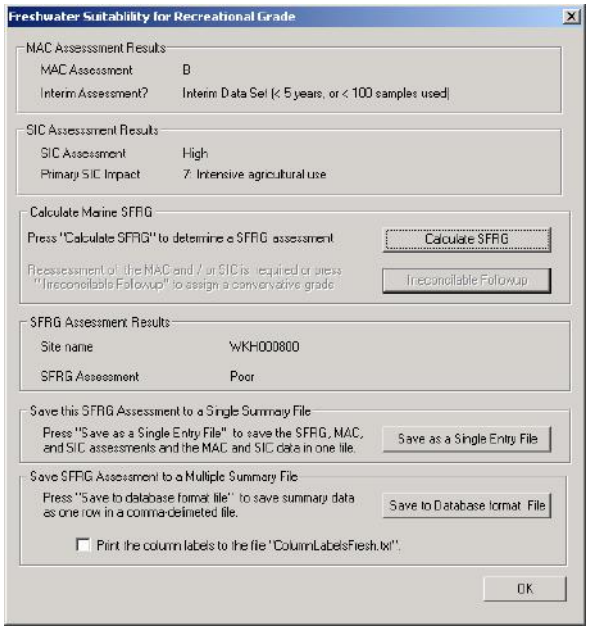
Lake Rotomanu



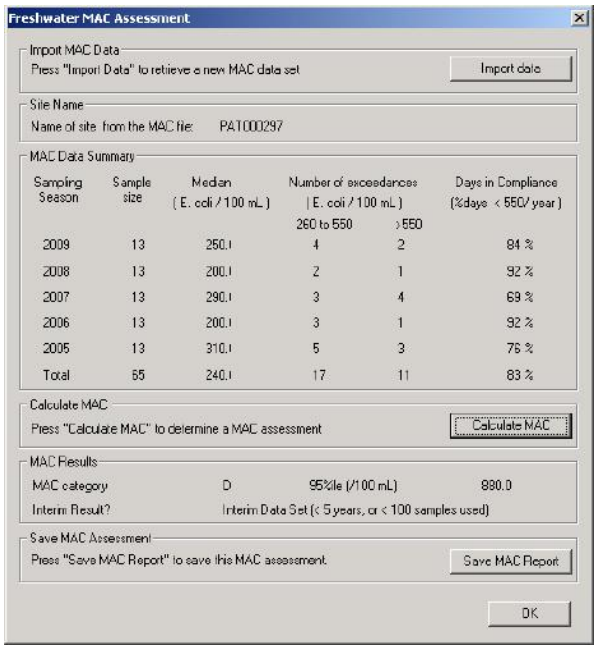


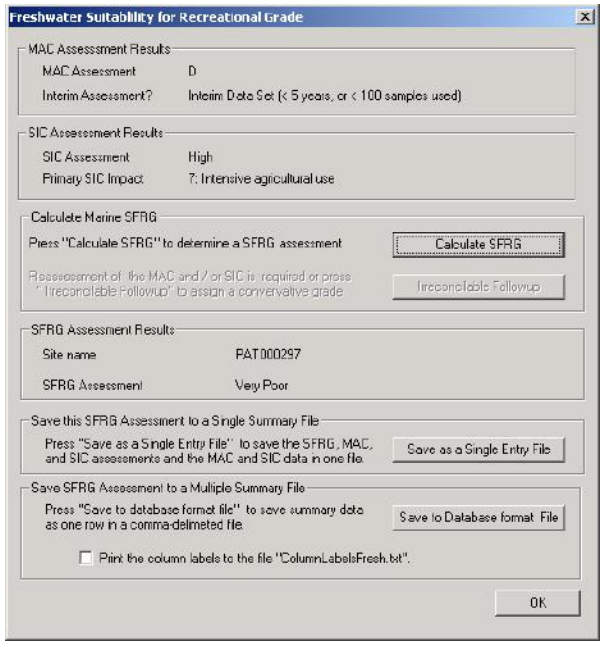
Waiwhakaiho River at Merrilands Domain



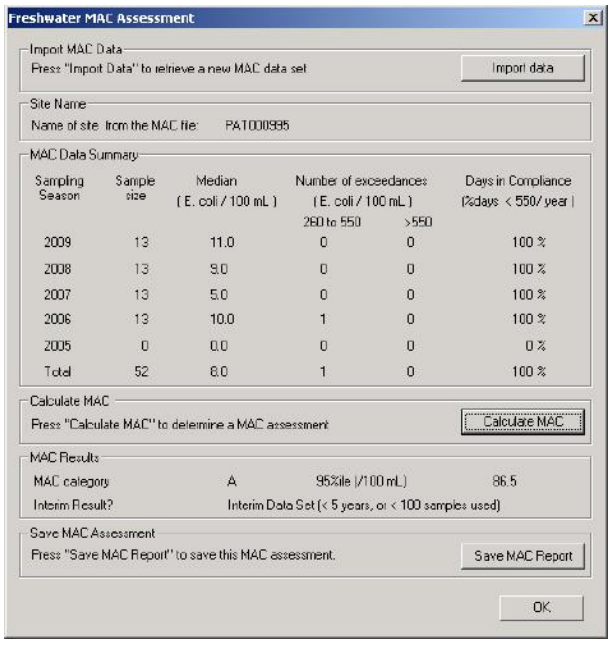


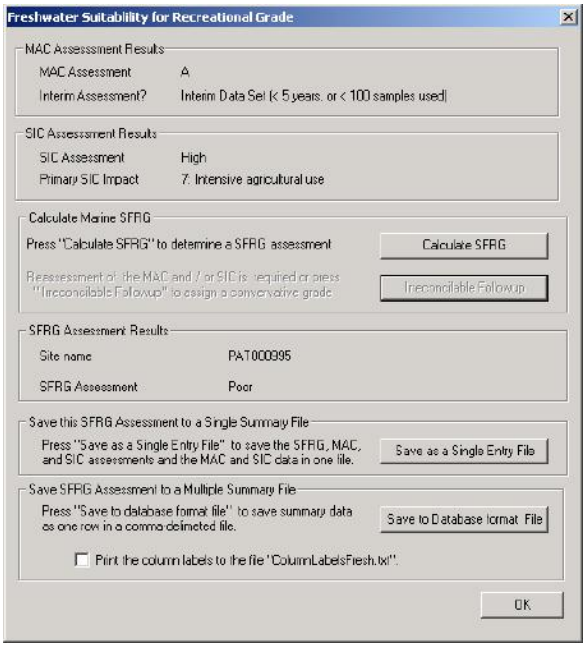
Patea River at Stratford



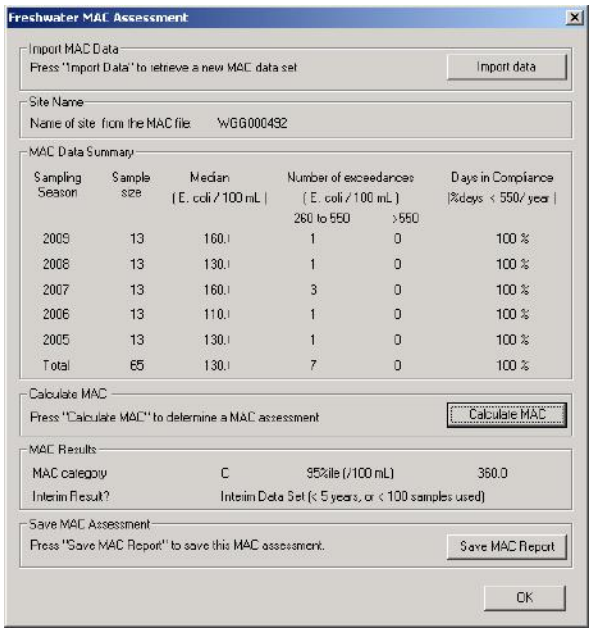


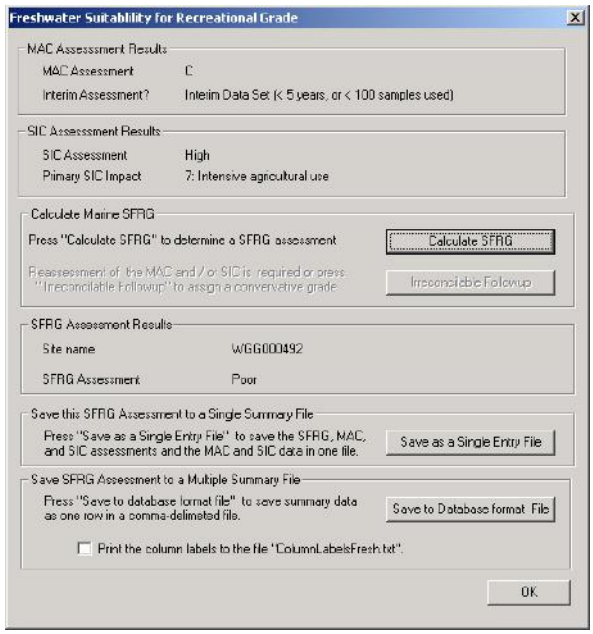
Patea River at boat ramp, Patea



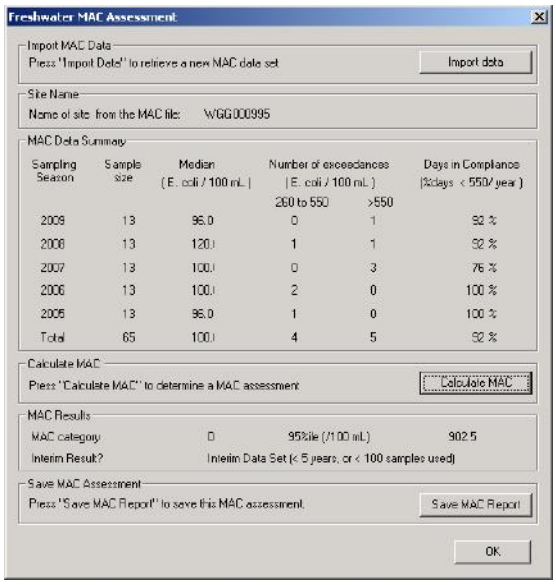


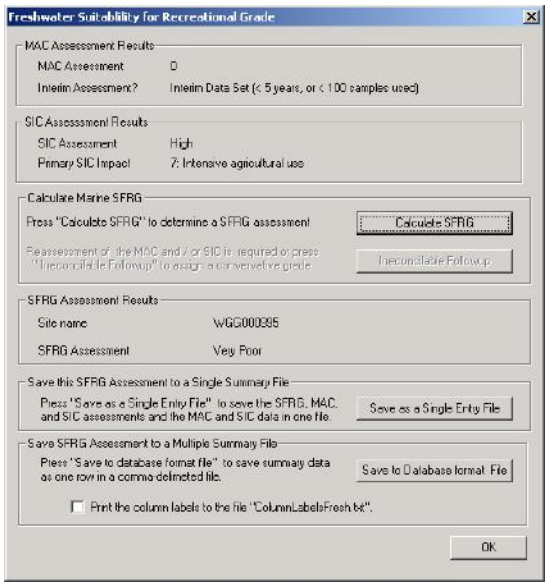
Waingongoro River at Eltham camp



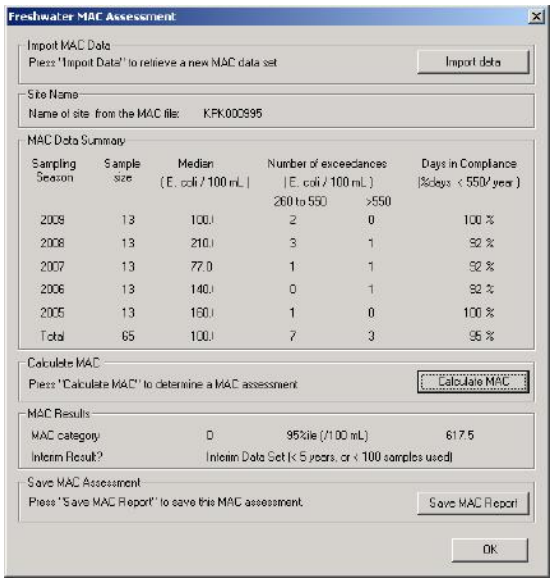


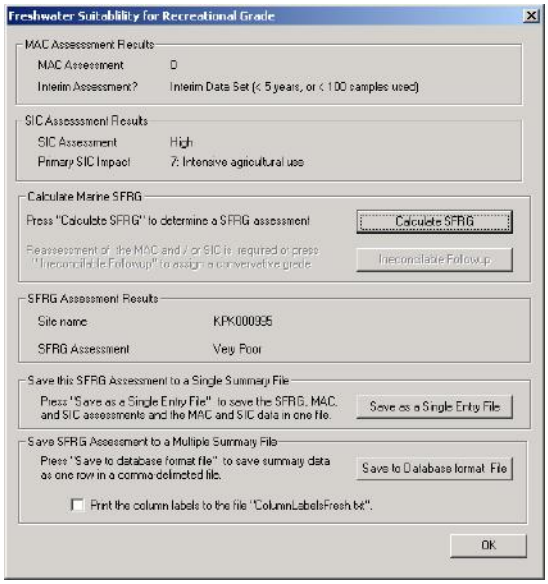
Waingongoro River at Ohawe beach



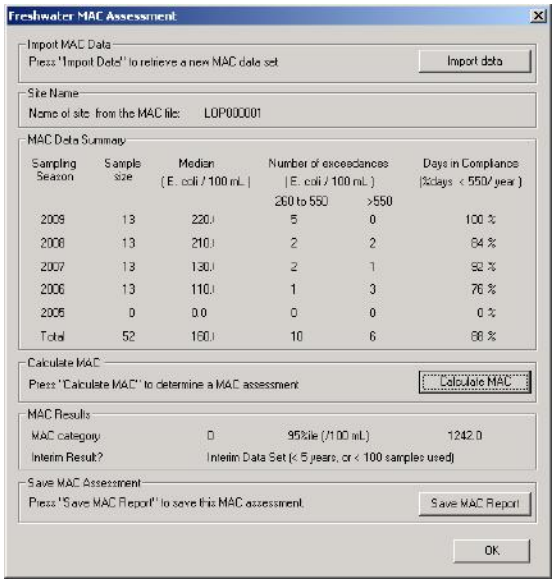


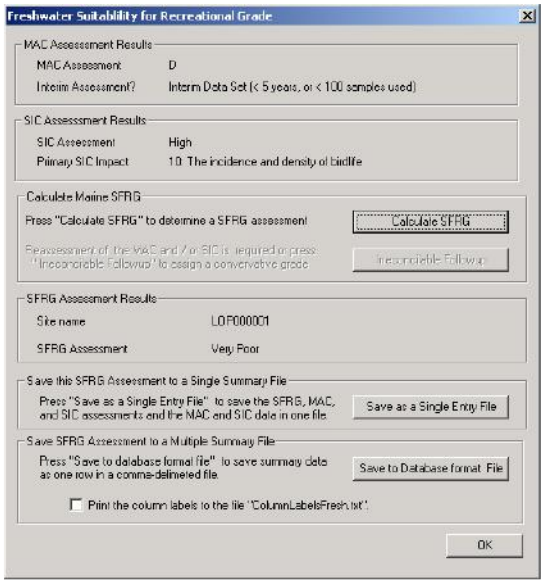
Kaupokonui River at beach domain



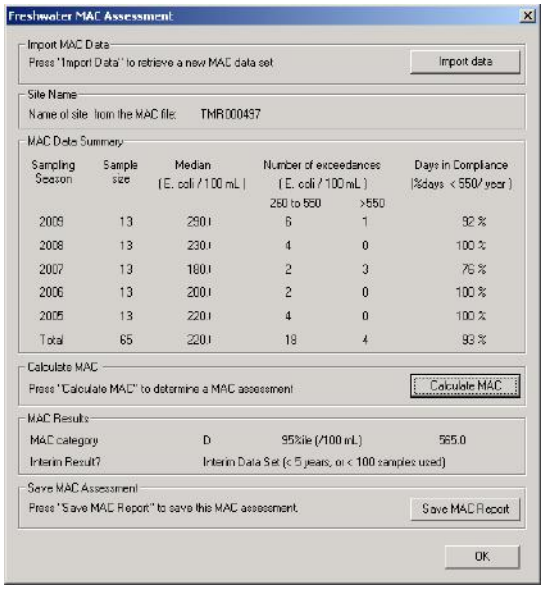


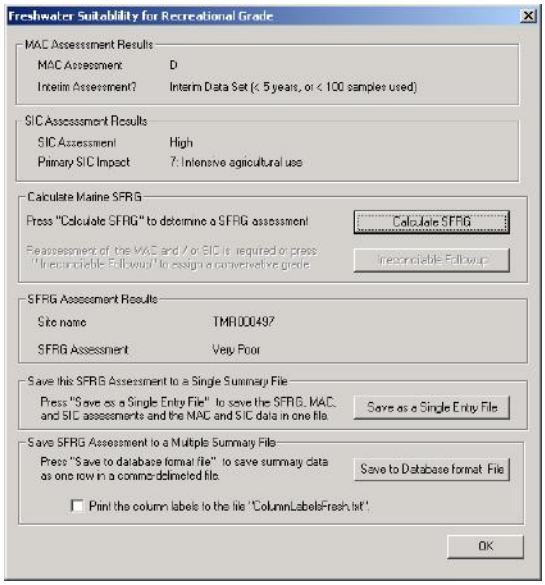
Lake Opunake



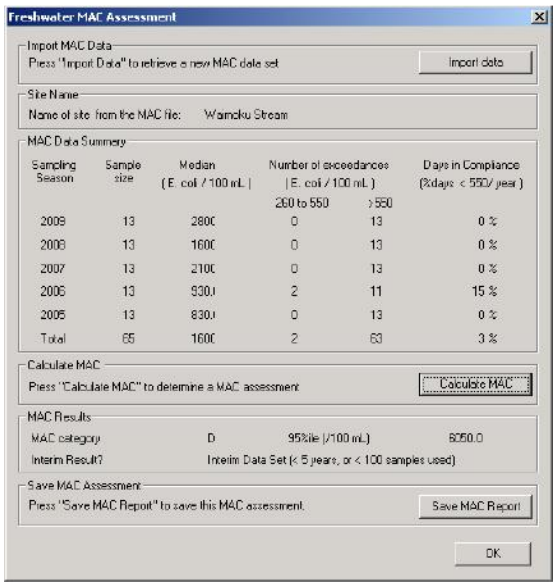


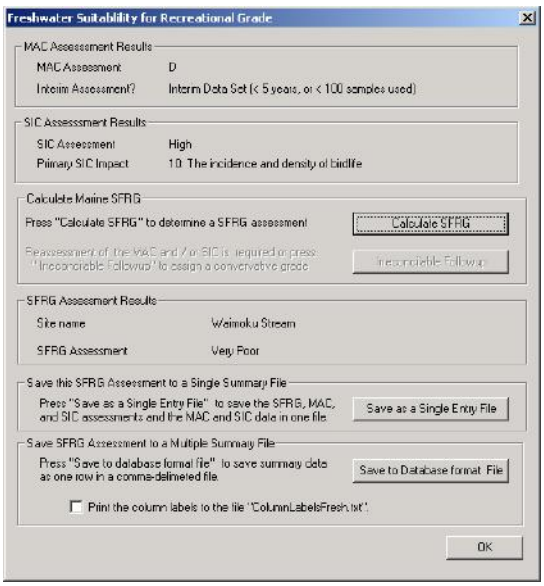
Timaru Stream at Weld Road



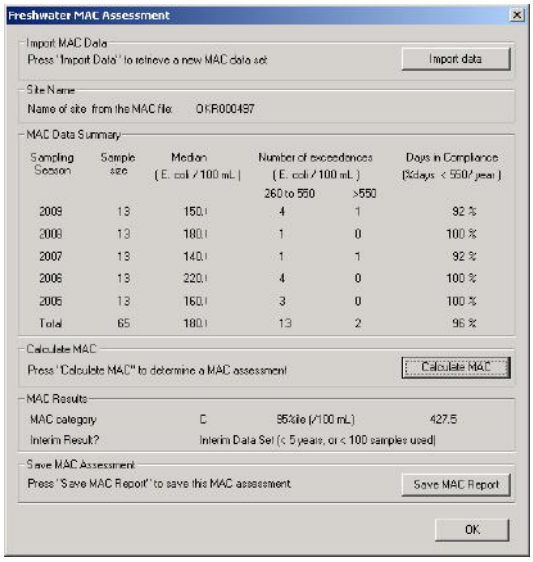


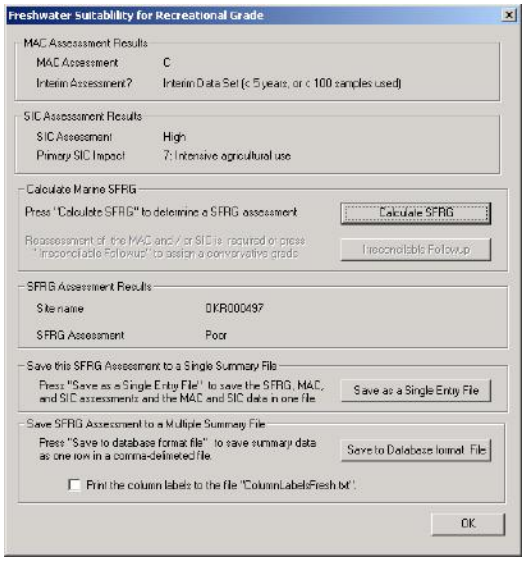
Waimoku Stream at Oakura beach



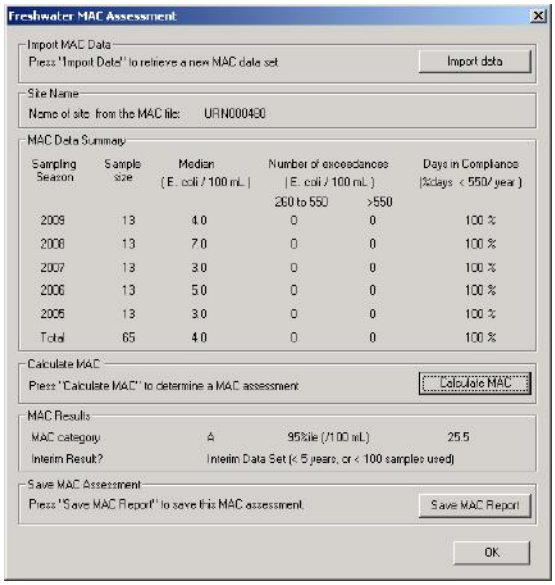


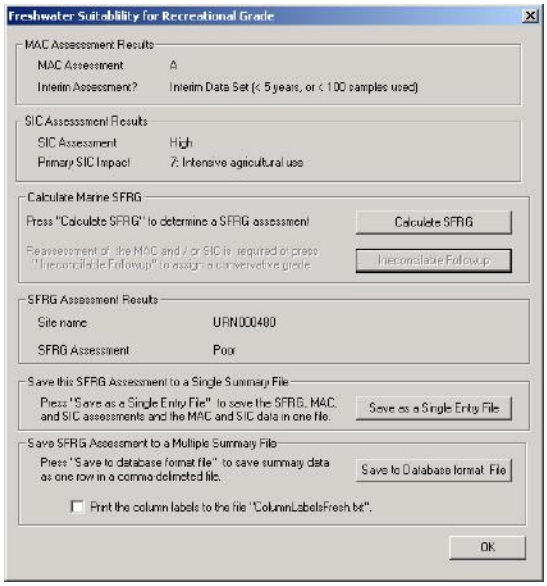
Oakura River d/s SH45



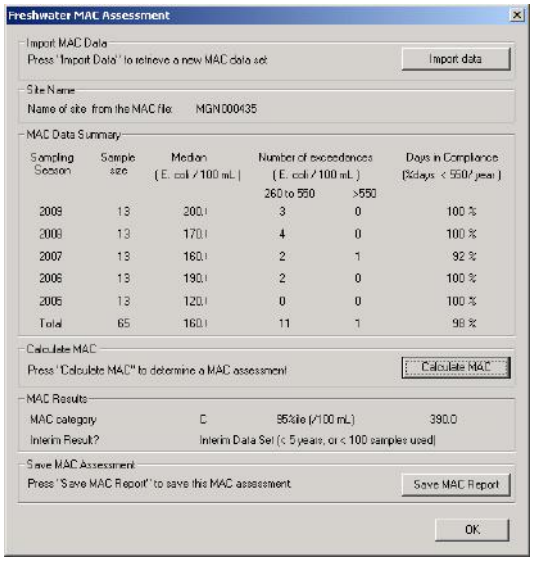


Urenui River at estuary

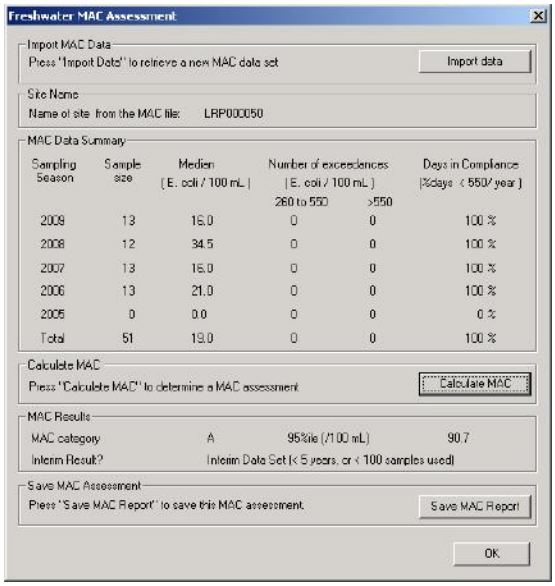


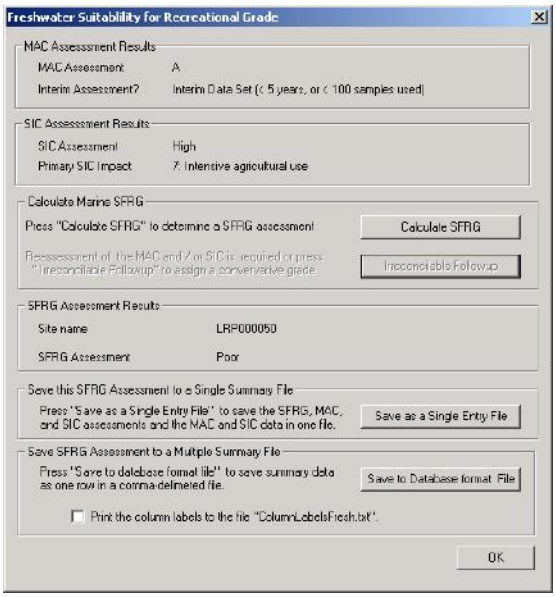


Manganui River at Everett Park

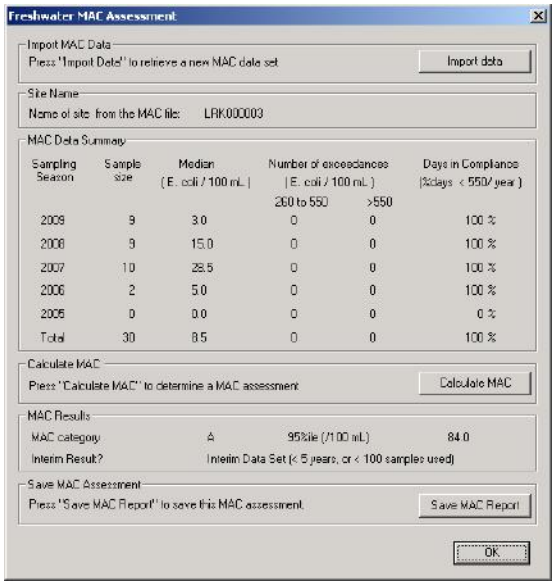


Lake Ratapiko





Lake Rotokare



Appendix II

High tide times

High tide times (NZST) at New Plymouth for 2010-2011 sampling dates

Date		Time of HT
Tuesday	9 November 2010	1129
Wednesday	24 November 2010	1107
Monday	6 December 2010	0950
Thursday	6 January 2011	1056
Monday	10 January 2011	1321
Thursday	3 February 2011	1001
Friday	11 February 2011	1451
Friday	18 February 2011	0936
Monday	21 February 2011	1149
Thursday	10 March 2011	1244
Monday	21 March 2011	1142
Friday	25 March 2011	1357
Tuesday	12 April 2011	1612

Appendix III

Sampling conditions and public usage recorded at each site by the SEM programme

Site Lake Rotomanu (Site Code: LRM000002)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Surface	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	2/8	None	Clear, brown	N/R	0/2 (banks)	Few ducks, seagulls (lake lowered)	0	0.5
24 November 2010	Fine	3/8	None	Clear, brown	N/R	0/4 (banks)	Few ducks (lake lowered)	0	0
6 December 2010	Fine	6/8	Some on surface	Clear, brown	N/R	0/0	Few ducks and seagulls	0	0
6 January 2011	Fine, overcast	8/8	N/R	Brown	N/R	4/12 (banks)	-	0	0
10 January 2011	Fine	1/8	None	Clear, pale brown	N/R	0/7 (boating/banks)	Few ducks	0	0
3 February 2011	Fine, overcast	8/8	None	Clear, brown-green	N/R	0/0	Few ducks	0	2
11 February 2011	Fine	5/8	None	Clear	Ripples	0/3 (boating/banks)	Few ducks	0.5	0.5
18 February 2011	Fine, overcast	8/8	Suspended	Turbid, brown	Calm	0/0	Few ducks	0	0
21 February 2011	Fine	0/8	Extensive	Brown	Ripples	0/0	Few ducks	0	0
10 March 2011	Fine	0/8	None	Blue-brown	N/R	0/0	Few ducks	0	0
21 March 2011	Fine, overcast	8/8	None	Brown	Ripples	0/0	Ducks common	0	0
25 March 2011	Fine, overcast	8/8	Abundant	Clear, uncoloured	Ripples	0/1 (paddle boarder)	-	0	0
12 April 2011	Fine	0/8	None	Clear	Ripples	0/0	Few ducks	0	0

Site Waiwhakaiho River at Merrilands (Site Code: WKH000800)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	0/8	50%	Clear	D/S	0/0		0	0.5
24 November 2010	Fine	0/8	80%	Clear	D/S	0/2 (bank)	Dog on bank	0	0
6 December 2010	Fine, overcast	7/8	20%	Clear, brownish	D/S	0/1 (bank)		0	0
6 January 2011	Fine, overcast	8/8	90%	Clear	D/S	0/3 (bank)	Two dogs on bank	0	0
10 January 2011	Fine	1/8	N/R	Clear, uncoloured	D/S	4/7 (bank)	One dog on bank	0	0
3 February 2011	Fine, overcast	8/8	40%	Clear, brown	D/S	0/0		0.5	2
11 February 2011	Fine	5/8	Moderate	Clear, uncoloured	D/S	2/0		0	0.5
18 February 2011	Fine, overcast	8/8	Abundant	Clear, uncoloured	D/S	0/0		0	0
21 February 2011	Fine	1/8	Moderate	Clear, uncoloured	D/S	3/0	Few dogs	0	0
10 March 2011	Fine	0/8	Thin	Clear, uncoloured	D/S	3/0		0	0
21 March 2011	Fine	4/8	Abundant	Clear, uncoloured	D/S	0/1 (bank)	One dog	0	0
25 March 2011	Fine, overcast	8/8	N/R	Clear, uncoloured	D/S	0/0		0	0
12 April 2011	Fine	0/8	Moderate	Clear, green	D/S	0/0		0	0

Site Patea River, King Edward Park, Stratford (Site Code: PAT000297)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	0/8	Thick mats	Relativey clear, pale brown	D/S	0/0		0	0
24 November 2010	Fine	1/8	Medium mats	Relatively clear, brown	D/S	0/0		0	0
6 December 2010	Fine	4/8	N/R	Clear, uncoloured	D/S	0/1 (bank)	Dog in river	0	0
6 January 2011	Fine, overcast	8/8	Thin mat	Clear, green	D/S	0/2 (banks)	Few ducks	0	0
10 January 2011	Fine	0/8	Thin mat	Relatively clear, pale brown-green	D/S	0/0		0	0
3 February 2011	Fine, overcast	8/8	N/R	Clear, uncoloured	D/S	0/0		0	1
11 February 2011	Fine	2/8	Present	Clear, uncoloured	D/S	2/4 (banks)		0	0
18 February 2011	Fine	3/8	Wide-spread	Slightly turbid, green	D/S	3/20 (banks/fishing)		0	0
21 February 2011	Fine	1/8	Wide-spread	Slightly turbid, brown	D/S	0/0	Few ducks	0	0
10 March 2011	Fine	0/8	N/R	Slightly turbid, green	D/S	0/0		0	0
21 March 2011	Fine	3/8	Wide-spread	Slightly turbid, green	D/S	0/0	Few ducks	0	0
25 March 2011	Fine, overcast	7/8	Thin, widespread	Relatively clear, pale brown	D/S	0/1 (fishing)		0	1.5
12 April 2011	Fine	0/8	Thin, widespread	Slightly turbid, pale green	D/S	0/0		0	0

Site Patea River, boatramp, Patea (Site Code: PAT000995)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	0/8	N/A	Slightly turbid, green	U/S (slow)	0/1 (boating)		0	0
24 November 2010	Fine	0/8	N/A	Relatively clear, pale green	U/S (slow)	0/1 (boating)		0	0
6 December 2010	Fine	6/8	N/A	Clear, pale green	U/S (slow)	0/0		0	0
6 January 2011	Fine, overcast	7/8	N/A	Turbid, grey-green	U/S (surges)	0/0		0	0
10 January 2011	Fine	0/8	N/A	Relatively clear, green	U/S (slow)	0/2 (fishing)		0	0
3 February 2011	Fine	2/8	N/A	Turbid, green-brown	U/S (slow)	0/0		0	5
11 February 2011	Fine	3/8	N/A	Green -grey	U/S	0/0		0	0
18 February 2011	Fine	0/8	N/A	Relatively, clear green	U/S (slow)	0/3 (boating)		0	0
21 February 2011	Fine	0/8	N/A	Clear, green	U/S (slow)	0/0		0	0
10 March 2011	Fine	0/8	N/A	Slightly turbid, pale green	U/S	0/1 (fishing)		0	0
21 March 2011	Fine	6/8	N/A	Slightly turbid,pale green	U/S (slow)	0/0		0	0
25 March 2011	Fine	3/8	N/A	Slightly turbid, pale brown-green	U/S (slow)	0/4 (boating)		0	1
12 April 2011	Fine	0/8	N/A	Slightly turbid, brown-green	U/S (slow)	0/2 (boating)		0	0

Site Waingongoro River, Eltham Camp (Site Code: WGG000492)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	0/8	Medium mats	Relatively clear, uncoloured	D/S	0/0		0	0
24 November 2010	Fine	0/8	Thin mats	Relatively clear, uncoloured	D/S	0/0		0	0
6 December 2010	Fine	4/8	N/R	Relatively clear, pale brown	D/S	0/0		0	0
6 January 2011	Fine, overcast	8/8	Medium mats	Clear, uncoloured	D/S	0/0		0	0
10 January 2011	Fine	0/8	Wide-spread thin mats	Relatively clear, brown	D/S	0/0		0	0
3 February 2011	Fine, overcast	8/8	N/R	Clear	D/S	0/0		0	1
11 February 2011	Fine	2/8	Present	Clear, brown	D/S	0/0		0	0
18 February 2011	Fine	3/8	Wide-spread, thin	Slightly turbid, yellow	D/S	0/0		0	0
21 February 2011	Fine	1/8	Wide-spread, thin	Slightly turbid, pale green	D/S	0/0		0	0
10 March 2011	Fine	0/8	None	Relatively clear, pale yellow	D/S	0/3 (banks)		0	0
21 March 2011	Fine	2/8	Wide-spread	Slightly turbid, pale brown	D/S	0/0		0	0
25 March 2011	Fine, overcast	8/8	Moderate, thin	Clear, colourless	D/S	0/0	Few sheep in adjacent paddock	0	1.5
12 April 2011	Fine	0/8	Wide-spread, thin	Slightly turbid, pale brown	D/S	0/0		0	0

Site Waingongoro River, near mouth (Site Code: WGG000995)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	0/8	Thin	Clear, pale yellow	D/S	0/8 (whitebaiting)	No cattle u/s	0	0
24 November 2010	Fine	1/8	Thin	Clear, pale green	D/S	0/8 (whitebaiting)		0	0
6 December 2010	Fine	4/8	N/R	Slightly turbid, brown	Surging	0/0		0	0
6 January 2011	Fine, overcast	7/8	Wide-spread	Relatively clear, green	D/S	0/0		0	0
10 January 2011	Fine	0/8	Thin mats	Relatively clear, pale brown	D/S	4/1 (fishing)		0	0
3 February 2011	Fine	1/8	N/R	Relatively clear, pale brown	D/S	0/0		0	8.5
11 February 2011	Fine	0/8	Present	Clear, green	D/S	0/0		0	0
18 February 2011	Fine	1/8	N/R	Slightly turbid, brown	D/S	0/0		0	0
21 February 2011	Fine	1/8	N/R	Slightly turbid, green	D/S	2/4 (banks)	Few dogs in water	0	0
10 March 2011	Fine	0/8	N/R	Slightly turbid, pale green	D/S	0/0		0	0.5
21 March 2011	Fine	2/8	N/R	Slightly turbid, green	Surging	0/0		0	0
25 March 2011	Fine	6/8	Moderate	Slightly turbid, green	D/S	0/0		0	3.5
12 April 2011	Fine	0/8	Thin mats	Slightly turbid, green	D/S	0/0		0	0

Site Kaupokonui River, beach domain (Site Code: KPK000995)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	0/8	N/R	Clear	U/S (slow)	0/7 (whitebaiting/kayaking)		0	0
24 November 2010	Fine	1/8	N/R	Clear, colourless	U/S (slow)	0/10 (whitebaiting)		0	0
6 December 2010	Fine	4/8	N/R	Clear, brown-green	D/S (slow)	0/30 (banks)		0	0
6 January 2011	Fine, overcast	7/8	Moderate	Clear, uncoloured	D/S	0/18 (fishing)		0	0
10 January 2011	Fine	1/8	N/R	Relatively clear, uncoloured	U/S (slow)	4/30 (banks)		0	0
3 February 2011	Fine, overcast	7/8	N/R	Relatively clear, pale green	D/S (slow)	0/1 (bank)		0	8.5
11 February 2011	Fine	0/8	N/R	Clear, uncoloured	D/S	0/4 (banks)		0	0
18 February 2011	Fine	2/8	N/R	Relatively clear, pale green	Surging	0/6 (fishing)		0	0
21 February 2011	Fine	1/8	N/R	Relatively clear, green	U/S	0/2 (fishing)		0	0
10 March 2011	Fine	0/8	N/R	Relatively clear, pale yellow	D/S (slow)	0/0		0	0.5
21 March 2011	Fine	3/8	N/R	Relatively clear, green	U/S (surging)	0/0		0	0
25 March 2011	Fine, overcast	7/8	N/R	Clear, very pale brown	D/S	0/5 (fishing/banks)	2 blue herons 2 black shags	0	3.5
12 April 2011	Fine	3/8	N/R	Relatively clear, pale green	D/S (slow)	0/0	1 shag	0	0

Site Lake Opunake (Site Code: LOP000001)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Surface	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	0/8	N/A	Clear, brown	Flat	0/0	Few ducks	0	0
24 November 2010	Fine	1/8	N/A	Clear, pale brown	Flat	0/0	Few ducks	0	0
6 December 2010	Fine	4/8	Floating mats	Clear, brown	N/R	0/0	Ducks common; thick algal surface scum	0	0
6 January 2011	Fine	5/8	Dense floating mats at edges	Turbid, dark-brown	Flat	0/6 (jetskiing/fishing)	Ducks very common	0	0
10 January 2011	Fine	0/8	Floating mats common	Relatively clear, pale brown	Ripple	0/5 (banks)	Ducks common	0	0
3 February 2011	Fine, overcast	8/8	Some floating mats	Relatively clear	Flat	0/0	Ducks very common	0.5	7
11 February 2011	Fine	1/8	Thick mats	Green-brown	Ripple	0/0	Ducks common; algal scum	0	0.5
18 February 2011	Fine	2/8	Thick	Green	Flat	0/0	Ducks common; some algal odour	0	0
21 February 2011	Fine	1/8	Very common, floating	Green	Flat	0/0	Ducks very common	0	0
10 March 2011	Fine	0/8	Very common	Slightly turbid	Flat	0/0	Ducks very common	0	0
21 March 2011	Fine	2/8	Minimal	Slightly turbid brown-green	Ripple	0/0	Ducks common	0	0
25 March 2011	Fine, overcast	8/8	Minimal	Slightly turbid, pale green	Flat	0/0	Ducks extremely common on lake and common on bank	0	6
12 April 2011	Fine	2/8	Minimal	Slightly turbid, pale brown	Flat	0/0	Ducks extremely common	0	0

Site Timaru Stream, near mouth (Site Code: TMR000497)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	0/8	Nil (sandy)	Clear	D/S	0/3 (biking)		0	0
24 November 2010	Fine	0/8	Nil	Clear, uncoloured	U/S (surging)	0/1 (bank)	Two dogs	0	2.5
6 December 2010	Fine	5/8	Nil	Clear, uncoloured	D/S	0/2 (bank)	Few seagulls	0	0
6 January 2011	Fine, overcast	7/8	Nil	Clear, uncoloured	U/S (surging)	0/0	Few seagulls	0	0
10 January 2011	Fine	1/8	Nil	Clear, uncoloured	D/S	3/6 (banks/fishing)	Two dogs on banks	0	0
3 February 2011	Fine, overcast	8/8	Nil	Clear	U/S (surging)	0/0		1	8
11 February 2011	Fine	1/8	Nil	Clear, uncoloured	D/S	0/0		0	0
18 February 2011	Fine	1/8	Nil	Clear	U/S (surging)	0/0		0	6
21 February 2011	Fine, overcast	7/8	Nil	Slightly turbid	U/S (surging)	0/1 (bank)	Seagulls and horses	0	0
10 March 2011	Fine	0/8	Nil	Clear, uncoloured	Ponded	0/0		0	0
21 March 2011	Fine	2/8	Nil	Clear, uncoloured	U/S (surging)	0/0		0	0
25 March 2011	Fine, overcast	8/8	Nil	Clear, uncoloured	Ponded	0/0		0	0
12 April 2011	Fine	0/8	Nil	Clear, uncoloured	Ponded	0/0		0	0

Site Waimoku Stream, Oakura (Site Code: WMK000298)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	2/8	70%	Clear, uncoloured	D/S	0/0		0	0
24 November 2010	Fine	0/8	100%	Pale brown,slightly turbid	D/S	0/0		0	2.5
6 December 2010	Fine	5/8	50%	Clear, uncoloured	D/S	0/0		0	0
6 January 2011	Fine,overcast	8/8	90%	Clear, uncoloured	D/S	0/0		0	0
10 January 2011	Fine	0/8	50%	Clear, uncoloured	D/S	0/25 (beach)		0	0
3 February 2011	Fine, overcast	8/8	Some	Clear, brown	D/S (some surges)	0/0	(channel direct to sea)	1	8
11 February 2011	Fine	1/8	Some	Clear, uncoloured	D/S	0/0	Few seagulls	0	0
18 February 2011	Fine	1/8	100%	Clear, uncoloured	D/S	0/0		0	6
21 February 2011	Fine, overcast	7/8	Abundant	Clear, brown	D/S	0/0	Few seagulls	0	0
10 March 2011	Fine	0/8	Abundant	Clear, uncoloured	D/S	2/0	(channel along beach to north)	0	0
21 March 2011	Fine	1/8	Moderate	Clear, uncoloured	D/S	0/0	(channel to north and ponding)	0	0
25 March 2011	Fine, overcast	8/8	Moderate	Clear, uncoloured	D/S	0/0	(channel to north and ponding)	0	0
12 April 2011	Fine	0/8	Thick mats	Clear, brown	D/S	0/0	(channel to north and ponding)	0	0

Site Oakura River, near mouth (Site Code: OKR000497)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	2/8	N/A (sandy)	Clear, uncoloured	Ponded	0/11 (whitebaiting/banks)	Dog d/s	0	0
24 November 2010	Fine	0/8	N/A	Clear, uncoloured	Ponded	0/2 (bank)		0	2.5
6 December 2010	Fine	4/8	N/A	Clear, uncoloured	U/S (slow)	0/1 (bank)	Dogs	0	0
6 January 2011	Fine, overcast	8/8	N/A	Clear, uncoloured	Ponded	0/8 (banks, fishing)	Few seagulls	0	0
10 January 2011	Fine	1/8	N/A	Clear, uncoloured	Ponded	3/10 (banks)	Few seagulls	0	0
3 February 2011	Fine, overcast	8/8	N/A	Clear, green	U/S (slow)	3/0		1	8
11 February 2011	Fine	2/8	N/A	Clear, brown	Ponded	15/1 (bank)	Dog u/s	0	0
18 February 2011	Fine	2/8	N/A	Clear, uncoloured	D/S	0/0	Few seagulls	0	6
21 February 2011	Fine, overcast	8/8	N/A	Clear, green	Ponded	0/0		0	0
10 March 2011	Fine	0/8	N/A	Clear, green	U/S	0/0		0	0
21 March 2011	Fine	1/8	N/A	Clear, green	Surging	0/1 (bank)	Dog in river	0	0
25 March 2011	Fine, overcast	8/8	N/A	Clear, uncoloured	D/S (slow)	0/0		0	0
12 April 2011	Fine	0/8	N/A	Clear, green	Ponded	0/0		0	0

Site Waitara River at town wharf, Waitara (Site Code: WTR000922)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	S.G	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	0/8	2.0	Clear, green	Still	0/1 (kayaking)	Few ducks	0	0
24 November 2010	Fine	0/8	1.5	Clear, green	D/S (slow)	0/2 (whitebaiting)		0	0
6 December 2010	Fine	5/8	1.9	Clear, green	Still	0/1 (bank)	Few ducks	0	0
6 January 2011	Fine,overcast	8/8	2.1	Brown-green	Still	0/0	Few ducks	0	0
10 January 2011	Fine	0/8	1.4	Turbid, blue-green	U/S	0/2 (rowing)	Few ducks	0	0
3 February 2011	Fine, overcast (fog)	8/8	2.0	Turbid, green-grey	Still	0/0		0	1.5
11 February 2011	Fine	0/8	1.3	Brown-green	U/S	0/0	Seagulls common	0	1
18 February 2011	Fine	0/8	2.3	Turbid, green	Still	1/0	Dog	0	0
21 February 2011	Fine	0/8	2.5	Turbid, green	Still	1/3 (banks)		0	0
10 March 2011	Fine	0/8	1.6	Turbid, brown	D/S (slow)	0/0	Few ducks, seagulls very common	0	0
21 March 2011	Fine	3/8	2.4	Turbid, green-brown	D/S (slow)	0/1 (fishing)	Few ducks	0	0
25 March 2011	Fine, overcast	8/8	1.5	Slightly turbid, green	Still	0/0	Gulls common, few ducks	0	0
12 April 2011	Fine	0/8	1.3	Slightly turbid, brown	U/S (slow)	0/0		0	0

Site Urenui River at estuary (Site Code: URN000480)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	0/8	N/A	Clear, green	U/S (slow)	0/0		0	0
24 November 2010	Fine	0/8	N/A	Clear, green	U/S	0/0		0	0
6 December 2010	Fine, overcast	8/8	N/A	Clear, blue-green	U/S (slow)	0/0		0	0
6 January 2011	Fine, overcast	8/8	N/A	Green	U/S	3/7 (banks)		0	0
10 January 2011	Fine	0/8	N/A	Slightly turbid; blue-green	Still	30/0		0	0
3 February 2011,	Fine, overcast	8/8	N/A	Turbid, grey-green	Still	0/4 (banks)		0	1.5
11 February 2011	Fine	1/8	N/A	Blue-green	U/S	0/4 (boating/fishing)		0	1
18 February 2011	Fine	4/8	N/A	Clear, green	Still	0/4 (banks)		0	0
21 February 2011	Fine	3/8	N/A	Green	U/S	2/2 (banks)		0	0
10 March 2011	Fine	0/8	N/A	Turbid, green	U/S (slow)	5/2 (banks)		0	0
21 March 2011	Fine, overcast	8/8	N/A	Turbid, green-grey	Still	0/3 (banks/fishing)		0	0
25 March 2011	Fine, overcast	8/8	N/A	Turbid, green	U/S (slow)	0/0		0	0
12 April 2011	Fine	0/8	N/A	Slightly turbid, green	U/S (slow)	0/0		0	0

Site Manganui River d/s of Kurapete Stream (Site Code: MGN000435)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	0/8	Common	Clear, pale brown	D/S	0/0	Few ducks	0	0
24 November 2010	Fine	0/8	Present	Clear, brown	D/S	0/0		0	0
6 December 2010	Fine	1/8	Present	Clear, brown	D/S	0/0		0	0
6 January 2011	Fine, overcast	8/8	Present	Green-brown	D/S	0/0		0	0
10 January 2011	Fine	0/8	Present	Clear, brown	D/S	0/0		0	0
3 February 2011	Fine, overcast	8/8	Present	Clear, green-brown	D/S	0/0		0.5	10.5
11 February 2011	Fine	4/8	Present	Clear, brown	D/S	0/0		0	0.5
18 February 2011	Fine	5/8	Present	Clear, brown	D/S	0/5 (kayakers)	Some foam	0	0
21 February 2011	Fine	3/8	Present	Clear, brown	D/S	0/0		0	0
10 March 2011	Fine	0/8	Thin	Clear, pale green	D/S	0/0		0	0
21 March 2011	Fine, overcast	7/8	Thin	Clear, pale green	D/S	0/0		0	0
25 March 2011	Fine, overcast	8/8	Present	Clear, pale green	D/S	0/0		0	0
12 April 2011	Fine	0/8	Present	Slightly turbid, brown-green	D/S	0/0		0	0

Site Lake Ratapiko (Site Code: LRP000050)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Surface	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
9 November 2010	Fine	7/8	N/A	Clear, brown	Ripple	0/0	Ducks common	0	0
24 November 2010	Fine	0/8	N/A	Clear, blue-brown	Ripple	0/0	Few ducks and stock at margin	0	0
6 December 2010	Fine, overcast	8/8	N/A	Clear, brown	Ripple	0/0		0	0
6 January 2011	Fine, overcast	8/8	N/A	Brown	Ripple	0/0	Ducks common; one swan. Herd of cows on bank	0	25
10 January 2011	Fine	0/8	N/A	Slightly turbid, brown	Ripple	0/0	Cow on bank	0	0
3 February 2011	Fine, overcast	8/8	N/A	Clear, brown	Ripple	0/0	Few ducks	0.5	10.5
11 February 2011	Fine	4/8	N/A	Clear, brown	Ripple	0/1 (bank)		0	0.5
18 February 2011	Fine	5/8	N/A	Clear, brown	Ripple	0/0		0	0
21 February 2011	Fine	3/8	N/A	Clear, brown	Ripple	0/0	Lake level low	0	0
10 March 2011	Fine	0/8	N/A	Clear; brown	Ripple	0/0		0	0
21 March 2011	Fine	6/8	N/A	Clear, brown	Ripple	5/0		0	0
25 March 2011	Fine, overcast	8/8	N/A	Clear, brown	Ripple	0/0	Shags common	0	0
12 April 2011	Fine	0/8	N/A	N/A	N/A	0/0	Lake level very low (maintenance) [No sampling possible]	0	0

Appendix IV

Sampling conditions and public usage recorded at two sites by the additional programme

Dates of additional sampling

Date	Preceding weather
Tuesday 16 November 2010	dry over 24 hours, wet over 48-72 hours
Monday 29 November 2010	dry over 72 hours
Tuesday 14 December 2010	wet over 72 hours, mainly last 24 hours
Thursday 13 January 2011	dry over 72 hours
Thursday 27 January 2011	dry over 72 hours
Tuesday 15 February 2011	relatively dry over 72 hours
Wednesday 16 March 2011	dry over 72 hours

Site Lake Rotomanu (Site Code: LRM000002): additional monitoring (seven samples)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
16 November 2010	Fine	1/8	N/R	Relatively clear	Calm	0/0	Ducks common, few gulls and swans; lake level lowered	0	10
29 November 2010	Fine, overcast	8/8	N/R	Relatively clear	Calm	0/0	Few ducks, weed common; level very low	0	0
14 December 2010	Fine, overcast	8/8	None	Relatively clear, brown-green	Calm	0/0	Few ducks, level still very low	19	19
13 January 2011	Fine	0/8	N/R	Relatively clear, pale brown	Ripples	0/0	Few ducks; level normal	0	0
27 January 2011	Fine, overcast	7/8	None	Relatively clear	Clam	5/10 (boating)	Few ducks, 1 dog; level normal	0	0
15 February 2011	Fine	0/8	None	Relatively clear, pale yellow	Ripples	0/0	Ducks common	0	0.5
16 March 2011	Fine	2/8	None	Pale brown	Ripples	0/0		0	0

Site Waiwhakaiho River at Merrilands (Site Code: WKH000800): additional monitoring (seven samples)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Direction of Flow	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
16 November 2010	Fine	1/8	N/R	Rel. clear, green	D/S	0/0		0	10
29 November 2010	Fine, overcast	8/8	N/R	Clear, green	D/S	0/0		0	0
14 December 2010	Fine, overcast	8/8	Thin, wide-spread	Clear, green-brown	D/S	0/0		19	19
13 January 2011	Fine	0/8	Thin, wide-spread	Relatively clear, pale-green	D/S	1/0	1 dog in water	0	0
27 January 2011	Fine, overcast	8/8	Thin, wide-spread	Clear, pale-green	D/S	0/0		0	0
15 February 2011	Fine	1/8	Thin	Relatively clear, colourless	D/S	0/0		0	0.5
16 March 2011	Fine	0/8	N/R	Relatively clear, green	D/S	0/4 (banks)	Few dogs on bank	0	0

Appendix IV

Sampling conditions and public usage recorded at three sites during the cyanobacteria programme

Site Lake Opunake (Site Code: LOP000001)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Surface	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
16 November 2010	Fine	5/8	N/A	Clear, pale-brown	Flat	0/0	Ducks common	0	10
29 November 2010	Fine, overcast	8/8	N/A	Clear, brown	Flat	0/0	Ducks common	0	0
14 December 2010	Fine, overcast	8/8	Floating mats, wide-spread	Clear, brown	Flat	0/0	Ducks common	4	10
13 January 2011	Fine	0/8	Floating mats very common	Relatively clear, pale brown	Ripple	0/0	Ducks very common	0	0
27 January 2011	Light rain, overcast	8/8	Floating mats present	Slightly turbid, brown	Flat	0.0	Ducks very common	0	3
15 February 2011	Fine, overcast	8/8	Floating algae very common	Slightly turbid, green-brown	Ripple	0/0	Ducks very common	0	4
16 March 2011	Fine	1/8	Some algae (not at edge)	Slightly turbid, brown	Ripple	0/1 (banks)	Ducks common	0	0

Site Lake Ratapiko (Site Code: LRP000050)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Surface	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
16 November 2010	Fine, overcast	7/8	N/R	Clear, green-brown	Ripple	0/0		0	2
29 November 2010	Fine, overcast (foggy)	8/8	N/R	Clear, pale brown	Flat	0/0	Few ducks	0	0
14 December 2010	Light rain, overcast	8/8	None	Clear, green-brown	Ripple	0/0	Few ducks, swan	28	52
13 January 2011	Fine	0/8	N/R	Slightly turbid, pale brown	Ripple	0/0		0	0
27 January 2011	Fine, overcast	8/8	N/R	Clear, uncoloured	Ripple	0/0		0	0
15 February 2011	Fine	1/8	N/R	Relatively clear, brown	Ripple	0/0		0	5.5
16 March 2011	Fine	(foggy)	N/R	Slightly turbid, brown	Flat	0/0		0	0

Site Lake Rotokare adjacent to boatramp (Site Code: LRK000003)

Sampling Date	Weather		Conditions			Site usage		Rainfall (mm)	
	General	Cloud Cover	Algal cover	Appearance	Surface	Bathers / Users	Miscellaneous	Previous 24 hrs	Previous 72 hrs
15 November 2010	Fine	0/8	Some suspended	Slightly turbid, pale brown	Ripple	0/0	Boat ramp locked	0	1
24 November 2010	Fine	0/8	Some suspended	Slightly turbid, brown	Ripple	0/0	Very few ducks	0	3
30 November 2010	Fine, overcast	7/8	Some suspended	Slightly turbid, green-brown	Ripple	0/2 (walkers)		0	0
15 December 2010	Light rain, overcast	8/8	Some suspended	Slightly turbid, brown	Flat	0/0	Boat ramp open	0	12
23 December 2010	Fine	4/8	Some suspended	Relatively clear, brown	Ripple	0/0	Health warning signs present, boat ramp open	0	0
13 January 2011	Fine	0/8	Some suspended	Turbid, pale-brown	Calm	0/4 (bank)	Health warning signs present, boat ramp open	0	0
31 January 2011	Light rain, overcast	8/8	Some suspended	Turbid, light-green	Ripple	0/0	Health warning signs present; few ducks	0	0
15 February 2011	Fine	2/8	Some suspended	Slightly turbid, brown	Calm	0/0	Health warning signs present	0	2
16 February 2011	Fine, overcast	7/8	Some suspended	Turbid, brown	Calm	0/3 (bank)	Health warning signs present	0	0
28 February 2011	Fine	1/8	Some suspended	Turbid brown	Ripple	0/0 [boat ramp gate closed; not locked]	Health warning signs present	0	0
8 March 2011	Fine	4/8	Some suspended	Slightly turbid, brown	Flat	0/0 [boat ramp gate closed; not locked]	Health warning signs present; few pukeko and black shags	0	14 (78: 5 days)
15 March 2011	Fine	5/8	Some suspended	Relatively clear, brown	Flat	0/1 (bank [boat ramp open]	No signage; few pukeko	0	0
30 March 2011	Fine	0/8	Some suspended	Relatively clear, brown-green	Flat	0/4 (bank)	No signage	0	3
12 April 2011	Fine	0/8	Some suspended	Relatively clear, pale brown	Ripple	0/10 (bank)	No signage	0	0

Appendix V

Comparative annual box and whisker plots of SEM data for *E. coli* for the period 1996 to 2010

Explanation of box and whisker plots

Box and whisker plots are a useful method of summarising data in a graphical form that allows rapid comparisons of data groups. The data is represented as a box with a whisker from each end.

The median (middle value of the sorted data; half of the data is either side of the median is represented by a single horizontal line. The notch, symmetrically spread around the median represents the 95% confidence interval of the median). It is a feature that allows rapid comparison between groups. If notches overlap, there is no significant difference between groups (at the 95 % confidence interval). If notches do not overlap, a statistical difference is expected.

The top and bottom of the box represent the upper and lower hinges respectively. The median splits the ordered group of data in half and the hinges split the remaining halves in half again. This means that 50% of the data lies within the box.

Hspread, comparable to the interquartile (25% and 75%) range is the difference between the values of the two hinges, ie, Upper hinge – Lower hinge = Hspread. The inner fences are defined as follows:

Lower fence = lower hinge – (1.5 x Hspread)
Upper fence = upper hinge + (1.5 x Hspread)

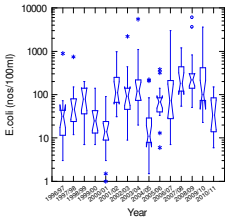
The outer fences are defined as follows:

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

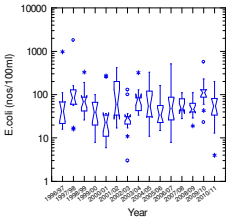
The whiskers show the range of values that lie within the inner fences. Values outside the inner fence (outliers) are plotted as asterisks (*). Values outside the outer fence (extreme outliers) are plotted as ˚.

E. coli

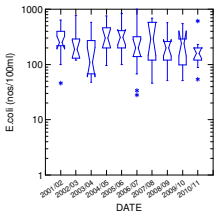
Lake Rotomanu



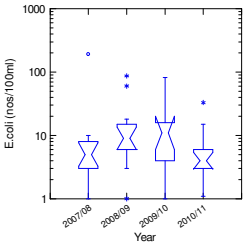
Waiwhakaiho River



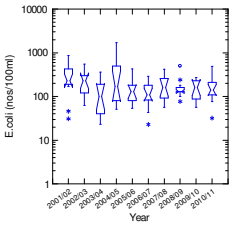
Patea River at Stratford



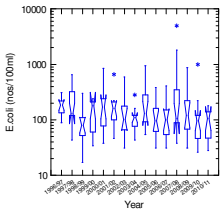
Patea River at Patea



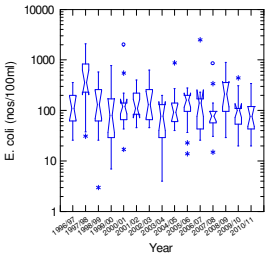
Waingongoro R at Eltham



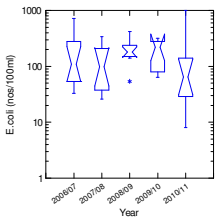
Waingongoro R at Ohawe



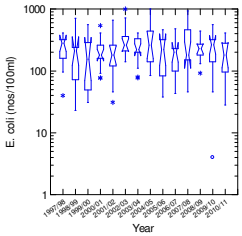
Kaupokonui River



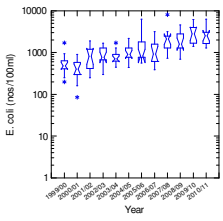
Lake Opunake



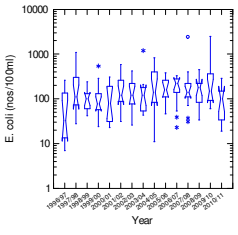
Timaru Stream



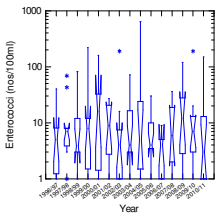
Waimoku Stream



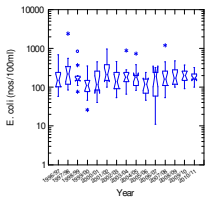
Oakura River



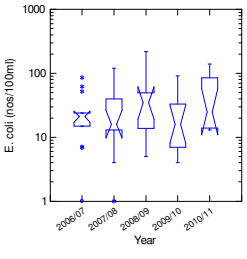
Urenui River



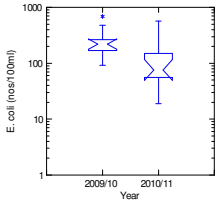
Manganui River



Lake Ratapiko



Waitara River at town wharf



Appendix VI

Publicity during the 2010-2011 season

Birds blamed for dirty stream

Local rivers up to guidelines

Jared Smith
jared.smith@dailynews.co.nz

Taranaki swimming holes are as clean as most in New Zealand.

The one repeat offender at the bottom of national rankings for faeces contamination is Oakura's Waimoku Stream, and the Taranaki Regional Council says "CSI-type forensics" found that resulted from ducks and pukekos.

The regional council said it would not exterminate the birdlife to meet perceptions of "distilled water quality" rivers.

"You'd expect us to be worse than the rest of New Zealand because of dairying," said the director of environment quality, Gary Bedford.

"We match up, we're not the bottom of the heap."

Sixteen Taranaki rivers, streams and lakes used for recreation were monitored over the summer during 13 periods suitable for bathing.

Results show 73 per cent of the sites complied with guidelines set by the Ministry for the Environment for at least 90 per cent of the season, compared with 72 per cent nationwide.

These are rated by the amount of E.coli per 100ml water sample, with up to 260 acceptable and more than 550 requiring action.

Mr Bedford said even with a reading of 550, about 99.9 per cent of swimmers would suffer no ill health effects.

He said using "CSI-type" DNA profiling techniques established beyond doubt waterfowl caused the consistently high bacteria levels in Waimoku Stream.

It was a theory long held by the regional council that several commentators had challenged, he said.

The source was most likely ducks and pukekos.

Committee members Tom Cloke and Michael Davey both asked if some control operation of the birdlife should be considered to bring the stream up to standard.

Mr Bedford said as long as the regional council encouraged riparian planting, natural birdlife would live in it.

Regional council chief executive, Basil Chamberlain, said it was a complex issue as all waterways have animals, and bird life was a natural phenomenon. All rivers had some bacteria.

"No-one's suggesting we kill our lovely pukekos. Our streams are like this, they're always like this, so what's the problem?"

Ranking waterways according to median bacterial readings, the Urenui River estuary, the Patea River at Patea and Lake Ratapiko top the list for quality.

At the bottom are Patea River at Stratford, the Timaru Stream at Weld Rd and the Waimoku Stream.

Mr Bedford said stock access and run-off during wet weather were other causes of contamination.

Appendix VII

Bacterial marker investigations in the lower Waitara River

Results of microbial source tracking investigations at four sites in the lower Waitara river

[DNA analyses undertaken by Cawthron Institute, Nelson: *E.coli* analyses by TRC laboratory]

Site: Bertrand Road (WTR000800) [GPS: 1708576E 5677176N]

Date:	3 Nov 2010	17 Nov 2010	29 Nov 2010	6 Dec 2010	7 Apr 2011
Source[1]	R	-[2]	-[2]	R	R
E. coli (nos/100ml)	25	37	66	62	2,700
Flow conditions Tide	low LT	low LT	low LT	low HT	flood recession 1-2hr <HT

[[1]source: R= ruminant; H= human; W= wildfowl; (duck, gull)]
[[2]origin not detectable: likely due to limited faecal contamination]

Site: Waitara Town Wharf (WTR000922) [GPS: 1707201ES 5682573N]

Date:	3 Nov 2010	17 Nov 2010	29 Nov 2010	6 Dec 2010	7 Apr 2011
Source[1]	R	R	-[2]	R,H	R,H
E. coli (nos/100ml)	50	64	260	97	2,000
Flow conditions Tide	low LT	low LT	low LT	low HT	flood recession 1-2hr <HT

[[1]source: R= ruminant; H= human; W= wildfowl; (duck, gull)]
[[2]origin not detectable: likely due to limited faecal contamination]

Site: River mouth left bank (WTR000992) [GPS: 1706405E 5683756N]

Date:	3 Nov 2010	17 Nov 2010	29 Nov 2010	6 Dec 2010	7 Apr 2011
Source[1]	R,Wd,Wg,H	R,H	-[2]	-[2]	R,H
E. coli (nos/100ml)	20	29	120	24	23,000
Flow conditions Tide	low LT	low LT	low LT	low HT	flood recession 1-2hr <HT

[[1]source: R= ruminant; H= human; W= wildfowl; (duck, gull)]
[[2]origin not detectable: likely due to limited faecal contamination]

Site: River mouth left bank (WTR000997) [GPS: 1706505E 5683756N]

Date:	3 Nov 2010	17 Nov 2010	29 Nov 2010	6 Dec 2010	7 Apr 2011
Source[1]	R	R,H	-[2]	-[2]	R,H
E. coli (nos/100ml)	28	36	120	<1	2,000
Flow conditions Tide	low LT	low LT	low LT	low HT	flood recession 1-2hr <HT

[[1]source: R= ruminant; H= human; W= wildfowl; (duck, gull)]
[[2]origin not detectable: likely due to limited faecal contamination]

Comments:

Following the analysis of samples collected on 26 November, 2010, Cawthron Institute reported that:

The samples received appear to contain limited or no recent faecal contamination (Figure 1). Universal Bacteroides marker, indicative of recent faecal contamination,

was detected in the samples collected at Bertrand Road and Town Wharf. No animal or human-specific markers were detected in any of the samples collected.

These results are in agreement with recent research indicating higher die-off rates of Bacteroides, compared to faecal indicator bacteria such as coliforms and enterococci (Ballesté and Blanch, 2010).
(Note: river temperatures ranged from 19.4˚C to 21.8˚C at the time of sampling (0810 to 0900 hrs (NZST)).

Reference: Balleste E, Blanch A R. 2010. Persistence of Bacteroids Species Populations in a River as Measured by Molecular and Culture Techniques. Applied and Environmental Microbiology 76: 7608-7616.