Recreational Waters Surveillance Report 2015-2016

Bay of Plenty Regional Council
Environmental Publication 2016/14

5 Quay Street
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Whakatāne 3158
NEW ZEALAND

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BAY OF PLENTY REGIONAL COUNCIL
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Cover Photo: Swimming in the Whakatane River

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Date: October 2016

Executive summary

The Bay of Plenty Regional Council undertakes annual water quality surveys of popular recreational (bathing) sites and shellfish collection areas over the warmer months (October to March). The surveys assist in identifying the risk to public health from faecal contamination in these areas. This information is then used by public health and local authorities to advise the community on the suitability of water for bathing or shellfish consumption.

The objective of this report is to detail the contact recreation suitability of approximately 70 river, lake and marine sites over the 2015-16 bathing season (October to March). A three tiered management framework has been adopted to help signal when recreational waters are potentially at risk to users. The system uses the colours green (safe mode), orange (cautionary mode) and red (unsafe mode) to denote risk to bathers.

Two indicator bacteria are used to assess the risk of faecal contamination in recreational waters. These are:

- Freshwaters – *Escherichia coli* (*E.coli*), and
- Marine waters – Enterococci.

The results from the 2015-16 bathing surveys show that most sites in the Bay of Plenty are generally suitable for swimming. However, the 'Suitability for Recreation Grading' (SFRG) highlights that there is some risk to recreational water users using rivers and streams, as they are more vulnerable to pathogen loading from runoff after rainfall events. For example, 91.5% of lake sites were graded 'very good' or 'good', while 21.7% of river sites were graded 'very good' or 'good'.

The table below shows the status of monitored bathing sites against the New Zealand Microbiological Water Quality Guidelines (Red/Action Mode). Generally, lake sites show the highest quality overall, followed by marine and river sites.

Table 1 *Percentage of samples from monitored bathing sites with indicator bacteria levels less than the Red/Action Mode, as defined by the New Zealand Microbiological Water Quality Guidelines Ministry for the Environment (MfE)/Ministry of Health (MoH) 2003).*

		Rivers	Lakes	Marine
Samples less than the Red/Action Mode	2015-16	89.9%	98.5%	93.4%
	Last 5 years	92.8%	99.3%	97.1%

River and stream sites had higher levels of faecal contamination compared to the previous season. Twenty five percent of results were above the Orange/Alert Mode and 10% results were above the Red/Action Mode. Of these, nine of the sites only had 5% instances of reaching the Red/Action mode and these can be attributed to heavy rainfall in the area.

Open coastal sites typically have excellent water quality with no sites reaching the Red/Action Mode in 2015-16. Fifteen of the 18 estuarine sites reached the Orange/Alert Mode in 2015-16 and only three of the estuarine sites were graded 'poor' (none were graded 'very poor').

The 2015-16 *E.coli* data was compared to the National Objectives Framework (NOF) attributes for human health given in the National Policy Statement (NPS) for Freshwater Management. All freshwater sites rate highly (i.e. very safe) for secondary contact recreation activities (e.g. wading or boating), however, eight sites are rated below the minimal acceptable standard for primary contact recreation activities (e.g. swimming, full immersion).

Faecal coliform concentrations from popular shellfish gathering sites revealed that two of the 13 sites monitored did not meet the Microbiological Water Quality Guideline levels for safe consumption of shellfish. These sites were at Waiotahe Estuary and Waihī Estuary.

Observations of toxin producing benthic cyanobacteria *Phormidium* in rivers and streams were also made. No sites reached alert levels as prescribed by the Cyanobacteria in Recreational Fresh Waters Interim Guidelines.

Further investigations of faecal contamination sources are recommended in catchments that have had consistently elevated indicator bacteria levels resulting in multiple health advisories.

A further recommendation is to develop a predictive warning system for high risk sites, rather than rely on weekly monitoring, which is often out of date before a warning can be initiated. A predictive model can be developed by undertaking event sampling and analyses of sites with adjacent flow/level and rainfall monitoring. A model would then be used to provide an early warning system of elevated pathogen levels in rivers.

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Part 1: Introduction

1.1 Overview

The Bay of Plenty Regional Council undertakes annual water quality surveys of popular recreational (bathing) sites and shellfish beds over the warmer months (October to March). The surveys assist in identifying the risk to public health from faecal contamination at these areas. The information is then used by public health and local authorities, to advise the community on the suitability of water for bathing or shellfish consumption.

There are a number of regional plans that have objectives based on a contact recreation standard. These are:

- On-site Effluent Treatment (OSET) Regional Plan.
- Regional Water and Land Plan.
- Regional Coastal Environmental Plan.
- Regional Policy Statement.

Due to the public health risk from cyanobacteria (blue-green algae) monitoring also includes surveys of benthic cyanobacteria (*Phormidium*) in rivers and streams. This report summarises the annual recreational waters survey monitoring results for the 2015-16 season and also presents recent shellfish monitoring results.

1.2 Legislative framework and responsibilities

The National Policy Statement (NPS) for Freshwater Management (2014) has the objective to safeguard the health of people and communities. The NPS has a National Objectives Framework (NOF) which sets thresholds for numeric attributes, ranked into four bands (A-D), defining water quality for "human" (and "ecosystem") health (Ministry for the Environment) (MfE), 2014) (Table 1).

Table 1 The National Objective Framework – values and related attributes for lakes and rivers (summarised from MfE, 2014).

Value	Attribute state (E.coli/100 ml)			
	A	**B**	**C (Bottom-line)**	**D**
Numeric state	≤260	>260 and ≤ 540	>540 and ≤1000	>1000
Human health for secondary* contact (annual median)	Very low risk of infection (<0.1%) secondary exposure	Low risk of infection (up to 1%) secondary exposure	Moderate risk of infection (<5.0%) from secondary exposure	High risk of infection (>5.0%) from secondary exposure
Human health for primary** contact (ninety fifth-Percentile)	Low risk of infection (up to 1%) primary exposure	Moderate risk of infection (<5.0%) from primary exposure. **Minimum Acceptable State**		

*Secondary activity occasional immersion and some ingestion: e.g. boating; wading. **Primary likely to involve full immersion.

The agencies responsible for managing recreational water quality for the community are the regional council, district councils, district health boards and the medical officer of health. There is no legislation dictating which agency is responsible for recreational bathing monitoring, but under the Health Act (1956) and the Resource Management Act (1991), local agencies and the health authority have defined responsibilities.

The Microbiological Water Quality Guidelines (MfE/MoH 2003) provide a recommended framework of roles and responsibilities of the agencies involved in recreational water quality monitoring. Based on this framework, a protocol for monitoring and reporting has been developed for the Bay of Plenty.

1.3 Recreational water quality objectives

The objectives of the Bay of Plenty Regional Council's recreational water quality monitoring programme are to:

- Assess the suitability of approximately 70 river, lake and marine sites in the Bay of Plenty for contact recreation.
- Provide information on the suitability of shellfish for human consumption.
- Assist in safeguarding the life-supporting capacity of water, including public health.
- Provide a mechanism to determine the effectiveness of regional plans.
- Provide information for State of the Environment monitoring, regionally and nationally.
- Assist in identifying areas of poor water quality to help identify the causes so remedial action can be initiated.
- Set the foundation for water quality accounting in freshwater management units and assist in the identification of values of each freshwater management unit.

The bathing surveillance monitoring sites are shown in the map that follows (Figure 1.1).

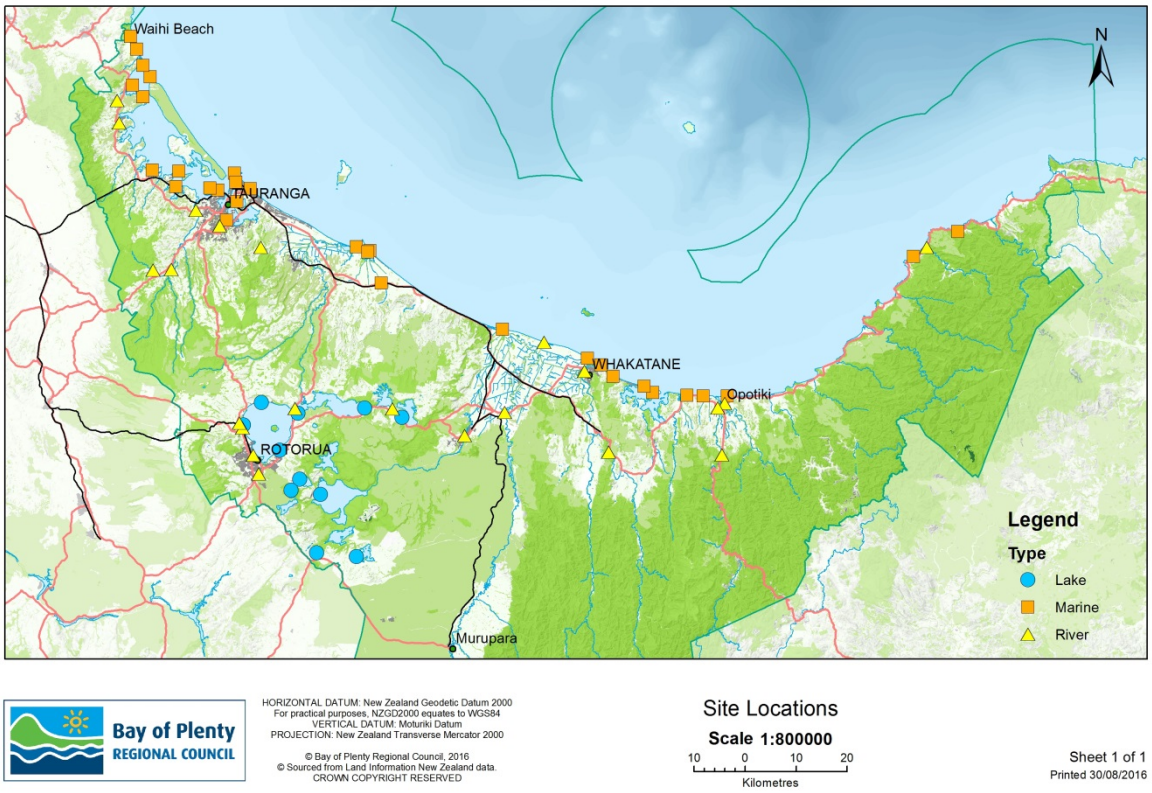

Figure 1.1 Bathing surveillance sites for the 2015-16 season, Bay of Plenty.

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Part 2: Microbiological guidelines, indicators and grading

2.1 Introduction

If human or animal faecal matter finds its way into waters of recreational value, there is a risk that water users will be exposed to a diverse range of pathogenic (disease causing) micro-organisms. A variety of organisms are present in faecal matter such as viruses, bacteria, protozoa (single cell organisms), and helminths (nematodes). These can reach water bodies via a variety of pathways and in varying concentrations.

The impacts of pathogenic micro-organisms on human health are commonly manifested as gastro-enteritis, but other common illnesses include respiratory problems and skin rashes. Serious illness can also be attributed to infection from pathogens contained in waters, for example, hepatitis A, giardiasis, cryptosporidiosis, campylobacteriosis and salmonellosis (MfE/MoH, 2003).

Indicator micro-organisms are used to assess recreational water quality. It is difficult and impractical to measure all potentially pathogenic micro-organisms in water. Indicator micro-organisms give an indirect measure of pathogen levels. The bacteriological indicators chosen are associated with the gut of warm blooded animals and are common in faecal matter. While these indicator bacteria are not generally harmful themselves, they do indicate the presence of harmful pathogens. Two indicator bacteria are commonly used in recreational waters:

- freshwaters – *Escherichia coli* (*E.coli*), and
- marine waters – Enterococci.

The use of these two indicators is stipulated in the New Zealand Microbiological Water Quality Guidelines (hereafter referred to as the microbiological guidelines). Research that relates illness to indicator bacterial levels has been used to develop guideline levels which are based on the tolerable risk to healthy people. The guidelines provide a method to grade recreational waters (see section 2.4) and trigger levels which can be used by water managers and the public, to assess the potential risk of using recreational waters. Single water sample results can then be compared to guideline values to help determine if a health alert or other action should be undertaken.

2.2 Sampling and analysis

Water sampling and analyses were performed in accordance with established internal procedures. Most analyses were performed by the Regional Council laboratory.

Table 2.1 Methods used for analysis of water samples.

Parameter (abbreviation)	Method	Detection limit/units
Escherichia coli (E.coli)	Membrane filtration (APHA 2005)	1 cfu/100 ml
Faecal coliform (FC)	Membrane filtration (APHA 2005)	1 cfu/100 ml
Enterococci (Ent)	Method No 1600, USEPA 1985 EPA-821-R-97-004	1 cfu/100 ml

Sampling occurred between 8:00 am and 3:30 pm and was completed by either wading or use of a sample pole. Sterile 200 ml polyethylene bottles were used to sample water at a representative location in the water column. Water quality analyses were completed using the methods in Table 2.1.

2.3 Microbiological guidelines

The microbiological guidelines provide the framework for assessing the health risk associated with faecal contamination of water. There are two tiers to the guidelines. The first tier is used to compare weekly monitoring results with the microbiological guidelines over a bathing season, providing water managers with a tool for assessing more immediate health risk to the public. The second tier is a site grading providing an analysis of the suitability for recreation over time, using a combination of information from microbiological bathing survey results and catchment characteristics.

A three-tiered management framework has been adopted to help signal when recreational waters are potentially at risk to users. The system uses the colours green (safe mode, 'surveillance'), orange (cautionary mode, 'alert') and red (unsafe mode, 'action') to denote the level of risk to users. The indicator bacteria levels and recommended management responses to these different modes are listed in Table 2.2. This framework is used to assess health risk of recreational waters weekly as individual sample results are obtained.

Table 2.2 Surveillance, alert and action levels for fresh and marine waters (MfE/MoH, 2003).

Mode	Guideline - freshwaters (*E.coli* count in colony forming units per 100 mL)	Recommended management response
Green/Surveillance	Single sample ≤ 260	Routine monitoring
Orange/Alert	Single sample > 260 and ≤ 550	Increased monitoring, identify possible sources
Red/Action	Single sample > 550	Public warnings, increased monitoring, source investigation

Mode	Guideline - marine (Enterococci count in colony forming units per 100 mL)	Recommended management response
Green/Surveillance	Single sample ≤ 140	Routine monitoring
Orange/Alert	Single sample > 140 and ≤ 280	Increased monitoring, identify possible sources
Red/Action	Two consecutive single samples > 280	Public warnings, increased monitoring, source investigation

Surveillance mode (green) indicates there is an acceptable risk to recreational water users. Should waters be found to be in *Alert Mode* (*orange)* then there is an increased risk of illness if contact is made with recreational waters. *Action Mode (red)* indicates waters pose an unacceptable health risk to recreational water users. In such a case, the health authority will assess the risk to public health and if necessary, issue health warnings in conjunction with local authorities. Use of microbiological guidelines and the issuing of health warnings are dependent on the circumstances surrounding any contamination event.

2.4 Bathing surveillance grading

The microbiological guidelines outline a process to grade the suitability of marine and fresh waters for recreational use. A 'Suitability for Recreation Grade' (SFRG) is generated through a combination of qualitative assessment of susceptibility of recreational sites to faecal contamination and by direct measurement of appropriate bacteriological indicators at the site. In contrast to the SFRG, the alert and action levels described above. provide a real time indication of the changing risk over a bathing season. The SFRG describes the risk of faecal contamination at a given site over several bathing seasons.

The beach grading is made up of two components:

- The *Sanitary Inspection Category (SIC)* is composed of five ratings from very low to very high, which are dependent upon the presence and potential effect of faecal contaminant sources. It generates a measure of susceptibility of a water body to faecal contamination, from potential water quality risk factors close to swimming spots, such as sewage outfalls, stormwater drains, stock in waterways and run-off from land, and
- Historical microbiological results are used to generate the *Microbiological Assessment Category (MAC)*, which provides a measurement of actual water quality over time.

These two combined, give an overall 'Suitability for Recreation Grade' (SFRG) (Figure 2.1), which describes the general condition of a site at any given time, based on both risk and indicator bacteria counts. The five grades in the SFRG range from 'Very Good' to 'Very Poor'. Grades help determine whether ongoing monitoring is required, and provide the basis for telling people whether or not water is suitable for recreational use from a public health perspective. If there is an incompatibility between the SIC and the MAC, (this may be due to limited data) then a 'Follow Up' grade is given.

The Sanitary Inspection Category is developed from a 'Catchment Assessment Checklist' (CAC) (see MfE & MoH, 2003) which explores land use, water use and characteristics, microbiological hazards, discharges, littoral drift, climatic influences, and other influences present in the catchment of the beach under analysis. Once a CAC is completed, a 'Sanitary Inspection Category' (SIC) can be allocated. Catchment checklists have been surveyed by respective councils and the Regional Council in 2014 to update the SIC. The SICs have been calculated using the Bathewatch software developed by MfE.

The grading system developed by MfE and MoH is prescriptive with a view to keeping it uncomplicated and user friendly. The only room for interpretation is within the CAC when determining microbiological hazards.

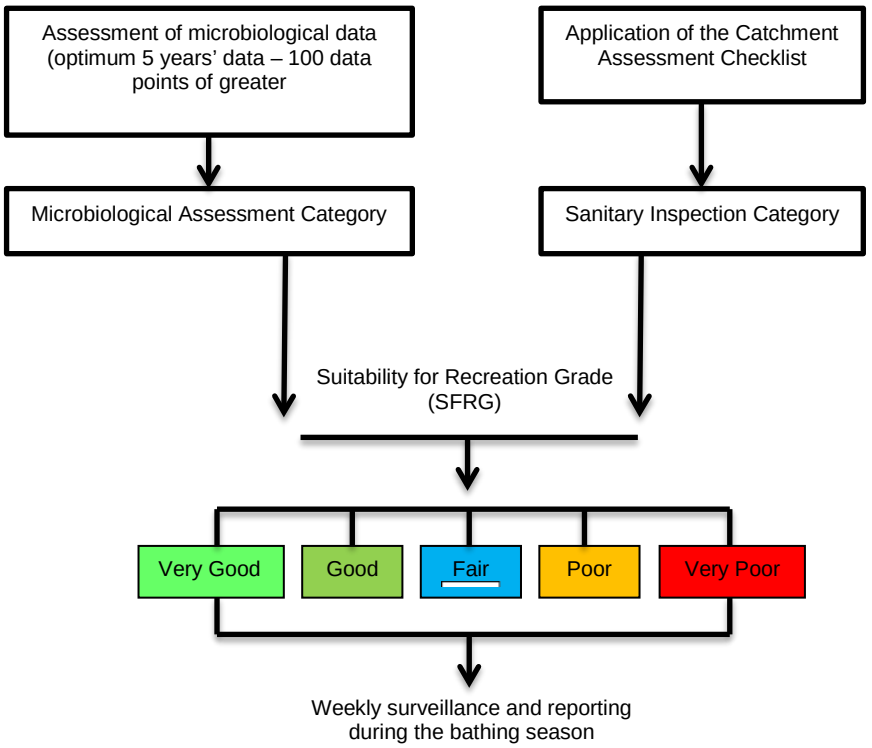


Figure 2.1 Components used to grade a beach (from MfE and MoH, 2003).

The MAC is calculated as the ninety fifth-percentile of the last five years of historic faecal bacteria indicator data. Enterococci are the preferred indicator bacteria for marine waters and *Escherichia coli* (*E.coli*) are the indicator bacteria for freshwaters. Ideally, at least 20 samples each taken weekly over a bathing season, over a five year period to provide at least 100 sample points, are required for the MAC assessment. This has not occurred for all Bay of Plenty sites, so MAC evaluations are based on available data.

The SFRG's have been determined for recreational sites in the Bay of Plenty region since 2005. Updated SFRG's incorporating the 2015/2016 microbiological water quality results are summarised in Appendix 1, which are based on the last five year's data.

2.5 Additional risk to recreational users

The Bay of Plenty Regional Council monitors a number of freshwater sites that experience blooms of potentially toxic blue-green algae. These include several of the Rotorua lakes and the Kaituna River. When monitoring indicates a high risk to water users, a health warning or health advisory is issued for the affected area. Media releases, websites and recorded telephone messages also provide the public with information on the status of these sites.

Monitoring for the mat-forming cyanobacteria *Phormidium* occurs in a number of Bay of Plenty rivers including the Rangitāiki, Whakatāne, Otara and Tauranga, and the Uretara and Te Rereatukahia streams. The beds of these rivers and streams can support substantial mats of this toxin producing algae, particularly during times of low flow. The mats can contain neurotoxins that are highly toxic to humans and animals. New Zealand studies have shown that at times of high biomass, *Phormidium* can also produce high levels of free floating toxins in the water (Heath 2009).

The microbiological guidelines do not include guidance on the risk posed by potentially toxic algal blooms. Therefore, the interim New Zealand Guidelines for cyanobacteria (MfE/MoH 2009) were used to assess the monitoring results.

Part 3: Recreational waters surveillance and grading results 2015-2016

3.1 Recreational surveillance monitoring

Before the start of the bathing season, a monitoring plan was designed and circulated for comment to Toi Te Ora Public Health and the district councils (Ōpōtiki, Kawerau, Rotorua, Western Bay and Tauranga). The criteria for selection of sites included whether they were high-use bathing locations and whether there was known contamination risk. Other sites have been included at the request of the community.

Monitoring began in late October 2015 and ran until the end of March 2016. Approximately 70 sites across the Bay of Plenty region were monitored with sites sampled weekly or once every two weeks.

Results of the water quality analyses are generally available after 24 hours and these are then posted onto the Bay of Plenty Regional Council website[1]. Media releases also help keep the public informed of the situation in regards to recreational water quality.

If 'orange' or 'red' modes are flagged, these results are directly communicated to Toi Te Ora Public Health and the relevant district council. Follow-up sampling then occurs within a 24-48 hour period. Should a water quality problem be found to recur, Toi Te Ora Public Health has the responsibility to decide if a public health warning needs to be issued. If a warning is required, Toi Te Ora Public Health will initiate media releases and inform the respective councils of their responsibility to warn the public of the risk. Warning signs are recommended as a good method communication method.

3.2 Results

The detailed results of the monitoring are presented in tabular form in Appendix 1. These tables give information on the ninety fifth percentile value, MAC score, SIC score, SFRG and a conservative interim grade where applicable. The SFRG's are presented in Figure 3.1 and 3.2.

The SFRG grading system illustrates that 85.7% of lake sites are graded 'very good' or 'good', with 7.1% graded 'followup'. River sites (52.2%) are graded 'poor', an improvement of 8% compared to the previous grading.

Estuarine sites (16.7%) were graded 'poor' or 'follow up', and 38.9% graded 'fair'. Almost all of the open coastal sites (91.7%) were graded as 'good' or 'very good', with the remaining 8.3% graded as 'follow up'.

[1] http://www.boprc.govt.nz/environment/water/swimming-water-quality/

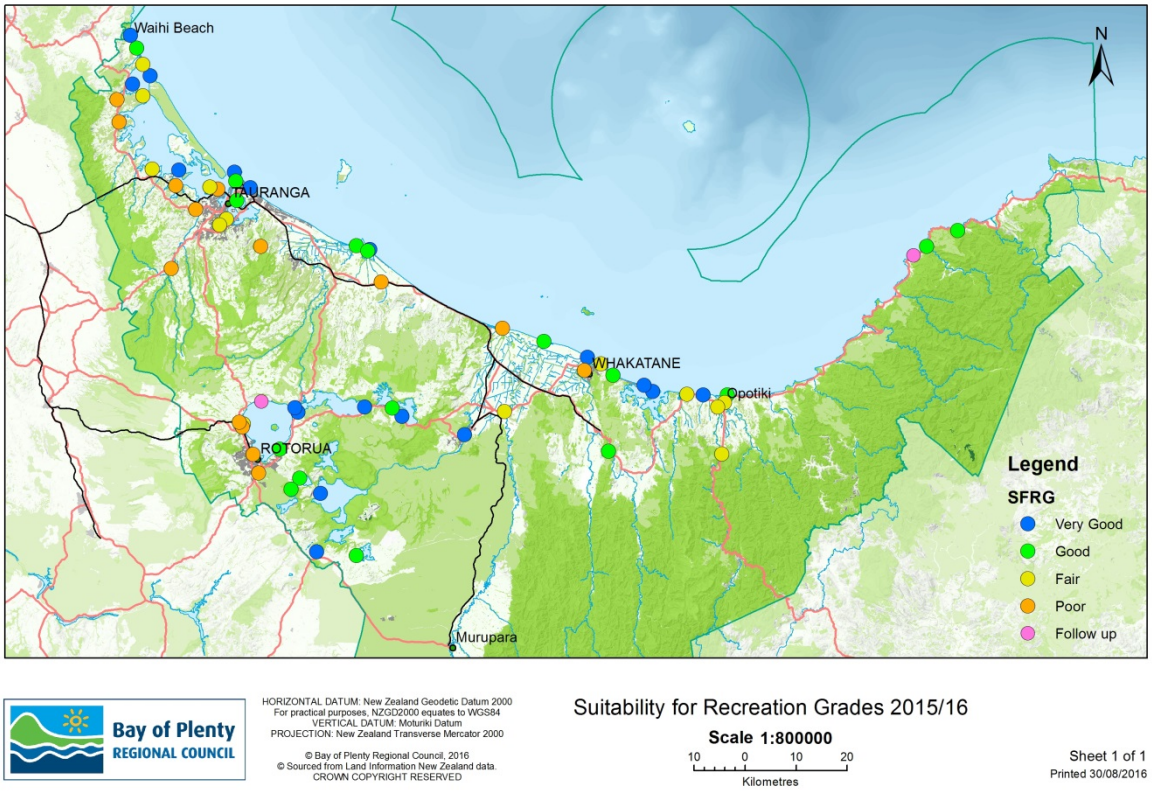


Figure 3.1 Suitability for Recreation Grades, 2015-16.

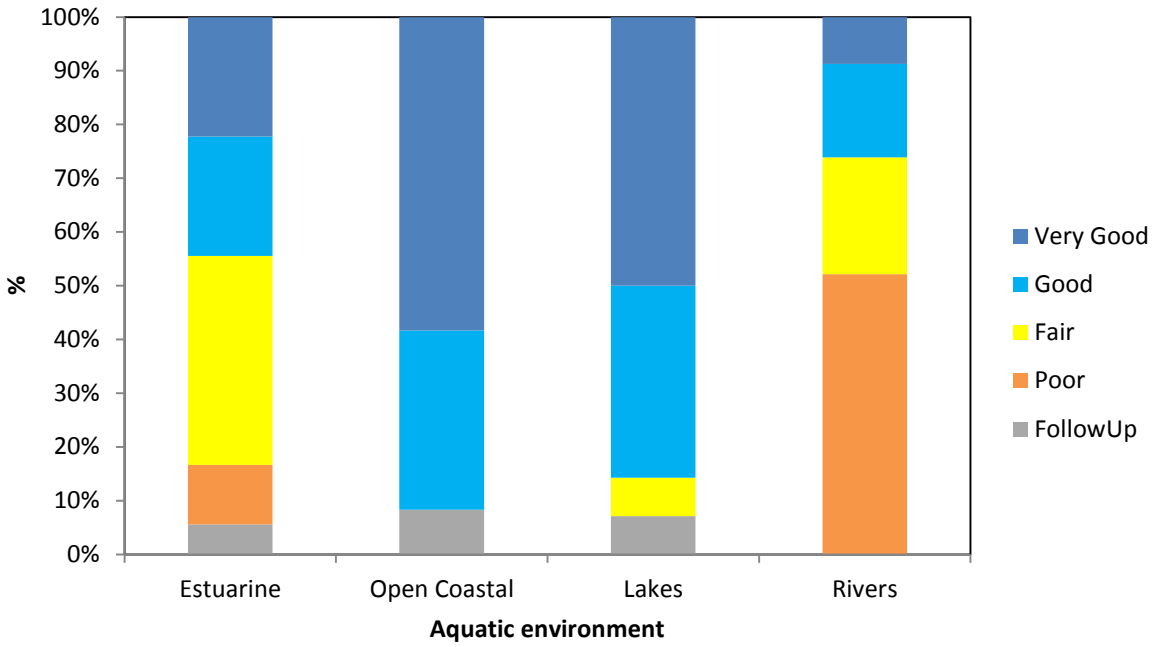


Figure 3.2 Comparison of the 2015-16 results for the SFRG.

Table 3.1 also shows the status of monitored contact recreation sites in the Bay of Plenty, against the microbiological guidelines (Red/Action Mode). Generally, lake sites showed the highest quality overall against the guidelines, followed by marine and river sites.

Table 3.1 Percentage of samples from monitored bathing sites, with indicator bacteria levels less than the Red/Action Mode, as defined by the New Zealand Microbiological Water Quality Guidelines (MfE/MoH 2003).

		Rivers	Lakes	Marine
Samples less than the Red/Action Mode	2015-16	89.9%	98.5%	93.4%
	Last 5 years	92.8%	99.3%	97.1%

More detailed results are presented in the following sections, presenting the percentage of samples at each site that exceeded guideline levels throughout the 2015-16 season. The five yearly ninety fifth-percentile and median (fiftieth percentile) data are also presented to give a longer-term perspective.

3.3 River and stream sites

River and stream sites were monitored on a weekly or two-weekly basis. Figure 3.3 shows the range of *E.coli* results recorded at each site, ranked in order of percentage of samples over the Red/Action Mode for the 2015-16 season. Of the 22 sites monitored, 19 had instances where the Orange/Alert Mode was reached and 15 of these had results over 550 *E.coli* cfu/100 ml (Red/Action Mode). In comparison to last season, of the 22 sites monitored, 17 had instances where the Orange/Alert Mode was reached and 12 of these had results over 550 *E.coli* cfu/100 mL (Red/Action Mode).

During the 2015-16 season, Kaiate Stream had the highest exceedances and these generally occurred in the absence of rainfall events. During the 2015-16 season, 60% of samples taken from the Kaiate Stream were over 550 *E.coli* cfu/100 ml (Red/Action Mode). This is discussed further in Section 3.3.1. The Ngongotahā, Uretara and Utuhina Streams and the Wairoa River and Waioeka River at the SH 2 Bridge also had a number of exceedances. These were generally caused by rainfall events throughout the summer season.

There are two points to note regarding the sampling sites over the last five years. Prior to the 2015-16 bathing season, the Tauranga River was called Waimana at Wardlaw Grove. For the Waioeka River at the river bend near the Pa, samples were collected up to March 2014 and did not resume until November 2015. For this reason, the past five year's data is based on data from November 2010.

Figure 3.4 shows that the ninety fifth-percentile data for eight sites are higher than the Red/Action Mode guideline. These can be classed as the highest priority sites for investigation and action. However, exceedances over the ninety fifth percentile guideline predominantly occur with rainfall events that generate surface runoff, when swimming is less likely to occur. Median values are also plotted in Figure 3.4 and this gives a measure of the average risk of infection to water uses (particularly primary contact). No median values were over the Orange/Alert Mode, indicating that on average, most rivers over the 2011-16 seasons were suitable for swimming.

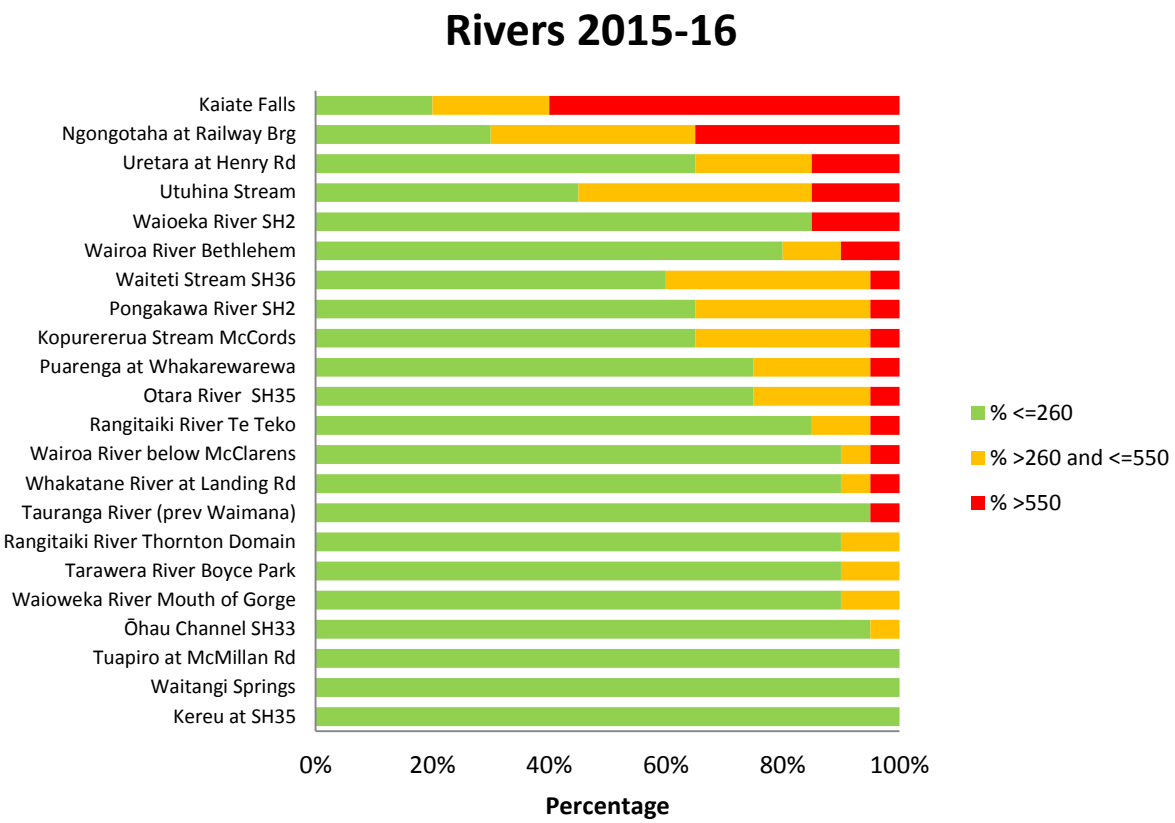


Figure 3.3 Percentage of samples from river and stream sites with E.coli concentrations (cfu/100 mL) in each of the modes in the Microbiological Water Quality Guidelines (MfE/MoH 2003), 2015-2016 bathing season.

The comparison of data with the NOF attributes (Table 3.2) shows that all rivers meet the 'A' category (very low risk of infection) for activities with occasional immersion and some ingestion of water (such as wading and boating).
Thirty six percent of sites do not meet the minimum acceptable criteria for full immersion activities (i.e. greater than 5% risk of infection), 32% rated 'A' and another 32% rated 'B'. In the previous 2014/2015 season, 54% of sites did not meet the minimum acceptable criteria for full immersion, 23% rated 'A' and 23% rated 'B'.

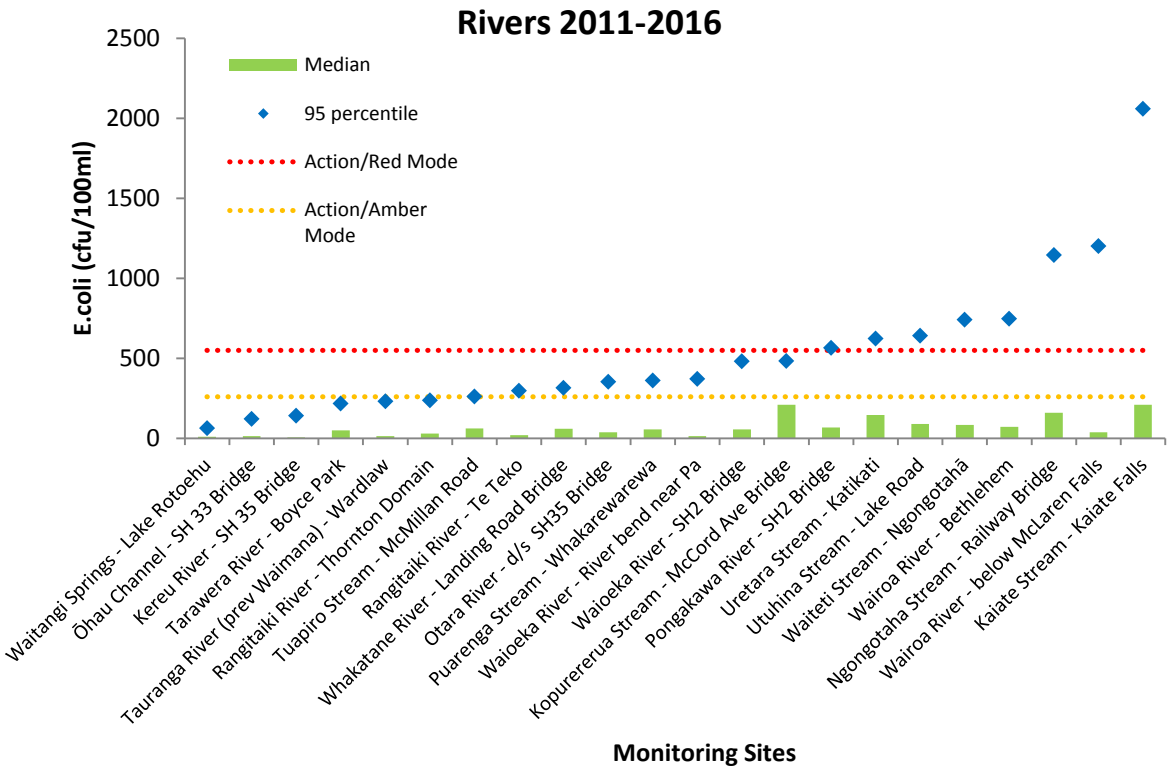


Figure 3.4 *Ninety fifth-percentile and median E.coli concentrations at river and stream sites over the past five years.*

Table 3.2 *River and lake sites (presented as the percentage of sites within each band) compared to the NOF for E.coli, based on 2015-16 data.*

Value	**Attribute State (*E.coli*/100 ml) for rivers**				
	A	**B**	**C**		**D**
Numeric state	≤260	>260 and ≤ 540	>540 and ≤1000	**(Bottom-line)**	>1000
Human health for secondary* contact (annual median)	100%	0%	0%		0%
Human health for primary** contact (95th Percentile)	32%	32%	36% **Below Minimum Acceptable State**		

*Secondary: activity occasional immersion and some ingestion: e.g. boating; wading. **Primary: likely to involve full immersion.

3.3.1 Kaiate Stream

Catchment description

The catchment above Kaiate Falls Road Bridge covers an area of approximately 798 ha, where 543 ha (68%) is covered in native vegetation, while the remaining 255 ha (32%) is used predominately for pastoral farm land, mostly cattle. The Kaiate Stream at the monitoring location is a third-order stream, and its main tributaries are the second-order Owairoa Stream and the second-order Otawera Stream. The Owairoa drains a large proportion of the native bush area, while the Otawera drains both native bush and farmland (Figure 3.5).

Figure 3.5 Map showing the Kaiate Stream main monitoring location at Kaiate Falls Road Bridge (red marker), the catchment (shaded area), and tributaries.

Kaiate Stream results 2015-16

Warning signs were erected early in the 2015-16 season due to consistently elevated results above the red action mode (Figure 3.6). Similar to the previous season, results remained elevated throughout the summer and a catchment and microbial source tracking survey was instigated.

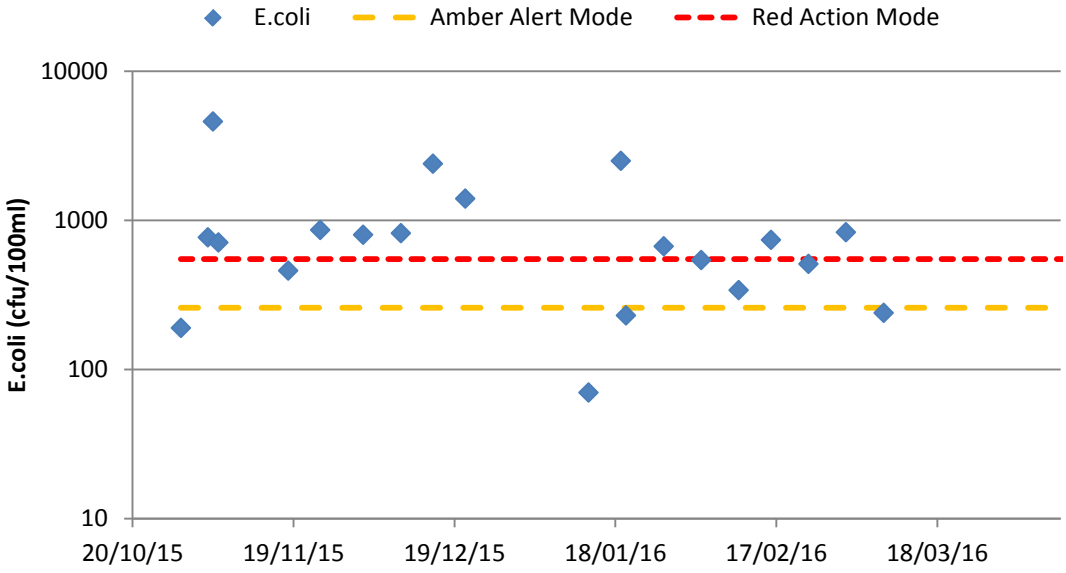


Figure 3.6 *E.coli concentrations at Kaiate Stream over the 2015-16 bathing season in relation to amber and red alert modes under the Microbiological Water Quality Guidelines (MfE/MoH, 2003).*

Catchment Survey and Microbial Source Tracking Results

In response to the high bacteria concentrations at Kaiate Falls Road Bridge, a catchment survey was conducted in conjunction with Microbial Source Tracking (MST) to determine sources of faecal contamination. Microbial Source Tracking uses *E. coli* or enterococci which are isolated from water samples. These isolates are then fingerprinted using either DNA-based or phenotypic/biochemical based-methods. Results can be compared to a library of DNA based markers to identify sources.

Samples were taken at surrounding tributaries and various locations along Kaiate Stream and analysed for genetic markers and *E.coli* concentrations. The genetic marker results are similar to last year's survey, showing that the dominant source of bacteria was ruminant (Figure 3.7), which picks up cow, sheep, deer and goats, and can be influenced by possum. Cattle and some deer are farmed locally and are the most likely ruminant influence. The MST markers also showed that there is an avian influence at several locations along Kaiate Stream, but these were not detected as consistently as the ruminant marker.

Figure 3.8 and Table 3.3 show *E.coli* concentrations over the 2015-16 summer period. One tributary, measured at site 3, stands out as a potential hotspot based on these results. Site 10 has recent elevated results including the highest *E.coli* concentration in this survey and is associated with the ruminant marker. Elevated results are distributed around the catchment above the falls, indicating diffuse faecal contamination from multiple sources. There is an influence from the tributary dominated by bush cover (site 7), however, *E.coli* concentrations are not as high in bush dominated areas compared to pastoral dominated areas.

Examination of data collected over the past nine years indicates that *E.coli* concentrations improved from 2007 to 2014, but have been elevated again over the past two summer seasons. Differences between average summer results may be explained by the quantity of the rainfall. Total seasonal rainfall for that summer period are highly correlated (R^2=0.82, Figure 3.10) with median *E.coli* concentrations. That is, the wetter the summer, the more likely swimming water quality standards will be exceeded.

Table 3.3 Kaiate Stream Catchment survey E.coli concentrations results (cfu/100 ml.)

Date	Site1	Site2	Site3	Site4	Site5	Site6	Site7	Site8	Site9	Site10
23/01/2015	430							1000	680	
15/12/2015	2400	150	1300	470	430	440	380	200	1400	240
20/01/2016	230	440	410	1400	220	430	360	360	260	260
03/02/2016	540	170	1600	220	70	510	130	270	430	6400
27/04/2016	130	220	15	67	51	160	180	120	180	430

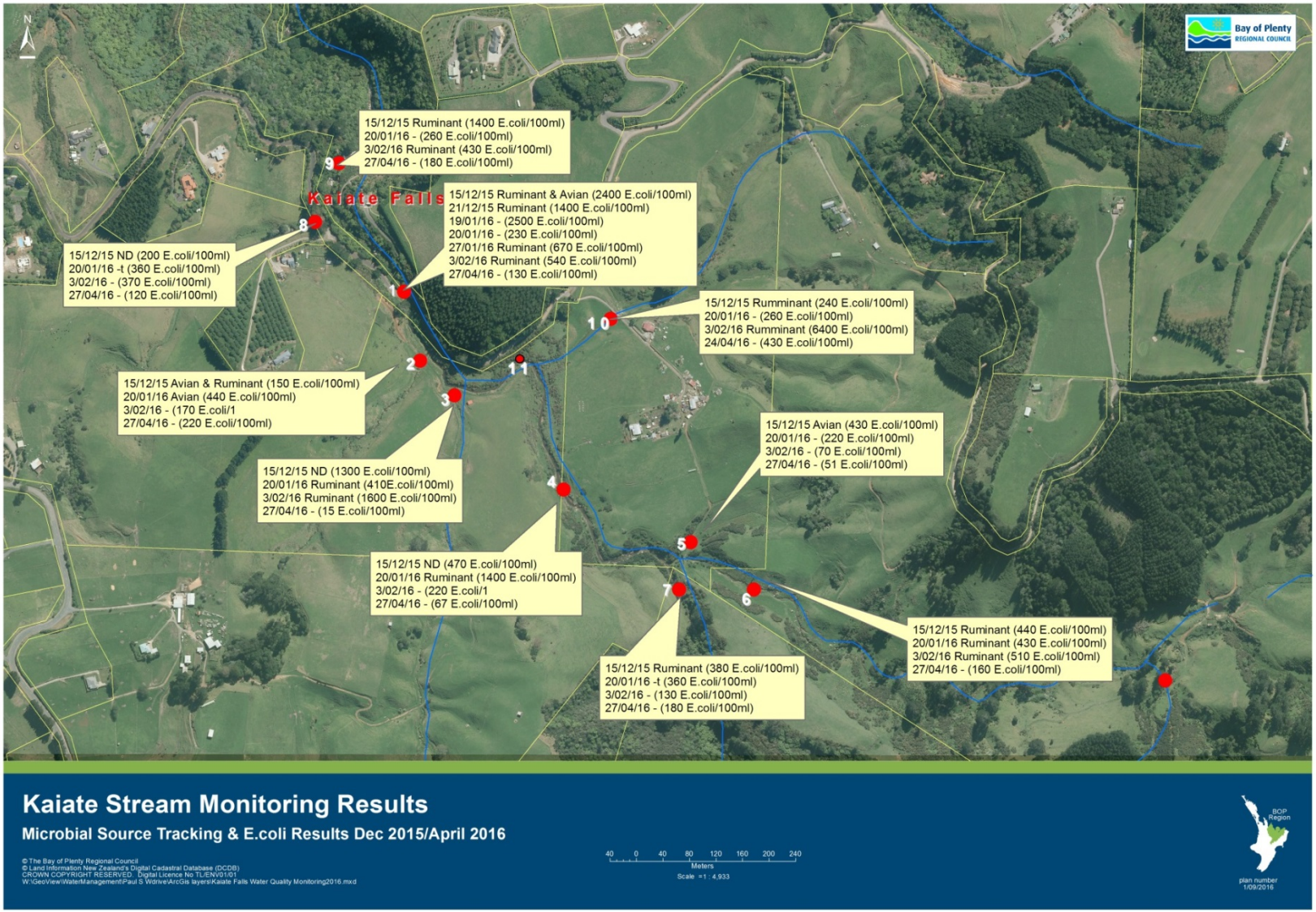


Figure 3.7 Kaiate Stream Microbial Source Tracking site locations and results, 2015-16. The dominant source of bacteria and E. coli concentration for each sampling occurrence are shown for each site. Site 1 is Kaiate Falls Road Bridge.

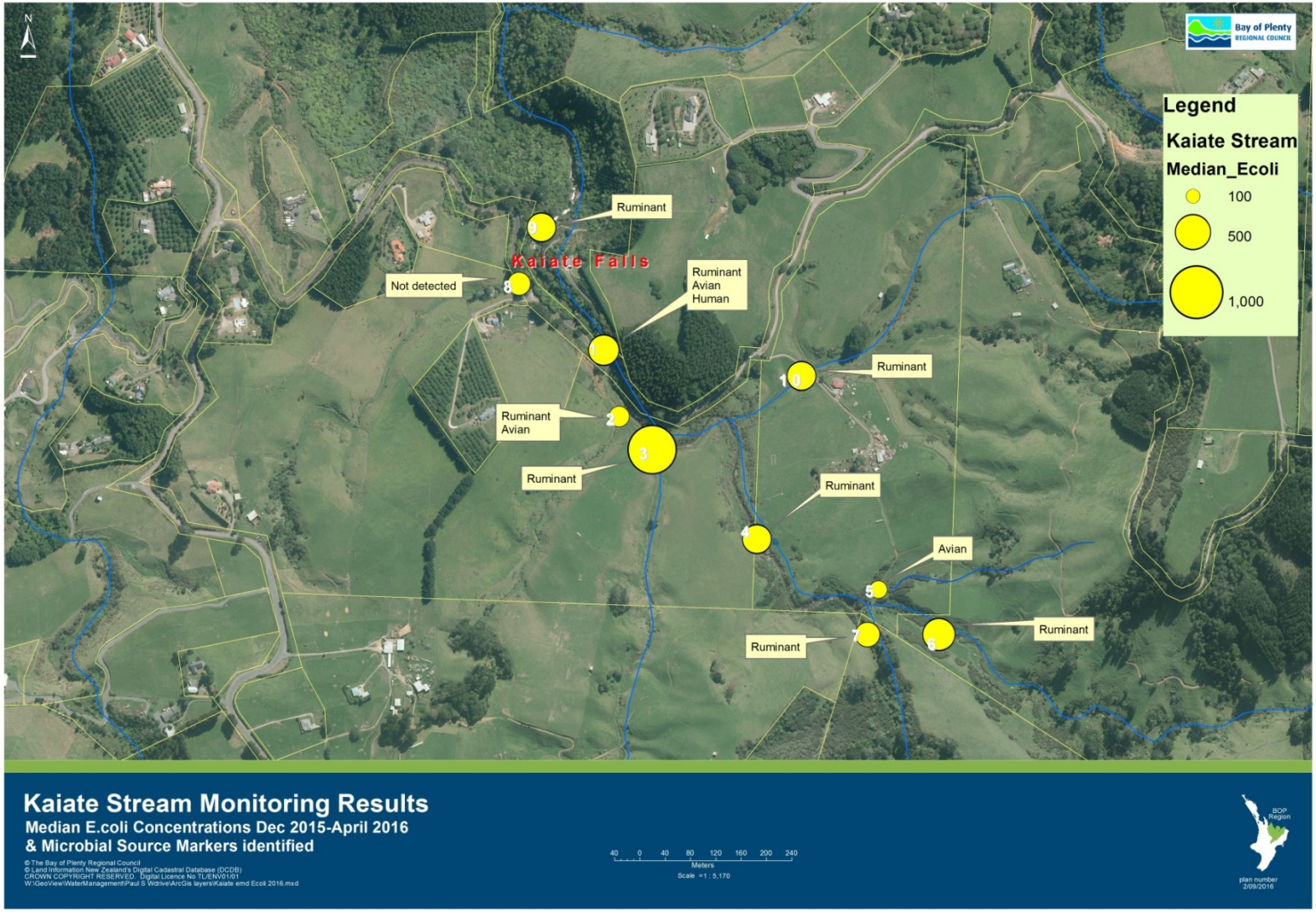


Figure 3.8 Kaiate Stream median E.coli concentrations, December 2015 to April 2016, and Microbial Source Tracking results. Dialogue boxes detail the dominant source of bacteria for each sampling site.

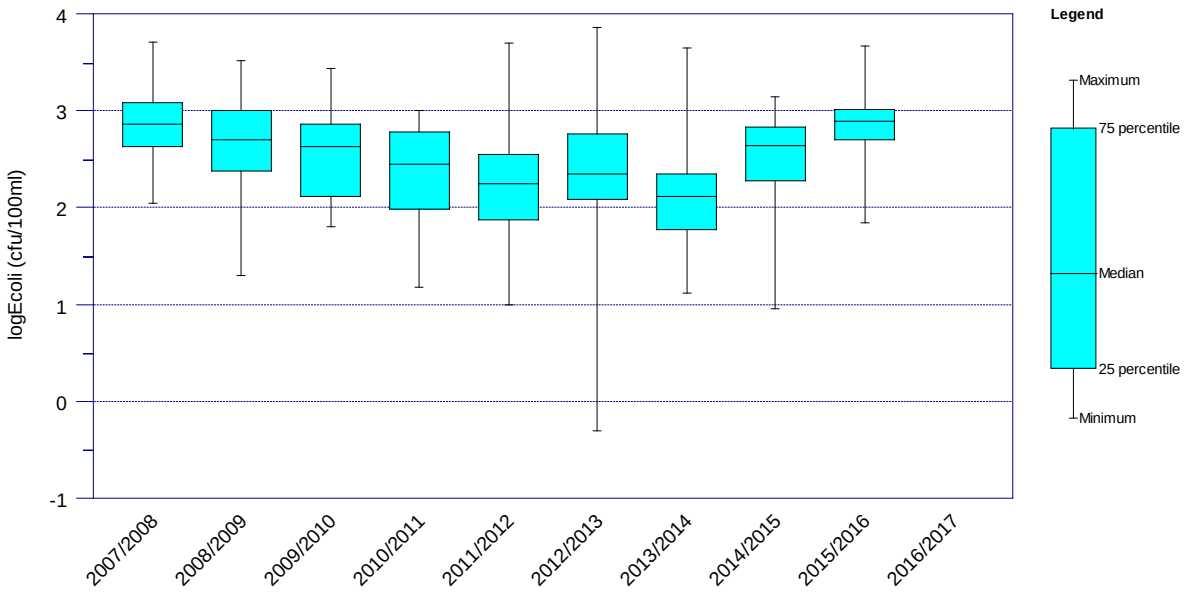


Figure 3.9 *Box whisker plot of E.coli concentrations at Kaiate Steam site 1 (bridge above falls).*

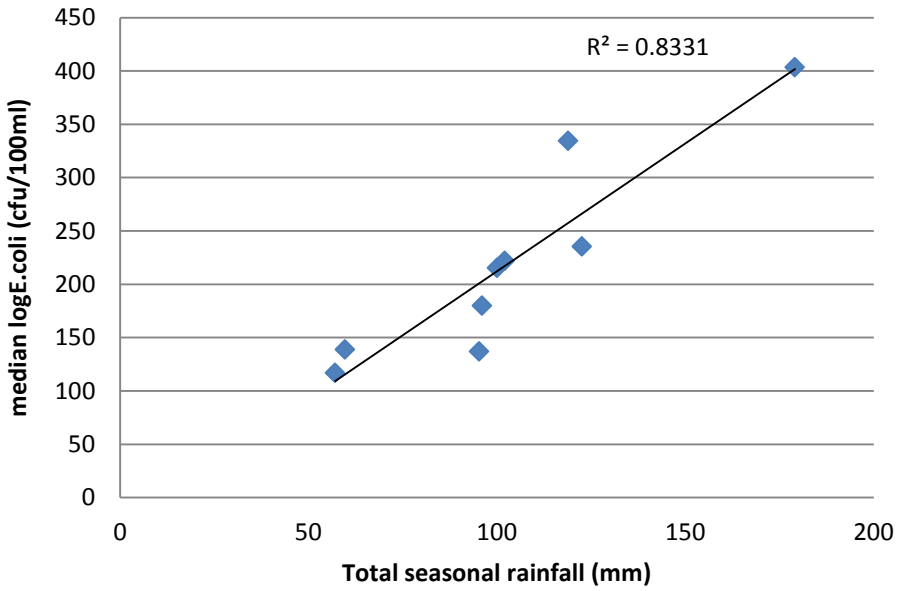


Figure 3.10 *Total seasonal rainfall (November-March, from the Waimapu rainfall recorder) versus median seasonal logE.coli concentrations from Kaiate Falls, 2007-2016.*

Discussion

Monitoring of the indicator bacteria *E.coli* at Kaiate Stream has shown the site to be consistently at a higher risk to recreational users than many other sites in the Bay of Plenty. On average, *E.coli* concentrations were decreasing from 2007 to 2014, possibly due to the fencing off and planting of many of the riparian margins. However, this decrease may have also been influenced by seasonal rainfall, since *E.coli* concentrations have increased in the past two seasons.

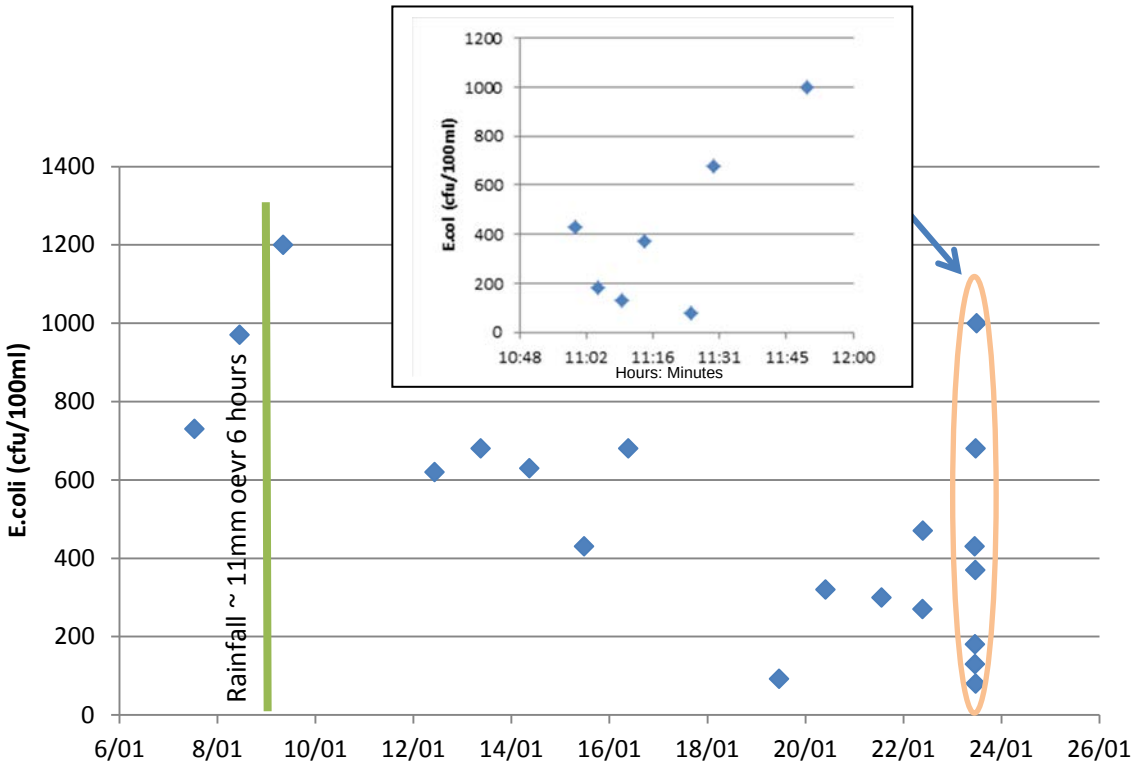


Figure 3.11 E.coli concentrations January 2015, Kaiate Stream Bridge.

More intensive monitoring was undertaken in January 2015 to see if any detection in *E.coli* patterns could be gauged. After a fairly reasonable dry period during which no rain fell for 18 days, with the exception of approximately 4 mm on 1 January, around 11 mm of rainfall occurred near the start of the intensive sampling period. *E.coli* concentrations were still elevated before rain on 9 January (Figure 3.11), but decreased in concentration over the next two weeks. Intensive sampling over an hour showed *E.coli* concentrations ranged from under 100 cfu/100 ml to 1000 cfu/100 ml. This shows that over this period *E.coli* concentrations are highly variable and more importantly are not necessarily generated by surface runoff from rainfall events.

Catchment surveys have not identified any point source discharges in the catchment. Human markers were only detected once in one location, suggesting limited potential contamination from septic tanks.

As such, it is likely that the faecal contamination is predominantly sourced from ruminants with intermittent avian sources (waterfowl are observed in the area). Contributions of *E.coli* from faecal matter can be entrained in runoff waters when runoff occurs. However, as is the case in Figure 3.11, *E.coli* can remain prevalent in the steam waters, even when little or no runoff has occurred for some time. Several mechanisms may explain the continued input of *E.coli* to the stream under antecedent conditions:

- Critical source areas where faecal matter has been deposited may continue to leach bacteria, which reaches the stream through subsurface flow.
- Faecal matter may be deposited directly into the stream by animals.
- *E.coli* reservoirs may be sustaining the *E.coli* population with release to the stream through in-stream processes.

A combination of these processes is also likely.

It is also possible that faecal indicator bacteria are surviving for extended periods in the soil. *E.coli* can survive for a long time in cow pats and have been found at high concentrations in soil. Seasonal changes in *E.coli* concentrations from cow pats has also been found, with the highest in summer and lowest in winter (Muirhead, 2009). Temperature can also impact the survival of *E.coli* which may explain seasonal differences, but this will also be dependent on ruminant numbers.

Although faecal contamination occurs with rainfall induced runoff, it was observed in this catchment that *E.coli* concentrations can remain elevated during periods with no rainfall runoff. Also observed is a strong relationship between the seasonal rainfall volume and seasonal median *E.coli* concentrations. Hence, a driver for the sustained *E.coli* concentrations found in the stream may be due to an ongoing supply from the soil reservoir. Higher seasonal rainfall sustains a higher water table fostering greater movement of *E.coli* higher in the soil profile or through preferential sub-surface flow paths to the stream.

Steep slopes and prominent v-shaped valleys, common in this catchment, are likely to promote quick sub-surface flow and run-off. Underlying this is rocks of volcanic origin comprising both andesite and rhyolite lavas. Rhyolite is overlain in places by welded and unwelded ignimbrite. Overlying soils are Kaharoa ash over more weathered ash which is inter-bedded with layers of lapilli. This complex geology and geomorphology may make identification of critical source areas difficult.

Next steps

Riparian planting and fencing of waterway in pastoral areas does not yet appear to have arrested *E.coli* concentrations in the stream. It may also be that sub-surface contributions of *E.coli* are bypassing these riparian enhancement areas, ruminants have direct access to stream waters, and reservoirs of *E.coli* are sustaining the *E.coli* population. Further riparian and critical source area management may be required. Identification of critical source areas and removal of faecal material from these areas may be the best way of controlling the input of faecal derived ruminant microbial species.

Monitoring is continuing to help understand the situation, including gathering stream level information and examination of indicator bacteria in sediments. Recent microbial analysis methods have also revealed that ‘natural’ populations of bacteria such as *E.coli* can exist in temperate environments. ‘Naturalised’ indicator bacteria are originally derived from faecal material but the microbe has been able to adapt to and maintain its population within a non-host environment such as sediment (Devane, 2015). Potentially, ’naturalised’ *E.coli* could inflate the estimated health risk due to the addition of the ‘naturalised’ population to incoming population. The stream itself does not have a large reservoir of sediment, so this contribution from a ‘naturalised’ population may be small, but warrants further investigation if the tools are available. It may be more likely that a seepage reservoir of indicator bacteria exists in fracture and seepage zones in the soils and are consistently flushed into the stream through subsurface flows. It could be that such critical source areas should be identified and examined as a potential method for reducing faecal contamination.

Monitoring for the presence of campylobacter or cryptosporidium could also be a course of action. This would help to ascertain the prevalence of these disease causing organisms in relation to indicator bacteria concentrations, and potentially help quantify the health risk to recreational water users, as it is possible that while *E. coli* concentrations in the stream are high, concentrations of disease causing organisms are low.

3.3.2 **Ngongotahā Stream**

The Ngongotahā Stream is monitored during the bathing season near the railway bridge, just downstream of the town centre. Elevated E.coli concentrations above the amber mode bathing guideline level (Figure 3.12) have resulted in health advisory notices being put in place.

The only discharge consents in the catchment are for onsite wastewater treatment systems, a jet boat operation and various stormwater discharges within the urban area. There is a wildlife park at the top of the catchment as well as various other tourism ventures and a trout rearing facility which attracts visitors, however, most of the catchment is a mixture of pastoral lands and forestry.

Catchment surveys were undertaken by Rotorua Lakes Council and Bay of Plenty Regional Council, to ascertain if elevated results were emanating from any particular source (Figures 3.13 and 3.14). Microbial Source Tracking, as described in section 3.3.1, has also been used to help track sources of contamination in the Ngongotahā Catchment.

Microbial Source Tracking results from sampling at the railway bridge site in December 2015 (two dates) and from three sites in April 2016 (railway bridge, SH 5, and No. 715 Ngongotahā Road) only returned positive results for ruminant sources. The other markers tested for were avian and human. These results imply that no leakage from seepage infrastructure of septic tanks is impacting the stream, more likely the contamination is from stock, referred as a diffuse source contamination.

Previous catchment surveys have shown variable results throughout the catchment, with no one definitive source being found. Catchment surveys show faecal contamination to be temporally and spatially variable, a result that is typical of diffuse source contamination.

Relationships between indicator bacteria, rainfall and flow are variable for the Ngongotahā Stream. Although strong rainfall events can result in elevated E.coli concentrations in the stream, there is no clear seasonal relationship. Stream sediment may hold a reservoir of indicator bacteria which are moved on by a combination of critical flow in the lower part of the stream and stream bed disturbance. The stream is popular with anglers and could be often disturbed by trout fishing activity. Potentially, there may be naturalised populations of E.coli within stream sediments. Both of these possibilities could be tested with sediment sampling and by testing the relationship of E.coli versus suspended sediment.

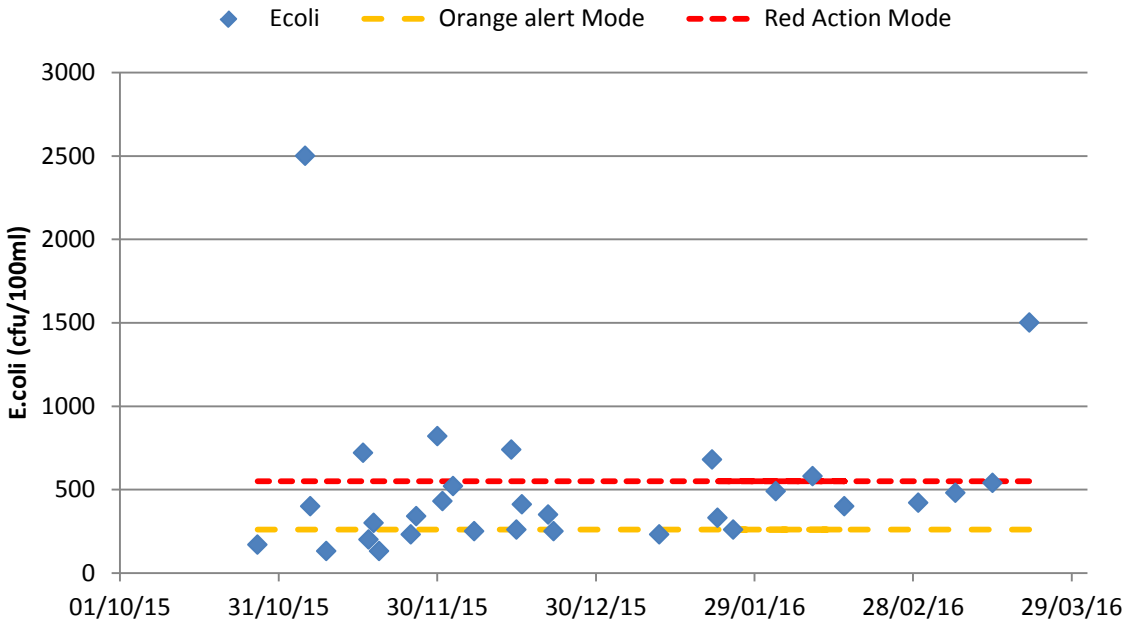


Figure 3.12 *E.coli concentrations at Ngongotahā Stream railway bridge site over the 2015-2016 bathing season, in relation to amber and red alert modes under the Microbiological Water Quality Guidelines (MfE/MoH, 2003).*

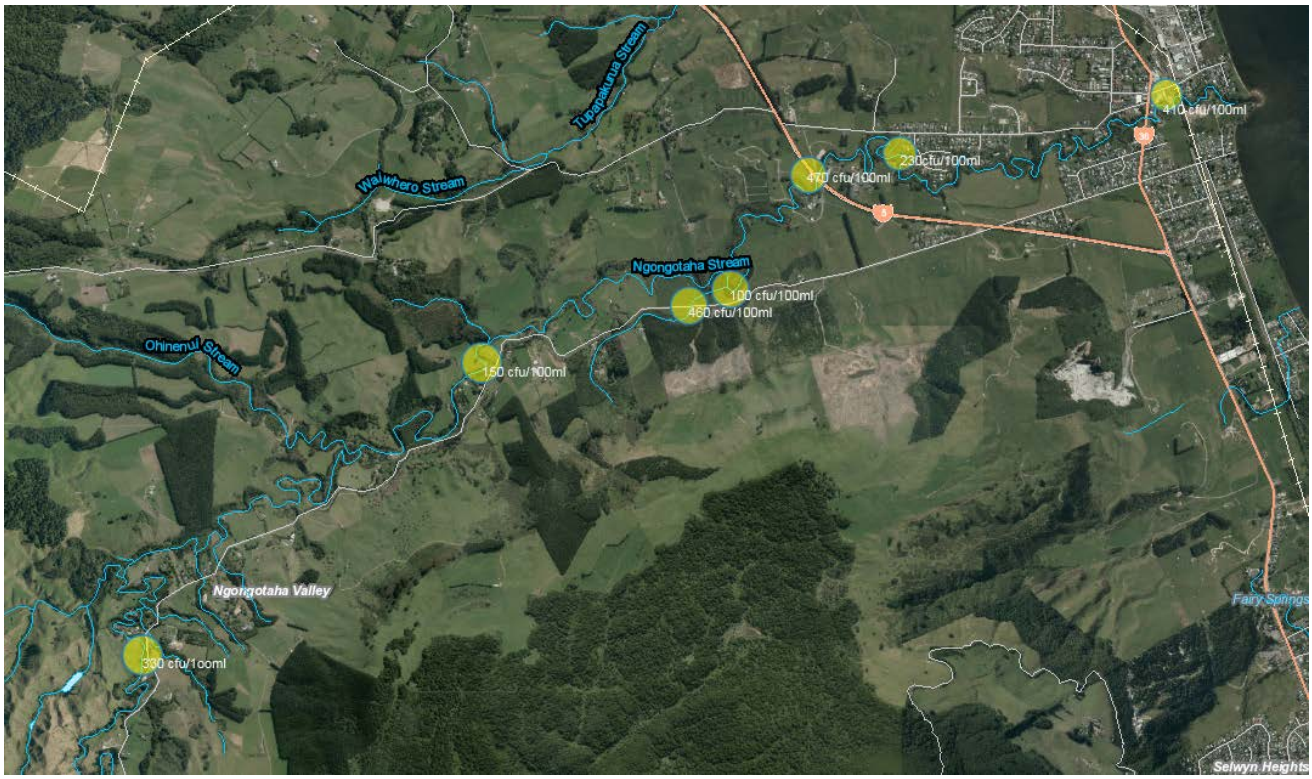


Figure 3.13 *E.coli concentrations, Ngongotahā Catchment, 4 December 2016. Detailed sampling results for the lower catchment are displayed in Figure 3.14.*

Figure 3.14 E.coli concentrations, lower Ngongotahā Catchment, December 2016.

Conclusion

The Ngongotahā Stream has been well managed in terms of riparian planting and fencing of waterway in pastoral areas. While this does not appear to have limited the *E.coli* concentrations in the stream, like Kaiate Falls, there may be other mechanisms contributing to the bacterial loading, other than surface run-off. It may be that sub-surface contributions of *E.coli* are bypassing the riparian protection areas, or that reservoirs of *E.coli* are building up in the stream and feeding the water column, especially with stream bed disturbance events. Monitoring to test the impact of stream bed disturbance is recommended, along with testing of naturalised *E.coli* populations.

Monitoring for the presence of campylobacter or cryptosporidium could also be a course of action. This would help to attain the prevalence of these disease causing organisms in relation to indicator bacteria concentrations, and potentially quantify the real health risk to recreational water users.

3.3.3 Lake sites

Sampling occurred at 13 lake sites once each week. Four sites - two at Lake Rotorua, one at Lake Rerewhakaaitu and one at Lake Ōkaro - reached the Red/Alert Mode on one occasion during the 2015-16 season (Figure 3.15).

Figure 3.16 shows that one site's ninety fifth-percentile data was higher than the Orange/Action Mode guideline. Only three of the 13 sites' median *E.coli* concentrations reached at or above 15 cfu/100 mL, indicating a low level of faecal contamination overall (Figure 3.16). Lake Rerewhakaaitu at the Brett Road boat ramp had the highest five year median *E.coli* concentrations of lake sites (15.5 cfu/100 mL).

Comparison of the 2015-16 *E.coli* data with the NOF attributes (Table 3.4) shows that all lakes meet the 'A' band (very low risk of infection) for activities with occasional immersion and some ingestion of water, such as wading and boating). A similar result occurred for full immersion activities (primary activities, i.e. greater than 5% risk of infection), with only one site being in the 'B' band (Lake Rotorua – Ngongotahā).

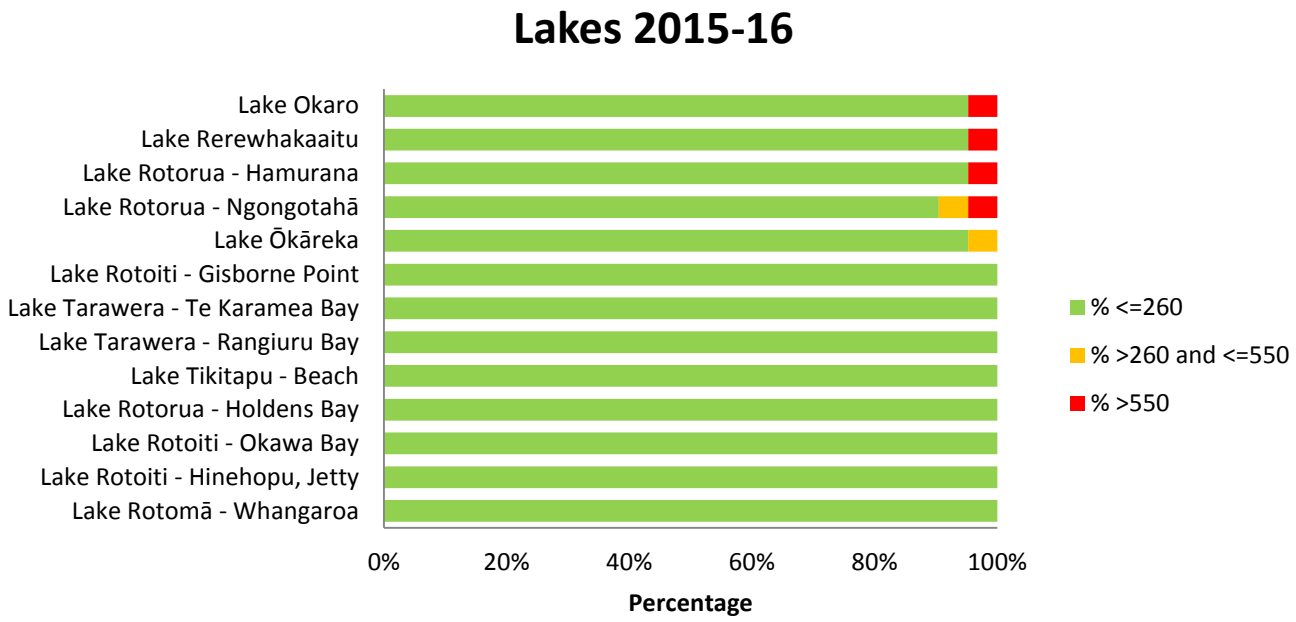


Figure 3.15 Percentage of samples from lake sites with E.coli concentrations (cfu/100 mL) in each of the modes in the Microbiological Water Quality Guidelines (MfE/MoH 2003), 2015-2016 bathing season.

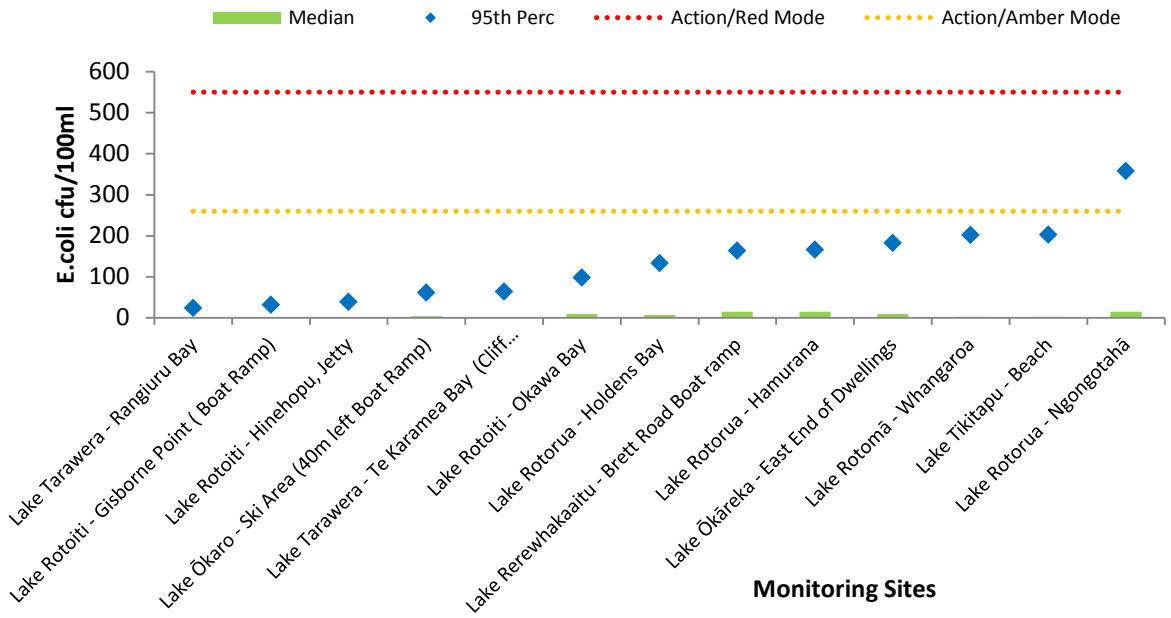


Figure 3.16 Ninety fifth-percentile and median results of E.coli concentrations for lake sites over the past five years

Table 3.4 Lake sites (presented as the percentage of sites within each band) compared to the National Objective Framework for E.coli, based on 2015-16 data.

Value	**Attribute State (*E.coli*/100 ml) for lakes**				
Numeric state	**≤260**	**>260 and ≤ 540**	**>540 and ≤1000**	**(Bottom-line)**	>1000
Human health for secondary* contact (annual median)	100%	0%	0%		0%
Human health for primary** contact (95th Percentile)	93%	7%	0% **Below Minimum Acceptable State**		

*Secondary: activity occasional immersion and some ingestion: e.g. boating; wading. **Primary: likely to involve full immersion.

3.3.4 Marine sites

Open coastal

The open coastal marine monitoring sites were sampled on a weekly basis. Figure 3.17 shows the percentage of samples at each site with enterococci concentrations that exceeded the microbiological guideline levels ranked in order. Three sites reached the Red/Alert Mode - Whanarua Bay, Waihī Beach Surf Club, and Waihī Beach at 3 Mile Creek. Alerts at 3 Mile Creek and the Waihī Surf Club were likely triggered by a large rain event.

Only three sites exceeded the Orange/Action Mode guideline (Figure 3.17). Maraetai Bay near Te Kaha has the highest 95th percentile, due to elevated results several years ago, but since this time the water quality has been good.

All 12 open coastal sites had median enterococci concentrations below 5 cfu/100 ml in both 2015/2016, and the last five years (Figure 3.18). This indicates overall a low level of enterococci indicator bacteria contamination for marine coastal waters in the Bay of Plenty.

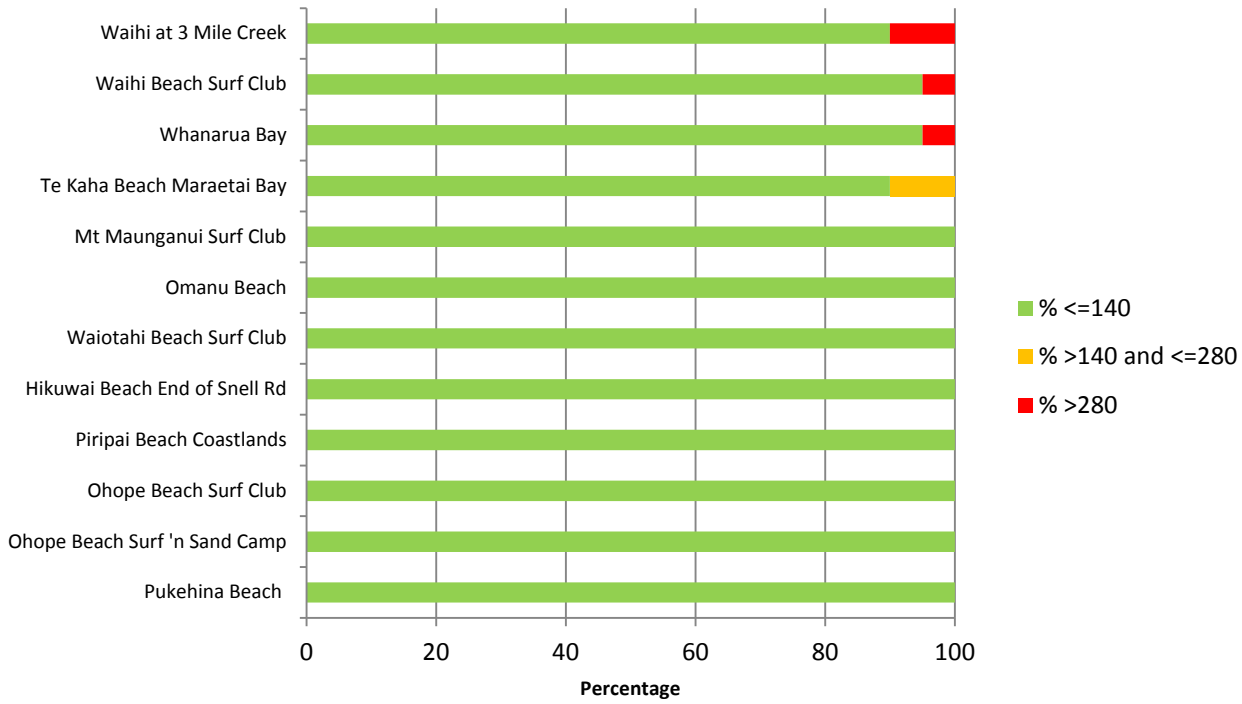


Figure 3.17 Percentage of samples from open coastal marine sites with enterococci concentrations in each of the modes in the Microbiological Water Quality Guidelines (MfE/MoH 2003), 2015-2016 bathing season.

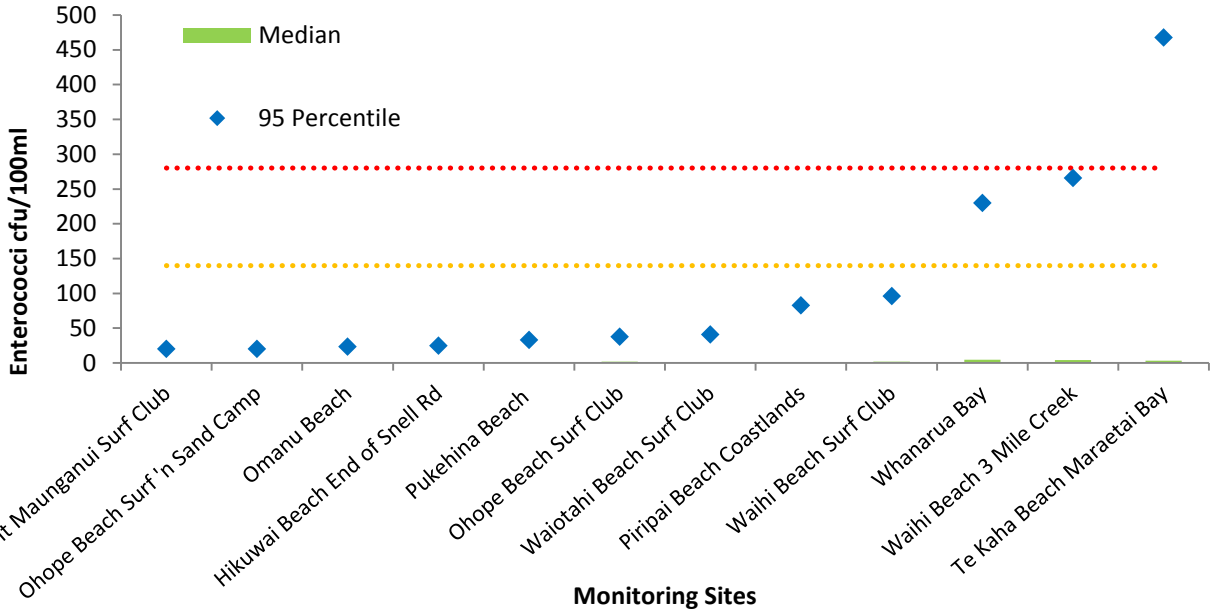


Figure 3.18 Ninety fifth-percentile and median results of enterococci concentrations, coastal marine sites over the past five years.

Estuarine

Most estuarine sites reached the Orange/Alert Mode during the 2015-16 season (Figure 3.19), with four sites reaching the Red/Action Mode. Median enterococci concentrations were generally well below the Orange/Alert Mode, with the highest median level of 39 cfu/100 mL at the Tarawera River Mouth (Figure 3.20).

Five sites have exceeded the 95th percentile Red/Action limit over the last five years. Athenree opposite the motor camp and Ongare Point both had a 95th percentile over 300. Pahoia's 95th percentile was much higher being 925 (Figure 3.20). This indicates a greater than five percent risk of contact with infectious organisms.

Many sites in Tauranga Harbour were impacted by an intensive rain event in early March 2016. One of the sites that was impacted was Tanners Point. It is unusual for Tanners Point to reach alert levels. However, the intensive rainfall event, which also showed high *E.coli* concentrations in the Tuapiro River, was not the only period of elevated results for this site. The other instance of elevated *E. coli* concentrations in February 2016 doesn't correspond to rainfall or elevated *E.coli* concentrations in the Tuapiro River, so the cause remains unknown.

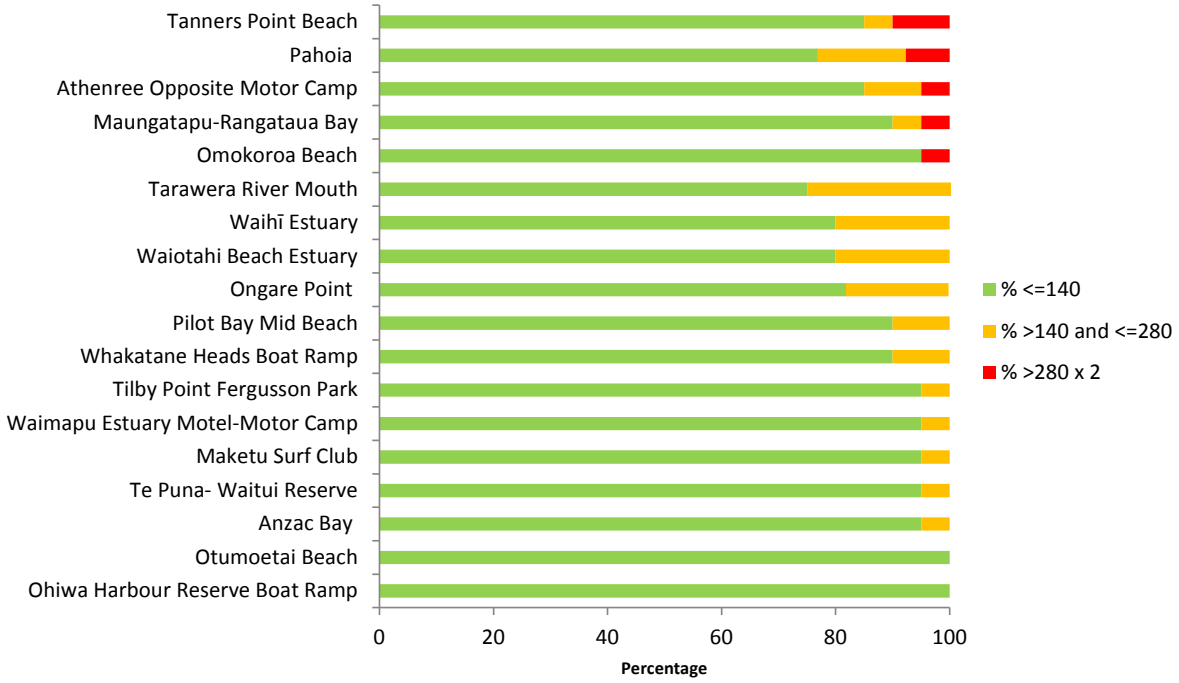


Figure 3.19 Percentage of samples from Estuarine sites with Enterococci concentrations in each of the modes in the New Zealand Microbiological Water Quality Guidelines (MfE/MoH 2003), 2015-2016 bathing season.

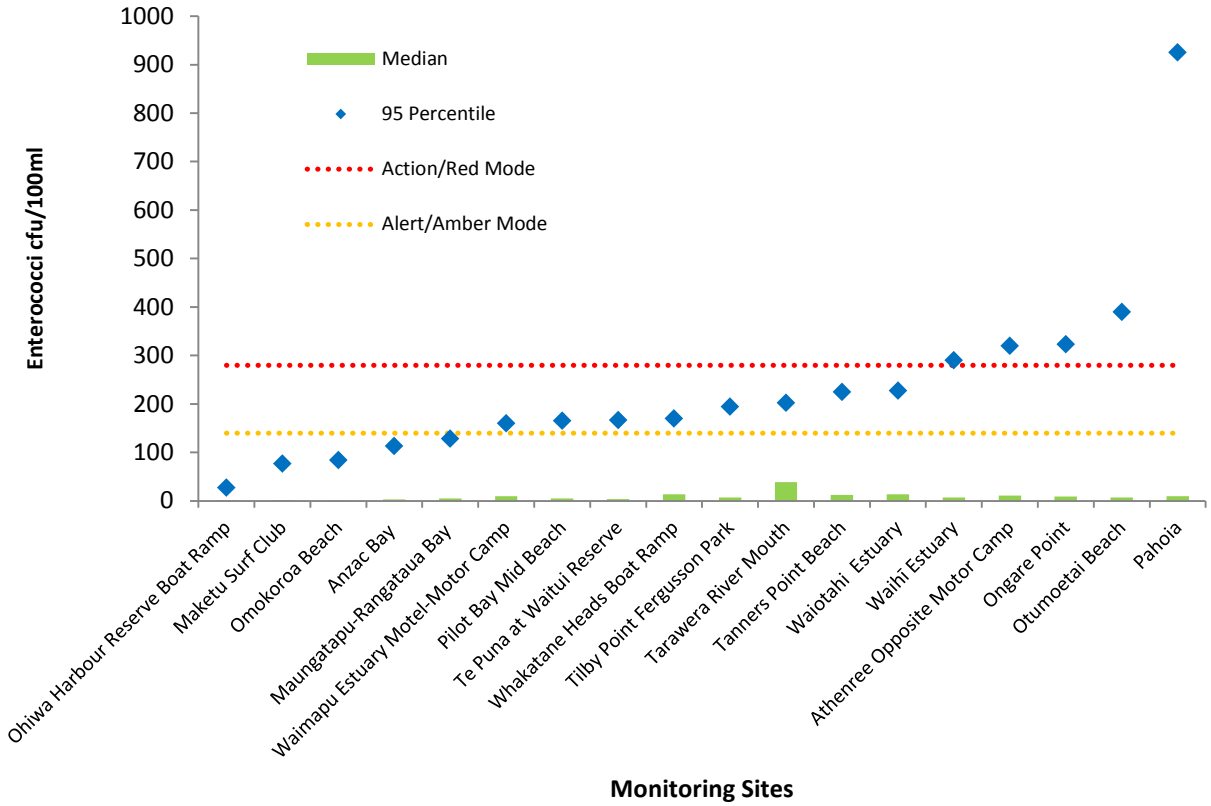


Figure 3.20 Ninety fifth-percentile and median results of enterococci concentrations, estuarine marine sites over the past five years.

Part 4: Shellfish and recreational gathering waters

4.1 Guidelines, sampling and analysis

Thirteen of the 30 open coastal and estuarine surveillance sites are regarded by communities as desirable shellfish gathering locations. Accordingly, water samples from these sites are additionally analysed for Faecal Coliforms (FC), which are suitable microbiological indicators for sanitary safety, with regards to public shellfish consumption. The FC values in accordance with the microbiological guidelines indicate the presence of pathogenic bacteria, protozoa and viruses. Furthermore, faecal coliforms have a stronger correlation with health risks associated with eating shellfish than enterococci (MfE/MoH, 2003), making them a useful indicator.

The guidelines for safe shellfish consumption are as follows:

- The median FC content should not exceed a Most Probable Number (MPN) of 14/100 mL, and
- No more than 10% of samples should exceed a MPN of 43/100 mL.

Compliance with these guidelines does not ensure that shellfish in the waters will be safe for consumption as they do not account for biotoxins. However, they do provide a useful management tool to assess the risk to human health. The sampling and analysis for FC is described in Section 2.2.

4.2 Results

Results for the shellfish sampled over the 2015-16 bathing season are presented in Figures 4.1 and 4.2.

The Waiotahe and Waihī estuaries were found to exceed the safe consumption guidelines as described above.

Maketū Estuary was also over the seasonal median guideline value, but well under the upper guideline. Figure 4.2 shows the percentage of samples with FC concentrations above 43 cfu/100 mL. It reveals that Otumoetai Beach, Waiotahe Estuary, Waihī Estuary, Pukehina, Ohope Beach (Surf Club), Waihi Beach and Waitui Reserve at Te Puna were all above the 10% threshold during the 2015/2016 bathing season. The remaining four sites were within safe consumption limits. Maketu Beach was the only site to have FC concentrations below 43 cfu/100 ml in all samples taken.

These results indicate that shellfish are likely to be contaminated microbiologically some of the time, elevating the risk of human health impacts. Highest risks sites have been noted as Waiotahe Estuary and Waihi Estuary. While other sites have not triggered both guideline conditions, one guideline has been triggered (e.g. Te Puna at Waitui Reserve) and hence there is likely to be times of elevated risk of contracting gastroenteritis from raw shellfish consumption.

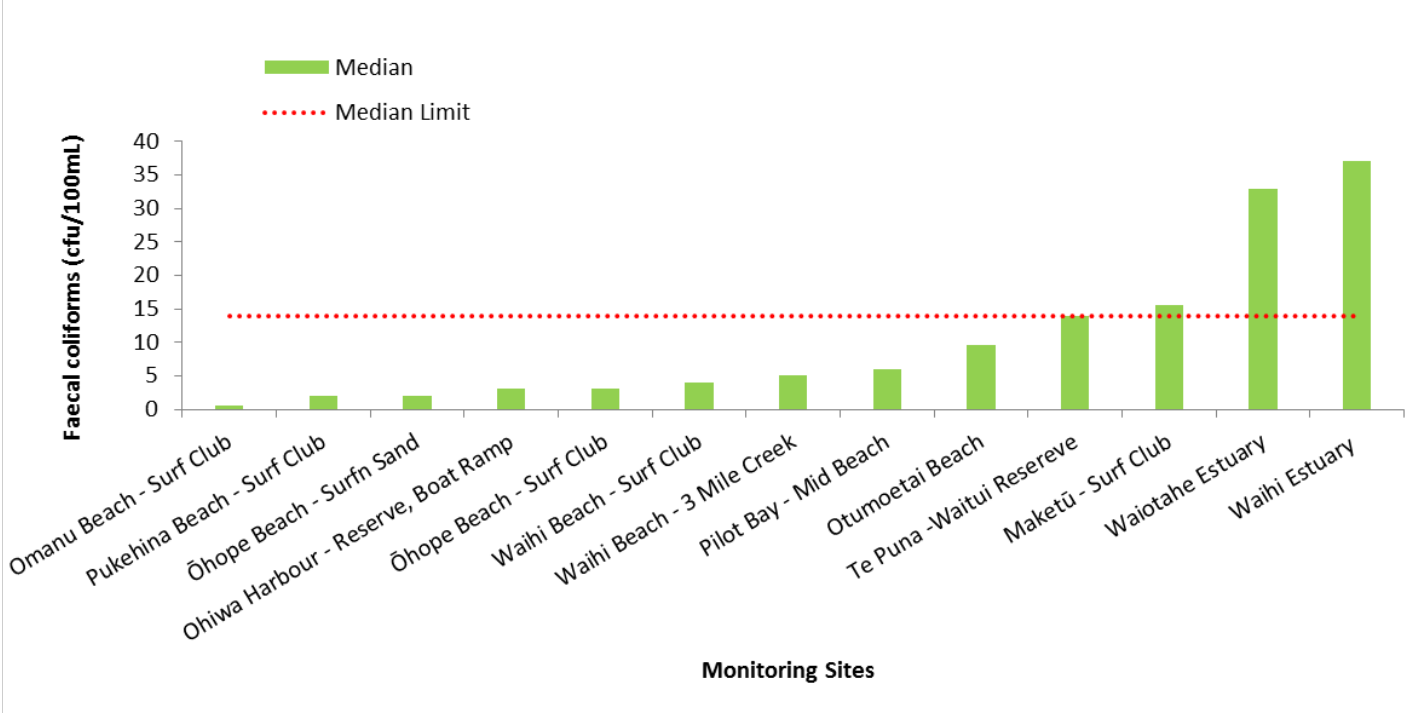


Figure 4.1 *Median faecal coliform concentrations at shellfish gathering locations for the 2015-2016 season.*

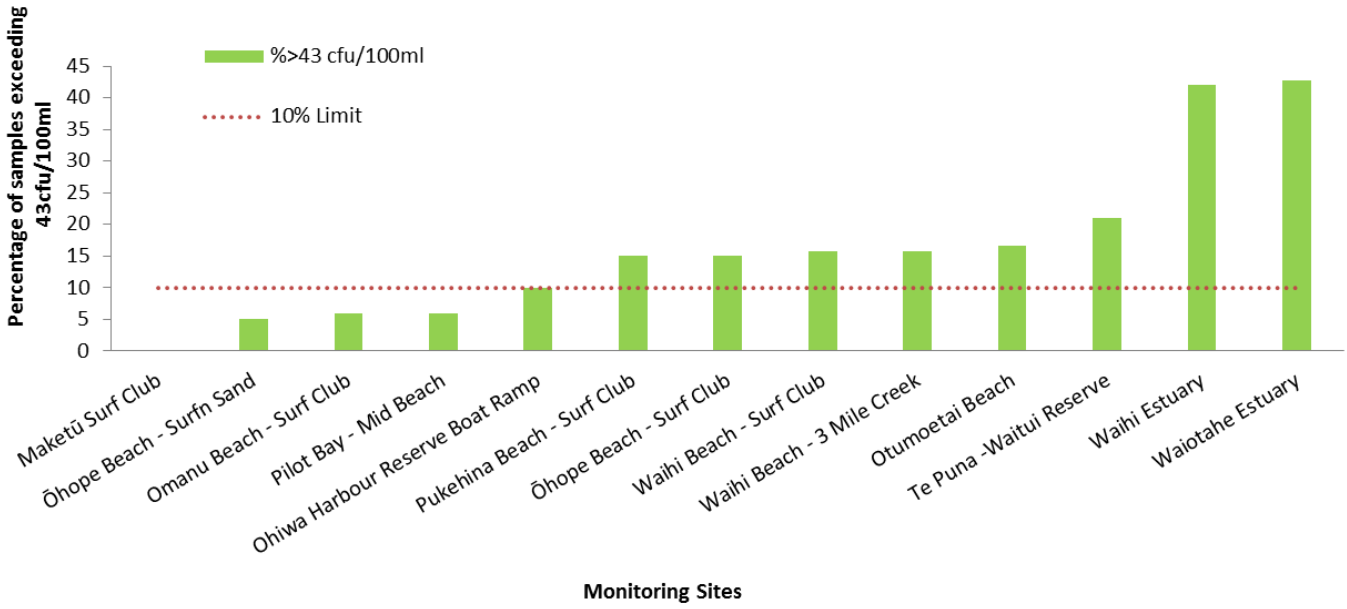


Figure 4.2 *Percentage of samples at shellfish gathering locations in the 2015-2016 season exceeding the limit of 43 cfu/100 mL stipulated by the Microbiological Water Quality Guidelines (MfE/MoH 2003) for the 13 marine sites.*

Part 5: River algae monitoring programme

5.1 Introduction

Blue-green algae are widespread throughout New Zealand. Lakes and rivers in the Bay of Plenty are affected by free living algal blooms at times (leading to soupy looking water or surface scums) or blooms of attached 'benthic' algae (often in the form of mats covering the river bed). These blooms may or may not be toxic.

Phormidium is a benthic mat-forming cyanobacteria that can proliferate during periods of sustained low river flows, and form expansive black/brown leathery mats across large areas of river bed (Wood and Heath, 2010). *Phormidium* produces a potent neurotoxin and has been linked worldwide with dog and stock deaths (Heath, 2009). While ingestion of the mats is the most direct route of exposure, there is one account in the international literature of dog deaths occurring after they drank from a bloom affected river.

Stable substrate provides attachment points for these cyanobacteria and other algae and for this reason, blooms are most often associated with cobbled river beds. However, investigation following the death of a dog near the Rangitāiki River in 2007, revealed that *Phormidium* can also form continuous mats over pumice beds after prolonged low-flow events. This has significant implications for a number of rivers in the Bay of Plenty.

When extensive mats of blue-green algae are found, a warning may be issued by the health authority. This will advise the public not to drink or use affected water and to keep away from the areas affected.

When a warning is issued, the district council places signs at major public access points. Updated information on warnings is also posted on the Bay of Plenty Regional Council and Toi Te Ora Public Health websites.

5.2 Monitoring methods

A periphyton (stream algae) monitoring programme began in October 2015, to monitor the state and trends of periphyton communities throughout the region. Geographic Information System (GIS) analysis was used to select 30 streams in the region which were unshaded and dominated by coarse, stable substrates (Table 5.1). These are two essential requirements for periphyton blooms to occur. No monitoring was therefore undertaken in either shaded streams, or streams dominated by highly mobile pumice streambeds.

Site selection was also based on selecting rivers with different flood frequency and nutrient regimes, as these factors also control periphyton communities. Thus, algal blooms will be more common in high nutrient streams with low flood frequency, and least common in low nutrient streams with high flood frequency. Sites were spread throughout the region, with five sites located in areas draining into the Tauranga Harbour, nine sites in the Rangitāiki Catchment, six sites in the Whakatāne and Tauranga river catchment, four sites in the Waiotahe Catchment, and six more sites in rivers draining Eastern Bay of Plenty catchments (Figure 5.1).

Table 5.1 List of the 30 river sampling sites (showing NZTM easting's and northings) where monthly algal monitoring is conducted.

BOP site #	Site label	Site name	Easting	Northing
BQ771149	PERI_001	Aongatete at Lockington Road Quarry	1857715	5831495
IH893640	PERI_002	Horomanga at Galatea Road	1928917	5746417
JH380190	PERI_003	Horomanga US of Troutbeck Road	1933800	5741900
IG825680	PERI_004	Mangamate at Troutbeck Road	1928250	5736800
OI354282	PERI_005	Manganuku US SH 2	1983542	5752821
JE730670	PERI_006	Mangapae at Ruatahuna Road	1937300	5716700
KE115490	PERI_007	Mimiha at Ruatahuna Road	1941150	5714900
CO542022	PERI_008	Ngamuwahine at Ngamuwahine Road 2 km	1864551	5811383
JH287392	PERI_009	Ohutu at Troutbeck Road	1932850	5743800
NI965512	PERI_010	Omaukora at Wairata	1979653	5755127
FD660605	PERI_011	Otangimoana at Forestry Road Bridge	1899007	5700775
FD900076	PERI_012	Otangimoana at Matea Road	1896603	5706057
KK502156	PERI_013	Owhakatoro at Owhakatoro	1945029	5771567
LJ497861	PERI_014	Raroa at Raroa Road	1954977	5768611
BQ708712	PERI_015	Te Rereatukahia at SH 2 Bridge	1857047	5837109
BR290802	PERI_016	Tuapiro at Farm Bridge	1855215	5845020
OK126554	PERI_017	Tutaetoko at Tutaetoko Road	1981261	5775544
LK445461	PERI_018	Tauranga at Wardlaw Glade	1954452	5774619
JI485995	PERI_019	Waihua at Galatea Road	1934850	5759950
JJ640275	PERI_020	Waikokopu at Galatea Road	1936400	5762750
BQ744465	PERI_021	Waitekohe at SH 2 Bridge	1857397	5834637
KL961127	PERI_022	Whakatane at Pekatahi Bridge	1950050	5781567
IE252438	PERI_023	Whirinaki US Waiparera Confluence	1922500	5714250
MK668495	PERI_024	Oruamanganui at Waiotahe Valley Road	1966683	5774951
MK705314	PERI_025	Atuarere at Waiotahe Valley Road	1967055	5773144
MK617044	PERI_026	Waiotahe DS of Kahunui Village Trust	1966171	5770448
MK689368	PERI_027	Waiotahe at 1100 Waiotahe Road	1966899	5773685
PK049969	PERI_028	Waiaua DS Oiratiti	1990496	5779697
QK038072	PERI_029	Waitukuaruha at Ngaupokotangata	2000387	5770726
QK200600	PERI_030	Mangaonuku at Takaputahi	2002005	5776006

The sites monitored include river entry points of known recreational value. River reaches that contain optimum habitat for *Phormidium*, and that are shown perennially to support large mats, are also monitored as these provide a comparative measure of mat development (even if they receive little recreational use).

Monitoring involves visually estimating the percentage cover of cyanobacteria along each of four transects. Transects begin downstream and progress upstream to avoid disturbance to areas not yet surveyed. A transect is made across the river, if shallow, or to a maximum depth of 0.6 m for larger, deeper rivers.

Periphyton cover was visually estimated at each of the 30 monitoring sites, with periphyton groups being classified into defined classes (e.g. filaments, mats, cyanobacteria). Visual observations were made at five equally spaced locations across the stream at each of four transects. Average cyanobacteria cover was calculated for each transect, and the average of each transect was calculated to determine the average cyanobacteria cover at a particular site on each sampling occasion. All observational data was recorded on electronic iPads using survey forms developed in Survey123.

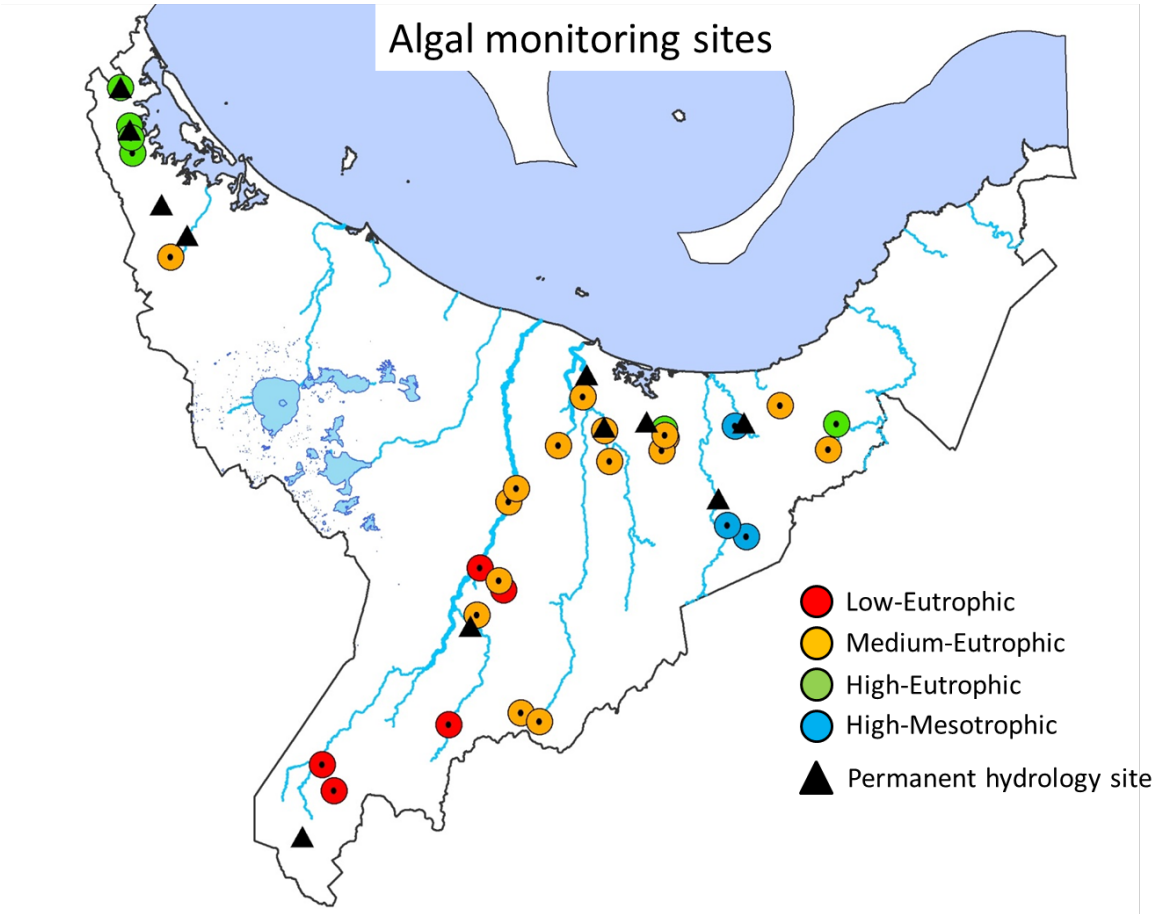


Figure 5.1 *Location of periphyton monitoring sites selected at random throughout the region from unshaded streams with large substrates. Streams are colour coded into different flood frequency and nutrient classes. Also shown are the locations of the permanent hydrological gauging stations.*

All cyanobacteria data was converted into the percentage cover of wadeable stream bed occupied by cyanobacteria. Values for these metrics were subsequently compared to existing MoH guidelines which set acceptable limits for the upper values for these metrics (see section 5.3).

5.3 Phormidium - monitoring framework

An early warning system is operated on the Whakatāne and Rangitāiki rivers based on telemetered flow recorders[2]. The status level for the Whakatāne River is also used to represent the situation in the Tauranga (previously Waimana) River. As each alert level is reached, a range of actions follow, potentially culminating in health warnings if and when mat cover reaches or exceeds 50% cover (Table 5.2). The alert level framework used by Bay of Plenty Regional Council, generally follows that given in the interim 'New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters' (MfE/MoH 2009).

A network of river users also informs the Council when *Phormidium* is present at levels that may require field measurements.

Table 5.2 Bay of Plenty Regional Council Alert Level Framework in place for Phormidium.*

Alert level	Trigger	Action
Phormidium Surveillance (green mode)	Up to 20% coverage of potentially toxigenic cyanobacteria attached to substrate	Undertake fortnightly surveys between spring and autumn at representative locations in the water body, where known mat proliferations occur and where there is recreational use
Phormidium Yellow Alert	No flush in last 14 days	Continue to monitor the situation
Phormidium Orange Alert	Flow <10-percentile	Begin field assessments. If coverage of potentially toxigenic cyanobacteria 20−50%, notify the public health unit and Increase sampling to weekly
Phormidium Red Alert	Phormidium mat covering ≥50% of the bed	Immediately notify the public health unit. Health warning instated. If municipal water takes are at risk, SPATT may be established to monitor for free toxins

*based upon Cyanobacteria in Recreational Fresh Waters Interim Guidelines

5.4 Results

No sites exceeded the guidelines based on the long-term average during the sampling period (October 2015-May 2016). Examination of the maximum average monthly cyanobacteria cover, also showed that only two sites (Omaukora and Te Rereatukahia) had average cover within the "Amber alert" mode (Table 5.3). All the other sites had cover well within the green surveillance mode levels.

[2] The telemetered flow recorder sites are based around established gauging stations at Valley Road (Whakatāne River) and Te Teko (Rangitāiki River).

Table 5.3. Summary of average cyanobacteria cover during the first eight months of data collection (October 2015 - May 2016) and the maximum average monthly cover observed in each stream. Where the observed values exceeded the MoH guidelines, the sites were colour-coded to the appropriate band (green = "surveillance mode"; orange = "Amber alert mode"; red = "public warnings required ").

Site	Average cover	Maximum average monthly cover
Aongatete at Lockington Road Quarry	0.1	0.8
Atuarere at Waiotahe Valley Road	0.0	0.0
Horomanga at Galatea Road	0.0	0.0
Horomanga upstream of Troutbeck Road	1.9	7.5
Mangamate at Troutbeck Road	4.0	16.0
Mangaonuku at Takaputahi	0.0	0.0
Mangaonuku upstream of SH2	0.0	0.0
Mangapae at Ruatahuna Road	0.9	3.5
Mimiha at Ruatahuna Road	0.0	0.0
Ngamuwahine at Ngamuwahine Road	6.0	18.1
Ohutu at Troutbeck Road	0.0	0.0
Omaukora at Wairata	11.6	28.0
Oruamanganui at Waiotahe Valley Road	1.5	9.3
Otangimoana at Forestry Road Bridge	0.7	4.0
Otangimoana at Matea Road	1.3	7.5
Owhakatoro at Owhakatoro	0.0	0.0
Raroa at Raroa Road	0.1	0.3
Tauranga at Wardlaw Glade	0.0	0.0
Te Rereatukahia at SH 2 Bridge	12.0	25.0
Tuapiro at Farm Bridge	0.0	0.0
Tutaetoko at Tutaetoko Road	3.0	9.0
Waiaua Stream - Below Bridge	0.2	1.3
Waihua at Galatea Road	0.0	0.0
Waikokopu at Galatea Road	1.4	8.5
Waiotahe at 1100 Waiotahe Road	0.0	0.0
Waiotahe downstream of Kahunui Village Trust	0.0	0.0
Waitekohe at SH 2 Bridge	3.8	16.5
Waitukuaruha at Ngaupokotangata	0.0	0.0
Whakatane at Pekatahi Bridge	0.7	4.0
Whirinaki upstream of Waiparera Confluence	0.6	2.8

Examination of the cyanobacterial cover over time showed a high variability at each site. For example, cover at the Te Rereatukahia site increased to a low Amber level in January and February 2016, before being reduced to approximately 10% cover in March and April. This reduction in cover reflected a flood event occurring in mid-February which removed excess cyanobacteria. In contrast, cover of cyanobacteria was low in the Ngamuwahine Stream from November until February, when it increased to just below Amber alert level in April (Figure 5.2).

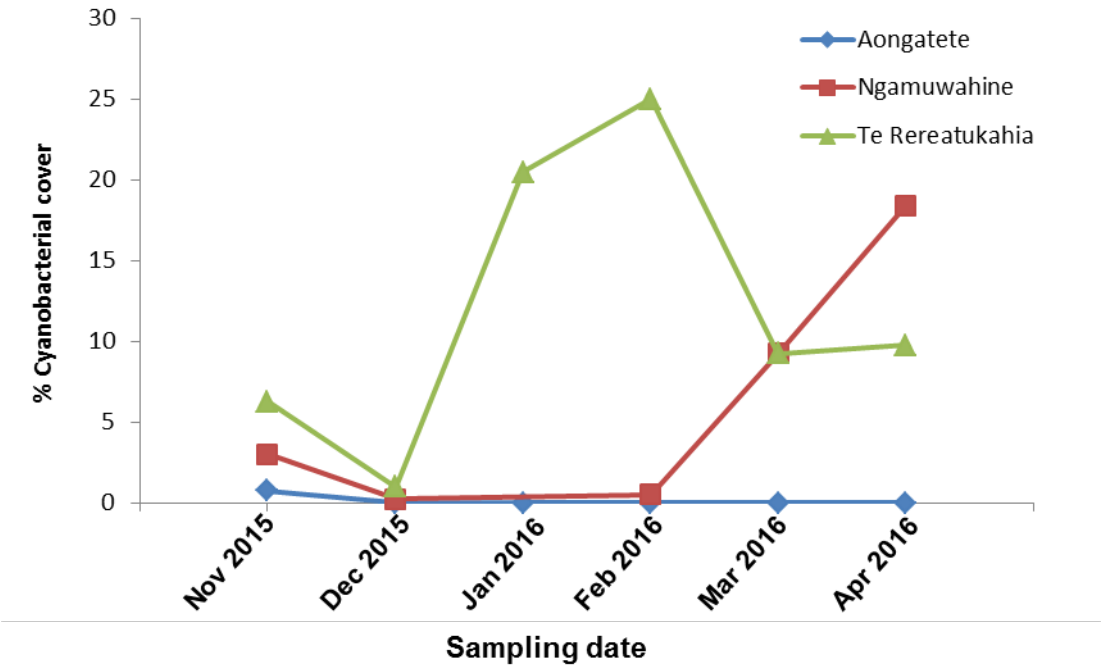


Figure 5.2 *Percentage cover of cyanobacterial mats at three western Bay of Plenty streams during the 2015 to 2016 summer monitoring period.*

Cover at other sites was also highly variable. For example, there were increases in cyanobacteria cover at the Horomanga, Mangamate and Oraumanganui Streams early on in the sampling period, followed by large reductions in cover from February onwards (Figure 5.3). This again reflected the impacts of large flood events in the region at the time.

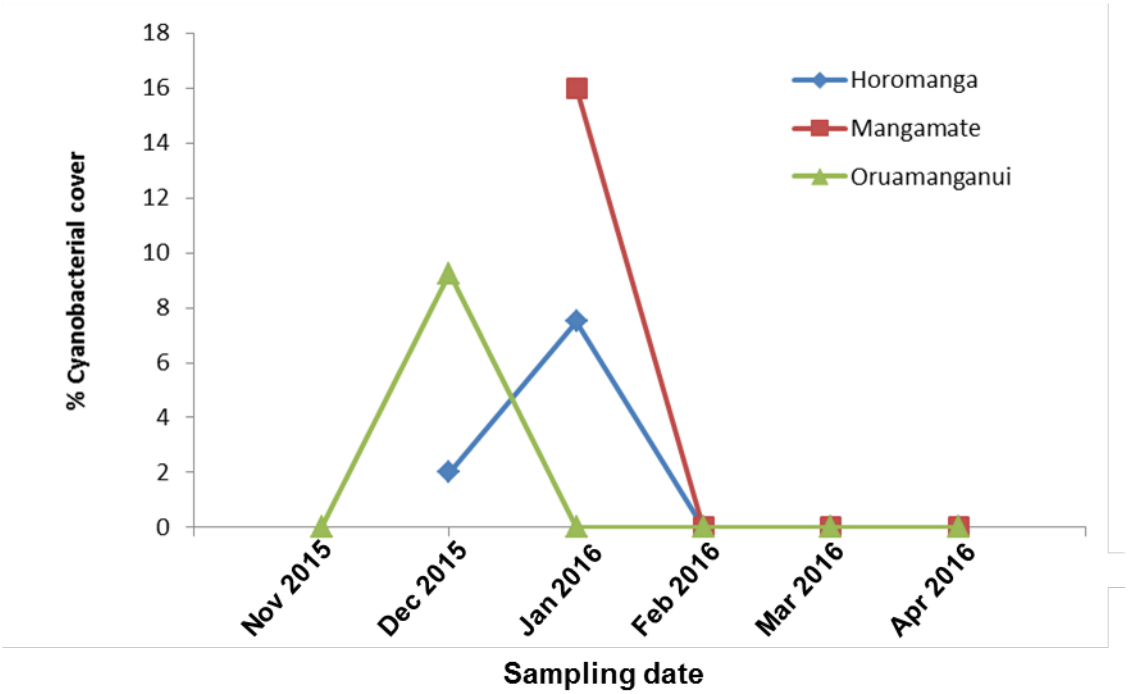
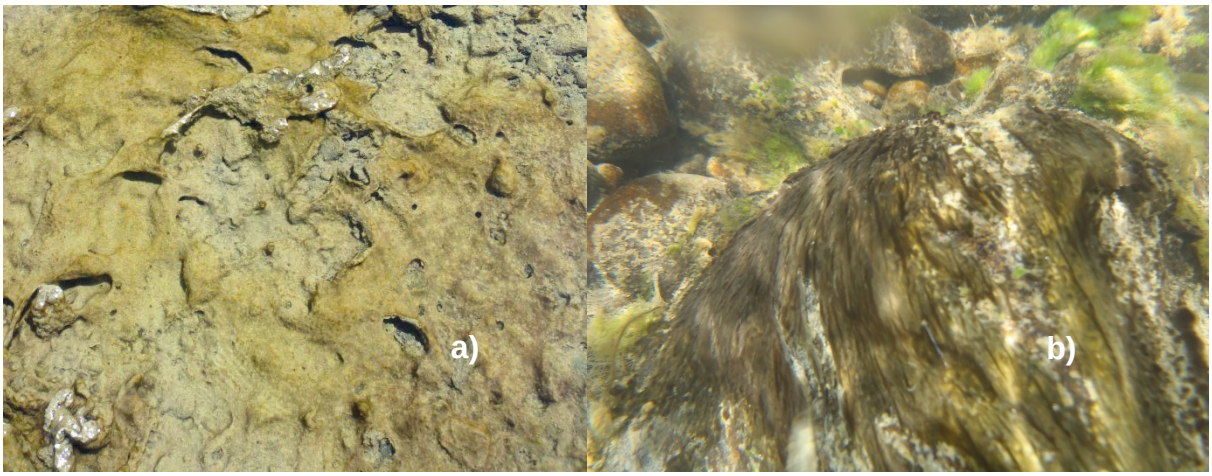


Figure 5.3 *Percentage cover of cyanobacterial mats at three streams in the centre and eastern parts of the region during the 2015 to 2016 summer monitoring period.*

Overall, cyanobacterial cover at the 30 monitoring sites was generally low during the summer of 2015-2016. This most likely reflected the large number of flood events that occurred in this period, which washed away cyanobacterial mats and maintained cover well below alert levels. Ongoing monthly periphyton monitoring will continue at all sites during the 2016-2017 summer. It is hoped that the results of this summer's monitoring will be made available to the public and public health by the Council web page as and when the data comes in.



Photos: a) Phormidium, Otara River; b) Phormidium, Waimana River.

Part 6: Summary and recommendations

6.1 Summary

A relatively wet summer season compared to previous seasons (see Figure 6.1) resulted in an increase in the number of exceedances of the microbiological water quality guidelines for some sites in the 2015-16 bathing season. Most sites in the Bay of Plenty still remained suitable for bathing over this period.

Under the SFRG, 85.7% of lake sites were graded ‘very good’ or ‘good’, with 7.1% graded ‘followup’. River Sites (52.2%) were graded ‘poor’, an improvement of over 7% on last season.

Of the estuarine sites, 16.7% were graded ‘poor’ or ‘followup’ while 38.9% were graded ‘fair’. Most (75%) of the open coastal sites were graded as ‘good’ or ‘very good’, with the remaining 25% graded as ‘follow up’. Compared to last season, the grading for estuary sites declined slightly while open coastal sites improved.

The SFRG grading shows that rivers continue to pose the highest risk to recreational water users, and that there is only a low risk of encountering water-borne pathogens in monitored lakes. This is consistent with previous monitoring and reflects the greater vulnerability of rivers and streams to diffuse and point source discharges due to contaminants sourced from faecal material.

The open coastal sites typically have excellent water quality with only three reaching the Red/Action Mode once in 2015-16. Several estuarine sites reached the Red/Action Mode in 2015-16, most notably Tanners Point, where such elevated results have not been previously observed. One event is explained by an intense rainfall event. Only 5.6% of the estuarine sites were graded ‘poor’ (none are graded ‘very poor’). However, 27.8% were graded as ‘followup’. The higher faecal contamination levels can be attributed to the enclosed nature of estuaries and the strong river influence.

During the 2015-16 bathing season, 15.0% of samples from rivers reached the Orange/Alert Mode and 10% reached the Red/Action Mode. Many of these can be explained by heavy rainfall events (see Figure 5.1).

Note that some SFRG grades are provisional as the microbiological data has not reached an optimum level according to the microbiological guidelines. The data does, however, provide useful information to allow an assessment of the risk to recreational users of waterways. Follow up grades are also assigned where not enough data has been collected, or the catchment assessment is not consistent with the indicator bacteria results. The grading system can be biased by only one or two elevated results, as these push the percentile figures upwards. Such results can be more frequent in years where monitoring has coincided with rainfall events.

All river and lake sites compare favourably with the NOF bands for human health (for secondary contact recreation activities) given in the NPS for Freshwater Management. However, eight river sites were found to be below the ‘minimal acceptable state’ for primary contact recreation (see Appendix 1a).

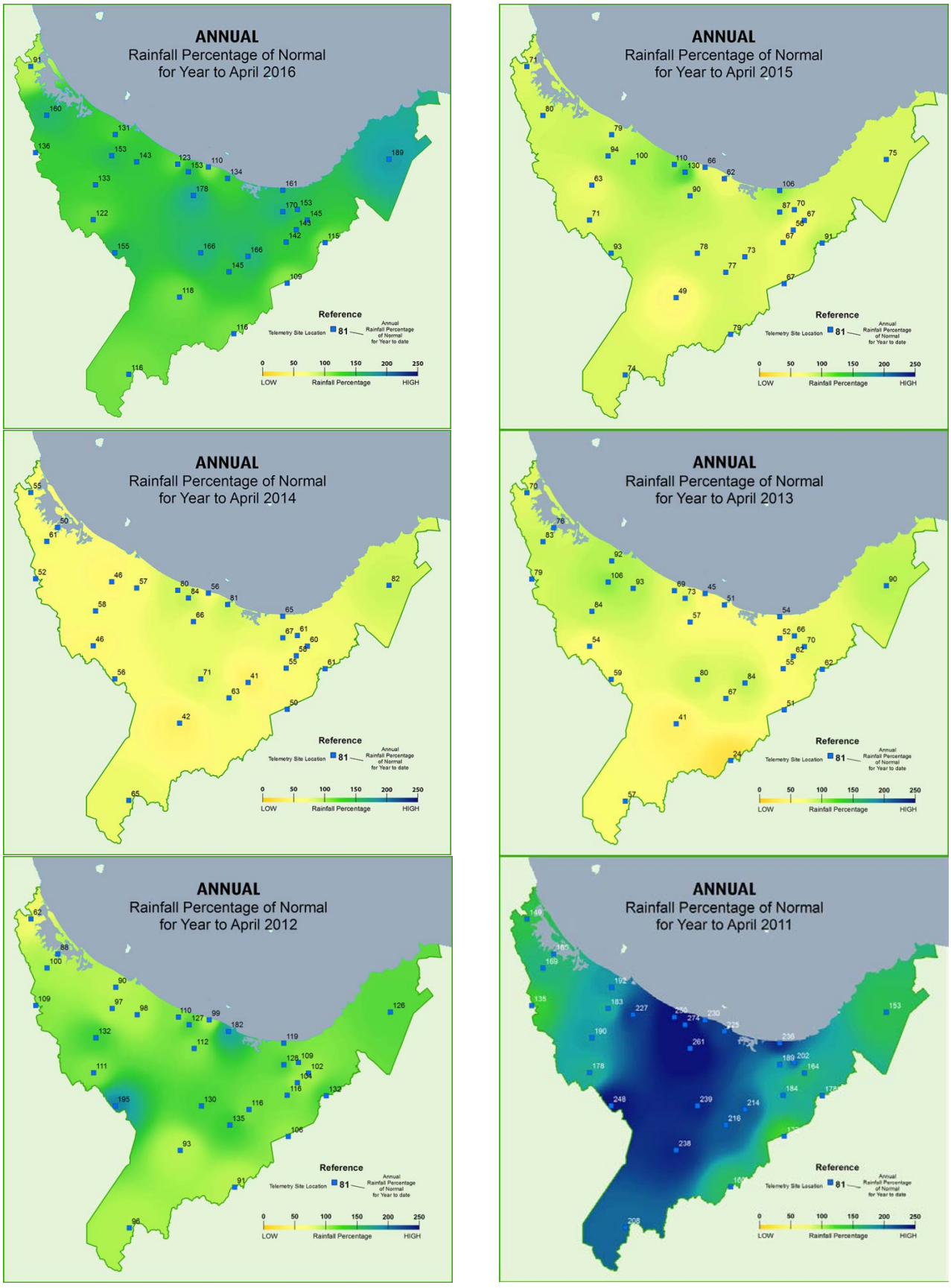


Figure 6.1 Annual rainfall percentage of normal for years 2010 to 2015.

Shellfish samples collected from eight estuarine sites exceeded the guideline levels for human consumption. Having elevated faecal coliform and enterococci levels, indicates some risk to human health if these shellfish are ingested uncooked.

Phormidium was observed in several rivers (Te Rereatukahia, Waitokohe, and Omaukora) but at levels below alert thresholds. The season was marked by consistent flow flushing events which reduced the ability of *Phormidium* to spread.

6.2 Recommendations

It is recommended that investigations continue to identify faecal contamination sources in the catchments that have had health warnings posted (e.g. the Ngongotahā Stream and Kaiate Falls). The use of microbial source tracking techniques may help delineate potential sources, but modelling and loading investigation are also likely to be required to ascertain the relative contribution within these catchments.

It is also recommended that systems that are able to forecast recreational water quality risk be investigated. Water quality models exist for several estuaries in the Bay of Plenty and it is possible to use these in conjunction with meteorological data to forecast indicator bacteria concentrations. Such a system would be akin to current weather forecasting models, where users could potentially see what the likely recreational risk is several days in advance. River models could also be developed into a predictive warning system, particularly for high risk sites. This would require undertaking event sampling and analyses of sites with adjacent flow/level and rainfall monitoring to calibrate sites. Again this would provide an early warning system of the risk of elevated pathogen levels in rivers.

Part 7: References

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Appendices

Appendix 1a – Suitability for recreation grading - Grades for river and stream sites

District	Site	BOP site number	Mean	Median	95th percentile	MAC	SIC	SFRG	% of samples less than Action/Red Mode	NOF primary contact attribute	NOF secondary contact attribute
Kawerau	Tarawera River at Boyce Park	BOP160110	59	50	216.00	A	Very Low	Very Good	100.0	A	A
Ōpōtiki	Waioeka River at SH 2	BOP160103	167	56	480.00	C	Moderate	Fair	95.0	B	A
Ōpōtiki	Otara River at SH 35	BOP160101	122	37	353.00	C	Moderate	Fair	96.4	B	A
Ōpōtiki	Kereu River at SH 35	BOP110165	108	6	139.50	B	Very Low	Good	96.1	A	A
Ōpōtiki	Waioeka River bend near Pa	BOP160102	84	58	370.00	C	Moderate	Fair	96.3	B	A
Rotorua	Ōhau Channel at SH 33	BOP160119	36	14	120.00	A	Very Low	Very Good	100.0	A	A
Rotorua	Waitangi Soda Springs	BOP160120	17	10	62.20	B	Moderate	Good	100.0	A	A
Rotorua	Utuhina Stream at Lake Road	BOP160117	191	90	640.00	D	Moderate	Poor	91.0	>MAS	A
Rotorua	Waiteti Stream at SH 36	BOP160115	259	83	740.00	D	Moderate	Poor	92.7	>MAS	A
Rotorua	Ngongotaha Stream at Railway Bridge	BOP160114	318	160	1145.00	D	Moderate	Poor	85.5	>MAS	A
Rotorua	Puarenga Stream at Whakarewarewa	BOP160113	137	55	360.00	D	Moderate	Poor	94.3	B	A
Tauranga	Kopurererua Stream at McCord Avenue	BOP291216	240	210	483.50	C	Moderate	Fair	97.7	B	A
WBOP	Uretara Stream at Henry Road	BOP210004	262	145	623.00	D	Moderate	Poor	93.0	>MAS	A
WBOP	Pongakawa River at SH 2	BOP110030	146	67	564.00	D	Moderate	Poor	94.1	>MAS	A
WBOP	Tuapiro Stream at McMillan Road	BOP160126	173	62	260.00	D	Moderate	Poor	98.8	A	A
WBOP	Wairoa River at SH 2	BOP160122	190	71	746.00	D	Moderate	Poor	91.9	>MAS	A
WBOP	Wairoa River below McLaren Falls	BOP160124	214	37	1200.00	D	Moderate	Poor	90.0	>MAS	A
WBOP	Kaiate Stream above Kaiate Falls	BOP160130	511	210	2060.00	D	Moderate	Poor	74.0	>MAS	A
Whakatāne	Rangitaiki River at Thornton Boat Ramp	BOP160109	73	30	236.50	B	Moderate	Good	99.1	A	A
Whakatāne	Rangitaiki River at Te Teko	BOP110018	54	20	297.50	C	Low	Fair	98.1	B	A
Whakatāne	Whakatane River at Landing Road	BOP160106	101	60	315.00	C	High	Poor	95.7	B	A
Whakatāne	Tauranga River at Wardlaw Glade	BOP160105	356	13	230.00	B	Very Low	Good	95.90	A	A

>MAS = does not meet minimum criteria; N/A represents new sites added in the 2014/15 season, which currently do not have an assigned SIC. **Note**: Numerical results and MAC are based on *E.coli* data.

Appendix 1b – Suitability for recreation grading - Grades for lake sites

Site	BOP site number	Mean	Median	95th percentile	MAC	SIC	SFRG	% of samples less than Action/Red Mode	NOF primary contact attribute	NOF secondary contact attribute
Lake Tarawera - Rangiuru Bay	BOP160072	4.5	1.0	24.20	A	Very Low	Very Good	100.0	A	A
Lake Rotoiti - Gisborne Point (boat ramp)	BOP160054	6.1	2.0	32.00	A	Very Low	Very Good	100.0	A	A
Lake Rotoiti - Hinehopu, jetty	BOP160053	8.1	1.0	39.30	A	Very Low	Very Good	100.0	A	A
Lake Ōkaro - Ski area (40 m left boat ramp)	BOP160073	20.8	4.0	61.80	A	Very Low	Very Good	98.5	A	A
Lake Rotomā - Whangaroa	BOP160052	23.4	2.5	202.00	B	Very Low	Good	100.0	A	A
Lake Rotoiti - Okawa Bay	BOP160056	22.7	10.0	98.00	A	Very Low	Very Good	100.0	A	A
Lake Ōkāreka - East end of dwellings	BOP160061	33.6	10.0	182.00	B	Very Low	Good	100.0	A	A
Lake Tikitapu - Beach	BOP160063	29.1	3.0	203.00	B	Very Low	Good	100.0	A	A
Lake Tarawera - Te Karamea Bay (Cliff Road)	BOP160291	12.5	1.0	64.25	A	Very Low	Very Good	100.0	A	A
Lake Rotorua - Holdens Bay	BOP160066	26.4	7.0	133	B	Moderate	Good	100.0	A	A
Lake Rotorua - Ngongotahā	BOP160069	96.8	11.0	357.50	C	Low	Fair	97.3	B	A
Lake Rotorua - Hamurana	BOP160070	97.2	53.3	166.00	B	High	Follow up	97.2	A	A
Lake Ōkaro - Ski Area (40 m left boat ramp)	BOP160073	21	4	62	A	Very Low	Very Good	97.2	A	A
Lake Rerewhakaaitu - Brett Road boat ramp	BOP160079	43	16	164.00	B	Very Low	Good	98.5	A	A

Note: Numerical results and MAC are based on E.coli data.

Appendix 1c – Suitability for recreation grading - Grades for marine sites

District	Site	Site Number	Mean	Median	95th percentile	MAC	SIC	SFRG	% of samples less than Action/Red Mode
Ōpōtiki	Whanarua Bay	BOP160002	26.7	3	152.6	B	Very Low	Good	95.5
Ōpōtiki	Te Kaha Beach - Maraeti Bay	BOP160003	50.6	3	224.6	C	Very Low	Follow up	93.8
Ōpōtiki	Hikuwai Beach	BOP160005	7.0	1	36.4	A	Moderate	Good*	100.0
Ōpōtiki	Waiotahe Beach - Surf Club	BOP160007	10.3	1	36.6	A	Low	Very Good	100.0
Ōpōtiki	Waiotahe Estuary	BOP160008	59.8	12	222.0	C	Moderate	Fair	95.5
Tauranga	Mt.Maunganui - Surf Club	BOP160025	4.3	1	19.1	A	Very Low	Very Good	100.0
Tauranga	Omanu Beach - Surf Club	BOP900096	8.1	1	24.0	A	Very Low	Very Good	100.0
Tauranga	Waimapu Estuary - Motel-Motor Camp	BOP160019	47.2	10.5	210.0	C	Low	Fair	98.6
Tauranga	Tilby Point - Fergusson Park	BOP160020	38.6	7	222.0	C	Moderate	Fair	95.9
Tauranga	Otumoetai Beach	BOP160021	70.8	11	518.0	D	Moderate	Poor	95.1
Tauranga	Pilot Bay	BOP160024	21.9	4	145.0	B	Moderate	Good	98.0
Tauranga	Maungatapu - Rangataua Bay	BOP160049	32.2	5	113.5	A	Moderate	Good*	98.7
WBOP	Maketu - Surf Club	BOP160017	9.2	1	44.7	A	Moderate	Good*	99.0
WBOP	Waihi Beach - Surf Club	BOP160027	14.8	2	77.0	A	Low	Very Good	98.6
WBOP	Pukehina Beach - Surf Club	BOP160170	3.8	0.5	12.7	A	Very Low	Very Good	100.0
WBOP	Waihi Beach - 3 Mile Creek	BOP900077	33.2	4	172.7	B	Moderate	Good	96.0
WBOP	Waihi Estuary	BOP160016	22.7	6	88.3	A	Moderate	Good*	94.9
WBOP	Omokoroa Beach	BOP160022	12.1	1	66.1	A	Very Low	Very Good	98.5
WBOP	Pahoia	BOP160023	53.4	7.5	255.8	C	Low	Fair	90.6
WBOP	Anzac Bay	BOP160028	17.4	2	47.8	A	Very Low	Very Good	98.5
WBOP	Athenree - Opposite motor camp	BOP160030	51.1	7.5	304.0	C	Low	Fair	92.8
WBOP	Tanners Point	BOP160031	27.0	12	114.3	A	Very low	Very Good	97.1
WBOP	Ongare Point	BOP160032	42.9	5.5	235.8	C	Low	Fair	94.6
WBOP	Te Puna - Waitui Reserve	BOP160293	23.0	4	147.4	B	High	Poor*	97.9
Whakatāne	Tarawera River - River mouth	BOP110125	51.6	38.5	176.5	B	High	Poor*	97.5
Whakatāne	Ohope Beach - Surf'n Sand Motor Camp	BOP160010	11.4	0.5	21.0	A	Very Low	Very Good	98.5
Whakatāne	Ohope Beach - Surf Club	BOP160011	8.6	2	53.2	A	Moderate	Good*	100.0
Whakatāne	Piripai Beach	BOP160014	8.6	1	46.0	A	Very Low	Very Good	97.2
Whakatāne	Ohiwa Harbour Reserve boat ramp	BOP160009	11.6	2	34.5	A	Very Low	Very Good	100.0
Whakatāne	Whakatane Heads - Boat ramp	BOP160013	57.0	12	259.5	C	Moderate	Fair	97.0

* indicates the sites originally graded as “Follow up” which have been assigned a conservative grade. **Note**: Numerical results and MAC are based on *Enterococci* data.