Marlborough's Coastal Recreational Water Quality 2007-08

Prepared by:

F S Tiernan

Environmental Science and Monitoring

Marlborough District Council

MARLBOROUGH DISTRICT COUNCIL

EXECUTIVE SUMMARY

A number of coastal locations in Marlborough are monitored on a weekly basis during the summer months and assessed against the Ministry for the Environments (MfE's) bathing water guidelines. Coastal water quality in Marlborough is generally very good and during the 2007-08 bathing water season, 50% of sites were categorised as safe for recreational use for more than 95% of the time. However there are some locations which fall short of this high standard e.g. Momorangi Bay and Moenui. Similarly poor water quality was also found at Momorangi during 2006-07, however poor water quality has not previously been reported at Moenui. The source of contamination at Momorangi Bay was explored through a combination of investigative techniques, including: microbial source tracking, extensive water quality surveys of the streams and bay and an inspection of the campground wastewater system and associated pipework. The results were inconclusive showing that faecal contamination in the bay had a complex origin, however it was thought that human input was likely to be minor and wildfowl and possums were likely to be major contributors to faecal contamination in the bay.

Investigative surveys were also carried out for Grove Arm and Ngakuta Bay where water quality in the streams entering the bays and several sites along the bays was analysed. The Grove Arm survey found that whilst septic tanks may have an impact on water quality in the bay during times of heavy rainfall, runoff from agricultural land use is more likely to have an adverse effect on water quality in the bay under such conditions. Conversely, although elevated levels of bacteria dominated the streams entering Ngakuta Bay and a previous microbial source tracking study showed that the contamination was human in origin, the contamination did not appear to be adversely affecting bathing water quality in the bay. Microbial source tracking has proved to be a useful tool when investigating sources of faecal contamination in the Sounds and will be considered for future work where faecal contamination is shown to be an issue. The enclosed nature of the Sounds and its prominence as a prime recreational area within Marlborough and New Zealand emphasizes its susceptibility to faecal contamination.

Suitability for recreation grades (SFRG) have been derived based on the most recent five years of microbiological data and information from sanitary inspections (carried out in 2004). Many sites do not have enough samples to determine a suitable beach grade and as such interim grades are allocated to the sites. Regular monitoring of each site is recommended to allow for comparisons in coastal water quality each year and to allow for complete SFRG bathing grades to be determined.

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1. INTRODUCTION

District councils are required under the Health Act 1956 to monitor environmental factors affecting public health and to abate conditions likely to be offensive or injurious to health. Water quality in our rivers and coastal areas can have an impact on public health. Regional councils have responsibilities under the Resource Management Act 1991 for the planning and management of natural resources including fresh and coastal waters. The Marlborough District Council as a unitary authority has responsibility for both district and regional functions. Guidelines for the safe use of recreational waters are defined by the Ministry of the Environment in the Microbiological Water Quality Guidelines (2003). The recreational waters in Marlborough are sampled in accordance with these guidelines.

2. SITES

During the summer of 2007-08 a total of 20 coastal bathing water sites were monitored on a weekly basis from November to March inclusive, the location of these sites are shown in Appendix 1. Sampling takes place independent of tidal levels. The bulk of the monitoring is carried out in the Queen Charlotte Sound due to its high recreational use and also due to its higher risk (enclosed nature, high population during the summertime etc.). Table 1 details the name, location and grid reference of each site. In general the coastal waters of Marlborough are suitable for contact recreational activities, however there are areas which are more susceptible to contamination, such as the Picton coastal waters and developed bays in Queen Charlotte Sound such as Momorangi Bay and Tirimoana.

Table 1: Coastal Bathing Water Sites 2007-08

Site name	Site ID	Grid Reference (NZTM)	
Anakiwia	GRO-1	2587083	5993201
Bobs Bay	PCT-3	2595183	5991849
Elaine Bay	ELB-001	2574740	6016607
Hakahaka Bay	PTU-001	2603350	5989250
Marfells Beach	MB-1	2610215	5941787
Moenui	MOE-1	2576696	5992100
Momorangi Bay	MOM-1	2588827	5992585
Ngakuta Bay	NGK-1	2590525	5992195
Okiwi Bay	OKB-2	2565320	6010385
Oyster Bay	PTU-002	2603188	5988691
Picton Foreshore	PCT-5	2594309	5990521
Portage	POR-1	2596786	6000405
Shelly Beach North	PCT4A	2594598	5990639
Te Mahia	TEM-1	2591405	5998456
Tennyson Inlet	TNY-001	2574026	6009581
Tirimoana	TIR-5	2586243	5992655
Waikawa Bay	WKB-1	2597707	5992797
Wairau Bar	WRR-7	2598590	5966903
Wairau Diversion	WDV-2	2596069	5973626
Whites Bay	WB-1	2598438	5979497

3. SAMPLING

The water quality at each site is tested for the presence of enterococci bacteria. The results are reported in MPN/100mL (most probable number). All laboratory testing is carried out by the Cawthron Institute in Blenheim. Enterococci are chosen as the indicator bacteria for coastal waters due to its higher survival rates in saline waters and as such it is deemed to be a good indicator of recent sewage and/or faecal contamination. Samples are taken at a water depth of 0.5m approximately 0.2m from the water surface.

3.1 Indicator Organisms

An indicator organism can be defined as an organism which is used to indicate the **potential** presence of another organism. Enterococci are the indicator organisms used when monitoring coastal water recreational sites. When monitoring coastal waters used for recreational purposes, the primary concern is the presence of organisms which can cause illness and/or infection in people. It may not always be possible to identify specific disease causing organisms due to their low numbers, difficulty and expense of analysis among other reasons; therefore the waters are tested for indicator organisms, in this case enterococci. The advantages of using enterococci as the indicator organism are 1) it is easy to sample and inexpensive to measure and 2) it can survive for several weeks in saline waters and is therefore a definite indication of recent faecal contamination. Enterococci are present in the gut of all warm blooded animals (including humans, mammals and birds), all of which are potential carriers of disease causing organisms in humans.

The number of enterococci present in a water sample (100mL) denotes the **potential** health risk of the waters to humans, it is not a direct measurement of the actual health risks, and therefore an exceedance of the guideline value indicates that there is an *increased* risk to bathers in the area. Further details on how this risk is quantified are available in Appendix 2 of the Microbiological Water Quality Guidelines (MfE, 2003).

3.2 Guideline Values

The guideline values for safe coastal recreational sites have been determined by MfE and are as follows:

	For a ***single*** sample		Requirement	
Acceptable '*Green Mode*'	< 140 Enterococci / 100mL	Highly likely to be uncontaminated	Routine monitoring	Safe ☺
Alert '*Amber Mode*'	> 140 Enterococci / 100mL	Potentially contaminated	Investigate likely causes	OK 😐
Action '*Red Mode*'	> 280 Enterococci / 100mL[1]	Highly likely to be contaminated	Further investigatation, inform relevant interested parties	Unsafe ☹

[1] Applies to *two* consecutive single samples (resampled as soon as practicable after receiving first result) greater than 280/100mL

In addition, the Ministry of the Environment has developed Suitability for Recreation Grades (SFRG's). These are defined using the Microbiological Assessment Category (MAC) and the Sanitary Inspection Category (SIC) as defined by MfE.

3.2.1 Microbiological Assessment Category (MAC)

The Microbiological Assessment Category is assessed using data from the previous 5 years. A minimum of 20 samples over the bathing water season (November to March inclusive) for each year is required in order to establish a complete MAC, if there are less than 100 samples over this 5 year period then the MAC status is defined as being incomplete. Marlborough District Council has been carrying out monitoring of coastal water bathing sites since 1996, however in order to obtain a completed MAC grade a minimum of 20 samples per site for each bathing water season is required. For each of the 20 sites sampled this year the number of samples over the last 5 years ranges from 83 to over 100. Just over half of sites assessed had more than 100 samples over a five year period. Table 2 below defines the MAC grades.

Table 2: Microbiological Assessment Category (MAC) definitions for marine waters (MfE, 2003).

Grade	95th Percentile	
A	≤ 40	Enterococci / 100mL
B	41 - 200	Enterococci / 100mL
C	≥ 201 - 500	Enterococci / 100mL
D	> 500	Enterococci / 100mL

The MAC grade will be assessed each year based on the previous 5 years of data. The MAC is used in conjunction with the SIC to obtain a Suitability for Recreation Grade (SFRG). There are between 20 and 22 weeks in the bathing water season so it is important to ensure each site is consistently monitored over the bathing water season to ensure accurate reporting of MAC grades and Suitability for Recreation Grades (SFRGs).

3.2.2 Sanitary Inspection Category (SIC)

The SIC assigns a category to the site based on the risk of contamination associated with faecal sources in the vicinity. Figure 1 details this risk. Marlborough District Council assigned SIC classes to the coastal water bathing sites in 2004.

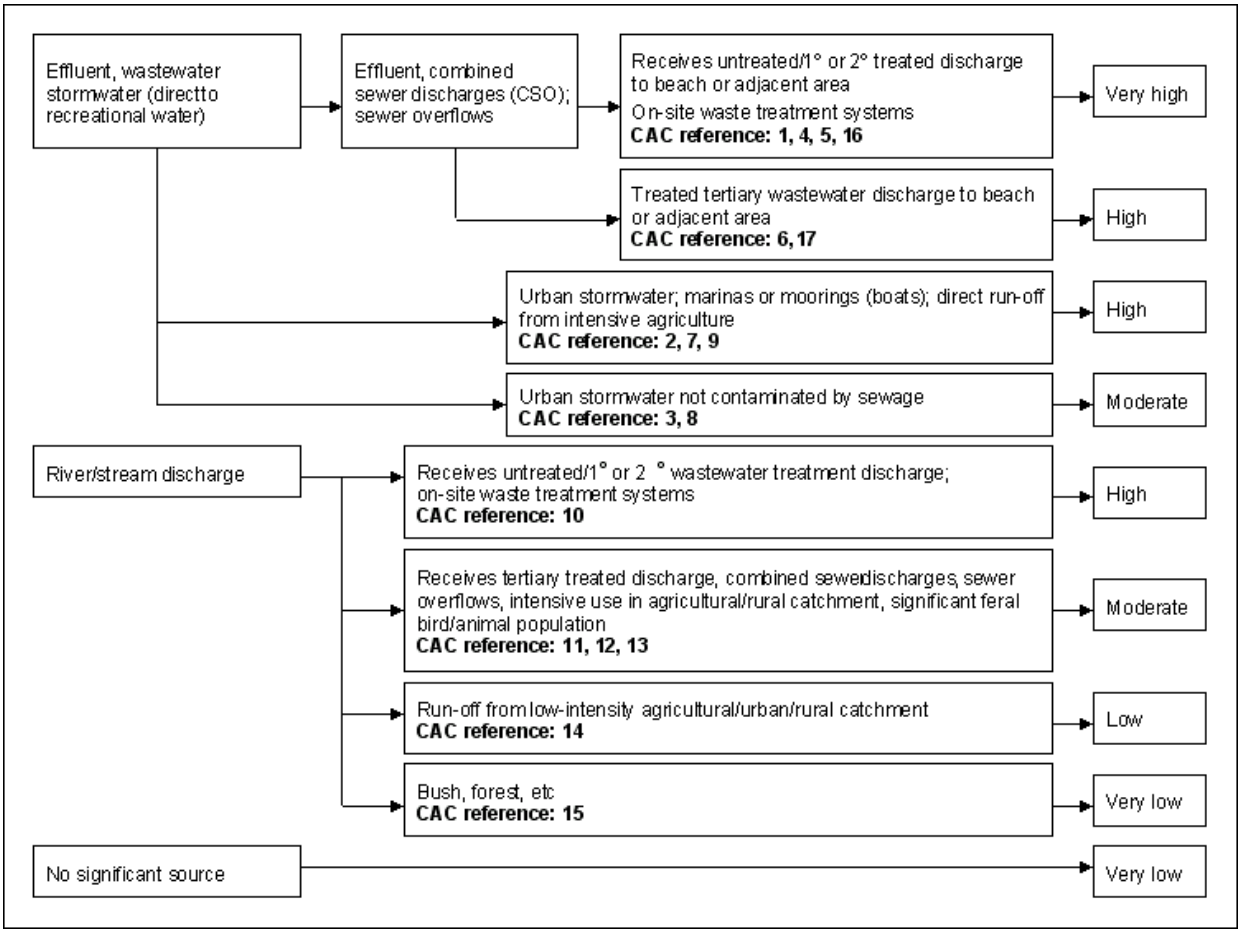


Figure 1: Sanitary Inspection Category for coastal water sites (MfE, 2003)

3.2.3 Suitability for Recreation Grade (SFRG)

Bathing water sites are graded according to the SFRGs, which are Very Good, Good, Fair, Poor and Very Poor. Suitability for Recreation Grades (SFRGs) are obtained using the MAC in conjunction with the SIC and are calculated using the MfE's Recreational Water Quality Assessment software called 'Bathewatch'.

4. BATHING WATER QUALITY RESULTS 2007-08

The results of the summer 2007-08 sampling are shown in Appendix 2. These results are graphed for each site and are shown in Appendix 3. The graphs show the enterococci numbers alongside rainfall (72 hour total) and plotted against both the alert and action level bathing water guideline standards.

Table 3 shows the percentage of time the sites were deemed safe or otherwise for swimming and are ranked accordingly. Momorangi was deemed unsuitable for recreational activity for nearly 40% of the time (i.e enterococci numbers in excess of 140/100mL). Many of the exceedances could not be attributed to heavy rainfall in the preceding days. The results from Momorangi are discussed further in section 5.1. The best water quality has been from Marfells Beach, Whites Bay, Ngakuta, Te Mahia, Portage and Elaine Bay, where results showed that water was safe for swimming 100% of the time, this includes periods during and after heavy rainfall. However, even in pristine environments bacteria levels can be elevated during and after heavy rainfall.

The median counts for each site show a similar result (Table 4), with Momorangi and Moenui having the highest median enterococci counts. High enterococci counts at Moenui are mostly associated with high rainfall events, the exception being a result of >2000 on the 26th March 2008. The beaches in Picton are susceptible to urban runoff and stormwater overflows among other sources and are therefore at high risk of contamination; however recent efforts in the maintenance and upgrading of the stormwater network and efforts to ensure minimal pollution from industrial/commercial sites are proving successful as water quality in this area continues to improve. Continued monitoring of the Foreshore and Shelley Beach is important to ensure this upward trend in water quality continues to be observed.

Table 3: Coastal water bathing sites ranked according to the percentage of time they were suitable for contact recreation.

SITE NAME	SITE ID	% of time Enterococci numbers < 140 MPN/100mL	% of time Enterococci numbers >140 <280 MPN/100mL	% of time Enterococci numbers > 280 MPN/100mL
		Suitable for recreational use ☺	OK for recreational use 😐	Unsuitable for recreational use ☹
Marfells Beach	**MB-1**	100	0	0
Whites Bay	**WB-1**	100	0	0
Ngakuta Bay	**NGK-1**	100	0	0
Te Mahia	**TEM-1**	100	0	0
Portage	**POR-1**	100	0	0
Elaine Bay	**ELB-001**	100	0	0
Wairau Diversion	**WDV-2**	95	0	5
Waikawa Bay	**WKB-1**	95	0	5
Oyster Bay	**PTU-002**	95	0	5

Hakahaka Bay	**PTU-001**	95	0	5
Tennyson Inlet	**TNY-001**	94	6	0
Okiwi Bay	**OKB-2**	94	0	6
Wairau Bar	**WRR-7**	90	0	10
Shelly Beach North	**PCT4A**	90	10	0
Bobs Bay	**PCT-3**	90	5	5
Picton Foreshore	**PCT-5**	86	0	14
Tirimoana	**TIR-5**	81	0	19
Anakiwia	**GRO-1**	81	10	10
Moenui	**MOE-1**	67	5	28
Momorangi Bay	**MOM-1**	62	14	24

Table 4: Coastal water bathing sites ranked in descending order according to the median enterococci count recorded during the 2007-08 bathing water season.

Site Name	Site ID	Median Enterococci count (MPN/100mL)
Anakiwia	**GRO-1**	5
Bobs Bay	**PCT-3**	5
Elaine Bay	**ELB-001**	5
Hakahaka Bay	**PTU-001**	5
Marfells Beach	**MB-1**	5
Ngakuta Bay	**NGK-1**	5
Okiwi Bay	**OKB-2**	5
Oyster Bay	**PTU-002**	5
Portage	**POR-1**	5
Te Mahia	**TEM-1**	5
Tennyson Inlet	**TNY-001**	5
Tirimoana	**TIR-5**	5
Waikawa Bay	**WKB-1**	5
Wairau Bar	**WRR-7**	5
Whites Bay	**WB-1**	5
Picton Foreshore	**PCT-5**	10
Shelly Beach North	**PCT4A**	10
Wairau Diversion	**WDV-2**	10
Moenui	**MOE-1**	30
Momorangi Bay	**MOM-1**	64

4.1 Rainfall Effects

The bacteria loading of streams and coastal waters are generally expected to increase during and after heavy rainfall. This is due to contaminants (including bacteria) being washed from land surfaces into waterways. The problem is exacerbated in urban and in intensive agricultural areas. Whilst measures can be put in place to ensure minimum contamination from various land-use practices some degree of bacterial contamination of waters will still occur after heavy rainfall due to the presence of wildlife. For this reason it is advised that swimming does not occur during and up to three days after heavy rainfall events. The corollary to this is that increased bacteria numbers in dry weather are a concern as they are often indicative of a localised source of pollution. High rainfall events do not always result in corresponding high bacteria counts due to factors such as the time of sampling in relation to the first flush event[2], change in tides etc.

Of the 38 exceedances of MfE's bathing water guidelines (>140) in 2007-08, 26 of them occurred after heavy rain. The remaining 12 are shown below in table 5. The results from Momorangi are discussed in more detail in section 5.1. Bobs Bay is a popular swimming beach in Picton and generally has very good water quality. Exceedances at Bobs Bay are not usually associated with rainfall, there are no houses or streams in the area so it is possible that illegal discharge of waste from boats has an impact on water quality at this site. The high bacteria count at Shelley Beach on the 24 December 2007 is likely to have been associated with the high bacteria counts at Bobs Bay on the same day. The exceedance at the Wairau Bar and Wairau Diversion are most likely as a result of heavy rain further up the catchment. Although there was no local rainfall, the water was a brown colour, clearly associated with high rainfall. During 2007/08 Moenui recorded its worst water quality since sampling began at the site in 2002. The exceedances were clearly associated with high rainfall but they are unusual in that this pattern was never recorded before. One possible explanation could be that all previous sampling occurred in dry weather, however this is unlikely. There was one exception to the rainfall related exceedances at Moenui and that was a result of >2000 on the 26 March 2008. No sites returned elevated enterococci numbers when resampled.

Table 5: Exceedance of MfE guidelines (action level in red, alert level in amber) when no rainfall was recorded.

Date	Site	Enterococci (MPN/100mL)
13 November 2007	Momorangi Bay	945
27 November 2007	Bobs Bay	207
24 December 2007	Shelley Beach	271
	Bobs Bay	831
7 January 2008	Picton Foreshore	738
	Waikawa Bay	1400

Date	Site	Enterococci (MPN/100mL)
14 January 2008	Wairau Bar	697
15 January 2008	Momorangi Bay	1400
20 February 2008	Momorangi Bay	150
25 February 2008	Wairau Bar	324
	Wairau Diversion	1400
26 March 2008	Moenui	2000

[2] The concentration of contaminants is usually highest at the beginning of a rainfall event, particularly after a period of dry weather.

4.2 Suitability for Recreation Grades (SFRGs) 2007-08

The Suitability for Recreation Grades have been calculated using the latest five years of microbiological data (Appendix 4) and the Sanitary Inspection Categories calculated in 2004 (MDC, 2004). Five of the twenty sites sampled in this years programme have no long term data and consequently only fifteen sites had an SFRG calculated. Only eight of these fifteen sites had complete datasets over the last five years for the calculation of the MAC grade. It was not deemed necessary to recalculate the SIC as there have been no major changes in land-use or point source discharges in any of the catchments. The results are shown in Table 6. Where there are apparent inconsistencies in the recorded microbiological data and the SIC, Bathewatch calculates the most conservative grade for the site and flags the grade as an 'Irreconcilable Follow-up Grade'.

Table 6: Suitability for Recreation Grades for Marlborough's Coastal Bathing water sites

Site	MAC Grade* Summer season 2007-08	MAC Grade** long term (5 years)	Trend	SFRG	Status of SFRG grade
Anakiwa	D	D	↔	Very Poor	Follow-up
Bobs Bay	C	B	↓	Very Good	Complete
Elaine Bay	A	n/a	-	-	-
Hakahaka Bay	C	n/a	-	-	-
Marfells Beach	A	B	↑	Very Good	Complete
Moenui	D	C	↓	Fair	Complete
Momorangi Bay	D	D	↔	Very Poor	Complete
Ngakuta Bay	B	B	↔	Very Poor	Follow-up
Okiwi Bay	B	n/a	-	-	-
Oyster Bay	B	n/a	-	-	-
Picton Foreshore	D	D	↔	Very Poor	Complete
Portage	A	D	↑	Very Poor	Complete
Shelly Beach North	B	C	↑	Fair	Follow-up
Te Mahia	A	B	↑	Very Good	Complete
Tennyson Inlet	B	n/a	-	-	-
Tirimoana	D	D	↔	Poor	Complete
Waikawa Bay	B	B	↔	Good	Complete
Wairau Bar	C	D	↑	Very Poor	Complete
Wairau Diversion	B	C	↑	Fair	Complete
Whites Bay	A	B	↑	Very Good	Complete

* Based on the 95th percentile for the 2007-08 Bathing Water season, calculated using Microsoft excel.

** Calculated using MfEs' Bathewatch programme, includes the latest 5 years of microbiological data

† 'Follow-up' grades, the Bathewatch model detected inconsistencies between the MAC and the SIC. A conservative default grade was subsequently calculated by Bathewatch. A complete sample set (>100 samples over the last 5 years) and/or a recalculation of the SIC is required to confirm the SFRG.

Figure 2 shows the percentage of sites that fall within each SFRG grade. Just under half of all sites are graded as poor or very poor. Table 6 shows that the majority of sites have improved water quality over the long term, with the exceptions of Moenui and Bobs Bay, which show a decline in water quality.

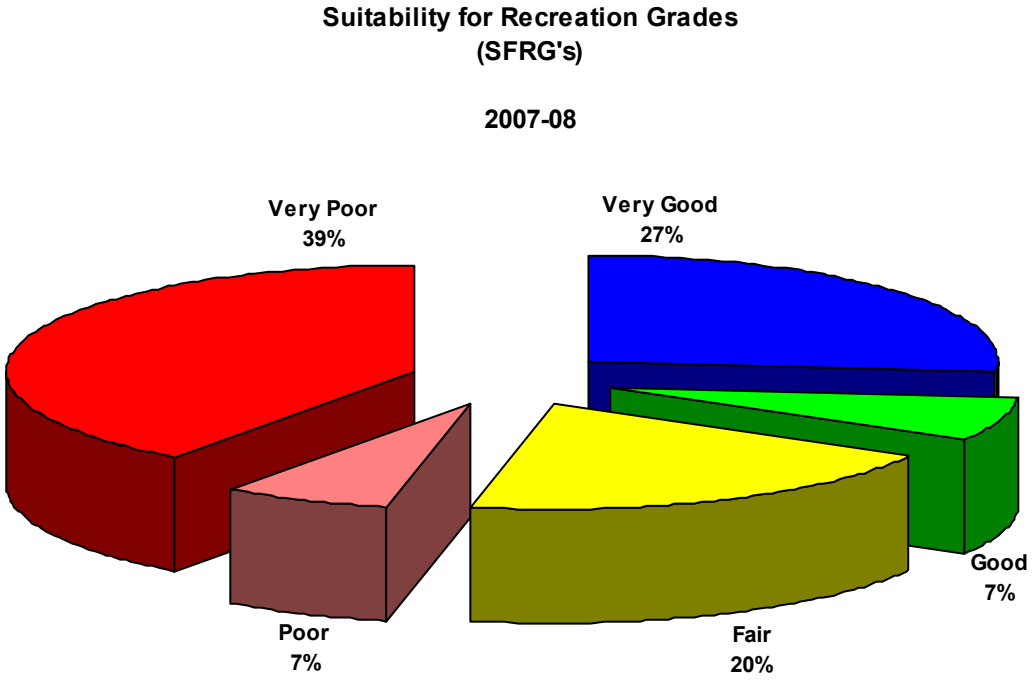


Figure 2: Pie-chart of SFRG's for the marine bathing water sites for the summer 2007-08.

5. Special investigations

A number of bays in the Queen Charlotte Sound have regularly reported poor water quality. Special investigations were set up for three of the most poorly performing bays. Each survey consisted of selecting a number of sites along the bay and a number of sites along the inflowing streams to the bay. Samples were analysed for bacterial contamination only i.e. Enterococci and/or *E. coli*. Sites were sampled at the same time as the regular weekly bathing water sample for the bay. The results of the sampling are shown in Appendix 5.

5.1 Momorangi Bay Investigation

Bathing water quality at Momorangi Bay during 2006-07 was the poorest of all the coastal bathing water sites (MDC, 2007). There has been a steady increase in enterococci numbers from 2002 to 2008 at Momorangi Bay (figure 3).

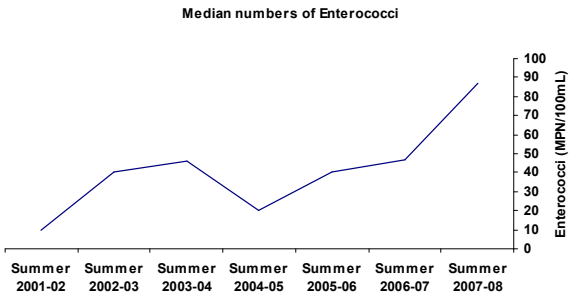


Figure 3: The median enterococci number for each bathing water season from 2002 to 2008.

Twelve sites (including the regular bathing water site at Momorangi Beach) were chosen to investigate the faecal contamination of the bay (figure 4).

Figure 4: Site locations for the Momorangi investigation.

Eight of the sites were located in the streams flowing into the bay and four were located in the bay. In addition microbial source identification was carried out for a selected number of samples (ESR, 2008). Sites MOS-8, MOS-009, MOS-004, MOS-005 and MOS-007 are all located upstream (or away) from the campground wastewater treatment works. Sites MOM-011, MOS-002 and MOS-006 are all located

downstream of the campground wastewater treatment works. The East Stream had higher bacteria numbers than the West Stream, although the flow in the East Stream was considerably lower than that of the West Stream. An increase in enterococci numbers in either or both East and West Streams resulted in high enterococci numbers in the bay (figure 5).

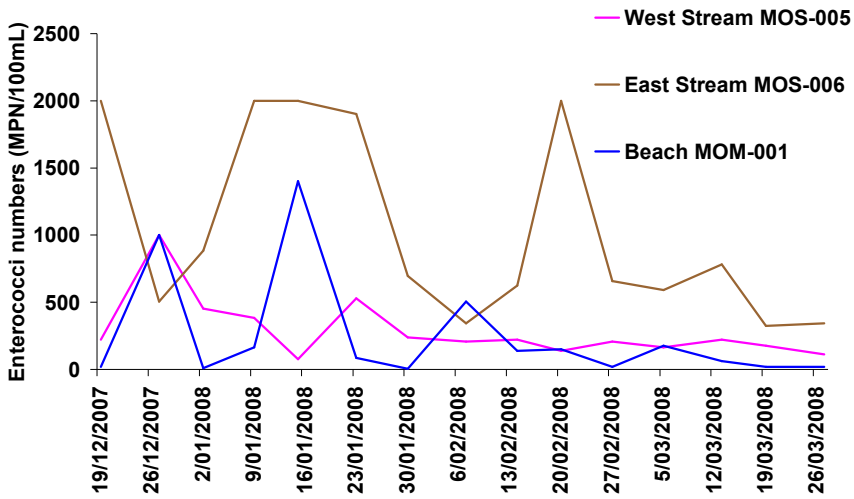


Figure 5: Enterococci numbers recorded at Momorangi beach in comparison with enterococci numbers in each of the inflowing streams.

For the East Stream the enterococci numbers at the campground sample site and at the road sample site correlate well with each other with increases and decreases in numbers being reflected in both sites (figure 6a). Enterococci numbers at the outlet do not follow the same pattern and have consistently higher numbers than the upstream sites (figure 6b). This would imply that there is an additional enterococci source between the road and the outlet. A similar observation was made for the West Stream.

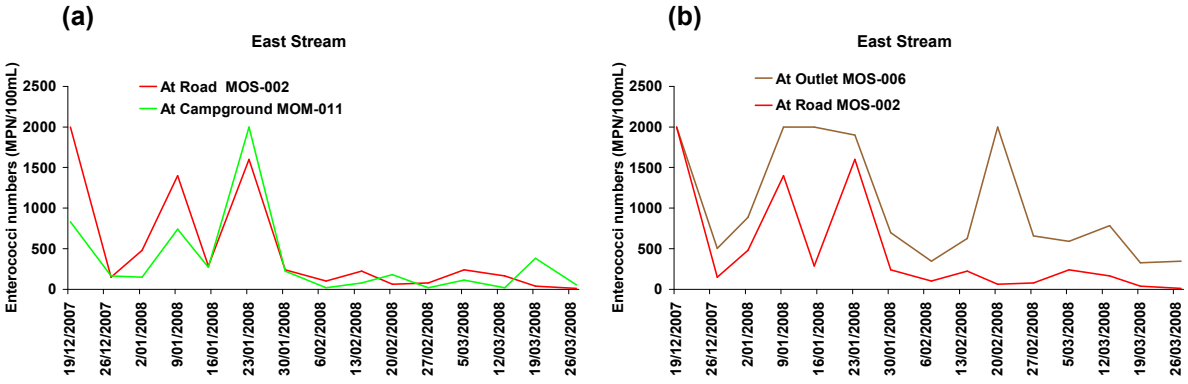


Figure 6: Comparison of enterococci numbers between the lower sites on East Stream.

Sampling showed that faecal contamination was not confined to the bathing beach at Momorangi. High bacteria numbers were recorded at all of the coastal monitoring sites, however the greatest number of exceedances were recorded at Momorangi bathing beach. This is shown on figure 7 where the median enterococci number for each site is represented by a red marker. The western sites (MOM-014 and

MOM-013) had the lowest number with the eastern site MOM-015 being only marginally higher. The beach site (MOM-001) recorded significantly higher enterococci numbers. This would suggest that the majority of faecal contamination is being sourced from the two inflowing streams to the bay but localised contamination (e.g. from boats) may also be occurring.

Figure 7: Median enterococci numbers recorded for the coastal sites.

Sampling showed that all but one of the elevated enterococci samples was associated with high tide (figure 8).

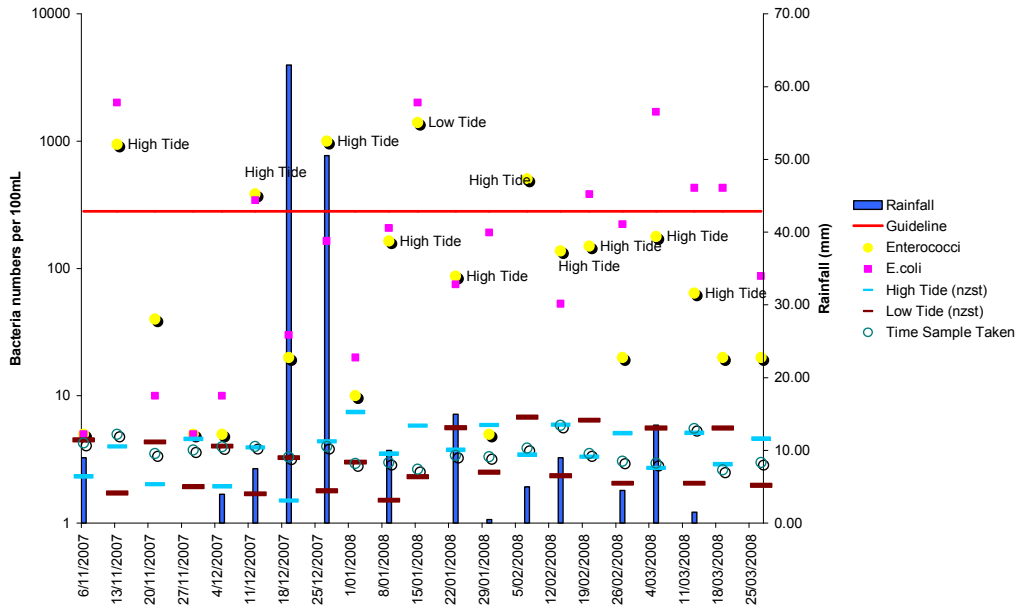


Figure 8: Sampling results for Momorangi Beach showing the tide times in relation to the enterococci numbers recorded during sampling.

A similar observation was observed during the 2006-07 bathing water season (MDC, 2007). A tidal survey was carried out to determine the validity of these observations. Samples were taken at hourly intervals from the beach site (MOM-001), West Stream (MOS-005) and East Stream (MOS-006) starting at low tide

at 6.30am and continuing until 2.40pm, 1 hour after high tide on the 15 January 2008. The results are shown in Appendix 6. Only one sample had a high bacteria count and that was taken 1 hour after low tide on the incoming tide at 8.40am (7.40am NZST), thus invalidating the observation of high bacteria numbers occurring at high tide.

It is concluded that the majority of the bacterial contamination at Momorangi is occurring between the road and the beach. A full engineering assessment of the pipe-work and pump-stations was carried out and all were found to be in good working order, furthermore dye tracing confirmed that there were no leaks in the system; these assessments were limited to areas north of the main road.

The likely sources of faecal contamination in Momorangi Bay are the two inflowing streams. What is less clear is the source of contamination in these streams. Investigations showed that contamination from the campground wastewater system is unlikely or at most minimal, this is further supported by the results from the faecal source investigation which identified birds and possums as likely major contributors with human inputs likely to be minor (ESR, 2008). Large numbers of ducks are observed at the beach and particularly in the lower reaches of the two streams.

Despite the in-depth investigation into faecal contamination in the bay no definitive conclusions on the source of contamination have been reached. It is likely that sources of faecal contamination in the bay are complex and not attributed to any one source.

5.2 Ngakuta Bay Investigation

Previous investigations into the water quality in Ngakuta Bay have suggested that water quality is generally poor and the perception of water quality in the bay is that it is one of the poorest performing bathing water sites in Marlborough. However bathing water results for 2006-07 showed that Ngakuta Bay was one of the best performing sites in terms of water quality. The longterm (5 year) Microbiological Assessment Grade is a B, implying good to very good water quality. The 2007-08 (1 year) Microbiological Assessment Grade is also a B suggesting that water quality in Ngakuta Bay has been reasonably good for at least 5 years.

Ten sites (including the regular bathing water site) were sampled on a weekly basis throughout the summer. All samples were taken within the space of an hour to allow for comparisons of results. Five coastal samples and five stream samples were taken (figure x). Enterococci and *E. coli* were analysed for at the coastal sites, whilst only *E. coli* were analysed for at the stream sites.

Figure 9: Site locations for the Ngakuta Bay investigation.

The median bacteria results for the stream sites and the coastal sites are shown in figure 10. The poorest coastal water quality was found at NGK-010, with NGK-011 having the second poorest coastal water quality. Water quality at the remaining coastal sites was found to be good or very good. It is likely that water quality at sites NGK-010 and NGK-011 is being affected by water quality in the inflowing streams. Sites NGS-004 and NGS-005 had the poorest water quality of the stream sites, however they also had the lowest flow of the stream sites thus it is likely that NGS-002, NGS-003, NGS-004 and NGS-005 all contribute to poor water quality in the immediate coastal area. Large bird populations in the tidal flats area between NGK-010 and NGK-011 will also contribute to high bacteria numbers in the coastal area.

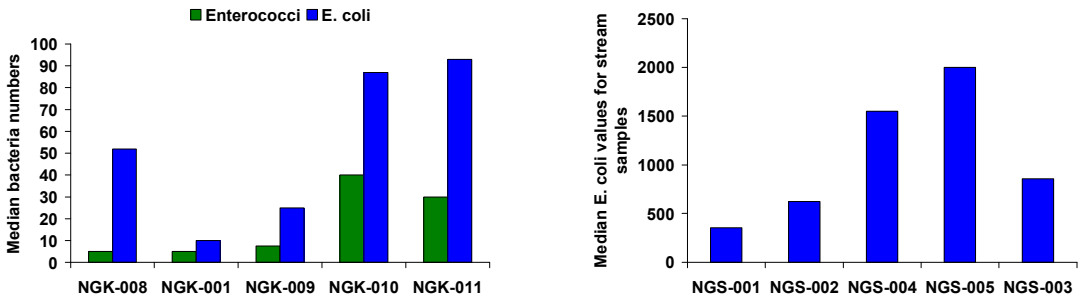


Figure 10: Median bacteria numbers for the coastal and stream sites at Ngakuta Bay.

The bathing water site at Ngakuta had no exceedance of the bathing water guideline for 2007-08. Due to its location it is unlikely that the bathing water site at Ngakuta is affected (or at most is minimally affected) by the bacterial contamination found in the streams.

5.3 Grove Arm Investigation

There are two bathing water sites situated in Grove Arm, located at Tirimoana and Anakiwa respectively. For years the residents of Tirimoana have complained about a noxious sewage like odour emanating from the estuary. Previous investigations could not ascertain the cause of the odour despite repeated sampling of inflowing streams to the bay, however several direct discharges from septic tanks to the bay were found and closed off but this did little to alleviate the odour. A site walkover in 2006-07 suggested that anoxic sediments emitting hydrogen sulphide and methane were likely to be responsible for the odour.

Both Tirimoana and Anakiwa record exceedances of the bathing water standard, particularly following heavy rainfall. Both have a long term (5 year) Microbiological Assessment Grade of D i.e. very poor bathing water quality. Seven sites were sampled as part of the investigation into bacterial contamination of the bay. Four were located along the coast and three were located in the inflowing streams to the bay (figure 11). The objective of the investigation was to ascertain the extent to which the localised and diffuse inputs were contributing to bacteria numbers in the bay.

Figure 11: Site locations for the Grove Arm investigation.

Exceedances of the bathing water guideline occur during rainfall but they are not exclusively associated with heavy rainfall. It is doubtful that the exceedance on the 22 January 2008 could be attributed to 4mm of rainfall, but it is possible that there was localised heavier rain in Grove Arm that was not picked up by the rainfall recording site located in Waikawa. Exceedance of the guideline generally occurs concurrently at the two bathing water sites (figure 12) and both sites are found to be highly correlated. Tirimoana generally recorded the highest bacteria numbers.

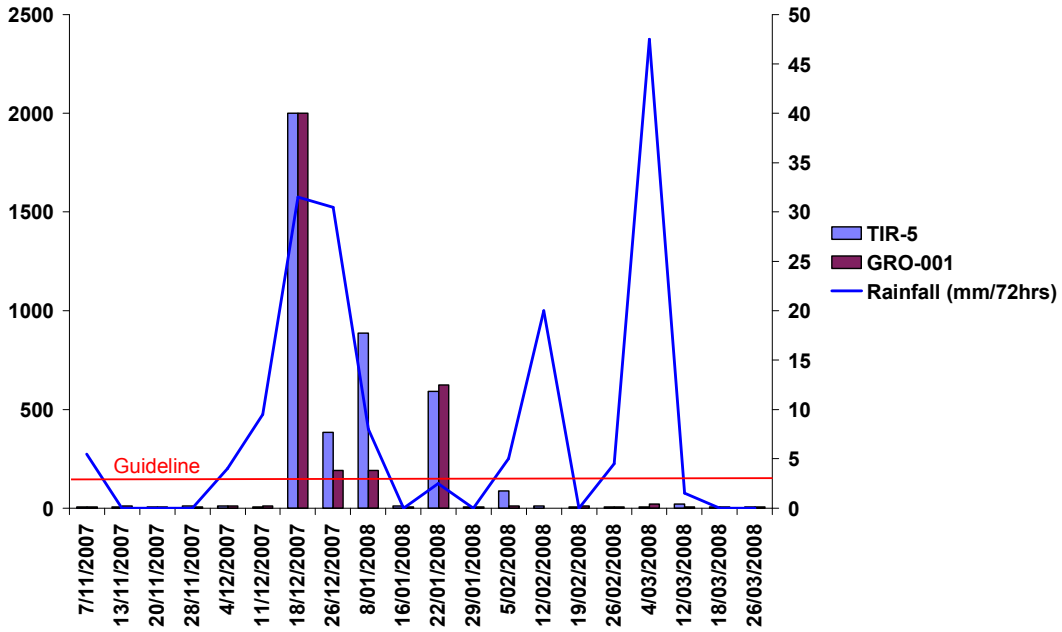


Figure 12: Enterococci numbers recorded at the two bathing water sites in Grove Arm.

Bathing water exceedances at Anakiwa were always associated with elevated bacteria numbers in both the upstream and downstream sites of Cobham Stream. Furthermore bacteria levels at the bathing water site at Anakiwa were more highly correlated with bacteria numbers at the upstream Cobham Stream site than at the downstream Cobham Stream site. It is likely that bacterial contamination which results in the exceedance of the bathing water guideline at Anakiwa is more strongly attributable to diffuse sources of pollution associated with landuse in the area rather than point source pollution from septic tanks or wastewater treatment systems.

There was no upstream site for which to compare the downstream Tirimoana Stream site (TIR-27) with; however similar bacteria numbers were recorded for the Tirimoana Stream as for Cobham Stream (GRO-018) (figure 13). It is possible that bacterial contamination from Duncan Stream in times of heavy rainfall contributes to the bacteria loading at Tirimoana.

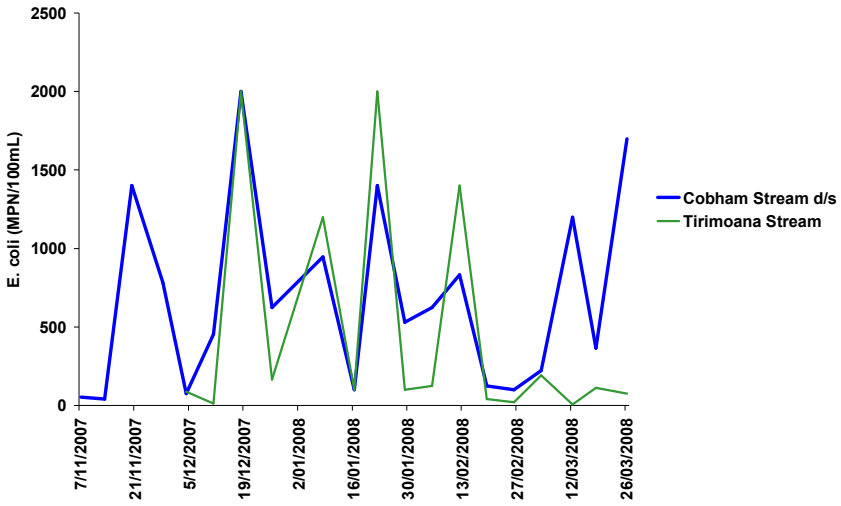


Figure 13: *E. coli* numbers recorded at Cobham Stream (GRO-18) and Tirimoana Stream (TIR-27).

Bacterial contamination was almost exclusively confined to the Western side of Grove Arm (figure 14). The coastal sites on the western side all showed similar bacterial contamination, however there was a gradual decrease in numbers from Tirimoana to Anakiwa.

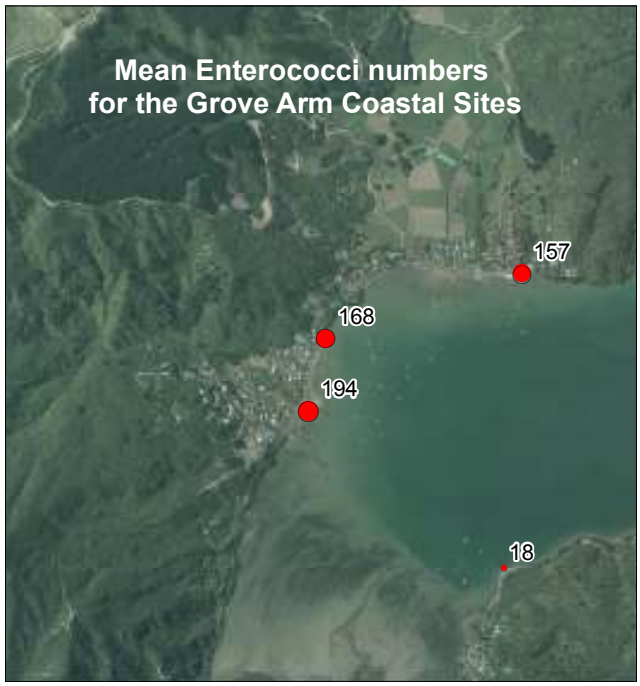


Figure 14: Comparison of average enterococci numbers for the coastal sites surveyed.

It is highly unlikely that the noxious odour detected at Tirimoana is a result of a direct sewage discharge. Concurrent sampling was undertaken to characterise the sediments in the estuary at Tirimoana and to assess the nutrient loadings from the two main streams (Duncan Stream and Ada Creek) entering Grove Arm. The results confirm that the noxious odour is a result of anoxic sediments and not a direct sewage discharge (MDC, 2008).

6. RECOMMENDATIONS FOR SUMMER SAMPLING 2008-09

1. Retain the sampling sites at Oyster Bay and Hakahaka Bay in Port Underwood.

2. Exclude the sites at Okiwi Bay, Tennyson Inlet and Elaine Bay due to the remoteness of the sites and the low risk associated with them.

3. Ensure all sites are sampled on a weekly basis throughout the summer period. Regular sampling is required in order to obtain complete MAC grades. MAC grades and SFRG's are regularly reported to MfE for inclusion into nationwide reporting.

4. Due to the number of 'irreconcilable follow-up' grades calculated it is recommended that the Sanitary Inspection Categories by re-assessed for all sites included in the 2008-09 summer sampling programme.

5. Look at trends over time in bathing water quality for each of the sites.

6. Microbial Source Tracking should be used where faecal contamination becomes an issue in bathing water areas.

7. REFERENCES`

MfE (2003) *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas.* Ministry of the Environment. http://www.mfe.govt.nz/publications/water/microbiological-quality-jun03/microbiological-quality-jun03.pdf

MDC (2004) *The Microbiological Quality of Marlborough Coastal Bathing Beaches 2003-2004*. November 2004. Marlborough District Council.

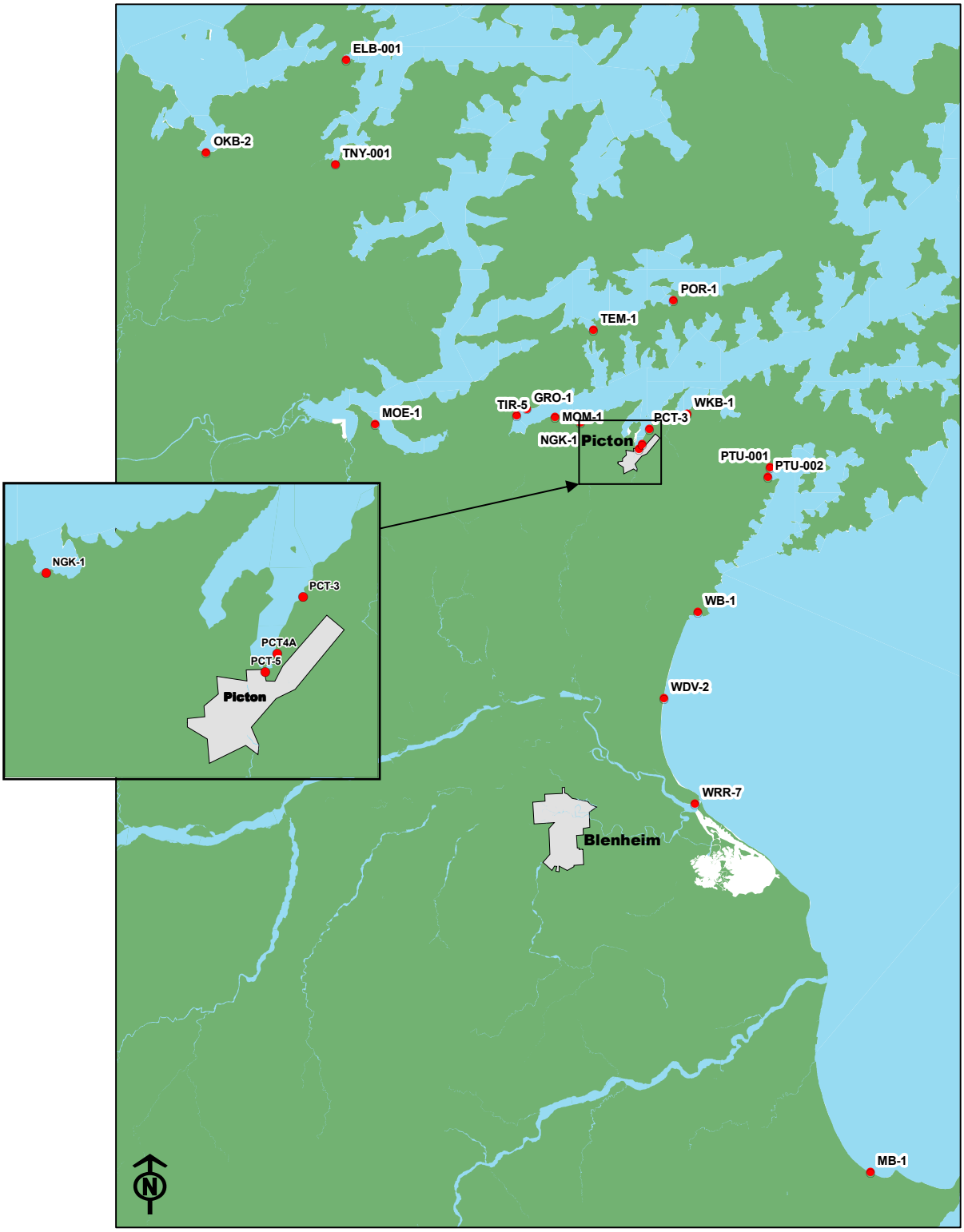
MDC (2007) *Marlborough's Coastal Bathing Water Quality, 2006-07*. May 2007. Marlborough District Council.

MDC (2008) Noxious odour at Tirimoana Terrace.

ESR (2008) *Bacterial contamination of seawater and shellfish*. Envirolink MLDC28.

APPENDIX 1

Coastal Bathing Water Site Locations



APPENDIX 2

Results from the Bathing Water (Coastal Waters) sampling from November 2007 to March 2008 inclusive

Date*	Marfells Beach	Wairau Bar	Wairau Diversion	Whites Bay	Picton Foreshore	Shelly Beach North	Bobs Bay	Waikawa Bay	Ngakuta Bay	Momorangi Bay	Tirimoana	Anakiwia	Te Mahia	Portage	Moenui	Oyster Bay	Hakahaka Bay	Elaine Bay	Tennyson Inlet	Okiwi Bay	Increased Risk	Significant Risk
	MB-1	WRR-7	WDV-2	WB-1	PCT-5	PCT4A	PCT-3	WKB-1	NGK-1	MOM-1	TIR-5	GRO-1	TEM-1	POR-1	MOE-1	PTU-002	PTU-001	ELB-001	TNY-001	OKB-2		
Week 1	5	5	10	5	10	5	5	5	5	5	5	5	5	10	5	5	5	NS	NS	NS	140	280
Week 2	5	5	40	5	5	10	5	5	5	945	5	10	20	5	30	10	5	5	5	5	140	280
Week 3	5	5	5	5	20	5	5	5	5	40	5	5	5	5	5	5	5	5	5	5	140	280
Week 4	5	5	5	5	10	64	207	5	5	5	10	5	5	5	10	5	5	5	10	5	140	280
Week 5	5	10	5	5	5	5	5	5	5	5	10	10	5	5	10	5	5	5	5	5	140	280
Week 6	5	5	5	30	531	150	5	30	30	384	5	10	5	5	324	5	5	5	5	5	140	280
Week 7	5	5	10	20	30	10	10	5	10	20	2000	2000	10	5	2000	531	2000	30	30	5	140	280
Week 8	10	10	5	5	20	271	831	20	30	1000	384	192	NS	NS	192	NS	NS	NS	NS	NS	140	280
Week 9	5	5	5	30	30	5	30	20	5	10	5	5	NS	NS	5	NS	NS	NS	NS	NS	140	280
Week 10	10	30	5	5	738	10	5	1400	87	164	885	192	5	5	1700	20	10	53	150	324	140	280
Week 11	5	697	5	10	124	10	5	10	10	1400	10	5	40	5	10	5	5	5	5	20	140	280
Week 12	5	5	10	10	5	5	5	10	10	87	591	624	5	5	324	5	10	5	5	10	140	280
Week 13	10	30	64	20	10	5	10	5	5	5	5	5	5	5	5	5	5	5	5	5	140	280
Week 14	5	40	53	5	10	5	5	5	10	504	87	10	5	5	20	5	5	5	5	5	140	280
Week 15	5	5	10	10	945	10	30	5	64	137	10	5	5	10	782	5	5	5	10	5	140	280
Week 16	10	5	20	5	5	10	20	5	5	150	5	10	5	5	40	5	10	5	5	5	140	280
Week 17	10	324	1400	5	30	30	53	5	5	20	5	5	5	10	5	5	5	5	5	5	140	280
Week 18	5	64	124	124	10	20	53	87	5	178	5	20	5	5	64	5	5	20	5	5	140	280
Week 19	64	5	87	10	5	53	5	20	5	64	20	5	5	10	5	10	40	10	5	5	140	280
Week 20	10	5	5	5	40	5	5	53	10	20	5	5	10	5	40	5	5	5	20	5	140	280
Week 21	5	5	5	5	5	10	5	10	5	20	5	5	5	5	2000	5	5	5	5	5	140	280

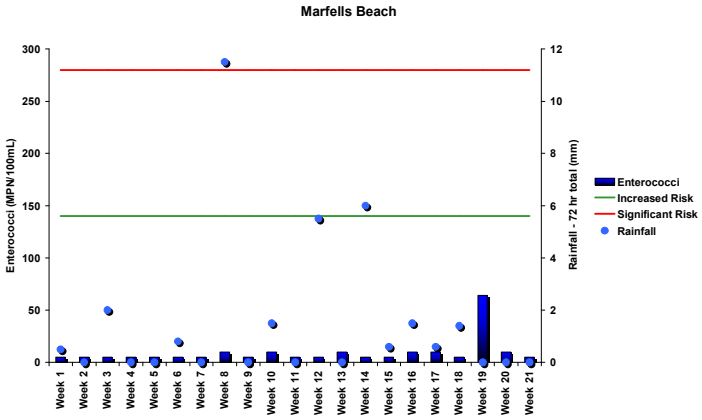
NS — No sample taken due to time constraints

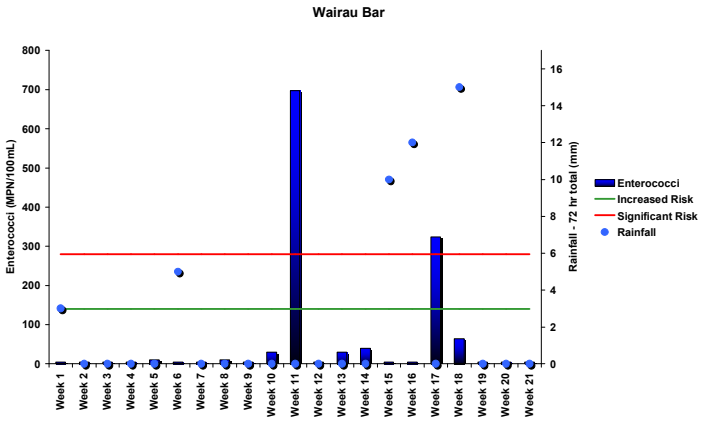
Less than values are halved i.e. <10 MPN/100mL becomes 5. No bacteria detected in the water sample

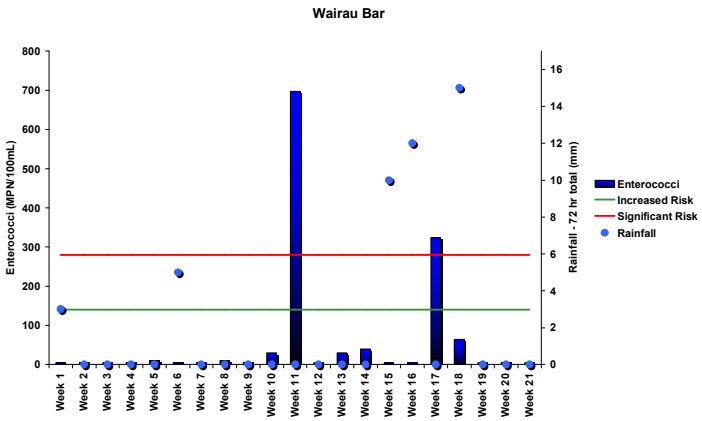
* Week 1 begins on the 5th November, with samples taken throughout that week, week 2 begins on the 12th November etc.

APPENDIX 3

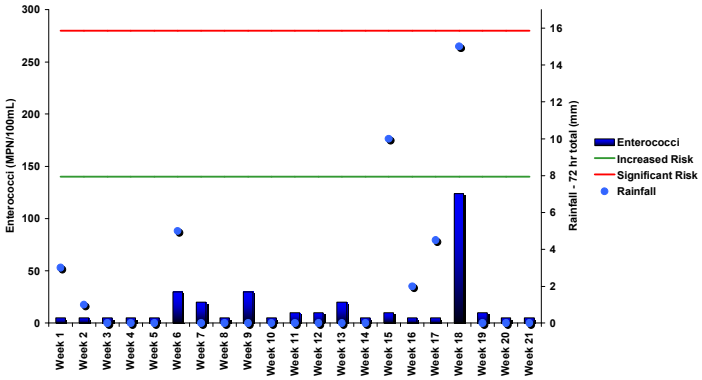
Graphed results for each Coastal Bathing Water site for the Summer 2007-08 period in relation to MfE's bathing water standards (action level and alert levels). Follow-up samples are not graphed as the SFRG grade calculations, as defined by MfE, do not include follow-up samples. A follow-up sample is taken when a routine sample exceeds the MfE guideline of 280 Enterococci/100mL.



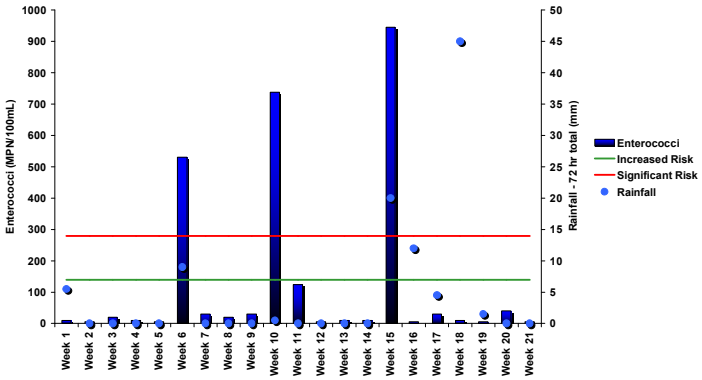




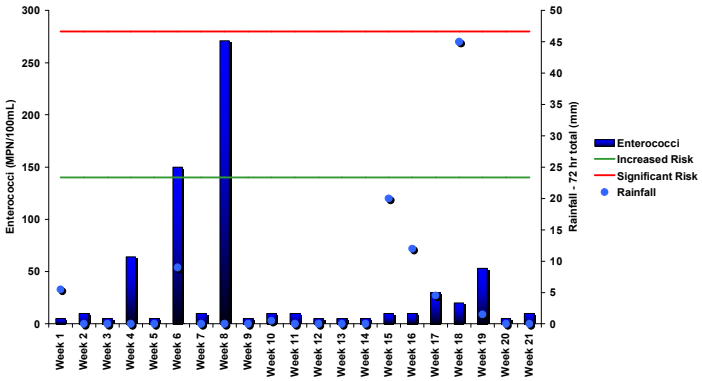
Whites Bay



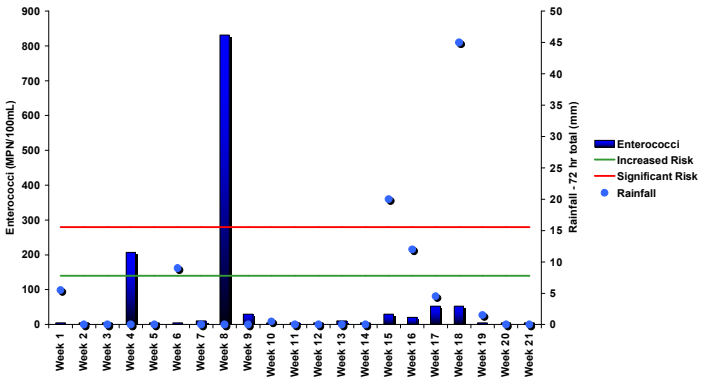
Picton Foreshore



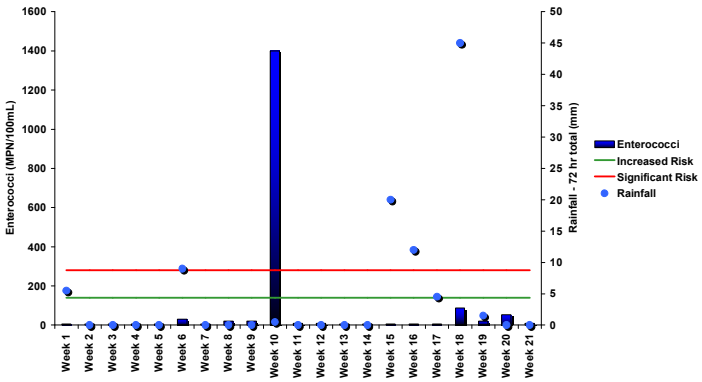
Shelly Beach



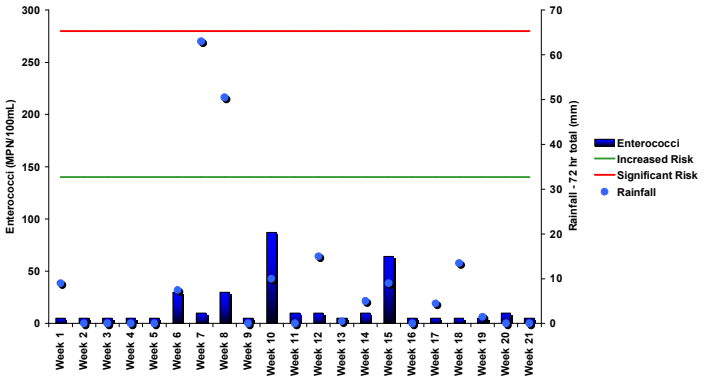
Bobs Bay



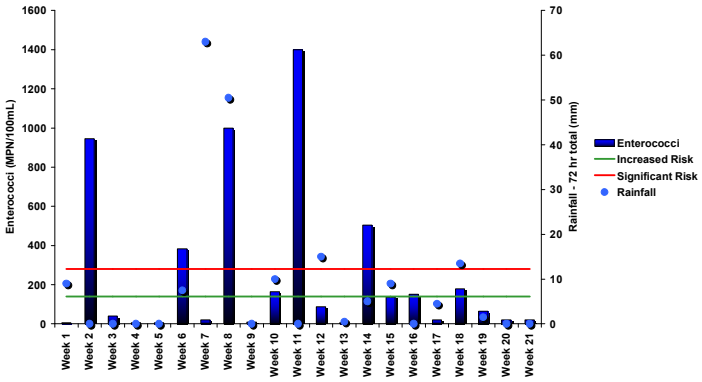
Waikawa Bay



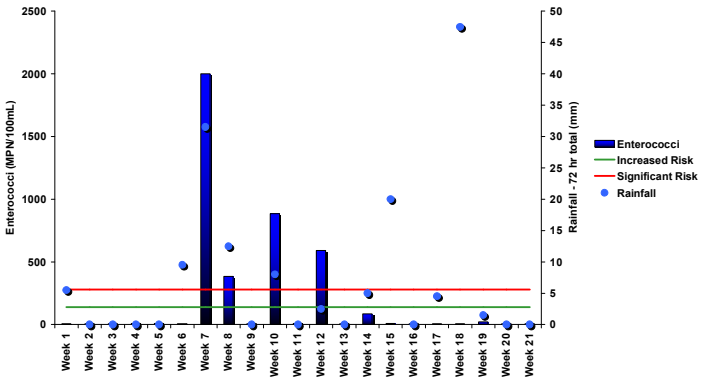
Ngakuta Bay



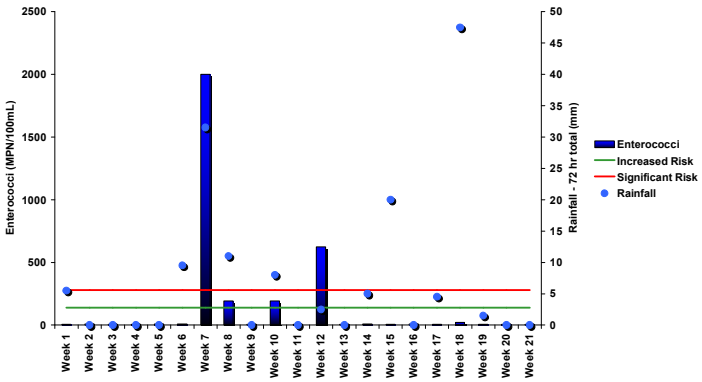
Momorangi Bay



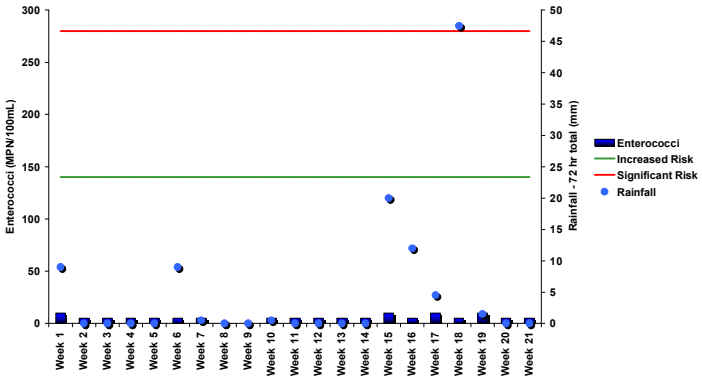
Tirimoana



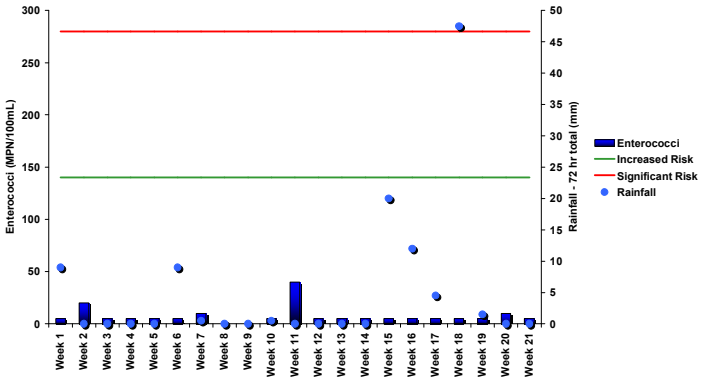
Anakiwa



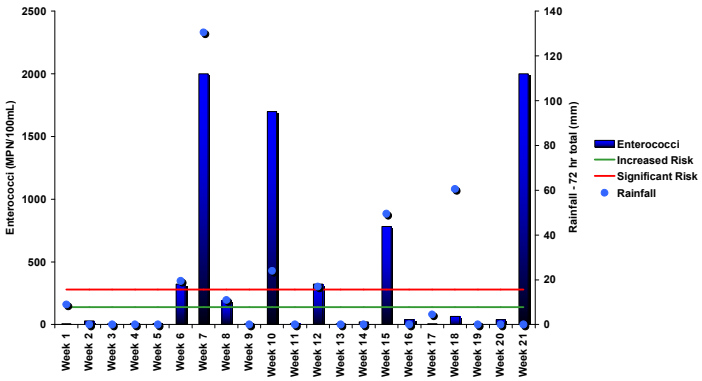
Portage



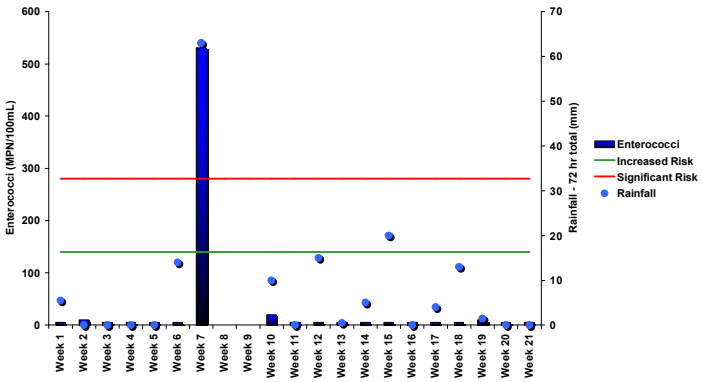
Te Mahia



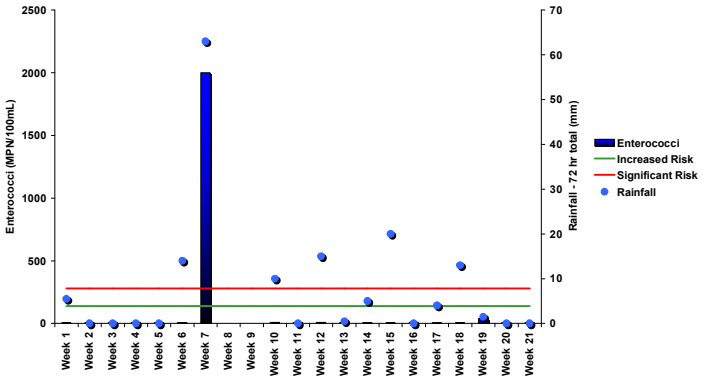
Moenui



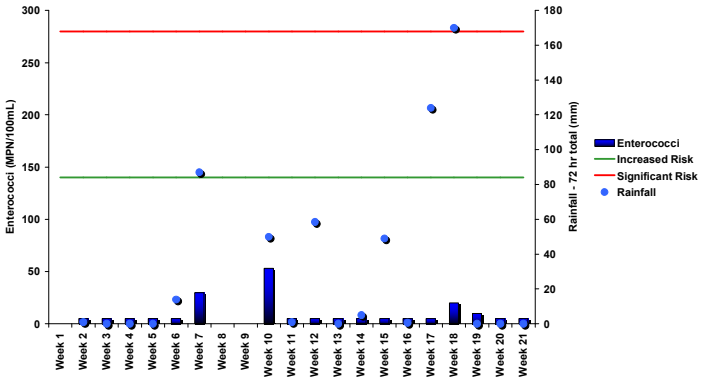
Oyster Bay



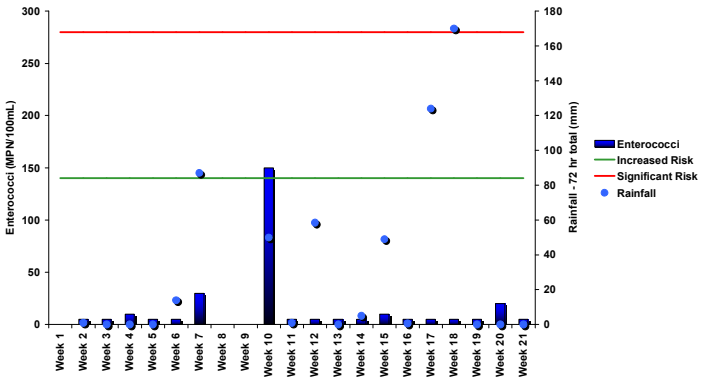
Hakahaka Bay

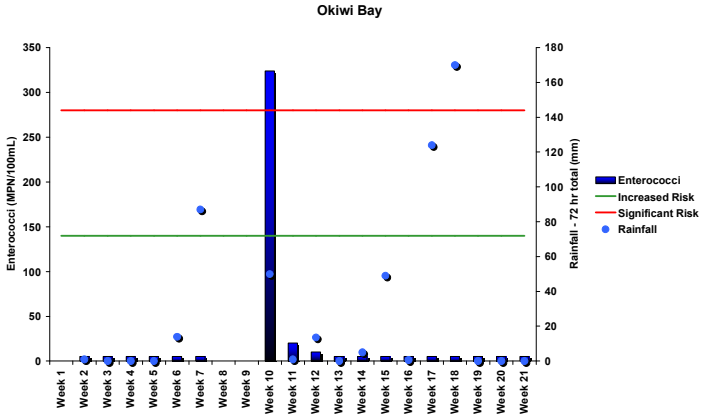


Elaine Bay



Tennyson Inlet




Okiwi Bay
Enterococci (MPN/100mL)
Rainfall - 72 hr total (mm)
350
300
250
200
150
100
50
0
180
160
140
120
100
80
60
40
20
0
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
Week 12
Week 13
Week 14
Week 15
Week 16
Week 17
Week 18
Week 19
Week 20
Week 21
Enterococci
Increased Risk
Significant Risk
Rainfall

APPENDIX 4

2007-08 Microbiological Assessment Category Results

Anakiwa

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	23	10	3	2	91
Year	2006	20	10	0	1	95
Year	2005	21	10	0	3	85
Year	2004	20	25	2	2	90
Year	2003	20	10	0	2	90
Total	0	104	10	5	10	90

Assessment Results

Microbiological Assessment Grade - D

Hazen Percentile Result - 1350
Data Set Extent - Complete Data Set (5 years with at least 100 samples)

Bobs Bay

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	20	10	1	1	95
Year	2006	16	10	0	0	100
Year	2005	14	10	0	0	100
Year	2004	18	10	0	0	100
Year	2003	15	10	0	1	93
Total	0	83	10	1	2	97

Assessment Results

Microbiological Assessment Grade - B

Hazen Percentile Result - 107.75
Data Set Extent - Interim Data Set (< 5 years or < 100 samples used)

Marfells Beach

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	20	10	1	1	95
Year	2006	16	10	0	0	100
Year	2005	14	10	0	0	100
Year	2004	18	10	0	0	100
Year	2003	15	10	0	1	93
Total	0	83	10	1	2	97

Assessment Results

Microbiological Assessment Grade - B

Hazen Percentile Result - 107.75
Data Set Extent - Interim Data Set (< 5 years or < 100 samples used)

Moenui

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	24	40	3	6	75
Year	2006	20	10	0	0	100
Year	2005	21	10	1	0	100
Year	2004	19	10	1	0	100
Year	2003	19	10	1	0	100
Total	0	103	10	6	6	94

Assessment Results

Microbiological Assessment Grade - C

Hazen Percentile Result - 324
Data Set Extent - Complete Data Set (5 years with at least 100 samples)

Momorangi

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	36	20	4	6	83
Year	2006	26	40	1	5	80
Year	2005	21	20	0	2	90
Year	2004	20	46.5	2	2	90
Year	2003	19	40	1	3	84
Total	0	122	30	8	18	85

Assessment Results

Microbiological Assessment Grade - D

Hazen Percentile Result - 967
Data Set Extent - Complete Data Set (5 years with at least 100 samples)

Ngakuta

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	21	10	0	0	100
Year	2006	20	10	0	1	95
Year	2005	21	10	1	0	100
Year	2004	20	10	0	0	100

Year	2003	21	10	0	1	95
Total	0	103	10	1	2	98

Assessment Results

Microbiological Assessment Grade - B

Hazen Percentile Result - 124
Data Set Extent - Complete Data Set (5 years with at least 100 samples)

Picton Foreshore

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	23	10	0	3	86
Year	2006	21	10	0	1	95
Year	2005	34	40	1	7	79
Year	2004	34	46.5	3	6	82
Year	2003	37	53	6	7	81
Total	0	149	20	10	24	83

Assessment Results

Microbiological Assessment Grade - D

Hazen Percentile Result - 1305
Data Set Extent - Complete Data Set (5 years with at least 100 samples)

Portage

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	19	10	0	0	100
Year	2006	18	10	1	1	94
Year	2005	19	10	1	0	100
Year	2004	20	10	0	2	90
Year	2003	16	10	0	2	87
Total	0	92	10	2	5	94

Assessment Results

Microbiological Assessment Grade - D

Hazen Percentile Result - 554.1
Data Set Extent - Interim Data Set (< 5 years or < 100 samples used)

Shelley Beach

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	23	10	2	0	100
Year	2006	21	10	1	1	95

Year	2005	21	10	2	1	95
Year	2004	21	10	0	1	95
Year	2003	22	20	3	0	100
Total	0	108	10	8	3	97

Assessment Results

Microbiological Assessment Grade - C

Hazen Percentile Result - 255.7
Data Set Extent - Complete Data Set (5 years with at least 100 samples)

Te Mahia

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	18	10	0	0	100
Year	2006	17	10	0	0	100
Year	2005	21	10	0	2	90
Year	2004	19	10	0	1	94
Year	2003	12	10	0	0	100
Total	0	87	10	0	3	96

Assessment Results

Microbiological Assessment Grade - B

Hazen Percentile Result - 102.75
Data Set Extent - Interim Data Set (< 5 years or < 100 samples used)

Tirimoana

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	21	10	0	4	80
Year	2006	20	10	0	1	95
Year	2005	21	10	0	1	95
Year	2004	21	10	0	1	95
Year	2003	20	10	0	2	90
Total	0	103	10	0	9	91

Assessment Results

Microbiological Assessment Grade - D

Hazen Percentile Result - 693.9
Data Set Extent - Complete Data Set (5 years with at least 100 samples)

Waikawa Bay

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280

Year	2007	21	10	0	1	95
Year	2006	20	10	0	0	100
Year	2005	21	10	0	1	95
Year	2004	19	10	1	0	100
Year	2003	19	10	1	0	100
Total	0	100	10	2	2	98

Assessment Results

Microbiological Assessment Grade - B

Hazen Percentile Result - 124
Data Set Extent - Complete Data Set (5 years with at least 100 samples)

Wairau Bar

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	22	10	0	2	90
Year	2006	20	10	0	1	95
Year	2005	16	10	0	1	93
Year	2004	20	10	0	4	80
Year	2003	19	10	1	1	94
Total	0	97	10	1	9	90

Assessment Results

Microbiological Assessment Grade - D

Hazen Percentile Result - 533
Data Set Extent - Interim Data Set (< 5 years or < 100 samples used)

Wairau Diversion

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	20	10	0	1	95
Year	2006	18	10	0	0	100
Year	2005	18	10	1	0	100
Year	2004	19	10	2	0	100
Year	2003	19	64	3	4	78
Total	0	94	10	6	5	94

Assessment Results

Microbiological Assessment Grade - C

Hazen Percentile Result - 278
Data Set Extent - Interim Data Set (< 5 years or < 100 samples used)

Whites Bay

******** Microbiological Assessment Category ********
Annual exceedance information (for water year 01 November to 31 October)

	sample season	sample size	median	exceed 140 to 280	exceed >280	%days <280
Year	2007	20	10	0	0	100
Year	2006	20	10	0	0	100
Year	2005	18	10	0	0	100
Year	2004	20	10	0	1	95
Year	2003	6	10	0	0	100
Total	0	84	10	0	1	98

Assessment Results

Microbiological Assessment Grade - B

Hazen Percentile Result - 90.6
Data Set Extent - Interim Data Set (< 5 years or < 100 samples used)

APPENDIX 5: Coastal investigations results.

All times in NZST. The alert and action levels for the bathing water guidelines are highlighted in green and red respectively, for the coastal sites only.

MOMORANGI BAY

Rainfall (mm/72hrs)	High Tide	Low Tide	Date	Time	Site	Enterococci	*E. coli*
9.00	6.42	11.42	6/11/2007	11.00	MOM-001	5	5
9.00	6.42	11.42	6/11/2007	10.50	MOM-013	5	5
9.00	6.42	11.42	6/11/2007	12.40	MOM-014	5	5
9.00	6.42	11.42	6/11/2007	11.10	MOM-015	5	5
9.00	6.42	11.42	6/11/2007	11.55	MOS-005		111
9.00	6.42	11.42	6/11/2007	11.35	MOS-006		178
9.00	6.42	11.42	6/11/2007	12.00	MOS-004		137
9.00	6.42	11.42	6/11/2007	11.45	MOS-002		111
9.00	6.42	11.42	6/11/2007	12.15	MOS-008		10
9.00	6.42	11.42	6/11/2007	12.30	MOS-009		5
9.00	6.42	11.42	6/11/2007	11.20	DIS-023		20
0	10.52	4.10	13/11/2007	12.20	MOM-001	945	2000
8.50	11.23	4.40	14/11/2007	11.00	MOM-014	53	87
8.50	11.23	4.40	14/11/2007	11.15	MOM-013	64	99
8.50	11.23	4.40	14/11/2007	12.00	MOM-015	1700	1400
8.50	11.23	4.40	14/11/2007	11.35	MOS-005		831
8.50	11.23	4.40	14/11/2007	11.55	MOS-006		2000
8.50	11.23	4.40	14/11/2007	11.30	MOS-004		40
8.50	11.23	4.40	14/11/2007	12.15	MOS-002		531
8.50	11.23	4.40	14/11/2007	12.35	MOS-008		87
8.50	11.23	4.40	14/11/2007	12.50	MOS-009		5
0	5.32	11.15	21/11/2007	9.30	MOM-014	10	10
0	5.32	11.15	21/11/2007	9.45	MOM-013	5	5
0	5.32	11.15	21/11/2007	9.55	MOM-001	40	10
0	5.32	11.15	21/11/2007	10.15	MOM-015	10	10
0	5.32	11.15	21/11/2007	11.00	MOS-005		624
0	5.32	11.15	21/11/2007	10.35	MOS-006		1700
0	5.32	11.15	21/11/2007	10.55	MOS-004		111
0	5.32	11.15	21/11/2007	10.45	MOS-002		1110
0	5.32	11.15	21/11/2007	10.25	DIS-023		222
0	5.32	11.15	21/11/2007	11.10	MOS-008		10
0	5.32	11.15	21/11/2007	11.25	MOS-009		5
0	5.32	11.15	21/11/2007	11.40	MOS-007		5
0	11.58	5.01	29/11/2007	9.45	MOM-014	5	5
0	11.58	5.01	29/11/2007	9.55	MOM-013	5	5
0	11.58	5.01	29/11/2007	10.05	MOM-001	5	5
0	11.58	5.01	29/11/2007	10.15	MOM-015	20	20
0	11.58	5.01	29/11/2007	10.45	MOS-002		137
0	11.58	5.01	29/11/2007	11.00	MOS-004		53
0	11.58	5.01	29/11/2007	12.00	MOS-005		2000
0	11.58	5.01	29/11/2007	10.30	MOS-006		1100
0	11.58	5.01	29/11/2007	11.40	MOS-007		10
0	11.58	5.01	29/11/2007	11.15	MOS-008		40
0	11.58	5.01	29/11/2007	11.25	MOS-009		5
4.00	5.04	10.57	5/12/2007	10.30	MOM-014	5	5
4.00	5.04	10.57	5/12/2007	10.40	MOM-013	10	10
4.00	5.04	10.57	5/12/2007	10.50	MOM-001	5	10

4.00	5.04	10.57	5/12/2007	11.05	MOM-015	5	5
4.00	5.04	10.57	5/12/2007	11.50	MOS-005		2000
4.00	5.04	10.57	5/12/2007	11.15	MOS-006		2000
4.00	5.04	10.57	5/12/2007	11.40	MOS-004		238
4.00	5.04	10.57	5/12/2007	11.25	MOS-002		2000
4.00	5.04	10.57	5/12/2007	12.00	MOS-008		150
4.00	5.04	10.57	5/12/2007	12.10	MOS-009		5
4.00	5.04	10.57	5/12/2007	12.25	MOS-007		10
7.50	10.38	4.01	12/12/2007	10.30	MOM-014	5	87
7.50	10.38	4.01	12/12/2007	10.45	MOM-013	178	384
7.50	10.38	4.01	12/12/2007	10.55	MOM-001	384	344
7.50	10.38	4.01	12/12/2007	11.05	MOM-015	10	137
7.50	10.38	4.01	12/12/2007	11.35	MOS-005		207
7.50	10.38	4.01	12/12/2007	11.10	MOS-006		2000
7.50	10.38	4.01	12/12/2007	11.25	MOS-004		238
7.50	10.38	4.01	12/12/2007	11.15	MOS-002		560
7.50	10.38	4.01	12/12/2007	11.50	MOM-011		40
7.50	10.38	4.01	12/12/2007	11.40	MOS-008		20
7.50	10.38	4.01	12/12/2007	11.55	MOS-009		10
7.50	10.38	4.01	12/12/2007	12.05	MOS-007		5
63.00	3.08	9.01	19/12/2007	8.45	MOM-014	40	40
63.00	3.08	9.01	19/12/2007	9.00	MOM-013	53	20
63.00	3.08	9.01	19/12/2007	9.10	MOM-001	20	30
63.00	3.08	9.01	19/12/2007	9.25	MOM-015	137	75
63.00	3.08	9.01	19/12/2007	10.05	MOS-005	222	1100
63.00	3.08	9.01	19/12/2007	9.40	MOS-006	2000	2000
63.00	3.08	9.01	19/12/2007	10.15	MOS-004	288	945
63.00	3.08	9.01	19/12/2007	9.50	MOS-002	2000	1700
63.00	3.08	9.01	19/12/2007	10.40	MOM-011	831	1000
63.00	3.08	9.01	19/12/2007	10.30	MOS-008	364	831
63.00	3.08	9.01	19/12/2007	10.50	MOS-009	40	1000
63.00	3.08	9.01	19/12/2007	11.00	MOS-007	99	324
63.00	3.08	9.01	19/12/2007	9.30	DIS-023	2000	2000
50.50	11.24	4.45	27/12/2007	10.30	MOM-014	53	87
50.50	11.24	4.45	27/12/2007	10.45	MOM-013	1400	1700
50.50	11.24	4.45	27/12/2007	10.55	MOM-001	1000	164
50.50	11.24	4.45	27/12/2007	11.10	MOM-015	150	124
50.50	11.24	4.45	27/12/2007	12.00	MOS-005	1000	207
50.50	11.24	4.45	27/12/2007	11.30	MOS-006	504	831
50.50	11.24	4.45	27/12/2007	11.50	MOS-004	40	192
50.50	11.24	4.45	27/12/2007	11.40	MOS-002	150	1200
50.50	11.24	4.45	27/12/2007	12.25	MOM-011	164	254
50.50	11.24	4.45	27/12/2007	12.15	MOS-008	75	831
50.50	11.24	4.45	27/12/2007	12.35	MOS-009	10	53
50.50	11.24	4.45	27/12/2007	12.50	MOS-007	5	30
0	15.26	8.40	2/01/2008	8.00	MOM-014	5	30
0	15.26	8.40	2/01/2008	8.10	MOM-013	5	40
0	15.26	8.40	2/01/2008	8.20	MOM-001	10	20
0	15.26	8.40	2/01/2008	8.30	MOM-015	10	20
0	15.26	8.40	2/01/2008	9.05	MOS-005	453	324
0	15.26	8.40	2/01/2008	8.45	MOS-006	885	1300
0	15.26	8.40	2/01/2008	9.00	MOS-004	20	87
0	15.26	8.40	2/01/2008	8.50	MOS-002	478	945
0	15.26	8.40	2/01/2008	9.55	MOM-011	150	178
0	15.26	8.40	2/01/2008	9.40	MOS-008	30	20

0	15.26	8.40	2/01/2008	10.00	MOS-009	5	20
0	15.26	8.40	2/01/2008	10.20	MOS-007	20	30
0	15.26	8.40	2/01/2008	8.35	DIS-023	2000	288
10.00	9.55	3.14	9/01/2008	8.15	MOM-014	5	30
10.00	9.55	3.14	9/01/2008	8.25	MOM-013	53	124
10.00	9.55	3.14	9/01/2008	8.35	MOM-001	164	207
10.00	9.55	3.14	9/01/2008	8.45	MOM-015	30	738
10.00	9.55	3.14	9/01/2008	9.25	MOS-005	384	111
10.00	9.55	3.14	9/01/2008	8.55	MOS-006	2000	1400
10.00	9.55	3.14	9/01/2008	9.20	MOS-004	137	64
10.00	9.55	3.14	9/01/2008	9.05	MOS-002	1400	831
10.00	9.55	3.14	9/01/2008	9.45	MOM-011	738	831
10.00	9.55	3.14	9/01/2008	9.35	MOS-008	137	75
10.00	9.55	3.14	9/01/2008	9.50	MOS-009	87	40
10.00	9.55	3.14	9/01/2008	10.00	MOS-007	111	75
0	13.37	6.36	15/01/2008	13.00	MOM-014	5	20
0	13.37	6.36	15/01/2008	13.10	MOM-013	5	20
0	13.37	6.36	15/01/2008	7.40	MOM-001	1400	2000
0	13.37	6.36	15/01/2008	13.20	MOM-015	10	111
0	13.37	6.36	15/01/2008	14.30	MOS-005	75	150
0	13.37	6.36	15/01/2008	14.35	MOS-006	2000	2000
0	13.37	6.36	15/01/2008	12.00	MOS-004	192	406
0	13.37	6.36	15/01/2008	12.10	MOS-002	288	2000
0	13.37	6.36	15/01/2008	13.55	MOM-011	271	271
0	13.37	6.36	15/01/2008	12.20	MOS-008	124	560
0	13.37	6.36	15/01/2008	14.05	MOS-009	40	30
0	13.37	6.36	15/01/2008	14.20	MOS-007	238	5
15.00	10.07	13.13	23/01/2008	8.00	MOM-014	20	30
15.00	10.07	13.13	23/01/2008	7.50	MOM-013	20	40
15.00	10.07	13.13	23/01/2008	9.30	MOM-001	87	75
15.00	10.07	13.13	23/01/2008	8.10	MOM-015	87	40
15.00	10.07	13.13	23/01/2008	9.00	MOS-005	530	1400
15.00	10.07	13.13	23/01/2008	9.10	MOS-006	1900	1100
15.00	10.07	13.13	23/01/2008	8.50	MOS-004	1100	1400
15.00	10.07	13.13	23/01/2008	8.40	MOS-002	1600	1500
15.00	10.07	13.13	23/01/2008	9.40	MOM-011	2000	2000
15.00	10.07	13.13	23/01/2008	10.25	MOS-008	324	738
15.00	10.07	13.13	23/01/2008	10.00	MOS-009	87	406
15.00	10.07	13.13	23/01/2008	10.10	MOS-007	150	164
0.50	13.47	7.00	30/01/2008	9.40	MOM-014	5	10
0.50	13.47	7.00	30/01/2008	10.15	MOM-013	124	10
0.50	13.47	7.00	30/01/2008	9.15	MOM-001	5	192
0.50	13.47	7.00	30/01/2008	8.45	MOM-015	40	254
0.50	13.47	7.00	30/01/2008	9.10	MOS-005	238	324
0.50	13.47	7.00	30/01/2008	9.20	MOS-006	697	271
0.50	13.47	7.00	30/01/2008	9.00	MOS-004	453	164
0.50	13.47	7.00	30/01/2008	9.30	MOS-002	238	222
0.50	13.47	7.00	30/01/2008	10.10	MOM-011	222	885
0.50	13.47	7.00	30/01/2008	9.55	MOS-008	64	192
0.50	13.47	7.00	30/01/2008	8.30	MOS-009	5	40
0.50	13.47	7.00	30/01/2008	8.15	MOS-007	40	164
5.00	9.40	14.55	7/02/2008	10.15	MOM-014	5	64
5.00	9.40	14.55	7/02/2008	10.25	MOM-013	20	207
5.00	9.40	14.55	7/02/2008	10.30	MOM-001	504	782
5.00	9.40	14.55	7/02/2008	12.05	MOM-015	5	384

5.00	9.40	14.55	7/02/2008	10.40	MOS-005	207	2000
5.00	9.40	14.55	7/02/2008	10.55	MOS-006	344	2000
5.00	9.40	14.55	7/02/2008	10.45	MOS-004	207	1400
5.00	9.40	14.55	7/02/2008	11.00	MOS-002	99	2000
5.00	9.40	14.55	7/02/2008	10.00	MOM-011	20	2000
5.00	9.40	14.55	7/02/2008	10.10	MOS-008	64	2000
5.00	9.40	14.55	7/02/2008	9.30	MOS-009	5	429
5.00	9.40	14.55	7/02/2008	9.20	MOS-007	20	453
9.00	13.54	6.52	14/02/2008	14.00	MOM-014	2000	364
9.00	13.54	6.52	14/02/2008	13.50	MOM-013	5	10
9.00	13.54	6.52	14/02/2008	13.45	MOM-001	137	53
9.00	13.54	6.52	14/02/2008	13.40	MOM-015	53	238
9.00	13.54	6.52	14/02/2008	13.35	MOS-005	222	222
9.00	13.54	6.52	14/02/2008	13.15	MOS-006	624	1700
9.00	13.54	6.52	14/02/2008	13.30	MOS-004	99	124
9.00	13.54	6.52	14/02/2008	13.20	MOS-002	222	478
9.00	13.54	6.52	14/02/2008	12.50	MOM-011	75	697
9.00	13.54	6.52	14/02/2008	13.00	MOS-008	40	124
9.00	13.54	6.52	14/02/2008	12.40	MOS-009	111	99
9.00	13.54	6.52	14/02/2008	12.20	MOS-007	10	324
0	9.15	14.16	20/02/2008	9.40	MOM-014	53	591
0	9.15	14.16	20/02/2008	9.50	MOM-013	10	150
0	9.15	14.16	20/02/2008	9.55	MOM-001	150	384
0	9.15	14.16	20/02/2008	10.00	MOM-015	254	945
0	9.15	14.16	20/02/2008	10.20	MOS-005	137	75
0	9.15	14.16	20/02/2008	10.30	MOS-006	2000	2000
0	9.15	14.16	20/02/2008	10.15	MOS-004	124	40
0	9.15	14.16	20/02/2008	10.35	MOS-002	64	192
0	9.15	14.16	20/02/2008	10.45	MOM-011	178	591
0	9.15	14.16	20/02/2008	10.50	MOS-008	64	192
0	9.15	14.16	20/02/2008	11.00	MOS-009	164	111
4.50	12.34	5.49	27/02/2008	8.35	MOM-014	10	75
4.50	12.34	5.49	27/02/2008	8.45	MOM-013	5	150
4.50	12.34	5.49	27/02/2008	8.50	MOM-001	20	222
4.50	12.34	5.49	27/02/2008	9.00	MOM-015	10	2000
4.50	12.34	5.49	27/02/2008	9.30	MOS-005	207	150
4.50	12.34	5.49	27/02/2008	9.10	MOS-006	659	406
4.50	12.34	5.49	27/02/2008	9.25	MOS-004	99	75
4.50	12.34	5.49	27/02/2008	9.15	MOS-002	75	111
4.50	12.34	5.49	27/02/2008	10.00	MOM-011	20	254
4.50	12.34	5.49	27/02/2008	9.50	MOS-008	30	344
4.50	12.34	5.49	27/02/2008	10.15	MOS-009	30	40
4.50	12.34	5.49	27/02/2008	10.30	MOS-007	10	10
13.50	7.58	13.08	5/03/2008	8.10	MOM-014	40	30
13.50	7.58	13.08	5/03/2008	8.20	MOM-013	20	64
13.50	7.58	13.08	5/03/2008	8.25	MOM-001	178	1700
13.50	7.58	13.08	5/03/2008	9.00	MOM-015	624	2000
13.50	7.58	13.08	5/03/2008	8.45	MOS-005	164	111
13.50	7.58	13.08	5/03/2008	9.10	MOS-006	591	1000
13.50	7.58	13.08	5/03/2008	8.40	MOS-004	75	164
13.50	7.58	13.08	5/03/2008	9.15	MOS-002	238	831
13.50	7.58	13.08	5/03/2008	9.40	MOS-008	53	406
13.50	7.58	13.08	5/03/2008	9.50	MOM-011	111	1000
13.50	7.58	13.08	5/03/2008	10.00	MOS-009	30	271
13.50	7.58	13.08	5/03/2008	10.20	MOS-007	64	150

1.50	12.43	5.47	13/03/2008	11.55	MOM-014	5	5
1.50	12.43	5.47	13/03/2008	12.05	MOM-013	40	150
1.50	12.43	5.47	13/03/2008	13.00	MOM-001	64	429
1.50	12.43	5.47	13/03/2008	13.10	MOM-015	5	99
1.50	12.43	5.47	13/03/2008	12.30	MOS-005	222	560
1.50	12.43	5.47	13/03/2008	12.50	MOS-006	782	478
1.50	12.43	5.47	13/03/2008	12.20	MOS-004	124	111
1.50	12.43	5.47	13/03/2008	12.40	MOS-002	164	5
1.50	12.43	5.47	13/03/2008	13.40	MOS-008	10	178
1.50	12.43	5.47	13/03/2008	13.50	MOM-011	20	306
1.50	12.43	5.47	13/03/2008	14.00	MOS-009	20	64
1.50	12.43	5.47	13/03/2008	14.15	MOS-007	254	150
0	8.11	13.07	19/03/2008	7.10	MOM-014	10	40
0	8.11	13.07	19/03/2008	7.20	MOM-013	5	20
0	8.11	13.07	19/03/2008	7.30	MOM-001	20	429
0	8.11	13.07	19/03/2008	8.10	MOM-015	30	364
0	8.11	13.07	19/03/2008	7.35	MOS-005	178	99
0	8.11	13.07	19/03/2008	7.50	MOS-006	324	238
0	8.11	13.07	19/03/2008	7.40	MOS-004	111	75
0	8.11	13.07	19/03/2008	8.00	MOS-002	40	30
0	8.11	13.07	19/03/2008	8.20	MOS-008	75	87
0	8.11	13.07	19/03/2008	8.30	MOM-011	384	324
0	8.11	13.07	19/03/2008	8.40	MOS-009	137	53
0	8.11	13.07	19/03/2008	9.00	MOS-007	99	20
0	11.59	5.19	27/03/2008	8.20	MOM-014	5	53
0	11.59	5.19	27/03/2008	8.30	MOM-013	10	124
0	11.59	5.19	27/03/2008	8.35	MOM-001	20	87
0	11.59	5.19	27/03/2008	8.45	MOM-015	5	831
0	11.59	5.19	27/03/2008	9.10	MOS-005	111	124
0	11.59	5.19	27/03/2008	9.00	MOS-004	75	150
0	11.59	5.19	27/03/2008	9.25	MOS-006	344	137
0	11.59	5.19	27/03/2008	9.20	MOS-002	10	10
0	11.59	5.19	27/03/2008	9.30	MOS-008	53	1200
0	11.59	5.19	27/03/2008	9.40	MOM-011	53	64
0	11.59	5.19	27/03/2008	10.00	MOS-009	40	30
0	11.59	5.19	27/03/2008	10.15	MOS-007	10	5

NGAKUTA BAY

Rainfall (mm/72hrs)	High Tide	Low Tide	Date	Time	Site	Enterococci	*E. coli*
9	6.42	11.42	6/11/2007	14.25	NGK-008	5	5
9	6.42	11.42	6/11/2007	13.10	NGK-001	5	5
9	6.42	11.42	6/11/2007	13.30	NGK-009	5	5
9	6.42	11.42	6/11/2007	14.15	NGK-010	5	20
9	6.42	11.42	6/11/2007	13.40	NGK-011	5	5
9	6.42	11.42	6/11/2007	13.50	NGS-001		2000
9	6.42	11.42	6/11/2007	14.05	NGS-002		271
9	6.42	11.42	6/11/2007	14.10	NGS-003		99
0	10.52	4.10	13/11/2007	12.40	NGK-001	5	5
8.5	11.23	4.40	14/11/2007	9.00	NGK-008	5	20
8.5	11.23	4.40	14/11/2007	9.15	NGK-009	5	5
8.5	11.23	4.40	14/11/2007	9.30	NGK-010	30	75
8.5	11.23	4.40	14/11/2007	9.50	NGK-011	5	10
8.5	11.23	4.40	14/11/2007	10.30	NGS-002		738

8.5	11.23	4.40	14/11/2007	10.00	NGS-003		87
8.5	11.23	4.40	14/11/2007	10.40	NGS-001		150
8.5	11.23	4.40	14/11/2007	10.15	NGS-004		2000
0	5.32	11.15	21/11/2007	11.50	NGK-008	5	5
0	5.32	11.15	21/11/2007	12.00	NGK-001	5	5
0	5.32	11.15	21/11/2007	12.40	NGK-009	10	5
0	5.32	11.15	21/11/2007	12.30	NGK-010	5	5
0	5.32	11.15	21/11/2007	13.05	NGK-011	10	40
0	5.32	11.15	21/11/2007	12.15	NGS-001		20
0	5.32	11.15	21/11/2007	12.50	NGS-002		504
0	5.32	11.15	21/11/2007	13.00	NGS-003		591
0	11.58	5.01	29/11/2007	12.20	NGK-008	40	10
0	11.58	5.01	29/11/2007	12.35	NGK-001	5	5
0	11.58	5.01	29/11/2007	12.55	NGK-009	10	10
0	11.58	5.01	29/11/2007	13.20	NGK-010	5	137
0	11.58	5.01	29/11/2007	14.05	NGK-011	164	384
0	11.58	5.01	29/11/2007	12.45	NGS-001		124
0	11.58	5.01	29/11/2007	13.00	NGS-002		1300
0	11.58	5.01	29/11/2007	13.55	NGS-003		306
0	11.58	5.01	29/11/2007	13.30	NGS-004		2000
0	11.58	5.01	29/11/2007	13.45	NGS-005		2000
4	5.04	10.57	5/12/2007	12.45	NGK-008	5	20
4	5.04	10.57	5/12/2007	13.00	NGK-001	5	5
4	5.04	10.57	5/12/2007	13.30	NGK-009	5	10
4	5.04	10.57	5/12/2007	13.40	NGK-010	20	40
4	5.04	10.57	5/12/2007	14.30	NGK-011	10	10
4	5.04	10.57	5/12/2007	13.15	NGS-001		150
4	5.04	10.57	5/12/2007	13.55	NGS-002		624
4	5.04	10.57	5/12/2007	14.20	NGS-003		254
4	5.04	10.57	5/12/2007	14.05	NGS-004		945
4	5.04	10.57	5/12/2007	14.15	NGS-005		2000
7.5	10.38	4.01	12/12/2007	9.00	NGK-008	5	10
7.5	10.38	4.01	12/12/2007	9.10	NGK-001	30	10
7.5	10.38	4.01	12/12/2007	9.30	NGK-009	87	75
7.5	10.38	4.01	12/12/2007	9.45	NGK-010	87	10
7.5	10.38	4.01	12/12/2007	10.25	NGK-011	2000	2000
7.5	10.38	4.01	12/12/2007	9.20	NGS-001		478
7.5	10.38	4.01	12/12/2007	9.40	NGS-002		254
7.5	10.38	4.01	12/12/2007	10.10	NGS-003		2000
7.5	10.38	4.01	12/12/2007	9.55	NGS-004		2000
7.5	10.38	4.01	12/12/2007	10.00	NGS-005		2000
63	3.08	9.01	19/12/2007	11.15	NGK-008	30	64
63	3.08	9.01	19/12/2007	11.25	NGK-001	10	5
63	3.08	9.01	19/12/2007	11.45	NGK-009	64	53
63	3.08	9.01	19/12/2007	12.00	NGK-010	5	64
63	3.08	9.01	19/12/2007	12.35	NGK-011	75	20
63	3.08	9.01	19/12/2007	11.35	NGS-001		2000
63	3.08	9.01	19/12/2007	11.55	NGS-002		624
63	3.08	9.01	19/12/2007	12.20	NGS-003		2000
63	3.08	9.01	19/12/2007	12.10	NGS-004		2000
63	3.08	9.01	19/12/2007	12.25	NGS-005		2000
50.50	11.24	4.45	27/12/2007	13.00	NGK-008	10	10
50.50	11.24	4.45	27/12/2007	13.10	NGK-001	30	30
50.50	11.24	4.45	27/12/2007	13.25	NGK-009	10	5
50.50	11.24	4.45	27/12/2007	13.50	NGK-010	75	30

50.50	11.24	4.45	27/12/2007	14.30	NGK-011	40	10
50.50	11.24	4.45	27/12/2007	13.20	NGS-001		453
50.50	11.24	4.45	27/12/2007	13.40	NGS-002		2000
50.50	11.24	4.45	27/12/2007	14.20	NGS-003		2000
50.50	11.24	4.45	27/12/2007	14.00	NGS-004		2000
50.50	11.24	4.45	27/12/2007	14.10	NGS-005		1200
10.00	9.55	3.14	9/01/2008	10.35	NGK-008	5	87
10.00	9.55	3.14	9/01/2008	10.44	NGK-001	87	53
10.00	9.55	3.14	9/01/2008	10.55	NGK-009	10	5
10.00	9.55	3.14	9/01/2008	11.15	NGK-010	344	504
10.00	9.55	3.14	9/01/2008	11.40	NGK-011	150	2000
10.00	9.55	3.14	9/01/2008	10.50	NGS-001		531
10.00	9.55	3.14	9/01/2008	11.00	NGS-002		2000
10.00	9.55	3.14	9/01/2008	11.35	NGS-003		531
10.00	9.55	3.14	9/01/2008	11.20	NGS-004		2000
10.00	9.55	3.14	9/01/2008	11.30	NGS-005		2000
0.00	14.27	7.21	16/01/2008	10.50	NGK-008	5	64
0.00	14.27	7.21	16/01/2008	11.00	NGK-001	10	10
0.00	14.27	7.21	16/01/2008	11.20	NGK-009	5	30
0.00	14.27	7.21	16/01/2008	11.45	NGK-010	87	150
0.00	14.27	7.21	16/01/2008	12.30	NGK-011	5	271
0.00	14.27	7.21	16/01/2008	11.10	NGS-001		306
0.00	14.27	7.21	16/01/2008	11.30	NGS-002		738
0.00	14.27	7.21	16/01/2008	12.25	NGS-003		1700
0.00	14.27	7.21	16/01/2008	12.00	NGS-004		1400
0.00	14.27	7.21	16/01/2008	12.15	NGS-005		2000
15.00	10.07	15.13	23/01/2008	10.50	NGK-008	10	87
15.00	10.07	15.13	23/01/2008	10.55	NGK-001	10	5
15.00	10.07	15.13	23/01/2008	11.20	NGK-009	164	99
15.00	10.07	15.13	23/01/2008	11.35	NGK-010	207	124
15.00	10.07	15.13	23/01/2008	12.20	NGK-011	30	20
15.00	10.07	15.13	23/01/2008	11.05	NGS-001		2000
15.00	10.07	15.13	23/01/2008	11.25	NGS-002		738
15.00	10.07	15.13	23/01/2008	12.10	NGS-003		2000
15.00	10.07	15.13	23/01/2008	11.45	NGS-004		1300
15.00	10.07	15.13	23/01/2008	11.55	NGS-005		2000
0.50	13.47	7.00	30/01/2008	10.35	NGK-008	5	40
0.50	13.47	7.00	30/01/2008	10.45	NGK-001	5	40
0.50	13.47	7.00	30/01/2008	10.50	NGK-009	5	20
0.50	13.47	7.00	30/01/2008	11.15	NGK-010	64	40
0.50	13.47	7.00	30/01/2008	11.40	NGK-011	10	124
0.50	13.47	7.00	30/01/2008	11.00	NGS-001		2000
0.50	13.47	7.00	30/01/2008	12.00	NGS-002		178
0.50	13.47	7.00	30/01/2008	11.30	NGS-003		2000
0.50	13.47	7.00	30/01/2008	11.55	NGS-004		782
0.50	13.47	7.00	30/01/2008	11.25	NGS-005		885
5.00	9.40	14.55	7/02/2008	11.25	NGK-008	10	271
5.00	9.40	14.55	7/02/2008	11.30	NGK-001	10	20
5.00	9.40	14.55	7/02/2008	11.45	NGK-009	5	429
5.00	9.40	14.55	7/02/2008	12.30	NGK-010	10	2000
5.00	9.40	14.55	7/02/2008	12.00	NGK-011	111	2000
5.00	9.40	14.55	7/02/2008	11.40	NGS-001		2000
5.00	9.40	14.55	7/02/2008	12.25	NGS-002		2000
5.00	9.40	14.55	7/02/2008	12.05	NGS-003		2000
5.00	9.40	14.55	7/02/2008	12.20	NGS-004		2000

5.00	9.40	14.55	7/02/2008	12.15	NGS-005		2000
9.00	13.54	6.52	14/02/2008	9.35	NGK-008	453	406
9.00	13.54	6.52	14/02/2008	9.45	NGK-001	64	137
9.00	13.54	6.52	14/02/2008	10.05	NGK-009	10	20
9.00	13.54	6.52	14/02/2008	10.30	NGK-010	40	64
9.00	13.54	6.52	14/02/2008	11.10	NGK-011	20	87
9.00	13.54	6.52	14/02/2008	9.55	NGS-001		406
9.00	13.54	6.52	14/02/2008	10.20	NGS-002		782
9.00	13.54	6.52	14/02/2008	11.00	NGS-003		2000
9.00	13.54	6.52	14/02/2008	10.40	NGS-004		1700
9.00	13.54	6.52	14/02/2008	10.50	NGS-005		192
0.00	9.15	14.06	20/02/2008	7.45	NGK-008	5	64
0.00	9.15	14.06	20/02/2008	7.55	NGK-001	5	40
0.00	9.15	14.06	20/02/2008	8.30	NGK-009	5	30
0.00	9.15	14.06	20/02/2008	8.55	NGK-010	478	384
0.00	9.15	14.06	20/02/2008	9.25	NGK-011	30	178
0.00	9.15	14.06	20/02/2008	8.10	NGS-001		222
0.00	9.15	14.06	20/02/2008	8.40	NGS-002		324
0.00	9.15	14.06	20/02/2008	9.20	NGS-003		1100
0.00	9.15	14.06	20/02/2008	9.00	NGS-004		2000
0.00	9.15	14.06	20/02/2008	9.10	NGS-005		1100
4.50	12.34	5.49	27/02/2008	10.50	NGK-008	5	178
4.50	12.34	5.49	27/02/2008	11.00	NGK-001	5	20
4.50	12.34	5.49	27/02/2008	11.20	NGK-009	5	20
4.50	12.34	5.49	27/02/2008	11.35	NGK-010	192	453
4.50	12.34	5.49	27/02/2008	12.10	NGK-011	192	207
4.50	12.34	5.49	27/02/2008	11.10	NGS-001		53
4.50	12.34	5.49	27/02/2008	11.30	NGS-002		453
4.50	12.34	5.49	27/02/2008	12.00	NGS-003		831
4.50	12.34	5.49	27/02/2008	11.45	NGS-004		254
4.50	12.34	5.49	27/02/2008	11.50	NGS-005		885
13.50	7.58	13.08	5/03/2008	10.50	NGK-008	5	30
13.50	7.58	13.08	5/03/2008	11.00	NGK-001	5	10
13.50	7.58	13.08	5/03/2008	11.10	NGS-001		659
13.50	7.58	13.08	5/03/2008	11.20	NGK-009	40	222
13.50	7.58	13.08	5/03/2008	11.30	NGS-002		137
13.50	7.58	13.08	5/03/2008	11.40	NGK-010	10	99
13.50	7.58	13.08	5/03/2008	11.50	NGS-004		406
13.50	7.58	13.08	5/03/2008	12.05	NGS-005		2000
13.50	7.58	13.08	5/03/2008	12.20	NGS-003		429
13.50	7.58	13.08	5/03/2008	12.25	NGK-011	254	10
1.00	12.43	5.47	13/03/2008	7.55	NGK-008	10	238
1.00	12.43	5.47	13/03/2008	8.10	NGK-001	5	5
1.00	12.43	5.47	13/03/2008	8.20	NGS-001		124
1.00	12.43	5.47	13/03/2008	8.30	NGK-009	10	40
1.00	12.43	5.47	13/03/2008	8.40	NGS-002		164
1.00	12.43	5.47	13/03/2008	8.50	NGK-010	40	20
1.00	12.43	5.47	13/03/2008	9.05	NGS-004		364
1.00	12.43	5.47	13/03/2008	9.15	NGS-005		1000
1.00	12.43	5.47	13/03/2008	9.25	NGS-003		478
1.00	12.43	5.47	13/03/2008	9.35	NGK-011	5	30
0.00	7.21	12.11	19/03/2008	9.25	NGK-008	10	137
0.00	7.21	12.11	19/03/2008	9.35	NGK-001	10	5
0.00	7.21	12.11	19/03/2008	9.45	NGS-001		192
0.00	7.21	12.11	19/03/2008	9.55	NGK-009	5	40

0.00	7.21	12.11	19/03/2008	10.05	NGS-002		222
0.00	7.21	12.11	19/03/2008	10.10	NGK-010	178	222
0.00	7.21	12.11	19/03/2008	10.20	NGS-004		591
0.00	7.21	12.11	19/03/2008	10.30	NGS-005		504
0.00	7.21	12.11	19/03/2008	10.35	NGS-003		885
0.00	7.21	12.11	19/03/2008	10.45	NGK-011	30	99
0.00	11.59	5.19	27/03/2008	10.40	NGK-008	5	20
0.00	11.59	5.19	27/03/2008	10.45	NGK-001	5	64
0.00	11.59	5.19	27/03/2008	10.50	NGS-001		238
0.00	11.59	5.19	27/03/2008	11.00	NGK-009	5	164
0.00	11.59	5.19	27/03/2008	11.25	NGS-002		2000
0.00	11.59	5.19	27/03/2008	11.30	NGK-010	20	222
0.00	11.59	5.19	27/03/2008	11.45	NGS-004		782
0.00	11.59	5.19	27/03/2008	12.00	NGS-005		2000
0.00	11.59	5.19	27/03/2008	12.15	NGS-003		254
0.00	11.59	5.19	27/03/2008	12.20	NGK-011	10	238

GROVE ARM

Rainfall (mm/72hrs)	High Tide	Low Tide	Date	Time	Site	Enterococci	*E. coli*
5.5	7.38	12.43	7/11/2007	10.25	TIR-5	5	10
5.5	7.38	12.43	7/11/2007	10.15	TIR-27		5
5.5	7.38	12.43	7/11/2007	10.35	TIR-28	5	10
5.5	7.38	12.43	7/11/2007	11.35	GRO-018		53
5.5	7.38	12.43	7/11/2007	11.05	GRO-017		10
5.5	7.38	12.43	7/11/2007	11.45	GRO-001	5	5
9	6.42	11.42	6/11/2007	10.05	OKW-10	5	5
0	10.52	16.15	13/11/2007	11.20	TIR-5	5	5
0	10.52	16.15	13/11/2007	11.40	GRO-001	10	10
0	10.52	16.15	13/11/2007	12.05	OKW-10	5	5
8.5	11.23	16.47	14/11/2007	13.15	TIR-27	5	
8.5	11.23	16.47	14/11/2007	13.30	TIR-28	5	20
8.5	11.23	16.47	14/11/2007	14.05	GRO-018		40
8.5	11.23	16.47	14/11/2007	13.50	GRO-017		5
0	16.50	9.48	20/11/2007	11.50	TIR-5	5	5
0	16.50	9.48	20/11/2007	11.35	TIR-27		64
0	16.50	9.48	20/11/2007	12.10	TIR-28	5	10
0	16.50	9.48	20/11/2007	12.40	GRO-001	5	5
0	16.50	9.48	20/11/2007	12.20	GRO-017		30
0	16.50	9.48	20/11/2007	13.00	GRO-018		1400
0	16.50	9.48	20/11/2007	13.20	OKW-10	5	5
0	11.23	16.51	28/11/2007	12.40	TIR-5	10	207
0	11.23	16.51	28/11/2007	12.55	TIR-27	40	
0	11.23	16.51	28/11/2007	12.25	TIR-28	5	53
0	11.23	16.51	28/11/2007	11.50	GRO-001	5	5
0	11.23	16.51	28/11/2007	11.40	GRO-017		5
0	11.23	16.51	28/11/2007	12.10	GRO-018		782
0	11.23	16.51	28/11/2007	13.15	OKW-10	5	5
4	16.44	9.39	4/12/2007	10.30	TIR-5	10	20
4	16.44	9.39	4/12/2007	10.15	TIR-27		87
4	16.44	9.39	4/12/2007	10.40	TIR-28	5	192
4	16.44	9.39	4/12/2007	11.00	GRO-001	10	
4	16.44	9.39	4/12/2007	11.15	GRO-018		75
4	16.44	9.39	4/12/2007	11.30	OKW-10	5	

4	16.44	9.39	4/12/2007	10.50	GRO-017		64
9.5	10.06	15.28	11/12/2007	13.40	TIR-5	5	75
9.5	10.06	15.28	11/12/2007	13.50	TIR-27		10
9.5	10.06	15.28	11/12/2007	12.35	TIR-28	75	2000
9.5	10.06	15.28	11/12/2007	12.15	GRO-001	10	10
9.5	10.06	15.28	11/12/2007	12.05	GRO-017		10
9.5	10.06	15.28	11/12/2007	12.25	GRO-018		453
9.5	10.06	15.28	11/12/2007	13.10	OKW-10	5	5
31.5	14.59	7.52	18/12/2007	12.35	TIR-5	2000	2000
31.5	14.59	7.52	18/12/2007	12.45	TIR-27		2000
31.5	14.59	7.52	18/12/2007	12.25	TIR-28	2000	2000
31.5	14.59	7.52	18/12/2007	11.55	GRO-001	2000	2000
31.5	14.59	7.52	18/12/2007	11.40	GRO-017		2000
31.5	14.59	7.52	18/12/2007	12.10	GRO-018		2000
31.5	14.59	7.52	18/12/2007	13.00	OKW-10	164	40
30.5	10.48	16.03	26/12/2007	12.55	TIR-5	384	504
30.5	10.48	16.03	26/12/2007	13.05	TIR-27		164
30.5	10.48	16.03	26/12/2007	12.45	TIR-28	254	406
30.5	10.48	16.03	26/12/2007	12.25	GRO-001	192	344
30.5	10.48	16.03	26/12/2007	12.15	GRO-017		697
30.5	10.48	16.03	26/12/2007	12.35	GRO-018		624
30.5	10.48	16.03	26/12/2007	13.30	OKW-10	10	5
8	9.20	14.38	8/01/2008	12.45	TIR-5	885	384
8	9.20	14.38	8/01/2008	12.55	TIR-27		1200
8	9.20	14.38	8/01/2008	12.35	TIR-28	207	1300
8	9.20	14.38	8/01/2008	12.10	GRO-001	192	384
8	9.20	14.38	8/01/2008	11.50	GRO-017		344
8	9.20	14.38	8/01/2008	12.20	GRO-018		945
8	9.20	14.38	8/01/2008	13.30	OKW-10	20	111
0	14.27	7.21	16/01/2008	14.10	OKW-10	5	5
0	14.27	7.21	16/01/2008	13.45	TIR-5	10	5
0	14.27	7.21	16/01/2008	13.55	TIR-27		99
0	14.27	7.21	16/01/2008	13.40	TIR-28	53	75
0	14.27	7.21	16/01/2008	13.20	GRO-001	5	5
0	14.27	7.21	16/01/2008	13.00	GRO-017		738
0	14.27	7.21	16/01/2008	13.30	GRO-018		99
2.5	9.26	14.28	22/01/2008	11.00	TIR-5	591	406
2.5	9.26	14.28	22/01/2008	11.05	TIR-27		2000
2.5	9.26	14.28	22/01/2008	10.55	TIR-28	831	2000
2.5	9.26	14.28	22/01/2008	10.40	GRO-001	624	324
2.5	9.26	14.28	22/01/2008	10.35	GRO-017		2000
2.5	9.26	14.28	22/01/2008	10.50	GRO-018		1400
2.5	9.26	14.28	22/01/2008	11.15	OKW-10	64	222
0	13.11	6.23	29/01/2008	11.35	TIR-5	5	30
0	13.11	6.23	29/01/2008	11.40	TIR-27		99
0	13.11	6.23	29/01/2008	11.25	TIR-28	5	429
0	13.11	6.23	29/01/2008	11.00	GRO-001	5	99
0	13.11	6.23	29/01/2008	10.50	GRO-017		150
0	13.11	6.23	29/01/2008	11.15	GRO-018		531
0	13.11	6.23	29/01/2008	12.00	OKW-10	30	5
5	8.25	13.37	5/02/2008	11.45	TIR-5	87	406
5	8.25	13.37	5/02/2008	11.50	TIR-27		124
5	8.25	13.37	5/02/2008	11.40	TIR-28	5	222
5	8.25	13.37	5/02/2008	11.20	GRO-001	10	53
5	8.25	13.37	5/02/2008	11.15	GRO-017		288

5	8.25	13.37	5/02/2008	11.30	GRO-018		624
5	8.25	13.37	5/02/2008	12.05	OKW-10	5	5
20	12.30	5.34	12/02/2008	13.45	TIR-5	10	178
20	12.30	5.34	12/02/2008	13.40	TIR-27		1400
20	12.30	5.34	12/02/2008	13.30	TIR-28	30	306
20	12.30	5.34	12/02/2008	13.00	GRO-001		5
20	12.30	5.34	12/02/2008	12.40	GRO-017		344
20	12.30	5.34	12/02/2008	13.10	GRO-018		831
20	12.30	5.34	12/02/2008	14.10	OKW-10	5	10
0	7.37	12.29	19/02/2008	12.35	TIR-5	5	75
0	7.37	12.29	19/02/2008	12.40	TIR-27		40
0	7.37	12.29	19/02/2008	12.25	TIR-28	5	137
0	7.37	12.29	19/02/2008	12.05	GRO-001	10	40
0	7.37	12.29	19/02/2008	11.50	GRO-017		87
0	7.37	12.29	19/02/2008	12.15	GRO-018		124
0	7.37	12.29	19/02/2008	12.55	OKW-10	5	306
4.5	12.05	5.19	26/02/2008	12.20	GRO-017		150
4.5	12.05	5.19	26/02/2008	12.40	GRO-001	5	20
4.5	12.05	5.19	26/02/2008	12.45	GRO-018		99
4.5	12.05	5.19	26/02/2008	13.00	TIR-28	20	40
4.5	12.05	5.19	26/02/2008	13.10	TIR-27		20
4.5	12.05	5.19	26/02/2008	13.15	TIR-5	5	20
4.5	12.05	5.19	26/02/2008	13.45	OKW-10	5	5
47.5	6.41	12.17	4/03/2008	12.45	GRO-017		87
47.5	6.41	12.17	4/03/2008	13.05	GRO-001	20	87
47.5	6.41	12.17	4/03/2008	13.15	GRO-018		222
47.5	6.41	12.17	4/03/2008	13.25	TIR-28	5	111
47.5	6.41	12.17	4/03/2008	13.40	TIR-27		192
47.5	6.41	12.17	4/03/2008	13.35	TIR-5	5	40
47.5	6.41	12.17	4/03/2008	14.00	OKW-10	5	10
1.5	12.05	5.11	12/03/2008	11.35	GRO-017		99
1.5	12.05	5.11	12/03/2008	11.55	GRO-001	5	5
1.5	12.05	5.11	12/03/2008	12.05	GRO-018		1200
1.5	12.05	5.11	12/03/2008	12.15	TIR-28	5	53
1.5	12.05	5.11	12/03/2008	12.25	TIR-27		5
1.5	12.05	5.11	12/03/2008	12.30	TIR-5	20	364
1.5	12.05	5.11	12/03/2008	12.50	OKW-10	5	5
0	7.21	12.11	18/03/2008	11.00	GRO-017		64
0	7.21	12.11	18/03/2008	11.20	GRO-001	5	30
0	7.21	12.11	18/03/2008	11.30	GRO-018		364
0	7.21	12.11	18/03/2008	11.40	TIR-28	5	30
0	7.21	12.11	18/03/2008	11.55	TIR-27		111
0	7.21	12.11	18/03/2008	12.00	TIR-5	5	20
0	7.21	12.11	18/03/2008	12.15	OKW-10	5	10
0	11.31	4.50	26/03/2008	12.15	GRO-017		75
0	11.31	4.50	26/03/2008	12.30	GRO-001	5	5
0	11.31	4.50	26/03/2008	12.40	GRO-018		1700
0	11.31	4.50	26/03/2008	12.45	TIR-28	5	831
0	11.31	4.50	26/03/2008	12.55	TIR-27		75
0	11.31	4.50	26/03/2008	13.00	TIR-5	5	364
0	11.31	4.50	26/03/2008	13.10	OKW-10	5	30

APPENDIX 6: Momorangi Tidal Survey

Times in NZST

Momorangi Tidal Survey
15 January 2008

LOW TIDE =6:36AM
HIGH TIDE = 1:37PM

Sample ID					Measurements					Observations	
QDAS Number	Site ID	Time	E.coli	Enterococci	Temp (°C)	Cond. @ 25°C	Salinity (ppt)	pH	DO (%sat)	Weather	Water
20080397	MOS-005	6:30	2000	288	16.2	115.6	0.1	6.84	83.3	60% cloud, no wind	clear
20080398	MOS-006	6:35	2000	1300	17.4	288.7	0.1	6.6	73.5	60% cloud, no wind	clear
20080399	MOM-001	6:40	30	10	18.8	5090	33.5	7.95		60% cloud, light wind	clear, small waves
20080400	MOS-005	7:30	2000	364	16.4	120.4	0.1	7.01	86	65% cloud, light wind	clear
20080401	MOS-006	7:35	10	5	18.6	270.9	0.1	6.62	75.8	65% cloud, light wind	clear
20080402	MOM-001	7:40	2000	1400	19	5100	33.6	8.01		65% cloud, light wind	clear, small waves
20080403	MOS-005	8:30	1300	288	16.6	125.6	0.1	7.11	87.3	70% cloud, light wind	clear
20080404	MOS-006	8:35	1400	1000	19	298.4	0.1	6.75	76.1	70% cloud, light wind	clear
20080405	MOM-001	8:40	5	5	19.1	5120	33.7	8.02		70% cloud, light wind	clear, 0.1m waves
20080406	MOS-005	9:30	738	178	17.1	118.3	0.1	7.23	89.8	80% cloud, light wind	clear
20080407	MOS-006	9:35	1300	1100	20.3	300.8	0.1	6.77	76.5	80% cloud, light wind	clear
20080408	MOM-001	9:40	5	5	19.7	5100	33.6	8.05		80% cloud, light wind	clear, small waves
20080409	MOS-005	10:30	697	306	16.9	118.1	0.1	7.21	88.7	80% cloud, light wind	clear
20080410	MOS-006	10:35	2000	885	21.5	268.9	0.1	6.78	79.1	80% cloud, light wind	clear
20080411	MOM-001	10:40	5	20	20	5090	33.5	8.02		80% cloud, light wind	clear, small waves
20080412	MOS-005	11:30	738	288	17.8	123.2	0.1	7.23	91.2	60% cloud, light wind	clear
20080413	MOS-006	11:35	1300	738	26.9	359.3	0.2	6.76	80.9	60% cloud, light wind	clear
20080414	MOM-001	11:40	10	5	21.4	5080	33.4	8.06		60% cloud, light wind	clear, 0.1m waves
20080415	MOS-005	12:30	591	150	21.6	121.9	0.1	7.11	90.6	40% cloud, sunny, no wind	clear
20080416	MOS-006	12:35	1200	406	27.7	4490	29.2	8.04	93.1	40% cloud, sunny, light wind	clear, mixing of fresh&salwater visible
20080417	MOM-001	12:40	150	20	24.3	5050	33.2	8.07		40% cloud, sunny, light wind	clear, small waves
20080418	MOS-005	13:30	782	137	21.5	131.5	0.1	7.45	91	30% cloud, sunny, light wind	clear
20080419	MOS-006	13:35	2000	429	26.2	4560	29.5	7.99		30% cloud, sunny, light wind	slightly turbid
20080420	MOM-001	13:40	10	5	24	5090	33.4	8.1		30% cloud, sunny, light wind	clear, 0.1m - 0.2m waves
20080421	MOS-005	14:30	150	75	22.8	139.7	0.1	7.39		20% cloud, sunny, light wind	clear
20080422	MOS-006	14:35	2000	2000	27.4	2870	17.7	7.51		20% cloud, sunny, light wind	slightly turbid
20080423	MOM-001	14:40	40	30	24	5120	33.6	8.06		20% cloud, sunny, light wind	clear, 0.1m waves