Selected Northern Manukau Beaches (French Bay, Titirangi Beach, Wood Bay) Water Quality Investigation 2015, 2016

Justine L Quinn and Martin W Neale

April 2018 Technical Report TR2018/009

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Justine L Quinn
Martin W Neale

Golder Associates (NZ) Limited
Golder Associates (NZ) Limited project reference: 1650312 1650312-R-Rev0

Auckland Council
Technical Report 2018/009

ISSN 2230-4525 (Print)
ISSN 2230-4533 (Online)

ISBN 978-1-98-856408-1 (Print)
ISBN 978-1-98-856409-8 (PDF)

This report has been peer reviewed by the Peer Review Panel.

Review completed on 12 April 2018
Reviewed by two reviewers

Approved for Auckland Council publication by:

Name: Eva McLaren

Position: Acting Manager, Research and Evaluation (RIMU)

Name: Mark Iszard

Position: Strategy and Resilience Manger, Healthy Waters

Name: Jonathan Benge

Position: Manager, Wai Ora Partnerships Team, Healthy Waters

Date: 12 April 2018

Recommended citation

Quinn, J L and Neale, M W (2018). Selected northern Manukau beaches (French Bay, Titirangi Beach, Wood Bay) water quality investigation 2015, 2016. Prepared by Golder Associates (NZ) Limited for Auckland Council. Auckland Council technical report, TR2018/009

Executive summary

A review of long-term bathing beach monitoring data from Auckland Council's (AC) Safeswim programme revealed a pattern of poor water quality due to microbiological contamination along the northern Manukau Harbour coastline. Following initial investigations within the wider northern Manukau Harbour catchment, French (Otitori) Bay, Wood Bay and Titirangi Beach were chosen for detailed investigation into potential sources of contamination within their respective coastal environments.

Fourteen sites across the three catchments were sampled over a total of 12 occasions, comprising four occasions between March and April 2015 and eight occasions between March and May 2016. In total, four freshwater (stream) sites, six coastal sites and four intertidal stormwater outfalls were sampled across the three catchments.

Microbial Source Tracking (MST) analysis was undertaken on selected samples in addition to standard faecal indicator bacteria (FIB) testing (*E. coli* and enterococci). All samples were compared to Ministry for the Environment recreational contact guidelines (MfE, 2003).

A total of 129 samples were collected and tested for faecal indicator bacteria across the three catchments. Of the 31 samples collected in the French Bay catchment, 16 of these (52%) exceeded the red/action trigger level for recreational contact. A total of 59 samples were collected in the Wood Bay catchment, 32 of which (54%) exceeded the red/action trigger level for recreational contact. Forty samples were collected within the Titirangi Beach catchment, of which 28 (70%) exceeded the red/action trigger level for recreational contact, making it the most frequently contaminated of the catchments sampled. The red/action trigger level was most commonly exceeded in stream and stormwater outfall samples compared to coastal samples.

Seventy-six samples were further analysed via MST, specifically for human, dog or avian host-specific markers using Polymerase Chain Reaction (PCR) analysis. All samples tested positive for the general faecal bacteria marker (GenBac), with host-specific markers identified in 44 of these samples (58%). Canine faecal source markers were identified in 30 samples, human markers were found in 20 samples, and avian markers in 24 samples. Specific markers were unable to be identified in 32 (42%) of the samples tested.

The following conclusions can be drawn from this investigation:

- For all catchments, the freshwater inputs (being both streams and stormwater pipes) entering the coastal environment typically exhibit high concentrations of FIB during dry and wet weather conditions.
- Titirangi Beach had the highest number of exceedances of recreational contact guidelines during this sampling including during dry weather, making it the most contaminated of the sites surveyed.

- Coastal FIB contamination is exacerbated during wet weather (particularly for French Bay and Wood Bay) when concentrations of FIB in the coastal environment increase, despite high levels of contamination present in the freshwater environments during dry weather as well.
- Human, canine and avian sources of contamination are present within all catchments for both freshwater inputs and the coastal environment.
- Given that the general microbiological water quality of the Manukau Harbour is good (Walker and Vaughan 2013), it is considered that land based contamination, through freshwater inputs, is likely to be the primary driver of the poor microbiological quality of the water at each of the northern Manukau beaches.

To better manage the faecal contamination of all of these beaches and to address the current public health risk, a range of recommendations are presented, including (but not limited to):

- Further investigations should be prioritised based on the presence of faecal contamination but also in relation to those beaches with the highest recreational use. Based on microbiological water quality data alone it is considered that Titirangi Beach is a priority.
- Undertake a streamwalk type survey of the streams within each catchment to their headwaters to document all piped inputs to the stream and identify potential sources of human wastewater contamination.
- Undertake an investigation of the Wood Bay WB1 outfall and upstream stormwater network to better understand the potential sources of regularly high FIB.
- Determine whether historic septic tanks may be an issue within the each of the catchments.
- Inspect the known wastewater overflow locations to determine if there is any evidence of overflow and to confirm the integrity of the seal for those that are sealed.
- Investigate whether any network improvements or changes may have contributed to a change in the sources of contamination with the catchments.
- Investigate options for improving dog and bird control at the beach and local reserves. Rubbish bins and signage outlining the implications for water quality may be necessary.

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1.0 Introduction

A review of bathing beach monitoring data from Auckland Council's Safeswim programme revealed a pattern of poor water quality due to microbiological contamination at several beaches along the northern Manukau Harbour coastline. To better understand the problem a pilot investigation was initiated in 2013 at six of these beaches - French Bay, Wood Bay, Titirangi Beach, Green Bay, Jenkins Bay (South Titirangi Beach) and Laingholm Beach (Auckland Council unpublished data). Nine sites across the six beaches were sampled for levels and sources of faecal contamination, with samples taken from either streams or stormwater outfalls discharging to the marine environment.

The pilot study involved faecal indicator bacteria (FIB) analysis of inputs to the marine environment over twelve sampling occasions which was supplemented by faecal sterol analysis (Sullivan *et al*., 2010) of some samples. For many of the samples the faecal sterol results did not provide sufficiently robust information to determine the source of contamination. Therefore it was determined that a more rigorous investigation was required to provide more comprehensive information regarding potential sources of microbiological contamination at these beaches.

A case study at Laingholm Beach was conducted in 2014/2015 (Quinn and Neale, 2016) which revealed the presence of human, avian and canine faecal contamination. The results of this study provided further guidance to inform the implementation of similar studies in other northern Manukau catchments with poor water quality.

1.1 Objectives

Following the Laingholm investigation, three other catchments were identified as having poor microbiological coastal water quality requiring further investigation: French Bay, Wood Bay and Titirangi Beach. All three beaches are located on the northern shoreline of the Manukau Harbour within the Waitakere Local Board area (Figure 1-1). They are popular recreational beaches over summer and are all part of the Safeswim monitoring programme. These beaches were selected for further investigation as they had an elevated public health risk for recreational contact in the coastal environment.

A more comprehensive investigation was undertaken to look at the microbiological water quality at multiple sites within these catchments, including testing the stormwater outlets and streams discharging to the coastal environment on four occasions in March and April 2015. The investigation aimed to determine the key sources of microbiological contamination at each of these beaches. The initial investigation was supplemented with additional sampling in March and April 2016, providing two years' worth of late summer data for comparison and analysis.

The overarching aims of this investigation were to provide more comprehensive information about the faecal sources contaminating these beaches than the Safeswim monitoring programme is able to provide and to inform appropriate management interventions in order to improve water quality. This was undertaken by testing numerous sites under different conditions and collecting associated environmental information to assess potential impacts on faecal indicator bacteria. This report presents the results of this investigation and the subsequent recommendations for management of microbiological contamination within these catchments.

1.2 Background

The Safeswim monitoring programme is designed to provide regular assessments of water quality at a range of locations in the region that are used for primary contact recreation, including marine and freshwater beaches (see Appendix A for more details regarding the trigger levels). Under the programme, the council monitors 71 (2015-2016 season) beaches in the Auckland region on a weekly basis over summer (November to March) and the results are communicated to the public via the Safeswim webpage. Consistent with the MfE guideline (Ministry for the Environment, 2003), the council takes action to warn the public of health risks if the results of testing indicate elevated levels of faecal indicator bacteria (*Escherichia coli* (*E. coli)* in freshwater or enterococci in marine waters, including erecting warning signs on the affected beach. Where there are regular exceedances of trigger levels, permanent health warning signs may be erected.

Microbiological data from the Safeswim monitoring programme indicates that relative to other beaches in Auckland, there are frequent exceedances of the recreational guidelines at all three beaches (Figure 1-2, Figure 1-3, and Figure 1-4).

The Microbiological Assessment Category (MAC) for French Bay, Titirangi Beach and Wood Bay were calculated in accordance with the national guidelines and uses data from the last five years. This provides a long-term measurement of actual coastal water quality over time (MfE/MoH 2003). Between 2010/11 and 2014/15 this was calculated to be a 'D' for all catchments, which is the poorest category (refer to Appendix A for the guidelines and information around how this is calculated).

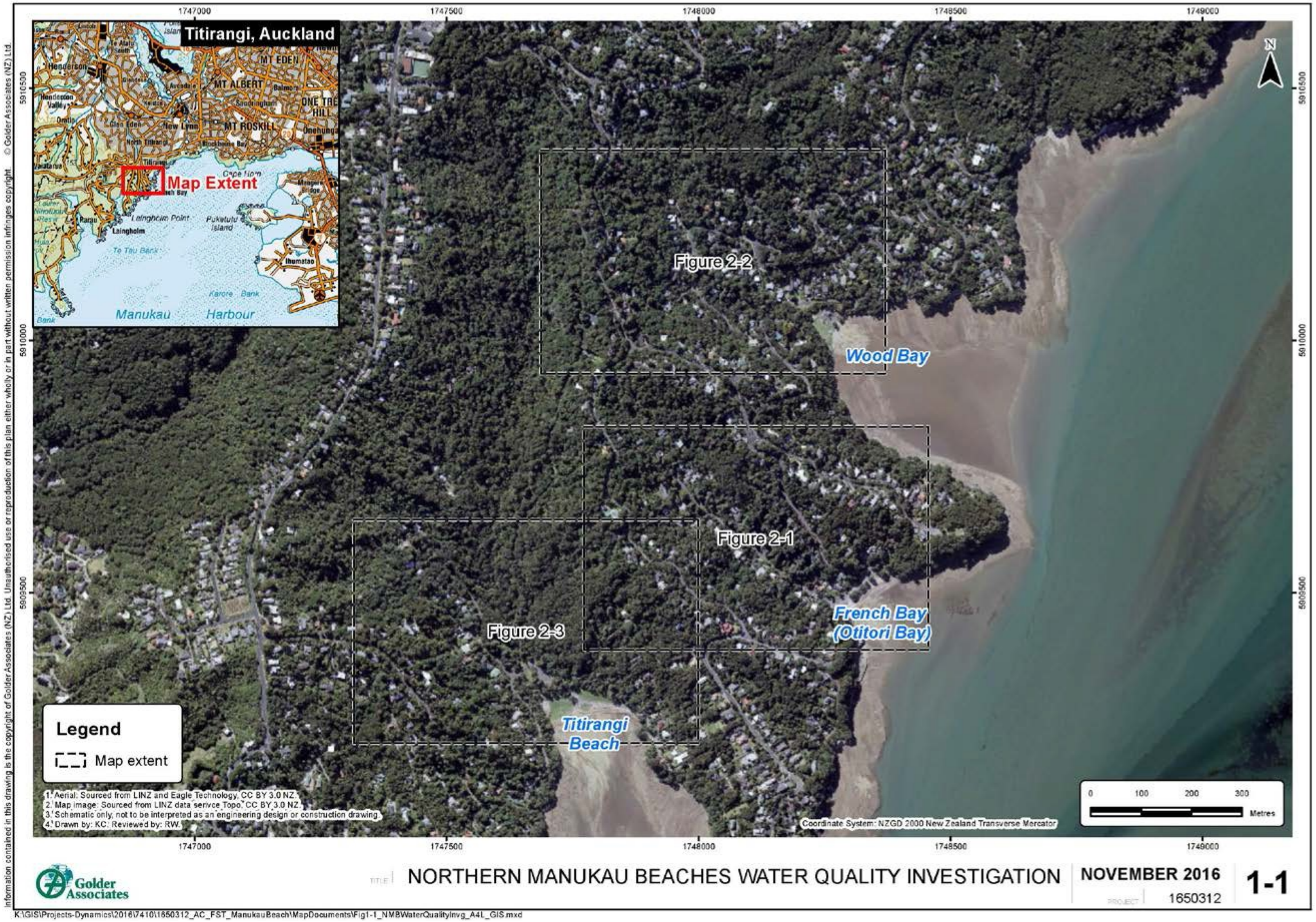

Figure 1-1 Location of beaches and bays in the northern Manukau beaches water quality Investigation

Based on the data from the last three years, all three beaches have an Overall Recreation Risk classification of ‘caution’. That is, people can be exposed to a high risk of infection (greater than 10%) at certain times from contact with coastal water (LAWA, 12/04/2016).

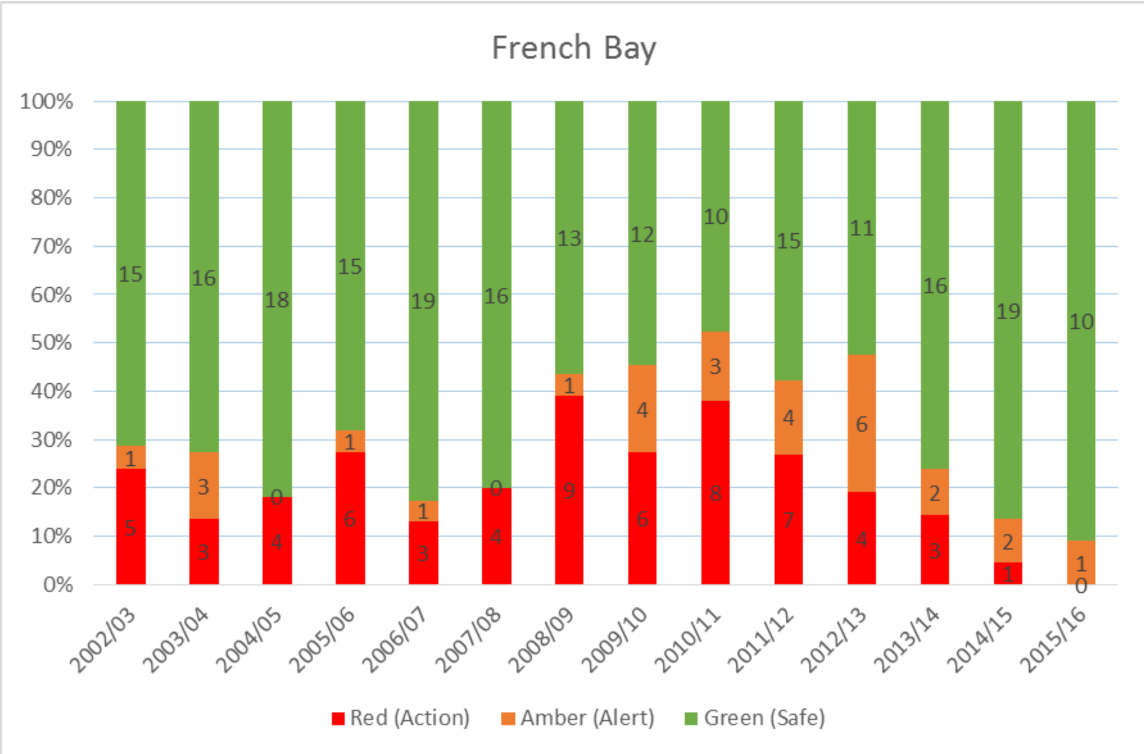

Figure 1-2 French Bay Safeswim monitoring results (Auckland Council website, historic Safeswim data) (Note: the number of samples in each trigger level mode is shown on the bar graph).

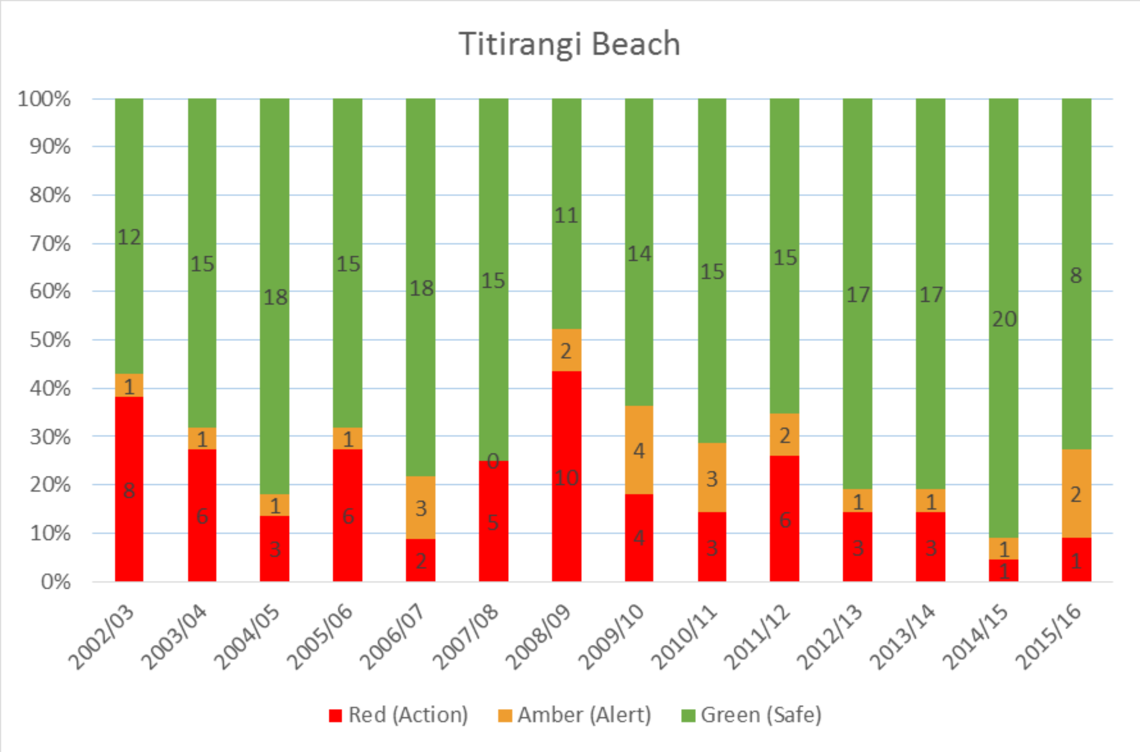

Figure 1-3 Titirangi Beach Safeswim monitoring results (Auckland Council website, historic Safeswim data) (Note: the number of samples in each trigger level mode is shown on the bar graph).

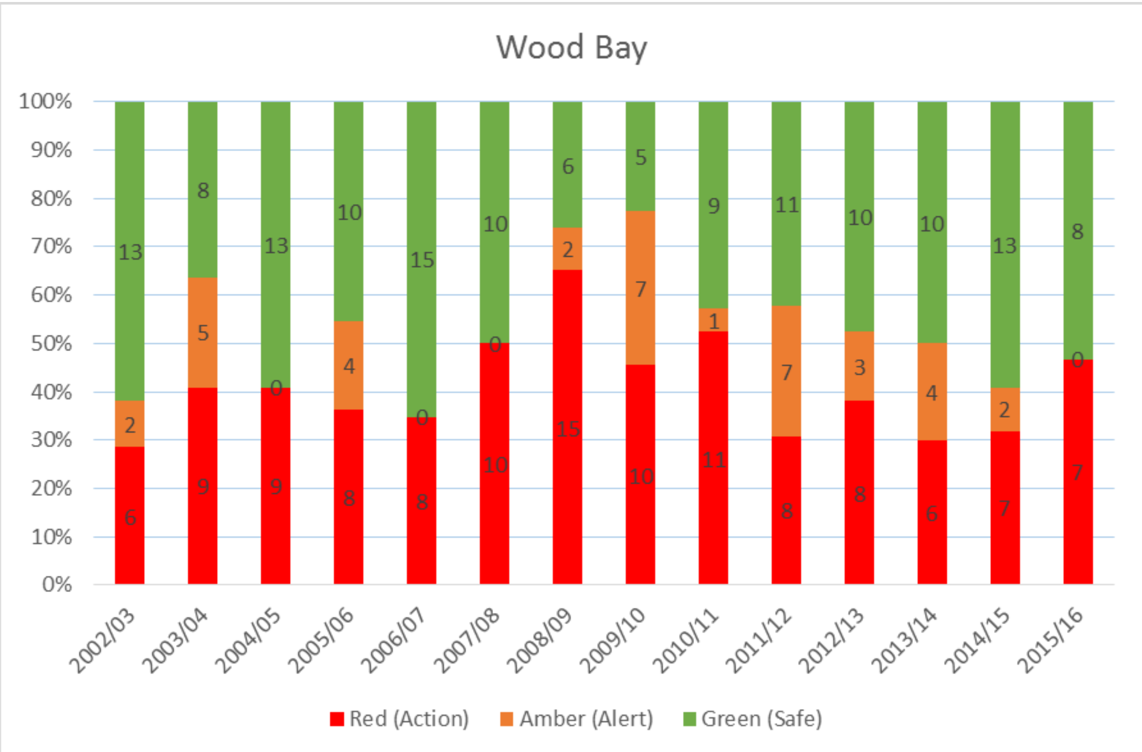

Figure 1-4 Wood Bay Safeswim monitoring results (Auckland Council website, historic Safeswim data) (Note: the number of samples in each trigger level mode is shown on the bar graph).

Several potential sources of microbiological contamination

The monitoring undertaken as part of the Safeswim project confirms that there is microbiological contamination of coastal waters at all three of these beaches on a frequent basis. Sample analysis is limited to enterococci (as per the MfE guidelines) and, as a result, is limited in terms of the information it can provide to guide future management interventions. The presence of enterococci does not necessarily confirm the presence of faecal contamination as they can exist in the environment without input from faecal sources (Byappanahalli et al, 2012). Further, enterococci, like *E. coli*, are ubiquitous in the intestines of warm-blooded animals. Therefore the presence of faecally-derived indicator bacteria may be from a range of possible animal hosts that makes effective management of any contamination difficult without further information (Walker et al, 2015).

All of the subject catchments are subject to several potential sources of microbiological contamination. Watercare identifies four potential overflows of wastewater into these catchments, which may be contributing to microbiological water contamination (Watercare, 2013). There is one existing engineered wastewater overflow point (#25) within the immediate French Bay catchment at the French Bay pump station. The overflow from the pump station is reported to have been sealed, however if it were to fail, the overflow would enter the marine environment at the beach directly via a pipe.

Two engineered wastewater overflows may enter the Titirangi Beach coastal environment. Watercare identifies that the beach potentially receives discharges directly from the Titirangi Pump Station (overflow ID # 1204) and indirectly from overflow #1206 via Paturoa Stream. Both overflow points are reported to be sealed and there are no known records of discharges from either of them. Pump station (#1204) is located to the east of the bay at the base of Okewa Road and potential overflows would likely be drawn back in towards the beach on an incoming tide. Overflow #1206 is located in the upper Titirangi Beach catchment at approximately 526 South Titirangi Road and, if it were to discharge, would discharge to the beach via the Paturoa Stream.

An engineered overflow within the Wood Bay catchment may discharge directly into the Wood Bay coastal environment via a pipe on the beach (Overflow ID #694). Watercare does not have any records of discharges at this location and, as such, considers that the frequency of discharges is ‘low’. Thus the overall effects of the discharge are ‘very low’ in terms of ecological health and ‘low’ with respect to public health, cultural and aesthetic values.

Auckland Council’s GIS wastewater layers show the wastewater network is located in close proximity to the streams within the catchments, which may be a source of microbial contamination through aged or leaky infrastructure.

There are also potential non-human sources of microbial contamination in the catchment. Dogs frequent the parks and reserves within the catchments, alongside streams and the beaches themselves. Birds are frequently observed at the beach, in the water, and within the recreational reserve alongside the beach. There are relatively large forested areas in the upper catchments that may contribute microbiological contamination through decomposing vegetation or additional wildlife inputs, and streams flow through residential properties along much of their length, any of which could be an additional source of contamination.

Therefore, there are a number of potential sources of microbiological contamination to the aquatic environment within the northern Manukau beaches. However the enterococci results alone do not provide adequate information to be able to identify whether human, dog or avian sources are present.

Recent advances in molecular techniques have led to the development of microbial source tracking (MST) tools based on ribosomal DNA markers associated with the Bacteroidales order of bacteria (Bernhard & Field 2000, Roslev & Bukh, 2011). General and host-specific markers potentially allow the identification of whether high faecal indicator bacteria concentrations are a result of faecally-derived contamination as well as the source animal. The benefits of knowing the source of faecal contamination allows a financially-efficient, targeted management response (Gilpin et al. 2002).

2.0 Methodology

Water samples were collected and tested for *E. coli* and/or enterococci and a range of faecal source markers using PCR analysis at a total of 17 sites in the freshwater and coastal environment at French Bay, Wood Bay, and Titirangi Beach. The sites were selected to provide information on the spatial distribution and potential sources of any identified contamination within each catchment. Depending on the salinity of the water at the sample site, one or both of the faecal indicator bacteria were tested for, consistent with MfE guidelines. The sampling rationale and site descriptions for each catchment are detailed below and photographs of the sites are included in Appendix B.

2.1 Sampling site description and rationale

Prior to identifying sample locations, a pre-sampling survey was undertaken by Auckland Council staff to confirm the number of stormwater and stream discharges to each of the beaches and to observe key infrastructure such as sewage trunk lines, public toilets and sewage pump stations. This information was used to determine the sampling locations for the 2015 investigation. Following the 2015 sampling effort, some sites were removed from the sampling regime for 2016 due to lack of flow or low concentrations of microbiological contamination. Figures 2-1, 2-2, 2-3 and Table 2-1 show and describe the sampling locations.

2.1.1 Five sites in French Bay catchment

Five sites were identified for sampling within the French Bay catchment. In 2015 all of these were sampled, with FB5 and FB1 excluded from the 2016 sampling regime. FB5 was removed from the 2016 sampling regime due to no flow recorded on all sampling occasions in 2015. FB1 was the northern coastal site and was removed from the 2016 sampling regime as FB2 was considered an appropriately representative coastal site, and is also the Safeswim monitoring site.

2.1.2 Five sites in Titirangi Beach catchment

Five sites were identified for sampling within the Titirangi Beach catchment. In 2015 all of these were sampled, with TB1 and TB4 excluded from the 2016 sampling regime. TB1 was the eastern marine site and was removed from the 2016 sampling regime as TB2 was considered an appropriately representative marine site and is the Safeswim monitoring site. TB4 was excluded from the 2016 sampling regime due to no flow present at all sampling occasions in 2015.

2.1.3 Seven sites in Wood Bay catchment

Seven sites were identified for sampling within the Wood Bay catchment. In 2015 all of these were sampled, with WB2 and WB7 excluded from the 2016 sampling regime. WB7 was removed from the 2016 sampling regime due to no flow recorded on all sampling occasions in 2015. WB2 was the northern coastal site and was removed from the 2016 sampling regime as WB3 was considered an appropriately representative coastal site and is also the Safeswim monitoring site.

2.2 Sampling frequency

A single sample was taken at each site on four occasions in 2015 and on eight occasions in 2016. The intention was to capture a combination of wet and dry weather conditions (Table 3-1). Samples were taken either at high tide or mid-high tide, when swimming (contact recreation) is most likely.

2.3 Rainfall records from Waituna at Huia gauge

Rainfall data for the dates of the investigation were obtained from Auckland Council's Research and Evaluation Unit (RIMU). This data was obtained from the closest rain gauge to the beaches, which is the Huia filter treatment station (Waituna, Site ID 649625).

Rainfall data were reported in terms of cumulative volume of rain that fell in the preceding 12, 24, 48 and 72 hours prior to sampling.

2.4 Wind records from Cornwallis weather station

Wind data for the dates of the investigation were also obtained from RIMU. The data were obtained from the closest weather station at Cornwallis Point (Cornwallis, Site ID 740601).

Wind data were analysed and reported in terms of dominant wind direction and average speed in the 4 hours prior to sampling.

Table 2-1 Site names, description and rationale.

AC Hydstra Database # Number	Site Name	Full Site Name	Easting (NZTM)	Northing (NZTM)	2015	2016	Site Salinity
Otitori Bay (French Bay)							
	FB1	Otitori Bay @ North	1748368	5909518	√		Saline
440911	FB2	Otitori Bay @ South (also French Bay Safeswim site)	1748315	5909475	√	√	Saline
440912	FB3	Otitori Bay Stormwater @ Foreshore Outfall 5564885	1748293	5909476	√	√	Intertidal
440913	FB4	Otitori Bay Stormwater @ Drain at 42 Valley Road	1748183	5909543	√	√	Freshwater
	FB5	Otitori Bay Stormwater @ Drain at 22 Valley Road	1748025	5909677	√		-
Titirangi Beach							
	TB1	Titirangi Beach @ East	1747851	5909251	√		Saline
440921	TB2	Titirangi Beach @ 35m Sth of Paturoa Stream Bridge 440920 (also Titirangi beach Safeswim site)	1747744	5909240	√	√	Saline
440922	TB3	Paturoa Stream 440920 @ Aydon Road	1747754	5909280	√	√	Intertidal
	TB4	Titirangi Beach Stormwater @ Manhole 280566	1747640	5909336	√		-
440924	TB5	Paturoa Stream 440920 @ Mahoe Rd Bridge	1747639	5909390	√	√	Freshwater
Wood Bay							
440860	WB1	Wood Bay Stormwater @ Foreshore Outfall 5566773	1748486	5910045	√	√	Intertidal
	WB2	Wood Bay @ North	1748303	5910039	√		Saline
440862	WB3	Wood Bay @ South (also Wood Bay Safeswim site)	1748277	5910008	√	√	Saline
440863	WB4	Wood Bay Stormwater @ Foreshore Outfall 282339	1748265	5910013	√	√	Intertidal
440864	WB5	Wood Bay Stream 440895 @ 29 Wood Bay Road	1748138	5910065	√	√	Freshwater
440865	WB6	Wood Bay Stormwater @ u/s of Confl at 57 Wood Bay Road	1748093	5910093	√	√	Freshwater
	WB7	Wood Bay Stormwater @ Drain Below Weir 586932	1748078	5910076	√		-

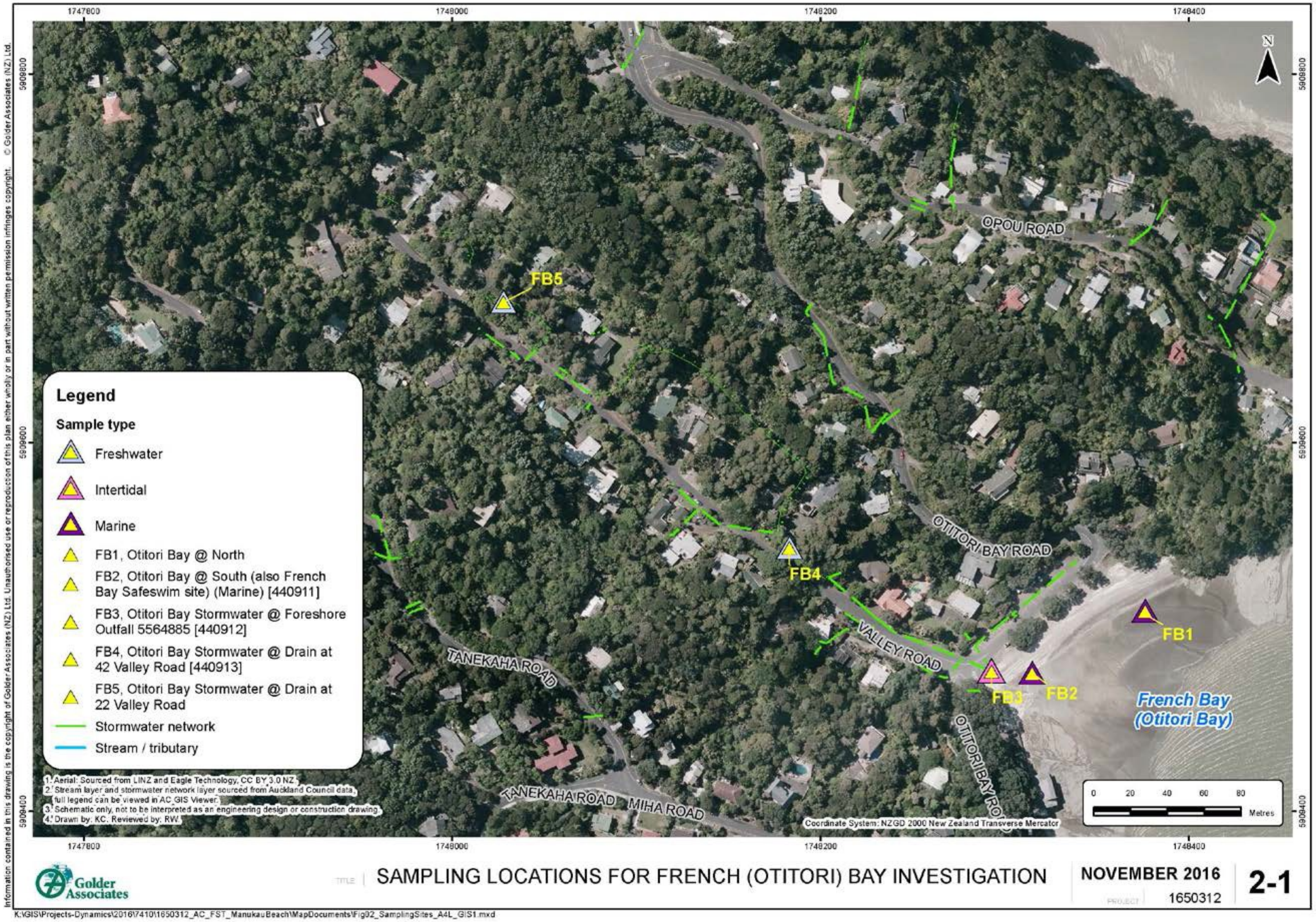

Figure 2-1 Sampling locations in the French (Otitori) Bay Water Quality Investigation

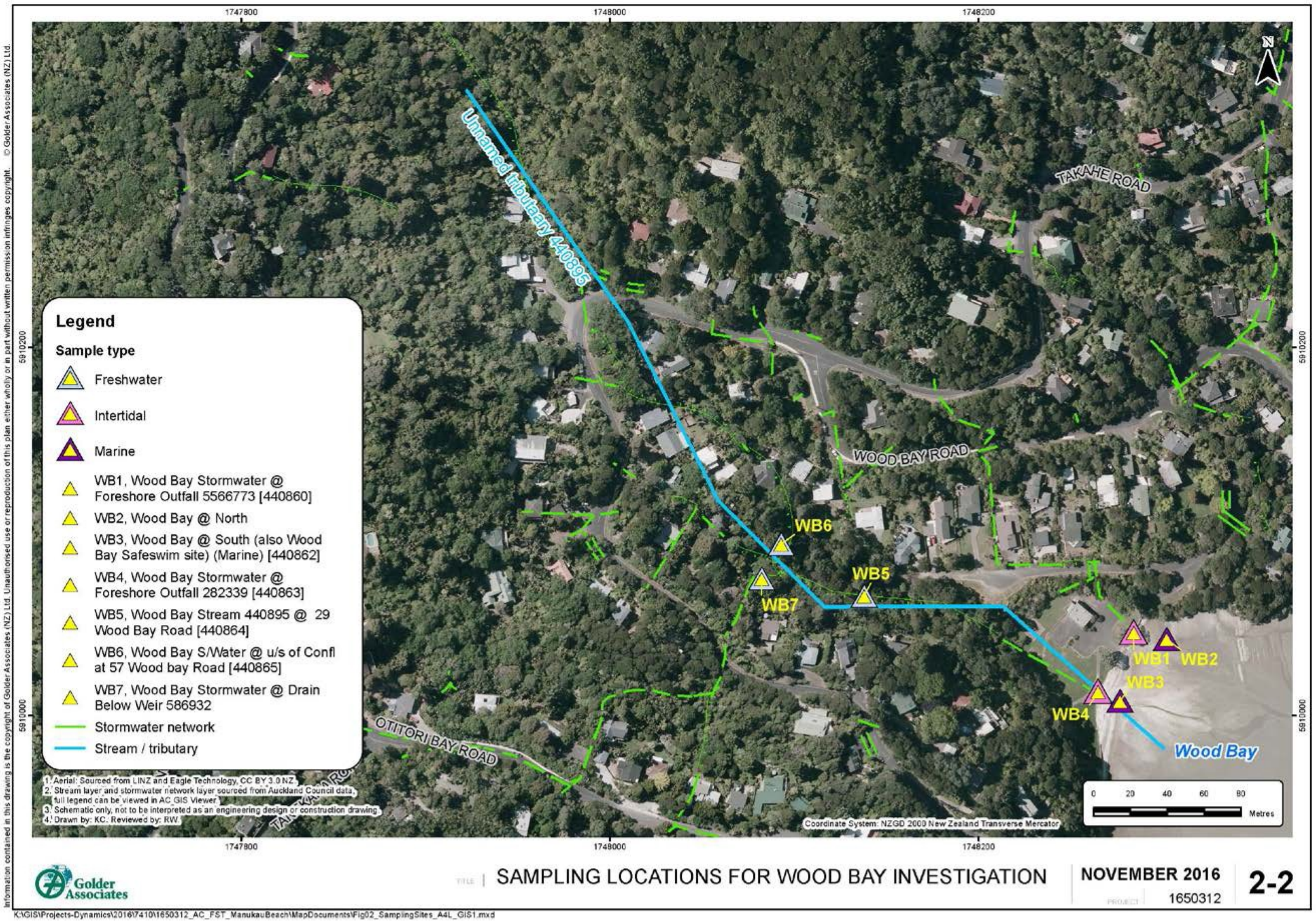

Figure 2-2 Sampling locations in the Titirangi Beach Water Quality Investigation

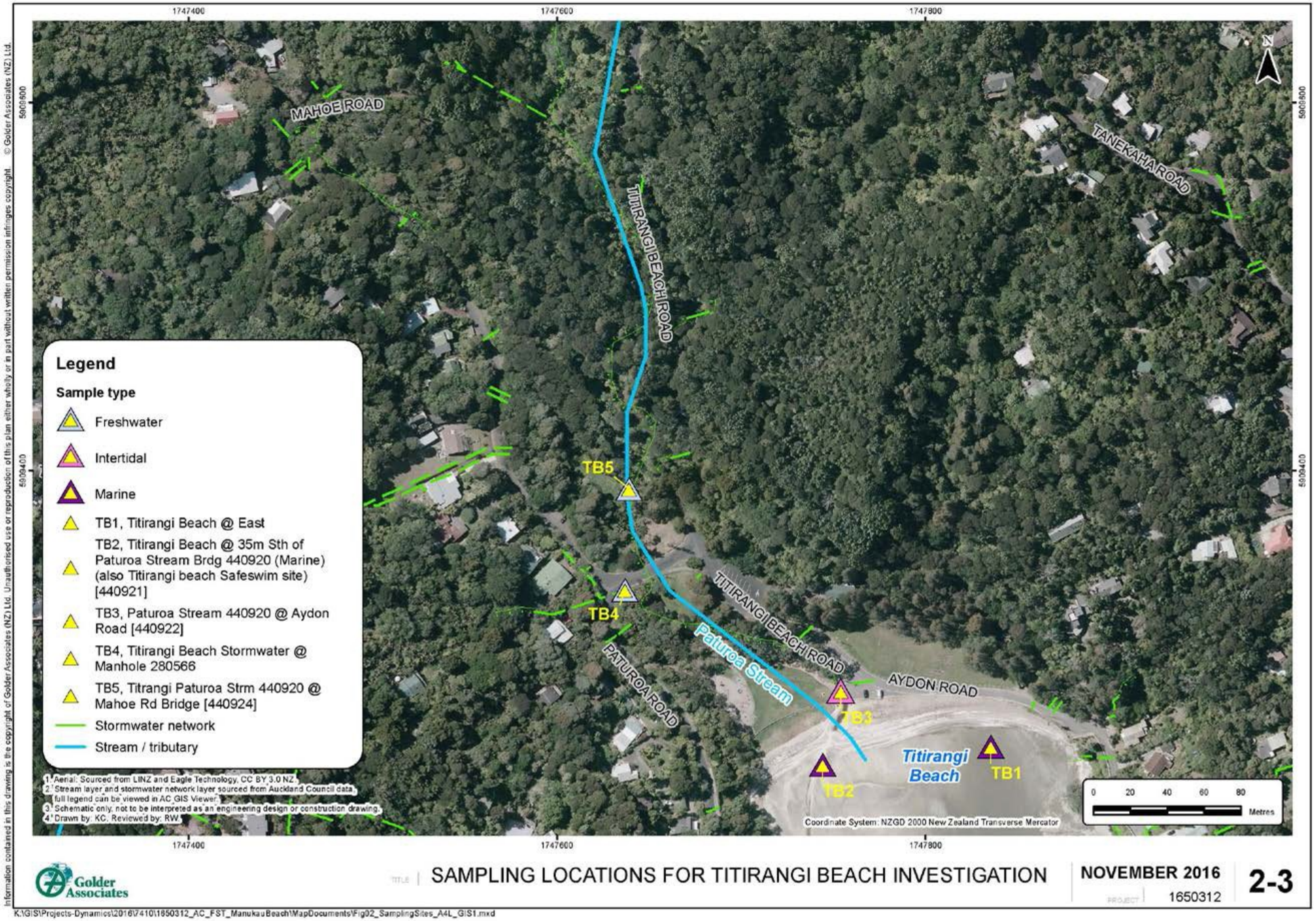

Figure 2-3 Sampling locations in the Wood Bay Water Quality Investigation

2.3 Sample collection and analysis

Water quality samples were collected by Auckland Council staff or contractors in sterile 100mL bottles for faecal indicator bacteria analysis. A 2L bulk sample was taken at the same sampling location immediately after the microbiological sample for microbiological source tracking.

Marine water samples were collected subsurface in knee deep water (0.5m) according to MfE guidelines (MfE, 2003). Samples taken from stormwater outfalls were collected only when the outfall was flowing and were collected from the water discharging from the pipe. Samples taken from the stream were collected subsurface according to MfE guidelines.

All samples were chilled following collection and delivered to AquaLab Laboratory (NZ) Limited (‘AquaLab’) for analysis. The samples were analysed within 24 hours of sample collection using the Colilert test (APHA, 2012), which provides a “Most Probable Number” (MPN) of *E. coli* (APHA 9223B) or enterococci (APHA 9230D) per 100mL (detection limit 10 MPN/100mL for each of *E. coli* and enterococci) in accordance with the 2003 MfE guidelines.

Enterococci are the recommended indicator for the marine environment and *E. coli* for freshwater (i.e. streams and stormwater) per the MfE guidelines, and these parameters were tested in the marine and freshwater inputs, respectively (Table 2-2). In some instances, both indicator bacteria were tested for where sites were located in the tidal interface or where conductivity testing on the day determined the site was saline-influenced. Refer to Table 2-2 for detail of parameters tested at each site.

Table 2-2 Faecal indicator bacteria tested for at each site.

Year	Enterococci	*E. coli*	Enterococci and *E. coli*
Otitori Bay (French Bay)			
2015	-	FB4	FB1, FB3
2016	FB2	FB4	FB2, FB3
Titirangi Beach			
2015	-	TB5	TB1, TB2, TB3
2016	TB2	TB5	TB3
Wood Bay			
2015	-	WB4, WB5, WB6	WB1, WB2, WB3
2016	WB3	WB5, WB6	WB1, WB4

Site observations were recorded on each sampling day, including the presence of animals (particularly dogs and birds), recreational usage and weather and tidal conditions (see Appendix C).

2.4 Microbial source tracking

The samples collected for microbial source tracking (MST) analysis were processed by AquaLab within 24 hours of sample collection. All samples collected were filtered through a 0.45µm membrane filter until blocked and then a GITC buffer was added. The filters were then frozen and stored, a process reported to maintain sample integrity for at least six months (Gilpin et al., 2013). Filters from the 2015 investigation were stored for approximately 12 months and selected samples were sent to the Institute of Environmental Science and Research (ESR) laboratory for MST analysis in early April 2016. The 2015 filters were initially tested for GenBac only, to determine whether degradation of bacterial DNA had occurred, and then additional testing for the source specific markers was undertaken if GenBac was present (a screening approach). Filters from the 2016 investigation were frozen and stored. At the close of the investigation the frozen samples were compared to their matching microbiological result and particular samples selected for MST analysis.

For both years, those filtered samples with corresponding microbiological concentrations >550 *E. coli* MPN/100mL for freshwater or >280 enterococci MPN/100mL for seawater (Red/Action trigger level exceedances) were sent to the ESR laboratory for MST analysis using the Polymerase Chain Reaction (PCR) method. This is consistent with previous studies that found the use of molecular techniques is more likely to yield useful results when faecal indicator bacteria are high (Cornelisen et al., 2012).

In addition, filtered samples from the 2016 investigation with corresponding microbiological concentrations of >260 ≤ 550 *E. coli* MPN/100mL for freshwater or >140 enterococci MPN/100mL for seawater (Amber/Alert trigger level exceedances) were also sent to ESR for analysis. These filtered samples were selected in addition to those samples with higher concentrations in an attempt to provide a greater degree of resolution to the catchment results.

The MST method amplifies the DNA from host specific bacteria in the filtered water samples and tests for the presence of markers for the animal species of interest. The markers chosen for analysis in this investigation were the general bacterial marker (GenBac), and specific markers for dog (DogBac), avian (GFD) and human (BiADO and BacH) sources. The presence of GenBac does not confirm absolutely that the FIB is of a faecal origin, as GenBac is *Bacteroidales* and has been recorded in the wastewater of potato processing plants for instance (pers. comm. P. Scholes, ESR, 2016). However when recorded in high quantities, it is highly likely that the source of FIB is faecal in origin (pers. comm. B Gilpin, ESR, date unknown).

The avian marker GFD detects duck, swan, seagull, geese and chicken faecal sources. No livestock were observed in the catchment so bovine and ruminant markers were not included in the analysis.

The human BacH marker is more sensitive than the BiADO marker, but it has higher non-specificity than the BiADO marker with other animal species such as possum, dog, cat, rabbit, goat and chicken faecal sources. Therefore the BacH marker cannot definitively show the faecal source is human (ESR, 2014). However the BiADO marker persists longer in the environment and is evidence of human (wastewater) contamination because it has low-level non-specificity with other animal markers such as possum, dog and waterfowl markers (pers. comm. P. Scholes, ESR, 2014). Where both BacH and BiADO markers are present, there is a higher level of confidence to conclude that a human source is present (ESR, 2014). For the purpose of this report, results are reported in tables and summarized in the text. Refer to both when interpreting results to ensure a clear understanding of reporting limitations.

2.4.1 Interpreting MST results

The general faecal bacteria indicator (GenBac) results are reported on a semi-quantitative scale from ‘extremely strong positive’ to ‘not detected’ (Table 2-3). Extremely strong positive results indicate recent faecal contamination and conversely very weak positive results indicate an aged or partially treated source, which may have degraded the faecal indicative markers.

All other specific markers are reported as ‘present’, ‘present/not detected’ or ‘not detected’ for each animal marker based on (Table 2-3). In some instances, where a marker has been detected at or below the normal level of detection for reporting, it is noted as ‘(positive)’. If a high GenBac level is present but no specific marker is identified, the samples are interpreted as not consistent with fresh or untreated faeces from the sources tested or may be due to the source being a specific marker not tested for (ESR, 2014).

Table 2-3 Interpretation of the ESR MST results.

Results	Marker type
Extremely strong positive	General faecal marker only
Very strong positive	General faecal marker only
Strong positive	General faecal marker only
Positive	General faecal marker only
Weak positive	General faecal marker only
Very weak positive	General faecal marker only
Present	Specific faecal source detected
Present/ND or (positive)	Weak specific faecal source at the limit of reporting
Not Detected (ND)	Specific faecal source not detected

3.0 Results

3.1 Rainfall

Four of the sampling days (Day 1, 4, 5 and 8) were considered dry weather days, with either no rain or less than 0.5mm in the preceding 48 hours. Days 2, 6, 7 and 9 were subject to some rainfall (up to 5.5mm in the 72 hours preceding sampling) and are therefore likely to have been influenced to some extent by rainfall. There was a significant rainfall event (40mm) in the 24 hours preceding sampling on Day 3, and Days 10 and 11 were subject to considerable rainfall in the 24 hours prior to sampling. These days are considered to be true wet weather sampling days. Day 12 is also considered to have been influenced by rainfall, with 11mm falling in the 48 hours prior to sampling.

Table 3-1 Rainfall records for Waituna @ Huia rain gauge (mm).

Day	Date	Estimated time of sampling	12hr	24hr	48hr	72hr
2015						
Day 1	6/03/2015	9:00	0	0	0	0
Day 2	9/03/2015	11:00	0.5	1.5	6	8.5
Day 3	16/03/2015	16:30	7	41	41	41
Day 4	2/04/2015	7:00	0	0	0	4
2016						
Day 5	29/03/2016	15:00	0	0	0	0.5
Day 6	31/03/2016	16:00	0	0	2.5	2.5
Day 7	5/04/2016	8:00	2	3	3	5.5
Day 8	8/04/2016	11:00	0	0	0	0
Day 9	11/04/2016	12:00	2	3	3	4
Day 10	13/04/2016	14:00	17.5	19	19.5	22
Day 11	18/04/2016	7:00	1	20.5	25.5	25.5
Day 12	20/05/2016	8:30	1.5	2	11	11

Note: Time of sampling for 2015 is unknown. For the purposes of determining rainfall, it has been assumed that sampling was taken at high tide and a time has been provided based on Onehunga tide chart sourced from LINZ. Rainfall is reported as cumulative rainfall in the hours preceding sampling.

3.2 Microbiological sampling results

A total of 129 samples were collected across the three catchments as part of this investigation, consisting of 45 samples in 2015 and 84 in 2016. The following sections summaries the results for each of the individual catchments sampled. Summarised microbiological results for each site are included in Table 7-4 and Table 7-5, Appendix D. Site observations, including salinity, are included in Appendix C and E.

3.2.1 French Bay

A total of 31 samples were collected at French Bay; ten in 2015 and 21 in 2016 (Table 3-2).

Five sites were sampled in the French Bay catchment in 2015, however FB5 recorded no flow for all sampling occasions. Sites FB3 and FB4 flowed only on Day 3, at which point *E. coli* concentrations were 46,000 MPN/100mL (FB3) and 61,000 MPN/100mL (FB4). Day 3 sampling followed a period of heavy rainfall (>40mm) in the preceding 12-24 hours.

In 2015, coastal sites FB1 and FB2 recorded *E. coli* or enterococci results above amber trigger levels on three and two occasions respectively, including during dry weather sampling. Samples taken on Day 1 and Day 2 recorded elevated enterococci in the marine environment despite no evidence of FIB from freshwater inputs recorded.

Three sites were sampled within the French Bay catchment in 2016. FB2, the coastal site, had enterococci concentrations within 'safe' (green) levels for five out of eight days. Days 11 and 12 showed the highest concentrations of enterococci in the marine environment, which were above the red trigger level for action (560 MPN/100mL and 4600 MPN/100mL respectively).

FB3 and FB4 were the only inputs sampled in 2016 and both had high concentrations of FIB. Concentrations of *E. coli* were notably higher following rainfall for FB4, whereas FB3 exceeded red trigger levels on all sampling occasions.

During dry weather site FB3 typically had no flow, while the upstream FB4 had FIB concentrations indicative of 'green' mode. On Day 8, following no rain, FB3 still had high concentrations of both *E coli* (amber) and enterococci (red). This indicates that when there is sufficient water in FB3 to flow, it is contaminated. The coastal environment was typically cleaner, with the majority of sites in the 'green' except for following rainfall on Days 11 and 12.

In general, the freshwater inputs to French Bay frequently exceeded MfE guidelines and are a contributing source of microbiological contamination into the coastal environment.

Table 3-2 Summary microbiological results for French Bay.

Site Name		**FB1**		**FB2**		**FB3**		**FB4**	**FB5**
Site Type		Marine		Marine		Stormwater outfall (intertidal)		Stream	Stream
2015									
FIB Parameter (MPN/100mL)		*E. coli*	Enterococci	*E. coli*	Enterococci	*E. coli*	Enterococci	*E. coli*	*E. coli*
Day 1	06/03/2015	1100	75	1900	86	NF	NF	NF	NF
Day 2	09/03/2015	390	63	420	190	NF	NF	NF	NF
Day 3	16/03/2015	480	830	120	41	46000	>24200	61000	NF
Day 4	02/04/2015	10	50	10	<10	NF	NF	NF	NF
2016									
FIB Parameter (MPN/100mL)				Enterococci		*E. coli*	Enterococci	*E. coli*	*E. coli*
Day 5	29/03/2016	N/A		10		NF	NF	63	N/A
Day 6	31/03/2016	N/A		63		NF	NF	10	N/A
Day 7	5/04/2016	N/A		170		NF	NF	260	N/A
Day 8	8/04/2016	N/A		20		460	480	41	N/A
Day 9	11/04/2016	N/A		10		610	330	1200	N/A
Day 10	13/04/2016	N/A		130		14000	17000	6900	N/A
Day 11	18/04/2016	N/A		560		12000	24000	1600	N/A
Day 12	20/05/2016	N/A		4600		N/A*	7700	2400	N/A

NB: *Lab error meant that *E. coli* was not tested for on this sampling occasion. NF = No flow, no sample taken, N/A = Not assessed, NT = Not tested. Highlighting represents MfE 2003 guidelines trigger levels of green/safe, amber/alert and red/action. Units are MPN/100mL. Refer to Appendix C and E for salinity records for each sampling time.

3.2.2 Titirangi Beach

A total of 40 samples were collected at Titirangi Beach; 16 in 2015 and 24 in 2016 (Table 3-3).

Five sites were targeted within the Titirangi Beach catchment in 2015; however TB4 was not flowing on any of the sampling occasions. Of the sixteen samples collected, three met the 'safe' (green) recreational contact guidelines, one was amber and the remainder were red. TB3 had the highest concentrations of *E. coli* across the sampling period during both wet and dry weather.

Three sites were sampled within the Titirangi Beach catchment in 2016. TB3 exceeded the red trigger level for either *E. coli* or enterococci on all sampling occasions, with a maximum concentration on Day 10 of 39,000 MPN/100mL and 69,000 MPN/100mL, respectively.

The highest concentrations of *E. coli* at TB5 were also recorded on Day 10, being 58,000 MPN/100mL. Days where rainfall exceeded 3mm in the preceding 24 hours were the days with the highest concentrations of FIB. With the exception of TB3 where it exceeded red levels on dry weather sampling days as well. The TB3 site is located at the base of the catchment, where the stream enters the coastal environment and may be subject to a similar flushing/non-flushing regime as Laingholm Beach where sandbanks can build up and restrict regular flushing of water from the stream (Quinn & Neale, in press, 2016). This may account for the generally higher concentration of FIB at the downstream TB3 site when compared to the upstream TB5 site.

The coastal site, TB2, was above red trigger levels for half of the samples taken and was above amber once. The three times when TB2 was in the green mode were associated with little or no rainfall in the preceding 48-72 hours (Days 5, 6, and 8).

Table 3-3 Summary microbiological results for Titirangi Beach.

Site Name		**TB1**		**TB2**		**TB3**		**TB4**	**TB5**
Site Type		Marine		Marine		Stream (intertidal)		Stream	Stream
2015									
FIB Parameter (MPN/100mL)		*E. coli*	Enterococci	*E. coli*	Enterococci	*E. coli*	Enterococci		*E. coli*
Day 1	06/03/2015	1500	960	210	<10	10500	160	NF	10
Day 2	09/03/2015	12000	400	1500	30	19900	NT	NF	960
Day 3	16/03/2015	2400	7700	4400	3900	27000	33000	NF	17300
Day 4	02/04/2015	1100	30	1300	4100	380	NT	NF	110
2016									
FIB Parameter (MPN/100mL)				Enterococci		*E. coli*	Enterococci		*E. coli*
Day 5	29/03/2016	N/A		<10		380	830	N/A	200
Day 6	31/03/2016	N/A		10		340	1900	N/A	20
Day 7	5/04/2016	N/A		470		19900	2900	N/A	100
Day 8	8/04/2016	N/A		98		1200	1200	N/A	670
Day 9	11/04/2016	N/A		150		1400	1800	N/A	98
Day 10	13/04/2016	N/A		710		39000	69000	N/A	58000
Day 11	18/04/2016	N/A		1000		8700	24000	N/A	6500
Day 12	20/05/2016	N/A		1900		1200	1200	N/A	910

NB: No flow = No sample taken, N/A = Not assessed, NT = Not tested . Highlighting represents MfE 2003 guidelines trigger levels of green/safe, amber/alert and red/action. Units are MPN/100mL. Refer to Appendix C and E for salinity records for each sampling time.

3.2.3 Wood Bay

A total of 59 samples were collected at Wood Bay: 19 in 2015 and 40 in 2016 (Table 3-4).

Seven sites were targeted within the Wood Bay catchment in 2015, however WB7 was not flowing on any of the sampling occasions. WB6 was sampled only once and WB3 twice due to no flow at other times.

The highest concentration of FIB was recorded on Day 2 from WB4, with 240,000 MPN/100mL *E. coli*. There had been some rainfall in the previous 24 hours (approximately 1.5mm) for a total of 8mm falling in the preceding 72 hours.

For all other sites, the highest concentrations were recorded from samples taken on Day 3, with WB3 (the Safeswim monitoring site) recording 24,200 MPN/100mL for both *E. coli* and enterococci. Elevated concentrations of FIB were recorded from samples at WB1 on three out of four sampling occasions, including during dry weather.

Five sites were sampled within the Wood Bay catchment in 2016. All freshwater inputs to the marine environment had concentrations of FIB above the recreational contact guidelines the majority of the time. Samples from the two stream sites showed evidence of contamination, with samples from WB6 exceeding the amber recreational contact level on all but one occasion and samples from WB5 all but three. Samples from WB4 (downstream of WB5 and WB6) exceeded the red trigger level seven out of eight times, while WB1 (a stormwater outfall) triggered red five out of eight times for enterococci.

WB3 was the only coastal site sampled in 2016 and samples from this site exceeded the red trigger level on only two occasions, being the wet weather events on Days 10 and 11.

WB1 and the stream (specifically WB4 at the downstream extent of the stream) exhibit the highest FIB for the samples tested and are considered to be key sources of microbial contamination into the coastal environment. WB1 is an outfall based at the downstream extent of a predominantly forested catchment, with some road and residential land use present. WB4 had FIB in the ‘red’ for 10 out of 12 times sampled. Despite this, the coastal environment (specifically WB3), had FIB concentrations in the ‘green’ for all but the three significant rainfall events (Day 3, 10 and 11). The marine environment generally seems cleaner than the other northern Manukau beach catchments, based on the higher concentrations to more significant rainfall events.

Table 3-4 Summary microbiological results for Wood Bay.

Site Name		**WB1**		**WB2**		**WB3**		**WB4**		**WB5**	**WB6**	**WB7**
Site Type		Stormwater Outfall		Marine		Marine		Stormwater Outfall		Stream	Stream	Stream
2015												
FIB Parameter (MPN/100mL)		*E. coli*	Enterococci	*E. coli*	Enterococci	*E. coli*	Enterococci	*E. coli*		*E. coli*	*E. coli*	
Day 1	06/03/2015	1100	10	3700	10	NF	NF	660		75	NT	NF
Day 2	09/03/2015	100	63	410	190	NF	NF	240000		340	NT	NF
Day 3	16/03/2015	280	960	500	430	24200	24200	2400		11200	13000	NF
Day 4	02/04/2015	470	340	6100	1600	98	NF	140		190	NT	NF
2016												
FIB Parameter (MPN/100mL)		*E. coli*	Enterococci			Enterococci		*E. coli*	Enterococci	*E. coli*		
Day 5	29/03/2016	52	160	N/A		30		170	460	520	990	N/A
Day 6	31/03/2016	20	20	N/A		20		73	280	240	400	N/A
Day 7	5/04/2016	10	560	N/A		41		230	1300	280	390	N/A
Day 8	8/04/2016	63	360	N/A		63		6900	6100	240	280	N/A
Day 9	11/04/2016	41	210	N/A		10		5500	20000	2800	860	N/A
Day 10	13/04/2016	860	1400	N/A		510		4600	16000	5200	3300	N/A
Day 11	18/04/2016	250	1200	N/A		380		14000	12000	980	540	N/A
Day 12	20/05/2016	160	430	N/A		20		400	2300	210	140	N/A

NB: N/A = Not assessed, NF = No Flow. Highlighting represents MfE 2003 guidelines trigger levels of green/safe, amber/alert and red/action. Units are MPN/100mL. Refer to Appendix C and E for salinity records for each sampling time.

3.2.4 High FIB in freshwater inputs to the marine environment

For all catchments sampled, the freshwater inputs from both the streams and outfalls into the coastal environment had a higher number of exceedances than the coastal samples during both dry and wet weather. They are considered to be the primary source of microbial contamination into the coastal environment.

All samples taken from freshwater inputs at Titirangi Beach exceeded the recreational contact guidelines, as did the majority of coastal samples. This suggests that the microbial load from the freshwater inputs is sufficiently high or consistent to the concentration of FIB in the coastal environment irrespective of weather conditions.

Wood Bay and French Bay differ from Titirangi Beach: despite regularly high exceedances of FIB within freshwater inputs, an interaction within the coastal environment typically only occurs following rainfall. Based on these results alone, it is hypothesised that during dry weather the microbial load in the freshwater inputs is insufficient to result in increased concentrations in the coastal environment at Wood Bay and French Bay. During wet weather conditions, however, the microbial load appears to increase to sufficient levels that the concentrations in the coastal environment are.

For all three catchments, the wet weather on Day 3 (2015) and Days 10 and 11 (2016) resulted in the highest concentrations of FIB entering the coastal environment from the freshwater inputs.

3.3 Microbial Source Tracking results

Twenty samples from the 2015 sampling round were analysed for microbial source tracking (MST) and 59 from the 2016 sampling round.

A weak positive detection of GenBac was recorded for two of the 2015 samples (WB1 collected on 16/03/2015 and TB2 on 16/03/2015) and, as such, no further testing for specific source markers was undertaken. WB6 (collected 16/03/2015) recorded a very weak positive detection for GenBac, however, this sample was tested for a specific source marker as it was the only sample for this site with sufficiently high faecal indicator bacteria.

For the remaining 76 samples, GenBac was detected as either weak positive (n=1), positive (n=10), strong positive (n=18) or very strong positive (n=47).
Specific source markers were detected in 44 (58%) samples, including canine (n=30), avian (n=24) and human (n=20). For some of these samples, specific markers were detected but at levels below normal reporting levels, including canine and avian in two samples and human in six samples. No specific markers were identified in 32 (42%) of these samples. Note that the total number of detections/ non-detects exceeds the number

of samples collected as multiple markers were identified in the same sample. The key points from the MST analyses for each catchment are described below; the full MST results from ESR are provided in Appendix F. The tables in the following section should be referred to when considering the results to determine the relevant levels of detection for each of the markers and the relevant reporting limitations.

3.3.1 French Bay

A total of 15 samples were analysed for MST at French Bay (2015 n=3, 2016 n=12). Evidence of canine contamination was present in eight samples, human contamination in six samples and avian in two samples. Of the human markers recorded, only one was recorded in the coastal environment, with the remainder present in the freshwater inputs.

Canine markers were recorded within both the freshwater and coastal environments, while the two avian markers recorded were both from samples taken in 2015 and in both marine and freshwater samples.

A specific source marker for results obtained in the 2016 sampling regime could not be identified for six of the 12 samples collected.

Table 3-5 French Bay MST results for sites tested in 2015 and 2016.

Site	Date	*E. coli* (MPN/100mL)	Enterococci (MPN/100mL)	General GenBac	Conclusion
2015					
FB2	6/03/2015	1,900	86	very strong positive	Dog & avian
FB3	16/03/2015	46,000	>24,200	very strong positive	Dog & human (BacH)
FB4	16/03/2015	61,000	-	very strong positive	Dog & human (BacH & BiADO) & avian
2016					
FB2	5/04/2016	-	170	positive	Unidentified
FB2	18/04/2016	-	560	positive	Human (BacH)
FB2	20/05/2016	-	7,700	very strong positive	Dog
FB3	8/04/2016	460	480	positive	Unidentified
FB3	11/04/2016	610	330	positive	Possible dog*
FB3	13/04/2016	14,000	17,000	strong positive	Dog, possible human*
FB3	18/04/2016	12,000	24,000	strong positive	Unidentified
FB3	20/05/2016	400	4,600	weak positive	Unidentified
FB4	11/04/2016	1,200	-	very strong positive	Unidentified
FB4	13/04/2016	6,900	-	strong positive	Dog, possible human*
FB4	18/04/2016	1,600	-	strong positive	Unidentified
FB4	20/05/2016	2,400		very strong positive	Dog & human (BacH)

Notes: * 'possible' source noted where marker present but below normal reporting levels. Refer to section 2.4.1 for detail about interpretation of results and Appendix F for full MST results.

3.3.2 Titirangi Beach

A total of 26 samples were analysed for MST at Titirangi Beach (2015 N=8, 2016 N=18). Canine (n=11) and avian markers (n=13) were most common with human markers recorded in eight samples. Human markers were detected in freshwater inputs in both 2015 and 2016. On only one occasion were human markers detected in the coastal environment (Day 11), when they were also present in the freshwater input at TB3, but not the upstream site – TB5.

Dog and avian markers were detected in both freshwater and marine waters. An additional two human and two canine markers were recorded as present but below the levels of reporting. Seven samples recorded a positive (or higher) detection of GenBac, but revealed no specific source markers.

Table 3-6 Titirangi Beach MST results for sites tested in 2015 and 2016.

Site	Date	*E. coli* (MPN/100mL)	Enterococci (MPN/100mL)	General GenBac	Conclusion
2015					
TB2	9/03/2015	1,500	30	very strong positive	Avian
TB2	16/03/2015	4,400	3,900	weak positive	Specific source not tested for[1]
TB2	2/04/2015	13,000	4,100	very strong positive	Dog & avian
TB3	6/03/2015	10,500	NA	very strong positive	Avian
TB3	9/03/2015	19,900	NA	very strong positive	Dog, avian & human (BacH)
TB3	16/03/2015	27,000	33,000	very strong positive	Dog & human (BacH* & BiADO)
TB5	9/03/2015	960	NA	very strong positive	Unidentified
TB5	16/03/2015	17,300	-	very strong positive	Dog & human (BacH & BiADO)
2016					
TB2	5/04/2016	-	470	very strong positive	Dog & avian
TB2	11/04/2016	-	150	very strong positive	Unidentified
TB2	13/04/2016	-	710	positive	Unidentified
TB2	18/04/2016	-	1,000	very strong positive	Human (BacH & BiADO*) & dog & avian
TB2	20/05/2016	-	1,900	strong positive	Unidentified
TB3	29/03/2016	380	830	very strong positive	Unidentified

Site	Date	*E. coli* (MPN/100mL)	Enterococci (MPN/100mL)	General GenBac	Conclusion
TB3	29/03/2016	380	830	strong positive	Unidentified
TB3	31/03/2016	340	1,900	very strong positive	Avian
TB3	5/04/2016	19,900	2,900	very strong positive	Dog & avian
TB3	8/04/2016	1,200	1,200	strong positive	Dog
TB3	11/04/2016	1,400	1,800	strong positive	Possible avian*
TB3	13/04/2016	39,000	69,000	very strong positive	Possibl e
TB3	18/04/2016	8,700	24,000	very strong positive	Human (BacH & BiADO*) & dog
TB3	20/05/2016	1,200	1,200	very strong positive	Dog & avian
TB5	8/04/2016	670	-	very strong positive	Possible avian*
TB5	13/04/2016	58,000	-	very strong positive	Human (BacH & BiADO)
TB5	18/04/2016	6,500	-	very strong positive	Dog, possible human*
TB5	20/05/2016	910	-	strong positive	Unidentified

Notes: [1]Based on a weak positive GenBac detection, further specific source markers were not tested for. *Source noted where marker present but below normal reporting levels. Refer to section 2.4.1 for detail about interpretation of results and Appendix F for full MST results.

3.3.3 Wood Bay

A total of 38 samples were analysed for MST at Wood Bay (2015 n=9, 2016 n=29).

Dog (n=10) and avian (n=9) markers were detected in the freshwater input samples from sites WB4, WB5 and WB6 and were also detected in the marine environment downstream of the discharge point, WB3.

Human markers were detected in six samples, all from 2015 samples in the freshwater inputs and at the marine site immediately downstream of the stream discharge point during a wet weather event. MST evidence points to the presence of human wastewater contamination within the freshwater environment and requires further investigation.

WB1 has high faecal indicator bacteria, clearly coming from within a stormwater pipe, but the actual source of contamination is unknown. Despite having consistently elevated faecal indicator bacteria concentrations, a specific source marker was not identified for the majority of the samples tested from WB1. Across both sample years, only one of the ten samples detected a specific marker, which was dog. The FIB does not appear to be related to a cross connection from the pump station or wastewater pipes as no human markers were recorded at WB1 in 2015 or 2016.

The MST results for Wood Bay were generally inconclusive, with the majority of samples indicative of at least a strong presence of GenBac but no specific marker identified. It is understood that there is no wastewater producing industry within the catchment, so it is anticipated that the FIB is related to either green waste, a specific source not tested for or aged faecal sources.

Table 3-7 Wood Bay MST results for sites tested in 2015 and 2016.

Site	Date	*E. coli* (MPN/100mL)	Enterococci (MPN/100mL)	General GenBac	Conclusion
2015					
WB1	6/03/2015	1,100	10	strong positive	Dog
WB1	16/03/2015	280	960	weak positive	Specific source not tested for[1]
WB1	2/04/2015	470	340	strong positive	Unidentified[2]
WB3	16/03/2015	>24200	>24200	very strong positive	Dog & human (BacH)
WB4	6/03/2015	660	NA	very strong positive	Human (BacH)
WB4	9/03/2015	240,000	NA	very strong positive	Dog & avian
WB4	16/03/2015	24,000	-	very strong positive	Dog & human (BacH & BiADO)
WB5	16/03/2015	11,200	-	very strong positive	Dog & human (BacH & BiADO)
WB6	16/03/2015	13,000	-	very weak positive	Unidentified
2016					
WB1	29/03/2016	52	160	positive	Unidentified
WB1	5/04/2016	10	560	positive	Unidentified
WB1	8/04/2016	63	360	strong positive	Unidentified
WB1	11/04/2016	41	210	positive	Unidentified
WB1	13/04/2016	860	1,400	strong positive	Unidentified
WB1	18/04/2016	250	1,200	positive	Unidentified
WB1	20/05/2016	160	430	positive	Unidentified
WB3	13/04/2016	-	510	very strong positive	Dog & avian, possible human*
WB3	18/04/2016	-	380	very strong positive	Avian & dog*
WB4	29/03/2016	170	460	strong positive	Unidentified
WB4	31/03/2016	73	280	very strong positive	Unidentified
WB4	5/04/2016	230	1,300	strong positive	Unidentified
WB4	8/04/2016	6,900	6,100	strong positive	Avian
WB4	11/04/2016	5,500	20,000	very strong positive	Avian
WB4	13/04/2016	4,600	16,000	very strong positive	Dog
WB4	18/04/2016	14,000	12,000	very strong positive	Possible avian*
WB4	20/05/2016	400	2,300	strong positive	Unidentified
WB5	29/03/2016	520	-	very strong positive	Avian
WB5	5/04/2016	280	-	strong positive	Unidentified
WB5	11/04/2016	2,800	-	very strong positive	Avian

Site	Date	*E. coli* (MPN/100mL)	Enterococci (MPN/100mL)	General GenBac	Conclusion
WB5	13/04/2016	5,200	-	very strong positive	Dog
WB5	18/04/2016	980	-	very strong positive	Avian
WB6	29/03/2016	990	-	very strong positive	Unidentified
WB6	31/03/2016	400	-	very strong positive	Unidentified
WB6	5/04/2016	390	-	very strong positive	Dog
WB6	8/04/2016	280	-	very strong positive	Unidentified
WB6	11/04/2016	860	-	very strong positive	Unidentified
WB6	13/04/2016	3,300	-	very strong positive	Possible human*
WB6	18/04/2016	540	-	very strong positive	Unidentified

Notes: [1]Based on a weak positive GenBac detection, further specific source markers were not tested for.[2]This sample was compromised and when received at ESR there was no GITC buffer in container as the lid was loose and contents had leaked, which may explain why no markers were identified. *Source noted where marker present but below normal reporting levels. Refer to section 2.4.1 for detail about interpretation of results and Appendix F for full MST results.

3.3.4 Human, canine or avian markers identified in all catchments

Dog, avian and human contamination was present in all catchments across the sampling period (Table 3-8). Human contamination was recorded at a higher frequency during wet weather compared with dry weather. The distinction between wet and dry weather for avian and canine markers was less obvious.

Within French Bay and Wood Bay, canine markers were the most frequently detected (n=8 and n=10 respectively). Avian markers (n=13) were detected most frequently in samples from Titirangi Beach catchment, followed closely by canine markers (n=11). Human markers were detected 20 times across samples from all catchments,

Table 3-8 Summary table for MST results for all sites.

Beach	No. of samples	Human	Canine	Avian	Unidentified
French Bay	15	6	8	2	6
Titirangi Beach	26	8	11	13	7
Wood Bay	38	6	10	9	19
Totals*	79	20 (25%)	29 (37%)	24 (30%)	32 (41%)

Note: The numbers within the human, canine, avian and unidentified column exceed the total number of samples collected as some samples detected multiple markers. *The (x%) refers to the proportion of total samples that detected each marker and exceeds 100% as some samples detected multiple markers.

Table 3-9 Summary table for detection versus non-detection of specific source markers for all sites.

Beach	2015			2016		
	Detects	Non-detects	% detection	Detects	Non-detects	% detection
French Bay	3	0	100%	6	6	50%
Titirangi Beach	6	1	86%	12	6	67%
Wood Bay	6	1	86%	12	17	41%
Totals	15	2	88%	30	29	51%

A greater proportion of samples collected in 2015 (88%) had source specific markers identified than 2016 (51%) (Table 3-9). This was particularly notable in Wood Bay where only 41% of the samples taken in 2016 had a specific source marker identified. This was despite detection of the GenBac marker in both years at a high frequency: positive or higher in 85% of samples in 2015 and 98% in 2016 (Table 3-10). There is a correlation between strength of GenBac signal and likelihood of a specific marker being detected. Those samples with a 'very strong positive' GenBac signal were more likely to also have an identified source marker. When comparing median FIB concentrations against each GenBac strength, there does not appear to be a correlation between FIB concentration and strength detected (Table 3-10).

Table 3-10 Summary table for strength of detection of GenBac for each sample year. Median values for each parameter are included for comparison.

General GenBac strength	2015	Median Concentration *E. coli* (Enterococci)	2016	Median Concentration *E. coli* (Enterococci)
very weak positive	1	*1,300* (N/A)	0	-
weak positive	2	*2,340* (2,430)	1	*400* (4,600)
positive	0	-	10	*160* (455)
strong positive	2	*175* (785)	16	*910* (1,600)
very strong positive	15	*15,150* (14,150)	32	*1,200* (1,550)

Table 3-11 Summary table for FIB parameters associated with samples tested for MST.

	2015		2016	
	E.coli	Enterococci	*E.coli*	Enterococci
Mean	25,919	9,083	4,653	5,805
Median	12,100	2,430	860	1,200
Minimum	280	10	10	150
Maximum	240,000	33,000	58,000	69,000

In addition, the concentration of FIB between sampling years was not markedly different, based on the range (minimum v maximum) of FIB measured (Table 3-11). The mean and median measures are lower in 2016 than 2015, which is in part a function of samples in the ‘amber’ trigger level included for MST analysis in 2016, whereas only ‘red’ samples were tested in 2015. While the amber results may have influenced the mean and median, of those samples where only an ‘amber’ level triggered MST analysis (n=10), GenBac was detected as either positive (n=3), strong positive (n=1), or very strong positive (n=6) and specific markers were detected in two of these (canine and avian).

3.4 Wind

Faecal indicator bacteria can reside and potentially replicate in coastal sediments. Winds and wave action can influence the concentration of FIB within the water column through resuspension of sediments (see for example Pachepsky and Shelton, 2011; Roslev et al., 2008; Townsend et al., 2006; Le Fevre and Lewis, 2003).

Of the samples taken during this investigation only two are considered to be potentially affected by wind/resuspension. The sites where wind may be a contributing factor are those where the coastal environment exhibits high FIB while the freshwater environment does not. During this investigation, there were very few occurrences when the marine environment was more contaminated than the freshwater or stormwater outfall inputs.

Samples taken from the two coastal sites in French Bay on Days 1 and 2 had elevated *E. coli* despite no flow recorded (and subsequently no samples taken) within the freshwater inputs. Wind direction was different on the two days (Table 3-12) and, as such, is insufficient to provide statistical significance in regards to the potential for sediment resuspension within the marine environment.

Table 3-12 Wind data records for Cornwallis Point weather station.

	Date	Estimated time of sampling	Mean degrees	Prevailing direction	Mean speed (m/s)
2015					
Day 1	6/03/2015	9:00	30	NNE	2.6
Day 2	9/03/2015	11:00	238	SW	2.21
Day 3	16/03/2015	16:30	245	WSW	4.8
Day 4	2/04/2015	7:00	303	NW	1.04
2016					
Day 5	29/03/2016	15:00	245	WSW	3.87
Day 6	31/03/2016	16:00	68	ENE	3.25
Day 7	5/04/2016	8:00	181	S	1.52
Day 8	8/04/2016	11:00	181	S	1.82
Day 9	11/04/2016	12:00	167	SSE	0.82
Day 10	13/04/2016	14:00	216	SW	2.60
Day 11	18/04/2016	7:00	214	SW	3.3
Day 12	20/05/2016	8:30	295	WNW	1.85

Notes: Time of sampling for 2015 is unknown. For the purposes of determining prevailing wind, it has been assumed that sampling was taken at high tide and a time has been provided based on Onehunga tide chart sourced from LINZ. Wind is calculated as the mean degrees in the 4 hours prior to sampling and a prevailing direction determined based on this.

4.0 Discussion

Monitoring results from the Auckland Council Safeswim programme have demonstrated long-term elevated levels of faecal indicator bacteria over summer months in French Bay, Titirangi Beach and Wood Bay in the northern Manukau Harbour. This investigation has expanded upon the regularly undertaken Safeswim monitoring programme through the inclusion of additional freshwater input sampling sites and supplementary MST analysis to provide more information about the potential sources (locations and animal origins) of contamination within each catchment.

While there are some engineered wastewater overflow locations in each of these catchments, there are no known records of overflows occurring and for several of these, the overflow location is reported to be permanently sealed.

This short-term investigation assessed the microbial water quality in the coastal and freshwater environments at French Bay, Titirangi Beach and Wood Bay, with commonly used faecal indicator bacteria which are used to indicate the level of public health risk. Additional faecal microbial source tracking was used to determine the biological source of the bacteria. The water quality of the coastal environment and freshwater inputs (streams and stormwater pipes) was investigated during both wet and dry weather conditions over twelve sampling occasions during late summer in 2015 and 2016.

4.1 Freshwater inputs are chronically contaminated in all catchments

The freshwater inputs to all catchments exhibited high levels of FIB during wet and dry weather conditions and are considered to be chronically contaminated over this period (March-April).

Of particular note, the freshwater inputs to Titirangi Beach and Wood Bay exhibited elevated FIB for all samples taken, including those collected during dry weather. This means that despite the amount of rainfall streams and stormwater outfalls (the freshwater inputs) exceeded recreational contact guidelines the majority of the time during this investigation.

Human, dog, and avian markers were recorded at least once within the freshwater sampling sites. Of the 79 samples tested for MST (within freshwater and coastal sites), human markers were recorded in 20 samples, canine markers in 29 samples, and avian in 42 samples. For some of these samples, the level of detection was below normal reporting levels, however for the purposes of this report, their inclusion is considered appropriate.

Although the MST results between years are not entirely consistent, it is clear that there is a general exceedance of FIB. This indicates that faecal contamination of the freshwater inputs requires some targeted management interventions.

4.2 Contamination in French Bay and Wood Bay is linked to rainfall

Even when the freshwater inputs exhibited high levels of FIB, the coastal environment displayed typically lower FIB (green mode) during dry weather. Higher levels of FIB within the coastal environment were linked to rainfall events across all catchments; this was most obvious within French Bay and Wood Bay.

The range of rainfall volumes means that statistical analysis has not been undertaken to determine the statistical correlation between the volumetric amount of rainfall and FIB concentration. This is mainly due to the influence that unusual results (outliers) can have on the analysis. For instance, samples taken on Day 8 (following no rain in the preceding 72 hours) revealed elevated FIB (into red mode) for the freshwater inputs across all catchments. Day 7 and 9 had very similar rainfall in the days preceding sampling, however samples taken from WB4 on these dates had quite different enterococci results (1300 MPN/100mL and 20,000 MPN/100mL respectively). A small amount of rain prior to Day 2 sampling resulted in an *E. coli* concentration of 240,000 MPN/100mL (at WB4) which was the highest FIB concentration recorded.

Re-suspension of sediments in the coastal environment has been known to contribute to high faecal indicator bacteria. There was no evidence, however, to conclude that this occurs at the beaches in this study. Specifically, of the 129 samples taken, only two of the samples had a high concentration of FIB in the marine environment at the same time as low concentrations of FIB in the freshwater inputs. For all other samples, high concentrations of FIB in the marine environment occur at the same time as high concentrations of FIB in the freshwater inputs.

Rainfall in the 12-48 hours preceding sampling resulted in an increase in the concentration of FIB contamination within the marine environment, particularly in French Bay and Wood Bay. Specific information regarding the time of concentration within each catchment and the actual rainfall within each catchment, rather than relying on a single rain gauge, may provide greater resolution to these data.

4.3 Reduced number of source specific markers in 2016

The return rate of host-specific markers was higher in 2015 (15 of 17) than in 2016 (30 of 59). The reasons for this are unknown, potential causes of this are worthy of discussion. Despite indications that a faecal source is present (based on the presence of GenBac), many of the samples did not identify a specific source marker. GenBac is a general faecal marker and indicates the presence of Bacteroidales, which is the dominant microflora in warm blooded animals. As they are anaerobes, they cannot persist in the wider environment for long periods. However, the presence of Bacteroidales is not a definitive indicator of a faecal source. There can be several reasons for its presence without identification of specific faecal source markers. For instance, Bacteroidales has been found in processing wastewater from industrial discharges (pers. comm. P. Scholes, ESR, 2016). No such industry exists in these catchments, however.

Filtered, frozen samples can be stored for a maximum of six months without considerable loss of PCR signal (Gilpin et al, 2013). The samples collected in 2015 were stored for just over twelve months. To address the uncertainty regarding sample integrity, an initial test for only GenBac was undertaken. There was no issue with detection of GenBac in 2015 samples, which indicates that storage of samples in excess of six months can still provide viable results.

A change in lab process could also contribute to the change in the detection rate of specific markers. The same laboratories were utilised on both sampling occasions and the samples were processed and stored in the same way. As such, it is considered that change in lab process is not likely to be a factor in the different results.

There may have been a change within the subject catchments where the source of potential contamination has changed between sampling years. There have been no specific changes within the subject northern Manukau beach catchments in regards to network improvements or changes to land use that might influence the results.

Where GenBac was detected as ‘very strongly positive’, source specific markers were more likely to be detected. Given the generally high qualitative results for MST (including ‘strong positive’ and ‘positive’ detections for GenBac), it is hypothesised that the most likely reason for the reduced detection rate of a specific source is that these samples are indicative of either an aged faecal source or the result of faecal inputs from a non-tested for source marker (i.e. pig, possum). In the nearby Laingholm catchment, evidence of pig activity in the upper forested catchment was observed (pers. obs., J Quinn, Golder Associates (NZ) Limited, 2016), which may contribute to elevated FIB concentrations.

A study undertaken by Schriewer et al (2010) found that samples that tested negative for human Bacteroidales were accurate 92% of the time (i.e. there were very few false negatives). Based on this return rate, we can be cautiously confident that the source of contamination is not one of the human markers tested in this study.

Notwithstanding the reduction in the MST detection rate between 2015 and 2016, Safeswim monitoring indicated that the levels of faecal indicator bacteria in the coastal environment are a risk to public health at certain times. Further, during this investigation, FIB levels in all freshwater inputs were determined to be sufficiently high to be considered chronically contaminated over the period of this study. The results of this investigation provide evidence that management interventions need to focus on the land-based discharges to address the marine based health risk.

5.0 Conclusions

This investigation revealed that the freshwater inputs to each of the catchments are contaminated and the source of contamination is from multiple sources.

1. For all catchments, the freshwater inputs (both streams and stormwater pipes) entering the coastal environment exhibit high concentrations of FIB during dry and wet weather.
2. FIB contamination of the coastal environment is exacerbated during wet weather (particularly French Bay and Wood Bay) when concentrations of FIB increase, despite high levels of contamination present in the freshwater environments during dry weather as well.
3. Titirangi Beach was the most contaminated of the sites, with the highest number of exceedances of recreational contact guidelines during sampling, including during dry weather.
4. Human, canine and avian sources of contamination were present within all catchments within the freshwater inputs and the coastal environment.
5. Given that the general microbiological water quality of the Manukau Harbour is good (Walker and Vaughan 2013), it is considered that land-based contamination, through freshwater inputs, is likely to be the primary driver of the poor microbiological quality of the water at each of the northern Manukau beaches.

6.0 Recommendations

Auckland Council is responsible for managing discharges to water under the Resource Management Act 1991 (s30) and health risks under the Health Act 1956 (s23). Where a human faecal source (wastewater) is polluting stormwater, Council is obligated to remedy this so that adverse effects on the environment and public health are minimised or eliminated. To better manage the faecal contamination of the northern Manukau beaches and to address the current public health risk, a range of recommendations are presented.

- Further investigations should be prioritised based on the presence of faecal contamination, exceedances of the recreational contact guidelines, and beaches with the highest recreational use. Discussions with Auckland Council Parks should be undertaken to determine whether this information is readily available or whether surveys are required to determine frequency of use of each beach. Based on the microbiological water quality data alone in this study, it is considered that Titirangi Beach is a priority.
- Undertake a streamwalk type survey of the streams within each catchment to their headwaters to document every input into the stream and identify potential sources of human wastewater contamination. This survey should specifically look to isolate potential sewage fungus or pipes flowing during dry weather. This would be a starting point to determine if there are cross connections or leaking pipes and may lead to additional, more targeted sampling of these inputs.
    - Based on overland flow path layers on Auckland Council GIS, this is expected to be approximately 1.5km to 2km for Titirangi Beach, 0.6km for French Bay, and 0.7km for Wood Bay.
- Undertake an investigation of the Wood Bay WB1 outfall and upstream stormwater network to better understand the potential sources of regularly high FIB. Based on aerial imagery and contours, it is possible that the stormwater network may be stream fed from within the north eastern Takahe Reserve. The section of upstream catchment is not identified as an overland flow path or stormwater network, however the forested area appears to be approximately 400m in length, and may be the source of some contamination.
- Inspect the known wastewater overflow locations to determine whether there is any evidence of overflow and to confirm the integrity of the seal for those that are sealed. Overflow # 1206 located within the upper Titirangi Beach catchment should be a priority for inspection.

- Determine whether there are any septic tanks within the catchments, particularly those that may be located within proximity of the streams. This information may be available from Watercare, LIM reports for properties, or may require a house-to-house survey.
- Investigate whether any network improvement measures or changes within the catchment may have contributed to a change in the sources of contamination within the catchments.
- Investigate options for improving dog and bird control at the beach and local reserves, including encouraging dog owners to pick-up after their dogs and discouraging bird feeding. Rubbish bins and signage outlining the implications for water quality may be necessary.

7.0 References

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Appendix A: Recreational Water Quality Guidelines

Bathing beach monitoring has been undertaken at the subject beaches according to the Ministry for the Environment (MfE) and Ministry of Health (MoH) national guidelines (MfE/MoH 2003). Table 7-1 below shows the national guideline trigger levels for each mode of the traffic light system. Amber and red exceedances require re-tests until results return to the green/surveillance mode. Red/action exceedances require public health warning signs to be erected until results return to the green/surveillance mode.

Table 7-1 Seawater trigger levels from the national guidelines

Enterococci MPN /100mL	Mode
Single sample ≤140	Green/Safe – Continue routine monitoring
Single sample >140	Amber/Alert – Daily sampling required until results return to green/safe
Two samples >280	Red/Action – Daily sampling required until results return to green/safe Erect warning signs after two consecutive samples >280

Table 7-2 below shows the national guidelines trigger levels for each mode for freshwater, which in this case have been applied to streams and stormwater discharges. Amber and red exceedances require re-tests until results return to the green/safe mode. One red/action exceedance requires public health warning signs to be erected until results return to the green/surveillance mode.

Table 7-2 Freshwater trigger levels from the national guidelines

Freshwater (*E. coli* /100mL)	Mode
Single sample ≤ 260	Green/Safe – Continue with routine sampling.
Single sample > 260 ≤ 550	Amber/Alert – Sampling increased to daily.
Single sample > 550	Red/Action – Sampling continues daily until levels return to green/safe mode. Council places warning signage.

Under the national guidelines the last five years of results (100 data points) can be used to generate a Microbiological Assessment Category (MAC) (Table 7-3). This was calculated to aid in the understanding of the historic coastal water quality results for Titirangi Beach, French Bay and Wood Bay.

Table A-1 Microbiological Assessment Category ranges for seawater (using hazen percentile calculations)

A	Sample 95th percentile ≤ 40 enterococci/100 mL
B	Sample 95th percentile 41-200 enterococci/100 mL
C	Sample 95th percentile 201-500 enterococci/100 mL
D	Sample 95th percentile > 500 enterococci/100 mL

Source: (MfE/MoH 2003)

Appendix B: Site photographs

<table>
<tr><th colspan="2">French Bay</th></tr>
<tr><td>
FB2</td><td>
FB4</td></tr>
</table>

NB: no photo for site FB3.

Titirangi Beach	
 TB2	 TB3
 TB5	

Wood Bay	
 WB1	 WB3
 WB4	 WB5
 *WB6*	

Appendix C 2016 Site observations

Date	29-Mar-16		**High Tide Time**	15:00			**Weather conditions**	Clear and sunny
Site Name	**Sampling Time**	**Water Colour and clarity**	**Conductivity (ms/cm^c)**	**Salinity (ppt)**	**Temp (ºC)**	**Odour**	**Evidence of pipe flows?**	**Additional notes**
TB3	15:20	Slightly cloudy, not concerning. Organic matter in bed of stream.	41	26	23	None	None obvious	Site immediately downstream of bridge. Fish in stream. 10x pied stilts, 2 gull and 10 ducks on beach downstream and grass lawn surrounding. Stream trickling out to beach but effectively ponded/isolated. ~10 people on beach and in water. Dog ran into stream immediately following sampling.
TB2	15:30	Clear	N/A	N/A	N/A	None	None obvious	13-20 people in on beach, birds as per TB3 on beach and lawn. Following sampling a dog ran into the water.
TB5	15:15	Brown water (tannins?), slightly turbid	0.85	0.42	17.8	None	None obvious	Some small fish in stream. Organic matter in stream/on stream bed. Riparian vege native and exotic, mown grass on TRB
FB4	14:55	Clear	0.385	0.19	17.88	None	None visible	D/s of bridge. Vege native. Beside road. Pool sampled from isolated. Small drain from residential property d/s on TLB. No flow at time of sampling.
FB2	14:45	Clear	N/A	N/A	N/A	none	None obvious	~30 - 50 people on beach and swimming.
FB3	-	-	-	-	-	-	-	Could not sample. No flow at outlet. No pooled water easily accessible. Sand build up to outlet.
WB6	14:30	Clear	0.344	0.16	17.4	None	None visible.	D/s of ww pipe bridge (according to GIS) - pipe bridge in good condition, no evidence of leaks. Native bush residential land use. Pool isolated, debris jam downstream. Trickle flow. Dog barking nearby.
WB1	13:51	Clear	0.259	0.12	19.79	None	Sample collected from flow from pipe outlet.	Water from pipe clear, piped outfall, trickling when sampling. Green algae build up, shells approx. 30cm up pipe indicating possible tidal influence.
WB3	13:40	Brown, turbid, incoming tide	N/A	N/A	N/A	none	outflow from sample locations WB1 and 4	Approx. 100 pied stilts and 4 gulls on beach. ~12 gulls in water. New pump station and old pump station building on reserve area. <10 people at beach during sampling time.
WB4	14:00	Clear	0.75	0.35	19	None	sampling from a submerged outfall	Standing water in outfall submerged. Deep at back (sampling taken ~1m up the pipe using mighty gripper. Banked up by sand at the mouth. Leaf litter and shells in water.
WB5	14:15	Murky, water trickly down pool, stable, not stagnant	0.39	0.19	18	Smell of wastewater in air. Definitely more prominent along water's edge. Could smell for ~50m when walking alongside stream	none visible	Pool d/s of small trib channel. Tradescantia on bank. Native vege and shaded.

Date	31-Mar-16		High Tide Time	16:35			Weather conditions	Overcast and sunny
Site Name	**Sampling Time**	**Water Colour and clarity**	**Conductivity (ms/cm^c)**	**Salinity (ppt)**	**Temp (ºC)**	**Odour**	**Evidence of pipe flows?**	**Additional notes**
TB3	16:45	Clear water that is slightly brown. Organic matter in bed of stream.	51.64	34.15	21.6	None	None obvious	Site immediately downstream of bridge. Inanga in stream. 10 ducks on beach downstream and grass lawn surrounding. Stream trickling out to beach but effectively ponded/isolated. ~10 people on beach and in water.
TB2	16:50	Clear	N/A	N/A	N/A	none	none obvious	1 person on beach, 15 pied stilts, 5 seagulls and two ducks on beach and lawn.
TB5	16:35	Milky brown water, turbid.	1.137	0.57	16.8	None	None obvious	Organic matter in stream/on stream bed. Riparian vege native and exotic, mown grass on TRB. Two dogs, 2 adults nearby walking of footpath next to stream
FB4	16:15	Clear	0.782	0.38	17.25	None	None visible.	D/s of bridge. Vege native. Beside road. Pool sampled from isolated. People walking nearby and 3 children watching sampling. Small drain from residential property d/s on TLB ~28mm. No flow at time of sampling.
FB2	16:10	Clear	N/A	N/A	N/A	none	none obvious	5 people on beach and 2 swimming. 2 seagulls, overhanging café over the water at end of beach.
FB3	-	-	-	-	-	-	-	Could not sample. No flow at outlet. No pooled water easily accessible. Sand build up to outlet.
WB6	15:26	Clear	0.673	0.33	16.68	None	None visible.	D/s of ww pipe bridge (according to GIS) - pipe bridge in good condition, no evidence of leaks. Native bush residential land use. Pool isolated, debris jam downstream. Trickle flow.
WB1	15:45	Clear	0.522	0.25	19.05	None	Sample collected from flow from pipe outlet.	Water from pipe clear, piped outfall, trickling when sampling. Green algae build up and brown algae at base of flow, shells approx. 30cm up pipe indicating possible tidal influence.
WB3	16:00	Brown, turbid, incoming tide	N/A	N/A	N/A	none	outflow from sample locations WB1 and 4	Approx. 100 pied stilts, 20 ducks, and 7 gulls on beach. New pump station and old pump station building on reserve area. 1 person at beach during sampling time.
WB4	15:50	Clear	1.484	0.75	18.02	None	sampling from a submerged outfall	Standing water in outfall submerged. Deep at back (sampling taken ~1m up the pipe using mighty gripper. Banked up by sand at the mouth. Leaf litter and shells in water. 1 person at picnic table nearby
WB5	15:35	murky, water trickly down pool, stable, not stagnant	0.79	0.39	16.99	Faint Smell of wastewater in air.	none visible	Pool d/s of small trib channel. Tradescantia on bank. Native vege and shaded.

Date	5-Apr-16		High Tide Time	8:38			Weather conditions	Clear and sunny
Site Name	**Sampling Time**	**Water Colour and clarity**	**Conductivity (ms/cm^c)**	**Salinity (ppt)**	**Temp (°C)**	**Odour**	**Evidence of pipe flows?**	**Additional notes**
TB3	8:38	Brown and highly turbid water	93.37	65.14	17.8	Strong Sulphurous smell	None obvious	Site immediately downstream of bridge. Three people nearby and 10 ducks in playground. Lots of debris and sea scum floating in the stream. Connected to the sea, was not previously.
TB2	8:45	Brown, highly turbid but incoming tide	N/A	N/A	N/A	none	none obvious	3 people nearby and 20 ducks, 2 gulls in water.
TB5	8:35	Stained brown water but clear	0.598	0.29	16.2	None	None obvious	Organic matter in stream/on stream bed. Riparian vege native and exotic, mown grass on TRB. Lots of birds flying overhead
FB4	8:17	Clear	0.643	0.31	16.77	None	Small drain from residential property d/s on TLB ~28mm. Small trickle at time of sampling	D/s of bridge. Vege native. Beside road. Pool sampled from isolated.
FB2	8:08	Clear, slightly turbid, incoming tide.	N/A	N/A	N/A	none	none obvious	3 people on beach overhanging café over the water at end of beach.
FB3		-	-	-	-	-	-	Did not sample.
WB6	8:00	Clear	0.613	0.3	15.96	None	None visible.	D/s of ww pipe bridge (according to GIS) - pipe bridge in good condition, no evidence of leaks. Native bush residential land use. Pool isolated, debris jam downstream. Trickle flow.
WB1	7:32	Clear	0.591	0.29	18.3	None	Sample collected from flow from pipe outlet.	Water from pipe clear, piped outfall, trickling when sampling. Green algae build up and brown algae at base of flow, shells approx. 30cm up pipe indicating possible tidal influence. Higher flows than last time.
WB3	7:25	Brown, turbid, incoming tide	N/A	N/A	N/A	none	outflow from sample locations WB1 and 4	Approx. 100 pied stilts, 15 ducks, and 1 person and a dog on beach. New pump station and old pump station building on reserve area.
WB4	7:38	Clear	0.971	0.46	17.17	None	sampling from a submerged outfall	Standing water in outfall submerged. Flowing halfway out to beach, a lot more water than previous. Deep at back (sampling taken ~1m up the pipe using mighty gripper. Banked up by sand at the mouth. Leaf litter and shells in water. 10 ducks, 100 stilts nearby.
WB5	7:48	Clear, slightly brown	0.713	0.35	16.2	No odour	none visible	Pool d/s of small trib channel. Tradescantia on bank. Native vege and shaded.

Date	8-Apr-16		High Tide Time	11:10		Weather conditions	Overcast and slight rain	
Site Name	**Sampling Time**	**Water Colour and clarity**	**Conductivity (ms/cm^c)**	**Salinity (ppt)**	**Temp (ºC)**	**Odour**	**Evidence of pipe flows?**	**Additional notes**
TB3	11:25	Clear, slightly turbid, incoming tide.	N/A - area was inundated with incoming high tide	N/A	N/A	Strong Sulphurous smell	None obvious	Site immediately downstream of bridge. 8 people nearby, 5 ducks and 2 birds in playground. Lots of debris and sea scum floating in the stream. Slight rain. Water is extremely high, almost overtopping bridge. Large spring tide.
TB2	11:30	Clear, slightly turbid	N/A	N/A	N/A	none	none obvious	2 people near water and 10 ducks, 2 gulls in water. Very high tide with slight rain.
TB5	11:20	Brown, slightly turbid	31.36	19.6	16.47	None	None obvious	Organic matter in stream/on stream bed. Riparian vege native and exotic, mown grass on TRB. Lots of birds flying overhead. Water level higher than previously.
FB4	11:10		0.334	0.16	15.78	None	Small drain from residential property d/s on TLB ~28mm. No flow at time of sampling	D/s of bridge. Vege native. Beside road. Pool sampled from isolated.
FB2	10:55	Clear, slightly turbid 0.5 m from beach, incoming tide.	N/A	N/A	N/A	none	none obvious	11 people on beach, 5 people sailing, 5 seagulls. Overhanging café over the water at end of beach. Slight rain
FB3	11:00	Clear	N/A - Inundated by high tide	N/A	N/A	None	1 inflow to the right of the outflow, completely inundated by high tide.	Sampled although pipe was completely inundated by high tide so results will be saline. Lots of organic matter. 2 people nearby.
WB6	10:45	Clear	0.298	0.14	15.1	None	None visible.	D/s of ww pipe bridge (according to GIS) - pipe bridge in good condition, no evidence of leaks. Native bush residential land use. Pool isolated, debris jam downstream. Trickle flow.
WB1	10:25	Clear	N/A - Inundated by high tide	N/A	N/A	None	Sample collected from flow from pipe outlet.	High tide inundating pipe slightly - hard to capture pipe sample alone. Green algae build up and brown algae at base of flow, shells approx. 30cm up pipe. Around 20 fish around outlet.
WB3	10:20	Clear	N/A	N/A	N/A	WB4 now connected to beach approx. 50 m from sampling site.	outflow from sample locations WB1 and 4	Approx. 15 pied stilts, 2 ducks, and 4 people on beach. Very high tide. New pump station and old pump station building on reserve area.
WB4	10:30	Clear	N/A - Inundated by high tide	N/A	N/A	None	None	Pipe 90% inundated with incoming high tide, around only 10 cm still open. Slight scum coming from pipe. 250 fish swimming around outflow of pipe.
WB5	10:35	Clear, slightly brown	0.374	0.18	15.54	No odour	none visible	Pool d/s of small trib channel. Tradescantia on bank. Native vege and shaded.

Date	11-Apr-16		High Tide Time	13:30		Weather conditions	Overcast and slight rain	
Site Name	**Sampling Time**	**Water Colour and clarity**	**Conductivity (ms/cm^c)**	**Salinity (ppt)**	**Temp (ºC)**	**Odour**	**Evidence of pipe flows?**	**Additional notes**
TB3	13:20	Clear, slightly milky, incoming tide.	N/A – area was inundated with incoming high tide	N/A	N/A	Slight Sulphurous smell	None obvious	Site immediately downstream of bridge. 3 people nearby. Lots of debris and sea scum floating in the stream. Slight rain. Water is very high.
TB2	13:25	Clear, slightly turbid	N/A	N/A	N/A	none	none obvious	3 people near water and 20 ducks, 5 gulls in water. Dry weather.
TB5	13:15	Brown, stained water but clear	17.23	10.15	16.16	None	None obvious	Water very orange-brown, looks like sediment run off from upper catchment. Organic matter in stream/on stream bed. Riparian vege native and exotic, mown grass on TRB. Lots of birds flying overhead. Dissipates 50m below stream site as weir blocks the flow.
FB4	13:00	Clear, slightly milky	0.264	0.13	16.65	None	Small drain from residential property d/s on TLB ~28mm. No flow at time of sampling	D/s of bridge. Vege native. Beside road. Pool sampled from isolated.
FB2	12:50	Clear	N/A	N/A	N/A	none	none obvious	4 people on beach, 1 person fishing in water, 1 dog on beach, 1 swimming in water, 5 seagulls. Overhanging café over the water at end of beach.
FB3	12:55	Clear	N/A – Inundated by high tide	N/A	N/A	None	1 inflow to the right of the outflow, completely inundated by high tide.	Sampled although pipe was completely inundated by high tide so results will be saline. Lots of organic matter. 2 people nearby, 1 dog on beach, 1 dog swimming. ~500 small fish near outflow.
WB6	12:37	Clear	0.217	0.11	16.1	None	None visible.	D/s of ww pipe bridge (according to GIS) – pipe bridge in good condition, no evidence of leaks. Native bush residential land use. Pool isolated, debris jam downstream. Trickle flow.
WB1	12:18	Clear	0.351	0.17	18.87	None	Sample collected from flow from pipe outlet.	2 people nearby. Higher than sampling two times ago. Slight rain. Green algae build up and brown algae at base of flow, shells approx. 30cm up pipe. Around 20 fish around outlet.
WB3	12:15	Clear	N/A	N/A	N/A	None	outflow from sample locations WB1 and 4	Approx. 40 pied stilts, 20 ducks on beach. Very high tide. New pump station and old pump station building on reserve area. Raining.
WB4	12:25	Clear, slightly milky	27.52	16.81	17.99	None	None	Pipe 90% inundated with incoming high tide, around only 10 cm still open. Slight scum coming from pipe. 250 fish swimming around outflow of pipe.
WB5	12:30	Clear, slightly milky	0.29	0.15	16.21	No odour	none visible	Higher flow than previous rounds. Wet understorey and ground cover. 'Pool d/s of small trib channel. Tradescantia on bank. Native vege and shaded.

Date	13-Apr-16		**High Tide Time**	15:18		**Weather conditions**	Overcast, sunny	
Site Name	**Sampling Time**	**Water Colour and clarity**	**Conductivity (ms/cm^c)**	**Salinity (ppt)**	**Temp (ºC)**	**Odour**	**Evidence of pipe flows?**	**Additional notes**
TB3	15:30	Brown, turbid, incoming tide.	1.729	0.55	17.89	Slight Sulphurous smell	None obvious	Sample taken from above bridge as sand has back up underneath it and preventing sampling below. Water a lot lower than previous.
TB2	15:35	Brown, very turbid	N/A	N/A	N/A	none	none obvious	3 people near water and 20 ducks, 30 pied stilts in water. Dry weather. 2 dogs on beach. Very windy and choppy
TB5	15:20	Brown, turbid	0.174	0.08	16.5	None	None obvious	Water still slightly brown, looks like sediment run-off recently. Wet understorey. Organic matter in stream/on stream bed. Riparian vege native and exotic, mown grass on TRB. Lots of birds flying overhead.
FB4	15:10	Clear, slightly milky	0.268	0.13	17.16	None	Small drain from residential property d/s on TLB ~28mm. Small trickle at time of sampling	D/s of bridge. Water very milky and looks like recent run-off into pool. Pool is also sitting at a higher level. Vege native. Beside road. Pool sampled from isolated.
FB2	15:00	Brown, turbid, incoming tide	N/A	N/A	N/A	none	none obvious	4 people on beach, 2 seagulls. Overhanging café over the water at end of beach. Very windy and choppy
FB3	15:05	Clear, stained yellow/brown	0.753	0.23	14.53	Slight odour	1 inflow to the right of the outflow, not flowing.	Only left side of pipe (When looking US) was flowing. Sample taken on left side where there was sufficient water. Flow on left is connected to the beach.
WB6	14:45	Clear, slightly turbid	0.217	0.11	16.1	None	None visible.	D/s of ww pipe bridge (according to GIS) - pipe bridge in good condition, no evidence of leaks. Native bush residential land use. Pool isolated, debris jam downstream. Trickle flow.
WB1	14:25	Clear	0.295	0.14	18.57	Slight Sulphurous smell	None.	A lot more water flowing out of pipe than previously. Flow connected to beach. Green algae build up and brown algae at base of flow, shells approx. 30cm up pipe. Around 20 fish around outlet.
WB3	14:20	Clear	N/A	N/A	N/A	None	outflow from sample locations WB1 and 4	Approx. 80 pied stilts, 30 ducks on beach. Tide lower than previous, overcast and windy. New pump station and old pump station building on reserve area. Raining.
WB4	14:30	Clear, stained brown.	0.584	0.3	17.2	None	None	Higher flow than previously - connected to beach. 1 person nearby.
WB5	14:35	Brown, slightly turbid	0.224	0.11	16.9	No odour	none visible	Higher flow than previous rounds. Wet understorey and ground cover. 'Pool d/s of small trib channel. Tradescantia on bank. Native vege and shaded.

Date	18-Apr-16		High Tide Time	8:00			Weather conditions	Sunny
Site Name	**Sampling Time**	**Water Colour and clarity**	**Conductivity (ms/cm^c)**	**Salinity (ppt)**	**Temp (ºC)**	**Odour**	**Evidence of pipe flows?**	**Additional notes**
TB3	8:05	Brown, turbid, incoming tide.	1.06	0.46	16.06	Slight Sulphurous smell	None obvious	Sample taken from above bridge as sand has back up underneath it and preventing sampling below.
TB2	8:10	Brown, very turbid	N/A	N/A	N/A	none	none obvious	1 person near water, 2 dogs swimming and 20 ducks, 100 pied stilts in water. Dry weather. Very windy and choppy
TB5	7:55	Brown, turbid	0.23	0.11	15.73	None	None obvious	Water still slightly brown, looks like sediment run-off recently. Wet understorey. Organic matter in stream/on stream bed. Riparian vege native and exotic, mown grass on TRB. Lots of birds flying overhead.
FB4	7:45	Clear, milky	0.313	0.15	16.69	None	Small drain from residential property d/s on TLB ~28mm. Small trickle at time of sampling	D/s of bridge. Water very milky and looks like recent run-off into pool. Pool is also sitting at a higher level. Vege native. Beside road. Pool sampled from isolated.
FB2	7:35	Clear turbid, incoming tide	N/A	N/A	N/A	none	none obvious	2 people on beach, 10 seagulls. Overhanging café over the water at end of beach. Very windy and choppy
FB3	7:40	Clear, milky	NA - Inundated	N/A	N/A	Slight odour	1 inflow to the right of the outflow, not flowing.	Sample taken in between the two outflows. Tide is inundating both sides so no YSI reading needed. Both pipes are discharging but left one has a higher water level.
WB6	7:25	Clear, milky	0.264	0.13	16.35	None	None visible.	D/s of ww pipe bridge (according to GIS) - pipe bridge in good condition, no evidence of leaks. Native bush residential land use. Pool isolated, debris jam downstream. Highest stream flow since sampling began.
WB1	7:05	Clear	0.257	0.12	17.35	Slight wastewater smell	None.	A lot of water flowing out of pipe. Flow connected to beach. Green algae build up and brown algae at base of flow, shells approx. 30cm up pipe. 20 ducks nearby. Outflow water connected to beach.
WB3	7:00	Brown, slightly turbid	N/A	N/A	N/A	None	Outflow from sample locations WB1 and 4	Approx. 80 pied stilts, 30 ducks on beach. Tide lower than previous, overcast and windy. New pump station and old pump station building on reserve area. Raining.
WB4	7:10	Clear, stained yellow	0.566	0.28	16.59	Slight odour	None	Flow deeper in pools and connected to beach. Deep point further in culvert than previously. 100 pied stilts nearby.
WB5	7:15	Clear, milky	0.288	0.14	16.32	Slight wastewater smell	none visible	Higher flows throughout pool. Wet understorey and ground cover. 'Pool d/s of small trib channel. Tradescantia on bank. Native vege and shaded.

Date 20-May-16 **High Tide Time** 9:38

Site Name	Sampling Time	Water Colour and clarity	Conductivity (ms/cm^{c})	Salinity (ppt)	Temp (ºC)	Odour	Evidence of pipe flows?	Additional notes
TB3	9:35	Clear	51.65	33.8	14.43	Slight odour	NA	Tide is pushing in, sample taken DS of bridge, 2 people nearby
TB2	9:40	Clear	N/A	N/A	N/A	None	No	3 people and two in playground. 5 gulls. No wind, very calm. 70 pied stilts
TB5	9:25	orange/brown and turbid	0.835	0.85	14.86	None	NA	Wet understory, looks like recent sediment runoff
FB4	9:20	clear, slightly brown	0.632	0.31	15.16	none	one on TR bank, not flowing	Pool is stable and low, recent rain.
FB2	9:05	Clear	N/A	N/A	N/A	None	FB3	No wind, very calm, 1 person, 3 gulls
FB3	9:10	Clear, brown	52.06	34.15	15.86	None	N/A	Oil sheens in water, foam, 1 person, sampled left pipe as was deeper, tide pushing in
WB6	8:55	Clear	0.249	0.12	14.68	None	pipe bridge, not leaking	Very wet understorey, slow stream flow
WB1	8:40	clear	0.249	0.12	16.53	None	none	Small pool at base of flow, not connected
WB3	8:30	clear	NA	None	WB1 and WB4	1 person, 5 gulls, very calm		
WB4	8:45	clear, slightly yellow	0.425	0.2	15.18	wastewater smell	NA	Connected to beach, low flow smells
WB5	8:50	clear, milky	0.311	0.15	15.86	none	none	Slow flow, pool is low, wet upstream

Appendix D: Summary microbiological results

Table D-1 *Escherichia coli* results for all sites in 2015 and 2016.

E. coli	2015					2016				
	N	Minimum	Maximum	Mean	Median	N	Minimum	Maximum	Mean	Median
French Bay										
FB1	4	10	1100	495	435	Site excluded from testing regime				
FB2	4	10	1900	612.5	270	1	400	400	400	400
FB3	1	46000	46000	46000	46000	4	460	14000	6767.5	6305
FB4	1	61000	61000	61000	61000	8	10	6900	1559.25	730
FB5	No flow					Site excluded from testing regime				
Titirangi Beach										
TB1	4	1100	12000	4250	1950	Site excluded from testing regime				
TB2	4	210	4400	1852.5	1400	Parameter not tested for				
TB3	4	380	27000	14445	15200	8	340	39000	9015	1300
TB4	No flow					Site excluded from testing regime				
TB5	4	10	17300	4595	535	8	20	58000	8312.25	435
Wood Bay										
WB1	4	100	1100	487.5	375	8	10	860	182	57.5
WB2	4	410	6100	2677.5	2100	Site excluded from testing regime				
WB3	2	98	24200	12149	12149	Parameter not tested for				
WB4	4	140	240000	60800	1530	8	73	14000	3984.125	2500
WB5	4	75	11200	2951.25	265	8	210	5200	1308.75	400
WB6	1	13000	13000	13000	13000	8	140	3300	862.5	470
WB7	No flow					Site excluded from testing regime				

Table D-2 *Enterococci* results for all sites in 2015 and 2016.

Enterococci	2015					2016				
	N	Minimum	Maximum	Mean	Median	N	Minimum	Maximum	Mean	Median
French Bay										
FB1	4	50	830	254.5	69	Site excluded from testing regime				
FB2	4	10	190	81.75	63.5	8	10	4600	695.375	96.5
FB3	1	24200	24200	24200	24200	5	330	24000	9902	7700
FB4	Parameter not tested for					Parameter not tested for				
FB5	Parameter not tested for					Site excluded from testing regime				
Titirangi Beach										
TB1	4	30	7700	2272.5	680	Site excluded from testing regime				
TB2	4	10	4100	2010	1965	8	10	1900	543.5	310
TB3	2	160	33000	16580	16580	8	830	69000	12853.75	1850
TB4	No flow					Site excluded from testing regime				
TB5	Parameter not tested for					Parameter not tested for				
Wood Bay										
WB1	4	10	960	343.25	201.5	8	20	1400	542.5	395
WB2	4	10	1600	557.5	310	Site excluded from testing regime				
WB3	1	24200	24200	24200	24200	8	10	510	134.25	35.5
WB4	Parameter not tested for					8	280	20000	7305	4200
WB5	Parameter not tested for					Parameter not tested for				
WB6	Parameter not tested for					Parameter not tested for				
WB7	No flow					No flow				

Appendix E: 2015 results

French Bay	FB1			FB2			FB3			FB4		FB5	
	E coli	Enterococci	Conductivity	*E coli*	Enterococci	Conductivity	*E coli*	Enterococci	Conductivity	*E coli*	Conductivity	*E coli*	Conductivity
Date	MPN/100 mL		mS/m	MPN/100 mL		mS/m	MPN/100 mL		mS/m	MPN/100 mL	mS/m	MPN/100 mL	mS/m
6/03/2015	1100	75	5160	1900	86	5140	No Flow			No Flow		No Flow	
9/03/2015	390	63		420	190		No Flow			No Flow		No Flow	
16/03/2015	480	830	5070	120	41	5150	46,000	>24200	37.2	61,000	24.5	No Flow	
2/04/2015	10	50	4710	10	<10	4740	No Flow			No Flow		No Flow	

Titirangi Beach	TB1			TB2			TB3			TB4		TB5	
	E coli	Enterococci	Conductivity	*E coli*	Enterococci	Conductivity	*E coli*	Enterococci	Conductivity	E coli	Conductivity	*E coli*	Conductivity
Date	MPN/100 mL		mS/m	MPN/100 mL		mS/m	MPN/100 mL		mS/m	MPN/100 mL	mS/m	MPN/100 mL	mS/m
6/03/2015	1500	960	5200	210	<10	5180	10500	160	5160	No Flow		10	1123
9/03/2015	12000	400		1500	30		19900			No Flow		960	
16/03/2015	2400	7700	4450	4400	3900	4720	27000	33000	82.3	No Flow		17300	21.9
2/04/2015	1100	30	4810	13000	4100	3770	380		111.8	No Flow		110	34.9

Wood Bay	WB1			WB2			WB3			WB4		WB5		WB6		WB7	
	E coli	Enterococci	Conductivity	*E coli*	Enterococci	Conductivity	*E coli*	Enterococci	Conductivity	*E coli*	Cond	*E coli*	Conductivity	*E coli*	Cond	*E coli*	Conductivity
Date	MPN/100 mL		mS/m	MPN/100 mL		mS/m	MPN/100 mL		mS/m	MPN/100 mL	mS/m	MPN/100 mL	mS/m	MPN/100 mL	mS/m	MPN/100 mL	
6/03/2015	1100	10	5200	3700	10	5170	No Flow			660	45.6	75	39.0	No Flow		No Flow	
9/03/2015	100	63		410	190		No Flow			240,000		340		No Flow		No Flow	
16/03/2015	280	960	5030	500	430	5030	>24200	>24200	19.4	24,000	21.7	11200	18.6	13000	19.4	No Flow	
2/04/2015	470	340	4720	6100	1600	4550	98		28.9	140	76.6	190	28.6	No Flow		No Flow	

Appendix F: Microbial Source Tracking results

2015

6th May 2016

To: Justine Quinn
Golder Associates (NZ) Limited
PO Box 33-849
Takapuna
AUCKLAND 0740

Email: JQuinn@golder.co.nz

From: Dr Brent Gilpin
ESR Christchurch Science Centre
PO Box 29181
CHRISTCHURCH

REPORT ON FAECAL SOURCE TRACKING ANALYSIS

The following samples were received on 14th April 2016 and were analysed for faecal source PCR markers as requested .

ESR Number	Client Reference	Date Sampled	Site Description	*E.coli* MPN/100mL	Entero MPN/100mL
CMB160576	19931/3	6-3-2015	TB3	10500	
CMB160577	19931/7	6-3-2015	FB2	1900	86
CMB160578	19931/11	6-3-2015	WB1	1100	10
CMB160579	19931/14	6-3-2015	WB4	660	
CMB160580	19935/4	9-3-2015	WB4	240000	
CMB160581	19935/9	9-3-2015	TB2	1500	30
CMB160582	19935/10	9-3-2015	TB3	19900	
CMB160583	19935/12	9-3-2015	TB5	960	
CMB160584	19958/2	16-3-2015	TB2	4400	3900
CMB160585	19958/3	16-3-2015	TB3	27000	33000
CMB160586	19958/5	16-3-2015	TB5	17300	
CMB160587	19958/8	16-3-2015	FB3	46000	>24200
CMB160588	19958/9	16-3-2015	FB4	61000	
CMB160589	19958/11	16-3-2015	WB1	280	960
CMB160590	19958/13	16-3-2015	WB3	>24200	>24200

Cont.

ESR Number	Client Reference	Date Sampled	Site Description	*E.coli* MPN/100mL	Entero MPN/100mL
CMB160591	19958/14	16-3-2015	WB4	24000	
CMB160592	19958/15	16-3-2015	WB5	11200	
CMB160593	19958/16	16-3-2015	WB6	13000	
CMB160594	20013/2	2-04-2015	TB2	13000	4100
CMB160595	20013/11	2-04-2015	WB1	470	340

Results of PCR Marker Analysis:

ESR Number	Client Reference	Description / Site ID	Date Sampled	*E. coli* MPN/100mL	Entero MPN/100mL	General GenBac	Human BacH	Human BiADO	Dog DogBac	Avian GFD	Conclusion
CMB160576	19931/3	TB3	6/03/2015	10,500	NA	very strong positive	ND	ND	ND	present	Faecal source - avian
CMB160577	19931/7	FB2	6/03/2015	1,900	86	very strong positive	ND	ND	present	present	Faecal source - dog + avian
CMB160578	19931/11	WB1	6/03/2015	1,100	10	strong positive	ND	ND	present	ND	Faecal source - dog
CMB160579	19931/14	WB4	6/03/2015	660	NA	very strong positive	present	ND	ND	ND	Faecal source - human? (only one marker detected)
CMB160580	19935/4	WB4	9/03/2015	240,000	NA	very strong positive	ND	ND	present (high levels)	present	Faecal source - dog + avian
CMB160581	19935/9	TB2	9/03/2015	1,500	30	very strong positive	ND	ND	ND	present	Faecal source - avian
CMB160582	19935/10	TB3	9/03/2015	19,900	NA	very strong positive	present	ND	present	present	Faecal source - dog + avian + human? (only one marker detected)
CMB160583	19935/12	TB5	9/03/2015	960	NA	very strong positive	ND	ND	ND	ND	Faecal source not identified
CMB160584	19958/2	TB2	16/03/2015	4,400	3,900	weak positive	not tested	not tested	not tested	not tested	
CMB160585	19958/3	TB3	16/03/2015	27,000	33,000	very strong positive	(positive)	present	present	ND	Faecal source - dog + human
CMB160586	19958/5	TB5	16/03/2015	17,300		very strong positive	present	present	present	ND	Faecal source - dog + human
CMB160587	19958/8	FB3	16/03/2015	46,000	>24200	very strong positive	present	ND	present	ND	Faecal source - dog + human? (only one marker detected)
CMB160588	19958/9	FB4	16/03/2015	61,000		very strong positive	present	present	present (high levels)	present	Faecal source - dog + human + avian
CMB160589	19958/11	WB1	16/03/2015	280	960	weak positive	not tested	not tested	not tested	not tested	
CMB160590	19958/13	WB3	16/03/2015	>24200	>24200	very strong positive	present	ND	present	ND	Faecal source - dog + human? (only one marker detected)
CMB160591	19958/14	WB4	16/03/2015	24,000		very strong positive	present	present	present	ND	Faecal source - dog + human
CMB160592	19958/15	WB5	16/03/2015	11,200		very strong positive	present	present	present	ND	Faecal source - dog + human
CMB160593	19958/16	WB6	16/03/2015	13,000		very weak positive	ND	ND	ND	ND	Faecal source not identified
CMB160594	20013/2	TB2	2/04/2015	13,000	4,100	very strong positive	ND	ND	present	present	Faecal source - dog + avian
CMB160595	20013/11	WB1	2/04/2015	470	340	strong positive	ND	ND	ND	ND	Faecal source not identified

Abbreviations: (positive) indicates the marker was detected, but below our normal reporting level. ND = sample was analysed, but the determinant was not detected.

Notes:
Brief details of the methods of analysis are available on request.
These results relate to samples as received.
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Paula Scholes
Laboratory Operations Coordinator

Beth Robson
Senior Technician

APPENDIX: Assay Interpretation Guidance Notes

PCR Marker interpretation notes

- Each marker is strongly associated with, but not exclusive to the source tested for. They each have some degree of non-specificity. The detection limit of these methods is 1.00E+03, or 1.00×10^3.
- Both Human markers are required to be present for a positve human result.
- Ruminant specific markers are reported using a percentage value based on levels of this marker relative to the general indicator in fresh ruminant faeces.
  - Samples reported as 50-100% ruminant are consistent with all of the general faecal marker having come from a ruminant source.
  - The lower levels reported (10-50%) may be a consequence of the presence of other sources of pollution, or in fact ruminant sources may still account for all the pollution, but this may include aged faecal material where relative levels of the ruminant marker decline more rapidly than the general indicator.
  - Levels less than 10% ruminant suggest a very minor contribution from ruminant sources.

FWA interpretation notes

The analysis of FWAs in septic tank and community wastewater consistently identifies levels between 10 and 70 µg/L. In previous analysis of water samples levels of FWA greater than 0.1 µg/L suggest human sewage, with levels greater than 0.2 µg/L strongly indicative of human sewage. Levels greater than 0.1 µg/L correlate well with other indicators of human pollution and indicate a local or recent source of pollution. FWAs degrade under sunlight exposure and will undergo dilution. Levels lower than 0.1 µg/L may be indicative of dilute or distant sources of human pollution.

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http://www.nzic.org.nz/CiNZ/articles/Devane_70_3.pdf

Faecal sterol Intepretation Notes:

Faecal sterol ratios must be interpreted with consideration to the levels of sterols, and relative to one another. For example H1 is typically also above 5-6% in ruminant faeces. Human and ruminant sources generally require at least two of three ratios to reach thresholds.
Plant sterols and mixed sources also have differing effects on sterol interpretations which must be considered.

Conclusions are the best interpretation of sterols in our opinion. Conclusions in **bold** are highly supported by the sterol data, conclusions in brackets are supported by sterol data with some variation from a pure source, or with a lower degree of certainty.

Ratio Key:

Ratios indicative of faecal pollution (either human or animal)		
F1	coprostanol/cholestanol..	>0.5 indicative of faecal source of sterols
F2	24ethylcoprostanol/ 24-ethylcholestanol.	>0.5 indicative of faecal source of sterols.
Human indicative ratios (values exceeding threshold in red)		
H3	coprostanol/ 24-ethylcoprostanol	Ratio >1 suggests human source
H1	% coprostanol	Ratio >5-6% suggests human source
H2	coprostanol/(coprostanol+cholestanol)	Ratio >0.7 suggests human source
H4	coprostanol/(coprostanol+24-ethylcoprostanol)	Ratio >0.75 suggests human source
Ruminant indicative ratios (values exceeding threshold in blue)		
R3	24-ethylcholesterol/24-ethylcoprostanol	Ratio <1 suggests ruminant source, ratio >4 suggests plant decay
R1	% 24-ethylcoprostanol	Ratio >5-6% suggests ruminant source
R2	coprostanol/(coprostanol+24-ethylcoprostanol)	Ratio <30% suggests ruminant source
Avian indicative ratios (values exceeding threshold in yellow)		
A1	24-ethylcholestanol/(24-ethylcholestanol+24-ethylcoprostanol+24-ethylepicoprostanol)	A1 Ratio >0.4 suggests avian source AND A2 Ratio >0.5 suggests avian source
A2	cholestanol/(cholestanol+coprostanol+epicoprostanol)	

Appendix F: Microbial Source Tracking results

2016

28 June 2016

To: Justine Quinn
Golder Associates (NZ) Limited
PO Box 33-849
Takapuna
AUCKLAND 0740

Email: JQuinn@golder.co.nz

From: Dr Brent Gilpin
ESR Christchurch Science Centre
PO Box 29181
CHRISTCHURCH

REPORT ON FAECAL SOURCE TRACKING ANALYSIS

The following samples were received on 2nd June 2016 and were analysed for faecal source PCR markers.

ESR Number	Client Reference	Date Sampled	Sample Site	*E.coli* MPN/100mL	Entero MPN/100mL
CMB160829	21021/1	29-3-2016	WB1	52	160
CMB160830	21021/3	29-3-2016	WB4	170	460
CMB160831	21021/4	29-3-2016	WB5	520	
CMB160832	21021/5	29-3-2016	WB6	990	
CMB160833	21021/9	29-3-2016	TB3	380	830
CMB160834	21032/3	31-03-2016	WB4	73	280
CMB160835	21032/5	31-03-2016	WB6	400	
CMB160836	21032/9	31-03-2016	TB3	340	1900
CMB160837	21041/1	5-04-2016	WB1	10	560
CMB160838	21041/3	5-04-2016	WB4	230	1300
CMB160839	21041/4	5-04-2016	WB5	280	
CMB160840	21041/5	5-04-2016	WB6	390	
CMB160841	21041/6	5-04-2016	FB2		170
CMB160842	21041/8	5-04-2016	TB2		470
CMB160843	21041/9	5-04-2016	TB3	19900	2900

Cont.

ESR Number	Client Reference	Date Sampled	Sample Site	*E.coli* MPN/100mL	Entero MPN/100mL
CMB160844	21049/1	8-04-2016	WB1	63	360
CMB160845	21049/3	8-04-2016	WB4	6900	6100
CMB160846	21049/5	8-04-2016	WB6	280	
CMB160847	21049/7	8-04-2016	FB3	460	480
CMB160848	21049/10	8-04-2016	TB3	1200	1200
CMB160849	21049/11	8-04-2016	TB5	670	
CMB160850	21058/1	11-04-2016	WB1	41	210
CMB160851	21058/3	11-04-2016	WB4	5500	20000
CMB160852	21058/4	11-04-2016	WB5	2800	
CMB160853	21058/5	11-04-2016	WB6	860	
CMB160854	21058/7	11-04-2016	FB3	610	330
CMB160855	21058/8	11-04-2016	FB4	1200	
CMB160856	21058/9	11-04-2016	TB2		150
CMB160857	21058/10	11-04-2016	TB3	1400	1800
CMB160858	21065/1	13-04-2016	WB1	860	1400
CMB160859	21065/2	13-04-2016	WB3		510
CMB160860	21065/3	13-04-2016	WB4	4600	16000
CMB160861	21065/4	13-04-2016	WB5	5200	
CMB160862	21065/5	13-04-2016	WB6	3300	
CMB160863	21065/7	13-04-2016	FB3	14000	17000
CMB160864	21065/8	13-04-2016	FB4	6900	
CMB160865	21065/9	13-04-2016	TB2		710
CMB160866	21065/10	13-04-2016	TB3	39000	69000
CMB160867	21065/11	13-04-2016	TB5	58000	
CMB160868	21077/1	18-04-2016	WB1	250	1200
CMB160869	21077/2	18-04-2016	WB3		380
CMB160870	21077/3	18-04-2016	WB4	14000	12000
CMB160871	21077/4	18-04-2016	WB5	980	
CMB160872	21077/5	18-04-2016	WB6	540	
CMB160873	21077/6	18-04-2016	FB2		560
CMB160874	21077/7	18-04-2016	FB3	12000	24000
CMB160875	21077/8	18-04-2016	FB4	1600	
CMB160876	21077/9	18-04-2016	TB2		1000
CMB160877	21077/10	18-04-2016	TB3	8700	24000
CMB160878	21077/11	18-04-2016	TB5	6500	
CMB160879	21190/1	20-05-2016	WB1	160	430
CMB160880	21190/3	20-05-2016	WB4	400	2300
					cont

ESR Number	Client Reference	Date Sampled	Sample Site	*E.coli* MPN/100mL	Entero MPN/100mL
CMB160881	211090/6	20-05-2016	FB2		7700
CMB160882	21190/7	20-05-2016	FB3	400	4600
CMB160883	21190/8	20-05-2016	FB4	2400	
CMB160884	21190/9	20-05-2016	TB2		1900
CMB160885	21190/10	20-05-2016	TB3	1200	1200
CMB160886	21190/11	20-05-2016	TB5	910	

NOTE:
Two samples vials were received labelled with the details for sample “21021/9. These were assigned the ESR numbers CMB160833A and CMB160833B and tested individually.

Results of PCR Marker Analysis:

ESR Number	Client Reference	Sample Site	Date Sampled	*E. coli* MPN/100 mL	Entero MPN/100 mL	General GenBac	Human BacH	Human BiADO	Dog DogBac	Avian GFD	Conclusion
CMB160829	21021/1	WB1	29/03/2016	52	160	positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160830	21021/3	WB4	29/03/2016	170	460	strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160831	21021/4	WB5	29/03/2016	520		very strong positive	ND	ND	ND	present	faecal source - avian
CMB160832	21021/5	WB6	29/03/2016	990		very strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160833A	21021/9	TB3	29/03/2016	380	830	very strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160833B	21021/9	TB3	29/03/2016	380	830	strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160834	21032/3	WB4	31/03/2016	73	280	very strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160835	21032/5	WB6	31/03/2016	400		very strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160836	21032/9	TB3	31/03/2016	340	1,900	very strong positive	ND	ND	ND	present	faecal source - avian
CMB160837	21041/1	WB1	5/04/2016	10	560	positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160838	21041/3	WB4	5/04/2016	230	1,300	strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160840	21041/5	WB6	5/04/2016	390		very strong positive	ND	ND	present	ND	faecal source - dog
CMB160841	21041/6	FB2	5/04/2016		170	positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160842	21041/8	TB2	5/04/2016		470	very strong positive	ND	ND	present	present	faecal source - dog + avian
CMB160843	21041/9	TB3	5/04/2016	19,900	2,900	very strong positive	ND	ND	present	present	faecal source - dog + avian
CMB160844	21049/1	WB1	8/04/2016	63	360	strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160845	21049/3	WB4	8/04/2016	6,900	6,100	strong positive	ND	ND	ND	present	faecal source - avian
CMB160846	21049/5	WB6	8/04/2016	280		very strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160847	21049/7	FB3	8/04/2016	460	480	positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160848	21049/10	TB3	8/04/2016	1,200	1,200	strong positive	ND	ND	present	ND	faecal source - dog

Abbreviations: (positive) indicates the marker was detected, but below our normal reporting level. ND = sample was analysed, but the determinant was not detected.

ESR Number	Client Reference	Sample Site	Date Sampled	*E. coli* MPN/100 mL	Entero MPN/100 mL	General GenBac	Human BacH	Human BiADO	Dog DogBac	Avian GFD	Conclusion
CMB160849	21049/11	TB5	8/04/2016	670		very strong positive	ND	ND	ND	(positive)	faecal source - possible avian
CMB160850	21058/1	WB1	11/04/2016	41	210	positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160851	21058/3	WB4	11/04/2016	5,500	20,000	very strong positive	ND	ND	ND	present	faecal source - avian
CMB160852	21058/4	WB5	11/04/2016	2,800		very strong positive	ND	ND	ND	present	faecal source - avian
CMB160853	21058/5	WB6	11/04/2016	860		very strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160854	21058/7	FB3	11/04/2016	610	330	positive	ND	ND	(positive)	ND	faecal source - possible dog
CMB160855	21058/8	FB4	11/04/2016	1,200		very strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160856	21058/9	TB2	11/04/2016		150	very strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160857	21058/10	TB3	11/04/2016	1,400	1,800	strong positive	ND	ND	ND	(positive)	faecal source - possible avian
CMB160858	21065/1	WB1	13/04/2016	860	1,400	strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160859	21065/2	WB3	13/04/2016		510	very strong positive	ND	(positive)	present	present	faecal source - dog + avian
CMB160860	21065/3	WB4	13/04/2016	4,600	16,000	very strong positive	ND	ND	present	ND	faecal source - dog
CMB160861	21065/4	WB5	13/04/2016	5,200		very strong positive	ND	ND	present	ND	faecal source - dog
CMB160862	21065/5	WB6	13/04/2016	3,300		very strong positive	(positive)	ND	ND	ND	no species specific faecal source identified
CMB160863	21065/7	FB3	13/04/2016	14,000	17,000	strong positive	(positive)	ND	present	ND	faecal source - dog
CMB160864	21065/8	FB4	13/04/2016	6,900		strong positive	(positive)	ND	present	ND	faecal source - dog
CMB160865	21065/9	TB2	13/04/2016		710	positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160866	21065/10	TB3	13/04/2016	39,000	69,000	very strong positive	(positive)	ND	ND	ND	no species specific faecal source identified
CMB160867	21065/11	TB5	13/04/2016	58,000		very strong positive	present	present	ND	ND	faecal source - human
CMB160868	21077/1	WB1	18/04/2016	250	1,200	positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160869	21077/2	WB3	18/04/2016		380	very strong positive	ND	ND	(positive)	present	faecal source - avian + possible dog

Abbreviations: (positive) indicates the marker was detected, but below our normal reporting level. ND = sample was analysed, but the determinant was not detected.

ESR Number	Client Reference	Sample Site	Date Sampled	*E. coli* MPN/100 mL	Entero MPN/100 mL	General GenBac	Human BacH	Human BiADO	Dog DogBac	Avian GFD	Conclusion
CMB160870	21077/3	WB4	18/04/2016	14,000	12,000	very strong positive	ND	ND	ND	(positive)	faecal source - possible avian
CMB160871	21077/4	WB5	18/04/2016	980		very strong positive	ND	ND	ND	present	faecal source - avian
CMB160872	21077/5	WB6	18/04/2016	540		very strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160873	21077/6	FB2	18/04/2016		560	positive	present	ND	ND	ND	faecal source - possible human (only one marker detected)
CMB160874	21077/7	FB3	18/04/2016	12,000	24,000	strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160875	21077/8	FB4	18/04/2016	1,600		strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160876	21077/9	TB2	18/04/2016		1,000	very strong positive	present	(positive)	present	present	faecal source - human + dog + avian
CMB160877	21077/10	TB3	18/04/2016	8,700	24,000	very strong positive	present	(positive)	present	ND	faecal source - human + dog
CMB160878	21077/11	TB5	18/04/2016	6,500		very strong positive	(positive)	ND	present	ND	faecal source - dog
CMB160879	21190/1	WB1	20/05/2016	160	430	positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160880	21190/3	WB4	20/05/2016	400	2,300	strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160881	21190/6	FB2	20/05/2016		7,700	very strong positive	ND	ND	present	ND	faecal source - dog
CMB160882	21190/7	FB3	20/05/2016	400	4,600	weak positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160883	21190/8	FB4	20/05/2016	2,400		very strong positive	present	ND	present	ND	faecal source - dog + possible human (only one marker detected)
CMB160884	21190/9	TB2	20/05/2016		1,900	strong positive	ND	ND	ND	ND	no species specific faecal source identified
CMB160885	21190/10	TB3	20/05/2016	1,200	1,200	very strong positive	ND	ND	present	present	faecal source - dog + avian
CMB160886	21190/11	TB5	20/05/2016	910		strong positive	ND	ND	ND	ND	no species specific faecal source identified

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A1	24-ethylcholestanol/(24-ethylcholestanol+24-ethylcoprostanol+24-ethylepicoprostanol)	A1 Ratio >0.4 suggests avian source AND A2 Ratio >0.5 suggests avian source
A2	cholestanol/(cholestanol+coprostanol+epicoprostanol)	

Find out more: phone 09 301 0101, email
rimu@aucklandcouncil.govt.nz or visit
aucklandcouncil.govt.nz and knowledgeauckland.org.nz

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