Otepuni Faecal Source Investigation

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Executive Summary

The Otepuni Creek has had a history of elevated faecal bacteria contamination since monitoring began in 1999 at Environment Southland's long term State of the Environment (SOE) site, Otepuni Creek at Nith Street. This data indicated water quality was poor (4th worst Water Quality Index score) compared with other sites monitored in the Southland region, with 56% of samples exceeding the Regional Water Plan standard for faecal bacteria in lowland streams over the last 5 years. The sources of faecal contamination in the Otepuni Creek were unknown and there was concern regarding the human health risk of the Otepuni Creek from potential sources including discharges from stormwater drains, industrial activity, rubbish in the Creek and the health of the New River Estuary.

This investigation aimed to identify the extent of faecal bacteria contamination by monitoring *E. coli* concentrations and the use of faecal sterols, a microbial source tracking (MST) method, to identify the sources of faecal bacteria contamination in the Otepuni Creek over summer 2012. Water quality samples were collected weekly at four sites over summer from 22 February to 18 May and analysed for *E. coli*, faecal sterols, fluoride and nutrients.

Results identified elevated *E. coli* at all sites monitored in the catchment, regularly above the faecal bacteria standard of 1,000/100ml in the Regional Water Plan. Faecal sterol analysis established *E. coli* of ruminant origin to be the dominant source in the upper Otepuni catchment above the Otepuni Dam. With human source *E. coli* the dominant source of contamination in the lower Otepuni catchment, below the dam.

It is recommended that future investigations focus on determining the spatial and temporal extent of human source faecal contamination in the New River Estuary and the risks to human health from fishing, swimming, kayaking and food gathering. Other pathogens likely to affect human health (e.g. *Cryptosporidium, Campylobacter* and viruses) also need to be characterised. Rainfall in the previous 48 hours has the potential to be used as a predictor of *E. coli* in the Otepuni Creek and possibly other Southland rivers however, further work is needed to determine whether river flow can be used to predict *E. coli* levels.

Further work is required to investigate whether septic tanks contribute to faecal contamination during winter and spring when soil moisture levels and contamination risk to surface waters is high. In addition, exploring the effectiveness of faster and more affordable indicators for tracking faecal contamination will allow Environment Southland to characterise faecal contamination sources in more Southland rivers.

The management recommendations as a result of this investigation are:

1. Work with Invercargill City Council to eliminate human faecal contamination from stormwater drains;
2. Review dairy consents to upgrade effluent systems used in the Otepuni catchment;
3. Exclude stock from the Otepuni Creek and its tributaries;
4. Employ stronger enforcement methods for repeated significant non-compliance;
5. Eliminate sources of faecal contamination in both the upper and lower Otepuni catchment;
6. Notify Public Health South and iwi of the presence of human foulwater contamination in the Otepuni Creek.

Introduction

The issue

The Otepuni Creek has had a history of elevated faecal bacteria contamination since monitoring began in 1999 at Environment Southland's long term State of the Environment (SOE) site, Otepuni Creek at Nith Street. The sources of faecal contamination in the Otepuni Creek were unknown and there is concern regarding the potential human health risk of potential sources including discharges from stormwater drains, industrial activity, rubbish in the Creek and the health of the New River Estuary.

The catchment

The Otepuni Creek catchment extends from Rimu in the east to the New River Estuary in the west and drains an area of 35 km^2 (Figure 1).

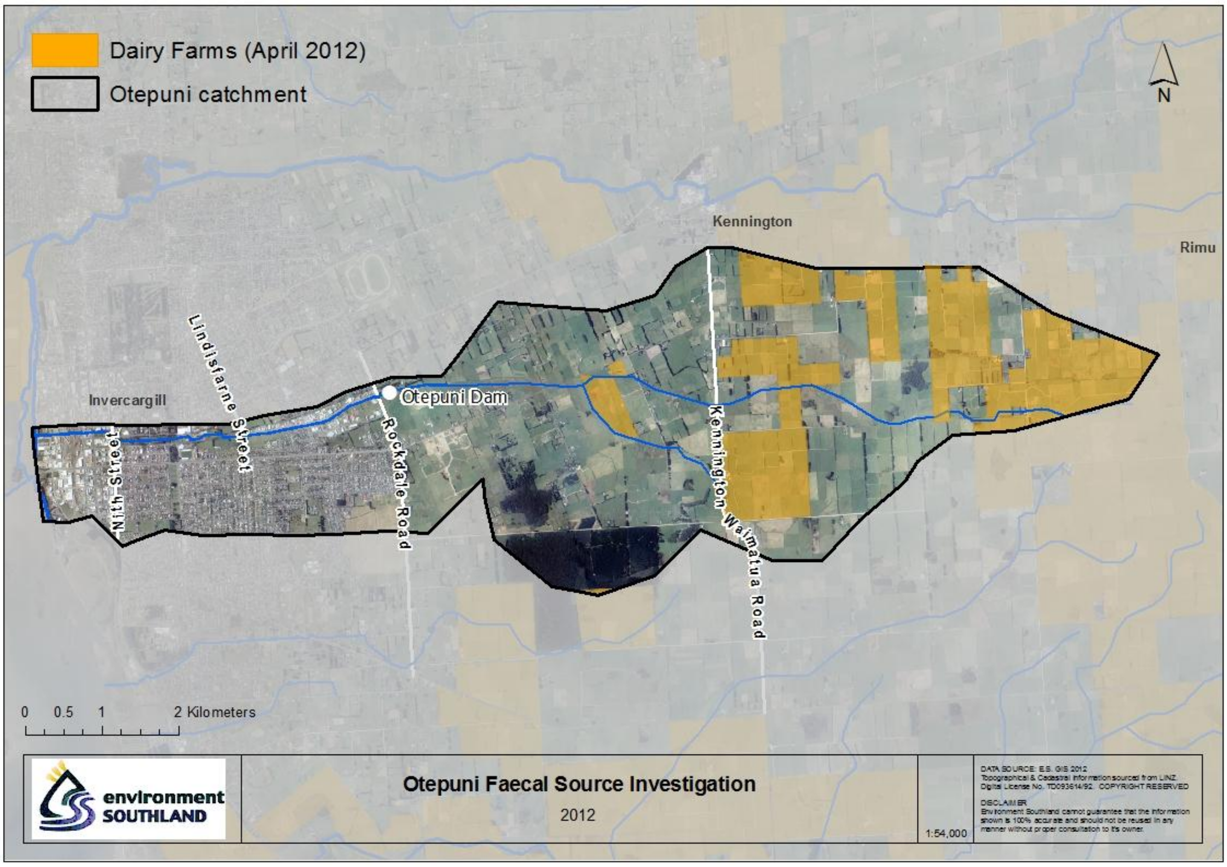

Figure 1: Otepuni Creek catchment

The Otepuni catchment has a total of 5 land use types, from intensive agriculture in the upper catchment, lifestyle farms in the mid-catchment and industrial, commercial and residential land uses in the lower part of the catchment (Table 1). Rural land use accounts for 76% of the total catchment area, with 66% classed as intensive agriculture (primarily sheep and dairy farming) and 10% lifestyle properties. Lifestyle properties are generally located between Kennington

Waimatua Road and Rockdale Road. There are currently 9 consented dairy farms, which cover a total 20% of the catchment, with the majority of these located above Kennington-Waimatua Road.

In total, urban land use comprises 19% of the Otepuni catchment, with 13% residential dwellings and 5% industrial and commercial activities. Industrial and commercial land uses are located in the lower catchment between Rockdale Road and Lindisfarne Street and between Nith Street and the New River Estuary. Residential dwellings are generally located between Rockdale Road and Nith Street, predominately south of the Otepuni Creek.

Table 1: Otepuni catchment land use

Type	Land use	Category	Area (km^2)	Percentage of catchment
Rural	Intensive agriculture	Total	23.1	66
		Dairy	7	20
	Lifestyle		3.4	10
Urban	Industrial and Commercial		1.9	5
	Residential		4.4	13
Other	Parks and reserves		2.2	6
		Total	35	100

Parks and reserves cover 6% of the Otepuni catchment. Included in this land use type are sports fields (rugby grounds and hockey turfs), stop bank reserve areas and remnant native bush (Seaward Bush Reserve at the southern extent of the catchment).

Values

The Otepuni Creek is valued both culturally and recreationally. Extensive walkways associated with the Environment Southland's flood protection scheme and associated stop banks below the Otepuni Dam provide good public access to the lower catchment. Although the Otepuni Creek is not commonly used for bathing, Southland Institute of Technology students have direct contact with the creek during Orientation Week in March each year. The New River Estuary is valued for its wāhi tapu (settlement sites), kai moana (including pātiki/flounder, shellfish), recreational activities (boating, bathing, rowing, water skiing, kayaking, duck hunting, trout fishing, whitebait), a wide range of wading and migratory bird species and its diverse estuarine habitat (Robertson & Stevens, 2008).

Current State of Water Quality

Water quality has been monitored at Environment Southland's State of the Environment site, the Otepuni Creek at Nith Street, for 13 years since July 1999 (Meijer, 2010). The Otepuni Creek at Nith Street site has recorded the highest maximum *E. coli* of 110,000 CFU/100ml (13 March 2007) out of 72 SOE water quality monitoring sites in the Southland Region over the period July 1999 to June 2012 (Figure 2). This site also has the highest median *E. coli* of 1,300 CFU/100ml over the same period, exceeding the standard of 1,000 faecal bacteria/100ml in the Regional Water Plan (Environment Southland, 2010a).

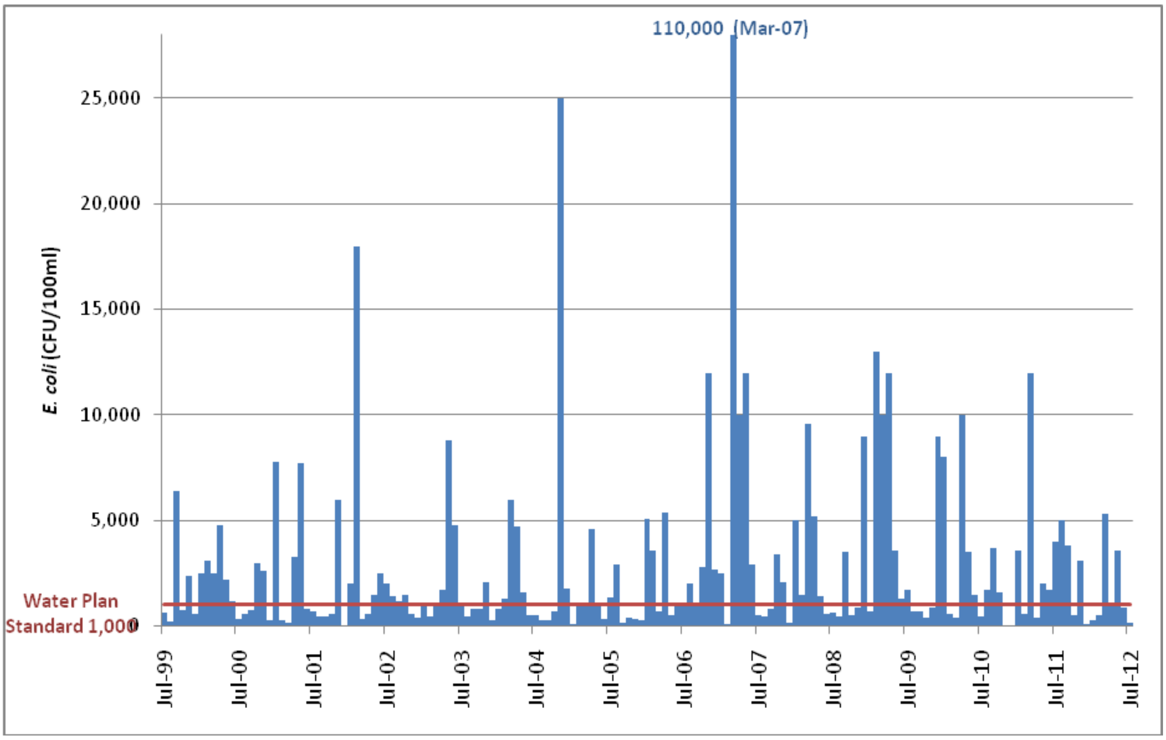

Figure 2: Otepuni Creek at Nith Street *E. coli* (1999-2012)

The compliance of key water quality parameters with standards in the Regional Water Plan and national guidelines was calculated for two time periods - all data for Otepuni at Nith Street (1 July 1999 to 30 June 2012) and the last five years (1 July 2007 to 30 June 2012). Compliance with guidelines and standards was similar for all parameters over both time periods. However, Dissolved Reactive Phosphorus (DRP) compliance with the ANZECC (2000) guideline of 0.010 mg/l has improved over the last five years, with 65% of samples breaching compared to 82% for the "all data" period (Figure 3).

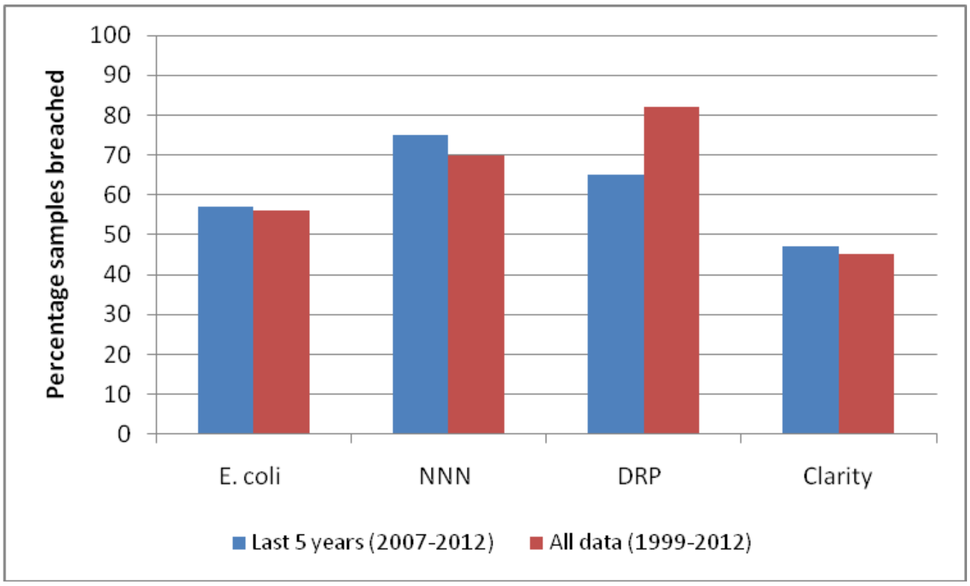

Figure 3: Otepuni Creek at Nith Street compliance with water quality guidelines and standards

Between 56 and 57% of samples breached the Water Plan *E. coli* standard of 1,000/100 ml and 70 to 75% of samples breached the Nitrate Nitrite Nitrogen (NNN) guideline of 1.7 mg/l for chronic aquatic toxicity (Hickey & Martin, 2009). Between 45 and 47% of samples breached the Water Plan standard for water clarity of 1.6m, below median river flow.

Water Quality Trends

Water quality trends for the Otepuni at Nith Street site showed no trend in *E. coli* over the 13 year monitoring period (July 1999 to June 2012) or over the last five years (July 2007 to June 2012) (Table 2). Water quality trends for Nitrate Nitrite Nitrogen (NNN) and black disc clarity at the Nith Street site show no trends for both time periods also. And, while there was an improving trend in Dissolved Reactive Phosphorus (DRP) over the 1999-2012 period (4.5% per year), there was no trend in data over the last five years.

Table 2: Otepuni Creek at Nith Street Water Quality Trends

Parameter	Recent Trend	*p*-value	All Data Trend	*p*-value
	5 years (2007-2012)		13 years (1999-2012)	
E. coli	No Trend	p=0.28	No Trend	p=0.67
Nitrate Nitrite Nitrogen	No Trend	p=0.26	No Trend	p=0.12
Dissolved Reactive Phosphorus	No Trend	p=0.33	Improving (4.5%)	p<0.01
Black Disc Clarity	No Trend	p=0.42	No Trend	p=0.68

While not statistically significant (p>0.05), some water quality parameters showed a seasonal pattern at the Nith Street site over the period 1999 to 2012. Nitrate Nitrite Nitrogen showed higher concentrations in winter than in summer, which could be due to lower nutrient uptake by aquatic plants in winter, increased land drainage/runoff or recharge of nitrate from groundwater (Figure 4). Some seasonality also exists for *E. coli*, with the highest levels evident in autumn, particularly March and April (Figure 5). This may indicate potential point source contributions during the summer low flow period, lower dilution or stock access.

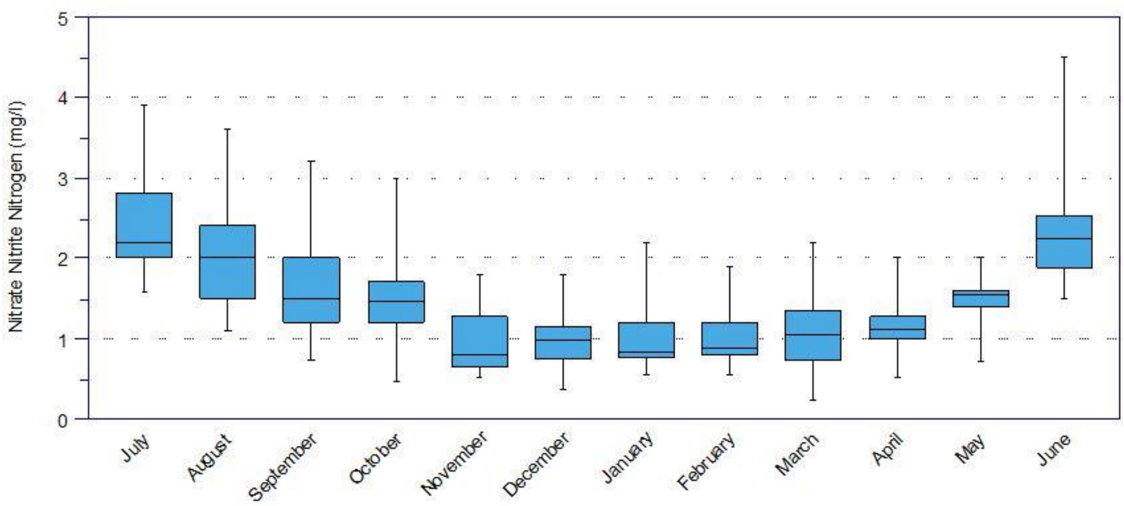

Figure 4: Otepuni Creek at Nith Street Seasonal Nitrate Nitrite Nitrogen (1999-2012)

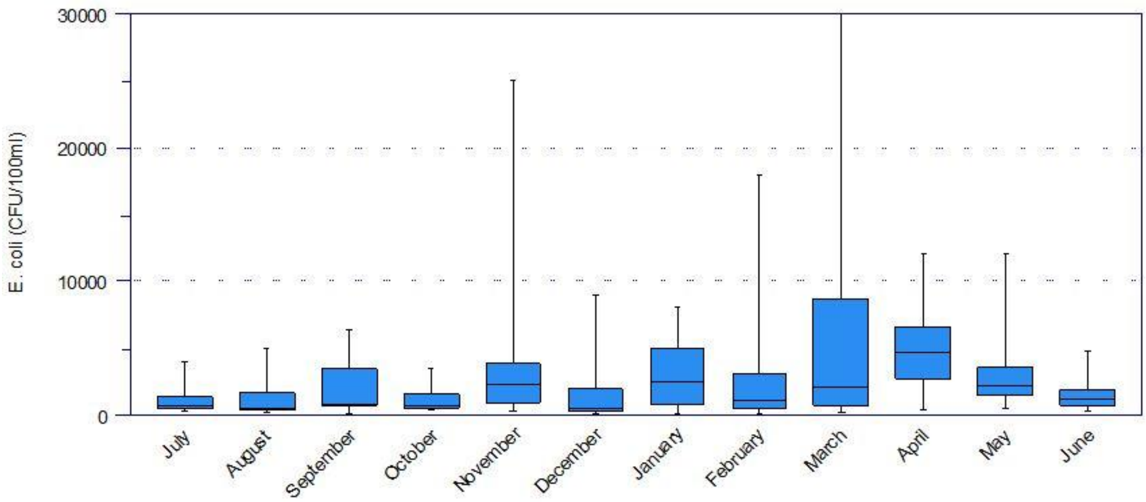

Figure 5: Otepuni Creek at Nith Street Seasonal *E. coli* (1999-2012)

How does water quality in the Otepuni compare regionally?

Water quality from the council's long term monitoring site on the Otepuni Creek at Nith Street indicates water quality is poor compared with other sites monitored in the Southland region. A Water Quality Index (WQI) used to summarise water quality compliance with standards and guidelines for a number of parameters was reported in Southland Water 2010: *Our Ecosystems* (Environment Southland, 2010b). Four water quality parameters were combined for this WQI (NNN, DRP, clarity and faecal coliforms). WQI scores were reported for all State of the Environment water quality sites over the period 2000-2010, with the Otepuni Creek at Nith Street classified as "very poor", ranking fourth worst (equal with three other sites) out of 69 sites analysed (Wilson *et al.*, 2012).

Water quality trends in the Otepuni Creek at Nith Street are generally consistent with other lowland streams monitored in Southland. And, with the exception of an improving DRP trend from 1999 to 2012, the Nith Street site showed no trends for all other parameters analysed (NNN, water clarity and *E. coli*) This is consistent with trends identified at other SOE sites, except for NNN where 48% of monitored sites showed an increasing trend between 2000 and 2010 (Environment Southland, 2010b).

Overall, water quality in the Otepuni Creek at Nith Street is poor (as determined by the WQI score and compliance with standards/guidelines) and has not shown any improvement, in particular over the last five years (2007-2012).

Consent monitoring and compliance

Stormwater consents

Stormwater discharges to water from reticulated networks require resource consent under Rules 1 and 11 of the Regional Water Plan for Southland (Environment Southland, 2010a). The Invercargill City Council (ICC) was granted consent to discharge stormwater into the Otepuni Creek in 2011. The consent was granted for a short term (five years) to allow the collection of stormwater quality data to assist with determining the effects of the discharges on the receiving environment. As such, consent conditions included the monitoring of water quality from selected stormwater drains, water quality in the receiving waters, sediment quality below selected stormwater drains and macroinvertebrate monitoring.

Initial water quality data collected to date between Rockdale Road and Mersey Street has identified several stormwater drains with elevated *E. coli* levels ranging from 545 to 75,900 MPN/100 ml in samples collected during March and April 2012 (Appendix 1). The ICC suspects the elevated *E. coli* from one of these stormwater drains (Camden Road) to be caused by a stormwater-sewer cross connection (Adrian Cocker, pers. Comm. 28/05/12). Results from ICC Otepuni Creek water quality sampling found *E. coli* levels ranging from 256 to 5,215 MPN/100 ml at the three prescribed monitoring sites during March and April 2012.

No sediment consent monitoring results are available to date, however an assessment of macroinvertebrate communities was carried out by Ryder Consulting Ltd at three sites in the Otepuni Creek during low river flows in March 2012 (Arthur, 2012). The sites were located upstream of Rockdale Road, downstream of Lindisfarne Street and a brackish estuarine site downstream of Mersey Street. This monitoring was included in the ICC stormwater consents to assess the effects of stormwater discharges from the ICC network on macroinvertebrate communities in the Otepuni Creek. Results showed Macroinvertebrate Community Index (MCI) scores ranged from 53 to 63, indicative of "poor" habitat quality and "probable severe pollution" (Figure 6).

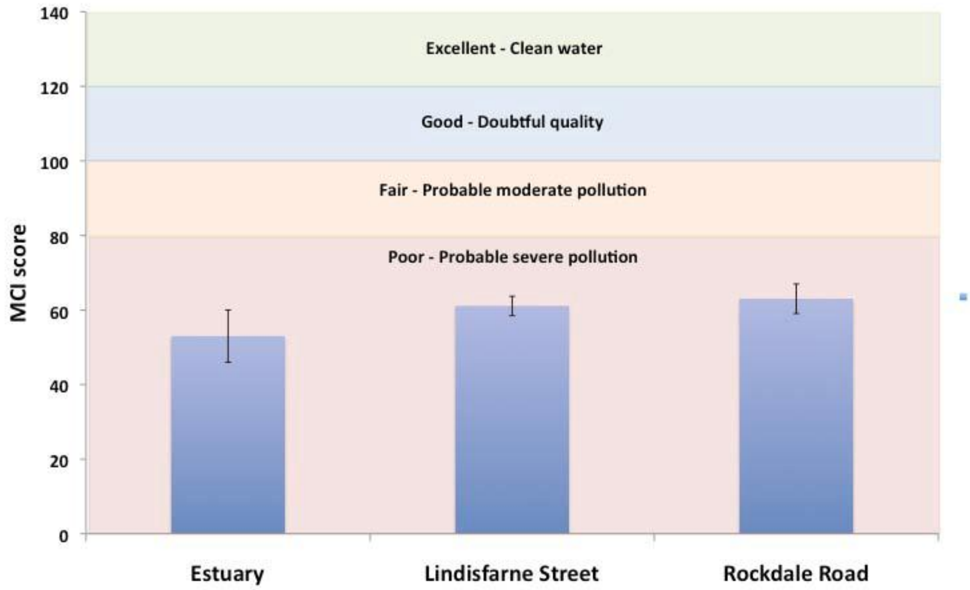

Figure 6: ICC stormwater consent monitoring – Macroinvertebrate Community Index (from Arthur, 2012)

Dairy consents

Resource consents are held by nine dairy farms in the Otepuni Creek catchment for the disposal of Farm Dairy Effluent (FDE) to land. Consents are typically granted for a period of 10 years and include limits on the location, number of stock, rate and depth of effluent applied, storage capacity and irrigation systems. Dairy farms in the Otepuni catchment are inspected by Environment Southland up to four times per year to assess FDE management and/or monitor surface or groundwater.

Dairy farms in the Otepuni Creek catchment range in size from 34 to 208 hectares, and have between 120 and 700 dairy cows (Table 3). Two of the nine farms also provide grazing for additional cows from outside the catchment during winter. Effluent disposal varies greatly in the catchment, with newer low rate "K-line" or "uni sprinkler" systems used by three of the nine farms in the catchment, all with consents granted in the last three years. Two of these three farms use a combination of K-line and slurry tankers, with just one farm using a K-line only disposal system.

The majority of farms (five of nine) use travelling irrigators. Four of these five farms consents expire over the next three years and will be updated to low rate effluent disposal systems. The other farm using a travelling irrigator has a consent, which was granted recently in June 2010. One farm uses a slurry tanker to dispose of all effluent.

Environment Southland has recorded some form of non-compliance at six of the nine farms to date. Significant non-compliance, determined by a score of 10 in an inspection, was identified at four of the nine farms. These farms also have a record of repeated significant non-compliance. Reasons for significant non-compliance include over-application of FDE resulting in ponding, overland flow and discharge to water, leaching slurry stacks and full effluent ponds. Significant non-compliance has been addressed by Environment Southland in the catchment by one prosecution (500 cows plus dairy support, travelling irrigator), but predominantly through "advice and education" only.

Table 3: Dairy farm compliance in Otepuni Creek catchment as at August 2012

Farm	Farm size (ha)	No. cows	Soil risk	Consent expiry	Disposal method	Significant Non-compliance (Score = 10)	Reason for non-compliance	Action taken
1	34	120	-	Oct-2021	Slurry tanker & uni sprinkler	N	N/A	N/A
2	77	250	-	Mar-2019	K-line & slurry tanker	N	K-line pods too close to SW, in swales, no farm environment management plan.	Advice & Education
3	129	150	-	Jul-2021	Slurry tanker	N	N/A	N/A
4	79	300	High	Oct-2014	Travelling irrigator	Y (May 2010)	Ponding of effluent on paddock, blocked nozzles, irrigator speed too slow, needs careful management of high risk soils.	Advice & Education
5	208	599 plus 400 wintering pad effluent	High	Dec-2015	Travelling irrigator	Y (May 2009, Jul 2008)	Effluent pond full, weeping wall issues, winter crop paddock runoff towards shed, uncontained leaching solids pile.	Advice & Education
6	171	500 plus wintering pad effluent	Med	Aug-2015	Travelling irrigator	Y (Feb, Sep 2011, Feb, Mar, Apr, Aug 2010, May 2009)	Over application of FDE resulting in ponding, overland flow & discharge, effluent systems need upgrading.	Prosecution, Advice & Education
7	131	280	-	Apr-2022	K-line	N	N/A	N/A
8	327	700	High	Oct-2013	Travelling irrigator	Y (Feb, Apr, May 2011, May 2010, Sep 2009)	Ponding of effluent, weeping wall not working well, solids pile not contained.	Advice & Education
9	171	500	-	Jun-2020	Travelling irrigator	N	Some sludge from bunker.	Advice & Education

Aim

The aim of this investigation was firstly to identify the spatial extent of faecal bacteria contamination in the Otepuni Creek. Secondly, to use faecal sterols, a microbial source tracking (MST) method, to identify the source of faecal bacterial contamination in the catchment over summer 2012.

Methods

Sample Collection

A total of 47 water quality samples were collected weekly at four sites over the summer period from 22 February to 18 May 2012. Sampling sites included the Otepuni Creek at Kennington Waimatua Road, Otepuni Dam, Lindisfarne Street and Environment Southland's long term State of the Environment (SOE) site at Nith Street (Table 4 and Figures 7 to 11).

Table 4: Otepuni Creek water quality monitoring sites

Site	Site Name	Easting	Northing	Project
1	Otepuni Creek at Kennington Waimatua Road	2160297	5411747	Otepuni Investigation
2	Otepuni Creek at Otepuni Dam	2156251	5412029	Otepuni Investigation
3	Otepuni Creek at Lindisfarne Street	2154159	5411403	Otepuni Investigation
4	Otepuni Creek at Nith Street	2152448	5411410	State of the Environment

A 2L sample was collected at each for faecal sterol analysis, a 300 ml sterile bottle for faecal coliform and *E. coli* bacteria and a 1L bottle for nutrient and fluoride analysis. Water quality samples were chilled and delivered to R.J. Hills Laboratory in Christchurch for analysis within 24 hours of collection. Faecal sterol samples were frozen and sent to ESR Laboratory in Christchurch.

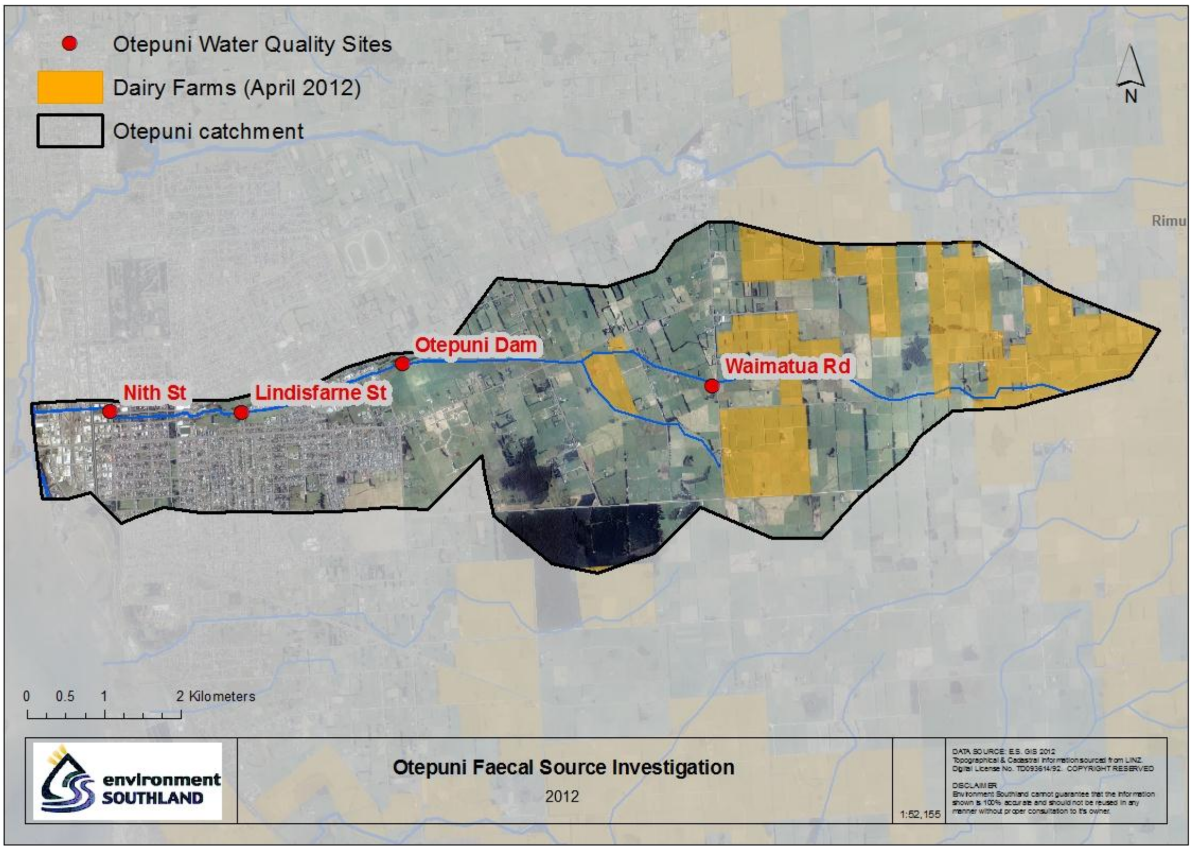

Figure 7: Otepuni Water Quality sites

Figure 8: Otepuni Creek at Kennington Waimatua Road, downstream

Figure 9: Otepuni Creek at Otepuni Dam, downstream

Figure 10: Otepuni Creek at Lindisfarne Street, downstream

Figure 11: Otepuni Creek at Nith Street, downstream

Field measurements were collected at each site for dissolved oxygen, water temperature and electrical conductivity with a YSI Pro2030 handheld meter. On each sampling occasion, any observations relevant to faecal contamination were recorded, such as the presence of ducks, unpleasant discharges from stormwater drains, stock in the waterway or odour.

Sample Analysis

Each sample was analysed for *E. coli*, faecal coliforms Total Phosphorus (TP), Total Nitrogen (TN), Nitrate Nitrite Nitrogen (NNN), Total Kjeldahl Nitrogen (TKN), fluoride and faecal sterols. These parameters were selected to indicate the presence of faecal contamination in the Otepuni Creek and assist in identifying the likely sources.

Faecal sterols

Faecal sterol analysis involved filtering 2 L of river water through glass fibre filters. The filters were stored frozen until analysed using the extraction procedure described in (Gregor, et al., 2002). Comparative analyses have indicated that sterols in surface water samples begin to degrade after 24 hours at 4°C, however, no sterol degradation was detected after three freeze-thaw cycles. Freezing is therefore the preferred sample preservation method for sterol analysis (Devane, et al., 2006).

Faecal sterols are a group of carbon 27-, carbon 28- and carbon 29- cholestane-based sterols found mainly in animal faeces (Moriarty & Gilpin, 2009). The sterols found in animal faeces are dependent on three variables; diet, synthesis by the animal (humans synthesise cholesterol) and most importantly, changes made by anaerobic bacteria in the animal's gut which biohydrogenate sterols to stanols of various isometric configurations.

The sterol, cholesterol, can be hydrogenated to one or more of four possible stanols. In humans cholesterol is preferentially reduced to coprostanol, whereas in the environment cholesterol is predominately reduced to cholestanol (Moriarty & Gilpin, 2009). Similarly, plant derived 24-ethylcholesterol is reduced to 24-ethylcoprostanol and 24-ethylepicoprostanol in the gut of herbivores, whereas in the environment it is predominately reduced to 24-ethylcholestanol. As such, analysis of the sterol composition of animal faeces can generate a sterol fingerprint.

Given cholesterol is preferentially reduced to coprostanol in the human gut, coprostanol is used as the principal biomarker for human faecal source contamination. High levels of coprostanol indicate fresh human faecal material and coprostanol comprises 60% of the total sterols found in human faeces. In comparison, dog and bird faeces have either no or trace coprostanol levels.

The interpretation of faecal sterol results is based on the comparisons of key sterol ratios. In this investigation, faecal sterol analysis was able to determine the presence/absence of faecal bacteria contamination from human, ruminant, wildfowl and plant derived faecal sources. The ratios included two indicators of faecal bacteria contamination, four human indicators, three ruminant indicators, two wildfowl indicators and one plant indicator (Appendix 3).

Simulated River Flow

Spot gaugings were carried out at each of the four Otepuni Creek sites on a number of the water quality sampling occasions in order to calculate a continuous simulated flow measurement for each site (Table 5). Concurrent gaugings were also carried out at the Waihopai River at

Kennington hydrological site, as this site correlates well with flow at two of the Otepuni Creek sites, Kennington Waimatua Road and Nith Street.

Table 5: Otepuni Creek simulated flow

Site	No. gaugings (Feb-May)	Site used for simulation	Flow relationship	r^2
Otepuni Creek at Kennington Waimatua Rd	5	Waihopai River at Kennington	Waihopai x 0.03 - 6.955 l/s	0.999
Otepuni Creek at Otepuni Dam	6	Otepuni Creek at Otepuni Dam	Rating curve (water level v spot gaugings)	n/a
Otepuni Creek at Lindisfarne St	5	Otepuni Creek at Otepuni Dam	Otepuni Dam x 1.3407 + 8.432 l/s	0.999
Otepuni Creek at Nith St	5	Waihopai River at Kennington	Waihopai x 0.2506 – 25 l/s	0.970

Results

River flow and rainfall

There were a total of five flow events above median flow in the Otepuni Creek at Otepuni Dam (0.534 m^3/s) over the investigation period, three of these were in March and two in May (Figure 12). There were two periods of extended low flows below median between 18 March and 30 April (43 days) and 1 to 18 May (17 days). Flow was at or below 7 day MALF (0.030 m^3/s) for a period of five days between 22 and 27 April. A total of 221 mm of rainfall was recorded at Environment Southland's Kingswell Creek at Tisbury Dam site over the investigation period (Figure 13). April was the driest month with a rainfall total of just 47 mm.

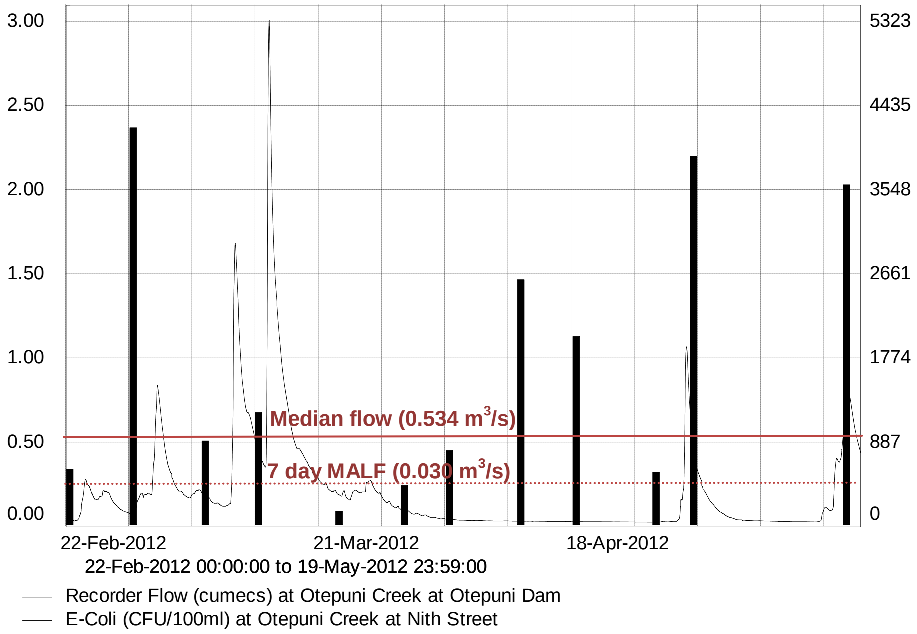

Figure 12: River flow Otepuni Creek at Otepuni Dam and *E. coli* at Nith St (22 February–18 May)

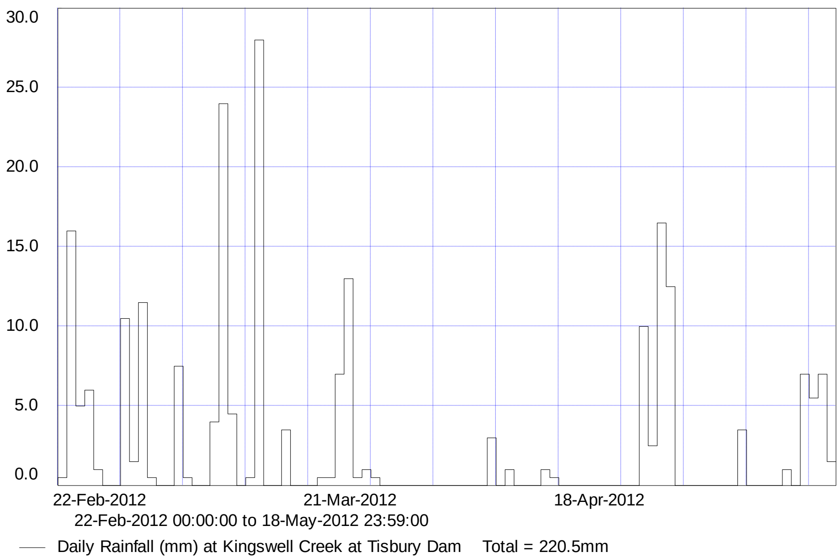

Figure 13: Total daily rainfall at Tisbury Dam (22 February–18 May)

Water quality analysis

Water quality was monitored at four sites in the Otepuni Creek from 22 February to 18 May 2012. Water quality monitoring was undertaken at the same time as faecal sterol sample collection. Results are presented as box plots where the boundary of the box closest to zero indicates the 25th percentile, the boundary farthest from zero indicates the 75th percentile and a line within the box marks the median value (Figures 14 to 17). Whiskers (error bars) above and below the box indicate the 90th and 10th percentiles. Raw data is available in Appendix 2.

E. coli

Median *E. coli* concentrations over the investigation period were highest at the Nith Street site (median 1,050 *E. coli*/100ml) and lowest at the Kennington-Waimatua Rd site (median 410 *E. coli*/100ml) (Figure 14). The highest *E. coli* value of 16,000 CFU/100ml was recorded at the Lindisfarne St site on 12th April 2012.

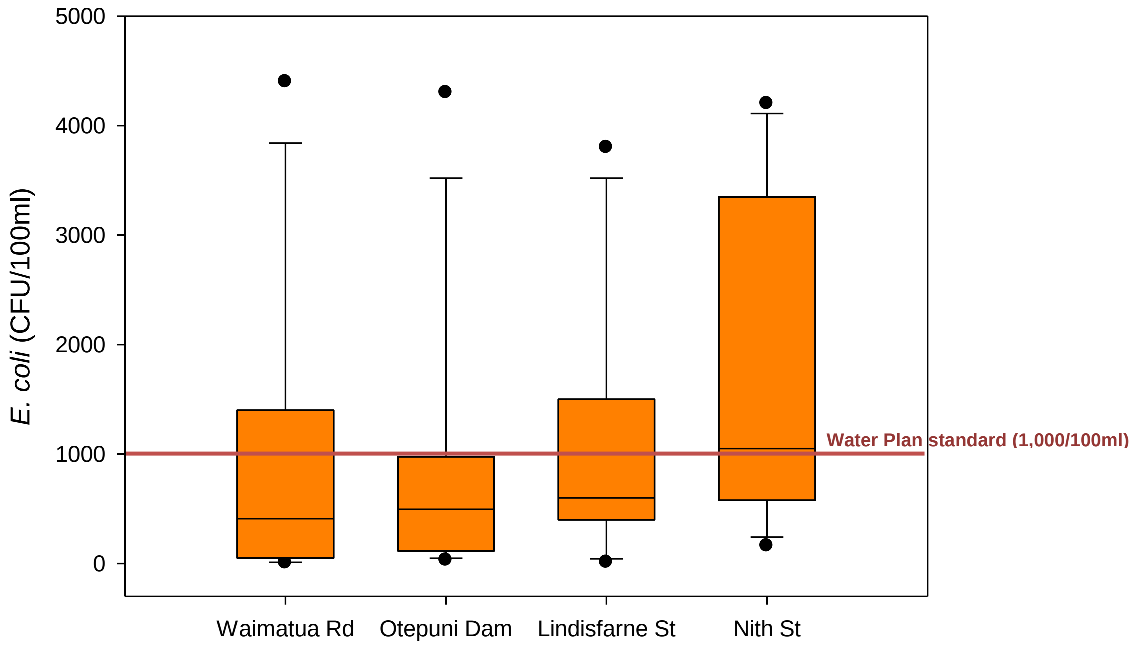

Figure 14: Median *E. coli* in the Otepuni Creek 22 February to 18 May 2012. *Note: one outlier removed from Lindisfarne St site (16,000 E.coli/100ml)*

Fluoride

Fluoride can be used as an indicator of anthropogenic contamination such as fluoride toothpaste use in human foulwater. Median fluoride concentration over the investigation period was highest at the Nith Street site (median 0.09 mg/l) (Figure 15). The two upper catchment sites (Kennington-Waimatua Rd and Otepuni Dam) had the lowest median fluoride concentration of 0.03 mg/l. There was a moderate increase in median fluoride concentrations between the Otepuni Dam and Lindisfarne Street sites, from a median of 0.03 to 0.08 mg/l, respectively.

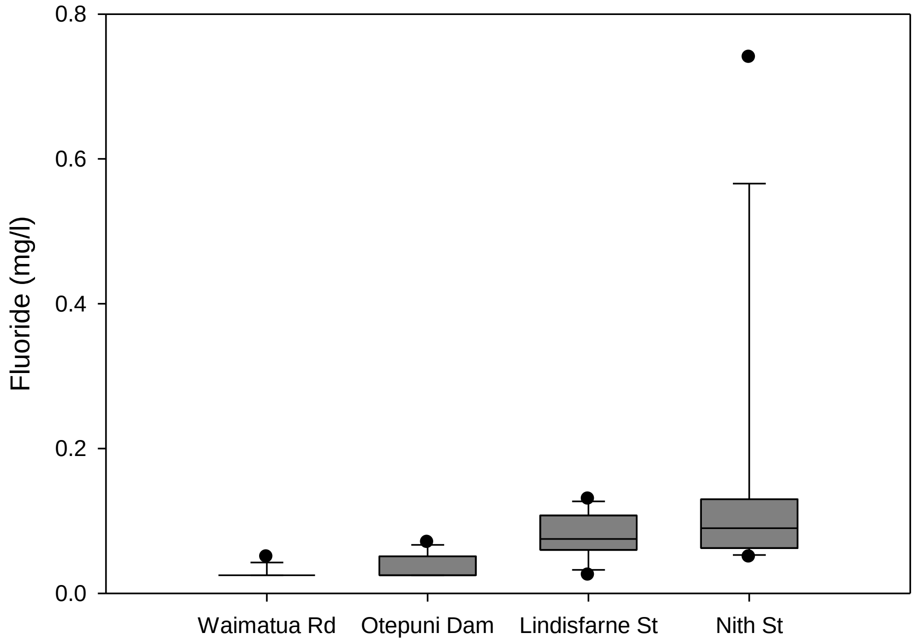

Figure 15: Median fluoride in the Otepuni Creek 22 February to 18 May 2012

Total Nitrogen

Median total nitrogen concentrations over the investigation period were similar at all sites, with medians ranging from 1.2 to 1.6 mg/l (Figure 16). High median TN concentrations at both upper and lower catchment sites (Kennington-Waimatua Road and Nith Street) indicates nitrogen in the Otepuni catchment is likely to be from both rural and urban sources.

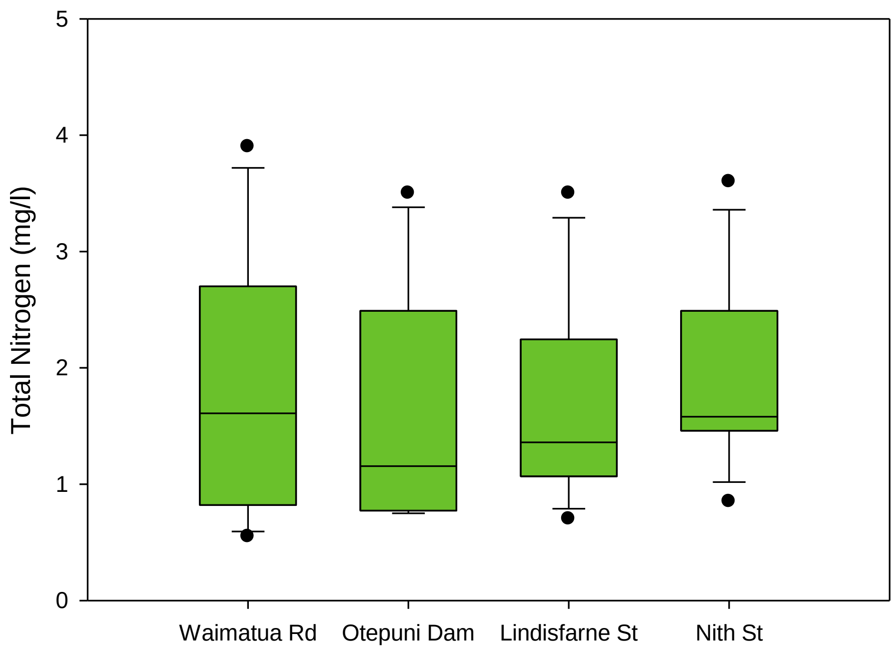

Figure 16: Median Total Nitrogen in the Otepuni Creek 22 February to 18 May 2012

Total Phosphorus

Median total phosphorus concentrations over the investigation period were similar at all sites, with medians ranging from 0.040 to 0.043 mg/l (Figure 17). This indicates there are likely to be consistent inputs of phosphorus occurring throughout the catchment, from both rural and urban sources.

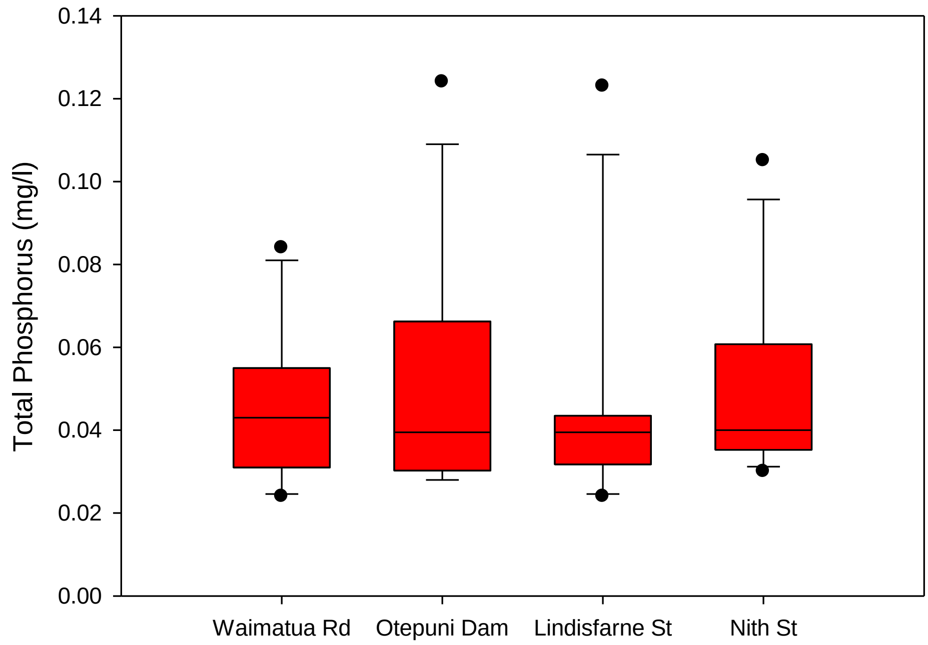

Figure 17: Median Total Phosphorus in the Otepuni Creek 22 February to 18 May 2012

Faecal sterol analysis

A total of 47 water samples from four sites on the Otepuni Creek were analysed for faecal sterols over the period 22 February to 18 May 2012. Sterol levels from 46 of the 47 samples were elevated and sufficient for faecal sterol ratio comparisons. Total sterol levels in the remaining sample (Otepuni Creek at Kennington Waimatua Road on 18 May 2012) were very low (290 ppt of total sterols) and not consistent with significant faecal contamination. As such, a comparison of sterol ratios was not possible for this sample.

A total of 45 of the 46 samples analysed showed sterol profiles consistent with typical human or animal faecal contamination (Appendix 3). None of the samples collected from the upper two sites at Kennington-Waimatua Road and the Otepuni Dam were consistent with human source sterols (Figure 18). In addition, all samples from the Kennington Waimatua Road site showed some ruminant source of sterols, 73% having only a ruminant source and 27% showing ruminant mixed with other sources including plant derived and wildfowl sterols. The Otepuni Dam site was similar, with 67% of samples consistent with ruminant source sterols and 33% showing a mix of ruminant, plant derived and undetermined faecal sterols.

Human source sterols were only present in samples from the two lower catchment sites at Lindisfarne St and Nith Street. A total of 42% of samples from the Lindisfarne Street site were consistent with a human source of sterols with the remainder of samples a mix of human, ruminant and plant, or undetermined faecal sources. The Nith Street site showed the highest percentage of human source sterol samples (75%), with the remaining 25% of samples a mix of ruminant and undetermined faecal sources. When sterol analysis was not able clearly identify a dominant source, the sample is classified as 'undetermined,' (Brent Gilpin, pers. Comm.).

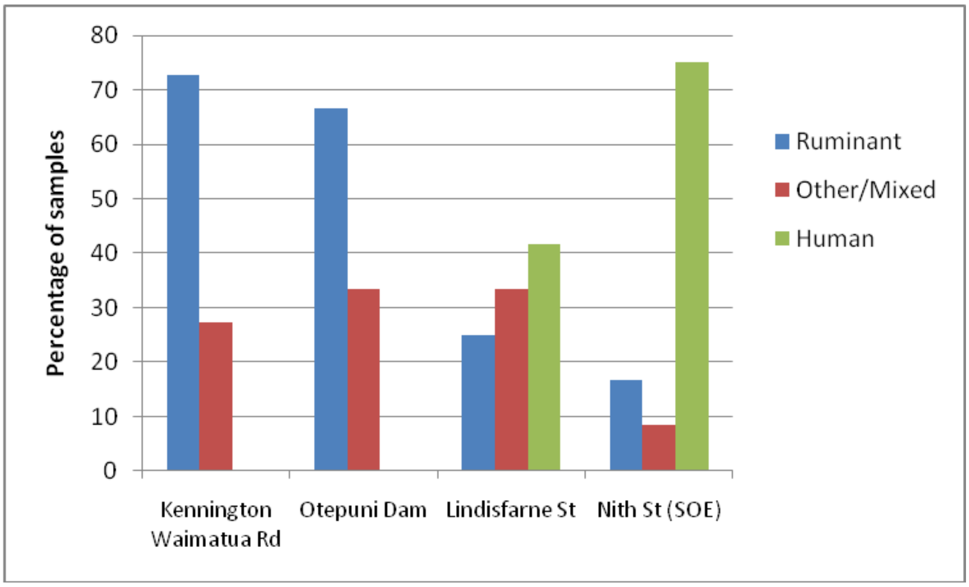

Figure 18: Otepuni Creek faecal sterol results (22 February–18 May 2012)

Relationship between Faecal Sterols and E. coli

No relationship was found between *E. coli* and faecal source (e.g. human, ruminant, plant etc.). It appears faecal source in the Otepuni Creek was variable, with high *E. coli* being attributed to human sources on some occasions and ruminant sources on others. *E. coli* values found to be of ruminant origin ranged from 30 to 4,400 CFU/100 ml and *E. coli* values identified as human source ranged from 10 to 16,000 CFU/100 ml (Table 6). All other sources including undetermined sources, plant decay and mixed (ruminant, wildfowl and plant decay) generally yielded lower *E. coli* values ranging from <10 to 800 CFU/100 ml.

Table 6: Measured *E. coli* range for each faecal source type (22 February–18 May)

Faecal source	*E. coli* range (CFU/100ml)	No. samples
Undetermined source	100 - 600	6
Plant decay	590 - 800	2
Ruminant/wildfowl/plant decay	<10 - 30	2
Ruminant	30 - 4,400	21
Human	10 - 16,000	15

Relationship between Rainfall and E. coli

All *E. coli* data from this investigation were plotted against rainfall at the nearest Environment Southland rainfall site (Kingswell Creek at Tisbury Dam). *E. coli* was not correlated to rainfall which fell in the previous 24 hours, however *E. coli* at all sites was positively correlated (R^2=0.8413) to greater than 8 mm of rainfall in the previous 48 (Figure 19).

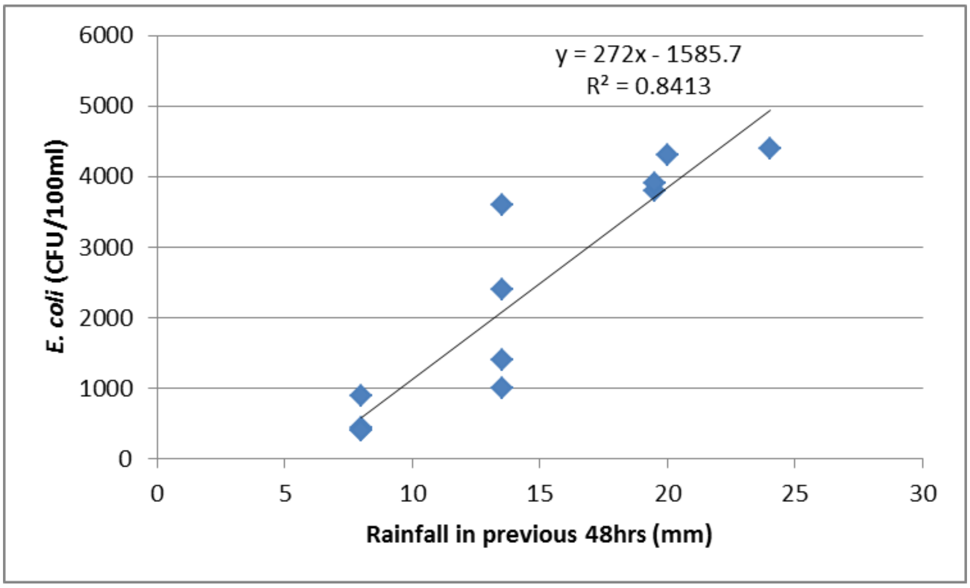

Figure 19: Relationship between *E. coli* (all sites) and greater than 8mm rainfall in previous 48 hours from Kingswell at Tisbury Dam site.

Relationship between River flow and E. coli

No relationship was found between river flow and *E. coli* in the Otepuni Creek over the period of this investigation. When long term data was analysed for the Nith Street SOE site, no relationship was found between river flow and rainfall either. As this investigation was carried out over summer (February–May), there were very few high flow events and SOE water quality data is intrinsically lacking in high flow data, in particular on the rising limb representing the "first flush".

Conclusion

A faecal source investigation carried out at four sites in the Otepuni Creek over summer 2012 identified elevated *E. coli* levels at all sites. Over the last 5 years, 56% of samples exceeded the Regional Water Plan standard for faecal bacteria in lowland streams at the Nith St SOE site.

Faecal sterol analysis carried out in this investigation identified *E. coli* of ruminant origin to be the dominant source in the upper Otepuni catchment above the Otepuni Dam. Human source *E. coli* was the dominant source in the lower Otepuni catchment below the dam, with no human contamination present above the dam. This finding may also apply to other Southland catchments with mixed rural and urban land uses.

The "upper" Otepuni catchment

The upper Otepuni catchment is predominately rural, with intensive agricultural land use and some lifestyle block areas. Ruminant source faecal sterols were identified at both upper Otepuni Creek sites with 73% and 67% of samples from the Kennington-Waimatua Road and Otepuni Dam sites, respectively, consistent with a primary ruminant source of sterols. This demonstrates the dominant source of faecal contamination in the upper Otepuni was from agricultural effluent during summer 2012. It is recommended that measures be put in place to address stock access and dairy effluent management on farms including low rate application systems, increased storage, fencing of all waterways and stronger enforcement measures for repeated non-compliance.

A small proportion of samples (between 27 and 33%) from the upper catchment sites were consistent with "mixed" faecal sources including ruminant, wildfowl and plant derived sterols. While aquatic weed (plant source) and ducks (wildfowl source) were present in the upper Otepuni Creek, these were not identified as dominant sources of faecal contamination over the investigation period.

No samples were found to be consistent with human source sterols in the upper catchment, suggesting there were no dominant septic tank leakage issues in the upper Otepuni catchment over the investigation period. However, future investigations may need to focus on septic tank sources during winter/spring periods when soil moisture levels and hydraulic connectivity is higher, increasing risk of surface and groundwater contamination.

The "lower" Otepuni catchment

The lower Otepuni catchment is predominately urban, with residential land use and some commercial and industrial areas. Human source contamination was identified at both lower Otepuni Creek sites with 42% and 75% of samples from the Lindisfarne and Nith Street sites, respectively, consistent with a primary human source of sterols. This demonstrates the presence of significant human foulwater contamination from urban stormwater drains to the Otepuni Creek during summer 2012. It is recommended that Environment Southland work with the Invercargill City Council to identify and eliminate sources of human faecal contamination from stormwater drains in the Otepuni Creek.

Sources of other faecal contamination (ruminant and mixed sources) in the lower Otepuni Creek catchment are likely to be a result of cumulative contamination from the upper and lower catchment. Therefore to reduce *E. coli* contamination and the levels of other associated contaminants in the Otepuni Creek both stock exclusion and effluent management in the upper catchment and human foulwater contamination in the lower catchment will need to be addressed together.

Other indicators of contamination

While fluoride did not correlate with *E. coli* in this investigation, an increase in median fluoride concentrations between the Otepuni Dam and Lindisfarne Street sites indicated an input of anthropogenic fluoride (e.g. human foulwater) between these sites. As such, fluoride shows potential as an affordable screening method (less than $20/sample) for identifying suspected human source faecal contamination in urban catchments.

Total nitrogen and phosphorus concentrations in the Otepuni Creek were moderately elevated at all sites (above ANZECC, 2000 lowland guidelines), indicating consistent inputs throughout the catchment from both rural and urban sources. Eutrophication is a key concern in the New River Estuary, with increasing levels of nitrogen and phosphorus causing nuisance macroalgae growth (Environment Southland, 2010b).

There may be scope to investigate the effectiveness of faster and more affordable indicators of tracking human source contamination in the Otepuni Creek, given faecal sterol analysis currently costs approximately $380 per sample. For example, the use of fluorescent whitening agents (FWAs), fluoride (used in this investigation) and halides such as chloride : bromide ratios. While PCR methods are more affordable than faecal sterol analysis (approximately $250 per sample), the techniques are not currently able to accurately distinguish between human and possum DNA (Kirs *et al.*, 2008).

River Flow and Rainfall

In this investigation, *E. coli* at all sites was positively correlated (R^2=0.8413) with greater than 8 mm of rainfall in the previous 48 hours at the Kingswell Creek at Tisbury Dam rainfall site. This demonstrates the use of rainfall data in predicting *E. coli* levels in the Otepuni Creek, but also potentially in other Southland catchments.

While *E. coli* was not correlated to river flow in the Otepuni Creek during this investigation, further work may need to consider *E. coli* sampling on the rising limb of high flow events to enable the possibility of using river flow data as a predictor.

Stormwater Consent Compliance

Stormwater discharge consents to water were granted for the Invercargill City area in 2011. Consents were granted for a five year term to allow the collection of a range of stormwater quality data, as little information existed prior to this. Preliminary stormwater quality and macroinvertebrate data for the Otepuni Creek was supplied by Invercargill City Council. Initial water quality data collected in March and April this year indicated faecal contamination in several stormwater drains, in particular Camden Street and Lindisfarne Street drains. It is recommended that the faecal contamination identified in these stormwater drains is investigated further and managed as a priority.

Dairy Consent Compliance

Resource consents are held by 9 dairy farms in the Otepuni Creek catchment. Environment Southland has recorded some form of non-compliance at six of the nine farms to date. In addition, significant non-compliance, determined by a score of 10 in an inspection, has been identified at four of these nine farms all of which have a record of repeated non-compliance. To date, all significant non-compliance has occurred on farms with older consents, due for renewal in the next 1-3 years. Significant non-compliance on these farms has been a result of poor effluent management and/or failure of travelling irrigator systems.

More recent dairy consents granted since 2010 routinely specify the use of low rate application rate systems, increased effluent storage and regional council auditing to reduce the risk of contamination to ground and surface water. If an immediate improvement in faecal bacteria contamination in the Otepuni Creek is desired then it is recommended that resource consents for the four farms with repeated significant non-compliance be reviewed and brought in line with current dairy consent conditions. Alternatively, these four consents could be updated to meet current consent conditions over the next three years, as they expire.

To date, all but one significant non-compliance incident has been addressed via "advice and education" only. Therefore, in addition to updating consents in the catchment, the implementation of stronger enforcement methods is needed for repeated significant non-compliance, to reduce the risk of faecal contamination in the Otepuni Creek.

Monitoring Recommendations

- Investigate the effectiveness of faster and more affordable indicators for tracking human source contamination in the Otepuni Creek. For example, the use of fluorescent whitening agents (FWAs), fluoride and halides such as chloride : bromide ratios.

- Determine the spatial and temporal extent of human source faecal contamination in the New River Estuary and the risks to human health and values.

- Identify other pathogens associated with faecal bacteria contamination in the Otepuni Creek which may affect human health (e.g. *Cryptosporidium, Campylobacter* and viruses).

- Investigate the extent of potential septic tank sources on *E. coli* levels in the Otepuni Creek during winter/spring periods, when soil moisture and hydraulic connectivity is higher and may pose a greater risk to surface and groundwater.

- Sample *E. coli* on the rising limb of high flow events to explore the possibility of using river flow data as a predictor of *E. coli* in the Otepuni Creek.

- Use rainfall data to predict *E. coli* levels in the Otepuni Creek, and potentially other Southland catchments. In this investigation *E. coli* at all sites was positively correlated to greater than 8mm of rainfall in the previous 48 hours.

- Repeat this study when significant progress has been made towards removing faecal bacteria contamination in both the upper and lower Otepuni Creek.

Management Recommendations

1. Work with the Invercargill City Council to identify and eliminate sources of human faecal contamination from stormwater drains in the Otepuni Creek, with a priority of addressing known foulwater contamination in the Otepuni Creek.

2. Review dairy consents to upgrade effluent management systems, reducing the risk of faecal contamination to the Otepuni Creek. Conditions may be added to consent renewals occurring over the next three years, or through immediate review of current consents to achieve a timelier result for four farms with repeated significant non-compliance.

3. Exclude all stock from the Otepuni Creek and its small, ephemeral tributaries to reduce direct faecal bacteria contamination.

4. Employ stronger enforcement methods to reduce repeated significant non-compliance in the Otepuni catchment. "Advice and education" has been the primary method for addressing significant non-compliance on dairy farms to date, however stronger enforcement measures along with effluent system upgrades and stock exclusion will be required to significantly reduce faecal bacteria contamination to the Otepuni Creek.

5. Address both upper and lower catchment sources in order to reduce total faecal contamination in the Otepuni Creek.

6. Notify Public Health South and Te Ao Marama Inc. of the presence of human foulwater contamination in the Otepuni Creek.

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Appendices

Appendix 1 Invercargill City Council stormwater consent monitoring – Water quality

When calling please ask for: Adrian
Contact Phone No.: (03) 216 2189
E-mail: *lab@icc.govt.nz*
10 August 2012

Graeme McKenzie
Environment Southland
Senior Technical Officer – Compliance
Private Bag 90116
Invercargill 9810

Dear Graeme
Re: Summary of Monitoring of ICC Discharge Permits 206936, 206937, 206938, 206939, 206940

As per requirements of the aforementioned discharge permits, details of results are reported.

Waihopai Discharge Permit – Consent 206936 Condition 3 (e) (ii)
Results referred to are appended at the end of this report.

Investigations to identify and remove human sewage contamination from previously stated drains are required within 9 months from the commencement of this consent (19 Sept 2012). Investigations into the quality of the stormwater from the drains has commenced.

274 Talbot Street Discharge
This discharge site has been tested for *E. coli* concentration on 9 occasions during dry flow. On one of the test series, samples were also taken from other sites within this reticulated system in order to gauge if any perceived contamination was evident. As part of Schedule A (i) (a) samples from the discharge have also been tested a further twice during low flow periods. *E. coli* concentrations have ranged between a low of 15 and 563 MPN/100ml with a median of 75 MPN/100ml. During testing for Schedule A, Fluorescent Whitening Agent (FWA) was also tested. During these occasions an *E. coli* concentration of 43 MPN/100ml and a FWA of 0.11μg/l was obtained March 22; and an *E. coli* concentration of 35 MPN/100ml and a FWA of <0.01μg/l was obtained July 4. On 28 April testing for Schedule A (wet weather flow) was also undertaken. On this occasion an *E. coli* concentration of 228 MPN/100ml and a FWA of <0.01μg/l resulted.

Results obtained do not indicate to the ICC that human sewage contamination was present in the discharge. There has been no sign of any reported faecal material as mentioned 'casually' during the hearing procedure of September 2011 (Murray, DoC). The catchment area for this discharge is relatively small with most housing circa 1960s.

The ICC is reluctant to investigate further within this catchment unless new evidence of human faecal contamination comes to light.

Prestonville Inflow
This discharge site has been tested for *E. coli* concentration on 13 occasions during dry flow. On four of the test series, samples were also taken from other sites within this reticulated system in order to gauge if any perceived contamination was evident. As part of Schedule A (i) (a) samples from the discharge have also been tested a further twice during low flow periods. *E. coli* concentrations have ranged between a low of 20 and 25993 MPN/100ml with a median of 323 MPN/100ml. During testing for Schedule A, FWA was also tested. During these occasions an *E. coli* concentration of 545 MPN/100ml and a FWA of 0.03μg/l was obtained March 22; and an *E. coli* concentration of 86 MPN/100ml and a FWA of <0.01μg/l was obtained July 4. On 28 April testing for Schedule A (Storm event) was also undertaken. On this occasion an *E. coli* concentration of 2160 MPN/100ml and a FWA of 0.04μg/l resulted.

The results to date establish that intermittent high faecal counts are obtained during dry weather. In spite of this, on the two such occasions when FWA was tested, the resultant FWA levels were either undetectable or below the level that would suggest human sewage. We are continuing to investigate the catchment in an attempt to narrow potential contamination into sub catchments using *E. coli* testing as the measurement tool. We have had limited success so far, so are in a period of gathering more data so as to identify patterns of possible faecal contamination. The catchment for the discharge is mixed light industrial/commercial/residential and covers an area of around 140 hectares.

Russell Street Discharge
This discharge site has been tested for *E. coli* concentration on 7 occasions during dry flow. As part of Schedule A (i) (a) samples from the discharge have also been tested a further three times during low flow periods. *E. coli* concentrations have ranged between a low of 242 and 5475 MPN/100ml with a median of 1115 MPN/100ml. During testing for Schedule A, FWA was also tested. During these two occasions an *E. coli* concentration of 378 MPN/100ml and a FWA of 0.50µg/l was obtained March 22; and an *E. coli* concentration of 3590 MPN/100ml and a FWA of 0.01µg/l was obtained July 4. On 28 April testing for Schedule A (wet weather flow) was also undertaken. On this occasion an *E. coli* concentration of 24420 MPN/100ml and a FWA of 0.13µg/l resulted. The catchment to this drain is generally old residential. To date we have not tested for *E. coli* up the pipeline so as to establish possible sites of human faecal contamination.

Waihopai River Discharge Permit – Consent 206936 Schedule A
Water quality in the Waihopai River and Drains are required to be monitored periodically during dry and storm weather conditions. The river and drains have been monitored as per the schedule twice during dry conditions and low flow and once during a storm event.

Waihopai River Monitoring - Dry Weather Low Flow
22 March 2012
On this occasion there had been zero rainfall in the previous 3 days and 28.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.66 cumecs at Kennington. *E. coli* concentrations decreased from 620 to 171 MPN/100ml from the Racecourse Road sample site to the North Road sample site.

5 July 2012
On this occasion there had been zero rainfall in the previous 3 days and 36.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 1.8 cumecs at Kennington. This flow was above the guideline flow level (median flow 1.25 cumecs) however the weather had been stable for several days and it was envisioned that the flow would not drop to 1.25 cumecs before rainfall was due. It was decided that we should proceed with the sample run. *E. coli* concentrations decreased from 354 to 132 MPN/100ml from the Racecourse Road sample site to the North Road sample site. There was a slight increase to 496 MPN/100ml at the Downstream Prestonville site.

Waihopai River Monitoring - Wet Weather Storm Event
28 April 2012
On this occasion there had been 7.5mm rainfall in the previous few hours with zero rainfall in the 3 days previous to that, and 8mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.3 cumecs at Kennington. *E. coli* concentrations increased from 1166 to 1526 MPN/100ml from the Racecourse Road sample site to the North Road sample site. There was an observed increase to 7796 MPN/100ml at the Queens Drive site.

Waihopai River Discharge Monitoring - Dry Weather Low Flow
22 March 2012
On this occasion there had been zero rainfall in the previous 3 days and 28.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.66 cumecs at Kennington. *E. coli* concentrations exceeded 1000 MPN/100ml at the Queens Drive discharge (3106 MPN/100ml) and the Gladstone Terrace discharge (1124 MPN/100ml). Elevated FWA at the Queens Drive site (5.9µg/l) and The Russell Street outfall (0.50µg/l) were reported. The Gladstone Terrace sample site used (at the discharge at about low flow river level) proved difficult to sample adequately, and it was decided that a sample site from a manhole in Gladstone terrace just before discharge would be more suitable. Repeat sampling was carried out the next day to confirm the *E. coli* transgressions. This

sampling showed continued elevated E. coli at the Queens Drive (3130 MPN/100ml) site but reduced contamination at the Gladstone Terrace site (100 MPN/100ml).

4 July 2012
On this occasion there had been zero rainfall in the previous 3 days and 42mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 2.2 cumecs at Kennington. *E. coli* concentrations exceeded 1000 MPN/100ml at the Queens Drive discharge (4730 MPN/100ml) and the Russell Street discharge (3590 MPN/100ml). Repeat sampling was carried out the next day to confirm the *E. coli* transgressions. This sampling showed continued elevated E. coli at the Queens Drive (5200 MPN/100ml) site and the Russell Street discharge (5040 MPN/100ml). FWA levels was detected at Queens Drive (0.08µg/l) and Russell Street (0.01µg/l) but the levels were low.

Waihopai River Discharge Monitoring - Wet Weather Storm Event
28 April 2012
On this occasion there had been 7.5mm rainfall in the previous hours with zero rainfall in the 3 days previous to that, and 8mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.3 cumecs at Kennington.

Waikiwi Stream Discharge Permit – Consent 206937 Schedule A
Water quality in the Waikiwi Stream and Discharge are required to be monitored periodically during dry and storm weather conditions. The river and drains have been monitored as per the schedule twice during dry conditions and low flow and once during a storm event.

Waikiwi Stream Monitoring - Dry Weather Low Flow
21 March 2012
On this occasion there had been zero rainfall in the previous 3 days and 34mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.79 cumecs at Kennington. *E. coli* concentrations were high but stable at 921 to 980 MPN/100ml from the Upstream sample site to the Downstream sample site.

5 July 2012
On this occasion there had been zero rainfall in the previous 3 days and 36.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 1.8 cumecs at Kennington. This flow was above the guideline flow level (median flow 1.25 cumecs) however the weather had been stable for several days and it was envisioned that the flow would not drop to 1.25 cumecs before rainfall was due. It was decided that we should proceed with the sample run. *E. coli* concentrations were stable at 106 to 108 MPN/100ml from the Upstream sample site to the Downstream sample site.

Waikiwi Stream Monitoring - Wet Weather Storm Event
28 April 2012
On this occasion there had been 7.5mm rainfall in the previous hours with zero rainfall in the 3 days previous to that, and 8mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.3 cumecs at Kennington. *E. coli* concentrations increased slightly from 521 to 857 MPN/100ml from the Upstream sample site to the Downstream sample site.

Waikiwi Stream Discharge Monitoring - Dry Weather Low Flow
21 March 2012
On this occasion there had been zero rainfall in the previous 3 days and 34mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.66 cumecs at Kennington. The *E. coli* concentration did not exceed 1000MPN/100ml (308 MPN/100ml). FWA at the discharge appeared elevated (0.57ug/l), however there was a dead sheep that had been decomposing in the ditch just before discharge for some time. It is not known whether interference from the carcass was a cause of the elevated FWA reported. We requested that the sheep carcass be removed from the ditch.

4 July 2012
On this occasion there had been zero rainfall in the previous 3 days and 42mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 2.2 cumecs at Kennington. The *E. coli* concentration did not exceed 1000MPN/100ml (5 MPN/100ml). The FWA level was undetectable.

Waikiwi Stream Discharge Monitoring - Wet Weather Storm Event
28 April 2012
On this occasion there had been 7.5mm rainfall in the previous hours with zero rainfall in the 3 days previous to that, and 8mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.3 cumecs at Kennington.

Otepuni Stream Discharge Permit – Consent 206938 Schedule A
Water quality in the Otepuni Stream and Discharge are required to be monitored periodically during dry and storm weather conditions. The river and drains have been monitored as per the schedule twice during dry conditions and low flow and once during a storm event.

Otepuni Stream Monitoring - Dry Weather Low Flow
22 March 2012
On this occasion there had been zero rainfall in the previous 3 days and 36.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.65 cumecs at Kennington. *E. coli* concentrations reduced from 663 to 441 MPN/100ml from the Rockdale Road sample site to the Mersey Street sample site.

5 July 2012
On this occasion there had been zero rainfall in the previous 3 days and 31.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 1.8 cumecs at Kennington. This flow was above the guideline flow level (median flow 1.25 cumecs) however the weather had been stable for several days and it was envisioned that the flow would not drop to 1.25 cumecs before rainfall was due. It was decided that we should proceed with the sample run. *E. coli* concentrations increased from 262 to 488 MPN/100ml from the Rockdale Road sample site to the Mersey Street sample site.

Otepuni Stream Monitoring - Wet Weather Storm Event
27/28 April 2012
On this occasion there had been 6.5mm rainfall in the previous hours with zero rainfall in the 3 days previous to that, and 10mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.3 cumecs at Kennington. *E. coli* concentrations reduced from 5215 to 1405 MPN/100ml from the Rockdale Road sample site to the Mersey Street sample site.

Otepuni Stream Discharge Monitoring - Dry Weather Low Flow
22 March 2012
On this occasion there had been zero rainfall in the previous 3 days and 34mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.66 cumecs at Kennington. The *E. coli* concentration exceeded 1000MPN/100ml at 16 Onslow Street (7765 MPN/100ml), Camden Street (75900 MPN/100ml) and Leven Street (1354 MPN/100ml) discharges. Elevated FWA at 16 Onslow Street (0.29µg/l); Lindisfarne Street (4.3µg/l); Camden Street (8.6µg/l); and Ythan Street (1.34µg/l) were reported. Repeat sampling was carried out the next day to confirm the *E. coli* transgressions. This sampling showed continued elevated E. coli at 16 Onslow Street (2589 MPN/100ml); Camden Street (23300 MPN/100ml) and Leven Street (3244 MPN/100ml).

4 July 2012
On this occasion there had been zero rainfall in the previous 3 days and 34.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 2.2 cumecs at Kennington. The *E. coli* concentration exceeded 1000MPN/100ml at Lindisfarne Street (2481 MPN/100ml), Camden Street (17250 MPN/100ml) and Leven Street (1483 MPN/100ml) discharges. FWA levels were not elevated at any sites. Repeat sampling was carried out the next day to confirm the *E. coli* transgressions. This sampling showed continued elevated E. coli at Lindisfarne Street (1720 MPN/100ml); Camden Street (16900 MPN/100ml) and Leven Street (1114 MPN/100ml).

Otepuni Stream Discharge Monitoring - Wet Weather Storm Event
27/28 April 2012
On this occasion there had been 6.5mm rainfall in the previous hours with zero rainfall in the 3 days previous to that, and 10mm in the previous 10 days. The flow at the time of sampling was 0.3 cumecs at Kennington.

Kingswell Creek Discharge Permit – Consent 206939 Schedule A

Water quality in the Kingswell Creek and Discharge are required to be monitored periodically during dry and storm weather conditions. The river and drains have been monitored as per the schedule twice during dry conditions and low flow and once during a storm event.

Kingswell Creek Monitoring - Dry Weather Low Flow
22 March 2012
On this occasion there had been zero rainfall in the previous 3 days and 36.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.65 cumecs at Kennington. *E. coli* concentrations reduced from 207 to 55 MPN/100ml from the Chesney Street sample site to the Bluff Road sample site.

5 July 2012
On this occasion there had been zero rainfall in the previous 3 days and 31.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 1.8 cumecs at Kennington. This flow was above the guideline flow level (median flow 1.25 cumecs) however the weather had been stable for several days and it was envisioned that the flow would not drop to 1.25 cumecs before rainfall was due. It was decided that we should proceed with the sample run. *E. coli* concentrations were stable at 601 to 620 MPN/100ml from the Chesney Street sample site to the Bluff Road sample site.

Kingswell Creek Monitoring - Wet Weather Storm Event
27 April 2012
On this occasion there had been 6.5mm rainfall in the previous hours with zero rainfall in the 3 days previous to that, and 9mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.3 cumecs at Kennington. *E. coli* concentrations increased from 610 to 1405 MPN/100ml from the Chesney Street sample site to the Bluff Road sample site.

Kingswell Creek Discharge Monitoring - Dry Weather Low Flow
22 March 2012
On this occasion there had been zero rainfall in the previous 3 days and 36.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.65 cumecs at Kennington. The *E. coli* concentration exceeded 1000MPN/100ml at Brown Street (79360 MPN/100ml) and Elles Road (97680 MPN/100ml). Elevated FWA at Brown Street (5.1μg/l) and Elles Road (0.18μg/l) were reported. Repeat sampling was carried out the next day to confirm the *E. coli* transgressions. This sampling showed continued elevated E. coli at Brown Street (5760 MPN/100ml) and Elles Road (48850 MPN/100ml).

4 July 2012
On this occasion there had been zero rainfall in the previous 3 days and 34.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 2.2 cumecs at Kennington. The *E. coli* concentration exceeded 1000MPN/100ml at Brown Street (17220 MPN/100ml) and Elles Road (290900 MPN/100ml). Slightly Elevated FWA at Brown Street (0.07μg/l) was reported. Repeat sampling was carried out the next day to confirm the *E. coli* transgressions. This sampling showed continued elevated E. coli at Brown Street (27200 MPN/100ml) and Elles Road (112500 MPN/100ml).

Kingswell Creek Discharge Monitoring - Wet Weather Storm Event
27 April 2012
On this occasion there had been 6.5mm rainfall in the previous hours with zero rainfall in the 3 days previous to that, and 9mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.3 cumecs at Kennington.

Clifton Channel Permit – Consent 206940 Schedule A

Water quality in the Clifton is required to be monitored periodically during dry and storm weather conditions. The channel have been monitored as per the schedule twice during dry conditions and low flow and once during a storm event.

Clifton Channel Monitoring - Dry Weather Low Flow
22 March 2012
On this occasion there had been zero rainfall in the previous 3 days and 36.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.65 cumecs at Kennington. *E. coli* concentrations reduced from 2909 to 221 MPN/100ml from the Bain Street sample site to the Lake Street sample site.

5 July 2012
On this occasion there had been zero rainfall in the previous 3 days and 31.5mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 1.8 cumecs at Kennington. This flow was above the guideline flow level (median flow 1.25 cumecs) however the weather had been stable for several days and it was envisioned that the flow would not drop to 1.25 cumecs before rainfall was due. It was decided that we should proceed with the sample run. *E. coli* concentrations reduced from 1080 to 97 MPN/100ml from the Bain Street sample site to the Lake Street sample site.

Clifton Channel Monitoring - Wet Weather Storm Flow
27/28 April 2012
On this occasion there had been 6.5mm rainfall in the previous hours with zero rainfall in the 3 days previous to that, and 9mm in the previous 10 days. The flow of the Waihopai River at the time of sampling was 0.3 cumecs at Kennington. *E. coli* concentrations reduced from 46040 to 995 MPN/100ml from the Chesney Street sample site to the Bluff Road sample site.

Yours sincerely

Adrian Cocker
Laboratory Manager

Sample Test Results

Condition 3 (e) (ii)

274 Talbot Street – Dry weather		
Date	E. coli MPN per 100ml	FWA µg/l
26 Jan 2012	29	
30 Jan 2012	189	
2 Feb 2012	216	
5 Feb 2012	20	
10 Feb 2012	240	
21 Feb 2012	563	
28 Feb 2012	75	
19 Mar 2012	530	
22 Mar 2012	43	0.11
18 April 2012	15	
4 Jul 2012	35	<0.01

Prestonville Inflow – Dry weather		
Date	E. coli MPN per 100ml	FWA µg/l
26 Jan 2012	341	
30 Jan 2012	226	
2 Feb 2012	109	
5 Feb 2012	3,255	
7 Feb 2012	1,396	
10 Feb 2012	1,868	
21 Feb 2012	20	
28 Feb 2012	435	
19 Mar 2012	25,993	
22 Mar 2012	545	0.03
21 May 2012	218	
2 Jul 2012	173	
3 Jul 2012	292	
4 Jul 2012	86	<0.01
26 Jul 2012	323	

Russell Street Discharge – Dry weather		
Date	E. coli MPN per 100ml	FWA µg/l
26 Jan 2012	242	
30 Jan 2012	1,245	
2 Feb 2012	435	
5 Feb 2012	959	
10 Feb 2012	3,155	
21 Feb 2012	5,475	
28 Feb 2012	985	
22 Mar 2012	378	0.50
4 Jul 2012	3,590	0.01
5 Jul 2012	5,040	

Schedule A

Receiving Dry Weather – Low Flow

Waihopai River *E. coli* MPN per 100ml: Dry weather – Low Flow		
Site	22 March 2012	5 July 2012
Racecourse Road 50m Up	620	354
Queens Drive 50m Down	805	411
Prestonville 50m Up	218	323
Prestonville 60m Down	232	496
North Road Bridge	171	132

Waikiwi Stream *E. coli* MPN per 100ml: Dry weather – Low Flow		
Site	21 March 2012	5 July 2012
Upstream	921	106
Down Stream	980	108

Otepuni Stream *E. coli* MPN per 100ml: Dry weather – Low Flow		
Site	22 March 2012	5 July 2012
Rockdale Road	663	262
Lindisfarne Street	255	256
Mersey Street	441	488

Kingswell Creek *E. coli* MPN per 100ml: Dry weather – Low Flow		
Site	22 March 2012	5 July 2012
Chesney Street	207	601
Bluff Road	55	620

Clifton Channel *E. coli* MPN per 100ml: Dry weather – Low Flow		
Site	22 March 2012	5 July 2012
Bain Street	2,909	1,080
Wicklow Street	52	100
Lake Street	221	97

Schedule A

Receiving Storm Event

Waihopai River *E. coli* MPN per 100ml: Storm Event	
Site	28 April 2012
Racecourse Road 50m Up	1,166
Queens Drive 50m Down	7,746
Prestonville 50m Up	2,582
Prestonville 60m Down	2,252
North Road Bridge	1,526

Waikiwi Stream *E. coli* MPN per 100ml: Storm Event	
Site	28 April 2012
Upstream	521
Down Stream	857

Otepuni Stream *E. coli* MPN per 100ml: Storm Event	
Site	27 April 2012
Rockdale Road	5,215
Lindisfarne Street	800
Mersey Street	1,405

Kingswell Creek *E. coli* MPN per 100ml: Storm Event	
Site	27 April 2012
Chesney Street	610
Bluff Road	1,405

Clifton Channel *E. coli* MPN per 100ml: Storm Event	
Site	27 April 2012
Bain Street	46,040
Wicklow Street	6,545
Lake Street	995

Schedule A

Discharges Dry Weather

Waihopai Discharges *E. coli* MPN per 100ml: Dry weather – Low Flow				
Site	22 March 2012	23 March 2012	4 July 2012	5 July 2012
274 Talbot	43		35	
61 Rosewood	5		1	
Queens Drive	3,106	3,130	4,730	5,200
Thomsons Bush	310,6173		20	
126 Gladstone	1,124	100	<1	
Prestonville	545		86	
Russell Street	378		3,590	5,040

Waihopai Discharges FWA µg per litre: Dry weather – Low Flow		
Site	22 March 2012	4 July 2012
274 Talbot	0.11	<0.01
61 Rosewood	<0.01	<0.01
Queens Drive	5.9	0.08
Thomsons Bush	0.14	<0.01
126 Gladstone	0.09	<0.01
Prestonville	0.03	<0.01
Russell Street	0.50	0.01

Waikiwi Discharge *E. coli* MPN per 100ml: Dry weather – Low Flow		
Site	22 March 2012	4 July 2012
Waikiwi Discharge	308	5

Waikiwi Discharge FWA µg per litre: Dry weather – Low Flow		
Site	22 March 2012	4 July 2012
Waikiwi Discharge	0.57	<0.01

Otepuni Discharges *E. coli* MPN per 100ml: Dry weather – Low Flow				
Site	22 March 2012	23 March 2012	4 July 2012	5 July 2012
34 Onslow	968		31	
16 Onslow	7,765	2,589	436	
Lindisfarne Street	828		2,481	1,720
Camden Street	75,900	23,300	17,250	16,900
Ythan Street	479		86	
Leven Street	1,354	3,244	1,483	1,114

Otepuni Discharges FWA µg per litre: Dry weather – Low Flow		
Site	22 March 2012	4 July 2012
34 Onslow	0.12	<0.01
16 Onslow	0.29	<0.01
Lindisfarne Street	4.3	0.08
Camden Street	8.6	0.02
Ythan Street	1.34	<0.01
Leven Street	0.15	0.01

Kingswell Discharges *E. coli* MPN per 100ml: Dry weather – Low Flow				
Site	22 March 2012	23 March 2012	4 July 2012	5 July 2012
Brown Street	79,300	5,760	17,220	27,200
Elles Road	97,680	48,840	290,900	112,500
Bluff Road	1		<1	

Kingswell Discharges FWA µg per litre: Dry weather – Low Flow		
Site	22 March 2012	4 July 2012
Brown Street	5.1	0.07
Elles Road	0.18	<0.01
Bluff Road	0.02	<0.01

Schedule A

Discharge Storm Event

Waihopai Discharges *E. coli* MPN per 100ml: Storm event	
Site	28 April 2012
274 Talbot	228
61 Rosewood	26
Queens Drive	9,080
Thomsons Bush	550
126 Gladstone	33
Prestonville	332,160
Russell Street	24,420

Waihopai Discharges FWA µg per litre: Storm event	
Site	28 April 2012
274 Talbot	0.01
61 Rosewood	<0.01
Queens Drive	0.22
Thomsons Bush	0.01
126 Gladstone	<0.01
Prestonville	0.04
Russell Street	0.13

Waikiwi Discharge *E. coli* MPN per 100ml: Storm event	
Site	28 April 2012
Waikiwi Discharge	610

Waikiwi Discharge FWA µg per litre: Storm event	
Site	28 April 2012
Waikiwi Discharge	0.03
Otepuni Discharges *E. coli* MPN per 100ml: Storm event	
Site	27/28 April 2012
34 Onslow	2,825
16 Onslow	34,335
Lindisfarne Street	4,410
Camden Street	8,800
Ythan Street	545
Leven Street	5,760

Otepuni Discharges FWA µg per litre: Storm event	
Site	27/28 April 2012
34 Onslow	<0.01
16 Onslow	<0.01
Lindisfarne Street	0.03
Camden Street	0.08
Ythan Street	<0.01
Leven Street	0.07

Kingswell Discharges *E. coli* MPN per 100ml: Storm event	
Site	27 April 2012
Brown Street	3,180
Elles Road	72,700
Bluff Road	4,300

Kingswell Discharges FWA µg per litre: Storm event	
Site	27 April 2012
Brown Street	0.05
Elles Road	0.04
Bluff Road	<0.01

Appendix 2 Environment Southland Water Quality data – Otepuni Creek 2012

Otepuni Creek at Kennington Waimatua Road

Date	Flow	Faecal Coliform	E-coli	Total Nitrogen	Total Kjeldahl Nitrogen	Nitrate Nitrite Nitrogen	Total Organic Nitrogen (calculated)	Total Phosphorous	Dissolved Oxygen Field	Water Temp	Conductivity	Fluoride
	cumecs	CFU/100ml	CFU/100ml	mg/l	mg/l-N	mg/l	mg/l	mg/l	g/m3	degC	uS/cm	mg/L
22/02/2012 0:00												
29/02/2012 13:20	0.002	540	540	0.82	0.79	0.037	0.783	0.069	8.51	14.4	241.5	<0.05
8/03/2012 12:40	0.008	410	410	0.99	0.76	0.23	0.76	0.051	12.03	11.4	264.8	<0.05
14/03/2012 10:00	0.048	1700	1600	2.7	1.04	1.7	1	0.055	10.7	10.5		<0.05
23/03/2012 8:15	0.02	510	510	1.66	0.65	1	0.66	0.038	9.14	11.4	239.2	<0.05
30/03/2012 14:10	0.008	380	380	1.61	1.15	0.46	1.15	0.027	12.42	11.9	255.8	<0.05
4/04/2012 13:35	0.006	80	70	0.86	0.44	0.42	0.44	0.024	11.48	9.8	272.4	0.05
12/04/2012 11:23	0.004	<10	<10	1.76	1.45	0.32	1.44	0.031	10.57	9.4	249.2	<0.05
18/04/2012 14:45	0.003	100	<100	0.77	0.59	0.176	0.594	0.049	10.85	9.7	255.4	<0.05
27/04/2012 11:00	0.001	30	30	0.55	0.4	0.152	0.398	0.034	8.79	10	169.7	<0.05
1/05/2012 13:23	0.058	4400	4400	3.9	1.26	2.6	1.3	0.084	11.28	9.6	300.8	<0.05
18/05/2012 12:44	0.247	1600	1400	3	1.04	1.94	1.06	0.043	11.07	9.4	270.5	<0.05
Median	**0.008**	**460**	**510**	**1.61**	**0.79**	**0.42**	**0.783**	**0.043**	**10.85**	**10**	**255.6**	**0.05**
Minimum	**0.001**	**30**	**30**	**0.55**	**0.4**	**0.037**	**0.398**	**0.024**	**8.51**	**9.4**	**169.7**	**<0.05**
Maximum	**0.247**	**4400**	**4400**	**3.9**	**1.45**	**2.6**	**1.44**	**0.084**	**12.42**	**14.4**	**300.8**	**0.05**

Otepuni Creek at Otepuni Dam

Date	Flow	Faecal Coliform	E-coli	Total Nitrogen	Total Kjeldahl Nitrogen	Nitrate Nitrite Nitrogen	Total Organic Nitrogen (calculated)	Total Phosphorous	Dissolved Oxygen Field	Water Temp	Conductivity	Fluoride
	m3/sec	CFU/100ml	CFU/100ml	mg/l	mg/l-N	mg/l	mg/l	mg/l	g/m3	degC	uS/cm	mg/L
22/02/2012 12:58	0.041	1200	800	1.08	0.81	0.27	0.81	0.124	10.76	17.5	273.3	0.06
29/02/2012 13:41	0.089	1700	1700	1.23	0.91	0.32	0.91	0.068	10.35	15.2	233.4	<0.05
8/03/2012 13:04	0.175	400	400	1.36	0.7	0.66	0.7	0.061	12.97	13.6	263.9	<0.05
14/03/2012 10:25	0.418	1200	900	2.8	0.95	1.8	1	0.043	11.6	10.8	285.9	<0.05
23/03/2012 8:44	0.185	350	350	1.56	0.59	0.97	0.59	0.036	9.57	11.5	261.3	<0.05
30/03/2012 14:31	0.098	30	30	1.01	0.53	0.48	0.53	0.028	14.45	13.3	264.9	<0.05
4/04/2012 13:58	0.043	90	90	0.77	0.39	0.38	0.39	0.028	13.52	11.4	208.1	0.06
12/04/2012 11:45	0.034	160	160	0.78	0.42	0.37	0.41	0.031	13.32	10.1	259.9	0.07
18/04/2012 15:21	0.031	100	100	0.75	0.37	0.38	0.37	0.035	14.49	11.5	261.5	<0.05
27/04/2012 11:20	0.029	590	590	0.75	0.4	0.35	0.4	0.03	9.38	10.6	253.1	<0.05
1/05/2012 15:18	0.401	4300	4300	3.5	1.28	2.2	1.3	0.074	11.79	10.2	281.1	<0.05
18/05/2012 13:06	0.819	1000	1000	3.1	1.21	1.93	1.17	0.06	11.07	9.6	266.2	<0.05
Median	**0.0935**	**495**	**495**	**1.155**	**0.645**	**0.43**	**0.645**	**0.0395**	**11.695**	**11.45**	**262.7**	**0.06**
Minimum	**0.029**	**30**	**30**	**0.75**	**0.37**	**0.27**	**0.37**	**0.028**	**9.38**	**9.6**	**208.1**	**<0.05**
Maximum	**0.819**	**4300**	**4300**	**3.5**	**1.28**	**2.2**	**1.3**	**0.124**	**14.49**	**17.5**	**285.9**	**0.07**

Otepuni Creek at Lindisfarne Street

Date	Flow	Faecal Coliform	E-coli	Total Nitrogen	Total Kjeldahl Nitrogen	Nitrate Nitrite Nitrogen	Total Organic Nitrogen (calculated)	Total Phosphorous	Dissolved Oxygen Field	Water Temp	Conductivity	Fluoride
	cumecs	CFU/100ml	CFU/100ml	mg/l	mg/l-N	mg/l	mg/l	mg/l	g/m3	degC	uS/cm	mg/L
22/02/2012 13:10	0.064	1700	600	1.18	0.46	0.72	0.46	0.04	15.55	17.1	210.9	0.13
29/02/2012 14:05	0.127	1500	1500	0.7	0.36	0.34	0.36	0.041	9.46	16.4		0.1
8/03/2012 13:27	0.243	430	430	1.48	0.6	0.88	0.6	0.039	16.47	15.9	224.2	0.07
14/03/2012 10:46	0.569	1300	1300	2.8	0.93	1.9	0.9	0.036	13.51	11.7	280.2	<0.05
23/03/2012 9:01	0.257	1200	1200	1.78	0.58	1.2	0.58	0.042	8.93	12.4	253.4	0.07
30/03/2012 14:37	0.14	600	600	1.3	0.46	0.84	0.46	0.034	16	14.7	260.5	0.06
4/04/2012 14:17	0.065	190	180	1.18	0.39	0.79	0.39	0.031	16.99	14.4	265.8	0.08
12/04/2012 12:00	0.054	16000	16000	1.42	0.67	0.76	0.66	0.044	16.04	11.1	250.3	0.12
18/04/2012 15:37	0.05	400	400	1.03	0.3	0.73	0.3	0.026		12.9	249.4	0.11
27/04/2012 11:35	0.047	10	10	1	0.23	0.77	0.23	0.024	10.64	11.3	257	0.1
1/05/2012 15:30	0.545	3800	3800	3.5	1.17	2.3	1.2	0.068	13.74	10.7	271.8	0.05
18/05/2012 13:21	1.11	2800	2400	2.4	0.66	1.75	0.65	0.123	11.7	9.7	264	0.06
Median	**0.1335**	**1250**	**900**	**1.36**	**0.52**	**0.815**	**0.52**	**0.0395**	**13.74**	**12.65**	**257**	**0.08**
Minimum	**0.047**	**10**	**10**	**0.7**	**0.23**	**0.34**	**0.23**	**0.024**	**8.93**	**9.7**	**210.9**	**<0.05**
Maximum	**1.11**	**16000**	**16000**	**3.5**	**1.17**	**2.3**	**1.2**	**0.123**	**16.99**	**17.1**	**280.2**	**0.13**

Otepuni Creek at Nith Street

Date	Flow	Faecal Coliform	E-coli	Total Nitrogen	Total Kjeldahl Nitrogen	Nitrate Nitrite Nitrogen	Total Organic Nitrogen (calculated)	Total Phosphorous	Dissolved Oxygen Field	Water Temp	Conductivity	Fluoride
	cumecs	**CFU/100ml**	**CFU/100ml**	**mg/l**	**mg/l-N**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**degC**	**uS/cm**	**mg/L**
22/02/2012 13:25	0.014	1000	600	1.41	0.6	0.81	0.6	0.06	13.77	17.5	211.1	0.16
29/02/2012 14:25	0.054	4200	4200	0.85	0.42	0.43	0.42	0.061	9.17	16.2		0.07
8/03/2012 13:45	0.095	900	900	1.63	0.51	1.11	0.52	0.04	13.77	15.5	250.4	0.1
14/03/2012 11:01	0.422	1200	1200	2.8	0.78	1.99	0.81	0.04	12.96	12	282.8	0.06
23/03/2012 9:24	0.195	220	160	1.86	0.49	1.37	0.49	0.04	9.77	12.7	252.7	0.08
30/03/2012 14:49	0.104	430	430	1.68	0.49	1.19	0.49	0.039	15.39	14.2	267.6	0.07
4/04/2012 14:34	0.08	900	800	1.46	0.36	1.1	0.36	0.034	15.61	13.6	276	0.74
12/04/2012 12:23	0.067	2600	2600	1.53	0.38	1.16	0.37	0.034	15.34	11.6	256.7	0.1
18/04/2012 15:54	0.054	2000	2000	1.5	0.31	1.19	0.31	0.042	15.14	12.6	258.4	0.13
27/04/2012 11:52	0.043	570	570	1.46	0.32	1.13	0.33	0.03	11.91	11.9	277.5	0.13
1/05/2012 15:44	0.462	3900	3900	3.6	1.29	2.3	1.3	0.074	13.08	10.8	273.2	0.06
18/05/2012 13:51	2.126	3600	3600	2.7	1.02	1.67	1.03	0.105	11.58	9.7	264.7	0.05
Median	**0.0875**	**1100**	**1050**	**1.58**	**0.49**	**1.175**	**0.49**	**0.04**	**13.425**	**12.65**	**264.7**	**0.09**
Minimum	**0.014**	**220**	**160**	**0.85**	**0.31**	**0.43**	**0.31**	**0.03**	**9.17**	**9.7**	**211.1**	**0.05**
Maximum	**2.126**	**4200**	**4200**	**3.6**	**1.29**	**2.3**	**1.3**	**0.105**	**15.61**	**17.5**	**282.8**	**0.74**

Appendix 3 Faecal sterol results

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15 Jun 2012

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REPORT ON FAECAL SOURCE TRACKING ANALYSIS

The following total of 47 water samples were received on 20 Apr 2012 (19 samples), 17 May 2012 (24 samples) or 25 May 2012 (4 samples). Two-litre of each sample was analysed for faecal sterols. All samples were from Otepuni Creek.

ESR Number	Client Reference	Sampled		Sample Site	*E .coli* (CFU/100mL)
		Date	Time		
CMB120307	20123059	29/02/2012	1320	Kennington-Waimatua Rd	540
CMB120311	20123150	08/03/2012	1240	Kennington-Waimatua Rd	410
CMB120315	20123311	14/03/2012	1000	Kennington-Waimatua Rd	1600
CMB120319	20123418	23/03/2012	0815	Kennington-Waimatua Rd	510
CMB120378	20123493	30/03/2012	1410	Kennington-Waimatua Rd	380
CMB120382	20123523	04/04/2012	1335	Kennington-Waimatua Rd	70
CMB120386	20123561	12/04/2012	1123	Kennington-Waimatua Rd	<10
CMB120390	20123652	18/04/2012	1445	Kennington-Waimatua Rd	<100
CMB120394	20123702	27/04/2012	1100	Kennington-Waimatua Rd	30
CMB120398	20123765	01/05/2012	1323	Kennington-Waimatua Rd	4400
CMB120433	20124039	18/05/2012	1244	Kennington-Waimatua Rd	1400
CMB120303	20122860	22/02/2012	1258	Otepuni Dam	800
CMB120306	20123058	29/02/2012	1341	Otepuni Dam	1700
CMB120310	20123149	08/03/2012	1304	Otepuni Dam	400
CMB120314	20123310	14/03/2012	1025	Otepuni Dam	900
CMB120318	20123417	23/03/2012	0844	Otepuni Dam	350
CMB120377	20123492	30/03/2012	1431	Otepuni Dam	30
CMB120381	20123522	04/04/2012	1358	Otepuni Dam	90
CMB120385	20123560	12/04/2012	1145	Otepuni Dam	160
CMB120389	20123651	18/04/2012	1521	Otepuni Dam	100
CMB120393	20123701	27/04/2012	1120	Otepuni Dam	590
CMB120397	20123764	01/05/2012	1518	Otepuni Dam	4300
CMB120432	20124038	18/05/2012	1306	Otepuni Dam	1000
CMB120301	20122858	22/02/2012	1310	Lindisfarne St	600
CMB120304	20123056	29/02/2012	1405	Lindisfarne St	1500
CMB120308	30123147	08/03/2012	1327	Lindisfarne St	430
CMB120312	20123308	14/03/2012	1046	Lindisfarne St	1300
CMB120316	20123415	23/03/2012	0901	Lindisfarne St	1200
CMB120375	20123490	30/03/2012	1437	Lindisfarne St	600
CMB120379	20123520	04/04/2012	1417	Lindisfarne St	180
CMB120383	20123558	12/04/2012	1200	Lindisfarne St	16000

ESR Number	Client Reference	Sampled		Sample Site	*E .coli* (CFU/100mL)
		Date	Time		
CMB120387	20123649	18/04/2012	1537	Lindisfarne St	400
CMB120391	20123699	27/04/2012	1135	Lindisfarne St	10
CMB120395	20123762	01/05/2012	1530	Lindisfarne St	3800
CMB120430	20124036	18/05/2012	1321	Lindisfarne St	2400
CMB120302	20122859	22/02/2012	1325	Nith St	600
CMB120305	20123057	29/02/2012	1425	Nith St	4200
CMB120309	20123148	08/03/2012	1345	Nith St	900
CMB120313	20123309	14/03/2012	1101	Nith St	1200
CMB120317	20123416	23/03/2012	0924	Nith St	160
CMB120376	20123491	30/03/2012	1499	Nith St	430
CMB120380	20123521	04/04/2012	1434	Nith St	800
CMB120384	20123559	12/04/2012	1223	Nith St	2600
CMB120388	20123650	18/04/2012	1554	Nith St	2000
CMB120392	20123700	27/04/2012	1152	Nith St	570
CMB120396	20123763	01/05/2012	1544	Nith St	3900
CMB120431	20124037	18/05/2012	1351	Nith St	3600

Detailed Interpretation of Sterols Results

- Sterols in sample 20124039 were very low (290 ppt of total sterols), and detailed comparison of ratios is not possible. Due to the low levels of sterols, the sample is not consistent with significant level of faecal pollution.

- Sterols in all other 46 samples are elevated and sufficient for faecal sterol ratio comparisons.

- Forty-five of the samples analysed have sterol profiles consistent with typical human/animal faecal pollution, with both faecal contamination indicators – Faecal ratios 1 and 2, reaching thresholds. The sterol profile of sample 20123561 is only positive with faecal ratio 2.

- None of samples from Kennington-Waimatua Rd and Otepuni Dam are consistent with a human source of sterols.

- All the Kennington-Waimatua Road samples are consistent with a ruminant source of sterols. There is also evidence of elevated levels of plant sterols in 20123561 and 20123702 samples, and the sterols in sample 20123561 are also consistent with wildfowl.

- Eight of the Otepuni Dam samples are consistent with a ruminant source of sterols, while, while 20122860 and 20123701 are dominated by plant sterols, and 20123560 and 20123651, while faecal in nature, could not be assigned to a faecal source.

- Six of the Lindisfarne Street samples are consistent with a human source of sterols, while 20123308, 20123762 and 20124036 samples are more similar to ruminant source of sterols, and 30123147, 20123490 and 20123520 samples could not be assigned to a faecal source.

- Nine of the Nith St samples are consistent with a human source of sterols, while the sixth (20123491) sample could not be assigned to a faecal source, and the last two samples (20123763 and 20124037) are consistent with a ruminant source of sterols.

Sterols Ratio Analysis

Kennington-Waimatua Rd

Client Reference	Date Sampled	*E. coli*	Faecal Ratios F1 >0.5	F2 >0.5	Human Indicative H3 >1	H1 >5%	H2 >0.7	H4 >75%	Ruminant Indicative R3 <1	R1 >5%	R2 <30%	Wildfowl Indicative A1 >30%	A2 >67%	Plant P1 >4	Conclusion
20123059	29/02/2012	540	1.06	3.58	0.17	2.2%	0.52	15%	2.08	12.8%	15%	19%	45%	2.08	Ruminant
20123150	8/03/2012	410	3.42	5.22	0.29	8.3%	0.77	23%	0.57	28.3%	23%	14%	20%	0.57	**Ruminant**
20123311	14/03/2012	1600	2.61	2.11	0.14	5.1%	0.72	12%	0.34	36.3%	12%	28%	25%	0.34	**Ruminant**
20123418	23/03/2012	510	1.86	2.72	0.18	4.4%	0.65	15%	0.81	24.7%	15%	23%	32%	0.81	**Ruminant**
20123493	30/03/2012	380	2.45	3.22	0.13	3.9%	0.71	11%	0.71	30.6%	11%	21%	26%	0.71	**Ruminant**
20123523	4/04/2012	70	1.28	1.79	0.23	3.3%	0.56	19%	1.80	14.3%	19%	31%	39%	1.80	Ruminant
20123561	12/04/2012	<10	0.41	1.81	0.18	1.0%	0.29	15%	6.39	5.3%	15%	30%	67%	6.39	Ruminant/wildfowl/plant decay
20123652	18/04/2012	<100	1.62	2.04	0.17	4.5%	0.62	15%	0.67	26.4%	15%	28%	34%	0.67	**Ruminant**
20123702	27/04/2012	30	0.64	2.14	0.21	1.4%	0.39	18%	4.93	6.4%	18%	28%	57%	4.93	Ruminant/Plant decay
20123765	1/05/2012	4400	1.33	1.94	0.18	3.2%	0.57	15%	1.56	18.1%	15%	30%	37%	1.56	Ruminant
20124039	18/05/2012	1400	-	-	-	-	-	-	-	-	-	-	-	-	Sterols too low. No evidence of faecal source

Otepuni Dam

Client Reference	Date Sampled	*E. coli*	Faecal Ratios F1 >0.5	F2 >0.5	Human Indicative H3 >1	H1 >5%	H2 >0.7	H4 >75%	Ruminant Indicative R3 <1	R1 >5%	R2 <30%	Wildfowl Indicative A1 >30%	A2 >67%	Plant P1 >4	Conclusion
20122860	22/02/2012	800	1.03	2.53	0.63	2.9%	0.51	**39%**	5.06	4.5%	39%	25%	46%	5.06	Plant decay
20123058	29/02/2012	1700	1.67	2.02	0.25	3.7%	0.62	20%	1.36	14.9%	20%	29%	35%	1.36	Ruminant
20123149	8/03/2012	400	1.88	2.57	0.41	5.3%	0.65	29%	1.75	12.9%	29%	25%	32%	1.75	Ruminant
20123310	14/03/2012	900	2.15	4.46	0.15	5.4%	0.68	13%	0.37	35.3%	13%	17%	29%	0.37	**Ruminant**
20123417	23/03/2012	350	3.06	4.06	0.41	6.6%	0.75	29%	1.28	16.3%	29%	17%	23%	1.28	Ruminant
20123492	30/03/2012	30	1.23	1.86	0.28	3.8%	0.55	22%	1.44	13.5%	22%	31%	41%	1.44	Ruminant
20123522	4/04/2012	90	2.01	4.19	0.29	5.2%	0.67	22%	0.99	18.1%	22%	17%	30%	0.99	**Ruminant**
20123560	12/04/2012	160	1.59	1.91	0.58	4.3%	0.61	37%	3.12	7.5%	37%	28%	35%	3.12	Faecal, source undetermined
20123651	18/04/2012	100	1.62	1.63	0.56	4.2%	0.62	36%	3.35	7.4%	36%	33%	32%	3.35	Faecal, source undetermined
20123701	27/04/2012	590	1.17	1.87	0.71	2.8%	0.54	42%	6.32	4.0%	42%	30%	42%	6.32	Plant decay
20123764	1/05/2012	4300	2.16	1.96	0.28	5.5%	0.68	22%	1.05	19.8%	22%	30%	29%	1.05	Ruminant
20124038	18/05/2012	1000	2.16	2.17	0.16	4.6%	0.68	14%	0.60	28.3%	14%	27%	28%	0.60	**Ruminant**

Lindisfarne Street

Client Reference	Date Sampled	*E. coli*	Faecal Ratios		Human Indicative				Ruminant Indicative			Wildfowl Indicative		Plant	Conclusion
			F1	F2	H3	H1	H2	H4	R3	R1	R2	A1	A2	P1	
			>0.5	>0.5	>1	>5%	>0.7	>75%	<1	>5%	<30%	>30%	>67%	>4	
20122858	22/02/2012	600	1.56	4.17	1.10	3.4%	0.61	52%	5.61	3.1%	52%	18%	38%	5.61	Human, Plant decay
20123056	29/02/2012	1500	2.43	2.24	1.25	5.5%	0.71	56%	5.97	4.4%	56%	28%	28%	5.97	**Human**
30123147	8/03/2012	430	1.96	2.46	0.73	4.5%	0.66	42%	3.42	6.2%	42%	26%	32%	3.42	Faecal, source undetermined
20123308	14/03/2012	1300	3.14	3.28	0.42	7.6%	0.76	30%	1.06	18.1%	30%	20%	22%	1.06	(Ruminant)
20123415	23/03/2012	1200	3.72	4.68	1.19	9.4%	0.79	54%	2.02	7.8%	54%	16%	21%	2.02	**Human**
20123490	30/03/2012	600	2.03	2.40	0.64	6.1%	0.67	39%	1.57	9.5%	39%	26%	31%	1.57	Faecal, source undetermined
20123520	4/04/2012	180	1.81	3.68	0.75	5.3%	0.64	43%	2.07	7.0%	43%	19%	34%	2.07	Faecal, source undetermined
20123558	12/04/2012	16000	1.65	1.51	1.41	4.2%	0.62	58%	8.09	3.0%	58%	35%	36%	8.09	Human
20123649	18/04/2012	400	1.31	1.39	1.74	3.8%	0.57	64%	7.27	2.2%	64%	35%	42%	7.27	Human
20123699	27/04/2012	10	1.28	2.04	1.31	3.2%	0.56	57%	6.85	2.5%	57%	30%	42%	6.85	Human
20123762	1/05/2012	3800	1.93	1.91	0.39	6.0%	0.66	28%	1.19	15.4%	28%	30%	32%	1.19	(Ruminant)
20124036	18/05/2012	2400	1.90	1.74	0.33	5.9%	0.65	25%	1.15	18.0%	25%	30%	31%	1.15	(Ruminant)

Nith Street

Client Reference	Date Sampled	*E. coli*	Faecal Ratios F1 >0.5	F2 >0.5	Human Indicative H3 >1	H1 >5%	H2 >0.7	H4 >75%	Ruminant Indicative R3 <1	R1 >5%	R2 <30%	Wildfowl Indicative A1 >30%	A2 >67%	Plant P1 >4	Conclusion
20122859	22/02/2012	600	2.11	4.31	1.50	4.7%	0.68	60%	7.31	3.2%	60%	16%	31%	7.31	Human
20123057	29/02/2012	4200	4.48	5.05	1.16	8.1%	0.82	54%	3.23	7.0%	54%	16%	18%	3.23	**Human**
20123148	8/03/2012	900	2.63	2.77	1.36	6.2%	0.72	58%	4.13	4.6%	58%	24%	27%	4.13	**Human**
20123309	14/03/2012	1200	2.88	3.51	0.43	7.4%	0.74	30%	1.11	17.0%	30%	20%	24%	1.11	(Human)
20123416	23/03/2012	160	1.94	7.30	0.96	6.8%	0.66	49%	2.05	7.1%	49%	11%	33%	2.05	(Human)
20123491	30/03/2012	430	2.02	2.65	0.62	6.0%	0.67	38%	1.56	9.8%	38%	24%	32%	1.56	Faecal, source undetermined
20123521	4/04/2012	800	2.12	2.78	1.96	7.9%	0.68	66%	4.16	4.1%	66%	24%	31%	4.16	**Human**
20123559	12/04/2012	2600	2.18	2.07	2.29	6.2%	0.69	70%	8.51	2.7%	70%	29%	31%	8.51	**Human**
20123650	18/04/2012	2000	4.15	2.32	2.57	10.6%	0.81	72%	4.38	4.1%	72%	28%	19%	4.38	**Human**
20123700	27/04/2012	570	1.67	2.05	2.14	5.0%	0.62	68%	8.36	2.3%	68%	30%	37%	8.36	Human
20123763	1/05/2012	3900	1.66	1.90	0.41	5.8%	0.62	29%	1.26	14.3%	29%	30%	36%	1.26	Ruminant
20124037	18/05/2012	3600	2.36	2.77	0.29	6.2%	0.70	22%	0.86	21.8%	22%	22%	27%	0.86	**Ruminant**

Sterols 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 orange)		
A1	24-ethylcholestanol/(24-ethylcholestanol+24-ethylcoprostanol+24-ethylepicoprostanol)	A1 Ratio >30% suggests avian source AND A2 Ratio >67% suggests avian source
A2	cholestanol/(cholestanol+coprostanol+epicoprostanol)	
Plant indicative ratios (values exceeding threshold in orange)		
P1	24-ethylcholesterol/24-ethylcoprostanol	Ratio >4 suggests plant decay

Note that 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. Greater weighting is given to H3 and R3 ratios. 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 pure source, and conclusions in brackets indicate likely source but with lower degree of certainty.

Results of Sterols Analysis:

ESR Number	Client Reference	Copro-stanol	24-ethyl-copro-stanol	epicopro-stanol	chole-sterol	chole-stanol	24-methyl-cholesterol	24-ethyl-epicopro-stanol	stigma-sterol	24-ethyl-chole-sterol	24-ethyl-chole-stanol	Total sterols
CMB120301	**20122858**	295	267	*18*	4033	189	1193	33	1000	1498	64	8590
CMB120302	**20122859**	635	422	37	5646	301	1705	76	1370	3086	98	13376
CMB120303	**20122860**	1233	1954	176	20681	1195	4213	313	2602	9884	772	43023
CMB120304	**20123056**	490	392	*24*	3299	202	1075	59	866	2341	175	8923
CMB120305	**20123057**	1097	944	33	4930	245	1594	62	1400	3051	187	13543
CMB120306	**20123058**	841	3355	114	7545	505	1999	644	1367	4553	1658	22581
CMB120307	**20123059**	314	1849	45	4658	295	1467	344	1116	3851	516	14455
CMB120308	**30123147**	434	596	32	3888	221	1173	99	863	2040	242	9588
CMB120309	**20123148**	611	448	32	4594	232	983	73	825	1850	162	9810
CMB120310	**20123149**	1039	2530	150	6676	554	1790	441	980	4438	983	19581
CMB120311	**20123150**	964	3281	145	2803	282	687	542	400	1875	629	11608
CMB120312	**20123308**	1001	2372	110	3853	319	1055	512	652	2503	724	13101
CMB120313	**20123309**	1027	2367	78	4306	357	1228	408	855	2635	675	13936
CMB120314	**20123310**	1184	7691	138	4452	550	1467	970	747	2843	1726	21768
CMB120315	**20123311**	2867	20519	344	6929	1098	2202	4564	1358	6996	9723	56600
CMB120316	**20123415**	1239	1038	39	5864	333	1283	131	983	2097	222	13229
CMB120317	**20123416**	689	715	37	4605	356	1137	99	916	1468	98	10120
CMB120318	**20123417**	643	1585	71	2962	210	943	322	550	2023	390	9699
CMB120319	**20123418**	694	3890	108	3447	373	1112	820	760	3142	1431	15777
CMB120375	**20123490**	414	647	38	3003	204	660	106	450	1017	270	6809
CMB120376	**20123491**	686	1115	46	4890	339	1192	205	769	1742	420	11404
CMB120377	**20123492**	406	1444	73	3555	329	1113	318	635	2074	778	10725
CMB120378	**20123493**	468	3659	82	1517	191	1120	545	631	2607	1137	11957
CMB120379	**20123520**	465	618	36	4064	257	1121	78	695	1280	168	8782

ESR Number	Client Reference	Copro-stanol	24-ethyl-copro-stanol	epicopro-stanol	chole-sterol	chole-stanol	24-methyl-cholesterol	24-ethyl-epicopro-stanol	stigma-sterol	24-ethyl-chole-sterol	24-ethyl-chole-stanol	Total sterols
CMB120380	**20123521**	633	323	*21*	3748	298	815	38	630	1343	116	7965
CMB120381	**20123522**	413	1428	64	2340	205	997	223	481	1414	341	7906
CMB120382	**20123523**	330	1441	75	2706	258	911	367	569	2597	805	10059
CMB120383	**20123558**	471	335	26	4542	285	1478	77	1055	2711	222	11202
CMB120384	**20123559**	507	221	*19*	3679	233	806	37	674	1880	107	8163
CMB120385	**20123560**	397	688	61	3149	250	1228	227	682	2149	360	9191
CMB120386	**20123561**	105	580	*22*	3543	258	1338	165	981	3709	320	11021
CMB120387	**20123649**	315	181	*20*	4360	241	871	60	779	1315	130	8272
CMB120388	**20123650**	785	306	*19*	3242	189	770	31	611	1341	132	7426
CMB120389	**20123651**	315	561	92	2746	194	872	126	457	1881	345	7589
CMB120390	**20123652**	1364	7960	275	5335	843	1863	2083	1197	5334	3893	30147
CMB120391	**20123699**	244	186	*17*	3648	191	1028	31	843	1275	91	7554
CMB120392	**20123700**	338	158	*14*	3081	203	895	*19*	689	1321	77	6795
CMB120393	**20123701**	326	458	61	4784	278	1498	123	836	2893	245	11502
CMB120394	**20123702**	115	536	*20*	2819	179	1006	101	676	2644	250	8346
CMB120395	**20123762**	1242	3181	118	6184	642	1785	640	1451	3771	1669	20683
CMB120396	**20123763**	1073	2630	91	5806	647	1617	552	1266	3311	1382	18375
CMB120397	**20123764**	1174	4197	161	4291	543	1901	844	1553	4404	2142	21210
CMB120398	**20123765**	1006	5611	270	5835	755	2536	1097	2241	8738	2895	30984
CMB120430	**20124036**	1184	3623	223	3940	624	1635	1216	1419	4171	2084	20119
CMB120431	**20124037**	1263	4404	169	4456	535	1593	1241	1192	3805	1589	20247
CMB120432	**20124038**	1092	6698	187	3762	505	1516	1790	999	4023	3086	23658
CMB120433	**20124039**	*7*	*7*	*1*	109	*9*	27	*1*	40	82	*7*	290

Italics = Below Lowest standard. Units for results are PPT (based on 1g sample).

Interpretation Guidance Notes:
Brief details of the methods of analysis are available on request.
These results relate to samples as received.
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