Stormwater Compliance Monitoring 2017: Stormwater discharges from Dunedin City to the coast

ORC Discharge Permits RM11.313.01 – RM11.313.10

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Executive Summary

This report presents the findings for the fourth round of annual monitoring of Dunedin's stormwater outfalls since new discharge consents were granted.

Monitoring comprised assessment of rain event grab samples from the ten major catchments and dry weather samples from all catchments. Also included were assessments of harbour water quality, harbour sediment quality at representative sites and biological monitoring at five sites.

Stormwater from all outfalls monitored showed variable levels of contamination.

Sediments too showed varying levels of contamination with levels of contaminants breaching Consent trigger values for arsenic at one site. Sediments were resampled with results showing no exceedance.

Biological sampling showed flora and fauna typical of moderately impacted shallow inlets from southern New Zealand with no discernible trend in community health attributable to stormwater discharges.

Contaminant levels in both stormwater and sediment were generally within the ranges observed in previous surveys. Although harbour water sampling has been carried out for three rounds it is a relatively new requirement and it is too early to detect potential trends in contaminant levels.

Introduction

1.1 Background

As with all urban centres throughout New Zealand and indeed most of the world, Dunedin's stormwater is reticulated to receiving environments via networks of gutters, open channels and pipes. The principal coastal receiving water environments for Dunedin's reticulated stormwater are the upper basin of Otago Harbour, Port Chalmers, and, on the open coast, Second Beach and St. Clair Beach.

Dunedin City Council (DCC) was, on 8th August 2013, granted resource consents for its major urban stormwater discharges. Those consents require monitoring of the outfalls during dry and wet weather, of harbour water under dry and wet weather conditions, of harbour sediments, and of biological communities.

The following report presents the results of sampling/monitoring carried out from the beginning of July 2016 to the end of June 2017.

1.2 Stormwater Outfalls

Stormwater is discharged from fourteen reasonably large and permanent stormwater outfalls, and from a number of smaller outfalls and non-point sources (Figures 1.1, 1.2 and 1.3). Many of the outfalls have very long histories dating back to the days of the early settlement of Dunedin.

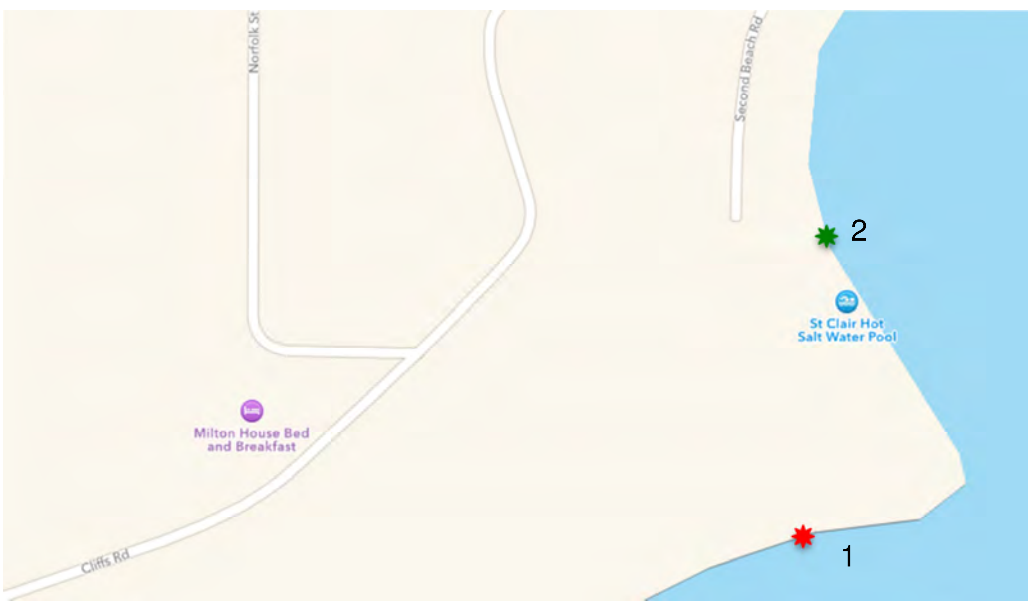


Figure 1.1 *Locations of current Dunedin stormwater outfalls being monitored. Numbers correspond to outfall numbers in Table 1, Appendix 1. Red stars denote monthly sampling; Green stars denote 6 monthly sampling.*

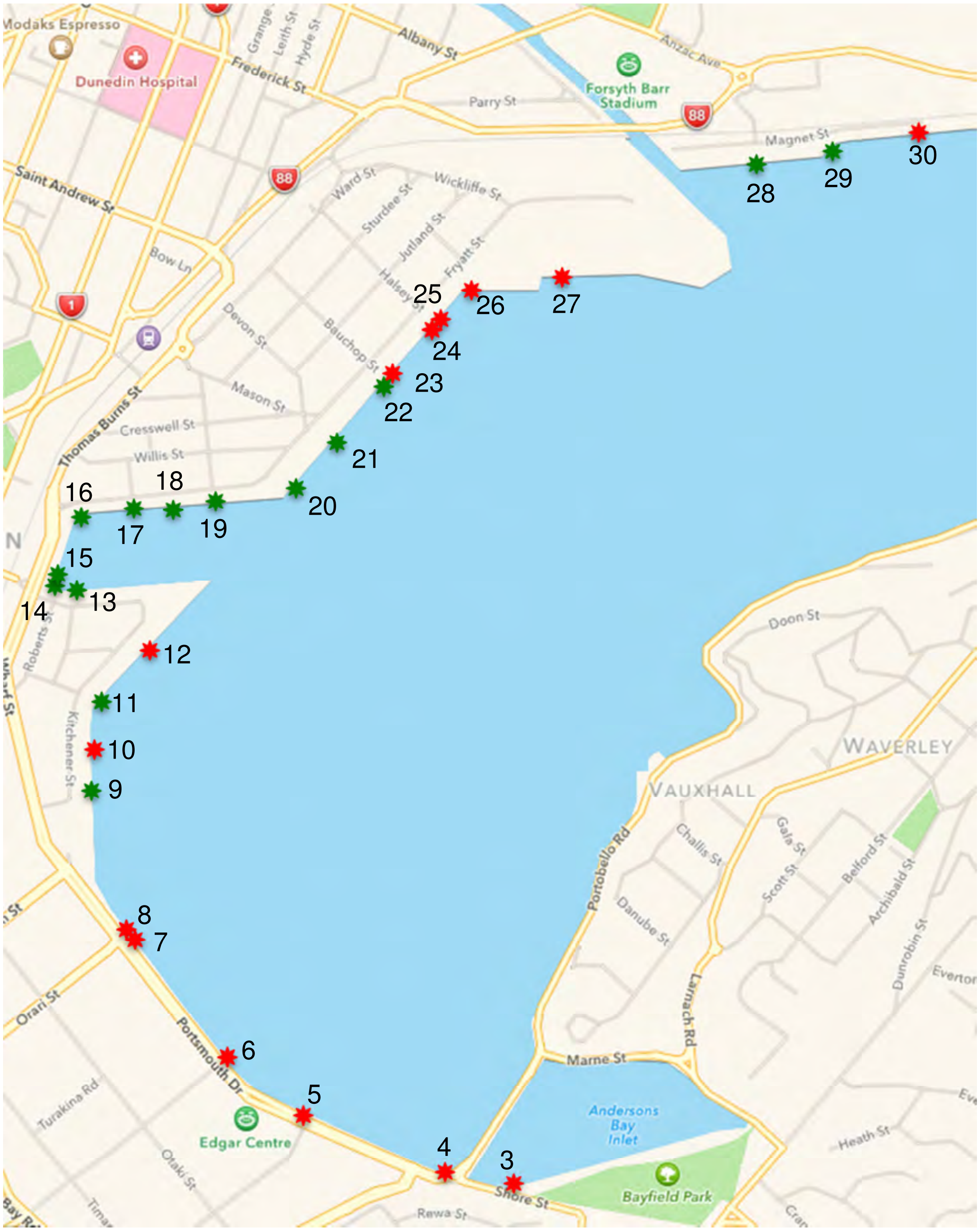


Figure 1.2 *Locations of current Dunedin stormwater outfalls being monitored. Numbers correspond to outfall numbers in Table 1, Appendix 1. Red stars denote monthly sampling; Green stars denote 6 monthly sampling.*

Figure 1.3 *Locations of current stormwater outfalls being monitored at Port Chalmers. Numbers correspond to outfall numbers in Table 1, Appendix 1. Red stars denote monthly sampling; Green stars denote 6 monthly sampling.*

2. Methods

2.1 Stormwater

A number of the outfalls shown in Figures 1.1, 1.2 and 1.3 do not have outfall structures or are located in places that are inaccessible. Consequently it is neither practical nor possible to sample the entire 33 outfalls listed, at the end of pipe. However, access to those that cannot be sampled at end of pipe is available via manholes a short distance up pipe.

Dry weather sampling

Dry weather flow sampling, as per Condition 2(a) (Appendix 6), involves collecting samples at low tide (to avoid seawater contamination) from each outfall during dry weather that includes an antecedent dry period of at least 72 hours. Samples are analysed for *E. coli,* and for fluorescent whitening agents (FWAs) to determine if high bacterial counts may be due to illegal human sewage cross-connections. FWAs are used in laundry detergents and indicate possible sewage infiltration to the stormwater system (Petch 1996, Gilpin *et al.* 2004) and are analysed on site using a hand-held fluorimeter.

The frequency of sampling has been decreased for outfalls where indicators of human sewage have not been detected. Consequently, some outfalls are now sampled on a six monthly basis while the remainder continued to be sampled on a monthly basis (Figures 1.1, 1.2 and 1.3, Appendix 1). In the event, the 2016/2017 summer was exceedingly wet and unsettled and samples were able to be collected for just August, September and December 2016 and February, March, May and June of 2017.

Wet weather grab sampling

Wet weather grab samples of stormwater were collected from each of the ten outfalls with the highest flows (as per consent condition Appendix A (b)(1)) within 1 hour of the commencement of a rain event (>2.5 mm) in an endeavour to ensure that first flush water containing the highest likely concentration of contaminants was gathered. Collections took place only if there was an antecedent period of at least 72 hours with no rain before the targeted rain event. Samples were, once again, collected at low tide.

Grab stormwater samples were sent to Citilab in Dunedin to be analysed, as per Appendix 2 A (c) of the consent conditions, for oil and grease, pH, arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn), oil and grease, suspended solids, pH, polycyclic aromatic hydrocarbons (PAHs) and *E. coli*.

Wet weather automated sampling

An ISCO automated sampler was installed approximately 280 m up-pipe of the Kitchener Street stormwater outfall in July 2016, to fulfil the requirements of Appendix 2A (a) of the consent conditions. The sampler had been programmed to collect samples over the first two-hour period of a rain event that produced at least 2.5 mm of rain following an antecedent dry period of at least 72 hours. Samples from the ISCO automated sampler are treated in the same manner as collected grab samples. i.e. samples were sent to Citilab for analysis for the analytes listed in the consent conditions, including *E. coli* (Appendix 5), and were also analysed on site for FWAs.

2.2 Harbour water sampling

Harbour water quality sampling was carried out at the locations shown in Figure 2.1 on four occasions. These occasions targeted two rainfall events and two dry periods, with samples being collected at mid-flood tide and mid-ebb tide for each occasion. Dry weather sampling allows the determination of background contaminant levels in harbour water.

Ebb tide flows are likely to move contaminants discharged during relatively brief rain events rapidly down harbour. Conversely, flood tide conditions may lead to higher concentrations of contaminants in the upper harbour. However, it must be noted that inputs from the Water of Leith further confuse contaminant levels, especially on the flood tide.

Since the upper harbour basin requires 4 - 6 tidal cycles to flush completely (Smith and Croot 1993, 1994), contaminants within the upper harbour basin may gradually increase in concentration throughout prolonged wet spells.

Harbour water samples were sent to Hill Laboratories in Hamilton and to Citilab in Dunedin to be analysed for cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), and enterococci.

2.3 Sediment sampling

Samples were collected from the top 20mm of sediment at the locations shown in Figure 2.1. At Halsey Street (H1) and Kitchener Street (H2) the sites are in deep water (~3 – 7 m deep) so sediment was collected using a petit ponar grab with a subsample being obtained from the top

20 mm of the contents of the grab. At Orari Street (H3) and Shore Street (H4) sediment samples are collected directly from the substrate by scraping the top 20 mm into a collection jar.

Samples were chilled and sent to Citilab for analysis for total arsenic, total cadmium, total chromium, total copper, total nickel, total mercury, total lead, total zinc, weak acid extractable copper, total petroleum hydrocarbons (TPH), organochlorine pesticides and PAHs.

2.3 Biological Monitoring

Biological monitoring was carried out at five sites (Figure 2.2). At Kitchener Street, Orari Street and Portobello Road epifauna and flora were assessed at the water's edge at low tide at three sites (0-5 m distant from the outfall, 15-20m from the outfall and 45-50m from the outfall). Assessment was made using 3 x 1 m^2 quadrats at each site for flora and 5 x 0.25 m^2 quadrats at each site for epifauna. Infauna were assessed from three 200 mm deep, 85 mm diameter cores collected at each site. Cores were sieved using 500µm mesh and retained organisms were returned to the laboratory for identification and enumeration.

The above techniques were all repeated at sites at Burkes and Macandrew Bay to give a comparison with sites that are not directly impacted by the presence of an outfall (control sites). In the absence of an outfall, all quadrats were randomly placed at three locations along the low tide level.

Lastly, samples of cockles were collected within 20 m of the outfall at the Kitchener Street, Orari Street and Portobello Road sites. Cockles were returned to the laboratory for measuring, then sent to Citilab for analysis for total As, Cd, Cr, Cu, Pb, PAHs and enterococci.

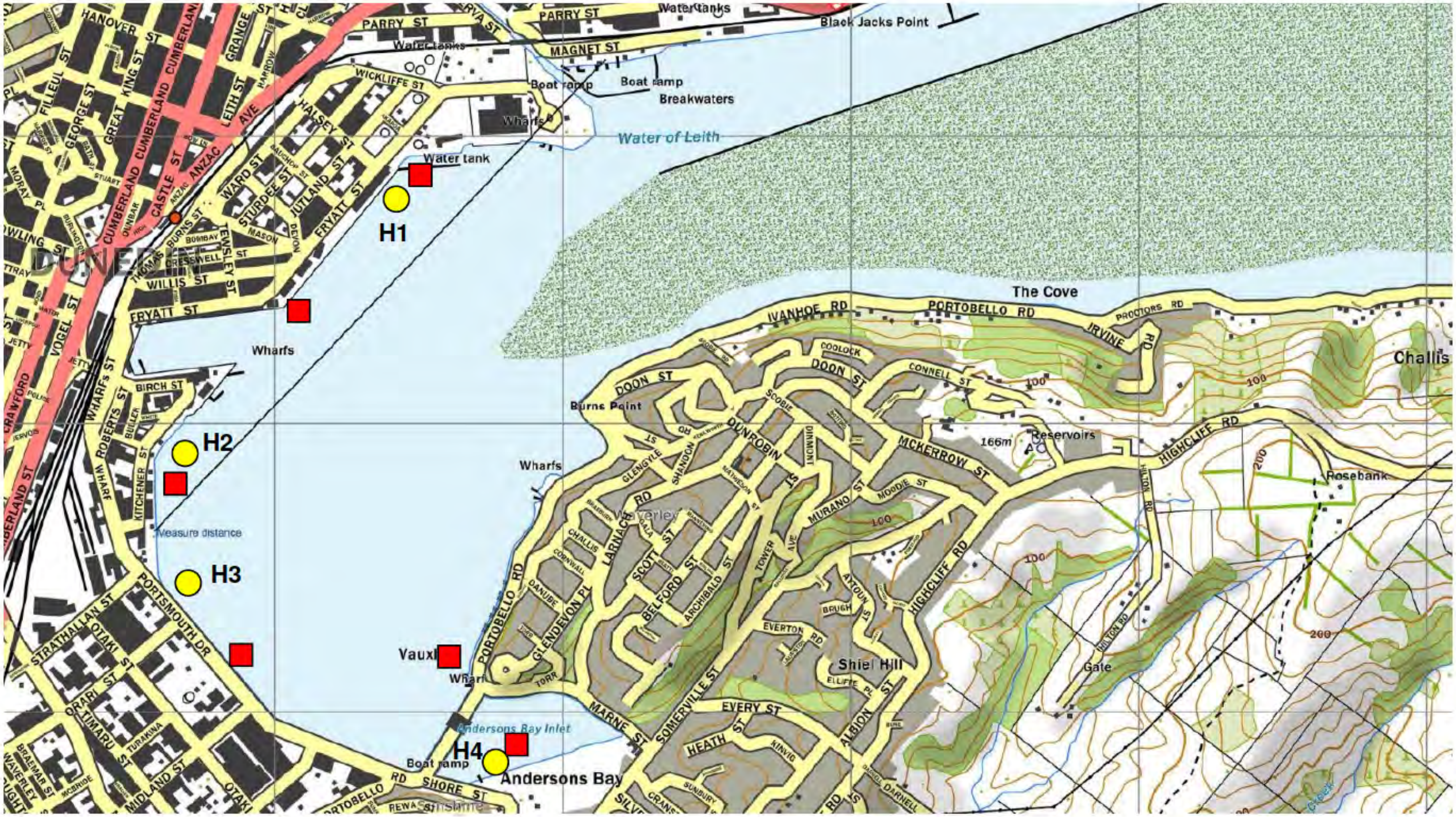


Figure 2.1 *Upper Harbour Basin seawater and sediment sampling sites. Red squares are harbour water quality sites; Yellow circles are sediment sites (see Table 2.1).*

Figure 2.2 *Upper Harbour Basin biological sampling sites. Anticlockwise from centre top: Burkes, Kitchener St, Orari St, Portobello Rd, Macandrew Bay.*

3. Results and Discussion

3.1 Stormwater

Dry weather sampling

Dry weather flow sampling was carried out on 17th August, 1st September, and 29th December 2016, and 28th February, 30th March, 17th May and 9th June 2017. Sampling at a number of outfalls has decreased to 6 monthly after three consecutive monitoring rounds due to there either being no flow, or consistently low results for both *E. coli* and FWAs.

A number of outfalls have had high but variable readings for *E. coli* and/or FWAs (Appendix 2). *E. coli* levels frequently exceed trigger levels, with numbers often exceeding 2400 MPN/100ml at outfalls 1, 3, 5, 7, 24, 25 and 33 (Figures 1.1, 1.2 and 1.3). However, the fact that FWAs at some of the same sites (e.g. outfalls 1, 24 and 25) are not always high suggests that contamination may not always be from human sewage, but rather from other sources.

Catchments that have had three consecutive monitoring rounds with both elevated *E. coli* and FWAs are under investigation. These include the Shore Street outfall (outfall 3), Teviot St outfall (outfall 5), and the George Street outfall at Port Chalmers (outfall 33). Outfalls that have had high levels of *E. coli* and FWAs in the past have been investigated. These include Bauchop Street, and the Wickcliffe Street and Magnet St outfalls (outfalls 27 and 30 respectively). An illegal connection, that has since been rectified, was found up-pipe at Bauchop Street. The entire Ravensbourne catchment has been subject to detailed investigated by the DCC in an attempt to ascertain possible sources of contamination, but nothing untoward was found.

Table 3.1.1 *FWA and E. coli levels in dry weather flow samples taken from DCC stormwater outfalls. Note that outfalls of little concern have been removed.*

Pink shaded cells denote trigger levels exceeded by E. coli on regular basis. Yellow shaded cells denote consistently high FWAs, but not E. coli; Orange shaded cells denote trigger level exceeded by both FWAs and E. coli. Red shaded cells denote prolonged exceedence by both FWAs and E. coli. Blue shaded cells denote intermittent exceedence by either FWAs OR E. coli. NF = no flow. Grey cells = sampling only 6 monthly.

Outfall	DCC ref	Consent ref.	Catchment	FWAs	E. coli	FWAs	E. coli	FWAs	E. coli	FWAs	E. coli	FWAs	E. coli	FWAs	E. coli	FWAs	E. coli
				Aug-16	Aug-16	Sep-16	Sep-16	Dec-16	Dec-16	Feb-17	Feb-17	Mar-17	Mar-17	May-17	May-17	Jun-17	Jun-17
1	SWX03979	RM11.313.10	St Clair	0.080	330	0.089	250	0.071	920	0.070	>2400	0.077	1600	0.059	>2400	0.088	>2400
3	SWX04625	RM11.313.04	Shore Street	0.132	>2400	0.146	>2400	0.133	690	0.144	440	0.088	19.9	0.115	30.2	0.143	1700
5	SWX03644	RM11.313.07	Portsmouth Drive	0.091	55.6	0.138	45.9	0.140	14.6	0.148	1700	0.123	>2400	0.152	>2400	0.154	>2400
6	SWX03640	RM11.313.07	Portsmouth Drive	0.149	58.8	0.121	23.5	0.181	6.1	0.146	2	0.097	8.4	0.174	>2400	0.178	1000
7	SWX03631	RM11.313.07	Portsmouth Drive	0.083	>2400	0.049	5	0.060	BDL	0.071	>2400	0.128	>2400	0.019	4.1	0.074	>2400
8	SWX03635 & SWX70740	RM11.313.08	Orari St	0.103	490	0.095	650	0.097	490	0.113	>2400	0.095	1400	0.096	310	0.123	1900
9	SWX03579	RM11.313.07	Portsmouth Drive	0.124	73.3							0.150	>2400				
24	SWX03455	RM11.313.03	Halsey St	0.035	2000	0.043	>2400	0.033	>2400	0.032	>2400	0.029	>2400	0.029	>2400	0.039	>2400
25	SWX03450	RM11.313.03	Halsey St	0.062	>2400	0.058	>2400	0.039	>2400	0.087	>2400	0.069	>2400	0.062	>2400	0.066	>2400
27	SWX03718	RM11.313.03	Halsey St	0.057	820	0.087	260	0.080	730	0.062	>2400	0.058	11.4	0.072	>2400	0.107	2400
30	SPN02502	RM11.313.02	Ravensbourne	0.172	1	0.163	16.1	NF	-	NF	-	0.178	2	0.156	<1.0	0.144	1
32	SWX12994	RM11.313.01	Port Chalmers	0.185	<1.0	0.180	<1.0	0.163	13.4	0.161	3.1	0.099	2	0.184	<1.0	0.224	<1.0
33	SWX12879	RM11.313.01	Port Chalmers	0.109	>2400	0.106	410	0.092	52.9	0.093	>2400	0.149	2400	0.119	>2400	0.144	>2400

Wet weather grab sampling

Wet weather grab samples were collected on 3rd May 2017 during a moderate storm event that yielded 8.8 mm of rainfall. Levels of some contaminants, notably arsenic, cadmium, chromium, nickel, oil and grease, and polycyclic aromatic hydrocarbons were below detectable limits at most sites (Appendix 3). However, levels of *E. coli* exceeded guidelines for secondary contact at all outfalls except Bauchop Street and Port Chalmers (Watson Park). This is not unusual during sampling of the first flush of rain events with runoff from impervious surfaces often carrying quantities of faecal matter from mammals and birds along with much decaying vegetation.

When compared with results from rain events through time the levels of contaminants in stormwater during the 3rd May rain event generally fall within the range of values observed at the various outfalls that have been sampled annually since 2007 (Appendix 3). Overall, there are generally lower contaminant concentrations reported in stormwater this year (Appendix 3).

PAHs at South Dunedin (Portobello Rd) are traditionally higher than at other sites. Values this year are lower than 2014, 2015 and 2016, but similar to values prior to that (Figure 3.1.1, Appendix 3,). The high readings obtained at Portobello Road in 2014, 2015 and 2016 are subject to ongoing investigations, focussed around the former Dunedin Gasworks site. The sampled rain events during 2015 and 2016 were lighter (3.8 mm and 4.0 mm respectively) than in the 2014 and 2017 (8.2 mm and 8.8 mm respectively, but the event in 2013 was 3.8 mm, so it is unlikely that flow is the influencing factor. Consideration should also be given to whether any resurfacing of bituminous impervious areas was carried out in the catchment prior to the sampled rain event as such activities may be a likely source.

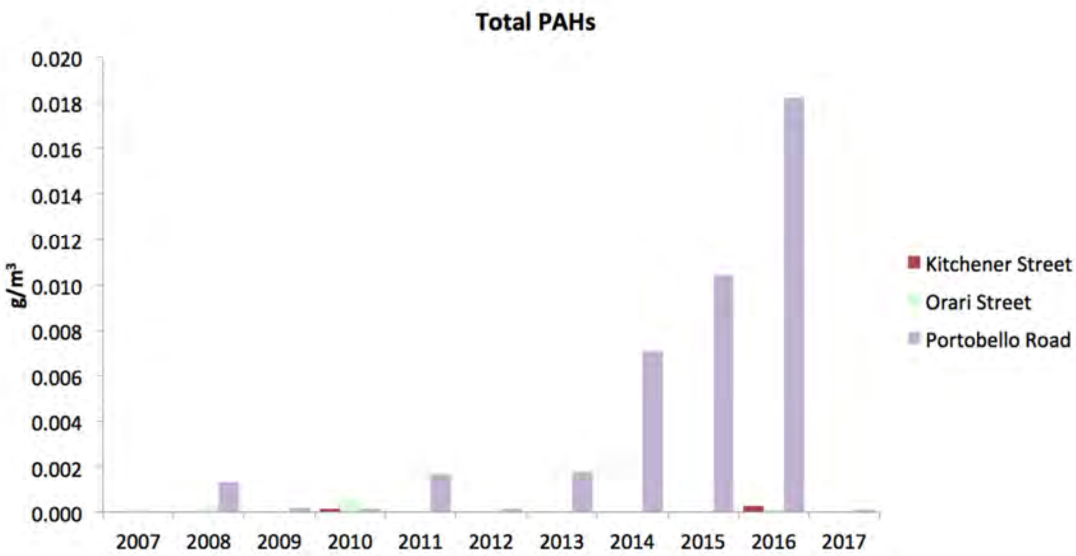


Figure 3.1.1 *Total PAH values in stormwater since 2007 for South Dunedin (Portobello Road), Orari Street and Kitchener Street.*

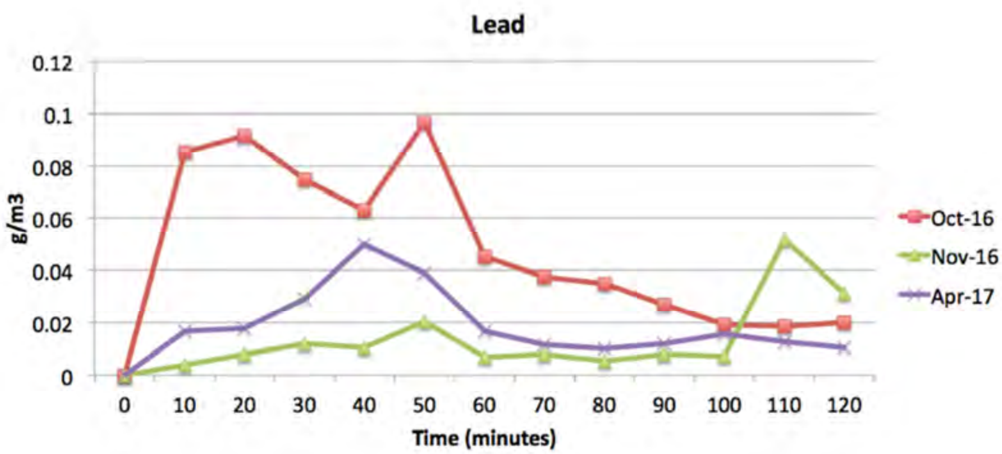
Wet weather automated sampling

The ISCO automated sampler at the Kitchener Street site was activated on 19th October 2016 (8.2 mm rain event), 24th November 2016 (17.6 mm rain event) and 5th April 2017 (2.6 mm rain event).

Concentrations for contaminants during a rainfall event are generally expected follow the usual pattern of starting low, then rising with the first flush of runoff, and finally gradually falling away as time progresses. However, it needs to be recognised that the intensity of the rainfall event and rate of onset have a bearing on values, as does the length of the antecedent dry period. Thus, the resultant curves for each contaminant may differ markedly.

This is certainly evident for the 2016 - 2017 results with, for example, the curves for lead and suspended solids following the expected pattern, but varying with event (Figure 3.1.2). Overall, values observed during the three sampled rainfall events this year compare reasonably well with values observed for sampling of rain events during previous years (Stewart 2007a, 2008c, 2009-2016) (Appendix 4). However, it should be noted that sampling prior to 2015 has been a single grab sample.

The amount of dilution available in the upper harbour basin will mean that concentrations within the receiving environment after reasonable mixing will likely be of little consequence.



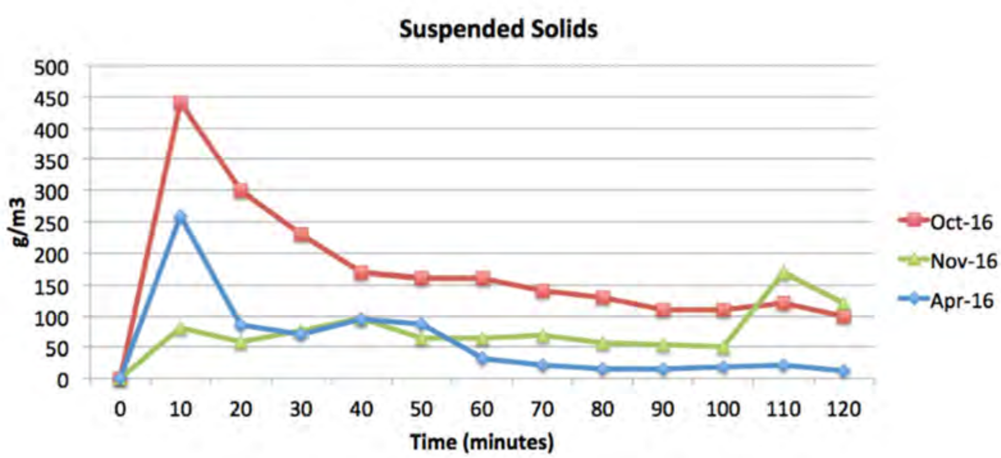


Figure 3.1.2 *Contaminant concentration through time during the first flush of three rainfall events in 2016/2017.*

3.2 Harbour Water

Harbour water is compared against trigger levels that have been derived from ANZECC (2000) trigger values for protection of 95% of species. ANZECC recommend that values be tailored to each site so local factors such as substrate, degree of modification, and catchment characteristics can be taken into consideration. However, this has not been done in this instance and the default ANZECC values have been applied. Considering the highly modified nature of the upper Otago Harbour Basin, ANZECC trigger values for protection of 80% of species may be more appropriate should the consent be reviewed.

First Round of Sampling

Harbour water was collected during a rainfall event that occurred on 15th November 2016 and during a dry weather spell on 21st November 2016. The storm event generated 15.6 mm of rain. Samples on each occasion were collected at mid-flood tide and again at mid-ebb tide. As explained in Section 2 this allows determination of contaminant levels in a dynamic environment that may alternately dilute or concentrate contaminants. It must be noted that the Lindsay Creek sewage overflow was operating at the time of the rain event, discharging 185m^3 into Lindsay Creek during the event.

Contamination of harbour water was low for cadmium and zinc at all sites. However, copper and lead concentrations for both the wet and dry weather monitoring rounds are occasionally above the Consent trigger levels, especially under wet conditions and on the ebb tide for copper. This may well be a reflection of the fact that levels of both copper and lead are higher in stormwater sampled at the Portobello Road, Kitchener Street, Mason Street and Bauchop street outfalls than at other outfalls during rain events. However, lead and copper contamination was neither universal across all sites nor consistent throughout the tidal cycle (Table 3.2.1). The observation that both copper and lead occasionally exceed trigger values for harbour water during dry weather suggests there may be some source other than stormwater.

Levels for enterococci contamination often exceed guidelines for marine waters (i.e. >140 cfu/100ml = amber alert; >280 cfu/100ml = red alert), especially during a rain event (Table 3.2.1). However, there is also evidence of bacterial contamination during dry spells, notably off Portsmouth Drive between Midland and Orari Streets, in the vicinity of the Kitchener Street outfall, and at Vauxhall. This generally echoes results for dry weather monitoring that finds high values for *E. coli* reasonably consistently at outfalls 5, 6 and 7, all of which discharge along Portsmouth Drive. Outfall 5 (Teviot Street) also exhibits high FWA readings during dry weather sampling.

It should be noted that the red alert level indicates a risk to bathers of around 2% or 19 per 1000 swimmers. Although the upper harbour basin is popular with wind surfers when conditions permit, it is not a recognised swimming area. Consequently, the trigger level may be considered to be very conservative and perhaps not appropriate.

Table 3.2.1 *Contaminants in upper harbour basin water during dry period and a rain event on 15th November 2016 that yielded 15.6 mm of rainfall. Pink shaded cells indicate exceedence of Consent trigger values.*

ANZECC 95% (g/m3)	Dry		Wet	
Cd (0.0055)				
Detection limit (0.0002)	Flood	Ebb	Flood	Ebb
Wickliffe (H1)	BDL	BDL	BDL	BDL
Mason (H2)	BDL	0.0005	BDL	BDL
Kitchener (H3)	BDL	BDL	BDL	BDL
Substation (H6)	BDL	BDL	BDL	0.0008
Vauxhall (H4)	BDL	BDL	BDL	BDL
Andy Bay Inlet (H5)	BDL	BDL	0.0004	BDL
	Dry		Wet	
Cu (0.0013)				
Detection limit (0.001)	Flood	Ebb	Flood	Ebb
Wickliffe (H1)	BDL	BDL	0.0118	0.0006
Mason (H2)	BDL	BDL	BDL	0.0224
Kitchener (H3)	0.0007	0.0648	0.0042	0.0103
Substation (H6)	BDL	BDL	BDL	0.0061
Vauxhall (H4)	0.0047	0.013	0.0757	0.0085
Andy Bay Inlet (H5)	BDL	0.0019	0.001	0.0061
	Dry		Wet	
Pb (0.0044)				
Detection limit (0.001)	Flood	Ebb	Flood	Ebb
Wickliffe (H1)	0.00188	0.00054	0.00251	0.00244
Mason (H2)	0.00194	0.00194	0.00156	0.00262
Kitchener (H3)	0.00303	0.0162	0.00369	0.0033
Substation (H6)	0.00489	0.00179	0.00273	0.00686
Vauxhall (H4)	0.00383	0.00656	0.00502	0.00277
Andy Bay Inlet (H5)	0.00339	0.00423	0.00249	0.00473
	Dry		Wet	
Zn (0.004)				
Detection limit (0.001)	Flood	Ebb	Flood	Ebb
Wickliffe (H1)	BDL	BDL	BDL	BDL
Mason (H2)	BDL	BDL	BDL	BDL
Kitchener (H3)	BDL	BDL	BDL	BDL
Substation (H6)	BDL	BDL	BDL	BDL
Vauxhall (H4)	BDL	BDL	BDL	BDL
Andy Bay Inlet (H5)	BDL	BDL	BDL	BDL
	Dry		Wet	
Enterococci (140 cfu/100ml)				
Detection limit (1.0)	Flood	Ebb	Flood	Ebb
Wickliffe (H1)	310	300	290	5500
Mason (H2)	10	BDL	120	1400
Kitchener (H3)	BDL	52	170	310
Substation (H6)	10	590	230	280
Vauxhall (H4)	10	BDL	31	390
Andy Bay Inlet (H5)	10	97	680	6900

Second Round of Sampling

Due to trigger level exceedences of copper, lead and enterococci in the first round of 2016 results harbour water was resampled at the first opportunity where rainfall and tide state allowed. This occurred on 19th January 2017 for the rain event and on 1st March for dry weather. The rain event produced 15 mm of rain and it should be noted that no wastewater overflows were occurring at the time.

Once again copper was moderately high at most sites in dry weather, and all sites under wet conditions. Lead trigger levels were exceeded at just Andersons Bay Inlet on the ebb tide during the wet weather event (Table 3.2.2). It is likely that road dust carrying particulate matter from car tyres and brake dust that is flushed into the stormwater system with runoff from impervious surfaces may be the source of such contamination. However, the fact that copper levels continue to exceed trigger values in dry weather again suggests a source other than stormwater. Re-suspension of contaminated sediments may be a possible source, but given that copper levels in harbour sediments consistently fall below Consent trigger levels (see Section 3.3), this is unlikely. It should be reiterated that trigger values aligned with the ANZECC values for protection of 80% of species may be more appropriate in the upper harbour. If this were the case the trigger level for copper would become 0.008 g/m^3 and for lead 0.012 g/m^3.

Table 3.2.2 *Contaminants in upper harbour basin water during resampling of a dry period and a rain event on 19th January 2017 that yielded 15.0 mm of rainfall. Pink shaded cells indicate exceedence of Consent trigger values.*

ANZECC 95% (g/m3)	Dry		Wet	
Cu (0.0013)				
Detection limit (0.001)	Flood	Ebb	Flood	Ebb
Wickliffe (H1)	0.0024	BDL	0.0049	0.0044
Mason (H2)	0.0028	0.0036	0.00173	0.0044
Kitchener (H3)	BDL	BDL	0.0038	0.0053
Substation (H6)	0.0016	BDL	0.0037	0.0029
Vauxhall (H4)	BDL	0.0045	0.00196	0.0069
Andy Bay Inlet (H5)	0.0053	0.0026	0.0049	0.0093
	Dry		Wet	
Pb (0.0044)				
Detection limit (0.001)	Flood	Ebb	Flood	Ebb
Wickliffe (H1)	BDL	BDL	BDL	0.0014
Mason (H2)	BDL	BDL	BDL	BDL
Kitchener (H3)	0.0012	BDL	BDL	BDL
Substation (H6)	BDL	BDL	BDL	0.0011
Vauxhall (H4)	BDL	BDL	BDL	0.002
Andy Bay Inlet (H5)	BDL	BDL	0.0011	0.0054
	Dry		Wet	
Enterococci (140 cfu/100ml)				
Detection limit (1.0)	Flood	Ebb	Flood	Ebb
Wickliffe (H1)	2500	BDL	500	4600
Mason (H2)	BDL	BDL	260	7300
Kitchener (H3)	85	20	130	220
Substation (H6)	74	41	560	590
Vauxhall (H4)	BDL	10	2900	1200
Andy Bay Inlet (H5)	BDL	310	1900	8700

Enterococci exceeded trigger levels at Wickliffe Street on the flood tide and at Andersons Bay Inlet on the ebb tide in dry weather. Dry weather sampling reveals that outfalls 3 (Shore Street catchment), 5 (Teviot Street), 7 and 8 (Orari Street), and 27 (Halsey Street catchment) do frequently give high readings for both *E. coli* and FWAs, and may well be the source of contamination in these areas.

Rainfall events are recognised as introducing high levels of microbiological contamination to receiving water environments. As stated, the 19th January rain event did not trigger any sewage overflows. Thus, while it is possible that some of the detected enterococci may be derived from illegal cross connections, especially given that dry weather results also show contamination, much of the contamination may be from animal faecal matter flushed into the harbour by runoff from impervious surfaces and/or rural land.

Overall, wet weather harbour water results reflect the results obtained from stormwater grab samples during the rain event 3rd May 2017.

As already noted in Section 2, ebb tides will likely carry the freshest contaminants while flood tides will likely bring already discharged contaminants back into the upper harbour, and may include contaminants from the Water of Leith. The fact that the upper harbour takes 4-6 tidal cycles to flush completely (Smith and Croot 1993, 1994) means that contaminants introduced with stormwater discharges may reside in the basin for up to three days after the cessation of any rain event. Thus, for prolonged rain events there is the possibility that concentration of contaminants in harbour water may increase throughout the rain event. However, the sheer volume of water in the upper harbour basin allows a great deal of dilution despite the residence time.

In past years the results of harbour water sampling have tended to support this hypothesis, with levels of most contaminants being well below the Consent trigger values, and even below detection limits for some. However, this year levels of copper and, slightly less so, for lead in harbour water are often higher than Consent trigger levels under both wet and dry conditions and on ebb and flood tides. Not unexpectedly, there appears to be a relationship between contaminant concentration and wet weather, with higher concentrations of copper and enterococci observed during a rain event. Resampling found similar results, despite the resample taking place two months after the initial sampling. All three contaminants (Cu, Pb and enterococci) are ubiquitous with urban stormwater runoff. Levels of Cu and Pb are expected to drop slowly over time as more environmentally friendly materials are used in the automotive and construction industries. For enterococci too, levels are expected to drop as wastewater network overflows into the harbour and illegal human sewage cross connections to the stormwater network are addressed.

Harbour water quality has not been specifically targeted in annual stormwater sampling rounds prior to 2014. However, there are limited historic data available (Stewart and Ryder 2004). Levels of Cd and Zn fall within ranges observed in the past, but Cu, Pb and enterococci do not. Unfortunately, there are no data on the state of the tide when these samples were collected, nor on whether or not it was raining at the time. Consequently, any comparisons must be viewed with caution.

3.3 Sediments

The Consent imposes trigger levels statistically derived from historic sampling at a variety of locations in the upper harbour. The new consent requires sampling at locations that do not necessarily correlate with locations sampled in the past. Consequently, the statistically derived trigger values may not be appropriate for the current locations.

Harbour sediments were sampled on 30th March 2017 at sites detailed in Figure 2.1. As in the past, surface sediments (where visible) were generally clean with little surface detritus apart from sparse clumps of beach cast red and green algae at the Orari Street site.

Levels of arsenic at Kitchener Street exceeded trigger values (Appendix 5, Table C 1) (Table 3.3.1). Values for all other contaminants were very low (Table 3.3.1). Resampling of sediment at Kitchener Street was carried out on 28th April 2017, with results for arsenic being below the Consent trigger value. It should be noted that the Kitchener Street site may be influenced by the reasonably close proximity of Sims Pacific Metals Ltd in Wharf Street, and a now defunct metal blasting and respraying plant further along Kitchener Street.

It is worthwhile pointing out that levels of contaminants in sediments are generally considerably lower at these sites than at other sites analysed within the upper harbour basin in the past (Table 3.3.2). However, historically, sediments were sampled much closer to stormwater outfalls than in 2014, 2015, 2016 and 2017 so, once again, comparisons must be viewed with caution.

This is particularly so for PAHs where the historic maximum is obtained from sediments collected close to the South Dunedin (Portobello Road) outfall, a site of particular concern with respect to PAH contamination (Stewart 2005, 2006).

Table 3.3.1 *Contaminant concentration (mg/kg dry weight) in sediments sampled at the head of the Otago Harbour Basin. Pink shaded cells indicate where concentration exceeds Consent trigger value.*

Site	As	Cd	Cr	Cu (WAE)	Cu	Pb	Hg	Ni	Zn	TPH	PAH	Organochlorine pesticides
Detection limit	2	0.1	2	1	2	0.4	0.01	2	4	100	0.03	0.001
Halsey Street	15.4	0.22	35	45	28	31	0.64	20	121	BDL	1.54	0.0013
Kitchener Street	26	0.13	25	16.8	19.5	39	0.04	11	220	210	6.12	0.0302
Orari Street	2.2	0.048	4.2	27	3.2	5.3	0.018	2.7	33	BDL	0.297	BDL
Shore Street	13.5	0.187	26	18.9	24	55	0.102	23	158	173	24.125	0.036

Table 3.3.2 *Maximum contaminant concentrations (mg/kg) in sediments sampled in 2017 and historically. Data from Royds Garden (1990); Grove (1995); Purdie and Smith (1994); Bioresearches (2002); Stewart and Ryder (2004); Stevenson (1998); Grove & Probert (1997).*

	AS	Cd	Cr	Cu	Pb	Hg	Ni	Zn	PAH
2017 Maximum	26	0.22	35	28	55	0.64	23	220	24.13
Historic maximum	46	6.2	98	433	800	0.17	44	4450	651

3.4 Biological Monitoring

On 31st March biological sampling was carried out at the Orari Street, Kitchener Street and Portobello Road, outfalls and at reference sites at Burkes and Macandrew Bay. The tide was moderately low at 0.97 m below mean sea level.

There was a low diversity of green and red algae at all sites, with Burkes and Portobello Rd having just one taxon each, and Kitchener Street, Orari Street and Macandrew Bay sites having two taxa each (Appendix 5, Table 1). Percentage cover was generally low at all sites (Appendix 5, Table 1). Cover was highest at Portobello Rd, site 3, although this was beach cast *Codium* (Appendix 5, Table 1). Overall, algal cover at outfall sites was slightly lower than in previous years (Stewart 2007a, Stewart 2008c, Stewart 2009, 2010, 2011, 2012, 2013, 2015). High algal cover may be indicative of high nutrient loads, but seasonality must also be considered. Thus, biological surveys are conducted at a similar time each year.

Epifauna was moderately abundant at all three outfalls (Appendix 5, Tables 2, 3 and 4), and somewhat less so at the two reference sites. As in previous years the small topshell *Micrelenchus tenebrosus* and cockles, *Austrovenus stutchburyi*, comprise the majority of animals, although the tubeworm, *Pomatoceros caerulus*, is abundant in patches on rocks, especially at Kitchener Street and Portobello Road.

Numbers of animals per square metre was higher nearer the Kitchener Street outfall than at 0-5 m than at 20m and >50 m of the outfall, largely due to the high density of tubeworms and barnacles on some rocks. This differs from previous years when higher numbers of tubeworms and *Micrelenchus* were observed at the >50m quadrats. For Orari Street epifaunal numbers per square metre were slightly higher at 20m than at >50m, while for Portobello Rd, highest numbers were found furthest away.

For the reference sites there was no readily discernible pattern of density, which is not unexpected considering there is no outfall to influence animal presence/absence. In 2010 numbers were similar irrespective of distance at all outfalls. With respect to outfall sites, the overall density of epifaunal animals was lowest at Orari Street and highest at Kitchener Street, due mainly to the higher abundance of tubeworms and barnacles at this site (Appendix 5, Tables 2, 3 and 4).

Diversity within animal communities was variable, but with all the Kitchener Street and Orari Street outfall sites show slightly greater diversity 20 m from the outfall than close to or further away, while Portobello Road shows highest diversity furthest away (Appendix 5, Tables 2, 3 and 4). Diversity indices at outfall sites were highest at Portobello Road and lowest at Orari Street, with the Burkes reference site being lower again (Appendix 5, Table 5). Overall diversity has not changed from that observed in previous years ($F_{8,21}$ = 0.223, p = 0.980 for 0-5 m sites; $F_{8,21}$ = 0.257, p = 0.969 for 20m sites; $F_{8,21}$ = 0.279, p = 0.962 for >50m sites). Neither is there a significant difference in epifaunal diversity among sites close to or further away from the outfalls ($F_{2,11}$ = 0.316, p = 0.737).

As in previous surveys cockles became noticeably smaller and less abundant as one moved from Kitchener Street to Portobello Road (Appendix 5, Table 6). However, when compared using ANOVA at a significance level of 0.05 the overall size of cockles at each site has not changed significantly from year to year ($F_{8,17}$= 1.55, p = 0.262). It should be pointed out that at all sites at the head of the harbour cockles are much slower growing than at prime cockle sites further down harbour or in Papanui and Waitati Inlets (Stewart 2006b, 2008d).

Infauna at all three sites was dominated by polychaete worms with glyceriids being the most abundant. Spionids were also moderately common at all sites (Appendix 5, Table 7). Nephtyid worms were present at Kitchener Street Portobello Road and Macandrew Bay, but totally absent from the Burkes and Orari Street sites. Phoxocephalid amphipods were less common than they have been in previous years and Lysianassid amphipods were completely absent from all sites except Orari Street.

Cockles (*Austrovenus stutchburyi*) were most common at the Kitchener Street and Orari Street sites (Appendix 5, Table 7), with overall abundance similar to previous years. Tanaid crustaceans, which were found in moderate numbers at most sites in 2010 and 2013, were not observed at many of the sites either this year or in 2015.

Numbers of animals per square metre at outfall sites was slightly higher than in 2012 and 2013, but lower than in 2015, and ranged from 1115 at replicate (sample) 3, Portobello Road, to 5129 at replicate (sample) 2, Orari Street. The higher value was largely due to high abundance of polychaetes in that core. Despite the variability in overall numbers of animals at the various sites, diversity has not changed significantly from year to year ($F_{8,21} = 0.907$, $p = 0.538$) (Appendix 5, Table 8) and neither has abundance ($F_{3,7} = 0.098$, $p = 0.957$).

Overall the infauna are typical of sheltered harbours in southern New Zealand. There is no evidence that contaminants carried by stormwater are having anything more than a very minor effect on the intertidal communities of the upper harbour basin.

3.5 Analyses of Cockle flesh

As in 2015, 2013, 2012 and 2010, levels of heavy metals in cockle flesh showed no clear trend for contamination in moving from Kitchener Street to Portobello Road across all metals (Appendix 5, Table 9). However, levels of chromium are higher this year at all sites. Lead and copper are higher this year at Kitchener Street and Portobello Road, with lead also higher at Portobello Road. PAHs on the other hand, remain by far the highest at Portobello Road (Appendix 5, Table 9).

Filter feeding shellfish tend to accumulate contaminants. However, while concentrations of contaminants in cockle flesh are higher than in harbour water sampled this year (compare Tables 3.3.1 and Table 9 in Appendix 5), they are generally one to two orders of magnitude lower than concentrations of contaminants in harbour sediment. PAH levels are likely higher in Portobello Road cockles as a result of historic contamination of that site.

Overall, levels are much the same as they have been in previous years. The anomalous results for arsenic seen across all sites in 2015 are no longer apparent. All heavy metals remain at concentrations at least one order of magnitude below accepted food standards (Table 3.5.1). Consequently, I would recommend that no further immediate action is necessary at this time. Note that there are no specific guidelines for PAH in shellfish flesh for New Zealand.

It should be noted that, as already stated, and as found in previous surveys, cockles became smaller as one nears the Portobello Road outfall (Appendix 5, Table 6). This may be due to the historic PAH contamination noted above, but is also likely due to exposure at low tides and to fresh water.

Cockles are not known to be gathered by recreational harvesters in the upper harbour basin as they are perceived to be contaminated and too small to be worthwhile.

Table 3.5.1 *Heavy metal concentrations for NZ and US FDA guidelines for adults (expressed as mg/kg dry weight). '-' means no guideline is available.*

	Cu	Pb	Cd	Cr
Food Regs/NZ DoH	150.0	10.0	5.0	-
US FDA	-	4.2	-	11.0
Australia NZ food standards code	-	2.0	2.0	-

4. Conclusion

Monitoring of stormwater quality in Dunedin this year differs in some respects from pre-2014 monitoring due to changes in consent conditions linked to the new discharge permits RM11.313.01-RM11.313.10. Overall, however, the results provided in this report and the 2016, 2015 and 2014 reports give a good indication of stormwater quality discharged from the city, with good coverage of catchment discharges in dry weather conditions (Stewart 2014, 2015, 2016).

Dry weather monitoring has been reasonably successful in locating possible illegal cross-connections. One source of contamination has been located and eliminated in the Bauchop Street catchment while investigations in the Ravensbourne catchment have been inconclusive. Other investigations are ongoing.

The efficacy of continuing to monitor all outfalls on a regular basis is questioned. I would recommend a review of the Consent conditions such that dry weather monitoring at outfalls that have regularly shown little or no sewage contamination could cease, thus dropping from 33 outfalls to just the 13 shown in Table 3.1.1. A further review of those could be carried out at the end of the 2017 - 2018 stormwater year or at the conclusion of the current investigations.

Microbiological contamination is a common problem with stormwater, especially after dry spells of more than a couple of days, and can be due to other factors such as contamination of roads and sidewalks by animal faeces. However, by the DCC continuing to work to eliminate cross connections of private sewerage laterals to stormwater drains, this issue can be minimised as far as practicable.

Regular street sweeping and the cleaning of mud tanks will go some way towards mitigating the ingress of contaminants such as heavy metals to the stormwater system, as will the gradual replacement of lead and copper pipes and the increased use of coated roofing materials.

Consent condition (Appendix 2 B(c)) requires re-sampling of harbour water if trigger values are exceeded. However, it should be noted that this poses a number of difficulties, not the least of which is in replicating conditions that prevailed at the time of sampling. Specifically, by the time laboratory test results are received for analysis and interpretation (two or even three weeks after sampling) the effects of a particular rain event or dry spell have well and truly passed. The only way around this situation is to collect replicate samples at the time of monitoring and re-analyse these if exceedences are found upon receipt of test results. Such an approach may be useful for some contaminants (e.g., metals) but will not work for bacteria.

Otago Harbour has, since early settlement, been a repository for contaminants generated by a wide variety of activities within and around Dunedin City (Stewart and Ryder 2004). Many of those contaminants settled out and become incorporated in the sediments of the harbour floor, often with quite patchy distributions (Stewart and Ryder 2004). Removal of such contaminants can only be achieved by dredging, or by relying on natural flushing, which in turn, relies on wind, wave and tidal action and can be exceedingly slow.

Consequently, the concentration of contaminants in harbour sediments has often exceeded Consent trigger levels in the past. However, this year, just arsenic was observed to exceed trigger levels and just at Kitchener Street. A resample collected a month later showed no exceedence The low levels of contaminants observed in harbour sediments this year compares favourably with previous results and suggests that levels of contaminants entering the harbour at present may be lower than what was discharged historically.

This is not unexpected considering that many industries that used to contribute significant quantities of harmful contaminants to the harbour have closed down or moved (e.g. tanning, timber treatment, gasworks, electroplating). Wastewater upgrades in the 1990's, and separation of the stormwater and wastewater networks from the 1960's - 1990's resulting in the removal of all wastewater discharges from the harbour, have also reduced the amount of contaminants entering the harbour. Thus, it is expected that the amount of contaminants in surficial harbour sediment will diminish as fewer contaminants enter the harbour and existing contaminants are either flushed out, or become buried under newer non-contaminated sediments.

It should be pointed out that the sites at which samples have been collected since 2015 differ from previous locations. Consequently caution is advised in interpreting these results as they are not directly comparable. Continued sampling at the new locations will better enable any trends in contaminant concentration to be discerned at these locations.

The level of PAHs in sediments adjacent to the South Dunedin (Portobello Road) outfall remains a moderate concern. The high levels of PAHs in stormwater observed in South Dunedin stormwater in 2015 and 2016 appears to have been a temporary aberration. As already mentioned, the DCC are currently undertaking investigations focussed on the former Dunedin Gas Works Site. Stewart (2006) investigated possible remediation measures for sediment in the area, but, given that historic sources of PAHs in the South Dunedin catchment (e.g. gas works) no longer function, it is expected that the contamination will gradually be buried by new sediment. This is already evident with a continued downward trend in PAH concentration in cockle flesh since monitoring began.

Benthic and infaunal communities in the vicinity of the Portobello Road, Orari Street and Kitchener Street outfalls have reasonably low diversity, as do communities at the reference sites at Burkes and Macandrew Bay. Such low diversity is generalised in the upper Otago Harbour Basin and is not associated with any one outfall. As in past years there is a trend towards smaller cockles as one nears the Portobello Road outfall, likely due to a number of extrinsic factors including historic PAH contamination, freshwater exposure and exposure at low tide.

Rainer (1981) and Grove (1995) certainly found less diversity in soft-bottom macrofaunal communities as one moves from harbour mouth to the head of Otago Harbour. It should be pointed out that much of the shoreline around the upper harbour has been extensively modified and as such cannot be regarded as an inlet typical of those found throughout the region.

Despite this the communities sampled in the upper Otago Harbour near stormwater outfalls are numerically dominated by polychaete worms and amphipods, as is usual for sheltered soft shores around New Zealand (Morton and Miller 1973), and show distinct similarities to communities found in other moderately impacted inlets in Otago (Stewart 2007b, 2008a,b).

While not pristine, the upper harbour and the communities associated with the intertidal areas adjacent to major stormwater outfalls appear not to be undergoing any significant further degradation as a result of stormwater inputs. It is to be hoped that if any slight trends towards lower contaminant levels in stormwater are continued, both water quality and community health in the harbour will gradually improve over time.

This report is designed to inform any required updates to the individual catchment management plans (ICMPS). Overall, it is expected that the implementation of actions suggested in this report, in conjunction with the DCC's long-term strategy for individual stormwater catchments developed through the Three Waters Strategy, will contribute to addressing the issue of unusually elevated contaminants in stormwater. It will be of interest to see if any long-term trends in contaminant levels can be discerned as monitoring continues.

However, only after problem areas and problem contaminants have been identified can measures be taken to mitigate any effects. Future monitoring, as prescribed in the conditions associated with the new discharge permits, will assist in defining problem areas such that further mitigation measures may be undertaken.

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6. Appendix 1. Stormwater outfalls

Table 1 *Frequency of dry weather sampling.*

Outfall	DCC ref	Consent ref.	Location	Catchment	Frequency
1	SWX03979	RM11.313.10	Second Beach	St Clair	Continue monthly sampling
2	SWX00011 & SWX00012	RM11.313.10	St Clair Beach	St Clair	6 monthly sampling
3	SWX04625	RM11.313.04	Shore Street	Shore Street	Continue monthly sampling
4	SWX03649	RM11.313.09	Portobello Rd	South Dunedin	Continue monthly sampling
5	SWX03644	RM11.313.07	Teviot St	Portsmouth Drive	Continue monthly sampling
6	SWX03640	RM11.313.07	Midland St	Portsmouth Drive	Continue monthly sampling
7	SWX03631	RM11.313.07	Orari St	Portsmouth Drive	Continue monthly sampling
8	SWX03635 & SWX70740	RM11.313.08	Orari St	Orari St	Continue monthly sampling
9	SWX03579	RM11.313.07	Kitchener St	Portsmouth Drive	6 monthly sampling
10	SWX03568	RM11.313.06	Kitchener St	Kitchener St	Continue monthly sampling
11	SWX70102	RM11.313.06	French St	Kitchener St	6 monthly sampling
12	SWX03547	RM11.313.06	Kitchener St	Kitchener St	Continue monthly sampling
13	SWX03562	RM11.313.06	Birch St	Kitchener St	6 monthly sampling
14	SWX03556	RM11.313.06	Birch St	Kitchener St	6 monthly sampling
15	SWX03559	RM11.313.06	Wharf St	Kitchener St	6 monthly sampling
16	SWZ70569	RM11.313.06	Fryatt St	Kitchener St	6 monthly sampling
17	SWX03540	RM11.313.06	Fryatt St	Kitchener St	6 monthly sampling
18	SWX03536	RM11.313.06	Fryatt St	Kitchener St	6 monthly sampling
19	SWX03532	RM11.313.06	Fryatt St	Kitchener St	6 monthly sampling
20	SWX70370	RM11.313.06	Fryatt St	Kitchener St	6 monthly sampling
21	SWX03489	RM11.313.05	Mason St	Mason St	6 monthly sampling
22	SWX03506	RM11.313.03	Mason St	Halsey St	Continue monthly sampling
23	SWX03466	RM11.313.03	Mason St	Halsey St	Continue monthly sampling
24	SWX03455	RM11.313.03	Halsey St	Halsey St	Continue monthly sampling
25	SWX03450	RM11.313.03	Halsey St	Halsey St	Continue monthly sampling
26	SWX03472	RM11.313.03	Halsey St	Halsey St	Continue monthly sampling
27	SWX03718	RM11.313.03	Wickliffe St	Halsey St	Continue monthly sampling
28	SWX02628	RM11.313.02	Magnet St	Ravensbourne	6 monthly sampling
29	SWX02623	RM11.313.02	Magnet St	Ravensbourne	6 monthly sampling
30	SPN02502	RM11.313.02	Ravensbourne Rd	Ravensbourne	Continue monthly sampling
31	SWX12941	RM11.313.01	George St/SH88	Port Chalmers	6 monthly sampling
32	SWX12994	RM11.313.01	Sawyers Bay, western side of Watson Park	Port Chalmers	Continue monthly sampling
33	SWX12879	RM11.313.01	George St (Port Otago)	Port Chalmers	Continue monthly sampling

7. Appendix 2. Raw data – FWAs and E. coli, dry weather rounds (Pink shaded cells denote exceedence of trigger values)

Outfall	DCC ref	Consent ref.	Catchment	FWAs Aug-16	E. coli Aug-16	FWAs Sep-16	E. coli Sep-16	FWAs Dec-16	E. coli Dec-16	FWAs Feb-17	E. coli Feb-17	FWAs Mar-17	E. coli Mar-17	FWAs May-17	E. coli May-17	FWAs Jun-17	E. coli Jun-17
1	SWX03979	RM11.313.10	St Clair	0.0804	330	0.08886	250	0.071	920	0.07	>2400	0.077	1600	0.059	>2400	0.088	>2400
2	SWX00011 & SWX00012	RM11.313.10	St Clair	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
3	SWX04625	RM11.313.04	Shore Street	0.13234	>2400	0.14562	>2400	0.133	690	0.144	440	0.088	19.9	0.115	30.2	0.143	1700
4	SWX03649	RM11.313.09	South Dunedin	0.01856	<1.0	0.01844	1	0.029	14.6	0.024	870	0.013	14.6	0.096	20.1	0.030	45.7
5	SWX03644	RM11.313.07	Portsmouth Drive	0.09062	55.6	0.13818	45.9	0.140	14.6	0.148	1700	0.123	>2400	0.152	>2400	0.154	>2400
6	SWX03640	RM11.313.07	Portsmouth Drive	0.14892	58.8	0.12052	23.5	0.181	6.1	0.146	2	0.097	8.4	0.174	>2400	0.178	1000
7	SWX03631	RM11.313.07	Portsmouth Drive	0.0825	>2400	0.0492	5	0.060	BDL	0.071	>2400	0.128	>2400	0.019	4.1	0.074	>2400
8	SWX03635 & SWX70740	RM11.313.08	Orari St	0.10252	490	0.0953	650	0.097	490	0.113	>2400	0.095	1400	0.096	310	0.123	1900
9	SWX03579	RM11.313.07	Portsmouth Drive	0.12406	73.3			0				0.15	>2400				
10	SWX03568	RM11.313.06	Kitchener St	0.0741	>2400	0.07352	1600	0.047	17.4	0.049	820	0.040	7.2	0.034	19.7	0.042	52
11	SWX70102	RM11.313.06	Kitchener St	0.08362	9.8			0				0.052	550				
12	SWX03547	RM11.313.06	Kitchener St	0	NF	NF	NF	0.110	8.3	NF	NF	0.026	28.5	0.034	7.4	0.041	720
13	SWX03562	RM11.313.06	Kitchener St	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
14	SWX03556	RM11.313.06	Kitchener St	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
15	SWX03559	RM11.313.06	Kitchener St	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
16	SWZ70569	RM11.313.06	Kitchener St	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
17	SWX03540	RM11.313.06	Kitchener St	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
18	SWX03536	RM11.313.06	Kitchener St	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
19	SWX03532	RM11.313.06	Kitchener St	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
20	SWX70370	RM11.313.06	Kitchener St	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
21	SWX03489	RM11.313.05	Mason St	0.02036	54.4							0.029	1700				
22	SWX03506	RM11.313.03	Halsey St	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
23	SWX03466	RM11.313.03	Halsey St	0.04374	490	0.04482	980	0.067	24	0.059	2400	0.033	370	0.041	93.5	0.06	300
24	SWX03455	RM11.313.03	Halsey St	0.03494	2000	0.04336	>2400	0.033	>2400	0.032	>2400	0.029	>2400	0.029	>2400	0.039	>2400
25	SWX03450	RM11.313.03	Halsey St	0.06246	>2400	0.05754	>2400	0.039	>2400	0.087	>2400	0.069	>2400	0.062	>2400	0.066	>2400
26	SWX03472	RM11.313.03	Halsey St	NF	NF	NF	NF	NF	NF	NF		NF	NF	NF	NF	0.042	4.1
27	SWX03718	RM11.313.03	Halsey St	0.05666	820	0.08688	260	0.080	730	0.062	>2400	0.058	11.4	0.072	>2400	0.107	2400
28	SWX02628	RM11.313.02	Ravensbourne	0.15322	61.3							0.1	12.1				
29	SWX02623	RM11.313.02	Ravensbourne	0.0949	5.2							0.128	12.2				
30	SPN02502	RM11.313.02	Ravensbourne	0.1716	1	0.1632	16.1	NF	-	NF	-	0.178	2	0.156	<1.0	0.144	1
31	SWX12941	RM11.313.01	Port Chalmers	0.10414	56.1							0.083	2400				
32	SWX12994	RM11.313.01	Port Chalmers	0.18478	<1.0	0.1804	<1.0	0.163	13.4	0.161	3.1	0.099	2	0.184	<1.0	0.224	<1.0
33	SWX12879	RM11.313.01	Port Chalmers	0.10872	>2400	0.10568	410	0.092	52.9	0.093	>2400	0.149	2400	0.119	>2400	0.144	>2400

8. Appendix 3. Historic values.

Levels of contaminants detected in stormwater from outfalls in and around Dunedin during 2017 and past storm events. BDL indicates Below Detectable Limits. Green cells indicate improvement over last year; no colour = no change; pink cells denote deterioration over last year.

Parameter	As (detection limit - 0.0002)									
units	g/m³									
Catchment	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
St Clair	BDL	0.0013	0.0015	BDL	0.0016	BDL	BDL	BDL	0.001	BDL
Shore Street	0.04	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.001	BDL
Portobello Road	BDL	0.002	BDL	BDL	BDL	BDL	BDL	0.003	0.002	BDL
Orari Street	BDL	BDL	0.032	0.00149	BDL	BDL	BDL	BDL	0.003	BDL
Kitchener Street	BDL	BDL	0.0096	BDL	BDL	BDL	BDL	BDL	0.002	BDL
Mason Street	0.006	BDL	0.0077	BDL	BDL	BDL	BDL	0.003	0.001	BDL
Bauchop Street	0.03	BDL	0.021	BDL	BDL	BDL	BDL	0.001	0.001	BDL
Halsey Street	0.03	BDL	0.01	0.0044	BDL	BDL	BDL	0.002	0.001	BDL
Wickliffe Street	0.03	BDL	0.003	BDL	0.0035	0.0027	BDL	0.008	0.004	BDL
Port Chalmers	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.003	BDL

Parameter	Cd (detection limit - 0.00005)									
units	g/m³									
Catchment	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
St Clair	BDL	0.00006	0.00006	0.00007	7.5E-05	BDL	BDL	0.0001	BDL	BDL
Shore Street	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Portobello Road	BDL	0.00023	BDL	BDL	BDL	BDL	BDL	0.0001	BDL	BDL
Orari Street	BDL	BDL	BDL	0.00016	BDL	BDL	BDL	BDL	BDL	BDL
Kitchener Street	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mason Street	BDL	BDL	0.0077	0.00051	BDL	BDL	BDL	0.0001	BDL	BDL
Bauchop Street	BDL	BDL	BDL	0.00049	BDL	BDL	BDL	BDL	BDL	BDL
Halsey Street	BDL	0.00022	BDL	0.00026	BDL	BDL	BDL	0.0004	BDL	BDL
Wickliffe Street	BDL	BDL	0.00052	0.00078	0.00092	0.0002	BDL	0.0002	BDL	BDL
Port Chalmers	BDL	BDL	BDL	BDL	BDL	BDL	0.0002	BDL	BDL	BDL

Parameter	Cr (detection limit - 0.0005)									
units	g/m³									
Catchment	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
St Clair	0.0007	0.0028	0.0035	0.00086	0.0038	0.0015	0.0023	0.0117	0.004	BDL
Shore Street	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0061	BDL	BDL
Portobello Road	BDL	0.002	BDL	BDL	BDL	BDL	BDL	0.0182	0.005	BDL
Orari Street	BDL	0.0032	BDL	0.00183	BDL	BDL	BDL	0.0027	BDL	BDL
Kitchener Street	0.004	0.002	BDL	BDL	BDL	BDL	BDL	0.001	0.002	BDL
Mason Street	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0183	0.006	BDL
Bauchop Street	BDL	0.0015	BDL	BDL	BDL	BDL	BDL	0.0182	0.003	BDL
Halsey Street	BDL	BDL	BDL	BDL	BDL	BDL	0.0019	0.0226	0.003	BDL
Wickliffe Street	BDL	0.0017	0.0076	0.00157	0.0046	0.0028	0.0026	0.0189	0.006	BDL
Port Chalmers	BDL	0.0064	BDL	BDL	BDL	0.0016	0.0025	0.0054	0.002	BDL

Parameter	Cu (detection limit - 0.0005)									
units	g/m³									
Catchment	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
St Clair	0.0027	0.012	0.019	0.0054	0.0172	0.0026	0.0099	0.026	0.006	BDL
Shore Street	0.01	0.014	0.02	0.0118	BDL	BDL	0.0159	0.025	0.007	BDL
Portobello Road	BDL	0.026	0.01	0.0057	0.029	0.012	0.0072	0.059	0.028	0.015
Orari Street	BDL	0.014	BDL	0.0096	BDL	0.0024	0.0057	0.004	BDL	BDL
Kitchener Street	0.034	0.0056	0.023	0.0118	BDL	BDL	0.015	0.003	0.019	0.022
Mason Street	0.022	0.012	0.021	0.0157	0.043	0.026	0.0065	0.041	0.016	0.038
Bauchop Street	0.029	0.0096	BDL	0.0026	BDL	0.021	0.0131	0.079	0.016	0.016
Halsey Street	0.024	0.0043	0.021	0.00162	0.029	0.0043	0.0183	0.084	0.019	BDL
Wickliffe Street	0.01	0.013	0.059	0.0058	0.022	0.025	0.0107	0.045	0.023	BDL
Port Chalmers	0.009	0.0025	BDL	BDL	BDL	0.008	0.0118	0.011	BDL	BDL

Parameter	Ni (detection limit - 0.0005)									
units	g/m³									
Outfall	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
Second Beach	0.0009	0.0021	0.0022	0.00133	0.0026	0.0011	0.0023	BDL	BDL	BDL
Shore Street	0.01	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0024	BDL
Portobello Road	BDL	0.0035	0.0028	0.0035	BDL	BDL	BDL	BDL	BDL	BDL
Orari Street	BDL	0.0033	BDL	0.00108	BDL	0.0008	BDL	BDL	BDL	BDL
Kitchener Street	0.003	BDL	0.0036	0.0035	BDL	BDL	BDL	BDL	BDL	BDL
Mason Street	0.004	BDL	0.0055	BDL	0.0039	BDL	BDL	BDL	BDL	BDL
Bauchop Street	0.01	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Halsey Street	0.009	BDL	0.0035	BDL	BDL	BDL	BDL	0.0254	BDL	BDL
Wickliffe Street	0.01	BDL	0.0042	BDL	0.0021	0.0046	BDL	0.0051	BDL	BDL
Port Chalmers	BDL	BDL	BDL	0.0035	BDL	0.0019	BDL	BDL	BDL	BDL

Parameter	Pb (detection limit - 0.0001)									
units	g/m^3									
Catchment	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
St Clair	0.001	0.011	0.013	0.00021	0.0127	0.001	0.0053	0.0557	0.00818	0.0039
Shore Street	0.003	0.0085	0.0069	BDL	BDL	BDL	0.0038	0.0635	0.00509	0.0044
Portobello Road	BDL	0.019	0.0067	0.00055	0.026	0.0081	0.0086	0.0869	0.02913	0.0133
Orari Street	BDL	0.023	BDL	0.00015	BDL	0.0012	0.0041	0.0295	0.00179	0.0029
Kitchener Street	0.0442	0.007	0.018	0.00196	BDL	0.0028	0.0055	0.0202	0.01638	0.0165
Mason Street	0.0258	0.0089	0.014	0.00102	0.0192	0.0101	0.0042	0.124	0.0235	0.025
Bauchop Street	0.01	0.0035	BDL	BDL	BDL	0.021	0.0026	0.115	0.01031	0.0119
Halsey Street	0.021	0.0022	0.0097	0.0021	0.0085	0.0043	0.0064	0.108	0.01176	BDL
Wickliffe Street	0.006	0.0084	0.033	BDL	0.0134	0.0153	0.0092	0.1	0.02461	0.0062
Port Chalmers	0.0141	0.0018	BDL	BDL	0.0041	0.0057	0.0127	0.0316	0.00458	BDL

Parameter	Zn (detection limit - 0.001)									
units	g/m^3									
Catchment	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
Second Beach	0.038	0.16	0.15	0.092	0.25	0.026	0.166	0.222	0.197	0.092
Shore Street	0.02	0.44	0.21	0.115	BDL	0.071	0.2	0.351	0.282	0.132
Portobello Road	0.08	0.94	0.64	0.153	0.87	0.15	0.57	0.744	0.557	0.34
Orari Street	BDL	0.22	0.031	0.3	BDL	0.0157	0.07	0.078	0.026	0.055
Kitchener Street	0.445	0.036	0.38	0.62	BDL	0.082	0.23	0.025	0.292	0.35
Mason Street	0.25	0.16	0.35	0.43	0.63	0.43	0.095	0.577	0.221	0.56
Bauchop Street	0.23	0.12	0.13	0.121	BDL	0.94	0.2	0.713	0.296	0.129
Halsey Street	0.12	0.033	0.3	0.136	0.36	0.089	0.23	0.576	0.119	0.055
Wickliffe Street	0.1	0.2	0.53	0.24	0.82	1.57	0.161	0.617	0.395	0.26
Port Chalmers	0.231	0.027	BDL	0.29	0.24	0.27	0.4	0.334	0.425	BDL

Parameter	pH									
units										
Catchment	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
St Clair	7.7	7.3	7.4	7.3	7.4	8	7.7	7.63	7.68	7.4
Shore Street	7.9	7.2	7.3	7.4	7.9	7.5	7.5	7.5	7.21	7.6
Portobello Road	7.9	7.3	7.6	7.6	7.4	8.1	7.6	7.58	7.61	7.2
Orari Street	7.8	7.4	8.1	7.1	7.9	7.9	7.6	7.87	7.88	7.9
Kitchener Street	7.1	7.7	7.4	6.9	8	7.6	7.7	7.43	7.52	6.9
Mason Street	7.1	7	7.4	7	7	7.1	7.6	8.4	7.44	7.2
Bauchop Street	7.6	7.8	8.1	7.4	8	7.4	7.9	8.83	7.76	7.9
Halsey Street	7.3	7.9	7.2	6.8	7.1	7.8	7.3	7.73	7.48	7.7
Wickliffe Street	7.7	7.5	8.0	7.3	9.7	7.0	7.5	7.67	7.45	2.6
Port Chalmers	6.8	7.9	8.2	7.1	7.5	7.5	7.5	7.48	7.66	8

Parameter	Suspended Solids (detection limit - 3)									
units	g/m^3									
Catchment	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
Second Beach	BDL	37	41	BDL	57	5	34	210	60	19
Shore Street	41	24	20	9.5	12	10	9	150	79	16
Portobello Road	18	46	30	8.1	53	43	27	200	110	27
Orari Street	28	77	16	130	4	BDL	38	130	92	10
Kitchener Street	104	41	45	50	BDL	27	37	45	63	73
Mason Street	62	37	37	138	30	31	63	210	92	101
Bauchop Street	44	16	13	53	5	38	47	350	74	103
Halsey Street	119	35	27	50	24	22	46	580	79	9
Wickliffe Street	35	27	100	86	46	30	92	490	120	114
Port Chalmers	37	39	7.4	240	24	24	58	170	76	9

Parameter	Oil & Grease (detection limit - 4)									
units	g/m^3									
Catchment	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
St Clair	5	BDL	BDL	BDL	BDL	11	5	27	9	BDL
Shore Street	BDL	BDL	BDL	BDL	BDL	10	5	BDL	BDL	BDL
Portobello Road	4	9.7	BDL	BDL	BDL	BDL	BDL	BDL	10	BDL
Orari Street	BDL	11	BDL	BDL	17	BDL	BDL	12	12	BDL
Kitchener Street	9	BDL	BDL	BDL	22	11	BDL	8	21	BDL
Mason Street	5	7.9	BDL	BDL	BDL	BDL	BDL	6	13	BDL
Bauchop Street	4	BDL	BDL	BDL	BDL	BDL	BDL	BDL	33	BDL
Halsey Street	9	BDL	BDL	BDL	BDL	BDL	BDL	6	13	4
Wickliffe Street	6	9.5	9.5	BDL	7	BDL	BDL	30	6	BDL
Port Chalmers	8	BDL	BDL	BDL	BDL	BDL	BDL	17	7	7

Parameter	FWA									
units	µg/L									
Catchment	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
Second Beach	0.147	0.19	0.098	0.04	0.075	0.069	0.064	0.084	0.15	0.088
Shore Street	0.081	0.031	0.142	0.98	0.142	0.156	0.104	0.087	0.112	0.12
Portobello Road	0.003	0.049	0.177	0.151	0.045	0.096	0.207	0.138	0.144	0.126
Orari Street	BDL	0.005	0.11	0.052	0.081	0.094	0.038	0.09	0.057	0.072
Kitchener Street	0.18	0.029	0.072	0.023	0.047	0.052	0.027	0.046	0.069	0.048
Mason Street	0.007	0.07	0.051	0.156	0.026	0.043	0.058	0.06	0.071	0.052
Bauchop Street	2.028	4.92	0.031	0.067	0.017	0.019	0.033	0.057	0.056	0.036
Halsey Street	BDL	0.004	0.011	0.061	0.025	0.038	0.027	0.07	0.058	0.044
Wickliffe Street	0.024	0.003	0.021	0.048	0.094	0.121	0.052	0.081	0.071	0.084
Port Chalmers	0.002	0.003	0.124	0.105	0.092	0.147	0.084	0.104	0.106	0.107

Total PAHs	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Kitchener Street	BDL	BDL	BDL	0.0001	BDL	BDL	BDL	8E-06	BDL	0.00029	BDL
Orari Street	0.00	0.00025	BDL	0.0005	BDL	BDL	BDL	BDL	BDL	0.00017	BDL
Portobello Road	BDL	0.00132	0.00017	0.00016	0.00168	0.0002	0.0018	0.00709	0.0104	0.0182	0.0001

For E. coli, green cells indicate acceptable levels; orange cells indicate a level that would trigger an amber alert; pink cells indicate a level that would trigger a red alert according to MoH/MfE guidelines. Detection limit = 1.

Parameter	E. coli									
units	MPN/100ml									
Catchment	2007	2008	2009	2010	2011	2012	2013	2015	2016	2017
Second Beach	560	6800	14000	4800	9000	300	1300	2000	1300	1200
Shore Street	300	5100	16000	7000	110	11000	780	2600	>2400	1300
Portobello Road	460	5000	2800	54000	6000	280	3300	1000	2000	>2400
Orari Street	50	6000	210	1700	BDL	1800	3300	2000	>2400	2400
Kitchener Street	13000	70	10000	92000	110	150	7900	990	1700	>2400
Mason Street	22000	26000	50000	350000	48000	32000	200	460	>2400	2400
Bauchop Street	2200	400	3000	7900	450	17000	1100	580	690	310
Halsey Street	9000	1700	70000	17000	78000	26000	92000	2900	>2400	>2400
Wickliffe Street	25000	10000	220000	35000	43000	96000	15000	24000	14000	>2400
Port Chalmers	14000	150	10	1600	1000	5900	1300	9200	>2400	11.8
Primary	Amber	>260								
Secondary	Red	>550								

9. Appendix 4. Kitchener St automated sampler results.

Detection limits as in Appendix 3

	19/10/16	24/11/16	5/04/17
Minutes	Oil & Grease (g/m3)		
0	0	0	0
10	14	5	BDL
20	12	5	BDL
30	7	7	BDL
40	8	5	BDL
50	BDL	8	6
60	5	6	BDL
70	BDL	5	BDL
80	17	7	5
90	8	4	BDL
100	BDL	7	8
110	BDL	9	8
120	5	8	BDL

	19/10/16	24/11/16	5/04/17
Minutes	Chromium (g/m3)		
0	0	0	0
10	0.022	BDL	BDL
20	0.019	0.004	BDL
30	0.005	BDL	BDL
40	0.01	BDL	BDL
50	0.021	BDL	0.0029
60	0.01	0.002	0.00139
70	0.009	BDL	0.00129
80	0.006	BDL	0.00126
90	0.002	0.002	0.00131
100	0.002	0.002	0.00128
110	0.003	0.013	0.00164
120	0.003	0.004	0.00106

	19/10/16	24/11/16	5/04/17
Minutes	Zinc (g/m3)		
0	0	0	0
10	0.173	BDL	0.27
20	0.129	0.03	0.24
30	BDL	0.072	0.3
40	BDL	0.038	0.4
50	BDL	BDL	0.47
60	0.073	0.038	0.42
70	0.101	0.004	0.36
80	BDL	0.04	0.33
90	BDL	0.138	0.31
100	BDL	0.15	0.32
110	BDL	0.232	0.32
120	BDL	0.244	0.31

Minutes	pH		
0	0	0	0
10	7.02	7.74	7.57
20	7.05	7.8	7.65
30	7.3	7.82	7.59
40	7.44	7.82	7.4
50	7.36	7.82	7.32
60	7.24	7.79	7.27
70	7.25	7.8	7.22
80	7.29	7.76	7.18
90	7.38	7.58	7.16
100	7.58	7.44	7.14
110	7.63	7.31	7.16
120	7.62	7.25	7.18

Time	Copper (g/m3)		
0	0	0	0
10	0.0997	0.01	BDL
20	0.103	0.0097	BDL
30	0.0429	0.016	0.014
40	0.0686	0.0133	0.029
50	0.121	0.0076	0.032
60	0.108	0.0564	0.023
70	0.0532	0.0072	0.0194
80	0.0498	0.0266	0.0175
90	0.0409	0.0434	0.0181
100	0.0237	0.026	0.0181
110	0.0179	0.0539	0.0169
120	0.0556	0.0374	0.0175

Minutes	Suspended Solids (g/m3)		
0	0	0	0
10	440	81	260
20	300	58	86
30	230	76	71
40	170	96	94
50	160	64	87
60	160	65	32
70	140	69	21
80	130	56	16
90	110	54	16
100	110	50	18
110	120	170	21
120	99	120	13

Minutes	Arsenic (g/m3)		
0	0	0	0
10	0.009	BDL	BDL
20	0.013	BDL	BDL
30	0.011	BDL	BDL
40	0.001	BDL	BDL
50	0.001	0.001	0.0023
60	0.007	0.001	0.0014
70	0.007	BDL	BDL
80	BDL	0.001	BDL
90	BDL	BDL	BDL
100	0.004	BDL	BDL
110	0.001	0.022	BDL
120	0.002	0.003	BDL

Minutes	Lead (g/m3)		
0	0	0	0
10	0.0854	0.00398	0.0167
20	0.0915	0.00774	0.0177
30	0.0748	0.0119	0.029
40	0.063	0.0106	0.05
50	0.0968	0.0202	0.039
60	0.0452	0.00676	0.0165
70	0.0374	0.00805	0.0114
80	0.0351	0.00539	0.01
90	0.0268	0.00796	0.012
100	0.0191	0.00715	0.0155
110	0.0185	0.0517	0.0126
120	0.0201	0.0312	0.0104

Time	E. coli (MPN/100ml)		
0	0	0	0
10	30000	1	2400
20	6500	5	130
30	5200	1	28
40	5200	2	600
50	6500	1	2400
60	30000	5.1	2400
70	30000	23	2400
80	24000	12.8	2400
90	30000	2400	2400
100	17000	2400	2400
110	14000	2400	2400
120	11000	2400	2400

Minutes	Cadmium (g/m3)		
0	0	0	0
10	0.0004	BDL	BDL
20	0.0006	BDL	BDL
30	BDL	0.0001	BDL
40	BDL	BDL	BDL
50	BDL	0.0005	0.00018
60	BDL	0.0006	0.00008
70	BDL	0.0004	0.000067
80	BDL	BDL	0.000054
90	0.0006	BDL	0.000065
100	BDL	BDL	0.000055
110	BDL	0.0024	BDL
120	BDL	0.0003	BDL

Time	Nickel (g/m3)		
0	0	0	0
10	0.0217	0.0059	BDL
20	0.0331	0.0039	BDL
30	0.0104	0.0063	BDL
40	0.0092	0.0023	BDL
50	0.01	BDL	0.0018
60	0.0092	0.0035	0.00102
70	0.0056	0.0016	0.00103
80	0.0092	BDL	0.00112
90	0.0019	0.0059	0.00104
100	0.0056	BDL	0.00111
110	0.0028	0.0178	0.00096
120	0.0096	0.0034	0.00085

Time	Total PAH		
0	0	0	0
10	0.00011	BDL	0.0001
20	BDL	BDL	0.00072
30	BDL	BDL	0.00082
40	BDL	BDL	0.00025
50	BDL	BDL	BDL
60	0.0001	BDL	BDL
70	BDL	BDL	BDL
80	BDL	BDL	BDL
90	BDL	BDL	BDL
100	BDL	BDL	BDL
110	BDL	BDL	BDL
120	BDL	BDL	BDL

10. Appendix 5. Biological monitoring data.

Table 1. *Macroalgal cover, expressed as a percentage at sites at Kitchener Street, Orari Street, Portobello Rd and Macandrew Bay. Green algae in green, red algae in pink, brown algae in orange.*

Burkes	Site 3		
Algae (% cover) >50m	Q1	Q2	Q3
Ulva lactuca	3		

Orari Street	Site 1		
0-5m	Q1	Q2	Q3
Gracileria chilensis	3		

Orari Street	Site 3		
Algae (% cover) >50m	Q1	Q2	Q3
Ceramium uncinatum	1		2

Portobello Rd	Site 3		
Algae (% cover) >50m	Q1	Q2	Q3
Codium fragilis		10	8

Macandrew Bay	Site 2		
Algae (% cover) 20m	Q1	Q2	Q3
Graciliera chilensis			2

Kitchener Street	Site 3		
Algae (% cover) >50m	Q1	Q2	Q3
Codium fragilis		1	
Ceramium uncinatum			1

Orari Street	Site 2		
Algae (% cover) 20m	Q1	Q2	Q3
Graciliera chilensis	2	2	1
Ceramium uncinatum	2	3	4

Portobello Rd	Site 2		
Algae (% cover) 20m	Q1	Q2	Q3
Codium fragilis	5	5	

Macandrew Bay	Site 1		
Algae (% cover) 0-5m	Q1	Q2	Q3
Graciliera chilensis	1		
Ceramium uncinatum	1	2	3

Table 2. *Epifauna at three locations at Burkes (left) and near the Kitchener Street outfall (right).*

Burkes

0-5m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Gastropod snails					
Diloma subrostrata	1				
Bivalves					
Austrovenus stutchburyi	1	1		1	1

20m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Gastropod snails					
Diloma subrostrata				1	
Bivalves					
Austrovenus stutchburyi		1	3	2	2

>50m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Bivalves					
Austrovenus stutchburyi	1	1	2	1	

Kitchener St

0-5m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Polychaete worms					
Pomatoceros caerulus		20			11
Barnacles					
Eminius modestus		84		7	9
Gastropod snails					
Melagraphis aethiops		1			1
Bivalves					
Mytilus galloprovincialis				1	1
Ostrea heffordi		3			2

20m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Polychaete worms					
Pomatoceros caerulus	4	2	8	28	
Barnacles					
Eminius modestus		1	1		
Chamaesipho columna		3			
Gastropod snails					
Austrolittorian cincta					2
Cominella glandiformis			1		
Micrelenchus tenebrosus				1	1
Bivalves					
Ostrea heffordi			1	9	

>50m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Anemones					
Anthopleura spp		3		1	13
Polychaete worms					
Pomatoceros caerulus	15		4	2	2
Barnacles					
Eminius modestus		2	1	2	1
Gastropod snails					
Micrelenchus tenebrosus	2	1	1		
Bivalves					
Ostrea heffordi	2		2		

Table 3. *Epifauna at three locations near the Orari Street outfall (left) and near the Portobello Road outfall (right).*

Orari Street

0-5m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Gastropod snails					
Micrelenchus tenebrosus					1
Bivalves					
Austrovenus stutchburyi	2	12	11	11	5

20m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Gastropod snails					
Cominella glandiformis			1		
Micrelenchus tenebrosus	1				
Zeacumantus subcarinatus	1				
Bivalves					
Austrovenus stutchburyi	12	14	16	13	15
Macomona liliana					1

>50m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Gastropod snails					
Cominella glandiformis		1			
Micrelenchus tenebrosus	1		1		
Zeacumantus subcarinatus					
Bivalves					
Austrovenus stutchburyi	8	10	13	16	12

Portobello Rd

0-5m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Gastropod snails					
Cominella glandiformis	1				
Micrelenchus tenebrosus				1	1
Zeacumantus subcarinatus	1		1	1	
Bivalves					
Austrovenus stutchburyi		3	1	1	1

20m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Crabs					
Macrophthalmus hirtipes					1
Gastropod snails					
Amphibola crenata				1	
Austrolittorina cincta		1			
Cominella glandiformis	1				
Diloma subrostrata	1	1	1		
Micrelenchus tenebrosus	2		2	2	1
Bivalves					
Austrovenus stutchburyi				1	1

>50m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Polychaete worms					
Pomatoceros caerulus	13	12	30		104
Barnacles					
Eminius modestus			3	2	
Gastropod snails					
Cominella glandiformis		1			
Melagraphis aethiops			1		
Micrelenchus tenebrosus	4	3	2	9	3
Zeacumantus subcarinatus	1				
Bivalves					
Ostrea heffordi					16

Table 4. *Epifauna at three locations at Macandrew Bay*

Macandrew Bay

0-5m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Gastropod snails					
Cominella glandiformis	1				
Diloma subrostrata		1			
Zeacumantus subcarinatus		2	1		
Bivalves					
Austrovenus stutchburyi	2	1		1	1

20m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Gastropod snails					
Cominella glandiformis				1	
Micrelenchus tenebrosus	1				
Bivalves					
Austrovenus stutchburyi	1	1			

>50m	Quadrat 1				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Anemones					
Gastropod snails					
Cominella glandiformis	1				1
Micrelenchus tenebrosus				2	
Bivalves					
Austrovenus stutchburyi	1			1	1

Table 5. *Diversity (H') of epifauna at five soft shore intertidal sites in the upper Otago Harbour basin. 2017 data compared with 2007, 2008, 2009, 2010, 2011, 2012, 2013 and 2015 data.*

	0-5m								
Site	2007	2008	2009	2010	2011	2012	2013	2015	2017
Burkes								0.1	0.22
Kitchener Street	0.48	0.48	0.55	0.53	0.55	0.51	0.52	0.45	0.35
Orari Street	0.36	0.37	0.3	0.12	0.29	0.31	0.38	0.2	0.5
Portobello Road	0.53	0.33	0.62	0.58	0.57	0.53	0.65	0.68	0.52
Macandrew Bay								0.1	0.51

	<20m								
Site	2007	2008	2009	2010	2011	2012	2013	2015	2017
Burkes								0.27	0.15
Kitchener Street	0.48	0.48	0.55	0.53	0.55	0.51	0.52	0.61	0.48
Orari Street	0.36	0.37	0.3	0.12	0.29	0.31	0.38	0.56	0.12
Portobello Road	0.53	0.33	0.62	0.58	0.57	0.53	0.65	0.82	0.65
Macandrew Bay								0.22	0.45

	>50m								
Site	2007	2008	2009	2010	2011	2012	2013	2015	2017
Burkes								0.55	0.05
Kitchener Street	0.71	0.57	0.42	0.2	0.57	0.57	0.65	0.26	0.56
Orari Street	0.05	0.25	0.31	0.16	0.15	0.39	0.44	0.56	0.1
Portobello Road	0.5	0.63	0.84	0.64	0.58	0.46	0.51	0.58	0.35
Macandrew Bay								0.46	0.47

Table 6. *Size of cockles collected at Kitchener Street, Orari Street and Portobello Road in 2007 to 2017.*

	2007		2008		2009		2010		2011		2012		2013		2015		2017	
	n =	Mean length (mm)	n =	Mean length (mm)	n =	Mean length (mm)	n =	Mean length (mm)	n =	Mean length (mm)	n =	Mean length (mm)	n =	Mean length (mm)	n =	Mean length (mm)	n =	Mean length (mm)
Kitchener	59	37.1	54	35.5	80	38.1	63	36.6	106	37.5	73	36.1	67	34.2	87	34.7	176	34.5
Orari St	62	32.4	74	29.8	80	33.0	82	30.2	73	30.0	83	31.5	83	30.5	116	28.6	279	30.9
Portobello	64	30.1	74	28.3	80	30.1	80	28.2	103	28.8	92	28.9	47	29.6	102	26.5	184	29.9

Table 7. *Abundance of species of infauna collected at outfall and reference sites.*

			Location	Burkes				Kitchener Street				Orari Street				Portobello Road				Macandrew Bay			
			Sample	1	2	3		1	2	3		1	2	3		1	2	3		1	2	3	
Phylum		**Family**	**Genus/species**				sum				sum				sum				sum				sum
Annelida	Polychaeta	Capitellidae			2	1	3		1		1	1		2	3								
		Glyceridae		5	5	8	18	3	3	4	10	8	2	10	20	4	3	1	8	4	6	3	13
		Lumbrineridae											6		6								
		Maldanidae		1			1			1	1												
		Nephtyidae								1	1						3		3	1			1
		Nereidae		1			1			1	1	1	1	1	3	2	2		4	1	1		2
		Spionidae		4	1	2	7	2	1	4	7	3	5	2	10	3	1	1	5	4	2	3	9
		Syllidae						1			1	1	1		2	5			5	1			1
Hemichordata	Enteropneusta					1	1									1			1	1	1		2
Nemertea													4		4	2	1	1	4				
Sipuncula																					1		1
Crustacea	Amphipoda	Haustoriidae							1		1												
		Lysianassidae												1	1								
		Phoxocephalidae		2		1	3	1	2	1	4	1		2	3			1	1			1	1
	Isopoda		Isocladus armatus																			1	1
	Tanaidacea			1			1					1	1		2			1	1				
Mollusca	Polyplacophora		Acanthochitona zelandica							1	1												
	Gastropoda	Amphibolidae	Amphibola crenata	1			1																
		Cominellidae	Cominella glandiformis	1	1		2					1			1		1		1	1			1
		Batilliidae	Zeacumantus subcarinatus													1			1				
		Trochidae	Micrelenchus tenebrosus			1	1	1	1		2	2	1		3								
			Diloma subrostrata																			1	1
		Nacellidae	Notoacmea spp.						1		1												
	Bivalvia	Veneridae	Austrovenus stutchburyi	3	4	1	8	1			1	2	2	2	6							1	1
		Tellinidae	Macomona liliana	1			1					1		1	2								
	Nematoda															22	3	2					
			Animals per core	20	13	15		9	10	13		22	23	21		18	11	5		13	11	10	
			Animals per m2	4460	2899	3345		2007	2230	2899		4906	5129	4683		4014	2453	1115		2899	2453	2230	
			Species per site	10	5	7	13	6	7	7	13	11	9	8	14	8	7	6	11	7	5	6	12

Table 8. *Diversity (H') of infauna at five soft shore intertidal sites in the upper Otago Harbour basin. 2017 data compared with 2007, 2008, 2009, 2010, 2011, 2012, 2013 and 2015 data.*

Site	2007	2008	2009	2010	2011	2012	2013	2015	2017
Burkes								0.73	0.86
Kitchener Street	0.67	0.53	0.44	0.9	0.81	0.9	0.91	0.97	0.91
Orari Street	1.01	0.86	0.74	0.98	0.99	1.14	1.04	0.85	0.98
Portobello Road	0.74	0.67	0.8	1.04	0.69	0.7	0.98	0.82	0.93
Macandrew Bay								0.85	0.82

Table 9. *Contaminant concentrations in cockle flesh from within 20m of the Kitchener Street, Orari Street and Portobello Road stormwater outfalls in 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2015 and 2017. Green shading indicates a decrease in contaminant level, pink indicates an increase, white = no change. BDL = below detectable limits.*

Parameter	Units		Portobello Rd	Orari Street	Kitchener St
As	mg/kg	2007	2.5	2.5	3.5
		2008	4.0	2.8	3.3
		2009	2.9	4.9	3.8
		2010	2.0	2.3	2.2
		2011	2.5	2.5	2.8
		2012	8.0	8.8	5.3
		2013	1.48	2.5	2.4
		2015	39.9	45	39.2
		2017	3.4	3.1	3.5
Cd	mg/kg	2007	0.014	0.011	0.016
		2008	0.023	0.010	0.015
		2009	0.021	0.024	0.017
		2010	0.014	0.013	0.010
		2011	0.015	0.014	0.015
		2012	0.053	0.027	0.025
		2013	0.011	0.009	0.0134
		2015	0.154	0.15	0.117
		2017	0.015	0.015	0.016
Cr	mg/kg	2007	0.32	0.32	0.34
		2008	0.65	0.15	0.27
		2009	0.22	0.30	0.31
		2010	BDL	0.18	0.13
		2011	0.02	0.17	0.22
		2012	0.33	0.41	0.33
		2013	0.29	0.29	0.37
		2015	BDL	BDL	BDL
		2017	0.25	0.3	0.34
Cu	mg/kg	2007	0.64	0.70	0.81
		2008	1.20	0.85	0.67
		2009	0.82	1.10	0.89
		2010	0.43	0.46	0.66
		2011	0.77	0.65	0.71
		2012	1.29	1.24	1.29
		2013	0.64	0.48	0.8
		2015	14.3	12.9	BDL
		2017	0.58	0.44	0.6
Pb	mg/kg	2007	0.17	0.11	0.08
		2008	0.42	0.07	0.08
		2009	0.099	0.110	0.082
		2010	0.151	0.082	0.089
		2011	0.130	0.094	0.082
		2012	0.35	0.11	0.20
		2013	0.28	0.073	0.105
		2015	BDL	1.25	BDL
		2017	0.084	0.056	0.094
PAH	mg/kg	2007	4.912	0.018	0.009
		2008	0.640	0.047	0.028
		2009	0.613	0.038	0.028
		2010	1.714	0.035	0.044
		2011	0.772	0.034	0.027
		2012	2.750	0.031	0.024
		2013	1.469	0.014	0.022
		2015	0.505	0.031	0.02
		2017	0.670	0.054	0.051
Enterococci	MPN/100g	2015	>18000	16000	1400
		2017	490	700	1300

11. Appendix 6. Consent conditions.

Environmental Monitoring

Condition 7.

The following monitoring shall be undertaken as specified in Appendix 2 and as shown in the plan in Appendix 3 to this consent.

(a) Stormwater quality monitoring

(b) Harbour receiving water quality

(c) Harbour sediment monitoring.

(d) Biological monitoring including cockles

Appendix 2 specifies:

A Stormwater Quality

TIME/FLOW PROPORTIONAL SAMPLES

(a) The consent holder shall install an automated monitoring device to record stormwater discharge quality over a duration of one year, once every five years, at the following outfalls in turn, being one outfall in each of the ICMP catchments of South Dunedin, Halsey Street, Shore Street, Kitchener Street and Mason Street:

(i) The automated monitoring device shall be set to take time or flow proportional samples within the first 2 hours of the sampled storm event within the catchment prior to any mixing with seawater and:

1. The monitoring device shall be set to be triggered by connection to either a rain gauge or a flow/water level monitor. If flows are used as the trigger, flow monitoring or stormwater modelling shall be used to set the trigger corresponding to a rainfall intensity of 0.5mm per hour. A period of flow and rainfall monitoring is to be undertaken prior to setting this trigger value, to ensure that the trigger is set appropriately to capture a full storm hydrograph.

2. There must be at least 72 hours of dry weather before the monitoring device is activated.

(ii) The consent holder shall sample a minimum of 3 storm events over the 1 year sampling duration at each outfall commencing six months from the date of granting of this consent. Any further sampling of the catchment may be at the discretion of the consent holder.

GRAB SAMPLES

(b) Once per year the consent holder shall take a grab sample of stormwater from an outfall in each of the 10 catchments described in the 10 permits that are subject to this appendix.

(i) The grab samples in the non priority catchments, i.e those that are not listed in (a) above shall be taken from the outfall in the non priority catchments with the highest flows during rainfall events or otherwise from an alternative outfall in agreement with the consent authority.

(ii) The grab samples in the priority catchments listed in (a) above shall not be required in the years when the automated monitoring device described in (a) above is operating in a catchment.

(iii) The grab sample shall be taken before the stormwater mixes with seawater, and shall be taken within the first 2 hours of a storm event, and following a period of 72 hours of no rainfall in the catchment.

ANALYTES

(c) All stormwater samples required under A(a) and (b) above shall be analysed for the following parameters:

(i) pH
(ii) suspended solids
(iii) Escherichia coli units
(iv) total copper
(v) total lead
(vi) total zinc
(vii) total arsenic
(viii) total nickel
(ix) total cadmium
(x) total chromium
(xi) polycyclic aromatic hydrocarbons
(xii) oil and grease

(d) The raw data results from each stormwater event shall be forwarded to the consent authority annually as part of the annual reporting required by condition 11.

B Harbour water quality monitoring

(a) Harbour water quality monitoring shall be undertaken annually to determine the effect the authorised stormwater discharge is having on water quality in

the Otago Harbour and to determine whether the trigger values in table B 1 are being exceeded.

(b) Harbour water quality sampling shall be undertaken at the six locations as identified within the plan attached in Appendix 3 during wet and dry weather.

(i) Samples are to be taken on 4 occasions (two rounds (see below) annually.

(ii) Samples shall be taken no closer than 20 metres horizontal distance from the location of the confluence of the stormwater outlet and the waters edge if there are stormwater discharges occurring from the outfall at the time of sampling.

(iii) Samples must be taken 100-200mm below the surface of the water.

(iv) First round sampling shall be three hours apart following high tide, and at mid ebb tide during a period when there has been no measurable rainfall for at least 72 hours prior to sampling.

(v) The second round sampling will occur at the same state of tides as the first round, no less than three hours after the commencement of a rain event that is likely to produce at last 2 mm of rainfall and that has had an antecedent dry period of at least 72 hours.

(c) If harbour water quality sampling identifies the following contaminants at a level exceeding the trigger values set out below in table B 1, the level of contamination shall be confirmed by re-sampling and re-analysis.

(i) total cadmium

(ii) total copper

(iii) total lead

(iv) total zinc

(v) enterococci cfu/100ml (indicator organism)

Table B 1. Harbour Water Trigger Levels

Indicator	*Unit*	*ANZECC 95%Marine Guideline value*	*2013 Trigger*	*Description*
Total Arsenic	*(g/m$^{3)}$*		*0.036*	*USEPA chronic trigger*
Total Cadmium	*(g/m$^{3)}$*	*0.00550*	*0.00550*	*ANZECC guideline*
Total Chromium	*(g/m$^{3)}$*	*0.00440*	*0.00440*	*ANZECC guideline*
Total Copper	*(g/m$^{3)}$*	*0.00130*	*0.00130*	*ANZECC guideline*
Total Nickel	*(g/m$^{3)}$*	*0.07000*	*0.07000*	*ANZECC guideline*

Total Lead	*(g/m^3)*	*0.00440*	*0.00440*	*ANZECC guideline*
Total Zinc	*(g/m^3)*	*0.01500*	*0.01500*	*ANZECC guideline*
Enterococci	*Cfu/100ml*	*-*	*140*	*MfE guideline (amber alert)*

(d) If the harbour water quality is confirmed as exceeding the trigger values outlined in Table B 1, the protocol outlined in Condition 10 of the permits shall be implemented.

C Harbour sediment quality

(a) The consent holder shall undertake sediment quality sampling using sediment samples taken from the top 200 millimetres of the seabed. Samples shall be collected from the 5 locations as identified within the plan attached as Appendix 3. The sampling point shall be at or about 20 metres from the nearest stormwater outfall to each site marked on Appendix 3. Samples shall be collected between January and June, on an annual basis.

(b) The sediment properties and contaminants from each sample site are to be tested. At a minimum the consent holder shall for each of the sites collect and analyse one composite surface sediment sample made up of 5 sub-samples for:

(i) weak-acid extractable copper,
(ii) total lead,
(iii) total zinc,
(iv) total arsenic,
(v) total cadmium,
(vi) total chromium,
(vii) total copper,
(viii) total mercury,
(ix) total nickel,
(x) polycyclic aromatic hydrocarbons (the 16 USEPA priority compounds, retene, 2,6- and 1,7-methylated phenanthrene, and hopanes),
(xi) total petroleum hydrocarbons, and
(xii) organochlorine pesticides.

(c) The sample results obtained are to be forwarded to the Consent Authority along with a comparison with any previous monitoring in accordance with the annual reporting required by condition 11 of the permits that apply to this appendix.

(d) *Table C 1 sets out the trigger levels for harbour sediments. The trigger levels may be changed with the written agreement of the consent authority, as new monitoring results or other information comes to hand. If agreement cannot be reached on (a) new trigger level/s the consent holder has the option of applying to vary the conditions under s127 of the Act.*

(e) *If harbour sediment sampling identifies the following contaminants at a level exceeding the trigger values set out below in table C 1, the level of contamination shall be confirmed by re-sampling and re-analysis. The effect of the trigger exceedence shall be assessed taking into account the results of biological monitoring that is nearest and/or most relevant to the sediment monitoring site.*

Table C 1 Harbour Sediment Trigger Levels

Indicator	Unit	ANZECC Guideline		2013 Trigger	Reason for 2013 trigger	Amended Trigger Reason
		Low	High			
Total Arsenic	(mg/kg dry wt)	20	70	19	80th percentile of samples collected to date	
Total Cadmium	(mg/kg dry wt)	1.5	10	1.7	80th percentile of samples collected to date	
Total Chromium	(mg/kg dry wt)	80	370	80	ANZECC trigger most samples to date below ANZECC	
Total Copper	(mg/kg dry wt)	65	270	122	80th percentile of samples collected to date	
Total Nickel	(mg/kg dry wt)	21	52	21	ANZECC trigger most samples to date below ANZECC	
Total Lead	(mg/kg dry wt)	50	220	209	80th percentile of samples collected to date	
Total Zinc	(mg/kg dry wt)	200	410	902	80th percentile of samples collected to date	
Total PAH	(mg/kg dry wt)	4	45	183	80th percentile of samples collected to date	
TPH	(mg/kg dry wt)			To be determined	To be determined	
Enterococci	Cfu/100ml			108	80th percentile of samples collected to date	

(c) If the harbour sediment contamination is confirmed as exceeding the trigger values outlined in table C 1 and analysis of biological monitoring under (e) above supports that confirmation, the protocol outlined in Condition 10 of the permits shall be implemented.

D Biological Monitoring

EPIFAUNA, INFAUNA AND MACROFLORA

(a) The consent holder shall undertake biological sampling from the five locations identified on the plan attached as Appendix 3 to the permits. Samples shall be collected between the months of January and June at two yearly intervals. The monitoring shall include:

(b) Sampling is to be at 3 sites per location as follows: the waters edge at low tide; within 20 metres of the confluence of the stormwater outlet and the waters edge at low tide, and a minimum of 50 metres from the confluence of the stormwater outlet and the waters edge at low tide.

(c) From the top 200 millimetres at each site, three randomly spaced 5 square metre quadrats shall be sampled for epifauna, infauna and macroflora.

(d) Sampling and species identification for each site shall include:

(i) For epifauna within each 5 square metre quadrat, the number of each species shall be recorded in five 0.1 square metre quadrats.

(ii) For infauna a sediment core shall be taken in three 0.1 square metre quadrats and the number of each species shall be recorded.

(iii) For macroflora, the percentage cover of each species shall be estimated in three 1.0 square metre quadrats.

COCKLES

(e) The consent holder shall undertake samples of the flesh of cockles (Austrovenus stutchburyi) at the 3 locations identified in Appendix 3 to the permits.

(i) Sampling shall be carried out at two yearly intervals.

(ii) Sampling from each location shall be at the waters edge at low tide and within 20 metres of the confluence of the stormwater outlet and the waters edge at low tide.

(iii) Analysis shall be from a composite sample from each location of at least 200 grams of cockle flesh. The number and size of cockles used shall be recorded.

(iv) If no cockles are present from in front of an outfall no sample to be taken at that location.

(v) The cockle flesh samples shall be analysed for:

1) total copper
2) total lead
3) total arsenic
4) total cadmium
5) total chromium
6) polycyclic aromatic hydrocarbons
7) Enterococcus Colony Forming Units in No/100 millilitres)

Dry weight sample results shall be recorded for each sample.

(f) The sample results from all biological monitoring shall be provided to the consent authority in accordance with the annual reporting required by condition 11 of the permits that apply to this appendix.