Compliance Monitoring 2011

Stormwater Discharges from Dunedin City

(ORC Resource Consents 2002.080-2002.110 and 2006.222)

Prepared for

Dunedin City Council

by

Ryder Consulting Ltd.

June 2011

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Brian Stewart

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Cover photo: Tide gates at the Orari Street stormwater outfall

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Executive Summary

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

The survey comprised assessment of benthic communities, of contamination of stormwater and of contamination of sediments and benthic fauna, including fish, cockles and mussels.

Stormwater from all outfalls monitored showed variable levels of contamination, with numerous parameters being present at concentrations above recommended ANZECC guidelines or trigger values.

Sediments too showed varying levels of contamination from outfall to outfall with levels of contaminants breaching ANZECC trigger values for lead, zinc and PAHs at the majority of sites. However, overall sediment contaminant levels appear to be falling through time

Contaminant levels were similar to those observed in previous surveys carried out in 2007, 2008, 2009 and 2010 with no clear trends in contaminant levels in stormwater discernible at this juncture.

1. 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 receiving water environments for Dunedin's reticulated stormwater are the upper basin of Otago Harbour, Second Beach/St. Clair Beach on the open coast, Kaikorai Stream and the Water of Leith. Dunedin City Council (DCC) was, on 29th November 2007, granted resource consents for its major urban stormwater discharges into the coastal marine environment (i.e. Otago Harbour, Sawyers Bay. Port Chalmers and Second Beach).

Conditions under which consents have been granted include compliance monitoring. Specifically:

Condition 2.

(a) *The consent holder shall undertake water quality sampling of the discharge following one storm event annually, unless the size and frequency of rainfall events means that sampling in the manner described in condition 2(b) is not possible.*

(b) *The sampling shall be undertaken during storms, preceded by at least 72 hours of no measurable precipitation, with an intensity of at least 2.5 millimetres (depth) of rain in a 24 hour period. Sampling shall be undertaken within the first hour of the storm discharge in order to obtain the maximum concentration of a pollutant. The samples shall be analysed for:*

(i) pH
(ii) suspended solids
(iii) faecal coliforms and Escherichia coli
(iv) total copper
(v) total lead
(vi) total zinc
(vii) total arsenic
(viii) total nickel

(ix) total cadmium
(x) total chromium
(xi) UV fluorescent (whitening agent)
(xii) HEM, oil and grease
(xiii) Polycyclic aromatic hydrocarbons ***(Portobello Road, Orari and Kitchener Street consents only)***

(c) *The consent holder shall also undertake targeted sampling of any visual slicks seen during the stormwater discharge sampling in conditions 2 (a) and (b).*

Results shall be reported to the Consent Authority in accordance with condition 8(e).

For the Portobello Road catchment discharge consent only

(a) *The consent holder shall undertake to determine the source and extent of the high levels of polycyclic aromatic hydrocarbons in the historic sediment deposits associated with discharge from the Portobello Road stormwater outlet.*

(b) *Updates on the progress of the investigation in condition 3(a) shall be provided in writing to the Consent Authority by 1 September each year.*

(c) *No later than six months prior to the expiry of this consent, the consent holder shall provide a report to the Consent Authority stating the outcomes of the investigation in condition 3(a) and outlining the best practicable option(s) to mitigate the effects of these contaminated sediments.*

For the Portobello Road, Orari and Kitchener Street discharge consents only

(a) *The consent holder shall undertake biological monitoring annually between the months of January to June inclusive. The monitoring shall be undertaken at four sites at the waters edge at low tide; two within 20 metres of the confluence of the stormwater outlet and the waters edge at low tide and two a minimum of 50 metres of the confluence of the stormwater outlet and the waters edge at low tide.*

(b) *At each site, three randomly spaced $5m^2$ quadrats shall be sampled. For epifauna within each $5m^2$ quadrat, the number of each species shall be recorded in five $0.1m^2$ quadrats. For infauna a sediment core shall be taken in three $0.1m^2$ quadrats and the number of each species shall be recorded. For macroflora, the percentage cover of each species shall be estimated in*

three 1.0m^2 quadrats.

(c) *Results shall be reported to the Consent Authority in accordance with condition 8(e).*

For the Portobello Road, Orari and Kitchener Street discharge consents only

The consent holder shall undertake sampling of the flesh of cockles (Austrovenus stutchburyi) annually, between the months of January to June inclusive. Sampling shall be carried out at the waters edge at low tide, within 20 metres of the confluence of the stormwater outlet and the waters edge at low tide. The size of each cockle sampled shall be recorded. The cockle flesh samples shall be analysed for:

(a) total copper
(b) total lead
(c) total zinc
(d) total arsenic
(e) total nickel
(f) total cadmium
(g) total chromium
(h) polycyclic aromatic hydrocarbons
(i) faecal coliforms

Results shall be reported to the Consent Authority in accordance with condition 8(e).

For the Portobello Road and Orari Street discharge consents only

The consent holder shall undertake sampling of deceased octopus annually, between the months of January to June inclusive (to align with the autumn die-off of octopus). Samples will include flesh and, if available, digestive gland. Sampling shall be carried out within 50 metres of the confluence of the outlet and the waters edge at low tide. The total arm span and weight of each octopus sampled shall be recorded. The samples shall be analysed for:

(a) total copper
(b) total lead
(c) total zinc
(d) total arsenic
(e) total nickel
(f) total cadmium
(g) total chromium
(h) polycyclic aromatic hydrocarbons

Results shall be reported to the Consent Authority in accordance with condition 8(e). Should no deceased octopus be present, the consent holder shall notify the Consent Authority that sampling is unable to be undertaken.

For the Mason Street discharge consents only

The consent holder shall undertake sampling of spotties (Notolabrus celidotus) or triplefin (*Tripterygion varium*) *annually. This sampling is to be carried out within the months of January to June inclusive. Sampling shall be carried out within 50 metres of the confluence of the outlet and the waters edge at low tide. The length and weight of each fish sampled shall be recorded. The samples shall be analysed for:*

(a) total copper
(b) total lead
(c) total zinc
(d) total arsenic
(e) total nickel
(f) total cadmium
(g) total chromium
(h) polycyclic aromatic hydrocarbons

Results shall be reported to the Consent Authority in accordance with condition 8(e).

For the Portobello Road, Orari and Kitchener Street discharge consents only

The consent holder shall undertake sediment quality sampling using three replicate sediment samples that shall be collected at each site as marked on the plans attached as Appendix 1 to this consent. Sampling shall be undertaken:

(a) annually between January and June at the locations marked by large orange stars; and

(b) between January and June 2007, and between January and June 2010, at the locations marked by large pink stars. The samples will comprise the top 20mm of sediment and shall be analysed for:

(i) total copper
(ii) total lead
(iii) total zinc
(iv) total arsenic
(v) total nickel
(vi) total cadmium

(vii) total chromium
(viii) faecal coliforms and enterococci
(ix) polycyclic aromatic hydrocarbons
Results shall be reported to the Consent Authority in accordance with condition 8(e).

Condition 3. *The biological sampling of epifauna, infauna, macroflora, cockles, octopus, spotties or triplefins and sediment quality sampling required by Coastal Permits etc, shall be undertaken within a 14 day period (within the months of January to June), unless it is not practicable to do so due to the absence of any fauna to be sampled.*

Condition 4. *All sampling techniques employed in respect of the conditions of this consent shall follow a written standard operating procedure to be developed by the consent holder and be acceptable to the Consent Authority.*

Condition 5. *Unless specifically approved otherwise by the Consent Authority, all analytical testing undertaken in connection with this consent shall be performed by a laboratory that meets ISO17025 standards.*

Second Beach

Condition 2.

(a) *The consent holder shall undertake water quality sampling of the discharge following one storm event annually, unless the size and frequency of the rainfall event means that sampling in the manner described in condition 2(b) is not possible.*

(b) *The sampling shall be undertaken during storms, preceded by at least 72 hours of no measurable precipitation, with an intensity of at least 2.5 millimetres (depth) of rain in a 24 hour period. Sampling shall be undertaken within the first hour of the storm discharge in order to obtain the maximum concentration of a pollutant. The samples shall be analysed for:*
(i) pH
(ii) suspended solids
(iii) faecal coliforms and Escherichia coli
(iv) total copper
(v) total lead
(vi) total zinc

(vii) total arsenic
(viii) total nickel
(ix) total cadmium
(x) total chromium
(xi) HEM, oil and grease
(xii) UV fluorescent (whitening agent)

(c) *The consent holder shall also undertake targeted sampling of any visual slicks seen during the stormwater discharge sampling in conditions 2 (a) and (b). Results shall be reported in accordance with condition 8(e).*

Condition 3.

(a) *The consent holder shall undertake sampling of mussels annually, between the months of January to June inclusive. Sampling shall be carried out at the waters edge at low tide, 50 metres to the east of the outlet. The shell length of each mussel sampled shall be recorded.*

(b) *The sampling of mussels shall be undertaken within a 14 day period (within the months of January to June) associated with the sampling rounds for Green Island and Tahuna WWTP discharge consents, unless it is not practicable to do so due to the absence of any fauna to be sampled.*

(c) *The samples shall be analysed for:*
(i) faecal coliforms
(ii) total copper
(iii) total lead
(iv) total zinc
(v) total arsenic
(vi) total nickel
(vii) total cadmium
(viii) total chromium

(d) *Results shall be reported in accordance with condition 8(e).*

Condition 4. *All sampling techniques employed in respect of the conditions of this consent shall follow a written standard operating procedure to be developed by the consent holder and be acceptable to the Consent Authority.*

Condition 5. *Unless specifically approved otherwise by the Consent Authority, all*

analytical testing undertaken in connection with this consent shall be performed by a laboratory that meets ISO17025 standards.

The following report presents the results of the latest round of sampling/monitoring carried out between January and June 2011.

1.2 Stormwater Outfalls

Stormwater is discharged from Dunedin City to the Upper Otago Harbour, Second Beach and Port Chalmers from fourteen reasonably large and permanent stormwater outfalls (Figures 1a, 1b and 1c), and from a number of smaller outfalls and non-point sources (Table 1). Many of the outfalls have very long histories dating back to the days of the early settlement of Dunedin and a numbers were dual-purpose outfalls, discharging both wastewater and stormwater. All current outfalls, however, are designated to discharge stormwater.

Figure 1a. *Major stormwater outfalls, labeled by catchment name, discharging from Dunedin City to the Upper Otago Harbour Basin.*

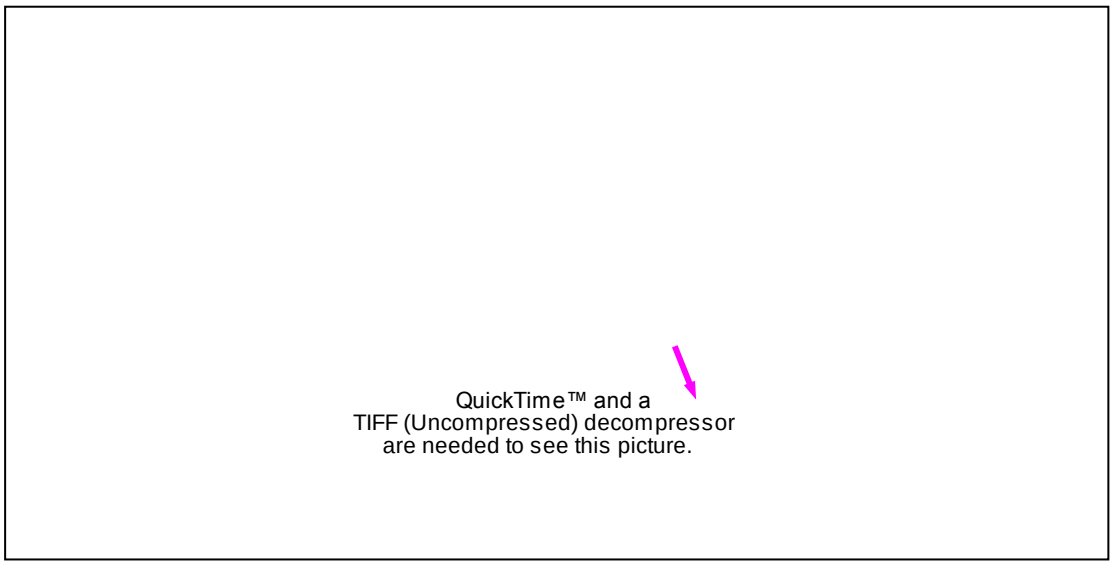


Figure 1b. *Location of the Second Beach stormwater outfall.*

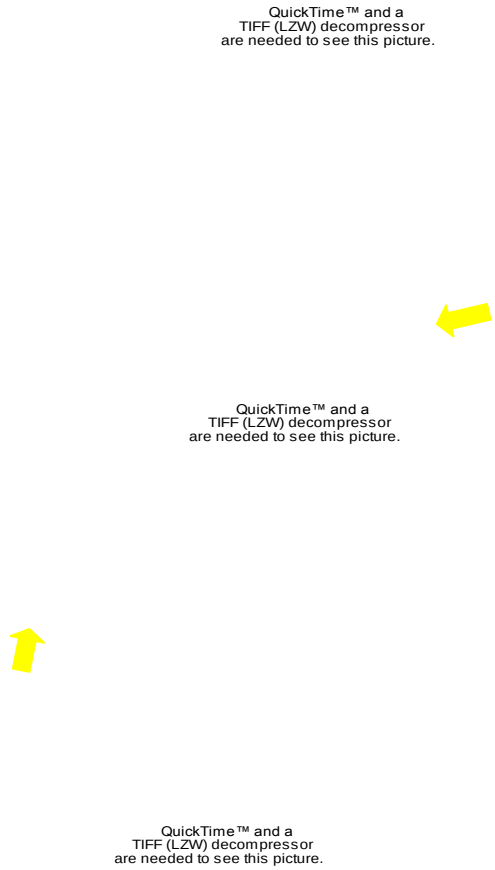


Figure 1c. *Location of major outfalls discharging stormwater from Port Chalmers.*

A total of 31 consents have been granted for the individual stormwater outfalls listed in Table 1.

Table 1. *List of stormwater outfalls for which discharge permits have been granted.*

Consent ref	DCC ref	Location	Catchment	Description	Max flow rate (l/s)	Outlet structure
2002.080	4	Shore St	Shore St	1500mm dia	2,380	Yes
2002.081	5	Portobello Rd	Portobello Rd	twin 1500mm dia conduits	pump rate 6,300	Yes
2002.082	6	Teviot St	Foreshore	375mm dia.	105	Yes
2002.083	7	Midland St	Foreshore	450mm dia	143	No
2002.084	8(a)	Orari St	Orari St	375mm dia	101	No
2002.085	8(b)	Orari St	Orari St	2700mm dia	10,350	Yes
2002.086	9(a)	Kitchener St	Kitchener St	600mm dia	310	Yes
2002.087	9(b)	Kitchener St	Kitchener St	1500mmdia	3,880	Yes
2002.088	10	French St	Foreshore	450mm dia	185	No
2002.089	11	Kitchener St	Foreshore	300 mm dia.	78	No
2002.090	12(a)	Birch St	Foreshore	225 mm dia.	37	No
2002.091	12(b)	Birch St	Foreshore	225 mm dia.	55	No
2002.092	12(c)	Wharf St	Foreshore	225 mm dia.	52	No
2002.093	13(a)	Fryatt St	Foreshore	150 mm dia.	40	No
2002.094	13(b)	Fryatt St	Foreshore	450mm dia	180	No
2002.095	13(c)	Fryatt St	Foreshore	300mm dia	54	No
2002.096	14	Fryatt St	Foreshore	300mm dia	116	No
2002.097	15(a)	Mason St	Mason St	2175mm dia. conduit	5,000	Yes
2002.098	15(b)	Mason St	Bauchop St	450mm dia	90	No
2002.099	15(c)	Mason St	Bauchop St	1350mm dia. culvert	1,500	No
2002.100	16(a)	Halsey St	Halsey St	1950mm conduit	3,800	No
2002.101	16(b)	Halsey St	Wickliffe St	1950mm conduit	2,600	No
2002.102	16(c)	Halsey St	Wickliffe St	300mm dia	113	Yes
2002.103	17	Wickliffe St	Wickliffe St	1,050 mm dia.	1,660	No
2002.104	18(a)	Magnet St	Magnet St	300mm dia	73	No
2002.105	18(b)	Magnet St	Magnet St	300mm dia	66	No
2002.106	19	Ravensbourne Rd	Gas Works	300 mm dia.	117	Yes
2002.108		George St (Port Otago)	Port Chalmers	750 mm dia.	1,000	No
2002.109		George St/SH88	Port Chalmers	1,250 mm dia.	1,200	Yes
2002.110		Second Beach Rd	St. Clair	1,050 x 1,050 mm tunnel	7,000	Yes
2006.222		Sawyers Bay, western side of Watson Park, Port Chalmers	Port Chalmers	150 mm dia.	20	Yes

2. Methods

2.1 Stormwater

A number of the outfalls listed in Table 1 do not have outfall structures or are located in places that are inaccessible. Consequently it is neither practical nor possible to sample from the entire 31 outfalls listed, as agreed by the ORC. However, the monitoring programme undertaken samples all major Dunedin stormwater catchments and gives a comprehensive picture of the state of contaminants in Dunedin's stormwater. Catchment names have been altered slightly from those used in 2009 to reflect the naming used under the DCCs Three Waters Strategy (See Table 2, page16). Grab samples of stormwater were collected from each stormwater outfall within 1 hour of the commencement of a rain event (>0.5mm) in an endeavour to ensure that first flush water was gathered. Collections took place only if there was an antecedent period of at least 72 hours with no rain before the target rain event. Samples were sent to Hill Laboratories in Hamilton to be analysed for arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn), faecal coliforms and *E. coli*. Samples collected from the Kitchener Street, Orari Street and Portobello Road outfalls were additionally analysed for polycyclic aromatic hydrocarbons (PAHs). Samples were also collected during a period of low flow a week after the targeted rainfall event and sent to ESR in Christchurch for analysis of fluorescent whitening agents (FWAs). FWAs are used in laundry detergents and indicate possible sewage infiltration to the stormwater system (Petch 1996). Gilpin *et al*., (2004) recommend that stormwater be sampled at low flows to get a more accurate picture of sewage infiltration because the FWAs are usually present in only very low concentrations and are more readily detected at low flows.

2.2 Sediments

Three replicate 250cm^3 samples were collected from the top 20mm of sediment

within 20m from each of the Kitchener Street, Orari Street and Portobello Road Outfalls. To gain a clear picture of sediment contamination within the upper harbour basin, further replicate sediment samples were collected at each of the sites indicated by orange stars in Figure 2. Samples were chilled and sent to Hill laboratories in Hamilton for analysis for total arsenic, total cadmium, total chromium, total copper, total nickel, total lead, total zinc, faecal coliforms, enterococci and PAHs.

2.3 Biological Monitoring

At the Portobello Road, Orari Street and Kitchener Street outfalls two sites within 20m of each outfall and at the waters edge at low tide were sampled for flora and fauna according to the protocols outlined in Kingsford and Battershill (1998). An additional two sites were sampled at no less than 50m from each outfall at the waters edge. At each site, three randomly spaced $5m^2$ quadrats were sampled, giving a total of 12 quadrats at each outfall. For epifauna within each $5m^2$ quadrat, the number of each species was recorded in five $0.1m^2$ quadrats. For infauna a sediment core was taken in three $0.1m^2$ quadrats per site, giving 12 cores per outfall. Sediment was returned to the laboratory, washed through a 500µm sieve and animals retained identified to at least family level (Bates *et al.* 2007). The abundance of each species was then recorded. For macroflora, the percentage cover of each species was estimated in three $1.0m^2$ quadrats per site, giving 12 quadrats per outfall. For both epifauna and infauna a Shannon Weiner diversity index (Zar 1996) was calculated to enable community diversity to be compared from year to year.

2.4 Cockle, Mussel, Fish and Octopus Flesh

Daily patrols of the shoreline at low tide adjacent to the Portobello Road and Orari Street stormwater outfalls were made, beginning in late March, to seek mature octopus (*Pinnoctopus cordiformis* – formerly *Octopus maorum* or *Octopus huttoni* – formerly *Robsonella australis*) during the annual autumn die-off.

For shellfish a minimum of 15-20 large cockles (*Austrovenus stutchburyi*) were collected from within 20m of the confluence of the stormwater outlet and the waters edge at low tide at each of the Portobello Road, Orari Street and Kitchener Street outfalls. Cockles were individually measured, bagged, and chilled and sent to Hill Laboratories for analysis for As, Cd, Cr, Cu, Ni, Pb and Zn. A further 15-20 cockles were collected at each site and sent for PAH analysis, and a further 15-20 to Hill Laboratories in Christchurch for analysis for faecal coliforms.

Within the same period that cockles were collected variable triplefins (*Tripterygion varium*) were caught using baited fish traps off the Mason Street wharf no more than 50m from the Mason Street stormwater outfall. Fish were weighed and measured, then chilled, bagged, and sent to Hill Laboratories for analysis for As, Cd, Cr, Cu, Ni, Pb and Zn and for PAHs.

At Second Beach a minimum of twelve mussels (*Perna canaliculus*) were collected from the rock reef to the east of the Second Beach stormwater outfall at a distance of no more than 50m from the outfall. Only mussels of mature size (≥80mm) were collected. Mussels were bagged and chilled and sent to Hill Laboratories in Hamilton for analysis for, As, Cd, Cr, Cu, Ni, Pb and Zn. A further 12-15 mussels were collected and sent to Hill Laboratories, Christchurch, for analysis for faecal coliforms.

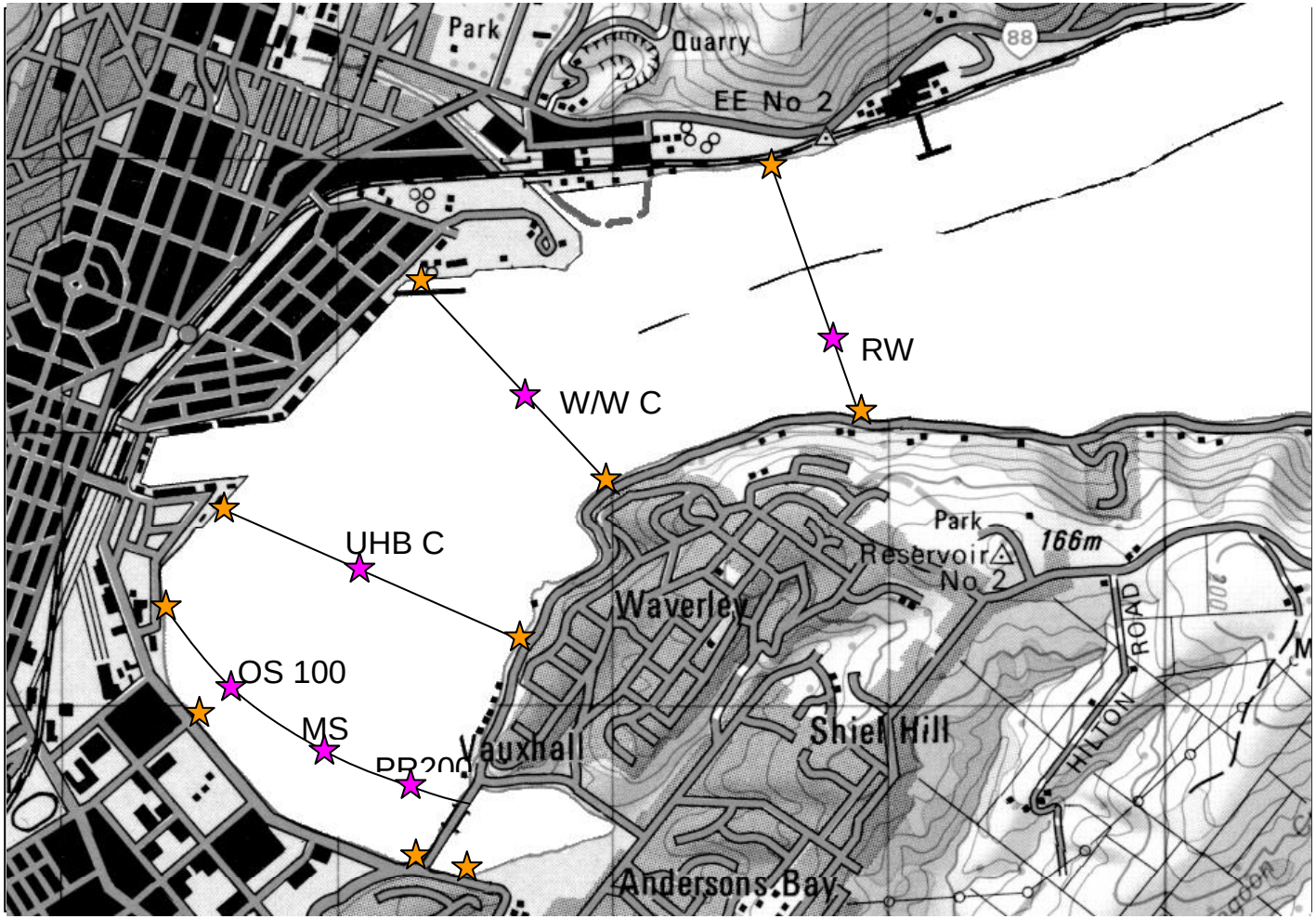


Figure 2. *Upper Harbour Basin sediment sampling sites. Orange stars sampled annually; pink stars sampled 5 yearly. Anticlockwise, starting at top, orange sites are: Rowing Club, Wickliffe St, White St, Kitchener St, Orari St, Portobello Rd, Shore St, Boatshed, Cove Drainage and Retaining Wall. Pink sites are coded according to location (see Table 4).*

3. Results

3.1 Stormwater

During the first two hours of a storm event that produced 7.4mm rainfall on 3 May 2011 water samples were collected from stormwater outfalls at Second Beach, Shore Street, Portobello Road, Teviot Street, Midland Street, Orari Street, Kitchener Street, Mason Street, Bauchop Street, Halsey Street, Wickliffe Street and Ravensbourne Road in Dunedin and from Watson Park and east George Street in Port Chalmers. This storm event had an antecedent dry period of 180 hours.

Stormwater at all sites was only moderately discoloured, testimony to the relatively gradual onset of the rain event. Contaminant levels are compared with levels in stormwater collected during a preliminary survey conducted in 2007 and the first, second and third annual surveys conducted in 2008, 2009 and 2010 (Table 2, Figure 3). This year all contaminants, with the exception of lead, zinc and copper were below ANZECC (2000) guidelines for protection of 80% of species (Table 2). Zinc was, however, not detected in stormwater at the Shore Street, Midland Street, Orari Street, Kitchener Street and Bauchop Street outfalls (Table 2). This is an improvement over results in 2010, 2009 and 2008. Lead levels this year were higher than last year, but similar to levels in 2007, 2008 and 2009 (Table 2, Figure 3). Copper levels show an improvement over 2010 with copper detected at just seven outfalls rather than the eleven outfalls seen in 2010. It should be noted that Orari Street and Portobello Road both operate with sump systems and it is not clear if, in fact, the first flush had reached the outfall for these sites at the time of sampling. However, these sumps were operating at the time of sampling so it is assumed the first flush for these two outfalls was sampled.

Like last year there was no outfall this year that was clearly "worse" than others. However, there were a number of outfalls (Shore Street, Midland Street, Orari Street, Kitchener Street and Bauchop Street) for which all heavy metal contaminants were below detectable levels. Wickliffe Street had the highest levels of arsenic, cadmium and chromium; Mason Street had the highest levels of copper and nickel; and Portobello Road had the highest levels of lead and zinc. Generally speaking, contaminant levels showed considerable variability with location when compared with results from 2007, 2008, 2009 and 2010. Lead at Mason Street, Ravensbourne and Portobello Road, zinc at Mason Street, Wickliffe Street and Portobello Road, and copper at Mason Street, Halsey Street, Wickliffe Street, Portobello Road and Teviot Street all stand out as being at levels higher than might be expected based on previous results (Figure 3). If such levels continue in future sampling it will be worthwhile carrying out further investigations in these catchments to determine possible sources, but, based on past results, this is just as likely to be a one-off occurrence.

Microbiological levels were high to very high at nine sites this year with values exceeding the guidelines for secondary contact recreation for both faecal coliforms and *E. Coli* at Second Beach, Portobello Road, Mason Street, Halsey Street and Wickliffe Street (Table 2, Figure 3) and for *E. coli* alone at Bauchop Street, Kitchener Street, Midland Street and Shore Street. Second Beach, Watson Park, Halsey Street and Wickliffe Street all show increases in *E. coli* levels compared with 2010, with Watson Park also showing an increase in faecal coliforms. However, bacterial levels at Portobello Road, Kitchener Street and Mason Street all show a marked decrease over the 2010 figures (Table 2, Figure 3). High microbial counts are not unexpected for first flush samples with a considerable amount of

animal faeces and decaying vegetable matter being washed into the stormwater system from streets and pavements. There are no clearly discernible trends in bacterial levels through time for any of the monitored stormwater outfalls.

FWAs were detected at low flows at all sites again this year, albeit at low levels for all but Shore Street, Teviot Street and Orari Street outfalls (Table 2). The levels at these three outfalls suggest there may be some contamination by human sewage. Overall, levels were generally comparable with previous years with values at some sites increasing slightly while those at others decreased slightly. As in 2009, Midland Street had the highest values, but well short of the extreme levels seen at Bauchop Street in 2007 and 2008 (Figure 3). There are no standards for FWAs in New Zealand but, as stated, levels above 0.1µg/L suggest some contamination and levels above 0.2µg/L are cause for concern (Brent Gilpin, ESR, pers. comm.). It is expected that contaminants of this nature will continue to be investigated as part of the development and implementation of the long-term stormwater catchment management plans and DCC's Three Waters strategy.

PAHs were not detected at Kitchener Street or Orari Street this year, but were detected at Portobello Road, albeit at very low levels. This differs from last year where PAHs were detected at all three outfalls, but is similar to 2009 when, once again, PAHs were detected at just the Portobello Road outfall. In 2007 PAHs were detected only in Orari Street stormwater (just Pyrene at very low levels) (Table 3), and in 2008 PAH levels were high at all three outfalls (Table 3). Total PAH levels were higher at Portobello Road than in 2010 and 2009, but much lower than in 2008 (Table 3). Anthracene, acepaphthylene, fluorene and biphenyl-d10, the four PAHs that contributed the major component of the 2008 total, were present at only

very low levels this year. Anthracene and biphenyl-d10 are components of coal tar and, as has been previously suggested, it may be that the input of these substances (a by-product of gas production) to the upper harbour via stormwater is tailing off. It will be of interest to note trends in PAH input at Portobello road over future years.

The one result that stood out last year was the high level of oil and grease at Teviot Street. This year no oil and grease was detected at Teviot Street but there were moderate levels at George Street, Midland Street, Orari Street, Kitchener Street and Wickliffe Street, with Orari and Kitchener Street values being particularly high and exceeding levels seen at any time in the past (Table 2; Figure 3).

Table 2. *Levels of contaminants detected in stormwater from outfalls in and around Dunedin during a storm events on 11 April 2007, 17 June 2008, 12 May 2009, 23 April 2010 and 3 May 2011. BDL indicates Below Detectable Limits. Pink shaded cells indicate levels above the ANZECC 2000 trigger level for protection of 80% of species. 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. For FCs orange cells exceed guidelines for primary contact recreation; pink cells exceed levels for secondary contact recreation.*

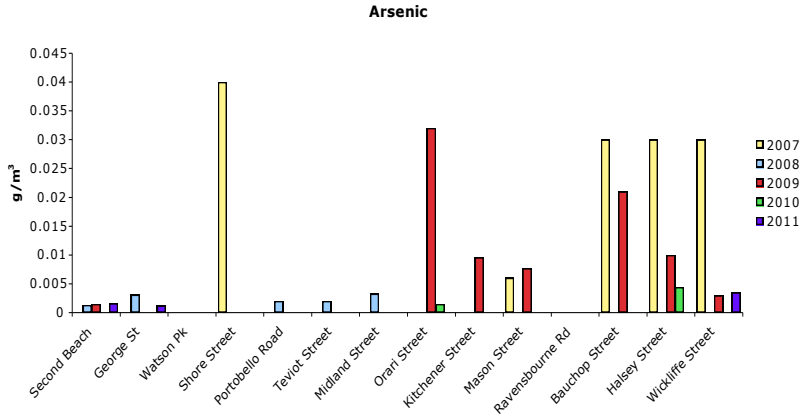
	Stormwater																				
Three Waters Project ICMP Catchment	Parameter	As					Cd					Cr					Cu				
	units	g/m^3					g/m^3					g/m^3					g/m^3				
	Outfall	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
St Clair	Second Beach	BDL	0.0013	0	BDL	0.002	BDL	0.00006	0.00006	0.00007	0.000075	0.0007	0.0028	0.0035	0.00086	0.0038	0.003	0.012	0.019	0.005	0.017
Port Chalmers	George St	BDL	0.0031	BDL	BDL	0.001	0.00028	0.00140	0.00011	0.00033	0.000168	0.005	0.012	0.0031	0.00136	0.0045	0.021	0.039	0.025	0.015	0.02
Port Chalmers	Watson Pk	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0064	BDL	BDL	BDL	0.009	0.003	BDL	BDL	
Shore Street	Shore Street	0.04	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.014	0.02	0.012	
South Dunedin	Portobello Road	BDL	0.002	BDL	BDL	BDL	BDL	0.00023	BDL	BDL	BDL	BDL	0.002	BDL	BDL	BDL	BDL	0.026	0.01	0.006	0.029
Andersons Bay	Teviot Street	BDL	0.002	BDL	BDL	BDL	BDL	0.00008	BDL	0.00026	BDL	BDL	0.0018	BDL	BDL	BDL	BDL	0.009	BDL	0.014	0.031
Andersons Bay	Midland Street	BDL	0.0033	BDL	BDL	BDL	BDL	0.00013	BDL	BDL	BDL	BDL	0.0035	0.0031	BDL	BDL	0.02	0.031	0.057	0.021	
Orari Street	Orari Street	BDL	BDL	0.03	0.00149	BDL	BDL	BDL	BDL	0.00016	BDL	BDL	0.0032	BDL	0.00183	BDL	BDL	0.014	BDL	0.01	
Kitchener Street	Kitchener Street	BDL	BDL	0.01	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.004	0.002	BDL	BDL	BDL	0.034	0.006	0.023	0.012	
Mason Street	Mason Street	0.01	BDL	0.01	BDL	BDL	BDL	BDL	0.0077	0.00051	BDL	BDL	BDL	BDL	BDL	BDL	0.022	0.012	0.021	0.016	0.043
Ravensbourne	Ravensbourne Rd		BDL	BDL	BDL	BDL		BDL	BDL	BDL	BDL		0.00061	BDL	BDL	BDL		0.002	BDL	0.003	
Halsey Street	Bauchop Street	0.03	BDL	0.02	BDL	BDL	BDL	BDL	BDL	0.00049	BDL	BDL	0.0015	BDL	BDL	BDL	0.029	0.01	BDL	0.003	
Halsey Street	Halsey Street	0.03	BDL	0.01	0.0044	BDL	BDL	0.00022	BDL	0.00026	BDL	BDL	BDL	BDL	BDL	BDL	0.024	0.004	0.021	0.002	0.029
Halsey Street	Wickliffe Street	0.03	BDL	0	BDL	0.004	BDL	BDL	0.00052	0.00078	0.00092	BDL	0.0017	0.0076	0.00157	0.0046	0.01	0.013	0.059	0.006	0.022
	Protection for 80% of species																				
	ANZECC guidelines	0.36					0.0008					0.04					0.0025				

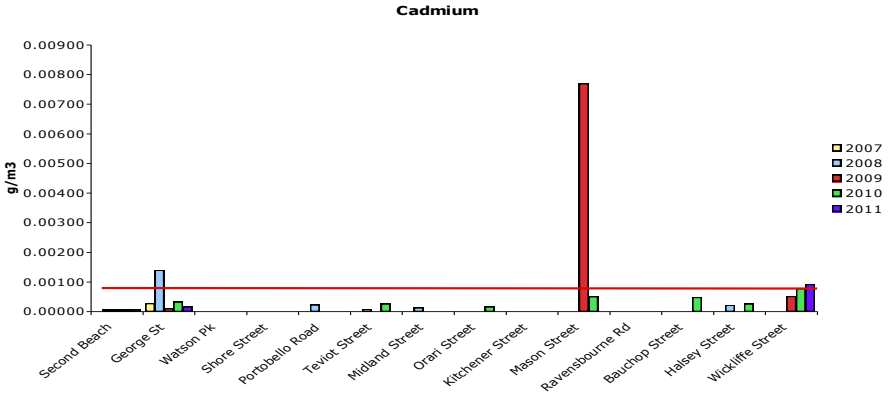
Three Waters Project ICMP Catchment	Parameter	Stormwater Ni					Pb					Zn				
	units	g/m^3					g/m^3					g/m^3				
	Outfall	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
St Clair	Second Beach	0.0009	0.0021	0.0022	0.0013	0.0026	0.001	0.011	0.013	2E-04	0.013	0.038	0.16	0.15	0.092	0.25
Port Chalmers	George St	0.0029	0.0093	0.0026	0.006	0.0037	0.0342	0.041	0.018	0.005	0.004	0.288	0.66	0.19	0.42	0.25
Port Chalmers	Watson Pk	BDL	BDL	BDL	0.0035	BDL	0.0141	0.0018	BDL	BDL	0.004	0.231	0.027	BDL	0.29	0.24
Shore Street	Shore Street	0.01	BDL	BDL	BDL	BDL	0.003	0.0085	0.0069	BDL	BDL	0.02	0.44	0.21	0.115	BDL
South Dunedin	Portobello Road	BDL	0.0035	0.0028	0.0035	BDL	BDL	0.019	0.0067	6E-04	0.026	0.08	0.94	0.64	0.153	0.87
Andersons Bay	Teviot Street	BDL	0.0019	BDL	0.0033	BDL	BDL	0.0066	BDL	BDL	0.007	BDL	0.13	BDL	1.79	0.61
Andersons Bay	Midland Street	BDL	0.0016	BDL	0.0075	BDL	0.005	0.0054	0.0083	BDL	BDL	0.1	0.35	0.18	0.22	BDL
Orari Street	Orari Street	BDL	0.0033	BDL	0.0011	BDL	BDL	0.023	BDL	2E-04	BDL	BDL	0.22	0.03	0.3	BDL
Kitchener Street	Kitchener Street	0.003	BDL	0.0036	0.0035	BDL	0.0442	0.007	0.018	0.002	BDL	0.445	0.036	0.38	0.62	BDL
Mason Street	Mason Street	0.004	BDL	0.0055	BDL	0.0039	0.0258	0.0089	0.014	0.001	0.019	0.25	0.16	0.35	0.43	0.63
Ravensbourne	Ravensbourne Rd		0.0007	BDL	0.0015	BDL		0.0015	0.0029	2E-04	0.025		0.053	0.05	0.144	0.27
Halsey Street	Bauchop Street	0.01	BDL	BDL	BDL	BDL	0.01	0.0035	BDL	BDL	BDL	0.23	0.12	0.13	0.121	BDL
Halsey Street	Halsey Street	0.009	BDL	0.0035	BDL	BDL	0.021	0.0022	0.0097	0.002	0.009	0.12	0.033	0.3	0.136	0.36
Halsey Street	Wickliffe Street	0.01	BDL	0.0042	BDL	0.0021	0.006	0.0084	0.033	BDL	0.013	0.1	0.2	0.53	0.24	0.82
	Protection for 80% of species															
	ANZECC guidelines			0.017					0.0094					0.031		

Table 2. *continued…*

Three Waters Project ICMP Catchment	Parameter	Stormwater pH					Suspended Solids					Oil & Grease					FWA				
	units						g/m^3					g/m^3					µg/L				
	Outfall	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
St Clair	Second Beach	7.7	7.3	7.4	7.3	7.4	BDL	37	41	BDL	57	5	BDL	BDL	BDL	BDL	0.147	0.19	0.098	0.04	0.075
Port Chalmers	George St	6.9	7.1	7.3	6.8	6.8	87	150	26	170	140	10	8.7	BDL	BDL	8	BDL	BDL	0.03	0.079	0.082
Port Chalmers	Watson Pk	6.8	7.9	8.2	7.1	7.5	37	39	7.4	240	24	8	BDL	BDL	BDL	BDL	0.002	0.003	0.124	0.105	0.092
Shore Street	Shore Street	7.9	7.2	7.3	7.4	7.9	41	24	20	9.5	12	BDL	BDL	BDL	BDL	BDL	0.081	0.031	0.142	0.98	0.142
South Dunedin	Portobello Road	7.9	7.3	7.6	7.6	7.4	18	46	30	8.1	53	4	9.7	BDL	BDL	BDL	0.003	0.049	0.177	0.151	0.045
Andersons Bay	Teviot Street	7.9	7.1	7.9	7	8	25	33	12	84	66	8	4.4	BDL	6.4	BDL	BDL	0.006	0.096	0.135	0.117
Andersons Bay	Midland Street	7.7	7.7	7.7	7.5	7.8	30	19	30	52	14	BDL	BDL	BDL	BDL	4	BDL	0.004	0.132	0.218	0.197
Orari Street	Orari Street	7.8	7.4	8.1	7.1	7.9	28	77	16	130	4	BDL	11	BDL	BDL	17	BDL	0.005	0.11	0.052	0.081
Kitchener Street	Kitchener Street	7.1	7.7	7.4	6.9	8	104	41	45	50	BDL	9	BDL	BDL	BDL	22	0.18	0.029	0.072	0.023	0.047
Mason Street	Mason Street	7.1	7	7.4	7	7	62	37	37	138	30	5	7.9	BDL	BDL	BDL	0.007	0.07	0.051	0.156	0.026
Ravensbourne	Ravensbourne Rd		7	8.1	7.3	8		8.5	18	61	5		8.8	BDL	BDL	BDL		BDL	0.096	0.136	0.014
Halsey Street	Bauchop Street	7.6	7.8	8.1	7.4	8	44	16	13	53	5	4	BDL	BDL	BDL	BDL	2.028	4.92	0.031	0.067	0.017
Halsey Street	Halsey Street	7.3	7.9	7.2	6.8	7.1	119	35	27	50	24	9	BDL	BDL	BDL	BDL	BDL	0.004	0.011	0.061	0.025
Halsey Street	Wickliffe Street	7.7	7.5	8.0	7.3	9.7	35	27	100	86	46	6	9.5	9.5	BDL	7	0.024	0.003	0.021	0.048	0.094
	Protection for 80% of species																				
	ANZECC guidelines			7.2-7.8																	

Three Waters Project ICMP Catchment	Parameter	Stormwater E. coli					Stormwater Faecal Coliforms					
	units	MPN/100ml					cfu/100ml					
	Outfall	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	
St Clair	Second Beach	560	6800	14000	4800	9000	560	8300	14000	92000	9000	
Port Chalmers	George St	1400	930	1000	1100	600	1400	1400	1000	1100	600	
Port Chalmers	Watson Pk	14000	150	10	>1600	1000	39000	150	10	>1600	1000	
Shore Street	Shore Street	300	5100	16000	7000	110	300	5100	16000	9400	110	
South Dunedin	Portobello Road	460	5000	2800	54000	6000	590	5000	2800	54000	6000	
Andersons Bay	Teviot Street	7	120000	210	16000	300	7	240000	210	16000	300	
Andersons Bay	Midland Street	290	130	6000	3500	600	290	130	6000	5400	600	
Orari Street	Orari Street	50	6000	210	1700	BDL	80	7000	210	3500	BDL	
Kitchener Street	Kitchener Street	13000	70	10000	92000	110	13000	70	10000	160000	110	
Mason Street	Mason Street	22000	26000	50000	350000	48000	22000	26000	50000	350000	48000	
Ravensbourne	Ravensbourne Rd		120	90	11000	130	150	130	90	11000	130	
Halsey Street	Bauchop Street	2200	400	3000	7900	450	2200	400	3000	35000	450	
Halsey Street	Halsey Street	9000	1700	70000	17000	78000	9000	1700	70000	92000	78000	
Halsey Street	Wickliffe Street	25000	10000	220000	35000	43000	30000	10000	220000	54000	43000	
	Primary	Amber	>260				>150					Primary
	Secondary	Red	>550				>1000					Secondary





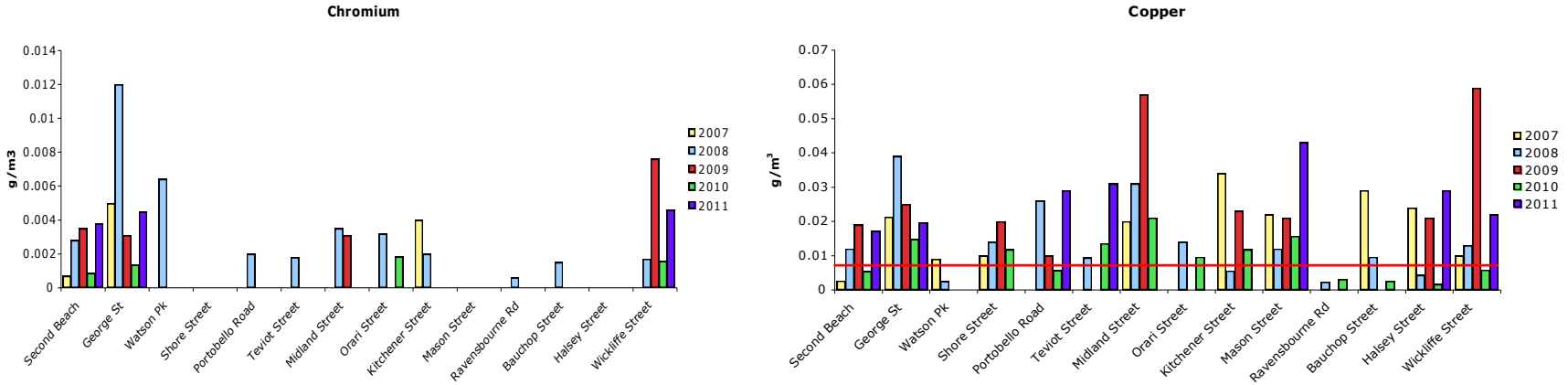


Figure 3. *Graphical representation of contaminant levels in stormwater at outfalls around upper Otago Harbour in 2007, 2008, 2009, 2010 and 2011. Red line indicates ANZECC trigger level for protection of 80% of species.*

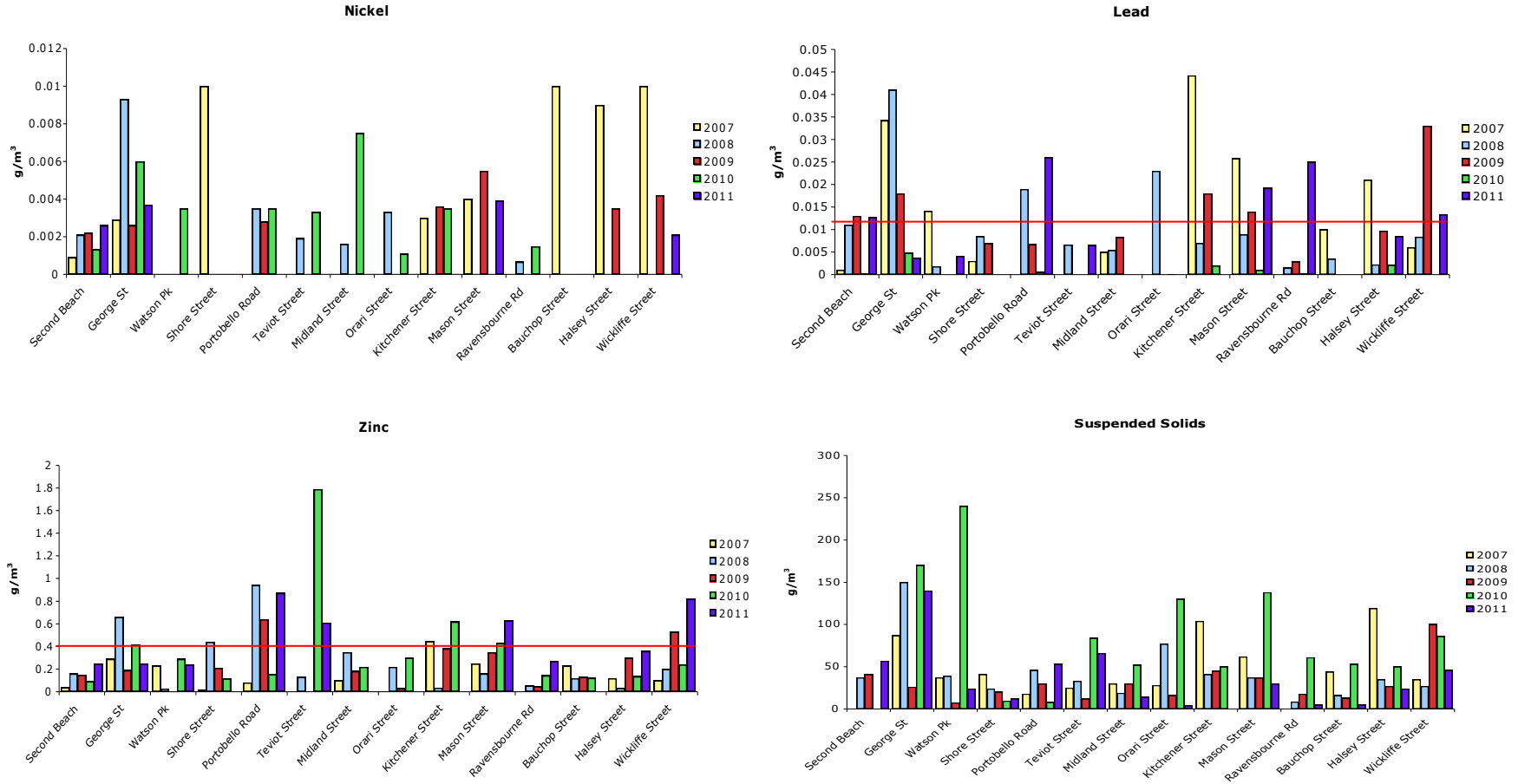
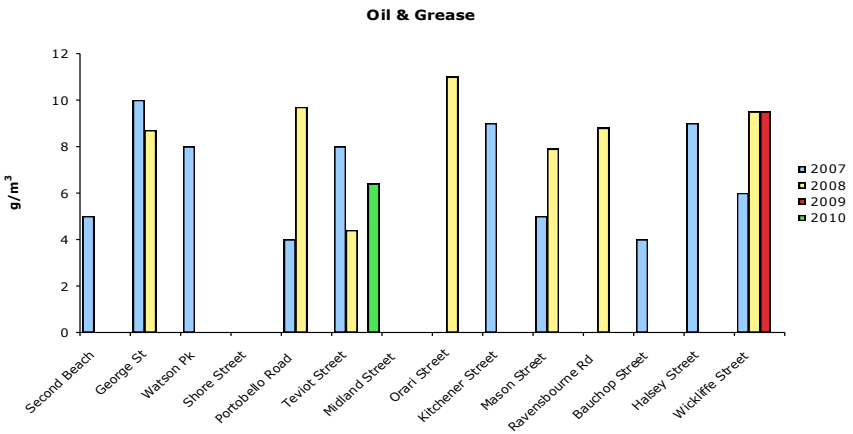
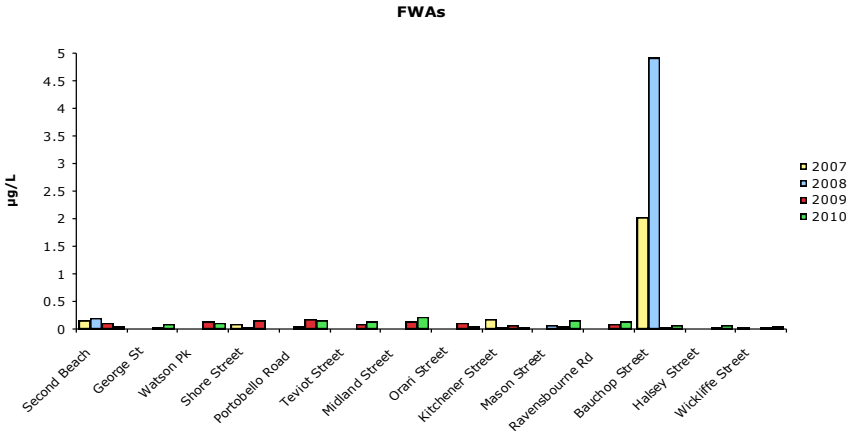
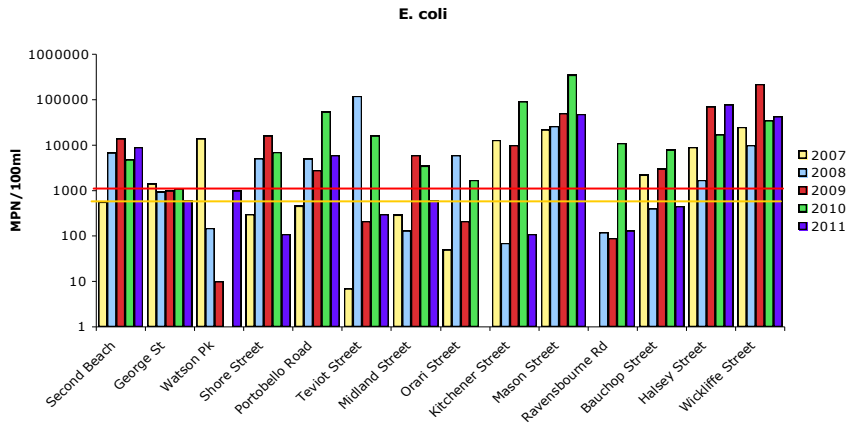


Figure 3. (continued….)


Oil & Grease
g/m³
0
2
4
6
8
10
12
Second Beach
George St
Watson Pk
Shore Street
Portobello Road
Teviot Street
Midland Street
Orari Street
Kitchener Street
Mason Street
Ravensbourne Rd
Bauchop Street
Halsey Street
Wickliffe Street
2007
2008
2009
2010


FWAs
µg/L
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Second Beach
George St
Watson Pk
Shore Street
Portobello Road
Teviot Street
Midland Street
Orari Street
Kitchener Street
Mason Street
Ravensbourne Rd
Bauchop Street
Halsey Street
Wickliffe Street
2007
2008
2009
2010


E. coli
MPN/100ml
1
10
100
1000
10000
100000
1000000
Second Beach
George St
Watson Pk
Shore Street
Portobello Road
Teviot Street
Midland Street
Orari Street
Kitchener Street
Mason Street
Ravensbourne Rd
Bauchop Street
Halsey Street
Wickliffe Street
2007
2008
2009
2010
2011

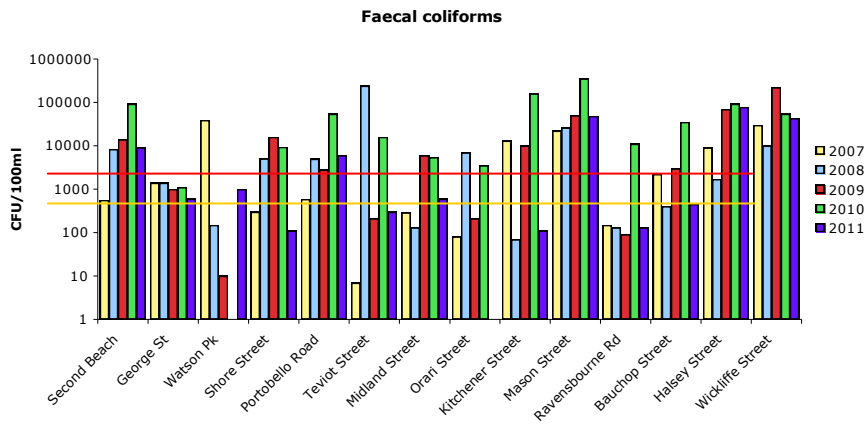

Faecal coliforms
CFU/100ml
1
10
100
1000
10000
100000
1000000
Second Beach
George St
Watson Pk
Shore Street
Portobello Road
Teviot Street
Midland Street
Orari Street
Kitchener Street
Mason Street
Ravensbourne Rd
Bauchop Street
Halsey Street
Wickliffe Street
2007
2008
2009
2010
2011

Figure 3. ***(continued)*** *Graphical representation of contaminant levels in stormwater at outfalls around upper Otago Harbour in 2007, 2008, 2009, 2010 and 2011. For microbiological graphs amber line indicates guideline for primary contact, red line indicates guideline for secondary contact.* ***Note log scale on Y axis of microbiological graphs.***

Table 3. *PAHs (g/m^3) detected in stormwater from the Kitchener Street, Orari Street and Portobello Road outfalls in 2007, 2008, and 2009, 2010 and 2011. BDL indicates Below Detectable Limits.*

	Kitchener St					Orari St					Portobello Rd				
	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Acenaphthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00034	0.000024	BDL	0.000015
Acepaphthylene	BDL	100	BDL	BDL	BDL	BDL	92	BDL	BDL	BDL	BDL	100	0.000029	BDL	0.00016
Anthracene	BDL	87	BDL	BDL	BDL	BDL	89	BDL	BDL	BDL	BDL	87	0.000008	BDL	0.000044
Benzo[a]anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00015	0.000014	BDL	0.000105
Benzo[a]pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000017	BDL	0.000167
Benzo[a]fluorathene + Benzo[j]fluorathene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00012	BDL	BDL	0.00018	0.000033	0.000158	0.00024
Benzo[g,h,i]perylene	BDL	BDL	BDL	BDL	BDL	BDL	0.00014	BDL	BDL	BDL	BDL	BDL	0.000014	BDL	0.000147
Benzo[k]fluorathene	-	67	BDL	BDL	BDL	-	67	BDL	BDL	BDL	-	67	BDL	BDL	0.000094
Chrysene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000093
Dibenzo[a,h]anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000026
Fluoranthene	BDL	BDL	BDL	0.00015	BDL	BDL	0.00011	BDL	0.00017	BDL	BDL	0.00028	0.00001	BDL	0.000182
Fluorene	BDL	73	BDL	BDL	BDL	BDL	70	BDL	BDL	BDL	BDL	74	BDL	BDL	0.000017
Indeno[1,2,3-c,d]pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000013	BDL	0.000107
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00008
Phenanthrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000041
Pyrene	BDL	BDL	BDL	BDL	BDL	0.0001	BDL	BDL	0.00023	BDL	BDL	0.00037	0.000011	BDL	0.00016
Total PAH	0.00	327.00	BDL	0.0001	BDL	0.00	318.00	BDL	0.0005	BDL	BDL	328.00	0.00017	0.00016	0.00168

3.2 Sediments

Sediments were sampled on 17th May 2011 at sites detailed in Figure 2. Surface sediments were generally clean at most sites with little surface detritus apart from a thick layer of organic particles (wood, leaves and bark fragments) at Portobello Road. Additionally, at Portobello Road, sediments were very dark and smelled strongly of petro-carbons with a visible oil slick forming in footprints and depressions dug to remove sediments. At Wickliffe Street, sediments were dark and smelled strongly of hydrogen sulphide, indicating anoxic conditions. Investigations into PAH levels at the Portobello Road outfall are detailed in Stewart (2005, 2006). Note that the South Dunedin (Portobello Road) catchment was used as the pilot for the stormwater catchment management plan development for the DCC's Three Waters Strategy and a complete ICMP has been finalised for this catchment. The ICMP contained recommendations for addressing problems and issues highlighted in this catchment that will be considered and programmed for action where practicable.

Generally speaking, levels of contaminants in sediments near outfalls are similar to previous years. The exceptions are White Street, where almost all metals occur at higher levels than last year, and at Portobello Road where all levels of all contaminants exceeded the levels observed last year (Table 4, Figure 4). The sites that most notably fly against this trend are Orari Street and Shore Street which both show decreases in all contaminant levels this year. Cadmium and chromium levels are higher than they have ever been at Portobello Road as are PAH levels at Wickliffe Street. Conversely, a number of outfalls show lower levels than seen previously of arsenic, cadmium copper and nickel (Orari Street and Shore Street) and chromium, lead and zinc at Shore Street. This year, ANZECC low trigger values are exceeded only by arsenic, nickel, zinc and copper at Portobello Road (Table 4) and by lead and zinc at most other outfalls.

As observed in previous investigations PAHs are to be found at moderate to high levels in much of the Upper Harbour Basin, with the highest levels adjacent to the Portobello Road outfall (Table 4, Figure 4). PAHs in sediments were lower this year than last year at the White Street, Orari Street and Shore Street outfalls and also at the Rowing Club site. Conversely PAH levels were higher than in the past at Wickliffe Street outfall and at the Boatshed and Cove Drainage sites indicating that, while PAHs are still being added to the upper harbour, the amount varies through time and with site. The extremely high levels of PAHs in older sediments off Portobello Road are believed to have been sourced from the now defunct gas works. The levels of PAHs off Portobello Road observed this year are higher than those from last year but similar to those observed in 2008 and 2009. Wave action disturbing surface sediments around the time of sampling will undoubtedly have a

bearing on PAH levels at any particular site. This year, sampling occurred on a very calm day.

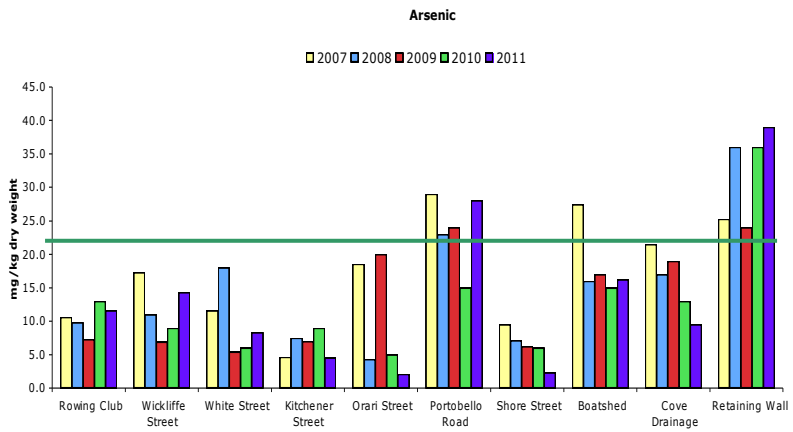
Microbial contamination in sediment is relatively low at most outfalls with just Wickliffe Street and Kitchener Street having high numbers of enterococci and Wickliffe Streets having moderate numbers of faecal coliforms (Table 4). Numbers are, however, not as high as they were in 2007 or 2008.

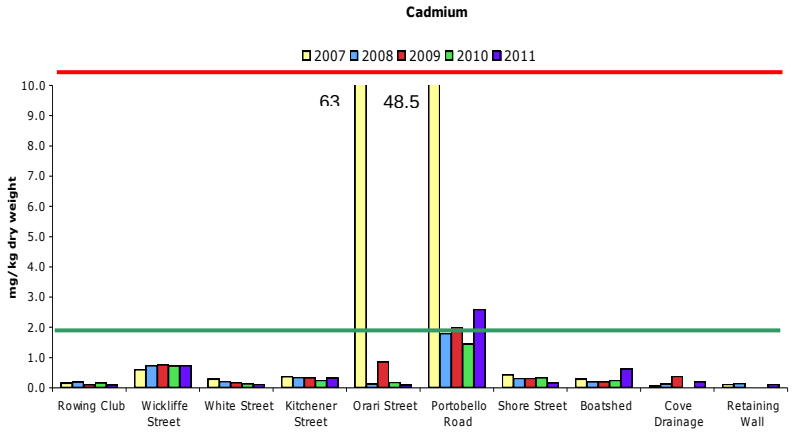
Trends in contaminant levels at the various sites through time remain unclear with five years of sampling revealing high variability among contaminants and among sites (Figure 4). However, as already stated, levels of some contaminants are lower this year at some sites than they have ever been. It will be of interest to see if this trend becomes more apparent with the addition of further data from future monitoring rounds.

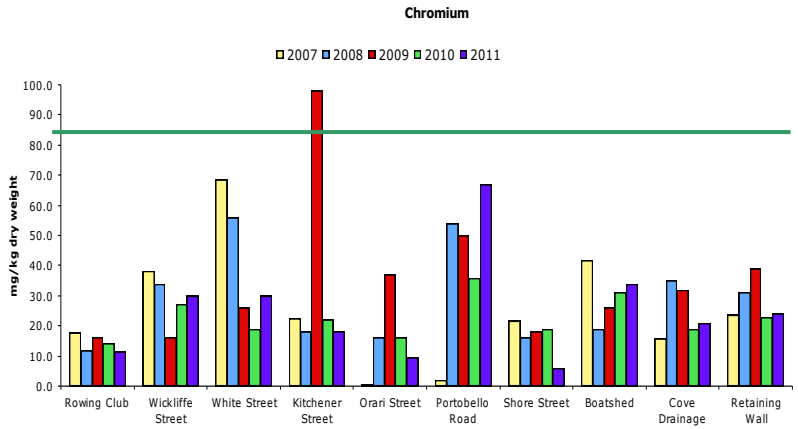
Table 4. *Contaminant levels in sediments at various locations within 20m of stormwater outfalls and within the Upper Otago Harbour Basin with 2007 (yellow) and 2008 (green) values compared with 2009 values (blue), 2010 values (grey) and 2011 values (purple). Shaded cells show sites where contaminant levels exceed either ANZECC Low (orange) or High (pink) trigger levels.*

Sediments within 20m of outfall																										
	As					Cd					Cr					Cu					Ni				
Units	mg/kg dry wt					mg/kg dry wt					mg/kg dry wt					mg/kg dry wt					mg/kg dry wt				
Parameter	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Rowing Club	10.6	9.8	7.3	13.0	11.6	0.2	0.2	0.1	0.2	0.1	17.6	12.0	16.0	14.0	11.6	14	13	14	9	12	11.3	14.0	13.0	11.0	12.1
Wickliffe Street	17.3	11.0	6.9	9.0	14.3	0.6	0.7	0.8	0.7	0.7	38.0	34.0	16.0	27.0	30.0	121	68	50	58	86	19.2	23.0	13.0	17.0	15.9
White Street	11.6	18.0	5.4	6.0	8.3	0.3	0.2	0.2	0.1	0.1	68.5	56.0	26.0	19.0	30.0	433	160	170	78	98	29.5	21.0	11.0	8.0	14.5
Kitchener Street	4.6	7.5	7.0	9.0	4.5	0.4	0.4	0.3	0.3	0.3	22.6	18.0	98.0	22.0	18.3	70	56	90	37	54	10.6	12.0	15.0	12.0	10.6
Orari Street	18.6	4.3	20.0	5.0	2.1	63.0	0.1	0.9	0.2	0.1	0.3	16.0	37.0	16.0	9.4	25	13	61	11	7	23.6	8.1	16.0	8.0	5.3
Portobello Road	29.0	23.0	24.0	15.0	28.0	48.5	1.8	2.0	1.5	2.6	1.8	54.0	50.0	36.0	67.0	60	160	190	123	176	169.3	18.0	26.0	19.0	24.0
Shore Street	9.5	7.1	6.2	6.0	2.3	0.4	0.3	0.3	0.3	0.2	21.8	16.0	18.0	19.0	5.8	51	44	41	35	11	10.7	9.0	11.0	10.0	5.2
Boatshed	27.4	16.0	17.0	15.0	16.2	0.3	0.2	0.2	0.3	0.6	41.7	19.0	26.0	31.0	34.0	108	33	49	35	53	24.5	16.0	17.0	16.0	18.5
Cove Drainage	21.5	17.0	19.0	13.0	9.5	0.1	0.1	0.4	<0.1	0.2	15.8	35.0	32.0	19.0	21.0	11	19	38	11	14	23.5	44.0	23.0	19.0	12.8
Retaining Wall	25.3	36.0	24.0	36.0	39.0	0.1	0.2	<0.1	<0.1	0.1	23.6	31.0	39.0	23.0	24.0	13	19	17	10	11	15.9	25.0	26.0	18.0	13.2
ANZECC Low trigger value	20					1.5					80					65					21				
ANZECC high trigger value	70					10					370					270					52				

Sediments within 20m of outfall																										
	Pb					Zn					PAH					Enterococci					Faecal coliforms				
Units	mg/kg dry wt					mg/kg dry wt					mg/kg dry wt					MPN/g					MPN/g				
Parameter	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Rowing Club	18.9	27	27	28	19	101	130	160	149	109	7.0	5.8	0.5	3.7	0.1	2	11	<2	<3	8	<2	17	5	2	<2
Wickliffe Street	76.1	140	77	92	127	412	740	810	740	700	9.2	1.2	7.3	7.2	11.3	580	>1600	330	<3	>160	2	540	33	540	110
White Street	147.0	180	170	124	147	4450	2500	2400	1280	1650	13.0	11.1	15.9	6.5	5.4	4	2	<2	23	35	<2	<2	<2	5	<2
Kitchener Street	117.9	97	130	155	132	249	280	300	280	260	8.9	140.5	4.8	5.0	5.5	66	920	5	<3	>160	20	13	70	<2	49
Orari Street	12.8	39	120	35	17	68	130	680	157	69	10.2	12.6	28.3	9.3	4.3	<2	8	23	<3	54	23000	4	33	33	17
Portobello Road	20.4	330	290	193	310	306	1400	1600	1040	1410	436.3	250.3	525.2	194.1	482.0	727	170	<2	<3	16	23	43	2	21	2
Shore Street	113.0	110	79	85	36	484	300	330	350	210	9.6	21.0	8.6	10.5	4.1	90	>1600	<2	460	35	<2	540	<2	130	49
Boatshed	112.0	800	170	86	89	339	370	360	290	300	6.7	5.5	38.8	7.9	40.4	34	33	33	<3	54	<2	2	79	5	22
Cove Drainage	19.7	20	55	18	44	99	150	270	125	119	0.4	0.0	0.1	0.1	1.0	8	17	<2	<3	35	2	8	<2	<2	6
Retaining Wall	26.9	27	42	24	23	141	170	150	152	138	0.3	3.9	0.0	9.4	0.2	<2	8	<18	<3	8	2	<2	33	<2	2
ANZECC Low trigger value	50					200					4														
ANZECC high trigger value	220					410					45														


Arsenic
2007 2008 2009 2010 2011
mg/kg dry weight
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Rowing Club
Wickliffe Street
White Street
Kitchener Street
Orari Street
Portobello Road
Shore Street
Boatshed
Cove Drainage
Retaining Wall


Cadmium
2007 2008 2009 2010 2011
mg/kg dry weight
63
48.5
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Rowing Club
Wickliffe Street
White Street
Kitchener Street
Orari Street
Portobello Road
Shore Street
Boatshed
Cove Drainage
Retaining Wall


Chromium
2007 2008 2009 2010 2011
mg/kg dry weight
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Rowing Club
Wickliffe Street
White Street
Kitchener Street
Orari Street
Portobello Road
Shore Street
Boatshed
Cove Drainage
Retaining Wall

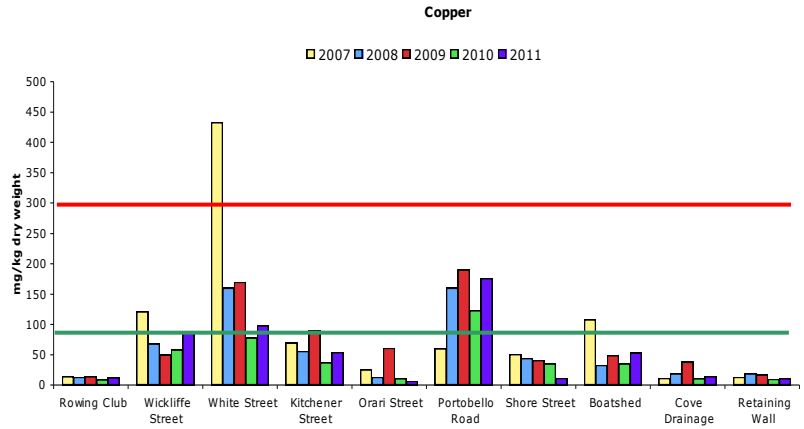
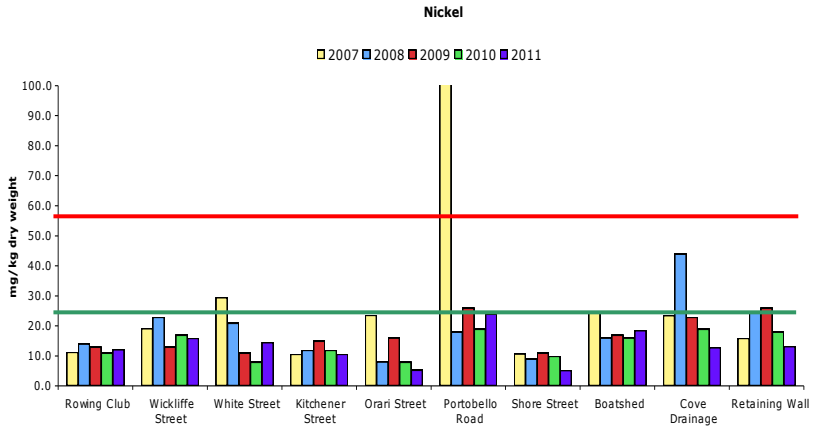
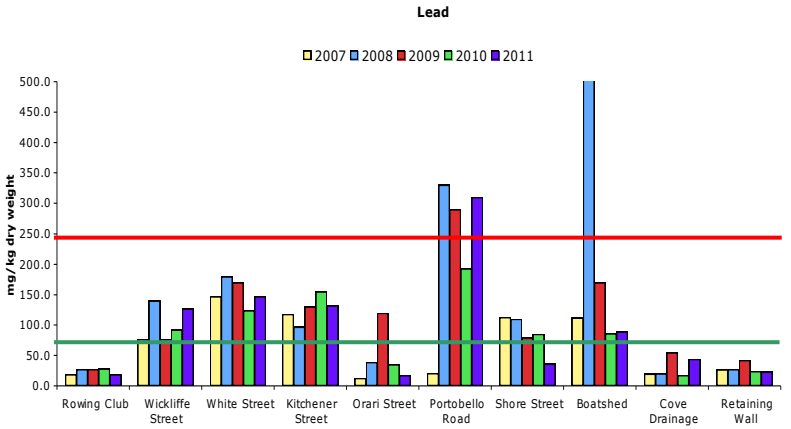
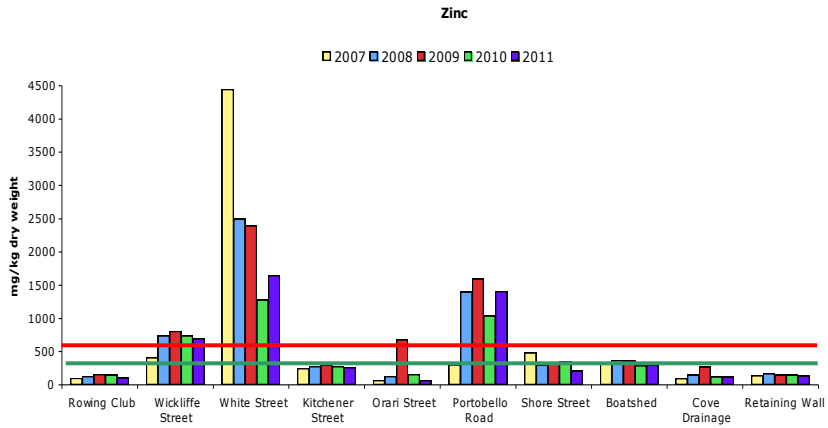

Copper
2007 2008 2009 2010 2011
mg/kg dry weight
500
450
400
350
300
250
200
150
100
50
0
Rowing Club
Wickliffe Street
White Street
Kitchener Street
Orari Street
Portobello Road
Shore Street
Boatshed
Cove Drainage
Retaining Wall

Figure 4. *Graphical representation of contaminant levels in sediment at sampling sites around upper Otago Harbour in 2007, 2008, 2009, 2010 and 2011. Green line indicates ANZECC low trigger level, red line is high trigger level.*







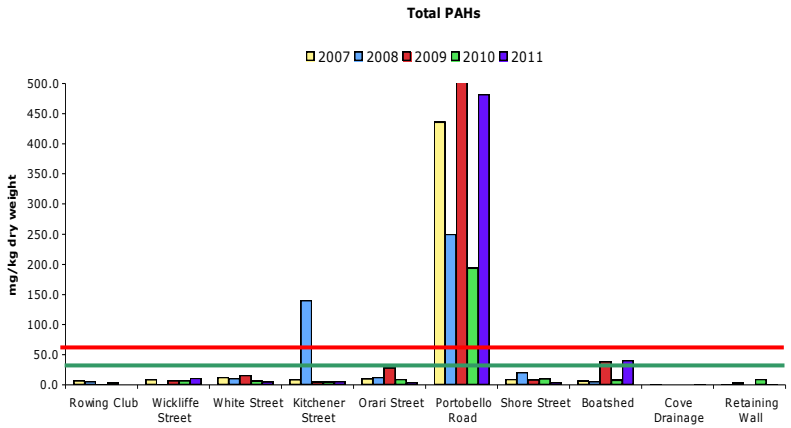


Figure 4 (continued). *Graphical representation of contaminant levels in sediment at sampling sites around upper Otago Harbour in 2007, 2008, 2009, 2010 and 2011. Green line indicates ANZECC low trigger level, red line is high trigger level.*

3.3 Biological Monitoring

On 18th and 19th May 2011 biological sampling was carried out at the Orari Street, Kitchener Street and Portobello Road, outfalls. The tide was reasonably low at 1.1m below mean sea level.

There was a low diversity of mainly red algae at all three sites with Orari Street having the highest diversity (7 taxa) and Portobello Road having the lowest diversity (3 taxa) (Table 5-7). Percentage cover was generally low at all sites with >50m from the Portobello Road outfall having on algae at all (Table 7). Cover was highest at both sites near the Orari Street outfall with occasional quite large clumps of *Ceramium uncinatum* and *Gracilaria chilensis* present (Table 6). Overall, cover at all sites was similar to previous years with the exception of the Portobello Road outfall sites where cover was lower than in previous surveys (Stewart 2007a, Stewart 2008c, Stewart 2009, Stewart 2010).

Table 5. *Macroalgal cover, expressed as a percentage, within 20m (left) and greater than 50m (right) of the Kitchener Street outfall. Green algae in green, red algae in pink.*

	Site 1			Site 2		
Algae (% cover) <20m	Q1	Q2	Q3	Q1	Q2	Q3
Bryopsis plumosa						
Codium fragilis						
Ulva lactuca						
Ceramium uncinatum						
Euptilota formosissima	10		1	10		
Gracilaria chilensis						
Lenormandia chauvinii	2					
Lomentaria umbellata						

	Site 1			Site 2		
Algae (% cover) >50m	Q1	Q2	Q3	Q1	Q2	Q3
Bryopsis plumosa						
Codium fragilis			1			
Ulva lactuca						
Ceramium uncinatum	1	1		1		
Euptilota formosissima				1		
Gracilaria chilensis				1		
Lenormandia chauvinii	10	3	3	12	5	7
Lomentaria umbellata	1	1				2

Table 6. *Macroalgal cover, expressed as a percentage, within 20m (left) and greater than 50m (right) of the Orari Street outfall. Green algae in green, red algae in pink.*

	Site 1			Site 2		
Algae (% cover) <20m	Q1	Q2	Q3	Q1	Q2	Q3
Bryopsis plumosa						
Codium fragilis					6	
Ulva lactuca		1	2	1	6	
Ceramium uncinatum			1	15	12	
Euptilota formosissima			4			
Gracilaria chilensis	1		4		2	2
Lenormandia chauvinii	1	1	1		2	
Lomentaria umbellata					1	

	Site 1			Site 2		
Algae (% cover) >50m	Q1	Q2	Q3	Q1	Q2	Q3
Bryopsis plumosa						
Codium fragilis						8
Ulva lactuca		1				
Ceramium uncinatum					3	8
Euptilota formosissima	2	2	1	1	1	
Gracilaria chilensis	10	15	2	4	3	1
Lenormandia chauvinii			1	1	1	1
Lomentaria umbellata						

Table 7. *Macroalgal cover, expressed as a percentage, within 20m (left) and greater than 50m (right) of the Portobello Rd outfall. Green algae in green, red algae in pink.*

	Site 1			Site 2		
Algae (% cover) <20m	Q1	Q2	Q3	Q1	Q2	Q3
Bryopsis plumosa						
Codium fragilis						
Ulva lactuca						
Ceramium uncinatum						
Euptilota formosissima		2	1			
Gracilaria chilensis	2	1				
Lenormandia chauvinii		1				
Lomentaria umbellata						

	Site 1			Site 2		
Algae (% cover) >50m	Q1	Q2	Q3	Q1	Q2	Q3
Bryopsis plumosa						
Codium fragilis						
Ulva lactuca						
Ceramium uncinatum						
Euptilota formosissima						
Gracilaria chilensis						
Lenormandia chauvinii						
Lomentaria umbellata						

Epifauna was moderately abundant at all three outfalls (Tables 8-10), although slightly less so than in 2010. As in previous years the small topshell *Micrelenchus tenebrosus* and cockles, *Austrovenus stutchburyi*, comprise the majority of animals. Numbers of animals per square metre was lower at more than 50m distant from the Kitchener Street outfall than within 20m of the outfall. This echoes the results observed in 2008, 2009 and 2010. For both Orari Street and Portobello Road numbers differed from last year in that at Orari Street the highest density was close to the outfall while the opposite applied at Portobello Road. In 2010 numbers were similar irrespective of distance at both outfalls. Overall density of epifaunal animals was lowest at Orari Street and highest at Kitchener Street, due mainly to the higher abundance of tubeworms at this site (Tables 8-10).

Diversity within animal communities was variable with Kitchener Street showing slightly greater diversity closer to the outfall while Orari Street and Portobello Road showed the no difference in diversity with distance (Table 11). Diversity was lowest at Orari Street. Overall diversity has not changed from that observed in 2007, 2008, 2009 and 2010 ($F_{4,10} = 0.123$, $p = 0.744$ for <20m sites; $F_{4,10} = 0.229$, $p = 0.926$ for >50m sites). Neither is there a significant difference in epifaunal diversity among sites <20m from the outfalls and sites >50m from the outfalls ($F_{1,4} = 0.048$, $p = 0.838$).

Table 8. *Epifauna within 20m (top) and greater than 50m (bottom) of the Kitchener Street outfall.*

<20m	Quadrat 1					Quadrat 2					Quadrat 3				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Polychaete worms															
Pomatoceros caerulus		6	14	62		28	21		19	15	11		6		2
Barnacles															
Eminius modestus			18		4			10							
Snails and Chitons															
Melagraphis aethiops						1							1		
Micrelenchus tenebrosus	21	18	26	3	9	24	9	3	6	9	13	17	21	9	11
Notoacmea spp			3												
Bivalves															
Mytilus galloprovincialis											1				
Austrovenus stutchburyi												1		3	
Ostrea heffordi		1		8			2		15	11	7		4		3

>50m	Quadrat 1					Quadrat 2					Quadrat 3				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Polychaete worms															
Pomatoceros caerulus	6						5		11	12	12		19	5	8
Barnacles															
Eminius modestus			6	3									13	4	1
Snails and Chitons															
Micrelenchus tenebrosus	3	18	8	12	9	18	3	8	9	8		3	4	9	16
Melagraphis aethiops		1		1											
Chiton glaucus								1							
Bivalves															
Austrovenus stutchburyi	1														
Ostrea heffordi	1						14		5	4	4	1	8	1	5

Table 9. *Epifauna within 20m (top) and greater than 50m (overleaf) of the Orari Street outfall.*

<20m	Quadrat 1					Quadrat 2					Quadrat 3				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Snails and Chitons															
Notoacmea spp					1										
Acanthochitona zelandica															
Micrelenchus tenebrosus	1	5	3	6	5	11	6	6	6	2	2	1	4	3	1
Zeacumantus subcarinatus			1												
Cominella galndiformis								1							
Bivalves															
Austrovenus stutchburyi	5	7	12	10	9	9	13	11	10	16	9	7	10	9	4
Ostrea heffordi															

>50m	Quadrat 1					Quadrat 2					Quadrat 3				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Polychaete worms															
Spirorbis spp															
Snails and Chitons															
Acanthochitona zelandica															
Buccinulum vittatum															
Cominella glandiformis				1											
Melagraphis aethiops															
Micrelenchus tenebrosus	2	1	1		1					1		1			1
Crustaceans															
Macrophthalmus hirtipes				1											
Bivalves															
Austrovenus stutchburyi	10	6	14	7	7	6	9	5	4	4	6	7	4	11	9

Table 10. *Epifauna within 20m (top) and greater than 50m (bottom) of the Portobello Rd outfall.*

<20m	Quadrat 1					Quadrat 2					Quadrat 3				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Polychaete worms															
Pomatoceros caerulus	30	8						7	16			5			12
Snails and Chitons															
Melagraphis aethiops												1			1
Micrelenchus tenebrosus		1			1			3	8	1	1	7	6	1	16
Zeacumantus subcarinata	1														
Bivalves															
Austrovenus stutchburyi				1		1		8	4	3	2	7	3	3	1
Mytilus galloprovincialis												2			
Ostrea heffordi	1														8

>50m	Quadrat 1					Quadrat 2					Quadrat 3				
Animals	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Polychaete worms															
Pomatoceros caerulus	28	7	47	31	12	5				63	2			13	37
Spirorbis spp															
Barnacles															
Eminius modestus	7		42												7
Snails and Chitons															
Notoacmea spp		1	1			5		1		2					2
Melagraphis aethiops	1	1			1					1			1		1
Micrelenchus tenebrosus		12	1	9	8	4			1	5			2		4
Bivalves															
Austrovenus stutchburyi															
Mytilus galloprovincialis			1						1						3
Ostrea heffordi	2		13	14	4	4				24				2	8

Table 11. *Diversity (H') of epifauna within 20m and greater than 50m of the Kitchener Street, Orari Street and Portobello Road outfalls. 2011 data compared with 2007, 2008, 2009 and 2010 data.*

	<20m					>50m				
Site	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Kitchener Street	0.67	0.53	0.44	0.9	0.55	0.98	0.73	0.56	0.9	0.57
Orari Street	1.01	0.86	0.74	0.98	0.29	0.88	0.87	0.74	1.03	0.15
Portobello Road	0.74	0.67	0.8	1.04	0.57	0.84	0.68	0.76	1.08	0.58

As in previous surveys cockles became noticeably smaller and less abundant as one moved from Kitchener Street to Portobello Road (Table 12). 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 ($F_{1,10}$ = 0.201, p = 0.932).

Table 12. *Size of cockles collected at Kitchener Street, Orari Street and Portobello Road in 2007, 2008, 2009, 2010 and 2011.*

	2007			2008			2009			2010			2011		
	n =	Mean weight (g)	Mean length (mm)	n =	Mean weight (g)	Mean length (mm)	n =	Mean weight (g)	Mean length (mm)	n =	Mean weight (g)	Mean length (mm)	n =	Mean weight (g)	Mean length (mm)
Kitchener Street	59	18.8	37.1	54	16.36	35.5	80	19.6	38.1	63	17.73	36.6	106	19.47	37.5
Orari Street	62	12.3	32.4	74	8.65	29.8	80	12.3	33.0	82	10.18	30.2	73	9.62	30.0
Portobello Road	64	9.4	30.1	74	7.87	28.3	80	10	30.1	80	7.7	28.2	103	8.77	28.8

A suggestion was made at the discussion of the 2008 report that growth rings should be measured on cockles to determine how age and size were related at the different sites. This was attempted for the 2009 sampling round and again last year but, due to most cockles having ill-defined and very closely spaced growth rings, results were considered to be too inaccurate to be meaningful and were disregarded. No attempt to count rings was made this year. It would be fair to say, however, 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 at all sites (Tables 14-16). Next most common were nereidid worms which were reasonably abundant both close to and further away from the Kitchener Street and Orari Street outfalls, but less so at Portobello Road. Spionid worms were present, but less common than last year. Phoxocephalid amphipods were far less common at all sites than they were in 2010. Cockles (*Austrovenus stutchburyi*) were most common at both the <20m and >50m sites near the Orari Street outfall and at the <20m site at Kitchener Street (Tables 14-16), with overall abundance similar to previous years. Tanaid crustaceans, which were found in moderate numbers at most sites last year, were observed at just the <20m site at

Orari Street this year. Numbers of animals per square metre were generally lower than last year, but similar to other surveys, and ranged from 669 at replicate 2, Site 1 at >50mm from the Portobello Road outfall to 7359 at replicate 4, Site 2 at <20m from the Orari Street outfall. The higher value was largely due to high abundance of polychaetes worms in that core. Despite the variability in overall numbers of animals at the various sites, diversity has not changed significantly from year to year for the <20m sites ($F_{4,10}$ = 1.898, p = 0.187). For >50m sites, however, there was a significant difference observed this year and in 2010 ($F_{4,10}$ = 7.65, p = 0.004), with diversity being higher over the past two years than in previous surveys at each of the three sites. That being said, there is no significant difference in diversity among the past two years for >50m ($F_{1,4}$ = 0.357, p = 0.582) or between the <20m locations and the >50m locations at any of the sites. ($F_{1,4}$ = 2.502, p = 0.189) (Table 13).

Table 13. *Diversity (H') of infauna within 20m and greater than 50m of the Kitchener Street, Orari Street and Portobello Road outfalls. 2011 data compared with 2007, 2008, 2009 and 2010 data.*

	<20m					>50m				
Site	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Kitchener Street	0.67	0.53	0.44	0.9	0.81	0.98	0.73	0.56	0.9	0.94
Orari Street	1.01	0.86	0.74	0.98	0.99	0.88	0.87	0.74	1.03	0.98
Portobello Road	0.74	0.67	0.8	1.04	0.69	0.84	0.68	0.76	1.08	0.99

Table 14. *Abundance of species of infauna collected <20m and >50m from the Kitchener Street outfall.*

Kitchener Street			Location	<20m							>50m						
2011				Site 1			Site 2				Site 1			Site 2			
			Sample	1	2	3	4	5	6	sum	1	2	3	4	5	6	sum
Phylum		**Family**	**Genus/species**														
Annelida																	
	Polychaeta																
		Eunicidae														1	1
		Glyceridae		4	5	2	2	6	5	24		3	3	2	1	3	12
		Maldanidae									1	1					2
		Nephtyidae			1					1		1					1
		Nereididae		3	9	4	3	7	3	29	3	3	1	2	3	2	14
		Orbiniidae		1		1				2						1	1
		Spionidae		4	2	1		2	2	11	1			1		1	3
Hemichordata																	
	Enteropneusta													1			1
Crustacea																	
	Amphipoda																
		Jassidae		1						1							
		Lysianassidae			1					1		1	1			1	3
		Oedicerotidae		2						2							
		Phoxocephalidae			1		1	1		3	1		1		1	3	6
Mollusca																	
	Gastropoda																
		Trochidae															
			Micrelenchus tenebrosus			1	1	1		3		2	1		1		4
	Bivalvia																
		Veneridae															
			Austrovenus stutchburyi	3	5	6	6	4	5	29	3		2	3	2	2	12
		Tellinidae															
			Macomona liliana			1	1	1	1	4		1		1			2
		Animals per core		18	24	16	14	22	16	110	9	12	9	10	8	14	62
		Animals per m^2		4014	5352	3568	3122	4906	3568	24530	2007	2676	2007	2230	1784	3122	13826
		Species per site		7	7	7	6	7	5	12	5	7	6	6	5	8	13

Table 15. *Abundance of species of infauna collected <20m and >50m from the Orari Street outfall.*

Orari Street			Location	<20m							>50m						
2011				Site 1			Site 2				Site 1			Site 2			
			Sample	1	2	3	4	5	6	sum	1	2	3	4	5	6	sum
Phylum		**Family**	**Genus/species**														
Annelida																	
	Polychaeta																
		Glyceridae		5	2	3	8	4	2	24	2		5	2	3	4	16
		Maldanidae				1	3	2	1	7			2	2	1		5
		Nephtyidae					1			1		2		2	1	1	6
		Nereidae			2	1	2		1	6	1	1					2
		Nereididae		6	4	4	6	3	5	28	1	4	6	3	6	3	23
		Spionidae		2	1	2			1	6		3	3		5	1	12
Hemichordata																	
	Enteropneusta				1		1	1		3					1		1
Sipuncula							1			1					1		1
Crustacea																	
	Amphipoda	Haustoriidae															
		Jassidae											1			1	2
		Lysianassidae				1	2			3							
		Oedicerotidae					1			1							
		Phoxocephalidae		1	1	1				3		1	1				2
	Isopoda																
			Isocladus armatus												1		1
	Malacostraca		*Macrophthalmus hirtipes*		1					1							
	Tanaidacea						1			1							
	Ostracoda								1	1							
Mollusca																	
	Gastropoda																
		Trochidae															
			Micrelenchus tenebrosus	1			1	1		3				1	1		2
		Nacellidae															
			Cellana ornata				1	1		2							
	Bivalvia																
		Veneridae															
			Austrovenus stutchburyi	6	5	1	4	7	5	28	4	3	1	4	4	5	21
			Nucula spp.				1		1	2	2	1	2	3		1	9
		Tellinidae															
			Macomona liliana	1	1	1		1	1	5	1	1	1			2	5
		Animals per core		22	18	15	33	20	18		11	16	22	17	24	18	108
		Animals per m^2		4906	4014	3345	7359	4460	4014	0	2453	3568	4906	3791	5352	4014	24084
		Species per site		7	9	9	14	8	9	19	6	8	9	7	10	8	15

Table 16. *Abundance of species of infauna collected <20m and >50m from the Portobello Road outfall.*

Portobello Rd			Location	<20m							>50m						
2011				Site 1			Site 2				Site 1			Site 2			
			Sample	1	2	3	4	5	6	sum	1	2	3	4	5	6	sum
Phylum		**Family**	**Genus/species**														
Annelida																	
	Polychaeta																
		Glyceridae		5	3	7	11	3	7	36		1			1	2	4
		Maldanidae		2	1	2	3		4	12	1						1
		Nephtyidae				3	4	1	5	13			1			1	2
		Nereididae		1		3	2			6			1				1
		Spionidae														1	1
		Syllidae				2	1	1		4		1	1				2
Hemichordata											1					1	2
	Enteropneusta					1				1							
Crustacea																	
	Amphipoda																
		Lysianassidae										1					1
		Phoxocephalidae			1	1		3	1	6			5				5
	Malacostraca		*Macrophthalmus hirtipes*											1			1
Mollusca																	
	Gastropoda																
		Nacellidae															
			Cellana ornata												1		1
	Bivalvia																
		Veneridae															
			Austrovenus stutchburyi		1					1	3		1	2	2		8
			Puyseguria spp.														
		Tellinidae															
			Macomona liliana											1	1		2
		Animals per core		8	6	19	21	8	17	79	5	3	9	4	5	5	31
		Animals per m^2		1784	1338	4237	4683	1784	3791	17617	1115	669	2007	892	1115	1115	6913
		Species per site		3	4	7	5	4	4	8	3	3	5	3	4	4	13

3.4 Analyses of Cockle, Mussels, Fish and Octopus flesh

st year, levels of heavy metals in cockle flesh showed no clear trend for contamination in moving from Kitchener Street to Portobello Road (Table 17). This differs from 2008 and 2009 when levels were highest at Portobello Road. PAHs on the other hand, remain by far the highest at Portobello Road (Table 17).

All heavy metals were at concentrations two orders of magnitude below accepted food standards (Table 18). There are no specific guidelines for PAH in shellfish flesh for New Zealand, but food standards for British Columbia recommend an upper limit for benzo[a]pyrene (Table 19).

It should be noted that, as already stated, and as found in previous surveys, cockles became smaller as one nears the Portobello Road outfall. Whether this is due to

PAH contamination or exposure at low tides and to fresh water, or some other factor, remains to be determined. As suggested last year, perhaps an investigation of cockle sizes at a site with similar fresh water and tidal exposure is merited.

Faecal coliform levels in cockle flesh were highest at Portobello Road and below detectable limits at Orari Street and Kitchener Street, much the same as in 2009. Last year they were highest at Kitchener Street and moderate at Orari Street and Portobello Road. Highest overall FC levels in cockles were in 2008 but FCs were not detected in any cockle samples in 2007.

To my knowledge, cockles are not gathered by recreational harvesters in the upper harbour basin as they are perceived to be contaminated and too small to be worthwhile.

Table 17. *Contaminant concentrations in cockle flesh from within 20m of the Kitchener Street, Orari Street and Portobello Road stormwater outfalls in 2007, 2008, 2009, 2010 and 2011. 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
Cockles	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
	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
	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
	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
	Ni	mg/kg	2007	0.71	1.00	0.64
			2008	1.30	1.10	1.30
			2009	0.89	0.93	1.00
			2010	0.72	1.24	1.30
			2011	0.69	1.02	1.10
	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
	Zn	mg/kg	2007	6.3	6.4	8.0
			2008	11.0	7.7	8.6
			2009	7.4	10.0	9.0
			2010	5.5	5.3	6.7
			2011	6.8	5.8	7.1
	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
	Faecal coliforms	MPN/100g	2007	<18	<18	<18
			2008	1300	230	78
			2009	78	<18	<18
			2010	68	68	220
			2011	45	<18	<18

Table 18. *Heavy metal concentrations for NZ and US FDA guidelines for adults (expressed as mg/kg dry weight). '-' means no guideline is available.*

	Cu	Zn	Pb	Cd	Cr	Ni
Food Regs/NZ DoH	150.0	2000.0	10.0	5.0	-	-
US FDA	-	-	4.2	-	11.0	80.0
Australia NZ food standards code	-	-	2.0	2.0	-	-

Table 19. *British Columbian guidelines for B[a]P concentration in shellfish for human consumption*

B[a]P concentration in the edible portion of fish/shellfish (µg B[a]P/kg wet weight)	Safe quantity for weekly consumption* on a regular basis (g wet weight)	B[a]P Portobello Road cockles 2007 (µg B[a]P/kg wet weight)	B[a]P Portobello Road cockles 2008 (µg B[a]P/kg wet weight)
4	50	249	34
2	100		
1	200		

*low and moderate consumption levels, according to the State of Washington, are 45 g/wk (or 6.5 g/d) and 140 g/wk (or 20 g/d).

As for cockles in the upper harbour basin, mussels from Second Beach showed levels of contamination that were well below accepted food guidelines (Table 20). Concentrations of most contaminants were not dissimilar to those observed in cockles (Table 17), but with nickel and arsenic slightly lower and copper and zinc slightly higher. Overall, however, there is little evidence of contamination of shellfish by stormwater at this site.

Seven triplefins were caught in baited fish traps set off the Mason Street wharf on 31st May 2011. The triplefins were small (Table 20), but representative of the size classes commonly seen amongst variable triplefins. Sizes and weights of the triplefins were slightly up on those caught in 2007 and 2008 but lower than last year and 2009 (Table 21). Levels of all contaminants in fish this year were generally similar to those observed in previous surveys. Overall, levels PAHs and of all metals except zinc were lower in fish than in cockles. Levels of chromium continue to be lowest in fish and Portobello Road cockles (Tables 17 & 22).

It could, therefore, be argued that the concentration of most contaminants in the fish, with the exception of zinc, were similar to or lower than in cockles (Table 22). This is similar to the situation in 2007, 2008, 2009 and 2010. At first glance one is tempted to say that this is not unexpected, given that the cockles are filter feeders while the fish are predators. However, contaminants tend to become more concentrated as one moves up the food chain. Triplefins do not prey on shellfish, but do eat smaller fish and a variety of other invertebrates. The fact that contaminant levels are relatively low in fish flesh suggests that heavy metal and PAH contamination around the Mason Street stormwater outfall is low.

Despite numerous patrols along the foreshore no octopus were found for collection of samples this year.

Table 20. *Contaminant concentrations in mussel flesh from within 20m of the Second Beach stormwater outfall.*

	Parameter	Units		Second Beach
Mussels	As	mg/kg	2007	1.6
			2008	1.9
			2009	1.9
			2010	1.5
			2011	1.7
	Cd	mg/kg	2007	0.078
			2008	0.083
			2009	0.084
			2010	0.094
			2011	0.014
	Cr	mg/kg	2007	0.33
			2008	0.20
			2009	0.11
			2010	0.19
			2011	0.21
	Cu	mg/kg	2007	1.00
			2008	0.69
			2009	1.50
			2010	0.94
			2011	1.03
	Ni	mg/kg	2007	0.4
			2008	0.3
			2009	0.3
			2010	0.5
			2011	0.4
	Pb	mg/kg	2007	0.14
			2008	0.11
			2009	0.20
			2010	0.18
			2011	0.16
	Zn	mg/kg	2007	12.0
			2008	9.4
			2009	14.0
			2010	9.8
			2011	11.3
	Faecal coliforms	CFU/100ml	2007	<18
			2008	20
			2009	45
			2010	<18
			2011	170

Table 21. *Size and weight of triplefins captured near the Mason Street Stormwater outfall in 2007, 2008, 2009, 2010 and 2011. Spotty values in blue shaded cells.*

2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Fish Sizes (mm)					Weight (g)				
75	70	101	151	74	4.7	4	13.1	41.3	5.12
71	67	88	72	53	3.9	2.9	9.8	4.9	1.52
73	46	96	75	64	4.4	0.9	10.6	5.2	2.71
61	65	71	88	68	2.2	3	4.5	7.0	3.24
49	63	62	83	87	1.1	2.7	2.8	7.3	7.28
78	75	81	80	77	5.3	5.5	6.9	6.5	5.1
77	58	70	78	90	5.6	2.4	4.1	4.8	9.88
79	67	78	62		6.1	3.4	6.6	2.5	
75	72	79	79		4.1	4.5	6	6.5	
46	83	59	76		0.9	6.4	2.1	5.1	
52	71				1.6	4.8			
74	68				4.6	3.8			
	72					4.8			
	65					2.8			
	59					2.7			
	56					2.2			
	60					2.4			
Mean = 67.5	65.71	78.50	84.40	73.29	3.7	3.48	6.65	9.11	4.98
Mean (excluding spotty) =			77.0					5.5	

Table 22. *Contaminant concentrations in the flesh of triplefins captured near the Mason Street Stormwater outfall. BDL = below detectable limits.*

	Parameter	Units		Mason Street
Fish	As	mg/kg	2007	1.90
			2008	1.60
			2009	1.90
			2010	1.56
			2011	1.24
	Cd	mg/kg	2007	0.0047
			2008	0.0047
			2009	0.0110
			2010	0.0091
			2011	0.0060
	Cr	mg/kg	2007	0.05
			2008	BDL
			2009	0.14
			2010	BDL
			2011	BDL
	Cu	mg/kg	2007	0.54
			2008	0.52
			2009	1.20
			2010	0.38
			2011	0.49
	Ni	mg/kg	2007	BDL
			2008	BDL
			2009	<0.095
			2010	BDL
			2011	0.13
	Pb	mg/kg	2007	0.140
			2008	0.120
			2009	0.43
			2010	0.14
			2011	0.14
	Zn	mg/kg	2007	21.00
			2008	20.00
			2009	21.00
			2010	18.10
			2011	19.70
	PAH	mg/kg	2007	7.0000
			2008	0.0023
			2009	0.0060
			2010	0.0150
			2011	0.0015
	Mean Size	(mm)	2007	67.5
			2008	65.7
			2009	78.5
			2010	84.4
			2011	73.3
	Mean Weight	(g)	2007	3.7
			2008	3.5
			2009	6.65
			2010	9.11
			2011	4.98

4. Discussion and Conclusion

In 2011 water samples were colleted from a total of 14 major Dunedin City stormwater outfalls. In addition, sediments were sampled from near 5 of these outfalls and from an additional 5 sites located some distance from the outfalls to

gain a clearer picture of the distribution of contaminants in sediment in the upper Otago Harbour. Flesh from fish, cockles and mussels was also collected for contaminant analysis. For interest sake historical data for some of the same sites have been included for comparison (Tables 23 and 24). Any trends observed in these data for historical sediment values should be viewed with extreme caution as sampling in some previous years may have used entirely different protocols. For example, sediments may have been collected from different depths within the substrate and by different methods meaning that results are not directly comparable. Stormwater sampling, however, should be comparable assuming previous investigators targeted the first flush.

There has been a decline in the levels of some contaminants at stormwater outfalls for which historic data are provided, but a rise in others. The reduction in lead levels continues at George Street and Kitchener Street, and is perhaps to be expected as it has been removed from paint and petrol and levels in the environment are very gradually declining. The reduction in the levels of other contaminants is very slight (e.g. Zn and Cu at four sites) and there is a slight increase in levels of all metals a few sites (Table 23). Such fluctuations are relatively small and may be merely a function of the intensity of the storm events when sampling occurred.

Overall levels of contaminants in sediment, however, appear to continue to fall slightly, suggesting build-up of contaminants in the environment may have plateaued, or is declining, and existing contaminants may be being buried (Tables

23 and 24). The increased levels of most metals seen at Wickliffe Street in the past is not apparent this year.

It is expected that the implementation of the long-term stormwater catchment management plans currently under development through the DCC's Three Waters Strategy will contribute to addressing the issue of future contaminants in stormwater. It will be of interest to see if any long-term trends in contaminant levels can be discerned as monitoring continues.

Benthic and infaunal communities in the vicinity of the Portobello Road, Orari Street and Kitchener Street outfalls have reasonably low diversity, but this is generalised and not associated with any one outfall and is likely symptomatic of a large proportion the upper harbour basin. As in past years there is a trend towards smaller cockles as one nears the Portobello Road outfall. This may be as a result of historic PAH contamination, which is extremely high beneath the surface at this site, but a number of other factors, not least of which are freshwater exposure and exposure at low tide, must also be considered.

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 the trend towards lower contaminant levels in stormwater is continued, both water quality and community health in the harbour will gradually improve over time.

Only after problem areas and problem contaminants have been identified can measures be taken to mitigate any effects. No additional mitigation measures have been undertaken by the DCC at this stage, apart from investigations into the remediation of PAH contamination at the Portobello Road outfall (Stewart 2006), the elimination of the source of FWAs at Bauchop Street in 2008, and the usual street sweeping and mud tank clearance. As already stated, the South Dunedin (Portobello Road) catchment has been investigated as the pilot catchment for the development of the Three Waters Strategy catchment management plans. It is expected that further stormwater monitoring over time and concurrent investigations under the Three Waters strategy will define problem areas such that mitigation measures may be undertaken.

It should be noted that the current stormwater monitoring programme is under review and a modified programme may help pinpoint areas of concern with more accuracy in future.

Table 23. *Contaminants in stormwater being discharged to the upper Otago harbour basin through time. BDL = below detectable limits. Pink cells denote levels higher than at any past sampling event; green cells denote levels lower than at any past sampling event.*

Parameter	Suspended Solids						Cd						Cr						Cu					
units	g/m^3						g/m^3						g/m^3						g/m^3					
	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011
Second Beach		BDL	37.0	41	BDL	57		BDL	0.00006	0.00006	0.00007	0.000075		0.0007	0.0028	0.0035	0.00086	0.0038		0.0027	0.012	0.019	0.0054	0.0172
Pt Chalmers George St		87.0	150.0	26	170	140		0.00028	0.00140	0.00011	0.00033	0.000168		0.005	0.012	0.0031	0.00136	0.0045		0.0213	0.039	0.025	0.0148	0.0197
Pt Chalmers Watson Pk		37.0	39.0	7.4	240	24		BDL	BDL	BDL	BDL	BDL		BDL	0.0064	BDL	BDL	BDL		0.009	0.0025	BDL	BDL	BDL
Shore Street	75.4	41.0	24.0	20	9.5	12		BDL	BDL	BDL	BDL	BDL		BDL	BDL	BDL	BDL	BDL		0.01	0.014	0.02	0.0118	BDL
Portobello Road	28.0	18.0	46.0	30	8.1	53	0.0003	BDL	0.00023	BDL	BDL	BDL	0.0029	BDL	0.002	BDL	BDL	BDL	0.03	BDL	0.026	0.01	0.0057	0.029
Teviot Street		25.0	33.0	12	84	66		BDL	0.00008	BDL	0.00026	BDL		BDL	0.0018	BDL	BDL	BDL		BDL	0.0094	BDL	0.0136	0.031
Midland Street		30.0	19.0	30	52	14		BDL	0.00013	BDL	BDL	BDL		BDL	0.0035	0.0031	BDL	BDL		0.02	0.031	0.057	0.021	BDL
Orari Street	38.1	28.0	77.0	16	130	4	0.0005	BDL	BDL	BDL	0.000164	BDL	0.002	BDL	0.0032	BDL	0.00183	BDL	0.0132	BDL	0.014	BDL	0.0096	BDL
Kitchener Street		104.0	41.0	45	50	BDL		BDL	BDL	BDL	BDL	BDL		0.004	0.002	BDL	BDL	BDL		0.034	0.0056	0.023	0.0118	BDL
Mason Street		62.0	37.0	37	138	30		BDL	BDL	0.0077	0.00051	BDL		BDL	BDL	BDL	BDL	BDL		0.022	0.012	0.021	0.0157	0.043
Ravensbourne Road			8.5	18	61	5			BDL	BDL	BDL	BDL			0.00061	BDL	BDL	BDL			0.0023	BDL	0.0031	BDL
Bauchop Street		44.0	16.0	13	53	5		BDL	BDL	BDL	0.00049	BDL		BDL	0.0015	BDL	BDL	BDL		0.029	0.0096	0.021	0.0026	BDL
Halsey Street		119.0	35.0	27	50	24		BDL	0.00022	BDL	0.00026	BDL		BDL	BDL	BDL	BDL	BDL		0.024	0.0043	BDL	0.00162	0.029
Wickliffe Street		35.0	27.0	100	86	46		BDL	BDL	0.00052	0.00078	0.00092		BDL	0.0017	0.0076	0.00157	0.0046		0.01	0.013	0.059	0.0058	0.022

Parameter	Ni						Pb						Zn						PAH					
units	g/m^3						g/m^3						g/m^3						g/m^3					
	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011
Second Beach		0.0009	0.0021	0.0022	0.00133	0.0026		0.001	0.011	0.013	0.00021	0.0127		0.038	0.16	0.15	0.092	0.25						
Pt Chalmers George St		0.0029	0.0093	0.0026	0.006	0.0037		0.0342	0.041	0.018	0.0048	0.0037		0.288	0.66	0.19	0.42	0.25						
Pt Chalmers Watson Pk		BDL	BDL	BDL	0.0035	BDL		0.0141	0.0018	BDL	BDL	0.0041		0.231	0.027	BDL	0.29	0.24						
Shore Street		0.01	BDL	BDL	BDL	BDL		0.003	0.0085	0.0069	BDL	BDL		0.02	0.44	0.21	0.115	BDL						
Portobello Road	0.002	BDL	0.0035	0.0028	0.0035	BDL	0.021	BDL	0.019	0.0067	0.00055	0.026	0.895	0.08	0.94	0.64	0.153	0.87	0.0031	BDL	328	0.00017	0.00016	0.00168
Teviot Street		BDL	0.0019	BDL	0.0033	BDL		BDL	0.0066	BDL	BDL	0.0065		BDL	0.13	BDL	1.79	0.61						
Midland Street		BDL	0.0016	BDL	0.0075	BDL		0.005	0.0054	0.0083	BDL	BDL		0.1	0.35	0.18	0.22	BDL						
Orari Street	0.002	BDL	0.0033	BDL	0.00108	BDL	0.022	BDL	0.023	BDL	0.00015	BDL	0.191	BDL	0.22	0.031	0.3	BDL	0.0026	0.0001	318	BDL	0.0005	BDL
Kitchener Street		0.003	BDL	0.0036	0.0035	BDL		0.0442	0.007	0.018	0.00196	BDL		0.445	0.036	0.38	0.62	BDL		BDL	327	BDL	0.0001	BDL
Mason Street		0.004	BDL	0.0055	BDL	0.0039		0.0258	0.0089	0.014	0.00102	0.0192		0.25	0.16	0.35	0.43	0.63						
Ravensbourne Road			0.00066	BDL	0.00148	BDL			0.0015	0.0029	0.00023	0.025			0.053	0.047	0.144	0.27						
Bauchop Street		0.01	BDL	0.0035	BDL	BDL		0.01	0.0035	0.0097	BDL	BDL		0.23	0.12	0.3	0.121	BDL						
Halsey Street		0.009	BDL	BDL	BDL	BDL		0.021	0.0022	BDL	0.0021	0.0085		0.12	0.033	0.13	0.136	0.36						
Wickliffe Street		0.01	BDL	0.0042	BDL	0.0021		0.006	0.0084	0.033	BDL	0.0134		0.1	0.2	0.53	0.24	0.82						

Table 24. *Contaminants in sediments in the upper Otago harbour basin in the vicinity of selected stormwater outfalls through time. Pink cells denote levels higher than at any past sampling event; green cells denote levels lower than at any past sampling event.*

	Arsenic						Cadmium						Chromium						Copper						Nickel					
	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011
Rowing Club		10.6	9.8	7.3	13.0	11.6	0.0	0.2	0.2	0.1	0.2	0.1	16.8	17.6	12	16.0	14.0	11.6	9.8	14.2	13	14	9	12		11.3	14	13.0	11.0	12.1
Wickliffe		17.3	11.0	6.9	9.0	14.3		0.6	0.74	0.8	0.7	0.7		38	34	16.0	27.0	30.0		121.0	68	50	58	86		19.2	23	13.0	17.0	15.9
White St		11.6	18.0	5.4	6.0	8.3		0.3	0.22	0.2	0.1	0.1		68.5	56	26.0	19.0	30.0		433.0	160	170	78	98		29.5	21	11.0	8.0	14.5
Kitchener St		4.6	7.5	7.0	9.0	4.5		0.4	0.35	0.3	0.3	0.3	7.1	22.6	18	98.0	22.0	18.3		69.5	56	90	37	54	5.8	10.6	12	15.0	12.0	10.6
Orari St		18.6	4.3	20.0	5.0	2.1	0.5	63.0	0.13	0.9	0.2	0.1	17.5	0.27	16	37.0	16.0	9.4	20	25.1	13	61	11	7	10.4	23.6	8.1	16.0	8.0	5.3
Orari 100		13.7					0.3	0.4					16	26.3					28	25.9					8.8	12.6				
Midland 200		15.4					0.4	0.3					22	22.4					24	19.0					8.3	10.7				
Portobello Rd		29.0	23.0	24.0	15.0	28.0	2.0	1.8	1.8	2.0	1.5	2.6	41	60.1	54	50.0	36.0	67.0	210	169.3	160	190	123	176	15	20.4	18	26.0	19.0	24.0
PR 200		17.4					1.0	0.5					32	41.8					100	52.6					13	17.3				
Shore St		9.5	7.1	6.2	6.0	2.3	0.5	0.4	0.32	0.3	0.3	0.2	9.6	21.8	16	18.0	19.0	5.8	30	50.9	44	41	35	11	5.4	10.7	9	11.0	10.0	5.2
Boatshed		27.4	16.0	17.0	15.0	16.2		0.3	0.21	0.2	0.3	0.6		41.7	19	26.0	31.0	34.0		108.0	33	49	35	53		24.5	16	17.0	16.0	18.5
Cove Drainage		21.5	17.0	19.0	13.0	9.5		0.1	0.13	0.4	<0.1	0.2		15.8	35	32.0	19.0	21.0		11.3	19	38	11	14		23.5	44	23.0	19.0	12.8
Retaining wall		25.3	36.0	24.0	36.0	39.0		0.1	0.15	<0.1	<0.1	0.1		23.6	31	39.0	23.0	24.0		13.3	19	17	10	11		15.9	25	26.0	18.0	13.2
RW 300		16.2					0.1	0.3					28.33	0.27					16.3	15.2					13.3	12.4				
W/W centre		11.1						0.2					2.75	30.8						15.3					3.63	14.6				
UHB Centre		10.5					0.3	0.2					26.8	24.3					15.2	15.2					10	11.3				

	Lead						Zinc						PAH						Enterococci					
	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011	Historic	2007	2008	2009	2010	2011
Rowing Club		18.9	27	27	28	19	80.8	101	130	160	149	109		6.97	5.78	0.5	3.7	0.1		200	11	<2		8
Wickliffe		76.1	140	77	92	127		412	740	810	740	700		9.21	1.18	7.3	7.2	11.3		58000	>1600	330	<3	>160
White St		147	180	170	124	147		4450	2500	2400	1280	1650		12.96	11.05	15.9	6.5	5.4		400	2	<2		35
Kitchener St		117.9	97	130	155	132	170	249.33	280	300	280	260		8.88	140.49	4.8	5.0	5.5	130	6633	920	5	<3	>160
Orari St	185	12.8	39	120	35	17	239	68.27	130	680	157	69	13.41	10.23	12.59	28.3	9.3	4.3	557	12.67	8	23	<3	54
Orari 100	170	170					230	227						6.67					1300	3600				
Midland 200	36	36					190	165						7.24					130	20000				
Portobello Rd	410	306.33	330	290	193	310	1300	1493	1400	1600	1040	1410	425.83	382.90	250.30	525.2	194.1	482.0	1120	72667	170	<2		16
PR 200	130	81.3					430	309					12.29	8.97					40	66000				
Shore St	130	113	110	79	85	36	300	484	300	330	350	210		9.56	21.01	8.6	10.5	4.1	2400	9000	>1600	<2		35
Boatshed		112	800	170	86	89		339	370	360	290	300		6.67	5.54	38.8	7.9	40.4		3400	33	33	<3	54
Cove Drainage		19.7	20	55	18	44		99.2	150	270	125	119		0.37	0.00	0.1	0.1	1.0		800	17	<2	<3	35
Retaining wall		26.9	27	42	24	23		141	170	150	152	138		0.30	3.91	0.0	9.4	0.2		<100	8	<18		8
RW 300	40	6.7					149	131						0.30						<2				
W/W centre	25	5.6						168						0.34						<2				
UHB Centre	27	23					118	119						0.65						24000				

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