Stormwater Compliance Monitoring 2013

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 2013

ryderconsulting
environment + planning + project management

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prepared by

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June 2013

Cover photo: Looking south from the Kitchener Street stormwater outfall

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Executive Summary

This report presents the findings for the sixth annual monitoring of Dunedin's stormwater outfalls since discharge consents were granted, but the last under the current consent regime.

The survey comprised assessment of benthic communities, of contamination of stormwater and of contamination of sediments and benthic fauna, including fish, cockles, octopus 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 at a variety of outfalls.

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 many sites. However, overall sediment contaminant levels at sites remote from the outfalls appear to have plateaued.

Contaminant levels in both stormwater and sediment were within the ranges observed in previous surveys carried out in 2007, 2008, 2009 2010 2011 and 2012 with no clear trends in contaminant levels discernible at this juncture.

However, it appears the ecology of the upper harbour basin is not being appreciably degraded as a result of the discharge of stormwater to Otago harbour.

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 2013. It should be noted that the DCC has recently been granted new resource consents to cover the discharge of stormwater into Otago Harbour so this will be the last report compiled under the original set of conditions.

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.*

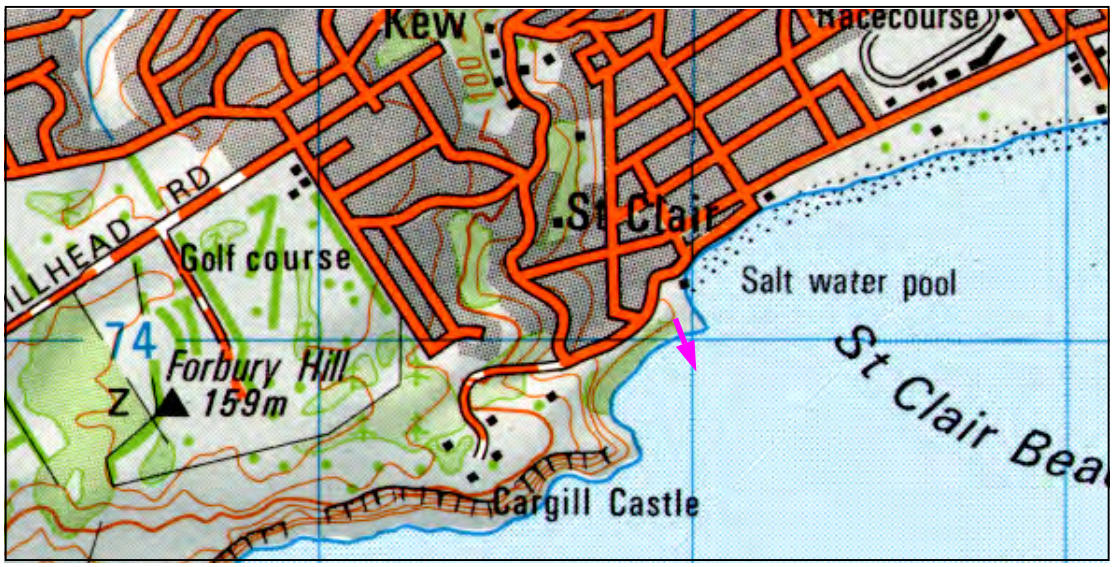

Figure 1b. *Location of the Second Beach stormwater outfall.*

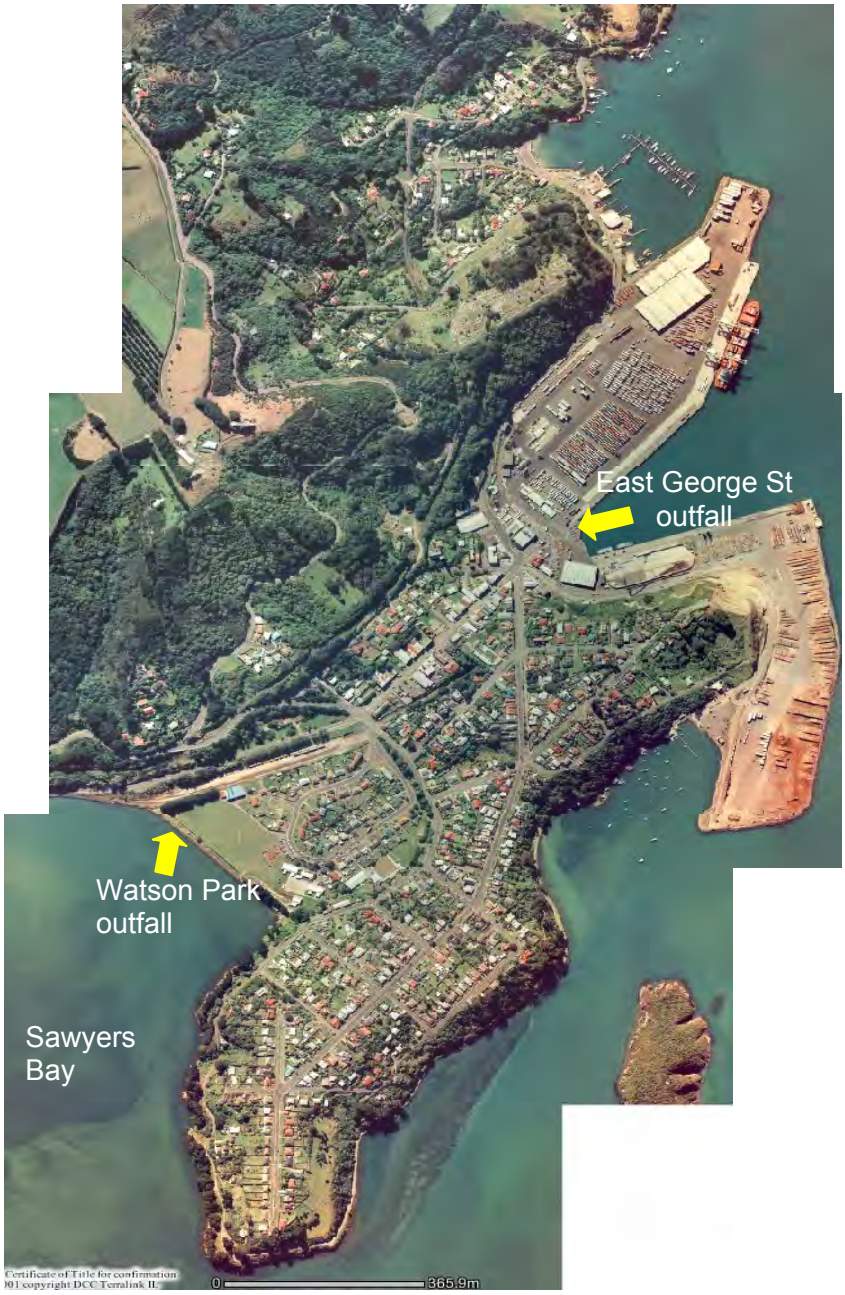

Figure 1c. *Location of major outfalls discharging stormwater from Port Chalmers.*

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 and pink 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.

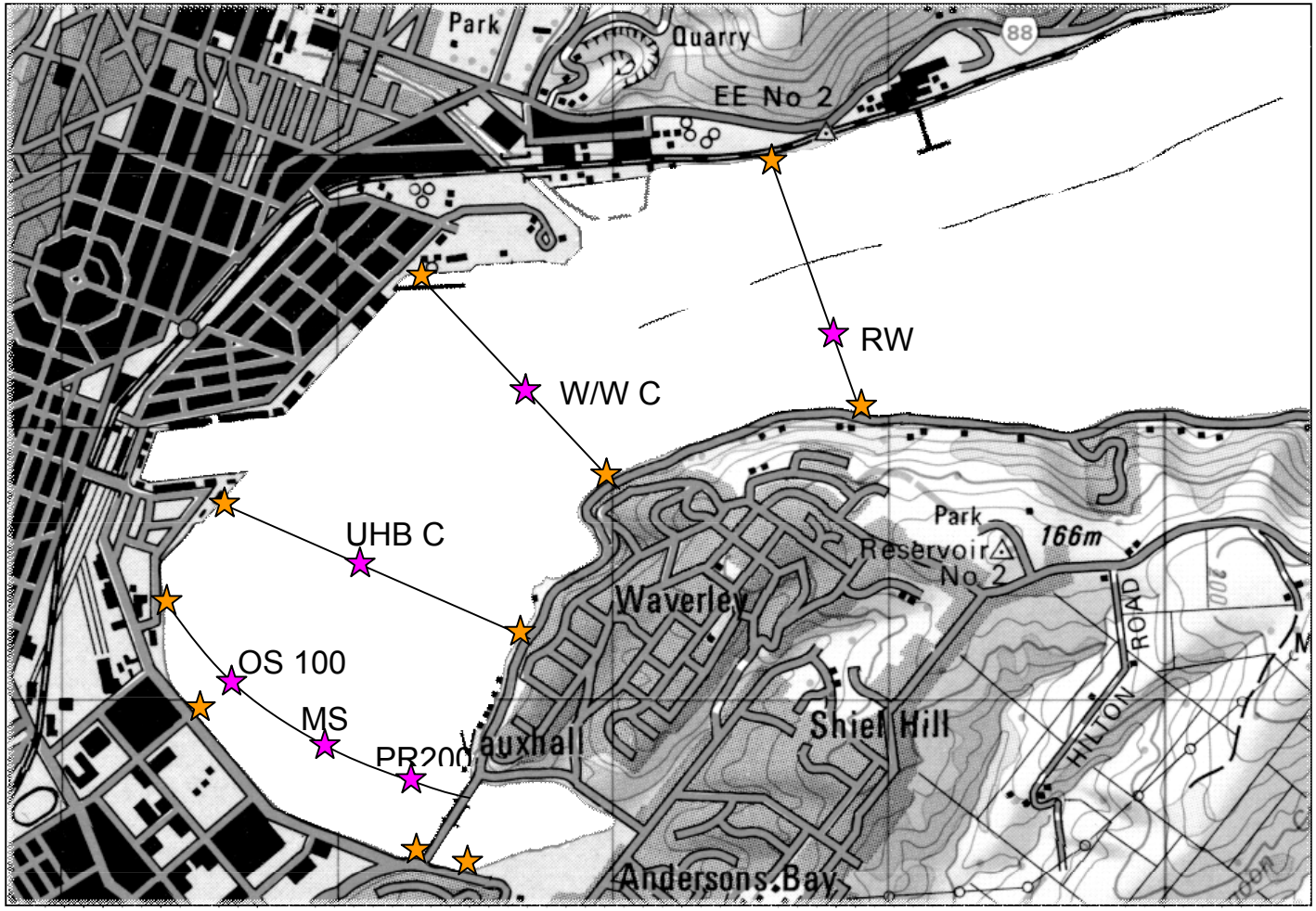

Figure 2. *Upper Harbour Basin sediment sampling sites. Orange stars sampled annually; pink stars sampled 5 yearly. Anticlockwise, starting at top, orange sites are: Rowing Club, Wickliffe St, White St, Kitchener St, Orari St, Portobello Rd, Shore St, Boatshed, Cove Drainage and Retaining Wall. Pink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

3. Results

3.1 Stormwater

During the first flush of a storm event that produced 3.8 mm rainfall on 13 June 2013 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 126 hours.

Stormwater at most sites was only very lightly discoloured, testimony to the relatively gradual onset of the rain event. At Midland Street and Kitchener Street, however, stormwater was more noticeably discoloured (Figure 3).

Contaminant levels are compared with levels in stormwater collected during a preliminary survey conducted in 2007 and all subsequent surveys (Table 2, Figure 4). As for last year and 2011 all contaminants, with the exception of lead, zinc and copper were below ANZECC (2000) guidelines for protection of 80% of species (Table 2). However, lead levels exceeded ANZECC guidelines at just the George Street and Watson Park outfalls in Port Chalmers. Overall, there are no trends in the levels of these contaminants evident, with levels at some outfalls being higher than last year while others are lower (Table 2, Figure 4). 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.

Unlike last 2011, when there was no outfall that was clearly "worse" than others, Teviot Street, Midland Street, Watson Park and George Street all show high levels of some contaminants this year, notably chromium, lead, copper, nickel and zinc (Table 2, Figure 4). In fact George Street had the highest levels of nickel, cadmium, copper, lead and chromium while Teviot Street had the highest levels of zinc. There were no outfalls this year for which all heavy metal contaminants were below ANZECC guidelines. Generally speaking, contaminant levels showed considerable variability with location when compared with results from previous surveys. Chromium, copper, lead and zinc at George Street and Chromium at Teviot and Midland Streets all stand out as being at levels higher than might be expected based on previous results (Figure 4).

Figure 3 *Discoloured stormwater discharging from (a) Kitchener Street; (b) Portobello Road; (c) Orari Street; (d) Midland Street; (e) Teviot Street; and (f) Shore Street.*

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 and is likely a function of rainfall intensity and antecedent dry period as much as other factors.

Microbiological levels were high to very high at all sites, with values exceeding the guidelines for secondary contact recreation for both faecal coliforms and *E. Coli* at all outfalls except Teviot Street Mason Street and Ravensbourne Road (Table 2, Figure 4). Second Beach, Portobello Road, Orari Street, Kitchener Street and, Halsey Street show increases in *E. coli* and faecal coliform levels compared with 2012. However, bacterial levels at Teviot Street and Mason Street show a marked decrease over the 2010, 2011 and 2012 figures (Table 2, Figure 4). 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. It could be argued that there appears to be an overall trend of increasing *E. coli* levels from year to year at the Halsey Street outfall, but this is by no means clear. For all other outfalls there are no clearly discernible trends in bacterial levels through time (Figure 4).

FWAs were detected at low flows at all sites again this year, albeit at low levels for all but Shore Street, Teviot Street, Midland Street, and Portobello Road (Table 2). The levels at these four 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. Portobello Road this year had the highest value, but well short of the extreme levels seen at Bauchop Street in 2007 and 2008 (Figure 4). 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.).

PAHs were not detected at Kitchener Street or Orari Street again this year, but were detected at Portobello Road, albeit at very low levels. This differs from 2010 where PAHs were detected at all three outfalls, but is similar to last year and 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 PAHs were detected at Orari St and Portobello Rd (Table 3). Total PAH levels were higher at Portobello Road this year than they have been at any survey since 2007 (Table 3). A possible explanation for the slightly higher levels of PAHs this year is the fact that sampling took place later in

the year when coal fires may have been inuse for home heating for a longer period. However, if that were the case, one would expect PAHs to register at Orari Street and Kitchener Street outfalls as well. This is not the case so one must assume the PAHs are due to the relatively higher first flush flow during this years rain event.

Oil and grease levels this year were lower than those observed last year for all outfalls except Teviot Street and Midland Street (Table 2; Figure 4).

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, 3 May 2011, 29 February 2012 and 13 June 2013. BDL indicates Below Detectable Limits. Pink shaded cells indicate levels above the ANZECC 2000 trigger level for protection of 80% of species.*

Stormwater																							
Parameter	As							Cd							Cr								
units	g/m^3							g/m^3							g/m^3								
Outfall	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013		
Second Beach	BDL	0.0013	0.0015	BDL	0.002	BDL	BDL	BDL	0.00006	0.00006	0.00007	8E-05	BDL	BDL	0.0007	0.0028	0.0035	0.00086	0.0038	0.00148	0.0023		
George St	BDL	0.0031	BDL	BDL	0.001	0.0016	0.0042	0.00028	0.00140	0.00011	0.00033	0.0002	0.0006	0.0004	0.005	0.012	0.0031	0.00136	0.0045	0.0053	0.0132		
Watson Pk	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0002	BDL	0.0064	BDL	BDL	BDL	0.0016	0.0025		
Shore Street	0.04	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL		
Portobello Road	BDL	0.002	BDL	BDL	BDL	BDL	BDL	BDL	0.00023	BDL	BDL	BDL	BDL	BDL	BDL	0.002	BDL	BDL	BDL	BDL	BDL		
Teviot Street	BDL	0.002	BDL	BDL	BDL	BDL	0.0017	BDL	0.00008	BDL	0.00026	BDL	0.0001	0.0002	BDL	0.0018	BDL	BDL	BDL	0.0019	0.005		
Midland Street	BDL	0.0033	BDL	BDL	BDL	BDL	0.0042	BDL	0.00013	BDL	BDL	BDL	BDL	BDL	BDL	0.0035	0.0031	BDL	BDL	BDL	0.0043		
Orari Street	BDL	BDL	0.032	0.00149	BDL	BDL	BDL	BDL	BDL	BDL	0.000164	BDL	BDL	BDL	BDL	0.0032	BDL	0.00183	BDL	BDL	BDL		
Kitchener Street	BDL	BDL	0.0096	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.004	0.002	BDL	BDL	BDL	BDL	BDL		
Mason Street	0.006	BDL	0.0077	BDL	BDL	BDL	BDL	BDL	BDL	0.0077	0.00051	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL		
Ravensbourne Rd		BDL	BDL	BDL	BDL	BDL	0.0014		BDL	BDL	BDL	BDL	BDL	0.0001		0.00061	BDL	BDL	BDL	BDL	0.0028		
Bauchop Street	0.03	BDL	0.021	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00049	BDL	BDL	BDL	BDL	0.0015	BDL	BDL	BDL	BDL	BDL		
Halsey Street	0.03	BDL	0.01	0.0044	BDL	BDL	BDL	BDL	0.00022	BDL	0.00026	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0019		
Wickliffe Street	0.03	BDL	0.003	BDL	0.004	0.0027	BDL	BDL	BDL	0.00052	0.00078	0.0009	0.0002	BDL	BDL	0.0017	0.0076	0.00157	0.0046	0.0028	0.0026		
Protection for 80% of species ANZECC guidelines	0.36							0.0008							0.04								

Stormwater																							
Parameter	Cu							Ni							Pb								
units	g/m^3							g/m^3							g/m^3								
Outfall	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013		
Second Beach	0.0027	0.012	0.019	0.0054	0.0172	0.0026	0.0099	0.0009	0.0021	0.0022	0.0013	0.0026	0.0011	0.0023	0.001	0.011	0.013	2E-04	0.013	0.00101	0.0053		
George St	0.0213	0.039	0.025	0.0148	0.0197	0.027	0.041	0.0029	0.0093	0.0026	0.006	0.0037	0.0061	0.0145	0.0342	0.041	0.018	0.005	0.004	0.029	0.048		
Watson Pk	0.009	0.0025	BDL	BDL	BDL	0.008	0.0118	BDL	BDL	BDL	0.0035	BDL	0.0019	BDL	0.0141	0.0018	BDL	BDL	0.004	0.0057	0.0127		
Shore Street	0.01	0.014	0.02	0.0118	BDL	BDL	0.0159	0.01	BDL	BDL	BDL	BDL	BDL	BDL	0.003	0.0085	0.0069	BDL	BDL	BDL	0.0038		
Portobello Road	BDL	0.026	0.01	0.0057	0.029	0.012	0.0072	BDL	0.0035	0.0028	0.0035	BDL	BDL	BDL	BDL	0.019	0.0067	6E-04	0.026	0.0081	0.0086		
Teviot Street	BDL	0.0094	BDL	0.0136	0.031	0.0104	0.03	BDL	0.0019	BDL	0.0033	BDL	0.0017	0.0027	BDL	0.0066	BDL	BDL	0.007	0.0028	0.0092		
Midland Street	0.02	0.031	0.057	0.021	BDL	0.0134	0.028	BDL	0.0016	BDL	0.0075	BDL	BDL	0.0024	0.005	0.0054	0.0083	BDL	BDL	0.0023	0.0092		
Orari Street	BDL	0.014	BDL	0.0096	BDL	0.0024	0.0057	BDL	0.0033	BDL	0.0011	BDL	0.0008	BDL	BDL	0.023	BDL	2E-04	BDL	0.00118	0.0041		
Kitchener Street	0.034	0.0056	0.023	0.0118	BDL	BDL	0.015	0.003	BDL	0.0036	0.0035	BDL	BDL	BDL	0.0442	0.007	0.018	0.002	BDL	0.0028	0.0055		
Mason Street	0.022	0.012	0.021	0.0157	0.043	0.026	0.0065	0.004	BDL	0.0055	BDL	0.0039	BDL	BDL	0.0258	0.0089	0.014	0.001	0.019	0.0101	0.0042		
Ravensbourne Rd		0.0023	BDL	0.0031	BDL	0.0032	0.0028		0.0007	BDL	0.0015	BDL	0.0007	0.002		0.0015	0.0029	2E-04	0.025	0.0039	0.0094		
Bauchop Street	0.029	0.0096	BDL	0.0026	BDL	0.021	0.0131	0.01	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.0035	BDL	BDL	BDL	0.021	0.0026		
Halsey Street	0.024	0.0043	0.021	0.00162	0.029	0.0043	0.0183	0.009	BDL	0.0035	BDL	BDL	BDL	BDL	0.021	0.0022	0.0097	0.002	0.009	0.0043	0.0064		
Wickliffe Street	0.01	0.013	0.059	0.0058	0.022	0.025	0.0107	0.01	BDL	0.0042	BDL	0.0021	0.0046	BDL	0.006	0.0084	0.033	BDL	0.013	0.0153	0.0092		
Protection for 80% of species ANZECC guidelines	0.0025							0.017							0.0094								

Table 2. *continued…*

Stormwater																							
Parameter	Zn							pH							Suspended Solids								
units	g/m^3														g/m^3								
Outfall	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013		
Second Beach	0.038	0.16	0.15	0.092	0.25	0.026	0.166	7.7	7.3	7.4	7.3	7.4	8	7.7	BDL	37	41	BDL	57	5	34		
George St	0.288	0.66	0.19	0.42	0.25	0.43	0.76	6.9	7.1	7.3	6.8	6.8	6.3	7.4	87	150	26	170	140	180	430		
Watson Pk	0.231	0.027	BDL	0.29	0.24	0.27	0.4	6.8	7.9	8.2	7.1	7.5	7.5	7.5	37	39	7.4	240	24	24	58		
Shore Street	0.02	0.44	0.21	0.115	BDL	0.071	0.2	7.9	7.2	7.3	7.4	7.9	7.5	7.5	41	24	20	9.5	12	10	9		
Portobello Road	0.08	0.94	0.64	0.153	0.87	0.15	0.57	7.9	7.3	7.6	7.6	7.4	8.1	7.6	18	46	30	8.1	53	43	27		
Teviot Street	BDL	0.13	BDL	1.79	0.61	1.22	1.26	7.9	7.1	7.9	7	8	7.1	7.4	25	33	12	84	66	32	67		
Midland Street	0.1	0.35	0.18	0.22	BDL	0.21	0.36	7.7	7.7	7.7	7.5	7.8	7.6	7.4	30	19	30	52	14	12	57		
Orari Street	BDL	0.22	0.031	0.3	BDL	0.0157	0.07	7.8	7.4	8.1	7.1	7.9	7.9	7.6	28	77	16	130	4	BDL	38		
Kitchener Street	0.445	0.036	0.38	0.62	BDL	0.082	0.23	7.1	7.7	7.4	6.9	8	7.6	7.7	104	41	45	50	BDL	27	37		
Mason Street	0.25	0.16	0.35	0.43	0.63	0.43	0.095	7.1	7	7.4	7	7	7.1	7.6	62	37	37	138	30	31	63		
Ravensbourne Rd		0.053	0.047	0.144	0.27	0.32	0.231		7	8.1	7.3	8	7.8	7.9		8.5	18	61	5	6	60		
Bauchop Street	0.23	0.12	0.13	0.121	BDL	0.94	0.2	7.6	7.8	8.1	7.4	8	7.4	7.9	44	16	13	53	5	38	47		
Halsey Street	0.12	0.033	0.3	0.136	0.36	0.089	0.23	7.3	7.9	7.2	6.8	7.1	7.8	7.3	119	35	27	50	24	22	46		
Wickliffe Street	0.1	0.2	0.53	0.24	0.82	1.57	0.161	7.7	7.5	8.0	7.3	9.7	7.0	7.5	35	27	100	86	46	30	92		
Protection for 80% of species ANZECC guidelines	0.031							7.2-7.8															

	Stormwater														
Three Waters Project ICMP Catchment	Parameter	Oil & Grease							FWA						
	units	g/m^3							µg/L						
	Outfall	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013
St Clair	Second Beach	5	BDL	BDL	BDL	BDL	11	5	0.147	0.19	0.098	0.04	0.075	0.069	0.064
Port Chalmers	George St	10	8.7	BDL	BDL	8	13	9	BDL	BDL	0.03	0.079	0.082	0.124	0.078
Port Chalmers	Watson Pk	8	BDL	BDL	BDL	BDL	BDL	BDL	0.002	0.003	0.124	0.105	0.092	0.147	0.084
Shore Street	Shore Street	BDL	BDL	BDL	BDL	BDL	10	5	0.081	0.031	0.142	0.98	0.142	0.156	0.104
South Dunedin	Portobello Road	4	9.7	BDL	BDL	BDL	BDL	BDL	0.003	0.049	0.177	0.151	0.045	0.096	0.207
Andersons Bay	Teviot Street	8	4.4	BDL	6.4	BDL	7	8	BDL	0.006	0.096	0.135	0.117	0.103	0.112
Andersons Bay	Midland Street	BDL	BDL	BDL	BDL	4	BDL	5	BDL	0.004	0.132	0.218	0.197	0.174	0.145
Orari Street	Orari Street	BDL	11	BDL	BDL	17	BDL	BDL	BDL	0.005	0.11	0.052	0.081	0.094	0.038
Kitchener Street	Kitchener Street	9	BDL	BDL	BDL	22	11	BDL	0.18	0.029	0.072	0.023	0.047	0.052	0.027
Mason Street	Mason Street	5	7.9	BDL	BDL	BDL	BDL	BDL	0.007	0.07	0.051	0.156	0.026	0.043	0.058
Ravensbourne	Ravensbourne Rd		8.8	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.096	0.136	0.014	0.23	0.088
Halsey Street	Bauchop Street	4	BDL	BDL	BDL	BDL	BDL	BDL	2.028	4.92	0.031	0.067	0.017	0.019	0.033
Halsey Street	Halsey Street	9	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.004	0.011	0.061	0.025	0.038	0.027
Halsey Street	Wickliffe Street	6	9.5	9.5	BDL	7	BDL	BDL	0.024	0.003	0.021	0.048	0.094	0.121	0.052

Table 2. *continued… 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	E. coli							Faecal Coliforms						
	units	MPN/100ml							cfu/100ml						
	Outfall	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013
St Clair	Second Beach	560	6800	14000	4800	9000	300	1300	560	8300	14000	92000	9000	300	1300
Port Chalmers	George St	1400	930	1000	1100	600	6000	2300	1400	1400	1000	1100	600	6000	2300
Port Chalmers	Watson Pk	14000	150	10	>1600	1000	5900	1300	39000	150	10	>1600	1000	5900	1300
Shore Street	Shore Street	300	5100	16000	7000	110	11000	780	300	5100	16000	9400	110	11000	780
South Dunedin	Portobello Road	460	5000	2800	54000	6000	280	3300	590	5000	2800	54000	6000	280	3300
Andersons Bay	Teviot Street	7	120000	210	16000	300	3000	200	7	240000	210	16000	300	3000	200
Andersons Bay	Midland Street	290	130	6000	3500	600	3700	2300	290	130	6000	5400	600	4900	2300
Orari Street	Orari Street	50	6000	210	1700	BDL	1800	3300	80	7000	210	3500	BDL	1800	3300
Kitchener Street	Kitchener Street	13000	70	10000	92000	110	150	7900	13000	70	10000	160000	110	230	7900
Mason Street	Mason Street	22000	26000	50000	350000	48000	32000	200	22000	26000	50000	350000	48000	32000	200
Ravensbourne	Ravensbourne Rd		120	90	11000	130	1300	450	150	130	90	11000	130	1300	450
Halsey Street	Bauchop Street	2200	400	3000	7900	450	17000	1100	2200	400	3000	35000	450	17000	2200
Halsey Street	Halsey Street	9000	1700	70000	17000	78000	26000	92000	9000	1700	70000	92000	78000	26000	92000
Halsey Street	Wickliffe Street	25000	10000	220000	35000	43000	96000	15000	30000	10000	220000	54000	43000	96000	15000
	Primary	Amber	>260						>150						Primary
	Secondary	Red	>550						>1000						Secondary

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, 2011, 2012 and 2013. BDL indicates Below Detectable Limits.*

	Kitchener St							Orari St							Portobello Rd						
	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013
Acenaphthene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00034	0.000024	BDL	0.000015	BDL	BDL
Acepaphthylene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000029	BDL	0.00016	0.000014	0.00044
Anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000008	BDL	0.000044	BDL	0.00011
Benzo[a]anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00015	0.000014	BDL	0.000105	0.000012	0.00014
Benzo[a]pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000017	BDL	0.000167	0.000021	0.00011
Benzo[a]fluorathene + Benzo[j]fluorathene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00012	BDL	BDL	BDL	BDL	0.00018	0.000033	0.000158	0.00024	0.000027	0.00016
Benzo[g,h,i]perylene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00014	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000014	BDL	0.000147	0.000015	BDL
Benzo[k]fluorathene	-	BDL	BDL	BDL	BDL	BDL	BDL	-	BDL	BDL	BDL	BDL	BDL	BDL	-	BDL	BDL	BDL	0.000094	0.000009	BDL
Chrysene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000093	0.00001	0.00012
Dibenzo[a,h]anthracene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000026	BDL	BDL
Fluoranthene	BDL	BDL	BDL	0.00015	BDL	BDL	BDL	BDL	0.00011	BDL	0.00017	BDL	BDL	BDL	BDL	0.00028	0.00001	BDL	0.000182	0.000024	0.00045
Fluorene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000017	BDL	BDL
Indeno[1,2,3-c,d]pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000013	BDL	0.000107	0.000012	BDL
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00008	BDL	BDL
Phenanthrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000041	BDL	BDL
Pyrene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0001	BDL	BDL	0.00023	BDL	BDL	BDL	BDL	0.00037	0.000011	BDL	0.00016	0.000022	0.0003
Total PAH	0.00	0.00	BDL	0.0001	BDL	BDL	BDL	0.00	0.00025	BDL	0.0005	BDL	BDL	BDL	BDL	0.00132	0.00017	0.00016	0.00168	0.000166	0.00183

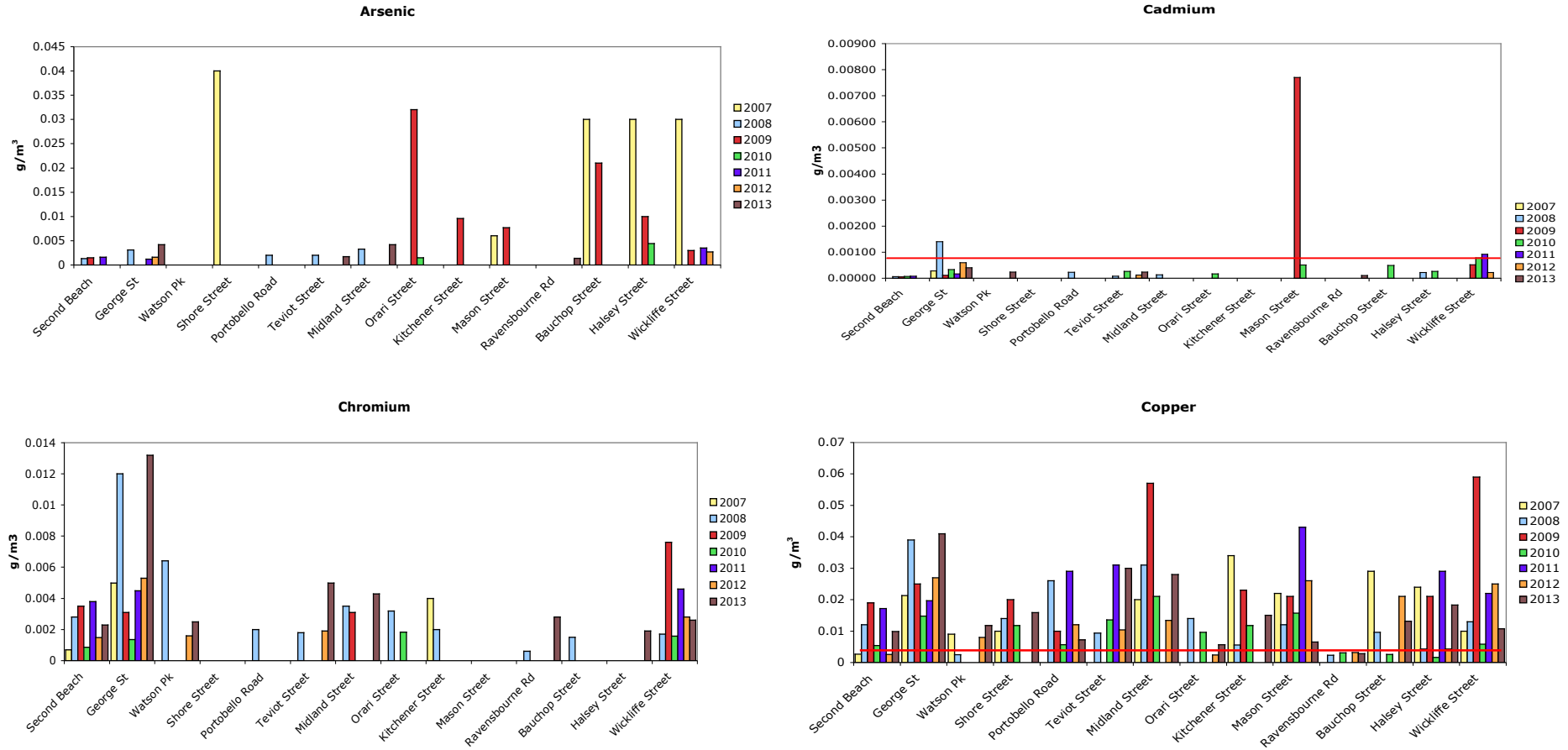

Figure 4. *Graphical representation of contaminant levels in stormwater at outfalls around upper Otago Harbour in 2007, 2008, 2009, 2010, 2011, 2012 and 2013. Red line indicates ANZECC trigger level for protection of 80% of species.*

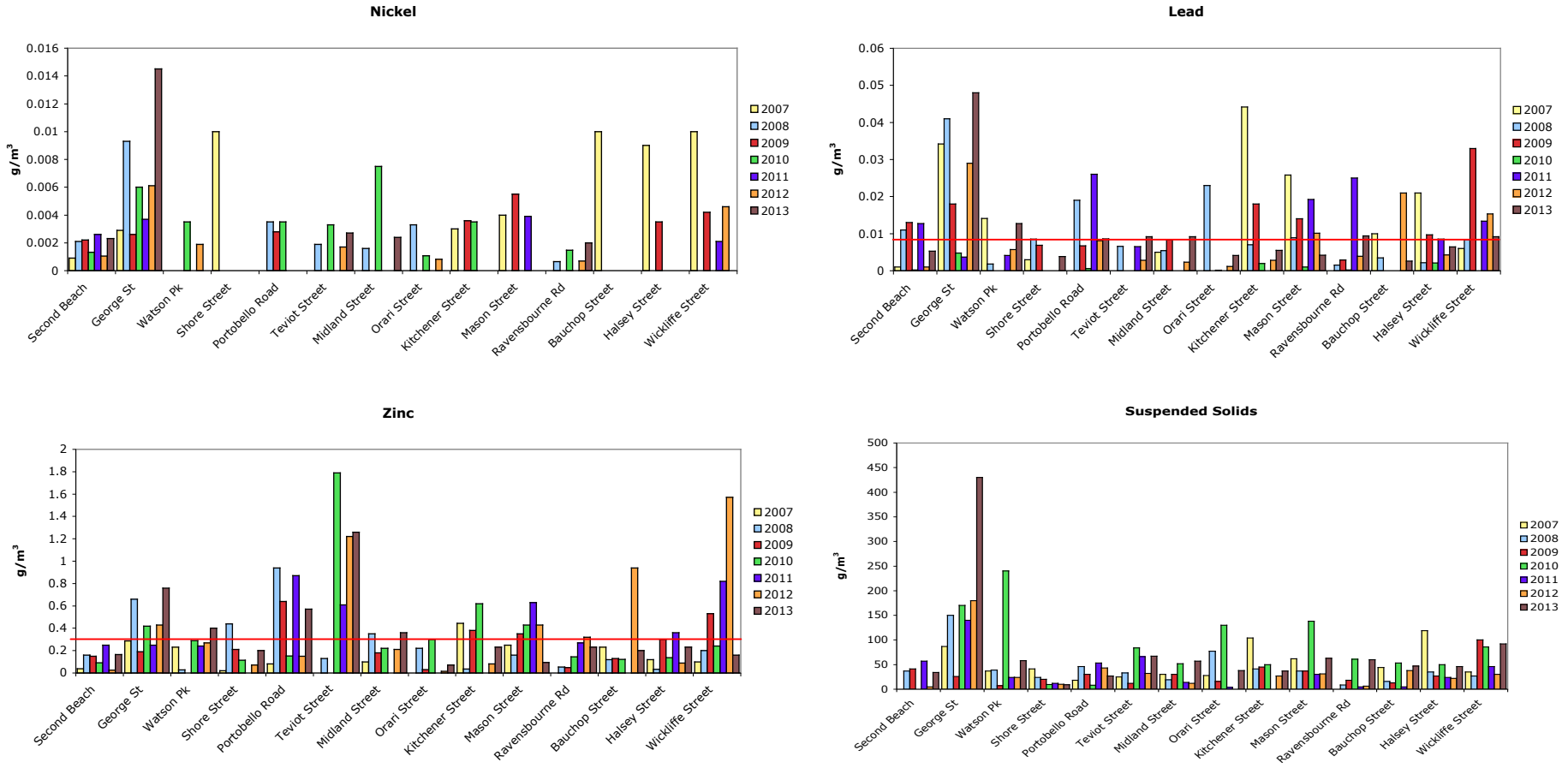

Figure 4. (continued….)

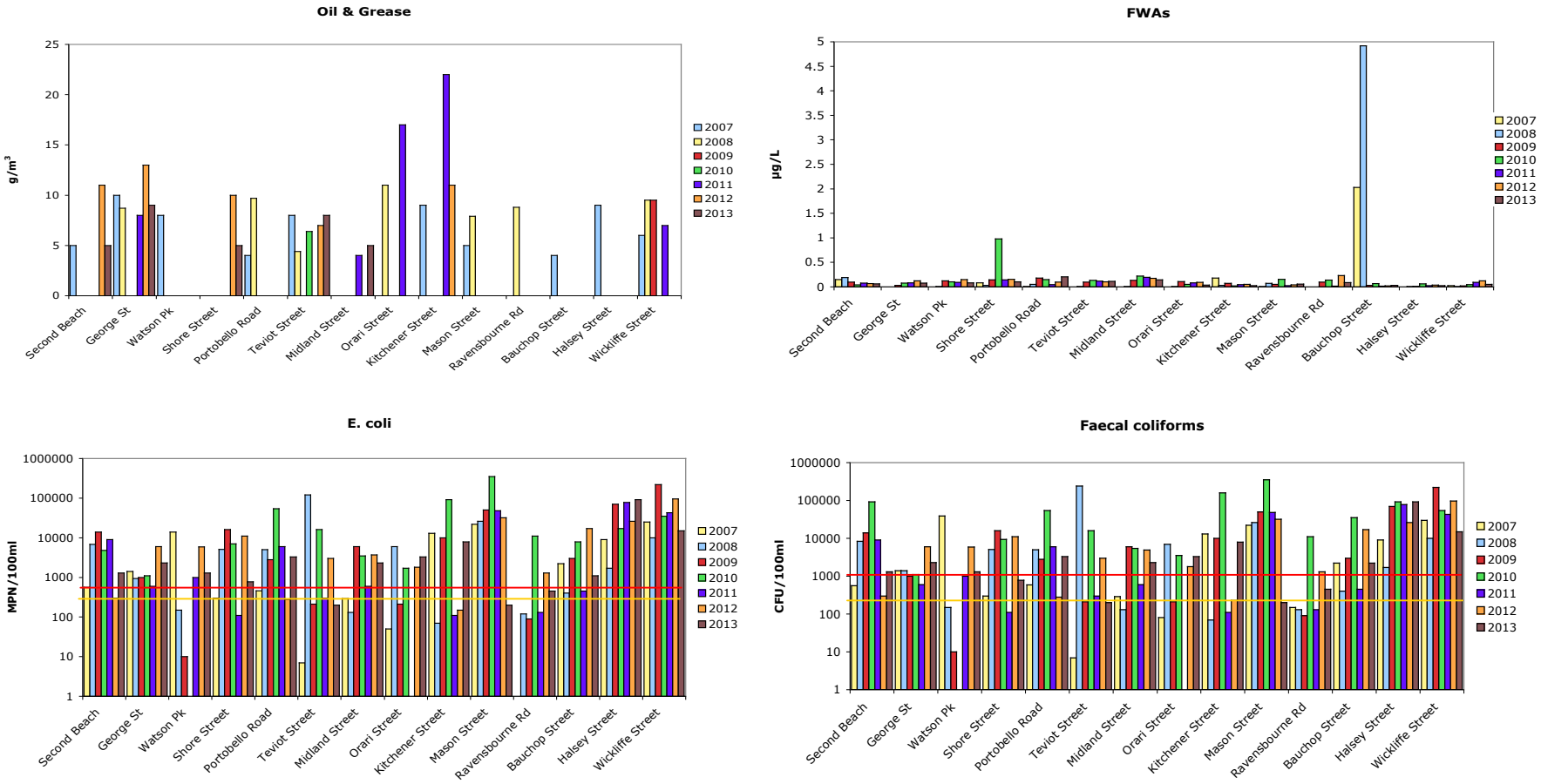

Figure 4. ***(continued)*** *Graphical representation of contaminant levels in stormwater at outfalls around upper Otago Harbour in 2007, 2008, 2009, 2010, 2011, 2012 and 2013. For microbiological graphs amber line indicates guideline for primary contact, red line indicates guideline for secondary contact.* ***Note log scale on Y axis of microbiological graphs.***

3.2 Sediments

Sediments were sampled on 30th May 2013 at sites detailed in Figure 2. As in the past, 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, as in past years 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 within the range observed for previous years. Portobello Road, cadmium and lead at Shore Street, nickel, lead and zinc at Orari Street, and copper at White Street which are all higher than last year (Table 4, Figure 5). The site that most notably flies against this trend is Wickliffe Street, at which levels of all contaminants except chromium are lower than they have ever been in the past. Sites at more remote locations (e.g. <100m from outfalls, such as Rowing Club, Boatshed, Cove Drainage and Retaining Wall) show quite variable levels of contaminants with some metals being higher than last year while others are lower.

This year, ANZECC high trigger values are exceeded only by cadmium, lead, zinc and PAHs at Portobello Road, and by zinc at Wickliffe Street, White Street, Kitchener Street, Orari Street, Shore Street and Boatshed (Table 4). Copper, nickel, lead, zinc and PAHs exceed the ANZECC low trigger value at most sites.

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 5). PAHs in sediments were lower this year than last year at the Wickliffe Street outfall and also at the White Street

and Portobello Road sites. Conversely PAH levels were higher than in the past at the Rowing Club, Orari Street, Shore Street and the 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. 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 calm day.

Microbial contamination in sediment is relatively low at most outfalls with just Wickliffe Street, Shore Street and Orari Street having high numbers of enterococci and just 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 seven 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. Shaded cells show sites where contaminant levels exceed either ANZECC Low (orange) or High (pink) trigger levels. Sites that are sampled only 5 yearly are not graphed, but green shading indicates where these sites are lower than at any time in the past.*

	As							Cd							Cr							Cu						
Units	mg/kg dry wt							mg/kg dry wt							mg/kg dry wt							mg/kg dry wt						
Parameter	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013
Rowing Club	10.6	9.8	7.3	13.0	11.6	8.0	15	0.2	0.2	0.1	0.2	0.1	0.2		17.6	12.0	16.0	14.0	11.6	20.0	19	14	13	14	9	12	16	13
Wickliffe	17.3	11.0	6.9	9.0	14.3	11.0	4	0.6	0.7	0.8	0.7	0.7	0.8	0.12	38.0	34.0	16.0	27.0	30.0	31.0	34	121	68	50	58	86	75	30
White St	11.6	18.0	5.4	6.0	8.3	8.0	8	0.3	0.2	0.2	0.1	0.1	0.2	0.21	68.5	56.0	26.0	19.0	30.0	43.0	39	433	160	170	78	98	149	250
Kitchener St	4.6	7.5	7.0	9.0	4.5	12.0	7	0.4	0.4	0.3	0.3	0.3	0.5	0.5	22.6	18.0	98.0	22.0	18.3	34.0	23	70	56	90	37	54	81	70
Orari St	18.6	4.3	20.0	5.0	2.1	4.0	7	0.3	0.1	0.9	0.2	0.1	0.3	0.46	0.3	16.0	37.0	16.0	9.4	26.0	48	25	13	61	11	7	28	58
Orari 100	13.7					10.7		0.4					0.32		26.3					22.0		25.9					20.0	
Midland 200	15.4					11.2		0.3					0.42		22.4					21.0		19.0					20.0	
Portobello Rd	29.0	23.0	24.0	15.0	28.0	42.0	46	1.8	1.8	2.0	1.5	2.6	3.1	2.8	60.0	54.0	50.0	36.0	67.0	82.0	79	169	160	190	123	176	220	198
PR 200	17.4					18.3		0.5					0.43		41.8					41.0		19.0					20.0	
Shore St	9.5	7.1	6.2	6.0	2.3	5.0	7	0.4	0.3	0.3	0.3	0.2	0.3	0.84	21.8	16.0	18.0	19.0	5.8	12.0	20	51	44	41	35	11	25	51
Boatshed	27.4	16.0	17.0	15.0	16.2	20.0	21	0.3	0.2	0.2	0.3	0.6	0.3	0.34	41.7	19.0	26.0	31.0	34.0	38.0	26	108	33	49	35	53	55	47
Cove Drainage	21.5	17.0	19.0	13.0	9.5	17.0	15	0.1	0.1	0.4	<0.1	0.2	<.1	0.11	15.8	35.0	32.0	19.0	21.0	27.0	18	11	19	38	11	14	20	13
Retaining wall	25.3	36.0	24.0	36.0	39.0	24.0	17	0.1	0.2	<0.1	<0.1	0.1	0.1	0.22	23.6	31.0	39.0	23.0	24.0	27.0	26	13	19	17	10	11	11	19
RW 300	16.2					15.2		0.3					0.15		27					28.0		15.2					14.7	
W/W centre	11.1					15.1		0.2					0.11		30.8					25.0		15.3					13.0	
UHB Centre	10.5					9.1		0.2					0.21		24.3					25.0		15.2					21.0	
ANZECC Low trigger value	20							1.5							80							65						
ANZECC high trigger value	70							10							370							270						

	Ni							Pb							Zn						
Units	mg/kg dry wt							mg/kg dry wt							mg/kg dry wt						
Parameter	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013
Rowing Club	11.3	14.0	13.0	11.0	12.1	14.0	10	18.9	27	27	28	19	27	38	101	130	160	149	109	127	170
Wickliffe	19.2	23.0	13.0	17.0	15.9	17.0	8	76.1	140	77	92	127	130	41	412	740	810	740	700	770	360
White St	29.5	21.0	11.0	8.0	14.5	18.0	12	147.0	180	170	124	147	95	126	4450	2500	2400	1280	1650	2700	2400
Kitchener St	10.6	12.0	15.0	12.0	10.6	16.0	10	117.9	97	130	155	132	220	210	249	280	300	280	260	530	550
Orari St	23.6	8.1	16.0	8.0	5.3	16.0	20	12.8	39	120	35	17	72	142	68	130	680	157	69	350	530
Orari 100	12.6					11.5		170					37		227					197	
Midland 200	10.7					10.2		36					38		165					270	
Portobello Rd	20.4	18.0	26.0	19.0	24.0	19.0	18	306.0	330	290	193	310	470	420	1493	1400	1600	1040	1410	2400	2000
PR 200	17.3					18.0		81.3					79		309					310	
Shore St	10.7	9.0	11.0	10.0	5.2	7.0	10	113.0	110	79	85	36	78	123	484	300	330	350	210	290	520
Boatshed	24.5	16.0	17.0	16.0	18.5	19.0	15	112.0	800	170	86	89	91	114	339	370	360	290	300	340	360
Cove Drainage	23.5	44.0	23.0	19.0	12.8	34.0	23	19.7	20	55	18	44	32	14.8	99	150	270	125	119	156	141
Retaining wall	15.9	25.0	26.0	18.0	13.2	16.0	20	26.9	27	42	24	23	27	54	141	170	150	152	138	112	220
RW 300	12.4					25.0		6.7					36		131					128	
W/W centre	14.6					21.0		5.6					25		168					117	
UHB Centre	11.3					16.0		23					40		119					157	
ANZECC Low trigger value	21							50							200						
ANZECC high trigger value	52							220							410						

Table 4. *Continued…*

	PAH							Enterococci							Faecal coliforms						
Units	mg/kg dry wt							MPN/g							MPN/g						
Parameter	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013
Rowing Club	7.0	5.8	0.5	3.7	0.1	0.7	28.5	2	11	<2	<3	8	BDL	49	<2	17	5	2	<2	BDL	2
Wickliffe	9.2	1.2	7.3	7.2	11.3	4.6	2	580	>1600	330	<3	>160	7	540	2	540	33	540	110	13	540
White St	13.0	11.1	15.9	6.5	5.4	10.7	9.66	4	2	<2	23	35	BDL	23	<2	<2	<2	5	<2	2	2
Kitchener St	8.9	140.5	4.8	5.0	5.5	10.0	11.75	66	920	5	<3	>160	12	49	20	13	70	<2	49	240	5
Orari St	10.2	12.6	28.3	9.3	4.3	10.4	22.46	<2	8	23	<3	54	9	920	23000	4	33	33	17	8	79
Orari 100	6.67					6.55		3600					BDL							BDL	
Midland 200	7.24					7.12		20000					BDL							BDL	
Portobello Rd	436.3	250.3	525.2	194.1	482.0	767.1	651.2	727	170	<2	<3	16	2	46	23	43	2	21	2	46	13
PR 200	8.97					9.16		66000					BDL							BDL	
Shore St	9.6	21.0	8.6	10.5	4.1	14.2	15.65	90	>1600	<2	460	35	7	350	<2	540	<2	130	49	79	22
Boatshed	6.7	5.5	38.8	7.9	40.4	9.7	17.28	34	33	33	<3	54	BDL	49	<2	2	79	5	22	2	BDL
Cove Drainage	0.4	0.0	0.1	0.1	1.0	1.4	4.61	8	17	<2	<3	35	BDL	49	2	8	<2	<2	6	BDL	BDL
Retaining wall	0.3	3.9	0.0	9.4	0.2	0.2	0.52	<2	8	<18	<3	8	BDL	4	2	<2	33	<2	2	BDL	BDL
RW 300	0.30					0.28		<2					BDL							BDL	
W/W centre	0.34					0.36		<2					BDL							BDL	
UHB Centre	0.65					0.67		24000					BDL							BDL	
ANZECC Low trigger value	4																				
ANZECC high trigger value	45																				

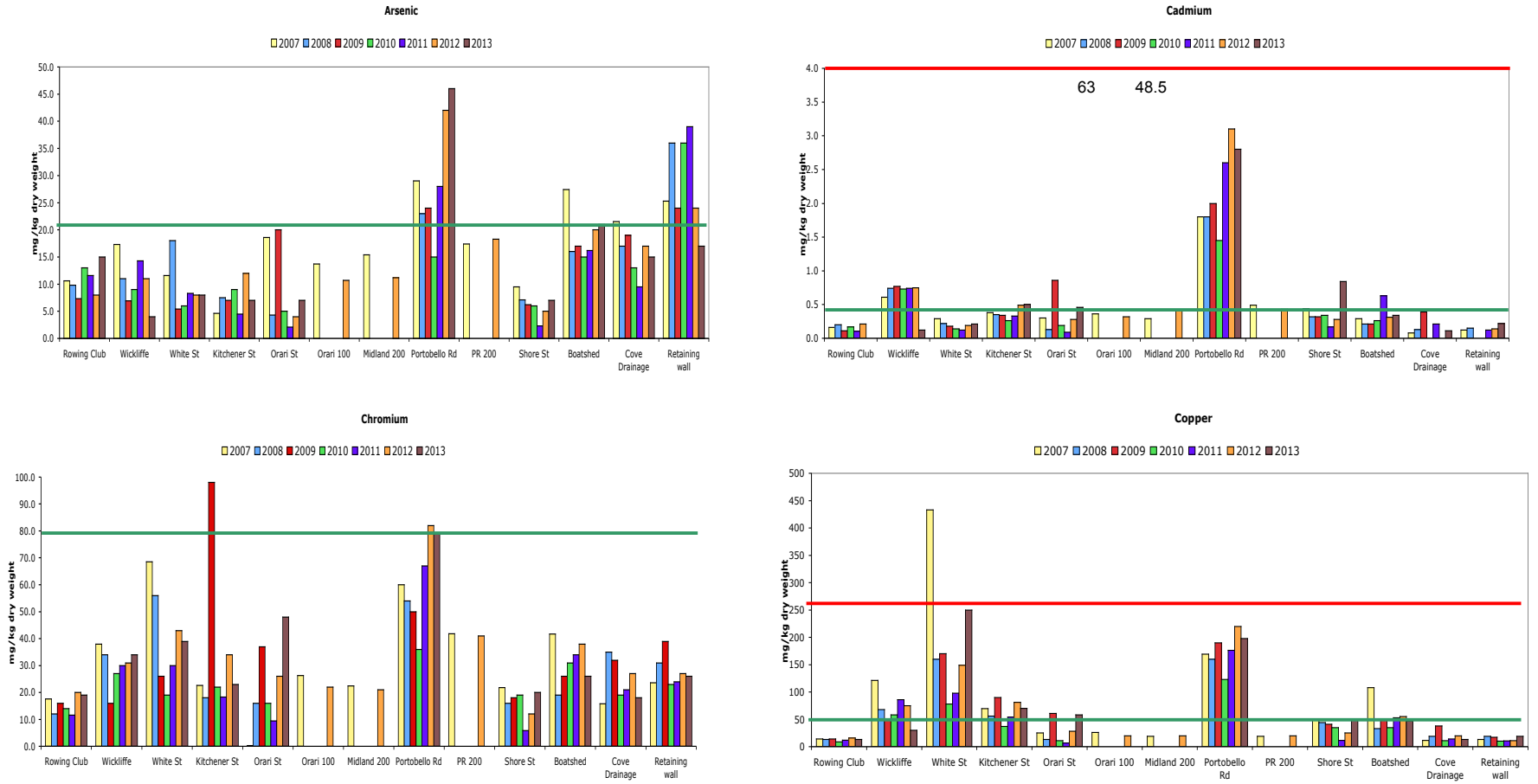

Figure 5. *Graphical representation of contaminant levels in sediment at sampling sites around upper Otago Harbour in 2007, 2008, 2009, 2010, 2011, 2012 and 2013. Green line indicates ANZECC low trigger level, red line is high trigger level.*

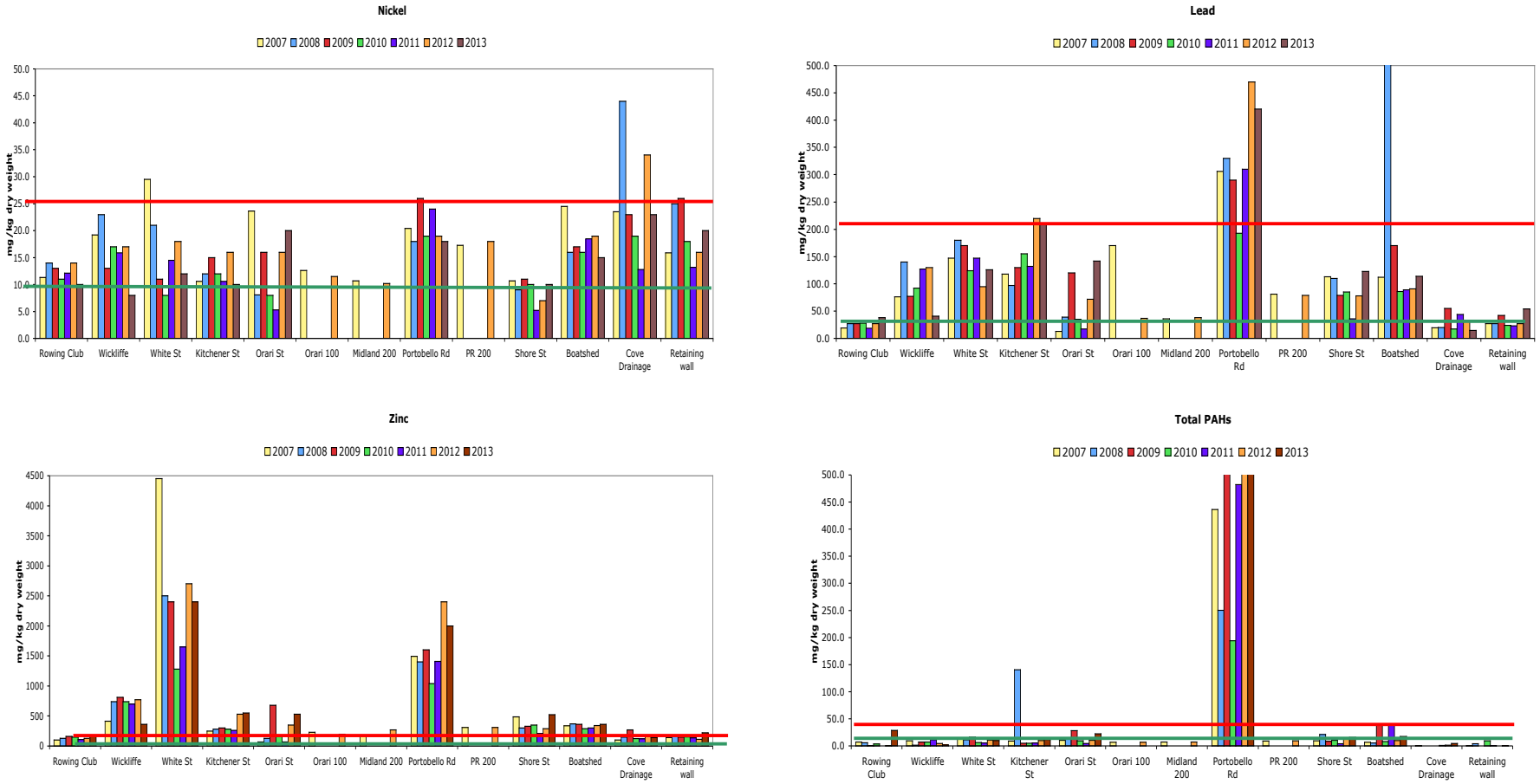

Figure 5 (continued). *Graphical representation of contaminant levels in sediment at sampling sites around upper Otago Harbour in 2007, 2008, 2009, 2010, 2011, 2012 and 2013. Green line indicates ANZECC low trigger level, red line is high trigger level.*

3.3 Biological Monitoring

On 27th March 2013 biological sampling was carried out at the Orari Street, Kitchener Street and Portobello Road, outfalls. The tide was moderately low at 1.06m below mean sea level.

There was a low diversity of green and red algae at all sites, with Orari Street having the highest diversity (6 taxa) and Kitchener Street having the lowest diversity (3 taxa) (Tables 5-7). Percentage cover was generally low at all sites with <20m from the Portobello road having very little algal cover (Tables 5-7). Cover was highest at both sites near the Orari Street outfall with occasional clumps of *Ulva lactuca* and *Gracilaria chilensis* present (Table 6). Overall, cover at all sites was similar to previous years (Stewart 2007a, Stewart 2008c, Stewart 2009, 2010, 2011, 2012).

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		2	2			2
Ceramium uncinatum						
Euptilota formosissima						
Gracilaria chilensis						
Lenormandia chauvinii		1	1		1	
Lomentaria umbellata				1	1	
Griffithsia						

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

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						
Ulva lactuca	2	4	1			1
Ceramium uncinatum						
Euptilota formosissima				1		1
Gracilaria chilensis	1	1		1		
Lenormandia chauvinii						
Lomentaria umbellata			1		1	
Griffithsia						

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

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	1		1			
Ceramium uncinatum						
Euptilota formosissima	1		1			
Gracilaria chilensis		1			1	
Lenormandia chauvinii						
Lomentaria umbellata						
Griffithsia						

	Site 1			Site 2		
Algae (% cover) >50m	Q1	Q2	Q3	Q1	Q2	Q3
Enteromorpha intestinalis						
Codium fragilis						
Ulva lactuca			2		1	1
Ceramium uncinatum						
Euptilota formosissima	2	7			3	1
Gracilaria chilensis						
Lenormandia chauvinii		1				
Lomentaria umbellata			1	1		
Griffithsia						

Epifauna was moderately abundant at all three outfalls (Tables 8-10), although somewhat less so than last year. 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. Numbers of animals per square metre was higher at more than 50m distant from the Kitchener Street outfall than within 20m of the outfall. This is the same as what was found last year and is largely due to high numbers of tube worms and *Micrelenchus* in the >50m quadrats (Table 8). For both Orari Street and Portobello Road epifaunal numbers per square metre were slightly higher at <20m than at >50m. This echoes last years result for both sites. In 2010 numbers were similar irrespective of distance at both outfalls. As for last year, the 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).

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											8				
Barnacles															
Eminius modestus												24		18	
Snails and Chitons															
Melagraphis aethiops				1								1			
Micrelenchus tenebrosus	8	2	4	2	12	6	9	1	10	1		5	5	9	
Notoacmea spp															
Bivalves															
Ostrea heffordi	1	1	5		2		3	1	2	1			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		26	12			24		15	21	2		8		9	
Barnacles															
Eminius modestus	14		6				2	9		2		2		7	
Snails and Chitons															
Micrelenchus tenebrosus	5	6		8	6		3	3		18	9	6	1		8
Melagraphis aethiops					1			1			1				
Chiton glaucus				1											
Notoacmea spp								1							
Bivalves															
Mytilus galloprovincialis							1								
Austrovenus stutchburyi	2			3	1		1		2			1	1	3	
Ostrea heffordi	1	1		2	5		2		5			8	8	1	

Diversity within animal communities was variable with Kitchener and Orari Streets showing slightly greater diversity further from the outfall while Portobello Road showed higher diversity further away (Table 11). Diversity was lowest at Orari Street. Overall diversity has not changed from that observed in previous years ($F_{6,14}$ = 0.238, p = 0.956 for <20m sites; $F_{6,14}$ =

0.258, p = 0.947 for >50m sites). Neither is there a significant difference in epifaunal diversity among sites <20m from the outfalls and sites >50m from the outfalls ($F_{1,4}$ = 0.028, p = 0.875).

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															
Micrelenchus tenebrosus	3	1	1	1	3	4	1	1	2	5	1	7		1	6
Zeacumantus subcarinatus				1						1					
Cominella galndiformis															
Bivalves															
Austrovenus stutchburyi	3	2	5	1	4	2	3	1	1	8	4	7	2	5	1
Macomona liliana									1			1			

>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
Snails and Chitons															
Buccinulum vittatum															
Cominella glandiformis							1	1					1		
Zeacumantus subcarinatus	1		1												
Micrelenchus tenebrosus	2	1			2	2			2	1	3	2	1	4	
Crustaceans															
Macrophthalmus hirtipes															
Bivalves															
Austrovenus stutchburyi	2	1	4	5	1	2	1	1	1		1	2	3	8	4
Macomona liliana						1									

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		5	18				2		8			26	3		
Barnacles															
Eminius modestus			15			2	2		1						
Snails and Chitons															
Amphibola crenata															
Maoricolpus roseus															
Melagraphis aethiops		2						1	1					1	
Micrelenchus tenebrosus	3	1	1	1			4	2	4		3		3	4	
Bivalves															
Austrovenus stutchburyi	1						2			1		2		2	
Macomona liliana											1				
Ostrea heffordi	2	5				4	1				2		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
Snails and Chitons															
Buccinulum vittatum															
Cominella glandiformis				1								1			
Melagraphis aethiops						1			1				1		
Micrelenchus tenebrosus	3		2		1	1		1	3	1		2	2		5
Bivalves															
Austrovenus stutchburyi		1		2					1						
Ostrea heffordi			1				2		1						

Table 11. *Diversity (H') of epifauna within 20m and greater than 50m of the Kitchener Street, Orari Street and Portobello Road outfalls. 2012 data compared with 2007, 2008, 2009, 2010. 2011 and 2012 data.*

	<20m						
Site	2007	2008	2009	2010	2011	2012	2013
Kitchener Street	0.48	0.48	0.55	0.53	0.55	0.51	0.52
Orari Street	0.36	0.37	0.3	0.12	0.29	0.31	0.38
Portobello Road	0.53	0.33	0.62	0.58	0.57	0.53	0.65

	>50m						
Site	2007	2008	2009	2010	2011	2012	2013
Kitchener Street	0.71	0.57	0.42	0.2	0.57	0.57	0.65
Orari Street	0.05	0.25	0.31	0.16	0.15	0.39	0.44
Portobello Road	0.5	0.63	0.84	0.64	0.58	0.46	0.51

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 ($F_{6,14}$ = 0.18, p = 0.978). 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).

Table 12. *Size of cockles collected at Kitchener Street, Orari Street and Portobello Road in 2007, 2008, 2009, 2010, 2011, 2012 and 2013.*

	2007			2008			2009			2010		
	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	59	18.8	37.1	54.0	16.4	35.5	80.0	19.6	38.1	63.0	17.7	36.6
Orari St	62	12.3	32.4	74.0	8.7	29.8	80.0	12.3	33.0	82.0	10.2	30.2
Portobello	64	9.4	30.1	74.0	7.9	28.3	80.0	10.0	30.1	80.0	7.7	28.2

	2011			2012			2013		
	n =	Mean weight (g)	Mean length (mm)	n =	Mean weight (g)	Mean length (mm)	n =	Mean weight (g)	Mean length (mm)
Kitchener	106.0	19.5	37.5	73.0	18.1	36.1	67	15.5	34.2
Orari St	73.0	9.6	30.0	83.0	11.2	31.5	83	10.1	30.5
Portobello	103.0	8.8	28.8	92.0	9.0	28.9	47	9.5	29.6

Infauna at all three sites was dominated by polychaete worms with glyceriids being the most abundant. Spionids were also moderately common at all three sites (Tables 14-16). Nereidids worms were present at Orari and Kitchener Streets, but totally absent from the Portobello Road site. Phoxocephalid amphipods were moderately common at all sites, but less common than they were in 2010. Lysianassid amphipods were common at Orari Street. 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. Cockle density was moderate at the >50m site at Kitchener Street and higher at both Portobello Road sites than it was last year. Tanaid crustaceans, which were found in moderate numbers at most sites in 2010, were observed at just the <20m sites at Kitchener Street and Orari Street this year. This differs from last year when they were found at just Orari Street.

Table 13. *Diversity (H') of infauna within 20m and greater than 50m of the Kitchener Street, Orari Street and Portobello Road outfalls. 2012 data compared with 2007, 2008, 2009, 2010, 2011, 2012 and 2013 data.*

	<20m						
Site	2007	2008	2009	2010	2011	2012	2013
Kitchener Street	0.67	0.53	0.44	0.9	0.81	0.9	0.91
Orari Street	1.01	0.86	0.74	0.98	0.99	1.14	1.04
Portobello Road	0.74	0.67	0.8	1.04	0.69	0.7	0.98

	>50m						
Site	2007	2008	2009	2010	2011	2012	2013
Kitchener Street	0.98	0.73	0.56	0.9	0.94	1.08	0.88
Orari Street	0.88	0.87	0.74	1.03	0.98	1	1.03
Portobello Road	0.84	0.68	0.76	1.08	0.99	0.9	0.92

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

Kitchener Street			Location	<20m							>50m						
2013				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																
		Cirratulidae											1				1
		Capitellidae			3					3							
		Eunicidae														1	1
		Glyceridae		4	7	19	2	8	1	41	7	1	2	1	1	3	15
		Maldanidae						2		2							
		Nephtyidae			1	1	1			3							
		Nereididae		3	3		2	3	5	16	1			3	1	2	7
		Orbiniidae		1						1						1	1
		Spionidae		4	4		2	3	1	14	10		3	3	2	1	19
Crustacea																	
	Amphipoda	Haustoriidae															
		Jassidae		1						1							
		Lysianassidae					1	2		3			1		1	1	3
		Oedicerotidae		2		1				3	2				1		3
		Phoxocephalidae			4		1			5	1	3	1	1	1	3	10
	Tanaidacea				1		1			2							
	Ostracoda				1					1							
Mollusca																	
	Gastropoda	Trochidae	*Micrelenchus tenebrosus*											1	2		3
	Bivalvia																
		Veneridae															
			Austrovenus stutchburyi		1	2	2	1		6					1		1
		Mesodesmatidae															
			Paphies subtriangulata	3						3						2	1
		Tellinidae															
			Macomona liliana		1		1		1	3				1			1
		Animals per core		18	26	23	13	19	8		21	4	8	10	10	14	
		Animals per m^2		4014	5798	5129	2899	4237	1784	3976.8	4683	892	1784	2230	2230	3122	2490
		Species per site		7	10	4	9	6	4	16	5	2	5	6	8	8	13

Numbers of animals per square metre were slightly higher than last year, but similar to other surveys, and ranged from 892 at replicate 2, Site 1 at >50mm from

the Kitchener Street and at replicate 6, Site 2 at the Portobello Road outfall, to 6467 at replicate 2, Site 1 at <20m from the Orari Street outfall. The higher value was largely due to high abundance of *Austrovenus stutchburyi* 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 ($F_{6,14}$ = 1.949, p = 0.142). For >50m sites, however, there has been a significant difference observed over the past three years ($F_{6,14}$ = 6.303, p = 0.002), with diversity being higher 2012 and 2013 than in previous surveys, especially 2008 and 2009, at each of the three sites. That being said, there is no significant difference in diversity among the past two years for the <20m site ($F_{1,4}$ = 0.228, p = 0.658) or for the >50m ($F_{1,4}$ = 0.529, p = 0.507), or between the <20m locations and the >50m locations at any of the sites. ($F_{1,4}$ = 324, p = 0.599) (Table 13).

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

Orari Street			Location	<20m							>50m						
2013				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		2	7	4	4	2	3	22	5	1	2	3	6	6	23
		Maldanidae				2		1		3	2		1				3
		Nephtyidae					5		1	6					1	1	2
		Nereidae		2			2	2		6		1	1	1	1		4
		Nereididae		4				1		5	6	2		3	1	1	13
		Cirratulidae				1				1							
		Spionidae		1	2	1				4	3	1	2	1		3	10
		Syllidae													1		1
Hemichordata																	
	Enteropneusta			1			1	1		3						1	1
Nemertea					2	1				3							
Sipuncula						1				1		1					1
Crustacea																	
	Decapoda																
			Helice crassa									1					1
	Amphipoda	Haustoriidae															
		Jassidae									1						1
		Lysianassidae			2	4				6			3			3	6
		Phoxocephalidae		1	1	2				4	1	1		2		1	5
	Isopoda																
			Isocladus armatus									1					1
	Malacostraca		*Macrophthalmus hirtipes*	1				1		2							
	Tanaidacea				3	1				4							
Mollusca																	
	Gastropoda	Cominellidae															
			Cominella glandiformis		1					1							
	Bivalvia																
		Veneridae															
			Austrovenus stutchburyi	5	10	2	3	5	4	29	1	5	3	3	1	5	18
			Nucula spp.		1				1	2	2	2	2	2	1	3	12
		Tellinidae															
			Macomona liliana	1		1	1		1	4	1	1	1	1	1		5
		Animals per core		18	29	20	16	13	10		22	17	15	16	13	24	
		Animals per m^2		4014	6467	4460	3568	2899	2230	3940	4906	3791	3345	3568	2899	5352	3977
		Species per site		9	9	11	6	7	5	18	9	11	8	8	8	9	17

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

Portobello Rd			Location	<20m							>50m						
2013				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																
		Capitellidae											1				1
		Glyceridae		3	6	2		1	8	20	3	2	5	8	3	2	23
		Maldanidae		1	1		3	2	1	8							
		Nephtyidae							3	3		1	2	3			6
		Nereidae			1		3	1		5			1	1		1	3
		Cirratulidae														1	1
		Orbiniidae				1				1							
		Spionidae						1		1		1	5	4			10
Hemichordata											2	1					3
	Enteropneusta					1			1	2							
Nemertea					8					8							
Crustacea																	
	Decapoda		*Macrophthalmus hirtipes*										2				2
	Amphipoda	Haustoriidae															
		Jassidae											1				1
		Oedicerotidae												1			1
		Phoxocephalidae		1	1	1			2	5				2			2
	Ostracoda														1		1
Mollusca																	
	Polyplacophora		*Chiton glaucus*										1				1
	Gastropoda	Batilliidae															
			Zeacumantus subcarinatus		1					1							
	Bivalvia																
		Veneridae															
			Austrovenus stutchburyi	1		1	3	2		7	2		2	5	2		11
			Nucula			1				1							
		Tellinidae															
			Macomona liliana			1	1			2				2			2
	Nematoda				2	5				7							
		Animals per core		6	20	13	10	7	15		7	5	20	26	6	4	
		Animals per m^2		1338	4460	2899	2230	1561	3345	2639	1561	1115	4460	5798	1338	892	2527.3
		Species per site		4	7	8	4	5	5	14	3	4	9	8	3	3	15

3.4 Analyses of Cockle, Mussels, Fish and Octopus flesh

Like last year and in 2010, levels of heavy metals in cockle flesh showed no clear trend for contamination in moving from Kitchener Street to Portobello Road (Table 17). However, it could be argued that levels of most metals are very slightly lower at Orari Street. 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 in 2011, perhaps an investigation of cockle sizes at a site with similar fresh water and tidal exposure is merited.

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, 2011, 2012 and 2013. 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
			2012	8.0	8.8	5.3
			2013	1.48	2.5	2.4
	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
	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
	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
	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
			2012	0.46	0.55	0.51
			2013	0.67	0.51	0.81
	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
	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
			2012	12.8	10.6	12.1
			2013	8.2	5.9	9.4
	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
	Faecal coliforms	MPN/100g	2007	<18	<18	<18
			2008	1300	230	78
			2009	78	<18	<18
			2010	68	68	220
			2011	45	<18	<18
			2012	<18	<18	<18
			2013	NA	NA	NA

Unfortunately, due to a laboratory error, no data for faecal coliform levels in cockles are available this year. However, 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.

As with 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), and, like last year, cadmium levels were slightly higher and chromium levels slightly lower than in cockles. Faecal coliform levels were not recorded this year due to an error at Hill Laboratories. Overall, there has been little evidence of heavy metal contamination of shellfish by stormwater at the Second Beach site.

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).

Ten triplefins were caught in unbaited fish traps set off the Mason Street wharf on 27th May 2013. 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 lower than those caught last year and lower than in 2007 and 2008 (Table 21). Levels of all contaminants in fish this year were generally similar to those observed in previous surveys. Overall, levels of PAHs and of all metals except lead and zinc were lower in fish than in cockles. Levels of

chromium in fish were somewhat higher this year, but continue to be low in Portobello Road cockles (Tables 17 & 22).

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	1.60
			2008	1.90
			2009	1.90
			2010	1.45
			2011	1.71
			2012	1.65
			2013	1.18
	Cd	mg/kg	2007	0.078
			2008	0.083
			2009	0.084
			2010	0.094
			2011	0.014
			2012	0.105
			2013	0.086
	Cr	mg/kg	2007	0.33
			2008	0.20
			2009	0.11
			2010	0.19
			2011	0.21
			2012	BDL
			2013	0.1
	Cu	mg/kg	2007	1.00
			2008	0.69
			2009	1.50
			2010	0.94
			2011	1.03
			2012	0.89
			2013	0.39
	Ni	mg/kg	2007	0.40
			2008	0.29
			2009	0.28
			2010	0.48
			2011	0.36
			2012	0.31
			2013	0.19
	Pb	mg/kg	2007	0.140
			2008	0.110
			2009	0.200
			2010	0.179
			2011	0.157
			2012	0.103
			2013	0.065
	Zn	mg/kg	2007	12.0
			2008	9.4
			2009	14.0
			2010	9.8
			2011	11.3
			2012	12.2
			2013	5.2
	Faecal coliforms	MPN/100g	2007	<18
			2008	20
			2009	45
			2010	<18
			2011	170
			2012	1300
			2013	NA

This is consistent with the results of surveys in previous years, with the concentration of most contaminants in the fish, with the exception of zinc, being similar to or lower than levels observed in cockles (Table 22). 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 just a single octopus was found this year. However it was over 400m from the Kitchener Street outfall and, as such, was not sampled. Results for octopus from previous years are included in Table 23.

Table 21. *Size and weight of triplefins captured near the Mason Street Stormwater outfall in 2007, 2008, 2009, 2010, 2011, 2012 and 2013. Spotty values in blue shaded cells.*

	2007	2008	2009	2010	2011	2012	2013	2007	2008	2009	2010	2011	2012	2013
	Fish Sizes (mm)							Weight (g)						
	75	70	101	151	74	0	71	4.7	4	13.1	41.3	5.12	4.2	4.5
	71	67	88	72	53	78	60	3.9	2.9	9.8	4.9	1.52	6.5	2.8
	73	46	96	75	64	76	58	4.4	0.9	10.6	5.2	2.71	5.5	2.1
	61	65	71	88	68	66	72	2.2	3	4.5	7.0	3.24	3.6	5.2
	49	63	62	83	87	74	59	1.1	2.7	2.8	7.3	7.28	4.8	2.3
	78	75	81	80	77	88	61	5.3	5.5	6.9	6.5	5.1	8.7	2.8
	77	58	70	78	90	70	48	5.6	2.4	4.1	4.8	9.88	3.9	0.9
	79	67	78	62		44	57	6.1	3.4	6.6	2.5		1.2	2.2
	75	72	79	79		72	58	4.1	4.5	6	6.5		4.2	2.1
	46	83	59	76		78	60	0.9	6.4	2.1	5.1		4.9	2.8
	52	71				64		1.6	4.8				3.1	
	74	68				62		4.6	3.8				3.2	
		72				62			4.8				2.8	
		65				58			2.8				2	
		59				70			2.7				4.4	
		56				66			2.2				3.6	
		60				60			2.4				2.5	
						64							3	
						60							2.5	
						48							1	
Mean =	67.5	65.71	78.50	84.40	73.29	64.00	60.40	3.7	3.48	6.65	9.11	4.98	4.06	2.77
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
			2012	1.09
			2013	1.50
	Cd	mg/kg	2007	0.0047
			2008	0.0047
			2009	0.0110
			2010	0.0091
			2011	0.0060
			2012	0.0020
			2013	0.0090
	Cr	mg/kg	2007	0.05
			2008	BDL
			2009	0.14
			2010	BDL
			2011	BDL
			2012	BDL
			2013	0.22
	Cu	mg/kg	2007	0.54
			2008	0.52
			2009	1.20
			2010	0.38
			2011	0.49
			2012	0.57
			2013	0.79
	Ni	mg/kg	2007	BDL
			2008	BDL
			2009	BDL
			2010	BDL
			2011	0.13
			2012	BDL
			2013	0.19
	Pb	mg/kg	2007	0.140
			2008	0.120
			2009	0.43
			2010	0.14
			2011	0.14
			2012	0.29
			2013	0.48
	Zn	mg/kg	2007	21.00
			2008	20.00
			2009	21.00
			2010	18.10
			2011	19.70
			2012	25.00
			2013	25.00
	PAH	mg/kg	2007	7.0000
			2008	0.0023
			2009	0.0060
			2010	0.0150
			2011	0.0015
			2012	0.0052
			2013	0.0177
	Mean Size	(mm)	2007	67.5
			2008	65.7
			2009	78.5
			2010	84.4
			2011	73.3
			2012	64.0
			2013	60.4
	Mean Weight	(g)	2007	3.7
			2008	3.5
			2009	6.65
			2010	9.11
			2011	4.98
			2012	4.06
			2013	2.8

Table 23. *Contaminant concentrations in the flesh (left) and digestive glands (right) of octopus collected near the Orari Street and Portobello Road Stormwater outfalls.*

	Parameter	Units		Portobello Road	Orari Street
Octopus	As	mg/kg	2007	12.0	7.7
			2008	-	20.0
			2009	4.9	24.0
			2010	-	21.0
			2011	-	-
			2012	-	4.3
	Cd	mg/kg	2007	0.001	0.008
			2008	-	0.0012
			2009	0.019	0.010
			2010	-	0.006
			2011	-	-
			2012	-	0.1
	Cr	mg/kg	2007	<0.02	<0.02
			2008	-	<0.02
			2009	0.15	0.62
			2010	-	<0.10
			2011	-	-
			2012	-	<0.10
	Cu	mg/kg	2007	3.30	3.90
			2008	-	2.60
			2009	7.30	2.60
			2010	-	5.50
			2011	-	-
			2012	-	30.0
	Ni	mg/kg	2007	0.1	0.1
			2008	-	0.023
			2009	<0.10	<0.10
			2010	-	<0.10
			2011	-	-
			2012	-	0.3
	Pb	mg/kg	2007	0.023	0.220
			2008	-	0.029
			2009	0.23	0.11
			2010	-	0.03
			2011	-	-
			2012	-	0.05
	Zn	mg/kg	2007	13.0	14.0
			2008	-	19.0
			2009	20.0	23.0
			2010	-	16.6
			2011	-	-
			2012	-	26.0
	PAH	mg/kg	2007	0.0043	-
			2008	-	0.0127
			2009	0.754	0.026
			2010	-	0.0115
			2011	-	-
			2012	-	0.0057
	Arm span	(mm)	2007	2603	680
			2008	-	2154
			2009	547	2168
			2010	-	1684
			2011	-	-
			2012	-	325
	Weight	(g)	2007	11784	197
			2008	-	10562
			2009	218	11252
			2010	-	3562
			2011	-	-
			2012	-	187

	Parameter	Units		Portobello Road	Orari Street
Octopus (digestive gland)	As	mg/kg	2007	12.0	7.7
			2008	-	13.0
			2009	5.7	22
			2010	-	12.6
			2011	-	-
			2012	-	6.1
	Cd	mg/kg	2007	0.260	3.300
			2008	-	0.066
			2009	1.4	9.6
			2010	-	0.21
			2011	-	-
			2012	-	1.6
	Cr	mg/kg	2007	<0.2	9.2
			2008	-	<0.02
			2009	<0.12	<0.20
			2010	-	<0.10
			2011	-	-
			2012	-	<0.10
	Cu	mg/kg	2007	44.0	740.0
			2008	-	27.0
			2009	230.0	520.0
			2010	-	49.0
			2011	-	-
			2012	-	368.0
	Ni	mg/kg	2007	0.5	5.2
			2008	-	2.8
			2009	1.7	0.66
			2010	-	<0.10
			2011	-	-
			2012	-	2.6
	Pb	mg/kg	2007	0.074	0.440
			2008	-	0.026
			2009	0.25	0.25
			2010	-	0.06
			2011	-	-
			2012	-	0.15
	Zn	mg/kg	2007	26.0	160.0
			2008	-	26.0
			2009	87.0	310.0
			2010	-	47.0
			2011	-	-
			2012	-	284.0
	PAH	mg/kg	2007	0.0599	-
			2008	-	0.0251
			2009	0.26	0.116
			2010	-	0.0291
			2011	-	-
			2012	-	0.0243
	Arm span	(mm)	2007	2603	680
			2008	-	2154
			2009	547	2168
			2010	-	1684
			2011	-	-
			2012	-	325
	Weight	(g)	2007	11784	197
			2008	-	10562
			2009	218	11252
			2010	-	3562
			2011	-	-
			2012	-	187

4. Discussion and Conclusion

In 2013 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 11 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.

There has been a decline in the levels of some contaminants at stormwater outfalls throughout the past 7 years, but a rise in others. The reduction in lead levels continues at some outfalls, but has risen at George Street, Watson Park, Teviot Street and Midland Street. This is a little surprising as one would expect that with the removal of lead from paint and petrol, levels in the environment should be very gradually declining. Any reduction in the levels of other contaminants is extremely inconsistent (e.g. Zn has risen at four sites, but fallen at the remainder) and there is an increase in levels of all metals a few sites (Table 24). Such fluctuations are generally relatively small and may be merely a function of the intensity of the storm events when sampling occurred.

Overall levels of contaminants in sediment appeared to have plateaued, with levels of contaminants at some outfall sites rising slightly while other have decreased slightly. Of some comfort is the fact that contaminant levels at sites more remote from the outfalls show a continued decline, suggesting that existing contaminants may be declining, being buried, or being flushed out of the harbour (Tables 24 and 25). The increased levels of most metals seen in sediment at Wickliffe Street in the past is not apparent this year, with the exception of chromium.

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 is not associated with any one outfall. Low diversity 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 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.

Only after problem areas and problem contaminants have been identified can measures be taken to mitigate any effects. Additional mitigation measures that have been undertaken by the DCC to date include 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. 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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