Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

TECHNICAL REPORT Investigations and Monitoring Group

Sediment quality at muddy intertidal sites in Canterbury

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Community summary

The sediment quality was assessed at muddy intertidal sites in Canterbury. We undertook this assessment to determine what the concentrations of contaminants in the sediments are and if could be influencing intertidal marine life.

We collected sediment samples from 18 sites: Saltwater Creek, Brooklands Lagoon, five sites in the Avon-Heathcote Estuary/Ihutai, four sites in Lyttelton Harbour/Whakaraupō, Port Levy/Koukourarata, Okains Bay, four sites in Akaroa Harbour and the Opihi River mouth. We tested the sediment from these sites to determine the level of selected contaminants: arsenic, copper, chromium, cadmium, mercury, lead, nickel, zinc and hydrocarbons (petrol and oil residues). One criterion for selecting a sampling site was that it had fine, muddy, sediment rather than coarse, sandy, sediment.

To determine whether levels of selected contaminants were caused by human activity, we compared our results to levels in nearby soil. We also compared levels among sites in each of the harbours and within the estuary. Finally, to assess whether the plants and animals of the mudflats could be affected by any contamination, we compared our measurements to national sediment quality guideline values.

We found that sediment from Brooklands Lagoon, Port Levy/Koukourarata, Okains Bay, Opihi River mouth, two sites in Lyttelton Harbour/Whakaraupō, and two sites in Akaroa Harbour is not contaminated. Sediment from the Charlesworth Drain site in the Avon-Heathcote Estuary/Ihutai, the Port Levy/Koukourarata site and two sites in both Lyttelton Harbour/Whakaraupō and Akaroa Harbour may be contaminated as a result of human activities, while sediment from Saltwater Creek and the remaining four sites in the Avon-Heathcote Estuary/Ihutai is definitely contaminated as a result of human activities. Details, including sediment quality results, are presented in site-by-site report cards (Appendix 1).

Levels of arsenic, copper, chromium, cadmium, mercury, lead, nickel and zinc are probably not affecting the plants and animals of any sampling site. However, hydrocarbon contamination is probably negatively affecting the plants and animals of the mudflats at three sites (City Outfall Drain, Mt. Pleasant Yacht Club and Causeway) in the Avon-Heathcote Estuary/Ihutai. We recommend that Environment Canterbury continues to monitor contaminant concentrations at these sampling sites by sampling frequently to determine if concentrations are increasing. Specifically, we recommend that Environment Canterbury undertakes bi-annual sediment quality monitoring at the sites that appear most vulnerable to human impacts and monitoring every six years at the remaining sites.

Executive summary

We collected sediment samples from 18 muddy intertidal sites in Canterbury between July and October 2010 and assessed the quality of the samples by analysing the sediment for eight metals (copper, chromium, cadmium, mercury, lead, nickel and zinc), the metalloid arsenic, and 16 polycyclic aromatic hydrocarbons (PAHs). We also measured sediment grain size distribution and the total organic carbon (TOC) content of each sample.

We selected sample locations based on the potential for contamination and sediment grain size – we needed sites with fine, muddy sediment. Thus, we chose sites at Saltwater Creek, Brooklands Lagoon, five sites in the Avon-Heathcote Estuary/Ihutai, four sites in Lyttelton Harbour/Whakaraupō, Port Levy/Koukourarata, Okains Bay, four sites in Akaroa Harbour and the Opihi River mouth.

To determine whether human activities had an influence on metal and metalloid concentrations, we used two methods. First we compared sample concentrations to background soil concentrations and then we compared them to other sample sites in the same locality where possible (Avon-Heathcote Estuary/Ihutai, Lyttelton Harbour/Whakaraupō, and Akaroa Harbour). Finally, to assess the potential for adverse ecological effects on the mudflats, we compared our metal, metalloid and PAH concentrations to national sediment quality criteria (ANZECC, 2000) guideline values.

Results show that the concentration of one or more metals at Saltwater Creek and four sites (South of Bridge Street, Charlesworth Drain, City Outfall Drain and Mt. Pleasant Yacht Club) in the Avon-Heathcote Estuary/Ihutai are elevated because of human activities. Human activities may also account for elevated metal and metalloid concentrations at the fifth site in the Avon-Heathcote Estuary/Ihutai, the site at Port Levy/Koukourarata and two sites in both Lyttelton Harbour/Whakaraupō and Akaroa Harbour. However, all metal and metalloid concentrations were below the low trigger value (ANZECC, 2000) so they are unlikely to be having an adverse impact on aquatic life. Details, including sediment quality results, are presented in site-by-site report cards (Appendix 1).

At two sites (City Outfall Drain and Mt. Pleasant Yacht Club) in the Avon-Heathcote Estuary/Ihutai, the concentration of four PAHs exceeded ANZECC (2000) low trigger values but were below the high trigger values. At the Mt. Pleasant Yacht Club site, concentrations of low molecular weight PAHs also exceeded the low trigger value. At the City Outfall Drain, Mt. Pleasant Yacht Club and Causeway sites the low trigger value for high molecular weight PAHs was exceeded. At these three sites, PAH concentrations are potentially having an ecological effect.

Sediment from the remaining nine sites (Brooklands Lagoon, two sites in Lyttelton Harbour/Whakaraupō and two sites in Akaroa Harbour, Port Levy/Koukourarata, Okains Bay and the Opihi River) contained concentrations of metal and metalloid comparable to background concentrations and/or had low PAH concentrations.

Based on our findings, we recommend conducting bi-annual sediment quality monitoring at all sampling sites in the Avon-Heathcote Estuary/Ihutai and at the Saltwater Creek, Governors Bay, Takamatua and Childrens Bay sites. The remaining nine sites should be monitored every six years.

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1 Introduction

1.1 Background

Human activities are a source of environmental contaminants such as trace metals and polycyclic aromatic hydrocarbons (PAHs). For example, many houses have galvanised iron roofing, a source of zinc, and other buildings have pipes and electrical wiring made of copper that can be washed into the environment. Additionally, numerous industrial processes result in waste that can contain contaminants, while vehicles contribute hydrocarbons to the environment through vehicle exhausts, tyre wear and oil spots left on the roads (Timperley *et al.,* 2005).

Contaminants such as hydrocarbons and trace metals enter the marine environment from either point sources or diffuse sources. Wastewater from Christchurch, which is now discharged into Pegasus Bay via an outfall, is an example of point source contamination. In the Canterbury region, there are ten point source discharges directly into the subtidal zone some distance from shore. Each of these discharges has a resource consent with a range of conditions attached. For a wastewater discharge, the consent conditions typically set the size of the mixing zone and require water and sediment quality monitoring. Environmental impacts of discharges are greatest near the point of discharge and decrease with distance from the pipe. Point source discharges are easier to manage than diffuse because contaminant loads can be measured and wastewater can be treated before discharge, thereby modifying the quantity and quality of the contaminants.

Runoff from land, roads and buildings, provide diffuse (or non-point) sources and transport pathways for contaminants. These sources are not easily managed as they are typically variable in quantity and quality and often go untreated. Marine environments in proximity to diffuse sources, particularly motorways, major ports and urbanised areas, are likely to receive levels of contaminants that could affect their ecological functioning.

Metals and other contaminants that reach the sea are either dissolved in water or adsorbed onto particles of silt, clay or organic matter (such as leaves, twigs), which have been transported into the sea. More metal contaminants are adsorbed onto particles than are dissolved in water. These contaminated sediment particles settle to the seabed and accumulate. Contaminants from diffuse sources near the high tide mark frequently accumulate in the intertidal zone with fine sediment particles often accumulating in the low energy intertidal areas of estuaries and coastal embayments. Any fine sediment particles that move beyond the intertidal zone are transported by tidal and wind-driven currents, dispersed and diluted, and eventually settle into the seabed in low-energy subtidal areas. There are known thresholds above which contaminant concentrations can be toxic to marine life, thus all contaminants that enter the marine environment can potentially affect the ecology. Our study focuses on the intertidal sediments in the Canterbury Region.

Before 2010, Environment Canterbury collected one-off sediment quality[1] data from selected intertidal mudflat sites as part of marine ecological studies. Sediment was collected from sites in the Ashley Estuary (Fenwick *et al.,* 2006), Brooklands Lagoon (Bolton-Ritchie, 2007), Okains Bay Estuary (Bolton-Ritchie, 2008), Caroline Bay, and Opihi and Orari River mouths (Bolton-Ritchie, 2006). Because of consent-condition monitoring, there are also sediment quality data for intertidal sites within the Avon-Heathcote Estuary/Ihutai (EOS Ecology, 2005) and an Environment Canterbury initiated investigation has provided sediment quality data for a drain-impacted area of this estuary (EOS Ecology, 2007). To date, Environment Canterbury has not undertaken any routine sediment quality monitoring.[2] Initiating the first round of a sediment quality monitoring programme, our study assessed the quality of intertidal mudflat sediment in the Canterbury region.

[1] Sediment quality refers to contaminant concentration in sediment and is determined by measuring the concentration of one or more contaminants such as a metal or a PAH in the sediment. The concentrations are then assessed against both background concentrations in the soil and national guideline values.

[2] Monitoring is routine sampling at a site over time.

1.2 Aims

The sediment quality monitoring programme aims to:

- provide an assessment of sediment quality at selected intertidal sites in the Canterbury region
- assess sediment quality for ecosystem health (i.e. compare contaminant concentrations to national sediment quality guideline values)
- detect and quantify trends in sediment quality
- identify any sediment quality issues
- provide a baseline and/or context for future investigations
- provide context to consent applications and to compliance monitoring results
- monitor the Regional Council's progress towards achieving the objectives of the Regional Coastal Environment Plan (Environment Canterbury, 2005).

2 Methods

2.1 Field methods

2.1.1 Sampling sites

In July – October 2010, we sampled eighteen intertidal sites once each (Figure 2-1, Table 2.1). We selected sites based on the following criteria:

1. Potential for contamination
2. Sediment grain size: Mud is fine-grained sediment while sand is a coarser-grained sediment. Because metals and other contaminants adsorb to fine-grained sediment rather than coarse-grained sediment we specifically selected muddy sites.

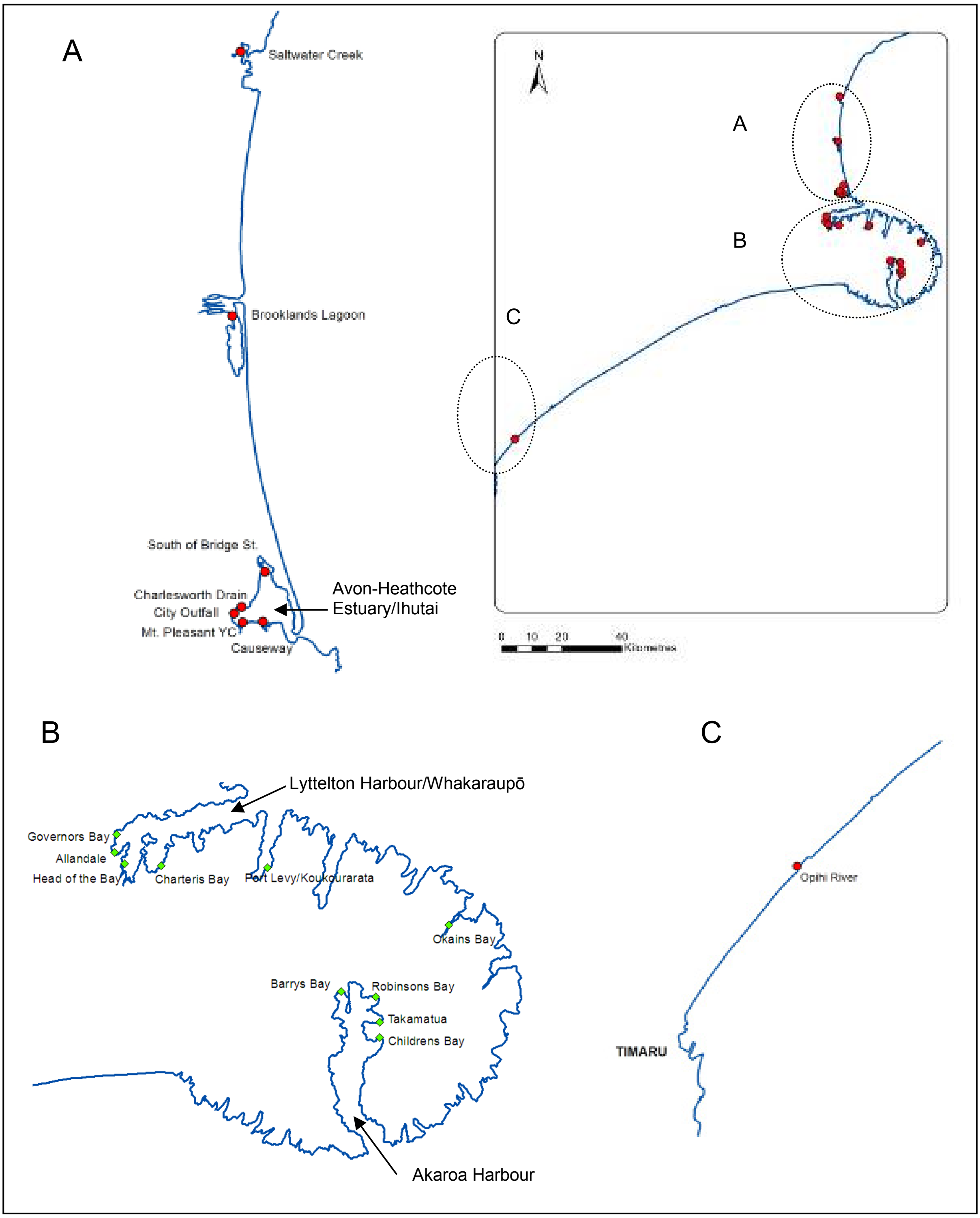

Figure 2-1: Location of sampling sites

Table 2.1: Details on the sampling sites with a list of potential contaminant sources

Site Locality	Site Name	Environment	Easting	Northing	Potential contaminant sources
Saltwater Creek downstream SH1	Saltwater Creek	Estuarine	2486482	5771653	Activities in the catchment and runoff from SH1
Brooklands Lagoon Styx River bank	Brooklands Lagoon	Estuarine	2486026	5756489	Activities in the Styx catchment and stormwater
Avon-Heathcote Estuary/Ihutai	South of Bridge Street	Estuarine	2487890	5741929	Activities in the Avon River catchment, stormwater and road runoff
	Charlesworth Drain	Estuarine	2486557	5739912	Activities in the catchment and stormwater
	City Outfall Drain	Estuarine	2486131	5739542	Activities in the catchment and stormwater
	Mt. Pleasant Yacht Club	Estuarine	2486609	5739034	Activities in the Heathcote River catchment, stormwater and road runoff
	Causeway	Estuarine	2488015	5739221	Road runoff and stormwater
Lyttelton Harbour/Whakaraupō	Governors Bay	Harbour	2481991	5731635	Road runoff and stormwater
	Allandale	Harbour	2481827	5729755	Road runoff
	Head of the Bay	Harbour	2482801	5728704	General harbour activities – reference site
	Charteris Bay	Harbour	2486315	5728576	Road runoff and stormwater
Port Levy /Koukourarata	Port Levy/Koukourarata	Harbour	2496304	5728554	Road runoff, stormwater and stream
Okains Bay estuary	Okains Bay	Estuarine	2513660	5722839	Road runoff and dump leachate
Akaroa Harbour	Barrys Bay	Harbour	2503420	5716519	Road runoff, activities in the catchment and the cheese factory
	Robinsons Bay	Harbour	2506720	5716059	General harbour activities – reference site
	Takamatua	Harbour	2507133	5713837	Road runoff and stormwater
	Childrens Bay	Harbour	2507093	5712155	Road runoff, stormwater, activtities in the catchment and boating activities
Opihi River Mouth	Opihi River	River mouth	2378058	5657299	Activities in the catchment

2.1.2 Sample collection

We based our sampling strategy on methods used by Auckland Council as described in ARC (2002, 2004 and 2006).

At each site, we sampled within a 50 m by 20 m rectangular area at the mid to low shore. The 50 m side was parallel to either the stream/drain/sea water and the 20 m side was perpendicular to the water. We set out two 50 m long measuring tapes (Figure 2-2) and collected the top 2 cm of sediment from alternative sides of the tape, at 2 m intervals.

We then placed our collected sediment in five labelled (1 – 5) sample bags in a methodical manner (Figure 2-2). That is, we placed the first and then every fifth sub-sample into sample bag one and so on, resulting in five composite samples each consisting of ten subsamples.

To collect our samples, we used a 5 cm high by 2.5 cm diameter polyvinyl chloride (PVC) pipe with 2 cm clearly marked (Figure 2-3) and a stainless steel knife. We cleaned the knife and PVC pipe between each sampling site but not between each sample within a site.

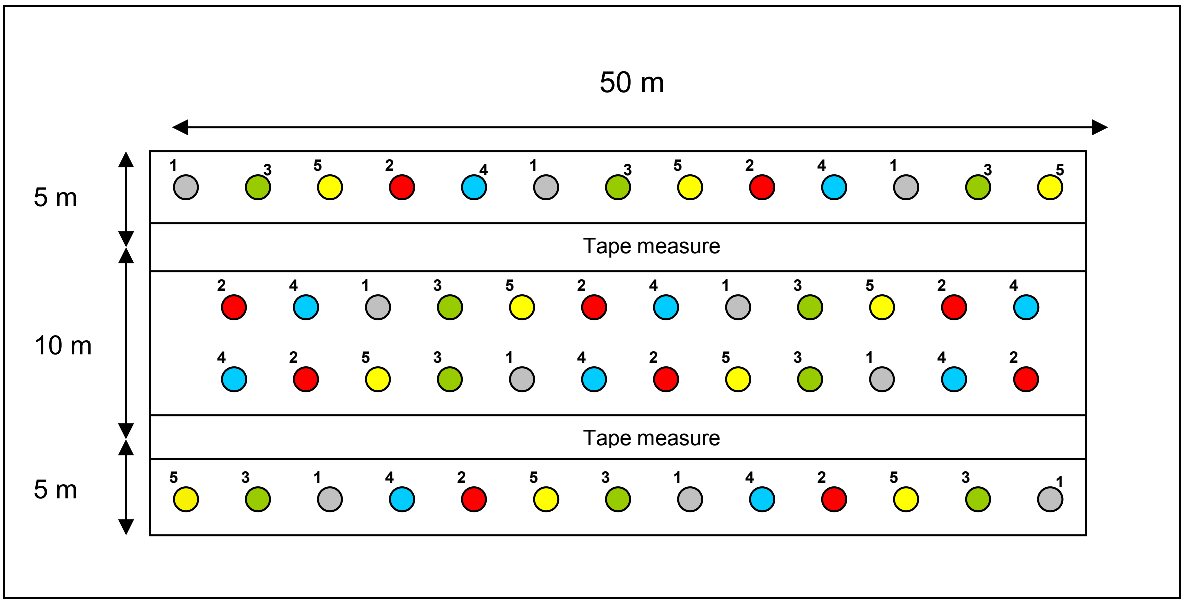

Figure 2-2: Schematic of sediment quality sampling strategy (adapted from ARC 2002; ARC 2004; ARC 2006)

2.2 Laboratory and data analysis

Hill Laboratories, Hamilton, and the Earth Sciences Department at Waikato University, Hamilton performed the sample analyses. Of the five samples collected from a site, three were analysed. We froze and stored the remaining two in case there was an issue with the results from the submitted samples. Because no issues arose during our study, we discarded the stored samples.

Each of the three replicate samples were analysed for:

- Total recoverable metals (copper (Cu), chromium (Cr), cadmium (Cd), mercury (Hg), lead (Pb), nickel (Ni), zinc (Zn))
- total recoverable metalloids (arsenic (As))
- total organic carbon (TOC)
- particle size distribution.

Additionally, the labs combined sub-samples from each of the three samples to create one sample for polycyclic aromatic hydrocarbons (PAHs) analysis (Table 2.2).

Figure 2-3: The PVC pipe and a surface sediment sample

Table 2.2: Description of the analytical methods

Analysis	Method	Analytical Detection limit
Polycyclic Aromatic Hydrocarbons Trace in Soil	Sonication extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C	<0.002 mg/kg dry wt, except Naphthalene at 0.01 mg/kg dry wt
Total Recoverable Arsenic	Dried sample, sieved (500µm). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.2 mg/kg dry wt
Total Recoverable Cadmium		0.010 mg/kg dry wt
Total Recoverable Chromium		0.2 mg/kg dry wt
Total Recoverable Copper		0.2 mg/kg dry wt
Total Recoverable Lead		0.04 mg/kg dry wt
Total Recoverable Mercury		0.010 mg/kg dry wt
Total Recoverable Nickel		0.2 mg/kg dry wt
Total Recoverable Zinc		0.4 mg/kg dry wt
Total Organic Carbon	Acid pretreatment to remove carbonates if present, Elementar Combustion Analyser.	0.05 g/100g dry wt
Sediment grain size	Malvern Laser Sizer particle size analysis.	

We tabulated the data in Microsoft Excel (2003 Microsoft Corporation) and used Statistica (version 7.1 StatSoft, Inc.) for summary data analysis and graphs.

We compared the recorded metal and metalloid concentrations to background concentrations[3] present in the soil at the site catchments (Table 2.3) based on established data (Tonkin and Taylor, 2007). There is a range in metal and metalloid concentrations for each soil type, hence Tonkin and Taylor (2007) proposed using the maximum-recorded concentration as the background concentration. However, because the metal and metalloid concentrations recorded in our study are below the maximum Tonkin and Taylor (2007) values for each soil type, we've included the range of values (Table 2.3). We consider metal and metalloid concentrations above the background concentrations and/or above those at other sites within the same general area to be a result of human activities.

We also compared metal, metalloid and PAH concentrations to national sediment quality criteria (ANZECC, 2000) (guideline values are not available for all of the measured PAHs). The criteria are defined as Interim Sediment Quality Guideline-low (ISQG-low) and Interim Sediment Quality Guideline-high (ISQG-high). The ISQG-low value indicates a *possible* biological effect and is intended as a trigger value for further investigation, while the ISQG-high value indicates a *probable* biological effect. We normalised the PAH concentrations to 1% total organic carbon to compare the results to the ANZECC (2000) guideline values. We then summed concentrations of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene and phenanthrene to obtain the Low molecular weight PAHs total, summed the concentrations of benzo[a]pyrene, dibenzo[a,h]anthracene, chrysene, fluoranthene and pyrene to obtain the High molecular weight PAHs total, and compared these totals to ANZECC (2000) values. When we calculated the Low and High molecular weight totals there were individual PAHs with a value below the analytical detection limit (ADL). For those PAHs, we halved the ADL for the calculation.

When comparing the collected metal, metalloid and PAH concentrations with the ANZECC (2000) guideline values, we made the following assumptions: (1) where the recorded concentration was below the ISQG-low guideline value, the sediment quality for that contaminant is unlikely to result in any adverse effects to aquatic life on/in the sediment; (2) where the recorded concentration was above the ISQG-low guideline value but below the ISQG-high guideline value, there is some potential for adverse effects to aquatic life on/in the sediment; or (3) where the recorded concentration was above the ISQG-high guideline value there is likely to be adverse effects to aquatic life on/in the sediment.

3 Results

3.1 Sediment grain size

All sites contained mud (grain size of <0.063 mm), very fine sand (grain size of 0.063 - 0.125 mm) and fine sand (grain size of 0.125 - 0.25 mm) particles and most sites had medium sand (grain size of 0.25 - 0.5 mm), coarse sand (grain size of 0.5 - 1 mm) and very coarse sand (grain size of 1 - 2 mm) particles (Figure 3-1). Apart from Saltwater Creek, there was a similar sediment grain size distribution among the three samples collected from each site. At Saltwater Creek, the percentage of the different grain size fractions varied between samples with the proportion of mud ranging from 43 – 63%.

Though one criterion for site selection was muddy sediment, mud content of samples differed between sites. For example, the mud content of samples collected from the Robinsons Bay site ranged from 5.9 - 7.1% while mud content of samples collected from Governors Bay ranged from 88.8 - 89.2%. The mud content of samples from Mt. Pleasant Yacht Club and Causeway (both in the Avon-Heathcote Estuary/Ihutai), and Barrys Bay, Robinsons Bay and Childrens Bay (all in Akaroa Harbour) was lower than 40%.

[3] Background concentration denotes the naturally occurring concentration attributable to the mineral content in the parent material of the soils and any modification due to the soil forming processes (Tonkin and Taylor, 2007).

Table 2.3: Metal and metalloid concentrations in soil types found in the different catchments (Tonkin and Taylor, 2007)

Applies to:	Banks Peninsula sites		Avon-Heathcote Estuary/Ihutai (spit and north of estuary)	Avon-Heathcote Estuary/Ihutai hill catchments and Lyttelton Harbour/Whakaraupō	Salwater Creek, Brooklands Lagoon and Avon-Heathcote Estuary/Ihutai (mouth of Avon River and Heathcote River)	Opihi River catchment, Saltwater Creek catchment, Avon-Heathcote Estuary/Ihutai catchment (city)	Avon-Heathcote Estuary/Ihutai catchment (city)
Soil type	Loess (intergrade)	Basalts (brown granular loam and brown granular clay)	Yellow-brown sand	Loess over greywacke gravels (yellow-grey earth)	Saline sands and silts (saline gley recent)	Greywacke gravels and loess (recent)	Loess and greywacke silts and sands (gley)
Number of samples	8	4	4	15	4	13	6
Arsenic (mg/kg)	1.6 - 6.1	1.13 - 5.1	2.6 - 3.4	2.1 - 4.6	2.2 - 6.8	2.7 - 8.4	0.9 - 8.7
Cadmium (mg/kg)	0.04 - 0.12	0.06 - 0.2	0.01 - 0.06	0.03 - 0.11	0.01 - 0.09	0.03 - 0.07	0.03 - 0.24
Chromium (mg/kg)	9.8 - 24.5	4.6 - 22.5	6.9 - 11	8.2 - 15.6	6.6 - 13.2	8.3 - 20	6.4 - 16.8
Copper (mg/kg)	6.2 - 15.2	10 - 27.3	2.3 - 7.1	4 - 11.5	3.3 - 12.2	6.6 - 18.8	2.1 - 15.5
Lead (mg/kg)	8.25 - 27.5	3.63 - 17.2	5.89 - 31.9	8.89 - 18.8	6.21 - 44.4	8.48 - 21.4	7.72 - 17.8
Mercury (mg/kg)	0.03 - 0.12	0.02 - 0.04	0.02 - 0.04	0.01 - 0.1	0.03 - 0.07	0.01 - 0.09	0.02 - 0.06
Nickel (mg/kg)	7.3 - 15.3	4.5 - 20.7	4.6 - 8.7	5.2 - 11.6	5.4 - 9.6	8.3 - 19	2.9 - 13.4
Zinc (mg/kg)	35.2 - 69.8	50 - 116	20.3 - 50.7	28.8 - 62.4	14.7 - 47.3	37.6 - 84	18.8 - 65.6

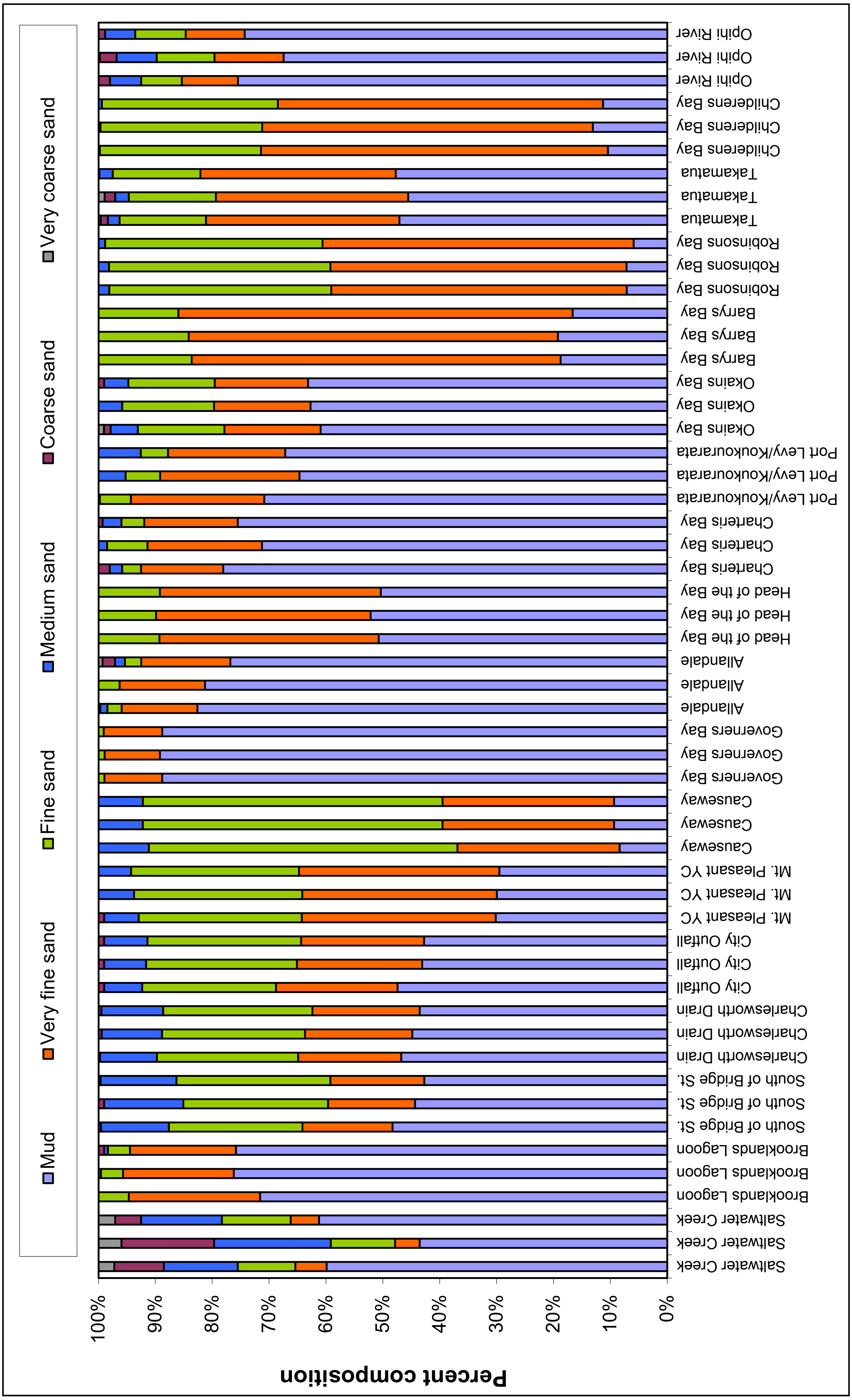

Figure 3-1: Sediment grain size in each sample from 18 sampling sites in Canterbury

3.2 Total organic carbon

Total organic carbon (TOC) is a measure of the organic matter content—living or dead plant and animal matter—in sediment samples.

TOC concentrations ranged from 0.1 to 1.3 g/100 g dry weight (Figure 3-2). The highest concentration occurred at the Opihi River Mouth site and the lowest concentration occurred at the Barrys Bay site.

The presence of organic matter can influence the presence of contaminants either by diluting them or by providing sites for adsorption thereby increasing the concentration. The low concentrations of TOC at our sites suggest that any such influences are unlikely.

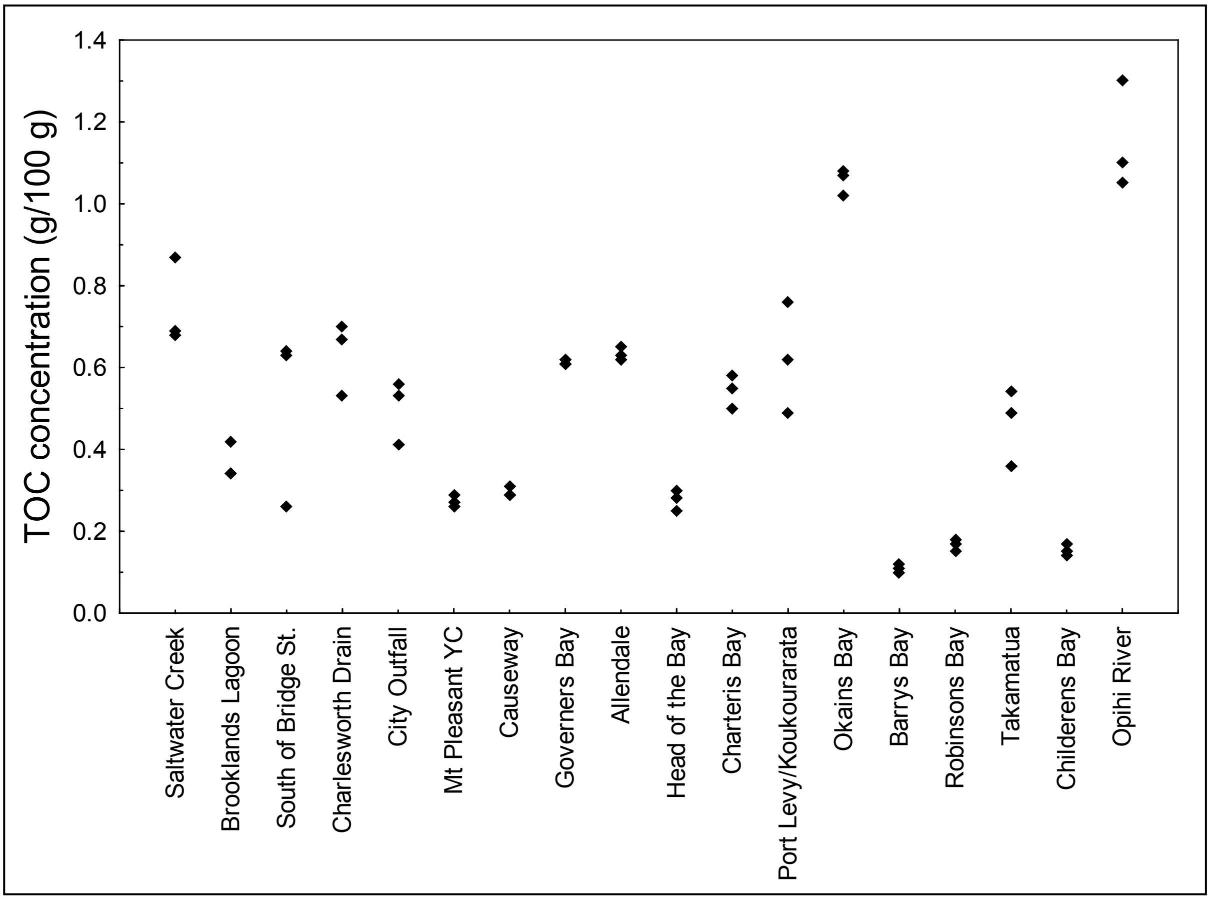

Figure 3-2: Total organic carbon (TOC) concentrations in sediment from 18 sampling sites in Canterbury

3.3 Metal and metalloid concentrations

We've presented the concentrations (mg/kg dry weight)[4] of each metal or metalloid at each site individually (Figures 3-3 through 3-10). The raw data are presented in site report cards (Appendix 2). All metal and metalloid concentrations in this study were below the relevant ISQG-low trigger value. Generally, metal and metalloid concentrations above background concentrations (Table 2.3) are likely

[4] For the remainder of this report mg/kg dry weight will be shortened to mg/kg.

a result of human activities and concentrations above those at other sites within the same sampling area may be a result of human activities.

3.3.1 Arsenic (As)

Historically, arsenic was used as an insecticide in sheep dip. Currently it's used to treat timber (tanalised timber) and with lead arsenate as a common pesticide in orchards.

We found the highest arsenic concentration (5.6 mg/kg) at the Port Levy/Koukourarata site and the lowest concentration (2.1 mg/kg) at the Robinsons Bay site in Akaroa Harbour (Figure 3-3). In the Avon-Heathcote Estuary/Ihutai, arsenic concentrations were higher at the Charlesworth Drain site than at the other sites. In Lyttelton Harbour/Whakaraupō, concentrations were highest at the Governors Bay site and lowest at the Allandale site. In Akaroa Harbour, concentrations at the Childrens Bay and Takamatua sites were higher than those at the Robinsons Bay and Barrys Bay sites.

All recorded arsenic concentrations were within the range of Tonkin and Taylor's (2007) background concentrations (Table 2.3), but the slightly elevated concentrations at Port Levy/Koukourarata may be a result of human activities. Additionally, the Charlesworth Drain site and the Governors Bay site had slightly elevated arsenic concentrations than other sites in their respective areas, which may be a result of human activities.

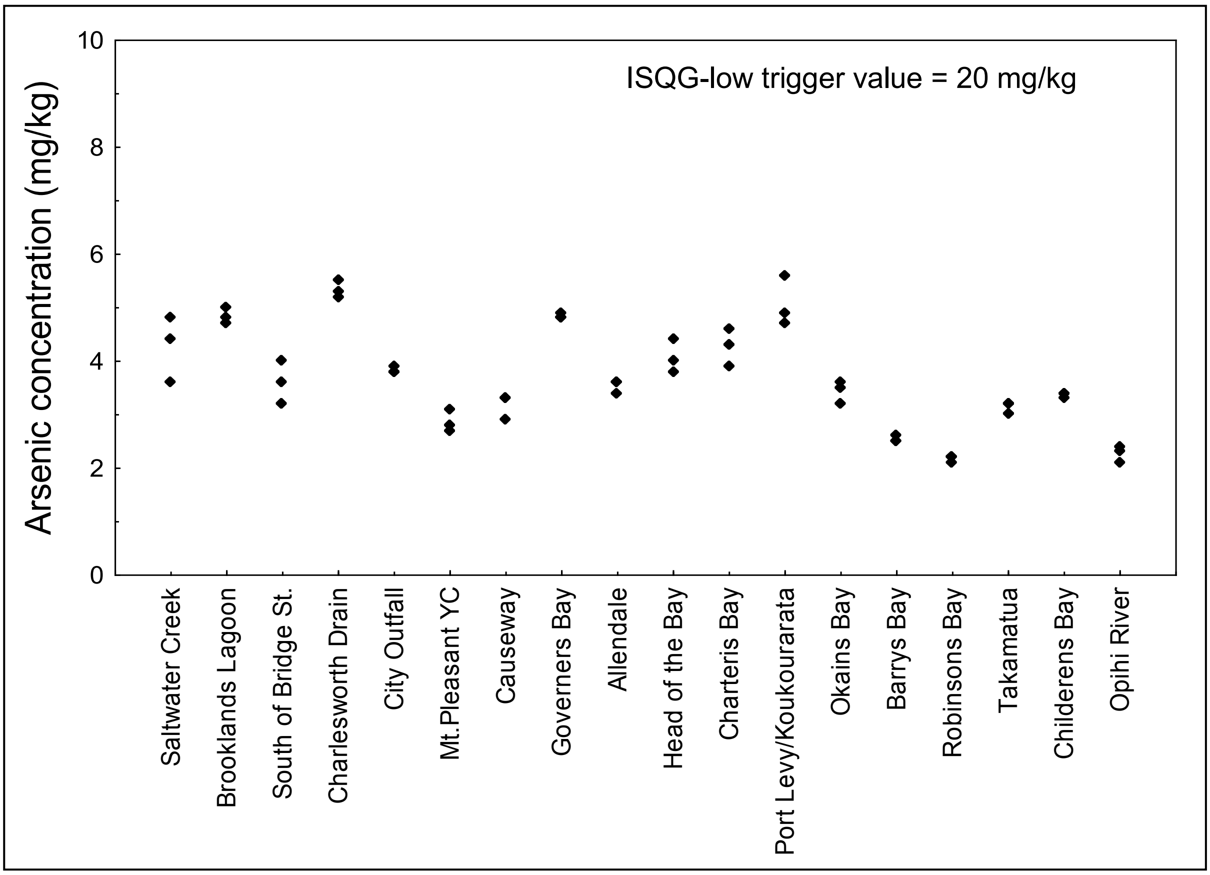

Figure 3-3: Arsenic concentrations in sediment from 18 sampling sites in Canterbury

3.3.2 Cadmium (Cd)

Cadmium is used in rechargeable nickel-cadmium batteries, solar panels, vehicle tyres and brakes, paint pigment, for electroplating of steel and is also present in superphosphate fertiliser.

We found the highest cadmium concentration (0.21 mg/kg) at the South of Bridge Street site in the Avon-Heathcote Estuary/Ihutai and the lowest concentration (0.021 mg/kg) in Lyttelton Harbour/Whakaraupō at the Head of the Bay site (Figure 3-4). Cadmium concentrations at the five Avon-Heathcote Estuary/Ihutai sites were higher than those at all other sampling sites. In Lyttelton Harbour/Whakaraupō, concentrations were similar among all sites. In Akaroa Harbour, the concentrations were higher at the Childrens Bay site than at the other three sites.

All recorded cadmium concentrations were within the range of background concentrations (Table 2.3), but the South of Bridge Street site and the Childrens Bay site had slightly elevated cadmium concentrations than other sites in their general area, which may be a result of human activities.

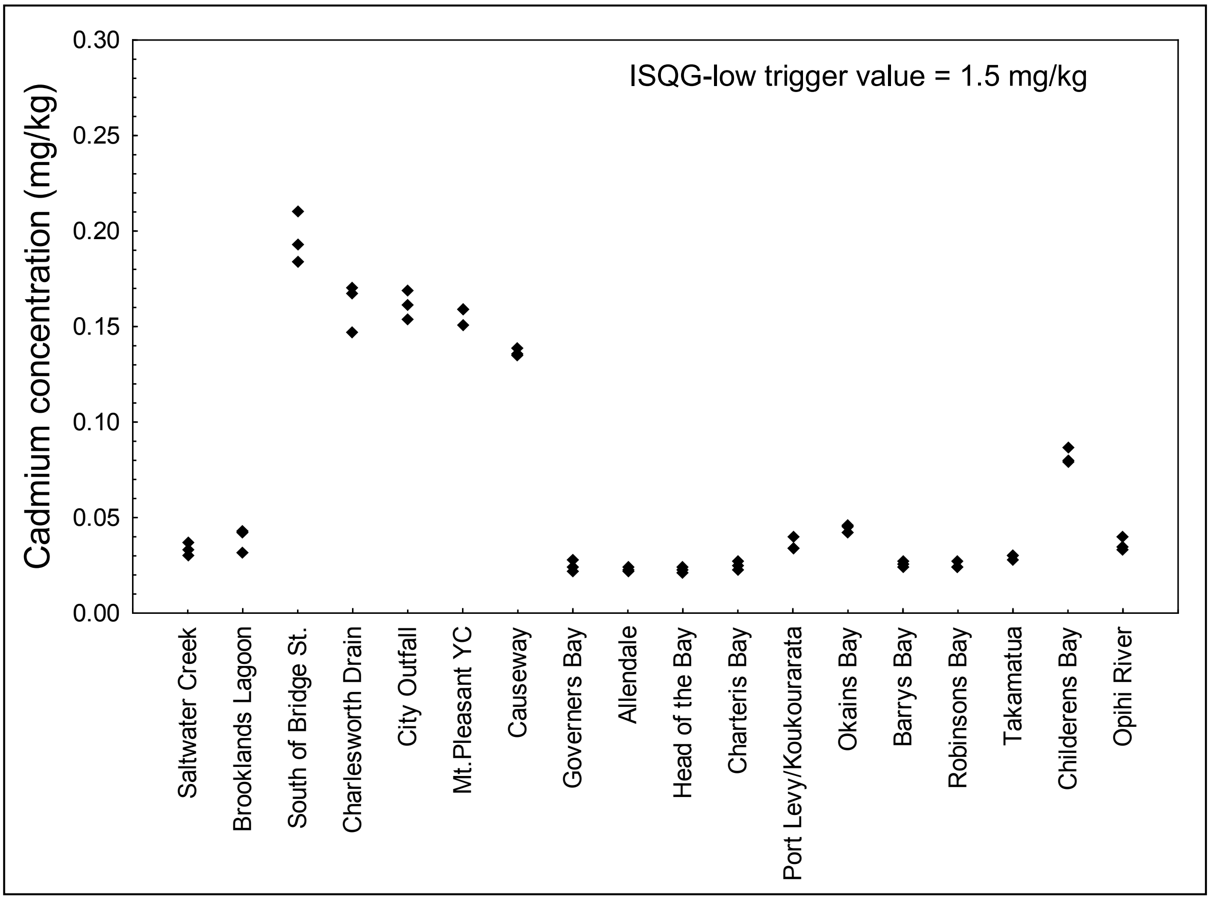

Figure 3-4: Cadmium concentrations in sediment from 18 sampling sites in Canterbury

3.3.3 Chromium (Cr)

Chromium is used as a pigment in paint and in processes such as manufacturing stainless steel, treating timber (tanalised wood), tanning leather, and electroplating.

In our study, the highest chromium concentration (25 mg/kg) occurred in the Avon-Heathcote Estuary/Ihutai at the South of Bridge Street site and the lowest concentration (5.3 mg/kg) occurred in Akaroa Harbour at the Barrys Bay site (Figure 3-5). In the Avon-Heathcote Estuary/Ihutai, chromium concentrations at South of Bridge Street, Charlesworth Drain and City Outfall Drain were higher than those at any of the other sampled sites. The Akaroa Harbour sites of Takamatua, Robinsons Bay and Barrys Bay had the lowest concentrations of any sites. In Lyttelton Harbour/Whakaraupō, the concentration was higher at the Governors Bay site than at the other three sites while in Akaroa Harbour, the concentration was higher at the Childrens Bay site than at the other three sites.

Three sites within the Avon-Heathcote Estuary/Ihutai, South of Bridge Street, Charlesworth Drain and City Outfall Drain, had chromium concentrations above the range of background concentrations for their soil type (Table 2.3). These elevated concentrations are because of human activities.

The recorded chromium concentrations at the fifteen other sites were within the range of background concentrations (Table 2.3), but the Governors Bay and Childrens Bay sites had slightly elevated chromium concentrations than other sites in their general areas, which may be a result of human activities.

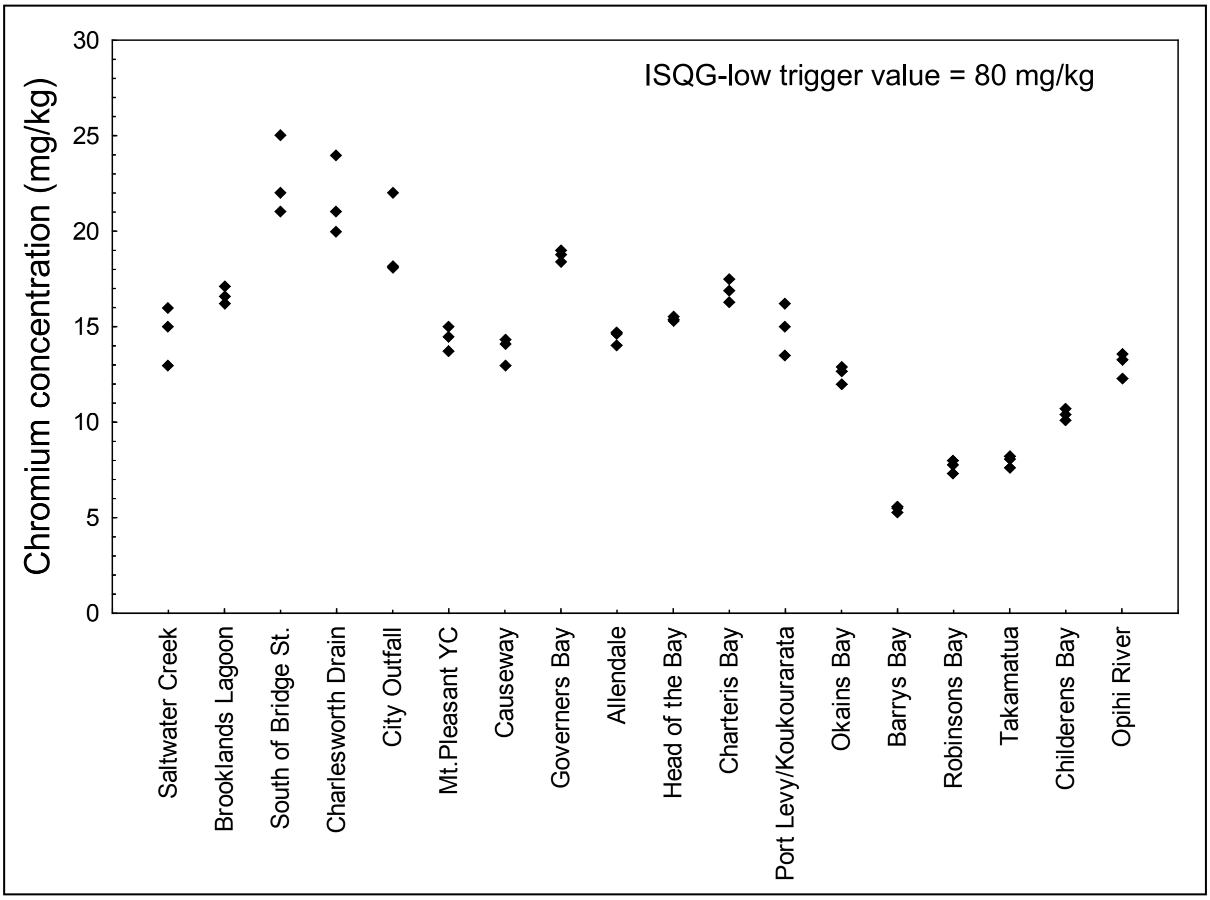

Figure 3-5: Chromium concentrations in sediment from 18 sampling sites in Canterbury

3.3.4 Copper (Cu)

Copper can be used in electrical wiring, vehicle brake pads, rooves, pipes, industrial machinery, fungicides and herbicides, boat antifouling paint and to treat timber (tanalised wood).

Among our sediment samples, we found the highest copper concentrations (15.4 and 13.7 mg/kg) in two samples from the Charlesworth Drain site in the Avon-Heathcote Estuary/Ihutai and the lowest concentration (1.5 mg/kg) at Barrys Bay in Akaroa Harbour (Figure 3-6). In the Avon-Heathcote Estuary/Ihutai, copper concentrations at the South of Bridge Street, Charlesworth Drain and City Outfall Drain sites were higher than those at the fifteen other sampled sites. In Lyttelton Harbour/Whakaraupō, concentrations varied among sites with the concentrations highest at Governors Bay and lowest at the Head of the Bay. Though copper concentrations from the four Akaroa Harbour sites were lower than any of the other sampling sites, concentrations varied among sites within the Harbour. The highest was found at the Takamatua site and the lowest at the Barrys Bay site.

All our recorded copper concentrations were within the range of background concentrations (Table 2.3). In the Avon-Heathcote Estuary/Ihutai, the South of Bridge Street, Charlesworth Drain and City Outfall Drain sites had slightly elevated copper concentrations than other sites in the estuary, which may be a result of human activities. Similarly, the Governors Bay, Takamatua and Childrens Bay sites had slightly elevated copper concentrations than other sites in their respective areas, possibly from human activity.

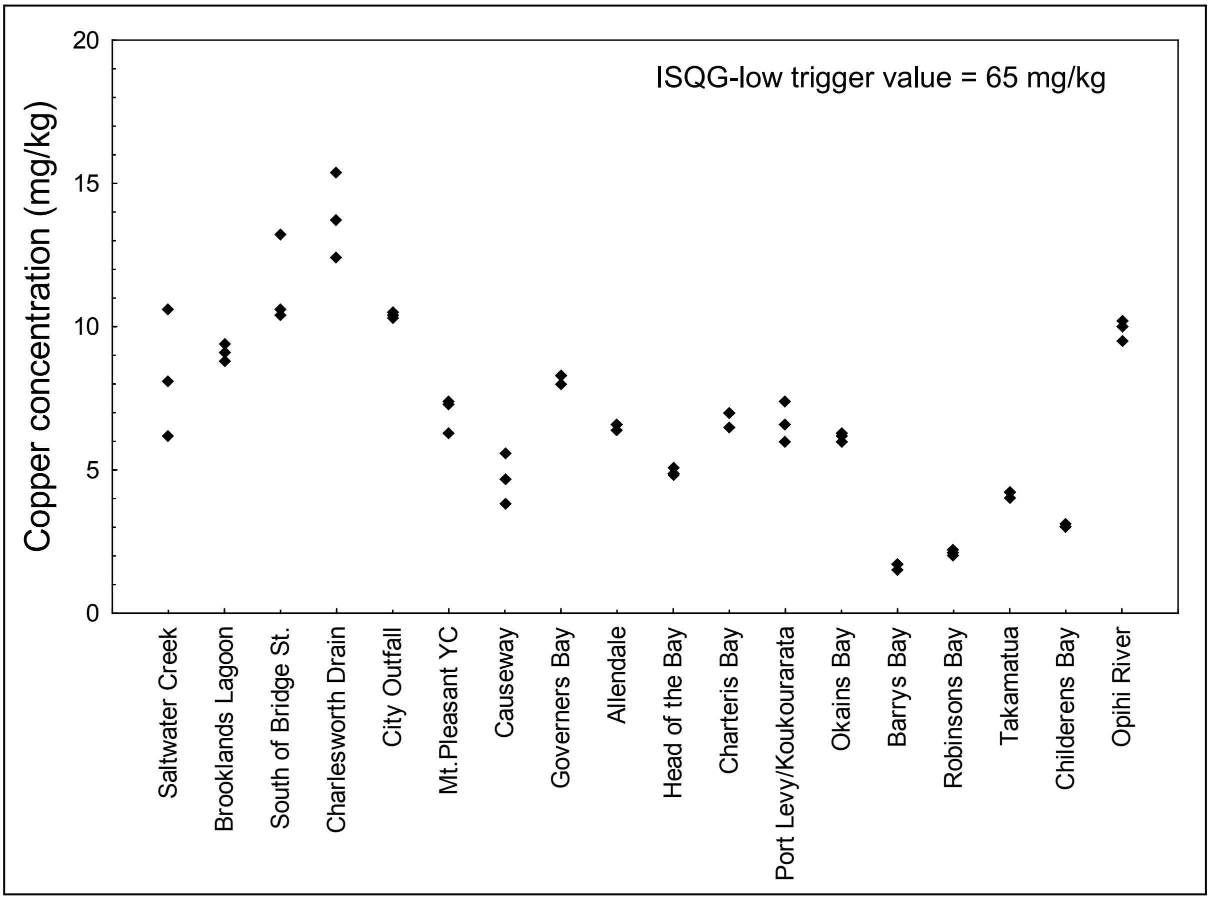

Figure 3-6: Copper concentrations in sediment from 18 sampling sites in Canterbury

3.3.5 Lead (Pb)

Lead can be found in lead acid batteries, SCUBA diving weight belts, bullets and shot, boat ballast, electrodes and solder, and in PVC plastic. It's also used in building construction and balancing car wheels. Lead used to be an additive in petrol.

We found the highest lead concentrations (25, 23 and 22 mg/kg) in the Avon-Heathcote Estuary/Ihutai at the Charlesworth Drain site and the lowest concentration (2.4 mg/kg) in Akaroa Harbour at the Robinsons Bay site (Figure 3-7). In the Avon-Heathcote Estuary/Ihutai, lead concentrations varied among sites with the highest concentrations at the Charlesworth Drain site and lowest concentrations at the Causeway site. In Lyttelton Harbour/Whakaraupō, concentrations were higher at the Governors Bay site than at the other three sites. In Akaroa Harbour, concentrations were higher in Childrens Bay than at the other three sites. Lead concentrations at the Takamatua, Robinsons Bay and Barrys Bay sites in Akaroa Harbour were lower than those at all other sites.

All recorded lead concentrations were within the range of background concentrations (Table 2.3). However the South of Bridge Street, Charlesworth Drain and City Outfall Drain sites, the Governors Bay site, and the Takamatua and Childrens Bay sites had slightly elevated lead concentrations than other sites in their areas, which may be a result of human activities.

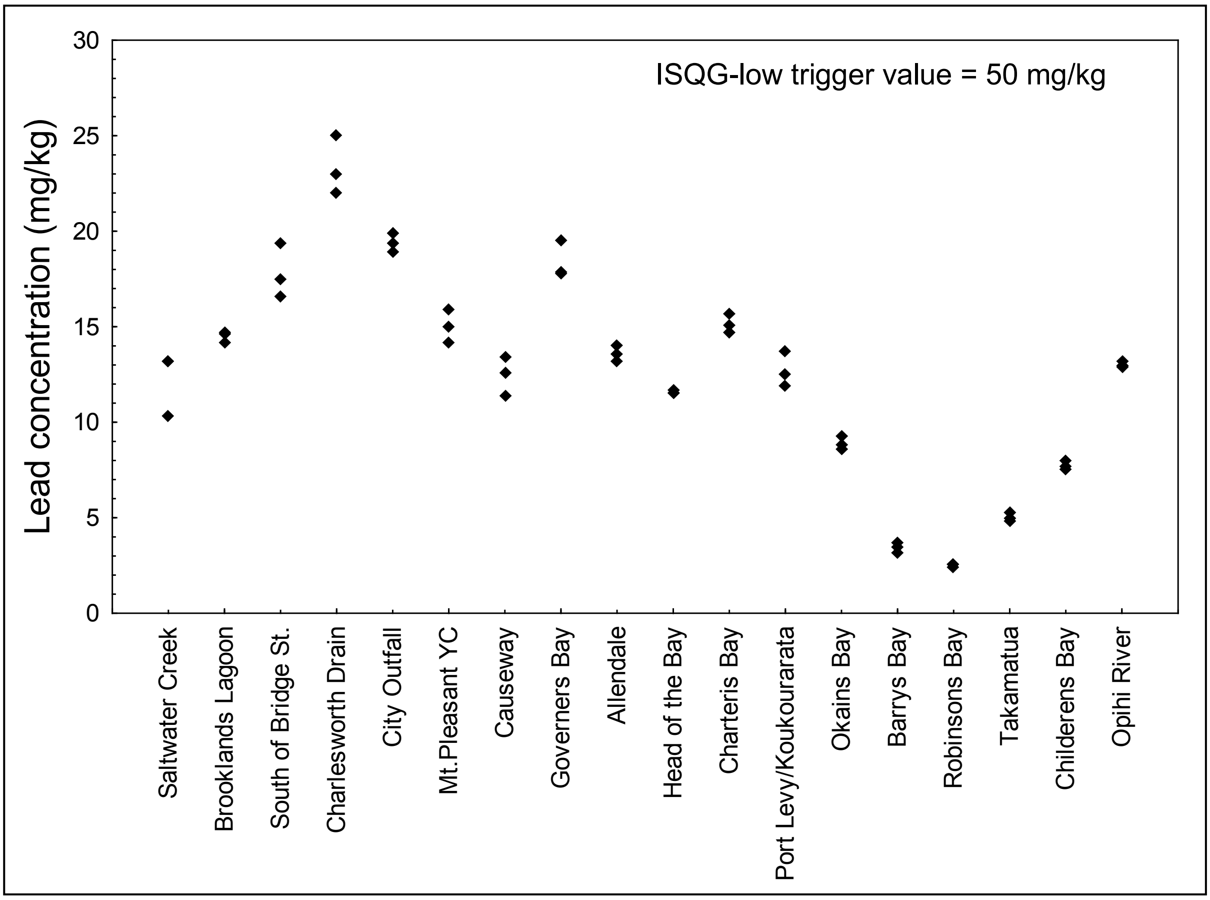

Figure 3-7: Lead concentrations in sediment from 18 sampling sites in Canterbury

3.3.6 Mercury (Hg)

Historically there were many uses for mercury. Now it is commonly used for the manufacture of industrial chemicals and in electrical and electronic applications. Mercury is also found in batteries and dental amalgams and gaseous mercury is used in fluorescent lamps.

Among our sediment samples, we found the highest mercury concentrations (0.113, 0.09 and 0.085 mg/kg) in the Avon-Heathcote Estuary/Ihutai at the South of Bridge Street site and the lowest (<0.01 mg/kg) in Akaroa Harbour at the Barrys Bay site (Figure 3-8). Mercury concentrations at two sites in the Avon-Heathcote Estuary/Ihutai and at Saltwater Creek were typically higher than those at other sites. In Lyttelton Harbour/Whakaraupō, concentrations at the Head of the Bay site were lower than those at the other three sites, while in Akaroa Harbour concentrations at the Takamatua site were higher than those at the other three sites.

Mercury concentrations at Saltwater Creek and at the South of Bridge Street site in the Avon-Heathcote Estuary/Ihutai were above the range of background concentrations for their areas (Table 2.3) and this is likely a result of human activities. Mercury concentrations at all other sites were within the range of background concentrations, though we found slightly elevated concentrations at the Takamatua site compared to others in the area, which may be a result of human activities.

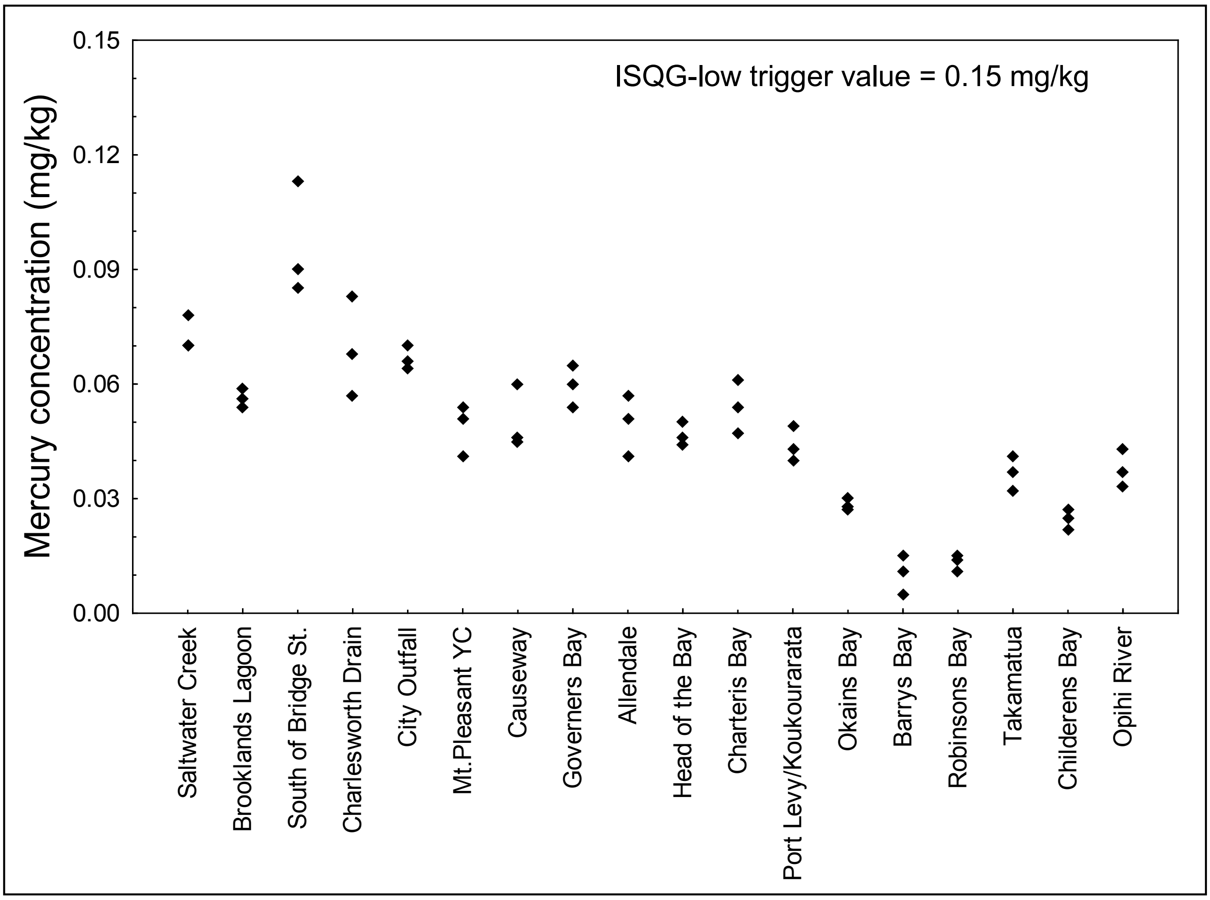

Figure 3-8: Mercury concentrations in sediment from 18 sampling sites in Canterbury

3.3.7 Nickel (Ni)

Nickel is used in many industrial and consumer products including stainless steel, magnets, coinage, rechargeable batteries, vehicle brake pads, electric guitar strings, and special alloys like nickel steels and nickel cast irons. It is also used for plating and as a green tint in glass.

In our study, we found the highest nickel concentrations (13.7 mg/kg) at the City Outfall Drain site in the Avon-Heathcote Estuary/Ihutai and at the Charteris Bay site in Lyttelton Harbour/Whakaraupō (Figure 3-9) and the lowest concentration (2.5 mg/kg) in Akaroa Harbour at the Barrys Bay site. In the Avon-Heathcote Estuary/Ihutai, concentrations were lower at the Mt. Pleasant Yacht Club and Causeway sites than at the other three sites. In Lyttelton Harbour/Whakaraupō, concentrations were higher at the Governors Bay and Charteris Bay sites than the other two sites and in the Akaroa Harbour, concentrations at the Takamatua site were higher than those at the other three sites. Nickel concentrations at all Akaroa Harbour sites were lower than those at all other sampled sites.

All recorded nickel concentrations were within the range of background concentrations (Table 2.3). However the Charlesworth Drain and City Outfall Drain sites, the Governors Bay and Charteris Bay sites, and the Takamatua and Childrens Bay sites had slightly elevated nickel concentrations than other sites in their areas, which may be a result of human activities.

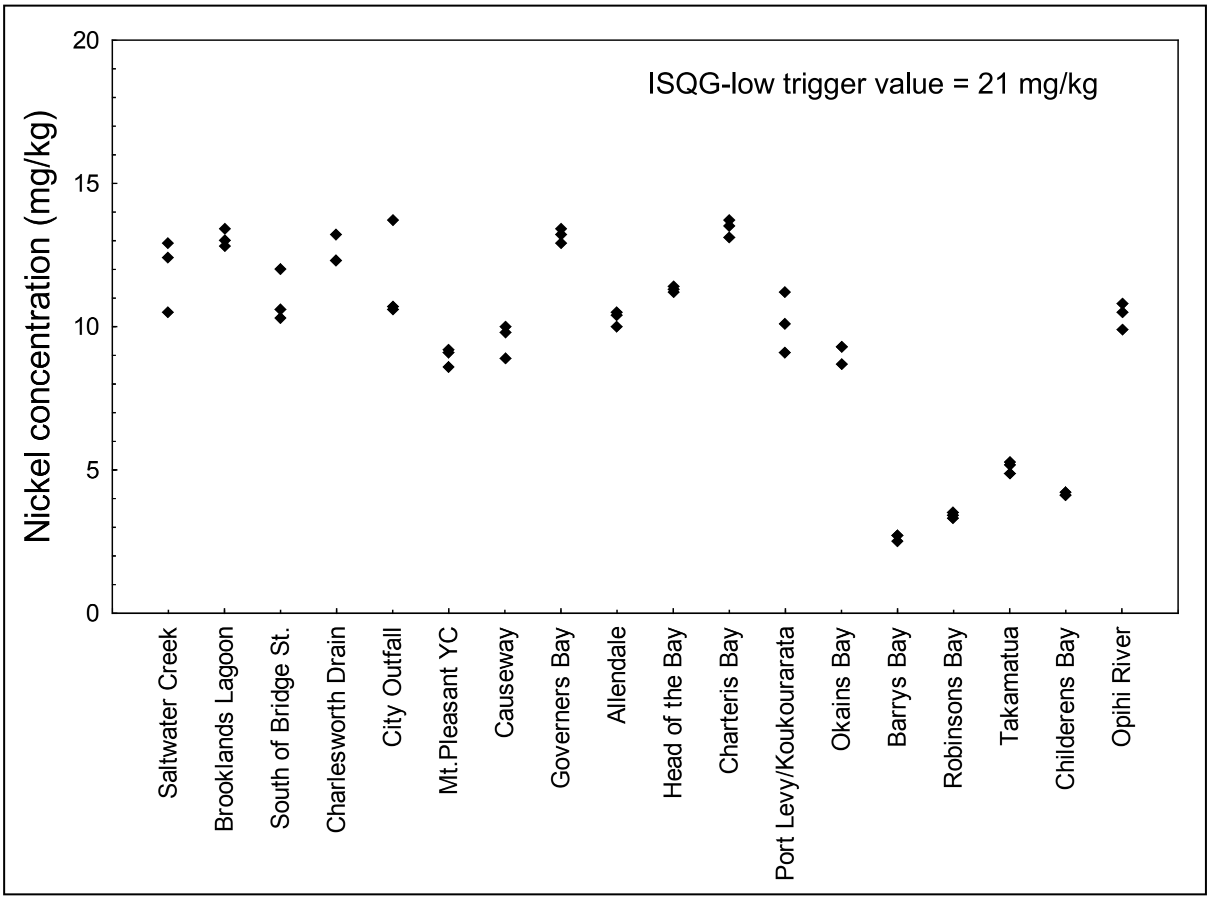

Figure 3-9: Nickel concentrations in sediment from 18 sampling sites in Canterbury

3.3.8 Zinc (Zn)

Zinc is used as an anti-corrosion agent in the galvanisation of iron and steel. It is found in metal fencing, lampposts, metal rooves, car bodies, batteries, as a sacrificial anode on ships, in alloys such as brass, in paints, in rubber to protect against UV damage, and in sunscreen.

We found the highest Zinc concentrations (143, 130 and 117 mg/kg) in the Avon-Heathcote Estuary/Ihutai at the Charlesworth Drain site, and the lowest concentrations (17.4, 18.1 and 18.7 mg/kg) at Robinsons Bay in Akaroa Harbour (Figure 3-10). Zinc concentrations at the four Avon-Heathcote Estuary/Ihutai sites were higher than those at any of the other sampled sites. In Lyttelton Harbour/Whakaraupō, zinc concentrations were similar at all sites, but the Childrens Bay and Takamatua sites in Akaroa Harbour were higher than those at the other two sites. Zinc concentrations at all Akaroa Harbour sites were lower than those at Lyttelton Harbour/Whakaraupō sites.

In the Avon-Heathcote Estuary/Ihutai, all but the Causeway site had concentrations above the range of background concentrations for that area (Table 2.3). These elevated concentrations are likely to be a result of human activities. Zinc concentrations at all other sites are within the range of background concentrations. The Governors Bay, Takamatua and Childrens Bay sites had slightly elevated zinc concentrations than other sites in their respective areas, which may be a result of human activities.

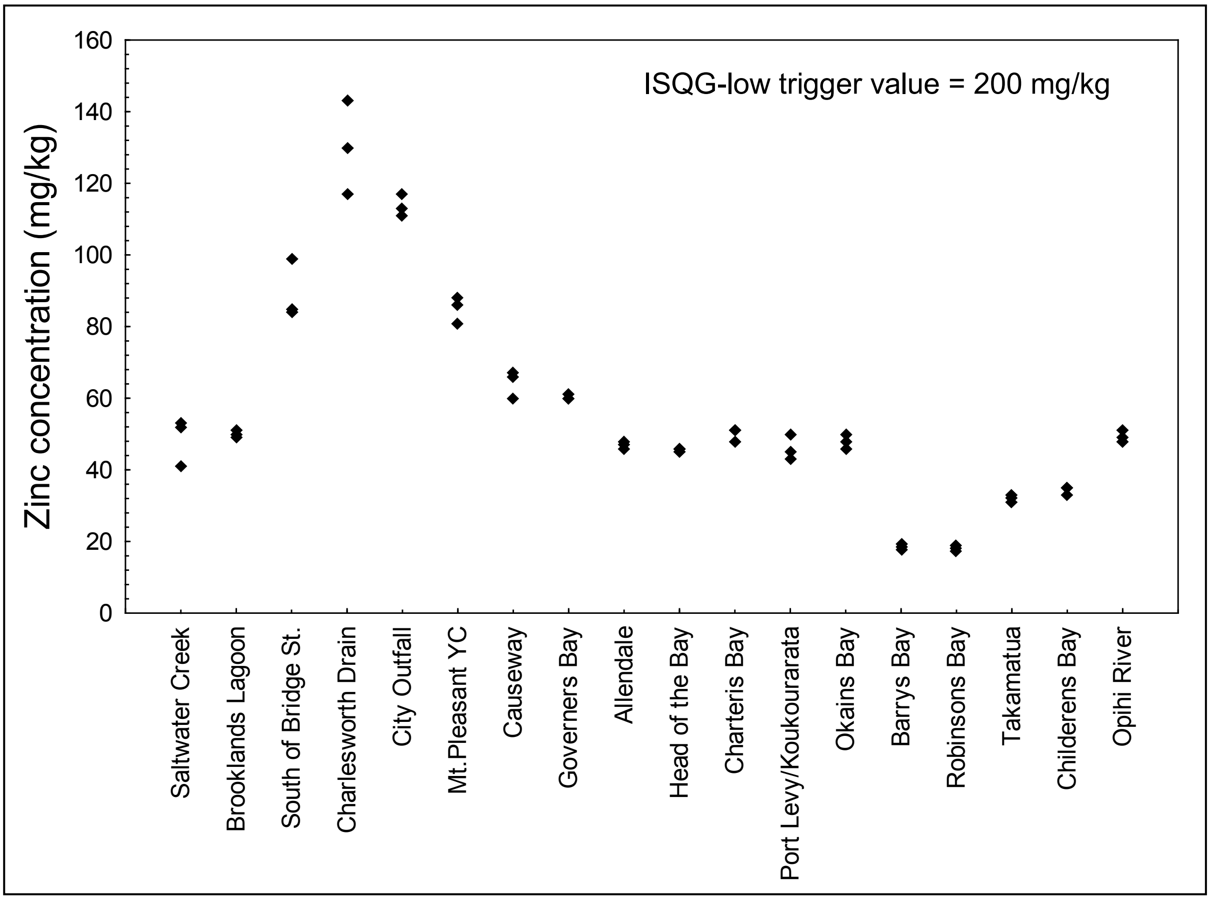

Figure 3-10: Zinc concentrations in sediment from 18 sampling sites in Canterbury

3.4 Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) occur in oil, coal and tar deposits, and are present in fossil fuels. Background levels of PAHs are found naturally in the environment from events such as forest fires and volcanic activity. However, they predominantly occur in the environment as they are released during the incomplete combustion of carbon-containing fuels like coal, oil, petrol, diesel, fuel oils, fats and tobacco. Other potential sources of PAHs in Canterbury intertidal areas are oil spills and fuel leakages from boats, and hydrocarbon residues from roads that are transported into the coastal environment by rainwater. As a pollutant, PAHs are concerning because some are carcinogenic and mutagenic. Numerous chemical compounds are PAHs, but, the 16 we've reported (Table 3.1) have been identified by the US Environmental Protection Authority as hazardous to human health.

For each of those 16 PAHs, we analysed one sediment sample from each site. We then normalised the PAH concentrations to 1% TOC in order to compare the results with ANZECC (2000) sediment quality values (Table 3.1).

Table 3.1: ANZECC (2000) sediment quality PAH guideline concentrations (mg/kg) normalised to 1% TOC

PAH	ANZECC ISQG-Low	ANZECC ISQG-High
Acenaphthene	0.016	0.50
Acenaphthylene	0.044	0.64
Anthracene	0.085	1.10
Fluorene	0.019	0.54
Naphthalene	0.160	2.10
Phenanthrene	0.240	1.50
Low molecular wt. PAH's[5]	0.552	3.16
Benzo[a]anthracene	0.261	1.6
Benzo[a]pyrene (BAP)	0.430	1.6
Chrysene	0.384	2.8
Dibenzo[a,h]anthracene	0.063	0.26
Fluoranthene	0.600	5.1
Pyrene	0.665	2.6
High molecular wt. PAH's[6]	1.7	9.6
Benzo[b]fluoranthene + Benzo[j] fluoranthene		
Benzo[g,h,i]perylene		
Benzo[k]flouranthene		
Indeno(1,2,3-c,d) pyrene		

[5] Low molecular weight PAHs are the sum of the concentrations of acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene and phenanthrene.

[6] High molecular weight PAHs are the sum of the concentrations of benzo[a]anthracene, benzo[a]pyrene, chrysene, Dibenzo[a,h]anthracene, fluoranthene and pyrene.

We summarised the normalised data (Table 3.2) and analysed the data by PAH (Figure 3-11) and by sampling site (Figure 3-12).

Of the 16 PAHs, we found nine above the ADL at more than 13 of 18 sites, but we didn't find any individual PAH that was present above the ADL at every site (Table 3.2). We only found acenaphthene at two sites and naphthalene at one site. The PAHs with the lowest concentrations were naphthalene, acenaphthene, acenaphthylene, fluorene, dibenzo[a,h]anthracene and anthracene while those with the highest concentrations were fluoranthene and pyrene (Figure 3-11).

At three sites in Akaroa Harbour, Barrys Bay, Robinsons Bay and Takamatua, we recorded no PAH concentrations above ADL concentration. At the Okains Bay site, we recorded five PAHs above the ADL and six above the ADL at the Brooklands Lagoon site. At seven sites, the Saltwater Creek site, the Governors Bay site, and all sites in the Avon-Heathcote Estuary/Ihutai, there were 14 or more PAHs above ADL concentrations (Figure 3-12). Only one site, the City Outfall Drain in the Avon-Heathcote Estuary/Ihutai, contained all PAHs above ADL concentrations.

Six PAHs (fluorene, phenanthrene, benzo[a]anthracene, benzo[a]pyrene, fluoranthene and pyrene) exceeded the ISQG-low trigger value at the City Outfall Drain site and the low molecular weight PAHs were just below the ISQG-low trigger value. At the Mt. Pleasant Yacht Club site, five PAHs (acenaphthene, fluorene, fluoranthene, benzo[a]anthracene and phenanthrene) and the low molecular weight PAHs exceeded the ISQG-low trigger value. Concentrations of high molecular weight PAHs exceeded the ISQG-low at the City Outfall Drain, Mt. Pleasant Yacht Club and Causeway sites.

Table 3.2: Summary of PAH occurrence above the analytical detection limit

PAH	Number of sites where above ADL		Site	Number of PAHs above the ADL
Acenaphthene	2		Saltwater Creek	14
Acenaphthylene	7		Brooklands Lagoon	6
Anthracene	9		South of Bridge St.	14
Benzo[a]anthracene	13		Charlesworth Drain	14
Benzo[a]pyrene (BAP)	13		City Outfall Drain	16
Benzo[b]fluoranthene + Benzo[j] fluoranthene	15		Mt. Pleasant YC	15
Benzo[g,h,i]perylene	15		Causeway	14
Benzo[k]flouranthene	12		Governors Bay	14
Chrysene	13		Allendale	13
Dibenzo[a,h]anthracene	10		Head of the Bay	11
Fluoranthene	15		Charteris Bay	13
Fluorene	12		Port Levy	10
Indeno(1,2,3-c,d) pyrene	13		Okains Bay	5
Naphthalene	1		Barrys Bay	0
Phenanthrene	15		Robinsons Bay	0
Pyrene	15		Takamatua	0
			Childrens Bay	11
			Opihi River	10

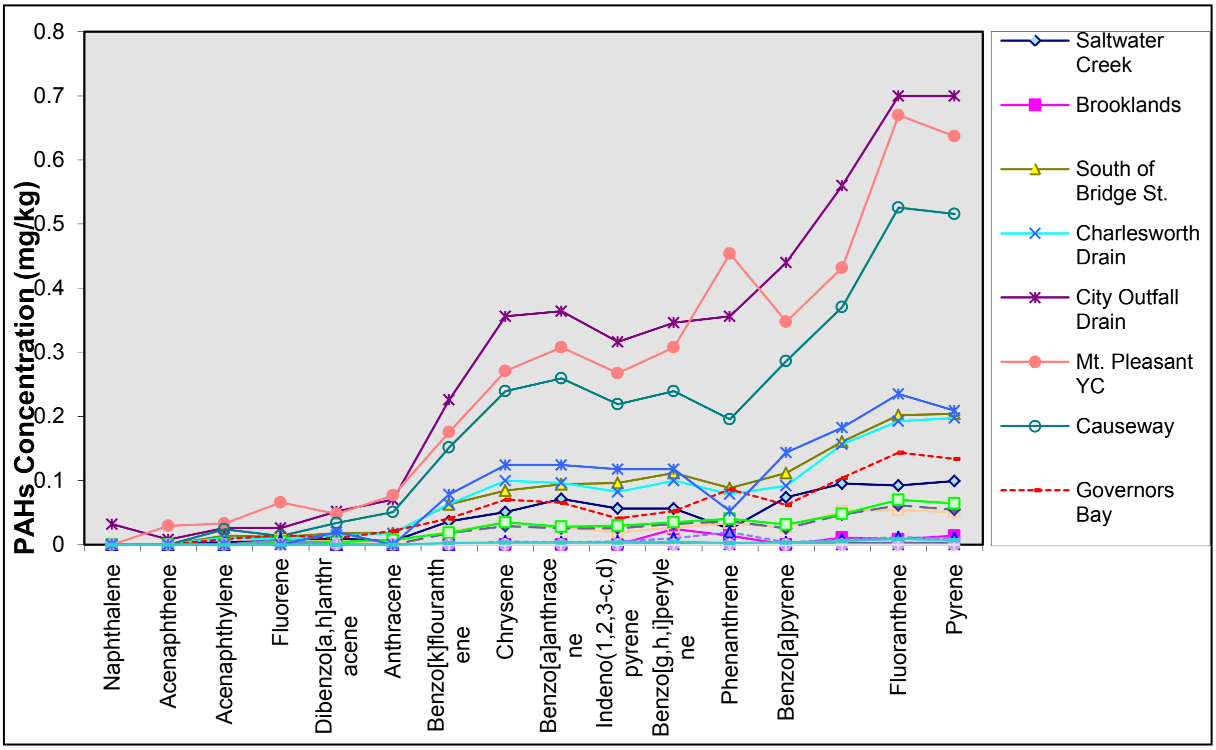

Figure 3-11: Normalised PAH concentrations in sediment at 18 sampling sites in Canterbury

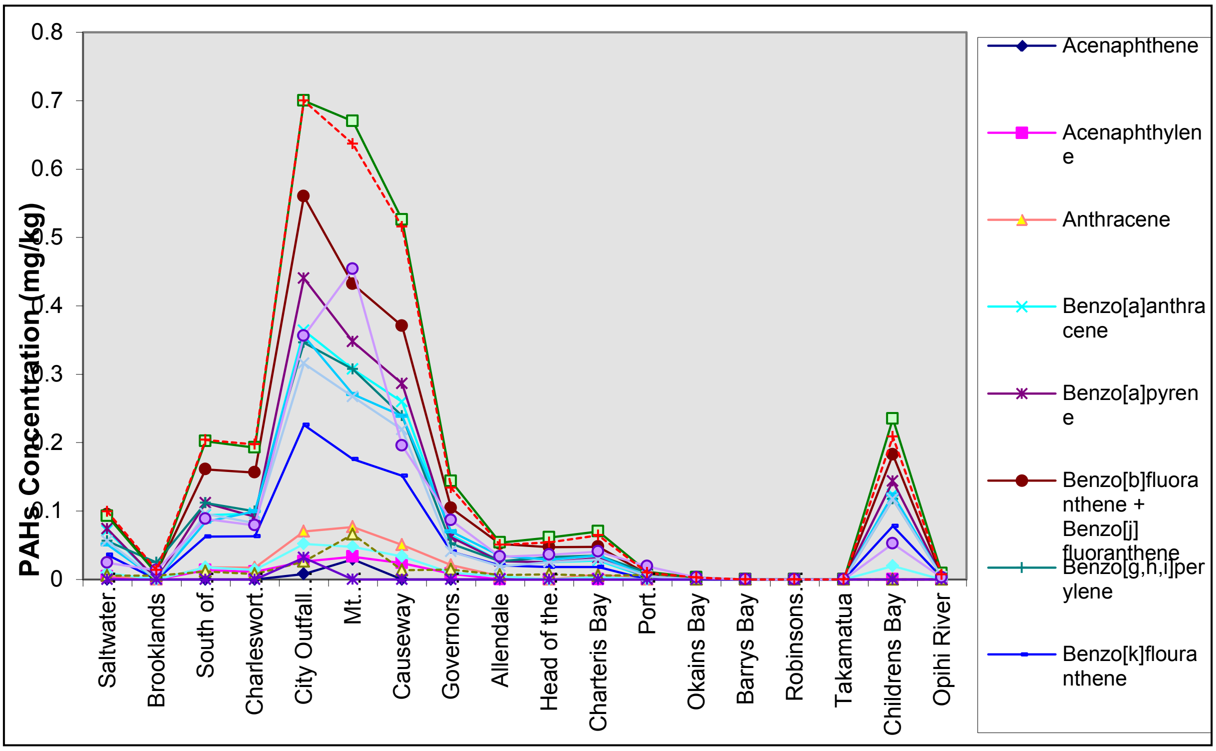

Figure 3-12: Normalised concentrations of each PAH in sediment from 18 sampling sites in Canterbury

4 Discussion of results

4.1 Metal and metalloid concentrations

In this study, we measured metal and metalloid concentrations from the surface (top 2 cm) of 18 muddy, intertidal sites in Canterbury and compared them to background concentrations (Tonkin and Taylor, 2007) in the soils of the catchment for each site. There is varying geology between catchments meaning there will be natural differences in seabed sediment metal and metalloid concentrations between sites. For each soil type, there is a different range in the background concentrations for each metal and metalloid and there is often more than one soil type in any site locality, complicating the interpretation of the results.

The Avon-Heathcote Estuary/Ihutai has five different soil types in its site locality (Tonkin and Taylor, 2007). The sampling sites on the northern and western side of the estuary (South of Bridge Street, Charlesworth Drain and City Outfall Drain) have yellow-brown sand, recent, and gley soil in their catchment. Additionally, there is saline gley recent soil present in the South of Bridge Street catchment. The Mt. Pleasant Yacht Club site has saline gley recent, recent, gley and some yellow-grey earth soils in its catchment while soil in the catchment of the Causeway site is predominantly yellow-grey earth. The surface seabed sediments of the larger estuary are probably well mixed as wind and tides redistribute sediment that enters the estuary from various points. Nonetheless, slight differences in metal and metalloid concentrations among the Avon-Heathcote Estuary/Ihutai sites could result from the different sediment sources at each sampling site.

There are clear differences in the metal and metalloid concentrations in the surface seabed sediment between sampling sites in Lyttelton Harbour/Whakaraupō, Port Levy/Koukourarata and Okains Bay, and sampling sites in Akaroa Harbour. This suggests that the background soil for Lyttelton Harbour/Whakaraupō, Port Levy/Koukourarata and Okains Bay is different to that for Akaroa Harbour. The chromium, lead, mercury and nickel concentrations in seabed sediment from Lyttelton Harbour/Whakaraupō, Port Levy/Koukourarata and Okains Bay are in line with the minimum concentrations in loess soil rather than those in basalt soil (Table 2.3). This is not the case for copper and zinc concentrations. However, the results indicate that the seabed sediment at those three site localities primarily originates from loess soil. The chromium, lead, mercury and nickel concentrations in seabed sediment from Akaroa Harbour indicate that it primarily originates from basalt soil, though we have oversimplified our evaluation of soil origin at all Banks Peninsula sites. The complexity of the volcanic geology on Banks Peninsula (Timm *et al.*, 2009) and the varying soil composition overlying that volcanic rock (Tonkin and Taylor, 2007) make soil origin evaluation complex at these site localities. Further complicating soil origin assessments, the sediment-laden Rakaia River and Waimakariri River water reaches the peninsula at times.

We compared the metal and metalloid concentrations in intertidal sediment to background concentrations. This comparison indicated that human activities have likely caused above background concentrations for some metals and metalloid at some intertidal sites. Moreover, metal and metalloid concentrations that are higher at one sampling sites, over others in the same locality, are probably a result of human activity. Human activity has probably (in bold) or possibly (not in bold) caused increased concentrations of one or more metals and metalloid at the following sites:

- Saltwater Creek – **Hg**
- South of Bridge Street – Cd, **Cr**, Cu, **Hg**, Pb, **Zn**
- Charlesworth Drain – As, **Cr**, Cu, Pb, Ni, **Zn**
- City Outfall Drain – **Cr**, Cu, Pb, Ni, **Zn**
- Mt. Pleasant Yacht Club – **Zn**
- Port Lev/Koukourarata – As
- Governors Bay – As, Cr, Cu, Pb, Ni, Zn
- Charteris Bay – Ni

- Takamatua – Cu, Hg, Pb, Ni, Zn
- Childrens Bay – Cd, Cr, Cu, Pb, Ni, Zn

Within the Avon-Heathcote Estuary/Ihutai, our findings indicate that sediment at three sites, South of Bridge, Charlesworth Drain and City Outfall Drain, contain elevated concentrations of metals and metalloids because of human activity. The source of these contaminants is likely to be from stormwater (rooves and roads) and industry. Stormwater is a likely source of the zinc contaminating the sediment at the Mt. Pleasant Yacht Club site as well. The source of mercury in the Saltwater Creek sediment is unknown.

Within Akaroa Harbour, our results for Governors Bay, Takamatua and Childrens Bay suggest human activity could account for metal and metalloid concentrations higher than those at other sites within the locality. Stormwater from Akaroa township and/or on-the-water activities within French Bay are potentially the sources of contaminants to the Childrens Bay sediment. Though no particular source can explain the results for Takamatua, tidal currents and wind driven water may be transporting metals from the Akaroa township area to Takamatua. Stormwater from Governors Bay or diffuse sources from the Lyttelton Harbour/Whakaraupō environs are potential sources of the contaminants to the Governors Bay sediment. Diffuse sources should influence sediment metal and metalloid concentrations at all sampling sites in a locality, however, water circulation patterns and sediment deposition likely varies in the harbour. If this is the case, metals discharged into the harbour from locations outside of Governors Bay end up there rather than at other sampling sites in the upper harbour.

Recorded metal and metalloid concentrations from all 18 sampling sites in 2010 were below the relevant ANZECC (2000) ISQG-low trigger value so they are not cause for ecological concern.

4.2 Polycyclic aromatic hydrocarbon concentrations

We measured the concentrations of 16 PAHs in one composite sediment sample from each site. At all sites except the City Outfall Drain, one or more PAH concentration was below the analytical detection limit (ADL). At the City Outfall Drain, all PAH concentrations were above the ADL. For each PAH above the ADL, concentrations occurred at one or more sites. For the ten PAHs with ANZECC (2000) ISQG-low trigger values, we recorded concentrations below the trigger value at all but two sampling sites. Those two sites were the City Outfall Drain and Mt. Pleasant Yacht Club sites in the Avon-Heathcote Estuary/Ihutai, where the concentration of five-six PAHs exceeded ISQG-low trigger values but not the ISQG-high trigger values.

The concentration of low molecular weight PAHs exceeded the ISQG-low trigger value at the Mt. Pleasant Yacht Club site and high molecular weight PAHs concentration exceeded the ISQG-low trigger value at the City Outfall Drain, Mt. Pleasant Yacht Club and Causeway sites. At these three sampling sites, PAH concentrations are potentially having an ecological effect, but the 2010 concentrations of PAHs at the other 15 sites are not cause for ecological concern.

Our recorded PAH concentrations indicate that, of the 18 sampling sites, those in the Avon-Heathcote Estuary/Ihutai are the most contaminated. Of those five sites, the most contaminated (most PAHs above ADL and highest total concentration of all PAHs) was the City Outfall Drain, followed in decreasing order by Mt. Pleasant Yacht Club, Causeway, South of Bridge Street, then Charlesworth Drain. The likely source of PAHs to these sites is the runoff of hydrocarbon residues from roads with rainfall.

In Lyttelton Harbour/Whakaraupō, we found concentrations above the ADL for 14 PAHs in Governors Bay, 13 PAHs at Allandale and Charteris Bay and 12 in Head of the Bay. PAH concentrations were typically higher at the Governors Bay site than the other three sites. The lowest concentrations occurred at Allandale and Head of the Bay. There is more traffic and roading near the Governors Bay sampling site than the others in the locality and the proximity of the Charteris Bay site to a busy road likely accounts for the higher concentrations there than at Allandale and Head of the Bay. For the remaining Banks Peninsula sites, we found concentrations above the ADL for, 11 PAHs in Childrens

Bay, ten in Port Levy/Koukourarata, five in Okains Bay and none at Barrys Bay, Robinsons Bay or Takamatua. PAH concentrations were low at the Okains Bay and Port Levy/Koukourarata sites, but concentrations at Childrens Bay were higher than all but the Avon-Heathcote Estuary/Ihutai sites. Childrens Bay is close to the Akaroa township and there is considerable boating activity in the area, thus the likely sources of PAHs to this sampling site are stormwater, runoff from roads with rainfall, and boating activities.

We recorded concentrations above the ADL for 14 PAHs at Saltwater Creek, six in Brooklands Lagoon and ten at the Opihi River mouth. Concentrations were higher at the Saltwater Creek site than at the Opihi River mouth and Brooklands Lagoon sites but not as high as at the Avon-Heathcote Estuary/Ihutai sites, or Governors Bay and Childrens Bay. The Saltwater Creek site is approximately 500 m downstream of SH1 so the likely source of PAHs to this site is runoff of hydrocarbon residues from the highway with rainfall.

5 Conclusions and recommendations

We found concentrations below ISQG-low trigger values for all recorded metal and metalloids. Additionally, apart from the City Outfall Drain, Mt. Pleasant Yacht Club and Causeway sites in the Avon-Heathcote Estuary/Ihutai, we found concentrations below ISQG-low values for all PAHs with ANZECC (2000) trigger values, including low and high molecular weight PAHs. These 2010 concentrations are not cause for ecological concern at 15 intertidal sites, but PAH concentrations at the City Outfall Drain, Mt. Pleasant Yacht Club and Causeway sites are concerning.

At the five sites in the Avon-Heathcote Estuary/Ihutai, human activities have caused elevated sediment metal, metalloid and PAH concentrations. Based on metal and metalloid concentrations the most contaminated sediment occurred at the South of Bridge Street and Charlesworth Drain sites followed in decreasing order by the City Outfall Drain, Mt. Pleasant Yacht Club and Causeway sites. Based on PAH concentrations the most contaminated sediment occurred at the City Outfall Drain site, followed in decreasing order by the Mt. Pleasant Yacht Club, Causeway, South of Bridge Street then Charlesworth Drain sites.

Human activities may have caused slightly elevated concentrations of metals and metalloid in the sediment from the Governors Bay, Charteris Bay, Takamatua and Childrens Bay sites (i.e. above concentrations at other sites within their respective localities). In Akaroa Harbour, PAHs were only present above ADL concentrations at the Childrens Bay site. PAHs above ADL concentrations were present at all Lyttelton Harbour/Whakaraupō sites, with concentrations at the Governors Bay site higher than the other sampling sites in the locality.

Saltwater Creek sediment contains PAHs that have likely originated from vehicles travelling along SH1. We also found an elevated concentration of mercury at this site, which may be a result of human activity, but the specific source is unknown.

Sediment from the remaining sampling sites, (Brooklands Lagoon, Port Levy/Koukourarata, Okains Bay, the Opihi River, two sites in Lyttelton Harbour/Whakaraupō and two sites in Akaroa Harbour), contain metal and metalloid concentrations comparable to background concentrations and below the ADL, and/or contained low PAHs concentrations.

Our results indicate human activities are or may be the cause of the contaminant concentrations in the sediment at all five sites in the Avon-Heathcote Estuary/Ihutai and at the Saltwater Creek, Governors Bay, Takamatua and Childrens Bay sites. Concentrations of some of the contaminants at these sampling sites are potentially concerning for the local ecology. We recommend that Environment Canterbury continues to monitor contaminant concentrations at these sampling sites by sampling frequently to determine if concentrations are increasing. Specifically, we recommend that Environment Canterbury performs bi-annual sediment quality monitoring at the sites that appear most vulnerable to human impacts (all five sites in the Avon-Heathcote Estuary/Ihutai and the Saltwater Creek, Governors Bay, Takamatua and Childrens Bay sites) and sediment quality monitoring every six years at the remaining nine sites.

6 Acknowledgements

Samples were collected by Patrick Lees and analysed by Hill Laboratories. This report was reviewed by Michele Stevenson and Tim Davie of Environment Canterbury.

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Appendix 1: Site report cards

Saltwater Creek

Site location
True right of Saltwater Creek, approximately 500 m east of the SH1 rest area

Sample area - right corner, close to sea co-ordinates E: 2486494 N: 5771553
Sampled 23 August 2010

Potential contaminant sources

- Activities within the Saltwater Creek catchment
- Runoff from SH1

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	59.9	43.5	63.0
Percent sand	40.1	56.5	37.0

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	3.6	4.4	4.8	20
Cadmium	0.03	0.033	0.037	1.5
Chromium	13	15	16	80
Copper	6.2	8.1	10.6	65
Lead	10.3	13.2	13.2	50
Mercury	0.07	0.078	0.07	0.15
Nickel	10.5	12.4	12.9	21
Zinc	41	52	53	200
TOC	0.69	0.87	0.68	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	0.004	0.044
Anthracene	0.0054	0.085
Fluorene	0.0054	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.024	0.240
Low molecular wt. PAHs	0.0898	0.552
Benzo[a]pyrene (BAP)	0.074	0.430
Benzo[a]anthracene	0.071	0.261
Chrysene	0.051	0.384
Dibenzo[a,h]anthracene	0.009	0.063
Fluoranthene	0.092	0.600
Pyrene	0.099	0.665
High molecular wt. PAHs	0.396	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.071	
Benzo[g,h,i]perylene	0.056	
Benzo[k]flouranthene	0.095	
Indeno(1,2,3-c,d) pyrene	0.056	

Brooklands Lagoon near the Styx River

Site location
True right of the Styx river mouth, Brooklands Lagoon

Sample area - right corner, close to sea co-ordinates E: 2486026 N: 5756489
Sampled 24 August 2010

Potential contaminant sources

- Activities within the Styx River catchment
- Activities within the Waimakariri catchment
- Stormwater from Brooklands township

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	71.6	76.2	76.6
Percent sand	28.4	23.8	23.4

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	4.8	4.7	5	20
Cadmium	0.032	0.043	0.042	1.5
Chromium	16.6	16.2	17.1	80
Copper	9.1	8.8	9.4	65
Lead	14.7	14.2	14.6	50
Mercury	0.059	0.054	0.056	0.15
Nickel	13	12.8	13.4	21
Zinc	50	49	51	200
TOC	0.34	0.34	0.42	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	below detection limit	0.044
Anthracene	below detection limit	0.085
Fluorene	0.005	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.014	0.240
Low molecular wt. PAHs	0.072	0.552
Benzo[a]pyrene (BAP)	below detection limit	0.430
Benzo[a]anthracene	below detection limit	0.261
Chrysene	below detection limit	0.384
Dibenzo[a,h]anthracene	below detection limit	0.063
Fluoranthene	0.008	0.600
Pyrene	0.014	0.665
High molecular wt. PAHs	0.026	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.011	
Benzo[g,h,i]perylene	0.025	
Benzo[k]flouranthene	below detection limit	
Indeno(1,2,3-c,d) pyrene	below detection limit	

South of Bridge Street

Site location
North-west corner of the estuary, downstream of the Bridge Street bridge, near the mouth of the Avon/Ōtākaro River

Sample area - right corner, close to sea co-ordinates E: 2487869; N: 5741934
Sampled 11 August 2010

Potential contaminant sources

- Activities within the Avon/Ōtākaro River catchment
- Stormwater
- Road runoff

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	48.3	44.4	42.7
Percent sand	51.7	55.7	57.3

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	4	3.6	3.2	20
Cadmium	0.21	0.184	0.193	1.5
Chromium	25	22	21	80
Copper	13.2	10.6	10.4	65
Lead	19.4	17.5	16.6	50
Mercury	0.09	0.113	0.085	0.15
Nickel	12	10.6	10.3	21
Zinc	99	85	84	200
TOC	0.54	0.64	0.63	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	0.014	0.044
Anthracene	0.018	0.085
Fluorene	0.012	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.088	0.240
Low molecular wt. PAHs	0.182	0.552
Benzo[a]pyrene (BAP)	0.112	0.430
Benzo[a]anthracene	0.094	0.261
Chrysene	0.084	0.384
Dibenzo[a,h]anthracene	0.018	0.063
Fluoranthene	0.202	0.600
Pyrene	0.204	0.665
High molecular wt. PAHs	0.713	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.161	
Benzo[g,h,i]perylene	0.112	
Benzo[k]flouranthene	0.063	
Indeno(1,2,3-c,d) pyrene	0.112	

Charlesworth Drain

Site location
Western side of the Humphreys Basin, Avon-Heathcote Estuary/Ihutai, on the true left bank of the Charlesworth Drain channel

Sample area - right corner, close to sea co-ordinates E: 2486557; N: 5739912
Sampled 29 July 2010

Potential contaminant sources

- Activities within the drain catchment
- Stormwater
- City rivers

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	46.8	44.8	43.5
Percent sand	53.2	55.2	56.5

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	5.3	5.5	5.2	20
Cadmium	0.1	0.2	0.2	1.5
Chromium	20	24	21	80
Copper	12.4	15.4	13.7	65
Lead	22	25	23	50
Mercury	0.083	0.068	0.057	0.15
Nickel	12.3	13.2	12.3	21
Zinc	117	143	130	200
TOC	0.53	0.7	0.67	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	0.011	0.044
Anthracene	0.017	0.085
Fluorene	0.008	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.079	0.240
Low molecular wt. PAHs	0.166	0.552
Benzo[a]pyrene (BAP)	0.092	0.430
Benzo[a]anthracene	0.096	0.261
Chrysene	0.099	0.384
Dibenzo[a,h]anthracene	0.014	0.063
Fluoranthene	0.193	0.600
Pyrene	0.197	0.665
High molecular wt. PAHs	0.692	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.156	
Benzo[g,h,i]perylene	0.099	
Benzo[k]flouranthene	0.063	
Indeno(1,2,3-c,d) pyrene	0.082	

City Outfall Drain

Site location
South-western side of Humphreys Basin, Avon-Heathcote Estuary/Ihutai, on the true right side of the City Outfall Drain channel

Sample area - right corner, close to sea co-ordinates E: 2486131; N: 5739542
Sampled 10 August 2010

Potential contaminant sources

- Activities within the City Outfall Drain catchment
- Stormwater
- Christchurch City rivers

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	47.87	43.5	43.19
Percent sand	52.13	56.5	56.81

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	3.9	3.8	3.8	20
Cadmium	0.154	0.169	0.161	1.5
Chromium	18.1	22	18.2	80
Copper	10.3	10.4	10.5	65
Lead	18.9	19.4	19.9	50
Mercury	0.07	0.066	0.064	0.15
Nickel	10.6	13.7	10.7	21
Zinc	111	113	117	200
TOC	0.41	0.56	0.53	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	0.008	0.016
Acenaphthylene	0.026	0.044
Anthracene	0.07	0.085
Fluorene	0.026	0.019
Naphthalene	0.032	0.160
Phenanthrene	0.356	0.240
Low molecular wt. PAHs	0.518	0.552
Benzo[a]pyrene (BAP)	0.44	0.430
Benzo[a]anthracene	0.364	0.261
Chrysene	0.356	0.384
Dibenzo[a,h]anthracene	0.052	0.063
Fluoranthene	0.7	0.600
Pyrene	0.7	0.665
High molecular wt. PAHs	2.612	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.56	
Benzo[g,h,i]perylene	0.346	
Benzo[k]flouranthene	0.226	
Indeno(1,2,3-c,d) pyrene	0.316	

Mount Pleasant Yacht Club

Site location
Southern side of the Humphreys Basin, Avon-Heathcote Estuary/Ihutai, near the mouth of the Heathcote/Ōpāwaho River

Sample area - right corner, close to sea co-ordinates E: 2486609 N: 5739034
Sampled 11 August 2010

Potential contaminant sources

- Activities within the Heathcote/Ōpāwaho River catchment
- Stormwater
- Road runoff

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	30.45	29.95	29.5
Percent sand	69.55	70.05	70.5

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	2.7	2.8	3.1	20
Cadmium	0.151	0.159	0.159	1.5
Chromium	14.5	13.7	15	80
Copper	7.3	6.3	7.4	65
Lead	15	14.2	15.9	50
Mercury	0.051	0.041	0.054	0.15
Nickel	9.2	8.6	9.1	21
Zinc	86	81	88	200
TOC	0.27	0.29	0.26	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	0.029	0.016
Acenaphthylene	0.033	0.044
Anthracene	0.077	0.085
Fluorene	0.066	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.454	0.240
Low molecular wt. PAHs	0.709	0.552
Benzo[a]pyrene (BAP)	0.348	0.430
Benzo[a]anthracene	0.307	0.261
Chrysene	0.271	0.384
Dibenzo[a,h]anthracene	0.048	0.063
Fluoranthene	0.670	0.600
Pyrene	0.637	0.665
High molecular wt. PAHs	2.280	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.432	
Benzo[g,h,i]perylene	0.307	
Benzo[k]flouranthene	0.176	
Indeno(1,2,3-c,d) pyrene	0.267	

Causeway

Site location
Southern side of the Avon-Heathcote Estuary/Ihutai, on the estuary side of the McCormacks Bay causeway

Sample area - right corner, close to sea co-ordinates E: 2487761 N: 5739086
Sampled 10 August 2010

Potential contaminant sources

- City rivers
- Stormwater
- Road runoff

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	8.38	9.36	9.36
Percent sand	91.62	90.64	90.64

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

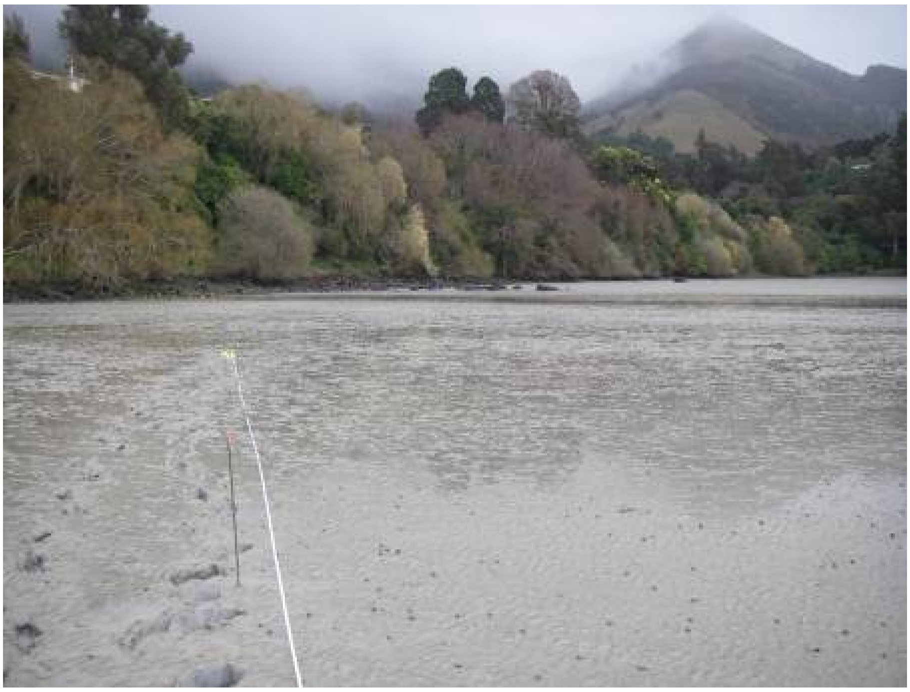
	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	3.3	2.9	3.3	20
Cadmium	0.139	0.136	0.135	1.5
Chromium	14.1	13	14.3	80
Copper	4.7	3.8	5.6	65
Lead	12.6	11.4	13.4	50
Mercury	0.046	0.045	0.06	0.15
Nickel	9.8	8.9	10	21
Zinc	66	60	67	200
TOC	0.31	0.29	0.29	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	0.024	0.044
Anthracene	0.051	0.085
Fluorene	0.013	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.195	0.240
Low molecular wt. PAHs	0.334	0.552
Benzo[a]pyrene (BAP)	0.286	0.430
Benzo[a]anthracene	0.259	0.261
Chrysene	0.239	0.384
Dibenzo[a,h]anthracene	0.034	0.063
Fluoranthene	0.526	0.600
Pyrene	0.516	0.665
High molecular wt. PAHs	1.860	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.371	
Benzo[g,h,i]perylene	0.239	
Benzo[k]flouranthene	0.152	
Indeno(1,2,3-c,d) pyrene	0.219	

Governors Bay

Site location
West of the Governers Bay jetty, Lyttelton Harbour/Whakaraupō



Sample area - right corner, close to sea co-ordinates E: 2482021 N: 5731438
Sampled 7 September 2010

Potential contaminant sources

- Road runoff
- Stormwater
- Harbour activities

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	88.82	89.21	88.81
Percent sand	11.18	10.79	11.19

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	4.9	4.8	4.8	20
Cadmium	0.022	0.028	0.024	1.5
Chromium	18.8	18.4	19	80
Copper	8.3	8	8.3	65
Lead	17.8	19.5	17.9	50
Mercury	0.054	0.06	0.065	0.15
Nickel	13.2	12.9	13.4	21
Zinc	61	60	60	200
TOC	0.62	0.61	0.61	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	0.008	0.044
Anthracene	0.021	0.085
Fluorene	0.015	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.086	0.240
Low molecular wt. PAHs	0.181	0.552
Benzo[a]pyrene (BAP)	0.062	0.430
Benzo[a]anthracene	0.065	0.261
Chrysene	0.070	0.384
Dibenzo[a,h]anthracene	0.010	0.063
Fluoranthene	0.143	0.600
Pyrene	0.134	0.665
High molecular wt. PAHs	0.484	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.104	
Benzo[g,h,i]perylene	0.052	
Benzo[k]flouranthene	0.041	
Indeno(1,2,3-c,d) pyrene	0.041	

Allandale

Site location
Directly out from the car park at Allandale, Lyttelton Harbour/Whakaraupō

Sample area - right corner, close to sea co-ordinates E: 2481827 N: 5729755
Sampled 7 September 2010

Potential contaminant sources
- Road runoff
- Harbour activities

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	82.62	81.29	76.8
Percent sand	17.38	18.71	23.2

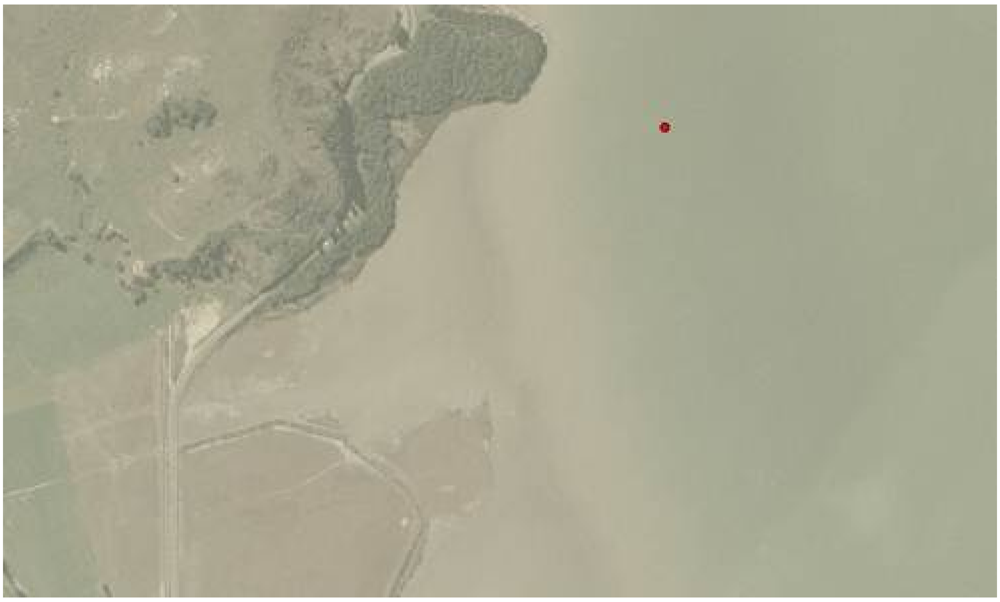
Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	3.6	3.6	3.4	20
Cadmium	0.022	0.024	0.023	1.5
Chromium	14.6	14.7	14	80
Copper	6.6	6.6	6.4	65
Lead	13.6	14	13.2	50
Mercury	0.041	0.057	0.051	0.15
Nickel	10.4	10.5	10	21
Zinc	47	48	46	200
TOC	0.65	0.63	0.62	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	below detection limit	0.044
Anthracene	0.005	0.085
Fluorene	0.006	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.033	0.240
Low molecular wt. PAHs	0.096	0.552
Benzo[a]pyrene (BAP)	0.027	0.430
Benzo[a]anthracene	0.027	0.261
Chrysene	0.035	0.384
Dibenzo[a,h]anthracene	0.005	0.063
Fluoranthene	0.054	0.600
Pyrene	0.051	0.665
High molecular wt. PAHs	0.197	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.052	
Benzo[g,h,i]perylene	0.027	
Benzo[k]flouranthene	0.021	
Indeno(1,2,3-c,d) pyrene	0.019	

Head of the Bay



Site location
Head of the Bay, approximately 1 km from the road at the northern end of the bay, Lyttelton Harbour/Whakaraupō

Sample area - right corner, close to sea co-ordinates E: 2482801 N: 5728704
Sampled 21 September 2010

Potential contaminant sources

- General harbour activities

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	50.73	52.14	50.39
Percent sand	49.27	47.86	49.61

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	4	4.4	3.8	20
Cadmium	0.024	0.021	0.023	1.5
Chromium	15.5	15.3	15.4	80
Copper	4.9	5.1	4.8	65
Lead	11.5	11.7	11.5	50
Mercury	0.046	0.05	0.044	0.15
Nickel	11.3	11.4	11.2	21
Zinc	46	46	45	200
TOC	0.3	0.28	0.25	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	below detection limit	0.044
Anthracene	below detection limit	0.085
Fluorene	0.007	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.036	0.240
Low molecular wt. PAHs	0.096	0.552
Benzo[a]pyrene (BAP)	0.025	0.430
Benzo[a]anthracene	0.025	0.261
Chrysene	0.029	0.384
Dibenzo[a,h]anthracene	below detection limit	0.063
Fluoranthene	0.061	0.600
Pyrene	0.054	0.665
High molecular wt. PAHs	0.196	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.047	
Benzo[g,h,i]perylene	0.033	
Benzo[k]flouranthene	0.018	
Indeno(1,2,3-c,d) pyrene	0.025	

Charteris Bay

Site location
Charteris Bay embayment, Lyttelton Harbour/Whakaraupō

Sample area - right corner, close to sea co-ordinates E: 2486270 N: 5728475
Sampled 21 September 2010

Potential contaminant sources

- Road runoff
- Stormwater
- General harbour activities

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	79.6	71.3	75.5
Percent sand	20.4	28.7	24.5

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	4.3	4.6	3.9	20
Cadmium	0.025	0.023	0.027	1.5
Chromium	16.9	17.5	16.3	80
Copper	7	7	6.5	65
Lead	15.1	15.7	14.7	50
Mercury	0.054	0.061	0.047	0.15
Nickel	13.1	13.5	13.7	21
Zinc	51	51	48	200
TOC	0.58	0.55	0.5	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	below detection limit	0.044
Anthracene	0.007	0.085
Fluorene	0.006	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.040	0.240
Low molecular wt. PAHs	0.105	0.552
Benzo[a]pyrene (BAP)	0.031	0.430
Benzo[a]anthracene	0.028	0.261
Chrysene	0.035	0.384
Dibenzo[a,h]anthracene	0.004	0.063
Fluoranthene	0.070	0.600
Pyrene	0.064	0.665
High molecular wt. PAHs	0.232	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.048	
Benzo[g,h,i]perylene	0.035	
Benzo[k]flouranthene	0.018	
Indeno(1,2,3-c,d) pyrene	0.029	

Port Levy/Koukourarata

Site location
Western side of the boat ramp, between the point and the island

Sample area - right corner, close to sea co-ordinates E: 2496388 N: 5728288
Sampled 5 October 2010

Potential contaminant sources

- Road runoff
- Activities in the stream catchment
- Stormwater

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	70.9	67.9	72.5
Percent sand	29.1	32.1	27.5

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	4.9	5.6	4.7	20
Cadmium	0.04	0.038	0.034	1.5
Chromium	15	16.2	13.5	80
Copper	6.6	7.4	6	65
Lead	12.5	13.7	11.9	50
Mercury	0.049	0.043	0.04	0.15
Nickel	10.1	11.2	9.1	21
Zinc	45	50	43	200
TOC	0.62	0.76	0.49	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	below detection limit	0.044
Anthracene	below detection limit	0.085
Fluorene	0.006	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.019	0.240
Low molecular wt. PAHs	0.079	0.552
Benzo[a]pyrene (BAP)	0.003	0.430
Benzo[a]anthracene	0.003	0.261
Chrysene	0.005	0.384
Dibenzo[a,h]anthracene	below detection limit	0.063
Fluoranthene	0.011	0.600
Pyrene	0.010	0.665
High molecular wt. PAHs	0.033	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.008	
Benzo[g,h,i]perylene	0.010	
Benzo[k]flouranthene	below detection limit	
Indeno(1,2,3-c,d) pyrene	0.005	

Okains Bay

Site location
Seaward of the Chorlton Road Bridge, on mudflat closest to the hill, Okains Bay estuary

Sample area - right corner, close to sea co-ordinates E 2378058; N 5657299
Sampled 24 September 2010

Potential contaminant sources

- Road runoff
- Leachate from the refuse transfer station
- Activities within the Opara catchment

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	61.0	62.7	63.8
Percent sand	39.1	37.3	36.2

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	3.2	3.5	3.6	20
Cadmium	0.046	0.042	0.045	1.5
Chromium	12	12.9	12.7	80
Copper	6	6.2	6.3	65
Lead	8.6	8.8	9.3	50
Mercury	0.03	0.028	0.027	0.15
Nickel	8.7	9.3	9.3	21
Zinc	46	48	50	200
TOC	1.08	1.07	1.02	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	below detection limit	0.044
Anthracene	below detection limit	0.085
Fluorene	below detection limit	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.003	0.240
Low molecular wt. PAHs	0.057	0.552
Benzo[a]pyrene (BAP)	below detection limit	0.430
Benzo[a]anthracene	below detection limit	0.261
Chrysene	below detection limit	0.384
Dibenzo[a,h]anthracene	below detection limit	0.063
Fluoranthene	0.003	0.600
Pyrene	0.003	0.665
High molecular wt. PAHs	0.010	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.002	
Benzo[g,h,i]perylene	0.002	
Benzo[k]flouranthene	below detection limit	
Indeno(1,2,3-c,d) pyrene	below detection limit	

Barrys Bay

Site location
Mid-way into the bay from the northern shoreline of Barrys Bay

Sample area - right corner, close to sea co-ordinates E: 2503420 N: 5716519
Sampled 24 September 2010

Potential contaminant sources
- Road runoff
- Various catchment activities
- Cheese factory

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	18.8	19.2	16.6
Percent sand	81.2	80.8	83.4

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	2.5	2.5	2.6	20
Cadmium	0.026	0.024	0.027	1.5
Chromium	5.5	5.3	5.6	80
Copper	1.7	1.5	1.7	65
Lead	3.5	3.2	3.7	50
Mercury	0.015	0.0011	<0.010	0.15
Nickel	2.7	2.5	2.7	21
Zinc	18.6	17.9	19.2	200
TOC	0.1	0.11	0.12	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	below detection limit	0.044
Anthracene	below detection limit	0.085
Fluorene	below detection limit	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	below detection limit	0.240
Low molecular wt. PAHs		0.552
Benzo[a]pyrene (BAP)	below detection limit	0.430
Benzo[a]anthracene	below detection limit	0.261
Chrysene	below detection limit	0.384
Dibenzo[a,h]anthracene	below detection limit	0.063
Fluoranthene	below detection limit	0.600
Pyrene	below detection limit	0.665
High molecular wt. PAHs		1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	below detection limit	
Benzo[g,h,i]perylene	below detection limit	
Benzo[k]flouranthene	below detection limit	
Indeno(1,2,3-c,d) pyrene	below detection limit	

Robinsons Bay

Site location
Northern corner of Robinsons Bay

Sample area - right corner, close to sea co-ordinates E: 2506720 N: 5716059
Sampled 20 September 2010

Potential contaminant sources

- General harbour activities

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	7.1	7.2	5.9
Percent sand	92.9	92.8	94.1

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	2.1	2.2	2.2	20
Cadmium	0.024	0.024	0.027	1.5
Chromium	7.3	7.8	8	80
Copper	2	2.1	2.2	65
Lead	2.4	2.6	2.6	50
Mercury	0.014	0.015	0.011	0.15
Nickel	3.3	3.4	3.5	21
Zinc	17.4	18.1	18.7	200
TOC	0.18	0.15	0.17	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	below detection limit	0.044
Anthracene	below detection limit	0.085
Fluorene	below detection limit	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	below detection limit	0.240
Low molecular wt. PAHs		0.552
Benzo[a]pyrene (BAP)	below detection limit	0.430
Benzo[a]anthracene	below detection limit	0.261
Chrysene	below detection limit	0.384
Dibenzo[a,h]anthracene	below detection limit	0.063
Fluoranthene	below detection limit	0.600
Pyrene	below detection limit	0.665
High molecular wt. PAHs		1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	below detection limit	
Benzo[g,h,i]perylene	below detection limit	
Benzo[k]flouranthene	below detection limit	
Indeno(1,2,3-c,d) pyrene	below detection limit	

Takamatua

Site location
South-eastern corner of the bay

Sample area - right corner, close to sea co-ordinates E: 2507065 N: 5713620
Sampled 24 September 2010

Potential contaminant sources
- Road runoff
- Stormwater

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	47.1	45.6	47.8
Percent sand	52.9	54.5	52.3

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	3.2	3.2	3	20
Cadmium	0.03	0.028	0.03	1.5
Chromium	7.6	8.1	8.2	80
Copper	4	4.2	4.2	65
Lead	5	5.3	4.8	50
Mercury	0.032	0.037	0.041	0.15
Nickel	4.9	5.2	5.3	21
Zinc	31	33	32	200
TOC	0.49	0.54	0.36	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	below detection limit	0.044
Anthracene	below detection limit	0.085
Fluorene	below detection limit	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	below detection limit	0.240
Low molecular wt. PAHs		0.552
Benzo[a]pyrene (BAP)	below detection limit	0.430
Benzo[a]anthracene	below detection limit	0.261
Chrysene	below detection limit	0.384
Dibenzo[a,h]anthracene	below detection limit	0.063
Fluoranthene	below detection limit	0.600
Pyrene	below detection limit	0.665
High molecular wt. PAHs		1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	below detection limit	
Benzo[g,h,i]perylene	below detection limit	
Benzo[k]flouranthene	below detection limit	
Indeno(1,2,3-c,d) pyrene	below detection limit	

Childrens Bay

Site location
Approximately 300 m into the bay from the DOC picnic area, Childrens Bay

Sample area - right corner, close to sea co-ordinates E: 2507093 N: 5712155
Sampled 20 September 2010

Potential contaminant sources
- Road runoff
- Stormwater from Akaroa township
- Boating activity
- Activities in the stream catchment

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	10.4	13.1	11.3
Percent sand	89.6	86.9	88.7

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	3.4	3.3	3.4	20
Cadmium	0.087	0.08	0.079	1.5
Chromium	10.4	10.1	10.7	80
Copper	3	3	3.1	65
Lead	8	7.5	7.7	50
Mercury	0.025	0.027	0.022	0.15
Nickel	4.2	4.1	4.1	21
Zinc	35	33	35	200
TOC	0.17	0.15	0.14	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	below detection limit	0.044
Anthracene	below detection limit	0.085
Fluorene	below detection limit	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.052	0.240
Low molecular wt. PAHs	0.106	0.552
Benzo[a]pyrene (BAP)	0.143	0.430
Benzo[a]anthracene	0.124	0.261
Chrysene	0.124	0.384
Dibenzo[a,h]anthracene	0.020	0.063
Fluoranthene	0.235	0.600
Pyrene	0.209	0.665
High molecular wt. PAHs	0.854	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.183	
Benzo[g,h,i]perylene	0.117	
Benzo[k]flouranthene	0.078	
Indeno(1,2,3-c,d) pyrene	0.117	

Opihi River

Site Location
Southern arm of the lower Opihi River hapua

Sample area - right corner, close to sea co-ordinates E: 2377885 N: 5657076
Sampled 27 September 2010

Potential contaminant sources

- Activities within the Opihi catchment

Sediment grain size

	Sample 1	Sample 2	Sample 3
Percent mud	75.5	67.5	74.3
Percent sand	24.5	32.6	25.7

Metals, metalloids (mg/kg dry wt) and total organic carbon (TOC) (g/100 g dry wt)

	Sample 1	Sample 2	Sample 3	ANZECC ISQG-Low
Arsenic	2.3	2.4	2.1	20
Cadmium	0.035	0.033	0.04	1.5
Chromium	12.3	13.6	13.3	80
Copper	9.5	10.2	10	65
Lead	12.9	13.2	13	50
Mercury	0.033	0.043	0.037	0.15
Nickel	9.9	10.8	10.5	21
Zinc	48	51	49	200
TOC	1.3	1.05	1.1	

Hydrocarbons (mg/kg dry wt) normalised to 1% TOC

PAHs	Sample	ANZECC ISQG-Low
Acenaphthene	below detection limit	0.016
Acenaphthylene	below detection limit	0.044
Anthracene	below detection limit	0.085
Fluorene	below detection limit	0.019
Naphthalene	below detection limit	0.160
Phenanthrene	0.003	0.240
Low molecular wt. PAHs	0.057	0.552
Benzo[a]pyrene (BAP)	0.003	0.430
Benzo[a]anthracene	0.003	0.261
Chrysene	0.003	0.384
Dibenzo[a,h]anthracene	below detection limit	0.063
Fluoranthene	0.009	0.600
Pyrene	0.007	0.665
High molecular wt. PAHs	0.027	1.7
Benzo[b]fluoranthene + Benzo[j] fluoranthene	0.005	
Benzo[g,h,i]perylene	0.004	
Benzo[k]flouranthene	0.003	
Indeno(1,2,3-c,d) pyrene	0.003	

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Everything is connected

Promoting quality of life through balanced resource management

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