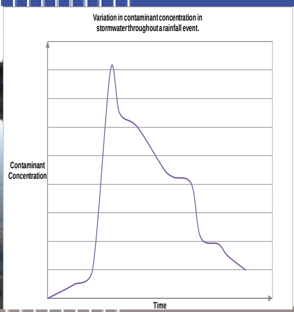

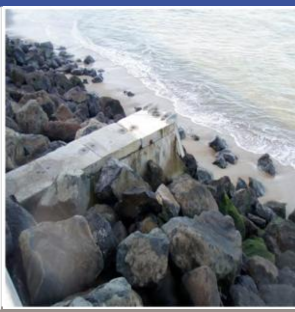

Stormwater Monitoring

Dunedin City Stormwater Monitoring Framework

29 MAY 2012

Prepared for

Dunedin City Council

42178807

DUNEDIN CITY COUNCIL
Kaunihera-a-rohe o Otepoti

ryderconsulting
environment + planning + project management

URS

Project Manager:	…………………………… Tim Ensor Associate Planner	**URS New Zealand Limited** **Level 1, 31 Orchard Road** **Christchurch Airport 8053** **PO Box 4479, Christchurch 8140** **New Zealand** **T: 64 3 374 8500** **F: 64 3 377 0655**	
Principal-In-Charge:	…………………………… Daniel Murray Principal Planner		
Authors	Helen Shaw, Golder Associates (NZ) Ltd Brian Stewart, Ryder Consulting Ltd		
Reviewer:	……………………………	Date: Reference: Status:	29 May 2012 42178807/01/1 Final

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Abbreviations

Abbreviation	Description
AEE	Assessment of Environmental Effects
DCC	
Amphipod	An order of small (but generally visible) shrimp-like crustaceans, such as sand fleas.
ANZECC	Australian and New Zealand Environmental and Conservation Council.
ARI	Average Recurrence Interval: describes the size of a flood event as the statistical average number of years between such occurrences.
BDL	Below detection limits.
Benthic	Of, or relating to, the ecological region at the lowest level of a body of water such as an ocean or a lake (i.e. on the seabed).
Biota	All the flora and fauna of a particular region.
Catchment	An area that drains naturally to a particular point, for example to a river, lake or a harbour / ocean outfall.
Coliform	A group of bacteria that inhabit the intestines (especially the colon) of mammals, and whose presence in water may indicate contamination by disease-causing microorganisms.
DCC	Dunedin City Council.
E. coli	Escherichia coli: bacteria naturally occurring in the lower intestine of many animals, and commonly used to indicate the presence of pathogenic bacteria in water.
Enterococci	(plural) An indicator organism used to assess the presence of human pollution (as distinct from animal pollution) in waterways or the sea.
Epifauna	Invertebrates that attach themselves to rocky reefs, the seafloor, or on the surface of other plants or animals.
First flush	The initial surface runoff of a rainstorm, typically containing higher contaminant concentrations than the remainder of the storm runoff.
Grab sample	A method of sampling whereby a single sample or measurement is taken at a specific time and place.
ICMP	Integrated Catchment Management Plan
Infauna	Aquatic animals that live within submerged sediments.
Invertebrate	An animal without a backbone. This includes 95% of all animal species.
Macroinvertebrate	An invertebrate large enough to be seen with the human eye.
Macrophyte	Large rooted or floating aquatic plant.
MHWS	Mean high water springs.
Microalgae	Microscopic types of algae.
Polchaete worms	Marine annelids (worms) possessing both sexes and having paired appendages (parapodia) bearing bristles.
Taxa	The plural form of taxon: - a taxonomic group is an animal or plant group having natural relations, based on genetic and morphological similarities.
TSS	Total Suspended Solids.

Executive Summary

The Dunedin City Council have applied for 35 year consents to continue discharge from the stormwater outfalls into the Otago Harbour and the Pacific Ocean. Accompanying the consent applications are Integrated Catchment Management Plans (ICMPs) for each stormwater catchment.

As part of the ICMP development, an Assessment of Environmental Effects (AEE) was undertaken, where stormwater monitoring information collected (historical and current) was collated and analysed, within the context of wider catchment stormwater management.

The ICMPs identified that, although the current stormwater discharges did not appear to be causing a significant ecological degradation in the environment, it was difficult to establish a direct link (for management purposes) between the quality of the stormwater discharged from the catchments and the state of the receiving environment.

There are potentially a number of reasons for the difficulty in establishing these links, as follows:

- The absence of pre-2005 'baseline' information regarding the natural state of the Upper Harbour, and the already altered state of the harbour due to the impact of historical activities such as reclamation and dredging, and industrial land uses.
- The close proximity of all outfalls, resulting in near-shore mixing of all catchment discharges.
- The presence of a number of other inputs to the harbour (particularly freshwater inputs, most notably the Water of Leith).
- The sampling techniques used (e.g. grab samples only providing 'snapshots' of stormwater quality).

In response to these issues, the ICMPs recommended that a revised monitoring framework for stormwater quality and harbour environment monitoring be designed and implemented. This framework has been developed in response to this recommendation, and provides a review of historical information, gap analysis and proposed methodologies for stormwater quality, harbour sediment quality, harbour ecology, and harbour water quality monitoring. It is proposed that some of this monitoring be carried out as stormwater discharge consent – related monitoring, however the methodologies presented will also ensure consistent results for DCC-initiated monitoring outside of the consent process, driven by a commitment to the community to improve the quality of stormwater discharged to the Harbour.

Improved data confidence will allow the further prioritisation of stormwater management recommendations based on the significance of stormwater quality issues. This would occur city-wide and form part of the 3 Waters Strategic Plan.

Proposed methods:

Stormwater Quality

The use of time proportional monitoring is preferred in order to develop a better understanding of stormwater quality being discharged from Dunedin's urban catchments. The main objective of this sampling is so that better estimates can be made of stormwater loads, and to ensure that stormwater quality sampling can be used to help measure the success of catchment-based stormwater management.

The proposed methodology is therefore as follows:

1. Phase 1: time/flow proportional monitoring to gather information (priority catchments, 1-5 years); and

Executive Summary

2. Phase 2: grab sampling or 'management effectiveness' monitoring (priority catchments, ongoing).

Resources will prohibit the simultaneous sampling of all catchments, therefore prioritisation will be necessary.

Harbour Sediments

Historical sediment sampling has provided a good picture of the status of the Upper Otago Harbour Basin, and indicates that contamination from stormwater discharges is likely to have occurred in the past. There are knowledge gaps, however, relating to the deposition rates in the harbour, and therefore the temporal trends (i.e. at what point in time contamination occurred, and whether the more recent discharges have been depositing 'cleaner' sediments).

It is proposed that sediment sampling and analysis be continued in the harbour, alongside ecological monitoring, to provide a picture of harbour environment health, and to enable a better assessment of current discharge effects versus historical contamination. A two-phased approach is recommended as follows, with the first phase aimed at filling in the knowledge gaps:

1. Phase 1: Sediment deposition rate monitoring and current deposit analysis using sediment traps, with discrete deep core sampling (1-5 years); and
2. Phase 2: Prioritised sediment monitoring (ongoing).

The inclusion of harbour reference sites is also recommended, to enable the comparison of data collected within and outside of the stormwater mixing zone.

Harbour Ecology

Ecological monitoring undertaken as part of the current consent compliance conditions has provided a good picture of harbour ecological health in the vicinity of stormwater discharge points.

The conclusions drawn from the ongoing monitoring indicate that benthic and infaunal communities at the monitored sites have reasonably low diversity, however this is likely to be symptomatic of a large proportion of the Upper Harbour Basin (Ryder, 2011b). It is possible that this is due to historical stormwater inputs (during the early 20th century), however a number of other factors, such as exposure at low tide and freshwater inputs are likely to be influential.

It is considered that the ecological monitoring currently undertaken can be used to provide a general indicator of environmental health within the upper harbour. In association with harbour water, sediment, and stormwater quality monitoring, ecological health monitoring will increasingly be able to give a broad picture of the effects of stormwater discharges; as links between the discharges and the sediments are better understood, ecological monitoring results should provide more useful feedback in terms of direct environmental effects.

The present monitoring regime is considered to be sufficient to determine trends in environmental health within the part of the Upper Harbour monitored, however it is proposed to also include monitoring at a number of 'reference sites' outside of the stormwater mixing zone, to enable comparisons to be undertaken. Detailed in this document are the sites, and ecological monitoring methodologies; an outline of indicator organisms and particular triggers is provided. Statistical analysis is used to detect a change in measurements such as diversity from year to year and between sites.

Harbour Water Quality

Harbour water quality has been monitored recently by DCC, however further monitoring provides an opportunity to assess the harbour with respect to the policies and objectives outlined in The Regional Plan: Coast for Otago (Coastal Plan), but also to help create linkages between stormwater discharges and contaminants in sediments.

It is proposed to monitor the harbour water quality both during dry weather and after rain events; this will provide both an indication of ongoing water quality, and also short-term changes in quality as a result of stormwater inputs. This monitoring also responds to the objectives of the Otago Regional Plan: Coast, specifically to Objective 10.3.1, which seeks '*to maintain existing water quality within Otago's coastal marine area and to seek to achieve water quality within the coastal marine area that is, at a minimum, suitable for contact recreation and the eating of shellfish within 10 years of the date of approval of this plan*'.

Triggers and Response

For stormwater management purposes, a 'feedback' loop is proposed, whereby triggers indicating potential contaminant discharges or effects are used to prompt a management response where appropriate. Table ES-1 summarises the key triggers identified for harbour sediment and water quality. Because a number of these triggers are based on previous sampling results, it will be necessary to review these triggers annually as part of consent compliance reporting, with the ANZECC guildeines for protection of 95 % of marine species being the minimum trigger. Triggers set at ANZECC guideline levels will only require review when the revised ANZECC guidelines are published. In terms of harbour ecology, a reduction in community diversity index over two years (using a one way ANOVA statistical analysis) has been selected as a trigger value. Additionally, sediment results will need to be reviewed alongside ecological results when sediment trigger values are exceeded.

Table ES-1: 2013 Trigger Values

Indicator	2013 Harbour Water Quality Trigger Value	2013 SedimentTrigger Value
Arsenic	0.024 g/m^3	19 mg/kg dry wt
Cadmium	0.00550 g/m^3	1.7 mg/kg dry wt
Chromium	0.00440 g/m^3	80 mg/kg dry wt
Copper	0.00130 g/m^3	122 mg/kg dry wt
Nickel	0.07000 g/m^3	21 mg/kg dry wt
Lead	0.00440 g/m^3	209 mg/kg dry wt
Zinc	0.01500 g/m^3	902 mg/kg dry wt
Total PAH	n/a	183 mg/kg dry wt
Enterococci	140 cfu/100 ml	n/a

Introduction

1.1 Background and Context

1.1.1 2007 Harbour Discharge Resource Consents

When applying for the resource consents for harbour discharges in 2005, DCC undertook a review of historical information, and some further monitoring to assess the likely impact of the stormwater discharge on the harbour receiving environment (Ryder Consulting, 2005a). While it was apparent that some historical contamination of the harbour environment had occurred (e.g. through discharges from a now disused gas works), there was evidence that the quality of discharges into the Upper Harbour were improving, with more recent (i.e. shallower) sediments containing lower concentrations of some PAHs than older sediments (Ryder Consulting, 2005b).

At the time, it was identified that further information was required in order to quantify links between stormwater discharge and the quality of the harbour environment.

In 2007, 31 short term (5 year) stormwater discharge consents were granted by the Otago Regional Council (ORC) permitting DCC to discharge stormwater into the Otago Harbour and the Pacific Ocean.

The short term discharge consents were granted with a number of conditions, including the following:

- *Stormwater Discharge Sampling and Monitoring* – the consent holder was required to undertake water quality sampling of the stormwater discharge from a number of catchments, following one storm annually (with conditions pertaining to the size of the event, the antecedent conditions, and the constituents to be monitored).

- *Biological Monitoring* – the consent holder was required to undertake biological monitoring at sites adjacent to and at some distance from a number of the outfalls. This monitoring included measuring diversity and abundance of infauna, epifauna, and macroflora, and testing the flesh of cockles and octopus for particular stormwater associated contaminants.

- *Sediment Monitoring* – the consent holder was required to undertake sediment sampling at a number of offshore sites. Conditions specified that the sediment was to be analysed for certain contaminants.

- *Management Plans* – The consent holder was required to prepare Long Term Stormwater Catchment Management Plans for each stormwater catchment. The emphasis of such plans was to be monitoring stormwater quality and mitigating adverse stormwater effects on the harbour's receiving environment.

The Dunedin City Council has met all of the above conditions and are currently in the process of applying for 35 year consents to continue discharge from the stormwater outfalls into the Otago Harbour and the Pacific Ocean. Accompanying the consent applications are Integrated Catchment Management Plans (ICMPs) for each stormwater catchment.

1 Introduction

1.1.2 Integrated Catchment Management Plans

In response to the consent conditions outlined in Section 1.1.1, the development of Integrated Catchment Management Plans (ICMPs) for consented stormwater catchments discharging to the Otago Harbour and the Pacific Ocean began in 2008, with ten ICMPs completed by mid 2011. Catchment boundaries, outfall locations and receiving environments are displayed in Figure 1-1 below.

The ten ICMPs cover discharges to six different receiving environments, outlined in Table 1-1.

Table 1-1 Receiving Environments

Catchments	Receiving Environment
South Dunedin Portsmouth Drive Orari Street Kitchener Street Mason Street Halsey Street Ravensbourne Road	Upper Otago Harbour Basin
Shore Street	Andersons Bay Inlet
Port Chalmers	Upper Otago Harbour
Port Chalmers	Lower Otago Harbour
St Clair	Second Beach
St Clair	St Clair Beach

As part of the ICMP development, an Assessment of Environmental Effects (AEE) was undertaken, where stormwater monitoring information collected (historical and current) was collated and analysed, within the context of wider catchment stormwater management.

The ICMPs identified that, using the current information, it was difficult to establish a direct link between the quality of the stormwater discharged from the catchments and the state of the receiving environment. The Pacific Ocean receiving environment (at St Clair Beach and Second Beach) was not identified as being as sensitive as the Upper Otago Harbour. The Lower Otago harbour hosts much more diverse and abundant communities (Ryder Consulting 2005c, 2008). This, however, is not unexpected in enclosed inlets such as Otago Harbour, and is more likely associated with proximity to the sea rather than stormwater inputs (Morton and Miller 1973, Raffaelli and Hawkins 1996, Ricketts *et al*. 1997, Probert and Jillet 1998).

There are potentially a number of reasons for the difficulty in establishing links between stormwater quality and the receiving environment, as follows:

- The absence of pre-2005 'baseline' information regarding the natural state of the Upper Harbour, and the already altered state of the harbour due to the impact of historical activities such as reclamation, dredging etc and industrial land uses.
- The close proximity of outfalls, resulting in near-shore mixing of all catchment discharges.
- The presence of a number of other inputs to the harbour (particularly freshwater inputs, most notably the Water of Leith).
- The sampling techniques used (e.g. grab samples only providing 'snapshots' of stormwater quality).

1 Introduction

In response to these issues, the ICMPs recommended that a revised monitoring framework for stormwater quality and harbour environment monitoring be designed and implemented.

Improved data confidence will allow the prioritisation of stormwater management recommendations based on the significance of stormwater quality issues. This would occur city-wide and form part of the 3 Waters Strategic Plan.

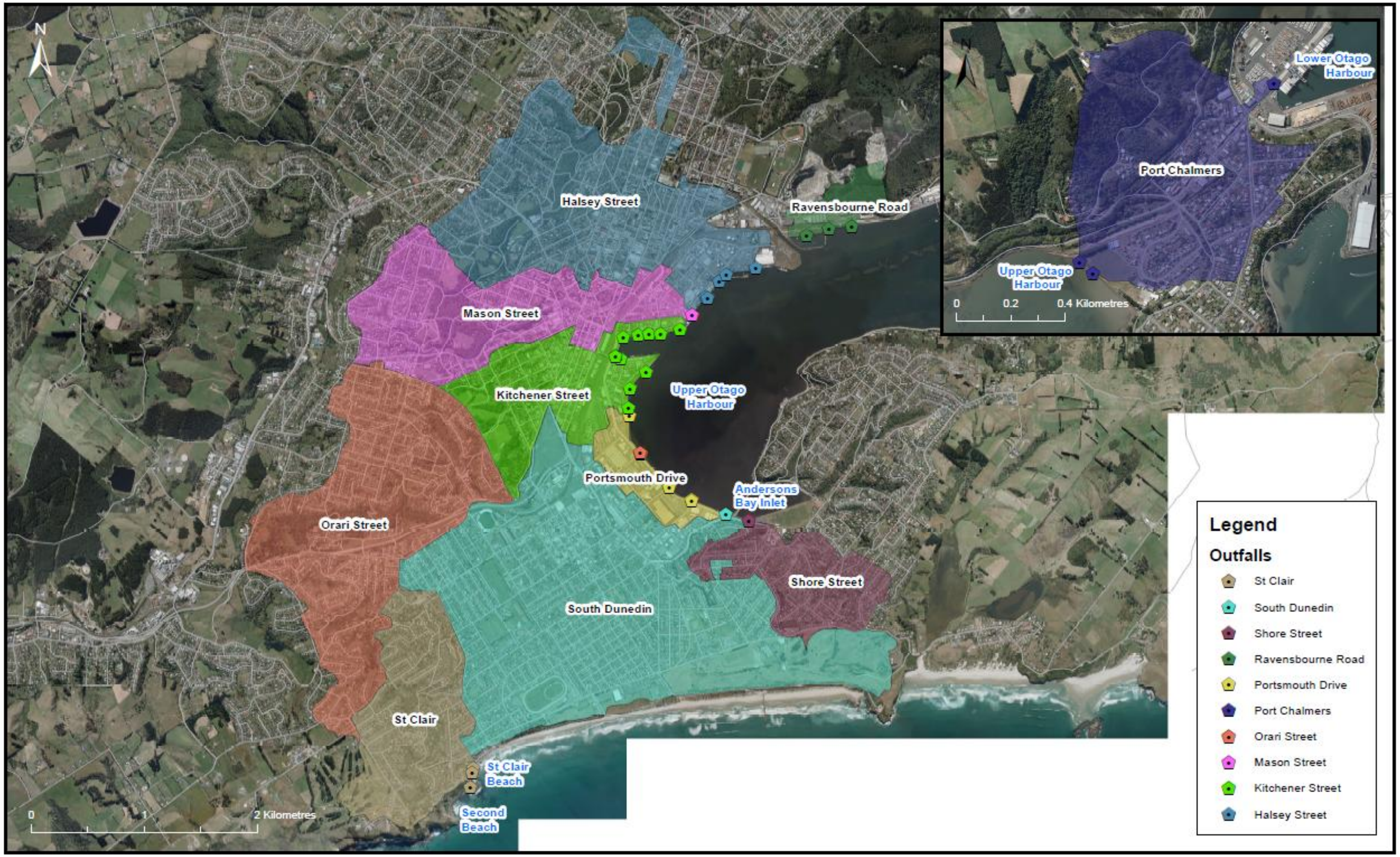

Figure 1-1 Catchments, Outfalls and Receiving Environments

1.2 Purpose and Objectives

The purpose of this monitoring framework is to provide a tool for Dunedin City Council to use as part of an adaptive approach to urban stormwater management. The framework is designed to measure the successes of DCC's stormwater management actions, but also seeks to provide better information on the influence of the stormwater discharges on the receiving environment and its values as outlined in the Regional Plan: Coast.

It is recognised that the Otago Harbour (the receiving environment for the majority of the urban stormwater discharges) has been contaminated historically, and also has a large number of other inputs and processes which influence the water quality, sediment quality and ecological health of the harbour. In order to manage stormwater discharges to help achieve regional environmental objectives for the receiving environment, however, it is considered necessary to also monitor the harbour. It is not the purpose of this monitoring to identify the effects of other discharges; however the ORC may wish to integrate the results of DCC's monitoring into a framework for the wider harbour.

The Objectives of the revised monitoring framework are as follows:

- Continuously improving confidence in stormwater quality data;
- Sound understanding of marine sediment quality, including the extent of historic contamination and rate of any ongoing contamination and potential sources;
- Identification of harbour biological health, using suitable indicators to attempt to isolate the effects of stormwater discharges on the harbour environment;
- Identification of any links between pipe discharge and sediment quality, marine water quality, marine biology; and
- Identification of catchments/discharges of concern and associated stormwater contaminants of concern.

This monitoring framework provides a methodology for ongoing monitoring in Dunedin, in order to support DCC's stormwater management framework, the actions within which are primarily driven by a commitment to the community to improve the quality of stormwater discharged to the environment.

A specific section of the framework (Section 8) outlines suggested monitoring for discharge consent compliance purposes. The monitoring framework focuses on monitoring in the Upper Otago Harbour Basin, where the majority of the outfalls are located.

1.3 Document Overview

This monitoring framework document is structured as follows:

Section 1 – Introduction – Background and Context, Purpose and Objectives

Section 2 – The Receiving Environments – A brief description of the physical nature of the different marine environments receiving stormwater from Dunedin City's stormwater network.

Section 3 – Stormwater Discharge Quantities – A summary of estimated discharge quantities from outfalls into the harbour basin in particular, and a discussion on mixing zones in the Upper Otago Harbour Basin.

Section 4 - Stormwater Quality – A summary of current knowledge, gaps and a proposed methodology for future monitoring.

Section 5 – Sediments – A summary of current knowledge, gaps and a proposed methodology for future monitoring.

1 Introduction

Section 6 – Ecosystems – A summary of current knowledge, gaps and a proposed methodology for future monitoring.

Section 7 – Harbour Water Quality - A summary of current knowledge, gaps and a proposed methodology for future monitoring.

Section 8 –Monitoring Programme Summary – An outline of the proposed monitoring programme, including key components, timeframes and 'trigger' values.

Receiving Environment Overview

2.1 The Upper Otago Harbour Basin

Stormwater from the majority of the Dunedin urban area (1,947 ha) discharges into the Upper Otago Harbour Basin. In addition to these discharges, a number of freshwater inputs have an effect on the Harbour – in particular the Water of Leith, which discharges water from a 9,416 ha catchment to the north west of the city.

The upper harbour basin is a highly modified environment as a result of reclamation, road works and dredging activities (Smith, 2007). These modifications have resulted in changes to the natural currents, flushing, and movement of sediments in the harbour. Historical activities in the Dunedin urban area (particularly industrial activities in the early 20th century) have also contaminated the marine environment. The harbour continues to be used for port activities, and a shipping channel is dredged (as is visible in Figure 2-1 below). Because of the long history of modification and anthropogenic influence, it has been difficult to establish a 'baseline' in terms of the Upper Harbour Ecology, against which to determine the effects of the current discharges. It is possible that a more recent baseline (eg 2005 or 2007) might be more appropriate for the assessment of effects of current discharges.

The tidal range in the Otago Harbour is approximately 2.2 m. Tidal current water velocities range from zero to 0.25 m/s (Stewart and Ryder 2005), and estimates for harbour flushing times range from 2 to 15 days (Grove and Probert, 1999, Smith and Croot 1993, 1994).

A study by Smith and Croot (1993), describes the circulation of water in the Otago Harbour as being dominated by the tide and inputs of heavy rainfall. Smith and Croot (1993) report that flushing times in the harbour are hard to establish as heavy rainfall has a dramatic effect on dilution displacement of the water in the upper harbour. Harbour flushing times, therefore, may vary and be greatly reduced during rainfall events.

Figure 2-1 below shows depths and water circulation patterns in the Upper Harbour Basin.

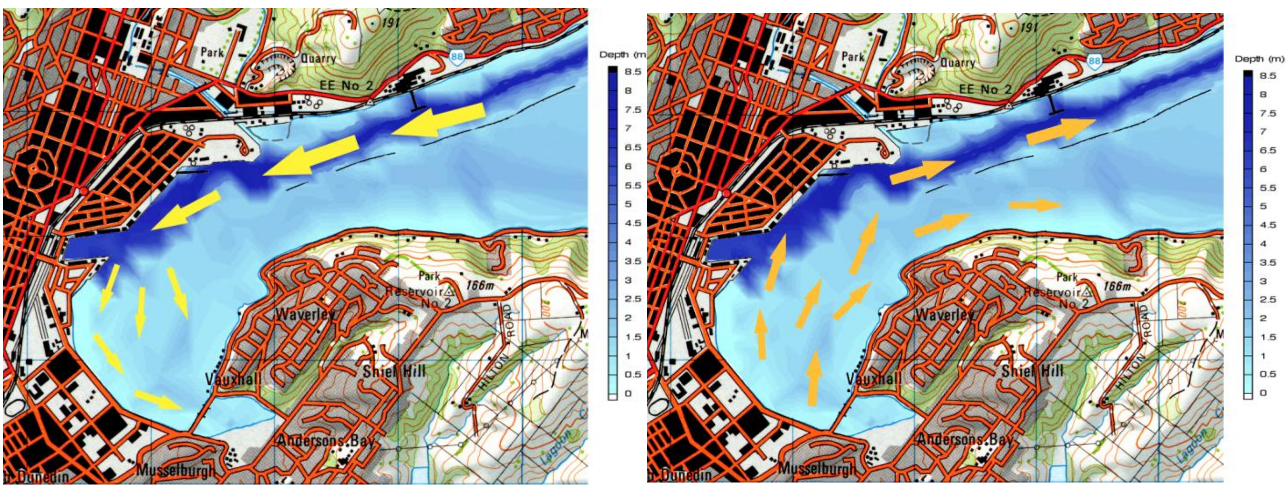

Figure 2-1 Flood Tide (left) and Ebb Tide (right), Upper Harbour Basin

2.2 Andersons Bay Inlet

The Andersons Bay Inlet causeway was completed in 1872. Dredging of the Inlet occurred as early as 1890, and there is a large area of reclaimed land adjacent to the inlet (Bayfield Park). Recently, a 'bird Island' has been constructed in the Inlet.

Flushing times in the Andersons Bay Inlet are long compared to the Upper Harbour; Smith and Croot (1993) estimate that between 4 and 10 tidal cycles are necessary for 99% flushing.

There is evidence of historical sediment contamination in the Andersons Bay inlet. As well as stormwater inputs, Somerville Stream discharges into the Inlet, and there is an emergency overflow facility from the Marne Street wastewater pumping station (currently being investigated via a monitoring programme).

2.3 St Clair / Second Beach

The main stormwater line from the St Clair stormwater catchment discharges via the Bell Chamber Outfall to Second Beach. A branch off the main stormwater line, as well as stormwater from a predominantly open watercourse, discharges to St Clair Beach.

As the marine environment at both Second Beach and St Clair Beach is a high energy environment; the stony/sandy substrates in these locations will be frequently re-worked by the tides. The opportunity for the deposition of sediments and build up of contaminants is therefore limited at these locations. Biological monitoring near the Second beach outfall has shown no indication of adverse effects from stormwater contaminants during annual rocky shore monitoring undertaken as part of current consent compliance monitoring.

2.4 The Upper and Lower Harbour

Two of the stormwater outfalls from the Port Chalmers catchment discharge into the Otago Upper Harbour at Sawyers Bay, the third discharges into the Lower Harbour to the north of the catchment in the port area.

The Upper Harbour extends from Goat and Quarantine Islands to the mouth of the Water of Leith. The long narrow shape of the Upper Harbour creates strong tidal flows with the residence time of the water being variable depending on location (Stevenson, 1998).

As the main outfall for the Port Chalmers catchment is in deep water, it is not a suitable environment to adequately assess the ecology, and data relating to the Port Chalmers catchment is more limited (Ryder Consulting, 2005d).

An environmental impact assessment (EIA) was carried out as part of Port Otago's reclamation programme, a component of which included an analysis of the marine ecology in the area (Probert 1990a, 1990b). Recent consent applications for dredging also included ecological assessments (NIWA, 2009). The relevant findings can be summarised as follows:

- Benthic communities in and around Port Chalmers are generally similar to those of mud bottoms throughout the Otago Harbour.
- The intertidal zone around Port Chalmers appears to include organisms similar to other rocky shore communities within Otago Harbour.

2 Receiving Environment Overview

- There are few remaining unmodified rocky shores around the harbour, however rocky shore communities around Port Chalmers are more diverse than in the Upper Harbour Basin but less diverse than those further out in the harbour and on naturally occurring rocky shores.
- Assessment of invertebrates, fish and shellfish showed that the fauna present were predominantly comprised of common species, and no rare or unique species were recorded.
- Harbours are naturally turbid at times, and most communities can tolerate periods of high suspended sediment concentrations and low water clarity, but many for only short periods.

Stormwater Discharge Quantities

3.1 Outfall Discharges

Table 3-1 below provides a summary of peak stormwater discharge from the upper harbour basin catchments during two modelled events, a 1 in 2 yr Average Recurrence Interval (ARI) rainfall event, and a 1 in 100 yr ARI rainfall event. In total, the peak discharge rates from all catchments entering the basin are approximately 26 m^3/s and 45 m^3/s for the 2 yr and 100 yr events respectively.

In contrast, the water of Leith (also discharging into the upper harbour basin) has a mean annual flow of approximately 43 m^3/s (NIWA WRENZ website), and a 1 in 100 yr ARI flow of approximately 171 m^3/s (Opus, 2005).

Table 3-1: Modelled urban stormwater discharge into Upper Harbour Basin during storm events

Catchment	**Discharge Location (Outfall Asset ID)**	**Peak Flow 1 in 2 20mins**	**Peak Flow 1 in 100 20mins**
		m^3/s	m^3/s
Halsey Street	SWX03718	0.88	1.46
	SWX03450	2.13	6.00
	SWX03455	3.12	5.49
	SWX03472	0.07	0.10
	SWX03466	0.90	1.57
	SWX03506	0.04	0.10
Kitchener Street	SWX70370	0.07	0.13
	SWX03532	0.13	0.18
	SWX03536	0.04	0.13
	SWX03540	0.04	0.04
	SWX70569	0.04	0.08
	SWX03559	0.08	0.07
	SWX03556	0.03	0.04
	SWX03562	0.05	0.05
	SWX03547	0.11	0.08
	SWX70102	0.18	0.25
	SWX03568	2.10	3.41
Mason Street	SWX03489	4.32	6.60
Orari Street	SWX03635	6.58	11.15

3 Stormwater Discharge Quantities

Catchment	Discharge Location (Outfall Asset ID)	Peak Flow 1 in 2 20mins	Peak Flow 1 in 100 20mins
		m^3/s	m^3/s
Portsmouth Drive	SWX03579	0.37	0.60
	SWX03631	0.29	0.34
	SWM03639	0.34	0.42
	SWX03644	0.17	0.21
Ravensbourne Road	SWX02628	0.06	0.10
	SWX02623	0.05	0.15
	SPN02502	0.03	0.12
South Dunedin	SWX03649 (twin outfalls)	1.88	3.20
		1.93	3.30
Total Discharge – Upper Harbour Basin		**26.03**	**45.37**
Shore Street	SWX04625	1.11	1.76
Total Discharge – Andersons Bay Inlet		**1.11**	**1.76**
St Clair	SWX03979	0.24	1.15
	SWX00011 and SWX00012 (twin outfalls)	0.56	0.94
Total Discharge – St Clair		**0.8**	**2.09**
Port Chalmers	SWX 12879 (lower harbour)	0.51	1.15
	SWX12941 (upper harbour)	0.63	1.53
	SWX12994 (upper harbour)	0.01	0.01
Total Discharge – Port Chalmers		**1.15**	**2.69**

3.2 Mixing Zones

This section provides an assessment of the extent of influence of stormwater discharges in the Upper Otago Harbour Basin. Throughout the remainder of the document, however, it is considered that monitoring is necessary within and outside of the area influenced by stormwater, in order to maintain an adaptive management process and respond to issues as they arise. Trigger values within the context of consent management, however, only apply outside of the zone of 'reasonable' mixing, as per the RMA and the Otago Regional Plan: Coast.

3.2.1 Modelling

DCC commissioned NIWA (NIWA, 2012) to undertake some modelling of the stormwater discharges into the Upper Otago Harbour, using a 2-dimensional model developed for the Ports of Otago. The NIWA modelling reports the following:

'The harbour model simulations demonstrated that the stormwater discharge plumes are generally localised to within 1 km of the outfall locations for the particular short flood-tide and longer ebb-tide scenario modelled. However, stormwater plumes from outlets along the northern perimeter of the

3 Stormwater Discharge Quantities

upper harbour eventually enter the main dredged channel, remain in the harbour channel, and are carried considerably further by the higher channel velocities (ebbing currents in this case). Due to the close proximity of some of the stormwater outfalls, particularly in the Dunedin basin, merged stormwater plumes are likely to occur, which will somewhat hinder mixing relative to an un-merged situation.'

Figure 3-1 below, from the NIWA (2012) report, provides an indication of the direction and extent of plumes from the stormwater discharges following a 1 in 100 yr ARI rainfall event (the choice of a large event compensates for the inability of the 2-D model to allow for the buoyancy effect of stormwater). This figure shows the direction and approximate extent of stormwater following low tide following discharges during high tide. As can be seen, the majority of the discharges move across the basin towards the dredged channel. Discharges from the Water of Leith have not been included in this model.

To estimate dilution factors, a CORMIX model was developed, and a 1 in 2 yr ARI storm event was modelled. Figure 3-2 shows the dilution factor estimated by the CORMIX model, overlaid on the direction of flow from the outfall predicted by the Mike 21 modelling in Figure 3-1.

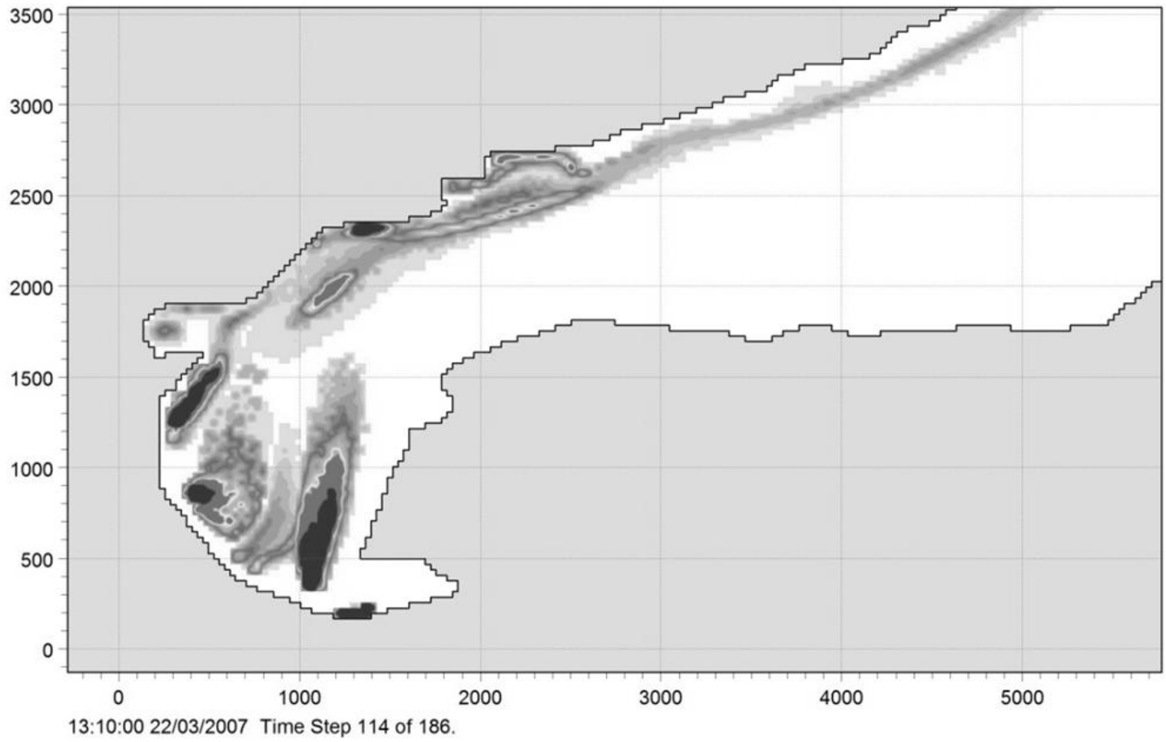

Figure 3-1: Predicted dispersion of stormwater in the Dunedin Basin over a 9.5 hour period: following low tide – 9.5 hours after the discharge began.

3 Stormwater Discharge Quantities

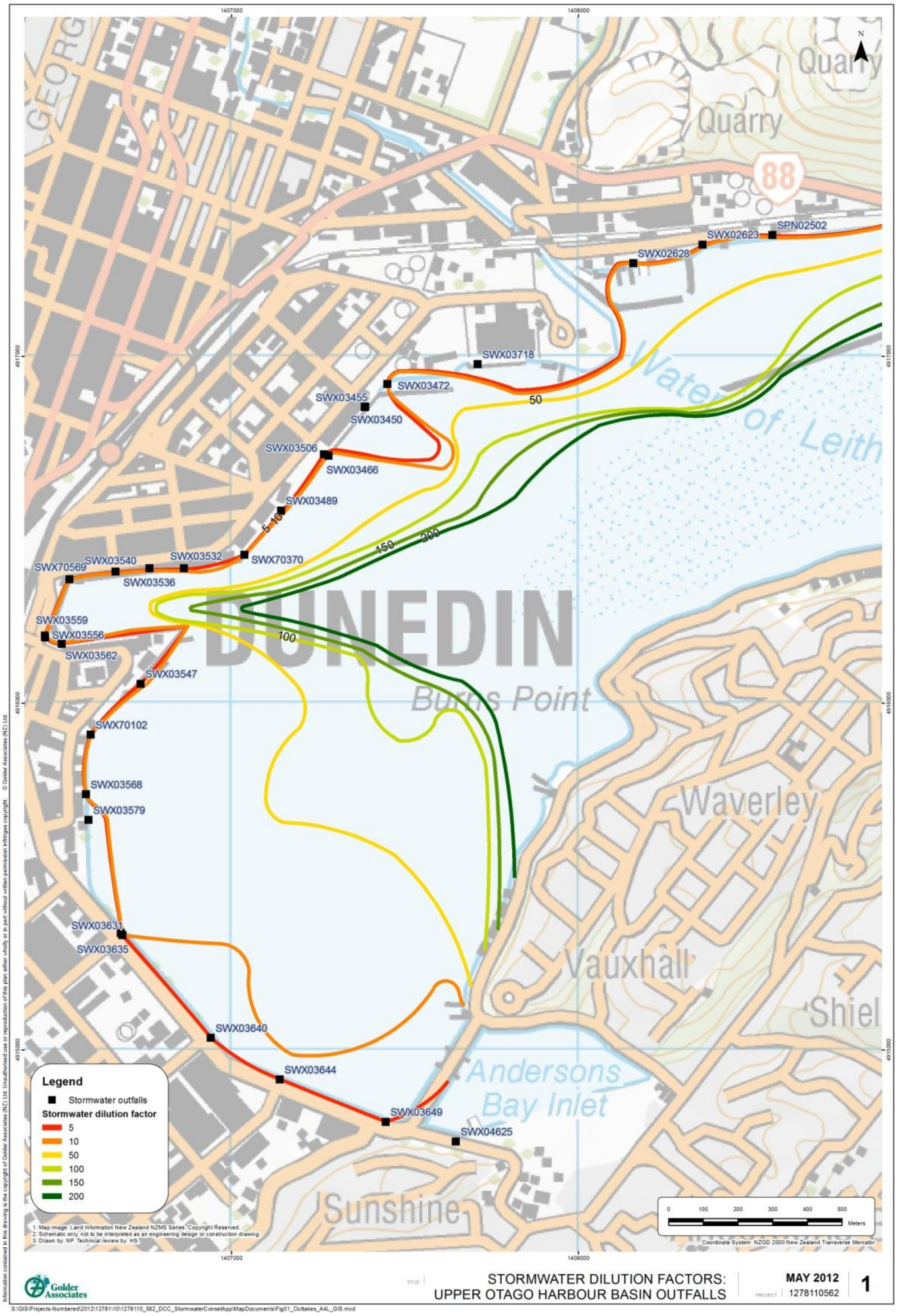

Figure 3-2: Dilution ‘bands’ in upper harbour

3.2.2 Regulatory Framework

In line with the RMA, Policy 10.4.4 of the Regional plan for Otago:Coast requires *'an effective mixing zone for discharges of water or contaminants into the coastal marine area which takes account of:*

(a) The sensitivity of the receiving environment; and

(b) The particular discharge, including contaminant type, concentration, and volume; and

(c) The physical processes acting on the area of discharge; and

(d) The community uses and values associated with the area affected by the discharge; and

(e) The ecological values associated with the area.'

When considering this policy, along with Figures 3-1 and 3-2 above, the following observations can be made:

- The upper harbour basin and the Port Chalmers area are highly modified environments (due to reclamation, port activities, dredging, and historical activities).
- The volume of discharge from stormwater is less than the discharge from the Water of Leith.
- The discharges do contain land-use associated contaminants (conveyed via stormwater).
- The harbour circulation patterns appear to ultimately direct stormwater into the channel to be conveyed towards the Lower Harbour. No modelling has been undertaken at Port Chalmers or St Clair, however St Clair is considered to be a 'high energy environment' (St Clair ICMP, URS, 2011).
- The harbour (including all its existing natural and human-induced influences) is a valued community resource, and areas within the upper harbour basin (such as the Kitchener Street windsurf launch area) are used by the public. However, there are no bathing beaches in this area. St Clair catchment discharges to bathing beaches.
- Ecological assessment has shown that the ecology in the Upper Harbour Basin does not appear to be in decline. However, it may have been adversely impacted in the past.

3.2.3 Mixing Zone Estimation

Given the above assessment, a mixing zone has been identified for the Upper Harbour Basin only, in order to distinguish between monitoring for DCC's management purposes (which will occur within and beyond the mixing zone), and monitoring as required by proposed consent conditions (which will occur outside of the mixing zone). As indicated on Figures 3-1 and 3-2 above, discharges from the stormwater outfalls merge, and are also influenced by the incoming and outgoing tide. Due to volume, the discharge from the Water of Leith during rainfall is likely to dominate the water quality within the Upper Harbour Basin, depending on the stage of the tidal cycle. For consent monitoring purposes, it is recommended that reasonable mixing in the upper harbour basin may be considered to be at the line delineating a dilution factor of approximately 50 in Figure 3-2. As discussed further in this document, however, monitoring will be undertaken within and outside of the mixing zone, in order to provide a way of confirming the extent of influence, along with the effects of the discharges.

Stormwater discharges from the St Clair catchment have been monitored, with no evidence of adverse effect; stormwater from the catchment has been monitored and is typical of a residential catchment. Discharges from residential catchments are currently permitted by the Otago Regional Plan: Coast,

3 Stormwater Discharge Quantities

however the St Clair catchment currently fails to comply with the permitted activity rules, due to the detection of wastewater in the stormwater. This issue is currently under investigation by DCC. The St Clair beach will be the subject of monitoring for the purposes of beach bathing assessments, and this will continue to ensure any wastewater overflow issues in the catchment are resolved, and that the beach is safe for bathing.

Part of the Port Chalmers catchment discharge into a highly modified environment in the lower harbour (beneath the wharfs), and into Sawyers Bay in the Upper Harbour. Little information is available regarding the effects of these discharges, however monitoring will continue near to the Sawyers Bay discharges, and at harbour reference sites. Proximity to the channel will also influence mixing in this location. At this stage, a mixing zone of 50 m may be reasonable at these locations.

Because of the sensitivity of the Andersons Bay Inlet, consent compliance monitoring has been recommended within the basin itself, to facilitate the adaptive management framework adopted by DCC. In order to allow ongoing comparison with sampling undertaken over the past six years, a mixing zone of 20 m is recommended.

4

Stormwater Quality

4.1 Historical Monitoring

Tables 4-1, 4-2, 4-3 and 4-4 summarise the results from the stormwater grab samples and time proportional samples taken at the sites indicated in Figure 4-1, grouped by land use and analyte. Appendix F of the AEE document contains the full results for total contaminant concentrations measured in the stormwater samples. Monitoring data is included from 2007 to 2012.

4.1.1 Grab Samples

Between 2007 and 2012 a single rainfall event each year has been sampled by the collection of a grab sample from the major stormwater catchment outfalls, obtained during what was presumed to be the first flush for each event. Whenever possible, sampled events were limited to those that met the criteria of a minimum of a 72 hours antecedent dry period and producing at least 2.5 mm of rainfall. These criteria were met on all but one occasion.

Results to date have been variable with no trends observed for any of the analytes for any catchment (Tables 4-1 to 4-4). Data analysis has, however, indicated that for the most part, stormwater contaminants have been within a range typical for the land use of the catchment, based on a review of data used nationally and internationally. Additionally, when compared to limited data collected historically, there is some indication that concentrations of key contaminants (e.g. metals) in stormwater may, in general, be lower than previously measured. In particular the concentration of lead has declined as a consequence of its removal from petrol between 1984 and 1996.

4.1.2 Time Proportional Samples

Three time-proportional stormwater quality samples have also been taken across Dunedin as part of the 3 Waters Strategy Project; one at South Dunedin (2009), one at Bauchop Street (2009), and one at Port Chalmers (2010). These three sites provide stormwater quality representing industrial/residential, commercial/residential, and residential land uses respectively. Flow monitoring was also undertaken simultaneously to enable stormwater loads to be estimated.

Tables 4-1 to 4-4 include the results of the time proportional sampling in Dunedin. The results provide an indication of the variations in contaminant concentrations throughout the duration of a rainfall event for catchments with differing urban land uses.

4 Stormwater Quality

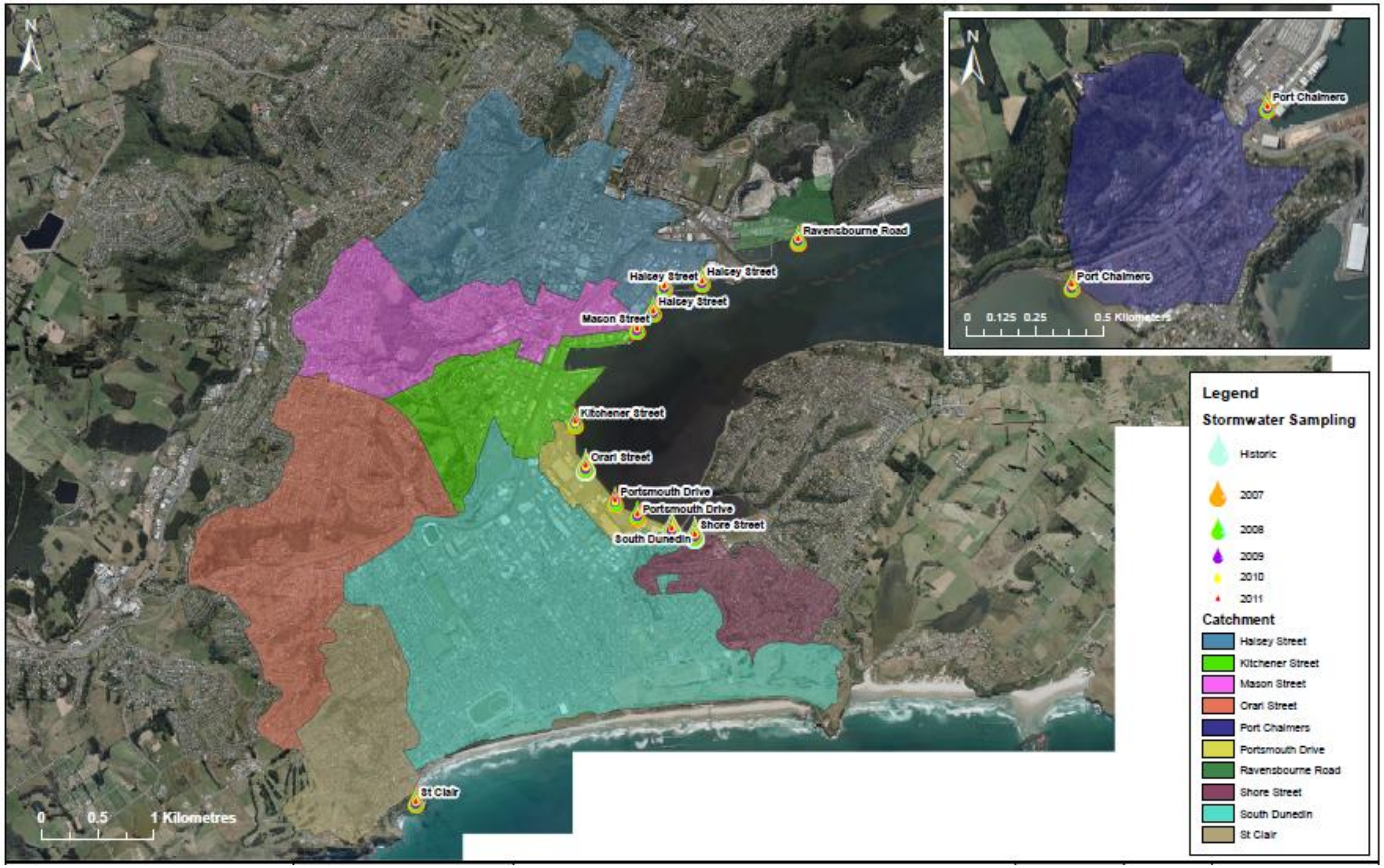

Figure 4-1 Compliance monitoring stormwater quality sampling sites

4 Stormwater Quality

Table 4-1 Dunedin Stormwater Monitoring Results Summary, Residential Catchments – Heavy Metals

Catchment	Outfall	Sample Type	Range of Contaminant Concentrations during sampling (2007 – 2012 for Grab Samples, event based in 2010 for Time Proportional samples) g/m³							
			As	**Cd**	**Cr**	**Cu**	**Ni**	**Pb**	**Zn**	**TSS**
St Clair	Second Beach	Grab Samples	BDL-0.002	BDL- 0.000075	0.0007-0.0038	0.0027-0.019	0.0009-0.0026	0.00021-0.013	0.038-0.25	BDL-57
Port Chalmers	George Street	Grab Samples	BD-0.0031	0.00011-0.0014	0.00136-0.012	0.0148-0.039	0.0026-0.0093	0.0037-0.041	0.19-0.66	26-180
Port Chalmers	Watson Park	Grab Samples	BDL	BDL	BDL-0.0064	0.0025-0.009	BDL-0.0035	BDL-0.0141	BDL-0.29	7.4-240
Shore Street	Shore Street	Grab Samples	BDL-0.04	BDL	BDL	BD -0.01	BDL-0.01	BDL-0.0085	BDL-0.44	9.5-75.4
Orari Street	Orari Street	Grab Samples	BDL-0.03	BDL-0.0005	BDL-0.0032	0.0096-0.014	BDL-0.0033	BDL-0.023	BDL-0.3	4-130
Port Chalmers		Time-Proportional Samples	BDL	BDL	BDL	BDL	BDL-0.1080	0.0024-0.0077	0.108-0.260	8-47
Maximum			0.04	0.0014	0.012	0.039	0.1080	0.041	0.66	240

BDL = Below Detection Limits, note that detection limits were variable based on test methodology or sample composition.

4 Stormwater Quality

Table 4-2 Dunedin Stormwater Monitoring Results Summary, Mixed Use Catchments – Heavy Metals

Catchment	Outfall	Sample Type	Range of Contaminant Concentrations during sampling (2007 – 2012 for Grab Samples, event based in 2010 for Time Proportional samples) g/m³							
			As	Cd	Cr	Cu	Ni	Pb	Zn	TSS
South Dunedin	Portobello Road	Grab Samples	BDL-0.002	BDL - 0.0003	BDL - 0.0029	0.0057 - 0.03	BDL - 0.0035	BDL - 0.026	0.08 - 0.94	8.1 - 53
Portsmouth Drive	Teviot Street	Grab Samples	BDL-0.002	BDL - 0.00026	BDL - 0.0019	0.0094 - 0.031	BDL - 0.0033	BDL - 0.0066	BDL - 1.79	12 - 84
Portsmouth Drive	Midland Street	Grab Samples	BDL-0.0033	BDL - 0.00013	BDL - 0.0035	0.02 - 0.057	BDL - 0.0075	BDL - 0.0083	BDL - 0.35	14 - 52
Ravensbourne Road	Ravensbourne Road	Grab Samples	BDL	BDL - BDL	BDL - 0.00061	0.0023 - 0.0032	BDL - 0.00148	0.00023 - 0.025	0.047 - 0.32	5 - 61
Kitchener Street	Kitchener Street	Grab Samples	BDL-0.01	BDL - BDL	BDL - 0.004	0.0056 - 0.034	BDL - 0.0036	BDL - 0.0442	BDL - 0.62	BDL - 104
Mason Street	Mason Street	Grab Samples	BDL-0.01	BDL - 0.0077	BDL - 0	0.012 - 0.043	BDL - 0.0055	0.00102 - 0.0258	0.16 - 0.63	30 - 138
Halsey Street	Bauchop Street	Grab Samples	BDL-0.03	BDL - 0.00049	BDL - 0.0015	0.0026 - 0.029	BDL - 0.01	BDL - 0.021	BDL - 0.94	5 - 53
Halsey Street	Halsey Street	Grab Samples	BDL-0.03	BDL - 0.00026	BDL - 0	0.00162 - 0.029	BDL - 0.009	BDL - 0.021	0.033 - 0.36	24 - 119
Halsey Street	Wickliffe Street	Grab Samples	BDL-0.03	BDL - 0.00092	BDL - 0.0076	0.0058 - 0.059	BDL - 0.01	BDL - 0.033	0.1 - 1.57	27 - 100
South Dunedin	Portobello Road	Time-Proportional Samples	0.0012-0.0052	<0.000- 0.00041	0.0011-0.0074	<0.003-0.064	0.0067-0.0730	0.0008 - 0.0044	0.230 -0.840	17 - 160
Halsey Street	Bauchop Street	Time-Proportional Samples	BDL-0.0038	BDL -0.00054	BDL -0.0500	0.040 -0.230	BDL -0.07	BDL -0.0870	0.05 - 2.50	26 - 330
Maximum			**0.03**	**0.0077**	**0.05**	**0.230**	**0.07**	**0.0870**	**2.5**	**330**

BDL = Below Detection Limits, note that detection limits were variable based on test methodology or sample composition

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Table 4-3 Dunedin Stormwater Monitoring Results Summary, Residential Catchments – PAHs and Microbial Indicators

Catchment	Outfall	Sample Type	Range of Contaminant Concentrations during sampling (2007 – 2012 for Grab Samples, event based in 2010 for Time Proportional samples)		
			PAH	E.Coli	Faecal Coliforms
				MPN/100ml	cfu/100 ml
St Clair	Second Beach	Grab Samples	na - na	300-14000	560-92000
Port Chalmers	George St	Grab Samples	na - na	600-6000	600-6000
Port Chalmers	Watson Pk	Grab Samples	na - na	10-14000	10-39000
Shore Street	Shore Street	Grab Samples	na - na	110-16000	110-16000
Orari Street	Orari Street	Grab Samples	BDL - 318	BDL-6000	BDL-7000
Port Chalmers		Time-Proportional Samples		n/a	320-1000
Maximum			318		

BDL = Below Detection Limits, note that detection limits were variable based on test methodology or sample composition

4 Stormwater Quality

Table 4-4 Dunedin Stormwater Monitoring Results Summary, Mixed Use Catchments – PAHs and Microbial Indicators

Catchment	Outfall	Sample Type	Range of Contaminant Concentrations during sampling (2007 – 2012 for Grab Samples, event based in 2010 for Time Proportional samples)		
			PAH	E.Coli	Faecal Coliforms
			MPN/100ml	cfu/100 ml	
South Dunedin	Portobello Road	Grab Samples	BDL - 328	280-54000	280-54000
Portsmouth Drive	Teviot Street	Grab Samples	na - na	7-120000	7-240000
Portsmouth Drive	Midland Street	Grab Samples	na - na	130-6000	130-6000
Ravensbourne Road	Ravensbourne Road	Grab Samples	na - na	90-11000	90-11000
Kitchener Street	Kitchener Street	Grab Samples	BDL - 327	70-92000	70-160000
Mason Street	Mason Street	Grab Samples	na - na	22000-350000	22000-350000
Halsey Street	Bauchop Street	Grab Samples	na - na	400-17000	400-35000
Halsey Street	Halsey Street	Grab Samples	na - na	1700-78000	1700-92000
Halsey Street	Wickliffe Street	Grab Samples	na - na	10000-220000	10000-220000
South Dunedin	Portobello Road	Time-Proportional Samples		3900-14000	5400-20000
Maximum			328	350,000	350,000

BDL = Below Detection Limits, note that detection limits were variable based on test methodology or sample composition

4.2 Gaps and Knowledge Required

The high variability of stormwater quality results has been identified as a key issue in all catchments studied during the 3 Waters Strategy Project, except St Clair (where stormwater from a residential catchment is discharged into a high-energy environment where adverse effects have not been observed).

The results of the time-proportional monitoring undertaken recently confirmed that the stormwater quality from a storm event varies considerably over that event (refer Figure 4-2:). The type of event (intensity, duration, antecedent conditions) can affect the contaminants present in runoff. Also, the time during a storm event that grab samples are taken can significantly affect the results.

While stormwater grab samples taken in the past were targeted at sampling the 'first flush' of stormwater, and consent conditions specified storm size and antecedent conditions, stormwater samples were taken at differing times during the first flush of rainfall events, resulting in data variability.

While also subject to the variability of rainfall, antecedent conditions and timing, further time or flow proportional monitoring of stormwater quality would yield results that provide a more accurate profile or range of contaminant concentrations within the stormwater from the catchment monitored. Because the management approach proposed involves targeting stormwater treatment (where necessary), catchment specific data is required – a number of the catchments discharging into the harbour are mixed land use, with a range of different activities.

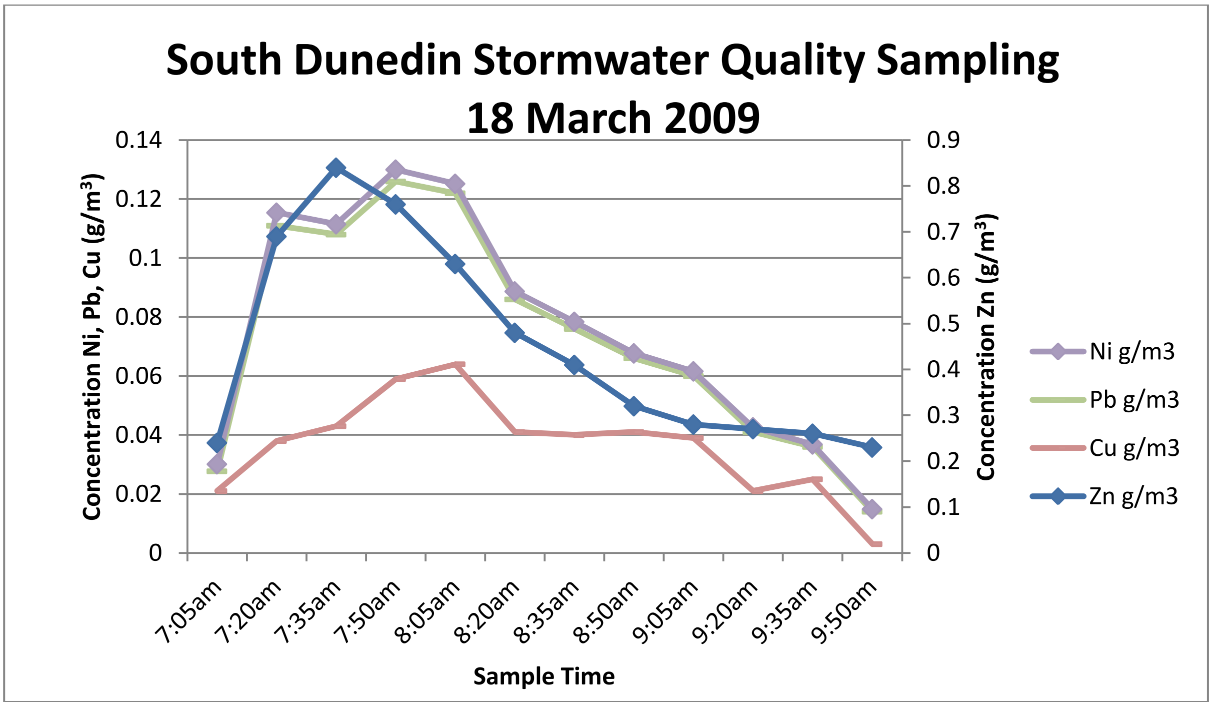

Figure 4-2: Concentration of contaminants in stormwater over duration of a 6 mm rainfall event sampled in South Dunedin.

4.3 Proposed Methodology – Stormwater Quality Monitoring

4.3.1 General

As identified above, the use of time proportional monitoring is preferred in order to develop a better understanding of stormwater quality being discharged from Dunedin's urban catchments. The main objective of this sampling is to obtain estimates of stormwater loads, and to identify areas where higher levels of stormwater contaminants are being generated. Monitoring can also be used to provide 'snapshots' of stormwater quality to ensure that stormwater discharge quality is improving in line with the Council's strategic objectives.

Outlined below are the proposed analytes, locations for sampling, and criteria for future sampling of stormwater quality in the ICMP- managed stormwater catchments.

The proposed methodology is therefore as follows:

1. Phase 1: time/flow proportional monitoring to gather information (priority catchments, 1-5 years)
2. Phase 2: grab sampling (priority catchments, ongoing)

4.3.2 Analytes

It is recommended that the analysis of stormwater consider the analytes outlined in Table 4-5 below. Analysis of stormwater samples shall be undertaken by an IANZ accredited laboratory. Laboratory advice will be followed regarding suitable collection container materials, preservatives required, and time lapses permitted between collection and analysis.

Table 4-5: Stormwater contaminants to be monitored.

Contaminant	Potential Anthropogenic Sources	Comment
Suspended Solids (TSS)	Can be intensified by vegetation stripping and construction activities. Road dust.	Currently measured at all sites sampled. To be continued.
Arsenic (As)	Combustion of fossil fuels; industrial activities, including primary production of iron, steel, copper, nickel, and zinc.	
Cadmium (Cd)	Zinc products (Cd occurs as a contaminant), soldering for aluminium, ink, batteries, paints, oils spills, and industrial activities.	
Chromium (Cr)	Pigments for paints & dyes; vehicle brake lining wear; corrosion of welded metal plating; wear of moving parts in engines; pesticides; fertilisers; industrial activities.	
Copper (Cu)	Vehicle brake linings; plumbing (including gutters and downpipes); pesticides and fungicides; industrial activities.	
Nickel (Ni)	Corrosion of welded metal plating; wear of moving parts in engines; electroplating and alloy manufacture	
Lead (Pb)	Residues from historic paint and petrol (exhaust emissions), pipes, guttering & roof flashing; industrial activities.	

4 Stormwater Quality

Contaminant	Potential Anthropogenic Sources	Comment
Zinc (Zn)	Vehicle tyre wear and exhausts, galvanised building materials (e.g. roofs), paints, industrial activities	
TPH	Vehicle / engine oil, industrial activities.	
Polycyclic aromatic hydrocarbons (PAH)	Vehicle / engine oil; vehicle exhaust emissions; erosion of road surfaces; pesticides.	Currently only monitored at three sites; to be expanded to all sites monitored using time-proportional methodology, however number of samples tested in each event may be limited to reduce costs.
Enterococci / E.coli	Wastewater. Animal faeces.	Replace current testing of faecal coliforms with better indicator of human sourced pathogens
Fluorescent Whitening Agents (FWAs)	Constituent of domestic cleaning products, indicator of human sewage contamination.	Monitored during dry weather, at low flows, to detect any cross connections.
Salinity	Saline intrusion.	Indicative of saline intrusion into network. Provides indication of sample including tidal influence.
References: ARC, 2005; ROU, 2002; Williamson, 1993.		

4.3.3 Locations

During the development of the ICMPs, some broad conclusions were able to be drawn in relation to stormwater contaminant discharge from catchments, based on land use, grab samples and time proportional sampling. Because resources will prohibit the simultaneous sampling of all catchments, it is necessary to prioritise the catchments for monitoring, based on this information.

Catchments prioritised for time proportional stormwater discharge quality monitoring are outlined in Table 4-6 below, based on information provided in the ICMPs for each catchment.

Receiving environment monitoring (outlined in Sections 5, 6 and 7) will be used to redirect monitoring to particular catchments if they are suspected to be contributing to issues identified in the environment. Where where microbial contamination is suspected, wastewater presence can be investigated during dry weather, using specific indicators, as discussed in Section 4.4 below.

4 Stormwater Quality

Table 4-6 Stormwater Monitoring Prioritisation

Catchment	Monitoring to date	Priority for monitoring
Halsey Street	Have already gathered one time proportional sample. Stormwater samples indicate potential elevated levels of metal contaminants. Moderate contamination evident in harbour adjacent to catchment.	High – can build on existing data. Possible contaminant sources present.
Shore Street	Low contaminants measured in stormwater. Sensitive environment - moderate contamination evident in inlet adjacent to catchment.	High – concerned with sensitivity of receiving environment. Large majority of land use residential.
South Dunedin	Low contaminants measured in stormwater. Have already gathered one time proportional sample. Moderate contamination evident in harbour adjacent to catchment. Historical contamination evident.	High – can build on existing data. concerned with ensuring low contaminant discharge due to high historical contamination. Industrial land uses in catchment.
Kitchener Street	Variable stormwater quality, some moderate zinc levels. Moderate contamination evident in harbour adjacent to catchment.	Medium – mixed use catchment, so potential for contaminant discharge present. Results from monitoring in Halsey Street may apply to Kitchener Street as general characterisation.
Mason Street	Variable stormwater quality. Moderate contamination evident in harbour adjacent to catchment.	Medium – mixed use catchment, potential for contaminant discharge present. Results from monitoring in Halsey Street may apply to Mason Street as general characterisation.
Portsmouth Drive	Typical contaminant discharge, moderate levels of zinc. Direct discharges to harbour from road may be having an effect also. Moderate contamination evident in harbour adjacent to catchment.	Medium – industrial catchment, so potential for contaminant discharge present.
Port Chalmers	Have already gathered one time proportional stormwater sample. Low contaminant levels in sediments in harbour adjacent to outfall (one year only).	Low – can build on existing data, however contamination not evident in monitoring to date. Monitoring location residential land use only.
Orari Street	Low concentrations of contaminants measured in stormwater discharge. Some contamination of sediments in harbour adjacent to outfall.	Low – Discharge not likely to change in near future, monitoring does not indicate significant concentrations of contaminants. Residential catchment
Ravensbourne Road	Low levels of contaminants detected in sampling. Low contaminant levels in sediments in harbour adjacent to outfall (one year only).	Low – small catchment, low levels of contaminants recorded to date, little indication of contamination in sediments.
St Clair	Contaminants typical of land use. Least concern with effects on environment.	Low – receiving environment not historically contaminated.

4.3.4 Sampling Criteria – Time / Flow proportional monitoring

The objective of stormwater quality monitoring is to gain a characterisation of stormwater quality from a catchment, throughout a storm event. Criteria below have been developed to ensure that within a monitoring year, a number of stormwater events can be captured from a single site that give a representation of stormwater quality being discharged from the catchment monitored. Ultimately, when a storm event results in a stormwater sample being collected, the rainfall records and flow data will be reviewed alongside the sample collection times to ensure that the samples have been collected at a time likely to correspond with the profile of stormwater discharged from the catchment, and include the 'first flush', where the highest contaminant concentrations are expected in stormwater from sealed sites.

The intention is that DCC will utilise a number of monitors, and 'move' around catchments as funding permits.

Rainfall / Flow

URS (2011) undertook an analysis of rainfall and tides in Dunedin for the purpose of establishing common design storms and tidal boundary conditions for stormwater modelling.

Adding analysis of rainfall data from the Musselburgh rain station to the base DDF (Depth, Duration, Frequency) data set developed for Dunedin by Raineffects Ltd (2006) provides a complete data set for all Dunedin 3 Water Strategy Project stormwater catchments except Mosgiel. Note that depths for the 10, 50 and 100 year ARI storms with durations up to 2 hours were generated by Raineffects (2006), with the remainder of data generated by URS (2010).

Table 4-7: Complete DDF Data (Depth mm) for All Catchments except Mosgiel

ARI	10 (min)	20 (min)	30 (min)	40 (min)	50 (min)	1 (hr)	1.5 (hr)	2 (hr)	4 (hr)	6 (hr)	12 (hr)	24 (hr)
2	4.6	6.8	8.3			11.9		17.2		29.9	42	54
5	6.6	9.7	11.3			15.1		20.9		37.6	54.4	68
10	11.69	13.52	15.22	16.78	18.23	19.6	23.35	26.72	38.7	46.2	62.6	82.5
50	16.28	18.35	20.36	22.23	23.97	25.61	30.1	34.13	47.7	58.9	83.6	109
100	18.16	20.38	22.55	24.56	26.43	28.2	33.04	37.38	51.5	64.3	92.5	120.2

Automatic sampling can be triggered via connection to a rain gauge or a flow / water level monitor. Previous monitoring in Dunedin for consent compliance purposes has indicated that to ensure that there is sufficient runoff to carry contaminants into the stormwater system any sampled rain event should yield at least 0.5 mm within the first two hours.

In the context of storm events (refer Table 4-7), this size event is of a very low intensity, however in order to capture a number of events within a sampling year, there is a need to consider smaller storms. Smaller, high frequency storms (and to some extent the number dry days) also result in the majority of the contaminant wash-off from the catchment, and are the storms most likely to be intercepted and treated by stormwater treatment devices.

Depending on the location of the flow monitor, it is proposed that either flow or rainfall will be used to trigger the automatic sampler; if flows are used as the trigger, flow monitoring or stormwater modelling will be used to set the trigger corresponding to a rainfall intensity of 0.5 mm / hour. A period of flow and rainfall monitoring is to be undertaken prior to setting the trigger value, to confirm that a trigger and collection frequency is set appropriately to capture a full storm hydrograph. Additionally, flow and rainfall results, coupled with sample collection times will be reviewed prior to laboratory analysis to ensure samples have been taken across the full storm event.

Antecedent conditions

To allow sufficient accumulation of contaminants of surfaces within a catchment there needs to be some requisite period before a rainfall event during which there is insufficient rainfall to generate runoff. A widely accepted antecedent dry period is 72 hours (USEPA 2002) and this is what has been used in the monitoring of Dunedin's stormwater to date, and is proposed for future monitoring. Of the 371 rainfall events analysed from the Otago University raingauge that produced >0.5mm of runoff between 2007 and 2011, 31.5% of the events met the 72 hour antecedent dry period criterion. This is equivalent to approximately 15 to 18 rain events per year.

Tides

Tidal influence on outfall pipes is evident in the majority of the catchment studied. To collect stormwater samples uncontaminated by sea water it is proposed that an automated sampler be located within the catchment above the influence of seawater (which is only possible in large catchments with sufficient land use of interest upstream of the sampling point), or that sampling be carried out when tidal influenced is minimal (2-3 hours either side of low tide).

The analysis of rainfall events between 2007 and 2011 indicates that such conditions occur for approximately one third of the rain events that had at least a 72 hour antecedent dry period. However, use of the criteria requiring a rainfall event with 0.5mm rainfall within the first two hours, restricts the percentage of events able to be sampled to approximately 7%.

4.4 Wastewater Detection Monitoring

It is proposed that domestic wastewater detection monitoring commence with dry weather sampling (grab sampling) in the following catchments at peak wastewater flow times (ie 9am and 6pm). The wastewater monitoring and modelling undertaken during the 3 Waters Strategy Project did not identify any significant overflow issues within the stormwater catchments studied. Therefore if any wastewater issues are present, they are most likely to be due to direct connections, which would be detected during dry weather. Samples from Halsey Street, St Clair and Mason Street catchments were found to have some elevated microbial levels in some samples, and are therefore prioritised for further monitoring. Samples will be analysed for the following:

- E.coli;
- Fluorescent whitening agents (FWA); and
- Salinity.

The presence of E.coli or FWA's in measurable quantities would indicate a direct wastewater connection in the catchment; during dry weather, the only baseflow in a stormwater system should be from natural springs or groundwater infiltration. A measurement of salinity would also indicate whether sea water is infiltrating into the network.

4.5 Interpretation of Results – Key Indicators, trends, ‘trigger’ points

Monitoring of key urban stormwater contaminants has been summarised in Tables 4-1 to 4-4. Monitoring to date has indicated that there is a wide range of concentrations of contaminants occurring throughout a storm event, however ‘ranges’ of typical stormwater values are available, both nationally and internationally, and have been referenced in the ICMP documents.

Data gathered and analysed from stormwater quality monitoring will be used for the following:

1. General characterisation of stormwater from Dunedin’s urban catchments;
2. To provide a baseline for future less intensive monitoring;
3. To prompt action where atypical or increasing contamination is identified (via statistical analysis);
4. To further prioritise catchments and adapt stormwater management actions where required;
5. To enable improvement in stormwater discharge quality to be measured; and
6. To inform DCC’s capital programmes and operations and maintenance schedules.

The majority of the data gathered into the future will be via the time or flow proportional methodology outlined above. The data set monitored may be reduced to include key urban stormwater contaminants, or targeted contaminants where stormwater treatment may have been implemented.

4.5.1 Trends and Triggers

In general, it is anticipated that the concentration of key urban contaminants in stormwater will reduce over time, particularly where stormwater management options have been implemented. As such, stormwater quality data gathered will be statistically examined each year. Data will be reviewed against DCC operational triggers, to re-prioritise areas for further investigation where necessary.

Because the stormwater monitoring will be undertaken as resources allow, it is proposed that trends in stormwater quality be assessed every 5 years; this allows time for collection of data across a number of catchments, and during a number of events.

5

Sediments

5.1 Historical Monitoring

Historical sediment monitoring has been undertaken in the Upper Otago Harbour for some years, with comprehensive data collection during the last 5 years at selected locations. Figure 5-1 displays the historical sampling locations. Appendix F in the AEE document details information collected to date.

Pre-2005

A review of historical information in 2005 concluded the following (Ryder Consulting, 2005):

- Iron is present in the sediments of the Upper Harbour Basin in quite significant concentrations in many areas, especially off the Portobello Road stormwater outfall and within Andersons Bay Inlet.
- Nickel concentrations within the harbour are quite high in places, but do not exceed the ANZECC (2000) guidelines for 80 % protection of species. Highest concentrations are off the Portobello Road stormwater outfall and approaching the Ravensbourne catchment (the receiving environment for stormwater from a fertilizer works).
- Copper concentrations are generally low in the sediments of the Upper Harbour Basin with the exception of off the Portobello Road stormwater outfall and in Andersons Bay Inlet.
- Chromium can be found in significant concentrations in many parts of the Upper Harbour Basin, most notably off the Portobello Road stormwater outfall, in mid harbour between Waverly and the Ravensdown Fertiliser works, and in Andersons Bay Inlet. Nowhere in the Upper Harbour Basin, however, do levels exceed the ANZECC (2000) guidelines.
- Manganese concentrations vary quite widely throughout the Upper Harbour Basin. Highest concentrations can be found off Vauxhall with medium concentrations further out in the harbour near the shipping channel.
- Zinc contamination is quite widely spread around the south and eastern borders of the Upper Harbour Basin. The highest concentrations occur off the Portobello Road stormwater outlet and in Andersons Inlet. The ANZECC (2000) guidelines for zinc levels are exceeded over substantial areas of the Upper Harbour Basin.
- Cadmium contamination in sediments in the Upper Harbour Basin is relatively localised and largely confined to the Portobello Road stormwater outfall/Andersons Bay Inlet area. The highest concentration is off the Portobello road outlet and the ANZECC (2000) guidelines are exceeded in this area.
- Lead contamination is quite wide spread around the south and western borders of the Upper Harbour Basin. The highest concentrations occur off the Portobello Road and Orari Street stormwater outlets and in Andersons Bay Inlet.
- Distribution of enterococci in sediments of the Upper Harbour Basin tends to be confined to Andersons Bay Inlet and the eastern and western shores of the upper harbour.

5 Sediments

2007 – 2011

Monitoring during the 5 year period from 2007 to 2011 is summarised in the ICMP Summary Report (URS, 2011). The sediment monitoring involved the following, per the stormwater discharge consents currently held by DCC:

'Replicate samples are collected from the top 20 mm of sediment within 20 m of each outfall monitored. The sediment is analysed for a suite of contaminants including heavy metals, bacteria and PAHs. In addition to the annual sampling, sediment is also analysed from four transects across the centre of the upper harbour, every 5 years'.

Table 5-1 below provides an analysis of the sediment samples, amended to include results from 2012 sampling. This aligns with the observations of historical data collected prior to 2004, detailed above, where higher levels of heavy metals are present in sediments near the south-eastern corner of the Upper Harbour Basin, and in Andersons Bay Inlet. Zinc, lead and PAHs would appear to be the dominant contaminants of concern in the sediments.

5.1.2 Rates of deposition

Rates of sediment deposition will vary with location within the upper harbour basin. Stevenson (1998) postulated a deposition rate of 2-3 mm per year since 1985 for the Andersons Bay Inlet and the areas at the head of the harbour, but this figure has not been verified since, and deposition rates are likely to be much lower closer to Victoria Channel due to higher tidal velocities.

5.1.3 Deep Cores

Deeper cores (500mm with subsamples taken at 100mm depths), providing more historical data on sediment contamination, have been obtained around the Portobello Road outfall. The results indicate that there may be a 'peak' of some PAH's beneath the surface, however due to uncertainties regarding sediment deposition rates in the harbour, it is difficult to establish a timeframe for these deposits.

5 Sediments

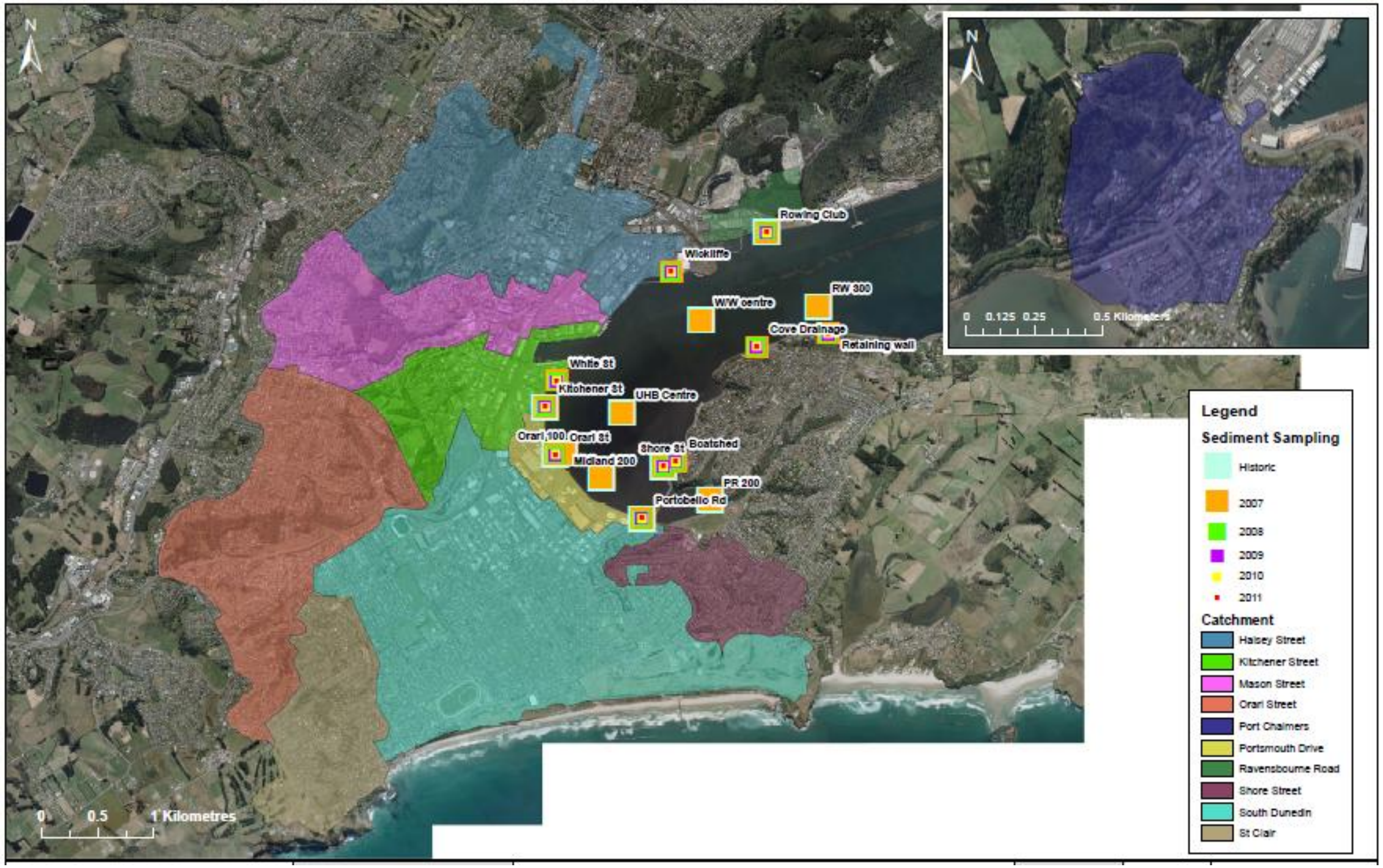

Figure 5-1: Location of Historical Sediment Monitoring

5 Sediments

Table 5-1: Marine Sediment Contaminant Assessment 2007-2012 (sediments within 20 m of outfall)

Contaminant	Shore Street	South Dunedin	Portsmouth Drive	Orari Street	Kitchener Street	Halsey Street	Ravensbourne Road	Port Chalmers (2010 only)	St Clair (2010 only)
	Andersons Bay Inlet	Upper Harbour Basin						Upper Harbour	St Clair Beach
Arsenic (As)									
Cadmium (Cd)									
Chromium (Cr)									
Copper (Cu)									
Nickel (Ni)									
Lead (Pb)									
Zinc (Zn)									
PAH									

All samples at or below ANZECC low trigger values.	Some samples exceed ANZECC low trigger value	All samples exceed ANZECC low trigger value	Some samples exceed ANZECC high trigger value	All samples above ANZECC high trigger value.

*Mason Street catchment sediments not monitored

5.2 Gaps and Knowledge Required

While it is clear that there is some contamination of harbour sediments, there is some uncertainty regarding the extent of current sources of the contaminants, due to uncertainty regarding harbour deposition rates, movement of sediments, and re-suspension of older contaminants in the harbour. The following information would provide additional information to enable an assessment of the likely 'recent' contaminant deposits, and also provide information to enable more focussed monitoring of future discharges:

- Sedimentation rate at different points around the Upper Harbour Basin; and
- Further analysis of contaminant concentrations in sediments at different depths to assess temporal trends.

5.3 Proposed Methodology

5.3.1 General

Harbour sediment monitoring provides an opportunity to better understand the fate of anthropogenic contaminants present in stormwater. Contaminant concentrations in sediments can be used to track trends over time, whereby ANZECC guidelines (or alternatively toxicology tests) may provide early warning signs of potential detrimental effects on ecology.

Monitoring data collected to date has enabled the 'hotspots' in the harbour to be identified, however the extent of current contaminant deposition is unclear, due to gaps in the data relating to deposition rates and movement within the upper harbour. It is likely based on available information, that the sediment sampling techniques used over the past 5 years have resulted in samples containing historical sediment deposits, along with recently deposited sediment. This creates difficulty with respect to stormwater catchment management, which only addresses contaminants currently in the discharge – information pertaining to current deposition is required to ensure management objectives are appropriately set.

The methodology presented below is therefore twofold:

1. Phase 1: Sediment capture and analysis, and deep core sampling (1-5 years); and
2. Phase 2: Prioritised sediment monitoring (ongoing).

5.3.2 Analytes

In order to provide linkages with stormwater quality, analytes outlined in Table 4-5 should also be monitored in harbour sediments (Refer table 5-2). Analysis of sediment samples shall be undertaken by a laboratory using IANZ accredited methods. A protocol for collection of samples, including storage, transport and analysis methods.

Table 5-2: Marine Sediment Monitoring - Analytes

Contaminant
Arsenic (As)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Nickel (Ni)
Lead (Pb)
Zinc (Zn)
Total Petroleum Hydrocarbons (TPH)
Polycyclic aromatic hydrocarbons (PAH)
Enterococci

5.3.3 Sediment Sampling Locations

Harbour 'Baseline' Monitoring Locations

Ravensdown have been monitoring sediment quality in a number of locations in the central harbour. Three reference sites have been monitored; 'Ref E' – opposite Ravensbourne, 'Ref F' – opposite the Water of Leith, and 'Ref G'' – centre of the Upper Harbour Basin. These coincide approximately with historical sediment sampling sites UHB centre, WW Centre and RW300, shown in Figure 5-1 above, Currently, sediments from these sites are analysed for Cadmium content, however it is proposed to include these sites into the DCC sediment monitoring as 'reference' sites, monitored at the same frequency as the other sediment sites; providing a comparison with near-shore sediment results.

5 Sediments

Phase 1 Locations – 1-5 years

Figure 5-2 provides proposed locations for short term monitoring for sediment deposition (Sites A-D) and one-off deep core sampling (Sites 1 and 2). Locations for sediment deposition rate determination and contaminant sampling (via 'trapping' of sediment), have been chosen to ensure effects of tidal circulation patterns and the Water of Leith influence are taken into account.

Deep cores adjacent to the Kitchener Street and Halsey Street catchment outfalls have been selected as contaminant 'hotspots' where historical contamination is expected. These will complement deep core information previously obtained from near the South Dunedin catchment outfall location and at the sediment deposition sites.

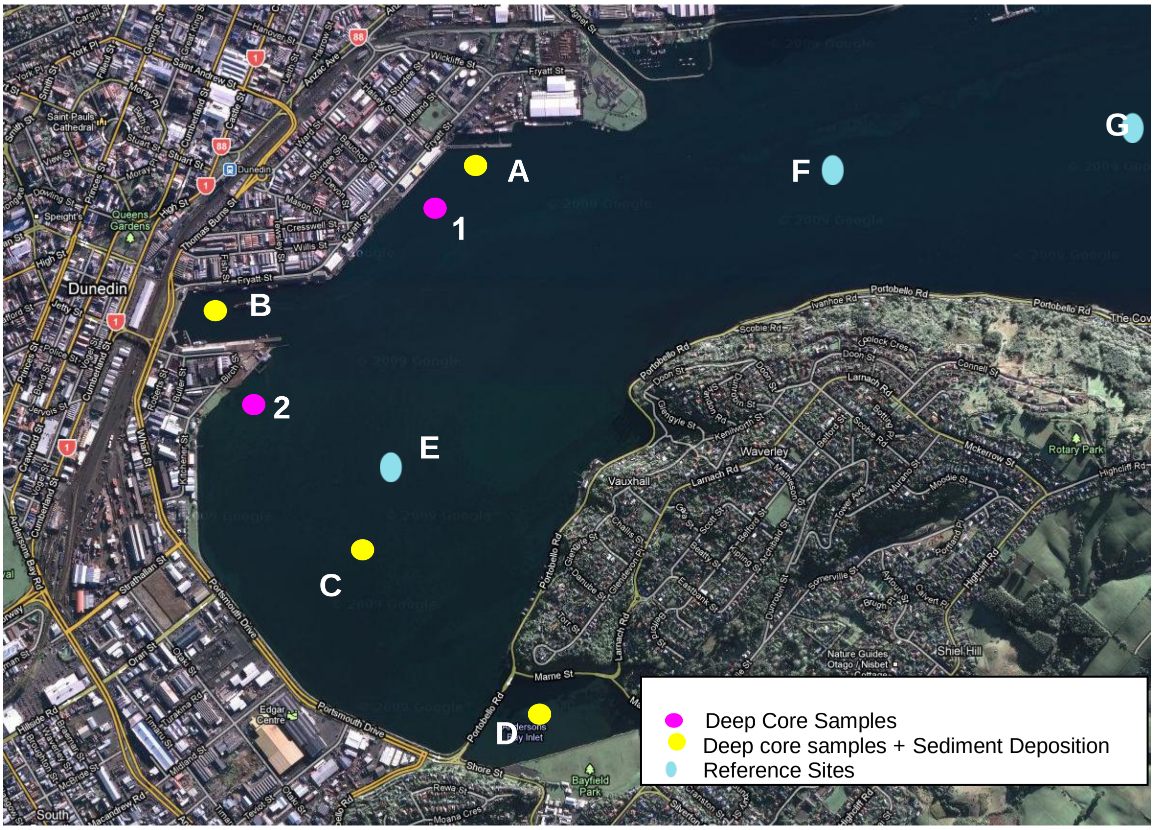

Figure 5-2: Phase 1 sediment monitoring locations

Phase 2 Locations - Ongoing

The Phase 1 sediment monitoring, together with the monitoring undertaken between 2007 and 2012, would provide the basis for the selection of ongoing monitoring sites for Phase 2. It is anticipated that the current set of 10 sites would be reduced, depending upon the success of the sediment trapping in identifying contaminants in the sediments discharged with stormwater. Analysis of the sites by catchment undertaken for stormwater quality sampling provides an indication of priority, however this would need to be reviewed with respect to the results from Phase 1 monitoring. As discussed in Section 1.2, linkages between stormwater quality and receiving environment health are required to ensure the monitoring programme is robust.

5.3.4 Phase 1 Sediment Monitoring Methodology

Sediment Deposition Rate Measurement and Analysis

Sediment traps would comprise a simple, weighted, high sided tray anchored on the bottom of the harbour at a depth beyond that at which wind generated waves will have significant influence (.i.e. >3m). Traps would be lowered into place by a snorkeler or diver, the location recorded using GPS, and retrieved after one year. Depth and volume of sediment collected would be recorded. Sediments would be analysed for all analytes tabulated in Table 5-2. Comparisons would be made between samples, and also with the core samples and harbour reference sites, to establish a 'zone of influence' of stormwater pollutants, but also gauge the significance of results.

Core Sample Depths and Analysis

Deep cores taken around the South Dunedin outfall were of 500mm depth, with 2 cm subsamples taken at 100 mm depths. It is anticipated that only one core sample to 500 mm depth will be required at each new location, and that initially,100 mm depths would be subsampled; cores would be archived so that further samples at finer resolution could be analysed at a later date if required. This would be revisited once better knowledge of sediment deposition rates was gained, through the sediment deposition measurement outlined above or review of cores with respect to historical events. Sediments would be analysed for all analytes detected in the stormwater; tabulated in Table 4-5.

5.3.5 Phase 2 Ongoing Sediment Monitoring Methodology

Currently, the top 200 mm of sediment is sampled at the locations outlined above. Given suspected slow sedimentation rates in the Upper Harbour, it is likely that annual sampling is not providing worthwhile trend analysis, and that sampling at longer intervals might yield acceptable results with respect to changes over a long period of time. Phase 2 monitoring would be undertaken from 2017, following completion of Phase 1, when better knowledge of deposition rates would be available. Review of this data would indicate whether sediment trapping was required for ongoing monitoring, or if collecting sediment samples per the current methodology would be sufficient for monitoring ongoing effects.

5.4 Interpretation of Results – Key Indicators, trends, 'trigger' points

5.4.1 Trends

Given the slow deposition rates predicted in the Upper Otago Harbour, it is likely that the effects of stormwater management on contaminant levels in sediments will only become apparent over a medium to long term timeframe (ie 10 – 50 years). Statistical analysis, and comparison with the core data and harbour reference sites will be required to measure trends.

During the Phase 1 sediment monitoring, it is anticipated that each sediment trap will provide information relating to sediments discharged into the harbour during that year (assuming that the influence of re-suspension of sediments in the harbour is minimised in the trap via the methodology). Annual analysis of trapped sediment will therefore allow a 'snapshot' of sediment quality to be obtained, with longer term trends establishing over time.

Following the Phase 1 sediment monitoring exercise, the rates of current sediment deposition in the harbour will be better understood. This may allow for a review of historical sediment data (deep cores and the 2007 – 2012 monitoring).

5.4.2 Trigger Values

In order to provide a way of quickly identifying if there may be a new contamination issue, based on sediment quality data, it is recommended that trigger values be set for key contaminants such that issues can be identified as quickly as possible. – as soon as a trigger value is exceeded, action can be taken to identify the issue, rather than waiting to review trends. These triggers should be reviewed at the same intervals as trend data, to ensure that upper levels are in keeping with international and national data, and that the triggers reflect the trends in contaminant discharge (i.e. reduce over time).

The comparison of sediment quality data with ANZECC guidelines (Table 5-1 above) indicates that there are a number of areas in the harbour where the sediments sampled have a high level of particular contaminants.

Ecological assessments undertaken for DCC in the past 5 years, however, indicate that the ecological health in the upper harbour area is not declining due to current stormwater inputs (Ryder Consulting, 2010). This indicates that the ecology in the harbour is not adversely affected by contaminants which have been detected in concentrations in excess of the ANZECC (2000) guidelines trigger values.

It is likely based on available information, that the sediment sampling techniques used over the past 5 years have resulted in samples including historical sediment deposits. The Phase 1 sampling methodology outlined above seeks to provide information relating to recently deposited sediments only, however due to re-suspension of sediments in the harbour, and multiple sources, it will be difficult to identify contaminant sources.

It is recommended, therefore, that site-specific triggers can be set in the future, based on the annual deposition rates and assessment of sediment cores.

Because of the lack of current evidence for correlations between the sediment quality, stormwater quality and the harbour ecology, it is recommended that where sediment contaminant concentrations exceed the trigger values, the results must be reviewed alongside the ecological monitoring results for the nearest location.

Trigger values for metals are shown in Table 5-2 below.

Based on the current data, the general approach applied has been as follows:

1. Use the ANZECC low sediment quality trigger value where the historical sampling data has indicated that values are already below the concentrations, otherwise use the 80^{th} percentile of all samples collected to date as the trigger. As noted above, review of ecological data will be undertaken in parallel.
2. For Enterococci, use 80^{th} percentile of South Dunedin samples collected between 2008 and 2012 (a catchment which is not subject to wastewater discharge influence, based on previous monitoring).

5 Sediments

Table 5-3: Phase 1 - Trapped Sediment quality triggers

Indicator	Unit	Sample Results 2007-2012			ANZECC Guideline Trigger Values		2013 Trigger Value	Description
		Mean	80th %ile	95th %ile	Low	High		
Arsenic	(mg/kg dry wt)	12	19	29	20	70	19	80th percentile of samples collected to date.
Cadmium	(mg/kg dry wt)	2.7	1.7	3	1.5	10	1.7	80th percentile of samples collected to date.
Chromium	(mg/kg dry wt)	30	39	72	80	370	80	Anzecc Low trigger - most samples to date below Anzecc
Copper	(mg/kg dry wt)	76	122	198	65	270	122	80th percentile of samples collected to date.
Nickel	(mg/kg dry wt)	14	19	24	21	52	21	Anzecc Low trigger - most samples to date below Anzecc
Lead	(mg/kg dry wt)	149	209.2	362	50	220	209	80th percentile of samples collected to date.
Zinc	(mg/kg dry wt)	613	902	1530	200	410	902	80th percentile of samples collected to date.
Total PAH	(mg/kg dry wt)	106	183	501	4	45	183	80th percentile of samples collected to date.
TPH	(mg/kg dry wt)						-	Not sampled to date
Enterococci	MPN/g						108	80th percentile of samples collected near South Dunedin 2008-2012 to date.

6

Ecosystems

6.1 Historical Monitoring

Pre-2005

Biological monitoring is a consent condition for a number of the current discharges. Historical monitoring of ecology in the harbour has been undertaken for a number of other projects. Table 6-1 summarises historical monitoring in the Otago Harbour.

In most historical studies cores of sediment were extracted and sieved to separate out benthic and infaunal macroinvertebrates. Number of different families of animals present (diversity), rather than the total number or animals is generally accepted as a reasonable indicator of environmental health and the state of the upper harbour in 2004, with respect to diversity, is shown in Figure 5.1.

The highest numbers of invertebrate families occur off Palmer's Quarry, in the channel which drains Andersons Bay Inlet, and "seaward" from the Ravensdown Fertiliser works. Lowest diversity is in the southern corner of the inner harbour.

The pollution tolerance for a number of benthic marine invertebrate species has long been theorised (Pearson and Rosenburg 1978; Thrush and Roper 1988; Roper 1990). Relatively few species for which pollution tolerance is known were found in the sediments of the Upper Harbour, however some species which are not pollution tolerant are also present.

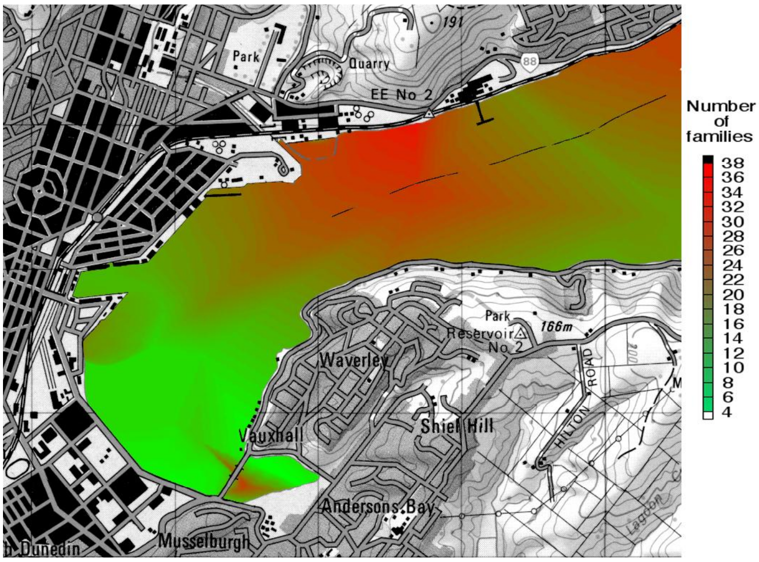

Figure 5.1 Number of invertebrate families present in sediments in the Upper Harbour Basin, 2004.

6 Ecosystems

Table 6-1: Accumulated biological data (algae and invertebrates) per m^{2*} for Otago Harbour sediments, 1991-2002.

Site	Source	Dominant algal type	# Families	Total individuals	Richness	Diversity (H')	Evenness
Ravensdown 25E	Bioresearches 2002	Red, fine red	21	166		1.42	
Ravensdown 350E	Bioresearches 2002	Red, fine red	26	436		2.05	
Ravensdown 1000E	Bioresearches 2002	Red, fine red	32	632		2.87	
Ravensdown 350W	Bioresearches 2002	Red, fine red	29	495		3.1	
Ravensdown E	Bioresearches 2002	red	18	341		1.21	
Mid Harbour Sth of beacon 60 (F)	Grove 1995	red	32	810	4.629	1.888	0.545
	Bioresearches 2002	red	26	364		1.89	
Centre Upper Harbour Basin (G)	Grove 1995	red,green, fine red	31	1998	3.947	1.625	0.473
	Bioresearches 2002	red,green, fine red	21	155		1.43	
Andersons Bay Inlet (J)	Grove 1995	none	40	1314	5.431	2.997	0.812
Off Orari St outlet in harbour (N)	Grove 1995	red	34	734	5.001	1.893	0.537
Between beacons 61 & 63, off Plamers quarry (O)	Grove 1995	green, fine red	37	1957	4.75	2.257	0.625
Mid Harbour due Sth of beacon 60 (B22)	Rainer 1981	red		1150		2.62	0.505
Upper Harbour Basin (40)	Grove & Probert 1997		16				
Upper Harbour Basin (41)	Grove & Probert 1997		21				
Off Kitchener St outlet (42)	Grove & Probert 1997		11				
Upper Harbour Basin (43)	Grove & Probert 1997		11				
Upper Harbour Basin (44)	Grove & Probert 1997		10				
Upper Harbour Basin (45)	Grove & Probert 1997		9				
Off Orari St outlet (46)	Grove & Probert 1997		5				
Upper Harbour Basin (47)	Grove & Probert 1997		8				
Upper Harbour Basin (48)	Grove & Probert 1997		9				
Upper Harbour Basin (49)	Grove & Probert 1997		10				
Centre Upper Harbour Basin (50)	Grove & Probert 1997		10				

6 Ecosystems

Site	Source	Dominant algal type	# Families	Total individuals	Richness	Diversity (H')	Evenness
Upper Harbour Basin (51)	Grove & Probert 1997		12				
Upper Harbour Basin (52)	Grove & Probert 1997		6				
Off Portobello Rd outlet (53)	Grove & Probert 1997		5				
Andersons Bay Inlet by causeway bridge (54)	Grove & Probert 1997		13				
Andersons Bay Inlet (J)(55)	Grove & Probert 1997		23				
Andersons Bay Inlet Shore St outlet (56)	Grove & Probert 1997		8.0				
Andersons Bay Inlet (57)	Grove & Probert 1997		8.0				
Andersons Bay Inlet (58)	Grove & Probert 1997		6.0				
Andersons Bay Inlet (59)	Grove & Probert 1997		4.0				

*Sampled to 200 mm depth

2007 - 2012

As part of consent conditions, the monitoring summarised in Table 5-2 has been previously undertaken (Ryder Consulting reports, 2005 – 2012). The conclusions drawn from the ongoing monitoring indicate that benthic and infaunal communities at the monitored sites have reasonably low diversity, however this is likely to be symptomatic of a large proportion of the Upper Harbour Basin (Ryder, 2011b). It is possible that this is due to historical stormwater inputs, however a number of other factors, such as exposure at low tide, are likely to be influential.

Table 6-2: Ecological Monitoring, 2007 - 2012

Catchments	Details – Annual monitoring
South Dunedin Orari Street Kitchener Street	Epifauna – number of species in quadrant Infauna – number of species in sediment Macrofalora – percentage cover in quadrant Cockles – analysis of flesh for contaminants
South Dunedin Orari Street	Octopus – analysis of flesh for contaminants
Mason Street	Spotties / Triplefin – length and weight, analysis of flesh for contaminants
St Clair (Second Beach)	Mussels – shell length, analysis of flesh for contaminants

6.2 Gaps and Knowledge Required

The present monitoring regime is considered to be sufficient to determine trends in environmental health within the part of the Upper Harbour monitored.

It is considered that the ecological monitoring currently undertaken can be used to provide a general indicator of environmental health within the upper harbour. In association with harbour water, sediment, and stormwater quality monitoring, ecological health monitoring will increasingly be able to give a broad picture of the effects of stormwater discharges; as links between the discharges and the sediments are better understood, ecological monitoring results should provide more useful feedback in terms of direct environmental effects.

With respect to cockle flesh, despite difficulties in differentiating effects from stormwater, exposure at low tide and freshwater inputs, chronic long-term effects may show up over a timeframe of 5-10 years, providing an effective measure of cumulative contamination effects.

The monitoring of mussels at Second Beach, and octopus and fish within the harbour has provided little in the way of useful information since monitoring began. The discharges at Second Beach are not considered to be a threat to the receiving environment because of the high energy environment. Because of the habitat/feeding range of Octopus and fish, it is considered that the source of any contaminants present in the flesh could not be determined. Their use as an indicator of health in response to stormwater discharges is therefore inconclusive.

Monitoring of algae and invertebrates over the past 5 years has provided very little useful information, due largely to the fact that there is a lack of diversity of both algae and infaunal animals in the sediments of the upper harbour basin. It is considered that analysis of algal cover could be discontinued. There may be an opportunity to undertake some periodic monitoring, to determine whether improving quality of stormwater discharges has an effect on diversity.

6.3 Proposed Methodology

6.3.1 General

As identified above, it is proposed that ecological monitoring be restricted to epifauna, infauna and cockles. Locations and methodology are outlined below. Monitoring of epifauna and infauna provides an effective indicator of ecological health. Monitoring of particular organisms that bioaccumulate contaminants can provide an indication of risk to human health via consumption.Analytes / Organisms

Table 5-3 below provides a list of key indicator organisms and ecological indices to be used.

Table 6-3 Ecological Monitoring Indicators

Indicator Species	Measure	Significance
Epifauna	Number of species in quadrant	Diversity of species indicator of ecological health.
Infauna	Number of species in sediment	Diversity of species indicator of ecological health.
Cockles	Analysis of flesh for metails: As, Cd, Cr, Cu and Pb. Also faecal coliforms and PAH.	These metals are notable for their toxicity in animals, including humans. Cockles are filter feeders and will bioaccumulate these metals, leading to biomagnifications in species further up the food chain.

6.3.2 Sites

Currently, six cores are sampled <20 m from the Kitchener Street, Orari Street and Portobello Road outfalls and analysed for invertebrates. A further six are sampled >50 m from each outfall. As there have been no changes evident over the past five years, it is recommended that four cores are sufficient at the three sites, monitored annually. A further four cores will be sampled at intertidal areas beyond the mixing zone (Figure 3-3). Sites at McAndrew Bay and Burkes Drive on either side of the harbour have been selected as reference ecology sites.

Epifauna are assessed in fifteen quadrats <20 m from the Kitchener Street, Orari Street and Portobello Road outfalls and 15 quadrats >50 m from each outfall. This could be reduced to 10 at each distance without any significant loss of analysing power, with an additional 10 outside the mixing zone (Figure 3-3).

The sites currently monitored are in the southern part of the upper harbour basin, where historically, higher contaminant levels have been measured. The additional sites outside of the mixing zone will allow ecology to be assessed relative to the sites likely to be more influenced by stormwater contaminants.

Cockles are currently collected from sites near Portobello Road, Orari Street and Kitchener Street outfalls. These sites are intended to remain, with cockles (if present) sampled at the sites in McAndrew Bay and Burkes Drive.

6.4 Interpretation of Results – Key Indicators, trends, 'trigger' points

Trends would be discerned using diversity indices compared statistically from year to year. Increasing diversity would suggest improving ecosystem health while decreasing diversity would suggest decreasing health.

Based on the fact that seven years of monitoring data show that there is no evidence that existing levels of contaminants are having an adverse effect on intertidal marine communities it is recommended that no reduction in the sediment trigger levels outlined in Section 4.4 occur unless there is also a deterioration in community health. This would be defined as a statistically significant reduction in community diversity index over two successive years. Ecological trigger values are outlined in Table 5-4.

Statistical analysis would also be undertaken to determine significant differences between the sites near to, and further from the outfalls.

Table 5-4: Ecological trigger values

Indicator	Method of Detection	Trigger Value	Timeframe
Diversity indices	Ecological monitoring	Reduction in community diversity index. Using a one way ANOVA statistical analysis.	2 years

Harbour Water Quality

7.1 Historical Monitoring

Limited harbour water quality monitoring has been undertaken, with variable results based on harbour conditions, weather, and stormwater inputs. Recent monitoring undertaken by DCC has revealed that possible re-suspension of sediments during rough weather conditions may result in high contaminant levels in the water column during storm events, however a dry weather event sampled also showed some elevated contaminants within the water column, when compared to ANZECC guidelines for marine water quality.

The Ministry for the Environment (MfE) undertakes monitoring in the Upper Otago Harbour for their Regional Water Quality Environmental Snapshot. Results published on MfEs website indicate that there is generally a low risk of microbiological contamination of water in Macandrew Bay where the measurements are taken (MfE, 2011).

7.2 Gaps and Knowledge Required

Monitoring of harbour water quality will be used to help create linkages between stormwater discharges and contaminants in sediments, however also. provides an opportunity to assess the impact of stormwater on the harbour, with respect to the policies and objectives outlined in The Regional Plan: Coast for Otago (Coastal Plan),

7.3 Proposed Methodology

7.3.1 General

The fact that the upper harbour is popular with wind and kite surfers suggests that the monitoring of enterococci in the harbour water at a prescribed site may be advantageous with respect to determining environmental health for recreational users. Monitoring during wet weather conditions may help to identify links between stormwater discharge and contaminants in sediments, however is not likely to demonstrate that the policy objectives of Coastal Plan are being met, as these primarily relate to recreational use of the harbour, where the majority of recreational activities take place during dry weather. It is proposed to undertake one wet weather and one dry weather sample each year.

7.3.2 Sites

It is proposed to sample at three sites – two of these sites are to be outside of the mixing zone identified in Figure 3-3, with a further site at the Kitchener Street windsurfing area, due to recreational use of the harbour. In keeping with Objective 10.4.4 of the Otago Regional Plan: Coast, it is proposed to monitor for bacterial indicators only at the windsurfing launch area, due to the recreational use of that part of the harbour. Other contaminants, such as metals, will be measured outside of the mixing zones.

7.3.3 Sampling Methodology

Samples are to be taken on four occasions (two rounds) annually and should be taken 100-200 mm below the surface of the water.

First round sampling occasions are 6 hours apart at mid flood tide and mid ebb tide (i.e 2.5 – 3.5 hours after successive slack waters) during a period when there has been no measurable rainfall for at least 72 hours prior to sampling. The second round sampling will occur at the same tides states no less than 3 hours after the commencement of a rain event that is likely to produce at least 2 mm of rainfall and that has had an antecedent dry period of at least 72 hours. Sampling rounds may take place within any 12 month period but should ideally be within one month of each other.

7.3.4 Analytes

All samples taken outside of the mixing zone will be analysed for the following dissolved contaminants:

- Arsenic (As)
- Cadmium (Cd)
- Chromium (Cr)
- Copper (Cu)
- Nickel (Ni)
- Lead (Pb)
- Zinc (Zn)
- Enterococci

Samples taken from the Kitchener Street windsurfing launch site will be tested for Enterococci only.

7.4 Interpretation of Results – Key Indicators, trends, 'trigger' values

The sampling of harbour water quality provides an opportunity to assess the effect of discharges during a rain event instantaneously. They provide a 'snapshot' of harbour water quality. By assessing the dry weather water quality, and sampling on an incoming and outgoing tide an assessment can be made of the longevity of effects of stormwater discharges on the harbour water.

Based on the Otago Regional Plan: Coast objectives for recreational quality water and shellfish gathering, it is recommended that ANZECC (2000) trigger values for protection of 95 % of species in marine water would be appropriate for contaminant levels in harbour water in the receiving environment outside of the mixing zone. MfE guidelines for beach bathing would be appropriate for sampling near the kite surfing launch area.

Given recent sampling events, dry weather sample analysis should be reviewed in conjunction with wet weather results, and used as 'ambient' levels. Because ANZECC guidelines do not have a trigger level for Arsenic, the USEPA chronic trigger has been recommended.

Trigger values for harbour water quality are summarised in Table 7-1. Exceedence of a trigger value would result in a confirmation of the exceedence, followed by investigation into the source of the contaminant, and management of the issue, should the source of contamination be stormwater discharge from one of DCC's outfalls.

7 Harbour Water Quality

Table 7-1: Phase 1 – Harbour water quality triggers

Indicator	Unit	ANZECC 95% Marine Guideline Value	2013 Trigger	Description
Arsenic	(g/m^3)	-	0.036	USEPA chronic trigger
Cadmium	(g/m^3)	0.00550	0.00550	ANZECC guideline
Chromium	(g/m^3)	0.00440	0.00440	ANZECC guideline
Copper	(g/m^3)	0.00130	0.00130	ANZECC guideline
Nickel	(g/m^3)	0.07000	0.07000	ANZECC guideline
Lead	(g/m^3)	0.00440	0.00440	ANZECC guideline
Zinc	(g/m^3)	0.01500	0.01500	ANZECC guideline
Enterococci	cfu/100mL	-	140	MfE guideline (amber alert)

8

Monitoring Programme Summary

8.1 Overview

This section summarises the proposed monitoring programme, presenting the discharge consent monitoring separately to the other discretionary monitoring to be undertaken by DCC.

In order to comply with the proposed harbour discharge consent conditions, monitoring of harbour water quality, harbour sediment quality and harbour ecology is required. The locations and methods for this monitoring are summarised below, but presented in more detail in Sections 6, 7 and 8 of this document.

This monitoring will be used to provide data for trend analysis and annual reporting to the ORC, but also to provide early warnings of potential contamination issues in the receiving environment where appropriate. The way in which receiving environment results will be assessed within the context of the ICMP stormwater management process is summarised in the AEE and consent conditions. The process describes how data will be used, should identified trigger values of any contaminant measured be exceeded.

Appendix A provides a map of the monitoring sites, and Table 8-1 provides a summary of the monitoring to be undertaken.

8 Monitoring Programme Summary

Table 8-1: Monitoring summary

Type of Monitoring	Method	Locations		Frequency	Duration	Analytes
		Consent Monitoring	DCC monitoring			
Stormwater Quality	Flow proportional monitoring		Minimum 1 site per year (more as funding allows)	3 samples / site,	5 years for baseline, or as required to assess management actions.	• Arsenic (As) • Cadmium (Cd) • Chromium (Cr) • Copper (Cu) • Nickel (Ni) • Lead (Pb) • Zinc (Zn) • Ecoli • Suspended Solids • Total Petroleum Hydrocarbons (TPH) • Polycyclic aromatic hydrocarbons (PAH) • Fluorescent whitening agents (FWA) • Salinity
Sediment Quality	Deep Core		1,2	One-Off	One-off	• Arsenic (As) • Cadmium (Cd) • Chromium (Cr)
	Trapped Sediment		A,B,C,D	Annually	5 years	

8 Monitoring Programme Summary

<table>
<tr><th rowspan="2">Type of Monitoring</th><th rowspan="2">Method</th><th colspan="2">Locations</th><th rowspan="2">Frequency</th><th rowspan="2">Duration</th><th rowspan="2">Analytes</th></tr>
<tr><th>Consent Monitoring</th><th>DCC monitoring</th></tr>
<tr><td></td><td>In-situ sediment</td><td>D, E,F,G,
Sawyers Bay (50 m from outfalls)</td><td></td><td>Annually</td><td>Ongoing</td><td>• Copper (Cu)
• Nickel (Ni)
• Lead (Pb)
• Zinc (Zn)
• Total Petroleum Hydrocarbons (TPH)
• Polycyclic aromatic hydrocarbons (PAH)
• Enterococci</td></tr>
<tr><td rowspan="3">Ecology</td><td>Epifauna</td><td rowspan="2">MacAndrew Bay (E1)
Burkes Drive (E2)</td><td rowspan="2">Portobello Road (E3)
Orari Street (E4)
Kitchener Street (E5)</td><td>Annual</td><td>Ongoing</td><td>• Number of species in quadrant</td></tr>
<tr><td>Infauna</td><td>Annual</td><td>Ongoing</td><td>• Number of species in sediment</td></tr>
<tr><td>Cockles</td><td>MacAndrew Bay (E1)
Burkes Drive (E2)</td><td>Portobello Road (C3)
Orari Street (C2)
Kitchener Street (C1)</td><td>Annual</td><td>Ongoing</td><td>• Arsenic (As)
• Cadmium (Cd)
• Chromium (Cr)
• Copper (Cu)
• Lead (Pb)
• PAH
• Faecal Coliforms</td></tr>
<tr><td>Harbour water quality</td><td>Grab sample</td><td>H, E, F</td><td></td><td>Sites E, F – twice / year (one wet and one dry weather)
Site H – once per year (dry weather)</td><td>Ongoing</td><td>• Arsenic (As)
• Cadmium (Cd)
• Chromium (Cr)
• Copper (Cu)
• Nickel (Ni)
• Lead (Pb)
• Zinc (Zn)
• Enterococci</td></tr>
</table>

9

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10 Limitations

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The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

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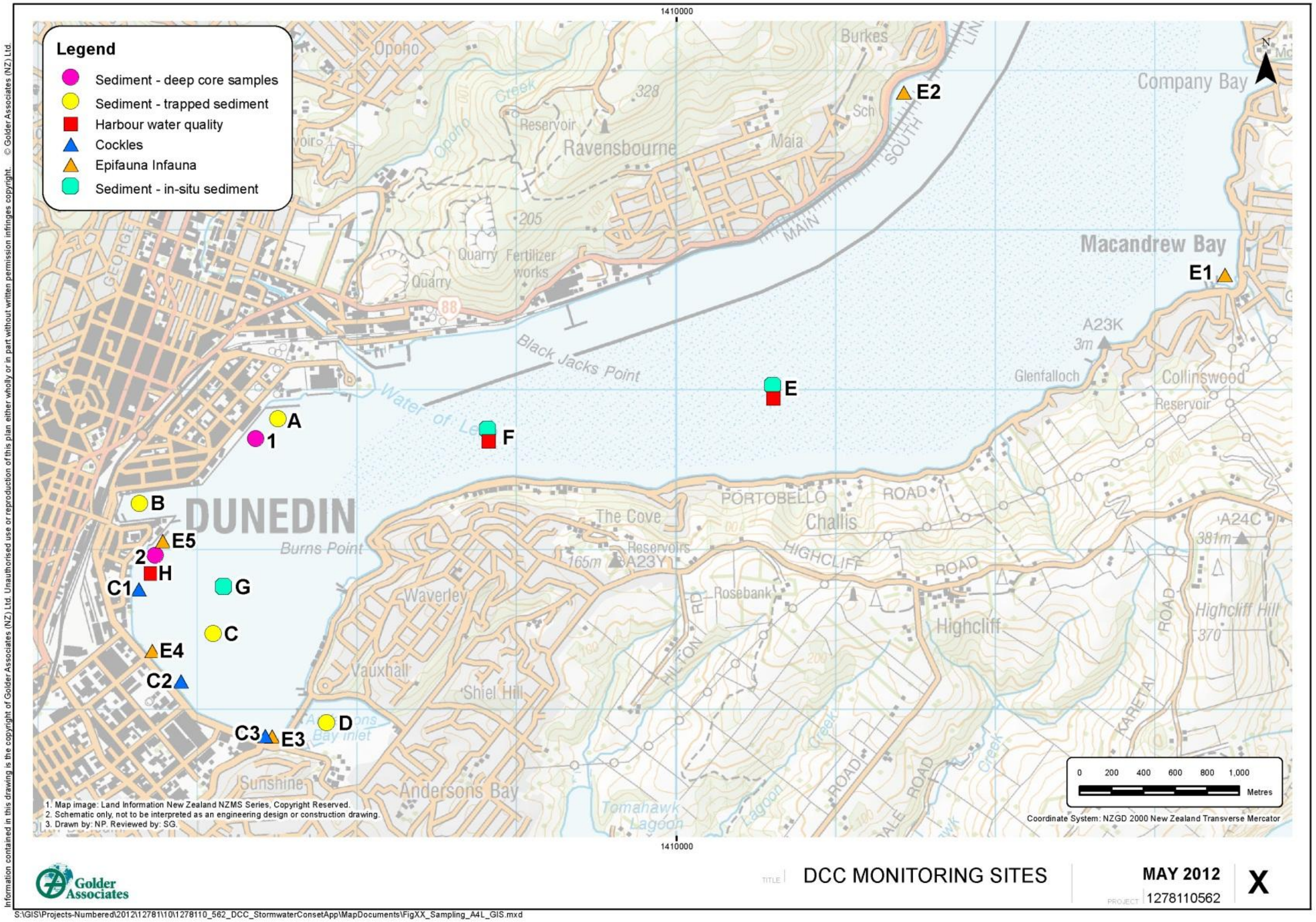
Appendix A Monitoring Sites

Appendix A


Legend
Sediment - deep core samples
Sediment - trapped sediment
Harbour water quality
Cockles
Epifauna Infauna
Sediment - in-situ sediment
1410000
E2
E1
E
F
A
1
B
E5
2
H
C1
G
C
E4
C2
C3
E3
D
DUNEDIN
Company Bay
Macandrew Bay
Ravensbourne
Black Jacks Point
Burns Point
Portobello Road
Challis
Highcliff
Andersons Bay
Shiel Hill
Vauxhall
Waverley
Sunshine
Glenfalloch
Collinswood
0 200 400 600 800 1,000 Metres
Coordinate System: NZGD 2000 New Zealand Transverse Mercator
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URS New Zealand Limited
Level 1, 31 Orchard Road
Christchurch Airport 8053
PO Box 4479, Christchurch 8140
New Zealand
T: 64 3 374 8500
F: 64 3 377 0655

www.urscorp.co.nz