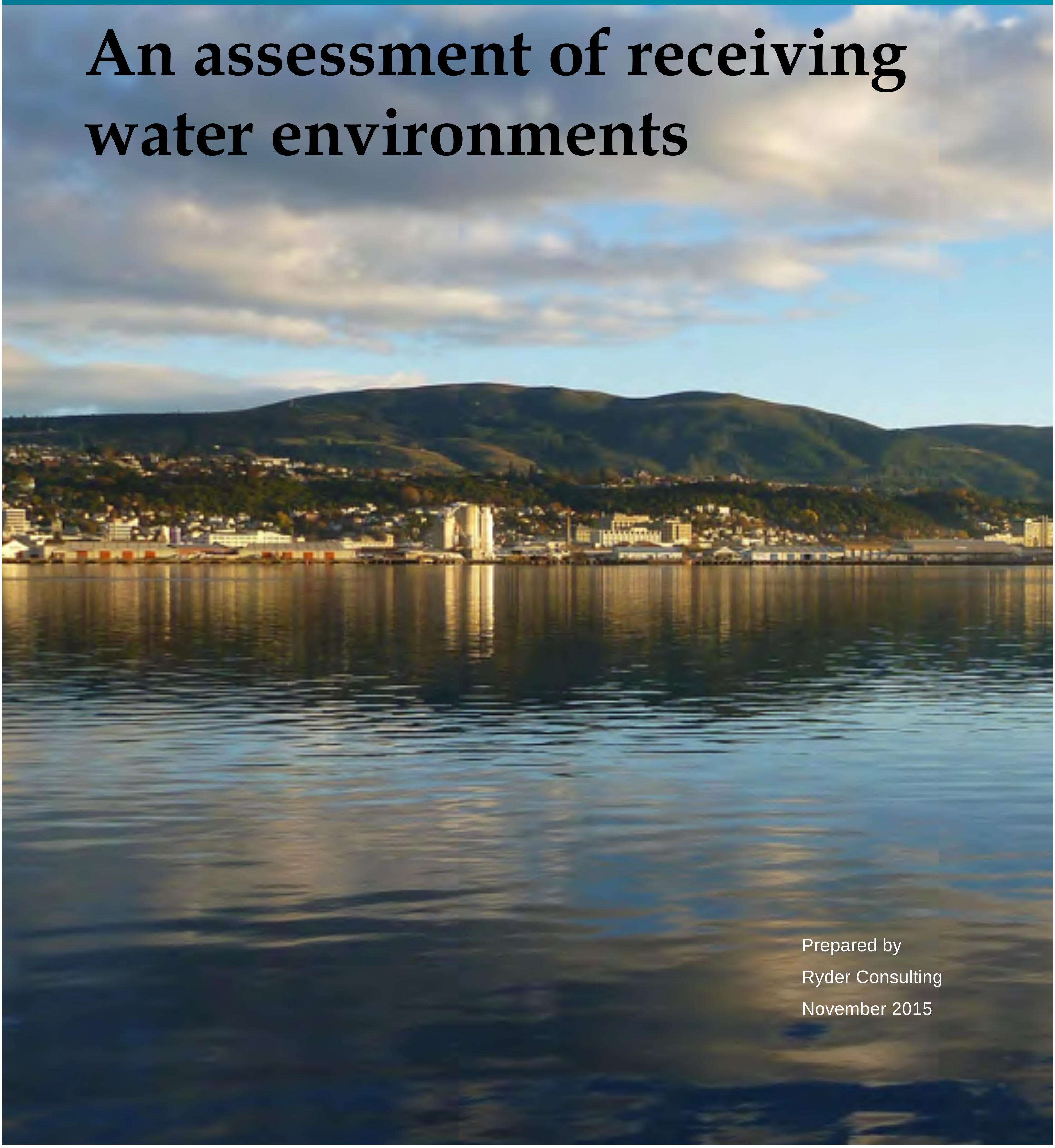
Dunedin City Wastewater Overflows

An assessment of receiving water environments



Prepared by

Ryder Consulting

November 2015

Dunedin City Wastewater Overflows:
An assessment of receiving water environments

November 2015

prepared for Dunedin City Council, Water and Waste Services
by Ryder Consulting

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document version: 23/11/2015

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Cover photo (G Ryder): Autumn sunrise on Dunedin.

Contents

1. Introduction

The Dunedin City Council (DCC) maintains an extensive underground wastewater network that services Dunedin City, Port Chalmers and other outlying suburbs. This network conveys toilet wastes, grey water (i.e., household wastewater from kitchens, bathrooms and laundries) and trade wastes from domestic, commercial and industrial premises to wastewater treatment plants. During large storm events, infiltration and inflow of groundwater and rainwater to the wastewater network causes some of the pipes reach to capacity and overflow into neighbouring freshwater and coastal water bodies via direct wastewater overflow pipes, or via overflow into the city's stormwater drainage network.

Because these overflows contain untreated wastewater, there is potential for them to degrade water quality and affect ecosystem health, natural values, recreational opportunities and cultural well-being of receiving environments. The receiving environments affected by the seven overflows are Kaikorai Stream, the Water of Leith/Lindsay Stream system, and Otago Harbour.

The DCC's capital expenditure programme for wastewater is focussed on minimising, and ultimately avoiding, overflows through removing inflow and infiltration, resizing sewers, and evaluating other network management options. In the interim, new wastewater network discharge consents are required. The DCC has been characterising the nature of individual overflows, how often they occur and under what conditions, and the rate and duration of the flow.

Ryder Consulting Ltd has been engaged to evaluate receiving waterbodies with respect to ecology and water quality, with the findings being presented in this report. The work has involved a combination of field surveys and reviews of existing information found in various reports and investigations over recent years.

This report summarises information on Dunedin City's freshwater and coastal environments that are subject to periodic overflows of wastewater from the foul sewer network. The report presents:

- physical descriptions of the overflows (Section 2);
- a summary of information on water quality and aquatic ecologyof the receiving water body, including findings from site-specific surveys undertaken over the last 12 months (Section 3); and
- an assessment of the effects of the overflows on local ecology and water quality (Section 4).

2. Wastewater Overflow Locations & Character

Wastewater overflows were identified through the development of the Dunedin 3 Waters Strategy. Hydraulic models to examine the entire water cycle within Dunedin's urban catchments, provided critical information on the performance of the networks. Automated samplers were installed at the overflows to record the frequency, duration and volume of overflow.

Wastewater overflows are listed in Table 1 and mapped in Figure 1. Two overflows are located in each of the Kaikorai Stream and Lindsay Creek / Water of Leith catchments, while three drain indirectly into Otago Harbour. The characteristics of each site are described in subsequent sections.

Table 1. DCC wastewater overflow sites and their respective map coordinate locations.

Catchment	Overflow site name	NZMG coordinates
Kaikorai Stream	Kaikorai Valley	E 2313278 N 5477556
	Shetland Street / Nairn Street	E 2314896 N 5479749
Lindsay Creek / Water of Leith	Lindsay Creek	E 2317388 N 5480793
	Harbour Terrace / Union Street East	E 2317388 N 5479374
Otago Harbour Basin	Hillside Road / Surrey Street	E 2314753 N 5475819
	Marne Street Pumping Station	E 2318018 N 5476558
	Sawyers Bay Pumping Station	E 2323834 N 5484780

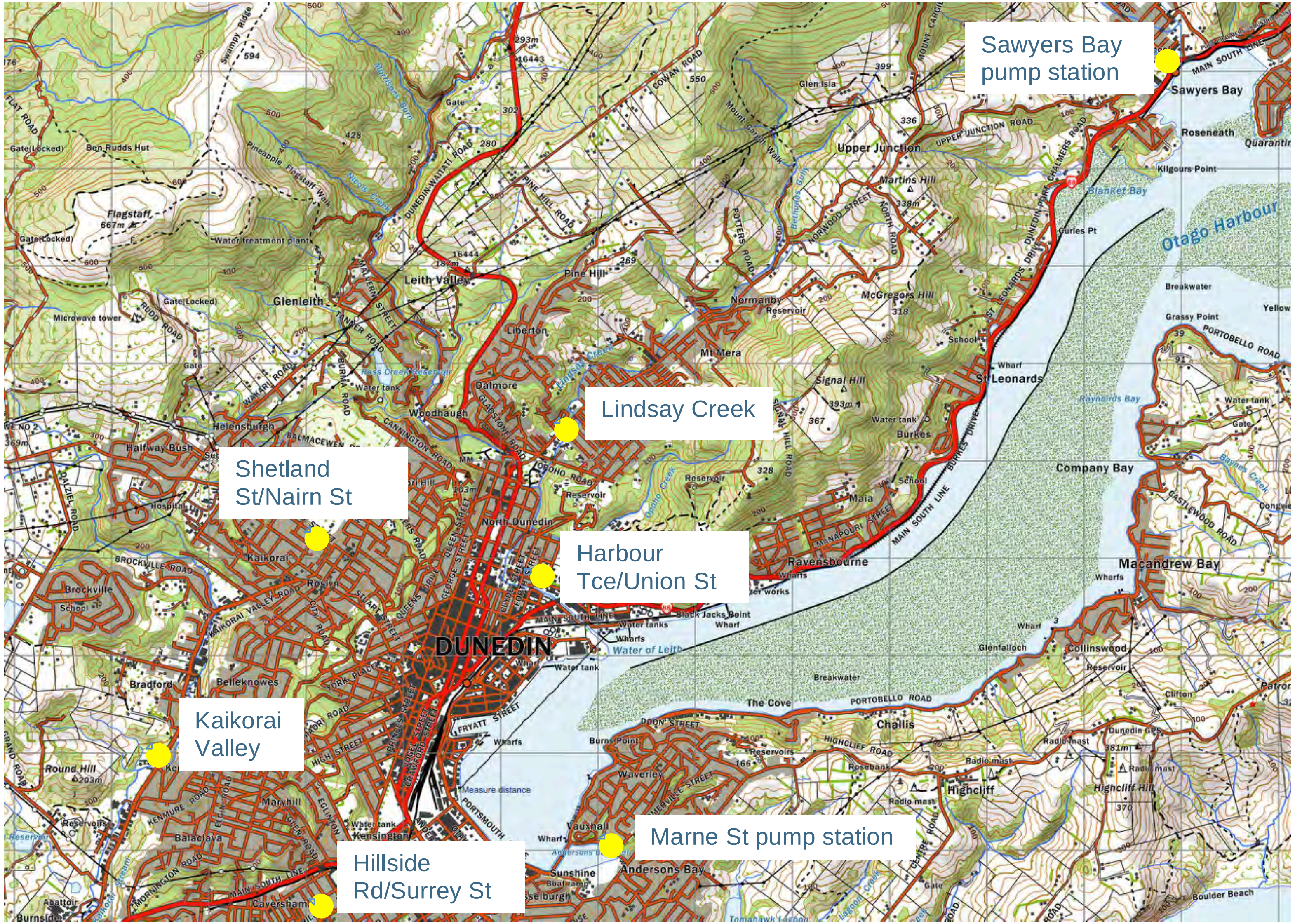

Figure 1. Map of Dunedin City showing the locations of wastewater overflows. Figures on the following pages show further detail of sewage overflow sites including nearby water-bodies and sites that may be exposed to contamination.

2.1 Kaikorai Stream Catchment

2.1.1 Kaikorai Valley overflow

The Kaikorai Valley overflow is located on Kaikorai Valley Road in the vicinity of Kaikorai Valley College (Figures 1 and 2). The piping is valved and, when operated, conveys wastewater directly into Kaikorai Stream (Figure 3). Monitoring of the discharge has indicated that it is the most severe of the seven DCC wastewater overflow sites assessed in this report. Both overflow frequency and discharge volumes are high at this site following high rainfall (Figure 1, Appendix 1) that dramatically increases inflow and infiltration (I&I).

This overflow alleviates sewage flooding of private land and buildings downstream in both the Kaikorai area and South Dunedin.

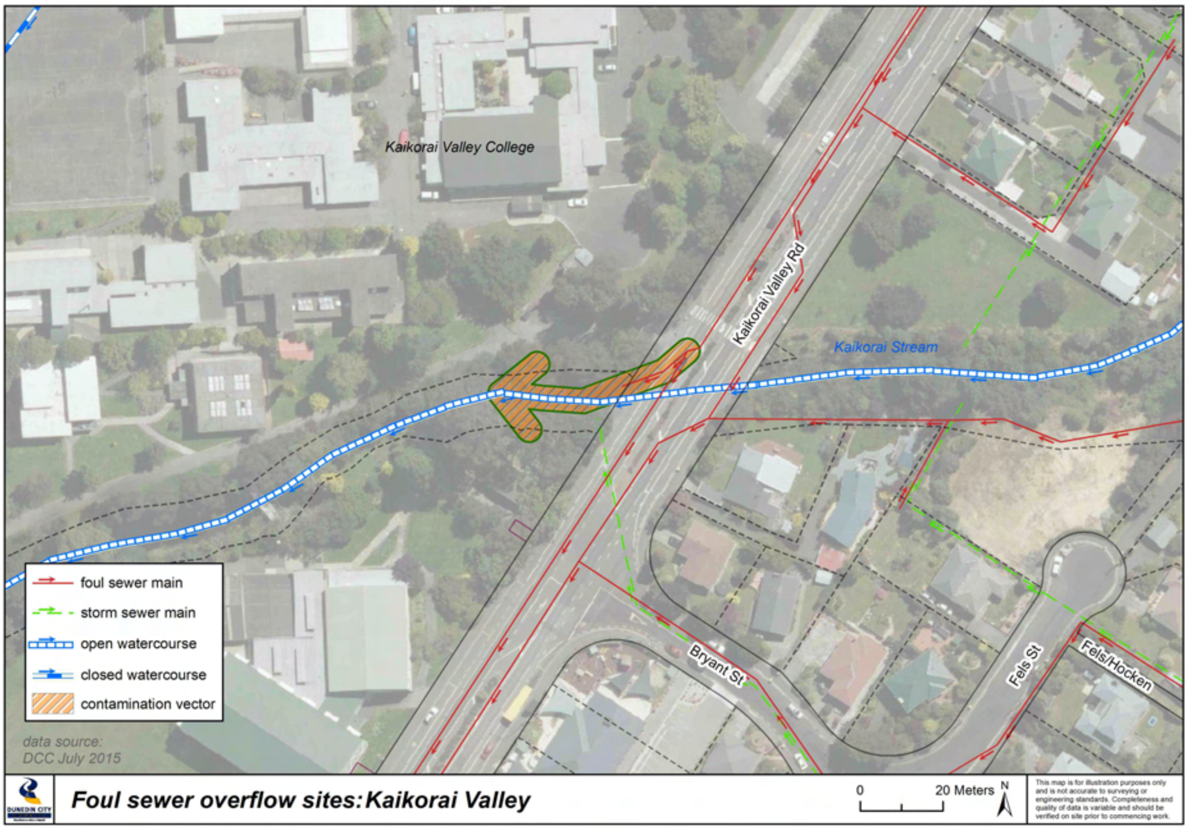

Figure 2. **Aerial photograph detailing Kaikorai Valley wastewater network pipes (red lines) and the location of the Kaikorai Valley wastewater overflow (orange arrow) which discharges to Kaikorai Stream (blue and white line) at Kaikorai Valley Road.**

Figure 3. Kaikorai Stream downstream of the Kaikorai Valley wastewater overflow. The overflow pipe is located underneath the Kaikorai Valley Road bridge on the true right of the stream.

2.1.2 Shetland Street / Nairn Street overflow

The Shetland Street / Nairn Street overflow is located in a residential block further upstream in the Kaikorai Stream catchment (Figures 1 and 4). It is regarded as a high level overflow that directly enters an unnamed tributary of Kaikorai Stream via a pipe (Figure 5). The tributary connects to a small duck pond adjacent to the tributary immediately downstream of the overflow pipe. Like the Kaikorai Valley overflow, it has a high overflow frequency and volume (Figure 1, Appendix 1) caused by a low in-line pipe capacity.

This overflow alleviates sewage flooding of private land and buildings downstream in both the Kaikorai area and South Dunedin.

Figure 4. **Aerial photograph detailing Kaikorai Valley wastewater network pipes (red lines) and the location of the Shetland Street / Nairn Street wastewater overflow (orange arrow) which discharges to a tributary of Kaikorai Stream (blue and white line).**

Figure 5. **Shetland Street / Nairn Street wastewater overflow and a small tributary of Kaikorai Stream.**

2.2 Lindsay Creek / Water of Leith Catchment

2.2.1 Lindsay Creek overflow

The Lindsay Creek overflow is located within North East Valley near Knox Street (Figures 1 and 6). The pipe has a relatively low in-line design capacity causing high volume overflows at a high frequency (Figure 2, Appendix 1) directly into Lindsay Creek. The Lindsay Creek overflow poses a potential risk to the water quality of Lindsay Creek (Figure 7) and the Water of Leith to which Lindsay Creek drains.

This overflow alleviates sewage flooding of private land and buildings downstream in Dunedin North.

Figure 6. Aerial photograph detailing North East Valley wastewater network pipes (red lines) and the location of the Lindsay Creek wastewater overflow (orange arrow) which discharges to Lindsay Creek (curved blue and white line).

Figure 7. Lindsay Creek 400 m downstream of the Lindsay Creek wastewater overflow located near Knox Street.

2.2.2 Harbour Terrace / Union Street East overflow

The Harbour Terrace/Union Street East overflow (Figure 8) also presents contamination issues for the lower Water of Leith and subsequently Otago Harbour. The overflow occurs at the corner of Harbour Terrace and Union Street, where it enters the stormwater network. The stormwater network enters the lower Leith (but within the coastal marine area) via an outfall (Butts Creek) located near Magnet Street (Figures 8 and 9). Overflow frequencies and volumes are moderate and typically occur during periods of high rainfall (Figure 2, Appendix 1).

This overflow alleviates sewage flooding of private land and buildings downstream in the University Campus area.

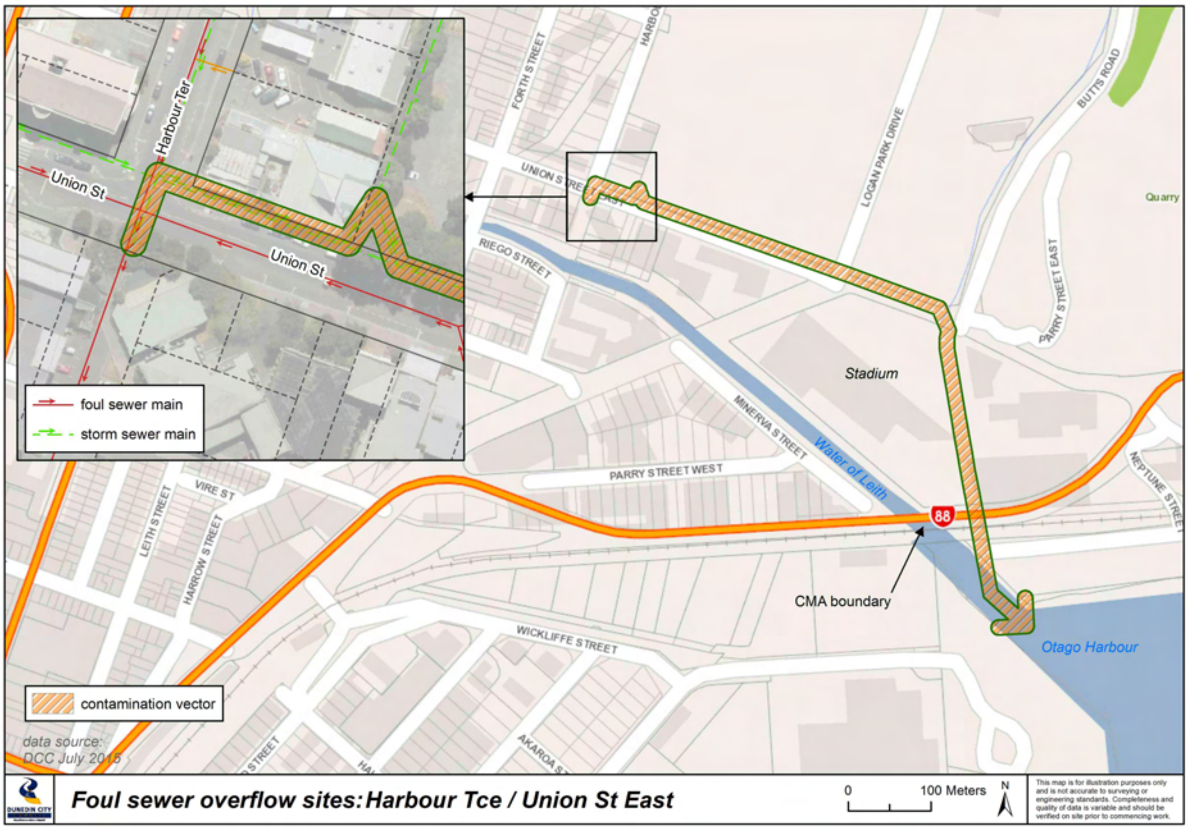

Figure 8. **Aerial photograph detailing North East Valley wastewater network pipes (red lines) and the location of the Harbour Terrace / Union Street East wastewater overflow (orange arrow) which discharges to stormwater pipes (green).**

Figure 9. **Photo of lower Water of Leith showing the conduit that discharges Butts Creek and stormwater that may carry wastewater from the Harbour Terrace / Union Street East overflow site.**

2.3 Otago Harbour Basin Catchment

2.3.1 Hillside Road / Surrey Street overflow

A wastewater overflow is located within the South Dunedin wastewater network on Hillside Road near its intersection with Surrey Street (Figures 1 and 10).

This overflow alleviates sewage flooding of private land and buildings downstream in South Dunedin.

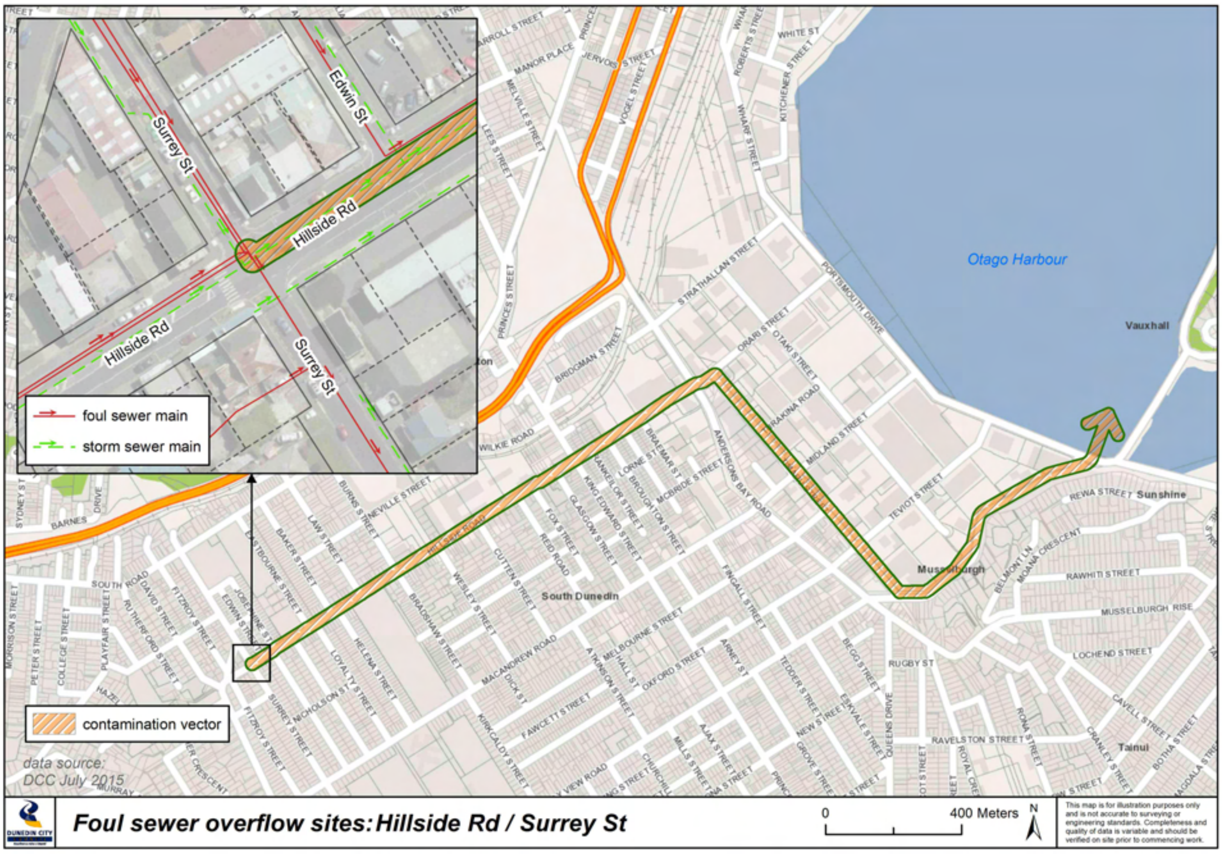

Figure 10. Map detailing South Dunedin wastewater network pipes (red lines) and the location of the Hillside Road / Surrey Street wastewater overflow (orange arrow) which discharges to stormwater pipes (green).

The wastewater overflows into the stormwater network, travelling down Hillside Road, along Timaru Street and into Portobello Road before passing through the Portobello Road pumping station and discharging to the upper Otago Harbour through the associated stormwater outfall (Figure 11). Its overflow frequency is regarded as moderate but it often discharges high volumes (Figure 3, Appendix 1). The discharge into the stormwater network is situated downstream of the Kaikorai Valley catchment and is significantly affected by the Kaikorai Valley flows.

Samples collected at this site are obtained via manholes immediately upstream and downstream of the overflow point.

Figure 11. Portobello Road stormwater outfall (centre of photo) that conveys overflow wastewater from the Hillside Road / Surrey Street site.

2.3.2 Marne Street Pumping Station overflow

Since recent capital works in Andersons Bay, overflows from the Marne Street Pumping Station (Figures 1 and 12) are not expected to occur except in extreme rain events (Figure 3, Appendix 1). Wastewater is pumped to the stormwater network to relieve the wastewater network in the event of emergency high flows.

This overflow alleviates sewage flooding of private land and buildings downstream in Andersons Bay.

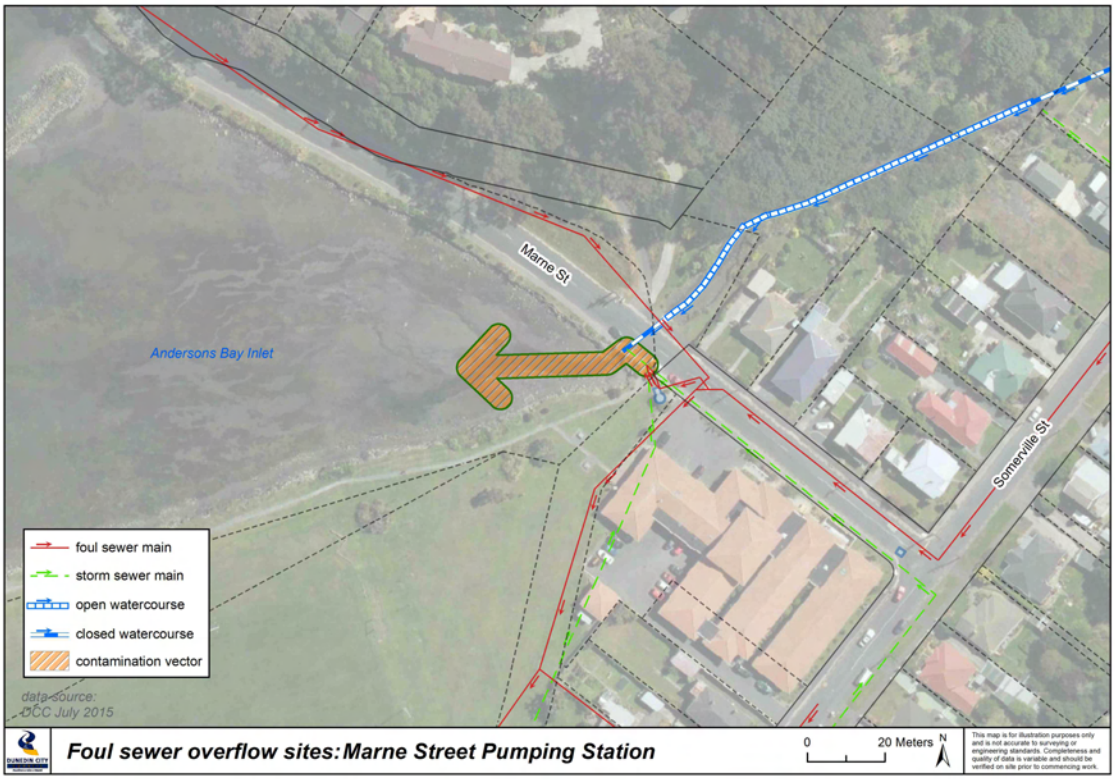

Figure 12. **Aerial photograph detailing the location of the Marne Street wastewater overflow which discharges to stormwater pipes (green) and eventually Andersons Bay inlet.**

The discharge is into the top end of Anderson's Bay Inlet (Figure 13) via a large opening under the road bridge (Figure 14).

Figure 13. **Upper north-east corner of Andersons Bay inlet at the Marne Street road bridge.**

Figure 14. Overflow Marne Street road bridge showing pumping station discharge outlet on right.

2.3.3 Sawyers Bay Pumping Station overflow

Sawyers Bay Pumping Station overflows from the pumping station wet-well through a pipe into the harbour at Sawyers Bay (Figures 1, 15 and 16).

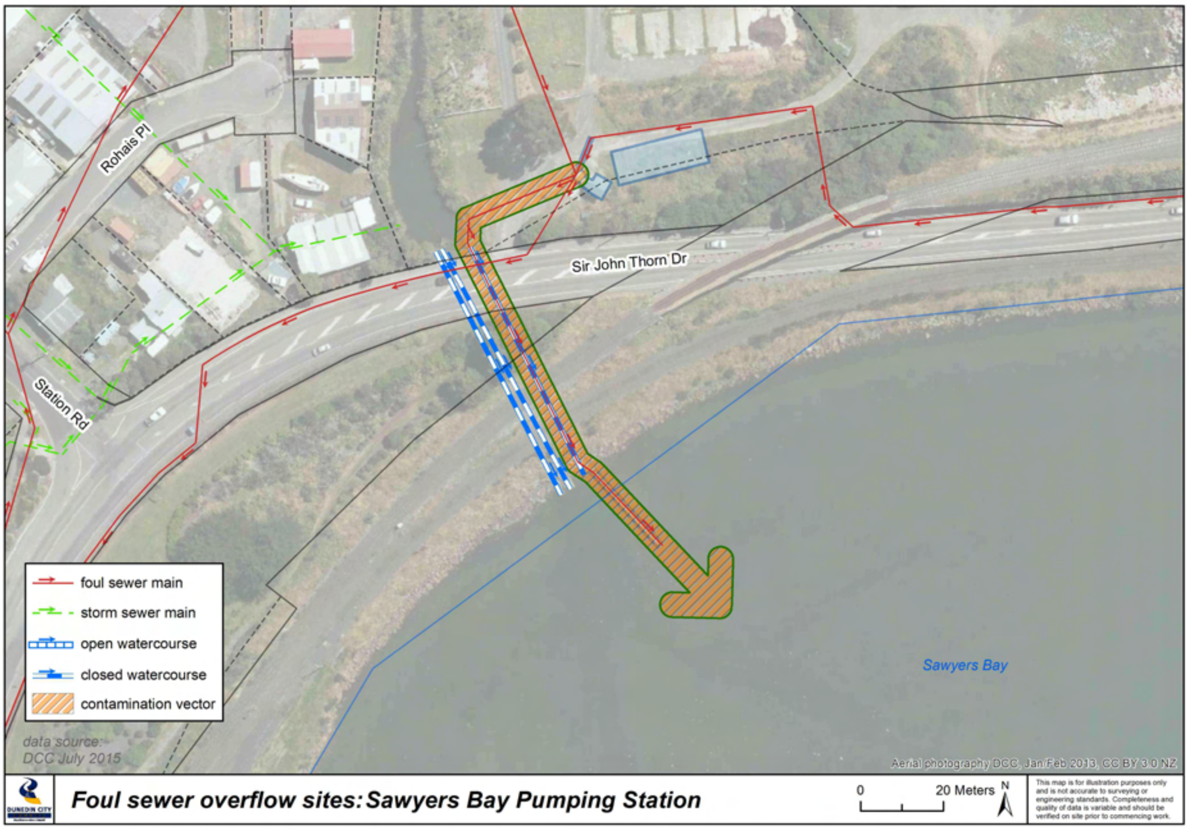

Figure 15. Aerial photograph the location of the Sawyers Bay Pumping Station wastewater overflow (orange arrow) which discharges to stormwater pipes (blue).

This overflow alleviates sewage flooding of private land and buildings downstream in

Sawyers Bay and at Burkes.

Overflow volumes are generally moderate (Figure 3, Appendix 1). This pumping station does have additional storage. However, pumping begins if the downstream Burkes Pumping Station suffers a malfunction. It is also affected by I&I within the system.

Figure 16. The extended pipe that conveys overflow wastewater and stormwater into Sawyers Bay.

3. Receiving Environment Character

The receiving environments associated with the seven overflow sites were assessed for water quality and ecological values. Background information was obtained from a range of sources and publications including previous investigations undertaken by the DCC and Otago Regional Council (ORC) 'state of the environment' monitoring. Existing information was supplemented by recent site-specific sampling of water quality and benthic biota (bottom dwelling organisms) within the stormwater line or near overflow discharge points, as described in the following sections, and assessed using a range of water quality and ecological guidelines and indicators.

3.1 Assessment Methodologies

3.1.1 Historic data

Both the DCC and the ORC have periodically undertaken monitoring and investigations to assess water quality and ecology of the local aquatic environment. The ORC has a state of the environment monitoring programme that includes long term monitoring sites on Kaikorai Stream and the Water of Leith. The DCC has an active monitoring programme within the harbour associated with consents to discharge stormwater to the coastal marine area. Information associated with these monitoring programmes has been reviewed, summarised and considered in light of this current assessment of wastewater overflows. The Regional Plan: Water (Water Plan) also lists natural and human use values of freshwater bodies, known at the time of publication (Schedule 1), and regionally significant wetlands (Schedule 9).

3.1.2 Site-specific water quality surveys

The site-specific water quality sampling programme aimed to gather information on ambient (or background) water quality conditions and water quality during a wastewater overflow event. For ambient monitoring, each site was visited during the first hour of a suitable rainfall event. Such events had to be preceded by at least 72 hours of dry weather and of sufficient intensity to result in measurable runoff within the catchment, but not of sufficient intensity to trigger an overflow event (i.e. 0.5mm – 2.5mm rain in one hour). The first hour was targeted to ensure the sample contained "first flush" stormwater.

Where possible, grab samples were collected at each site immediately upstream of the overflow point and downstream of the overflow point. In the case of the Hillside Road overflow, samples were collected from manholes upstream and downstream of the wastewater discharge point into the stormwater pipe to the Portobello Road outfall. For the Marne Street overflow to Andersons Bay Inlet, samples were collected from Somerville

Stream immediately upstream of the Marne Street road bridge and immediately downstream of the bridge as the stream enters the inlet. For the Sawyers Bay overflow, upstream samples were collected from the stream that flows through the Sawyers Bay suburb (and discharges to Sawyers Bay via a concrete pipe adjacent to the stormwater outfall pipe), and the ‘downstream’ sample was collected from the sump that receives stormwater and wastewater overflow.

Samples were analysed on-site for general water quality indicators using field instruments (YSI Professional Plus multi-probe and a hand held fluorimeter). Subsamples were then sent to a testing laboratory for analysis of a range of other water quality parameters.

Overflow events were sampled in the same manner as described above. As such, a comparison between water quality upstream and downstream of an overflow outlet during a “normal” rain event could be made with water quality upstream and downstream of an outlet during an overflow event.

Over a nine-month period all sites were sampled for ambient water quality however, dry and generally stable weather for this duration of this project meant that relatively few overflow events were able to be sampled. Overflows that did occur included a likely event that was targeted in October 2014 (7.4 mm rainfall) and definite events targeted in February 2015 and the major flood event of 3-4 June 2015. However, the Harbour Terrace/Union Street outfall has not yet been adequately sampled. The sampling of this outfall will take place at the next practicable overflow event and results will be forwarded to the DCC.

3.1.3 Benthic community surveys

For overflows that discharged to freshwater environments, surveys of benthic macroinvertebrates were undertaken in October 2014.

Macroinvertebrate communities are used as an indicator of stream ecosystem health and general water quality. Semi-quantitative samples were collected upstream and downstream of wastewater overflow pipes in Kaikorai Stream and its tributary using techniques from the Ministry for the Environment’s “Protocols for sampling macroinvertebrates in wadeable streams” (Stark *et al.* 2001). Samples were also collected downstream of the Lindsay Creek wastewater overflow but not upstream, as historical baseline data, collected since 2006, was already available at this site.

3.1.4 Water quality contaminants, guidelines and ecological indicators

Field testing of receiving water was undertaken for conductivity, dissolved oxygen (DO), pH and 'fluorescent whitening agents' (FWAs). FWAs are found in laundry detergents and so are a useful indicator of possible sewage infiltration in stormwater systems and receiving waters (Petch 1996, Gilpin *et al.* 2004). The following levels of FWAs can be used as a guide to likely sewage contamination:

< 0.08	unlikely sewage contamination;
> 0.08 but < 0.1	sewage contamination possible;
> 0.1	sewage contamination likely.

Dissolved oxygen is essential for aquatic biota and, although ANZECC and ARMCANZ (2000) guideline levels for freshwater ecosystems are quite high (see Table 2 below), levels in excess of 80% saturation are typically regarded as being indicative of well oxygenated water. Trout are regarded as the fish species most sensitive to a reduction in dissolved oxygen saturation, with a minimum standard of 80% recommended for lowland river environments (Third Schedule of the Resource Management Act 1991, Dean and Richardson 1999).

Laboratory testing of samples was undertaken to determine biological oxygen demand (BOD), suspended solids, turbidity and the faecal bacteria *Escherichia coli* (*E. coli*). Organic material associated with sewage and other wastewaters typically exert an oxygen demand on the water due to the action of bacteria breaking down the organic material and consuming dissolved oxygen from the water as they do so. This effect is assessed by measuring the BOD concentration of a sample. Raw sewage can have a BOD level of between 200-400 mg/L while background levels in aquatic environments are less than 1-2 mg/L.

Wastewaters are also high in suspended solids, which increases turbidity and decreases water clarity. Suspended solids levels are measured as a concentration (e.g., g/m^3 which is equivalent to mg/L or parts per million) while turbidity is usually measured in nephelometric turbidity units or NTUs. Water with good clarity usually has an NTU level of 1-2 NTUs and a suspended solids concentration of <1 g/m^3.

The sensitivity of aquatic biota to suspended solids varies with species and the receiving environment, and the effects of suspended sediment on New Zealand fish species are highly variable. For example, banded kokopu (a whitebait species commonly found in Dunedin coastal streams) displayed a 50% avoidance response at turbidity levels of 17-25 NTU, while koaro and inanga (other whitebait species) were found to be less sensitive, with a 50% avoidance response at 70 and 420 NTU respectively (Boubée *et al.* 1997). Shortfin and longfin elvers and redfin bullies showed no avoidance behaviour, even at the highest turbidities tested (1100 NTU) (Boubée *et al.* 1997). Rowe *et al.* (2004) determined the maximum turbidity levels that could be tolerated by four native fish species over a 24-hour period. Juvenile banded kokopu and adult redfin bullies were able to tolerate turbidity levels of up to 38,000 NTU with low mortality. In contrast, smelt and inanga were much more sensitive to high turbidity levels. Fifty per cent mortality rates ranged from 1,700 to 3,000 NTU for smelt, and 17,500 to 21,000 NTU for inanga (Rowe *et al.* 2004).

Excessive levels of nutrients can cause problems associated with eutrophication. These are typically associated with nuisance growths of freshwater algae and plants, and seaweed in the marine environment. Bioavailable forms of nitrogen (e.g., ammonia and nitrate) and phosphorus (e.g., dissolved reactive phosphorus) are typically of greatest concern although forms that settle on the sea bed and the bed of lakes and rivers can ultimately become available for uptake by algae and plants. Sewage is typically quite high in ammonia. While acting as a nutrient for algae and plant growth at low concentrations, ammonia at elevated concentrations can be toxic to aquatic biota. Nutrient guidelines to avoid nuisance growths and toxicity effects are listed in (Table 2).

Table 2. Water quality standards for lowland New Zealand streams such as Kaikorai Stream, its tributary and Lindsay Creek.

Parameter	Guideline level
pH	6.5 – 9.0
Dissolved oxygen saturation (%)	98 - 105
Dissolved reactive phosphorus (g/m^3)	< 0.026[a]
Ammoniacal nitrogen (g/m^3)	< 0.021, < 0.9*
Nitrite/nitrate nitrogen (g/m^3)	< 0.295[a], < 3.8**
Escherichia coli (CFU/100 mL)*	< 260[b]
Suspended solids (g/m^3)	< 7.2[c]
Total phosphorus (g/m^3)	< 0.033[d]
Total nitrogen (g/m^3)	< 0.614[d]

*Guidelines sourced from [a] Biggs (2000), [b] Ministry for the Environment (MfE) (2003), [c] ANZECC and ARMCANZ (2000) and [d] Young and Hayes (1999). * concentration limit to avoid toxicity effects. ** concentration limit to avoid toxicity effects in freshwater, Chronic – highly disturbed systems (90% protection).*

The ORC's Regional Plan: Water for Otago, contains a schedule of characteristics and numerical standards for good quality water in Otago lakes and rivers (Schedule 15). Schedule 15 includes numerical water quality standards for Kaikorai Stream and the Water of Leith relating to nitrate-nitrite nitrogen, dissolved reactive phosphorus, ammoniacal nitrogen (all three are bioavailable nutrients that promote algae and plant growth) *E. coli*, and turbidity as follows:

Discharge quality parameter	Standard value	Date to be met	
		Kaikorai Stream	Water of Leith
Nitrate-nitrite nitrogen	0.444 mg/L	31 March 2012	31 March 2025
Dissolved reactive phosphorus	0.026 mg/L	31 March 2012	31 March 2025
Ammoniacal nitrogen	0.1 mg/L	31 March 2012	31 March 2012
Escherichia coli	260 CFU/100 mL	31 March 2025	31 March 2025
Turbidity	5 NTU	31 March 2012	31 March 2012

However, the ORC Schedule 15 standards are 5-year 80th percentile values applicable when water flow is at or below median.

Freshwater benthic invertebrate community indices were examined to assess general ecosystem health and habitat quality. Key indices used were:

EPT Three key insect groups that are generally dominated by taxa that are indicative of higher quality conditions. In stony bed rivers, these indexes usually increase with improved water quality and increased habitat diversity;

MCI The MCI uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream;

SQMCI The SQMCI uses the same approach as the MCI but weights each taxa score based on how abundant the taxa is within the community.

MCI and SQMCI scores can be interpreted in comparison with national standards as follows:

Quality Class A*	Quality Class B**	MCI score	SQMCI score
Clean water	Excellent	≥ 120	≥ 6.00
Doubtful quality	Good	100 – 119	5.00 – 5.99
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00

** Boothroyd & Stark (2000), ** Stark & Maxted (2007).*

3.2 Kaikorai Catchment

3.2.1 Natural character

(i) General

Kaikorai Stream is approximately 14.5 km long and sits within a catchment of 55.4 km^2 (ORC 2008). It drains the south eastern and eastern slopes of Flagstaff, Kaikorai Hill and the Balmacewen area, then flows through residential and industrial land along Kaikorai

Valley and Green Island before discharging into the Kaikorai Lagoon. Kaikorai Lagoon is a large brackish water body with an extensive saltmarsh located south west of Dunedin City between Black Head and Brighton.

Kaikorai Stream is not noted for containing any significant natural values under Schedule 1A of the Water Plan (ORC 2014). Kaikorai Lagoon, however, is recognised under Schedule 9 of the Water Plan for its estuarine area downstream of the wetland that provides significant habitat for waterfowl. Cultural values for Kaikorai Stream in Schedule 1D include those related to food gathering and processing, and nursery and breeding areas for birds and fish. The Mt. Grand Water Treatment Plant is the major source of water to Kaikorai Stream (discharging unrequired raw water into the upper reaches of Fraser Stream at Brockville), but numerous stormwater outfalls throughout the urban parts of the catchment also contribute to the flow particularly during and immediately following rain events.

(ii) Kaikorai Stream (Kaikorai Road overflow site)

Large areas of the stream channel near the Kaikorai Valley overflow are deep and channelized. Further downstream the channel consists of fast flowing riffles and runs with beds of large cobbles and gravels (Figure 3). It is well shaded in parts by large exotic trees. In general, Kaikorai Stream is heavily modified.

(iii) Kaikorai Stream Trib. (Shetland Street / Nairn Street)

The Kaikorai Stream tributary, to which the Shetland Street/Nairn Street overflow drains, flows through residential property and joins Kaikorai Stream near the intersection of Kaikorai Valley and Brockville Roads. The water quality and ecological health within this tributary therefore influences Kaikorai Stream directly. The tributary is very small and mainly consists of shallow runs and scattered riffles with a bed of fine gravels (Figure 6). At the point of discharge the channel is shaded by native vegetation that has been restored by community projects, and larger exotic tree species.

3.2.3 Water quality

(i) General

Water quality within the Kaikorai Stream catchment has been sampled regularly by the ORC at four sites of interest. These include three sites on the main stem (Table 3). The sites at Donald Street and Townsleys Road are located approximately 950 m and 1,450 m downstream of the Kaikorai Valley overflow respectively, while the monitoring site at the Fraser Stream confluence is approximately 2.5 km upstream (Figure 17). Note that sampling takes place under settled flow conditions. i.e. not after a rainfall or flood event.

Figure 17. Location of ORC monitoring sites (blue dots) in relation to overflow sites (red dots).

Median values for conductivity are generally high and are typical of urban waterways that are heavily affected by contaminants from urban stormwater runoff and other sources. Dissolved oxygen is typically high with median values greater than 90% at all sites, and pH levels are consistently between 6.5–9.0 which is considered appropriate for freshwater environments in New Zealand (ANZECC 1992, Table 2). Dissolved reactive phosphorus, and ammoniacal nitrogen levels in Kaikorai Stream are typically within water quality guidelines and suspended solids levels are also typically low (Table 3). Faecal bacterial (*E.*

coli) regularly exceed the Ministry for the Environment (MfE 2003) guideline for an acceptable level (260 CFU/100 mL) at all sites. Levels are particularly high near the confluence with Fraser Stream. Turbidity, nitrite-nitrate nitrogen, total nitrogen and total phosphorus levels are also particularly high near the Fraser Stream confluence but are variable in relation to freshwater guidelines at Townleys Road and Donald Street.

Comparing rainfall for five days prior to the date of water sampling occasions with levels of faecal contaminants in the stream reveals that high *E. coli* and faecal coliform (both faecal indicator bacteria) levels are generally found at both sites following low rainfall events (i.e. under low river flows) (see Figure 18 for the Townsleys Road site). Faecal indicator bacteria levels tended to be lower following high rainfall events (i.e. high river flows), likely due to increased dilution due to higher water volumes in the stream. These results indicate that the water quality of Kaikorai Stream is generally poor, and the poor quality is more pronounced under lower river flow conditions.

The high levels of faecal contaminants in Kaikorai Stream often exceed guideline levels for recreational activities. The Ministry for the Environment Action/Red Mode level for *E. coli* is a single sample greater than 550 *E. coli* per 100 mL (Ministry for the Environment 2003). For faecal coliforms, ANZECC and ARMCANZ (2000) state that for primary contact (e.g. swimming) over the bathing season there should not be more than 150 faecal coliform organisms per 100 mL. For secondary contact (e.g. boating, fishing) there should not be more than 1000 faecal coliform organisms per 100 mL. These guidelines are regularly exceeded in Kaikorai Stream in all conditions, indicating that recreational activities are likely limited by poor water quality.

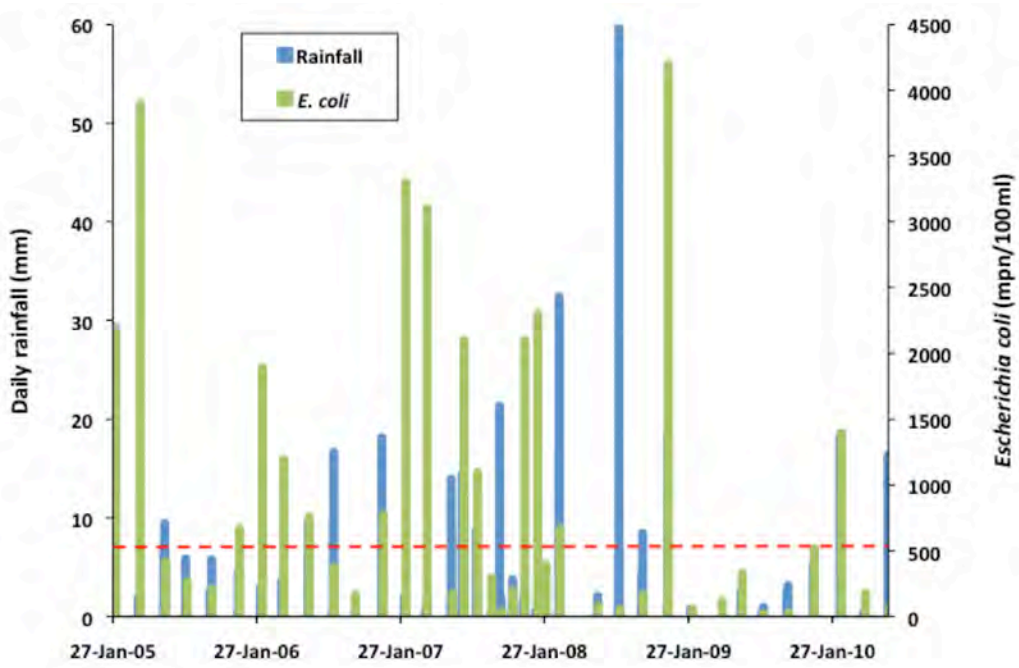

Figure 18. ***Escherichia coli*** **levels (green bars) and rainfall for five days prior to water sampling (blue bars) between January 2005 and June 2010 for Kaikorai Stream at Townleys Road. Water quality data from ORC, rainfall data from NIWA CliFlo (National Climate Database). Red dashed line indicates Ministry for the Environment action/red mode level, above which there could be a health-risk for swimming.**

An ORC water quality monitoring site is located on the tributary of Kaikorai Stream at Arai Te Uru Marae. This site is approximately 200 m upstream of the Shetland Street / Nairn Street overflow (Figure 17).

The tributary of Kaikorai Stream is characteristic of a small, heavily modified urban stream with almost all median water quality variables measuring above water quality standards for lowland New Zealand streams (Table 4). The notable exceptions are dissolved reactive phosphorus, pH and suspended solid levels that can be regarded as acceptable and within current guideline levels (Table 4).

Table 3. Kaikorai Stream water quality monitoring data for three sites monitored by the Otago Regional Council from February 2005 to August 2009 (Townleys Road) and March 2008 (for Fraser Stream confluence and Donald Street). Number of sampling occasions for each site ranged between 7 – 10 (Fraser Stream confluence and Donald Street) and 8 – 15 (Townleys Road). Data obtained from Otago Regional Council.

Water Quality Parameter	Fraser St. confluence (upstream)		Donald Street (950m downstream of wastewater overflow)		Townleys Road (1,450m downstream of wastewater overflow)	
	Range	Median value	Range	Median value	Range	Median value
Conductivity (µS/cm)	171 – 313	239	57 – 181	109	60 – 190	72
pH	7 – 7.4	7.2	7.4 – 8.0	7.6	6.9 – 7.5	7.3
Dissolved oxygen (% saturation)	25 – 100	91	89 – 106	98	82 – 112	97
Escherichia coli (MPN/100 mL)	240 – 4300	1200	100 – 4200	280	10 – 2600	300
Faecal coliforms (CFU/100mL)	240 – 4900	1650	160 – 5400	280	130 – 4400	360
Ammoniacal nitrogen (g/m^3)	0.010 – 0.210	0.070	0.005 – 0.050	0.005	0.005 – 0.050	0.010
Nitrite/nitrate nitrogen (g/m^3)	1.67 – 2.86	2.31	0.25 – 1.98	0.68	0.04 – 1.21	0.25
Total nitrogen (g/m^3)	2.01 – 3.71	2.81	0.41 – 2	0.95	0.19 – 1.21	0.49
Dissolved reactive phosphorus (g/m^3)	0.014 – 0.081	0.025	0.007 – 0.029	0.015	0.007 – 0.019	0.011
Total phosphorus (g/m^3)	0.056 – 0.413	0.109	0.015 – 0.099	0.034	0.019 – 0.123	0.027
Suspended solids (g/m^3)	1.5 – 110	6	1.5 – 24	2	1.5 – 110	4
Turbidity (NTU)	4.0 34	9.8	1.9 – 23.2	3.5	1.79 – 35	3.31

Table 4. Kaikorai Stream tributary water quality assessed at Arai Te Uru Marae, Shetland Street, between July 2007 and March 2008. Site is situated approximately 200 upstream of the Shetland Street / Nairn Street overflow. Data from Otago Regional Council.

Water Quality Parameter	Shetland Street (Arai Te Uru Marae)	
	Range	Median value
Conductivity (µS/cm)	101 – 214	188
pH	9.1 – 6.9	6.8
Dissolved oxygen (% saturation)	35 – 79	66
Escherichia coli (MPN/100 mL)	42 – 70,000	900
Faecal coliforms (CFU/100mL)	50 – 70,000	1,200
Ammoniacal nitrogen (g/m^3)	0.06 – 11.2	0.11
Nitrite/nitrate nitrogen (g/m^3)	0.8 – 2.01	1.59
Total nitrogen (g/m^3)	1.52 – 16.1	2.26
Dissolved reactive phosphorus (g/m^3)	0.003 – 0.950	0.011
Total phosphorus (g/m^3)	0.04 – 1.45	0.098
Suspended solids (g/m^3)	3 – 9	5
Turbidity (NTU)	7.24 – 11.4	9.86

(ii) Site-specific water quality monitoring at wastewater overflow sites

Monitoring during recent targeted rain events found that *E. coli* levels were generally high to very high at monitoring sites upstream and downstream of the Kaikorai catchment wastewater overflow points (Tables 5 and 6). This is not unexpected given that high microbiological loads in runoff are often encountered during rain events during routine stormwater monitoring. The highest levels by far were recorded during the recent extreme rainfall event in June 2015. FWAs showed no strong variation in the stream monitoring sites relative to the overflow discharge points, except for Kaikorai Stream tributary, where FWA readings indicated sewage contamination was possible downstream of the Shetland St. / Nairn St. overflow point and more widespread during the June 2015 flood. While suspended solids were higher at the Kaikorai Stream downstream site during rain events apart from the June 2015 event, other water quality parameters generally remained similar.

Table 5. Site-specific water quality monitoring of Kaikorai Stream in relation to recent ambient and overflow events and the Kaikorai Road overflow.

Water Quality Parameter	Ambient rain event (no overflow) (4.0 mm rain) 2/7/14		Possible overflow rain event (7.4 mm rain) 11/8/14		Overflow rain event (23.4 mm rain) 9/2/15		Overflow rain event (163 mm rain) 3/6/15	
	upstream	downstream	upstream	downstream	upstream	downstream	upstream	downstream
Dissolved oxygen (% sat.)	85.6	88.3	80.8	82.3	93.7	99.0	97.2	97.0
Conductivity (µS/cm)	50.8	56.9	37.2	37.6	470	470	50.9	51.8
pH	8.51	9.00	8.60	8.71	7.30	7.24	7.09	6.79
Turbidity (NTU)	11.5	14.7	174.0	196.0	50.0	46.0	220	220
FWAs	0.039	0.034	0.047	0.044	0.042	0.044	0.076	0.063
BOD_5 (g/m^3)	3	7	7	9	3	3	7	7
Suspended solids (g/m^3)	13	17	180	230	92	120	430	430
Escherichia coli (MPN/100 mL)	>2,400	130	1,400	1,400	>2,400	>2,400	12,000	9,900

Table 6. Site-specific water quality monitoring of the Kaikorai Stream tributary and the Shetland Street / Nairn Street overflow.

Water Quality Parameter	Ambient rain event (4.0 mm rain) 2/7/14		Possible overflow rain event (7.4 mm rain) 11/8/14		Overflow rain event (163 mm rain) 3/6/15	
	Kaikorai St. Trib. upstream	Kaikorai St. Trib. downstream	Kaikorai St. Trib. upstream	Kaikorai St. Trib. downstream	Kaikorai St. Trib. upstream	Kaikorai St. Trib. downstream
Dissolved oxygen (% saturation)	77.0	77.3	Not flowing		92.4	91.9
Conductivity (µS/cm)	63.4	67.3			45.3	47.9
pH	8.01	8.04			7.22	6.69
Turbidity (NTU)	93.7	101.0			32	32
FWAs	0.064	0.086			0.101	0.098
BOD_5 (g/m^3)	18	18			8	4
Suspended solids (g/m^3)	100	73			70	56
Escherichia coli (MPN/100 mL)	1,300	1,400			8,800	18,000

3.2.3 Stream ecology

(i) Benthic communities (algae and invertebrates) – historic data for Kaikorai Stream

Relatively few data exist for algal communities in the vicinity of the two Kaikorai Valley catchment wastewater overflow sites. Monitoring in 2006 and 2008 by ORC showed that an average six species were identified near Townleys Road, the majority of which were diatoms such as *Melosira spp.*, *Gomphoneis spp.* and *Cocconeis spp*. The filamentous green algae *Microspora spp.* and *Ulothrix spp.* were also present in 2006. More extensive ORC state of the environment monitoring data is available for lower Kaikorai Stream at Brighton Road. Monitoring in February 2014 shows that black/dark brown films (39%) and light brown mats (53%) typically dominate algae communities during summer. In comparison, annual ORC monitoring between 2006 and 2014 shows that algae communities were dominated by diatom species with the occasional presence of filamentous green algae, and rarely the presence of filamentous red algae and cyanobacteria. Common diatom taxa include *Melosira spp.*, *Frustulia spp.* and *Synedra spp.* These are common taxa and not unexpected in urban streams.

Macroinvertebrate monitoring has been undertaken at by the ORC at Townleys Road and more extensively at Brighton Road (Tables 7 and 8). Orthoclad midges, *Potamopyrgus* snails and oligochaete worms dominate the site at Townleys Road. However, low numbers of stoneflies and caddisflies are present on occasions. Dipterans are the most diverse insect order followed by molluscs. Again, this assemblage of taxa is typical of that found in modified urban streams.

MCI and SQMCI scores are consistently low across sampling years indicating low to moderate and even poor habitat quality (Table 7 and 8). Downstream at Brighton Road, invertebrate communities are characterised by similar insect groups, namely orthoclad midges, *Potamopyrgus* snails, oligochaete worms and at times, *Oxyethira* caddisflies. Low EPT diversity and abundance are common from year to year, while MCI and SQMCI scores are low indicating poor habitat quality.

There are no historical data available for invertebrate, algal or fish communities in the tributary of Kaikorai Stream to which the Shetland Street / Nairn Street wastewater overflow discharges.

Table 7. Results of invertebrate monitoring in Kaikorai Stream at Townleys Road between 2003 and 2008. Displayed is the number of taxa identified during each sampling occasion for each invertebrate order. Data from Otago Regional Council.

Stream invertebrate taxon	Kaikorai Stream at Townleys Road (1,450m downstream of wastewater overflow)			
	2003	2004	2006	2008
Acarina (mites)				1
Cnidaria (freshwater sponge)				1
Crustacea (small shrimp-like animals)	1		1	1
Diptera (truefly larvae)	4	3	4	6
Hirudinea (leaches)			1	
Mollusca (snails)	3	2	2	2
Nematoda (round worms)				1
Oligochaeta (worms)	1	1	1	1
Platyhelminthes (flatworms)		1	1	1
Plecoptera (stoneflies)	1			
Trichoptera (caddisflies)	2			2
Number of taxa	12	7	10	16
Number of EPT taxa	3	0	0	2
MCI score	83	49	58	65
SQMCI score	3.3	1.6	1.6	1.8

Table 8. Results of annual invertebrate monitoring in Kaikorai Stream at Brighton Road between 2003 and 2014. Displayed is the number of taxa identified during each sampling occasion for each invertebrate order. Data from Otago Regional Council.

Stream invertebrate taxon	Kaikorai Stream at Brighton Road										
	2003	2004	2006	2007	2008	2009	2010	2011	2012	2013	2014
Acarina (mites)							1				
Cnidaria (freshwater sponge)											1
Coleoptera (beetles)					1			2			
Crustacea (small shrimp-like animals)		1	2			1		3	2	1	2
Diptera (truefly larvae)	4	2	1	5	4	3	6	5	6	5	3
Mollusca (snails)	2	3	3	2	2	2	2	3		2	
Oligochaeta (worms)	1	1	1	1	1	1	1	1	1	1	1
Plecoptera (stoneflies)			1								
Trichoptera (caddisflies)			1		1	1	1	2	3	3	2
Number of taxa	7	7	9	8	9	8	11	15	12	12	9
Number of EPT taxa	0	0	2	0	1	1	1	2	3	3	2
MCI score	54	54	62	73	73	63	64	75	72	68	73
SQMCI score	1.5	1.5	2.6	1.7	1.7	1.4	2.4	1.9	2.1	2.2	1.7

(ii) Site-specific benthic invertebrate surveys at the wastewater overflow sites

Benthic sampling in October 2014 found that macroinvertebrate communities both upstream and immediately downstream of wastewater overflows in Kaikorai Stream and it's tributary were of poor health (Table 9). Taxonomic diversity was low consisting of only six to ten taxa at each site, which is considerably less than the median of 18 taxa per stream site found in a nation-wide survey (Scarsbrook *et al.* 2000). Oligochaete worms and *Potamopyrgus* snails dominated communities with crustaceans and dipteran fly larvae also common. The abundance of these 'low-scoring' taxa groups (i.e., taxa indicative of poor water quality and habitat) and that absence or very low abundance of 'high-scoring' EPT taxa resulted in very low MCI and SQMCI scores for each sampling site, indicative of poor habitat quality. These assessments were relevant for sites both upstream and downstream of overflow discharge points and are similar to historical ORC state of the environment data collected from the Kaikorai Stream at Townleys and Brighton Roads (Tables 7 and 8).

(iii) Fish communities

New Zealand Freshwater Fish Database records show that a total of fourteen different fish species have been caught within the Kaikorai Stream catchment (Figure 20, Table 10). Only one species is introduced (brown trout) while three are marine wanderers (cockabully, yelloweyed mullet and yellowbelly flounder). The remainder are native species including two species of galaxiid or whitebait (inanga and banded kokopu), eel (shortfin and longfin), three species of bully (common, upland and redfin) and lamprey. The majority of surveys have been conducted in Kaikorai Lagoon or the lower reaches of the catchment, including Abbotts Creek which is located far downstream from the nearest wastewater outflow. Of three surveys conducted by the ORC within 1.5 km downstream of the Kaikorai Valley wastewater outfall at Kaikorai Valley Road, only longfin eels and brown trout have been caught. A solitary ORC 2002 survey in the headwaters of the stream identified a brown trout at Fraser Stream Recreational Reserve. The overflow of Mt. Grand Water Treatment water (raw water sourced from the Deep Stream/Deep Creek catchments) to the upper Fraser Stream is known to transfer trout into the Kaikorai Stream catchment.

Department of Conservation 2013 threat classifications for New Zealand freshwater fish (Goodman *et al.* 2014) are shown in Table 10.

Table 9. Stream macroinvertebrate taxa collected in kick-net samples from upstream and downstream of DCC wastewater overflow pipes in October 2014. VVA = very very abundant, VA = very abundant, A = abundant, C = common, R = rare.

Stream invertebrate taxon	Kaikorai Stream @ Kaikorai Road		Kaikorai Stream Trib.		Lindsay Creek
	Upstream	Downstream	Upstream	Downstream	Downstream
Acarina				R	
Coleoptera					
Elmidae					R
Crustacea					
Isopoda			R	R	
Talitridae			R		
Diptera					
Austrosimulium species					A
Empididae					C
Maoridiamesa species	A	C			C
Muscidae			R		
Orthocladiinae	A	A	C	C	VA
Polypedilum species	R	R			
Psychodidae	R				
Tanypodinae	C	C			
Ephemeroptera					
Deleatidium species	R				
Hirudea	R				
Mollusca					
Physella species			R	R	
Potamopyrgus antipodarum	A	A	VA	A	VA
Sphaeriidae			R	C	
Oligochaeta	VA	VA	VVA	VA	VA
Platyhelminthes			C	R	
Trichoptera					
Hydrobiosis umbripennis group					R
Olinga species					R
Psilochorema species					A
Number of taxa	9	6	9	8	10
Number of EPT taxa	1	0	0	0	3
MCI score	67	60	64	65	88
SQMCI score	1.9	1.7	1.5	1.6	2.7

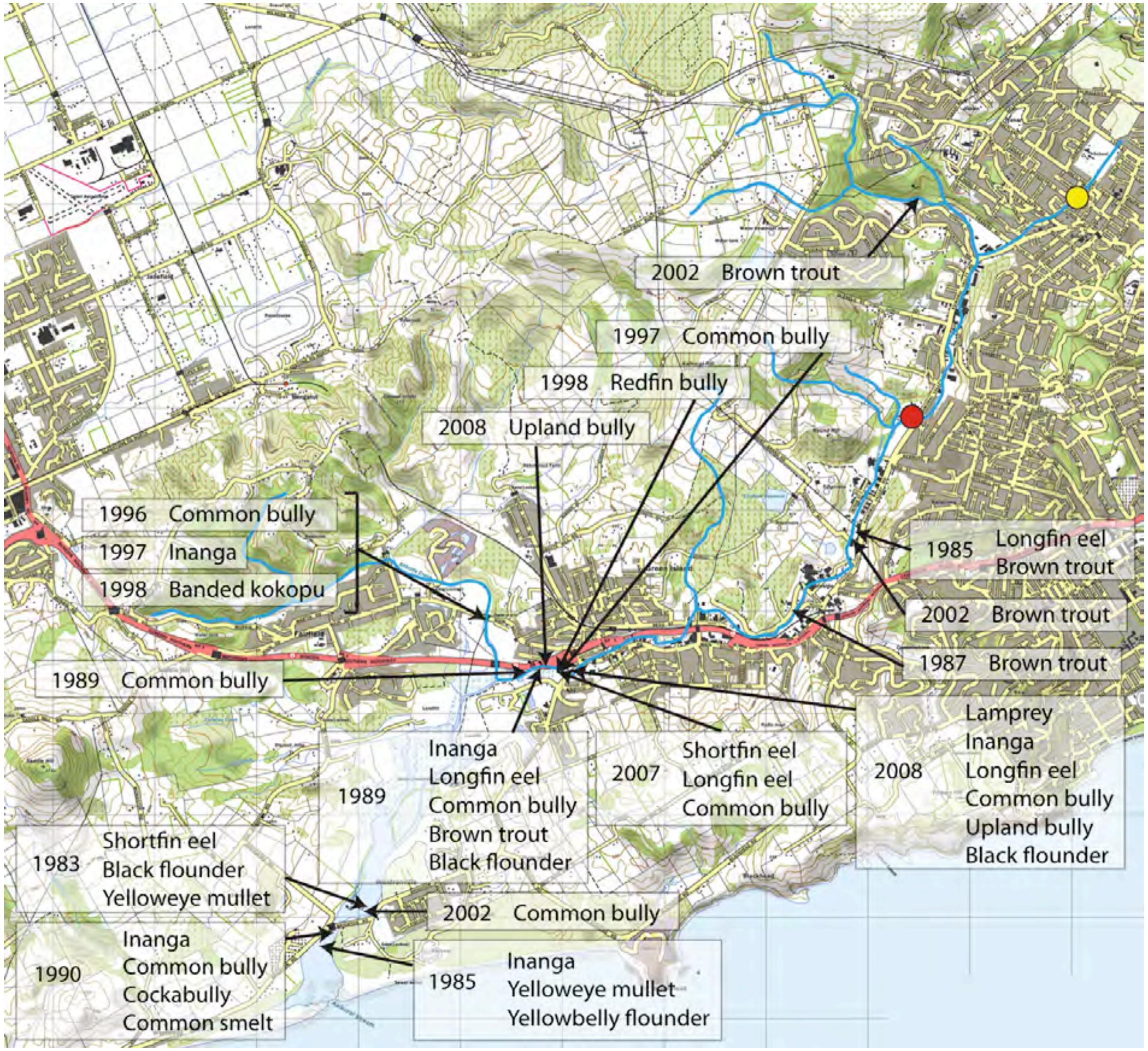

Figure 19. Known fish distribution in the Kaikorai Stream catchment (blue line) as obtained from the New Zealand Freshwater Fish Database (NIWA). The red (Kaikorai Valley) and yellow (Shetland Street / Nairn Street) circles indicate the points of discharge for DCC wastewater overflows.

Table 10. Conservation status of fish species caught in the Kaikorai Stream catchment (Goodman *et al.* 2014).

Common name	Species	Native	Migratory	Threat status	Criteria
Lamprey	*Geotria australis*	Y	Y	Nationally vulnerable	[1]C (3/1)
Longfin eel	*Anguilla dieffenbachii*	Y	Y	Declining	[2]C (2/1)
Shortfin eel	*Anguilla australis*	Y	Y	Not threatened	
Banded kokopu	*Galaxias fasciatus*	Y	Y	Not threatened	
Inanga	*Galaxias maculatus*	Y	Y	Declining	[3]C (1/1)
Redfin bully	*Gobiomorphus huttoni*	Y	Y	Declining	[3]C (1/1)
Common bully	*Gobiomorphus cotidianus*	Y	Y/N	Not threatened	
Upland bully	*Gobiomorphus breviceps*	Y	N	Not threatened	
Brown trout	*Salmo trutta*	N	Y/N	Introduced and naturalised	
Cockabully	*Forsterygion nigripenne*	N/A	N	Not threatened	
Common smelt	*Retropinna retropinna*	Y	Y	Not threatened	
Yelloweyed mullet	*Aldrichetta forsteri*	N/A	N	Not threatened	
Black flounder	*Rhombosolea retiaria*	Y	Y	Not threatened	
Yellowbelly flounder	*Rhombosolea leporine*	N/A	N	No threat classification	

[1]C (3/1) = total area of occupancy ≤ 100 ha (1 km^2), predicted decline 10–50%; [2]C (2/1) = total area of occupancy > 10,000 ha (100 km^2), predicted decline 10–70%; [3]C (1/1) = > 100,000 mature individuals, predicted decline 10–70%.

3.3 Lindsay Creek / Water of Leith Catchment

3.3.1 Natural character

Lindsay Creek (Figure 9) has a total catchment area of 115.2 km^2. Its headwaters on Mt. Cargill are steep and drain land covered by native bush, pasture, scrub and forestry. From here, it flows southwards through the Bethunes Gully Reserve before entering residential land along North East Valley. It eventually joins the Water of Leith immediately downstream of the Dunedin Botanic Gardens. The Water of Leith discharges into Otago Harbour after passing through a dense urban catchment. Within this section, its channel is a mixture of gravel and concrete-lined bed and banks. The lower reaches of both Lindsay Creek and the Water of Leith have undergone significant instream works in recent years to minimise the flooding risk to surrounding property.

Although Lindsay Creek possesses no significant natural values under Schedule 1A of the Water Plan, the Water of Leith is recognised to contain a variety habitats that can support diverse life cycle requirements of species, significant areas for trout and salmon spawning and development, riparian vegetation of significance to aquatic habitats, and an absence of aquatic pest plants. It also contains a significant presence of trout, salmon and indigenous fish species threatened with extinction, and habitat suitable for giant and banded kokopu (see section 3.3.3 below). Lindsay Creek is not recognised for containing cultural values in Schedule 1D, whereas the Water of Leith is identified as containing sacred places that hold spiritual values of importance to Kai Tahu and resources that are treasured by Kai Tahu.

3.3.2 Water quality

(i) General

The ORC have undertaken state of the environment water quality monitoring at Lindsay Creek at North Road, approximately 500 m upstream of the Lindsay Creek wastewater overflow site, for over ten years (Table 11).

This monitoring indicates relatively high *E. coli*, nitrite-nitrate nitrogen, and total nitrogen levels on a regular basis that exceed water quality guidelines. Other water quality parameters monitored regularly (ammoniacal nitrogen, dissolved reactive phosphorus, total phosphorus, suspended solid and turbidity) are mostly within recommended guidelines.

Table 11 Lindsay Creek water quality measured at North Road between September 2000 and July 2014. Data obtained from Otago Regional Council.

Water Quality Parameter	Lindsay Creek at North Road	
	Range	Median value
Escherichia coli (MPN/100 mL)	8 – 6,900	480
Ammoniacal nitrogen (g/m^3)	0.01 – 0.04	0.01
Nitrite/nitrate nitrogen (g/m^3)	0.177 – 2.14	0.745
Total nitrogen (g/m^3)	0.4 – 2.33	0.96
Dissolved reactive phosphorus (g/m^3)	0.005 – 0.034	0.017
Total phosphorus (g/m^3)	0.018 – 0.710	0.029
Suspended solids (g/m^3)	1 – 16	3
Turbidity (NTU)	1.6 – 10.9	2.7

(ii) Site-specific water quality monitoring at wastewater overflow sites

As already discussed, dry and generally stable weather for this duration of this project meant for relatively few sampling opportunities that met the criteria for sampling (see section 3.1.2). Monitoring of a small rain event that did not result in overflows indicated little change in water quality immediately downstream of the Lindsay Creek overflow discharge point (Table 12). For a slightly larger ambient rain event (4.6mm), water quality monitoring the Water of Leith immediately downstream of the Harbour Terrace / Union Street overflow discharge point indicated much higher levels of oxygen demand and *E. coli* indicator bacteria, and an FWA level indicative of likely sewage contamination (Table 12).

The conductivity levels were indicative of freshwater (i.e., at the time of sampling there was no saline intrusion into this lower section of the Water of Leith, which is tidal). Dissolved oxygen levels were similar at both sites and adequate for aquatic biota.

For the large June 2015 rain event, water quality contaminants were found to be elevated and at broadly similar levels both upstream and downstream of the overflow point. If sewage overflow was present in the stormwater discharge (most likely given the conditions at the time of sampling), it was well diluted by background contaminant levels from runoff. It was evident to anyone who viewed Lindsay Creek and the Water of Leith during the flood that they were carrying very high sediment and organic loads, most likely sourced from throughout the catchment. Consequently, it is not surprising that the contribution of contaminants from sewage overflows were not able to be detected.

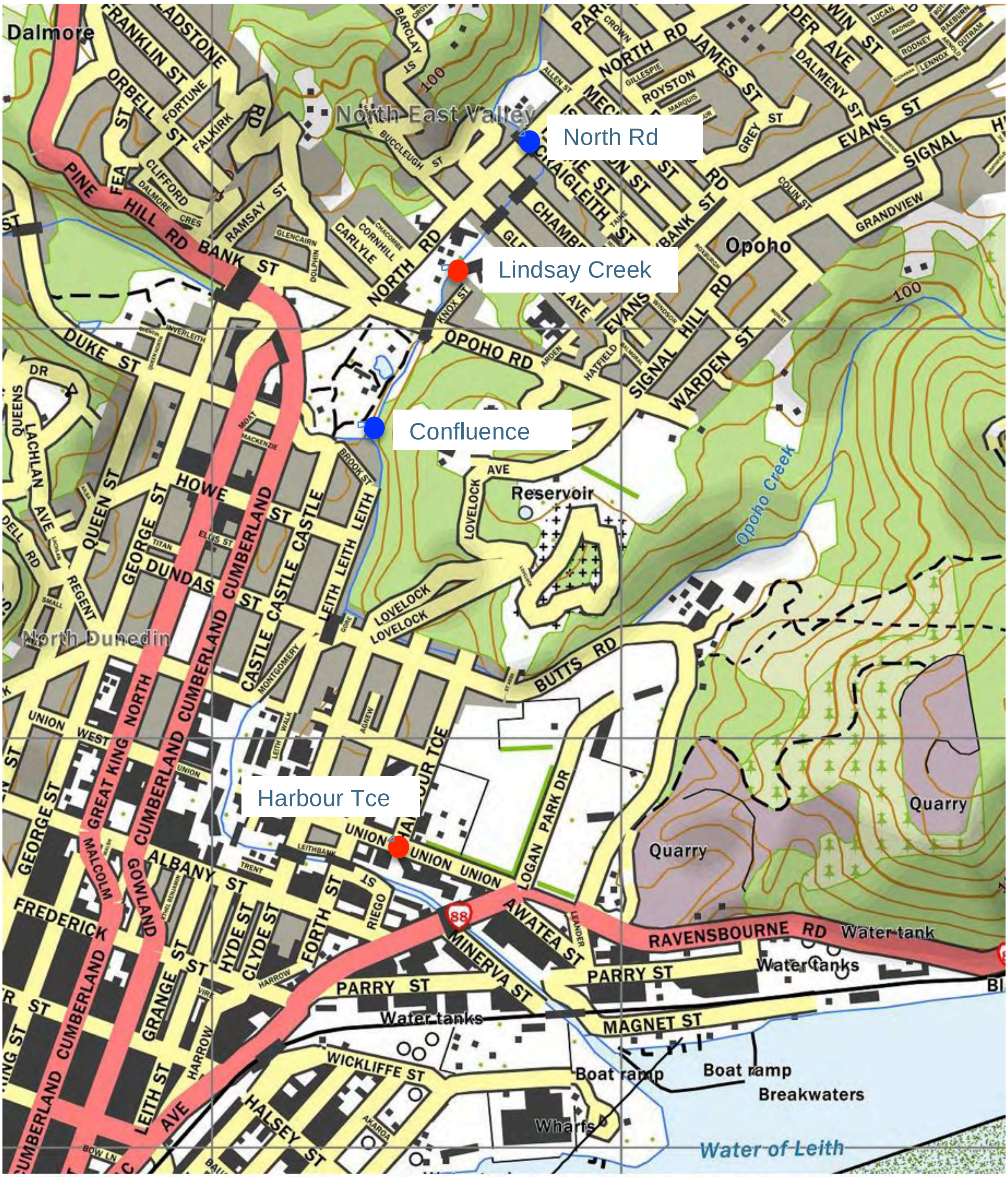

Figure 20. Location of ORC monitoring sites (blue dots) in relation to overflow sites (red dots).

Table 12. Site-specific water quality monitoring of Lindsay Creek and lower Water of Leith (in vicinity of Harbour Terrace / Union Street discharge point) in relation to recent ambient rain events (no wastewater overflows triggered at Lindsay Creek site or the Harbour Terrace / Union Street sites).

Water Quality Parameter	Ambient rain event (4.0 mm rainfall) 2/7/14		Ambient rain event (4.6 mm rainfall) 11/8/14		Possible overflow rain event (7.4 mm rainfall) 9/2/15		Overflow rain event (163 mm rain) 3/6/15	
	Lindsay Ck. upstream	Lindsay Ck. downstream	Harbour Tce. (lower Leith) upstream	Harbour Tce. (lower Leith) downstream	Lindsay Ck. upstream	Lindsay Ck. downstream	Lindsay Ck. upstream	Lindsay Ck. downstream
Dissolved oxygen (% sat.)	85.1	86.4	87.1	89.2	Not flowing		97.6	96.6
Conductivity (µS/cm)	88.0	86.9	83.3	222.0			77.7	74.7
pH	7.93	8.00	10.30	7.74			7.29	7.21
Turbidity (NTU)	21.2	22.3	45.0	12.0			180	180
FWAs	0.038	0.057	0.065	0.183			0.078	0.085
BOD_5 (g/m^3)	3	3	8	88			7	7
Suspended solids (g/m^3)	21	32	72	16			310	340
Escherichia coli (MPN/100 mL)	>2,400	>2,400	4,000	>24,000			13,000	13,000

3.3.3 Stream ecology

(i) Benthic communities (algae and invertebrates) – historic data for Lindsay Creek and Water of Leith

While relatively little data exists for algae communities in Lindsay Creek, the information available indicates that communities are sparse and dominated by diatoms, mainly *Melosira.* There is some evidence of less desirable filamentous green forms such and *Mougeotia* and *Ulothrix,* but once again, these do not appear to be common. Surveys in past years have noted a moderate cover of a dark brown periphyton film that may be diatoms or perhaps cyanobacteria, but identification was not carried out.

Three years of invertebrate monitoring has been undertaken in Lindsay Creek immediately upstream of its confluence with the Water of Leith (Table 13). While reasonably diverse with and average of 14 taxa being found each year and up to 21 taxa on a single sampling occasion, this site is dominated by 'low scoring' molluscs and worms. Particularly dominant is the freshwater snail *Potamopyrgus antipodarum*, while ostracod crustaceans, *Oxyethira* caddisflies, *Physella* snails and *Sphaeriidae* clams are often very abundant. A low presence of 'high scoring' EPT taxa means that MCI and SQMCI community health indices are typically low at the site, indicating poor habitat quality. Notable exceptions were MCI scores greater than 80 during 2004 and 2006 which indicated fair habitat quality.

More extensive monitoring of Lindsay Creek has been conducted further upstream at North Road as part of ORC's annual state of the environment monitoring programme (Table 14). Since 2006, MCI scores have typically been indicative of fair habitat quality, averaging a score of 89. This is due to greater diversity of invertebrate taxa than upstream of the Water of Leith confluence, including more frequent occurrence of higher scoring taxa such as *Psilochorema* caddisflies and *Deleatidium* mayflies from year to year. However, SQMCI scores remain low due to the dominance of *Potamopyrgus* snails, worms and orthoclad midges.

Table 13. Invertebrate monitoring data for Lindsay Creek upstream of the Water of Leith confluence. Displayed is the number of taxa identified during each sampling occasion for each invertebrate order. Data from Otago Regional Council.

Stream invertebrate taxon	Lindsay Creek u/s Water of Leith confluence		
	2003	2004	2006
Coleoptera (beetles)			1
Crustacea (small shrimp-like animals)	1	2	1
Diptera (truefly larvae)	3	2	6
Ephemeroptera (mayflies)			2
Mollusca (snails)	2	3	3
Oligochaeta (worms)	2	1	1
Plecoptera (stoneflies)			2
Trichoptera (caddisflies)	2	4	5
Number of taxa	9	12	21
Number of EPT taxa	2	4	9
MCI score	64	82	94
SQMCI score	2.6	2.7	2.7

Table 14. Results of annual invertebrate monitoring in Lindsay Creek at North Road between 2006 and 2014. Displayed is the number of taxa identified during each sampling occasion for each invertebrate order. Data obtained from Otago Regional Council.

Stream invertebrate taxon	Lindsay Creek at North Road								
	2006	2007	2008	2009	2010	2011	2012	2013	2014
Acarina (mites)					1				
Cnidaria (freshwater sponge)									1
Collembola (springtails)					1				
Coleoptera (beetles)	1	1	1		1	1		1	1
Crustacea (small shrimp-like animals)	1	1	1	1	1	1		1	1
Diptera (truefly larvae)	3	5	5	5	7	5	4	4	7
Ephemeroptera (mayflies)	1	1	1	1	1	1	1	1	1
Megaloptera (toe-biter)				1					
Mollusca (snails)	2	1	2	1	2	2	1	2	2
Nematoda (round worms)					1				
Oligochaeta (worms)	1	1	1	1	2	1	1	1	1
Platyhelminthes (flatworms)									1
Plecoptera (stoneflies)	1	1			1	3		2	
Trichoptera (caddisflies)	4	5	5	4	4	5	4	2	3
Number of taxa	14	15	16	14	21	19	11	14	18
Number of EPT taxa	6	7	6	5	6	9	5	5	4
MCI score	89	95	83	91	90	97	87	93	79
SQMCI score	3.2	2.9	3.0	3.0	3.0	3.3	2.5	3.0	3.3

(ii) Site-specific benthic invertebrate community survey at the Lindsay Creek wastewater overflow site

A survey of Lindsay Creek downstream of the wastewater overflow discharge point in October 2014 found the invertebrate community was also dominated by worms and snails, but Orthoclad midge larvae abundance was also high (Table 9). The community had low taxonomic diversity with only ten macroinvertebrate species found, of which only three were EPT taxa. As a result, the site had a low to moderate MCI score indicative of fair habitat quality and a SQMCI score indicative of poor habitat quality. These community health scores are similar to that found in ORC monitoring data where MCI scores ranged between 64–94 (2003-2006) and 79–95 (2006-2014) downstream (upstream of the Water of Leith confluence) and upstream (North Road) of the wastewater overflow site respectively (Tables 11 and 12).

(iii) Fish communities

New Zealand Freshwater Fish Database records show that a total of four different fish species have been caught within the Lindsay Creek catchment with an additional three species being found in the Water of Leith just upstream of the Lindsay Creek confluence (Table 15, Figure 21). Two species are introduced (brown trout and chinook salmon) while the remainder of fish caught are native species. It is likely that giant kokopu, koaro and redfin bullies also inhabit Lindsay Creek having been found nearby. Koura (freshwater crayfish) are common (Figure 21).

Table 15. Conservation status of fish species caught in the Lindsay Creek catchment and nearby in the Water of Leith (Goodman et al. 2014).

Common name	Species	Native	Migratory	Threat status	Criteria
Longfin eel	*Anguilla dieffenbachia*	Y	Y	Declining	[1]C (2/1)
Shortfin eel	*Anguilla australis*	Y	Y	Not threatened	
Giant kokopu	*Galaxias argenteus*	Y	Y/N	Declining	[2]B (1/1)
Koaro	*Galaxias brevipinnis*	Y	Y/N	Declining	[3]C (1/1)
Redfin bully	*Gobiomorphus huttoni*	Y	Y	Declining	[3]C (1/1)
Chinook salmon	*Oncorhynchus tshawytscha*	N	Y	Introduced and naturalised	
Brown trout	*Salmo trutta*	N	Y/N	Introduced and naturalised	

[1]C (3/1) = total area of occupancy ≤ 100 ha (1 km^2), predicted decline 10–50%; [2]B (1/1) = 20,000–100,000 mature individuals, predicted decline 10–50%; [3]C (1/1) = > 100,000 mature individuals, predicted decline 10–70%.

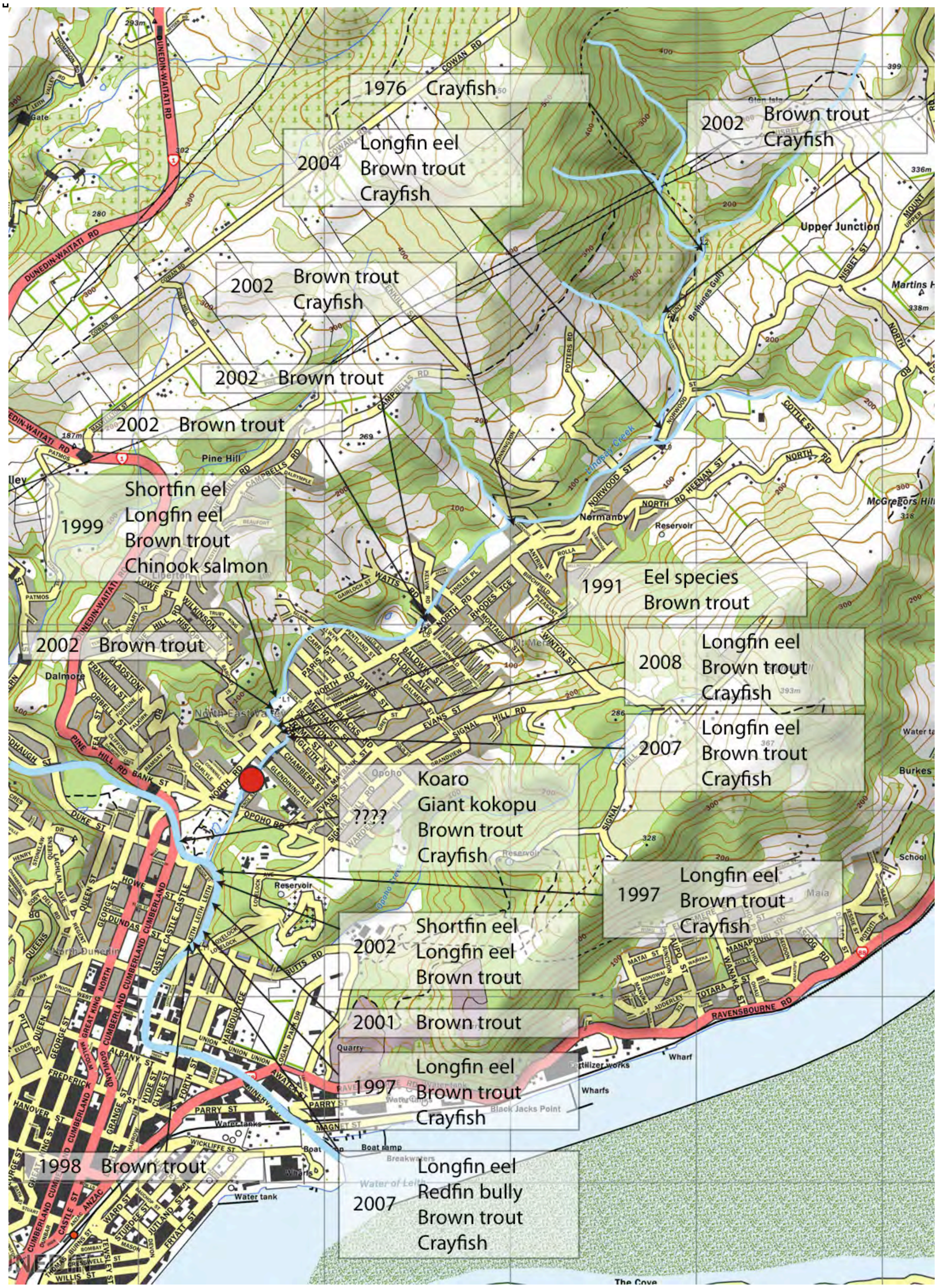

Figure 21. **Known fish distribution in Lindsay Creek (thin blue line) and the lower Water of Leith (thick blue line) as obtained from the New Zealand Freshwater Fish Database (NIWA). The red circle indicates the point of discharge for the DCC Lindsay Creek sewage overflow.**

3.4 Otago Harbour

3.4.1 General

The remaining receiving water bodies affected by the DCC wastewater overflows consist of concrete conduits that are unlikely to contain any natural or ecological values. These include piped watercourses that eventually drain into Otago Harbour (Figures 8, 10, 12 and 15). Note that the Harbour Terrace / Union Street East overflow discharges into a piped watercourse (Butts Creek) that flows into the lower Water of Leith, which is an estuarine environment. At this point, however, the Water of Leith is a large concreted flood channel with no significant natural values downstream (Moore *et al*. 2015).

Both the upper Otago Harbour basin and Sawyers Bay are moderately impacted by past discharges of sewage, stormwater and industrial wastes (Stewart and Ryder 2004; Stewart 2005a,b; Stewart 2012). However, flushing is significant, especially in the shipping channel, and ensures stormwater discharges are diluted reasonably rapidly, with 1-2 days required for flushing of the channel and 2-3 days for the upper harbour as a whole (Smith and Croot 1993, 1994).

Andersons Bay Inlet, however, is generally less well flushed, with Smith and Croot (1993) estimating that 2-5 days (4-10 tidal cycles) were necessary for 99% flushing. These residence times, of course, have implications for sediments and other contaminants introduced into the harbour, with heavy metals having more time to be incorporated into the substratum (Baird 1997).

Smith and Croot (1993, 1994) noted that freshwater inputs (e.g. Water of Leith) had a significant impact on upper harbour flushing times, with “new” fresh water readily pushing seawater down the harbour and markedly reducing flushing time, especially during heavy rainfall events.

3.4.2 Sediment and water quality

Water quality of Otago Harbour is affected by DCC and private stormwater discharges, direct discharges from land, and other freshwater inputs such as the Water of Leith. These inflows have greatest influence under wet weather conditions. Major urban stormwater discharges are monitored by the DCC as a part of resource consent requirements (RM11.313).

Urban stormwater can contain a wide range of contaminants, including suspended sediments, organic material, micro-organisms, metals and petroleum compounds. Some of these contaminants end up in the marine sediments particularly in the area immediately surrounding the outfalls. Many of the contaminants found in these sediments are historic in nature. As part of a stormwater re-consenting process, a survey was carried out on sediments in Sawyers Bay, with high levels of chromium and copper being found (Stewart 2005b). The day on which samples were collected was very windy with sizeable waves rolling across the bay. As a result the waters of Sawyers Bay were discoloured with re-suspended sediments and it is likely that the metals detected at this site are historic in nature.

The Marne Street (Andersons Bay Inlet), Hillside Road (Portobello Road stormwater outfall) and Sawyers Bay wastewater overflows were recently monitored under ambient rainfall conditions (Table 16). All sites had mixed water quality upstream of the overflow points with high levels of suspended sediments and *E. coli*. BOD levels were above background concentrations but not excessively so. The Hillside Road site was particularly high in *E. coli* and FWA levels both upstream and downstream of the overflow point indicated that sewage contamination was likely. Dissolved oxygen levels at all sites were relatively good.

The Sawyers Bay site was able to monitored under a 7.4mm rain event that resulted in a possible sewage overflow (Table 16) and the downstream site, situated within the sump, exhibited strong evidence of sewage contamination under this situation, characterised by very high BOD, FWA and *E. coli* levels.

The large June 2015 rain event was also monitored and BOD, FWA and *E. coli* levels in the sump were very high relative to the 'upstream' monitoring site and indicative of sewage contamination (Table 16).

3.4.3 Ecology

A variety of surveys of benthic and intertidal flora and fauna have shown a relatively low diversity of benthic flora and infauna with a trend towards lower diversity as one moves up-harbour. Communities sampled in the upper Otago Harbour near stormwater outfalls are numerically dominated by polychaete worms and amphipods, as is usual for sheltered soft shores around New Zealand (Morton and Miller 1973), and show distinct similarities to communities found in other moderately impacted inlets in Otago (Stewart 2007b, 2008a,b).

Table 16. Site-specific water quality monitoring of stormwater conveying wastewater overflows into Otago Harbour.

Water Quality Parameter	Ambient rain event (4.0 mm rainfall)		Ambient rain event (4.0 mm rainfall)		Ambient rain event (4.6 mm rainfall)	
	Marne Street upstream	Marne Street downstream	Sawyers Bay upstream	Sawyers Bay downstream	Hillside Road (Portobello Rd. outfall) upstream	Hillside Road (Portobello Rd. outfall) downstream
Dissolved oxygen (% saturation)	81.5	82.6	79.3	85.6	95.8	94.5
Conductivity (μS/cm)	5,024	11,143	1,154	27,696	84.8	70.6
pH	8.09	7.84	7.29	6.83	8.50	7.85
Turbidity (NTU)	14.0	21.5	42.1	11.3	54.0	32.0
FWAs	0.069	0.072	0.063	0.014	0.120	0.101
BOD_5 (g/m^3)	3	4	3	5	12	5
Suspended solids (g/m^3)	36	57	43	120	76	32
Escherichia coli (MPN/100 mL)	360	360	1,800	270	10,000	11,000

Water Quality Parameter	Possible overflow rain event (7.4 mm rainfall)				Overflow rain event (163 mm rain)	
	Sawyers Bay upstream	Sawyers Bay downstream	Marne Street upstream	Marne Street downstream	Sawyers Bay upstream	Sawyers Bay downstream
Dissolved Oxygen (% saturation)	83.1	64.2			87.1	83.9
Conductivity (μS/cm)	267	586			374.6	232.2
pH	7.93	7.56			7.55	7.33
Turbidity (NTU)	57.2	256.0			200	68
FWAs	0.056	0.571	Not flowing		0.062	0.253
BOD_5 (g/m^3)	6	200			18	69
Suspended Solids (g/m^3)	46	220			320	90
Escherichia coli (MPN/100 mL)	410	>2,400			16,000	240,000

Intertidal communities of the upper harbour show a relatively depauperate flora and fauna due largely to the artificial nature of much of the shore and the sheltered aspect of the embayments (Probert and Jillett 1998). Some animals usually found in rocky shore high tide zones (e.g. the periwinkles *Nodilittorina cincta* and *N. unifasciata*, and the barnacle *Chamaesipho columna*) are notably absent, probably because of a lack of a splash zone (Clayton 1982). Other possible contributing factors to the paucity of plant and animal life, at least in the upper harbour region are anthropogenic inputs (Stewart and Ryder 2004) and freshwater inputs from the Water of Leith, Somerville Stream, and a variety of other smaller watercourses.

There is also a reduction in biodiversity with increasing shore height, as found by Probert and Jillett (1998). This is typical of all shores and reflects increasing aerial exposure and stress (Raffaelli and Hawkins 1996, Ricketts *et al* 1997). Under rocks and in crevices where moisture is retained, however, there is a reasonably diverse and abundant fauna at all tide heights, with both diversity and abundance peaking at the low tide level.

Despite a long history of human activity, the receiving environment at Sawyers Bay has received less attention than the upper harbour. An environmental monitoring programme conducted in the early 1990s for the DCC stated that the sediments of Sawyers Bay were composed of generally fine muds that showed signs of nutrient enrichment and that chromium levels were generally high (Probert 1990a,b). Grove (1995) conducted an extensive study of benthic habitats in Sawyers Bay and the upper Otago Harbour as a part of an MSc in Marine Science. He found a variety of infaunal species, notably maldanid polychaete worms and phoxocephalid amphipods, and a limited epifauna comprising mainly burrowing crabs (*Macrophthalmus hirtipes*). He concluded that Sawyers Bay communities are different from communities in the rest of the harbour but could find no environmental variables that adequately explained this difference (Grove 1995).

Intertidal species along the shoreline at Sawyers Bay were not abundant but were moderately diverse and included topshells, cockles, a variety of limpets, and chitons and shore crabs under rocks.

Overall it is expected that high dilution rates resulting from tidal currents will ensure that effects on marine organisms in Sawyers Bay are negligible.

Generally speaking, in the upper harbour basin and Sawyers Bay, there is a paucity of infaunal species present, exacerbated by exposure at low tide and freshwater inputs. Neither area is considered ecologically significant, but the upper harbour basin is valued as a water sports recreation area, especially for kite surfing and wind surfing.

While not pristine, the upper harbour and the communities associated with the intertidal areas adjacent to major stormwater outfalls appear not to be undergoing any significant further degradation as a result of stormwater or wastewater inputs. It is unlikely that wastewater overflows will have a significant impact on harbour ecology.

4. Conclusion

The seven wastewater overflows assessed in this report all have different characteristics which influence their potential effects on receiving waters. As well as located in different areas and sub-catchments, the overflows vary in size and frequency, and in the degree of mixing with stormwater before discharging to either streams or harbour water. Consequently, their effects on water quality may vary. However, they all have two key features in common. One is that they discharge primarily as a result of meaningful rain events only, which means the discharges are occasional only, and when they do occur, they are subject to considerable dilution either within the stormwater reticulation network and/or within the receiving water environment. The other is that the receiving waters they discharge into are all highly modified through decades of physical alteration. As such, they maintain ecological characteristics that are modest in terms of ecosystem health and value, which invariably means they are relatively tolerant of degraded water quality. However, these characteristics do not necessarily mean that they hold no value and indeed many of them can be regarded as having value for aesthetic, cultural and recreational reasons, particularly in an urban context. These matters are outside the scope of this report although we have assessed water quality with respect to contact recreation.

4.1 Water Quality

4.1.1 General

During and probably immediately following rain events, Dunedin's urban streams carry substantial levels of contaminants, and a number exceed recommended guidelines. This is not unexpected and most guidelines and standards do not apply to short term situations such as freshes and floods. For example, the ORC Water Plan Schedule 15 standards for good water quality are 5-year 80th percentile values when a stream is at or below its median flow. Therefore, they are unlikely to apply to wastewater overflow events which typically occur during elevated stream flows associated with rainfall.

Only a limited number of occasions have enabled sampling during wastewater overflow events during the 12 month study period. The Kaikorai Valley Road and Lindsay Creek events found no meaningful change in contaminant levels downstream of the discharge points. Similarly, stormwater downstream of the Hillside Road overflow site had a similar contaminant profile to that of stormwater immediately upstream. The stormwater sump below the Sawyers Bay overflow site showed much higher levels of contamination relative to the Sawyers Bay stream upstream, however this site would have had received relatively little dilution prior to entering Sawyers Bay via the stormwater outfall.

4.1.2 Human values

Wastewater discharges have the potential to adversely affect the natural and human use values of a waterbody, including conditions suitable for drinking and contact recreation. No water takes for the purpose of potable water supplies are present downstream of the overflow discharge points to the Kaikorai Stream or Water of Leith catchments, therefore the Ministry of Health (2008) and ANZECC and ARMCANZ (2000) human and livestock drinking water standards are not relevant.

Shellfish contamination (particularly faecal bacteria) in the Otago harbour has not been addressed directly in this report. It is almost impossible to differentiate the contribution of wastewater overflows to shellfish contamination from that caused by general urban 'background' stormwater and land runoff, which monitoring has shown to be very high in faecal indicator bacteria during rain events. Shellfish monitoring is undertaken as a condition of the stormwater discharge consents (RM11.313). A synopsis of the findings of cockle monitoring is shown in Table 17.

4.1.3 Contact recreation

Swimming is not a popular activity in the lower reaches of either the Kaikorai or Water of Leith catchments, let alone during rain events, however secondary contact is possible as each stream flows through densely populated urban environments. For example, angling usage is documented (Unwin 2009) and anglers are often observed in the lower Water of Leith, as is kayaking during high flow events. The ANZECC and ARMCANZ (2000) *E. coli* guideline for swimming and direct water-contact sports is 150 CFU/100 mL and the Ministry for the Environment (MfE) Action/Red Mode level is a single sample greater than 550 MPN/100 mL (MfE 2003). The ORC has previously interpreted this guideline such that if it is exceeded there could be a health-risk for direct recreational contact. Ambient (and overflow) rainfall monitoring events indicate that *E. coli* levels are typically much greater (up to >2,400 MPN/100 mL) than these guidelines both upstream and downstream of wastewater overflow discharges in Kaikorai Stream. Thus, even in the absence of wastewater overflows, guidelines for contact recreation would be exceeded.

Table 17 Contaminant concentrations in cockle flesh from within 20m of the Kitchener Street, Orari Street and Portobello Road stormwater outfalls in 2007, 2008, 2009, 2010, 2011, 2012, 2013 and 2015. Green shading indicates a decrease in contaminant level, pink indicates an increase, white = no change. BDL = below detectable limits.

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

As noted earlier, the upper Harbour basin is a popular area for contact recreation. As such, occasions when overflow discharges may cause contaminant concentrations to breach MfE trigger values would be of concern. Harbour water monitoring is undertaken as a condition of consent for DCC's stormwater discharges. However, it has not been targeted specifically at the time of overflow events. Sampling of harbour water during 2014 indicated that enterococci levels did occasionally exceed MfE trigger values, especially during moderate to heavy rainfall events (Stewart 2014). Given the high background levels of faecal bacteria in stormwater and land runoff during rain events, it is unlikely that the wastewater overflows significantly exacerbate the general level of faecal bacteria contamination that occurs in the upper Harbour Basin during and following rainfall events.

4.2 Ecological Effects

4.2.1 General

We find that the ecological values of Kaikorai Stream, its tributary, and Lindsay Creek are unlikely to be affected by the DCC wastewater overflows. Each stream is characteristic of a highly modified urbanised environment, affected by channel straightening, removal of obstructions and riparian vegetation, re-contouring of banks and concrete reinforcement of the channel. These modifications are made to allow the channel to convey flows more efficiently and prevent storm flows from overtopping the banks (Suren and Elliot 2004). Water quality data (see Section 3) also show that each waterway is impacted by its urban catchment by displaying relatively elevated levels of contaminants, even outside of rainfall events for some parameters. Physical modifications and background water quality have combined to support degraded benthic communities (see section 4.1.2 below). Despite these effects, fish communities have remained relatively diverse, although not necessarily within the urban reaches of the catchments.

4.2.2 Stream communities

Urban streams typically have macroinvertebrate communities with very few 'sensitive' taxa such as mayflies and stoneflies, and are dominated by worms, snails, midges, small crustaceans like ostracods and blackfly larvae (Suren and Elliot 2004). High flows in urban streams can wash away invertebrates, especially in concrete-lined sections, and cause extensive substrate movement, which has detrimental effects on invertebrate communities (Suren and Elliot 2004). Low flows also affect invertebrate communities, as they can be associated with elevated water temperature, low dissolved oxygen levels and sediment deposition (Suren and Elliot 2004).

Both long-term background monitoring data and one-off sampling in October 2014 found invertebrate communities to be of a similar composition both upstream and downstream of overflow outfall points in Kaikorai Stream, its tributary and Lindsay Creek. These stream benthic communities have low health index scores, and are generally characteristic of the poor habitat conditions that are present in these urban waterways.

Stormwater, land runoff, and wastewater overflows can export fine sediments to waterways. Fine sediments, such as silts and clays, can remain in suspension for considerable periods of time. They can settle out in low velocity environments, potentially affecting benthic communities by changing the nature of the bed (e.g., blanketing the bed). Overflow events in Kaikorai Stream resulted in minor elevations in suspended sediments and minor changes in turbidity levels. Regardless, overflow events occur during periods of high rainfall that dramatically increase river flows. Under such conditions, water velocities are elevated and fine sediments are washed away and unlikely to settle on the bed. Visual inspections found no evidence of increases in fine sediment deposition or sludge deposits downstream of overflow discharge points.

Freshwater fish communities are also unlikely to be directly affected by the wastewater overflows. Toxicity levels, particularly in relation to ammonia, do not appear to be an issue during rainfall events (based on survey data), and dissolved oxygen levels remain adequate. Other contaminants such as nutrients, sediments and faecal bacteria, either are irrelevant in terms of direct effects on fish, or do not reach levels to exert significant effects at the population level.

4.2.3 Harbour ecology

Benthic communities in the vicinity of urban stormwater outfalls are influenced mainly by the overall water quality character of stormwater discharges rather than the contribution of wastewater overflows. The overflows are high in oxygen demanding substances, suspended sediments and faecal bacteria, but so is the background stormwater. Further, the historic effects of urban stormwater on local ecology can be observed through sediment contamination. While the recent contributions of wastewater overflow will do not act to improve ecosystem health, they are unlikely in themselves to be the cause of further degradation because their contaminant load is minor relative to the contaminant load from urban stormwater in general.

4.3 Summary

Overflow events are triggered during heavy rainfall events or during sustained moderate rainfall events. Under such conditions, the receiving waters for the overflows are typically at elevated flow (in the case of streams) or are receiving high inflows from the surrounding land relative to dry weather conditions (in the case of the harbour). Flows in the wastewater reticulation system are also high, due to I&I, and flowing at rates well in excess of those observed during dry weather. As such, the wastewater is considerably more dilute than one would expect during dry weather.

Due to the unpredictable and sporadic nature of heavy rainfall events, there is a paucity of data on water quality during wastewater overflow events. There is no doubt that water quality suffers during overflow events. However, due to increased volumes in both overflow sewage and stormwater, and the quality of general land runoff, the increase in contaminant levels observed downstream of overflow sites is usually not markedly higher than background levels observed during moderate to heavy rainfall events that are likely to trigger overflows.

There is, during any rainfall event, the potential for a number of water quality guidelines and standards to be exceeded, as shown by annual stormwater compliance monitoring (e.g. Stewart 2014). This is potentially heightened when wastewater is discharged to stormwater systems during an overflow event. However, this effect is mitigated to a certain extent by the very nature of the conditions that trigger overflows.

The wastewater overflows that discharge to permanent water bodies are typical of moderate to highly impacted hard substrate lowland streams and harbour environs. Ecological values in waterways examined are not particularly high and discharges from overflow conduits on their own appear to have little impact on biological communities.

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Appendix 1 – Graphs of overflow events.

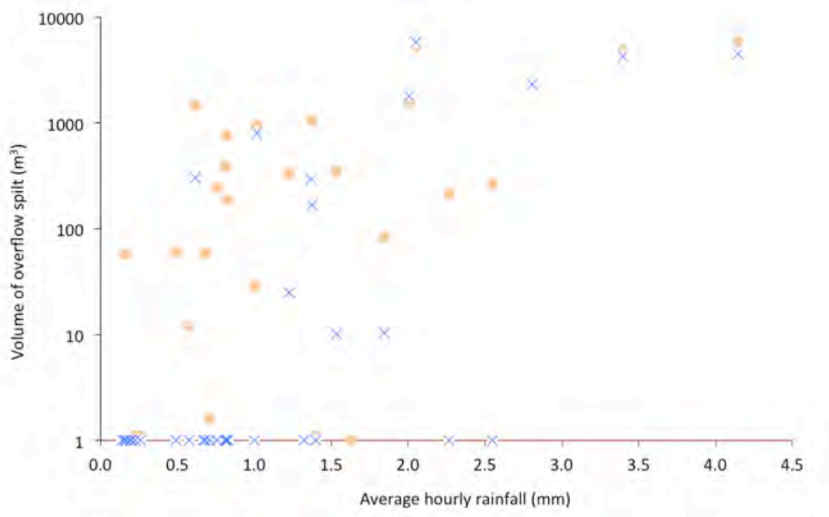

Figure 1. **Scatter graph of Kaikorai Valley (●) and Shetland Street / Nairn Street (x) overflow volumes during rainfall events. Monitoring data obtained from DCC records between October 2011 and December 2013.**

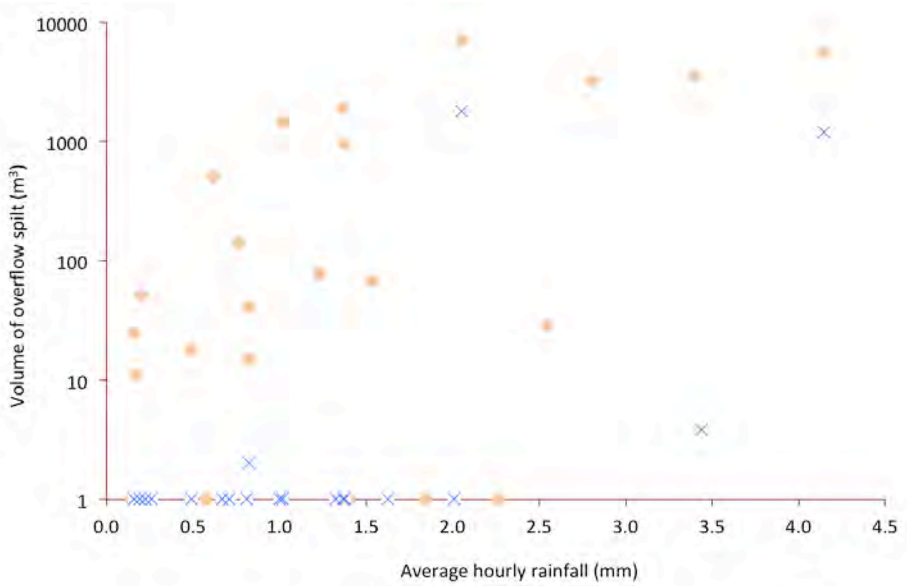

Figure 2. **Scatter graph of Lindsay Creek (●) and Harbour Terrace / Union Street East (x) overflow volumes during rainfall events. Monitoring data obtained from DCC records between October 2011 and December 2013.**

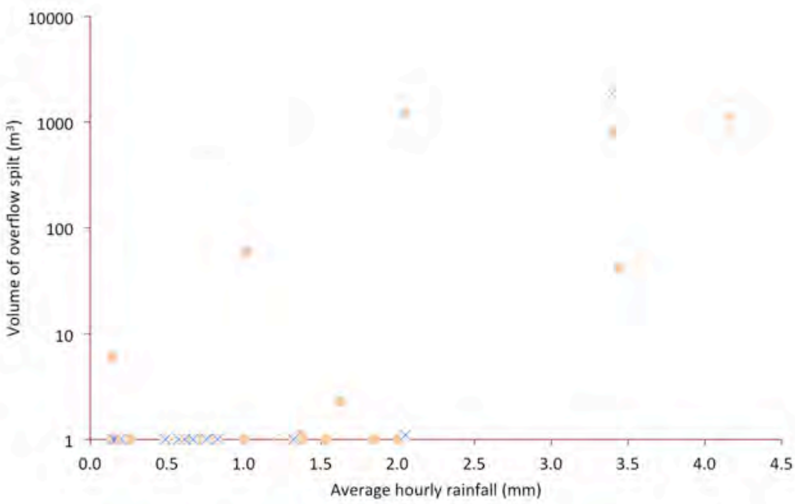

Figure 3. Scatter graph of Hillside Road / Surrey Street (●), Marne Street pump station (X) and Sawyers Bay pump station (○) overflow volumes during rainfall events. Monitoring data obtained from DCC records between October 2011 and December 2013.