DUNEDIN CITY COUNCIL | kaunihera a-rohe o Ōtepoti

STORMWATER DISCHARGES TO THE COASTAL MARINE AREA: RM11.313.01 – RM11.313.10

JULY 2021 TO JUNE 2022 MONITORING

For Dunedin City Council

September 2022

REPORT INFORMATION AND QUALITY CONTROL

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EXECUTIVE SUMMARY

Dunedin City Council operates the Dunedin stormwater system. Monitoring of stormwater and the receiving environments is required by Otago Regional Council resource consents (RM11.313.01 – RM11.313.10). Between July 2021 and June 2022, sampling included stormwater quality during dry weather conditions, harbour water quality during dry and wet weather conditions, automated sampling of stormwater quality during two wet weather events, and sampling of harbour sediments. Further sampling/re-sampling was restricted by weather/tidal conditions not being met.

Dry weather sampling of stormwater found that trigger levels of *Escherichia coli* were exceeded at most outfalls on at least one sampling occasion. Nine stormwater outfalls (1, 3, 4, 5, 10, 24, 25, 27 and 33) had three consecutive sampling rounds (but not always consecutive months due to the weather/tide conditions) with elevated *E. coli* concentrations. Three of these outfalls, 25, 27, and 33, had samples from three consecutive months greater than the trigger level, with the consents requiring investigation and remedial action, if required.

Wet weather sampling of stormwater, at outfalls during a rainfall event at low tide following a period of dry weather, was not undertaken between July 2021 and June 2022 as the required conditions were not met.

Automated sampling was undertaken during two wet weather events in April 2022 in the Halsey Street catchment. Contaminant profiles during the rain events differed, with peak concentrations of suspended solids and metals at 60 and 30 minutes into the April 12 and April 21 rain events respectively. *E. coli* concentrations were very high during the April 21 event, with two peaks in concentrations. Between December 2021 and up to the end of June 2022, the sampler was incorrectly triggered (‘false alarms’) on 17 occasions.

Harbour water quality sampling was undertaken during a rain event and during dry weather in 2022. Sampling revealed copper, zinc, and enterococci concentrations exceeded consented trigger levels at multiple sites during the rain event, while copper, lead, zinc, and enterococci concentrations exceeded consented trigger levels at multiple sites during dry weather.

Harbour sediment contaminant concentrations were similar to those from recent years and there are no obvious patterns in concentrations through time. Concentrations in 2022 were all below 2013 trigger levels listed in the consents. Concentrations of lead, zinc and PAHs at some sites were above ANZECC (2000) ISQG-Low levels, which represent the threshold for potential effects to occur and is a trigger for further investigation, but remained well below ISQG-High levels, which represent a point where a high probability of effects is possible.

1 INTRODUCTION

Dunedin City Council (DCC) operates the Dunedin stormwater system which comprises a network of gutters, open channels, pipes, mud tanks, and outfalls. The principal coastal receiving water environments for Dunedin's reticulated stormwater are the upper basin of Otago Harbour, Port Chalmers, and, on the open coast, Second Beach and St Clair Beach. Otago Regional Council (ORC) resource consents (RM11.313.01 – RM11.313.10) authorise the discharge of stormwater from ten stormwater catchments (St Clair, Shore Street, South Dunedin, Portsmouth Drive, Orari Street, Kitchener Street, Mason Street, Halsey Street, Ravensbourne, and Port Chalmers catchments) to these receiving environments (Figure 1). Conditions of the consents require monitoring of stormwater quality during dry and wet weather conditions, harbour water quality during dry and wet weather conditions, harbour sediments, and on a biennial basis, harbour biological communities.

DCC engaged Ryder Environmental, now part of 4Sight Consulting (4Sight) to undertake the required monitoring between July 2021 and June 2022. This report summarises the results of that monitoring.

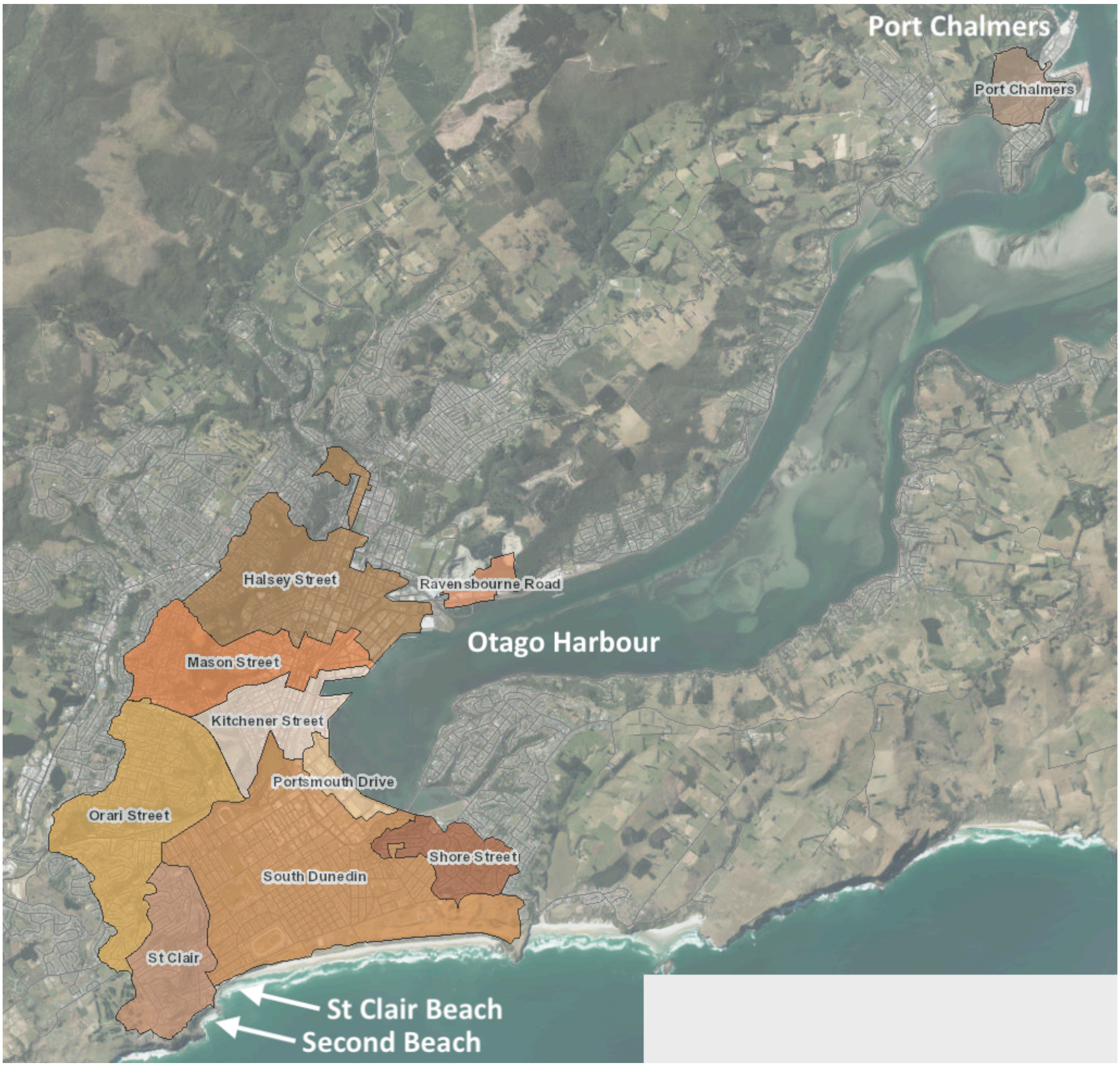

Figure 1: Dunedin stormwater catchments. Modified from DCC webpage.

2 STORMWATER OUTFALL LOCATIONS

Monitoring of Dunedin's stormwater quality is required at 14 large outfalls and many smaller outfalls (Figure 2; Appendix A). Many of Dunedin's outfalls have long histories dating back to the early settlement of the city. A number of the outfalls do not have outfall structures or are inaccessible for sampling, and it is therefore neither practical nor possible to sample all 33 outfalls at the discharge point (outfall) to the receiving environment. However, access at many sites is available via manholes a short distance upstream from the outfall.

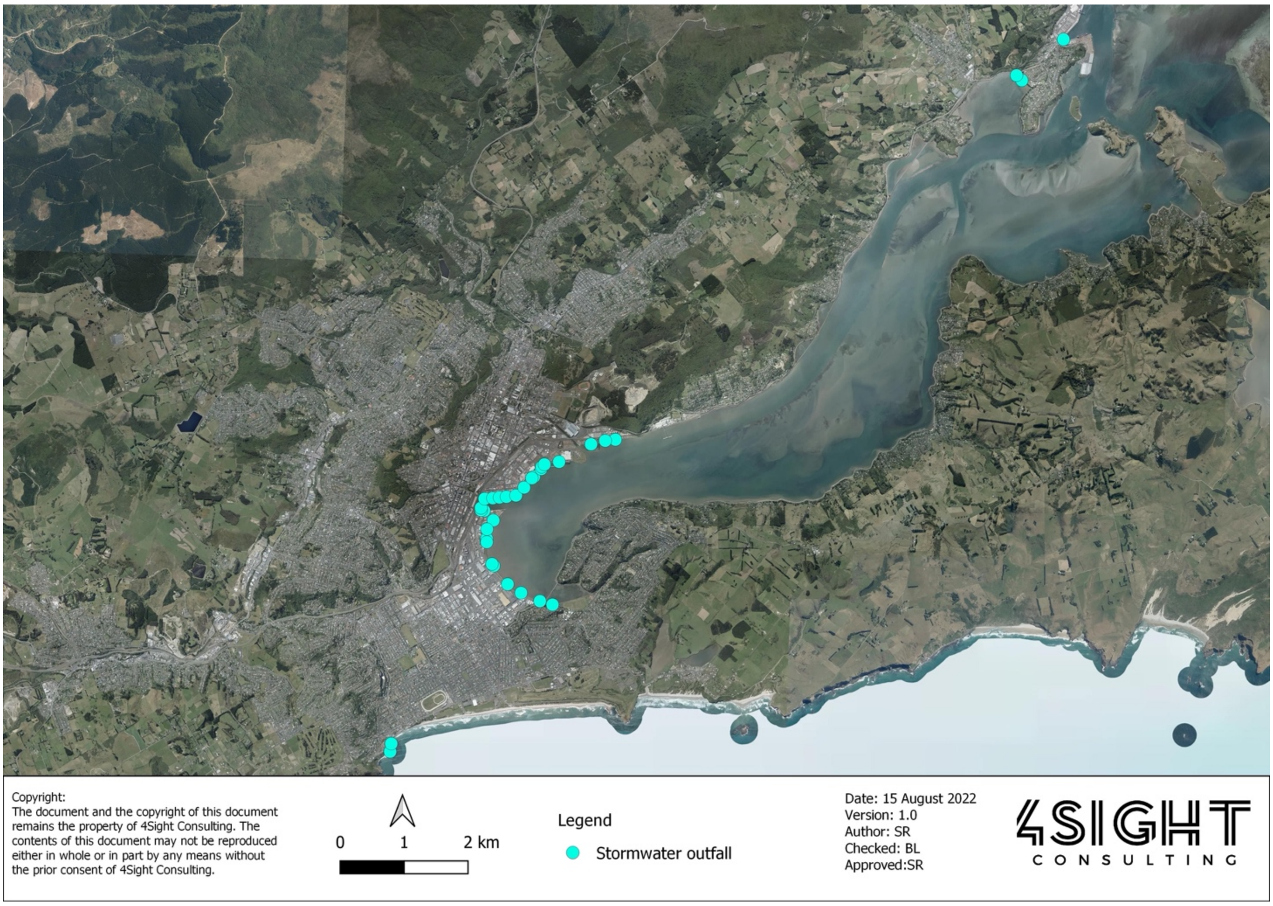

Figure 2: Dunedin stormwater outfalls.

3 SAMPLING REQUIREMENTS AND METHODS

3.1 Dry weather stormwater sampling

Dry weather water sampling is undertaken to determine background contaminant levels entering the receiving environments via stormwater outfalls, and can indicate possible cross-connections between stormwater and wastewater systems. At some outfalls where indicators of human wastewater have not been detected or there is generally no flow, sampling is only required six-monthly, while sampling at other outfalls is required monthly (when all conditions for sampling are met) (Figure 3 and Figure 4; Appendix A). At many six-monthly sampling sites, there is no access to the outfall. However, due to the small size of the receiving catchments for these outfalls, there is not expected to be any flow under dry conditions.

Dry weather water sampling is required at stormwater outfalls under low tide conditions, to avoid dilution by seawater. Dry weather is defined as a period of at least 72 hours with no more than 1 mm of measurable rainfall. If no dry weather conditions occur within a calendar month, no sampling is undertaken for that month.

When conditions are suitable, grab samples of water are collected in laboratory-provided containers from the end of the outfall pipe, or as near as practicable prior to the discharge mixing with seawater, for laboratory analysis (Eurofins) for *Escherichia coli* (*E. coli*). *E. coli* is a type of bacteria commonly found in the gut of humans and other warm-blooded animals, and is used as an indicator of faecal contamination in freshwater. The indicator bacteria themselves do not necessarily pose a significant risk to human health, but rather indicate the likely presence of faecal material, which contains disease-causing pathogens, including a range of bacteria and viruses. Potential sources of *E. coli* in stormwater include sewage and faecal deposition by animals (e.g., birds, rodents, domestic pets). If the *E. coli* concentration in samples from three consecutive months is greater than 550 units per 100 millilitres, the consent requires investigation and remedial action, if required. The *E. coli* trigger level is based on Ministry for the Environment (MfE) (2003) action (red) level guidelines where water poses an unacceptable health risk from bathing.

Grab samples of water are also collected and analysed on site for fluorescent whitening agents (FWAs) using an AquaFluor handheld fluorometer. Measurement of FWAs is not required by resource consents, however they provide a useful indicator of potential contamination. FWAs are used in laundry detergents and, as household plumbing mixes effluent from toilets with washing machine 'grey water', FWAs can be associated with human faecal contamination and indicate possible wastewater infiltration to the stormwater system. Detection of 0.1 ppb of FWA is suggestive of contamination from grey/wastewater and a level of 0.2 ppb is strongly indicative of contamination from grey/wastewater (Gilpin and Devane 2003). While samples with higher levels of FWAs generally also contain high levels of *E. coli*, a direct linear relationship between the two is not always evident as FWAs are chemicals that may have different movement and survival characteristics to microbial pathogens (Gilpin and Devane 2003).

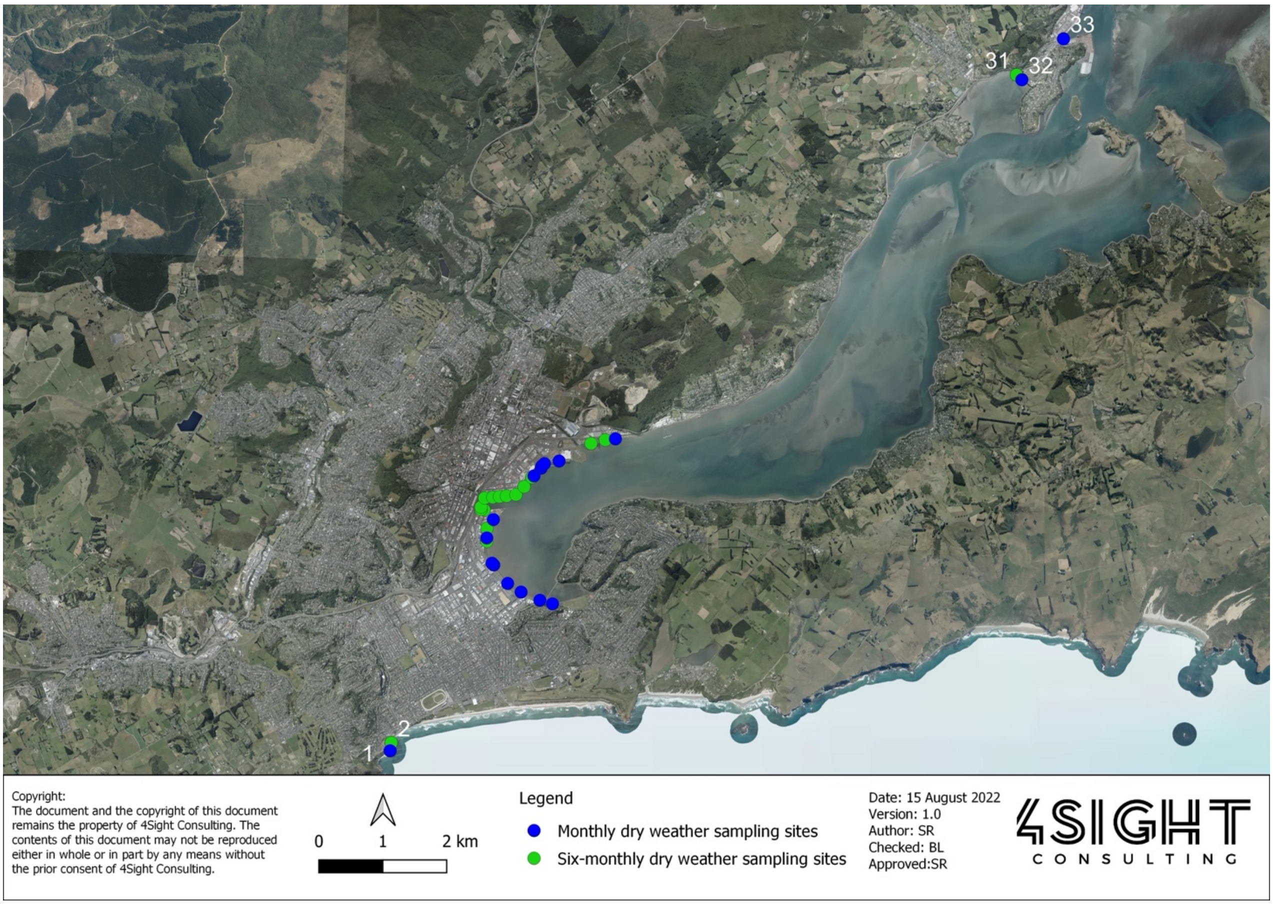

Figure 3: Dunedin stormwater outfalls – monthly and six-monthly dry weather sites (all sites).

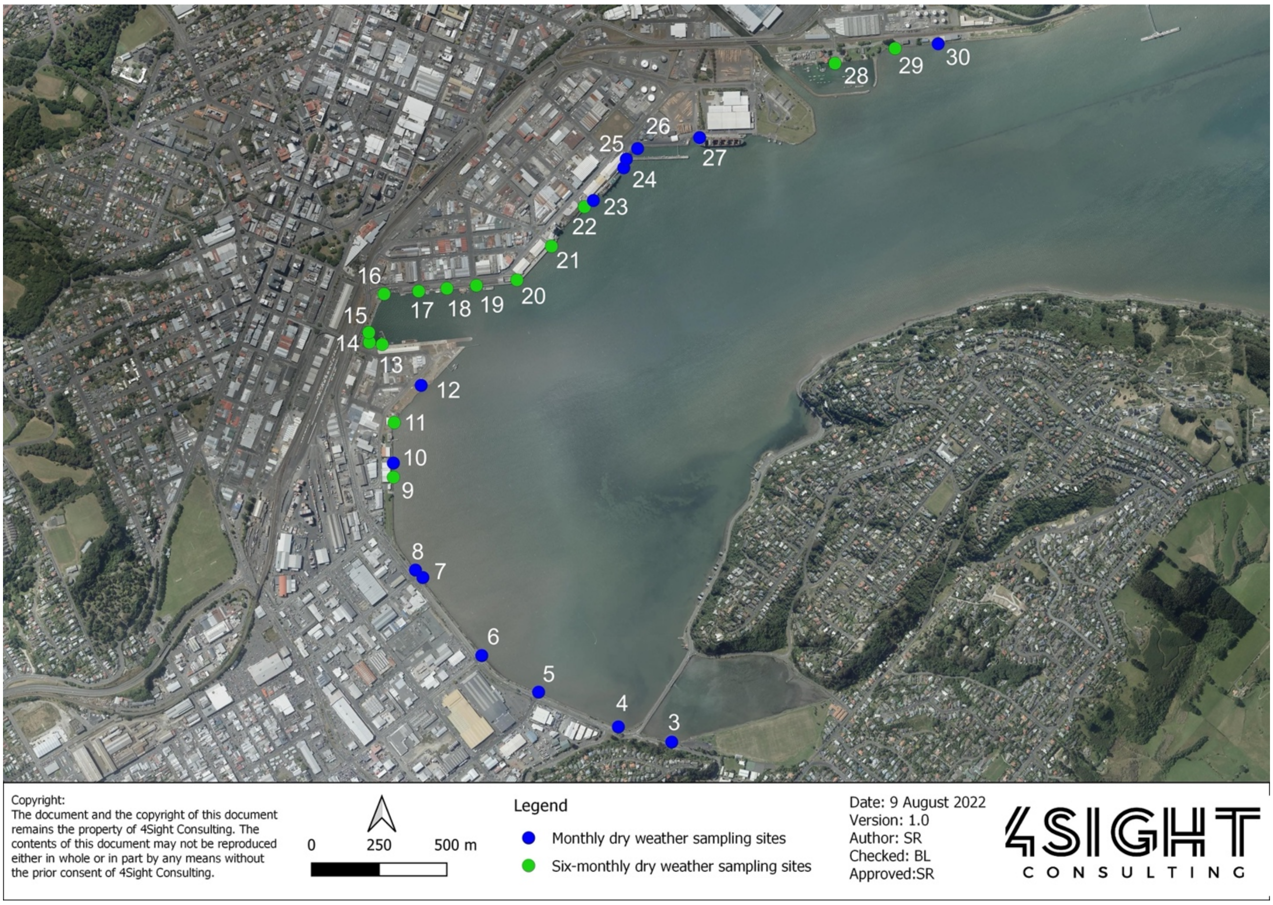

Figure 4: Dunedin stormwater outfalls – monthly and six-monthly dry weather sites (upper harbour sites).

3.2 Wet weather stormwater sampling

Wet weather water sampling is undertaken in an endeavour to sample the first flush of stormwater, which typically contains the highest concentration of contaminants, into the receiving environment.

Wet weather water sampling is required annually at ten major stormwater outfalls (Figure 5 and Figure 6, Appendix A) at low tide within two hours of the commencement of a rain event (more than 2.5 mm of rain), following an antecedent dry period of at least 72 hours of no rainfall in the catchment.

When conditions are suitable, grab samples of water are collected in laboratory-provided containers from the end of the outfall pipe, or as near as practicable prior to the discharge mixing with seawater, for laboratory analysis (Eurofins) for total arsenic, cadmium, chromium, copper, nickel, lead, and zinc, and oil and grease, suspended solids, pH, polycyclic aromatic hydrocarbons (PAH), and *E. coli*.

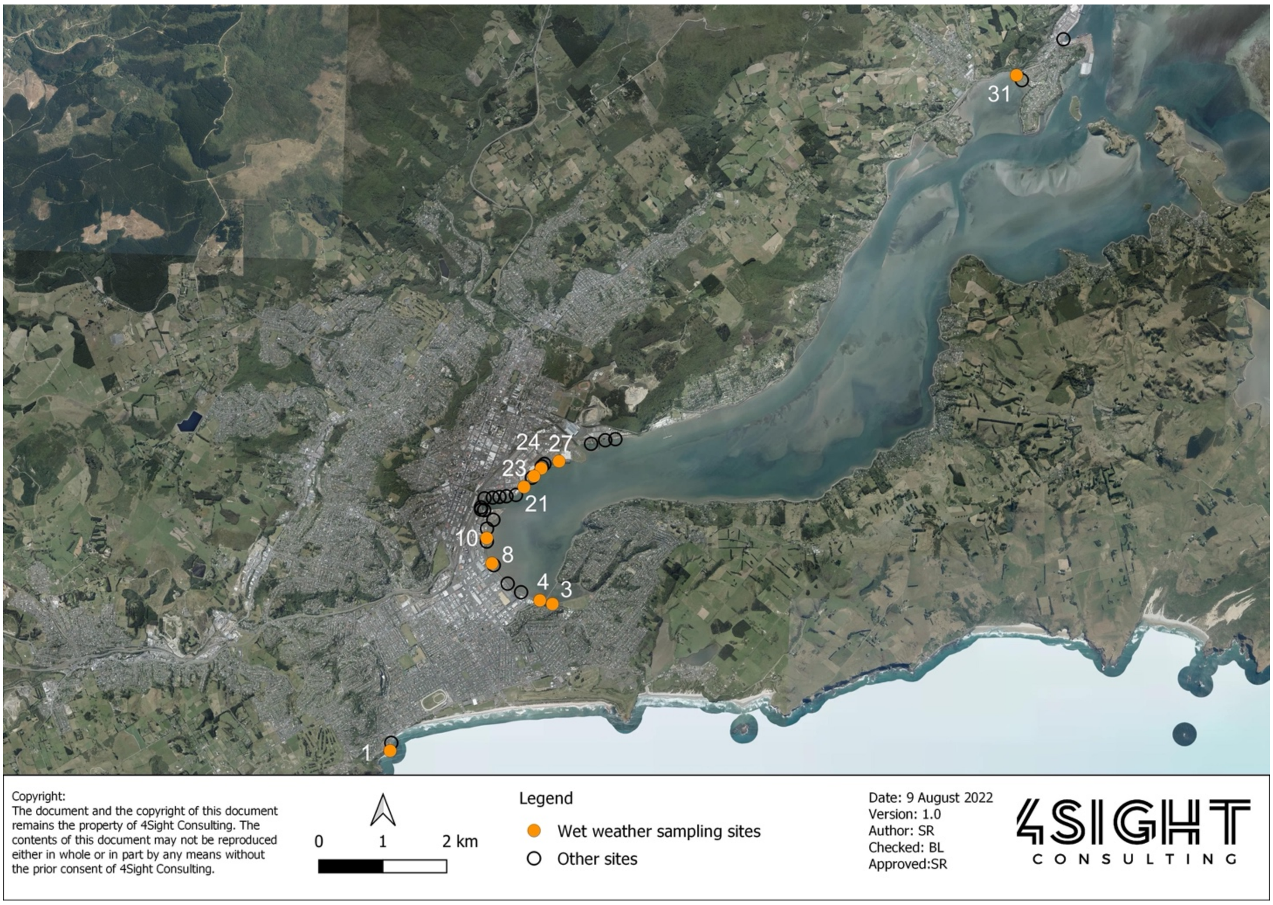

Figure 5: Dunedin stormwater outfalls – wet weather sampling sites (all sites).

Figure 6: Dunedin stormwater outfalls – wet weather sampling sites (upper harbour sites).

3.3 Wet weather stormwater sampling – automated sampler

An ISCO automated sampler is a sampling device used to remotely collect water samples. The sampler is installed next to an opening into the stormwater network (e.g., manhole), and a tube installed from the sampler into the stormwater pipe. When the required conditions are met, the sampler is triggered to collect water samples with a pump used to extract water from the stormwater pipe and fill bottles within the sampling device. Samples from these bottles can then be analysed to provide a contaminant profile through time.

The sampler can only be installed within one stormwater catchment at a time, and is used to target specific outfalls within certain stormwater catchments (South Dunedin, Halsey Street, Shore Street, Kitchener Street and Mason Street catchments), as required by resource consents. Consent conditions require sampling of three storm events per year, with the sampler to be moved yearly such that each catchment is sampled once every five years. However, the sampler has remained at a site longer than one year due to the difficulty in capturing three suitable events (that meet all required conditions) within this period.

Between February 2018 and October 2021, the automated sampler was located near Toitū, approximately 600 m up-pipe of the Mason Street stormwater outfall (Figure 7). Three rain events were captured at this site during this period: February 2019, March 2019, and June 2021. With the third event captured in June 2021, the sampler was to be moved to the next site in the Halsey Street catchment. Installation at the Halsey Street catchment, approximately 75 m up-pipe of a Halsey Steet stormwater outfall (Figure 8), was completed in early December 2021.

The sampler is programmed to collect 1 L water samples every five minutes over the first two-hour period of a rain event (more than 2.5 mm of rain), to provide a contaminant profile across the rain event including the first flush of stormwater. Consent conditions for sample analysis require an antecedent dry period of at least 72 hours of no rainfall in the catchment and no mixing with seawater (i.e., low tide).

When the automated sampler is triggered under suitable conditions, water samples are collected within the sampler's 24 internal 1 L bottles. These bottles need to be emptied within four hours of collection, to ensure the integrity of the samples. Due to the volume of water required for laboratory analysis, samples from two bottles are combined to make one 10-minute sample (12 samples in total over the two-hour rain event), and these samples are transferred into laboratory-provided containers. Following removal of the samples, the internal 1 L bottles are thoroughly rinsed with distilled water and replaced within the sampler, which is reset in preparation for further sampling. Samples are transferred to the laboratory (Eurofins) and analysed for total arsenic, cadmium, chromium, copper, nickel, lead, and zinc, and oil and grease, suspended solids, pH, PAH, and *E. coli*. In addition, FWAs are measured using an AquaFluor handheld fluorometer.

The sampler can be triggered when not all the required conditions have been met, which results in 'false alarms'. False alarms can occur when the sampler is triggered at the time of a higher tide that could result in potential saltwater intrusion into the collected samples, or when the rain event does not continue with sufficient rainfall and the sample bottles do not get filled sufficiently. Other causes for false alarms include malfunctions or maintenance issues with the sampler (e.g., perforated tubing within the sampler, flat battery, errors with communication between sampler and rain gauge). Following false alarms, the sampler is checked, bottles emptied (if required) and rinsed with distilled water, and the sampler reset.

Figure 7: The location of the ISCO automated sampler between February 2018 and October 2021, near Toitū, sampling the Mason Street catchment.

Figure 8: The location of the ISCO automated sampler since December 2021, sampling the Halsey Street catchment.

3.4 Harbour water sampling – dry and wet weather

Monitoring of harbour water quality is undertaken during dry weather and during wet weather (i.e., a rain event). Dry weather sampling allows the determination of background contaminant levels in harbour water, while wet weather sampling assesses the contribution of contaminants from high volume stormwater inputs. Ebb tides (outgoing tides) are likely to move stormwater contaminants down harbour while flood tides (incoming tides) may lead to higher concentrations of stormwater contaminants in the upper harbour. However, inputs from the Water of Leith can complicate contaminant levels, especially during flood tides. The upper harbour basin requires 4 - 6 tidal cycles to flush completely (Smith and Croot 1993, 1994) and therefore contaminants within the upper harbour basin may gradually increase in concentration throughout prolonged wet spells.

Harbour water sampling is required at six sites in the upper harbour (Figure 9) for one dry weather period and for one rainfall event each year. Dry sampling follows high tide and occurs three hours apart on the mid ebb tide and then mid flood tide during a period when there has been no measurable rainfall for at least 72 hours prior to sampling. Wet sampling occurs at the same state of tides as the dry round, no less than three 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.

When conditions are suitable, grab samples of water are collected, from approximately 20 cm below the water surface, in laboratory-provided containers for laboratory analysis (Eurofins) for total cadmium, copper, lead, and zinc and enterococci.

Results for heavy metals are assessed against 2013 trigger levels specified in the consents, which originate from ANZECC (2000) 95% protection trigger values for ‘slightly to moderately disturbed’ ecosystems, with 95% signifying the percentage of species expected to be protected. For marine systems, this ecosystem condition would typically have largely intact habitats and associated biological communities. Examples are marine ecosystems lying immediately adjacent to metropolitan areas, such as Otago Harbour. Trigger values are concentrations that, if exceeded, could indicate a potential environmental problem, and so 'trigger' a management response.

Enterococci is a type of bacteria commonly found in the gut of humans and other warm blooded animals, and is used as an indicator of faecal contamination in marine water. Enterococci have been identified as having the best relationship with health effects in marine waters (MfE 2003). The indicator bacteria themselves do not necessarily pose a significant risk to human health; instead they indicate the presence of faecal material, which contains disease-causing pathogens. Potential sources of enterococci bacteria in Otago Harbour include sewage and faecal deposition by animals (e.g., birds, rodents, domestic pets, livestock). Results for enterococci are compared against MfE (2003) bacteriological 'trigger' values for bathing. In the consent, the trigger value has been set at the 'amber/alert' mode, where if a single sample has greater than 140 cfu/100 mL, a management response is triggered, which includes increased monitoring, investigation of source and risk assessment. Although the upper harbour basin is popular with wind surfers, paddle boarders, and other boat users when conditions permit, it is not a recognised swimming area. Consequently, the alert (amber) limit could be considered conservative and potentially not appropriate for much of the time.

Re-sampling of harbour water is required if trigger levels are exceeded, with re-sampling to be undertaken when the conditions are next suitable.

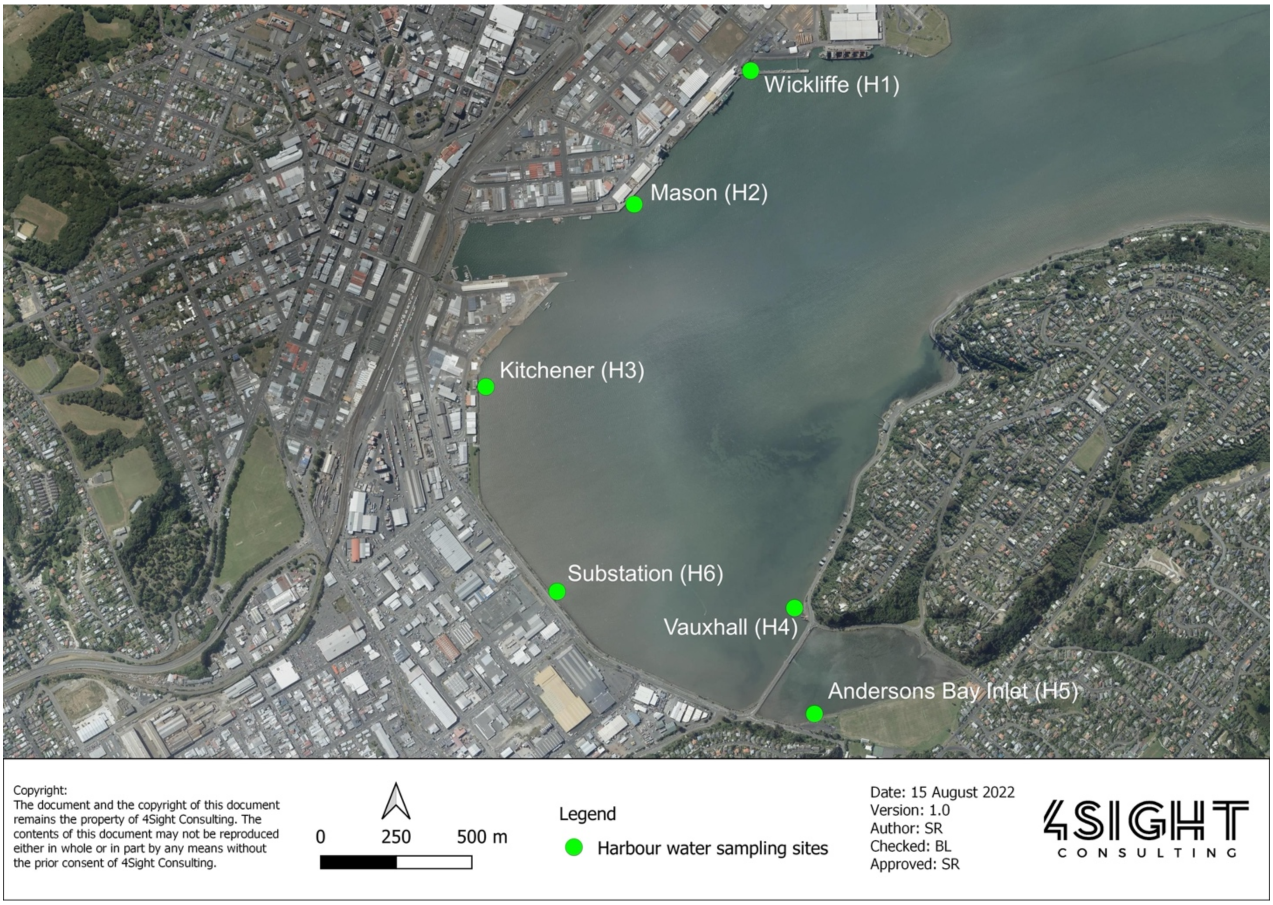

Figure 9: Otago Harbour water quality sampling sites.

3.5 Harbour sediment sampling

Monitoring of harbour sediment quality is undertaken as sediments are a potential source and sink for dissolved contaminants. Assessing sediment quality can identify where contaminant concentrations could result in adverse effects on ecological communities.

Harbour sediment sampling is required once annually at four sites in the upper harbour (Figure 10).

Samples are collected from the uppermost 20 mm of sediment from the area within approximately 20 m from the nearest stormwater outfall. At the Orari Street and Shore Street sites, samples are collected by scooping the top 20 mm of the harbour bed sediment and transferring the sediments into laboratory-provided containers. At the Halsey Street and Kitchener Street sites, sampling is required in deep water (approximately 3-7 m deep). Sediment at these sites is therefore collected using a petit ponar grab, with a subsample obtained from the uppermost 20 mm of the contents of the grab and transferred into laboratory-provided containers. Samples are collected for laboratory analysis (Eurofins) for total arsenic, cadmium, chromium, copper, nickel, mercury, lead, and zinc, and weak-acid extractable (WAE) copper, total petroleum hydrocarbons (TPH), organochlorine pesticides (OCP), and PAH.

Concentrations of contaminants in each sediment sample are assessed against 2013 trigger levels specified in the consents. Total arsenic, cadmium, copper, lead and zinc and PAH trigger levels were determined from the 80th percentile of samples collected to that date. Total chromium and nickel trigger levels originate from ANZECC (2000) interim sediment quality guidelines (ISQG). Trigger values for TPH and WAE copper are yet to be determined, but TPH can be compared with 2018 sediment quality default guideline values (ANZG 2018). ANZECC (2000) ISQG-low values indicate concentrations at which there could be a possible biological effect and is intended as a trigger value for further investigation, whereas ISQG-high values indicate concentrations at which toxic-related adverse effects are expected.

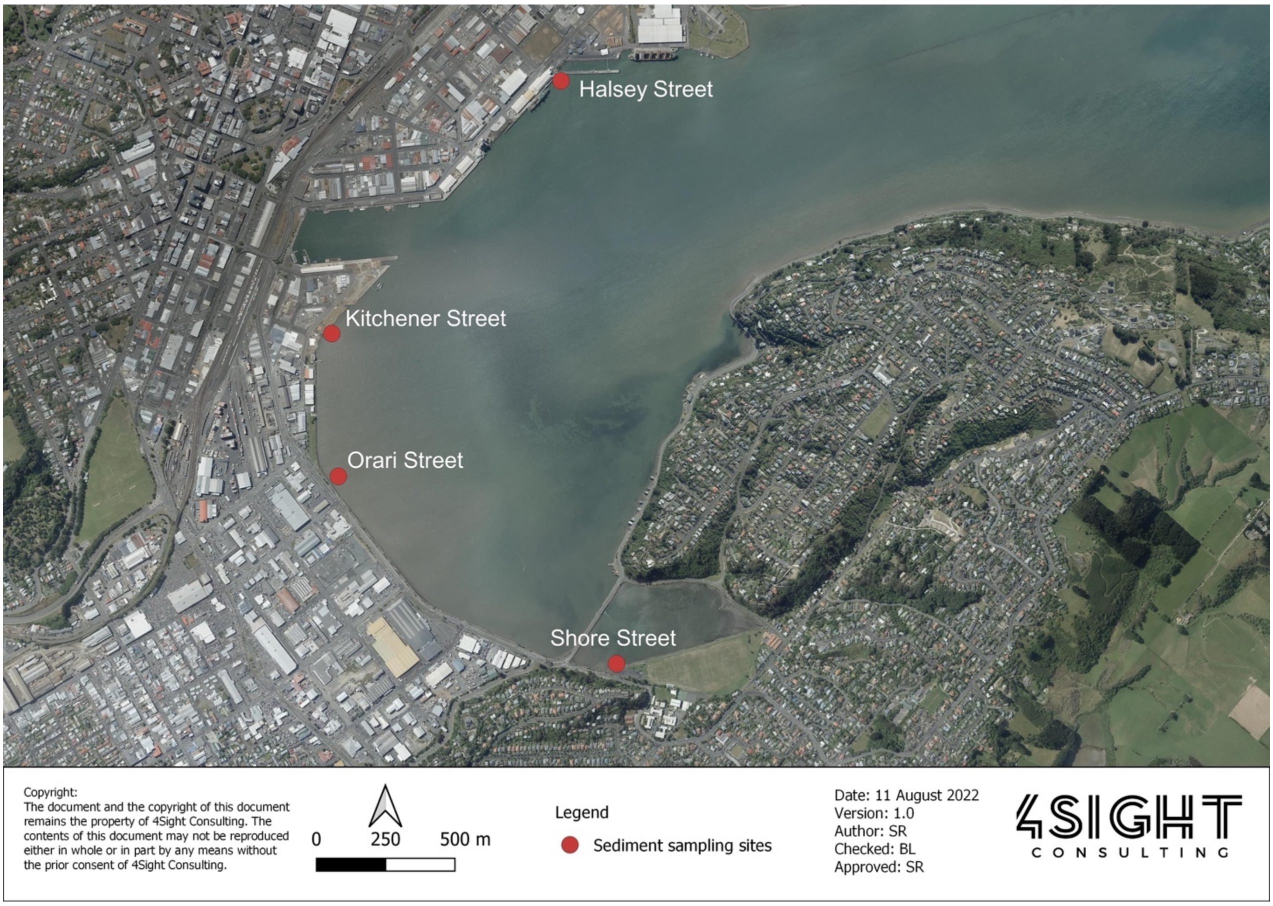

Figure 10: Otago Harbour sediment sampling sites.

3.6 Sampling overview

Table 1 provides an overview of the sampling requirements, parameters, and relevant guidelines, as specified by the consents.

Table 1: Dunedin stormwater sampling requirements.

Sampling type	Requirements	Locations	Parameters	Guidelines (from consents)
Dry weather sampling: outfalls	**Monthly/six-monthly:** Low tide 72 hours dry weather	33 outfalls	*E. coli*, FWA	**MfE (2003):** *E. coli*: 550 cfu/100mL
Wet weather sampling: outfalls	**One rain event per year:** Low tide 72 hours dry weather >2.5 mm rain in first 2 hours	10 outfalls	Total arsenic, cadmium, chromium, copper, nickel, lead, zinc, oil and grease, suspended solids, pH, PAH, *E. coli*	–
Wet weather sampling: automated sampler	**Three rain events per year:** Low tide 72 hours dry weather >2.5 mm rain in first 2 hours	Currently at Halsey Street site	Total arsenic, cadmium, chromium, copper, nickel, lead, zinc, oil and grease, suspended solids, pH, PAH, *E. coli*	–
Harbour water	**One rain event and one dry weather period per year:** 72 hours dry weather Incoming and outgoing tide Rain event: >2mm rain	6 sites	Total cadmium, copper, lead, zinc, enterococci	**2013 trigger levels (from ANZECC 2000):** Cadmium: 0.0055 g/m^3 Copper: 0.0013 g/m^3 Lead: 0.0044 g/m^3 Zinc: 0.015 g/m^3 **MfE (2003):** Enterococci: 140 cfu/100mL
Harbour sediments	**Once per year (between January and June):** Low tide (required for access)	4 sites	Total arsenic, cadmium, chromium, copper, nickel, mercury, lead, zinc, WAE copper, TPH, OCP, PAH	**2013 trigger levels (from 80th percentile of previous samples):** Arsenic: 19 mg/kg Cadmium: 1.7 mg/kg Copper: 122 mg/kg Lead: 209 mg/kg Zinc: 902 mg/kg PAH: 183 mg/kg **ANZECC (2000) ISQG-Low:** Chromium: 80 mg/kg Mercury: 0.15 mg/kg Nickel: 21 mg/kg

4 RESULTS AND DISCUSSION

4.1 Stormwater – Dry weather

4.1.1 Sampling results

Dry weather sampling of stormwater outfalls was undertaken under the required weather and tidal conditions during eight of the twelve months: July, October, November, and December 2021, and January, March, April, and June 2022 (see Appendix B). Dry weather sampling could not be undertaken in other months between July 2021 and June 2022 due to weather conditions not being suitable (e.g., no antecedent dry period of at least 72 hours) and/or tidal conditions not being suitable for sampling (e.g., low tide in the middle of the night, or low tides not suitable for accessing outfalls).

Most of the stormwater outfalls sampled had concentrations of *E. coli* that exceeded the consented trigger level (550 cfu/100 mL) on at least one occasion during the monitoring period (Table 2). Outfalls 9 (Portsmouth Drive catchment), 11 and 12 (Kitchener Street catchment), 28 and 29 (Ravensbourne catchment), and 31 and 32 (Port Chalmers catchment) were the only outfalls sampled that did not exceed the trigger level. Of these outfalls, 9, 11, 28, and 29 are only sampled on a six-monthly basis. Outfall 2 is also sampled six-monthly, but there was no flow at this site when this was last undertaken. Similarly, outfalls 13-22 are only to be sampled on a six-monthly basis, but there is no access to these outfalls. However, due to the small size of the receiving catchments for these outfalls, there is not expected to be any flow under dry conditions.

Outfalls 1 (St Clair catchment), 3 (Shore Street catchment), 4 (South Dunedin catchment), 5 (Portsmouth Drive catchment), 10 (Kitchener Street catchment), 24, 25 and 27 (Halsey Street catchment), and 33 (Port Chalmers catchment) all had *E. coli* concentrations that exceeded the trigger level on three consecutive sampling rounds (Table 2). As dry weather sampling was not able to be undertaken every month, only outfalls 25, 27, and 33 actually had concentrations above the trigger level on three consecutive months.

FWA concentrations were variable at the stormwater outfalls, with only outfalls 5 (Portsmouth Drive catchment) and 30 (Ravensbourne catchment) having elevated FWA concentrations on multiple occasions during the 2021-22 monitoring period. This indicates that possible cross-connections between stormwater and wastewater systems are unlikely.

Overall, over the 2021-22 monitoring period, dry weather sampling at stormwater outfalls revealed several outfalls with elevated *E. coli* concentrations on multiple occasions. According to the consent conditions, if the *E. coli* concentration in samples from three consecutive months is greater than the trigger level, the consent requires investigation and remedial action, if required.

4.1.2 Future

It is important to note that the *E. coli* trigger level for this dry weather sampling is based on MfE guidelines for recreation, with results above the trigger level indicating water is considered unsafe for swimming. The dry weather sampling is useful to assist with determining whether there are any cross-connections between stormwater and wastewater systems, however as recreation/bathing would not be undertaken within the stormwater pipes, it is arguable whether this sampling is useful for determining whether the water poses a health risk for bathing; harbour water quality sampling would be more useful for determining any health risks for bathing associated with any dry-weather discharges from the stormwater outfalls.

It could be worthwhile to review the sampling regime for dry weather monitoring, to remove the requirement for sampling of some outfalls. These could be outfalls where there has consistently been no indicators of wastewater in previous sampling or frequently contain no flowing water (e.g., outfalls 12, 26, 32), or are sampled six-monthly (due to previously been found to have no indicators of wastewater or be frequently dry) and are consistently dry during dry weather (e.g., outfall 2, 9, 11, outfalls 13-22 which are also inaccessible).

Table 2: *E. coli* dry weather sampling results between July 2021 and June 2022, compared with the *E. coli* trigger level of 550 cfu/100mL (MfE (2003) action (red) limit). Grey cells: no sampling or no access or no flow. Green cells: results below trigger levels. Red cells: results above trigger levels.

Outfall	Location	Frequency	Jul 2021	Oct 2021	Nov 2021	Dec 2021	Jan 2022	Mar 2022	Apr 2022	Jun 2022
1	Second Beach	Monthly								
2	St Clair Beach	Six-monthly								
3	Shore Street	Monthly								
4	Portobello Road	Monthly								
5	Teviot Street	Monthly								
6	Midland Street	Monthly								
7	Orari Street	Monthly								
8	Orari Street	Monthly								
9	Kitchener Street	Six-monthly								
10	Kitchener Street	Monthly								
11	French Street	Six-monthly								
12	Kitchener Street	Monthly								
13-22	Birch, Wharf, Fryatt, Mason, Bauchop Streets	Six-monthly								
23	Bauchop Street	Monthly								
24	Halsey Street	Monthly								
25	Halsey Street	Monthly								
26	Halsey Street	Monthly								
27	Wickliffe Street	Monthly								
28	Magnet Street	Six-monthly								
29	Magnet Street	Six-monthly								
30	Ravensbourne Road	Monthly								
31	George Street / SH88	Six-monthly								
32	Sawyers Bay, Watson Park	Monthly								
33	George Street (Port Otago)	Monthly								

4.2 Stormwater – Wet weather

Between July 2021 and June 2022, the conditions required to undertake wet weather sampling at stormwater outfalls (i.e., at low tide, within two hours of the commencement of a rain event (more than 2.5 mm of rain), and following an antecedent dry period of at least 72 hours of no rainfall in the catchment), were not met within daylight hours (required for safety reasons). There were therefore no suitable occasions for wet weather sampling to be completed in 2021-22. There have not been suitable conditions for sampling for several years, given the difficulty in having all conditions coinciding with daylight hours to allow safe sampling of the outfalls. Given the difficulty in meeting the required conditions, consideration should be given to reducing the length of the antecedent dry period in an effort to capture a rain event.

4.3 Automated sampler – Wet weather

4.3.1 Sampling results

The automated sampler was successfully triggered and captured two rain events at the Halsey Street site, where it has been located since October 2021. Despite sampling of wet weather events not being undertaken between July 2021 and June 2022, the automated sampler can capture events at all times of the day and night and captured events on 12 April 2022 (9.1 mm total rainfall) and 21 April 2022 (4 mm total rainfall) (Figure 11, Figure 12 and Figure 13). See Appendix C for results tables for these sampling events.

During both rain events, concentrations of cadmium and PAH were all below laboratory detectable limits for the duration of each event (Appendix C). pH levels were relatively stable, and between 6.5 and 7.7 during the first rain event, and between 6.3 and 7.5 during the second rain event (Figure 11). Suspended solids concentrations were elevated during both events, with the 12 April event having a high peak in concentrations (805 g/m^3) 60 minutes into the rain event, while the 21 April event had a much lower peak in concentrations (311 g/m^3) within the first 30 minutes of the event. The intensity, and amount, of rainfall during a rain event can influence the timing and extent of any peaks in contaminant concentrations – shorter, more intense rain events can have high peaks in concentrations, compared with longer and less intense rain events. As the automated sampler collects stormwater during the first two hours of a rain event, the difference in timing of peak concentrations is influenced by the initial intensity of rainfall. For the 12 April events, approximately 8.3 mm of rain fell within the first two hours of the event (total rainfall during the event of 9.1 mm), while the 21 April event had only approximately 3.5 mm in the first two hours (total rainfall 4 mm).

Concentrations of oil and grease followed a similar pattern to suspended solids during each event, however the earlier (30 minute) peak during the 21 April event had similar concentrations as the later (60 minute) peak during the 12 April event (Figure 11). Interestingly, both rain events had further elevations in oil and grease concentrations after the initial peaks, with the 21 April concentration approaching the initial peak concentration. Concentrations of faecal indicator bacteria, *E. coli*, also had two peaks during the 21 April event (Figure 11). Concentrations were very high at the first (420,000 cfu/100mL) and second (310,000 cfu/100mL) peaks, but dropped to much lower concentrations (4,000 cfu/100mL) between the peaks and after the second peak (Figure 11). These results could be influenced by the introduction of contaminants (e.g., from runoff from roads and/or industrial yards) into the stormwater at different times during the rain event, which could be due to different rain intensity during the rain events and/or differing rain intensities in different areas of the stormwater catchment. Unfortunately, laboratory analysis for *E. coli* during the 12 April rain event did not allow for very high concentrations, with a maximum of 8,000 cfu/100mL, which was exceeded in each sample collected over the rain event.

Concentrations of metals all followed similar patterns to suspended solids, with peak concentrations 60 minutes into the 12 April rain event and 30 minutes into the 21 April rain event (Figure 12 and Figure 13). Zinc concentrations were the highest of the metals during both events, followed by lead and copper, with chromium, nickel, and arsenic concentrations being the lowest of the metals. Common sources of zinc include tyre wear and roofing materials, lead sources include paints and contaminated soil, and copper sources include dust from wear of vehicle brake linings, building/roofing materials and industrial activities. Many of these contaminants can accumulate on impervious surfaces, with the length of the antecedent dry period influencing the amount of build-up on surfaces and therefore influencing 'first flush' concentrations.

4.3.2 Comparison with previous events

To compare the April 2022 rain events with previous wet weather sampling, undertaken in the Mason St catchment, maximum contaminant concentrations can be compared (Table 3). While the peak concentrations might not necessarily be at the same time during each event, comparison of the peak concentration is useful to determine how any 'pulse' of contaminants into the harbour during the peak of the rain events compares between catchments.

Overall, peak concentrations of the metals chromium, lead, and zinc, and concentrations of the faecal indicator bacteria *E. coli*, were higher during the April 2022 rain events in the Halsey Street catchment than during previous rain events in the Mason Street catchment. However, concentrations of oil and grease were lower in the Halsey Street events than in the Mason Street events. The composition of land uses in the different stormwater catchments would influence these results, as well as other influences such as the length of the antecedent dry period prior to each rain event and the intensity of rain during each event.

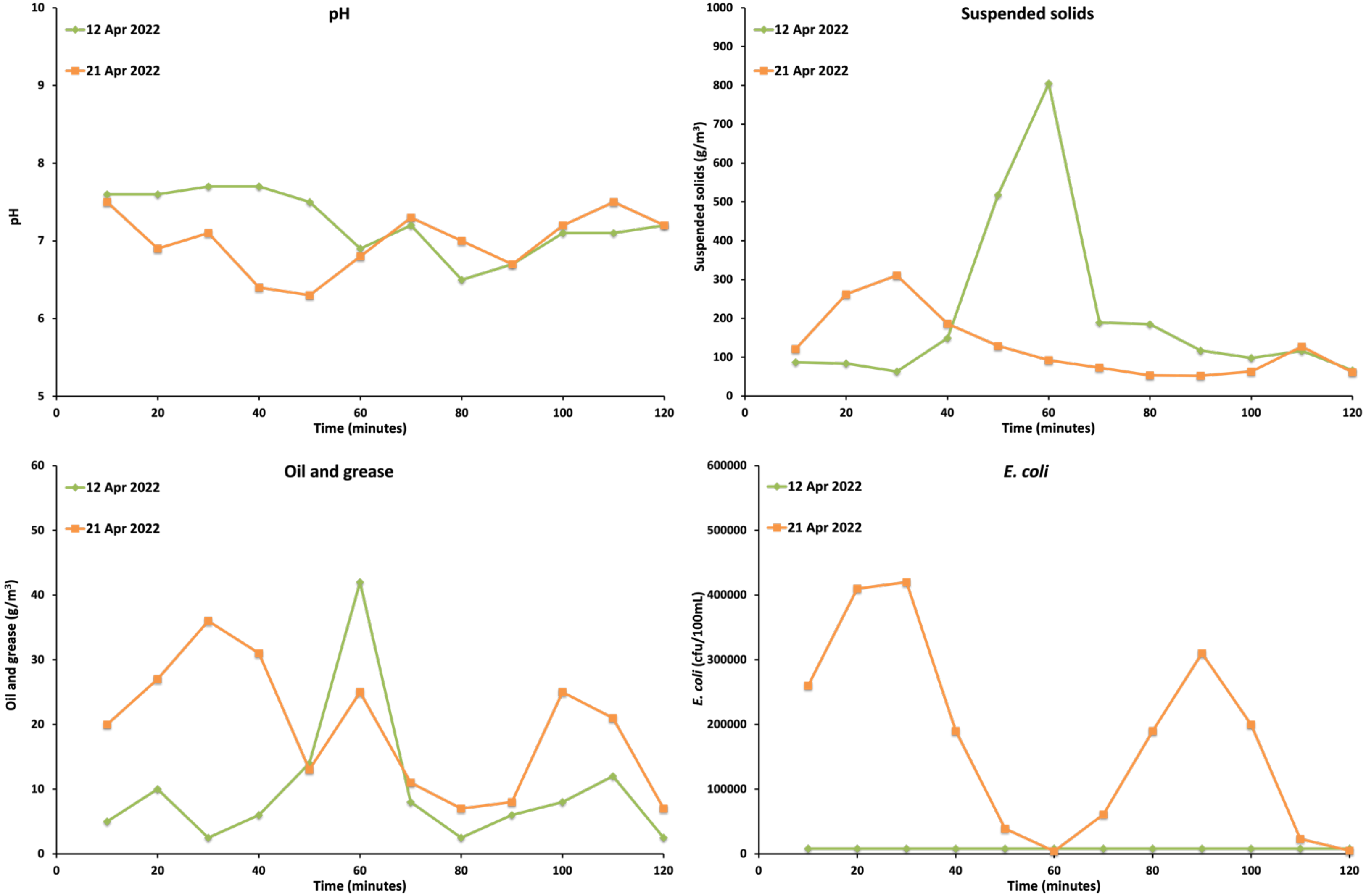

Figure 11: Contaminant concentrations collected during April 2022 rainfall events by the ISCO automated sampler in the Halsey Street stormwater catchment.

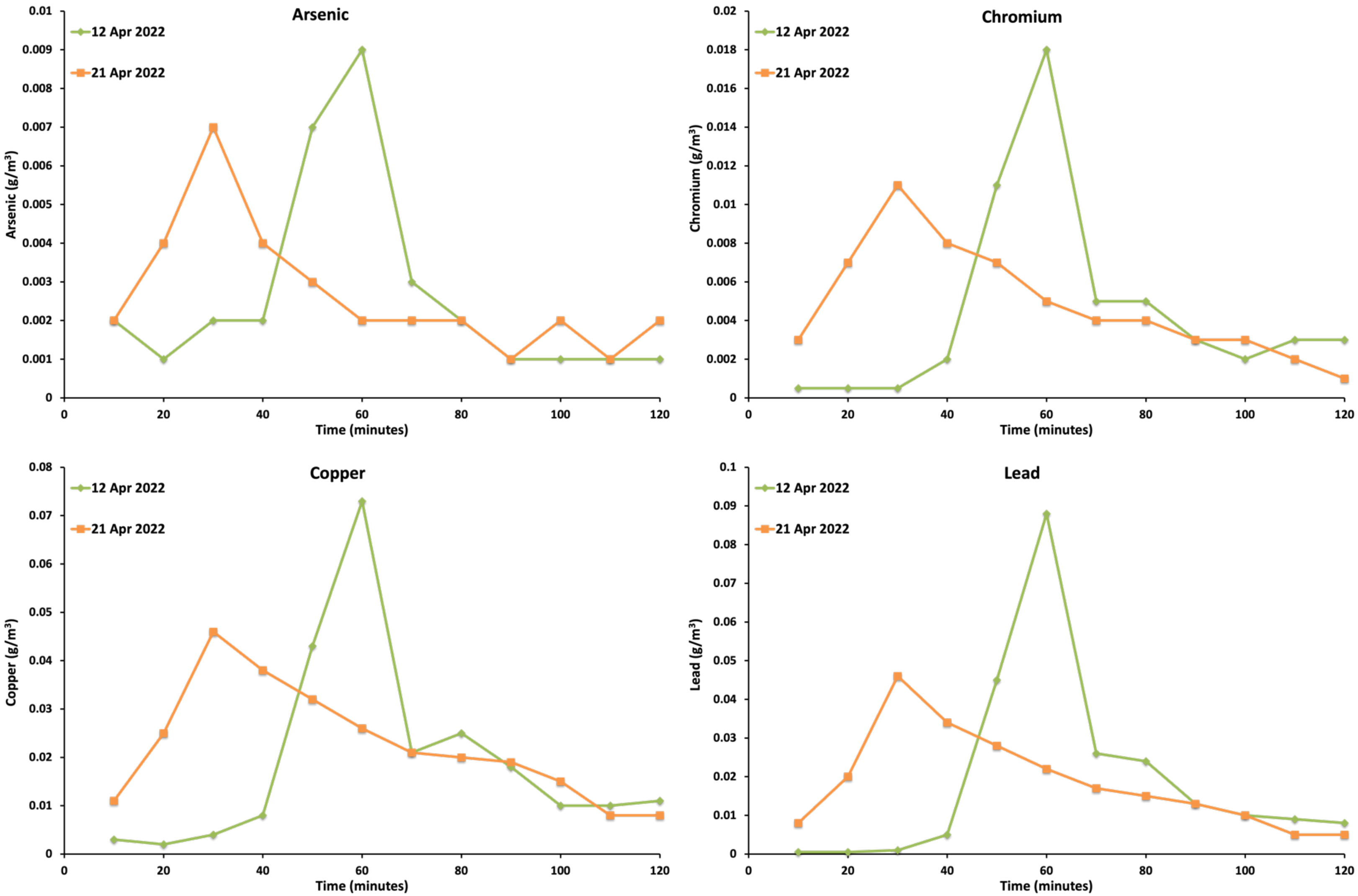

Figure 12: Contaminant concentrations collected during April 2022 rainfall events by the ISCO automated sampler in the Halsey Street stormwater catchment.

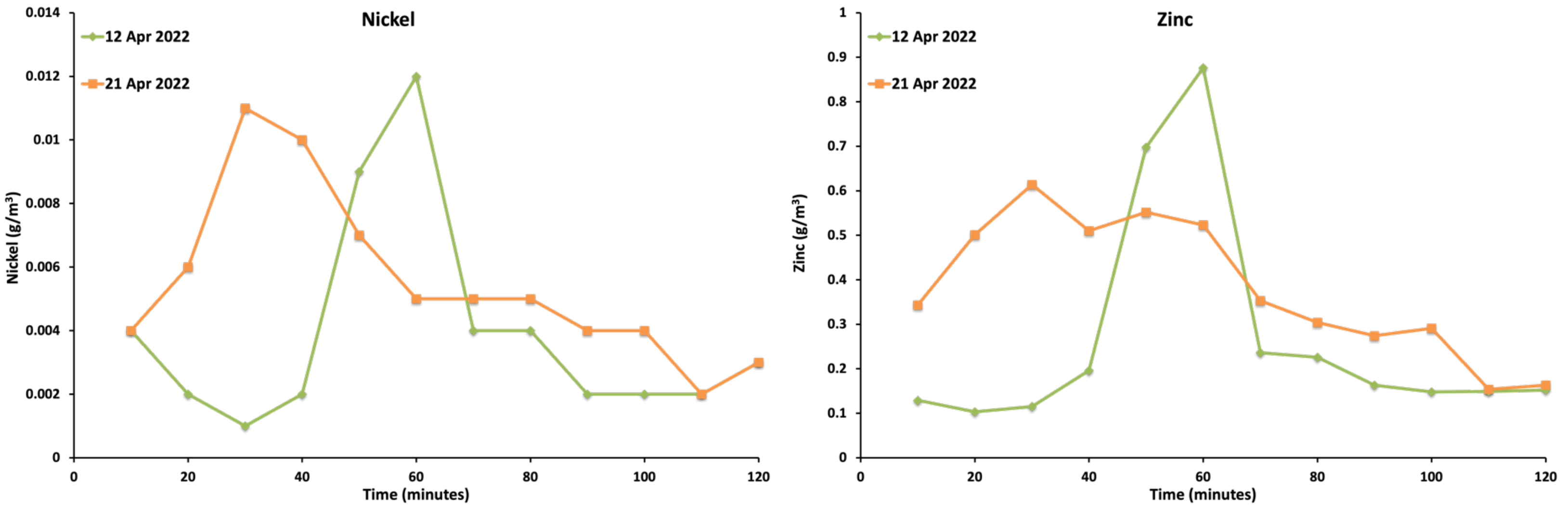

Figure 13: Contaminant concentrations collected during April 2022 rainfall events by the ISCO automated sampler in the Halsey Street stormwater catchment.

Table 3: Maximum contaminant concentrations collected during rainfall events by the ISCO automated sampler in the Mason and Halsey Street stormwater catchments, 2019 to 2022. ‘< value’ indicates all concentrations below laboratory detection limits. ‘> value’ indicates concentrations above laboratory range for test.

Rainfall event	pH	Total suspended solids (g/m^3)	Oil and grease (g/m^3)	Arsenic (g/m^3)	Cadmium (g/m^3)	Chromium (g/m^3)	Copper (g/m^3)	Lead (g/m^3)	Nickel (g/m^3)	Zinc (g/m^3)	*E. coli* (cfu/100mL)	PAH (mg/L)
Mason Street: 25 February 2019 5.2 mm rain	-	-	9	0.003	<0.001	0.003	<0.002	<0.001	0.006	0.031	420	<0.0051
Mason Street: 26 March 2019 6.4 mm rain	7.9	246	92	0.005	<0.001	0.006	0.003	<0.001	0.003	0.152	2,600	<0.0051
Mason Street: 10 June 2021 2.6 mm rain	7.5	83	156	<0.002	<0.001	0.006	0.028	0.02	0.007	0.37	16,200	<0.0051
Halsey Street: 12 April 2022 9.1 mm rain	7.7	805	42	0.009	<0.001	0.018	0.073	0.088	0.012	0.876	> 8000	<0.0051
Halsey Street: 21 April 2022 4 mm rain	7.5	311	36	0.007	<0.001	0.011	0.046	0.046	0.011	0.614	420,000	<0.0051

4.3.3 False alarms

Monitoring of the automated sampler includes monitoring for 'false alarms', which occur when the sampler is triggered when a rainfall event starts, but the event ends up not being suitable for sampling as the required conditions have not all been met. This often occurs when rainfall intensity is high at the start of an event, but then rain stops after only a short period of time, and also when rainfall starts at high tide, and thus the sampler would collect harbour water that had entered the stormwater pipes.

Following the capture of the final rain event at the Mason Street site, in June 2021, there were nine false alarms until the automated sampler was removed from the site in preparation for installing at the Halsey Street site. Following the installation of the automated sampler at the Halsey Street site in December 2021, and up to the end of June 2022, the sampler had been incorrectly triggered on 17 occasions.

4.3.4 Future

The ISCO automated sampler has been located within the Halsey Street catchment since early December 2021. Consent conditions require sampling of three rain events per year, with the sampler to be moved yearly such that each of the specified catchments is sampled once every five years. However, only the two April 2022 rain events have been captured at the Halsey Street catchment site, and the sampler should therefore remain at the current site until a third rain event is captured.

The stormwater catchments where the automated sampler is required to capture rain events are the South Dunedin, Halsey Street, Shore Street, Kitchener Street and Mason Street catchments. The automated sampler has been in the South Dunedin catchment (2014 to 2015), the Shore Street catchment (2015 to 2016), the Kitchener Street catchment (2016 to 2018), the Mason Street catchment (2018 to 2021), and the Halsey Street catchment (since December 2021). Following the conclusion of the deployment at the Halsey Street catchment site, the automated sampler can be re-deployed in the other catchments, potentially starting with the South Dunedin catchment (to retain the same order as previous deployments).

4.4 Harbour water

4.4.1 Sampling results – wet weather

Harbour water sampling can be used to determine the effects of stormwater discharges on water quality in Otago Harbour, and sampling during both a rain event and during a dry period each year allows comparison of results under the different conditions.

Wet weather sampling was undertaken on 12 April 2022. On the mid-ebb tide (i.e., outgoing tide), cadmium and lead concentrations at all six sites were lower than laboratory detection limits (Table 4). Copper concentrations were lower than laboratory detection limits at four sites, but were above the consent trigger level at the Substation and Andersons Bay Inlet sites. Zinc concentrations were all below laboratory detection limits except at the Wickliffe site, while concentrations of the faecal indicator bacteria enterococci were above trigger levels at the Wickliffe and Vauxhall sites.

On the mid-flood tide (i.e., incoming tide), cadmium concentrations at all six sites were lower than laboratory detection limits (Table 4). Copper and lead concentrations were lower than laboratory detection limits at Wickliffe, Mason, and Kitchener sites, but copper concentrations at the Substation, Vauxhall, and Andersons Bay Inlet sites were above the consented trigger level. Zinc concentrations at all six sites were above the trigger level, while enterococci concentrations at all sites except Kitchener were also above the consented trigger level.

As trigger levels were exceeded for copper, zinc, and enterococci at different sites, re-sampling for these contaminants during similar weather conditions was required. However, suitable weather conditions did not coincide with the required tidal conditions to allow re-sampling. As each rain event can be very different, re-sampling the next suitable event is unlikely to replicate the same conditions as the initial sampling. Subsequently, sampling the next suitable rain event, even during the next year, will allow useful comparison of contaminant inputs into the harbour during rain events.

Table 4: Harbour water sampling data from a wet weather sampling event on 12 April 2022. Blue cells indicate values exceed trigger levels.

	Wet weather – sampling: 12 April 2022				
	Cadmium (g/m³)	**Copper (g/m³)**	**Lead (g/m³)**	**Zinc (g/m³)**	**Enterococci (cfu/100mL)**
Trigger levels	0.0055[1]	0.0013[1]	0.0044[1]	0.015[1]	140[2]
Mid-ebb tide					
Wickliffe (H1)	<0.001	<0.002	<0.001	0.025	420
Mason (H2)	<0.001	<0.002	<0.001	0.011	10
Kitchener (H3)	<0.001	<0.002	<0.001	0.010	< 10
Substation (H6)	<0.001	0.002	<0.001	0.013	< 10
Vauxhall (H4)	<0.001	<0.002	<0.001	0.008	270
Andersons Bay Inlet (H5)	<0.001	0.002	<0.001	0.014	110
Mid-flood tide					
Wickliffe (H1)	<0.001	<0.002	<0.001	0.026	3,900
Mason (H2)	<0.001	<0.002	<0.001	0.024	900
Kitchener (H3)	<0.001	<0.002	<0.001	0.018	40
Substation (H6)	<0.001	0.002	0.001	0.245	460
Vauxhall (H4)	<0.001	0.002	0.001	0.054	2,100
Andersons Bay Inlet (H5)	<0.001	0.002	0.001	0.027	460

1. ANZECC (2000) trigger values for protection of 95% of species (from resource consent).
2. MfE (2003) alert (amber) limit (from resource consent). The alert (or amber) mode is triggered when a single sample is greater than 140 enterococci per 100 mL for marine waters.

4.4.2 Sampling results – dry weather

Dry weather sampling was undertaken on 20 April 2022. On the mid-ebb tide, cadmium concentrations at all six sites were lower than laboratory detection limits (Table 5). Copper concentrations exceeded trigger values at the Kitchener, Substation, Vauxhall, and Anderson's Bay Inlet sites. Concentrations of lead at the Substation site, and zinc at the Substation and Vauxhall sites, exceeded trigger levels, however all other sites had low concentrations. Enterococci concentrations were low at all six sites.

On the mid-flood tide, cadmium concentrations at all six sites were lower than laboratory detection limits, while copper concentrations exceeded trigger levels at all sites (Table 5). Lead concentrations exceeded trigger levels at the Substation and Andersons Bay Inlet sites, while zinc exceeded trigger levels at all sites except the Mason and Vauxhall sites. Enterococci concentrations exceeded the trigger level at the Wickliffe and Substation sites.

As trigger levels were exceeded for copper, lead, zinc, and enterococci at different sites, re-sampling for these contaminants during similar weather conditions was required. However, there were no suitable occasions with the required conditions to complete re-sampling.

Table 5: Harbour water sampling data from a dry weather sampling event on 20 April 2022. Blue cells indicate values exceed trigger levels.

	Dry weather – sampling: 20 April 2022				
	Cadmium (g/m³)	**Copper (g/m³)**	**Lead (g/m³)**	**Zinc (g/m³)**	**Enterococci (cfu/100mL)**
Trigger levels	0.0055[1]	0.0013[1]	0.0044[1]	0.015[1]	140[2]
Mid-ebb tide					
Wickliffe (H1)	<0.001	<0.002	<0.001	0.009	30
Mason (H2)	<0.001	<0.002	<0.001	0.011	< 10
Kitchener (H3)	<0.001	0.003	0.001	0.012	10
Substation (H6)	<0.001	0.004	0.007	0.024	40
Vauxhall (H4)	<0.001	0.002	<0.001	0.063	50
Andersons Bay Inlet (H5)	<0.001	0.004	0.002	0.014	80
Mid-flood tide					
Wickliffe (H1)	<0.001	0.004	<0.001	0.026	150
Mason (H2)	<0.001	0.004	<0.001	0.010	20
Kitchener (H3)	<0.001	0.007	0.004	0.030	20
Substation (H6)	<0.001	0.022	0.028	0.180	320
Vauxhall (H4)	<0.001	0.006	0.002	0.010	10
Andersons Bay Inlet (H5)	<0.001	0.014	0.017	0.080	30

1. ANZECC (2000) trigger values for protection of 95% of species (from resource consent).
2. MfE (2003) alert (amber) limit (from resource consent). The alert (or amber) mode is triggered when a single sample is greater than 140 enterococci per 100 mL for marine waters.

4.4.3 Dry weather and rain event comparison

Dry weather sampling results from 2022 indicate background contaminant levels in harbour water without any influence from high volume stormwater inputs that occur during a rainfall event. Copper and zinc concentrations exceeded the consented trigger levels at the most sites during the mid-flood tide, which is when contaminants in harbour water would be moved into the upper harbour rather than out towards the harbour mouth. Previous sampling of harbour water has also found elevated copper concentrations at most sites during dry weather sampling, with elevated zinc concentrations more variable by site and year. Common sources of copper include dust from wear of vehicle brake linings that have accumulated on impervious surfaces, copper building materials such as roofs, spouting and cladding, and a range of agricultural and industrial activities. Common sources of zinc include tyre wear and zinc-coated roofing materials.

Comparing contaminant concentrations during rain events and dry weather reveals the relative inputs of contaminants during the different weather types. Figure 14 and Figure 15 display contaminant concentrations from sampling undertaken between 2017 and 2022, with results only shown where concentrations were above laboratory detection limits. The comparison indicates that copper concentrations are frequently higher during dry weather conditions than during rain events, while there are no obvious patterns with zinc concentrations, with similarly high concentrations irrespective of weather conditions (Figure 14). Lead concentrations are higher in harbour water during dry weather conditions, with only a few results from rain event sampling being above laboratory detection limits (Figure 15). Conversely, enterococci concentrations are higher during rain events, although there have been some high sampling results during dry conditions.

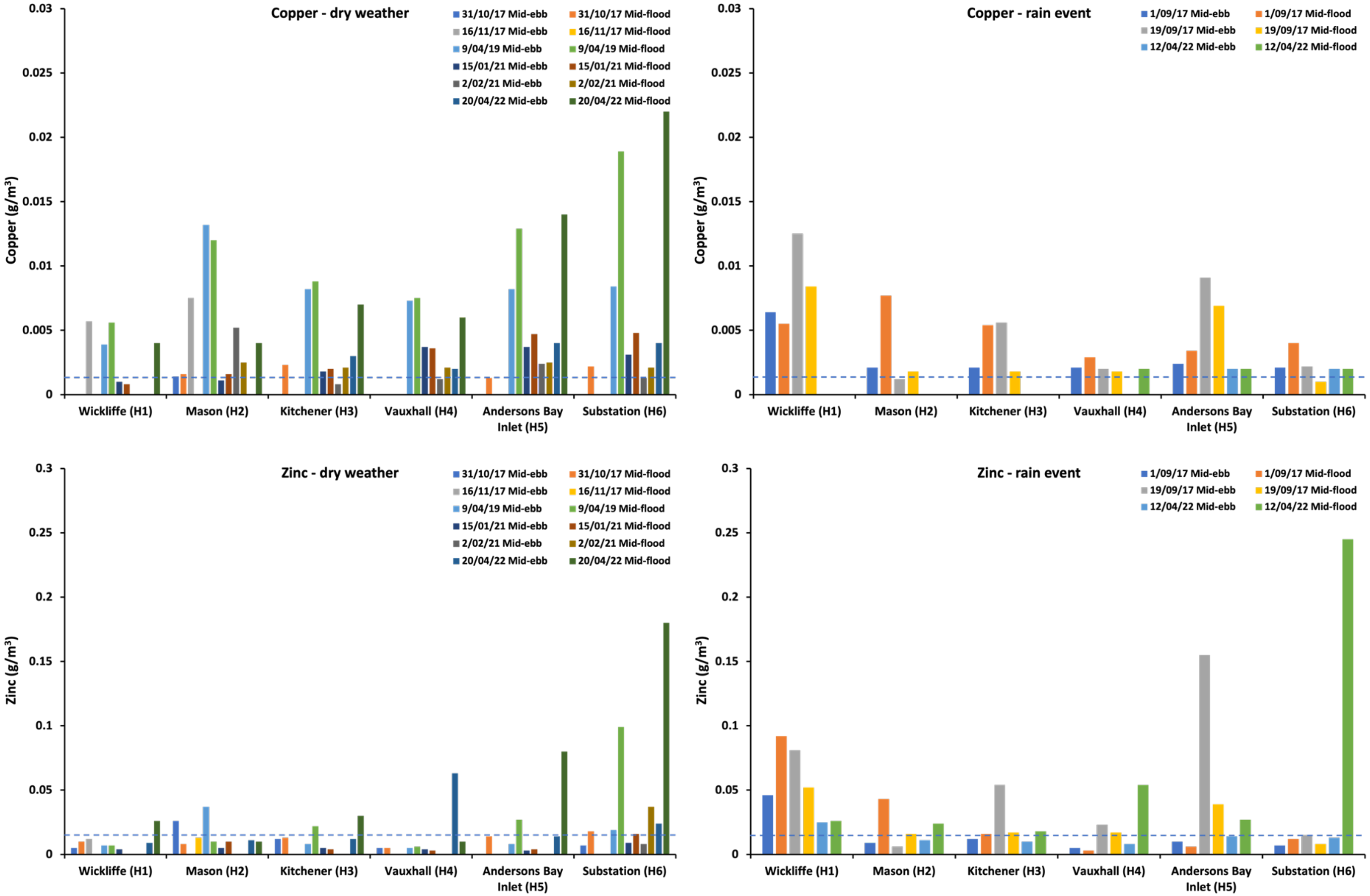

Figure 14: Contaminant concentrations in harbour water during dry weather and rain events, 2017-2022. Dashed lines indicate consent trigger levels.

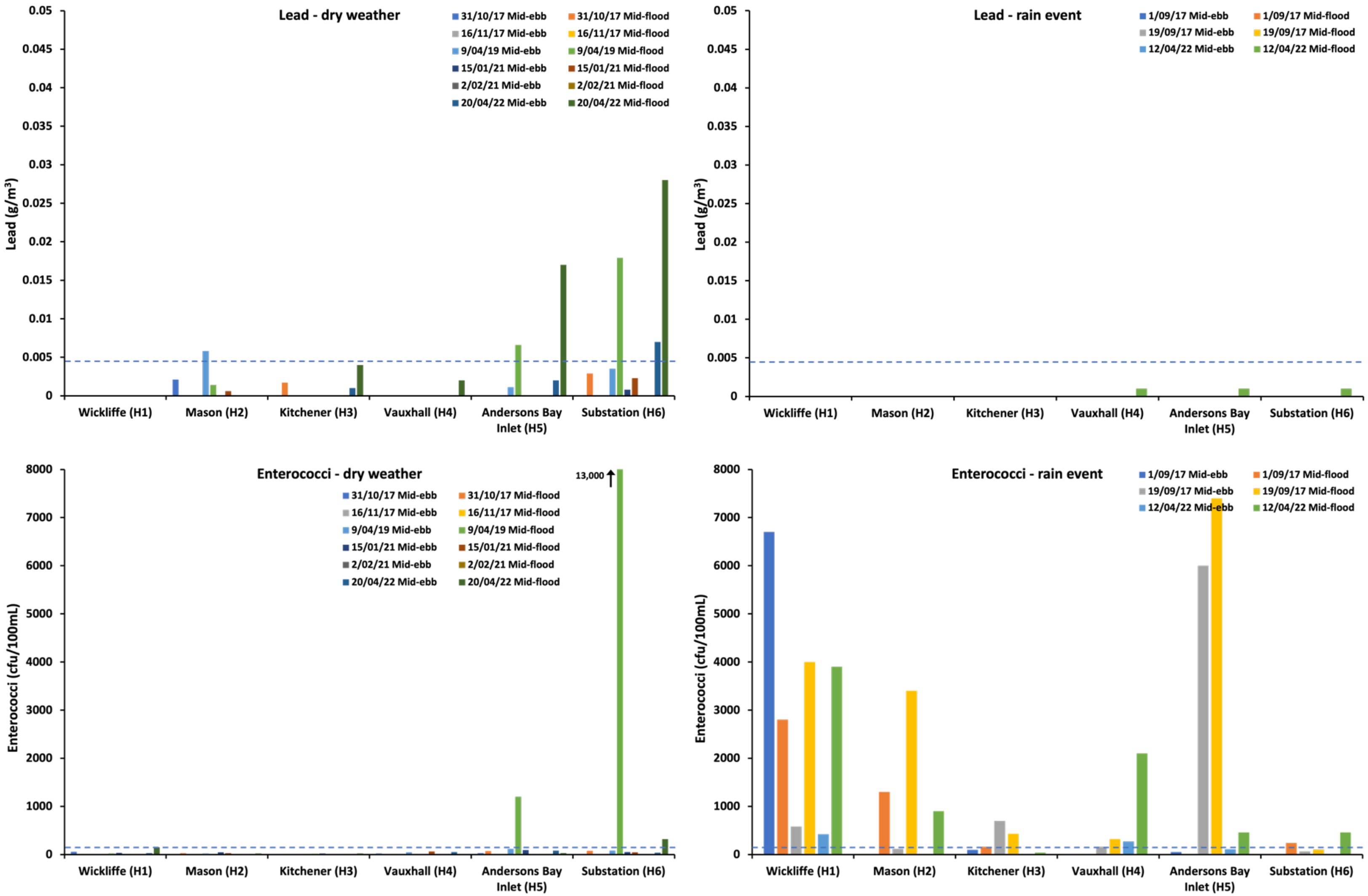

Figure 15: Contaminant concentrations in harbour water during dry weather and rain events, 2017-2022. Dashed lines indicate consent trigger levels.

4.5 Harbour sediment

4.5.1 Sampling results

Sampling of harbour sediment quality was undertaken at the four upper harbour sites on 18 May 2022 . See Appendix D for a results table for this sampling.

Contaminant concentrations in harbour sediments at all sites were below the 2013 trigger levels listed in the resource consent (where applicable; Appendix D). The ANZECC (2000) ISQG-Low guideline levels were exceeded for lead (Orari Street and Shore Street), zinc (Kitchener Street and Shore Street) and PAH (Orari Street and Shore Street), but contaminant concentrations were well below the ISQG-High levels at all sites. The ISQG-Low represents the threshold for potential effects to occur and is a trigger for further investigation, while the ISQG-High represents a point where a high probability of effects is possible. These results are all the same as found from the 2021 sampling, except in 2021 PAH concentrations at the Kitchener Street site exceeded the ISQG-Low guideline levels rather than at the Orari Street site.

ANZECC (2000) guidelines, specified in the consents, do not provide guideline values for WAE copper, OCP and TPH. However, 2018 sediment quality default guideline values (DGV) (ANZG 2018) are available for TPHs (DGV 280 mg/kg, DGV-high 550 mg/kg) and individual OCPs (DGV range from 900-4500 mg/kg). TPH (less than laboratory detection limits, <35 mg/kg) and total OCP (less than laboratory detection limits, <0.75 mg/kg) concentrations were all low in 2022, and considerably lower than the relevant ANZG (2018) DGVs.

Overall, sediment sampling in 2022 found generally similar concentrations at all four sites as in recent years, and there are no obvious patterns in concentrations through time (Figure 16, Figure 17, and Figure 18). Some variation is expected between years, due to movement and disturbance/redistribution of sediments, and elevated concentrations at some sites should not be cause for immediate alarm. For instance, in 2022, the zinc concentration at Shore Street was the highest found in recent years. However, a high PAH concentration of approximately 143 mg/kg at Orari Street in 2018 was followed by much lower concentrations in 2019 (below laboratory detection limits), and a high mercury concentration at Halsey Street in 2017 has since been followed by much lower concentrations.

Contaminant concentrations in sediments in recent years have been considerably lower than at some historic sites. For instance, Kitchener Street's catchment has historically included a scrap metal yard and a sandblasting operation, with high metal contaminants, while other sites have historically been influenced by the old gas works, which contributed high PAH concentrations to stormwater. Improvements in wastewater/stormwater connections and the cessation of many industrial activities have reduced many sources of contaminant inputs to the harbour.

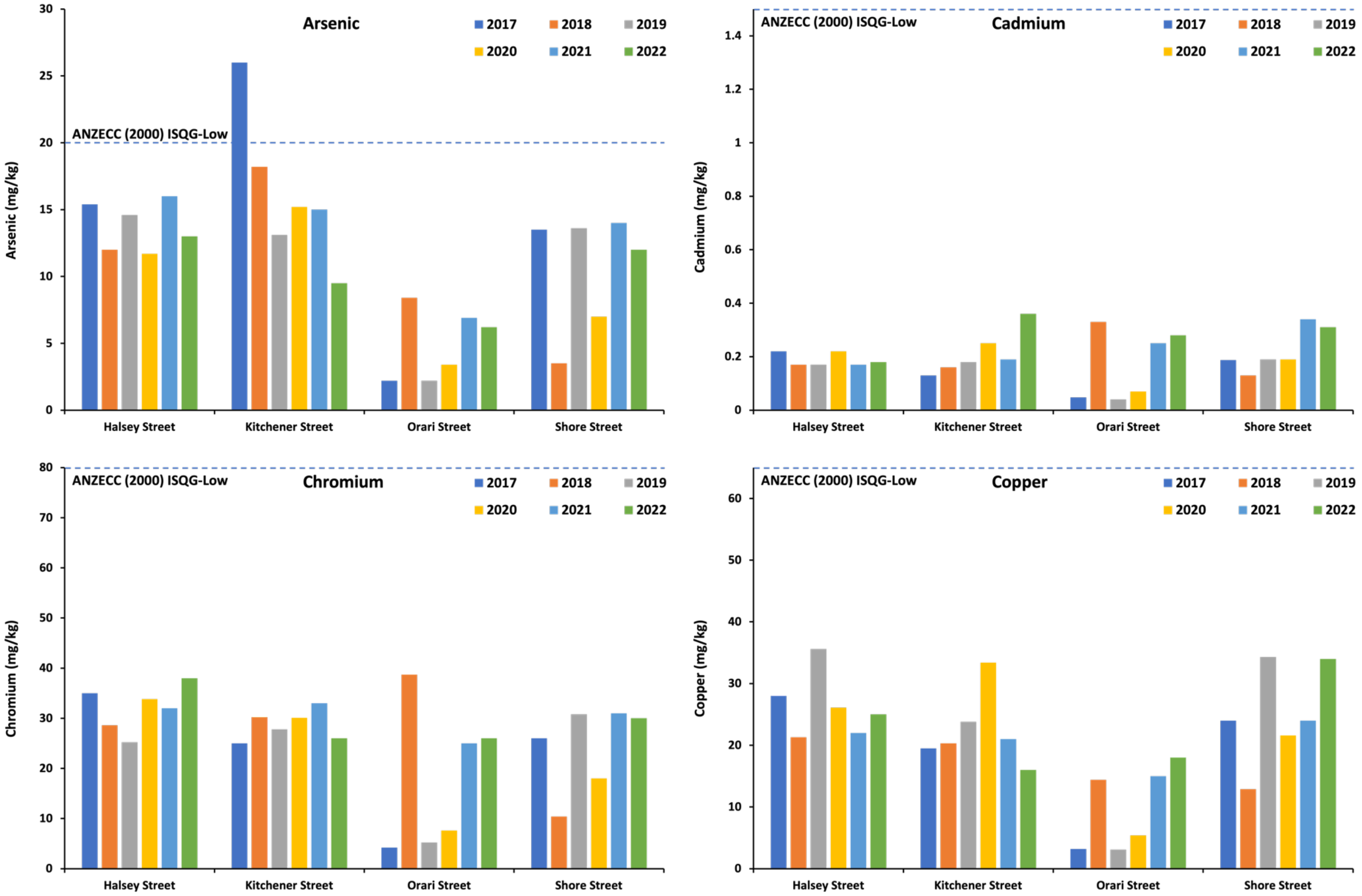

Figure 16: Contaminant concentrations collected from harbour sediments between 2017 and 2022. Dashed lines indicate ANZECC (2000) ISQG guideline levels.

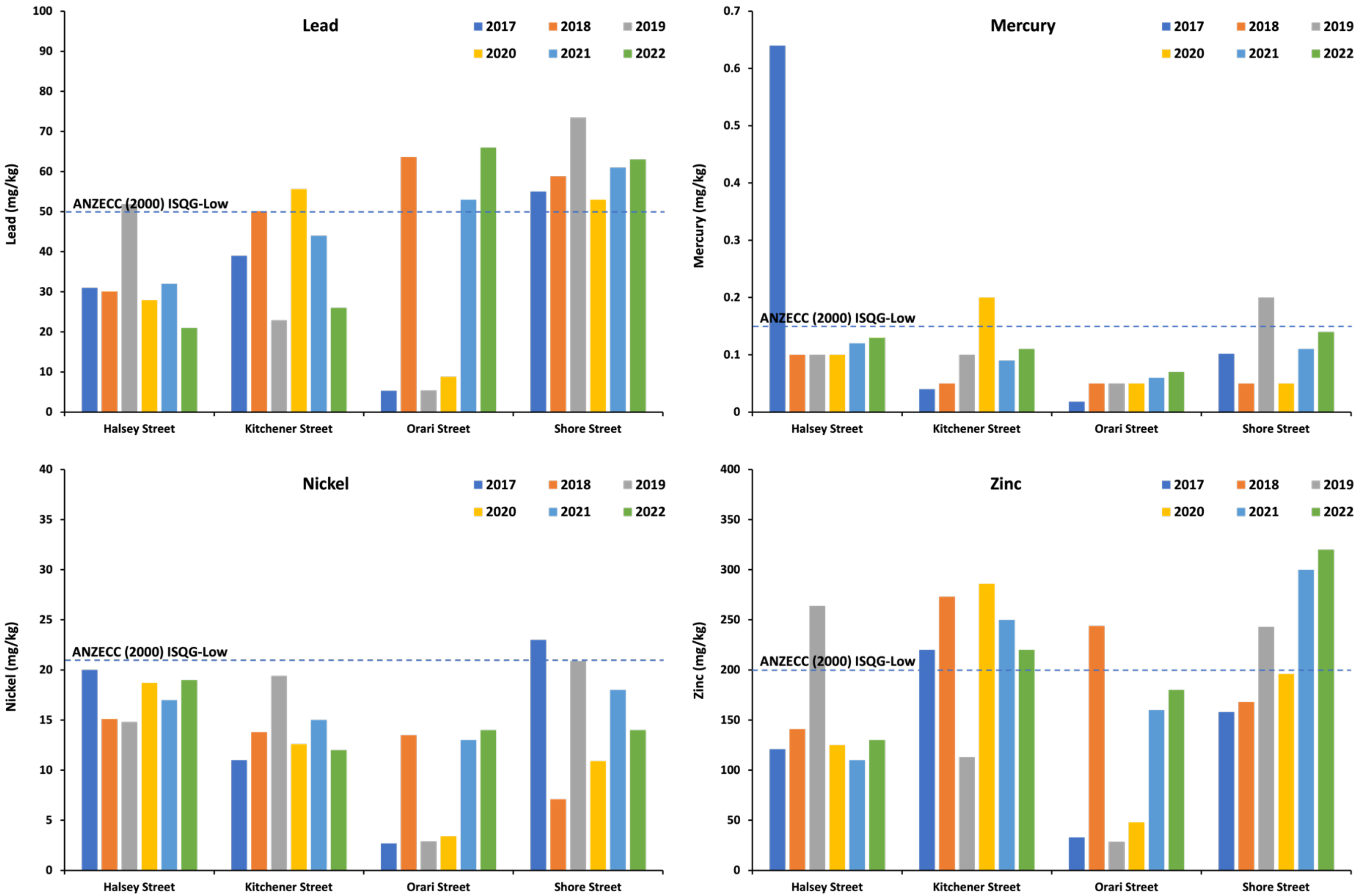

Figure 17: Contaminant concentrations collected from harbour sediments between 2017 and 2022. Dashed lines indicate ANZECC (2000) ISQG guideline levels.

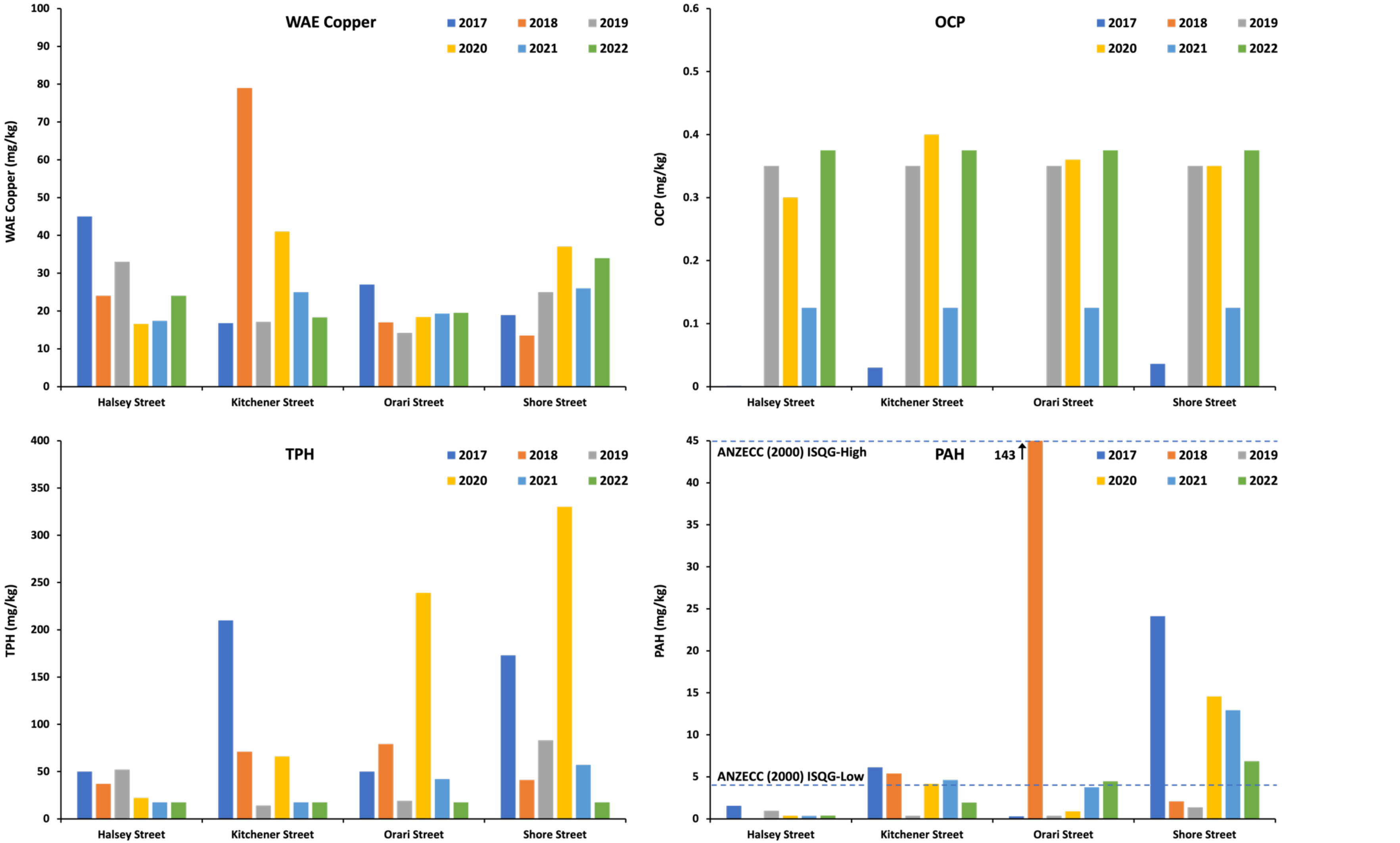

Figure 18: Contaminant concentrations collected from harbour sediments between 2017 and 2022. Dashed lines indicate ANZECC (2000) ISQG guideline levels.

5 SUMMARY AND CONCLUSION

Monitoring of Dunedin's stormwater discharges and receiving environments (Otago Harbour) was undertaken between July 2021 and June 2022, as required of DCC by ORC resource consents (RM11.313.01 - RM11.313.10). Sampling included stormwater quality during dry weather conditions, harbour water quality during dry and wet weather conditions, automated sampling of stormwater quality during two wet weather events, and sampling of harbour sediments. Further sampling/re-sampling was restricted by weather/tidal conditions not being met.

Results from dry weather sampling of stormwater quality identified several stormwater outfalls with elevated faecal contaminant indicators, a result which has been found in previous years. Previous investigations for some catchments, following elevated results, have identified cross-connections between stormwater and wastewater systems. As potential sources of *E. coli* in stormwater include sewage but also faecal deposition by animals (e.g., birds, rodents, domestic pets), such contamination is a common problem with stormwater.

Sampling of stormwater at outfalls during a rainfall event was not undertaken between July 2021 and June 2022 as the required conditions were not met.

Despite rain event sampling not being undertaken, the automated sampler captured two rain events at the Halsey Street site. Each rain event had different timing for peak concentrations of contaminants, which indicates the difference between each rain event as a result of differing rainfall intensity and the length of antecedent dry periods. These factors influence the amount of build-up on surfaces and therefore the amount of contaminants available for the 'first flush' during the rain event. Peak concentrations of metals and suspended solids were higher during the rain event with higher rainfall levels, while concentrations of *E. coli* reached very high levels in the lower rainfall event. These results indicate the importance of contaminants in run-off from surfaces throughout the catchment, with contaminants such as lead and copper commonly found in high levels in street dust and faecal contaminants from roofs, roads and sidewalks from the build-up of animal faeces. The automated sampler has now captured two events in the Halsey Street catchment, and following one further event being captured, can be moved to the next catchment required by consent. Based on the order of previous deployments, this is the South Dunedin catchment.

Harbour water quality sampling was undertaken during a rain event and during dry weather in 2022. Sampling revealed copper, zinc, and enterococci concentrations exceeded consented trigger levels at multiple sites during the rain event, while copper, lead, zinc, and enterococci concentrations exceeded consented trigger levels at multiple sites during dry weather. Elevated concentrations of several contaminants have previously been found during dry weather conditions at multiple sites, indicating inputs are unlikely to be from single point sources. Contaminants can be sourced from vehicles/roading and also from building materials and industrial activities. Harbour water quality is influenced by stormwater inputs, but also other sources such as the Water of Leith. During rainfall events, contaminant inputs from other sources can be considerable, and flood tides (incoming) can concentrate contaminants in the upper harbour, leading to elevated concentrations during rainfall events. Comparison of sampling results from previous years indicates elevated copper and lead concentrations during dry weather rather than during rain events, and elevated faecal indicator bacteria concentrations during rain events than during dry weather conditions. These results support the discussion above regarding potential sources of contaminants in the stormwater and into the harbour. It must also be recognised that sampling during rainfall events is undertaken during relatively high intensity rainfall, to capture the peak concentrations during the 'first flush'. However, there are many rain events where rainfall levels remain low (e.g., drizzle) that would also contribute contaminants to the harbour and therefore contribute to harbour water contaminant levels.

Sampling of contaminants in harbour sediments revealed similar concentrations to those from recent years , with no obvious patterns in concentrations through time. Concentrations in 2022 were all below 2013 trigger levels listed in the consents. Concentrations of lead, zinc and PAHs at some sites were above ANZECC (2000) ISQG-Low levels, which represent the threshold for potential effects to occur and is a trigger for further investigation, but remained well below ISQG-High levels, which represent a point where a high probability of effects is possible. Some sites have historically had high concentrations of some contaminants (e.g., PAHs at Portobello Road) however the cessation of some industrial activities (e.g., gas works) have reduced many sources of contaminant inputs to the harbour. Contaminant concentrations are expected to be variable year to year as contaminated sediment is buried or disturbed.

Overall, stormwater monitoring between July 2021 and June 2022 revealed similar results for contaminants concentrations for many of the variables monitored. Continued monitoring, which will include assessments of harbour biological communities in 2022-23, will continue to provide information to assist with identifying areas where improvements and/or remediation could be required.

6 REFERENCES

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Appendix A:

Stormwater outfalls

Table A1: Dunedin stormwater outfall information.

Outfall	DCC reference	Resource consent	Location	Catchment	Frequency of dry weather sampling	Wet weather sampling?
1	SWX03979	RM11.313.10	Second Beach	St Clair	Monthly	Yes
2	SWX00011 & SWX00012	RM11.313.10	St Clair Beach	St Clair	Six-monthly	-
3	SWX04625	RM11.313.04	Shore Street	Shore Street	Monthly	Yes
4	SWX03649	RM11.313.09	Portobello Road	South Dunedin	Monthly	Yes
5	SWX03644	RM11.313.07	Teviot Street	Portsmouth Drive	Monthly	-
6	SWX03640	RM11.313.07	Midland Street	Portsmouth Drive	Monthly	-
7	SWX03631	RM11.313.07	Orari Street	Portsmouth Drive	Monthly	-
8	SWX03635 & SWX70740	RM11.313.08	Orari Street	Orari Street	Monthly	Yes
9	SWX03579	RM11.313.07	Kitchener Street	Portsmouth Drive	Six-monthly	-
10	SWX03568	RM11.313.06	Kitchener Street	Kitchener Street	Monthly	Yes
11	SWX70102	RM11.313.06	French Street	Kitchener Street	Six-monthly	-
12	SWX03547	RM11.313.06	Kitchener Street	Kitchener Street	Monthly	-
13	SWX03562	RM11.313.06	Birch Street	Kitchener Street	Six-monthly	-
14	SWX03556	RM11.313.06	Birch Street	Kitchener Street	Six-monthly	-
15	SWX03559	RM11.313.06	Wharf Street	Kitchener Street	Six-monthly	-
16	SWZ70569	RM11.313.06	Fryatt Street	Kitchener Street	Six-monthly	-
17	SWX03540	RM11.313.06	Fryatt Street	Kitchener Street	Six-monthly	-
18	SWX03536	RM11.313.06	Fryatt Street	Kitchener Street	Six-monthly	-
19	SWX03532	RM11.313.06	Fryatt Street	Kitchener Street	Six-monthly	-
20	SWX70370	RM11.313.06	Fryatt Street	Kitchener Street	Six-monthly	-
21	SWX03489	RM11.313.05	Mason Street	Mason Street	Six-monthly	Yes
22	SWX03506	RM11.313.03	Bauchop Street	Halsey Street	Six-monthly	-
23	SWX03466	RM11.313.03	Bauchop Street	Halsey Street	Monthly	Yes
24	SWX03455	RM11.313.03	Halsey Street	Halsey Street	Monthly	Yes
25	SWX03450	RM11.313.03	Halsey Street	Halsey Street	Monthly	-
26	SWX03472	RM11.313.03	Halsey Street	Halsey Street	Monthly	-
27	SWX03718	RM11.313.03	Wickliffe Street	Halsey Street	Monthly	Yes
28	SWX02628	RM11.313.02	Magnet Street	Ravensbourne	Six-monthly	-
29	SWX02623	RM11.313.02	Magnet Street	Ravensbourne	Six-monthly	-
30	SPN02502	RM11.313.02	Ravensbourne Road	Ravensbourne	Monthly	-
31	SWX12941	RM11.313.01	George Street / SH88	Port Chalmers	Six-monthly	Yes
32	SWX12994	RM11.313.01	Sawyers Bay, Watson Park	Port Chalmers	Monthly	-
33	SWX12879	RM11.313.01	George Street (Port Otago)	Port Chalmers	Monthly	-

Appendix B:

Stormwater – dry weather sampling results, 2021-2022

Table B1: Contaminant concentrations (FWA, *E. coli*) in water from dry weather sampling between July 2021 and June 2022. Outfalls marked with grey cells are sampled six-monthly. Blue cells indicate values exceed trigger levels: FWA level of 0.1 ppb is suggestive of human faecal pollution (Gilpin and Devane 2003). *E. coli* trigger level of 550 cfu/100mL (MfE (2003) action (red) limit). NF = no flow; No Access = no available access to stormwater (Outfalls 23, 24, 25 were sealed over during road repairs in February 2021).

Outfall	13 July 2021		8 October 2021		5 November 2021		21 December 2021		18 January 2022		31 March 2022		20 April 2022		1 June 2022	
	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)
1	0.076	250	0.060	3,300	0.059	198	0.088	1,400	0.056	7,700	0.044	1,800	0.051	700	0.049	460
2					NF	NF										
3	0.065	260	0.077	210	0.058	280	0.065	2,100	0.065	4,200	0.047	4,500	0.046	3,900	0.051	6,400
4	0.048	<10	0.043	<10	0.008	<10	0.084	600	0.084	7,600	0.024	800	0.052	10	0.055	<10
5	0.129	140	0.131	120	0.137	240	0.134	670	0.147	6,000	0.138	5,500	0.145	120	0.146	150
6	0.077	130	0.064	230	0.073	260	0.092	1,500	0.104	710	0.058	400	0.047	70	0.088	510
7	0.056	2,200	0.055	120	0.057	230	0.065	700	0.085	6,600	0.044	400	0.068	>8000	0.020	4,100
8	0.076	1,000	0.070	200	0.080	350	0.075	1,200	0.068	590	0.063	480	0.068	180	No access	No access
9					0.087	110										
10	0.038	>8000	0.051	7,200	0.049	172	0.031	1,500	0.035	950	0.038	800	0.029	490	No access	No access
11					0.032	10										
12	0.073	<10	0.035	<10	0.068	<10	0.079	20	0.019	120	NF	NF	0.028	<10	0.016	<10
13-22					No access	No access										
23	No access	No access	No access	No access	No access	No access	No access	No access	No access	No access	0.040	>8000	0.043	250	0.015	60
24	No access	No access	No access	No access	0.018	256	0.044	68,000	0.025	90,000	0.028	>8000	0.023	>8000	0.006	610
25	No access	No access	No access	No access	0.046	>80,000	0.024	29,000	0.040	710,000	0.024	>8000	0.037	>8000	0.015	>8000
26	0.041	10	0.045	20	NF	NF	NF	NF	NF	NF	NF	NF	0.052	720	NF	NF
27	0.083	1,800	0.049	8,000	0.046	87,000	0.046	34,000	0.053	4,200	0.077	>8000	0.044	1,200	0.017	1,000
28					0.059	212										
29					0.063	30										
30	0.102	<10	0.087	<10	0.123	10	0.083	1,100	0.122	3,000	0.151	30	NF	NF	NF	NF
31					0.017	20										
32	0.121	<10	0.114	<10	0.116	<10	0.086	40	NF	NF	NF	NF	NF	NF	NF	NF
33	0.043	7,700	0.052	290	0.061	12,600	0.049	1,600	0.043	900	0.070	>8000	0.075	4,000	0.057	500

Appendix C:

Automated sampler – wet weather sampling results, 2021-2022

Table C1: Contaminant concentrations in water from wet weather automatic sampling (ISCO) in the Halsey Street catchment, for a rain event on 12 April 2022. PAH = polycyclic aromatic hydrocarbons. '< value' indicates all concentrations below laboratory detection limits. '> value' indicates concentrations above laboratory range for test.

Time (minutes)	pH	Total suspended solids (g/m³)	Oil and grease (g/m³)	Arsenic (g/m³)	Cadmium (g/m³)	Chromium (g/m³)	Copper (g/m³)	Lead (g/m³)	Nickel (g/m³)	Zinc (g/m³)	*E. coli* (cfu/100mL)	PAH (mg/L)
10	7.6	87	5	0.002	<0.001	<0.001	0.003	<0.001	0.004	0.129	> 8,000	<0.0051
20	7.6	84	10	<0.002	<0.001	<0.001	0.002	<0.001	0.002	0.103	> 8,000	<0.0051
30	7.7	63	<5	0.002	<0.001	<0.001	0.004	0.001	0.001	0.115	> 8,000	<0.0051
40	7.7	149	6	0.002	<0.001	0.002	0.008	0.005	0.002	0.196	> 8,000	<0.0051
50	7.5	518	14	0.007	<0.001	0.011	0.043	0.045	0.009	0.698	> 8,000	<0.0051
60	6.9	805	42	0.009	<0.001	0.018	0.073	0.088	0.012	0.876	> 8,000	<0.0051
70	7.2	189	8	0.003	<0.001	0.005	0.021	0.026	0.004	0.236	> 8,000	<0.0051
80	6.5	185	<5	0.002	<0.001	0.005	0.025	0.024	0.004	0.226	> 8,000	<0.0051
90	6.7	117	6	<0.002	<0.001	0.003	0.018	0.013	0.002	0.163	> 8,000	<0.0051
100	7.1	98	8	<0.002	<0.001	0.002	0.010	0.010	0.002	0.148	> 8,000	<0.0051
110	7.1	116	12	<0.002	<0.001	0.003	0.010	0.009	0.002	0.149	> 8,000	<0.0051
120	7.2	66	<5	<0.002	<0.001	0.003	0.011	0.008	0.003	0.152	> 8,000	<0.0051

Table C2: Contaminant concentrations in water from wet weather automatic sampling (ISCO) in the Halsey Street catchment, for a rain event on 21 April 2022. PAH = polycyclic aromatic hydrocarbons. '< value' indicates all concentrations below laboratory detection limits.

Time (minutes)	pH	Total suspended solids (g/m^3)	Oil and grease (g/m^3)	Arsenic (g/m^3)	Cadmium (g/m^3)	Chromium (g/m^3)	Copper (g/m^3)	Lead (g/m^3)	Nickel (g/m^3)	Zinc (g/m^3)	*E. coli* (cfu/100mL)	PAH (mg/L)
10	7.5	121	20	0.002	<0.001	0.003	0.011	0.008	0.004	0.343	260,000	<0.0051
20	6.9	262	27	0.004	<0.001	0.007	0.025	0.020	0.006	0.501	410,000	<0.0051
30	7.1	311	36	0.007	<0.001	0.011	0.046	0.046	0.011	0.614	420,000	<0.0051
40	6.4	186	31	0.004	<0.001	0.008	0.038	0.034	0.010	0.510	190,000	<0.0051
50	6.3	129	13	0.003	<0.001	0.007	0.032	0.028	0.007	0.552	39,000	<0.0051
60	6.8	92	25	0.002	<0.001	0.005	0.026	0.022	0.005	0.523	4,000	<0.0051
70	7.3	73	11	0.002	<0.001	0.004	0.021	0.017	0.005	0.353	61,000	<0.0051
80	7.0	53	7	0.002	<0.001	0.004	0.020	0.015	0.005	0.304	190,000	<0.0051
90	6.7	52	8	<0.002	<0.001	0.003	0.019	0.013	0.004	0.274	310,000	<0.0051
100	7.2	63	25	0.002	<0.001	0.003	0.015	0.010	0.004	0.291	200,000	<0.0051
110	7.5	127	21	<0.002	<0.001	0.002	0.008	0.005	0.002	0.154	23,000	<0.0051
120	7.2	61	7	0.002	<0.001	0.001	0.008	0.005	0.003	0.163	5,000	<0.0051

Appendix D:

Harbour sediment sampling results, 2021-2022

Table D1: Harbour sediment contaminant concentrations, 18 May 2022. Trigger and guideline values are specified in resource consents.

	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	WAE Copper[1] (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Nickel (mg/kg)	Zinc (mg/kg)	PAH[2] (mg/kg)	TPH[3] (mg/kg)	OCP[4] (mg/kg)
2013 trigger levels	19	1.7	80	-	122	209	-	21	902	183	-	-
ANZECC (2000) ISQG-Low[5]	20	1.5	80	-	65	50	0.15	21	200	4	-	-
ANZECC (2000) ISQG-High[5]	70	10	370	-	270	220	1	52	410	45	-	-
Halsey Street	13	0.18	38	24.0	25	21	0.13	19	130	0.15-0.61	<35	<0.75
Kitchener Street	9.5	0.36	26	18.3	16	26	0.11	12	220	1.84-2.03	<35	<0.75
Orari Street	6.2	0.28	26	19.5	18	66	0.070	14	180	4.38-4.54	<35	<0.75
Shore Street	12	0.31	30	34.0	34	63	0.14	14	320	6.78-6.91	<35	<0.75

1. WAE copper = Weak-acid extractable copper.
2. PAH = polycyclic aromatic hydrocarbons. Concentration ranges are between known concentrations and the maximum possible concentrations (as some samples below laboratory detection limits). '< value' indicates all concentrations below laboratory detection limits.
3. TPH = total petroleum hydrocarbons – maximum content.
4. OCP = organochlorine pesticides. Concentration ranges are between known concentrations and the maximum possible concentrations (as some samples below laboratory detection limits). '< value' indicates all concentrations below laboratory detection limits.
5. ANZECC (2000) interim sediment quality (ISQG) guideline values, as listed in the resource consent.

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