Avon River Catchment Aquatic Ecology 2019

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EXECUTIVE SUMMARY

This report describes the current state and trends in aquatic ecology and sediment quality of the Avon River, following the most recent round of monitoring in 2019.

Monitoring data from 2019 indicate that riparian and instream habitat quality is unchanged compared to previous years at most of the monitoring sites. Most sites have minimal buffering with riparian vegetation, many have artificial banks (including timber, stone, and concrete), and most have minimal shading. Despite some localised examples of habitat restoration, the current state of riparian and instream health of the Avon River is overall poor compared to the less urbanised Styx River and Otukaikino River catchments, and is more comparable to the Heathcote River catchment.

Sediment concentrations of common stormwater contaminants exceeded ANZECC (2018) guidelines for at least some parameters in 2019, but there were no increasing trends at most of the sites. A halving of lead concentrations in sediments since the 1980s coincides with the banning of leaded petrol for cars. Zinc is the contaminant of greatest concern in Avon catchment sediments, as zinc is elevated at most locations and zinc is the only sampling parameter to exceed the high guideline values.

Invertebrate community composition in 2018 was similar to previous years, being dominated by pollution-tolerant snails and crustaceans that are common in Christchurch waterways. The abundance and diversity of pollution-sensitive EPT taxa also remains lower in the Avon River catchment than in the Otukaikino or Styx Rivers, but is slightly higher than in the Heathcote River.

The range of fish species caught in 2019 was also similar to previous years and the fauna was dominated by native species, particularly shortfin eels. The Avon River fish community is similar to that present in other Christchurch waterways, with a dominance of native species and few introduced species. However, the presence of At Risk longfin eel, inanga, bluegill bully, giant bully, and torrentfish, and Threatened lamprey elevates the overall conservation value of the catchment, particularly given the highly modified urban setting. It is unknown to what extent fish barriers such as culverts, weirs and pump stations currently affect the distribution and ecology of native fish in the Avon River catchment.

Canterbury Land and Water Regional Plan (LWRP) freshwater outcomes for filamentous algae cover, emergent macrophyte cover, and invertebrate QMCI scores were met at most of the Avon catchment monitoring sites in 2019. Approximately one third of sites did not meet LWRP freshwater outcomes for fine sediment cover, which is similar to previous monitoring results. Fewer sites complied with LWRP freshwater outcomes for total macrophyte cover than in 2009, which likely reflects impacts of recent weed clearance prior to previous monitoring. Importantly, there is no overall increasing or decreasing trend in QMCI scores evident across the sites monitored. This indicates that, while the overall ecological state of the Avon River is poor to fair, there is no indication of a declining trend that could be attributable to stormwater discharges or other landuse impacts.

Recommendations include: increased riparian planting and protection alongside waterways (high priority); ecological restoration of the Avon River Corridor in the lower river; monitoring effectiveness of restoration projects; investigate locations with high zinc concentrations in river sediments; undertake dedicated surveys for At Risk kākahi (freshwater mussels), Threatened lamprey, and trout spawning; and identify fish barriers and prioritise them for remediation.

1. INTRODUCTION

The Avon River / Ōtakaro flows through the centre of Christchurch city and it has a predominantly urban catchment. Christchurch City Council (CCC) monitors aquatic ecology of the Avon River, both to fulfil stormwater discharge consent requirements under the Interim Global Stormwater Consent (CRC090292) and as part of its long-term environmental monitoring programme. The first two rounds of regular monitoring were in 2009/2010 and 2013, and this report presents the most recent results, from 2019.

The purpose of this report is to present the results of the most recent ecology and sediment quality monitoring, describe the state of the monitored waterways, and identify any trends over time. The following key components are included in this report:

- Current state and trends of aquatic ecology and sediment quality.
- Comparison of monitoring data to relevant standards and guidelines.
- Discuss any environmental trends in relation to potential stormwater impacts.
- Describe other relevant ecological matters not covered by routine monitoring.

This report does not include a detailed analysis of the monthly water quality monitoring undertaken by CCC at eight sites in the Avon catchment. Those data are summarised separately as part of an annual city-wide summary report (e.g., Margetts & Marshall 2018).

2. METHODS

2.1. Sampling Sites

Eighteen sites were sampled in 2019 for the aquatic ecology monitoring programme. The sampling sites comprise 15 wadeable and three non-wadeable sites, ranging from upstream tributaries north and west of Hagley Park, downstream to the estuary at Bridge Street, (Figure 1, Table 1). Ten of the wadeable ecology sites were sampled previously for habitat and invertebrates in 2009 (McMurtrie 2009) and all 15 wadeable sites were sampled for habitat, invertebrates, and fish in 2013 (Boffa Miskell 2014). Some fish sampling was also undertaken in 2010 (Main and Taylor 2010), but there was little overlap with present monitoring sites, so the data are not discussed in detail here. Sediment quality sampling occurred at 14 sites in 2019 and earlier data were available from 1980 (Robb 1988) and 2013 (Gadd & Sykes 2014).

We also collected ecology and sediment quality data from several additional sites along Addington Brook and Riccarton Main Drain for Environment Canterbury (ECan). These data are not reported here but are available from ECan on request.

Adjacent landuse varies amongst sites, and comprises a mix of residential and commercial properties, and urban parkland. Landuse and monitoring site locations were largely unchanged from 2013. The only exception was Site 12 on Addington Brook, where the monitoring site was moved from upstream of the Avon River confluence (in Christchurch Botanical Gardens) in 2013 to upstream of Riccarton Avenue (in Hagley Park) in 2019.

Ecology monitoring occurred from 18 February to 21 March 2019, under baseflow conditions.

Figure 1: CCC Avon River ecology and sediment quality monitoring sites.

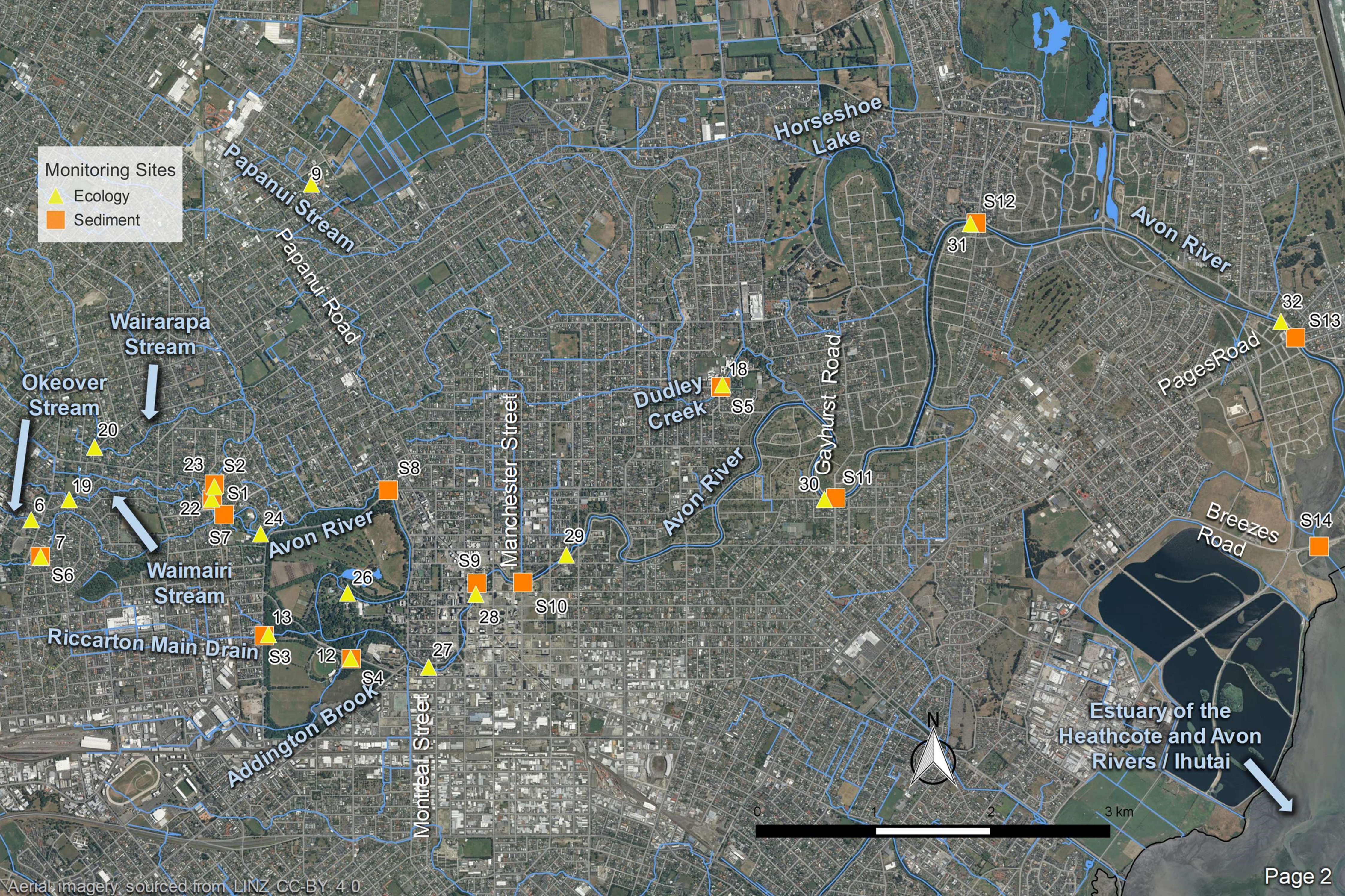


Table 1: Avon catchment ecology and sediment quality monitoring sites. Asterisks indicate non-wadeable sites.

Site Code	Waterway	Site Name/Location	Easting	Northing
Ecology Monitoring Sites				
6	Okeover Stream	University of Canterbury Glasshouses	1566687	5180996
7	Avon River	Clyde Road	1566766	5180682
9	Papanui Stream	Erica Reserve	1569069	5183866
12	Addington Brook	Upstream of Riccarton Avenue	1569427	5179826
13	Riccarton Main Drain	Downstream of Deans Avenue	1568683	5180019
18	Dudley Creek	North Parade	1572574	5182150
19	Waimairi Stream	Fendalton Park	1567011	5181168
20	Wairarapa Stream	Upstream of Glandovey Road	1567225	5181608
22	Waimairi Stream	Downstream of Railway Bridge	1568233	5181172
23	Wairarapa Stream	Downstream of Fendalton Road	1568250	5181303
24	Avon River	Downstream of Mona Vale Loop	1568634	5180880
26	Avon River	Botanical Garden North Car Park/in Hagley Park	1569390	5180398
27	Avon River	Upstream of Montreal Street/near Durham Street	1570089	5179759
28	Avon River	Victoria Square Near Armagh Street	1570498	5180473
29	Avon River	Downstream of Kilmore Street (Ōtautahi)	1571260	5180717
30*	Avon River	Dallington Terrace/Gayhurst Road	1573560	5181210
31*	Avon River	Avondale Road	1574752	5183557
32*	Avon River	Pages/Seaview Bridge	1577484	5182589
Sediment Monitoring Sites				
S1	Waimairi Stream	Downstream of Railway Bridge	1568233	5181172
S2	Wairarapa Stream	Downstream of Fendalton Road	1568251	5181303
S3	Riccarton Main Drain	Downstream of Deans Avenue	1568683	5180019
S4	Addington Brook	Upstream of Riccarton Avenue	1569427	5179826
S5	Dudley Creek	North Parade	1572574	5182151
S6	Avon River	Clyde Road	1566766	5180682
S7	Avon River	Mona Vale	1568335	5181046
S8	Avon River	Carlton Mill Corner	1569737	5181259
S9	Avon River	Victoria Square Near Armagh Street	1570498	5180473
S10	Avon River	Manchester Street	1570890	5180481
S11*	Avon River	Dallington Terrace/ Gayhurst Road	1573560	5181210
S12*	Avon River	Avondale Road	1574752	5183557
S13*	Avon River	Pages/ Seaview Bridge	1577484	5182589
S14*	Avon River	Bridge Street	1577691	5180813

Note: Eastings and northings use the New Zealand Transverse Mercator 2000 (NZTM2000) projection. Grid references were updated for ecology sites in 2019, to reflect actual site locations. Sediment sites remained unchanged.

2.2. New Sampling Methods for 2019

Previous monitoring involved invertebrate and habitat sampling at 10 wadeable sites in 2009, and invertebrate, habitat, and fish sampling at 29 wadeable sites in 2013. Each sampling occasion used slightly different methods than the now-standard CCC ecology sampling method. As of the 2019 sampling round, the standard CCC ecology sampling methods are being used at sites previously sampled. This section summarises similarities and differences between the methods, while the next sections detail the new standard methods.

Both new and old methods involve:

- Measuring habitat along a 20 m reach, with detailed measurements along 3 transects.
- Dissolved oxygen, temperature, pH, and conductivity measured once per site.

The major differences between the new and old methods are as follows:

- At each transect, detailed habitat measurements at:
  - 3 or 12 points or site-wide estimates (old methods).
  - 5 points (new method). Only edge habitat sampled at non-wadeable sites.
- At each transect, velocity measured at:
  - 10 points per transect (2009) or 3 random points per reach (2013).
  - 1 point per transect (new method). Mid-channel for wadeable sites; approx. 1.5 m (safely wadable) from edge for non-wadeable sites.
- Invertebrate kicknet samples per site:
  - 3 (2009). Each sample is approx. 0.45 m² (1.5 x 0.3 m).
  - 1 (2013 and 2019). Each sample is approx. 0.6 m² (2.0 x 0.3 m). Only edge habitat sampled at non-wadeable sites.
- Fish sampling effort for wadeable sites:
  - "Multiple pass"[1] electrofishing over minimum 20 m reach (2013).
  - Single pass electrofishing over minimum 30 m reach (new method).
- Fish sampling effort for non-wadeable sites:
  - 2 baited fyke nets (unknown mesh size) and 6 baited Gee minnow traps (2013).
  - 2 fyke nets (4 mm mesh, double-trap – per Joy et al. (2013)) baited with cat food, 5 Gee minnow traps baited with marmite (new method).

2.3. Habitat and Water Quality Sampling

At three representative transects located 10 metres apart, the following were collected:

- Bank and riparian habitat (for each bank for a 5 metre bank width): surrounding land use, bank material, bank height, bank erosion, bank slope, riparian vegetation, canopy cover, undercut banks, overhanging vegetation and ground cover vegetation

- Instream habitat (for five locations across each transect): wetted width, water depth, fine sediment depth, embeddedness and substrate composition using the following size classes: silt/sand (<2 mm); gravels (2-16 mm); pebbles (16-64 mm); small cobbles (64-

[1] Note that the methods given by Boffa Miskell (2014) state that electric fishing involved multiple passes, but the data for all passes were combined.

128 mm), large cobbles (128-256 mm), boulders (256-4000 mm) and bedrock/concrete/artificial hard surfaces (>4000 mm) (modified from Harding et al., 2009).

Substrate composition data was converted to a substrate index to aid comparison of data amongst sites and over years. The substrate index was calculated using the following formula (modified from Harding et al. 2009):

Substrate index (SI) = (0.03 x %silt / sand) + (0.04 x %gravel) + (0.05 x %pebble) + (0.06 x (%small cobble + %large cobble)) + (0.07 x %boulder) + (0.08 x %bedrock).

Note that the substrate index calculation was slightly different in the 2013 round of sampling, so we have recalculated 2013 substrate index for consistency with this report and standard methods.

Water velocity was measured once per transect at the mid-channel using a Seba Mini velocity meter. At the reach scale, the relative percentage of riffle, run, and pool flow habitat was estimated visually.

Field measurements were taken of dissolved oxygen, water temperature, pH and conductivity in an area representative of the site (usually mid-channel). The water quality measurements were made using calibrated Hanna water quality meter (model HI 9829).

Macrophyte cover and composition, depth and type (emergent and total) was measured at five locations across each of the three transects. Periphyton cover and composition was also measured at the five locations across each of the three transects. Periphyton categories were adapted from those outlined in Biggs & Kilroy (2000). These categories include: thin films; thin, medium, and thick mats; short and long filamentous algae. Percentage cover and description of organic matter was also recorded.

2.4. Sediment Quality

Sediment samples were collected by making multiple sweeps with a sampling container across the stream bed, with at least five subsamples composited into one sample, preferably of at least 1 kilogram. Sampling aimed to collect texturally similar sediment between sites, with the preferential collection of fine sediments (<2 mm) to ensure sufficient material for laboratory analysis. Samples were collected from the surface at a depth of no greater than 3 cm. Water was drained off directly from the jars.

After collection, samples were placed in a chilly bin containing ice-bricks and transported to Hill Laboratories (an International Accreditation New Zealand laboratory) within 24 hours. Samples stored overnight we kept chilled in a refrigerator.

Sediment samples were analysed at all sites for the following using the most relevant US EPA methods and the <2 mm fraction (where relevant), with the detection limits for each parameter suitable to enable comparison of the results with relevant guideline levels and previous monitoring:

- Particle size distribution using the following size classes: silt and clay (<0.063 mm); fine sand (0.063-0.25 mm); medium sand (0.25-0.50 mm); coarse sand (0.5-2.0 mm); gravel and cobbles (>2 mm).
- Total recoverable copper, lead and zinc.
- Total organic carbon.

* Polycyclic aromatic hydrocarbons (PAHs).

Sediment sampling fieldwork was undertaken during baseflow conditions on 22 March and 9 April 2019. Seven additional sites along Addington Brook and Riccarton Stream were sampled on 9 April 2019 for ECan (data are not presented here but are available from ECan).

2.5. Macroinvertebrates

Benthic macroinvertebrates were sampled at each site by collecting a single kicknet sample from the range of available habitats present, in proportion to the habitat types present, and covering a total area of approximately 0.6 m². Samples were preserved in the field using denatured ethanol and were sent to Biolive consultants for identification and enumeration. Invertebrates were counted and identified to species level where possible, using Protocol P2 (individual fixed count with scan for rare taxa) of Stark et al (2001). This method differs to the previous full count with subsampling method used by Boffa Miskell (2009), reflecting a change to standard methods used by CCC. The change in laboratory protocols was in response to recommendations by Stark (2018) that fixed counts should be used for kicknet samples.

2.6. Fish

At the fifteen wadeable sites the fish community was sampled using backpack electric fishing, while a combination of fyke nets and Gee minnow traps were used to sample fish at the three non-wadeable sites. For the fifteen wadeable sites, the length of stream electric fished at each site was a minimum of 30 m and 30 m² in area. All habitat types within the reach were sampled without bias (e.g., pools, riffles, underhangs and backwaters). For the three non-wadeable sites, sampling involved deploying five Gee Minnow traps baited with marmite and two fyke nets (4 mm mesh and two internal traps, as per Joy et al. (2013)) baited with cat food. Fyke nets were set at a 15° – 30° angle to the bank, with the leader downstream. Nets and traps were left overnight and checked the following morning.

For both trapping and electric fishing, all fish caught were identified to species level where possible, counted, measured and released back into the waterway. Fish seen but not caught were recorded as missed fish (e.g. 'missed bully' or 'missed fish' if identification was uncertain), but not included in the total tally.

2.7. Data Analyses

2.7.1. Data Management

All ecology and sediment quality data collected in 2019 was collated into a single Excel spreadsheet. In addition, summary data from 2019 and all previous years of ecology and sediment monitoring (data provided by CCC) were combined into a single Microsoft Excel spreadsheet. Both spreadsheets were provided to CCC in electronic form at the time this report was submitted, and they are available from CCC on request.

2.7.2. Habitat and Water Quality Data

Field-measured water quality results were tabulated and compared against relevant freshwater outcomes and receiving water standards in the Canterbury Land and Water Regional Plan (LWRP).

Relevant habitat data that were chosen for statistical analyses included the following parameters: channel width, water depth, water velocity, substrate index, fine sediment (<2 mm diameter) depth, fine sediment cover, and bed cover with emergent macrophytes, total macrophytes, and long filamentous algae (>2 cm long). Of these parameters, LWRP freshwater outcomes are associated with fine sediment cover, emergent macrophytes, total macrophytes and long filamentous algae (Table 2).

Prior to 2013, there were single, site-wide estimates for emergent and total macrophyte cover, long filamentous algae cover and fine sediment cover (estimated by summing estimated cover of sediment <2 mm). In 2013 and 2019, these parameters were estimated as per other transect data (i.e., the average of five (2019) or twelve (2013) measurements per transect, and the site average obtained by the mean of three transects) excluding emergent macrophyte cover in 2013. Only a single measurement for velocity was recorded in 2013.

Habitat data were averaged for each transect (where relevant), plotted, compared with LWRP freshwater outcomes, and inspected for evidence of any patterns over time or amongst sites.

Table 2: LWRP freshwater outcomes for streams classified as "spring-fed plains (urban)".

Parameter	LWRP freshwater outcome
Minimum QMCI	3.5
Maximum fine sediment (<2 mm) cover	30%
Maximum emergent macrophyte cover	30%
Maximum total macrophyte cover	60%
Maximum filamentous algae cover	30%

Differences amongst sites over time were assessed using two-way analysis of variance (ANOVA) for the following parameters: width, depth, substrate index, fine sediment depth, fine sediment cover, total macrophyte cover, and long filamentous algae cover. Tukey post-hoc tests were used to examine the statistical significance of site x year interactions, particularly in terms of any increasing or decreasing trends in habitat quality over time.

It was not possible to use ANOVA or GLM to test for trends in velocity or emergent macrophyte cover over time, due to a lack of replication in previous years. Trend analysis using tests such as the Mann-Kendall trend test were also not possible, as they typically require more than three years of record. Therefore, these data were just examined visually for any indication of trends.

2.7.3. Sediment Quality Data

Particle size data from the laboratory was converted into a modified substrate index, to allow for easy comparison in particle size amongst sites and over time. Particle size categories common to all four years of monitoring were as follows: silt and clay (< 0.063 mm); fine sand (0.063-0.25 mm); medium sand (0.25-0.5 mm); coarse sand (0.5-2.0 mm). The modified substrate index (modified SI) was calculated as follows:

Modified SI = (0.01 x %silt and clay) + (0.02 x %fine sand) + (0.03 x %medium sand) + (0.04 x %coarse sand).

Total PAHs were calculated by summing the same 16 PAHs analysed in previous monitoring rounds, which include the PAHs listed as priority pollutants by the USEPA (1982). Total PAHs were normalised to 1% TOC, as recommended by ANZECC (2018), before comparison to the guidelines. Where one or more PAH compound was below the detection limit, half the detection limit was used in the calculation, which is consistent with previous reporting (Gadd & Sykes 2014).

Sediment quality data from the 14 sites sampled in 2019 were summarised and tabulated for comparison against ANZECC (2018) sediment quality guidelines. Sediment quality data from 2019 were also compared against data collected in 1980 and 2013, using historic data provided by CCC. Statistical comparison amongst sites and over time was not possible, due to the lack of replicates. Therefore, these data were just examined visually for any indication of trends.

2.7.4. Macroinvertebrates

The following biological indices were calculated from the raw invertebrate data:

Taxa Richness: The number of different invertebrate taxa (families, genera, species) at a site. Richness may be reduced at impacted sites, but is not a strong indicator of pollution.

%EPT: The percentage of all individuals collected made up of pollution-sensitive Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa. %EPT is typically reduced at polluted sites, and is particularly sensitive to sedimentation. This metric was calculated excluding pollution-tolerant hydroptilid caddisflies, which can skew %EPT results at sites where they are abundant.

EPT Taxa Richness: The number of different EPT taxa at a site. It is reduced at polluted sites. Calculated without hydroptilid caddisflies included.

MCI and QMCI: The Macroinvertebrate Community Index and the Quantitative MCI (Stark 1985). Invertebrate taxa are assigned scores from 1 to 10 based on their tolerance to organic pollution. Highest scoring taxa (e.g., many EPT taxa) are the least tolerant to organic pollution. The MCI is based on presence-absence data: scores are summed for each taxon in a sample, divided by the total number of taxa collected, then multiplied by a scaling factor of 20. The QMCI requires abundance data: MCI scores are multiplied by abundance for each taxon, summed for each sample, then divided by total invertebrate abundance for each sample. We calculated site MCI and QMCI scores using the tolerance scores for hard-bottomed streams for Sites 6 to 29 and soft-bottomed streams for Sites 30, 31, and 32, to reflect the dominant substrate present (Stark & Maxted 2007). MCI and QMCI scores can be interpreted as per the quality classes of Stark & Maxted (2007), as summarised in Table 3.

The MCI, QMCI, and EPT indices were developed for assessing ecological health of wadeable streams. Non-wadeable river reaches often have naturally fine bed sediments, which are not favoured by pollution-sensitive invertebrate taxa. Therefore, macroinvertebrate for the non-wadeable reaches of the lower Avon River (Sites 30, 31, and 32) should be interpreted with caution, as pollution will not necessarily be the cause of low MCI, QMCI, or EPT scores in these reaches.

Table 3: Interpretation of MCI and QMCI scores (from Stark & Maxted 2007).

Quality Class	MCI	QMCI
Excellent	>119	>5.99
Good	100-119	5.00-5.90
Fair	80-99	4.00-4.99
Poor	<80	<4.00

As with reach-scale habitat data, it was not possible to conduct two-way ANOVA or trend analyses on the five-yearly macroinvertebrate data, due to a lack of replication.

Macroinvertebrate community composition was also compared amongst sites and over time using non-metric multi-dimensional scaling (NMDS), a form of ordination. The ordination was based on a Bray-Curtis dissimilarity matrix, using square-root transformed data on percent abundance and the Ecodist package in R. Percent abundance was used, rather than total abundance, because of the different sampling areas and sorting methods (total count vs fixed count) used over time. Spearman rank correlation was used to reveal which taxa most closely correlated with NMDS axis scores. Habitat data from the nine wadeable sites were also correlated with NMDS axis scores.

There were eight sites for which ecology, sediment quality, and monthly water quality monitoring sites are in close proximity. These are ecology sites 12, 13, 18, 22, 23, 30, 31, and 32. For these sites, NMDS axis scores for 2018 were correlated against sediment quality data (copper, lead and zinc), and key median water quality data from April 2017 to March 2018 (dissolved copper, dissolved lead, dissolved zinc, total suspended solids, dissolved reactive phosphorus, and dissolved inorganic nitrogen). Median water quality data was based on monthly water quality samples and the data were provided by CCC.

QMCI scores were compared with the LWRP freshwater outcome minimum QMCI of 3.5 for spring-fed plains (urban) streams (Table 2).

3. RESULTS

3.1. Habitat and Water Quality

Water temperatures were cool (<17 °C) at most sites sampled in 2018, with the exception of Dudley Creek and the two most-downstream Avon River sites, which all had water temperatures just below 20 °C (Table 4). Warmer temperatures at these three sites were likely due to a lack of shading, as well as a tidal influence for the two lower Avon River sites. Dissolved oxygen saturation exceeded (i.e., complied with) the LWRP freshwater outcome of 70% at all sites except for Papanui Stream and Dudley Creek (Table 4). Dissolved oxygen levels were lowest at Papanui Stream (42% saturation), and although a direct cause is not immediately obvious, it should be remembered that dissolved oxygen varies markedly throughout the day and not too much can be inferred from a single low reading.

Conductivity was typically in the range of 100 to 200 µS/cm for most wadeable sites, reflecting their common groundwater source of flow (Table 4). Higher conductivity at Riccarton Main Drain (267 µS/cm) and Addington Brook (313 µS/cm) likely reflects the more industrial catchments they drain and associated stormwater contaminants. Conductivity was greatest at the Avon River at Pages Road site (524 µS/cm), reflecting brackish estuarine conditions. Water pH was circum-neutral (i.e., around pH 7) and within LWRP receiving environment standards of pH 6.5 to 8.5 for most sites. Higher pH at the Avon River at Avondale Road (pH = 8.8) may been due to the high macrophyte cover at this site, because high macrophyte cover can result in largely daily fluctuations in pH (Davies-Colley & Wilcock 2004).

Water temperatures in 2019 were generally warmer than those reported in 2013, which most likely reflects warmer air temperatures when sampling was undertaken in March/April 2019, compared to sampling in October/November in 2013. Conductivity and pH were comparable between 2013 and 2019. It is notable that Addington Brook had high conductivity in both 2013 and 2019 compared to other wadeable sites, which is suggestive of persistent water quality issue. See Margetts & Marshall (2018) for a detailed analysis of CCC monthly water quality monitoring data.

Table 4: Water quality measured at the 18 ecology monitoring sites.

Site No.	Site name	Dissolved oxygen (%)	Temper-ature (°C)	pH	Conduc-tivity (µS/cm)
6	Okeover Stream at University of Canterbury Glasshouses	101	14.8	7.2	181
7	Avon River at Clyde Road	114	13.4	6.6	188
9	Papanui Stream at Erica Reserve	42	14.6	6.6	135
12	Addington Brook Upstream of Riccarton Ave	96	16.3	7.7	313
13	Riccarton Main Drain Downstream of Deans Avenue	99	14.7	6.9	267
18	Dudley Creek at North Parade	64	19.9	7.5	159
19	Waimairi Stream at Fendalton Park	128	15.9	6.9	193
20	Wairarapa Stream upstream of Glandovey Rd	138	14.8	7.2	172
22	Waimairi Stream downstream of railway bridge	118	14.7	6.8	176
23	Wairarapa Stream downstream of Fendalton Rd	132	14.8	7.1	173
24	Avon River downstream of Mona Vale loop	125	14.1	6.7	89
26	Avon River at Botanical Garden North Car Park/in Hagley Park	98	16.3	7.1	182
27	Avon River Upstream of Montreal Street/near Durham St	99	15.9	7.3	186
28	Avon River at Victoria Square Near Armagh St	85	14.9	7.1	189
29	Avon River Downstream of Kilmore St (Otautahi)	74	14.8	6.7	169
30	Avon River at Dallington Terrace/ Gayhurst Rd	99	16.4	6.8	188
31	Avon River at Avondale Rd	175	19.8	8.8	201
32	Avon River at Pages/ Seaview bridge	127	19.7	7.8	524
LWRP Freshwater Outcome or Receiving Environment Standard		**≥70**	**–**	**6.5 - 8.5**	–

Adjacent landuse and riparian habitat remains largely unchanged in 2019 compared with 2013 at most sites (Boffa Miskell 2014). The majority of sites have minimal riparian buffer widths (typically <2 m), and many have artificial timber or stone banks and are subjected to regular maintenance to maintain a garden-like appearance. This is true for nearly all mid to upper river sites, from Site 29 (Avon River downstream of Kilmore Street) upstream (Figure 2). The only exceptions in the upper river are Okeover Stream (Site 6) and Papanui Stream (Site 9), which both have natural banks and native plants dominating the riparian zone (Figure 3). Riccarton Main Drain (Site 13) has the most highly modified riparian and bank habitat, with concrete lining and mown grass banks, although there is reasonable shading from tall oak trees (Figure 3). In general, the smaller tributary streams are better-shaded than the mainstem of the Avon River, while Okeover stream is the best shaded, with near-complete canopy cover from native trees and shrubs (Figure 3).

The Avon River changes character from Site 30 (Gayhurst Road) downstream, with the lower river becoming deeper and broader, and with increasing tidal influence on water levels and vegetation (Figure 4). The lower river is also constrained by stopbanks, resulting in artificially-steep banks that greatly limit the development of native riparian vegetation. This is particularly acute at Site 32 (Pages Road), where the steep stopbanks are composed of rock and only sparse grasses occur (Figure 4). See Appendix 1 for photographs of all the sites in 2019.

Figure 2: Sites in the mid to upper reaches of the Avon catchment often have timber or stone banks, such as Site 7 at Clyde Road (left) and the riparian zone has a manicured appearance with minimal native plants, such as Site 26 at Botanical Garden North Car Park (right).

Figure 3: Contrasting riparian and bank habitat conditions in tributary waterways, with Riccarton Main Drain (Site 13) on the left and Okeover Stream (Site 6) on the right.

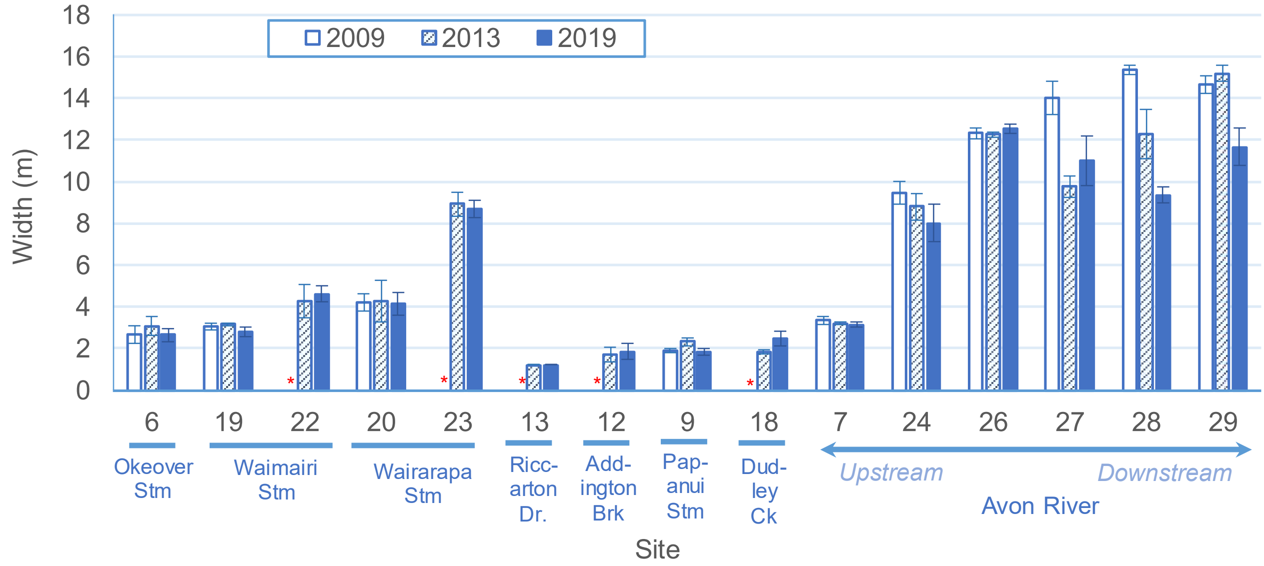
Figure 4: Images from Site 30 at Gayhurst Road (left) and Site 32 at Pages Road (right) illustrate how the lower Avon River is lined by stopbanks, which prevent development of a natural floodplain and associated ecosystems.

The only site with a marked habitat difference in riparian and instream habitat between 2013 and 2019 was Site 12 on Addington Brook. That is because sampling in 2013 occurred in Christchurch Botanical Gardens, immediately upstream of the Avon River, whereas in 2019 sampling was further upstream in Hagley Park. While the two sites were less than 200 m apart, they have markedly different habitat conditions; the old downstream site has a stony bed and extensive native planting in the riparian zone, whereas the new upstream site has grass banks and silt-dominated bed sediments (Figure 5). This illustrates how quickly riparian and habitat conditions can change over short distances along urban waterways, due to different land ownership and maintenance regimes.

Figure 5: Addington Stream at the 2013 monitoring site in the Botanical Gardens (left) and less than 200 m upstream at the 2019 monitoring site in Hagley Park (right), showing major habitat differences.

The mainstem Avon River sites are generally wider and deeper than the tributaries, reflecting increasing flow with distance downstream (Figure 6). At the wadeable sites, mean width across all years ranges from 1.2 m at Site 13 (Riccarton Main Drain) up to 13.8 m at Site 29 (Avon River at Kilmore Street), while mean depth ranges from 12 cm at Site 6 (Okeover Stream) and Site 20 (Wairarapa Stream downstream of Glandovey Road) to 11 to 39 cm at

Site 23 (Wairarapa Stream downstream of Fendalton Road) and Site 28 (Avon River at Victoria Square; Figure 6Figure 6). Two-way ANOVA revealed significant differences amongst sites for width (P<0.001) and depth (P<0.001), and significant differences amongst years for both width (P<0.001), and depth (P=0.004), with narrower widths overall in 2019 and greater depths overall in 2013 (Figure 6). There was no significant site x year interaction for width (P>0.05), but there was for depth (P=0.001). Despite the significant differences in width and depth over time and amongst sites, the differences were typically small and were not indicative of a ecologically-meaningful trend.



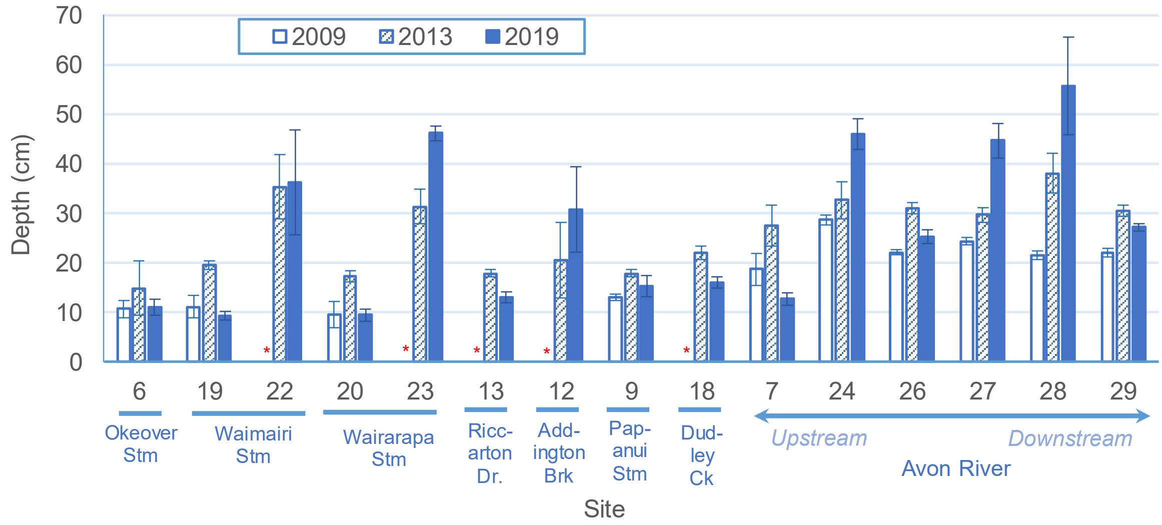


Figure 6: Mean (±1 SE) width (upper) and water depth (lower) at the 15 wadeable sites. Asterisks indicate no data collected for that year.

Water velocity varies from site to site, but is generally greater in the mainstem Avon River sites, where flow is greater (Figure 7). Mean velocity across all years was 0.32 m/s at the tributary sites and 0.54 m/s at the wadeable Avon River mainstem sites. There was no clear pattern in velocity indicative over time amongst the different sampling sites (Figure 7).

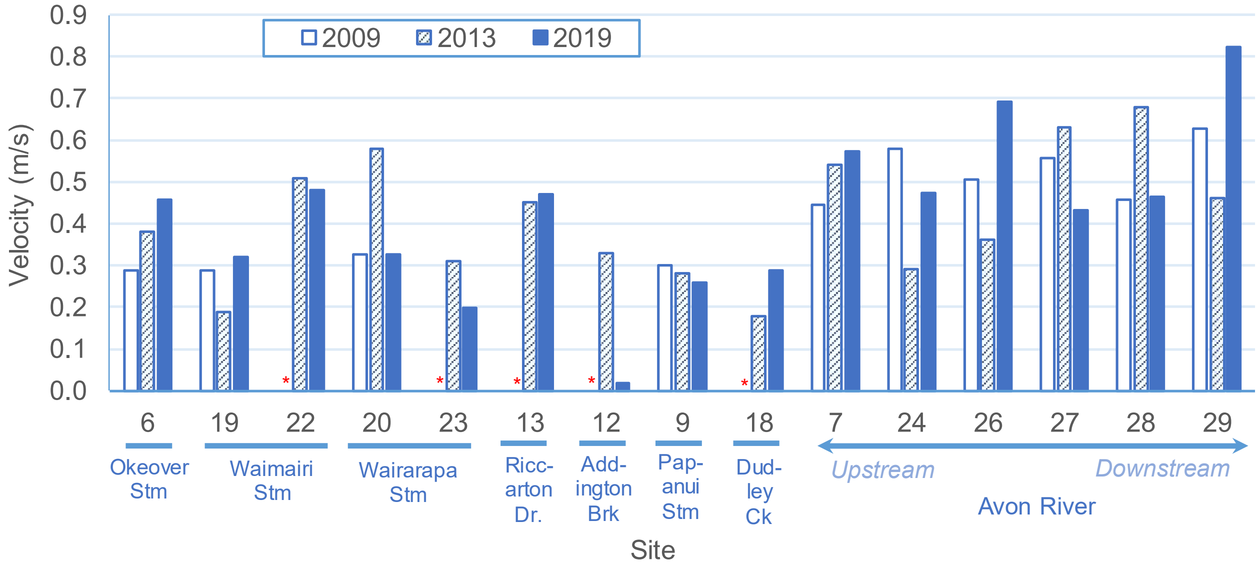


Figure 7: Mean water velocity at the 15 wadeable sites. Asterisks indicate no data collected for that year

Bed sediments are typically dominated by coarse gravel and pebble substrates (substrate index 4 to 5) at the wadeable sites, with the exception of Site 23 (Wairarapa Stream at Fendalton Road), which is dominated by fine sediments <2 mm; Figure 8). Two-way ANOVA revealed significant differences amongst sites (P<0.001) and no difference between sampling years (P>0.05), but there was a significant site x year interaction (P<0.001). The most notable difference in substrate composition between 2013 and 2019 was a shift from predominantly fine silt/sand sediments (substrate index 3) to coarse pebble-size sediments (substrate index 5) at Site 13 (Riccarton Main Drain) and Site 29 (Avon River at Kilmore Street; Figure 8). This difference was supported with significant Tukey post-hoc comparison (P<0.05). It is unclear what caused the increase in substrate size at these two sites; there are no related changes to recorded water velocity or macrophyte cover that could explain the difference.

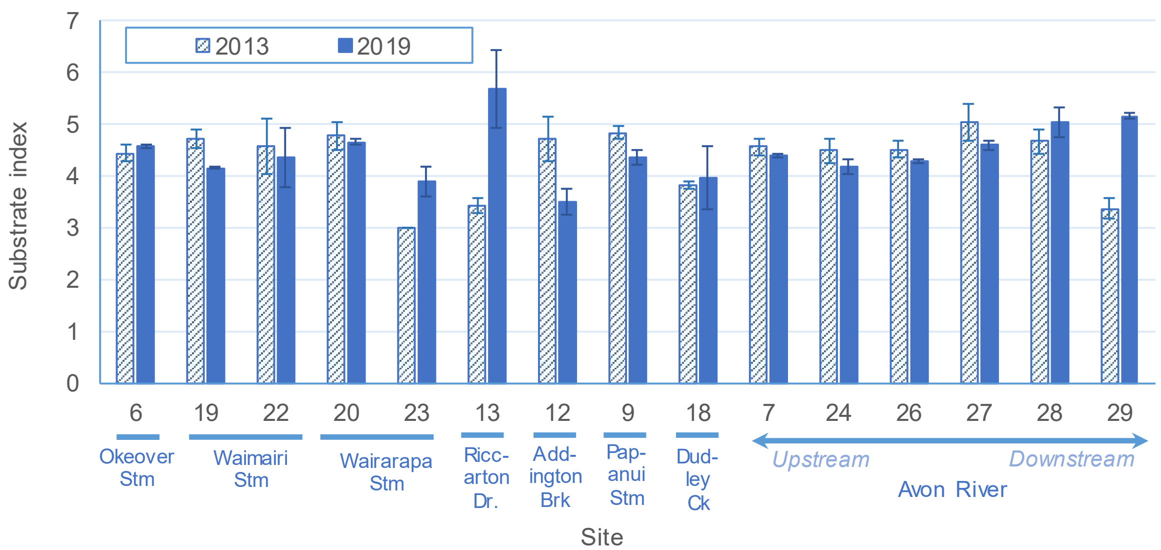


Figure 8: Mean (±1 SE) substrate index score at the 15 wadeable sites.

Fine sediment depth is low (<3 cm) at many wadeable sites, but there is considerable variation amongst sites and between years (ANOVA site x year interaction; Figure 9). Sites 9, 22, and 23 all had markedly lower fine sediment depths in 2019 and 2013. Importantly, there is no indication in an overall increasing trend in fine sediment depths over time across the monitoring sites

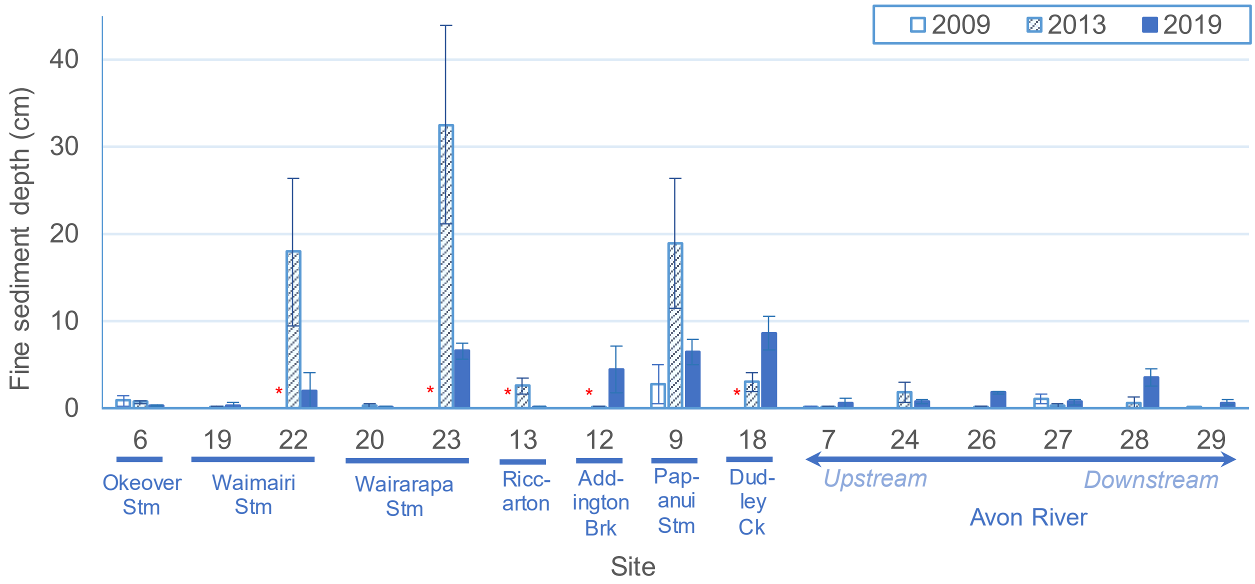


Figure 9: Mean (±1 SE) depth of fine sediment (<2 mm diameter) at the 15 wadeable sites. Asterisks indicate no data collected for that year.

Bed cover with fine sediment (<2 mm diameter) complied with the LWRP outcome of 30% cover at 10 of the 15 wadeable sites in 2019, compared to only 5 out of 15 sites in 2013 (Figure 10). Considerable variation in fine sediment cover between years and sites was reflected in significant ANOVA main effects and site x year interactions (ANOVA P<0.001). Site 12 on Addington Brook was the only site to see a substantial increase in fine sediment cover between sampling years (Figure 10); this reflects the dominance of fine sediments at the new sampling location in Hagley park in 2019 compared to the stony bed sediments at the 2013 sampling site downstream in the Christchurch Botanical Gardens.

All of the wadeable sites have low cover with emergent macrophytes, complying with the LWRP outcome of 30% bed cover (Figure 11). In contrast, total macrophyte cover was higher and exceeded the LWRP outcome of 60% cover at 4 of the 15 wadeable sites in 2019 (Figure 12). Inspection of data from previous monitoring years revelated that bryophytes were previously included in macrophyte cover estimates, resulting in slightly higher macrophyte cover estimates than actually occurred. This is particularly apparent at several tributary sites, where byrophytes are relatively abundant. Indeed, adding bryophytes to the total macrophyte cover would result in Site 22 (Waimari Stream) exceeding the LWRP outcome of 60% cover in 2019, when total cover was just below the outcome (Figure 12).

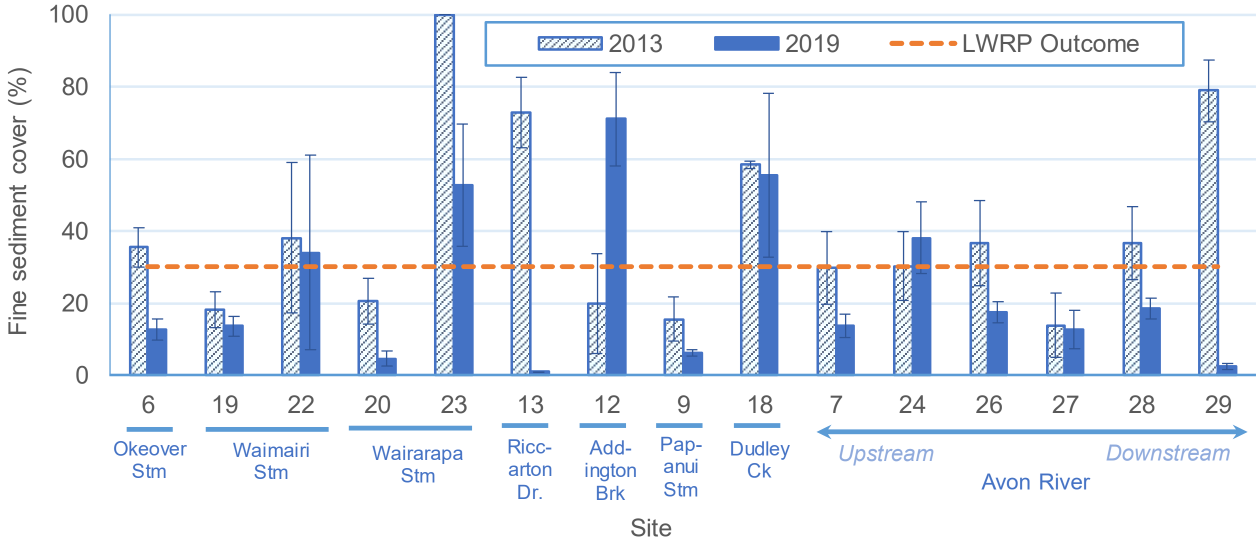


Figure 10: Mean (±1 SE) percent bed cover with fine sediment (<2 mm diameter) at the 15 wadeable sites in comparison to the LWRP outcome target of 30%.

Total macrophyte cover varied between years and sites, which was reflected in significant ANOVA main effects and site x year interactions (ANOVA P<0.001). There was a general pattern of higher macrophyte cover in 2019 compared to previous years (Figure 12). All sites are subject to macrophyte removal by CCC contractors. It is likely that greater macrophyte cover in 2019 reflected a greater time since macrophyte clearance prior to monitoring compared to previous years.

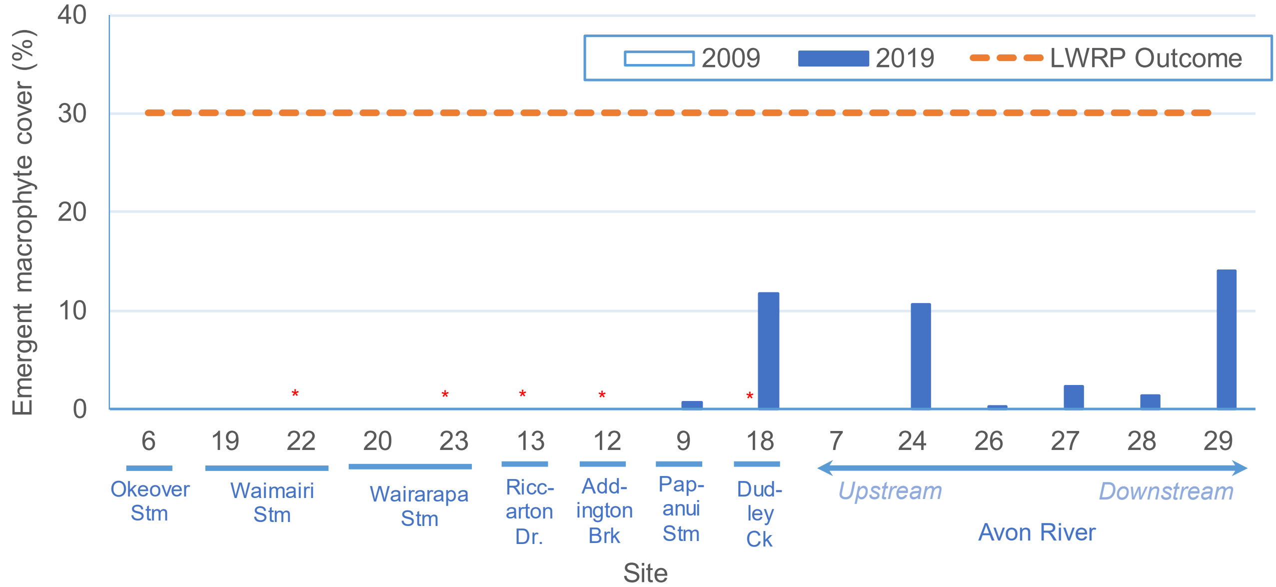
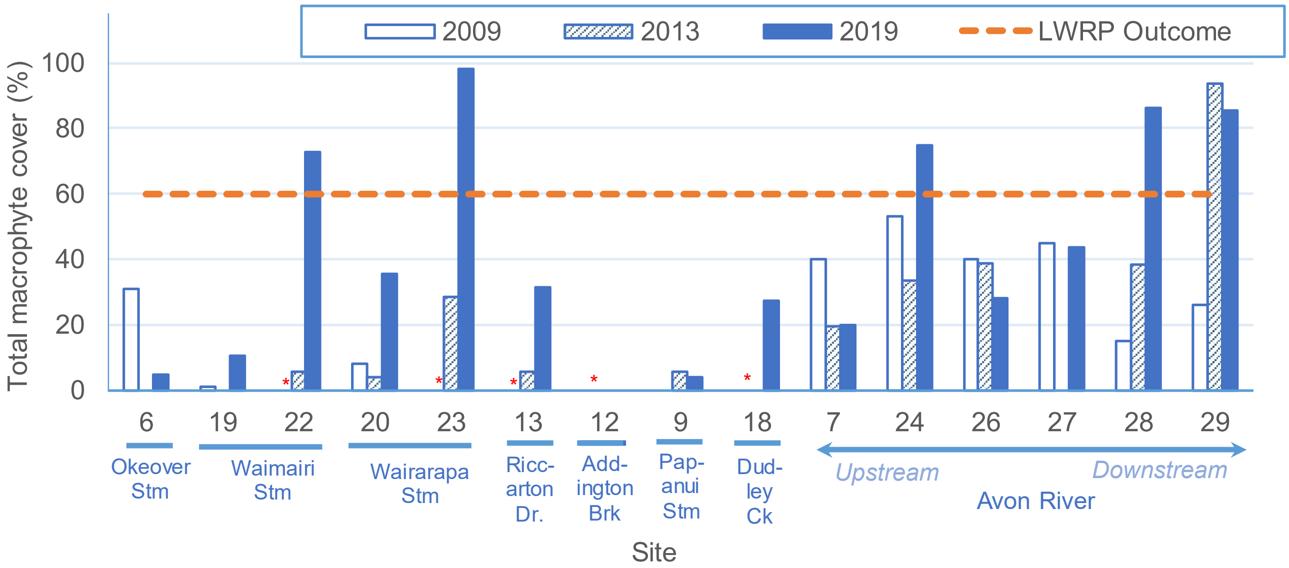


Figure 11: Bed cover with emergent macrophytes in comparison with the LWRP freshwater outcome of 30% for Spring-fed plains (urban) streams.



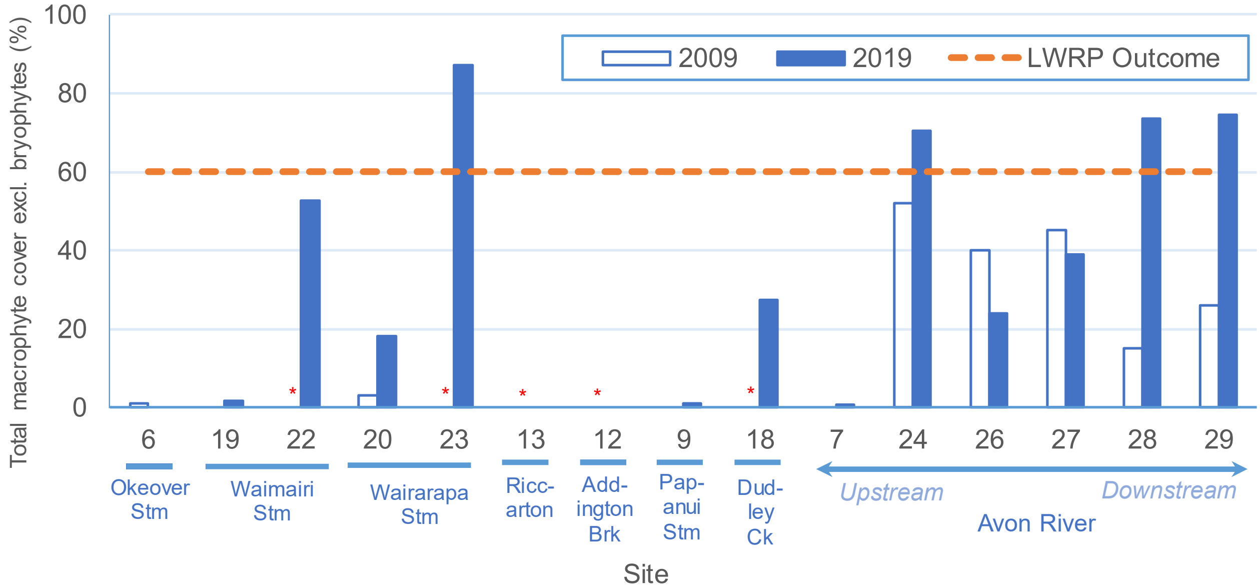


Figure 12: Bed cover with total macrophytes in comparison with the LWRP freshwater outcome of 60% for spring-fed plains (urban) streams. The upper plot includes bryophytes in the total cover estimate (as reported in previous years), while the lower plot excludes bryophytes.

Bed cover with long filamentous algae (>2 cm) is typically low at all wadeable sites, and complied with the LWRP outcome of 30% cover at all sites in 2019 (Figure 13). Long filamentous algae cover varied between years and sites, which was reflected in significant ANOVA main effects and site x year interactions (ANOVA P<0.001). Overall, long filamentous algae cover was lower in 2019 than in 2013 (Tukey <0.001).

Figure 13: Mean (±1 SE) percent bed cover with long filamentous algae.

3.2. Sediment Quality

Sediment quality data from 2019 is summarised in Table 5 and all laboratory results are provided in Appendix 2. Laboratory-analysed sediments from all sites were dominated by particles in the range of fine to medium sand, with corresponding modified substrate index (SI) values falling between 1 (silt/clay) to 3 (medium sand; Table 5). Total organic carbon (TOC) content varied amongst sites, ranging from a low of 0.25 g/100g for Site S14 (Avon River at Bridge Street), up to 10.6 g/100g at Site S10 (Avon River at Manchester Street). These variations in TOC content likely reflect the influences of a combination of underlying geology, adjacent landuse, and local hydrology.

In 2019 zinc had the highest concentrations of the three metals tested, while lead concentrations were considerably lower, followed by copper (Table 5). In addition, there was a general pattern of increasing metal concentrations from Mona Vale (Site S7) downstream to Manchester Street in the Avon River (Site S10; Table 5). Zinc concentrations exceeded the upper ANZECC (2018) Guideline Value (GV-high) at three locations: Addington Brook, Avon River at Armagh Street, and Avon River at Manchester Street. No other parameters exceeded GV-high levels. However, the lower Default Guideline Value (DGV) level was exceeded at 10 sites for lead, six sites for zinc, and one site for copper (Table 5). Total PAHs were generally low, but they did exceed the lower DGVs at four locations (Table 5).

The two most downstream Avon River sites complied with sediment quality guidelines for all parameters tested (Table 5). However, 12 of the 14 sites did not meet ANZECC (2018) guidelines for at least one sediment quality parameter, including:

- Three sites that exceeded guidelines for only 1 parameter;
- Six sites that exceeded guidelines for two parameters; and
- Three sites that exceeded guidelines for three parameters.

Table 5: Sediment quality at monitoring sites in 2019. Units are mg/kg dry weight, except for total organic carbon (TOC), which is g/100 g dry weight, and substrate index (SI), which is unitless. Values exceeding the ANZECC (2018) Default Guideline Value (DGV) are in orange font and those exceeding GV-high are in red.

Site Code	Site	Copper	Lead	Zinc	TOC	SI	Total PAHs
S1	Waimairi Stream Downstream of Railway Bridge	22	**71**	173	2.4	2.1	**19.6**
S2	Wairarapa Stream Downstream of Fendalton Road	27	**139**	182	4.0	1.8	2.1
S3	Riccarton Main Drain Downstream of Deans Avenue	17	23	**250**	0.6	2.8	2.4
S4	Addington Brook Upstream of Riccarton Avenue	32	**63**	**540**	2.5	1.7	3.2
S5	Dudley Creek at North Parade	19	**71**	**360**	2.2	2.1	**13.2**
S6	Avon River at Clyde Road	24	**53**	**300**	3.6	1.8	1.5
S7	Avon River at Mona Vale	39	**56**	**270**	3.7	1.9	1.6
S8	Avon River at Carlton Mill Corner	41	**78**	**300**	6.8	2.4	1.5
S9	Avon River at Victoria Square Near Armagh Street	51	**78**	**540**	7.6	1.9	**11.6**
S10	Avon River at Manchester Street	**65**	**110**	**760**	10.6	1.8	1.5
S11	Avon River at Dallington Terrace/Gayhurst Road	14	**51**	161	1.3	2.1	**20.9**
S12	Avon River at Avondale Road	26	48	**360**	5.4	1.3	0.7
S13	Avon River at Pages/Seaview Bridge	19	32	154	2.6	2.1	0.5
S14	Avon River at Bridge Street	3	9	46	0.2	1.9	1.1
DGV		65	50	200	N/A	N/A	10
GV-high		270	220	410	N/A	N/A	50

Notes: Total PAHs are normalised to 1% TOC. N/A indicates no applicable guideline values.

The ANZECC (2018) sediment quality guidelines indicate the overall risk of toxicity effects on biota. Thus, sites meeting lower DGVs have a low risk of effects, sites exceeding DGVs have an increased risk of adverse effects, and there is a relatively high risk of adverse for sites exceeding GV-high values. This means that there is an increased risk of adverse ecological effects at most sites sampled, and a higher level of risk at the three sites that exceed the GV-high for zinc.

Comparison of sediment quality data from 2013 to 2018 shows that laboratory-measured sediments have typically been in the fine to coarse sand range for most sites (substrate index of 1-3; Figure 14). There is no indication of an increasing or decreasing trend in substrate index across the monitoring sites. The lack of trend may be expected, given that the field sampling method targets areas of fine sediment deposits, and is not intended to be representative of overall substrate composition at the reach scale.

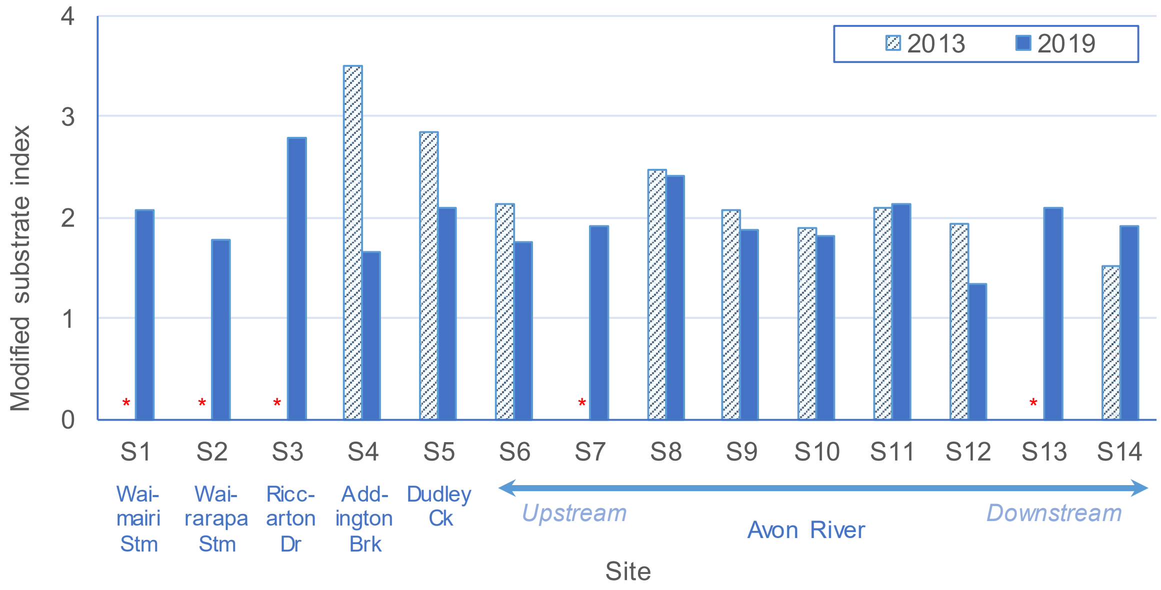


Figure 14: Modified substrate index for sediments analysed by the laboratory. An index score of 1 represents silt and clay-sized particles (<0.063 mm, 2 indicates fine sand (0.063-0.25 mm), and 3 indicates medium sand (0.25-0.5 mm). Asterisks indicates no data collected for that date.

Copper concentrations in sediment have varied over time from 1980 to 2018, but they have almost always been well below the ANZECC (2018) low-level DGV (Figure 15). Copper concentrations were higher in 2019 than in 2013 at seven of the nine sites where sampling occurred on both dates, but no overall increasing trend is apparent when compared with data from 1980. Thus, when comparing 2019 and 1980 data, six sites had higher copper concentrations in 2019 and seven sites had lower concentrations in 2019. Copper concentrations remain well below the ANZECC (2018) GV-high level at all sites.

Sediment lead concentrations have also varied considerably over time, with numerous sites exceeding the DGV, but no sites have exceeded the GV-high level on any occasion (Figure 16). The most notable trend over time is that lead concentrations declined markedly at most sites between 1980 and subsequent monitoring in 2013 and 2019. For the 13 sites with lead data for 1980 and 2019, the overall mean lead concentrations nearly halved, declining from 123 mg/kg in 1980 to 66 mg/kg in 2019. While lead concentrations in 2019 were higher at six of the nine sites monitored in 2013, the difference was typically small compared to the overall reduction in lead levels since 1980 (Figure 16).

Zinc concentrations in sediment exceeded the GV-high level at three locations in 1980 (Addington Brook, Dudley Creek, and Avon River at Gayhurst Road), at no locations 2013, and at three locations in 2019 (Addington Brook, Avon River at Armagh Street, and Avon River at Manchester Street; Figure 17). At the nine sites where data is available for all three years of monitoring, zinc concentrations in 1980 and 2019 were approximately double those in 2013, which is a similar pattern to that observed for copper. Thus, despite higher zinc concentrations recorded in 2019 compared to 2013, there is no apparent long-term trend when compared with earlier data from 1980.

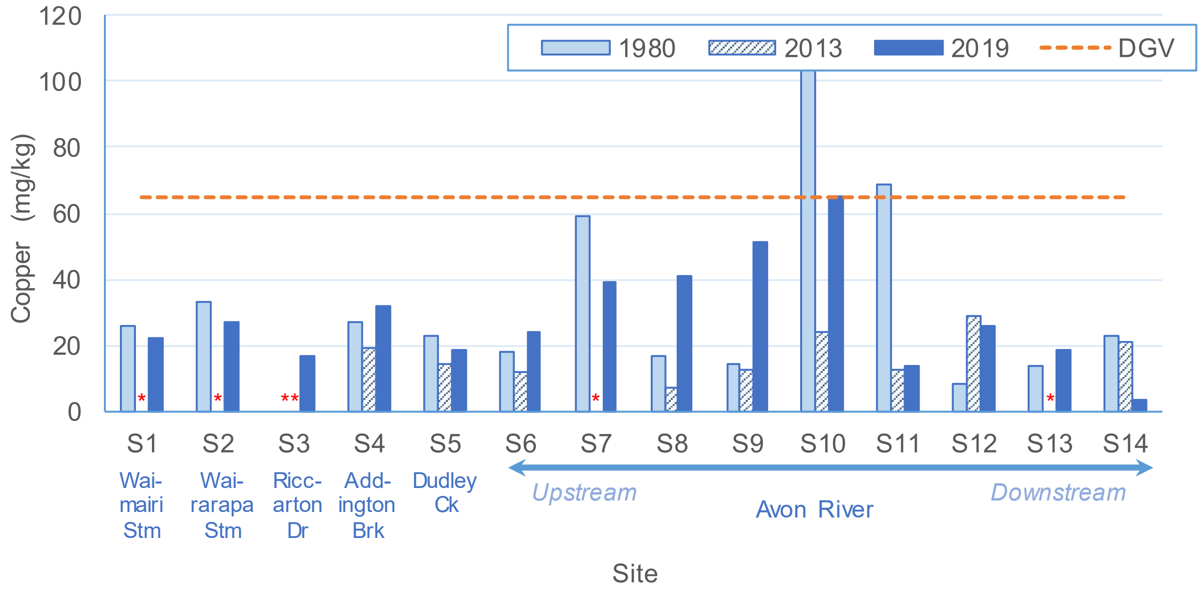


Figure 15: Sediment copper concentrations compared to ANZECC (2018) guidelines. Asterisks indicate no data collected for that date.

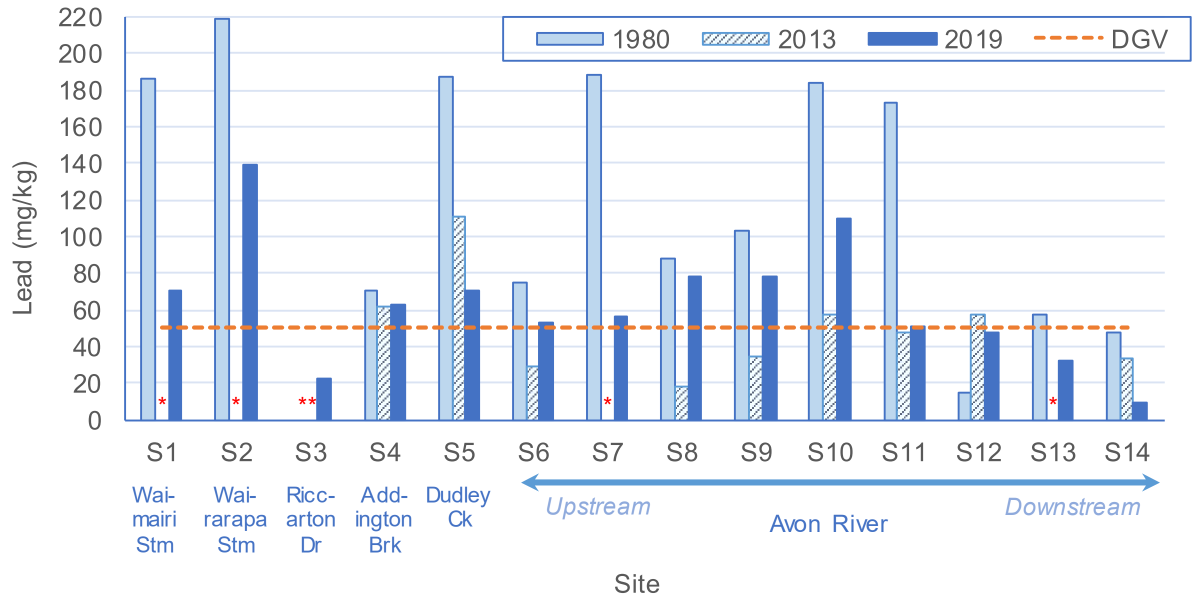


Figure 16: Sediment lead concentrations compared to ANZECC (2018) guidelines. Asterisks indicate no data collected for that date.

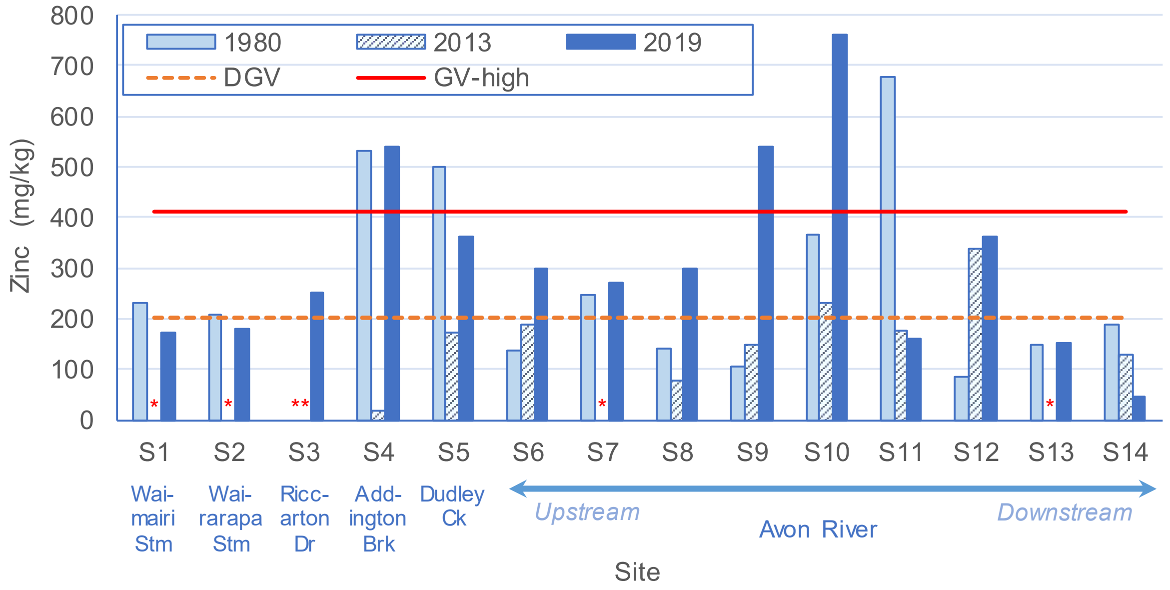


Figure 17: Sediment zinc concentrations compared to ANZECC (2018) guidelines. Asterisks indicate no data collected for that date.

Total PAH sediment concentrations remained low, but variable amongst most sites sampled in both 2013 and 2019 (Figure 18). Total PAHs exceeded the DGV level at the same three sites in both 2013 and 2019: Dudley Creek (Site S5), Avon River at Armagh Street (S9), and Avon River at Gayhurst Road (Site S11). However, all sites have been below the GV-high on all occasions and there is no indication of an overall increasing or decreasing trend in total PAHs between sampling years (Figure 18).

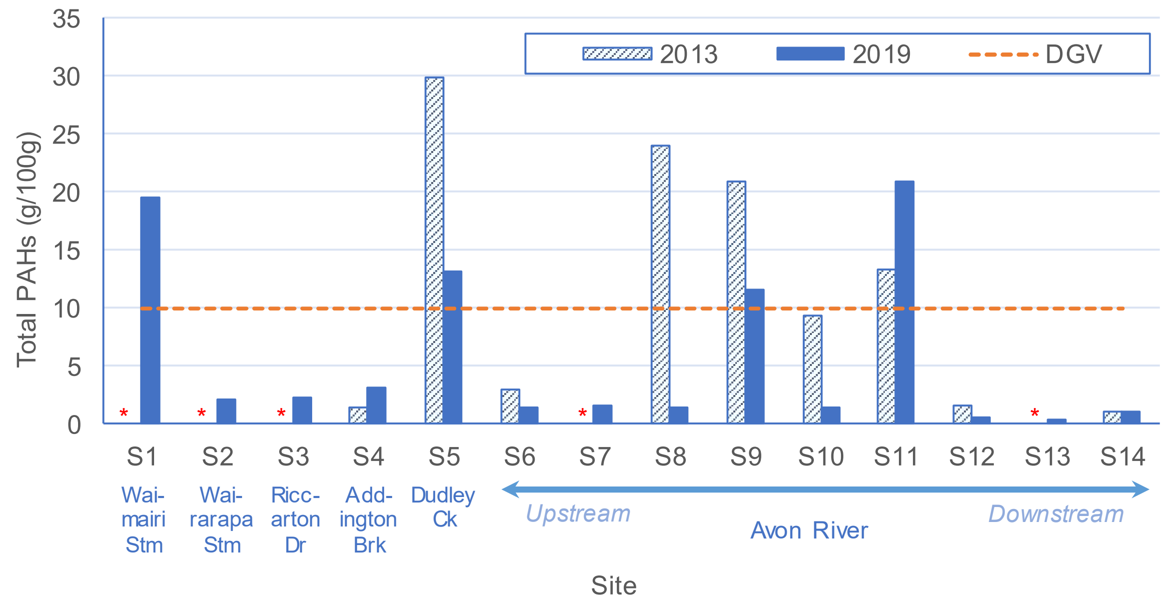


Figure 18: Sediment total PAH concentrations compared to ANZECC (2018) guidelines. Asterisks indicate no data collected for that date.

3.3. Macroinvertebrates

Invertebrate taxa richness in 2019 ranged from a low of 9 taxa at Site 23 (Wairarapa Stream at Fendalton Road) to a high of 20 taxa at Site 20 (Wairarapa Stream at Glandovey Road), Site 12 (Addington Brook), and Site 7 (Avon River at Clyde Road; Figure 19). For the ten sites with invertebrate data from all three sampling occasions, taxa richness was 18 in 2009, 13 in 2013, and 15 in 2019. Higher taxa richness overall in 2009 likely reflects the greater sampling area in 2009 (a total of 1.35 m² sampled per site) compared to 2013 and 2019 (0.6 m² per site). The most marked difference in taxa richness between 2013 and 2019 was observed at Site 12 (Addington Brook), where taxa richness increased from 6 taxa in 2013 to 20 taxa in 2019, despite the same sampling effort (Figure 19). This coincided with the monitoring site shifting to upstream of Rolleston Avenue in 2019. There was no indication of an overall increasing or decreasing trend in taxa richness between 2013 and 2019.

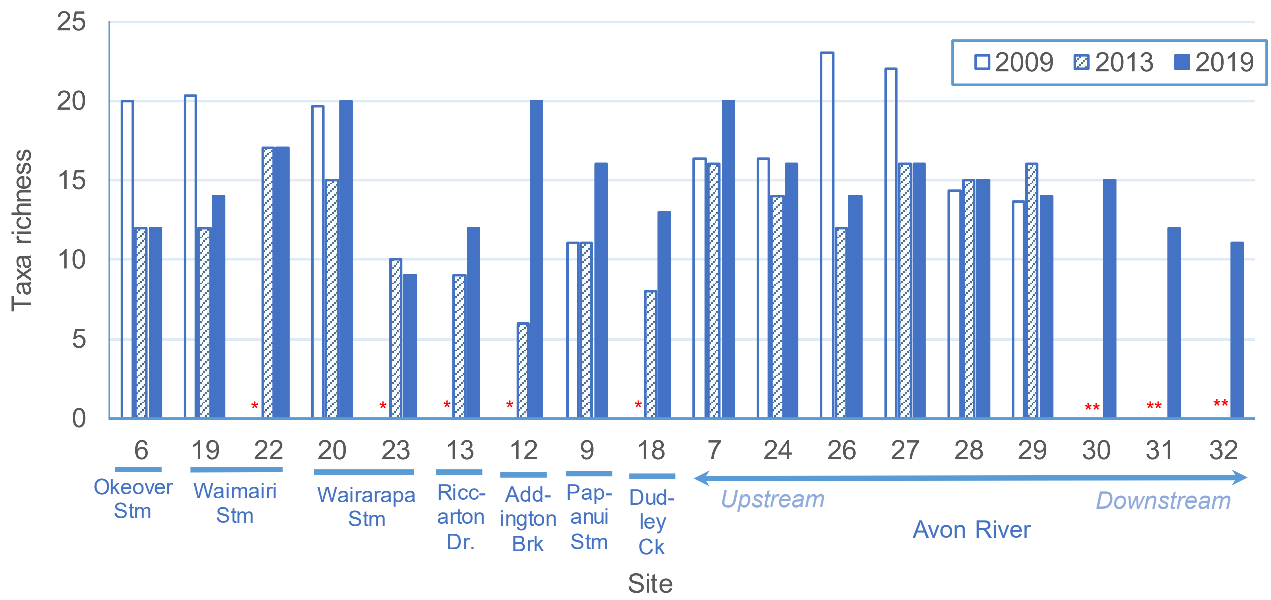


Figure 19: Invertebrate taxa richness at each monitoring site. Asterisks indicate no data collected for that year.

Invertebrate community composition was similar in 2019 to previous years, being dominated by the amphipod crustacean *Paracalliope fluviatilis* and the common mud snail *Potamopyrgus antipodarum* (Figure 20). These two pollution-tolerant taxa are very common in Christchurch waterways, and they have dominated the invertebrate community every year. The third to fifth most common taxa in 2019 were ostracod crustaceans, oligochaete worms and *Physa* snails, which are also relatively pollution-tolerant taxa. The most abundant EPT taxon, the cased caddisfly *Pycnocentrodes*, maintained its sixth rank between 2013 and 2019 however it was ranked third in 2009. The axehead cased caddisfly *Oxyethira* was ranked as the seventh most common taxa in 2019 which was the first time this taxon had been ranked in the top ten (it was ranked 13th and 14th in 2009 and 2013, respectively). The cased caddisfly *Hudsonema* was ranked eighth in 2019, which is similar to previous years (ninth and eleventh in 2009 and 2013, respectively). The ninth and tenth most abundant taxa were orthoclad midge larvae and sphaeriid bivalves, also being relatively common pollution-tolerant taxa.

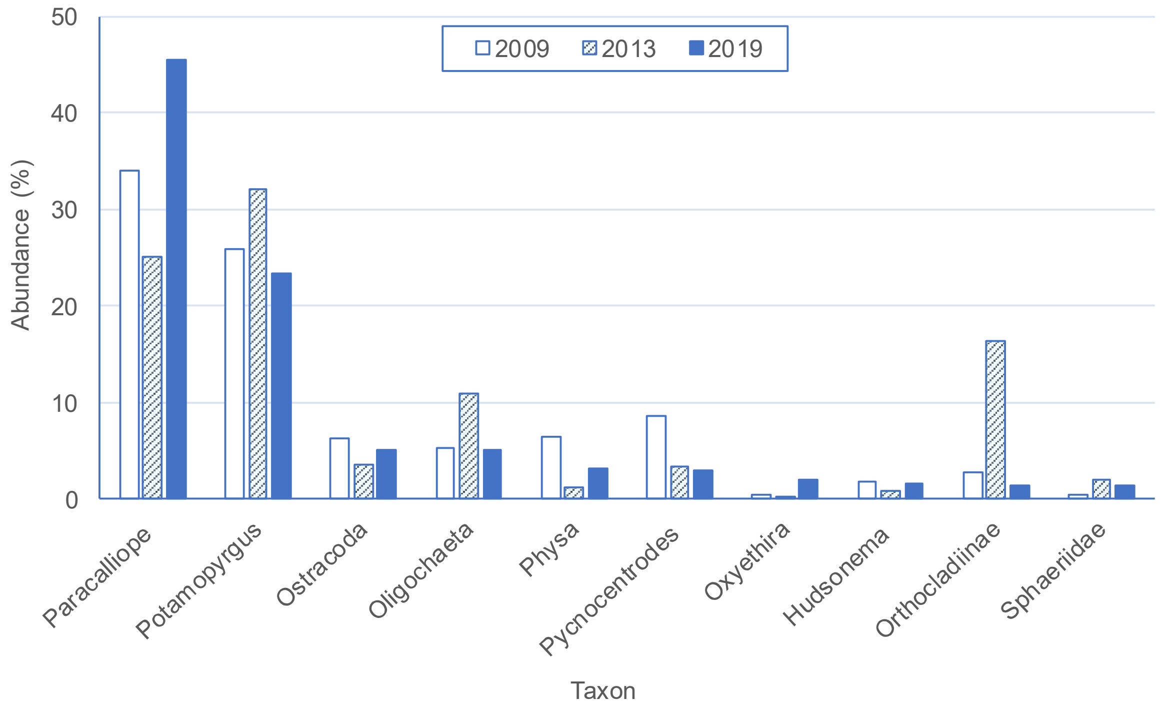


Figure 20: Abundance of the ten most common taxa across all sites in 2019 compared to previous years.

A total of four pollution-sensitive taxa (MCI scores ≥7) were recorded from the Avon River catchment in 2019, all of them cased caddisflies: *Oeconesus, Polyplectropus, Psilochorema* and *Pycnocentria* (Table 6). All of these taxa were recorded in 2009 but not for 2013, when *Polyplectropus* was not recorded. It should be noted that *Psilochorema* were not identified to species level in previous years, but the genus was recorded, and similarly, *Oeconesus* were not identified to genus level in 2013 but the family Oeconesidae was recorded.

Nine of the 18 monitoring sites recorded pollution-sensitive taxa in 2019, compared with six of the 15 sites monitored in 2013 and nine of the ten sites monitored in 2009 (Table 6). The disappearance of the free-living caddisflies *Psilochorema* and *Polyplectropus* (both with MCI scores of 8) between 2009 and 2013 at Site 6 (Okeover Stream) is notable as neither taxa have been recorded there since. Examination of raw data sheets provided by CCC indicate that *Psilochorema* and *Polyplectropus* were found in low abundances in 2009 and were potentially simply not detected in 2013 and 2019, due to the smaller area sampled.

Table 6: Pollution-sensitive invertebrate taxa (MCI scores of ≥7) at monitoring sites from 2009 to 2019.

Waterway	Site	2009	2013	2019
Okeover Stream	6	*Oeconesus sp.* *Polyplectropus* *Psilochorema sp.* *Pycnocentria*	*Oeconesidae* *Pycnocentria*	*Oeconesus sp.* *Pycnocentria*
Waimairi Stream	19	*Oeconesus sp.* *Psilochorema sp.*	*Psilochorema sp.* *Pycnocentria*	*Oeconesus sp.* *Polyplectropus* *Psilochorema bidens.*
	22	No data	*Oeconesidae* *Psilochorema sp.* *Pycnocentria*	*Oeconesus sp.* *P. bidens*
Wairarapa Stream	20	*Oeconesus sp.*	No taxa with MCI ≥ 7	*P. bidens*
Papanui Stream	9	No taxa with MCI ≥ 7	*Psilochorema sp.*	*Oeconesus sp.* *P. bidens*
Avon River (upstream)	7	*Psilochorema sp.*	*Oeconesidae* *Psilochorema sp.* *Pycnocentria*	*P. bidens* *Pycnocentria*
	24	*Oeconesus sp.* *Psilochorema sp.*	No taxa with MCI ≥ 7	*Oeconesus sp.* *P. bidens*
	26	*Psilochorema sp.*	*Psilochorema sp.* *Pycnocentria*	*P. bidens*
Avon River (downstream)	27	*Psilochorema sp.*	No taxa with MCI ≥ 7	*P. bidens.*

Note: No species with an MCI score ≥ 7 were found at sites 18, 28 and 29 for all years. Sites 12, 13 and 23 were not sampled in 2009 and no species with an MCI score ≥ 7 were found in 2013 and 2019. No species with an MCI score ≥7 were found for sites 30, 31 and 32 in 2019 and these sites were not sampled in 2009 or 2013.

All pollution-sensitive taxa that had previously been detected were detected again in 2019. One taxon, *Polyplectropus,* was not detected in 2013 but was collected from Site 6 (Okeover Stream) in 2009 and Site 19 (Waimari Stream at Fendalton Park) in 2019. *Polyplectropus* have always been found at low densities of fewer than 5 per sample. *Oeconesus* is the only taxon with an MCI score of 9 recorded from the Avon catchment from 2009 to 2019. *Oeconesus* were recorded from four sites in 2008, three sites in 2013 (when they were only recorded at family level) and five sites in 2019. *Oeconesus* have always been found at densities of fewer than 15 per sample. Overall, there is no indication of a general increasing or decreasing trend in the presence of uncommon pollution-sensitive taxa from 2009 to 2019.

Caddisflies (Trichoptera) are the only EPT taxa recorded in the Avon River catchment since regular monitoring commenced in 2009. EPT taxa richness is overall low in the Avon River catchment, which is typical for urban waterways (Suren 2000). In 2019, EPT taxa richness ranged from zero at Sites 23, 31, and 32, to a maximum of 7 taxa at Sites 19 and 24 (Figure 21). EPT taxa richness in 2019 followed a similar pattern to previous years, where richness is typically lowest in the lower reaches of tributaries (Sites 23, 13, 12, and 18), and higher in the upper to mid-reaches of the Avon River (Figure 21). Non-wadeable reaches of the Avon River sampled in 2019 had few or no EPT taxa, reflecting the fine bed sediments and tidal influence at these sites. There is no indication of an increasing or decreasing trend in EPT taxa richness over time across the sites sampled.

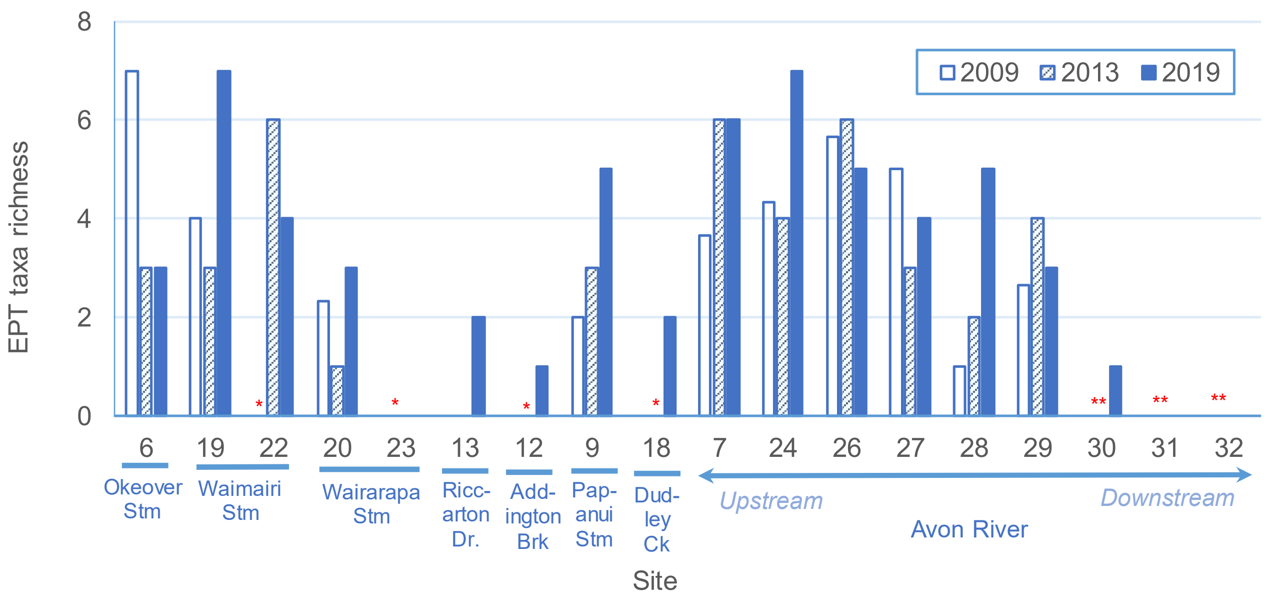


Figure 21: EPT taxa richness at each monitoring site. Asterisks indicate no data collected for that year.

Percent EPT abundance is low overall in the Avon catchment, with all sites recording less than 50% EPT abundance and most sites with less than 20% EPT, for all monitoring years (Figure 22). In 2019, percent EPT ranged from a low of zero at multiple sites, up to a high of 29% at Site 6 (Okeover Stream). EPT abundance has fluctuated over the years, but there is no indication of an overall increasing or decreasing trend (Figure 22).

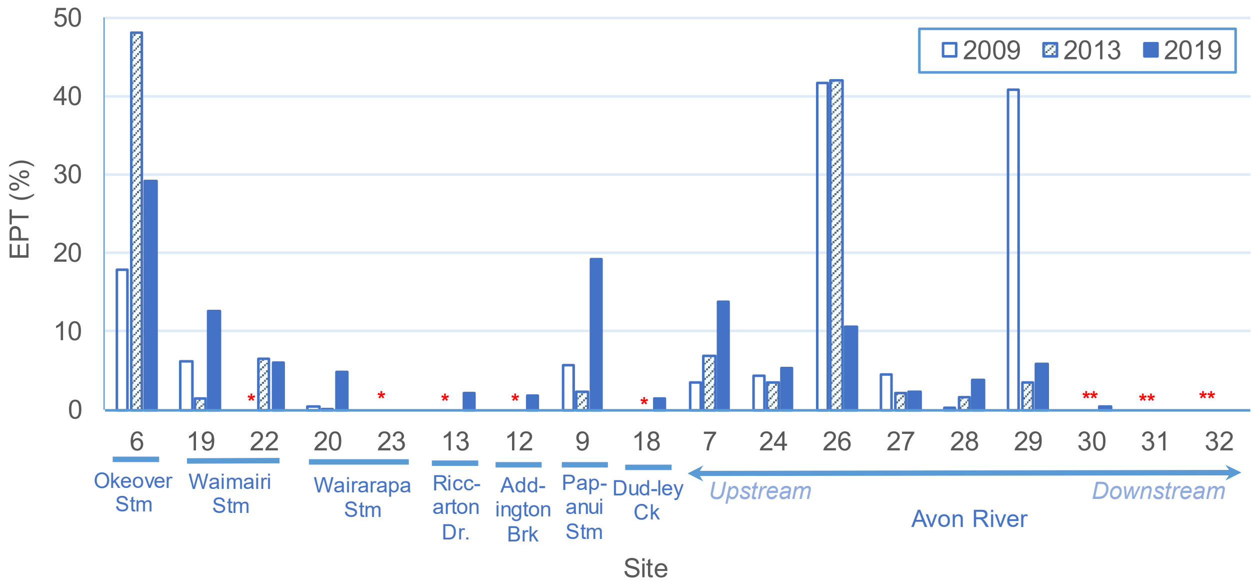


Figure 22: Percent EPT abundance at each monitoring site. Asterisks indicate no data collected for that year.

MCI scores at wadeable, non-tidal sites in 2019 ranged from a low of 56 at Site 23 (Wairarapa Stream at Fendalton Road) to a high of 97 at Site 19 (Waimairi Stream at Fendalton Park; Figure 23). MCI scores at wadeable sites in 2019 followed a similar pattern to previous years, with higher scores in upper tributary sites and the mid-reaches of the Avon River, and lower scores in the lower reaches of tributaries, particularly Wairarapa Stream and Dudley Creek. Overall, MCI scores in all sampling years have been indicative of poor to fair quality (MCI scores less than 100) at all sites. The lowest MCI score in 2019 was at Site 31 (Avon River at Avondale Road; Figure 23). However, this is a deep, tidally-influenced reach and the MCI was not developed for such settings (Stark & Maxted 2007). There is no indication of an overall increasing or decreasing trend in MCI scores at Avon River monitoring sites over time.

QMCI scores in 2019 met or exceeded the LWRP outcome of 3.5 at 14 of the 18 monitoring sites, including all eight Avon River monitoring sites from Site 7 (Clyde Road) downstream to Site 31 (Avondale Road; Figure 24). Proposed changes to the LWRP (in draft form at the time of writing) would see the LWRP outcome for spring-fed plains (urban) waterways such as the Avon River increase from a QMCI of 3.5 to 4.5. Based on the proposed LWRP outcome QMCI of 4.5, only 9 sites would comply in 2019. Overall, QMCI scores at all sites are indicative of fair (QMCI 4 to 5) to poor (QMCI <4) quality, with no sites indicative of good or better quality (i.e., QMCI scores >5). For the 10 sites with invertebrate data for all three monitoring years, mean QMCI scores were lowest overall in 2013 (mean = 3.6) and highest in 2019 (mean = 4.5), but there was no indication of an overall increasing or decreasing trend.

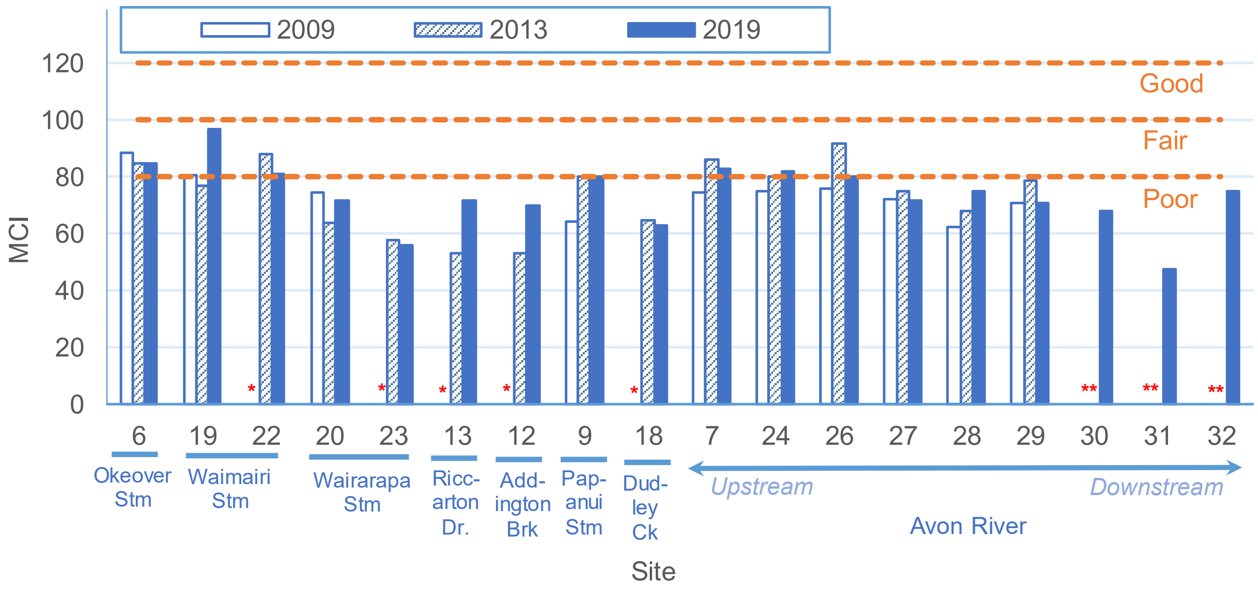


Figure 23: MCI scores at each monitoring site. Asterisks indicate no data collected for that year.

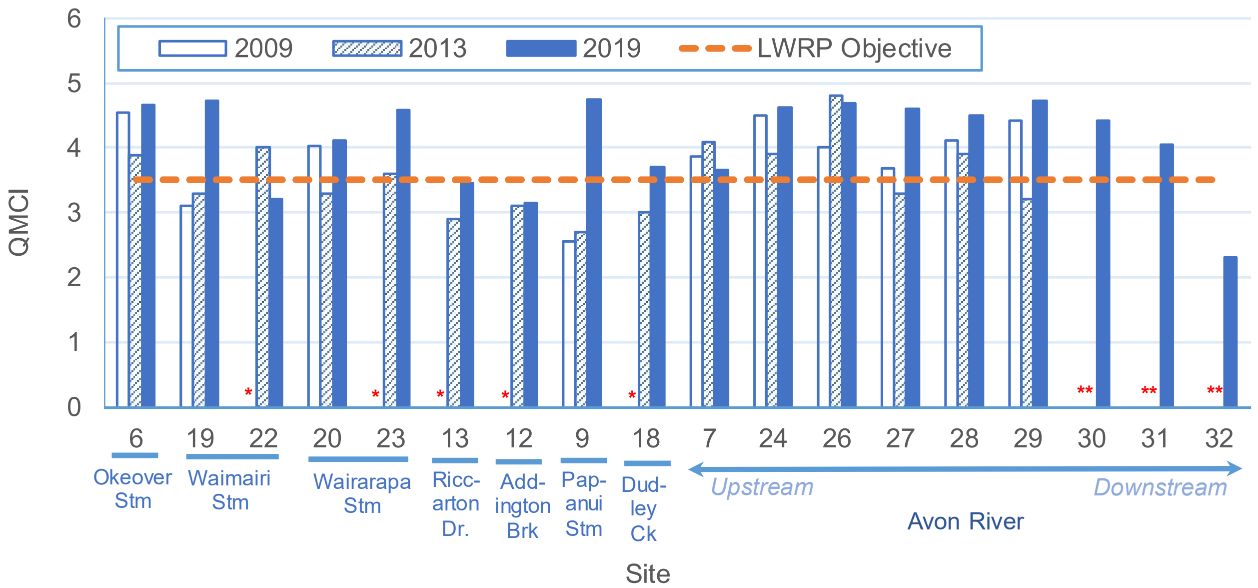


Figure 24: QMCI scores at each monitoring site. Asterisks indicate no data collected for that year.

No freshwater crayfish (kōura, *Paranephrops zealandicus*) or freshwater mussels (kākahi, *Echyridella menziesii*) have been recorded at any of the Avon River ecology monitoring sites from 2009 to 2019. Kōura and kākahi were also not collected in early surveys of the Avon catchment in the 1980s and early 1990s (Robb 1988, 1992; Eldon & Kelly 1992).

The NMDS ordination yielded a two-dimensional solution with a stress value of 0.19, indicating a fair relationship with the underlying similarity matrix (Clarke 1993). Site 32 (Avon River at Pages Road) sits well to the right of all other sites along ordination Axis 1 (Figure 25), due to its distinctive estuarine fauna, particularly the estuarine snail *Halopyrgus pupoides*. The other non-wadeable sites, Sites 30 and 31, were located towards the upper right corner of the ordination (Figure 25), indicating their community composition is distinct from the wadeable sites.

For the wadeable sites, there was a general pattern of sites from the upper tributaries and the mainstem Avon River (Sites 24 to 29) tending towards the upper half of the ordination (Figure 25). These sites tended to have more pollution-sensitive taxa, such as the caddisflies *Pycnocentrodes* and *H. parumbrepennis*. Conversely, wadeable sites towards the right of the ordination tended to be dominated by more pollution-tolerant taxa such as *P. antipodarum* and oligochaete worms. There was no clear trend in invertebrate community composition over time, with considerable overlap of samples from different years in ordination space.

Channel width was positively correlated ($P<0.01$) with Axis 2 scores and dissolved reactive phosphorus was weakly and negatively correlated with Axis 1 ($P<0.05$). No other habitat quality, water quality, or sediment quality parameters were significantly correlated with either axis ($P>0.05$). This likely reflects the relative similarity in invertebrate community composition for the sites sampled, with most sites dominated by a similar core of pollution-tolerant taxa.

3.4. Fish

A total of ten fish species were caught in 2019, comprising nine native species and one introduced species, brown trout (Table 7, Figure 26, Figure 27). Shortfin eel were the most widespread species and they were found at 16 of the 18 sites. Longfin eel were found at 15 sites, but they were less abundant at each site. Common bully were found at 13 sites and they were particularly abundant at Site 13 (Riccarton Main Drain) and at the second and third most downstream Avon River sites (Table 7).

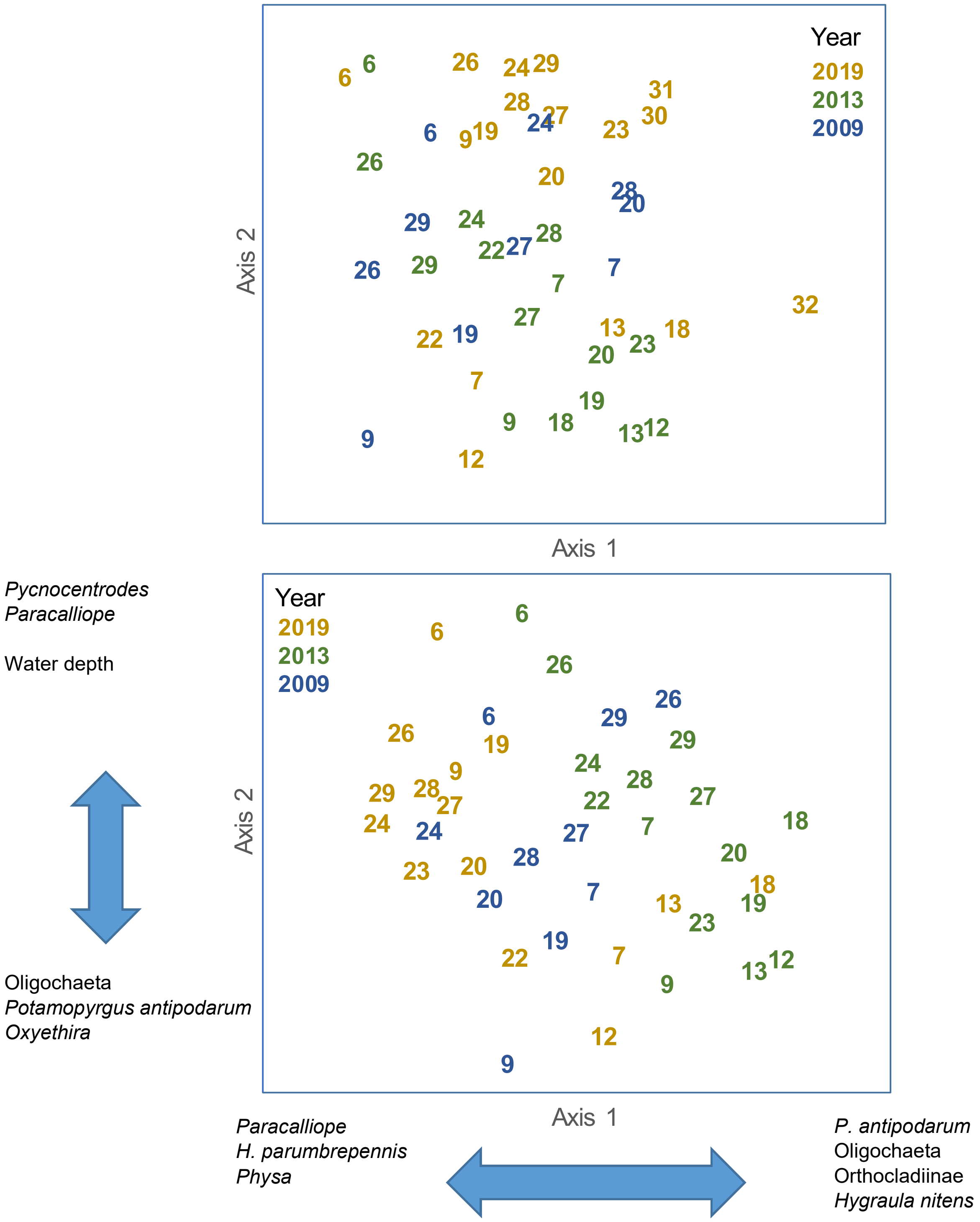


Figure 25: NMDS plot of invertebrate communities for all sites (top) and wadeable sites only (bottom). Coloured numbers indicate site codes and colours refer to sampling years. Habitat parameters and species most strongly correlated with wadeable site axis scores (P<0.01) are shown. Plot stress is 0.19 for both ordinations.

Table 7: Total number of fish caught per site in 2019. Size range (mm) is in brackets.

Waterway	Site	Brown Trout	Common Bully	Elver	Giant Bully	Inanga	Longfin Eel	Shortfin Eel	Upland Bully	Juvenile Bully	Triple fin	Mullet	Bluegill Bully
Okeover Stream	6						7 (283-1150)						
Waimairi Stream	19	6 (97-218)					3 (236-386)	6 (156-543)	4 (44-66)	2 (26-32)			
	22						3 (280-495)	5 (208-410)	1 (62-62)				
Wairarapa Stream	20	3 (72-108)	3 (37-45)				6 (306-524)	2 (363-426)	11 (39-104)	4 (30-34)			
	23						1 (492)	4 (284-572)					
Riccarton Main Drain	13		23 (32-70)					1 (240)	6 (36-66)	6 (28-34)			1 (30)
Addington Brook	12						1 (1200)	11 (160-627)					
Papanui Stream	9		4 (43-50)						17 (43-76)	3 (33-36)			
Dudley Creek	18		8 (47-64)	19 (73-146)				13 (123-320)					
Avon River	7	1 (88)	2 (43-63)				7 (236-894)	2 (403-621)	13 (36-77)	1 (33)			
upstream	24		1 (100)				2 (314-459)	9 (218-371)	1 (60)				
	26		7 (36-98)	4 (95-145)	2 (104-115)		5 (517-1280)	7 (169-772)	42 (34-72)	1 (32)			1 (44)
	27		13 (38-92)	3 (127-161)	3 (72-110)		14 (165-678)	17 (171-634)	11 (34-57)	2 (34-37)		1 (300)	
	28		14 (54-99)	5 (73-131)	1 (150)		4 (144-463)	5 (130-183)		2 (33-40)			
	29		13 (41-83)	10 (82-130)		1 (75-75)	7 (165-422)	8 (153-538)	16 (36-58)	2 (27-34)			170 (30-62)
	30		192 (53-98)	1 (107)	47 (71-140)	2 (86-89)	9 (399-653)	18 (336-668)		21 (26-47)			
	31		155 (53-99)		61 (55-132)	75 (54-106)	4 (381-490)	23 (368-891)		3 (29-36)			
downstream	32		24 (46-88)	1 (117)	20 (88-126)	25 (68-91)	7 (271-450)	12 (275-824)		2 (25-26)	133 (35-92)	3 (161-258)	

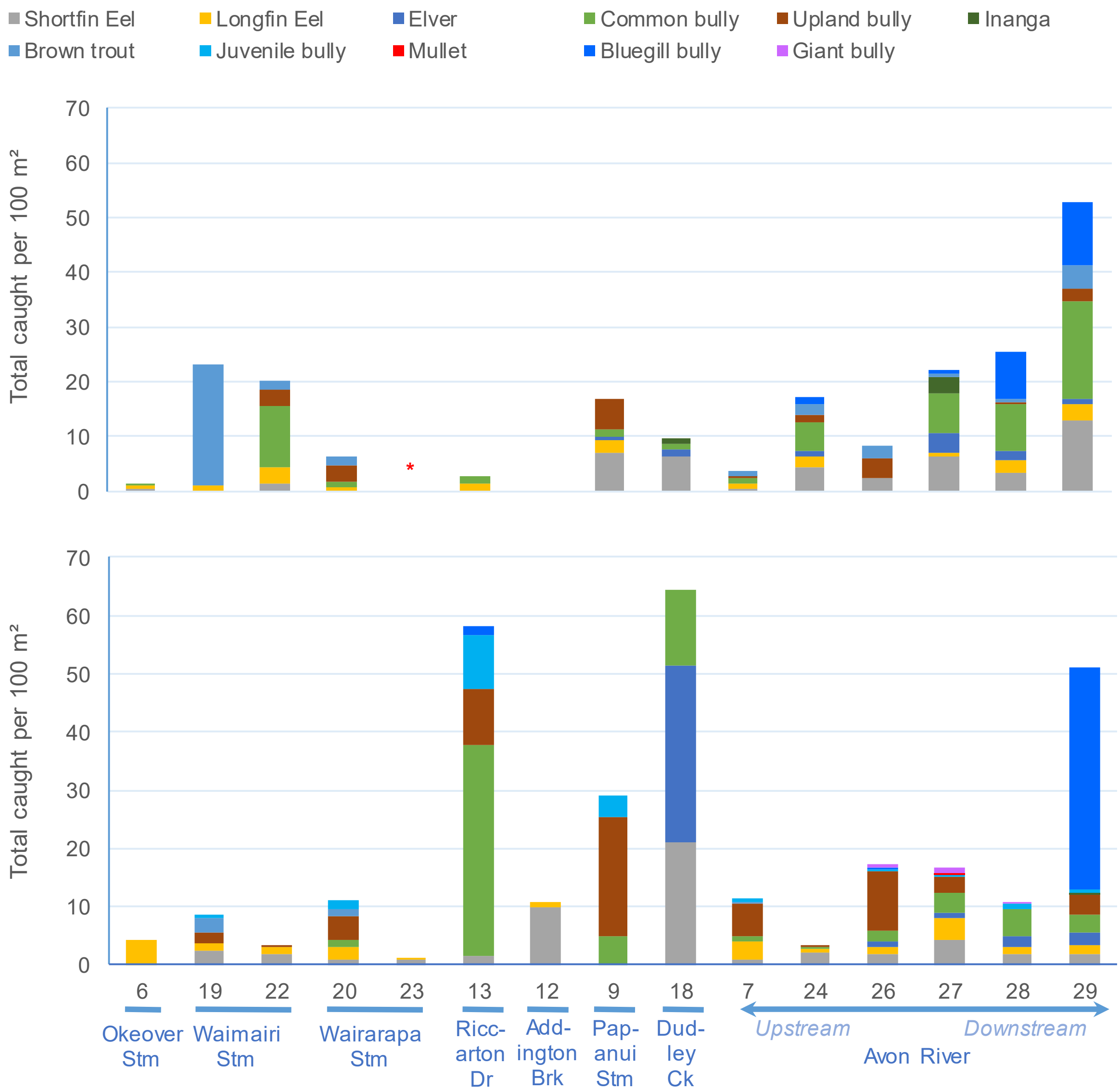


Figure 26: Comparison of electric fishing results at wadeable sites from 2013 (top) and 2019 (bottom). Asterisk indicates no electric fishing data available for that date.

There was a general pattern of greater fish taxa richness at sites closer to the coast in 2019. Thus, fish taxa richness was greatest at the most downstream Avon River site at Pages Road (Site 32), where seven species were caught, and was lowest at Okeover Stream (Site 6) in the upper catchment, where only longfin eels were caught (Table 7). Greater fish diversity closer to the coast is common in New Zealand rivers, because many of our native species migrate to and from the sea to complete their life history. However, artificial barriers such as weirs, culverts, flap gates, and pump stations can further restrict fish distribution. Two major weirs are in close vicinity to Avon River monitoring sites: one at Mona Vale and another downstream of Clyde Road (Figure 28). While there is a fish ladder beside the Mona Vale weir, its efficacy at passing native fish is unknown. There is no fish passage remediation past the Clyde Road weir.

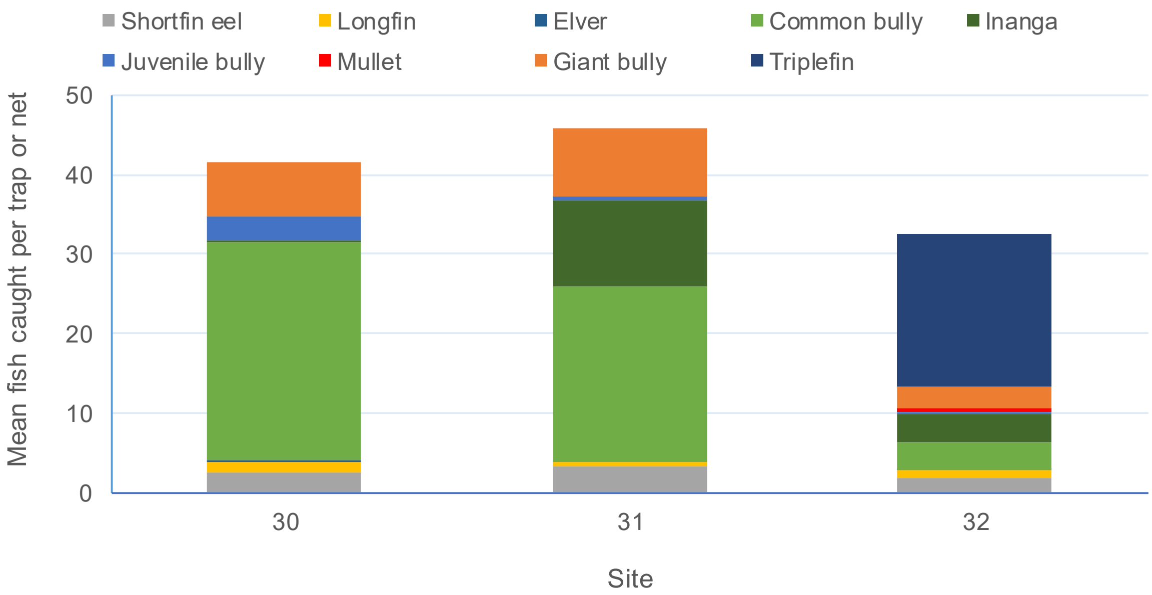


Figure 27: Fish caught at the three non-wadeable sites in 2019.

Several fish species were primarily found in the lower reaches of the Avon River, including estuarine triplefin (also known as cockabully), yelloweye mullet, inanga, and giant bully (Table 7, Figure 27). Yelloweye mullet are primarily a marine species, following the tide into the lower reaches of rivers. However, mullet can be found considerable distances inland in low-gradient waterways, as evidenced by a single yelloweye mullet caught in the Avon River at Montreal Street (Site 27), which was part of a school of mullet disturbed during electric fishing. As their name suggests, estuarine triplefin have a primarily estuarine habitat. Giant bully are a freshwater species, but they also tend to be more common near the coast. In contrast, the lack of inanga at sites upstream of Kilmore Street likely reflects the influence of sampling methodology (Joy et al. 2013), with inanga more readily caught by the combination of fyke nets and minnow traps used at the non-wadeable sites in the lower river than via electric fishing methods used at the wadeable sites.

Figure 28: Weirs on the Avon River at Mona Vale (left) and downstream of Clyde Road (right) present barriers to fish migrating upstream.

A similar core of fish species were caught at the wadeable sites in 2013 and 2019, but there were two main differences between sampling years. Firstly, brown trout were more widespread in 2013, where they were found at ten sites, compared with only three sites in 2019. Secondly, giant bully were not recorded at any sites in 2013, but they were found at three wadeable and three non-wadeable sites in 2019. Not too much weight should be placed on these differences, given the different time of year sampling occurred (spring in 2013 and autumn in 2019). Similar species composition was recorded at the non-wadeable sites found previously in 2012 using different methods (James & McMurtrie 2012).

A total of four native species with a conservation status were caught in 2019. These species are longfin eel, inanga, giant bully, and bluegill bully, which all have an At Risk threat status (Dunn et al. 2018). All of these species were also recorded in 2013, except for giant bully. The widespread presence of longfin eels – including many large specimens – throughout the catchment is noteworthy, because shortfin eels tend to be more abundant and widespread in lowland Canterbury rivers (Figure 29). Also noteworthy was the large numbers of bluegill bullies caught at Site 29 (Avon River at Kilmore Street) in 2019, where a total of 170 individuals were caught, mainly juveniles (Figure 29). A surprising find was an individual bluegill bully at Riccarton Main Drain (Site 13); the channel is concrete-lined throughout much of this site, but the bluegill bully was found in a short stony riffle immediately downstream of Deans Avenue.

Figure 29: At Risk bluegill bullies (left) and large longfin eels (right) were present at several sites in the Avon River catchment.

Lamprey, torrentfish, and smelt were not caught in 2013 or 2019, but they were caught in low numbers during monitoring of the Avon River Precinct restoration project in 2017 (Boffa Miskell 2017). During that survey, a combined total of four lamprey were found at three sites, and a single torrentfish and a single smelt were each found at one site. Torrentfish have an At Risk - Declining conservation status, while lamprey have a higher Threatened – Nationally Vulnerable conservation ranking (Dunn et al. 2018). The presence of lamprey in low numbers in the Avon River catchment is of particular interest, as they are the most threatened fish species present in the catchment.

Overall, the majority of Avon River fish community is similar to that present in other Christchurch waterways. However, the presence of At Risk longfin eel, inanga, bluegill bully, giant bully, and torrentfish, and Threatened lamprey elevates the overall conservation value of the catchment, particularly given the highly modified urban setting.

4. DISCUSSION

4.1. Current State and Trends in Aquatic Ecology

Monitoring data from 2019 indicate that riparian and instream habitat quality remains largely unchanged compared to previous years at most of the monitoring sites. The majority of sites have minimal buffering with riparian vegetation, many have artificial banks (including timber, stone, and concrete), and most have minimal shading. Lack of shading is associated with excessive aquatic weed growth in many locations and aquatic weed is removed by CCC contractors two to three times a year throughout the catchment. Overall, the current state of riparian and instream health of the Avon River is poor compared to the less urbanised Styx River and Otukaikino River catchments, and is more comparable to the Heathcote River.

Poor habitat quality in the Avon River can be partly attributed to the fact that the catchment was largely developed prior to any awareness of stormwater contaminants, and when catchment planning was focussed on draining land and floodwater conveyance, and maintaining the appearance of a tidy English-style waterway in the urban centre. The negative impact of habitat quality on aquatic ecology was identified over 20 years ago, in a report describing the first comprehensive fisheries survey of the Avon River catchment (Eldon & Kelly 1992). In that report, the authors noted that artificial banks lack the *"… natural indentations, undercuts and hollows which create a favourable habitat for many species of fish…"*, while river maintenance aimed at achieving *"…weedless channels, mown banks and neat walls…make[s] for a rather barren fisheries habitat...".* It is therefore disappointing that these comments still hold true 27 years later at many locations, despite plenty of time to improve habitat conditions.

Riparian vegetation is often better established along waterways adjoining private properties, which was also noted by Eldon & Kelly (1992). However, there is an ongoing threat to the riparian buffer beside private properties, in the form of new buildings and paved surfaces. This is particularly an issue in the upper Avon River and its tributaries to the north and west of the city, where post-earthquake rebuilding has seen many homes edge closer to waterway margins. While provisions in the District Plan restrict development within the riparian zone (referred to as a "waterway setback" in the Plan), building within the setback is not prohibited. Building within the waterway setback is often regarded by landowners as a negotiable matter compared to, for example, impinging on an easement for a transportation corridor. Education, advocacy, and perhaps strengthening of District Plan rules is needed in this area, to help limit further loss of the riparian corridor.

Sediment concentrations of common stormwater contaminants exceeded ANZECC (2018) guidelines at many sites in 2019, but there was no indication of increasing trends. The most obvious trend over time is a halving of lead concentrations in sediment between 1980 and recent monitoring in 2013 and 2019. This coincides with the banning of leaded petrol for cars in 1996, in response to public health risks. This is a clear example of how rapidly a change in legislation can have a substantial positive environmental outcome. Banning of copper brake pads in cars is currently advocated by some New Zealand local authorities, because brake pads are a major source of copper in urban waterways. While this may be beneficial for some urban centres, copper is not a major contaminant of concern in the Avon River catchment, with levels within ANZECC (2018) guidelines at 13 of the 14 sites sampled in 2019.

Zinc is the contaminant of greatest concern in Avon catchment sediments, as zinc is elevated at most locations and zinc is the only parameter to exceed the GV-high guideline. Unpainted and poorly painted galvanised steel roofs are the major source of zinc in the Avon River catchment, while roads are also a significant source, because zinc is present in tyres (CCC 2016). Zinc concentrations exceeding GV-high levels are worthy of further investigation at three locations: Addington Brook, Avon River at Armagh Street, and Avon River at Manchester Street. High zinc levels in the Avon River catchment reflect the long history of urban development, with most of the catchment urbanised well before the early 2000s, when stormwater treatment became recognised as a source of waterway contamination. It is therefore difficult to address the legacy of untreated stormwater entering the Avon River. However, opportunities do exist for retrofitting the stormwater network, including the use of source-control methods such as the recently-patented “Storminator™”, which treats roof runoff as it runs through downpipes.

Invertebrate community composition in 2019 was similar to previous years, being dominated by pollution-tolerant snails and crustaceans that are common to urban Christchurch waterways. The abundance and diversity of pollution-sensitive EPT taxa remains low in the Avon River catchment compared to the Otukaikino and Styx rivers, but higher than recorded from the Heathcote catchment. Thus, a total of 12 EPT taxa, comprised solely of caddisflies, were recorded from the 18 Avon monitoring sites in 2019. This compares with a total of 15 EPT taxa recorded from 9 Otukaikino catchment sites in 2017 (Boffa Miskell 2017), 18 EPT taxa from 12 Styx catchment sites in 2018 (Instream 2018), and 9 EPT taxa from 15 Heathcote catchment sites (Boffa Miskell 2015).

Pollution-sensitive mayflies have not been recorded at any site in the Avon River catchment for at least the last decade (McMurtrie 2009; Boffa Miskell 2014; and this report). Mayflies were last recorded at several sites in Avon River in the late 1980s (Robb 1992), albeit in low and declining numbers. Robb (1992) reported that the mayfly *Deleatidium* had declined *“almost to the point of extinction”* compared to sampling ten years previously. Repeated sampling over the last decade has sadly shown this to be the case and that Robb’s observation was prescient.

Kōura (freshwater crayfish) and kākahi (freshwater mussels) are valued both culturally and from a conservation perspective, because of their At Risk – Declining threat status (Grainger et al. 2014). However, kōura and kākahi have not been recorded at any of the Avon River monitoring sites from the 1980s to present. This is in contrast to both the Styx River and upper Heathcote River catchments, where both species are found (Instream 2018; Boffa Miskell 2015). Kōura are relatively easy to catch using electrofishing methods, so their absence during routine monitoring likely reflects low abundance overall in the catchment. However, kākahi are not often caught using standard invertebrate or fish sampling methods, and they require more targeted visual or tactile hand searching. Contractors responsible for cutting aquatic weeds in the lower Avon River have reported seeing kākahi in moderate numbers near the confluence of Horseshoe Lake. Empty mussel shells have also been reported from Dudley Creek . Kākahi are therefore likely to be present at various locations in the Avon River catchment, but they have not been the subject of targeted sampling to date.

The range of fish species caught in 2019 was similar to previous years and the catch was dominated by native species, particularly shortfin eels. The Avon River fish community is similar to that present in other Christchurch waterways, with a dominance of native species and few introduced species (brown trout was the only introduced species caught in 2019). However, the presence of At Risk longfin eel, inanga, bluegill bully, giant bully, and torrentfish, and Threatened lamprey elevates the overall conservation value of the catchment, particularly given the highly modified urban setting.

Brown trout were caught at markedly fewer sites and in lower numbers in 2019 compared to 2013. As noted in the results section, differences in fish community composition in the two years could partly be because sampling was conducted at different times of the year (spring in 2013 and autumn in 2019). However, previous trout spawning surveys have tracked a decline in trout spawning numbers in the Avon River catchment since the early 1990s, associated with siltation of spawning redds (Taylor et al 2012). It would therefore be prudent to undertake a trout spawning survey throughout the Avon catchment, to better understand the state of the trout population.

Potential barriers to fish migration in the form of weirs, culverts, and pump stations are found throughout the Avon River catchment, but their impact on fish distributions has not been assessed. However, in the order of 20-40% of existing structures in waterways impede fish passage nationally (Franklin 2018), and the same is likely true for Christchurch waterways. Studies in the Waikato region have also highlighted impacts of pump stations on downstream migrating fish, with high levels of mortality for migratory eels (Vaipuhi 2017). There is a major pump station on the outlet of Horseshoe Lake into the Avon River, and although it has an Archimedes-type pump that is less susceptible to causing fish damage, its impacts on fish have not been assessed.

With the recent introduction of national fish passage guidelines (Franklin 2018), there is a renewed push by the Department of Conservation for local authorities to comply with their obligations to provide for fish passage under the Fisheries Regulations (1983). Many of the existing potential barriers have already been identified in the Avon River catchment, but to date there has been no attempt to prioritise these barriers for remediation. A new mobile application, the Fish Passage Assessment Tool, was released by NIWA in December 2018, and it includes a prioritisation tool. The Fish Passage Assessment Tool has been trialled by CCC on some Banks Peninsula waterways and at the time of writing it was about to be applied to previously identified barriers in the Avon, Styx, and Heathcote River catchments. This new data will be useful for identifying the extent of the fish barrier issue in the Avon River catchment and where to prioritise efforts to improve passage.

4.2. Comparison to LWRP Freshwater Outcomes

The Canterbury Land and Water Regional Plan (LWRP) includes freshwater outcomes for QMCI scores, and maximum bed cover with fine sediment, macrophytes, and filamentous algae. The LWRP freshwater outcomes for emergent macrophyte cover and filamentous algae cover have been consistently met at most sites over the last ten years (Table 8). In contrast, total macrophyte cover complied with the LWRP freshwater outcome at 11 of the 15 wadeable sites in 2019, compared to all 10 of the sites sampled in 2009. High macrophyte cover is common throughout the Avon River catchment, and higher levels in 2019 likely reflected the timing of sampling in relation to regular macrophyte removal by CCC contractors, rather than an overall increasing trend, as considerable care was taken to ensure sampling was undertaken well after any macrophyte removal in 2019. The LWRP freshwater outcome for fine sediment cover was complied with at 10 of the 15 wadeable sites in 2019 and only 6 out of 15 sites in 2013 (Table 8).

Table 8: Compliance with LWRP freshwater outcomes at wadeable sites over time. Note that fewer sites were sampled in 2009.

Parameter	LWRP outcome	Complying sites each year		
		2009 (10 sites)	2013 (15 sites)	2019 (15 sites)
Minimum QMCI	3.5	8	7	14
Maximum fine sediment (<2 mm) cover	30%	-	6	10
Maximum emergent macrophyte cover	30%	10	-	15
Maximum total macrophyte cover	60%	10	-	11
Maximum filamentous algae cover	30%	10	14	15

Note: Dashes indicate data were either not collected, or methods differed from 2019.

Of particular interest is the LWRP freshwater outcome for QMCI, because the QMCI is an indicator of invertebrate community health, and invertebrates are influenced by both water quality and habitat. The LWRP freshwater outcome has a minimum QMCI of 3.5, and this was met on 14 out of 15 sites in 2019, compared with 7 out of 15 sites in 2013 and 8 out of 10 sites in 2009 (Table 8). Although QMCI scores have been overall low across all sites, and have varied within sites over the years, there has been no overall increasing or decreasing trend in QMCI scores evident across all of the sites monitored every five years. This indicates that although the overall ecological health of the Avon River is poor to fair, there is no indication of a declining trend that could be attributable to stormwater discharges or other landuse impacts.

4.3. Major Waterway Restoration Projects

Since the damaging Canterbury earthquakes of 2010/2011, the council's Land Drainage Recovery Programme has overseen a massive programme of restoring pre-earthquake levels of service for flooding. While the programme is ostensibly focussed on repairing waterways for better floodwater conveyance, it has resulted in large-scale habitat enhancements in the process. In much the same way as earthquake-damaged houses were brought up to modern building code standards during their repairs, the aquatic habitat of a number of Christchurch's earthquake-damaged waterways has been restored, or "brought up to code" to varying degrees. Hence, despite the prevalence of highly modified habitat throughout the Avon River catchment, there are examples where positive changes have been made.

Specific examples of recent restoration projects include:

- **Avon River Precinct.** This involved narrowing of riffles, addition of cobbles for habitat, fine sediment removal, and native plantings in adjacent "fresh plains" at multiple locations in central Christchurch. Post-construction monitoring three years after restoration activities indicated a promising increase in fish abundance and diversity, but further monitoring was recommended (Boffa Miskell 2017).

- **Dudley Creek.** This included narrowing of the low flow channel, native planting along fresh plains and the insertion of "eel hotel" plastic pipes into the banks, along approximately 2 km of Dudley Creek and St Albans Creek. Some limited follow-up ecological monitoring is proposed later this year, primarily aimed at assessing whether large eels have returned to the new channel.

- **Buller Stream.** Replacement of a straight, timber-lined channel with natural banks, logs, and undercuts reinforced with tree stumps, along 400 m of stream adjacent to a new stormwater wetland (Figure 30). No follow-up monitoring is currently planned.
- **No. 1 Drain.** Replacement of a shallow, concrete-lined channel with a combination of narrow stream sections and broad stormwater wetland basins, with wetland and riparian planting, over a length of 400 m through Shirley Golf Course (Figure 31). The stormwater basins include a floating wetland for stormwater treatment, one of the first of its kind in Christchurch. Follow-up ecological monitoring is proposed within the next two years.

Figure 30: Buller Stream on January 2017 (left) and on May 2019, after waterway restoration (right).

Figure 31: No. 1 Drain in Shirley Golf Course, on May 2017 (left) and nearing completion of restoration work on November 2018 (right).

The draft regeneration plan for the Avon River Corridor covers an area of 602 hectares in the lower river and it holds by far the most significant and exciting potential for ecological restoration in the Avon catchment (Regenerate Christchurch 2018). At the time of writing, draft plans recommended the creation of a “green spine” along the length of the lower river, including pushing back stopbanks, regeneration of native forest and estuarine vegetation, and recreation opportunities. However, restoration concepts are currently very high level and are only partially funded. There is strong ecological support for pushing stopbanks further bank from the river, as that would provide more room for ecological processes, native plant succession, and resilience against climate change. There is also a clear environmental and social gain to be made from the establishment of native vegetation and opportunities for the public to interact within natural areas along the river.

5. RECOMMENDATIONS

Based on the results and discussion presented above, we recommend the following:

- Increase the length and width of riparian planting alongside waterways on public land, to improve stream shading, filtering of contaminants in surface runoff, provide habitat for fish and invertebrates, and reduce the need for mowing grass down to the water's edge. This recommendation remains unchanged from the first Avon catchment fisheries report written 27 years ago.
- Promote the protection and enhancement of the riparian corridor on private land, through public education, and either a strengthening of District Plan rules, or better adherence to existing waterway setback rules, to limit the further loss of natural habitat and aquatic species.
- Undertake ecological restoration of the Avon River Corridor in earthquake-affected reaches of the lower river. Restoration should include pushing back stopbanks, promoting regeneration of native riparian and estuarine vegetation, and providing opportunities for city residents and visitors to interact with the river.
- Monitoring the effectiveness of new, existing, and historic waterway restoration projects, to better inform future decisions about where to invest restoration money. For new capital projects, ecological monitoring should be included as part of the project budget, given the relatively small cost involved and the valuable knowledge gained.
- Zinc concentrations exceeding high guideline values are worthy of further investigation at three locations: Addington Brook, Avon River at Armagh Street, and Avon River at Manchester Street. If removal of contaminated sediment is considered necessary, this should be done at the same time as encouraging source control of zinc throughout the catchment (e.g. via treatment of roof runoff prior to entering the stormwater network). That is because there is little point removing contaminated sediments without also addressing the contaminant source.
- Undertake dedicated surveys for:
    - At Risk kākahi in the mainstem of the Avon River and in tributaries, focussing on areas with anecdotal records (e.g., from maintenance contractors).
    - Nationally Vulnerable lamprey in the Avon River catchment. This may be best achieved using a combination of electric fishing and pheromone trapping (a new technique recently used at multiple sites in the Styx River catchment).
    - Brown trout spawning. This is to confirm the state of the fishery, given the lower numbers caught during the latest round of monitoring.
- Identify fish barriers, prioritise them for remediation, and construct a schedule to progressively remediate barriers over time, starting with the highest priority structures.

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APPENDIX 1: SITE PHOTOGRAPHS FROM 2019

Figure 1: Site 6 (Okeover Stream at University of Canterbury Glasshouses) - downstream end of reach looking upstream.

Figure 2: Site 7 (Avon River at Clyde Road) - downstream end of reach looking upstream.

Figure 3: Site 9 (Papanui Stream at Erica Reserve) - downstream end of reach looking upstream.

Figure 4: Site 12 (Addington Brook Upstream of Riccarton Avenue) - upstream end of reach looking downstream.

Figure 5: Site 13 (Riccarton Main Drain Downstream of Deans Avenue) - downstream end of reach looking upstream.

Figure 6: Site 18 (Dudley Creek at North Parade) - downstream end of reach looking upstream.

Figure 7: Site 19 (Waimairi Stream at Fendalton Park) - upstream end of reach looking downstream.

Figure 8: Site 20 (Wairarapa Stream Upstream of Glandovey Road) - upstream end of reach looking downstream.

Figure 9: Site 22 (Waimari Stream downstream of railway bridge) – downstream end of reach looking upstream.

Figure 10: Site 23 (Wairarapa Stream downstream of Fendalton Road) – upstream looking downstream.

Figure 11: Site 24 (Avon River downstream of Mona Vale loop) – downstream end of reach looking upstream.

Figure 12: Site 26 (Avon River at Botanical Garden North Car Park/in Hagley Park) - downstream end of reach looking upstream.

Figure 13: Site 27 (Avon River Upstream of Montreal Street/near Durham Street) - downstream end of reach looking upstream.

Figure 14: Site 28 (Avon River at Victoria Square Near Armagh Street) - upstream end of reach looking downstream.

Figure 15: Site 29 (Avon River Downstream of Kilmore Street (Ōtautahi)) - downstream end of reach looking upstream.

Figure 16: Site 30 (Avon River at Dallington Terrace/ Gayhurst Road) - downstream end of reach looking upstream.


Figure 17: Site 31 (Avon River at Avondale Road) - upstream end of reach looking downstream.


Figure 18: Site 32 (Avon River at Pages/ Seaview Bridge) - upstream end of reach looking downstream.

APPENDIX 2: SEDIMENT QUALITY LABORATORY RESULTS

Hill Laboratories
TRIED, TESTED AND TRUSTED

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Certificate of Analysis

SPv2

Client:	Instream Consulting Limited	**Lab No:**	2147272
Contact:	G Burrell C/- Instream Consulting Limited PO Box 28173 Christchurch 8242	**Date Received:**	22-Mar-2019
		Date Reported:	16-May-2019
		Quote No:	96869
		Order No:	
		Client Reference:	Avon
		Submitted By:	G Burrell

Sample Type: Sediment

Sample Name:		S5 22-Mar-2019 8:05 am	S10 22-Mar-2019 8:35 am	S9 22-Mar-2019 8:55 am	S8 22-Mar-2019 9:15 am	S7 22-Mar-2019 9:40 am
Lab Number:		2147272.1	2147272.2	2147272.3	2147272.4	2147272.5
Individual Tests						
Dry Matter	g/100g as rcvd	47	22	22	30	41
Total Recoverable Copper	mg/kg dry wt	18.6	65	51	41	39
Total Recoverable Lead	mg/kg dry wt	71	110	78	78	56
Total Recoverable Zinc	mg/kg dry wt	360	760	540	300	270
Total Organic Carbon*	g/100g dry wt	2.2	10.6	7.6	6.8	3.7
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample*	g/100g as rcvd	46	25	24	32	38
Fraction >/= 2 mm*	g/100g dry wt	5.8	6.4	6.4	15.2	2.6
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.7	1.3	0.9	1.4	0.9
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	1.6	1.2	1.5	2.9	1.3
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	9.6	3.6	4.1	9.1	3.3
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	34.5	17.8	23.2	22.2	34.6
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	24.9	23.2	23.3	26.3	32.8
Fraction < 63 µm*	g/100g dry wt	22.8	46.5	40.6	22.9	24.5
Polycyclic Aromatic Hydrocarbons Trace in Soil						
1-Methylnaphthalene	mg/kg dry wt	0.027	0.023	0.041	0.021	0.033
2-Methylnaphthalene	mg/kg dry wt	0.027	0.027	0.053	0.020	0.022
Acenaphthene	mg/kg dry wt	0.062	0.039	0.073	0.038	0.036
Acenaphthylene	mg/kg dry wt	0.184	0.149	0.94	0.085	0.079
Anthracene	mg/kg dry wt	0.40	0.24	1.56	0.169	0.22
Benzo[a]anthracene	mg/kg dry wt	1.90	1.36	6.5	0.81	0.49
Benzo[a]pyrene (BAP)	mg/kg dry wt	3.0	1.49	9.2	0.88	0.43
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	2.2	1.76	5.9	1.00	0.47
Benzo[e]pyrene	mg/kg dry wt	1.34	1.04	3.6	0.57	0.25
Benzo[g,h,i]perylene	mg/kg dry wt	2.1	1.02	5.2	0.59	0.22
Benzo[k]fluoranthene	mg/kg dry wt	0.87	0.65	2.4	0.38	0.174
Chrysene	mg/kg dry wt	1.87	1.35	6.2	0.81	0.43
Dibenzo[a,h]anthracene	mg/kg dry wt	0.28	0.22	0.87	0.127	0.057
Fluoranthene	mg/kg dry wt	5.8	2.6	18.7	1.75	0.99
Fluorene	mg/kg dry wt	0.140	0.066	0.30	0.077	0.140
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	2.2	1.08	5.5	0.63	0.25
Naphthalene	mg/kg dry wt	0.076	0.07	0.15	0.03	0.017
Perylene	mg/kg dry wt	0.54	0.40	1.38	0.21	0.098
Phenanthrene	mg/kg dry wt	2.1	1.02	6.3	0.93	0.95
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES	mg/kg dry wt	4.0	2.2	12.4	1.31	0.63
Benzo[a]pyrene Toxic Equivalence (TEF)	mg/kg dry wt	4.0	2.2	12.3	1.31	0.63

Sample Type: Sediment						
Sample Name:		S5 22-Mar-2019 8:05 am	S10 22-Mar-2019 8:35 am	S9 22-Mar-2019 8:55 am	S8 22-Mar-2019 9:15 am	S7 22-Mar-2019 9:40 am
Lab Number:		2147272.1	2147272.2	2147272.3	2147272.4	2147272.5
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Pyrene	mg/kg dry wt	5.9	2.7	18.4	1.76	0.96
Total of Reported PAHs in Soil*	mg/kg	31	17.3	93	10.9	6.3

Sample Name:		S1 22-Mar-2019 9:55 am	S2 22-Mar-2019 10:10 am	S6 22-Mar-2019 10:40 am	S11 22-Mar-2019 12:05 pm	S14 22-Mar-2019 12:45 pm
Lab Number:		2147272.6	2147272.7	2147272.8	2147272.9	2147272.10
Individual Tests						
Dry Matter	g/100g as rcvd	42	38	41	58	71
Total Recoverable Copper	mg/kg dry wt	22	27	24	13.8	3.3
Total Recoverable Lead	mg/kg dry wt	71	139	53	51	9.2
Total Recoverable Zinc	mg/kg dry wt	173	182	300	161	46
Total Organic Carbon*	g/100g dry wt	2.4	4.0	3.6	1.26	0.23
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample*	g/100g as rcvd	47	38	47	60	71
Fraction >/= 2 mm*	g/100g dry wt	5.3	0.6	1.0	5.9	0.8
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.8	0.3	0.8	1.4	0.2
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	1.4	0.8	1.1	0.8	0.2
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	5.1	2.1	3.2	12.4	2.0
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	42.2	26.8	23.5	50.6	75.6
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	26.3	40.4	37.0	8.3	7.4
Fraction < 63 µm*	g/100g dry wt	19.0	28.9	33.4	20.5	13.8
Polycyclic Aromatic Hydrocarbons Trace in Soil						
1-Methylnaphthalene	mg/kg dry wt	0.094	0.014	0.046	0.022	< 0.002
2-Methylnaphthalene	mg/kg dry wt	0.062	0.014	0.045	0.023	< 0.002
Acenaphthene	mg/kg dry wt	0.145	0.024	0.034	0.064	< 0.002
Acenaphthylene	mg/kg dry wt	0.39	0.073	0.069	0.21	0.003
Anthracene	mg/kg dry wt	1.71	0.111	0.151	0.28	0.003
Benzo[a]anthracene	mg/kg dry wt	3.2	0.69	0.39	1.71	0.019
Benzo[a]pyrene (BAP)	mg/kg dry wt	4.0	0.80	0.39	2.8	0.026
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	2.6	0.90	0.44	2.2	0.030
Benzo[e]pyrene	mg/kg dry wt	1.45	0.52	0.24	1.41	0.017
Benzo[g,h,i]perylene	mg/kg dry wt	1.99	0.53	0.24	2.2	0.019
Benzo[k]fluoranthene	mg/kg dry wt	1.10	0.34	0.162	0.86	0.011
Chrysene	mg/kg dry wt	2.7	0.70	0.37	1.82	0.019
Dibenzo[a,h]anthracene	mg/kg dry wt	0.37	0.110	0.055	0.33	0.003
Fluoranthene	mg/kg dry wt	8.9	1.50	0.86	4.8	0.035
Fluorene	mg/kg dry wt	0.84	0.048	0.152	0.093	< 0.002
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	2.2	0.56	0.25	2.2	0.021
Naphthalene	mg/kg dry wt	0.037	0.030	0.027	0.070	< 0.010
Perylene	mg/kg dry wt	0.58	0.193	0.098	0.50	0.007
Phenanthrene	mg/kg dry wt	8.4	0.64	0.86	1.66	0.015
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES	mg/kg dry wt	5.3	1.18	0.58	3.9	0.038
Benzo[a]pyrene Toxic Equivalence (TEF)	mg/kg dry wt	5.3	1.17	0.57	3.9	0.038
Pyrene	mg/kg dry wt	8.4	1.53	0.84	5.0	0.038
Total of Reported PAHs in Soil*	mg/kg	49	9.3	5.7	28	< 0.3

Sample Name:		S13 22-Mar-2019 1:05 pm	S12 22-Mar-2019 1:35 pm			
Lab Number:		2147272.11	2147272.12			
Individual Tests						
Dry Matter	g/100g as rcvd	40	25	-	-	-
Total Recoverable Copper	mg/kg dry wt	18.5	26	-	-	-
Total Recoverable Lead	mg/kg dry wt	32	48	-	-	-
Total Recoverable Zinc	mg/kg dry wt	154	360	-	-	-
Total Organic Carbon*	g/100g dry wt	2.6	5.4	-	-	-

Sample Type: Sediment						
Sample Name:		S13 22-Mar-2019 1:05 pm	S12 22-Mar-2019 1:35 pm			
Lab Number:		2147272.11	2147272.12			
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample*	g/100g as rcvd	50	22	-	-	-
Fraction >/= 2 mm*	g/100g dry wt	22.8	2.3	-	-	-
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	1.8	0.9	-	-	-
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	0.7	1.1	-	-	-
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	0.9	1.3	-	-	-
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	4.3	4.1	-	-	-
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	3.9	11.8	-	-	-
Fraction < 63 µm*	g/100g dry wt	65.5	78.5	-	-	-
Polycyclic Aromatic Hydrocarbons Trace in Soil						
1-Methylnaphthalene	mg/kg dry wt	< 0.004	0.008	-	-	-
2-Methylnaphthalene	mg/kg dry wt	0.005	0.010	-	-	-
Acenaphthene	mg/kg dry wt	< 0.004	0.014	-	-	-
Acenaphthylene	mg/kg dry wt	0.015	0.046	-	-	-
Anthracene	mg/kg dry wt	0.014	0.038	-	-	-
Benzo[a]anthracene	mg/kg dry wt	0.082	0.25	-	-	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.123	0.38	-	-	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.143	0.45	-	-	-
Benzo[e]pyrene	mg/kg dry wt	0.084	0.26	-	-	-
Benzo[g,h,i]perylene	mg/kg dry wt	0.096	0.31	-	-	-
Benzo[k]fluoranthene	mg/kg dry wt	0.051	0.162	-	-	-
Chrysene	mg/kg dry wt	0.092	0.27	-	-	-
Dibenzo[a,h]anthracene	mg/kg dry wt	0.016	0.059	-	-	-
Fluoranthene	mg/kg dry wt	0.181	0.52	-	-	-
Fluorene	mg/kg dry wt	0.008	0.023	-	-	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.096	0.32	-	-	-
Naphthalene	mg/kg dry wt	< 0.017	< 0.03	-	-	-
Perylene	mg/kg dry wt	0.035	0.104	-	-	-
Phenanthrene	mg/kg dry wt	0.072	0.196	-	-	-
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES	mg/kg dry wt	0.179	0.56	-	-	-
Benzo[a]pyrene Toxic Equivalence (TEF)	mg/kg dry wt	0.179	0.57	-	-	-
Pyrene	mg/kg dry wt	0.20	0.54	-	-	-
Total of Reported PAHs in Soil*	mg/kg	1.3	4.0	-	-	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-12
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-12
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. (Free water removed before analysis, non-soil objects such as sticks, leaves, grass and stones also removed). US EPA 3550.	0.10 g/100g as rcvd	1-12
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-12
Total Recoverable Copper	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.2 mg/kg dry wt	1-12

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Recoverable Lead	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.04 mg/kg dry wt	1-12
Total Recoverable Zinc	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.4 mg/kg dry wt	1-12
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-12
Polycyclic Aromatic Hydrocarbons Trace in Soil*	Sonication extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C. Tested on as received sample [KBIs:5784,4273,2695]	-	1-12
7 Grain Sizes Profile as received			
Dry Matter for Grainsize samples (sieved as received)*	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-12
Fraction >/= 2 mm*	Wet sieving with dispersant, as received, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-12
Fraction < 2 mm, >/= 1 mm*	Wet sieving using dispersant, as received, 2.00 mm and 1.00 mm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 1 mm, >/= 500 µm*	Wet sieving using dispersant, as received, 1.00 mm and 500 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 500 µm, >/= 250 µm*	Wet sieving using dispersant, as received, 500 µm and 250 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 250 µm, >/= 125 µm*	Wet sieving using dispersant, as received, 250 µm and 125 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 125 µm, >/= 63 µm*	Wet sieving using dispersant, as received, 125 µm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12
Fraction < 63 µm*	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-12

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental

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Certificate of Analysis

Client:	Instream Consulting Limited	**Lab No:**	2158202 SPv2
Contact:	G Burrell	**Date Received:**	10-Apr-2019
	C/- Instream Consulting Limited	**Date Reported:**	17-May-2019
	PO Box 28173	**Quote No:**	98246
	Christchurch 8242	**Order No:**	
		Client Reference:	
		Submitted By:	G Burrell

Sample Type: Sediment

Sample Name:		Riccarton Stm at Picton Avenue Pond 09-Apr-2019 11:40 am	Riccarton Stm at Paeroa Res 09-Apr-2019 12:55 pm	Addingon Brook Upstream of Riccarton Ave 09-Apr-2019 1:35 pm	Addington Brook at Confluence with Avon 09-Apr-2019 2:00 pm	Riccarton Stm at Confluence with Avon 09-Apr-2019 2:35 pm
Lab Number:		2158202.1	2158202.2	2158202.3	2158202.4	2158202.5
Individual Tests						
Dry Matter	g/100g as rcvd	33	35	54	42	47
Total Recoverable Phosphorus	mg/kg dry wt	1,770	980	1,060	1,240	530
Total Organic Carbon*	g/100g dry wt	6.1	6.7	2.5	4.0	2.9
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	36	15.9	17.5	19.6	7.8
Total Recoverable Cadmium	mg/kg dry wt	0.53	0.35	0.30	0.39	0.196
Total Recoverable Chromium	mg/kg dry wt	30	23	25	22	15.8
Total Recoverable Copper	mg/kg dry wt	82	77	32	39	19.7
Total Recoverable Lead	mg/kg dry wt	89	75	63	56	37
Total Recoverable Nickel	mg/kg dry wt	14.0	10.8	15.0	13.0	9.0
Total Recoverable Zinc	mg/kg dry wt	640	570	540	790	300
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample*	g/100g as rcvd	29	42	54	36	44
Fraction >/= 2 mm*	g/100g dry wt	4.9	8.6	5.0	15.7	12.3
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.6	0.8	1.8	1.4	0.9
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	0.5	1.4	1.1	1.4	1.6
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	1.1	5.9	2.2	3.3	12.7
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	3.6	23.4	9.9	18.4	42.0
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	11.5	19.9	22.7	25.1	14.1
Fraction < 63 µm*	g/100g dry wt	77.9	40.0	57.4	34.7	16.4
Polycyclic Aromatic Hydrocarbons Trace in Soil						
1-Methylnaphthalene	mg/kg dry wt	0.030	0.078	0.038	0.054	0.078
2-Methylnaphthalene	mg/kg dry wt	0.037	0.081	0.035	0.064	0.057
Acenaphthene	mg/kg dry wt	0.017	0.056	0.030	0.035	0.074
Acenaphthylene	mg/kg dry wt	0.064	0.101	0.067	0.060	0.106
Anthracene	mg/kg dry wt	0.100	0.186	0.147	0.22	0.40
Benzo[a]anthracene	mg/kg dry wt	0.47	0.73	0.63	0.74	1.15
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.60	0.90	0.67	0.84	1.11
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.79	1.12	0.77	0.96	1.24
Benzo[e]pyrene	mg/kg dry wt	0.46	0.61	0.43	0.57	0.67
Benzo[g,h,i]perylene	mg/kg dry wt	0.66	0.66	0.57	0.74	0.70
Benzo[k]fluoranthene	mg/kg dry wt	0.30	0.43	0.31	0.38	0.52
Chrysene	mg/kg dry wt	0.50	0.75	0.54	0.58	0.98
Dibenzo[a,h]anthracene	mg/kg dry wt	0.109	0.129	0.111	0.137	0.162
Fluoranthene	mg/kg dry wt	0.81	1.37	1.24	1.38	2.2

Sample Type: Sediment

Sample Name:		Riccarton Stm at Picton Avenue Pond 09-Apr-2019 11:40 am	Riccarton Stm at Paeroa Res 09-Apr-2019 12:55 pm	Addingon Brook Upstream of Riccarton Ave 09-Apr-2019 1:35 pm	Addington Brook at Confluence with Avon 09-Apr-2019 2:00 pm	Riccarton Stm at Confluence with Avon 09-Apr-2019 2:35 pm
Lab Number:		2158202.1	2158202.2	2158202.3	2158202.4	2158202.5
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Fluorene	mg/kg dry wt	0.053	0.161	0.091	0.087	0.31
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.54	0.67	0.54	0.70	0.75
Naphthalene	mg/kg dry wt	0.05	0.111	0.049	0.070	0.080
Perylene	mg/kg dry wt	0.27	0.181	0.156	0.23	0.26
Phenanthrene	mg/kg dry wt	0.46	1.29	0.85	0.93	1.90
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES	mg/kg dry wt	0.93	1.35	1.02	1.28	1.67
Benzo[a]pyrene Toxic Equivalence (TEF)	mg/kg dry wt	0.94	1.34	1.02	1.28	1.66
Pyrene	mg/kg dry wt	1.18	1.67	1.32	1.55	2.1
Total of Reported PAHs in Soil*	mg/kg	7.5	11.3	8.6	10.3	14.9

Sample Name:		Riccarton Main Dr Downstream of Deans Ave 09-Apr-2019 3:10 pm	Addington Brook Downstream of Deans Ave 09-Apr-2019 3:55 pm	Addington Brook Adjacent to Netball Pavillion 09-Apr-2019 4:25 pm	Addington Brook Downstream of Main Foot Bridge 09-Apr-2019 4:43 pm	
Lab Number:		2158202.6	2158202.7	2158202.8	2158202.9	
Individual Tests						
Dry Matter	g/100g as rcvd	69	42	63	53	-
Total Recoverable Phosphorus	mg/kg dry wt	580	1,610	1,010	1,870	-
Total Organic Carbon*	g/100g dry wt	0.58	4.3	1.70	3.4	-
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	8.3	42	14.9	26	-
Total Recoverable Cadmium	mg/kg dry wt	0.140	0.35	0.34	0.47	-
Total Recoverable Chromium	mg/kg dry wt	13.6	52	21	31	-
Total Recoverable Copper	mg/kg dry wt	17.0	65	36	52	-
Total Recoverable Lead	mg/kg dry wt	23	87	46	86	-
Total Recoverable Nickel	mg/kg dry wt	9.0	13.9	11.7	15.7	-
Total Recoverable Zinc	mg/kg dry wt	250	1,100	520	910	-
7 Grain Sizes Profile as received						
Dry Matter of Sieved Sample*	g/100g as rcvd	72	44	60	51	-
Fraction >/= 2 mm*	g/100g dry wt	8.0	8.4	3.1	4.9	-
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.9	1.2	0.7	1.3	-
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	5.0	1.9	0.8	1.7	-
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	49.5	4.0	4.7	3.7	-
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	27.0	20.3	30.6	27.6	-
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	4.0	18.8	26.1	24.2	-
Fraction < 63 µm*	g/100g dry wt	5.6	45.4	33.9	36.5	-
Polycyclic Aromatic Hydrocarbons Trace in Soil						
1-Methylnaphthalene	mg/kg dry wt	< 0.003	0.129	0.021	0.048	-
2-Methylnaphthalene	mg/kg dry wt	0.003	0.145	0.024	0.046	-
Acenaphthene	mg/kg dry wt	< 0.002	0.089	0.018	0.036	-
Acenaphthylene	mg/kg dry wt	0.012	0.162	0.049	0.060	-
Anthracene	mg/kg dry wt	0.016	0.45	0.104	0.177	-
Benzo[a]anthracene	mg/kg dry wt	0.099	1.59	0.54	0.53	-
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.137	1.45	0.55	0.55	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.169	0.82	0.69	0.64	-
Benzo[e]pyrene	mg/kg dry wt	0.096	1.01	0.38	0.36	-
Benzo[g,h,i]perylene	mg/kg dry wt	0.114	0.95	0.37	0.39	-
Benzo[k]fluoranthene	mg/kg dry wt	0.065	0.74	0.27	0.26	-
Chrysene	mg/kg dry wt	0.098	1.43	0.48	0.44	-
Dibenzo[a,h]anthracene	mg/kg dry wt	0.023	0.24	0.078	0.082	-
Fluoranthene	mg/kg dry wt	0.21	2.8	1.06	1.05	-

Sample Type: Sediment						
Sample Name:		Riccarton Main Dr Downstream of Deans Ave 09-Apr-2019 3:10 pm	Addington Brook Downstream of Deans Ave 09-Apr-2019 3:55 pm	Addington Brook Adjacent to Netball Pavillion 09-Apr-2019 4:25 pm	Addington Brook Downstream of Main Foot Bridge 09-Apr-2019 4:43 pm	
Lab Number:		2158202.6	2158202.7	2158202.8	2158202.9	
Polycyclic Aromatic Hydrocarbons Trace in Soil						
Fluorene	mg/kg dry wt	0.006	0.28	0.049	0.123	-
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.114	1.02	0.39	0.39	-
Naphthalene	mg/kg dry wt	< 0.010	0.141	0.038	0.057	-
Perylene	mg/kg dry wt	0.042	0.31	0.138	0.146	-
Phenanthrene	mg/kg dry wt	0.095	2.4	0.61	0.84	-
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES	mg/kg dry wt	0.21	2.1	0.84	0.82	-
Benzo[a]pyrene Toxic Equivalence (TEF)	mg/kg dry wt	0.21	2.1	0.83	0.82	-
Pyrene	mg/kg dry wt	0.22	3.1	1.10	1.10	-
Total of Reported PAHs in Soil*	mg/kg	1.5	19.3	7.0	7.3	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Individual Tests			
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-9
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-9
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. (Free water removed before analysis, non-soil objects such as sticks, leaves, grass and stones also removed). US EPA 3550.	0.10 g/100g as rcvd	1-9
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-9
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-9
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-9
Heavy metal, trace level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	1-9
Polycyclic Aromatic Hydrocarbons Trace in Soil*	Sonication extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C. Tested on as received sample [KBIs:5784,4273,2695]	-	1-9
7 Grain Sizes Profile as received			
Dry Matter for Grainsize samples (sieved as received)*	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-9
Fraction >/= 2 mm*	Wet sieving with dispersant, as received, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-9
Fraction < 2 mm, >/= 1 mm*	Wet sieving using dispersant, as received, 2.00 mm and 1.00 mm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-9
Fraction < 1 mm, >/= 500 µm*	Wet sieving using dispersant, as received, 1.00 mm and 500 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-9
Fraction < 500 µm, >/= 250 µm*	Wet sieving using dispersant, as received, 500 µm and 250 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-9
Fraction < 250 µm, >/= 125 µm*	Wet sieving using dispersant, as received, 250 µm and 125 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-9
Fraction < 125 µm, >/= 63 µm*	Wet sieving using dispersant, as received, 125 µm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-9
Fraction < 63 µm*	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-9

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental