Christchurch Aquatic Ecology Monitoring 2021

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Prepared for:
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EXECUTIVE SUMMARY

This report describes the current state and trends in aquatic ecology and sediment quality of waterways sampled as part of Christchurch City Council's 2021 monitoring programme. This year, aquatic ecology monitoring was undertaken by Instream Consulting at: eight sites in the Halswell River catchment, as part of the five-yearly monitoring programme; four sites in the Wilsons Drain catchment, including two annual monitoring sites and two one-off sampling sites; and at two Cashmere Stream annual monitoring sites. Sediment quality sampling was undertaken at five of the Halswell catchment ecology monitoring sites. Desktop analysis was undertaken on annual ecology monitoring data provided by Environment Canterbury for two sites on Balguerie Stream, and of monthly deposited sediment monitoring data for 15 sites, provided by the city council.

Habitat quality is generally poor at most of the sites monitored, with high levels of fine sediment deposition, little riparian buffering and shade, and associated high macrophyte cover. A notable exception is Balguerie Stream, which has good riparian cover, shade, and macrophyte cover. Cases Drain is noteworthy, with native plantings replacing closely cropped grass since the site was last monitored in 2011. Creamery Stream is also notable, as removal of riparian vegetation and recent bank works have degraded habitat.

Consent targets for fine sediment cover were complied with at five of the 15 monthly monitoring sites across the district. Deposited sediment data collection only commenced in June 2020, so trend analysis was not yet possible. Concentrations of common stormwater contaminants in sediments were low and within guidelines at most sites in the Halswell catchment. Nottingham Stream has consistently had elevated levels of copper, zinc and total PAHs compared with the other monitoring sites. There was no increasing or decreasing trend in metals or PAHs over time.

Invertebrate communities at most sampling sites were dominated by pollution-tolerant snails and crustaceans that are common to Christchurch urban waterways. In contrast, Balguerie Stream was dominated by pollution-sensitive mayflies, stoneflies, and caddisflies (also known as EPT taxa). Significant correlations between habitat variables and macroinvertebrate health indices showed a clear pattern of more pollution-sensitive invertebrate taxa occurring at sites with lower macrophyte cover, swifter water velocities, and coarser substrates. There were no clear increasing or decreasing trends in invertebrate metrics at most sites. The only exception is at annual monitoring Site HE28 on Cashmere Stream, where all invertebrate metrics have been increasing since 2016.

Wai kōura (freshwater crayfish) were caught in Creamery Stream in 2021, which is the first time they have been recorded since before the Canterbury earthquakes of 2010–11. Wai kōura were also found at Cases Drain for the first time. No kākahi (freshwater mussels) were found during dedicated searches within the Halswell (within the Christchurch district) or Wilsons Drain catchments.

The fish community present at all sites surveyed was dominated by native species that are common in urban Christchurch waterways, including shortfin eels, longfin eels, inanga, common bullies, and upland bullies. There was no overall trend in fish abundance or community composition over time. The presence of threatened lamprey in Creamery Stream and the Wilsons Drain catchment is notable, although densities were low. The presence of perch, an introduced pest fish, in the Halswell River is consistent with previous surveys and reflects the fact that the river supports a recreational perch fishery.

Consent attribute target levels for long filamentous algae cover have been met at all monitoring sites over the last 10 years. In contrast, consent targets for invertebrate QMCI scores have seldom been met and consent targets for fine sediment cover have never been met in the Halswell catchment. Compliance with consent targets for total macrophyte cover was higher in 2011 and 2016 than in 2021, reflecting recent macrophyte clearance activities prior to sampling in 2011 and 2016. Consent targets for sediment metals and total PAHs are typically complied with in the Halswell catchment. Overall, there has been no trend of improving or declining compliance with consent targets at monitoring sites in the Halswell catchment, Cashmere Stream, or Balguerie Stream.

Recommendations include: increased planting with riparian trees and shrubs to increase waterway shade and reduce the need for aquatic weed removal; more widespread enhancement of waterway habitat across the Halswell catchment; ecological monitoring of waterway enhancements; investigate recent instream works and vegetation removal beside Creamery Stream; and enhancement and realignment of Wilsons Drain when the area is developed for stormwater treatment.

1. INTRODUCTION

Christchurch City Council (CCC) monitors water and sediment quality, and aquatic ecology at numerous sites across Christchurch city and Banks Peninsula. Water quality and deposited fine sediment (<2 mm) monitoring occurs monthly, sediment quality is monitored five-yearly, and aquatic ecology monitoring is undertaken annually or five-yearly, depending on the site. The monitoring is required as part of the council's Comprehensive Stormwater Network Discharge Consent (CSNDC, CRC190445) and it is also part of the council's long-term environmental monitoring programme.

This year, the five-yearly aquatic ecology and sediment quality monitoring was undertaken in the Huritini / Halswell River catchment. Annual aquatic ecology monitoring was also undertaken in Cashmere Stream, and in the Wilsons Drain catchment. In addition, monthly monitoring of deposited fine sediment cover commenced at multiple sites across the city in 2020.

The purpose of this report is to describe results of the most recent ecology and sediment 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, fine sediment cover, and sediment quality.
- Comparison of monitoring data to relevant standards and guidelines, including consent attribute target levels.
- Discussion of any environmental trends in relation to potential stormwater impacts.
- Details of 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. Those data are summarised separately as part of an annual city-wide summary report (e.g.,Margetts and Marshall 2021).

2. METHODS

2.1. Sampling Sites

Aquatic ecology sampling was undertaken at 14 sites in March 2021, including:

- 8 sites in the Halswell River catchment (five-yearly monitoring sites).
- 2 sites in Cashmere Stream (annual monitoring sites)
- 4 sites in Wilsons Drain, a tributary of Ōtūkaikino Creek. Of these sites:
    - 2 are new annual monitoring sites.
    - 2 were sampled to provide additional information in a developing catchment.

In addition, this report includes a desktop review of macroinvertebrate data collected from two sites on Balguerie Stream by Environment Canterbury (ECan). The CSNDC only requires one of the Balguerie Stream sites (at Balguerie Road) to be reported on, but the additional upstream site (at Stoney Bay Road) is included here to provide context. Macroinvertebrate monitoring data was available from both Balguerie Stream sites from November 2005 to November 2020. We undertook sediment quality sampling at five of the eight ecology monitoring sites in the Halswell catchment, as part of the five-yearly monitoring programme. This report includes desktop analysis of monthly fine sediment cover monitoring undertaken by CCC at 15 sites[1] across the city in 2020. This is the first year of sediment cover monitoring under the CSNDC, with a total of seven monthly samples available for each site. Therefore, data are compared against guidelines, but no trend analysis was undertaken.

Sampling site locations for ecology and sediment quality are shown in Figure 1 to Figure 4 and summarised in Table 1. Deposited sediment sampling site locations are in Appendix 3.

The Huritini / Halswell River catchment lies to the southwest of Christchurch. The headwaters of the river fall within the Christchurch district, but 88% of the total 190 km² catchment area falls within the Selwyn district (Christchurch City Council 2016). Normal baseflows are fed by springs, although runoff from the Port Hills contributes to flows in the mid to lower reaches of the river. Major tributaries of the Halswell River include Creamery Drain and its spring-fed tributaries along Quaifes Road, Te Tauawa a Maka / Nottingham Stream, and Knights Stream. While the headwaters of the catchment include urban landuse, much of the Halswell River catchment is located within rural land. Prior to discharging into Te Waihora / Lake Ellesmere, flows in the Halswell River are diverted into a 4.5 km canal that was created to improve drainage. Of the eight Halswell catchment sites sampled in 2021, three are located on the mainstem of the Halswell River, while five are located along tributaries, including Knights Stream, Nottingham Stream, Creamery Stream, and Cases Drain.

Cashmere Stream is a spring-fed tributary of the Ōpāwaho / Heathcote River, located to the southwest of the centre of Christchurch city. Its headwaters arise as springs near Sutherlands Road, and it passes through a rapidly urbanising catchment, before discharging into the Heathcote River at Cashmere Road. Water quality is affected by the adjacent rural and residential land, as well as sediment-laden runoff from the Port Hills following rainfall. The two annual monitoring sites are located along Cashmere Road, upstream and downstream of a stormwater outlet.

Ōtūkaikino Creek is a medium-sized spring-fed river north of the city that drains an urban and rural catchment and flows into the Waimakariri River near State Highway 1. The four sites sampled for this report all fall within the Wilsons Drain sub-catchment. Wilsons Drain is spring-fed and there is a mix of rural and urban (including industrial) landuse in the catchment. Wilsons Drain flows through Ōtūkaikino Reserve and is then piped under State Highway 1, before discharging into Ōtūkaikino Creek.

Balguerie Stream is a small, hill-fed stream that drains the flanks of Stony Bay Peak and flows into Akaroa Harbour after passing through the town of Akaroa. The mid to upper reaches of the catchment include a mix of native bush and pasture, while the lower reaches include a mix of native bush and urban landuse. The Stony Bay Road monitoring site is located within native bush in the upper catchment, while the Balguerie Road site is located adjacent to residential properties and native bush in the lower catchment.

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[1] An additional site, Kaputone Creek at Belfast Road (STYX05), is included in the fine sediment monitoring programme, but has not been sampled to date due to safety concerns over water depths and thick deep mud (ironically). Monitoring at the Ōtūkaikino River & Creek site (OTUKAI07) was also not instigated, as this site is no longer considered suitable. Monitoring in following years will be at an alternative site, as specified in the CSNDC Environmental Monitoring Programme.

Figure 1: Halswell catchment ecology sampling sites.

Figure 2: Cashmere Stream ecology sampling sites.

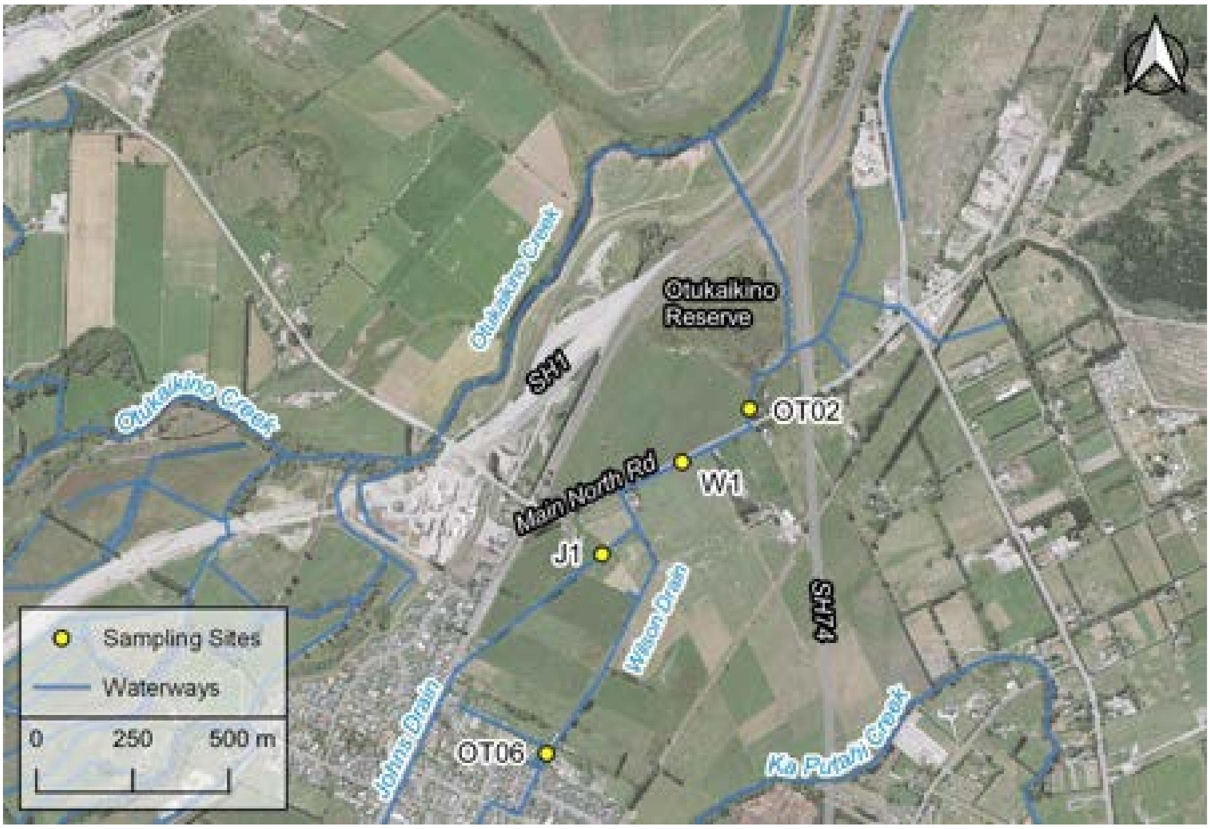

Figure 3: Wilsons Drain catchment ecology sampling sites.

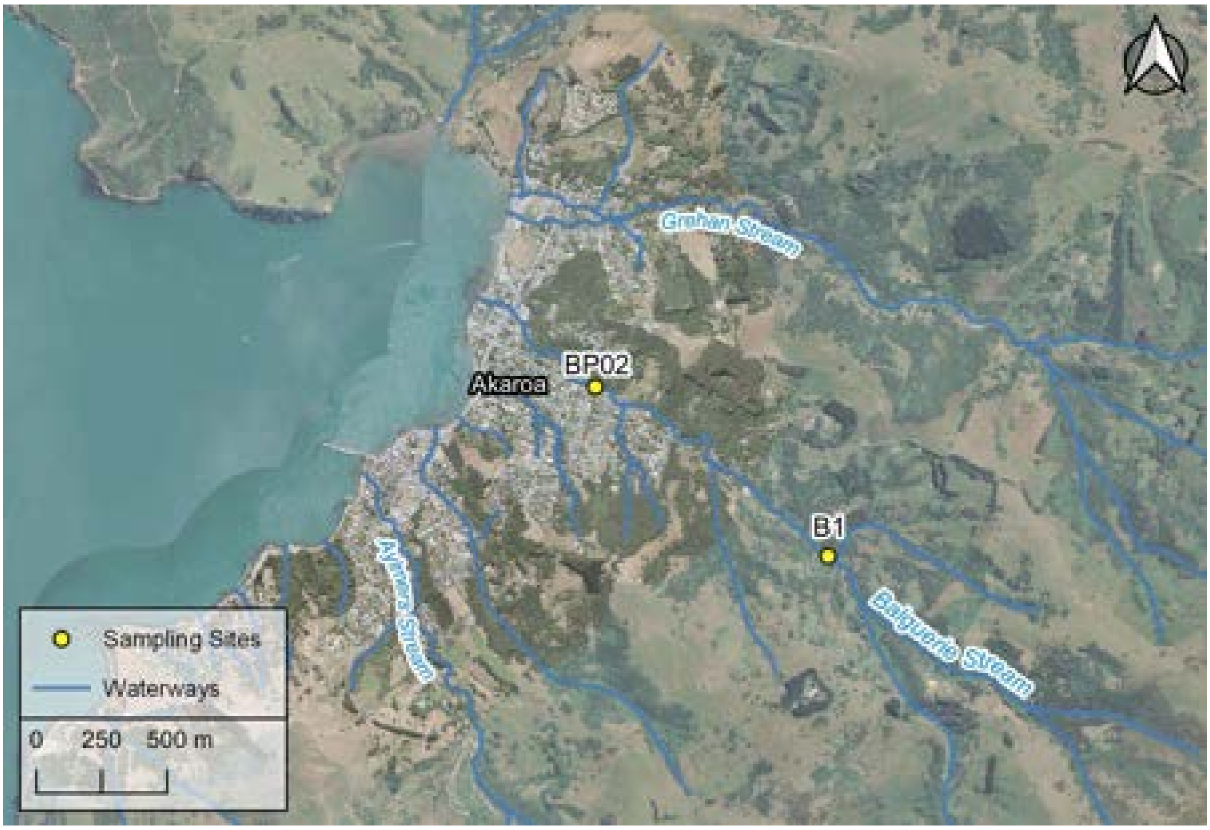

Figure 4: Balguerie Stream ecology sampling sites.

Table 1: Ecology monitoring sites in 2021. Asterisks (*) indicate both sediment quality and ecology monitoring.

Site Code	Waterway	Site Name / Location	Easting (NZTM)	Northing (NZTM)
Five-Yearly Monitoring Sites				
HA10*	Knights Stream	Upstream of Whincops Road	1562637	5174486
HA05*	Knights Stream	At Sabys Road	1563716	5172819
HA09	Cases Drain	Upstream of Downies Road	1563622	5173605
HA08*	Creamery Stream	Downstream of Sabys Road	1564275	5173204
HA03*	Nottingham Stream	At Candys Road	1564509	5173070
HA07*	Halswell River	At Wroots/Halswell Roads	1564359	5172476
HA04	Halswell River	At Tai Tapu Road	1564347	5171664
HA06	Halswell River	Downstream of Early Valley Road	1565270	5170099
Annual Monitoring Sites				
HE28	Cashmere Stream	Behind 420–426 Cashmere Road (upstream of stormwater discharge)	1567362	5174782
HE27	Cashmere Stream	Behind 406 Cashmere Road (downstream of stormwater discharge)	1567453	5174866
OT02	Wilsons Drain	At Main North Road (Ōtūkaikino Reserve)	1571246	5190823
OT06	Wilsons Drain	At Tyrone Street	1570719	5189928
Additional Wilsons Drain Catchment Sites				
W1	Wilsons Drain	At Main North Road	1571071	5190685
J1	Johns Drain	At 888 Main North Road	1570863	5190445
ECan Monitoring Sites				
B1	Balguerie Stream	At Stoney Bay Road	1598639	5148931
BP02	Balguerie Stream	Downstream of Settlers Hill	1597746	5149579

2.2. Differences in Ecology Sampling Methods Between Years

All sampling years involved sampling ecology and habitat along a 20 m reach, with detailed measurements along three equally spaced transects. The same sampling methods were used in 2016 and 2021, with two exceptions. First, macroinvertebrates were processed using full counts in 2016 and using fixed counts in 2021 (see Section 2.6 for macroinvertebrate methods). Second, sediment quality sampling comprised a single composite sample per site in 2016 and earlier sampling, but three replicate composite samples were taken per site in 2021.

The major differences between the old (2011) and the new (2016 and 2021) monitoring methods were as follows:

- Field-measured water quality:
  - Not measured in 2011.
  - Dissolved oxygen, temperature, pH, and conductivity measured once per site (new methods).
- At each transect, detailed habitat measurements at:
  - 3 or 12 points or site-wide estimates (old methods).

    - 5 points (new methods). Only edge habitat sampled at non-wadeable sites.
- At each transect, velocity measured at:
    - 10 points per transect (old methods).
    - 1 point per transect (new methods). Mid-channel for wadeable sites; approximately 1.5 m (safely wadable) from edge for non-wadeable sites.
- Invertebrate kicknet samples per site:
    - 3 (old methods). Each sample is approximately 0.45 m² (1.5 x 0.3 m).
    - 1 (new methods). Each sample is approximately 0.6 m² (2.0 x 0.3 m). Only edge habitat sampled at non-wadeable sites.
- Fish sampling using traps and nets:
    - 4 baited coarse mesh fyke nets (12 mm mesh) and 10 baited Gee minnow traps (old methods).
    - 2 baited fine mesh fyke nets (4 mm mesh) and 5 baited Gee minnow traps (new methods).

2.3. Habitat and Water Quality

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

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

- Instream habitat (for five locations across each transect, unless otherwise stated): wetted width (once per transect), water depth, fine sediment depth, fine sediment (<2 mm) cover, embeddedness, and substrate composition using the following size classes: silt/sand (<2 mm); gravels (2-16 mm); pebbles (16–64 mm); small cobbles (64–128 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).

Water velocity was measured once per transect at the mid-channel using a Hach model FH950.1 electromagnetic 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 a calibrated YSI ProDSS water quality meter.

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 mat forming algae (<0.5 mm thick), medium mat forming algae (0.5–3 mm thick), thick mat forming algae (>3 mm thick), short filamentous algae (<20 mm long) and long filamentous algae (>20 mm long). Percentage cover and description of organic matter was also recorded.

2.4. Fine Sediment Cover

Bed cover with fine sediment (<2 mm diameter) was estimated monthly at 15 sites by CCC staff. Methods were as per described in the Environmental Monitoring Plan for the CSNDC consent. Briefly, this involves estimating fine sediment cover of the wetted perimeter using a bathyscope at 10 equidistant points along a 30 m reach. The overall site cover is taken as the median of the 10 observations. Importantly, fine sediment cover estimates are not made at points where the bed is obscured (e.g., by macrophytes) and estimates do include fine sediment that settles on macrophytes and other substrates. Estimates were rounded to the nearest 5% and values that were recorded in the field as "<5%" were given a nominal value of 1% cover, while 0% was recorded if no fine sediment was present.

2.5. 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. Three replicate samples were collected at each site. 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 were 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.
- Total phosphorus.
- Polycyclic aromatic hydrocarbons (PAHs).

Sediment sampling fieldwork was undertaken during baseflow conditions on 25 March 2021.

2.6. 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 prior to laboratory analysis by Instream Consulting. In the laboratory invertebrates were counted and identified to species level where possible, using Protocol P2 (individual fixed count of 200 with scan for rare taxa) of Stark *et al.* (2001). This method differs to the full count with subsampling method used in previous years, 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, and it is consistent with new standards for macroinvertebrate sampling (National Environmental Monitoring Standards 2020).

Searches for kākahi, also known as freshwater mussel or *Echyridella menziesii,* were conducted in the four Wilsons Drain catchment tributaries, as well as Nottingham Stream (Site HA03). These timed rapid searches were undertaken as a gap-filling exercise to complement other recent surveys in both catchments. The timed searches involved one or two field staff searching the bed, using a bathyscope if the water was deep, for a combined total of 30 minutes (i.e., two people searching for 15 minutes or one person searching for 30 minutes).

2.7. Fish

Fish sampling was undertaken at the Halswell River and Wilsons Drain catchment sites. Fishing is not routinely undertaken at the annual monitoring sites. The fish community was sampled using backpack electric fishing at sites where there was an appropriate mix of water depth, velocity, and substrate for electric fishing. Fish were sampled using a combination of fyke nets and Gee minnow traps at sites that were either too deep, velocities were too low, or they were dominated by sediments that were too deep and fine to sample effectively with electric fishing. For the electric fishing 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, undercuts and backwaters). For the remaining 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.

Electric fishing at the Creamery Stream site was split into three sub-reaches, to assess impacts of polythene sheeting recently placed on the bed by the landowner. These three reaches comprised (in order from upstream to downstream): an upstream, 17 m long polythene-lined reach; a middle 13 m long reach without polythene, immediately downstream of the polythene-lined reach; and a downstream 30 m long control reach, with its upstream end 5 m downstream of the middle reach. The upper two reaches overlapped with the habitat and invertebrate sampling reach, while the downstream control was in similar habitat, but without recent bank works and it had more intact riparian vegetation.

Additional electric fishing was undertaken for lamprey at five locations near the four Wilsons and Johns Drain sites. This additional fishing was done to inform future decisions around waterway realignment and restoration in the area. The lamprey fishing involved using a higher voltage (five lights, rather than the usually recommended two or three lights) and shocking for a longer time than usual (10 seconds on, 5 seconds off, then repeated at the same location). This fishing method was used because juvenile lamprey require a higher voltage and multiple passes to draw them out of fine sediments.

2.8. Consent Target Levels and Guidelines

Water quality, sediment quality, habitat, and macroinvertebrate data were compared against the relevant consent attribute target levels and other guidelines shown in Table 2. All of the ecology and sediment quality monitoring sites in the Halswell and Wilsons Drain catchments are classified as "Spring-fed – plains" under the LWRP, while the two Cashmere Stream and Balguerie Stream monitoring sites are classified as "Banks Peninsula". Waterway classifications for the deposited sediment monitoring sites are included with the site details in Appendix 3.

Table 2: Consent attribute target levels and other relevant guidelines used in this report.

Parameter	Consent Attribute Target Level	LWRP[1]	NPSFM[2] 2020	ANZG[3] (2018)
Water quality				
Dissolved oxygen		≥70%	4 mg/L	
Temperature (°C)		<20		
pH		6.5–8.5		
Fine sediment cover (%)	SPU[4]: 30 SP[5]: 20 BP[6]: 20		21–29	
Sediment quality				
Copper (mg/kg)	65			270
Lead (mg/kg)	50			220
Zinc (mg/kg)	200			410
Total PAHs (mg/kg)	10			50
Emergent macrophyte cover (%)		SP: 30		
Total macrophyte cover (%)	SP: 50 BP: 30			
Long filamentous algae (>2 cm long) cover (%)	SP: 30 BP: 20			
Macroinvertebrates				
QMCI[7]	SP: 5 BP: 5		4.5	
MCI[8]			90	
ASPM[9]			0.3	

Notes: [1]Land and Water Regional Plan Receiving Water Standards for dissolved oxygen and temperature, and Freshwater Outcome for pH. [2]National Policy Statement for Freshwater Management 2020 national bottom line values. [3]Australia New Zealand Water Quality Guidelines (2018) for sediment quality are GV-high. [4]Spring-fed – Plains – Urban. [5]Spring-fed – Plains. [6]Banks Peninsula. [7]Quantitative Macroinvertebrate Community Index. [8]Macroinvertebrate Community Index. [9]Average Score per Metric.

Consent target levels for sediment quality are the same as default guideline value (DGV) levels in the ANZG (2018) sediment quality guidelines. The ANZG (2018) upper and lower guidelines indicate the overall risk of toxicity effects on biota. Sites meeting the lower DGVs (equal to the consent target levels) have a low risk of toxicity effects, sites exceeding DGVs have an increased risk of adverse effects, and there is a relatively high risk of adverse effects for sites exceeding GV-high levels.

2.9. Data Analyses

2.9.1. Data Management

All ecology and sediment quality data collected in 2021 was collated into a single Excel spreadsheet. In addition, summary data from 2021 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.

2.9.2. Habitat and Water Quality

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[2], and bed cover with emergent macrophytes, total macrophytes, and long filamentous algae (>2 cm long). Of these parameters, consent attribute target levels are associated with bed cover with fine sediment, total macrophytes, and long filamentous algae (Table 2).

Prior to 2016, 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 2016 and 2021, these parameters were estimated as per other transect data (i.e., the average of five measurements per transect, and the site average obtained by the mean of three transects).

Habitat data were averaged for each transect (where relevant), plotted, compared with consent attribute target levels, and inspected for evidence of any patterns over time or amongst sites.

Differences amongst sites over time were assessed using two-way analysis of variance (ANOVA) for the following parameters: width, depth, velocity, substrate index, fine sediment depth, emergent and total macrophyte cover, and long filamentous algae cover. Fine sediment cover was not assessed using ANOVA, due to different sampling methods being used for each sampling year. Data were transformed (rank or arcsine) when required to meet the assumptions of ANOVA.

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[2] This refers to fine sediment cover data collected as part of the March 2021 fieldwork, not the monthly fine sediment cover data provided by CCC.

2.9.3. Fine Sediment Cover

Monthly fine sediment monitoring data was summarised using box plots by calculating site medians, the interquartile range and 5th and 95th percentiles. We used the Hazen method to calculate percentiles, which is consistent with the approach used by the council for annual water quality reporting (Margetts and Marshall 2021). Site medians for fine sediment cover were compared against consent target levels. There is currently insufficient data to conduct trend analysis.

2.9.4. Sediment Quality

Total PAHs were calculated by summing the following 18 PAHs listed in the ANZG (2018) guidelines for total PAH: naphthalene, acenaphthylene, acenaphthene, fluorene, anthracene, phenanthrene, fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[a]pyrene, perylene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[e]pyrene, benzo[ghi]perylene, dibenz[a,h]anthracene and indeno[1,2,3-cd]pyrene. Total PAHs were normalised to 1% TOC, as recommended by ANZG (2018). 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 (Boffa Miskell Limited 2016).

Sediment quality data from the five Halswell catchment sites sampled in 2021 as part of the five-yearly monitoring programme were summarised and tabulated for comparison against consent attribute target levels and ANZG (2018) upper guideline values (Table 2). Sediment quality data from 2021 were compared against data collected at similar locations at three sites in 2003 (Kingett Mitchell Ltd 2005), one site in 2012 (Golder Associates 2012), and three sites in 2016 (Boffa Miskell Limited 2016). Differences in mean values amongst sites for 2021 data were assessed using permutation tests. 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.

2.9.5. 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 soft-bottomed streams for all sites except for the two Balguerie Stream sites, where hard-bottom tolerance scores were used. Hard and soft-bottomed tolerance scores were based on the dominant substrate present (Stark and Maxted 2007).

ASPM: The Average Score Per Metric combines %EPT, EPT taxa richness and MCI indices into a single metric (Collier 2008). Following recommendations in the National Policy Statement for Freshwater Management 2020, the ASPM was calculated as the average of the following: %EPT / 100, EPT taxa richness / 29, and MCI / 200.

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. However, trend analysis was conducted on invertebrate metrics from the Balguerie Stream and Cashmere Stream sites, using TimeTrends software.

Spearman rank correlation was used to explore relationships between habitat variables and invertebrate metrics at the 14 ecology sites sampled in 2021. Spearman correlation was also used to compare invertebrate metrics with sediment quality data at the five sediment quality sites sampled in the Halswell catchment in 2021. We acknowledge that a sample size of five provides low statistical power and the results are therefore treated with caution. No correlations were undertaken between invertebrate metrics and council monthly water quality monitoring data. That is because there were only four water quality monitoring sites near the 14 ecology sites sampled in 2021, and we considered a sample size of four to be too small to undertake reliable correlation analysis. Instead, we qualitatively compared invertebrate data with the most recent analysis of monthly water quality monitoring data in the district (Margetts and Marshall 2021).

2.9.6. Fish

The fish catch was converted to catch per unit effort to enable comparison between sites and years. Catch per unit effort was calculated as total catch per 100 m² fished for electric fishing sites and number of fish per net or trap for the trapping and netting sites. Data were compared graphically amongst sites and sampling years, but no statistical comparison was possible, due to the lack of replication.

3. RESULTS

3.1. Recent Flow Conditions

Sampling in March 2021 occurred during an exceptionally dry period. A total of 52 mm of rain was recorded from January to March 2021 at the Botanic Gardens monitoring site, which is the second lowest rainfall amount for the January to March period for the last 100 years of record. Most months in the preceding year had much lower than average rainfall (Figure 5), with January 2020 recording the lowest January rainfall for the 100 years of record. Total rainfall for 2020 was 469 mm, which is 28% lower than the annual mean of 651 mm for the preceding 100-year period. Flow records for the sampled waterways are comparatively recent, so it is difficult to make historical comparisons. However, we repeatedly heard from local landowners that stream flows were lower than they had seen before. Overall, these data indicate that sampling in March 2021 occurred following a period of very stable, low flow conditions.

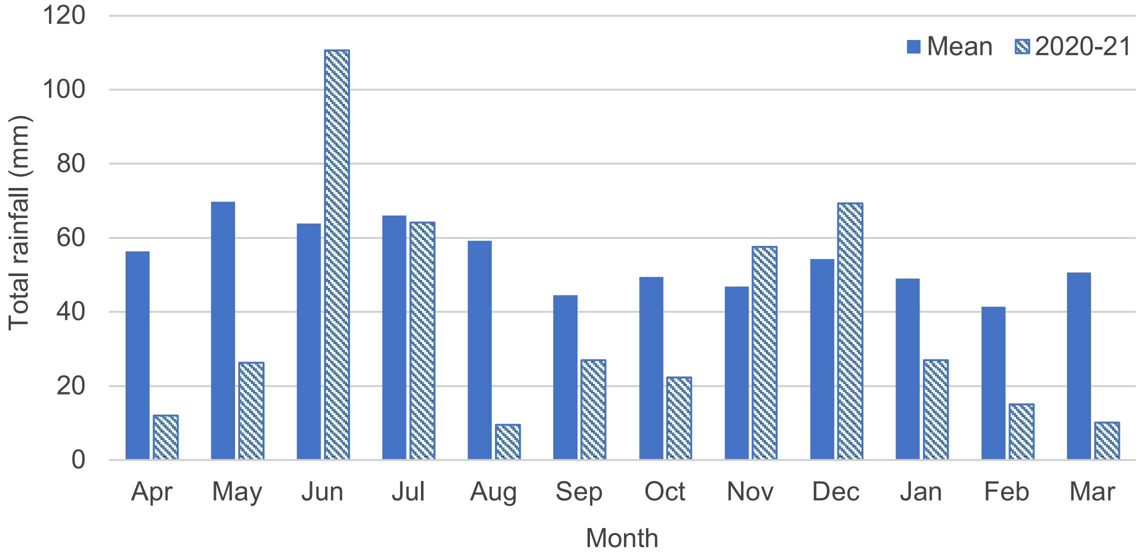

Figure 5: Christchurch monthly mean rainfall data for the last 100 years compared to monthly totals from 2020-21. Data are from the Botanic Gardens monitoring site and are courtesy of NIWA.

3.2. Habitat and Water Quality

In this section, habitat and water quality data are presented for all ecology sites sampled by Instream in 2021. Trends in five-yearly habitat data for the Halswell catchment are also discussed in this section, while trends at annual monitoring sites are discussed separately in Section 3.2.1.

Water temperatures were cool (<17 °C) at all sites sampled in March 2021, ranging from a minimum of 12.8 °C at Johns Drain (Site J1) to a maximum of 16.4 °C at Nottingham Stream (Site HA03, Table 3). Temperatures at all sites complied with the LWRP Receiving Environment standard of <20 °C. Dissolved oxygen saturation exceeded (i.e., complied with) the LWRP Freshwater Outcome of 70% at all sites in 2021, except for at Site HE28 in Cashmere Stream and Site OT06 in Wilsons Drain. However, oxygen saturation levels were still moderate at both sites, measuring 62 to 65%. Electrical conductivity was in the range of 102 to 232 µS/cm at all sites. Water pH was circum-neutral (i.e., around pH 7) and within LWRP receiving environment standards of pH 6.5 to 8.5 for all sites in 2021.

All field-measured water quality results were similar to previous measurements in 2020 for Cashmere Stream and 2016 for the Halswell catchment sites.

Table 3: Field-measured water quality in 2021. Values in red do not comply with the relevant LWRP Freshwater Outcome or Receiving Environment Standard.

Site number	Waterway	Location	Dissolved oxygen (%)	Temperature (°C)	pH	Conductivity (µS/cm)
HA10	Knights Stream	Upstream of Whincops Road	70.9	13.3	6.93	173
HA05	Knights Stream	At Sabys Road	84.2	13.0	7.61	191
HA09	Cases Drain	Upstream of Downies Road	105.4	14.9	7.70	195
HA08	Creamery Stream	Downstream of Sabys Road	127.1	16.5	8.48	232
HA03	Nottingham Stream	At Candys Road	88.1	16.4	7.85	173
HA07	Halswell River	At Wroots/Halswell Roads	104.7	16.0	7.93	205
HA04	Halswell River	At Tai Tapu Road	83.9	13.1	8.08	192
HA06	Halswell River	Downstream of Early Valley Road	97.7	13.6	7.99	188
HE28	Cashmere Stream	Behind 420- 426 Cashmere Road (upstream of stormwater discharge)	**65.4**	14.0	7.43	197
HE27	Cashmere Stream	Behind 406 Cashmere Road (downstream of stormwater discharge)	77.4	13.3	7.35	204
OT02	Wilsons Drain	At Ōtūkaikino Reserve	87.8	12.9	8.05	121
OT06	Wilsons Drain	At Tyrone Street	**62.7**	12.9	7.70	102
J1	Johns Drain	At 888 Main North Road	84.1	12.8	7.77	116
W1	Wilsons Drain	Main North Road	95.6	14.1	8.08	117
LWRP Freshwater Outcome or Receiving Environment Standard			**≥70**	**<20**	**6.5 - 8.5**	**–**

Representative site photographs from the monitoring sites are shown in Figure 6 to Figure 9, and photographs of all ecology and sediment quality sites monitored by Instream in 2021 are in Appendix 1.

There was little change in local landuse or riparian conditions between 2016 and 2021 at Site HA10 (Knights Stream at Whincops Road) and Site HA07 (Halswell River at Wroots/Halswell Roads). However, riparian vegetation cover has improved dramatically at Cases Drain (Site HA09) since 2011, when it was last sampled. In 2011, riparian vegetation comprised short pasture grass and weeds, with negligible shade or fish cover. In 2021 native plantings of *Carex* sedges and flax (*Phormium* sp.) were overhanging the channel, providing more shade and fish cover (Figure 7).

Figure 6: Representative photographs of the ecology monitoring sites in 2021.

Figure 7: Cases Drain (Site HA09) in 2011 (left) and 2021 (right), showing improved native riparian cover.

Longer riparian grass and shrubs resulted in more overhanging vegetation and improved fish cover in 2021 than in 2016 at Site HA06 on the Halswell River. Longer riparian grass and more overhanging vegetation was observed in 2021 than in 2020 at Sites HE27 and HE28 on Cashmere Stream (Figure 8). Care was taken to sample all sites prior to maintenance crews visiting the sites in 2021, whereas 2016 and 2020 sampling occurred soon after water maintenance activities. Thus, improved habitat conditions at these sites in 2021 was primarily because there had been a longer time since the last round of waterway maintenance had been done. Presumably riparian habitat conditions declined again following the next round of waterway maintenance.

Figure 8: Cashmere Stream at Site HE27, photographed in 2020 (left) and 2021 (right). The 2020 image was taken shortly after waterway bank maintenance contractors had trimmed the banks, whereas the maintenance crew had not yet visited the site prior to the 2021 survey.

In 2021 riparian and instream habitat was dramatically reduced at Creamery Stream (Site HA08) compared to 2011. Riparian trees and shrubs on the true left bank had been removed since 2011, substantially reducing stream shade and fish cover (Figure 9). In addition, black polythene plastic had recently been placed on the stream bed, associated with bank works that were underway. Placement of the polythene occurred after we had completed habitat and invertebrate sampling and before fish sampling.

The two ECan monitoring sites on Balguerie Stream have extensive native tree cover, with mean channel shading exceeding 80% at Site BP02[3]. For most of the remaining monitoring sites, riparian habitat is highly modified, typically comprising a narrow strip (<3 m wide) of long grass, sedges (*Carex* spp), or native plantings. Knights Stream at Whincops Road (Site HA10) is a notable exception, as it was well-shaded by a mix of native and exotic trees, providing an average of 77% shade (Figure 10). Nottingham Stream (Site HA03) was also well-shaded by taller exotic and native trees and shrubs on the true left bank, providing an average of 73% shade across the reach. Wilsons Drain at Ōtūkaikino Reserve (Site OT02) and Cases Drain (Site HA09) were both lined with dense shrubs and *Carex* grasses, but their low stature provides less shade than at the Nottingham Stream and Knights Stream sites (Figure 10).

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[3] Shade data is from Instream Consulting (2020). ECan habitat measurements do not include channel shading.

Figure 9: Contrasting riparian and instream habitat conditions at Creamery Stream (Site HA08) between 2016 (left) and 2021 (right). Note black polythene lining the bed in the 2021 image.

Shading was greater in 2021 compared to 2016 at Site HA10 (Knights Stream) and HA06 (Halswell River at Early Valley Road), due to recent waterway maintenance activities prior to the survey in 2016. In contrast, shading at Creamery Stream (Site HA08) halved from 2016 to 2021, due to removal of riparian vegetation. These contrasting changes in stream shade were associated with a significant site x year interaction (ANOVA P=0.02).

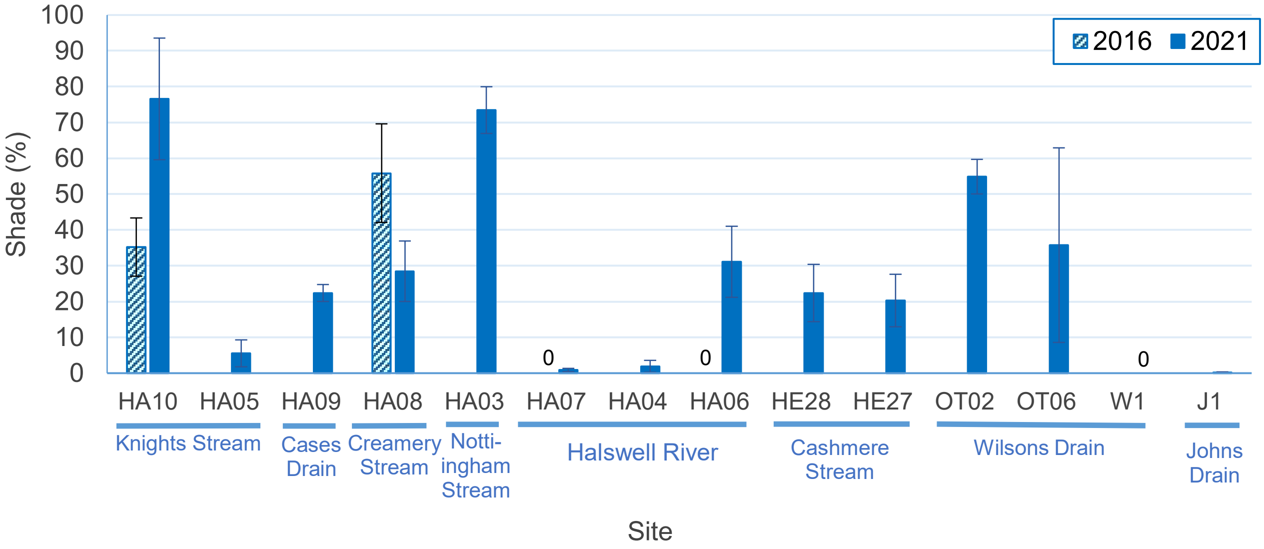

Figure 10: Mean (±1 SE) waterway shading at all sites sampled in 2021 compared with Halswell sites sampled in 2016. Blanks for Halswell sites in 2016 indicate no data collected. Zeroes indicate zero shade for that location.

Waterway widths and depths were lowest for the small tributaries of the Halswell River and the Wilsons Drain sites and greatest for the Halswell River and Cashmere Stream sites (Figure 11, Figure 12). Water depths were generally deeper and water velocities slower in 2021 than in previous years, despite the dry conditions, because macrophytes had been recently cleared prior to sampling in 2011 and 2016 (Figure 12 and Figure 13). Nuisance introduced species, such as *Elodea canadensis* and *Potamogeton crispus* have a major impact on water depths and velocities, slowing water down and increasing water depths. Sampling in 2021 occurred immediately prior to weed clearance at most sites, resulting in significantly greater depths (ANOVA $P<0.001$ for “year” effect) and slower velocities (ANOVA $P=0.002$ for “year” effect) compared to previous years.

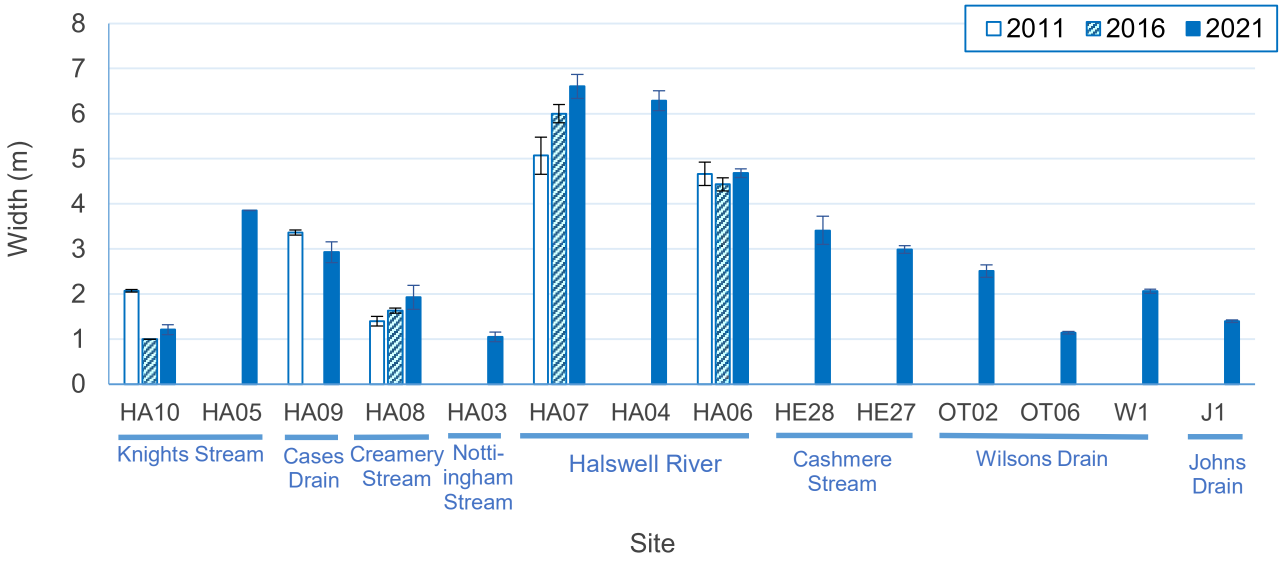

Figure 11: Mean (±1 SE) water width at all sites sampled in 2021 compared with 2011 and 2016 data for Halswell catchment sites. Blanks for Halswell sites in 2011 and 2016 indicate no data collected for that year.

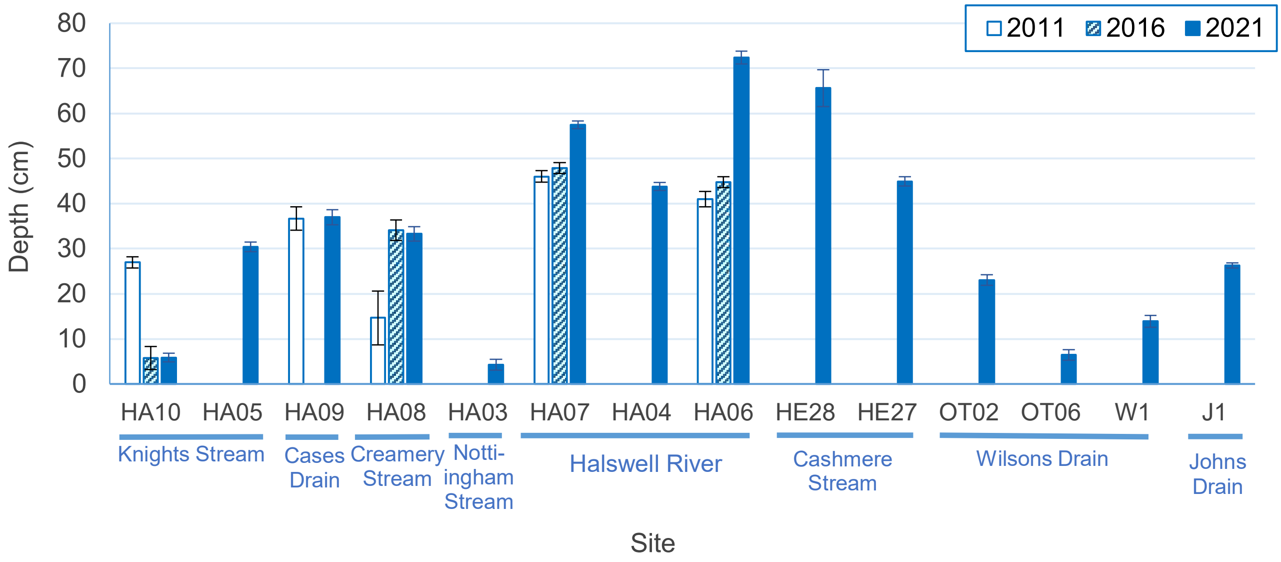

Figure 12: Mean (±1 SE) water depth at all sites sampled in 2021 compared with 2011 and 2016 data for Halswell catchment sites. Blanks for Halswell sites in 2011 and 2016 indicate no data collected for that year.

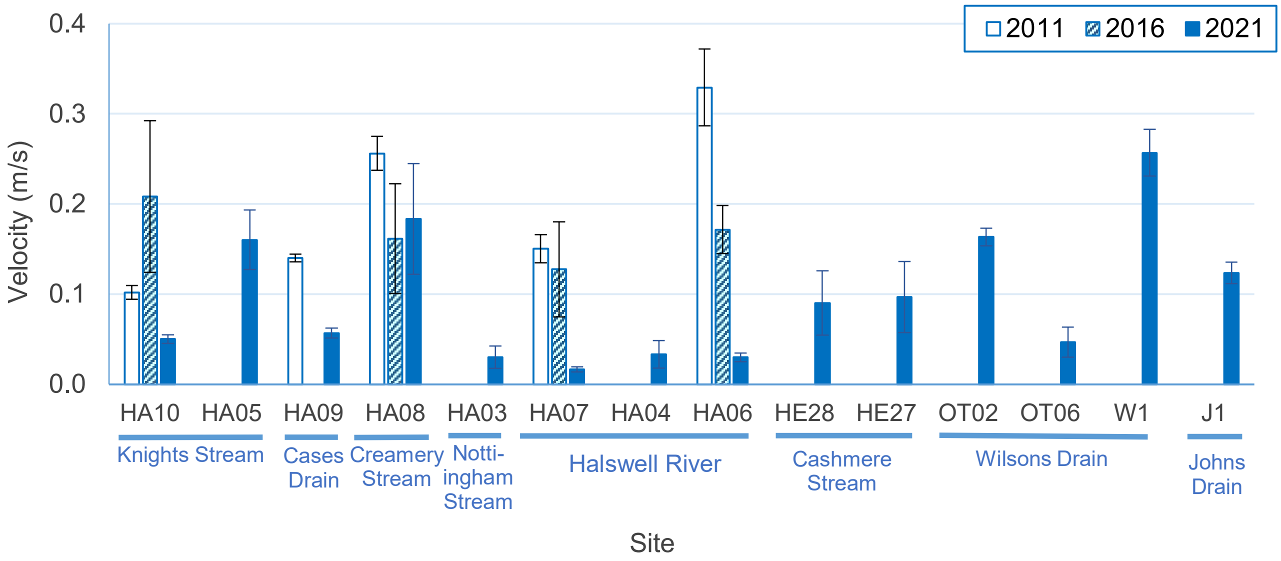

Figure 13: Mean (±1 SE) water velocity at all sites sampled in 2021 compared with 2011 and 2016 data for Halswell catchment sites. Blanks for Halswell sites in 2011 and 2016 indicate no data collected for that year.

At most sites sampled in 2021 mean substrate index values were around 3, indicating a dominance of fine sediments <2 mm diameter (Figure 14). Site HE27 on Cashmere Stream and Site J1 on Johns drain were the only sites with a predominantly stony substrate, with mean substrate index scores of approximately 4, indicating gravel substrates in the range of 2–16 mm. There was a significant site x year ANOVA interaction (P=0.02), mainly due to slightly coarser substrate recorded at Site HA08 on Creamery Stream. This was associated with large boulders recently placed on the bed, associated with bank works.

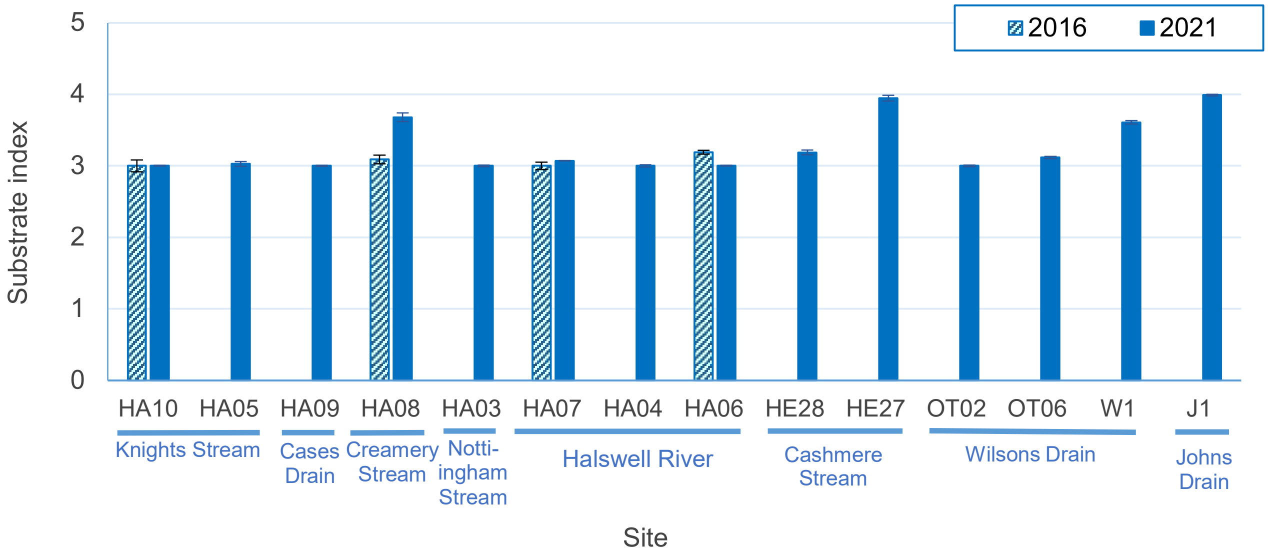

Figure 14: Mean (±1 SE) substrate index at all sites sampled in 2021 compared with 2016 data for Halswell catchment sites. Blanks for 2016 Halswell sites indicate indicate no data collected for that year. Substrate index values ≤3 equate to sand/silt (i.e., ≤2 mm) and index values of 3–4 equate to gravels (2–16 mm).

Bed cover with fine sediment <2 mm diameter at ecology sites monitored in 2021 was very high and exceeded the consent target of 20% at all sites (Figure 15). The lowest mean bed cover with fine sediment was 67%, recorded at Site HE27 in Cashmere Stream. The high levels of deposited fine sediment recorded at all the sampling sites would exclude most sensitive invertebrate taxa, especially mayflies (Ephemeroptera), which prefer sediment-free stony beds. No comparison was made in fine sediment cover between sampling years, due to inconsistent sampling methods.

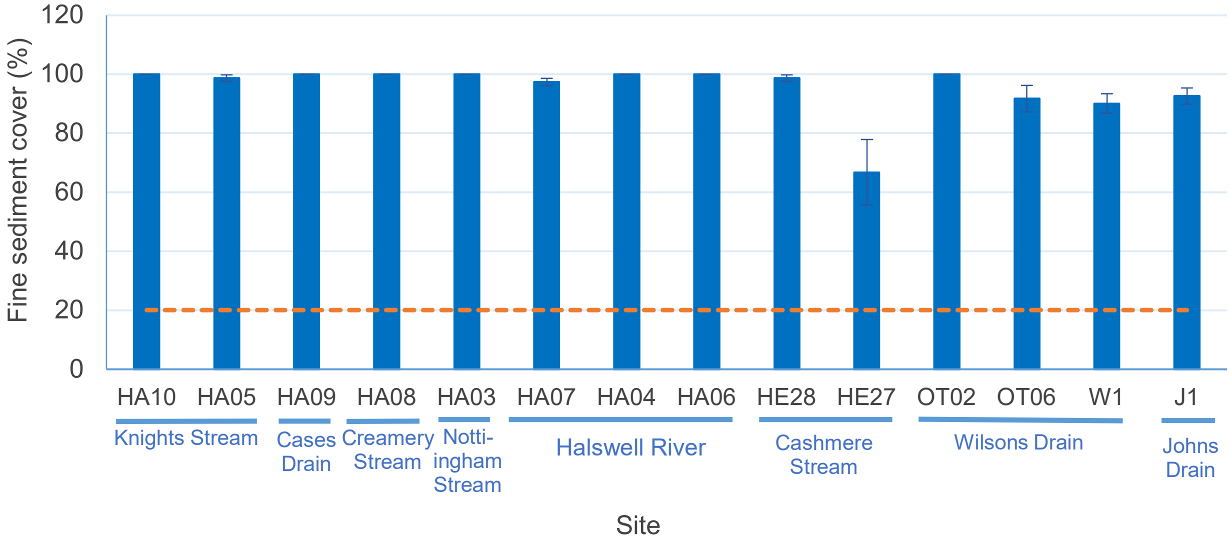

Figure 15: Mean (±1 SE) bed cover with fine sediment (≤2 mm diameter) in 2021. Dashed line is the 20% consent target.

Total macrophyte cover was high and exceeded consent target levels at eight of the 14 sites sampled in 2021 (Figure 16). Three of the sites with the lowest macrophyte cover were Site HA03 on Nottingham Stream, Site OT02 on Wilsons Drain, and Site HA10 on Knights Stream. These three streams had the greatest amount of stream shade of the 14 sites sampled, which shows the value of high levels of stream shade in preventing nuisance plant growths. Low macrophyte levels in Creamery Stream were largely due to recent in-channel works by the adjacent landowner. As noted above, macrophyte cover was significantly higher in 2021 than in previous years at the Halswell catchment sites (ANOVA P<0.001 for "year" effect), due to the impacts of recent weed clearance in previous years.

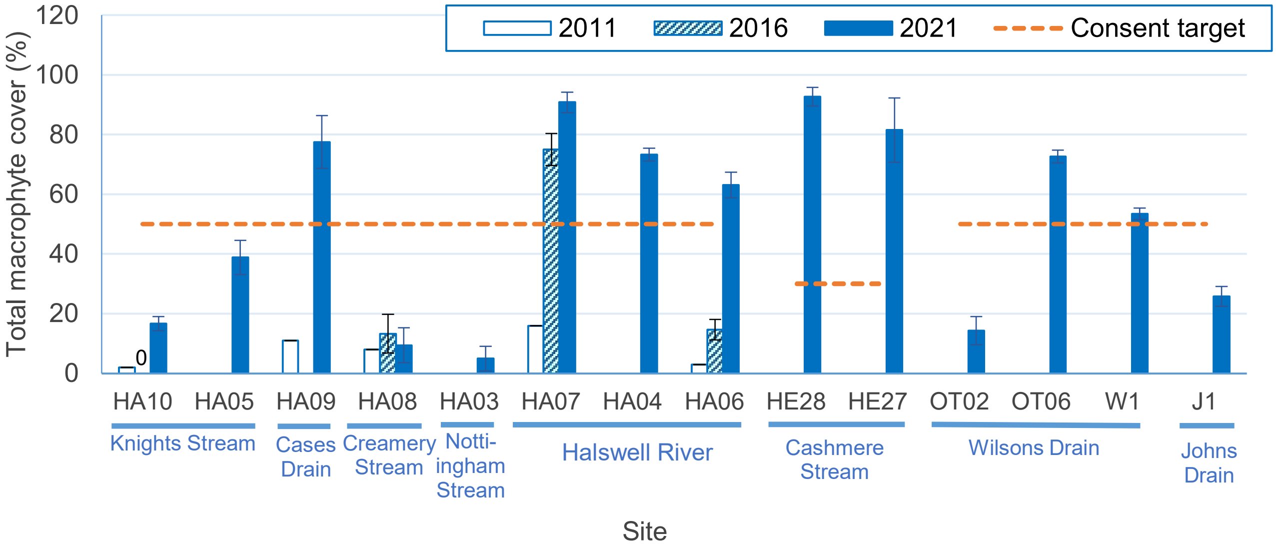

Figure 16: Mean (±1 SE) total macrophyte cover at all sites sampled in 2021 compared with 2011 and 2016 Halswell catchment data. Dashed lines are consent target levels. Blanks for Halswell catchment sites indicate no data collected for that year. Zeroes indicate zero macrophyte cover for that location.

Bed coverage with long green filamentous algae (>2 cm long) has always been relatively low and complied with consent target levels at all sites (Figure 17). There was significantly greater bed cover with filamentous algae in 2021 than in previous years for the Halswell catchment sites (ANOVA P<0.001 for "year" effect). This reflected the relatively long time since aquatic weed removal in 2021, and therefore a longer period for periphyton accrual, compared with previous years.

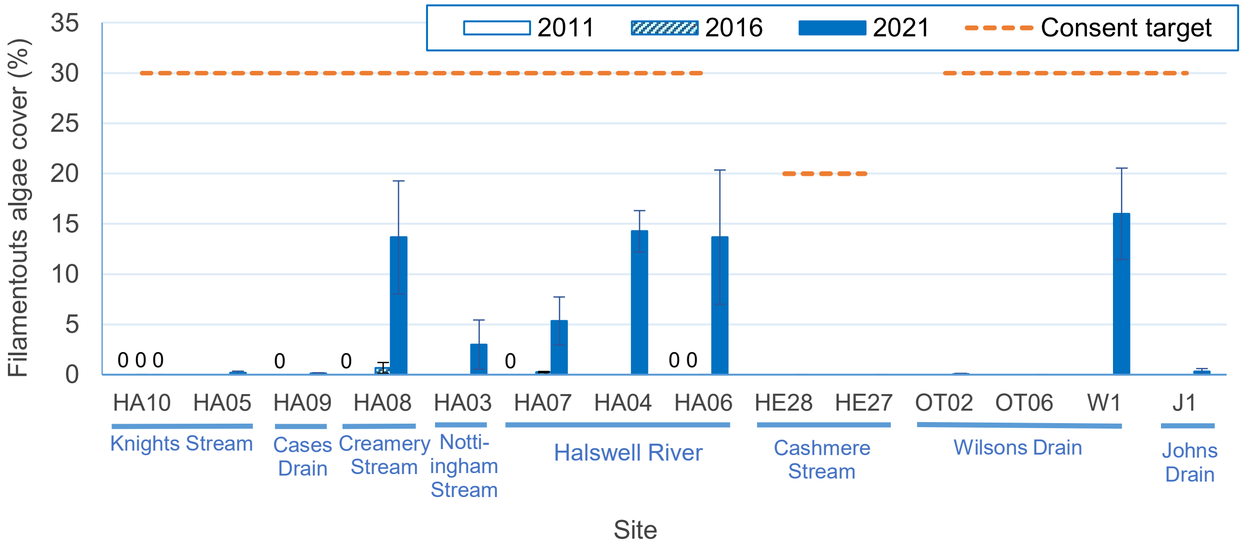

Figure 17: Mean (±1 SE) cover with long filamentous algae (>2 cm) at all sites sampled in 2021 compared with 2011 and 2016 Halswell catchment data. Dashed lines indicate consent target levels. Blanks for Halswell catchment sites indicate no data collected. Zeroes indicate zero cover for that location.

3.2.1. Trends at Annual Monitoring Sites

Total macrophyte cover is typically high and exceeds the consent target of 30% cover at both Cashmere Stream monitoring sites (Figure 18). However, macrophyte cover at both monitoring sites was much lower in 2020 compared with 2021, and cover at Site HE28 was lower in 2020 than in any previous monitoring years (Figure 18). Low macrophyte cover in 2020 was due to sampling occurring after weed removal had occurred (due to impacts of the COVID-19 pandemic on fieldwork timing). Lower macrophyte cover in 2020 was associated with swifter water velocities and lower water depths at both sites, compared to 2021. Trend analysis was not carried out on macrophyte cover, depth, or velocity, as they are all primarily influenced by CCC maintenance activities.

Bed cover with fine sediment has consistently been high and exceeded the consent target of 30% bed cover at both Cashmere Stream sites. A slight decline in fine sediment cover at Site HE28 in recent years was statistically significant (Mann-Kendall P=0.017), but the change is small and unlikely to be biologically meaningful, given that fine sediment cover still remains well in excess of ecological guidelines. There is insufficient data available for trend analysis at Site HE27. Bed cover with long filamentous algae (>2 cm long) is consistently low and below the consent target of 20% at both Cashmere monitoring sites.

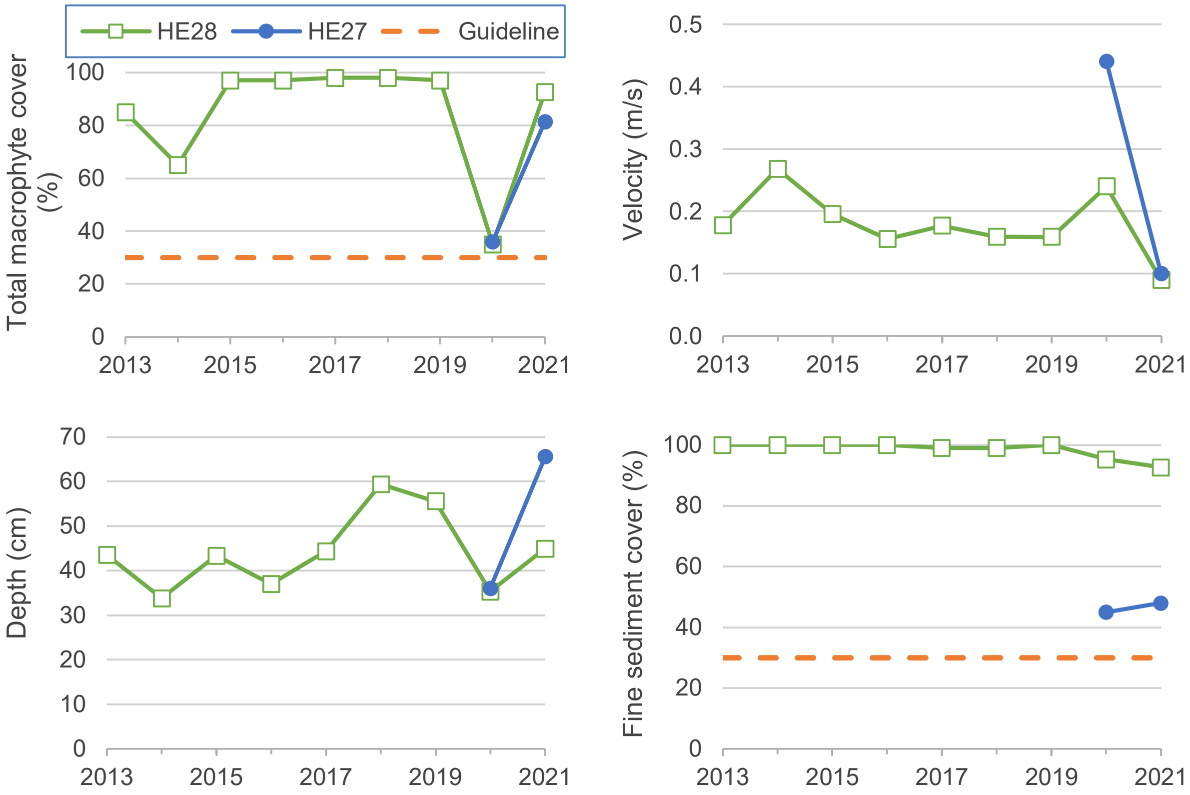

Figure 18: Changes in total macrophyte cover, water velocity, water depth and fine sediment cover over time at the two Cashmere Stream monitoring sites. See Table 2 for guidelines.

Bed cover with long filamentous algae has consistently been <10% for all years of monitoring at the two Balguerie Stream sites monitored by ECan. Similarly, macrophyte cover has been low and below the consent target of 20% at both sites. Fine sediment deposition data is not routinely measured at these sites. However, measures of fine sediment deposition and substrate embeddedness at both sites show considerable variation over time (Figure 19). Trend analyses showed no significant increasing or decreasing trend (Mann-Kendall P>0.05) in sediment deposition score at either site. However, there was a significant (Mann-Kendall P=0.02) increasing or improving trend in substrate embeddedness score at both sites. This suggests a general reduction in the amount of fine sediment accumulating on the bed over time at both sites.

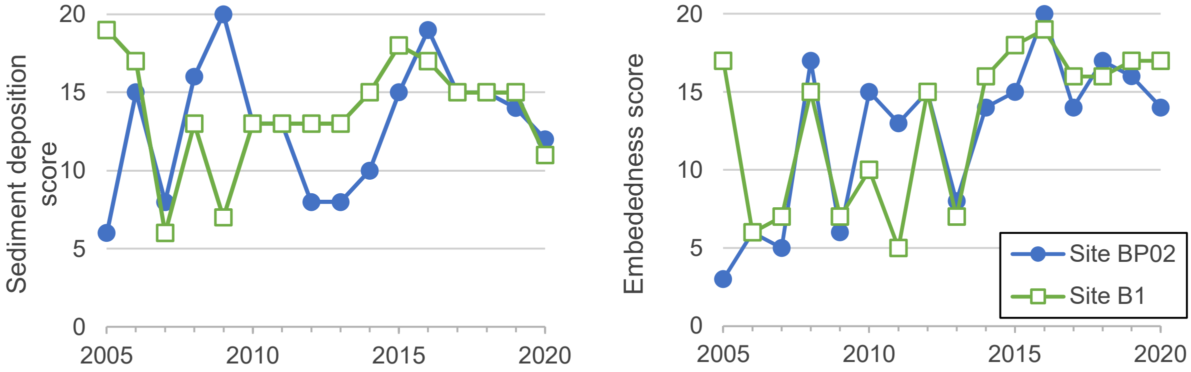

Figure 19: Sediment deposition and embeddedness at the two Balguerie Stream monitoring sites. Index scores range from 1 to 20, with 20 indicating optimal habitat quality. Data are courtesy of ECan.

3.3. Deposited Fine Sediment

Consent targets for fine sediment cover were complied with at five of the 15 monitoring sites, based on site medians (Figure 20). Data collection only commenced in June 2020, so trend analysis is not yet possible. Four of the five catchments monitored by CCC included some waterways that complied with consent targets and some waterways that did not. Only the Halswell catchment had no waterways that complied with the consent target.

3.4. Sediment Quality

Sediment quality data from 2021 is summarised in Table 4 and all laboratory results are in Appendix 2. Mean total organic carbon (TOC) content was low and varied little amongst sites in 2021 (Table 4), reflecting similar broad patterns in hydrology, landuse, and underlying geology. Total mud content was high and varied little amongst sites, reflecting the predominantly fine sediments present in stable, spring-fed waterways.

Mean concentrations of copper, lead, and total PAHs in sediment were low and complied with consent attribute target levels at all sites in 2021 (Table 4). Mean zinc concentrations were also low and complied with consent target levels at four of the five sites sampled. Site HA03 on Nottingham Stream had a mean zinc concentration of 293 mg/kg, which exceeded the consent target of 200 mg/kg but complied with the ANZG (2018) upper guideline value (GV-high) of 220 mg/kg.

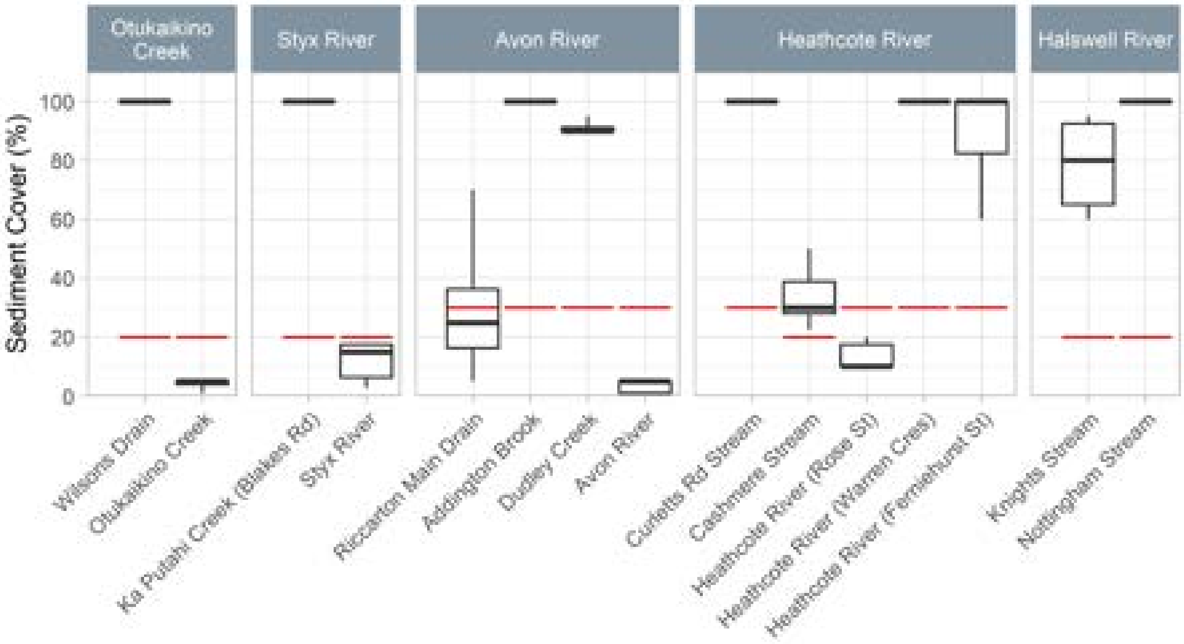

Figure 20: Summary of monthly fine sediment monitoring data collected by CCC in 2020, compared with consent target levels (dashed red lines). Boxes include the interquartile range, whiskers extend to 5th and 95th percentiles, and medians are solid black lines within the boxes.

Permutation tests run on 2021 sediment quality data revealed significant differences between sites for copper and lead (both P=0.01), and zinc (P<0.01), and a weak, but not statistically significant difference for total PAH (P=0.08). These site differences were mostly caused by data from Nottingham Stream, which had higher concentrations of copper, lead, zinc, and total PAHs than then other four sites.

As noted in Section 2.8 above, consent target levels are the same as default guideline value (DGV) levels in the ANZG (2018) sediment quality guidelines. The ANZG (2018) upper and lower guidelines indicate the overall risk of toxicity effects on biota. Sites meeting the lower DGVs (equal to the consent target levels) have a low risk of toxicity effects, sites exceeding DGVs have an increased risk of adverse effects, and there is a relatively high risk of adverse effects for sites exceeding GV-high levels. This means that there is a low risk of adverse ecological effects due to sediment toxicity at most sites sampled, and an increased risk of zinc toxicity at Site HA03 in Nottingham Stream. None of the sites are exposed to a higher level of ecological risk associated with exceedances of GV-high levels.

Table 4: Mean sediment quality data for 2021. Total PAHs are normalised to 1% TOC. Total mud is percent of particles <63µm in sample. Values exceeding consent targets are in orange. No values exceeded ANZG (2018) Guideline Value-high levels.

Site code	Site name/ Location	Copper (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Total PAHs (mg/kg)	TOC (g/100g)	Total mud (%)
HA10	Knights Stream Upstream of Whincops Road	7	20	55	0.035	3.0	30
HA05	Knights Stream at Sabys Road	7	15	62	0.043	2.7	41
HA08	Creamery Stream downstream of Sabys Road	6	13	52	0.051	1.6	29
HA03	Nottingham Stream at Candys Road	14	31	**293**	0.113	3.5	31
HA07	Halswell River at Wroots/Halswell Roads	10	21	127	0.091	3.3	44
Consent Attribute Target Level		65	50	200	10	–	–
ANZG 2018 GV-high		270	220	410	50	–	–

Sediment concentrations of metals and PAHs have varied over time from 2003 to 2021, but they have always been below consent attribute target levels, with the exception of zinc at Site HA03 (Nottingham Stream) in 2021 (Figure 21 to Figure 24). There was no consistent trend of increasing metal or PAH concentrations over time across the sampling sites. However, zinc concentrations at Site HA03 on Nottingham Stream were markedly higher in 2021 than in previous years (Figure 23).

Increased sediment zinc concentrations in sediment at Site HA03 in Nottingham Stream are potentially of concern, as it could reflect an increase in catchment zinc loads. However, comparison of mud (particles <63 µm) content across sampling years indicates that there was also greater mud content in 2021 samples compared with previous years at Site HA03 (Figure 25). Metal concentrations are typically higher in sediments with a higher proportion of mud, because the contaminant binding capacity of sediments increases with decreasing grain size (ANZG 2018). Therefore, greater zinc concentrations at Site HA03 in 2021 reflect the greater proportion of fine sediments present, which act as a magnet for heavy metals.

Normalising zinc concentrations to 1% mud (as per Gadd 2015 and Instream Consulting 2020) shows the impact of sediment texture on zinc levels (Figure 26). Thus, zinc concentrations normalised to mud content were lower in 2021 at all three sites sampled in 2016, higher in 2021 than at the one site sampled in 2012, and lower in 2021 at two of the four sites sampled in both 2003 and 2021 (Figure 26). Normalising zinc concentrations to mud content may not change zinc toxicity, but it does help indicate potential metal sources. The fact that there is no overall increasing or decreasing trends of normalised zinc concentrations suggests no overall trend in the supply of zinc to the Halswell catchment.

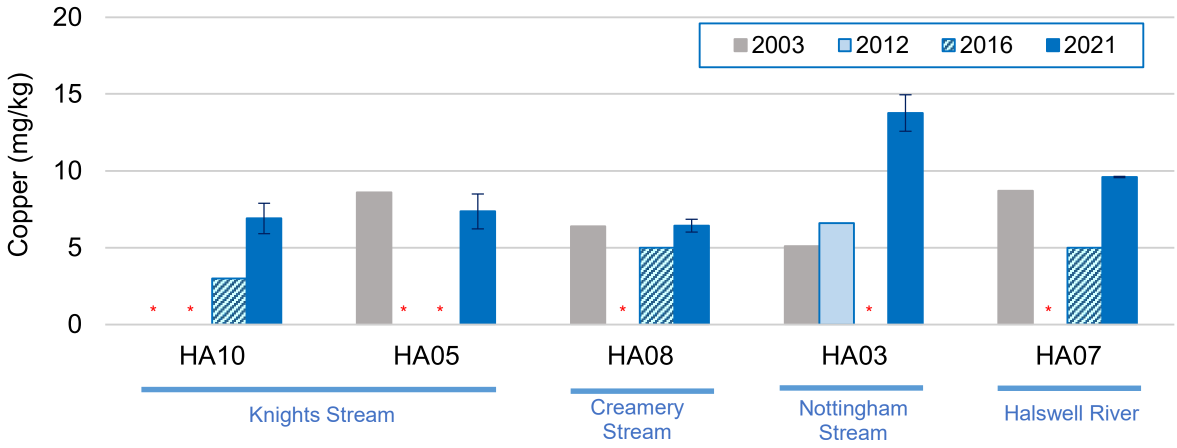

Figure 21: Sediment copper concentrations over time. Data are means ±1 SE for 2021 and single grab samples for previous years. Asterisks indicate no data for that year. The consent target level of 65 mg/kg is not shown, as all values fall well below it.

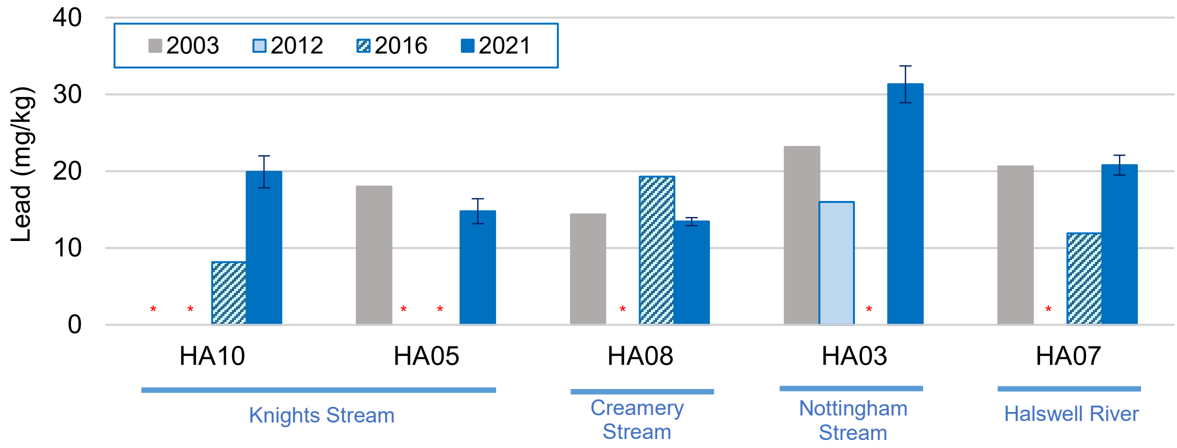

Figure 22: Sediment lead concentrations over time. Data are means ±1 SE for 2021 and single grab samples for previous years. Asterisks indicate no data for that year. The consent target level of 50 mg/kg is not shown, as all values fall well below it.

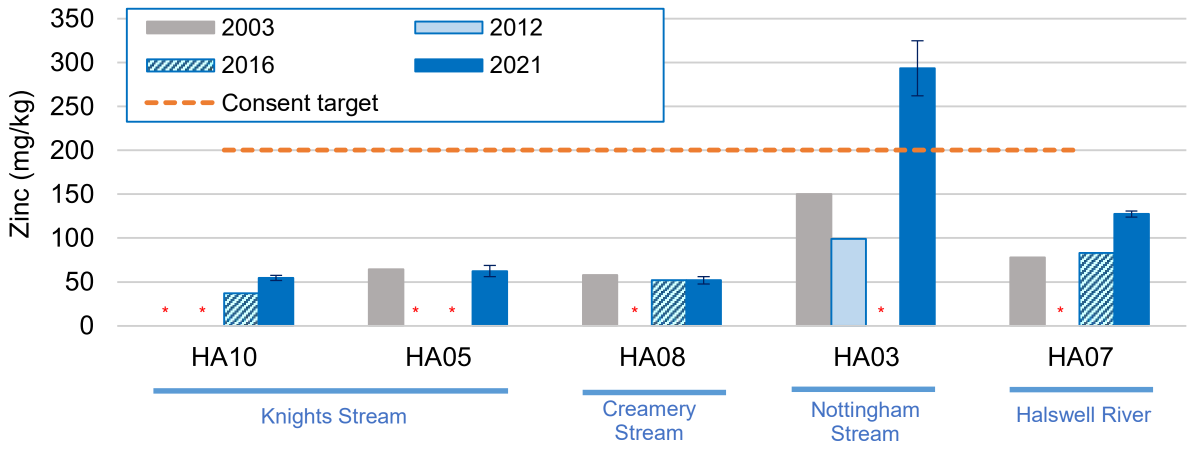

Figure 23: Sediment zinc concentrations over time compared with the consent attribute target level. Data are means ±1 SE for 2021 and single grab samples for previous years. Asterisks indicate no data for that year.

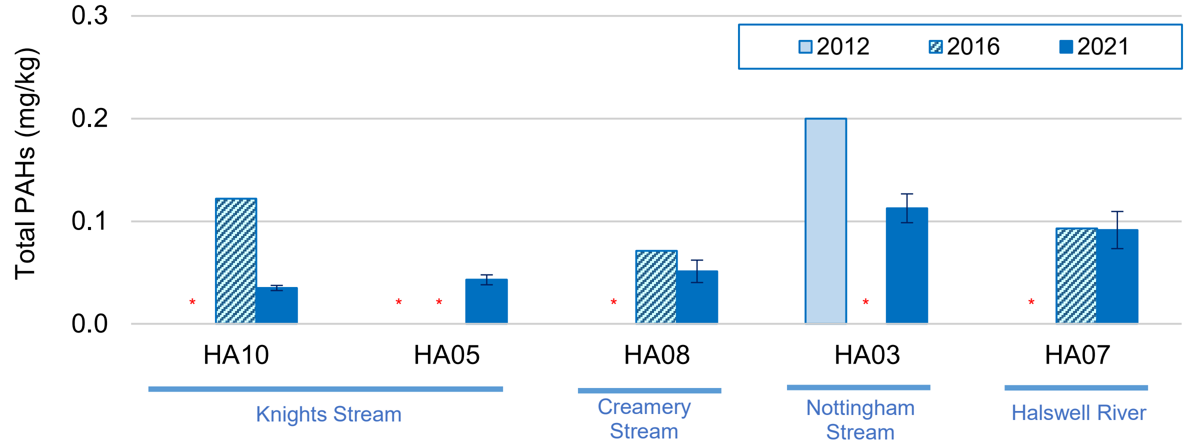

Figure 24: Sediment total PAH concentrations over time. PAH concentrations are normalised to 1% TOC. Data are means ±1 SE for 2021 and single grab samples for previous years. Asterisks indicate no data for that year. The consent target level of 10 mg/kg is not shown, as all values fall well below it.

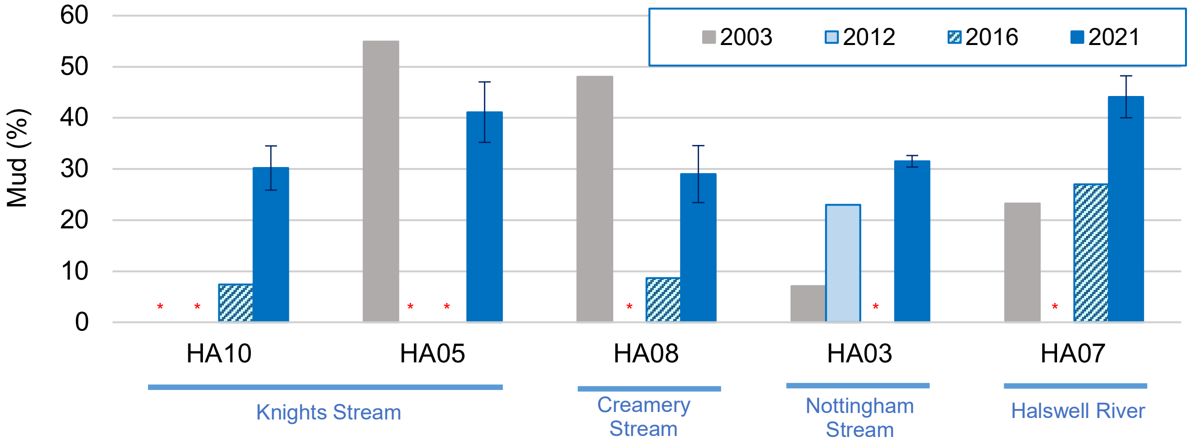

Figure 25: Percent mud content in sediments over time. Data are means ±1 SE for 2021 and single grab samples for previous years. Asterisks indicate no data for that year.

In summary, concentrations of common stormwater contaminants in sediments have remained low and within guidelines at most sites in the Halswell catchment. Over time, Nottingham Stream has consistently had elevated levels of copper, zinc and total PAHs compared with the other four monitoring sites. That reflects the greater proportion of urban landuse in the Nottingham Stream catchment, coupled with the fact that urbanisation occurred decades before stormwater treatment was undertaken as part of residential subdivision.

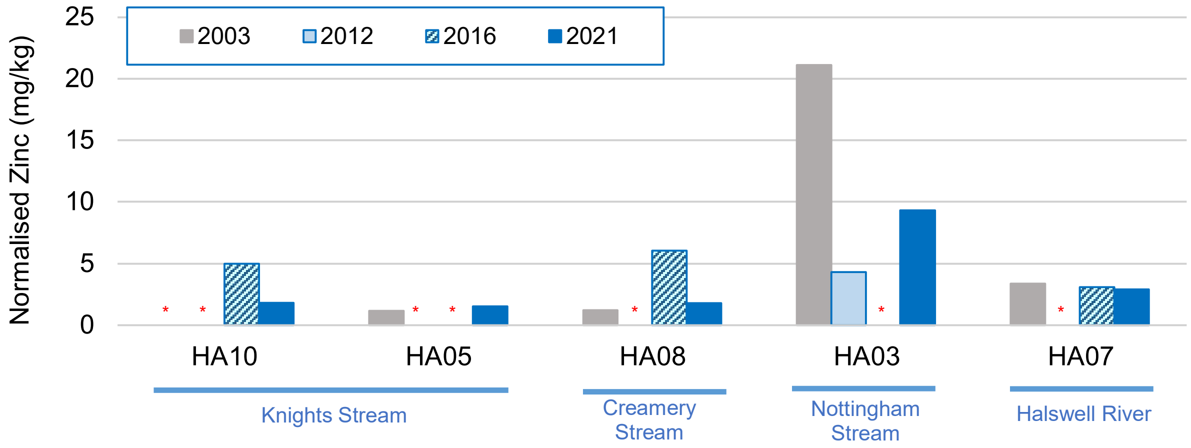

Figure 26: Zinc concentrations normalised to 1% mud content. Data are means for 2021 and single grab samples for previous years. Asterisks indicate no data for that year.

3.5. Macroinvertebrates

3.5.1. Five-Yearly Halswell and Wilsons Drain Sites

In this section, invertebrate data are presented for all ecology sites sampled by Instream in 2021. Trends in five-yearly invertebrate data for the Halswell catchment are also discussed in this section, while trends at annual monitoring sites are discussed separately in Section 3.5.2.

Invertebrate taxa richness in 2021 ranged from a low of 12 at Site HA06 on the Halswell River and Site HA10 on Knights Stream, to a high of 24 at Site HA08 at Creamery Stream (Figure 27). For the four Halswell catchment sites with invertebrate data from all three sampling occasions, mean taxa richness per site was 19 in 2011, 18 in 2016, and 17 in 2021. Slightly higher taxa richness in 2011 may reflect the greater area sampled per site in 2011 (a total of 1.35 m² sampled per site) compared to 2015 and 2020 (0.6 m² sampled per site). There was no indication of an overall increasing or decreasing trend in taxa richness across Halswell catchment monitoring sites between 2011 and 2021, with richness increasing at some sites and declining at others.

Invertebrate community composition at the Halswell catchment sites was similar in 2021 to previous years (Figure 28). The fauna was dominated by the amphipod crustacean *Paracalliope fluviatilis* and the common mud snail *Potamopyrgus antipodarum* in all monitoring years, with both taxa responsible for at least 70% of all individuals counted every year. Others amongst the top 10 most abundant taxa include: ostracod crustaceans; *Physella*, *Gyraulus*, and Sphaeriidae molluscs; and Orthocladiinae and *Chironomus* dipterans. The cased caddisfly *Oxyethira* is the only EPT taxon in the top 10 most abundant taxa, however it is pollution-tolerant (MCI = 2). Eight of the 10 most abundant taxa in 2021 had MCI scores of 3 or lower, which indicates they are very tolerant of poor water quality and habitat quality. The highest MCI score amongst the 10 most abundant taxa was for *P. fluviatilis*, which has an MCI score of 5.

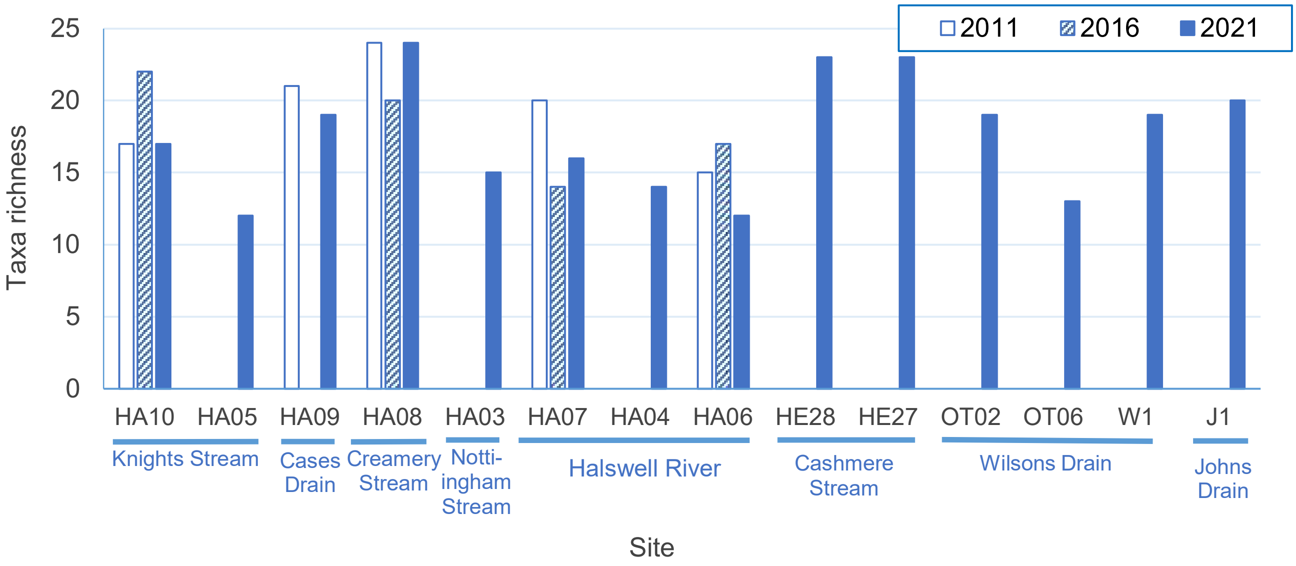

Figure 27: Number of invertebrate taxa collected at all sampling sites in 2021 compared with 2011 and 2016 data from Halswell catchment sites. Blanks for Halswell catchment sites indicate no data collected at that location.

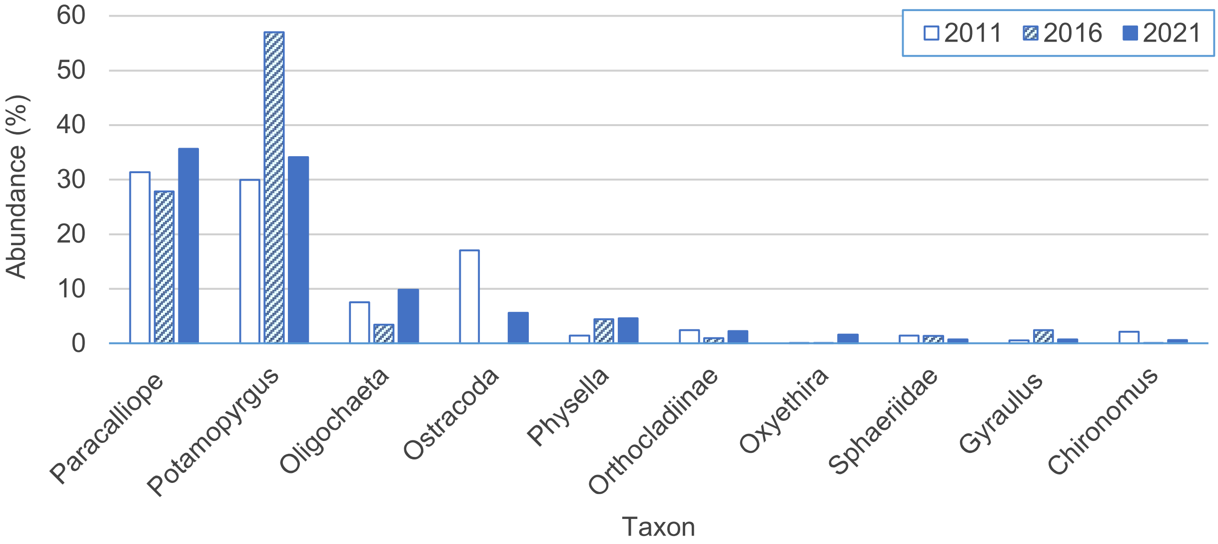

Figure 28: Abundance of the 10 most common taxa across all Halswell catchment sites in 2021 compared to previous years.

P. antipodarum snails and ostracod crustaceans also dominated the invertebrate community at the four Wilsons Drain sites in 2021, comprising 76% of the total invertebrate count (Figure 29). Pollution-tolerant taxa dominated the remaining top 10 most abundant taxa. The cased caddisfly *Hudsonema* was the most pollution-sensitive taxon amongst the 10 most abundant taxa, with an MCI score of 6. However, *Hudsonema* were relatively uncommon, comprising less than 2% of the total individuals counted.

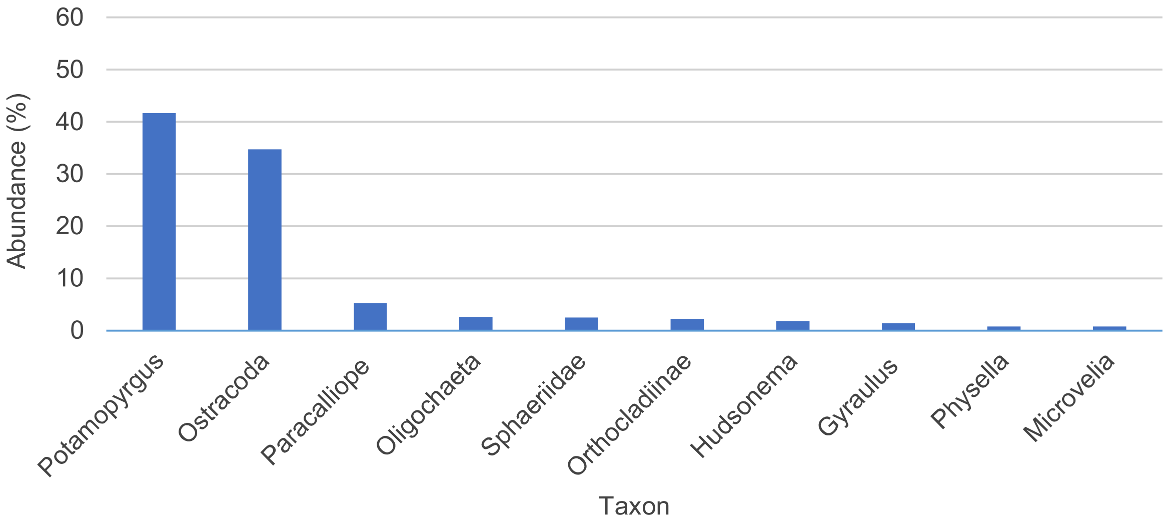

Figure 29: Abundance of the 10 most common taxa across the four Wilsons Drain catchment sites in 2021.

A total of four pollution-sensitive taxa (MCI scores ≥7) were recorded from the Halswell and Wilsons Drain catchment sites in 2021. Three of the pollution sensitive taxa were free-living caddisflies, *Oeconesus* (MCI = 9), *Polyplectropus* (MCI = 8), and *Psilochorema* (MCI = 8), plus one beetle from the family Hydraenidae (MCI = 8, Table 5). All three caddisfly taxa have been recorded previously from the Halswell catchment, but 2021 was the first year Hydraenidae were recorded.

In the Halswell catchment, three of the eight sites monitored in 2021 recorded pollution-sensitive taxa, compared with one of the five sites monitored in 2016, and four of the nine sites monitored in 2011 (Table 5). Pollution-sensitive taxa have consistently been rare within the Halswell catchment, with individual taxa comprising <1% of the total abundance each year. Overall, the data indicate that pollution-sensitive taxa are uncommon in the Halswell catchment and there is no increasing or decreasing trend in the presence of sensitive taxa over the ten-year monitoring period.

Caddisflies (Trichoptera) are the only EPT taxon recorded from the Halswell catchment since regular monitoring commenced in 2011. Caddisflies were also the only EPT taxon recorded from the four Wilsons Drain sites sampled in 2021. EPT taxa richness was low overall at all of the sites monitored in 2021 and in previous years in the Halswell catchment, with a maximum of five EPT taxa recorded at several sites (Figure 30). Low EPT taxa richness is typical for urban waterways, such as those in the Halswell, Cashmere Stream, and Wilsons Drain catchments (Suren 2000). EPT taxa richness varied by only one or two taxa over time at most Halswell catchment sites sampled between 2011 and 2021. EPT taxa richness declined by 4 taxa between 2016 and 2021 at Site HE06 on the Halswell River. Site HE06 also saw the greatest increase in macrophyte cover, greatest increase in water depth, and greatest decrease in water velocity compared to the sites sampled in 2016. It is therefore likely that the decline in EPT taxa richness in 2021 was due to the greater macrophyte cover and associated change in physical habitat. As noted in Section 3.2, changes in macrophyte cover at Site HE06 over time reflect timing of weed maintenance relative to invertebrate sampling, rather than any effect related to stormwater discharges.

Table 5: Pollution-sensitive invertebrate taxa (MCI scores of ≥7) at Halswell and Wilsons Drain catchment monitoring sites from 2011 to 2021.

Waterway	Site	2011	2016	2021
Knights Stream	HA10	*Oeconesus* *Psilochorema*	*Oeconesus* *Polyplectropus* *Psilochorema*	*Oeconesus* *Polyplectropus* *Psilochorema*
Cases Drain	HA09	*Polyplectropus*	No data	*Polyplectropus*
Creamery Stream	HA08	No taxa with MCI ≥ 7	No taxa with MCI ≥ 7	Hydraenidae
Wilsons Drain	W1	No data	No data	*Psilochorema* *Pycnocentria*
Johns Drain	J1	No data	No data	*Oeconesus* *Psilochorema* *Pycnocentria*

Note: Only sites with MCI scores ≥ 7 on at least one monitoring occasion are shown. Sites with no data were not sampled that year.

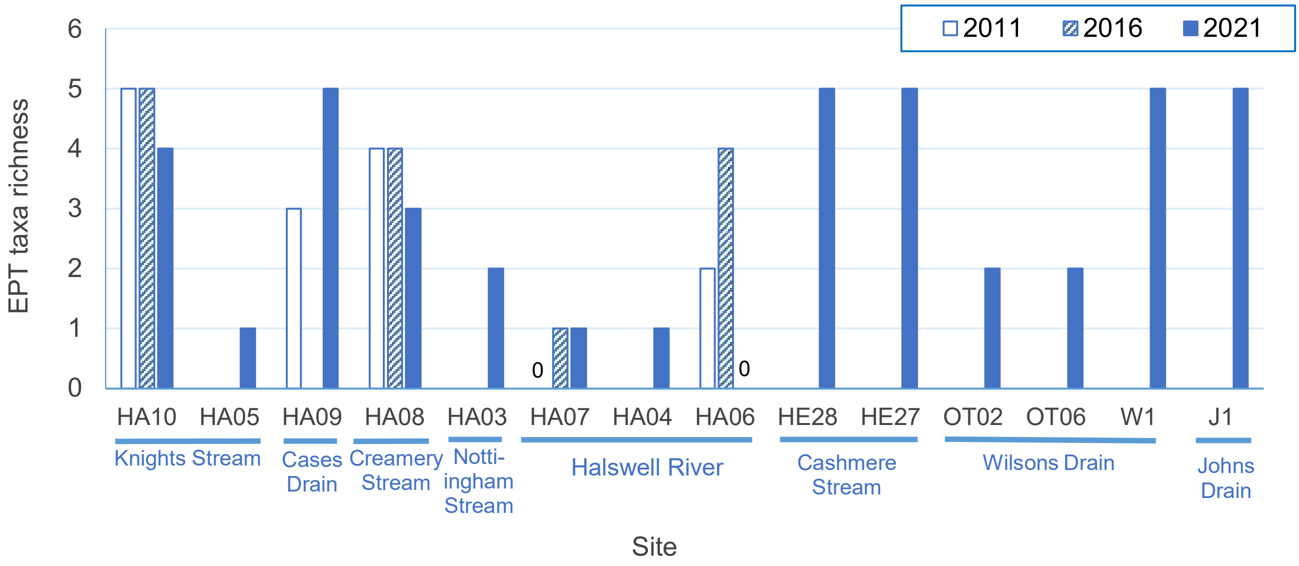

Figure 30: EPT taxa richness at all sampling sites in 2021 compared with 2011 and 2016 data from Halswell catchment sites. Blanks for Halswell catchment sites indicate no data collected at that location. Zeroes indicate zero EPT taxa for that location.

All sites sampled in 2021 had low QMCI scores (Figure 31), reflecting the dominance of pollution-tolerant taxa. Site HE28 in Cashmere Stream was the only site to comply with the consent target of a QMCI of 5 or greater, with a site score of 5.1. QMCI scores have increased at some Halswell catchment sites and declined at others over time, but there is no indication of an overall increasing or decreasing trend. Thus, mean QMCI scores for the four Halswell catchment sites sampled in all three years were 3.9 in 2011, 3.0 in 2016, and 3.8 in 2021.

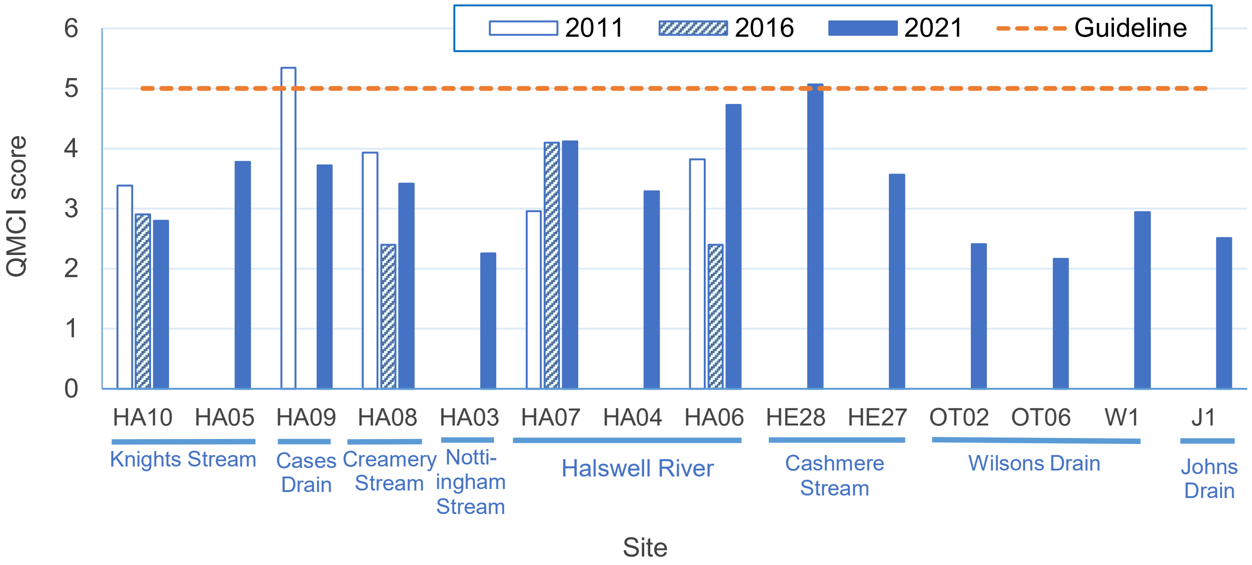

Figure 31: QMCI scores at richness at all sampling sites in 2021 compared with 2011 and 2016 data from Halswell catchment sites. Blanks for Halswell catchment sites indicate no data collected at that location.

All sites sampled in 2021 had low MCI scores, with all of them failing to meet the NPSFM 2020 National Bottom Line value of 90 (Figure 32). Mean MCI scores for the four Halswell catchment sites sampled in all three years were 72 in 2011, 78 in 2016, and 72 in 2021. Thus, there is no obvious increasing or decreasing trend in MCI scores over time.

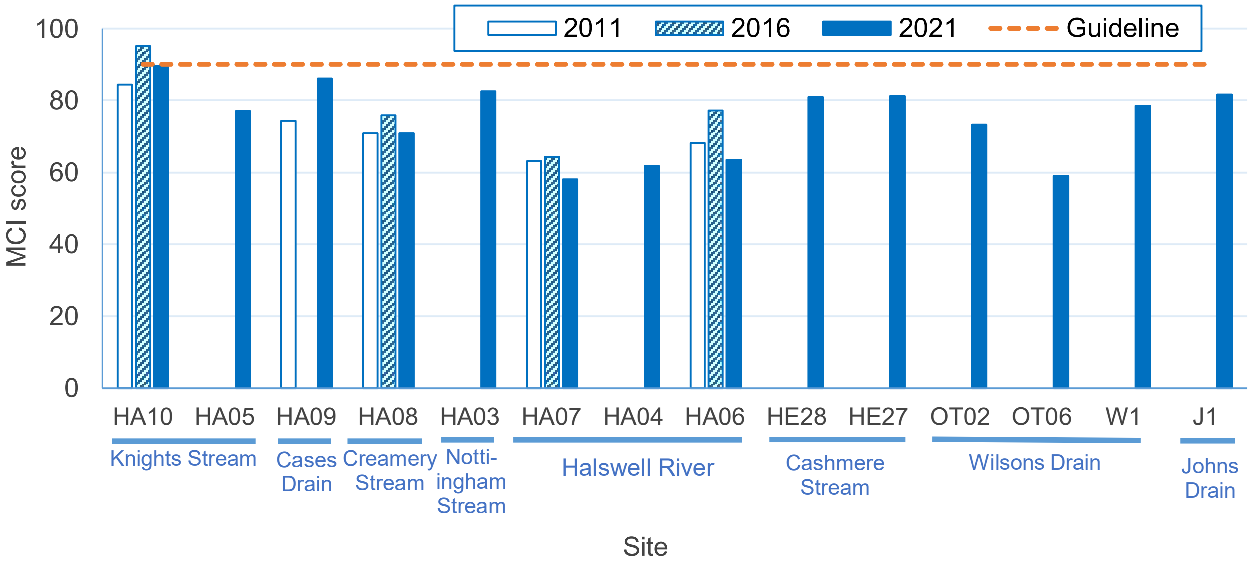

Figure 32: MCI scores at all sampling sites in 2021 compared with 2011 and 2016 data from Halswell catchment sites. Blanks for Halswell catchment sites indicate no data collected at that location.

Average Score Per Metric (ASPM) scores for all sites sampled in 2021 were very low and well below the NPSFM 2020 National Bottom Line of 0.3 (Figure 33). The ASPM is a composite of %EPT, EPT taxa richness, and MCI scores, so a very low ASPM score is indicative of a lack of sensitive taxa and strong dominance of pollution-tolerant taxa. Mean ASPM scores for the four Halswell catchment sites sampled in all three years were 0.16 in 2011, 0.17 in 2016, and 0.14 in 2021. There was no overall increasing or decreasing trend evident in ASPM scores over time.

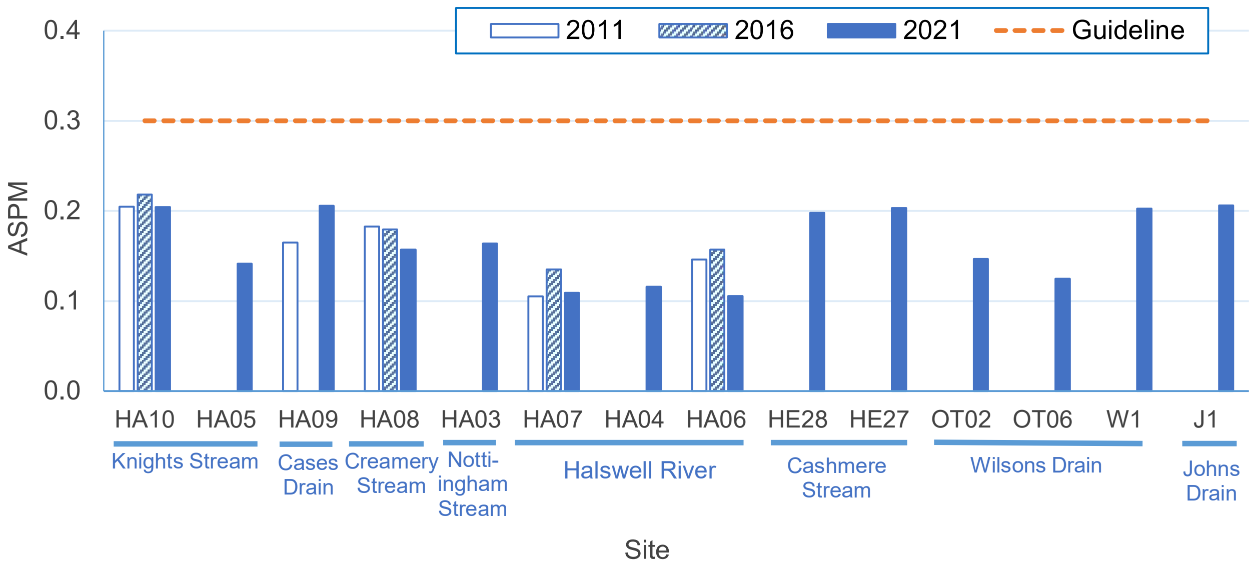

Figure 33: Invertebrate Average Score Per Metric (ASPM) at all sampling sites in 2021 compared with 2011 and 2016 data from Halswell catchment sites. Blanks for Halswell catchment sites indicate no data collected at that location.

For the 14 sites sampled in 2021 significant positive correlations were found between: substrate index scores and invertebrate taxa richness, EPT taxa richness and %EPT ($P<0.05$); and water velocity and taxa richness and %EPT ($P<0.05$). Significant negative correlations were found between: QMCI scores and water depth ($P<0.001$), width ($P=0.001$), and total macrophyte cover ($P=0.019$); and sediment depth and EPT taxa richness ($P=0.012$) and %EPT ($P=0.002$). Overall, these significant correlations reflect a general preference of pollution-sensitive taxa for sites with lower macrophyte cover, swifter water velocities, and coarser substrates.

There were no significant correlations between sediment metals or PAHs and any invertebrate community metrics ($P>0.05$) at the five Halswell catchment sites sampled in 2021. This partly reflects the low levels of metals and PAHs in the sediments, but it is also a reflection of the low number of sites monitored and the associated low statistical power to detect a significant correlation.

As noted in Section 2.9.5, no correlations were attempted between data from CCC's monthly water quality monitoring sites and the ecology sites sampled in 2021, due to low sample size and weak statistical power. Qualitative comparison of invertebrate data with a recent summary of monthly water quality data did not reveal any clear patterns. For example, the Nottingham Stream at Candys Road water quality site had particularly poor water quality, with elevated dissolved zinc, copper, and dissolved reactive phosphorus concentrations, and elevated *E. coli* counts (Margetts and Marshall 2021). However, we found that Nottingham Stream invertebrate community metrics were intermediate to values measured at other Halswell catchment sites. The lack of a strong association between surface water quality data and invertebrate data partly reflects the overall degraded state of the invertebrate community and partly reflects the impact of multiple other factors on invertebrate communities (e.g., habitat quality, riparian conditions, and regular waterway maintenance).

Freshwater crayfish (*Paranephrops zealandicus*), also known as wai kōura or kēwai, were caught during electric fishing in 2021 at Site HA08 in Creamery Stream and during invertebrate sampling at Site HA09 in Cases Drain. Wai kōura are valued mahinga kai and they also have an At Risk – Declining threat status (Grainger *et al.* 2018). Wai kōura were once abundant in Creamery Stream (EOS Ecology Ltd *et al.* 2005), but none were caught during monitoring in 2011 (Taylor and Blair 2012) or 2016 (Boffa Miskell Limited 2016). Wai kōura have not previously been recorded from Cases Drain.

No kākahi were found at any of the Halswell or Wilsons Drain catchment sites where searching was undertaken for this project. This is consistent with other searches undertaken elsewhere in both catchments by Instream Consulting in 2020 and 2021 (Instream Consulting 2021).

3.5.2. Trends in Annual Monitoring Data

The invertebrate fauna at both Cashmere Stream sites is dominated by pollution-tolerant taxa, particularly *Potamopyrgus* snails and the amphipod *Paracalliope*, as well as ostracods. EPT taxa are only represented by caddisflies (Trichoptera), with no mayflies (Ephemeroptera) or stoneflies (Plecoptera) recorded, and EPT taxa richness is low overall. Only three pollution-sensitive taxa (MCI ≥ 7) have been recorded from these two monitoring sites over time. The free-living caddisflies *Polyplectropus* and *Psilochorema* (both MCI=8) have been recorded at both monitoring sites over time. In addition, a single specimen of a beetle belonging to the Hydraenidae family was recorded for the first time at Site HE28 in 2021.

This dominance of pollution-tolerant taxa results in low index scores for both Cashmere Stream sites, with QMCI, MCI, and ASPM scores typically below guidelines (Figure 34). There is only sufficient data to conduct trend analysis for Site HE28. Mann-Kendall trend analysis revealed a significant increasing trend in %EPT ($P=0.001$) and QMCI ($P=0.038$), and this is clear on the QMCI plot (Figure 34). The increasing QMCI trend was associated with the consent target level of 5 being met for the first time in 2021 at Site HE28. There was no overall trend in taxa richness, EPT taxa richness, MCI score, or ASPM scores ($P>0.05$). This means that there has been an increase in the relative abundance of pollution-sensitive taxa over time, but no increase in the total number of pollution-sensitive taxa at the site.

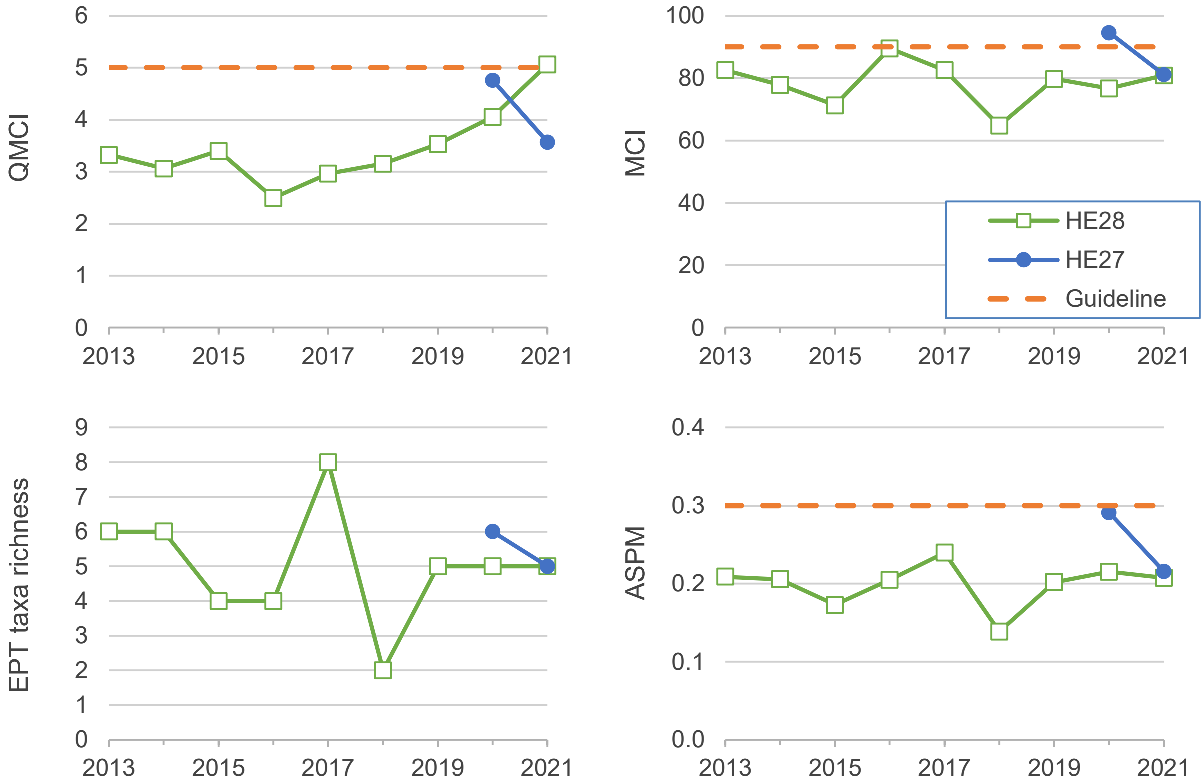

Figure 34: Macroinvertebrate metrics over time at two Cashmere Stream monitoring sites. Site HE28 is located upstream of a stormwater discharge and HE27 is downstream. See Table 2 for guidelines.

The two Cashmere Stream monitoring sites are located upstream and downstream of a stormwater discharge, to monitor potential stormwater effects on the biota. All invertebrate metrics declined downstream of the discharge at Site HE27 in 2021. However, there were also major differences in aquatic habitat between the two years, associated with low macrophyte cover in 2020 due to recent weed clearance (see Section 3.2.1. above). The difference in macroinvertebrate metrics was largely driven by increased abundance of *Paracalliope* amphipods (MCI_{HB}=5, MCI_{SB}=5.5) at Site HE28 and increased abundance of Ostracoda at Site HE27 (MCI_{HB}=3, MCI_{SB}=1.9). Both these invertebrate taxa are strongly associated with macrophytes and their relative abundance likely reflects changes in macrophyte cover from year to year, rather than indicating a stormwater discharge effect.

The invertebrate fauna of Balguerie Stream is dominated by EPT taxa, including mayflies, caddisflies and low numbers of stoneflies. The ubiquitous snail *Potamopyrgus* is also often abundant. All macroinvertebrate community metrics are consistently lower at Site BP02, compared to the upstream monitoring location, Site B1 (Figure 35). Thus, QMCI scores at Site BP1 typically comply with the consent target of 5, but they do not at Site BP02. Both sites consistently comply with the NPSFM 2020 National Bottom Line MCI value of 90. The National Bottom Line ASPM value of 0.3 is typically complied with at both sites.

Time trend analysis revealed no significant increasing or decreasing trend (P>0.05) in QMCI, MCI, EPT taxa richness, or ASPM scores for either of the two Balguerie Stream monitoring sites for the 15-year period. Similarly, there was no significant trend (P>0.05) in the difference between metric scores between sites over time for any of the four metrics examined.

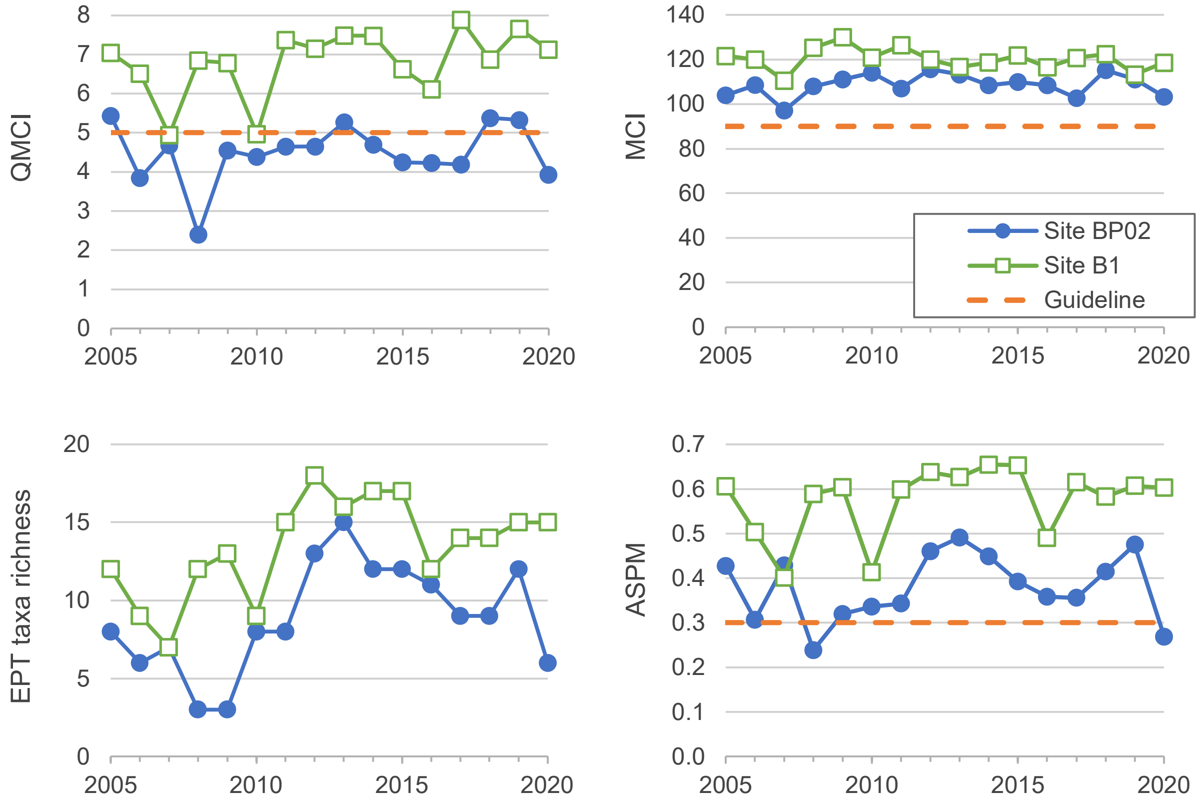

Figure 35: Macroinvertebrate metrics over time at two ECan monitoring sites on Balguerie Stream. Site BP02 is located within Akaroa township and is downstream of Site B1. See Table 2 for guidelines.

No kākahi or wai kōura were found at any of the Cashmere Stream or Balguerie Stream annual monitoring sites. Both species are known from the Cashmere Stream catchment, but they are not usually caught using standard invertebrate sampling methods.

3.6. Fish

A total of seven fish species were caught from the 12 sites sampled in 2021, with seven species caught from the eight Halswell catchment sites and six species from the four Wilsons Drain sites. All the fish species caught were native, except for one introduced pest species, perch (*Perca fluviatilis*), which was caught at Site HA06 in the Halswell River (Figure 36, Figure 37, and Table 6). Common bullies (*Gobiomorphus cotidianus*), upland bullies (*G. breviceps*), shortfin eels (*Anguilla australis*) and longfin eels (*A. dieffenbachii*) were all widespread, each occurring at nine of the 12 sampling sites. Upland bullies and juvenile bullies were typically the most abundant fish caught. However, large numbers of shortfin eels and elvers (juvenile eels) were caught at Site W1 on Wilsons Drain, where 43 shortfin eels and 62 elvers were caught during electric fishing. The high elver numbers were associated with areas of higher velocity and stony bed sediments, which is preferred elver habitat.

A total of three native fish species with a conservation status were caught during the 2021 fish sampling (Table 7). These species are longfin eel and inanga, which both have an At

Risk – Declining threat status, and lamprey, which have a Threatened – Nationally Vulnerable status (Dunn *et al.* 2018). All these species were caught in both the Halswell and Wilsons Drain catchments, and longfin eel and inanga have been caught previously in the Halswell catchment (Boffa Miskell Limited 2016). Lamprey were not caught during previous monitoring, but there are lamprey records in the New Zealand Freshwater Fish database for the Halswell catchment.

The same core of fish species were caught from Halswell catchment sites in 2016 and 2021, and overall fish taxa richness was low, with a mean of four fish species caught per site in both years. Introduced brown trout (*Salmo trutta*) was the only species previously caught in the Halswell catchment that was not caught this year. However, most brown trout in the catchment are found in the deeper waters of the Halswell River and Knights Stream, where trapping and netting methods were used to fish in 2021, and these methods are not as efficient at catching brown trout as electric fishing.

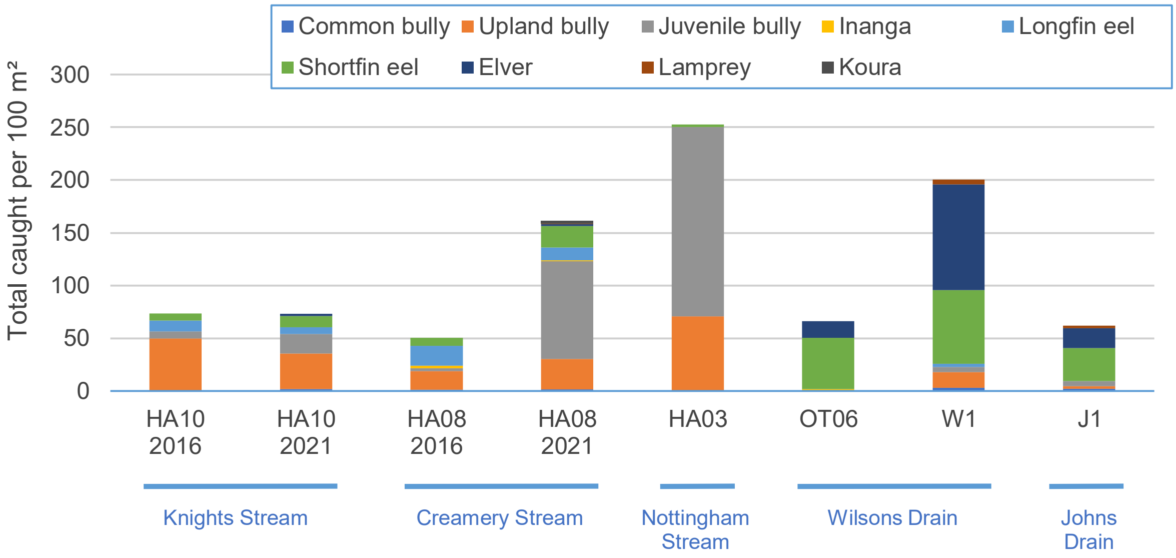

Figure 36: Electric fishing results. Data are from 2021, except for Knights Stream and Creamery Stream, where data are shown for 2016 and 2021.

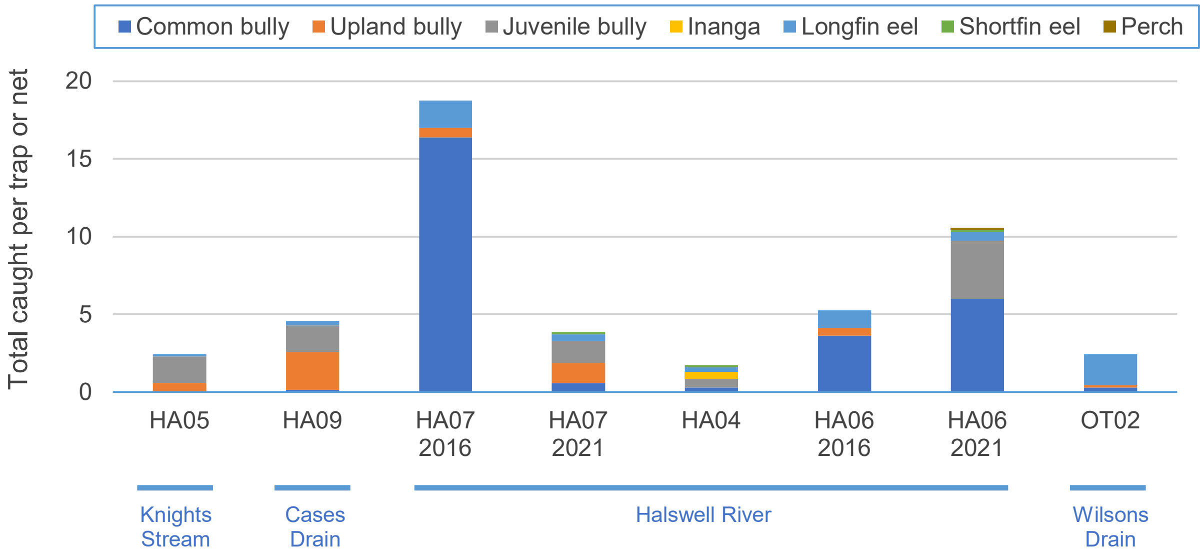

Figure 37: Fish trapping and netting results. Data are from 2021, except for Sites HA07 and HA06 on the Halswell River, where data are shown for 2016 and 2021.

Table 6: Fish caught during electric fishing and trapping surveys in 2021. Data are number of fish caught, with the size range (in mm) in brackets.

Site Code	Waterway	Common bully	Upland bully	Juvenile bully	Inanga	Longfin eel	Shortfin eel	Elver	Lamprey	Wai kōura	Perch
HA10	Knights Stream at Whincops Rd	1 (70)	16 (29–66)	9 (17–38)		3 (232–527)	5 (183–623)	1 (151)			
HA05	Knights Stream at Sabys Rd		4 (31–48)	12 (22–35)		1 (680)					
HA09	Cases Drain	1 (39)	17 (39–67)	12 (17–32)		2 (610–806)					
HA08	Creamery Stream	2 (55–56)	35 (34–54)	113 (16–40)	1 (124)	15 (160–630)	25 (125–499)	2 (131–155)	1 (91)	3 (11–29)	
HA03	Nottingham Stream		24 (35–56)	61 (12–42)			1 (388)				
HA07	Halswell River at Wroots Rd	4 (49–73)	9 (40–54)	10 (23–40)		3 (649–1179)	1 (661)				
HA04	Halswell River at Tai Tapu Rd	2 (59–94)		4 (32–38)	3 (103–124)	2 (512–572)	1 (228)				
HA06	Halswell River at Early Valley Rd	42 (35–86)		26 (21–38)		4 (367–698)	1 (152)				1 (89)
OT02	Wilsons Drain at Ōtūkaikino Reserve	2 (85–89)	1 (41)			14 (502–816)					
OT06	Wilsons Drain at Tyrone St				1 (65)		25 (191–552)	8 (97–149)			
W1	Wilsons Drain at Main North Rd	2 (36–63)	9 (35–59)	3 (25–38)		2 (526–601)	43 (130–455)	62 (67–145)	3 (81–97)		
J1	Johns Drain	1 (72)	1 (38)	2 (27–32)			13 (148–229)	8 (124–149)	1 (90)		

Note: Site HA08 (Creamery Stream) includes combined data from the three sub-reaches sampled. See Section 2.7 for methods.

Table 7: Conservation status of fish species and wai kōura caught in 2021.

Common name	Scientific name	Conservation status
Common bully	*Gobiomorphus cotidianus*	Not threatened
Upland bully	*G. breviceps*	Not threatened
Inanga	*Galaxias maculatus*	At Risk – Declining
Shortfin eel	*Anguilla australis*	Not threatened
Longfin eel	*A. dieffenbachii*	At Risk – Declining
Lamprey	*Geotria australis*	Threatened – Nationally vulnerable
Perch	*Perca fluviatilis*	Introduced Pest
Wai kōura (freshwater crayfish)	*Paranephrops zealandicus*	At Risk – Declining

The fish community in Creamery Stream in 2021 was impacted by recent instream works. Electric fishing results showed lower fish abundance overall in the section of stream covered by polythene sheeting (Figure 38). Effects were not restricted to just one species, with lower numbers of both small, juvenile bullies and larger longfin eels in the polythene section.

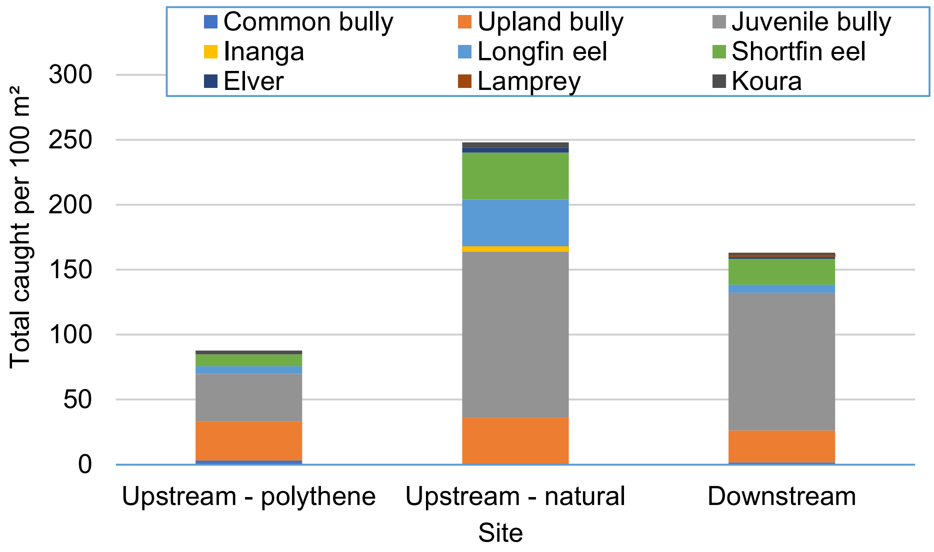

Figure 38: Electric fishing results from three sub-reaches in Creamery Stream (Site HA08), where half the upstream site was covered with polythene.

Fishing at an additional five locations in the Wilsons Drain catchment turned up no additional juvenile lamprey to the four found at Sites W1 (Wilsons Drain) and J1 (Johns Drain). This indicates that the Wilsons Drain catchment is not a major lamprey spawning area.

4. DISCUSSION

4.1. Current State and Trends in Aquatic Ecology

Monitoring data from 2021 indicate similar instream and riparian habitat conditions to previous years at most monitoring sites. Sites in the Halswell catchment and Cashmere Stream typically have beds dominated by fine sediments, minimal variation in hydraulic habitat, minimal shade and buffering with riparian vegetation, and high macrophyte cover. The Wilsons Drain tributary sites also generally had poor quality habitat, including timber-lined banks, lack of riparian shading, and high levels of fine sediment deposition. In contrast, the two Balguerie Stream sites had relatively diverse run-riffle-pool habitat, predominantly stony beds, good riparian shade and buffering, and very low macrophyte cover. The greatest improvement in riparian conditions observed in 2021 was at Cases Drain (Site HA09), where extensive riparian planting was associated with improved fish cover and shading. Habitat quality was dramatically reduced at Creamery Stream (Site HA08), due to removal of riparian vegetation, recent bank regrading, and lining of the channel with polythene, with marked reductions to riparian and instream habitat quality.

This was the first year that monthly deposited sediment data was available to summarise. Fine sediment cover was high and exceeded consent target levels at 10 of the 15 monitoring sites. This partly reflects the naturally high fine sediment cover present in the spring-fed streams sampled, but it also reflects the negative impacts of rural and urban landuse on sediment erosion and fine sediment deposition. Further monitoring will indicate whether there are any improving or declining trends in fine sediment cover over time.

Sediment concentrations of copper, lead, and total PAHs were low in 2021 and complied with consent target levels, as in previous years. Zinc levels were elevated and exceeded consent target levels in Nottingham Stream in 2021, and this was associated with greater mud content in 2021 samples. When zinc concentrations were normalised to mud content, there was no indication of an increasing or decreasing trend in zinc loads in the catchment. Overall, sediment concentrations of metals and total PAHs in the Halswell catchment are much lower than those recorded from the more heavily urbanised Avon and Heathcote River catchments (Instream Consulting 2019, 2020a).

Although sediment concentrations of metals and total PAHs were low overall, they were elevated in Nottingham Stream relative to the other Halswell sites. In the most recent surface water quality monitoring report for the city, Margetts and Marshall (2021) found that Nottingham Stream had amongst the worst water quality of all sites monitored. They noted that there is currently no stormwater treatment in the Nottingham Stream catchment, and they recommended that the addition of stormwater treatment in the catchment should be a priority.

Invertebrate community composition in 2021 was similar to previous years at the Halswell and Cashmere Stream monitoring sites, being dominated by pollution-tolerant snails and crustaceans common to Christchurch urban waterways. The invertebrate fauna at the four Wilsons Drain sites was also dominated by pollution-tolerant taxa, whereas the two Balguerie Stream sites are dominated by pollution-sensitive EPT taxa. The Halswell, Heathcote and Linwood Canal catchments have the lowest number of pollution-sensitive EPT taxa in the district. Thus, a total of seven EPT taxa, comprised solely of caddisflies, were recorded from the eight Halswell catchment sites this year and from the 15 Heathcote and Linwood Canal sites in 2020 (Instream Consulting 2020a). This compares with a total of ten EPT taxa recorded from the three Banks Peninsula sites in 2020 (Instream Consulting 2020a), 12 EPT taxa recorded from the 18 Avon monitoring sites in 2019 (Instream Consulting 2019), 15 EPT taxa recorded from nine Ōtūkaikino catchment sites in 2017 (Boffa Miskell Limited 2017), and 18 EPT taxa from 12 Styx catchment sites in 2018 (Instream Consulting 2018). The lack of pollution-sensitive taxa in the Halswell, Cashmere Stream, and Wilsons Drain catchment sites sampled reflects the dominance of fine bed sediments and general lack of riparian trees and shrubs that shade waterways and provide habitat for adult aquatic insects. Nuisance macrophyte growth, associated with inadequate shading, also reduces velocities and catches suspended sediments, with both factors resulting in further siltation of the coarse substrates preferred by sensitive EPT taxa.

There was no overall increasing or decreasing trend over time observed in invertebrate community health at the Halswell catchment or Balguerie Stream monitoring sites. QMCI scores steadily improved from 2016 to 2021 at Site HE28 in Cashmere Stream, but QMCI scores still remain low and indicative of degraded habitat and water quality. All invertebrate community metrics declined between 2020 and 2021 at Site HE27 in Cashmere Stream. This decline was associated with recent weed removal in 2020, resulting in lower macrophyte cover, greater water velocities, and lower water depths. This observation illustrates the major impact of waterway maintenance activities on invertebrate communities. Having greater channel shade would reduce the need and associated cost of regular weed clearance, as evidence by low macrophyte cover at the three sites with the highest levels of shade sampled in 2021.

The rediscovery of wai kōura (freshwater crayfish) at Creamery Stream is encouraging, following their disappearance after the Canterbury earthquakes in 2010–11. Wai kōura densities were very high in Creamery Stream during a baseline survey conducted in 2003–04, with 31 individuals caught during electric fishing along a 7 m length of drain (EOS Ecology Ltd *et al.* 2005). Their disappearance after the Canterbury earthquakes was associated with earthquake-induced lateral spread and sedimentation (Taylor and Blair 2012). While only three wai kōura were caught from Creamery Stream in 2021, their numbers could potentially increase over time. However, recent bank and instream works may have further disturbed the recovering population.

No kākahi were found at any of the Halswell or Wilsons Drain catchment sites searched for this project. This indicates that either kākahi are absent or present in very low numbers in both catchments within the Christchurch district. However, kākahi do occur in the lower reaches of the Halswell River, close to its confluence with Te Waihora / Lake Ellesmere, within the Selwyn district. During the 2011 monitoring round, empty kākahi shells were observed amongst weed clearance spoil piles along the banks of the Halswell River (James 2011). It is unknown whether the kākahi shells observed along the bank were already empty prior to their removal from the stream, or whether the weed and sediment removal process caused their demise. However, experience from the Cashmere Stream catchment has shown that kākahi are absent from waterways subjected to regular sediment removal (Instream Consulting 2020b).

The fish community present at all sites surveyed was dominated by native species that are common in urban Christchurch waterways. There was no overall trend in fish abundance or community composition over time. The presence of threatened lamprey in Creamery Stream and the Wilsons Drain catchment is notable, although densities were low. The presence of perch, an introduced pest fish, in the Halswell River is consistent with previous surveys and reflects the fact that the river supports a recreational perch fishery (Taylor and Blair 2012).

4.2. Comparison to Consent Attribute Target Levels

The council's Comprehensive Stormwater Network Discharge Consent (CRC190445) has consent attribute target levels for total macrophyte cover, long filamentous algae cover, fine sediment cover, QMCI scores, and sediment concentrations of copper, lead, zinc, and total PAHs. Consent targets for long filamentous algae cover have been met at all Halswell catchment sites sampled over the last ten years (Table 8). In contrast, consent targets for QMCI scores have seldom been met and consent targets for fine sediment cover have never been met[4]. Compliance with consent targets for total macrophyte cover was higher in 2011 and 2016 than in 2021, reflecting recent macrophyte clearance activities prior to sampling in 2011 and 2016.

Table 8: Compliance with consent attribute target levels over time. 2011 and 2016 data only include sampling sites that were also sampled in 2021.

Parameter	Consent target level	Complying sites each year		
		2011 (5 sites)	**2016** (4 sites)	**2021** (8 sites)
Halswell River catchment				
Minimum QMCI	5	1	0	0
Maximum fine sediment (<2 mm) cover	20%	-	-	0
Maximum total macrophyte cover	50%	5	3	3
Maximum filamentous algae cover	30%	5	4	8
Wilsons Drain catchment		**2011** (0 sites)	**2016** (0 sites)	**2021** (4 sites)
Minimum QMCI	5	-	-	0
Maximum fine sediment (<2 mm) cover	20%	-	-	0
Maximum total macrophyte cover	50%	-	-	2
Maximum filamentous algae cover	30%	-	-	4

There has been high levels of compliance with consent targets over time for sediment copper, lead, zinc, and total PAHs in the Halswell catchment, with no historic non-compliances and only zinc exceeding the consent target at one site (Nottingham Stream) in 2021. There is no indication of an increasing or decreasing trend in the concentration of metals or PAHs over time in Halswell catchment sediments.

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[4] Fine sediment cover was sampled using different methods each year, so data are not shown here. However, inspection of the data indicates fine sediment cover has always been high.

All of the four Wilsons Drain catchment sites complied with the consent target for filamentous algae cover in 2021, while half the sites complied with the consent target for macrophyte cover and none complied with consent targets for fine sediment cover and QMCI scores.

The two Cashmere Stream annual monitoring sites complied with the consent target for filamentous algae cover in 2021, but did not comply with consent targets for fine sediment cover or total macrophyte cover. This was the first year the consent target for QMCI was met at Site HE28 on Cashmere Stream (QMCI=5.1), but it was not met at Site HE27 (QMCI=3.6). There was a decline in QMCI scores at Site HE27 between 2020 and 2021, and this was associated with greater macrophyte cover, and associated greater water depths and lower water velocities in 2021. This is a result of recent weed removal prior to sampling in 2020, rather than a stormwater discharge effect.

The two Balguerie Stream sites monitored annually have consistently low cover with deposited fine sediment, macrophytes, and filamentous algae. The consent target of 5 for QMCI has typically been met at upstream monitoring Site B1 and not been met at Site BP02 downstream. There is no obvious increasing or decreasing trend in QMCI score at either site evident in the 16 years of annual monitoring.

Ten of the 15 monthly monitoring sites across the district complied with the deposited sediment consent target. Monthly fine sediment monitoring only commenced in 2020, so there is insufficient data to determine trends over time.

4.3. Waterway Enhancement

Waterway restoration work is being undertaken at a rapid rate in many urban waterways in Christchurch, notably in the Heathcote River catchment (Instream Consulting 2020a). There are fewer examples of recent restoration activities in the Halswell River catchment within the Christchurch district. This largely reflects the greater impacts of the Canterbury earthquakes on the flood-carrying capacity of Heathcote catchment waterways, and therefore the greater focus on waterway restoration overall. Two notable areas of waterway enhancement in the Halswell catchment within the Christchurch district include Quaifes Drain No. 1 and Cases Drain, as summarised in the following paragraphs.

Quaifes Drain No. 1 flows alongside Quaifes Road and becomes Creamery Stream upstream of Sabys Road. In 2020 a new stormwater wetland was built in farmland beside the drain and the adjacent section of drain was enhanced (Figure 39). Drain enhancements included native riparian plantings and the addition of habitat features such as boulders and wood. While the wetland is principally for stormwater detention and treatment, the native plantings enhance local plant biodiversity and they will provide habitat for birds, lizards and terrestrial invertebrates as the plantings mature. The enhanced section of Quaifes Drain No. 1 includes some improved habitat diversity compared to pre-enhancement. However, the drain is currently poorly shaded with young sedges and low shrubs; shading will increase as riparian plantings mature, but shading would be greater if the new plants were located closer to the water's edge, along with more trees and shrubs. We understand that planting away from the edge of Quaifes Drain No. 1 was a requirement of an ECan flood protection and drainage bylaw. The channel also appears to be broader and shallower than prior to its realignment, resulting in poorer quality habitat for larger fish, such as eels.

As noted in Section 3.2 above, recent plantings along Cases Drain have improved riparian buffering, fish cover, and channel shading. Additional planting with taller-growing shrubs and trees is recommended at this location, as the low-stature native grasses and shrubs do not shade the waterway sufficiently to prevent nuisance plant growths.

Figure 39: Images of Quaifes Road drain and wetland taken in 2019 (upper) and 2021 (lower).

5. RECOMMENDATIONS

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

- **Plant more trees and shrubs to shade waterways.** This will reduce the need for regular weed removal. Waterways with greater shade and lower macrophyte cover also provide better aquatic habitat for fish and invertebrates.

- **Waterway enhancement.** There is little physical enhancement of waterways in the Halswell catchment compared to the nearby Heathcote and Cashmere catchments. Physical habitat enhancements should include: greater variation in hydraulic habitat (e.g., deeper pools and shallower riffles); more bank cover in the form of overhanging vegetation; and more in-channel cover, such as wood, cobbles, and boulders.

- **Monitor waterway enhancements.** Ecological monitoring should follow all enhancement and realignment projects, including Quaiffes Drain No. 1. Monitoring data can be used to determine the effectiveness of various enhancement techniques, and provide direction to future enhancement projects.

- **Investigate recent works in Creamery Stream.** Recent removal of bank vegetation, bank regrading, and polythene on the bed of the stream all degraded habitat within Creamery Stream. This is worth following-up by council, given At Risk wai kōura and threatened lamprey are present in Creamery Stream.

- **Realign and enhance Wilsons Drain.** This should be done when the area is developed into a stormwater treatment facility. Habitat enhancements should include: creating a diversity of run, riffle, and pool habitats for a range of aquatic species; a gravel-cobble bed that provides cover for fish and invertebrates; and riparian planting with trees and shrubs to shade the waterway and provide riparian habitat.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

ANZG (2018). ‘Australian and New Zealand guidelines for fresh and marine water quality’. (Australian and New Zealand Governments and Australian state and territory governments: Canberra ACT, Australia.) Available at: www.waterquality.gov.au/anz-guidelines

Boffa Miskell Limited (2016). Halswell River sediment and aquatic ecology survey. *Aquatic Ecology Technical Report prepared for Christchurch City Council by Boffa Miskell Limited, July 2016*.

Boffa Miskell Limited (2017). Ōtūkaikino River catchment aquatic ecology: long-term monitoring of the Ōtūkaikino River catchment. *Report prepared for Christchurch City Council by Boffa Miskell Limited, June 2017.*

Christchurch City Council (2016). Huritini / Halswell River catchment:tauākī wai pātaua / vision and values. *Christchurch City Council Report, July 2016*.

Collier, K. J. (2008). Average score per metric: an alternative metric aggregation method for assessing wadeable stream health. *New Zealand Journal of Marine and Freshwater Research* **42**, 367–378.

Dunn, N. R., Allibone, R. M., Closs, G. P., Crow, S. K., David, B. O., Goodman, J. M., Griffiths, M., Jack, D. C., Ling, N., Waters, J. M., and Rolfe, J. R. (2018). ‘Conservation status of New Zealand freshwater fishes, 2017’. (Department of Conservation: Wellington.)

EOS Ecology Ltd, Aquatic Ecology Ltd, and Kingett Mitchell Ltd (2005). Aquatic values and management. South-west Christchurch integrated catchment management plan technical series. Report No. 3. *Prepared for Christchurch City Council, July 2005*.

Gadd, J. (2015). Sediment quality survey for Heathcote River catchment, City Outfall Drain and Estuary Drain. *Report prepared for Christchurch City Council by NIWA, September 2015*.

Golder Associates (2012). Canterbury regional urban stream sediment and biofilm quality survey. *Report prepared for Environment Canterbury, Report No. R12/5, January 2012.*

Grainger, N., Harding, J., Drinnan, T., Collier, K., Smith, B., Death, R., Makan, T., and Rolfe, J. (2018). Conservation status of New Zealand freshwater invertebrates, 2018. *Department of Conservation New Zealand Threat Classification Series 28*.

Instream Consulting (2019). Avon River catchment aquatic ecology 2019. *Report prepared for Christchurch City Council, August 2019*.

Instream Consulting (2020a). Heathcote River, Linwood Canal, and Banks Peninsula aquatic ecology 2020. *Report prepared for Christchurch City Council, September 2020*.

Instream Consulting (2020b). Kākahi in Cashmere Stream: distribution and current state of the population. *Report prepared for Christchurch City Council by Instream Consulting, June 2020*.

Instream Consulting (2021). Monitoring of kākahi (freshwater mussels) in Christchurch waterways. *Report prepared for Christchurch City Council, July 2021*.

Instream Consulting (2018). Styx River catchment aquatic ecology 2018. *Prepared for Christchurch City Council, August 2018*.

James, A. (2011). Long-term monitoring of aquatic invertebrates in Christchurch's waterways: Halswell River catchment 2011. *EOS Ecology Report prepared for Christchurch City Council, December 2011*.

Kingett Mitchell Ltd (2005). Sediment quality survey. *South-West Christchurch Integrated Catchment Management Plan Technical Series, Report No. 2, July 2005*.

Margetts, B. I., and Marshall, W. (2021). Christchurch City water quality annual report 2020. *Christchurch City Council Report, Christchurch, New Zealand*.

National Environmental Monitoring Standards (2020). Macroinvertebrates. Collection and processing of macroinvertebrate samples from rivers and streams. *Issued November 2020*.

Stark, J. (2018). Improving the cost-effectiveness of macroinvertebrate state of the environment monitoring. *Paper presented at the 50th New Zealand Freshwater Sciences Society Conference in Nelson, 10-14 December 2018*.

Stark, J. D. (1985). A macroinvertebrate community index of water quality for stony streams. *Water and Soil Miscellaneous Publication* **87**, 53 p.

Stark, J. D., Boothroyd, I. K. G., Harding, J. S., Maxted, J. R., and Scarsbrook, M. R. (2001). 'Protocols for sampling macroinvertebrates in wadeable streams'. (Ministry for the Environment: Wellington.)

Stark, J. D., and Maxted, J. R. (2007). A user guide for the Macroinvertebrate Community Index. *Report prepared for the Ministry of the Environment. Cawthron Report No. 1166.*

Suren, A. M. (2000). Effects of urbanisation. In 'New Zealand stream invertebrates: ecology and implications for management'. (Eds K. J. Collier and M. J. Winterbourn.) pp. 260–288. (New Zealand Limnological Society: Christchurch.)

Taylor, M., and Blair, W. (2012). Halswell and Heathcote aquatic values; selected aspects; monitoring round # 4. *Report prepared by Aquatic Ecology Ltd for Christchurch City Council, September 2012*.

APPENDIX 1: SITE PHOTOGRAPHS FROM 2021

Figure 1: Site HA10 (Knights Stream upstream of Whincops Rd) – downstream looking upstream.

Figure 2: Site HA05 (Knights Stream at Sabys Rd) – upstream looking downstream.

Figure 3: Site HA09 (Cases Drain upstream of Downies Rd) – downstream looking upstream.

Figure 4: Site HA08 (Creamery Stream downstream of Sabys Rd) – upstream looking downstream. Note that this photograph was taken at the time of the habitat survey, prior to polythene sheeting being placed in the waterway.

Figure 5: Site HA03 (Nottingham Stream at Candys Rd) – downstream looking upstream.

Figure 6: Site HA07 (Halswell River at Wroots / Halswell Rds) – downstream looking upstream.

Figure 7: Site HA04 (Halswell River at Tai Tapu Rd) – downstream looking upstream.

Figure 8: Site HA06 (Halswell River downstream of Early Valley Rd) – downstream looking upstream.

Figure 9: Site HE28 (Cashmere Stream behind 420–426 Cashmere Rd) – upstream looking downstream.

Figure 10: Site HE27 (Cashmere Stream behind 406 Cashmere Road) – downstream looking upstream.

Figure 11: Site OT02 (Wilsons Drain at Main North Rd, Ōtūkaikino Reserve) – upstream looking downstream.

Figure 12: Site OT06 (Wilsons Drain at Tyrone Street) – upstream looking downstream.

Figure 13: Site W1 (Wilsons Drain at Main North Rd) – upstream looking downstream.

Figure 14: Site J1 (Johns Drain at 888 Main North Rd) – downstream looking upstream.

APPENDIX 2: SEDIMENT QUALITY LABORATORY RESULTS

Hill Laboratories
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Certificate of Analysis

Client:	Instream Consulting Limited	**Lab No:**	2567843 SPv1
Contact:	G Burrell C/- Instream Consulting Limited PO Box 28173 Christchurch 8242	**Date Received:**	25-Mar-2021
		Date Reported:	11-May-2021
		Quote No:	110041
		Order No:	
		Client Reference:	Halswell River
		Submitted By:	G Burrell

Sample Type: Sediment

Sample Name:		HAL510A 25-Mar-2021 12:37 pm	HAL510B 25-Mar-2021 12:42 pm	HAL510C 25-Mar-2021 12:47 pm	HAL505A 25-Mar-2021 1:00 pm	HAL505B 25-Mar-2021 1:05 pm
Lab Number:		2567843.1	2567843.2	2567843.3	2567843.4	2567843.5
Individual Tests						
Dry Matter	g/100g as rcvd	57	30	42	46	43
Total Recoverable Copper	mg/kg dry wt	4.6	8.7	7.4	4.9	7.5
Total Recoverable Lead	mg/kg dry wt	14.8	23	22	11.0	15.7
Total Recoverable Phosphorus	mg/kg dry wt	360	460	400	410	480
Total Recoverable Zinc	mg/kg dry wt	48	59	57	48	64
Total Organic Carbon*	g/100g dry wt	1.88	4.2	2.9	2.0	2.7
7 Grain Sizes Profile as received*						
Dry Matter of Sieved Sample*	g/100g as rcvd	43	31	43	53	42
Fraction >/= 2 mm*	g/100g dry wt	4.3	4.1	4.7	1.9	1.4
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.8	0.9	0.7	0.4	0.4
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	1.0	1.0	0.8	0.3	0.4
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	5.2	3.8	5.4	5.7	2.9
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	26.6	15.7	31.6	36.4	26.8
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	37.5	33.6	31.6	28.4	22.2
Fraction < 63 µm*	g/100g dry wt	24.6	40.8	25.2	26.9	45.8
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Total of Reported PAHs in Soil	mg/kg dry wt	< 0.06	0.18	0.11	0.07	0.16
1-Methylnaphthalene	mg/kg dry wt	< 0.003	< 0.005	< 0.004	< 0.003	< 0.004
2-Methylnaphthalene	mg/kg dry wt	< 0.003	< 0.005	< 0.004	< 0.003	< 0.004
Acenaphthene	mg/kg dry wt	< 0.003	< 0.005	< 0.004	< 0.003	< 0.004
Acenaphthylene	mg/kg dry wt	< 0.003	< 0.005	< 0.004	< 0.003	< 0.004
Anthracene	mg/kg dry wt	< 0.003	< 0.005	< 0.004	< 0.003	< 0.004
Benzo[a]anthracene	mg/kg dry wt	< 0.003	0.008	0.006	< 0.003	0.006
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.003	0.009	0.007	< 0.003	0.007
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.005	0.016	0.011	0.007	0.013
Benzo[e]pyrene	mg/kg dry wt	0.002	0.009	0.006	0.003	0.006
Benzo[g,h,i]perylene	mg/kg dry wt	0.004	0.012	0.009	0.005	0.011
Benzo[k]fluoranthene	mg/kg dry wt	< 0.003	0.005	0.003	< 0.003	0.004
Chrysene	mg/kg dry wt	0.003	0.011	0.008	0.004	0.009
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.003	< 0.005	< 0.004	< 0.003	< 0.004
Fluoranthene	mg/kg dry wt	0.008	0.023	0.016	0.008	0.017
Fluorene	mg/kg dry wt	< 0.003	0.005	< 0.004	< 0.003	0.004
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.004	0.012	0.008	0.004	0.008
Naphthalene	mg/kg dry wt	< 0.012	< 0.03	< 0.016	< 0.015	< 0.016
Perylene	mg/kg dry wt	0.003	0.023	0.009	0.017	0.029
Phenanthrene	mg/kg dry wt	0.004	0.014	0.007	0.006	0.018

Sample Type: Sediment

Sample Name:		HAL510A 25-Mar-2021 12:37 pm	HAL510B 25-Mar-2021 12:42 pm	HAL510C 25-Mar-2021 12:47 pm	HAL505A 25-Mar-2021 1:00 pm	HAL505B 25-Mar-2021 1:05 pm
Lab Number:		2567843.1	2567843.2	2567843.3	2567843.4	2567843.5
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Pyrene	mg/kg dry wt	0.007	0.022	0.015	0.009	0.018
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	< 0.006	0.016	0.011	< 0.008	0.011
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	< 0.006	0.015	0.011	< 0.008	0.011

Sample Name:		HAL505C 25-Mar-2021 1:10 pm	HAL508A 25-Mar-2021 1:30 pm	HAL508B 25-Mar-2021 1:35 pm	HAL508C 25-Mar-2021 1:40 pm	HAL503A 25-Mar-2021 2:05 pm
Lab Number:		2567843.6	2567843.7	2567843.8	2567843.9	2567843.10
Individual Tests						
Dry Matter	g/100g as rcvd	37	31	59	58	49
Total Recoverable Copper	mg/kg dry wt	9.7	7.4	6.2	5.7	16.6
Total Recoverable Lead	mg/kg dry wt	17.7	14.1	12.2	14.0	36
Total Recoverable Phosphorus	mg/kg dry wt	550	570	410	370	640
Total Recoverable Zinc	mg/kg dry wt	75	62	48	46	370
Total Organic Carbon*	g/100g dry wt	3.3	3.1	1.09	0.74	4.6
7 Grain Sizes Profile as received*						
Dry Matter of Sieved Sample*	g/100g as rcvd	39	37	56	66	46
Fraction >/= 2 mm*	g/100g dry wt	1.8	8.8	1.8	0.8	1.7
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.3	0.3	0.4	1.1	0.6
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	0.3	0.4	0.2	0.4	0.9
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	1.9	0.9	1.2	2.5	6.7
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	23.5	10.6	22.9	37.9	28.7
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	21.7	38.4	44.0	40.4	28.5
Fraction < 63 µm*	g/100g dry wt	50.6	40.6	29.5	16.9	32.8
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Total of Reported PAHs in Soil	mg/kg dry wt	0.21	0.11	< 0.06	0.06	0.62
1-Methylnaphthalene	mg/kg dry wt	< 0.004	< 0.005	< 0.003	< 0.003	0.028
2-Methylnaphthalene	mg/kg dry wt	< 0.004	< 0.005	< 0.003	< 0.003	0.025
Acenaphthene	mg/kg dry wt	< 0.004	< 0.005	< 0.003	< 0.003	< 0.003
Acenaphthylene	mg/kg dry wt	< 0.004	< 0.005	< 0.003	< 0.003	0.006
Anthracene	mg/kg dry wt	< 0.004	< 0.005	< 0.003	< 0.003	0.014
Benzo[a]anthracene	mg/kg dry wt	0.007	< 0.005	< 0.003	0.003	0.035
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.008	< 0.005	< 0.003	0.003	0.041
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.018	0.009	0.004	0.005	0.052
Benzo[e]pyrene	mg/kg dry wt	0.009	0.005	< 0.003	0.002	0.028
Benzo[g,h,i]perylene	mg/kg dry wt	0.016	0.010	0.003	0.004	0.040
Benzo[k]fluoranthene	mg/kg dry wt	< 0.004	< 0.005	< 0.003	< 0.003	0.018
Chrysene	mg/kg dry wt	0.012	0.005	0.003	0.003	0.044
Dibenzo[a,h]anthracene	mg/kg dry wt	< 0.004	< 0.005	< 0.003	< 0.003	0.007
Fluoranthene	mg/kg dry wt	0.021	0.011	0.006	0.007	0.071
Fluorene	mg/kg dry wt	0.008	0.005	0.002	< 0.003	0.005
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.010	0.010	0.002	0.004	0.034
Naphthalene	mg/kg dry wt	< 0.019	< 0.03	< 0.012	< 0.012	0.014
Perylene	mg/kg dry wt	0.049	0.018	0.005	0.008	0.030
Phenanthrene	mg/kg dry wt	0.019	0.007	0.005	0.006	0.047
Pyrene	mg/kg dry wt	0.024	0.013	0.006	0.007	0.073
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	0.014	< 0.012	< 0.006	< 0.006	0.064
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	0.014	< 0.011	< 0.006	< 0.006	0.063

Sample Type: Sediment						
Sample Name:		HAL503B 25-Mar-2021 2:10 pm	HAL503C 25-Mar-2021 2:15 pm	HAL507A 25-Mar-2021 2:25 pm	HAL507B 25-Mar-2021 2:30 pm	HAL507C 25-Mar-2021 2:35 pm
Lab Number:		2567843.11	2567843.12	2567843.13	2567843.14	2567843.15
Individual Tests						
Dry Matter	g/100g as rcvd	48	51	48	41	39
Total Recoverable Copper	mg/kg dry wt	12.8	11.9	9.6	9.7	9.5
Total Recoverable Lead	mg/kg dry wt	26	32	24	19.6	18.8
Total Recoverable Phosphorus	mg/kg dry wt	490	570	650	690	720
Total Recoverable Zinc	mg/kg dry wt	250	260	119	131	132
Total Organic Carbon*	g/100g dry wt	3.0	3.0	3.2	3.8	3.0
7 Grain Sizes Profile as received*						
Dry Matter of Sieved Sample*	g/100g as rcvd	47	53	45	42	44
Fraction >/= 2 mm*	g/100g dry wt	2.9	3.0	1.5	1.3	1.4
Fraction < 2 mm, >/= 1 mm*	g/100g dry wt	0.6	0.5	0.9	0.7	0.6
Fraction < 1 mm, >/= 500 µm*	g/100g dry wt	1.2	0.9	0.5	0.9	0.4
Fraction < 500 µm, >/= 250 µm*	g/100g dry wt	7.1	4.9	2.5	2.0	1.8
Fraction < 250 µm, >/= 125 µm*	g/100g dry wt	27.3	30.1	16.8	24.9	20.0
Fraction < 125 µm, >/= 63 µm*	g/100g dry wt	32.2	27.7	24.7	34.2	32.7
Fraction < 63 µm*	g/100g dry wt	28.7	32.9	53.2	35.9	43.1
Polycyclic Aromatic Hydrocarbons Trace in Soil*						
Total of Reported PAHs in Soil	mg/kg dry wt	0.48	0.28	0.31	0.25	0.45
1-Methylnaphthalene	mg/kg dry wt	0.006	< 0.003	0.003	< 0.004	0.004
2-Methylnaphthalene	mg/kg dry wt	0.005	0.003	0.003	< 0.004	0.004
Acenaphthene	mg/kg dry wt	< 0.003	< 0.003	< 0.003	< 0.004	0.005
Acenaphthylene	mg/kg dry wt	0.006	0.003	0.003	< 0.004	< 0.004
Anthracene	mg/kg dry wt	0.010	0.006	0.005	0.004	0.011
Benzo[a]anthracene	mg/kg dry wt	0.030	0.018	0.018	0.013	0.022
Benzo[a]pyrene (BAP)	mg/kg dry wt	0.030	0.021	0.021	0.015	0.024
Benzo[b]fluoranthene + Benzo[j] fluoranthene	mg/kg dry wt	0.038	0.026	0.028	0.023	0.036
Benzo[e]pyrene	mg/kg dry wt	0.020	0.015	0.015	0.012	0.018
Benzo[g,h,i]perylene	mg/kg dry wt	0.028	0.021	0.022	0.018	0.024
Benzo[k]fluoranthene	mg/kg dry wt	0.014	0.010	0.011	0.007	0.013
Chrysene	mg/kg dry wt	0.034	0.023	0.022	0.016	0.029
Dibenzo[a,h]anthracene	mg/kg dry wt	0.005	0.004	0.004	< 0.004	0.004
Fluoranthene	mg/kg dry wt	0.070	0.036	0.040	0.030	0.062
Fluorene	mg/kg dry wt	0.008	0.003	0.006	0.006	0.012
Indeno(1,2,3-c,d)pyrene	mg/kg dry wt	0.023	0.017	0.018	0.014	0.021
Naphthalene	mg/kg dry wt	< 0.015	< 0.014	< 0.014	< 0.017	< 0.018
Perylene	mg/kg dry wt	0.022	0.014	0.024	0.027	0.028
Phenanthrene	mg/kg dry wt	0.058	0.020	0.028	0.023	0.065
Pyrene	mg/kg dry wt	0.069	0.037	0.041	0.029	0.058
Benzo[a]pyrene Potency Equivalency Factor (PEF) NES*	mg/kg dry wt	0.046	0.032	0.033	0.024	0.039
Benzo[a]pyrene Toxic Equivalence (TEF)*	mg/kg dry wt	0.046	0.032	0.032	0.024	0.038

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 simple 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. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. 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%.	-	1-15
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%.	-	1-15

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
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	1-15
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-15
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	1-15
Total Recoverable Lead	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.08 mg/kg dry wt	1-15
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	1-15
Total Recoverable Zinc	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.8 mg/kg dry wt	1-15
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	1-15
Polycyclic Aromatic Hydrocarbons Trace in Soil*	Sonication extraction, GC-MS analysis. Tested on as received sample. In-house based on US EPA 8270.	0.002 - 0.03 mg/kg dry wt	1-15
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	1-15
Fraction >/= 2 mm*	Wet sieving with dispersant, as received, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-15
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	1-15
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	1-15
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	1-15
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	1-15
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	1-15
Fraction < 63 µm*	Wet sieving with dispersant, as received, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-15

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

Testing was completed between 29-Mar-2021 and 11-May-2021. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

APPENDIX 3: DEPOSITED SEDIMENT MONITORING SITES

Table 1: Locations of monthly fine sediment cover monitoring sites in the Christchurch district, including relevant LWRP waterway classifications.

Catchment	Location Description	LWRP Classification	Easting (NZMG)	Northing (NZMG)
Ōtūkaikino Creek	Wilsons Drain at Main North Road	Spring-fed - plains	2481242	5752409
Ōtūkaikino Creek	Ōtūkaikino Creek at Omaka Scout Camp	Spring-fed - plains	2475663	5749653
Styx River	Ka Putahi Creek at Blakes Road	Spring-fed - plains	2480401	5749645
Styx River	Styx River at Main North Road	Spring-fed - plains	2479066	5748834
Avon River	Riccarton Main Drain Downstream of Deans Avenue	Spring-fed - plains - urban	2478683	5741631
Avon River	Addington Brook Upstream of Riccarton Avenue	Spring-fed - plains - urban	2479427	5741438
Avon River	Dudley Creek at North Parade	Spring-fed - plains - urban	2482575	5743763
Avon River	Avon River at Carlton Mill Corner	Spring-fed - plains - urban	2479737	5742871
Heathcote River	Curletts Road Stream Upstream of Heathcote River Confluence	Spring-fed - plains - urban	2476927	5739322
Heathcote River	Cashmere Stream, Behind 406 Cashmere Road (downstream of stormwater discharge)	Banks Peninsula	2477452	5736476
Heathcote River	Heathcote River at Rose Street	Spring-fed - plains - urban	2478700	5737528
Heathcote River	Heathcote River at Warren Crescent	Spring-fed - plains - urban	2476033	5738970
Heathcote River	Heathcote River at Ferniehurst Street	Spring-fed - plains - urban	2479157	5737222
Halswell River	Knights Stream at Sabys Road (upstream of Nottingham Stream)	Spring-fed - plains	2473720	5734461
Halswell River	Nottingham Stream at Candys Road	Spring-fed - plains	2474530	5734689