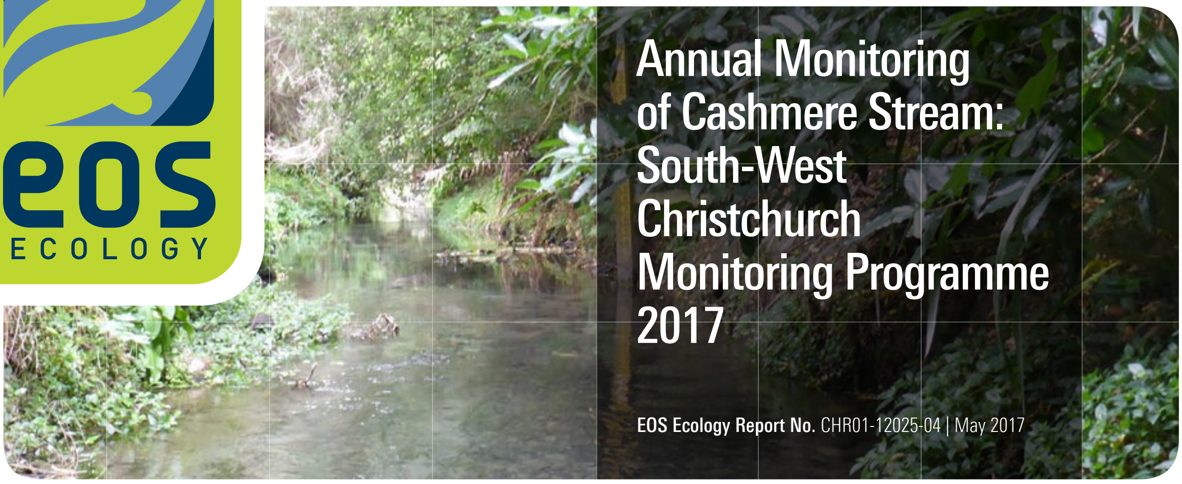
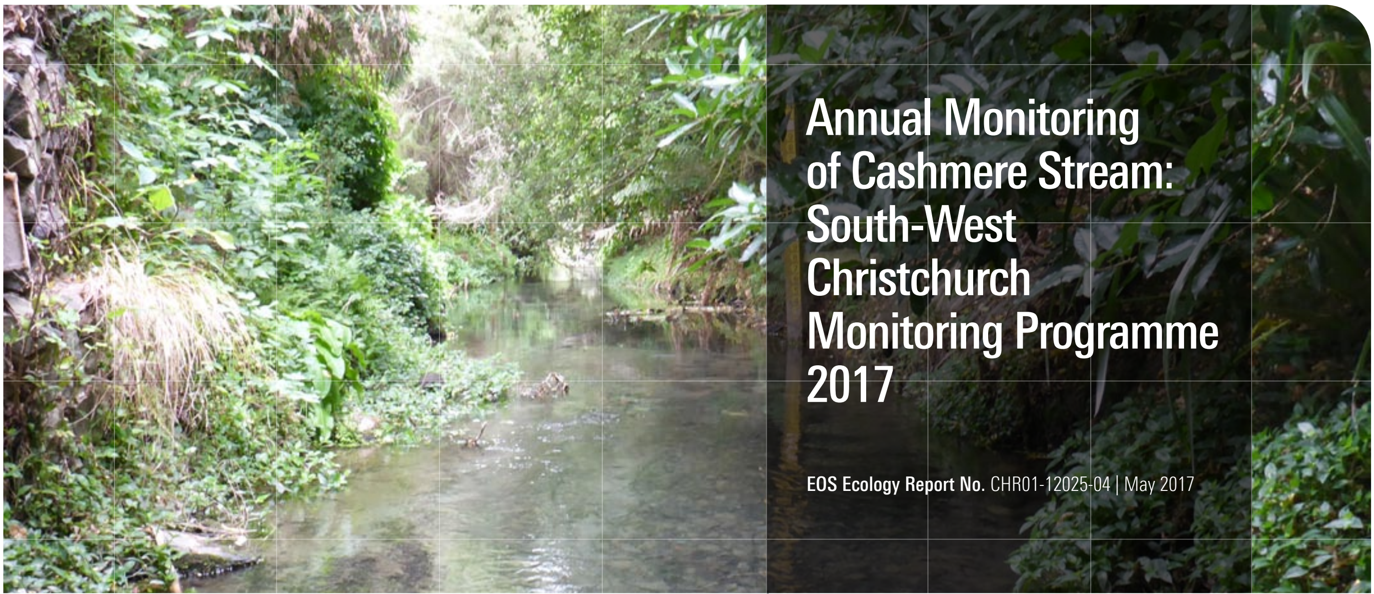


Annual Monitoring of Cashmere Stream: South-West Christchurch Monitoring Programme 2017

EOS Ecology Report No. CHR01-12025-04 | May 2017

AQUATIC SCIENCE & VISUAL COMMUNICATION



Annual Monitoring of Cashmere Stream: South-West Christchurch Monitoring Programme 2017

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REPORT

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Christchurch City Council

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CONTENTS

EXECUTIVE SUMMARY

Christchurch City Council (CCC) holds a stormwater discharge consent (CRC120223) from Environment Canterbury (ECan) that requires monitoring of aquatic invertebrates and habitat characteristics at three sites (downstream of Ballantines Drain (Site 1), downstream of Hendersons Rd Drain (Site 2), and downstream of Dunbars Drain (Site 3)) within Cashmere Stream. The primary aim is to determine whether stormwater discharges are having negative impacts on the streams' aquatic ecology (as measured by aquatic invertebrates and physical habitat) and determine if the surface water quality objectives of the consent are being met. This report represents the fifth year of monitoring (undertaken on the 10 February 2017), with the previous rounds having been undertaken in February 2013, 2014, 2015, and 2016.

The table below compares the relevant 2017 results with the surface water quality objectives from Consent CRC120223 (cells are shaded where the objectives were not met).

Parameter	Surface water quality objectives from Consent CRC120223	SITE 1: DS of Ballantines Drain	SITE 2: DS of Hendersons Rd Drain	SITE 3: DS of Dunbars Drain
		2017	2017	2017
Fine sediment cover	Maximum of 30%	4	15	99
Total macrophyte cover	Maximum of 30%	21	6	98
Filamentous algae cover (>20 mm long)	Maximum of 20%	0	0	0
Quantitative macroinvertebrate community index (QMCI)	Minimum score of 4–5	3.99	3.94	3.06

Instream habitat has changed little over the monitoring period, with Sites 1 and 2 having a stony, hard-bottomed streambed and swifter water flow, which contrasts to Site 3 with slower water velocities and a silty, soft-bottomed bed. Consequently, these habitat conditions resulted in relatively modest macrophyte cover at Sites 1 and 2, and high macrophyte cover at Site 3, which has resulted in this site exceeding the maximum fine sediment and total macrophyte cover water quality objectives of Consent CRC120233 every year since 2013 when the monitoring programme began.

The macroinvertebrate community has shown only minor variation over time, and remains dominated by taxa typical of New Zealand low gradient, lowland streams impacted by agricultural and/or urban development (i.e., snail *Potamopyrgus antipodarum,* the amphipod crustacean *Paracalliope fluviatilis,* Ostracoda seed-shrimps, and oligochaete worms). The dominance of such taxa that are tolerant of degraded conditions mean the Quantitative macroinvertebrate community index (QMCI) scores at all sites were low and in the 'poor' quality class. Consequently, all three sites failed to meet the surface quality objective of a minimum QMCI score of 4–5.

The low QMCI scores are indicative of degraded water quality and/or habitat condition which result from the prevalence of urban and agricultural land uses of the catchment. However, Cashmere Stream retains valued native fauna including freshwater crayfish/kōura and freshwater mussels/kakahi.

The recent Port Hills fire has burned a significant area within the Cashmere Stream catchment. Before vegetation re-establishes fine sediment runoff from this area will increase and potentially have adverse effects on Cashmere Stream. If sediment inputs are large, then this is likely to override any effects that may be caused by stormwater discharges. Thus undertaking of immediate strategies to reduce erosion in these burnt areas is recommended. Consequently the CCC Port Hills Recovery Group has identified this as a priority and is focussing on re-vegetation of erosion prone areas and detention/treatment of sediment-laden runoff in burnt catchments (Greg Burrell, CCC, pers. comm).

1 INTRODUCTION

Christchurch City Council (CCC) holds a stormwater discharge consent from Environment Canterbury (ECan) that requires annual ecological monitoring of Cashmere Stream. This consent, for the South-West Christchurch Stormwater Management Plan (SMP; CRC120223), requires monitoring of aquatic invertebrates and habitat characteristics at three sites within Cashmere Stream. This monitoring programme, including the selection of sampling sites and sampling methodology, was established by the CCC, who commissioned EOS Ecology to undertake the aquatic surveys in 2013, 2014, 2015, 2016 and 2017. The 2014, 2015, and 2016 results are presented in Drinan (2014), James (2015), and James (2016) respectively. This report covers the 2017 results.

The aim of this report, based on the objectives of the CCC stormwater discharge consent monitoring programme, is to (i) compare the results with the receiving environment objectives (both habitat characteristics and invertebrate community indices) included as part of the resource consent conditions for consent CRC120223, (ii) compare the results with the previous years' (2013–2016) monitoring results to investigate if any trends/ patterns are evident, and (iii) to assess whether stormwater discharges are negatively affecting the aquatic ecology of Cashmere Stream.

2 METHODS

2.1 Site Selection

The three monitoring sites on Cashmere Stream were the same as those surveyed on 8 February 2013, 3 February 2014, 3 February 2015, 10 February 2016, which represent the yearly monitoring programme for the South-West Christchurch Stormwater Management Plan. Each of the three survey sites (Sites 1–3) are located on the main stem of Cashmere Stream, downstream (DS) of three tributaries (Figure 1):

- » DS of Ballantines Drain (Site 1) [E1567915 N5175095],
- » DS of Hendersons Rd Drain (Site 2) [E1567664 N5175040], and
- » DS of Dunbars Drain (Site 3) [E1567370 N5174795].

According the to CCC these sites were selected to represent a waterway with high ecological values, where it would be useful to observe trends over time because of the level of development planned within the catchment.

Two sites on Cashmere Stream (upstream of Sutherlands Road and at Penroddock Rise) are also subject to five-yearly monitoring as part of a Heathcote River catchment survey. The site at Sutherlands Road is has predominantly lifestyle blocks upstream although these are being encroached by suburban development and is currently upstream of major stormwater inputs.

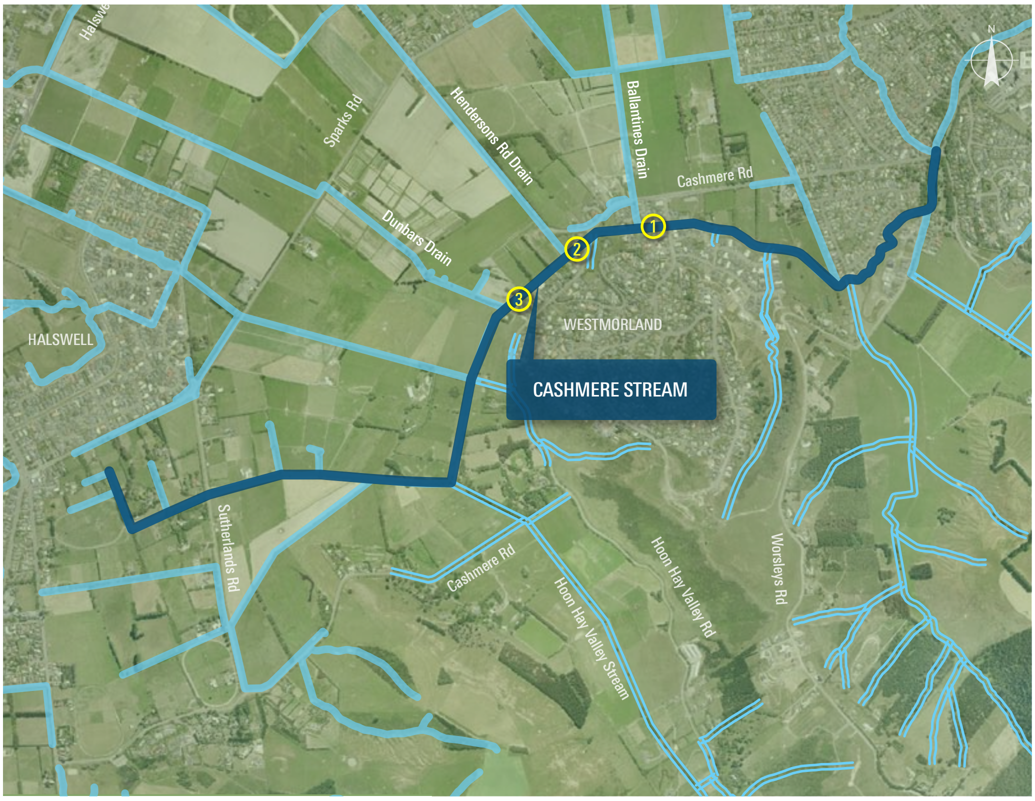

FIGURE 1 Location of the three monitoring sites on Cashmere Stream. Site photographs are provided in the Appendix (Section 8.1).
Site 1: DS of Ballantines Drain
Site 2: DS of Hendersons Rd Drain
Site 3: DS of Dunbars Drain

2.2 Sampling

Following fine weather conditions, EOS Ecology undertook habitat and aquatic invertebrate surveys at each of the three monitoring sites on 10 February 2017. This was three days before the Port Hills fire began. At each site, aspects of the instream habitat and aquatic invertebrate community were quantified along three transects across the stream, spaced at 10 m intervals (i.e. at 0, 10 and 20 m).

Instream habitat variables were quantified at 12 equidistant points across each of the three transects, with the first and last measurements across each transect at the water's edge. Habitat variables measured at each of these 12 points on each of the three transects (i.e. 36 points per site) included substrate composition (mud/silt/clay: <0.06 mm; sand: 0.06–2 mm; gravel: 2–16 mm; pebble: 16–64 mm; small cobble: 64–128 mm; large cobble: 128–256 mm; boulder: >256mm; bedrock/manmade concrete), presence and type of organic material (submerged and emergent macrophytes, filamentous algae and algal mats, moss/liverworts, fine/coarse detritus, and terrestrial vegetation), depths (water, macrophyte and sediment). Water velocity was measured using a Sontek ADV meter at 10 of the 12 points across each of the three transects (points 1 and 12 along each transect were excluded as these points were at the water's edge). As per standard convention, water velocity was measured at 0.4 x the water depth, and was measured at each sampling point over a 30 second interval. General bank attributes, including lower and upper bank height and angles, lower bank undercut, and lower bank vegetative overhang were measured for each bank at each transect. Bank material composition and stability were also recorded.

A visual qualitative assessment of macrophyte cover was also assessed across each of the three transects. This involved qualitatively assessing macrophyte cover within a 1 m band along each of the three transects with the following variables recorded: visual estimation of streambed cover (%), identification of the dominant species present, and identification of the type present (emergent or submerged). Because macrophyte cover is often patchy at the site scale, looking at only three transects does not necessarily give a good estimate of cover or composition. Therefore, a visual qualitative assessment of macrophyte cover was also undertaken over the entire site (see below).

A visual qualitative assessment of a number of habitat parameters was also carried out over the entire site (i.e. site-wide assessments). The parameters measured at the site-scale included the following:

- Habitat type (% riffle/run/pool, and maximum pool depth).
- Visible sky was assessed as one of five percentage cover categories (<5%, 5-25%, 25-50%, 50-75%, >75%), as per the Christchurch River Environment Assessment Survey (CREAS) criteria (McMurtrie & Suren, 2008). As per CREAS, measurements were taken in each half of the stream (by splitting the channel down the centreline) and categorised as for the true right bank (TRB) or true left bank (TLB). Visible sky is a measure of how much sky is visible from the centre of the stream, and so takes into account steep banks, buildings and other objects that may be situated back from the channel but still block the sky in some way.
- Canopy tree cover was assessed as one of five percentage cover categories (<5%, 5-25%, 25-50%, 50-75%, >75%), as per the CREAS criteria. As per CREAS, measurements were taken in each half of the stream (by splitting the channel down the centreline) and categorised as for the true right bank (TRB) or true left bank (TLB). This is also a measure of channel shading as it is an estimate of how much of the channel is shaded by tree cover within the site.

- Substrate embeddedness (the percentage of fine sediment surrounding large particles within the streambed) was assessed as one of five percentage cover categories (<5%, 5-25%, 25-50%, 50-75%, >75%), as per the CREAS criteria.
- Bank attributes (bank erosion and bank vegetation cover), were assessed as one of five percentage cover categories (<5%, 5-25%, 25-50%, 50-75%, >75%), as per the CREAS criteria.
- Lower bank material was categorised into one of seven categories: earth (includes soil, sand, and gravel), wood, brick, rock, concrete, iron, and tyres.
- Substrate composition. The percentage cover of the following particle size categories: mud/silt/clay: <0.06 mm; sand: 0.06–2 mm; gravel: 2–16 mm; pebble: 16–64 mm; small cobble: 64–128 mm; large cobble: 128–256 mm; boulder: >256mm; bedrock/manmade concrete, as per the CREAS criteria. Percentage fine sediment cover was calculated as the combined coverage of mud/silt/clay and sand particle size categories.
- Bryophyte (moss, liverworts) coverage.
- Macrophyte coverage and composition. Macrophytes were identified to the lowest practicable level (either to genus or species), including whether it was a submerged or emergent growth form.
- Periphyton (including algae) coverage and composition. The periphyton types recorded were classified using the groups outlined in Biggs & Kilroy (2000): thin mat/film (<0.5 mm thick); medium mat (0.5–3 mm thick); thick mat (<3 mm thick); filaments, short (<2 cm long); and filaments, long (>2 cm long).

The riparian zone condition was assessed within a 5 m band on either side of the bank within the 20 m site. The cover of 15 different vegetation types was estimated on a ranking scale of present (<10%), common (10–50%), and abundant (>50%). The vegetation was assessed three dimensionally so included ground, shrub, and canopy cover levels. The vegetation categories were taken from the CREAS criteria (McMurtrie & Suren, 2008).

Aquatic benthic invertebrates were collected at each transect by disturbing the substrate across an approximate 1.5 m width and within a 0.3 m band immediately upstream of a conventional kick net (500 μm mesh size). The full range of habitat types were surveyed across each transect, including mid-channel and margin areas, inorganic substrate (e.g. the streambed), and macrophytes (aquatic plants). Each invertebrate sample was kept in a separate container, preserved in 70% isopropyl alcohol, and taken to the laboratory for identification. The contents of each sample were passed through a series of nested sieves (2 mm, 1 mm, and 500 μm) and placed in a Bogorov sorting tray. All invertebrates were counted and identified to the lowest practical level using a binocular microscope and several identification keys (Winterbourn *et al.*, 2006; Winterbourn, 1973; Chapman *et al.*, 2011). Sub-sampling was utilised for particularly large samples and the unsorted fraction scanned for taxa not already identified. The lowest sub-sampling level used for any particular size fraction of a sample collected was 12.5% (i.e. one eighth of the sample).

There were two aspects of habitat sampling that was slightly different in 2014–2017 compared to 2013. These methodological differences were:

- The macrophyte cover assessment was altered in 2014 and subsequent years, compared with 2013. In 2013, macrophytes were assessed over the whole site, while in 2014 and subsequent years they were assessed over the entire site as well as across each transect. We have chosen to present the site wide percentage cover assessment as this allows comparison with 2013 and earlier data. Additionally, site wide percentage cover provides a better indication of macrophyte cover than only looking at three transects, as macrophytes often have a patchy distribution at the site scale.

- The algal cover assessment (both site-wide and across each transect) was altered in 2014 and subsequent years, compared with 2013. In 2013, only the 'algal mats' and 'filamentous algae' categories were used, while in 2014 and subsequent years the categories of Biggs & Kilroy (2000) were recorded: (thin mat/film (<0.5 mm thick); medium mat (0.5–3 mm thick); thick mat (<3 mm thick); filaments, short (<2 cm long); and filaments, long (>2 cm long)). Filamentous algae were not recorded at any of the three sites in 2013, so this change of is no consequence for inter-year comparisons.

2.3 Data Analysis

The data describing the substrate composition was simplified by creating a substrate index, such that:

Substrate index = [(0.7 x % boulders) + (0.6 x % large cobbles) + (0.5 x % small cobbles) + (0.4 x % pebbles) + (0.3 x % gravels) + (0.2 x % sand) + (0.1 x % silt) + (0.1 x % concrete/bedrock)] / 10

Where derived values for the substrate index range from 1 (i.e., a substrate of 100% silt) to 7 (i.e., a substrate of 100% boulder); the larger the index, the coarser the overall substrate. In general, coarser substrate (up to cobbles) represents better instream habitat than finer substrate. The same low coefficients for silt and concrete/bedrock reflect their uniform nature and lack of spatial heterogeneity, and in the case of silt, instability during high flow.

Invertebrate data were summarised by taxa richness, total abundance, abundance of the five most common taxa, and non-metric multidimensional scaling ordination (NMS). Biotic indices calculated were the number of Ephemeroptera-Plecoptera-Trichoptera taxa (EPT taxa richness), %EPT abundance, the Macroinvertebrate Community Index (MCI), Urban Community Index (UCI), and their quantitative equivalents (QMCI and QUCI, respectively). The points below provide brief clarification of these metrics.

- Taxa richness is the number of different taxa identified in each sample. Taxa is generally a term for taxonomic groups, and in this case refers to the lowest level of classification that was obtained during the study. Taxa richness is a useful community metric related to habitat diversity, with sites with more diverse habitats often having greater richness. However, there are numerous aquatic invertebrate taxa that prefer or tolerate degraded instream conditions such that taxa richness on its own should not be used to infer stream health.

- NMS is an ordination of data that is often used to examine how communities composed of many different taxa differ between sites. It can graphically describe communities by representing each site as a point (an ordination score) on an x–y plot. The location of each point/site reflects its community composition, as well as its similarity to communities in other sites/points. Thus points situated close together indicate sites with similar macroinvertebrate communities, whereas points with little similarity are situated further away. Habitat variables can also be associated with the different axes, indicating whether the macroinvertebrate communities are responding to habitat differences.

- EPT refers to three Orders of invertebrates that are generally regarded as 'cleanwater' taxa. These Orders are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies); forming the acronym EPT. These taxa are relatively intolerant of organic enrichment or other pollutants and habitat degradation. The exception to this are the hydroptilid caddisflies (e.g. Trichoptera: Hydroptilidae: *Oxyethira, Paroxyethira*), which are algal piercers and often found in high numbers in nutrient enriched waters with high algal content. For this reason, EPT metrics are presented with and without these taxa.

EPT taxa richness and %EPT abundance can provide a good indication as to the health of a particular site. The disappearance and reappearance of EPT taxa also provides evidence of whether a site is impacted or recovering from a disturbance. EPT taxa are generally diverse in non-impacted, non-urbanised stream systems, although there is a small set of EPT taxa that are also found in urbanised waterways.

» In the mid-1980s the MCI was developed as an index of community integrity for use in stony riffles in New Zealand streams and rivers, and can be used to determine the level of organic enrichment for these types of streams (Stark, 1985). Although developed to assess nutrient enrichment, the MCI will respond to any disturbance that alters macroinvertebrate community composition (Boothroyd & Stark, 2000), and as such is used widely to evaluate the general health of waterways in New Zealand. Recently a variant for use in streams with a streambed of sand/silt/mud (i.e. soft-bottomed) was developed by Stark & Maxted (2007a) and is referred to as the MCI-sb. Both the hard-bottomed (MCI-hb) and soft-bottomed (MCI-sb) versions calculate an overall score for each sample, which is based on pollution-tolerance values for each invertebrate taxon that range from 1 (very pollution tolerant) to 10 (pollution-sensitive). MCI-hb and MCI-sb are calculated using presence/absence data and a quantitative version has been developed that incorporates abundance data and so gives a more accurate result by differentiating rare taxa from abundant taxa (QMCI-hb, QMCI-sb). MCI (QMCI) scores of ≥120 (≥6.00) are interpreted as 'excellent', 100–119 (5.00–5.99) as 'good', 80–99 (4.00–4.99) as 'fair', and <80 (<4.00) as 'poor' (Stark & Maxted, 2007b). As mud/silt/clay (<0.06 mm) was the dominant substrate size class at Site 3 (DS of Dunbars Drain), only the soft-bottomed variants (MCI-sb and QMCI-sb) were used at this site. The hard-bottomed variants were used at the remaining two sites (Sites 1 & 2) as these sites were dominated by stony substrata.

» The UCI/QUCI score can be used to determine the health of urban and peri-urban streams by combining tolerance values for invertebrates with presence/absence or abundance invertebrate data (Suren *et al.*, 1998). This biotic index is indicative of habitat relationships, and to some degree incorporates urban impacts. Negative scores are indicative of invertebrate communities tolerant of slow-flowing water conditions associated with soft-bottomed streams (and often with a high biomass of macrophytes), whereas positive scores are indicative of communities present in fast-flowing streams with coarse substrates (Suren *et al.*, 1998).

One-way analysis of variance (ANOVA) was used to investigate differences in habitat attributes and aquatic macroinvertebrate community metrics between sites (Sites 1–3) in 2017. Where there were multiple measures across a transect, these were averaged prior to ANOVA. Data transformations were used (e.g. log10), where necessary, to fulfil the requirements of the parametric tests (i.e., equal variance and normality). The level of significance was set at p=0.05. Where significant differences were observed, the *post-hoc* Holm-Sidak test was used to identify site means that were significantly different. Where the requirements of the parametric tests (i.e. equal variance and normality) could not be achieved with data transformation, the non-parametric Kruskal-Wallis test was used along with the *post hoc* Tukey test where significantly different site medians were observed.

In addition, two-way ANOVAs – with site and time as main factors – were used to investigate differences in aquatic macroinvertebrate community metrics and habitat attributes between sites (Sites 1–3) and years (2013, 2014, 2015, 2016, and 2017). For the purposes of considering temporal change, only significant year and site × year interactions are discussed within the text. Although significant site results are also included in the tables for completeness, they were not relevant to discuss further as site-based differences are better interpreted on the current year's data only.

For the ANOVAs on macroinvertebrate community metrics, tests were all based on a single value per transect (i.e., three values per site). With respect to the ANOVAs on habitat attributes, tests were based on a single value per transect for channel width, substrate index, total water depth, fine sediment depth and macrophyte depth. Although total water depth, fine sediment depth and macrophyte depth are measured across each of the 12 equidistant points on each transect, normality could not be achieved by including all 36 data points per transect due to the high level of variation between transect points, thus the average for each transect was used. For water velocity, all 10 data points per transect were used.

Temporal trends for habitat parameters and macroinvertebrate community metrics over the 2013–2017 period at each site were examined using the Mann-Kendall trend test in Time Trends version 5.

With respect to figures, the mean and standard error (SE) values presented on the graphs were calculated from the full set of data points recorded for each attribute at each site (e.g., 36 data points for total water depth, fine sediment depth, and macrophyte depth; 30 data points for water velocity, three data points for channel width, substrate index, and all the invertebrate community indices).

3 RESULTS

3.1 Habitat

3.1.1 Overview of 2017 Results

In general the riparian and instream habitat of the three Cashmere Stream sites was similar to previous years. Adjacent land use has not changed greatly overtime at Site 1 (mix of residential and park/reserve) or Site 2 (mix of residential and rural)(Table 1). Site 3 remains residential on the true right bank, while the true left bank was now rural with horticulture rather than rural with stock as it was the previous year, however the landowner may well alternate land use between cropping and grazing (Table 1). All sites have riparian vegetation composed typically of a grass/herb mix, with various native and exotic shrubs and trees (Table 1). Site 1 was well shaded, while Site 3 was relatively open. The bridge overhead at Site 2 provided substantial permanent shading of the stream. Site 3 continues to be a more depositional environment than Sites 1 and 2 in having a 100% silt bottom, 100% run habitat, lower water velocities, greater water depths water, and greater macrophyte depths (Table 1, Figure 2). Compared to Site 3, Sites 1 and 2 had greater habitat variability with both run and riffle habitats and a coarser bed substrate dominated by cobble-sized particles (Table 1).

There were statistically significance differences amongst sites for five of the six analysed instream habitat variables in 2017 (Table 2). These differences all result from the contrast in instream habitat at Site 3 compared to Sites 1 and 2. Water depth, fine sediment depth, and macrophyte depth were significantly greater at Site 3 while water velocity and substrate index were greater at Sites 1 and 2 (Table 2).

Macrophyte cover was greatest at Site 3 (total cover 98%) and much lower at Site 1 (21%) and Site 2 (6%) (Table 3). This indicates the physical habitat (along with sunlight availability and nutrient concentrations) at Site 3 is particularly amenable to developing high macrophyte biomass. Apart from minor amounts of the ubiquitous native *Lemna minor* (duckweed) and endemic *Myriophyllum triphyllum* at Site 3, all other identified macrophytes were exotic, with *Elodea canadensis* (Canadian pondweed; 89% cover at Site 3) and *Potamogeton crispus* (curly pondweed; 20% cover at Site 1 and 5% cover at Sites 2 and 3) the dominant species (Table 3). Thin algal mats were particularly abundant at Site 2 (89% cover) and also present at Site 1 (15% cover), while filamentous algae were not observed at any site (Table 3). Site 1 differed from the other two sites in having a relatively high cover (42%) of bryophytes (mosses/liverworts) attached to the coarse substrate, implying the streambed is stable (minimal scour and movement of substratum during high flow events).

TABLE 1 Habitat attributes from each of the three monitoring sites on Cashmere Stream for 2017. These attributes were measured over the entire site (i.e. a single site-wide value). TLB = true left bank, TRB = true right bank. The dominant substrate size is shown in bold.

Habitat attributes		SITE 1: DS of Ballantines Drain	SITE 2: DS of Hendersons Rd Drain	SITE 3: DS of Dunbars Drain
Substrate composition (dominant substrate is emboldened)	Man-made (concrete)	1%	1%	1%
	Boulder	5%	1%	0%
	Large cobble	15%	3%	0%
	Small cobble	35%	10%	0%
	Pebble	**40%**	30%	0%
	Gravel	0%	**40%**	0%
	Sand	1%	0%	0%
	Mud/silt/clay	3%	15%	**99%**
Surrounding land use	TLB	70% residential (new) & 30% park/reserve	50% rural with stock (unfenced) & 50% residential (old)	100% rural with horticulture (unfenced)
	TRB	50% residential (new) & 50% park/reserve	50% rural with stock (unfenced) & 50% residential (old)	100% residential (old)
Habitat type (% riffle:run:pool)		20:80:0	50:50:0	0:100:0
Bank material composition		Earth and rock with some concrete on TLB	Earth, rock & concrete (with minor wood)	Earth (with some rock and wood)
Riparian vegetation		Grass/herb mix, some low ground cover, ferns, rushes, native shrubs, native trees and exotic deciduous trees.	Grass/herb mix, some low ground cover and native trees.	Grass/herb mix, some low ground cover, exotic and native shrubs, native trees and exotic deciduous trees.
Canopy cover (% stream shade)	TLB	25–50%	<5% (25-50% when including bridges)	5–25%
	TRB	>75%	<5% (25-50% when including bridges)	25–50%
Substrate embeddedness		25–50%	25–50%	>75%

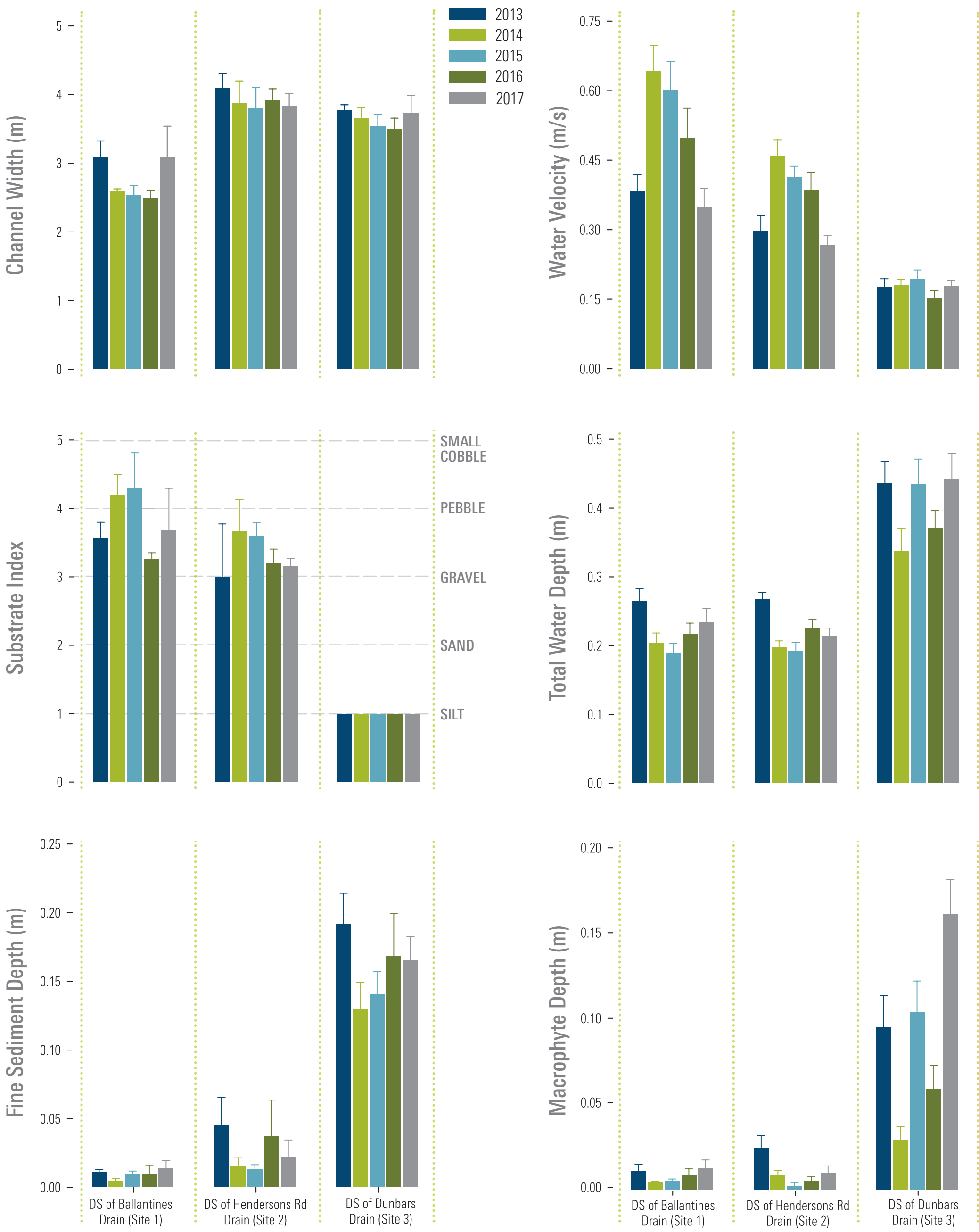

FIGURE 2 Mean (+ 1 standard error) habitat attribute values at each of the three monitoring sites on Cashmere Stream for 2013–2017. Aquatic invertebrate and habitat surveys were undertaken on 8 February 2013, 3 February 2014, 3 February 2015, 10 February 2016 and 10 February 2017 by EOS Ecology.

TABLE 2 Results of the one-way analysis of variance (ANOVA) or Kruskal-Wallis test on aquatic habitat attributes from 2017 data. The Holm-Sidak *post-hoc* test (ANOVA) or Tukey test (Kruskal-Wallis) was used to find which site means (or medians) were significantly different.

Habitat parameter	ANOVA result	Significant site differences
Channel width	$F_{2,8}$= 4.01, p=0.075	None
Water velocity	H= 14.96, p<0.001	1=2>3
Substrate index	$F_{2,8}$= 16.24, p=0.004	1=2>3
Total water depth	$F_{2,8}$= 42.02, p<0.001	3>2=1
Fine sediment depth	$F_{2,8}$= 58.79, p<0.001	3>2=1
Macrophyte depth	$F_{2,8}$= 39.70, p<0.001	3>2=1

TABLE 3 Macrophyte and periphyton attributes from each of the three monitoring sites on Cashmere Stream for 2017. These attributes were measured over the entire site (i.e. a single site-wide value). Total macrophyte cover includes both emergent and submerged macrophytes.

Macrophyte & periphyton attribute	SITE 1: DS of Ballantines Drain	SITE 2: DS of Hendersons Rd Drain	SITE 3: DS of Dunbars Drain
Aquatic vegetation & organic material cover*	Algae – thin mat/film (<0.5 mm thick): 15%	Algae – thin mat/film (<0.5 mm thick): 89%	*E. canadensis*: 89%
	Algae – medium mat (0.5–3 mm thick): 5%	Moss/liverworts: 2%	*P. crispus:* 5%
	Moss/liverworts: 42%	*P. crispus*: 5%	*Myriophyllum triphyllum:* 2%
	Potamogeton crispus (curly pondweed): 20%	*E. canadensis*: 1%	*Lemna minor* (duckweed): 1%
	Elodea canadensis (Canadian pondweed): 1%	Terrestrial roots/vegetation: 1%	*Ranunculus trichophyllus:* 0.5%
	Terrestrial roots/vegetation: 15%	Fine detritus: 1%	*Glyceria*: 0.5%
	Woody debris: 2%	Woody debris: 1%	Woody debris: 1%
			Terrestrial roots/vegetation: 1%
			Fine detritus: 1%
Emergent macrophyte cover	0%	0%	1.5%
Total macrophyte cover†	21%	6%	98%

* Only those aquatic vegetation and organic material cover categories that were present are shown (i.e. all other macrophyte and periphyton attributes had zero values).

† Total macrophyte cover only includes those macrophyte species from the 'aquatic vegetation and organic material cover' category, and so excludes algae, moss/liverworts, terrestrial roots/vegetation, fine detritus and woody debris.

3.1.2 Temporal Change (2013–2017)

Two of the six analysed instream habitat variables had significant site by year interactions. Mean water velocity was relatively variable at Site 1 over the years, hence had a complex array of yearly comparisons, while at Site 2 2014 was significantly greater than 2017 and 2013 only (Figure 2, Table 4). In contrast there were no differences in mean water velocity over the years at Site 3. It should be noted, however that water velocity data could not meet the ANOVA assumptions of normality and equal variance even after transformation so those results are likely unreliable. Macrophyte depth was significantly greater at Site 3 in all years except for 2014 (Figure 2, Table 4). The only other relevant two-way ANOVA result was water depth across all sites being significantly greater in 2013 (Figure 2, Table 4).

Trend analysis of key habitat parameters showed no trends although macrophyte depth was significant at Site 3 but had 0% annual change (Table 5).

TABLE 4 Results of the two-way analysis of variance (ANOVA) (with site and year as main factors) on aquatic habitat attributes from 2013–2017. The Holm-Sidak *post-hoc* test was used to find which site means were significantly different. n/s = not significant; n/a = not applicable. Note the water velocity, substrate index, fine sediment depth, and macrophyte depth data could not meet the normality assumption even after transformation. Water velocity could also not meet the equal variance assumption following transformation. For comparisons among means the letters denote where there are differences.

<table>
<tr><th rowspan="2">Habitat parameter</th><th rowspan="2">Site</th><th rowspan="2">Year</th><th rowspan="2">Site × Year</th><th colspan="6">Year or Interaction Comparisons</th></tr>
<tr><th>Site</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th></tr>
<tr><td>Channel width</td><td>$F_{2, 30}$= 53.32, p<0.001</td><td>n/s</td><td>n/s</td><td colspan="6">n/a</td></tr>
<tr><td rowspan="3">Water velocity</td><td rowspan="3">$F_{2, 437}$= 93.29, p<0.001</td><td rowspan="3">$F_{4, 437}$= 10.97, p<0.001</td><td rowspan="3">$F_{8, 437}$= 3.03, p=0.003</td><td>1</td><td>ad</td><td>c</td><td>bc</td><td>ab</td><td>d</td></tr>
<tr><td>2</td><td>a</td><td>b</td><td>ab</td><td>ab</td><td>a</td></tr>
<tr><td>3</td><td>a</td><td>a</td><td>a</td><td>a</td><td>a</td></tr>
<tr><td>Substrate index</td><td>$F_{2, 30}$= 99.16, p<0.001</td><td>n/s</td><td>n/s</td><td colspan="6">n/a</td></tr>
<tr><td>Total water depth</td><td>$F_{2,30}$= 158.24, p<0.001</td><td>$F_{4, 30}$= 7.11, p<0.001</td><td>n/s</td><td></td><td>a</td><td>b</td><td>bc</td><td>bc</td><td>ac</td></tr>
<tr><td>Fine sediment depth</td><td>$F_{2, 30}$= 63.88, p<0.001</td><td>n/s</td><td>n/s</td><td colspan="6">n/a</td></tr>
<tr><td rowspan="3">Macrophyte depth</td><td rowspan="3">$F_{2, 30}$= 69.81, p<0.001</td><td rowspan="3">$F_{4, 30}$= 6.47, p<0.001</td><td rowspan="3">$F_{8, 30}$= 5.17, p<0.001</td><td>1</td><td>a</td><td>a</td><td>a</td><td>a</td><td>a</td></tr>
<tr><td>2</td><td>a</td><td>a</td><td>a</td><td>a</td><td>a</td></tr>
<tr><td>3</td><td>a</td><td>b</td><td>a</td><td>ab</td><td>c</td></tr>
</table>

TABLE 5 Results of Mann-Kendall trend analysis for selected habitat parameters measured February 2013–2017. Where a significant trend was determined the direction and annual change is shown. In the majority of instances there were no significant trends.

Habitat Parameter	Site 1: DS of Ballantines Drain	Site 2: DS of Hendersons Rd Drain	Site 3: DS of Dunbars Drain
Channel width	No trend (p=0.22)	No trend (p=0.58)	No trend (p=0.44)
Water velocity	No trend (p=0.30)	No trend (p=0.08)	No trend (p=0.72)
Substrate index	No trend (p=0.54)	No trend (p=0.38)	Insufficient data (all data points the same value)
Total water depth	No trend (p=0.48)	No trend (p=0.06)	No trend (p=0.64)
Fine sediment depth	No trend (p=0.18)	No trend (p=0.59)	No trend (p=0.97)
Macrophyte depth	No trend (p=0.71)	No trend (p=0.22)	No trend (0% annual change; p=0.01)

3.2 Aquatic Invertebrates

3.2.1 Overview of 2017 Results

A total of 31 invertebrate taxa were recorded from the three aquatic invertebrate and habitat monitoring sites in 2017, with taxa richness per site ranging from 22 to 28. The most diverse groups were true flies (Diptera: 9 taxa) followed by caddisflies (Trichoptera: 8 taxa), molluscs (Mollusca: 4 taxa) and crustaceans (Crustacea: 3 taxa). Hydra (Cnidaria), true bugs (Hemiptera), roundworms (Nematoda), proboscis worms (Nemertea), damselflies (Odonata), worms (Oligochaeta), and flatworms (Platyhelminthes) were each represented by a single taxon.

The three most abundant taxa overall were the snail *Potamopyrgus antipodarum* (56%), the amphipod *Paracalliope fluviatilis* (17%) and ostracod seed shrimps (6%), which together accounted for 79% of all invertebrates captured. 'Cleanwater' EPT taxa were uncommon across all sites, with no mayflies (Ephemeroptera) or stoneflies (Plecoptera) recorded. Of the caddisflies (Trichoptera), the most abundant taxon recorded was the cased caddis *Hudsonema amabile* (2% of total invertebrate abundance). The other caddisfly taxa combined (*Triplectides, Hydrobiosis, Psilochorema, Oxyethira albiceps, Oecetis,* early instar *Hudsonema* spp., *Polyplectropus* and *Hudsonema alienum*) accounted for 3.1% (including the pollution-tolerant *O. albiceps*) or 2.7% (excluding *O. albiceps*) of total invertebrate abundance.

In terms of the five most abundant taxa, the communities of all three sites in 2017 were similar and dominated by mostly non-insect taxa that are common in lowland Canterbury waterways (e.g., *P. antipodarum, P. fluviatilis,* ostracod crustaceans, oligochaete worms, and Sphaeriidae pea-clams (Figure 3). However, it was notable the cased caddis *H. amabile* appeared among the five most abundant taxa at Site 2; the first time an EPT taxon (with the exception of the pollution-tolerant *O. albiceps*) has done so since the current monitoring scheme began in 2013 (Figure 3).

In 2017, all macroinvertebrate community metrics were statistically similar between the three sites (Figure 4; Table 6). Both the mean MCI and QMCI indicated all sites were in the "poor" quality class of Stark & Maxted (2007b), however the QMCI scores of Sites 1 and 2 were close to the "fair" threshold (Figure 4). At Site 3 mean UCI was a positive value for the first time since the monitoring scheme began in 2013, however QUCI remained negative as it had for the previous three years (Figure 4). Being based on taxon presence/absence, the UCI in 2017 was a positive value because of the presence of small numbers of EPT taxa with high UCI scores such as *H. amabile*, *Psilochorema,* and *Triplectides*.

FIGURE 3 **Photographs of the five most abundant taxa (% relative abundance per site indicated) from the three monitoring sites for 2013–2017.**

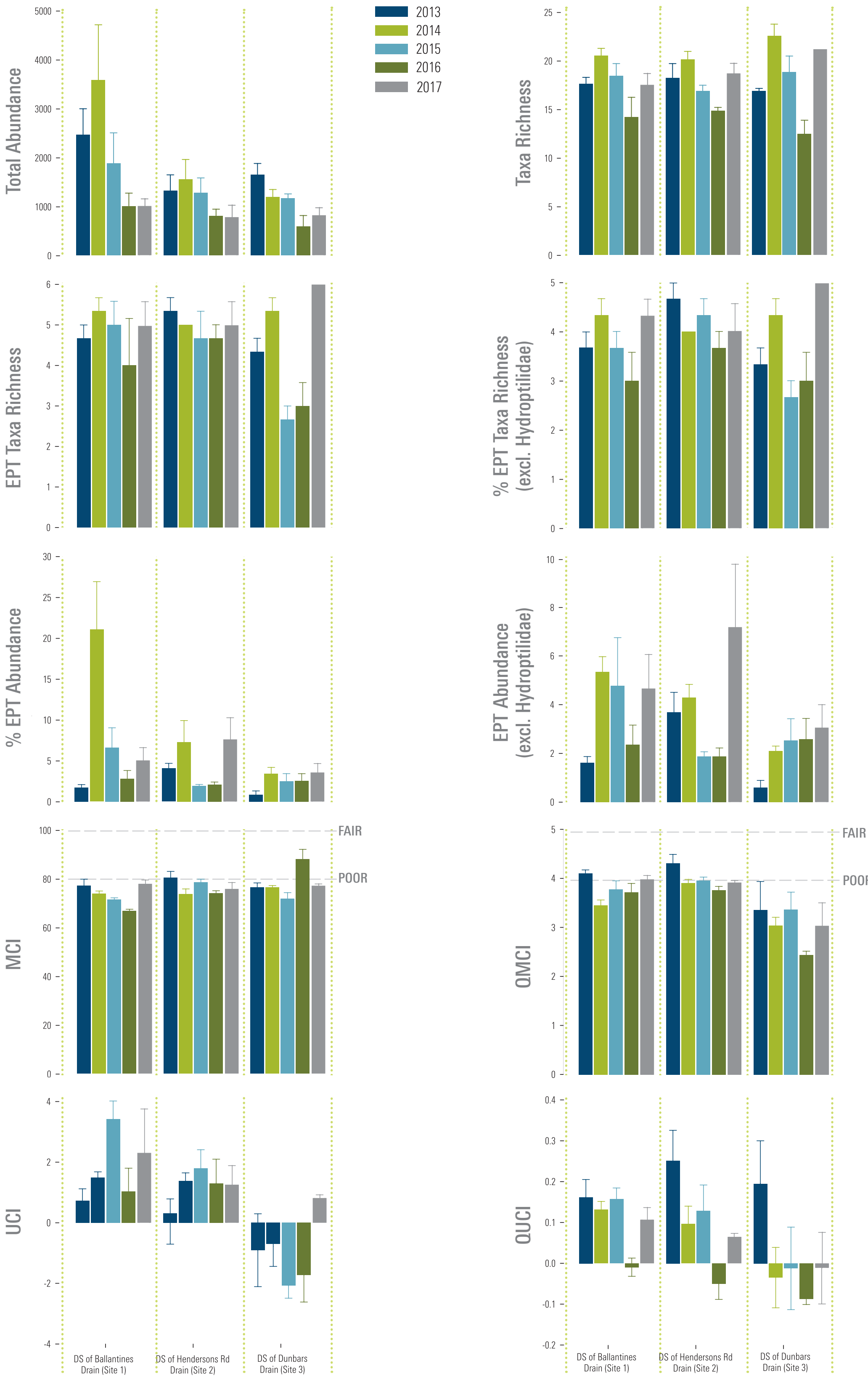

FIGURE 4 Mean (± 1 standard error) community indices at each of the three monitoring sites on Cashmere Stream for 2013–2017. EPT metrics are presented with and without Hydroptilidae, as hydroptilid trichopterans (*Oxyethira* and *Paroxyethira*) are algal piercers that are often abundant in polluted waterways. N = 3 (per individual bar) for all indices. The dashed lines on the MCI and QMCI graphs show the 'quality class' interpretation categories of Stark & Maxted (2007b)..

TABLE 6 **Results of the one-way analysis of variance (ANOVA) on community indices from 2017. n/s = not significant; n/a = not applicable.**

Community indices	ANOVA result	Signifcant site differences
Total abundance	n/s	n/a
Taxa richness	n/s	n/a
EPT taxa richness	n/s	n/a
% EPT abundance	n/s	n/a
EPT taxa richness (excl. Hydroptilidae)*	n/s	n/a
% EPT abundance (excl. Hydroptilidae)*	n/s	n/a
MCI	n/s	n/a
QMCI	n/s	n/a
UCI	n/s	n/a
QUCI	n/s	n/a

* Hydroptilidae trichopterans (*Oxyethira* and *Paroxyethira*) are excluded as they are algal piercers that are often abundant in nutrient-enriched waterways.

3.2.2 Temporal Change (2013–2017)

In terms of the five most abundant taxa, the communities of all three sites in 2017 were similar to previous years with the same core taxa dominating (Figure 3). The snail *P. antipodarum* typically dominated numerically, being the most abundant taxon for 13 of the 15 site/year combinations (Figure 3). The amphipod *Paracalliope* is also often among the top three most abundant taxa at all sites. Ostracods were particularly prevalent at the soft-bottomed Site 3 (Figure 3).

The NMS ordination showed samples from Site 1 and 2 to be separated from those of Site 3 most strongly along Axis 2, and were associated with higher water velocities and a coarser streambed substrate, on both Axis 1 and 2 (Figure 5). Along Axis 2, samples towards the top of the plot (mostly from Site 3) were associated with taxa such as ostracods, tanypod and *Chironomus* midge larvae, and *Physa* snails. On Axis 2 samples toward the bottom of the plot (mostly from Sites 1 and 2) were associated with taxa such as Empididae fly larvae, orthoclad midge larvae, oligochaete worms, and the caddisflies *Psilochorema* and *Oxyethira* (Figure 5). Samples towards the left of Axis 1 (which includes the majority of those from Site 1 and 2) were associated with the snails *P. antipodarum* and *Physa*, while those to the left were associated with ostracods and *Paracalliope* (Figure 5).

Total abundance, taxa richness, EPT richness, QMCI, and QUCI all displayed significant differences among years (Table 7). Total abundance was significantly greater in 2013 and 2014 than in 2016 and 2017 and at Site 1 compared to Sites 2 and 3 (Table 7). Taxa richness was significantly lower in 2016 compared to all other years. In comparison EPT taxa richness showed 2014 and 2017 being greater than 2016 and 2017, which were greater than 2015 (Figure 4; Table 7). For QMCI and QUCI all years were the same with the exception of 2013 being greater than 2016 (QMCI) and 2013 being greater than 2016 and 2017 (QUCI) (Table 7).

The percentage EPT abundance, EPT abundance (excl. hydropts), EPT richness (excl. hydropts), and MCI all had significant site × year interactions (Table 7). For EPT abundance 2015, 2016, and 2017 were the same, while there were site differences in 2013 (Site 2 > Site 3) and 2014 (Site 1 > Site 3). Mean EPT taxa richness (excl. hydropts) was the same among sites in 2013, 2014, 2016, and 2017, while in 2015 Site 2 was greater than Site 3. Mean EPT abundance (excl. hydropts) was the same from 2014–2017, while in 2013 Sites 1 and 2 were greater than Site 3 (Table 7). Mean MCI was the same among sites in 2013, 2014, and 2017, while there were site differences in 2015 (Site 1> Sites 2 and 3) and 2016 (Site 3 > Site 2 > Site 1) (Table 7). Overall, the ANOVA results do not indicate any consistent differences among the three sites over the five years of monitoring.

Trend analysis found trends in only three instances among any of the macroinvertebrate community metrics at any of the sites (Table 8). Total abundance showed decreasing trends at Site 1 (29% annual decrease) and Site 3 (19% annual decrease), while %EPT abundance (excl. hydropts) showed a 27% annual increase at Site 3 (Table 8). It would be unwise to place much emphasis on the decreasing trends in total abundance as the kick net sampling methodology is only semi-quantitative and therefore is not a reliable indicator of overall macroinvertebrate abundance (quantitative Surber or Hess sampling would be required if more accurate abundance data was desired). While an increase in %EPT abundance is encouraging at Site 3 it must be noted in real terms, that EPT continue to account for only a very small proportion of the macroinvertebrate community (Figure 4).

The two-way ANOVA results, trend analysis, or NMS do not show any consistent changes at any of the three sites that is indicative of significant degradation or improvement of instream conditions (based on the macroinvertebrate community). Any variations in the macroinvertebrate community over time have resulted primarily from changes in the relative abundances of common taxa rather than any drastic alteration to community structure (such as declines in pollution-sensitive taxa).

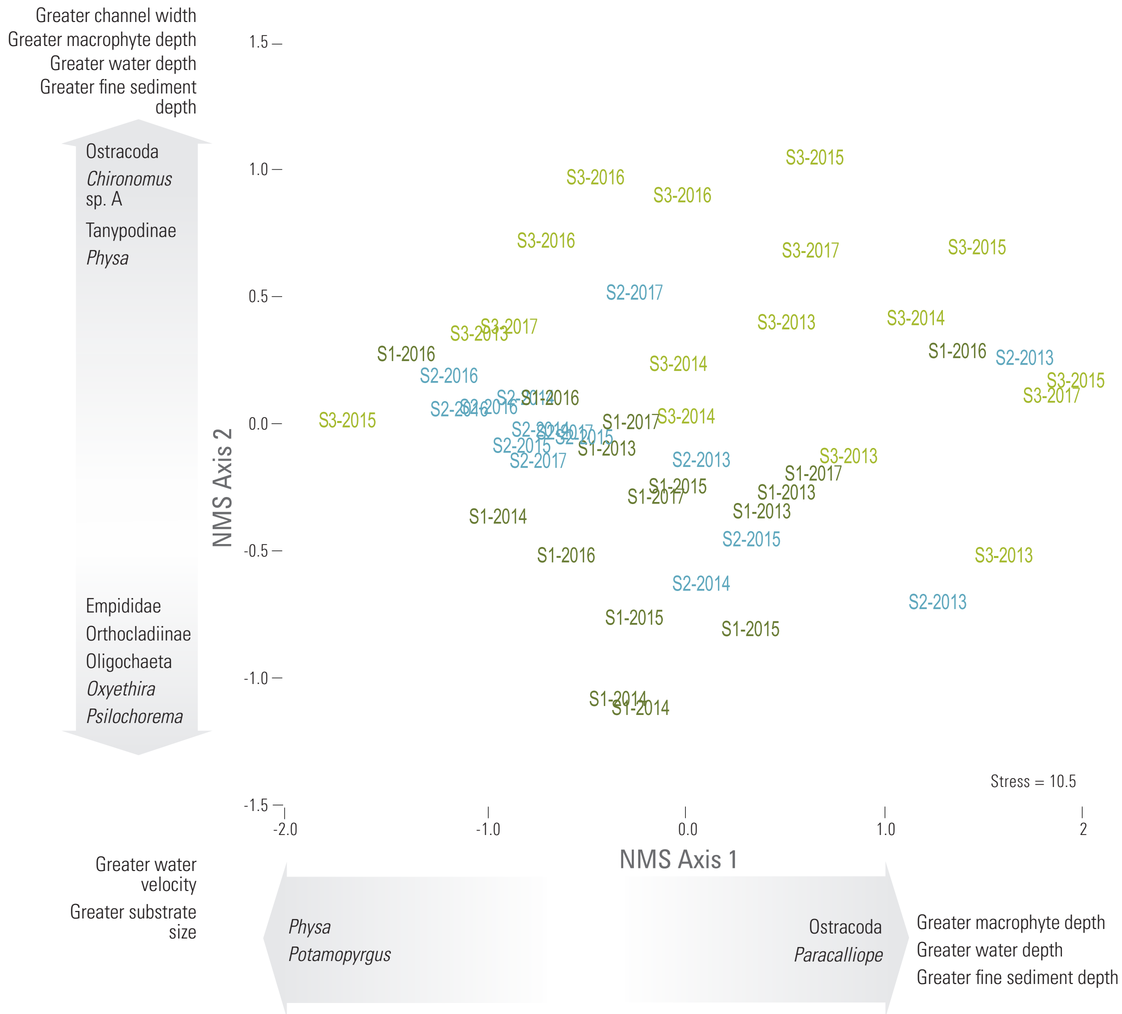

FIGURE 5 Non-metric multidimensional scaling ordination of benthic macroinvertebrate samples collected at the three sites along Cashmere Stream in 2013–2017:
S1 = Site 1 (downstream of Ballantines Drain)
S2 = Site 2 (downstream of Hendersons Rd Drain)
S3 = Site 3 (downstream of Dunbars Drain)
Macroinvertebrate taxa and habitat variables that were correlated with each axis are shown. A stress value of 10.5 is indicative of a fair ordination that is useable.

TABLE 7 Results of the two-way analysis of variance (ANOVA) (with site and year as main factors) on community indices from 2013–2017. The Holm-Sidak *post-hoc* test was used to find which site means were significantly different. n/s = not significant; n/a = not applicable. For some variables ANOVA assumptions could not be met despite data transformation (EPT taxa richness: equal variance; QMCI: normality and equal variance).

Community indices	Site	Year	Site × Year	Site Comparisons	Year or Interaction Comparisons
Total abundance	$F_{2, 30}$= 5.4, p=0.01	$F_{4, 30}$= 6.9, p<0.001	n/s	1>2=3	2013=2014>2016=2017, 2015=2016=2017, 2015=2014=2013
Taxa richness	n/s	$F_{4, 30}$= 16.8, p<0.001	n/s	n/a	2013=2015=2017>2016, 2014>2013=2015, 2014>2016, 2014=2017
EPT taxa richness	n/s	$F_{4, 30}$= 4.9, p=0.004	n/s	n/a	2014=2017>2016, 2017>2015, 2013=2015=2016, 2013=2014=2017, 2014=2015,
% EPT abundance	$F_{2, 30}$= 8.0, p=0.002	$F_{4, 30}$= 9.2, p<0.001	$F_{8, 30}$= 2.5, p=0.033	n/a	2013: 2>3, 1=3, 1=2, 2014: 1>3, 1=2, 2=3, 2015, 2016, 2017: 1=2=3
EPT taxa richness (excl. hydrops)*	n/s	$F_{4, 30}$= 5.2, p=0.003	$F_{8, 30}$= 2.4, p=0.041	n/a	2013, 2014, 2016, 2017: 1=2=3, 2015: 2>3, 1=3, 1=2
% EPT abundance (excl. hydrops)*	$F_{2, 30}$= 7.1, p=0.003	$F_{4, 30}$= 6.6, p<0.001	$F_{8, 30}$= 2.5, p=0.030	n/a	2013: 1=2>3, 2014, 2015, 2016, 2017: 1=2=3
MCI	$F_{2, 30}$= 7.9, p=0.002	n/s	F8, 30= 7.1, p<0.001	n/a	2013, 2014, 2017: 1=2=3, 2015: 1>2=3, 2016: 3>2>1
QMCI	$F_{2, 30}$= 21.4, p<0.001	$F_{4, 30}$= 2.9, p=0.039	n/s	1=2>3	2013>2016, 2014=2015=2016=2017, 2013=2014=2015=2017
UCI	$F_{2, 30}$= 18.7, p<0.001	n/s	n/s	1=2>3	n/a
QUCI	F2, 30= 4.4, p=0.021	$F_{4, 30}$= 6.9, p<0.001	n/s	1>3, 2=3, 1=2	2013>2016=2017, 2013=2014=2015, 2014=2015=2016=2017

* Hydroptilidae trichopterans (*Oxyethira* spp. and *Paroxyethira* spp.) are excluded as they are algal piercers that are often abundant in nutrient-enriched waterways.

TABLE 8 Results of Mann-Kendall trend analysis for macroinvertebrate community indices measured February 2013–2017. Where a significant trend was determined the direction and annual change is shown. In the majority of instances there were no significant trends.

Parameter	Site 1: DS of Ballantines Drain	Site 2: DS of Hendersons Rd Drain	Site 3: DS of Dunbars Drain
Total abundance	29% annual decrease (p=0.023)	No trend (p=0.076)	19% annual decrease (p=0.005)
Taxa richness	No trend (p=0.258)	No trend (p=0.283)	No trend (p=0.959)
EPT taxa richness	No trend (p=1.00)	No trend (p=0.432)	No trend (p=0.717)
% EPT abundance	No trend (p=1.00)	No trend (p=0.879)	No trend (p=0.116)
EPT taxa richness (excl. hydrops)*	No trend (p=0.954)	No trend (p=0.162)	No trend (p=0.342)
% EPT abundance (excl. hydrops)*	No trend (p=0.336)	No trend (p=0.879)	27% annual increase (p=0.029)
MCI	No trend (p=0.447)	No trend (p=0.075)	No trend (p=0.510)
QMCI	No trend (p=0.960)	No trend (p=0.076)	No trend (p=0.288)
UCI	No trend (p=0.244)	No trend (p=0.244)	No trend (p=0.389)
QUCI	No trend (p=0.116)	No trend (p=0.061)	No trend (p=0.172)

3.3 Receiving Environment Objectives

Sites 1 and 2 have met the surface water quality objectives from Consent CRC120223 for fine sediment cover, total macrophyte cover, and filamentous algae cover for the last four years. Conversely, Sites 1 and 2 have not met the QMCI objective for the last four years (Table 9). Site 3 has not met the fine sediment, total macrophyte cover, or QMCI objectives for the entire monitoring period (Table 9).

A comparison with selected 'Freshwater Outcomes for Canterbury Rivers' for Banks Peninsula rivers from the Canterbury Land and Water Regional Plan (LWRP), indicates all sites would have consistently failed to meet the minimum QMCI score from 2013–2017, while Site 3 would also have exceeded the 20% maximum fine sediment cover for all years (Table 10).

TABLE 9 Comparison of 2013–2017 results with the surface water quality objectives from Consent CRC120223. Parameters that do not meet the objectives are shaded. Total macrophyte cover includes both emergent and submerged macrophytes.

Parameter	Surface water quality objectives from Consent CRC120223	SITE 1: DS of Ballantines Drain					SITE 2: DS of Hendersons Rd Drain					SITE 3: DS of Dunbars Drain				
		2013	2014	2015	2016	2017	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Fine sediment cover	Maximum of 30%	15	15	7	1	4	14	15	8	5	15	100	100	100	100	99
Total macrophyte cover	Maximum of 30%	55	8	23	18	21	31	15	6	4	6	79	65	97	97	98
Filamentous algae cover (>20 mm long)	Maximum of 20%	0	0	1	1	0	0	0	0	1	0	0	0	0	1	0
Quantitative macro-invertebrate community index (QMCI)	Minimum score of 4–5	4.10	3.45	3.77	3.72	3.99	4.31	3.90	3.95	3.76	3.94	3.35	3.03	3.36	2.44	3.06

TABLE 10 Comparison of 2013–2017 results with selected 'Freshwater Outcomes for Canterbury Rivers' from Table 1a of the Canterbury Land and Water Regional Plan (Environment Canterbury, 2017) for "Banks Peninsula" class waterways. Parameters that would not meet these limits are shaded.

Parameter	Proposed Canterbury Land & Water Regional Plan – Decisions Version (18 January 2014)	SITE 1: DS of Ballantines Drain					SITE 2: DS of Hendersons Rd Drain					SITE 3: DS of Dunbars Drain				
		2013	2014	2015	2016	2017	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Fine sediment (<2 mm diameter)	Maximum cover of 20%	15	15	7	1	4	14	15	8	5	15	100	100	100	100	99
Filamentous algae (>20 mm long)	Maximum cover of 20%	0	0	1	1	0	0	0	0	1	0	0	0	0	1	0
Quantitative macro-invertebrate community index (QMCI)	Minimum score of 5	4.10	3.45	3.77	3.72	3.99	4.31	3.90	3.95	3.76	3.94	3.35	3.03	3.36	2.44	3.06

3.4 Port Hills Fires

The Port Hills fires commenced burning three days after the completion of the 2017 surveys, and burned a significant area within the Cashmere Stream catchment (Figure 6, Appendix 8.2). Given the presence of erodible loess soils in the catchment there is considerable concern in the community that fine sediment runoff from this area will increase and potentially have adverse effects on Cashmere Stream until vegetation becomes re-established. If sediment inputs are large, then this is likely to override any effects that may be caused by stormwater discharges. Thus undertaking of immediate strategies to reduce erosion in these burnt areas is recommended. Consequently the CCC Port Hills Recovery Group has identified this as a priority and is focussing on re-vegetation of erosion prone areas and detention/treatment of sediment-laden runoff in burnt catchments (Greg Burrell, CCC, pers. comm).

FIGURE 6 An example of fire-scorched earth in the Port Hills following the February 2017 fire. Note grass is already growing. Photo taken on 14 March by EOS Ecology.

4 CONCLUSIONS

4.1 Habitat and Macrophytes

» The general habitat attributes of the three sites are unchanged with the hard-bottomed Site 1 and Site 2 and the soft-bottomed Site 3 remaining as such. No trends in measured habitat parameters were identified, with the exception of a stable (0% annual change) trend in macrophyte depth at Site 3.

» Of the three sites, Site 3 is clearly a more depositional environment and monitoring over the last five years show the fine sediment cover and total macrophyte cover objectives of Consent CRC120223 are unlikely to be ever met at this site.

» The macrophyte community at the monitoring sites was dominated by exotic species, which despite being introduced weedy species still provide habitat and food for aquatic invertebrates (including kōura) and cover for fish especially at Site 3, which is otherwise devoid of stable habitat.

» A summary of the overall state and pressures in the Cashmere Stream catchment is provided by McMurtrie & James (2013), however the Port Hills fires that started on 13 February 2017 burnt a large part of the Cashmere Stream catchment (see Appendix 8.2). This burnt area previously had significant vegetation cover that is now scorched earth and will generate greater volumes of sediment-laden runoff than before the fires (Figure 6). There is the potential this will have adverse impacts on the Cashmere Stream and the burnt tributaries.

4.2 Aquatic Macroinvertebrates

» Taxa typical of sluggish, soft-bottomed streams with abundant macrophyte growth in agricultural and urban catchments in New Zealand dominate the macroinvertebrate community of the three Cashmere Stream sites (i.e., the snail *P. antipodarum,* the amphipod crustacean *P. fluviatilis,* Ostracoda seed-shrimps, and oligochaete worms).

» As in previous years, of the cleanwater pollution-sensitive EPT taxa (mayflies, stoneflies and caddisflies), only caddisflies were recorded from the three monitoring sites. All caddisfly taxa captured in 2017 were known previously from Cashmere Stream and other Christchurch urban streams, thus are a subset of 'cleanwater' caddisfly taxa are able to persist in urban waterways. However, it was notable the cased caddis *H. amabile* appeared among the five most abundant taxa at Site 2, the first time a 'cleanwater' taxon has been in such a position since monitoring began in 2013.

» There was some separation in ordination space of samples from Site 3 from those of Sites 1 and 2. These were likely the result of key habitat differences (i.e., the cobble-pebble substratum, faster velocities, and fewer macrophytes at Site 1 and 2, and the fine sediment substratum and abundant macrophytes at Site 3).

» The only trends in any of the calculated macroinvertebrate community indices identified were significant decreases in total abundance at Site 1 and Site 3 and a significant increase in the %EPT abundance (excl. Hydroptilidae) at Site 3. It would be unwise to place much emphasis on the decreasing trends in total abundance as the kick net sampling methodology is only semi-quantitative and therefore is not a reliable indicator of overall macroinvertebrate abundance. While it was encouraging to see an increased in %EPT abundance at Site 3, these cleanwater taxa remain a very minor proportion of the total macroinvertebrate community (approximately 3%).

- The macroinvertebrate community differences over time and among the three sites were relatively minor and mostly resulted from variations in the relative abundance of dominant taxa rather than any major changes in macroinvertebrate community structure.
- QMCI (and MCI) scores in 2017 indicated all sites were categorised as ‘poor’. However it must be remembered a QMCI score does not have a strong bearing on the ecological value of Cashmere Stream. The macroinvertebrate fauna is dominated by endemic species in a highly modified landscape and Cashmere Stream retains populations of freshwater crayfish/kōura and freshwater mussels/kākahi –two notable mega-invertebrate species that are rare in urban or peri-urban waterways in Christchurch – and has a good diversity of fish species (nine species), with most widely distributed and some limited to specific habitats (e.g., bluegill bully) (McMurtrie & James, 2013). Hence it is considered the best quality sub-catchment of the Heathcote River (James, 2010).

4.3 Assessment of Stormwater Effects

The comments regarding study design in James (2015) are still relevant and will not be repeated in full here. In summary the survey design lacks any control or reference sites, hence it is impossible to determine if stormwater discharges are having any impact on Cashmere Stream. Despite these limitations the annual monitoring does allow for the detection of ‘rapid’ (i.e., yearly) changes over time. In this instance, such annual monitoring has indicated that habitat conditions and macroinvertebrate communities at the three sites have changed little since 2013.

5 RECOMMENDATIONS

The drastic reduction in vegetation cover in the Port Hills part of the Cashmere Stream catchment as a result of the 13 February 2017 fire event will result in increased sediment inputs to Cashmere Stream (see Appendix 8.2). This will be particularly evident over this winter as vegetation regrowth will be sluggish until next spring/summer. The Cashmere Stream Care Group is advocating a range of measures to rehabilitate the catchment (Appendix 8.2). These include immediate actions such as identification of areas with greatest risk of erosion (e.g. excavated fire breaks), implementation of erosion control measures to reduce erosion and sediment runoff, and construction of sediment retention ponds (and use of flocculants) where possible. In the medium to long term it would be advisable to replant the burnt areas in appropriate native species.

The recommendations given in Drinan (2014) and James (2015) are still relevant and all of these will not be repeated here. James (2016) also provided some key recommendations that relate directly to the aims and management outcomes of undertaking such resource consent monitoring. These are still relevant here and are repeated below:

» The greatest limitation of this study (in relation to achieving its reporting objectives) is its design, including site selection, sample replication, and lack of supporting water quality data. Alteration to the study design is required to isolate the effects of stormwater discharges from other temporal variability.

» The site selection of the current monitoring of Cashmere Stream fails to take into account hillside urban developments, which disturb and mobilise erosion-prone loess soils. CCC is partly addressing this in a joint project with Environment Canterbury measuring sediment loads in the Heathcote River and its major tributaries (Greg Burrell, CCC, pers. comm.).

» Some of the surface water quality objectives from Consent CRC120223 are not necessarily in alignment with maintaining ecological health, or directly related to the effects of stormwater discharges. Macrophyte cover in Cashmere Stream is related to maintenance practices and lack of canopy cover rather than stormwater discharges. Additionally, as there is currently little physical habitat diversity within Cashmere Stream, macrophytes provide a major habitat and food source for macroinvertebrates including kōura, provide cover for fish, and trap sediment that is otherwise continuously transported along the stream. Thus keeping macrophyte cover below 30% could be counter to the actual benefits that macrophytes provide this system. I would therefore regard macrophyte cover of greater than 30% to be of no ecological concern, and indeed may be better for the ecological health of this stream.

» The low QMCI scores ("poor"), which in 2017 do not meet the surface water quality objective from Consent CRC120223, reflect the degraded water quality and/or habitat conditions that result from the high proportion of agricultural and urban land use in the catchment. However, Cashmere Stream retains populations of kākahi and kōura as well as nine species of fish, while the macroinvertebrate community is comprised of mostly endemic species in a heavily modified landscape dominated by exotic species. Hence it is important to look beyond single metrics when making conclusions about ecological condition or value.

6 ACKNOWLEDGEMENTS

Thank you to EOS Ecology technical staff for their efforts with fieldwork, laboratory processing and report formatting.

7 REFERENCES

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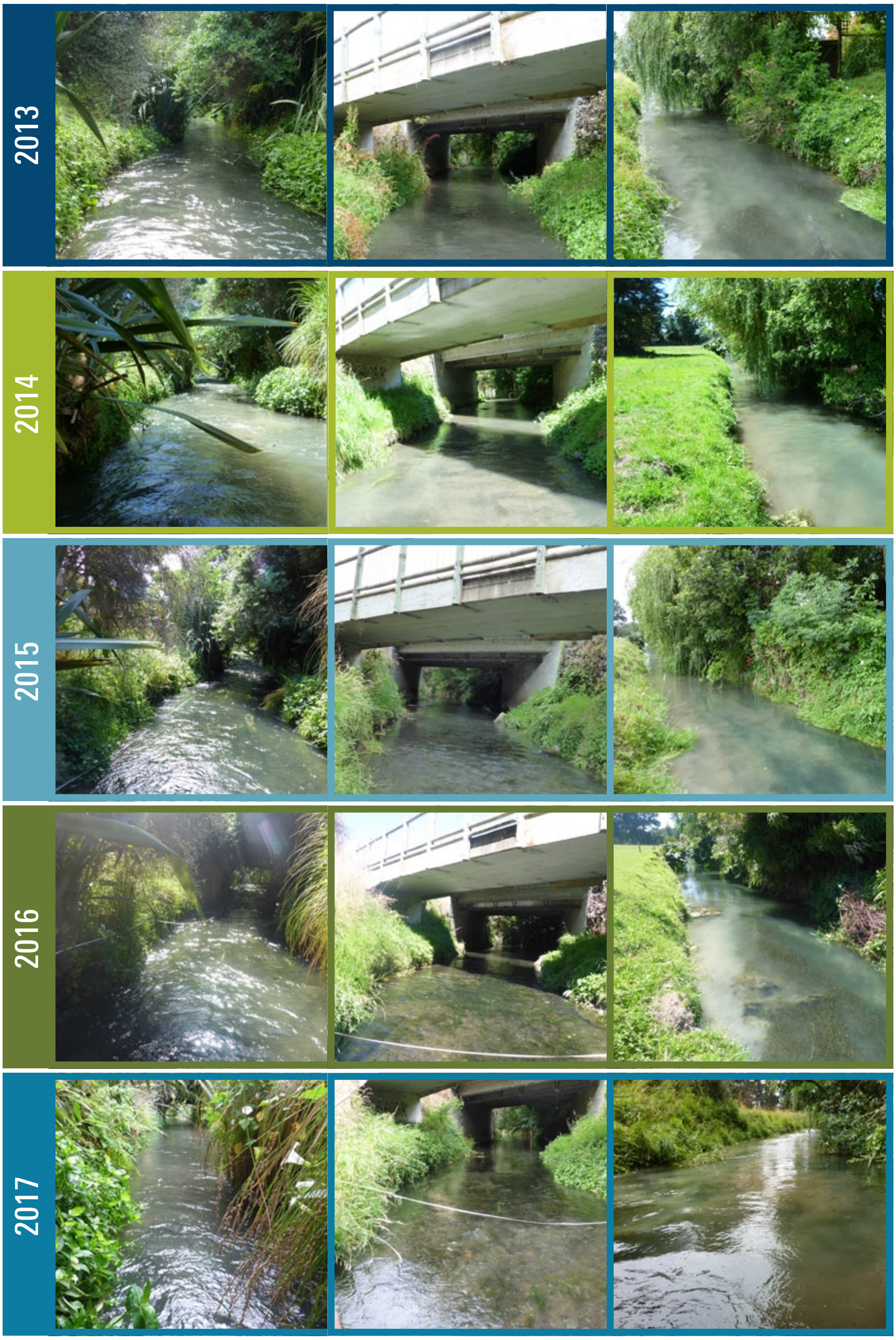
8 APPENDICES

8.1 Site Photographs

SITE 1	SITE 2	SITE 3
Downstream of Ballantines Drain, looking downstream	Downstream of Hendersons Rd Drain, looking upstream	Downstream of Dunbars Drain, looking downstream



8.2 Cashmere Stream Care Group March Newsletter

Port Hills fire,
photo taken 15/02/17, 10:31 pm

IN THIS ISSUE: Post fire situation | Catchment map | What's next ...

SPECIAL EDITION
Post Fire Situation

Christchurch and its residents have paid dearly due to the Port Hills fire. Some personal tolls can never be compensated for, but damage to local environments, wildlife and habitats are within our power to reinstate... with planning and commitment.

Immediate issues facing the Cashmere Stream and Ōpāwaho/Heathcote River catchments in the aftermath of the fire are **erosion** and **sediment runoff**.

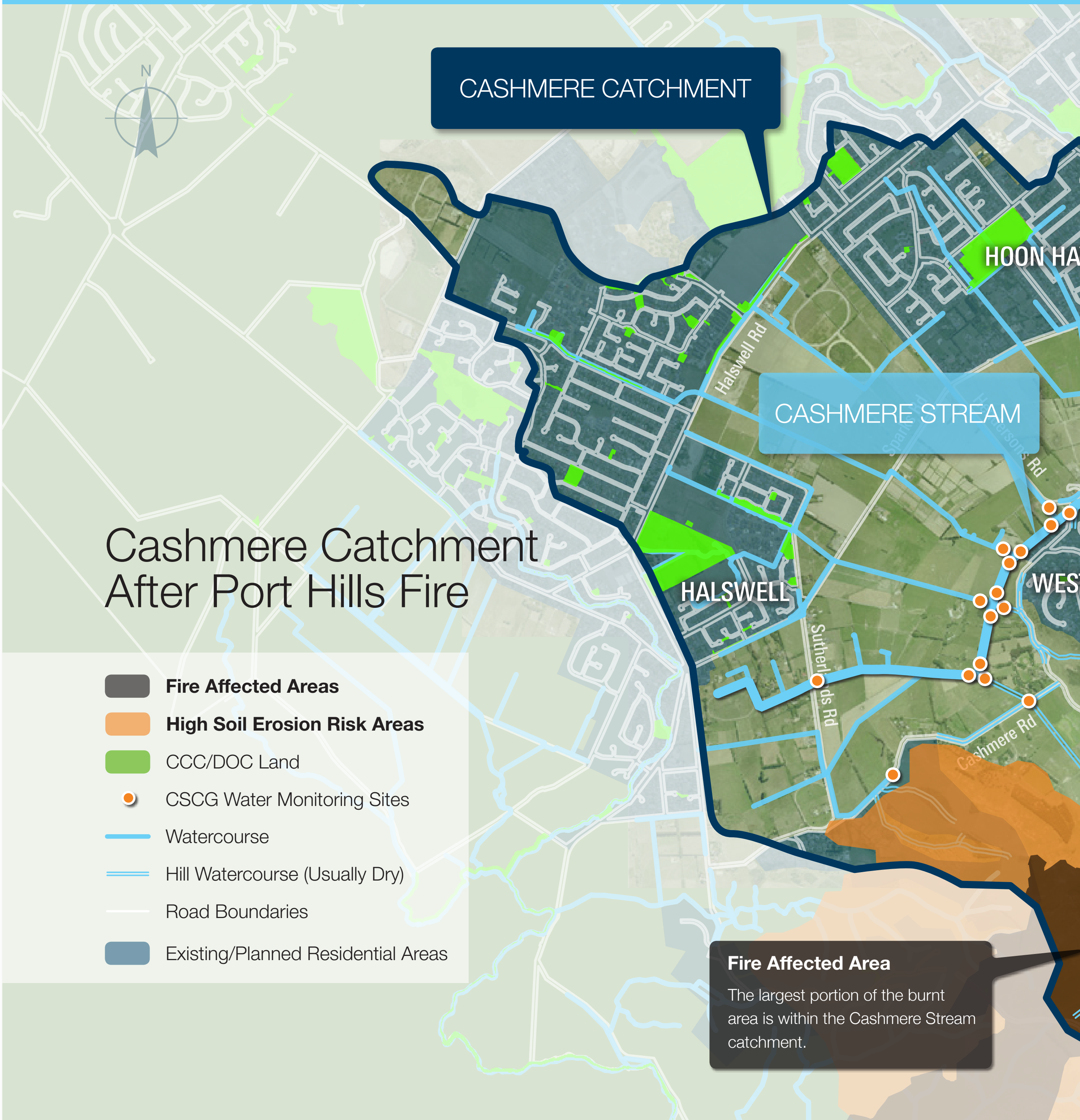
Even before the fires these were serious threats due to the steep, erosion prone terrain and unstable loess soil of the Port Hills. But with substantially less vegetation now holding soil on the Hills, upcoming winter storms could worsen this situation, with potentially thousands of tonnes of soil eroding into the valley catchments – ending up in our waterways.

Once sediment gets into waterways it smothers kōura/freshwater crayfish and kakahi/freshwater mussel populations (both present in Cashmere Stream), as well as other important wildlife and insects in these habitats. This excess sediment build-up could also worsen flooding in some areas.

Now is the time for us to plan for these probabilties and start implementing solutions to ease the outcomes.

Port Hills fire aftermath,
photos taken 13/03/17

Cashmere Catchment After Port Hills Fire



Fire Affected Area

The largest portion of the burnt area is within the Cashmere Stream catchment.

kōura/freshwater crayfish

kakahi/freshwater mussels

All photos © Shelley McMurtrie

Aquatic W

Kōura, kakah
invertebrates
Stream are s
exposure to
in the water.

Port Hills fire aftermath, photos taken 13/03/17

High Soil Erosion Risk Area

...as shown in the Land and Water Regional Plan (supplied by Environment Canterbury). One of the contributing factors for this classification is the soil type in these areas. The Port Hills are cloaked in loess – a fine yellow-brown silty soil. Loess soil is free-draining/fast-drying, but when exposed to rain can erode quickly. The fine silt particles are high in sodium and rapidly disperse in water. It has difficulty settling to the bottom once suspended in water. Exposed loess soils is the biggest contributor of suspended sediment (dirty looking water) in Cashmere Stream.

ildlife Affected

i and other cleanwater
s found in Cashmere
sensitive to prolonged
sediment suspended

CASHMERE STREAM CARE GROUP

What can we do next to improve the situation?

Steps forward advocated by CSCG:

RECOVERY MANAGEMENT

Managing a recovery of this nature is complex. To be effective it needs to be properly scoped and financed with the appropriate expertise onboard. Local authorities are primarily responsible for the recovery – but community groups, private organisations and regional authorities must all play their part. In the immediate future, the recovery team and its key quantifiable targets need to be identified. Once up and running progress needs to be regularly reported on.

- Reseed/replant as large an area as resources permit with local indigenous plant species.
- However, recognise that immediate erosion AND sediment control solutions must also be considered to provide protection whilst vegetation is becoming established.

EROSION CONTROL

- Look at all available options for keeping soil in place, including a mix of soil stabilisers, straw and other materials, and/or hydroseeding – different products will be more or less suitable for different conditions/areas. Reapplication of some products may be required to ensure erosion control is maintained. Guidance on some erosion control measures tested in the catchment can be downloaded at www.ecan.govt.nz/document/download?uri=3002288
- Areas of greatest risk of erosion should be identified and prioritised for control treatment e.g., where subsoils have been exposed such as fire breaks.
- Look at incorporating erosion control measures into revegetation plans.

SEDIMENT RUNOFF CONTROL

- The fine loess soils that cloak the Port Hills are highly dispersive, so uphill erosion control is needed to reduce the burden on downhill sediment control systems.
- Look at all options to create sediment retention ponds and wetlands in flatter downstream areas of tributaries to help trap sediment before it reaches Cashmere Stream. This will also help to reduce flood peaks in the Stream.
- Consider the use of flocculants – substances that promote loess sediment particles clumping together so it sinks, instead of staying suspended in the water.
- Look at other ways to slow down the water as it's moving downhill i.e., a series of small interception points before it reaches the larger downhill treatment systems.

COMMUNITY INVOLVEMENT

- Set up a robust water quality monitoring programme to record performance and efficacy of solutions. The CSCG has an established, long-running monitoring programme that can provide a valuable 'before' data set.
- Allow the public to get involved with these solutions where practical. There are many wanting to do their part, including members of the Cashmere Stream Care Group.

Have your say...

No one knows how many heavy rains we'll get before the Port Hills environment has been re-established. One thing is certain however – they will happen. The recovery management team needs to harness all the goodwill available in the community and employ all the tools recommended above to ensure we don't compound our losses.

We urge YOU to phone or email your local councillors and impress upon them the need for urgency in dealing with these issues BEFORE the first big storm event arrives.

Let us know your comments & find out what else we're up to at...
www.facebook.com/CashmereStreamCareGroup

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