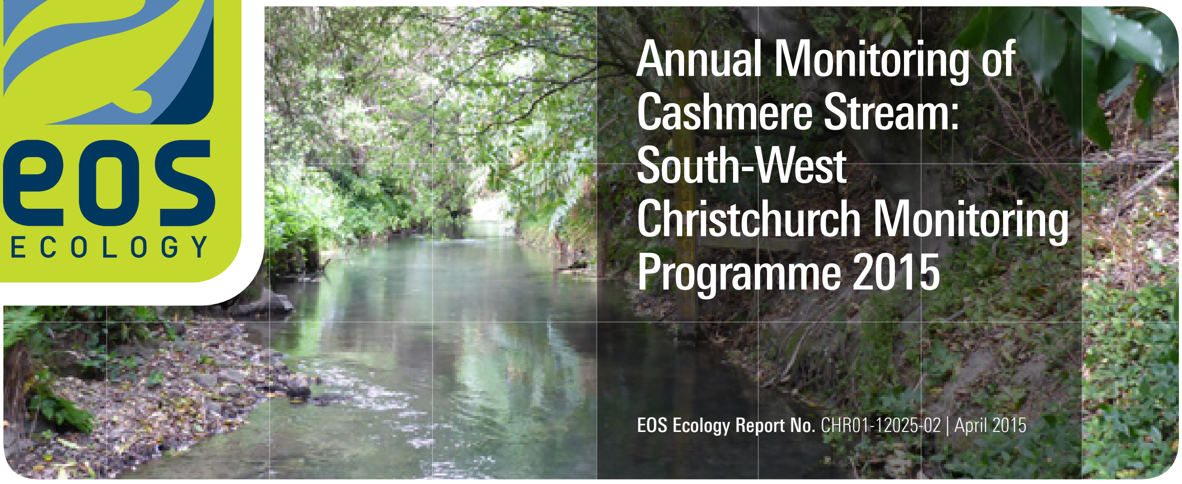

Annual Monitoring of Cashmere Stream: South-West Christchurch Monitoring Programme 2015

EOS Ecology Report No. CHR01-12025-02 | April 2015

AQUATIC SCIENCE &
VISUAL COMMUNICATION

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REPORT

Prepared for
Christchurch City Council

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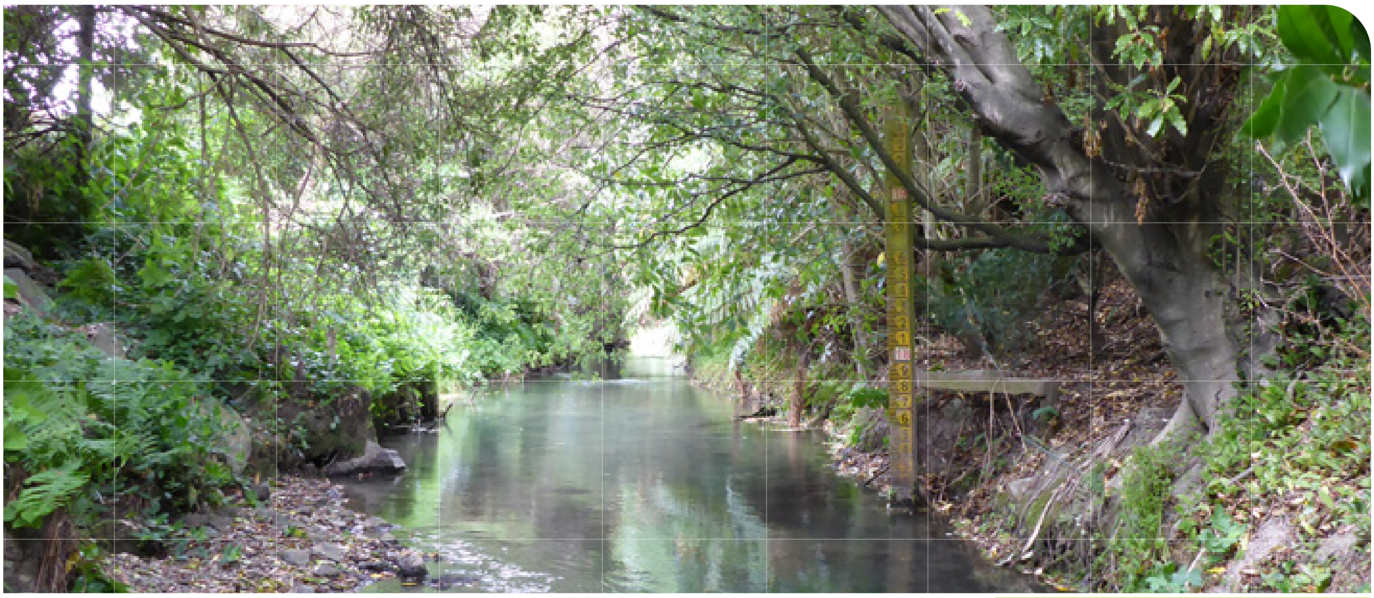

CONTENTS

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 negatively affecting 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 third year of monitoring (undertaken on the 3 February 2015), with the previous rounds having been undertaken in February 2013 and February 2014.

The table below compares the relevant 2015 results with the surface water quality objectives from Consent CRC120223 (cells are shaded where the objectives are 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
		2015	2015	2015
Fine sediment cover	Maximum of 30%	7	8	**100**
Total macrophyte cover	Maximum of 30%	23	6	**97**
Filamentous algae cover (>20 mm long)	Maximum of 20%	1	0	0
Quantitative macroinvertebrate community index (QMCI)	Minimum score of 4–5	**3.77**	**3.95**	**3.36**

Cashmere Stream is a primarily soft-sediment system, although two of the monitoring sites are in some of the few areas of gravel habitat remaining in the system. In terms of the surface water quality objectives of the consent that relate to habitat conditions, Site 3 exceeded the maximum 30% fine sediment cover, given that this site was a soft-sediment site with a 100% cover of fine sediment. The habitat conditions (i.e., slow flowing with a soft sediment base and little shading) of Site 3 also made this site particularly amenable to macrophyte growth compared to Site 1 and 2, and it almost had complete macrophyte cover at 97%, well above the 30% maximum total macrophyte cover objective.

Overall, the macroinvertebrate community was typical of that found in low gradient, lowland streams impacted by agricultural and/or urban development throughout Canterbury. The invertebrate communities of the three sites were dominated by taxa such as the snail *Potamopyrgus antipodarum*, the amphipod crustacean *Paracalliope fluviatilis*, Ostracoda seed-shrimps, and oligochaete worms that prefer and are typical of low gradient, macrophyte-filled streams that are impacted by agricultural and urban land use. The dominance of such taxa that are tolerant of degraded conditions mean the 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. Of the more sensitive "cleanwater" EPT taxa, only caddisflies were present in Cashmere Stream, and then in small relative abundances. All the caddisfly taxa found were known previously from Cashmere Stream and other Christchurch waterways.

Over the three years there have not been any major changes in habitat condition or in the macroinvertebrate community. There have however, been some variations in a few parameters that are worth noting; at Sites 1 and 2 water depths were greater in 2013, at all sites water velocities were greater in 2014, and macrophyte depth was higher at Site 3 in 2013 and 2015. In terms of the macroinvertebrate community, at all sites taxa richness was greater in 2014 compared to other years, and EPT taxa richness (with hydroptilid caddisflies excluded) was significantly lower at Site 3 in 2015. While not statistically significant, QMCI at Sites 1 and 2 decreased from being in the "fair" quality class in 2013 to being in the "poor" quality class in 2014 and 2015. Due to the limitations of the current study design – particularly the lack of any control or reference site – it is not possible to determine whether stormwater discharges (or any other anthropogenic or natural factors) were responsible for any changes or observed variations in the aquatic habitat or macroinvertebrate communities. There are also a number of stormwater discharges from large developments on the south (hill) side of the catchment, which given the location of the current monitoring sites, cannot be differentiated from South West Christchurch developments that are the focus of this consent monitoring.

Despite exceeding the surface water quality objective for macrophyte cover at Site 3, given the otherwise poor habitat at this site (i.e., a heavily silted channel) I would regard a higher level of macrophyte cover as being beneficial to the ecology of the stream rather than detrimental. In addition, without a significant change to catchment management to reduce sediment input, followed by a clearance of existing sediment in Cashmere Stream and its tributaries and a change to channel morphology, I do not see that Site 3 will ever have fine sediment cover much below 100%. It therefore seems beyond the realms of a stormwater discharge consent to be able to meet this objective for this site.

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 and first carried out in February 2013. The CCC then commissioned EOS Ecology to undertake the aquatic surveys in 2014 and 2015. The 2014 results are presented in Drinan (2014), while this report covers the 2015 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 and 2014) 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 and 3 February 2014, 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: 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] (Figure 1). 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.

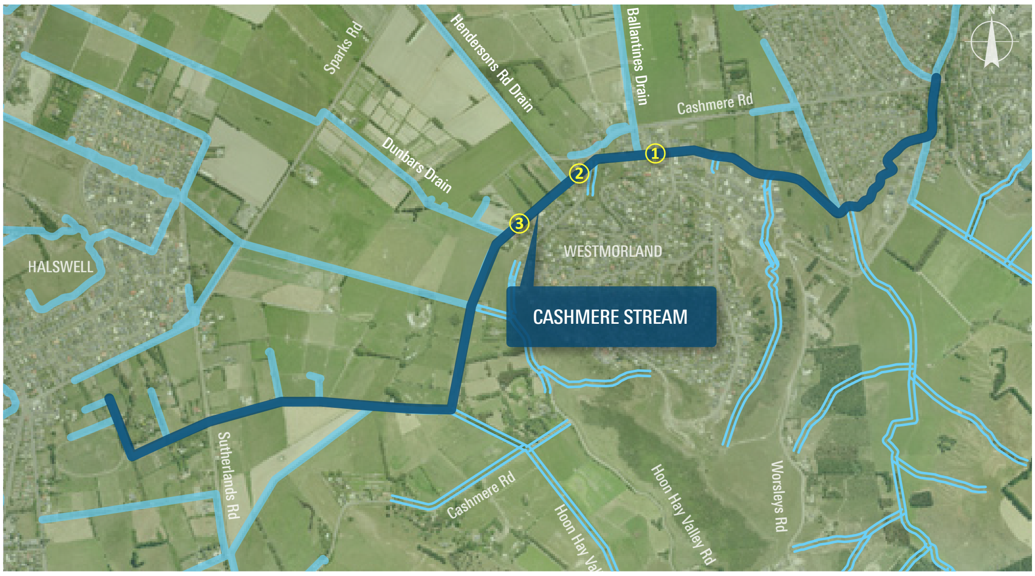

FIGURE 1 Location of the three monitoring sites on Cashmere Stream. Site photographs are provided in the Appendix (Section 9.1). SITE 1: DS of Ballantines Drain, SITE 2: DS of Hendersons Rd Drain, and SITE 3: DS of Dunbars Drain.

2.2 Sampling

Following fine weather conditions, EOS Ecology undertook habitat and aquatic invertebrate surveys at each of the three monitoring sites on 3 February 2015. At each site aspects of the instream habitat and aquatic invertebrate community were quantified along three transects across the stream placed 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: >256 mm; 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: >256 mm; 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 along the 20 m site on either side of the bank. 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 kicknet (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 and 2015 compared to 2013. These methodological differences were:

- The macrophyte cover assessment was altered in 2014 and 2015, compared with 2013. In 2013, macrophytes were assessed over the whole site, while in 2014 and 2015 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 2015, compared with 2013. In 2013, only the 'algal mats' and 'filamentous algae' categories were used,

while in 2014 and 2015 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 can be used as an indication of stream health or habitat type, where sites with greater taxa richness are usually healthier and/or have a more diverse habitat.

» 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 and degraded 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 invertebrate community indices between sites (Sites 1–3) in 2015. Data transformations were used (e.g., square root and fourth root), 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 find 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 means were observed.

In addition, two-way ANOVAs – with site and time as main factors – were used to investigate differences in aquatic invertebrate community indices and habitat attributes between sites (Sites 1–3) and years (2013, 2014, and 2015). For the purposes of considering temporal change, only significant year and site × year interactions were discussed within the text. Although significant site results were 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 invertebrate community indices, 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.

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 2015 Results

The adjacent land use for Cashmere Stream near the three monitoring sites is of rural (farming) and residential use. The banks of Site 1 (DS of Ballantines Drain) and Site 3 (DS of Dunbars Drain) were comprised mainly of natural earth and rock (Table 1). As a road bridge and footbridge were present at Site 2 (DS of Hendersons Rd Drain), the banks were comprised of a mixture of both natural earth and brick/concrete (Table 1). Riparian vegetation composition was typically comprised of a grass/herb mix at all three sites, with Site 1 having a canopy of mainly native trees and shrubs, while Site 3 had a canopy comprising mostly of exotic trees and shrubs (Table 1). Canopy shade was greatest at Site 1 (up to 50–75% on the TRB), but only reached 5–25% at Site 3. While canopy shade was low at Site 2 (<5% on both banks), site-wide shading was higher when the shade from the overhead bridge and footbridge was taken into account. Sites 1 and 2 were a 50/50 mix of run and riffle habitat, while Site 3 was 100% run habitat (Table 1). Sites 1 and 2 were dominated by a coarser substrate, while Site 3 was soft-bottomed with a 100% cover of mud/silt/clay (Table 1). Due to the predominance of fine substrate at Site 3, substrate embeddedness was also greatest at this site (Table 1).

All of the six analysed instream habitat variables were significantly different between sites in 2015 (Figure 2; Table 2). The wetted channel width at Site 1 was significantly narrower than the other two sites (Figure 2; Table 2), while water velocity at Sites 1 and 2 was significantly faster than that at Site 3 (Figure 2; Table 2). The highest mean water velocity (0.61 m/s) was recorded at Site 1 (Figure 2; Table 2). In terms of substrate, Site 3 had a significantly lower substrate index value (made up of fine silt) than the other two sites that had a greater proportion of pebble/cobble substrate (Figure 2; Table 2). As a result of the 100% fine sediment cover of Site 3, this site also had a significantly greater fine sediment depth than the other two sites (Figure 2; Table 2). Site 3 was also had significantly deeper water than the other two sites (Figure 2; Table 2). Macrophyte depth was significantly greater at Site 3 in comparison to the other two sites (Figure 2; Table 2).

In terms of macrophyte cover, Site 3 had the greatest total cover (at 97%), which was primarily made up of the exotic macrophytes *Elodea canadensis* (Canadian pondweed; 50%) and *Potamogeton crispus* (curly pondweed; 45%) (Table 3). Total macrophyte cover was low at Site 1 and 2 (23% and 6%, respectively), and was made up mostly of *P. crispus* (20 and 5% cover, respectively) (Table 3). With the exception of *Lemna minor* (native duckweed), all macrophyte taxa recorded were exotic (i.e.,introduced) species. In terms of algal cover, four of the five Biggs & Kilroy algal types were recorded, and only at Sites 1 and 2. Algal mats (thin) had 14% and 40% cover at Sites 1 and 2, respectively, while medium algal mats were the dominant (50%) algal cover at Site 2. Filamentous algae (long and short) were only present at Site

1, and then at only 1% cover for each category (Table 3). At 50% cover, bryophytes (mosses/liverworts) had a greater coverage at Site 1 (where they would have been attached to the coarse substrate) than at the other sites (Table 3).

TABLE 1 Habitat attributes from each of the three monitoring sites on Cashmere Stream for 2015. These attributes were measured over the entire site (i.e., a single site-wide value). TLB = true left bank, TRB = true right bank. DS = downstream.

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%	None
	Boulder	2%	2%	None
	Large cobble	20%	10%	None
	Small cobble	**40%**	**40%**	None
	Pebble	30%	19%	None
	Gravel	None	20%	None
	Sand	None	8%	None
	Mud/silt/clay	7%	None	**100%**
Surrounding land use	TLB	70% residential (new) & 30% park/reserve	50% rural with stock (unfenced) & 50% residential (old)	100% rural with stock (fenced)
	TRB	50% residential (new) & 50% park/reserve	50% rural with stock (unfenced) & 50% residential (old)	100% residential (old)
Habitat type (% riffle:run:pool)		50:50:0	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 minor rock)
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, ferns and native trees	Grass/herb mix, some low ground cover, exotic shrubs, native trees and exotic deciduous trees
Canopy cover (% stream shade)	TLB	25–50%	<5% (25–50% when including bridges)	<5%
	TRB	50–75%	<5% (25–50% when including bridges)	5–25%
Substrate embeddedness		25–50%	25–50%	>75%

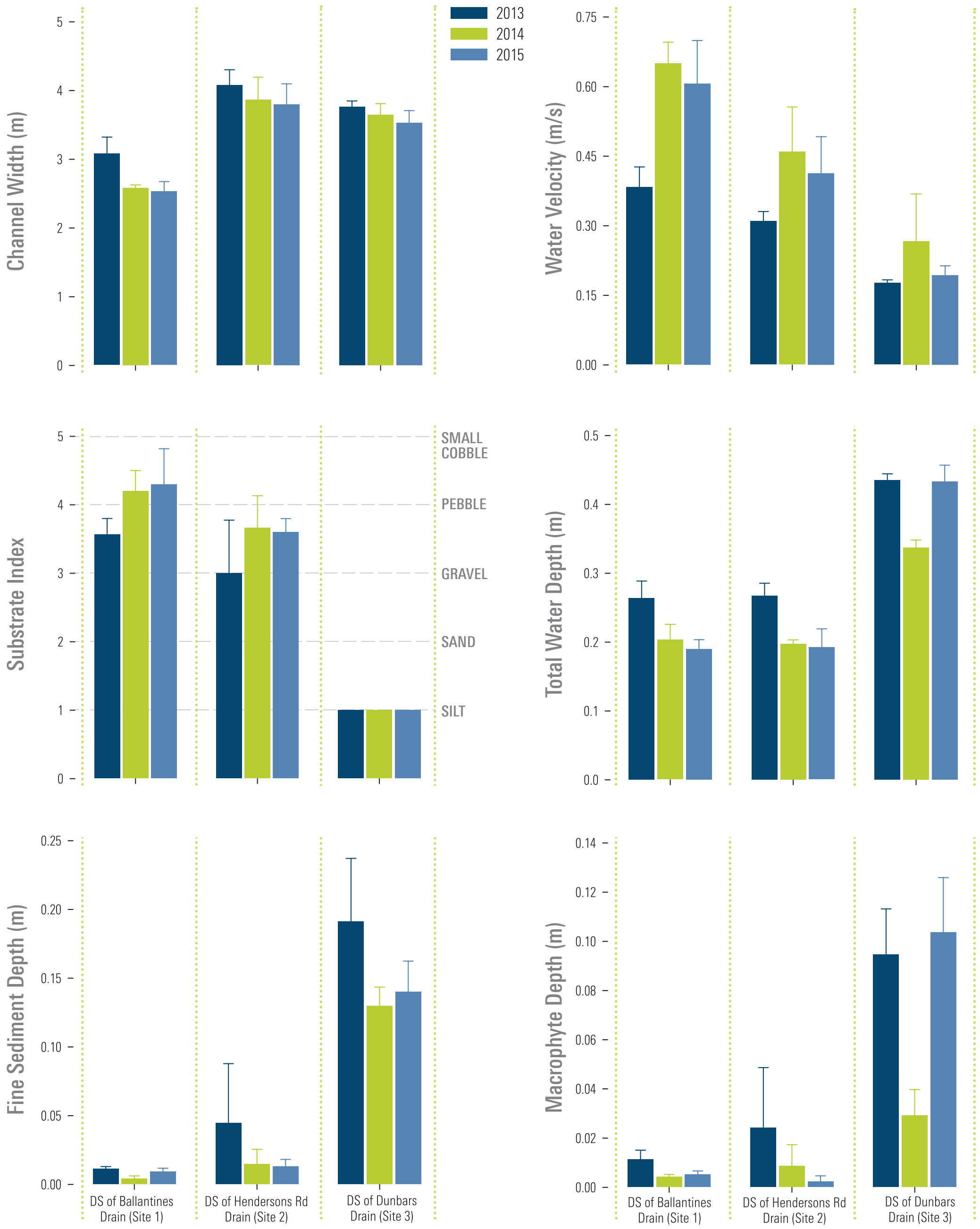

FIGURE 2 Mean (± 1 standard error) habitat attribute values at each of the three monitoring sites on Cashmere Stream for 2013–2015. Aquatic invertebrate and habitat surveys were undertaken on 8 February 2013, 3 February 2014, and 3 February 2015 by EOS Ecology.

TABLE 2 Results of the one-way analysis of variance (ANOVA) or Kruskal-Wallis test on aquatic habitat attributes from 2015 data. The Holm-Sidak *post-hoc* test was used to find which site means were significantly different.

Habitat parameter	ANOVA result	Significant site differences
Channel width	$F_{2,8}$= 9.46, p<0.05	2=3>1
Water velocity	H= 31.30, p<0.001	1=2>3
Substrate index	$F_{2,8}$= 29.26, p<0.001	1=2>3
Total water depth	H=25.95, p<0.001	3>2=1
Fine sediment depth	H= 67.15, p<0.001	3>2=1
Macrophyte depth	H=36.71, p<0.001	3>2=1

TABLE 3 Macrophyte and periphyton attributes from each of the three monitoring sites on Cashmere Stream for 2015. 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): 14%	Algae – thin mat/film (<0.5 mm thick): 40%	*Elodea canadensis* (Canadian pondweed): 50%
	Algae – filaments long (>20 mm long): 1%	Algae – medium mat (0.5–3 mm thick): 50%	*Potamogeton crispus* (curly pondweed): 45%
	Algae – filaments short (<20 mm long): 1%	Moss/liverworts: 1%	*Lemna minor* (duckweed): 1%
	Moss/liverworts: 50%	*Potamogeton crispus* (curly pondweed): 5%	*Glyceria* (sweetgrass): 1%
	Potamogeton crispus (curly pondweed): 20%	*Elodea canadensis* (Canadian pondweed): 1%	
	Callitriche: 1%	Terrestrial roots/vegetation: 1%	
	Glyceria (sweetgrass): 1%	Fine detritus: 1%	
	Elodea canadensis (Canadian pondweed): 1%	Woody debris: 1%	
	Terrestrial roots/vegetation: 10%		
	Woody debris: 1%		
Emergent macrophyte cover	0%	0%	2%
Total macrophyte cover†	23%	6%	97%

* 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 (2013–2015)

Two of the six analysed instream habitat variables were significantly different over the three years (Figure 2; Table 4). Water velocity overall was significantly greater in 2014 in comparison with 2013 and 2015 (Figure 2; Table 4). Total water depth was significantly greater in 2013 compared to 2014 and 2015 (Figure 2; Table 4). There was a significant site × year interaction for macrophyte depth with Site 3 having greater macrophyte depth than the other two sites, but only in 2013 and 2015 (Figure 2; Table 4).

TABLE 4 Results of the two-way analysis of variance (ANOVA) (with site and year as main factors) on aquatic habitat attributes from 2013–2015. The Holm-Sidak *post-hoc* test was used to find which site means were significantly different. n/s = not significant; n/a = not applicable.

Habitat parameter	Site	Year	Site × Year	Comparisons between years
Channel width	$F_{2, 18} = 26.65$, $p<0.001$	n/s	n/s	n/a
Water velocity	$F_{2, 261} = 3.44$, $p=0.033$	$F_{2, 261} = 3.60$, $p=0.029$	n/s	2014>2013=2015
Substrate index	$F_{2, 18} = 54.19$, $p<0.001$	n/s	n/s	n/a
Total water depth	$F_{2, 18} = 97.23$, $p<0.001$	$F_{2, 18} = 13.01$, $p<0.001$	n/s	2013>2014=2015
Fine sediment depth	$F_{2, 18} = 35.94$, $p<0.001$	n/s	n/s	n/a
Macrophyte depth	$F_{2, 18} = 24.39$, $p<0.001$	$F_{2, 18} = 3.94$, $p=0.038$	$F_{4, 18} = 2.99$, $p=0.047$	Site 3 > than other sites in 2013 & 2015

3.2 Aquatic Invertebrates

3.2.1 Overview of 2015 Results

A total of 35 invertebrate taxa were recorded from the three aquatic invertebrate and habitat monitoring sites in 2015, with taxa richness per site ranging from 23 to 27. The most diverse groups were the true flies (Diptera: 11 taxa), followed by caddisflies (Trichoptera: 8 taxa), crustaceans (Crustacea: 4 taxa) and molluscs (Mollusca: 4 taxa) and water bugs (Hemiptera: 2 taxa). Damselflies (Odonata), mites (Arachnida: Acari), leeches (Hirudinea), roundworms (Nematoda), worms (Oligochaeta), and *Hydra* (Cnidaria: Hydrozoa) were each represented by a single taxon.

The snail *Potamopyrgus antipodarum* was the dominant species, accounting for 46% of all invertebrates captured. This was followed by the amphipod crustacean *Paracalliope fluviatilis*, which accounted for 22% of all invertebrates captured. These taxa were widespread, being recorded from all three sites. 'Cleanwater' EPT taxa were uncommon across all sites, with no mayflies (Ephemeroptera) or stoneflies (Plecoptera) recorded. Of the caddisflies (Trichoptera), the most abundant and widespread taxon recorded was the cased caddis *Hudsonema amabile* (2% of total invertebrate abundance). The remaining seven caddisfly taxa included the pollution-tolerant hydroptilids *Oxyethira albiceps* (0.9%) and *Paroxyethira* (0.12%), and the 'cleanwater' species –*Hydrobiosis parumbripennis* (0.29%), *Triplectides* (0.66%), *Psilochorema* (0.55%), *Oecetis unicolor* (0.31%) and *Polyplectropus* (0.02%) – which combined accounted for 2.8% of total invertebrate abundance.

In terms of the five most abundant taxa, the communities of all three sites in 2015 were broadly similar. *P. antipodarum* and *P. fluviatilis* were the dominant taxa at Site 1 and 2, while at Site 3 *P. fluviatilis* and Ostracoda dominated, with *P. antipodarum* third (Figure 3). Species evenness was low at all sites, with the five most abundant taxa at each site accounting for over 85% of total abundance.

With respect to community indices, total abundance (i.e.,total number of invertebrate individuals per sample), taxa richness, percentage EPT abundance, QMCI, and QUCI were statistically similar between the three sites (Figure 4; Table 5). While not statistically significant, percentage EPT abundance (both including and excluding hydroptilids) tended to be greater at Site 1 and least at Site 3 (Figure 4). EPT taxa richness (both including and excluding hydroptilids) showed statistically significant differences, although these were small with the *post-hoc* means test not being able to separate means when hydroptilid caddisflies are included (Figure 4; Table 5). With hydroptilid caddisflies excluded, Site 2 had greater EPT taxa richness than Site 3, however Site 1 was similar to both Site 2 and 3 (Figure 4, Table 5). While there was a significant difference in MCI scores between sites, the *post-hoc* means test was not able to separate the means, which were all below 80 and therefore in the "poor" 'quality class' of Stark & Maxted (2007b). In 2015, the QMCI also indicated all three sites were in the 'poor' quality class. The UCI scores were significantly different between sites, with Site 3 having a significantly lower score than the other two sites (Figure 4; Table 5). Site 3 also recorded the lowest QUCI score of the three sites; however, the difference between sites was not statistically significant due to a large within-site variation (Figure 4; Table 5).

FIGURE 3 Photographs of the five most abundant taxa (% relative abundance per site indicated) from the three monitoring sites for 2013–2015. Those taxa designated as 'widespread' were found at all three monitoring sites in that particular survey year.

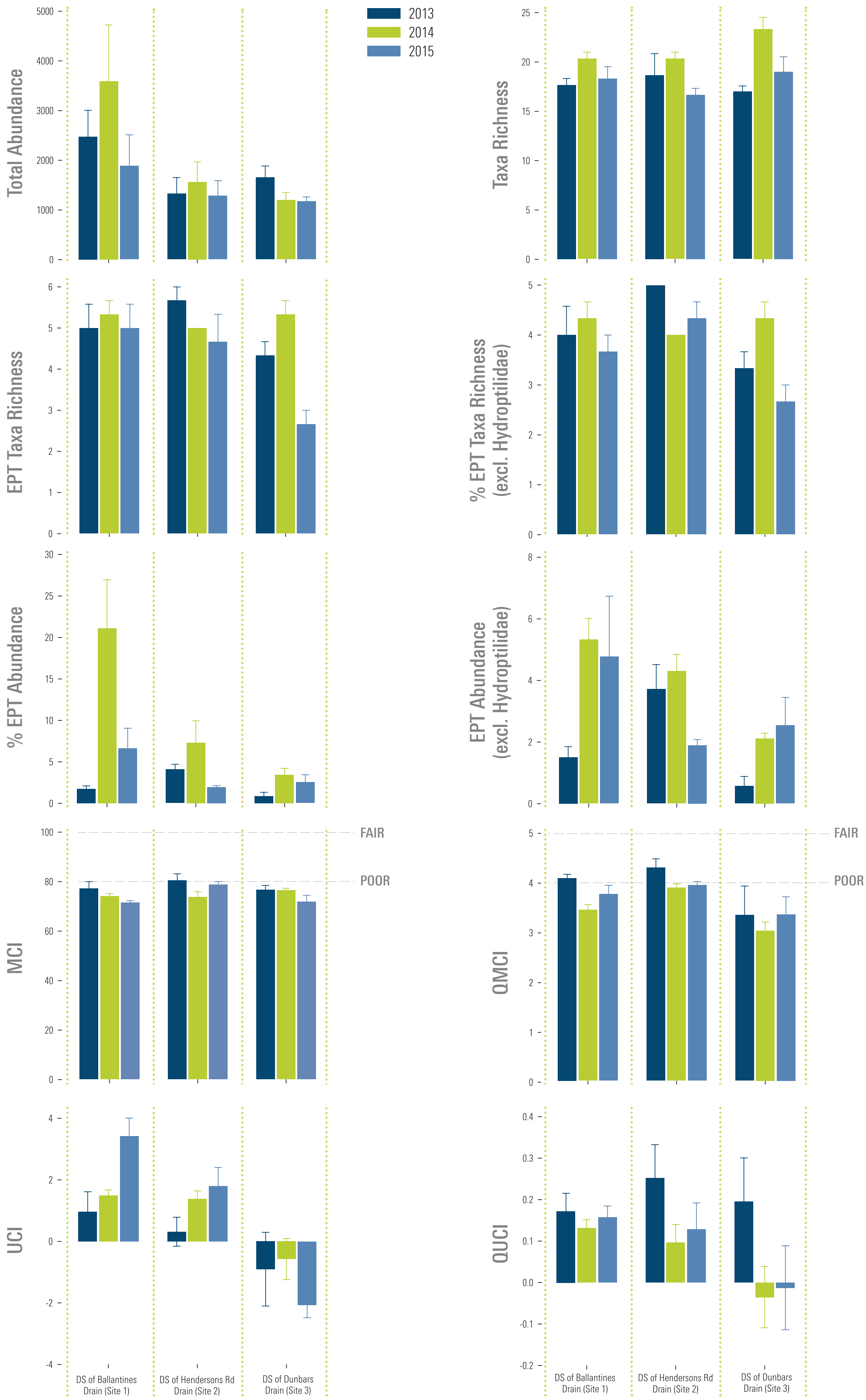

FIGURE 4 Mean (± 1 standard error) community indices at each of the three monitoring sites on Cashmere Stream for 2013–2015. EPT metrics are presented with and without Hydroptilidae, as hydroptilid trichopterans (*Oxyethira* and *Paroxyethira*) are algal piercers that are often abundant in polluted waterways. 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 5 **Results of the one-way analysis of variance (ANOVA) on community indices from 2015. The Holm-Sidak *post-hoc* test was used to find which site means were significantly different. n/s = not significant; n/a = not applicable.**

Community indices	ANOVA result	Signifacnt site differences
Total abundance	n/s	n/a
Taxa richness	n/s	n/a
EPT taxa richness	$F_{2, 8}$= 5.4, p=0.046	Differences too weak for *post-hoc* test to determine
% EPT abundance	n/s	n/a
EPT taxa richness (excl. Hydroptilidae)*	$F_{2, 8}$= 6.3, p=0.03	2>3, 1=3, 1=2
% EPT abundance (excl. Hydroptilidae)*	n/s	n/a
MCI	$F_{2, 8}$= 5.7, p=0.04	Differences too weak for *post-hoc* test to determine
QMCI	n/s	n/a
UCI	$F_{2, 8}$= 16.5, p<0.05	1=2>3
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 (2013–2015)

In terms of the five most abundant taxa, the communities of all three sites in 2015 were broadly similar to previous years with the same core taxa dominating (Figure 3). *P. antipodarum* and *P. fluviatilis* were the dominant two taxa at all sites for all years, with the two exceptions of Site 1 in 2014 (where there was a high abundance of *O. albiceps* (20%) that was not observed in 2015) and Site 3 in 2015 (where Ostracoda were particularly abundant (24%))(Figure 3).

With respect to community indices, taxa richness at all three sites was significantly greater in 2014 in comparison with 2013 and 2015 (Figure 4; Table 6). EPT taxa richness was significantly lower in 2015 compared to 2013 and 2014 (mostly because of the particularly low value observed at Site 3 in 2015), and EPT taxa richness excluding hydroptilids had a significant site × year interaction, which was related to Site 3 being less than the other sites in 2015 (Figure 4; Table 6). Percentage EPT abundance also had a significant site × year interaction, with Site 1 being much greater than other sites in 2014; a relationship that was not evident in 2013 or 2015 (Figure 4; Table 6). This was largely driven by an increase in the abundance of the algal-piercing hydroptilid *O. albiceps* at Site 1, which increased dramatically from 2013 to 2014, before dropping again in 2015 (i.e., 0.2% relative abundance in 2013, 20% in 2014, and 2% in 2015). With hydroptilids excluded, percentage EPT abundance was greater in 2014 than in 2013, while 2015 was not significantly different between 2015 and the two previous years (Table 6). There was a significant change in MCI scores with year, although these were small with the *post-hoc* means test not being able to separate means (Figure 4; Table 6). Apart from the mean MCI score at Site 2 in 2013 just falling in the 'fair' quality class of Stark & Maxted (2007b), all other sites and times have consistently been ranked as 'poor' by this metric (Figure 4). Neither UCI or QMCI showed any statistically significant changes over time, however QMCI did decrease at both Sites 1 and 2 from 2013 to 2014 and remained lower in 2015 (compared to 2013) such that these sites were both ranked as 'poor' in 2014 and 2015 after being 'fair' in 2013 according to the water quality classes of Stark & Maxted (2007b) (Figure 4).

The QMCI score at Site 3 has remained within the ‘poor’ quality category for all years (Figure 4). While not statistically significant, UCI showed a clear increase at Site 1 and a clear decrease at Site 3 in 2015 compared to previous years (Figure 4). QUCI scores displayed a significant difference over time although the post-hoc means test was unable to separate the means, although the overall trend is for a decrease at all sites from 2013 to 2014, with a small but consistent increase in values in 2015 across all sites (Figure 4; Table 6).

The NMS ordination showed samples from Site 3 were more variable in terms of their macroinvertebrate community composition over the three years than the other two sites (Figure 5). Samples from Site 1 and 2 tended to be separated from those of Site 3 and were associated with higher water velocities and substrate index values (indicating a coarser substratum) on both Axis 1 and 2. Along Axis 1, the majority of Site 1 and 2 samples were associated with the snail *P. antipodarum*, oligochaete worms, Empididae fly larvae, and the caddisflies *Psilochorema*, and *Hydrobiosis*, while along Axis 2 these samples were associated with orthoclad midge larvae, oligochaete worms, and the caddisflies *Psilochorema*, *Hydrobiosis*, and *Oxyethira*. Samples from Site 3, in particular those from 2015, were associated with Ostracoda seed shrimps, the amphipod crustacean *P. fluviatilis*, a midge larvae (*Chironomus* sp.), Sphaeriidae pea clams, and greater water, macrophyte, and fine sediment depths (Figure 5).

TABLE 6 Results of the two-way analysis of variance (ANOVA) (with site and year as main factors) on community indices from 2013–2015. The Holm-Sidak *post-hoc* test was used to find which site means were significantly different. n/s = not significant; n/a = not applicable.

Community indices	Site	Year	Site × Year	Comparisons between years
Total abundance	$F_{2, 18}$ = 6.2, p<0.05	n/s	n/s	n/a
Taxa richness	n/s	$F_{2, 18}$ = 8.8, p<0.01	n/s	2014>2013=2015
EPT taxa richness	$F_{2, 18}$ = 5.4, p<0.05	$F_{2, 18}$ = 5.6, p<0.05	n/s	2013=2014>2015
% EPT abundance	$F_{2, 18}$ = 10.4, p<0.01	$F_{2, 18}$ = 14.9, p<0.001	$F_{4, 18}$ = 4.3, p=0.013	Site 1 > other sites in 2014
EPT taxa richness (excl. hydrops)*	$F_{2, 18}$ = 6.7, p<0.01	n/s	$F_{4, 18}$ = 3.1, p=0.041	Site 3 < other sites in 2015
% EPT abundance (excl. hydrops)*	$F_{2, 18}$ = 5.3, p<0.05	$F_{2, 18}$ = 4.1, p<0.05	n/s	2014>2013, 2013=2015, 2014=2015
MCI	n/s	$F_{2, 18}$ = 3.9, p<0.05	n/s	Differences too weak for *post-hoc* test to determine
QMCI	$F_{2, 18}$ = 7.6, p<0.01	n/s	n/s	n/a
UCI	$F_{2, 18}$ = 20.5, p<0.001	n/s	n/s	n/a
QUCI	n/s	$F_{2,18}$ = 3.6, p<0.05	n/s	Differences too weak for *post-hoc* test to determine

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

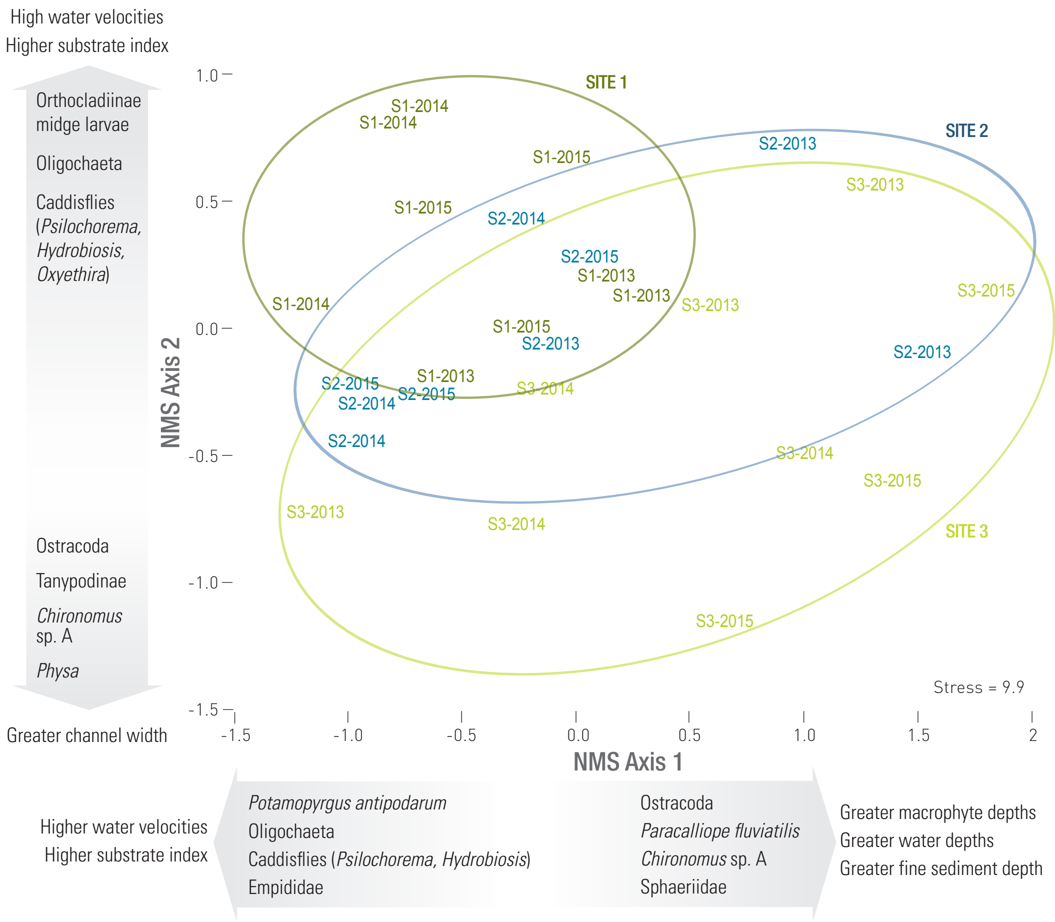

FIGURE 5 Non-metric multidimensional scaling ordination of benthic macroinvertebrate samples collected at the three sites along Cashmere Stream in 2013, 2014, and 2015. S1 = SITE 1 (downstream of Ballantines Drain, S2 = SITE 2 (downstream of Hendersons Rd Drain), and S3 = SITE 3 (downstream of Dunbars Drain). Macroinvertebrate taxa and habitat variables that were correlated with each axis are shown.

3.3 Comparison of Results with Receiving Environment Objectives and Other Guidelines

Just as they did in 2014, in 2015 Sites 1 and 2 meet the surface water quality objectives from Consent CRC120223 with the exception of QMCI (Table 7). Site 3 has consistently not met the fine sediment, total macrophyte, and QMCI objectives in any of the years. Given this site had a fine sediment bed and was dominated by macrophytes it was not surprising that it exceeds the fine sediment cover and macrophyte cover objectives.

A comparison with the latest version of selected 'Freshwater Outcomes for Canterbury Rivers' for Banks Peninsula rivers from the Canterbury Land and Water Regional Plan (LWRP), indicates that all sites consistently fail to meet the minimum QMCI score from 2013–2015, while Site 3 would also have exceeded the 20% maximum cover of fine sediment for all years (Table 8).

TABLE 7 Comparison of 2013–2015 results with the surface water quality objectives from Consent CRC120223. Parameters that breach 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	2013	2014	2015	2013	2014	2015
Fine sediment cover	Maximum of 30%	15	15	7	14	15	8	**100**	**100**	**100**
Total macrophyte cover	Maximum of 30%	**55**	8	23	**31**	15	6	**79**	**65**	**97**
Filamentous algae cover (>20 mm long)	Maximum of 20%	0	0	1	0	0	0	0	0	0
Quantitative macroinvertebrate community index (QMCI)	Minimum score of 4–5	4.10	**3.45**	**3.77**	4.31	**3.90**	**3.95**	**3.35**	**3.03**	**3.36**

TABLE 8 Comparison of 2013–2015 results with selected ‘Freshwater Outcomes for Canterbury Rivers’ for Banks Peninsula rivers from the Canterbury Land and Water Regional Plan – Decisions version (18 January 2014) (Environment Canterbury, 2014). Parameters that would breach the 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	2013	2014	2015	2013	2014	2015
Fine sediment (<2 mm diameter)	Maximum cover of 20%	15	15	7	14	15	8	**100**	**100**	**100**
Filamentous algae (>20 mm long)	Maximum cover of 20%	0	0	1	0	0	0	0	0	0
Quantitative macroinvertebrate community index (QMCI)	Minimum score of 5	**4.10**	**3.45**	**3.77**	**4.31**	**3.90**	**3.95**	**3.35**	**3.03**	**3.36**

4 DISCUSSION

4.1 Habitat

Like all waterways, the current condition of Cashmere Stream is a result of historic and current land use in the catchment. The current state of, and pressures on, Cashmere Stream is summarised in McMurtrie & James (2013) and will not be repeated here. In summary, the Cashmere Stream and its catchment has been significantly modified by land use change since European settlement and suspended and deposited sediment have been identified as major ecological stressors. The majority of the main stem of Cashmere Stream has a fine sediment streambed and the coarser cobble-pebble stony beds at Site 1 and 2 are atypical of the majority of Cashmere Stream.

There have been no notable changes in the physical habitat at any of the sites, with the hard-bottomed Sites 1 and 2 consistently having shallower water depths, faster water velocities, and a higher substrate index value than Site 3, which consistently had greater fine sediment depths, primarily resulting from the 100% fine sediment cover at that site. However, the fine sediment depth at Site 3 in 2015 was very similar to that in 2014, indicating the reduction from 2013 levels has been maintained. The reduction in fine sediment depth between 2013 and 2014 was likely associated with the macrophyte removal carried out along the stream. Macrophytes act a natural filter for fine sediment, trapping it within their roots and stems. Therefore, it is likely that fine sediment is being removed with the macrophytes themselves during stream maintenance. The timing of macrophyte removal compared to this study is discussed in Section 4.2 below.

The only site to fail any of the surface water quality objectives (from Consent CRC120223) relating to sediment cover or filamentous algal cover in 2015 was Site 3. This site had a 100% fine sediment substratum, as per large reaches of Cashmere Stream; therefore it it recorded a percentage fine sediment cover value far greater than the consent objective (maximum fine sediment cover of 30%). This situation is unlikely to change given current management of Cashmere Stream; hence this site is likely to constantly not meet this consent objective.

4.2 Macrophytes

The macrophyte community of Cashmere Stream is dominated by exotic species such as *P. crispus* (curly pondweed) and *E. canadensis* (Canadian pondweed), however patches of native large water milfoil (*Myriophyllum propinquum*) and the macroalga *Nitella/Chara* are also present. Macrophytes are an integral part of the aquatic habitat in Cashmere Stream and provide habitat and food for aquatic macroinvertebrates, kōura/freshwater crayfish and cover for fish. Thick macrophyte growth also reduces the channel's flood capacity; hence macrophyte removal is regularly undertaken in Cashmere Stream. Such activities will obviously have a significant effect on measures of macrophyte cover and on the macroinvertebrate community that exists on and among macrophyte beds (see James, 2011). In Cashmere Stream the timing of macrophyte removal varies from year to year. There was a considerable difference in timing of macrophyte removal prior to sampling in 2013 and 2014: in 2012 it was completed in November (two months before the sampling undertaken on 8 February 2013), while in 2013 it was completed a month later in December (one month before sampling undertaken 3 February 2013) (Dale Wilheim, City Care, pers. comm.). This may have been responsible for the large change in total macrophyte cover observed at Site 1 between the 2013 and 2014 surveys (55% cover in 2013 compared to 8% in 2014). In 2015, macrophyte removal was undertaken in late November–early December 2014 (Ben Lay, City

Care, pers. comm.) meaning there was an approximate two-month recovery period prior to sampling on 3 February 2015. This should be sufficient for macrophyte and macroinvertebrate communities to sufficiently recover, and for the 2015 sampling to be considered representative of the conditions in Cashmere Stream.

In terms of total macrophyte cover, the results of 2015 mirrored those of 2014 with Site 1 and 2 not exceeding the total macrophyte cover surface water quality objective of a maximum total macrophyte cover of 30% (from Consent CRC120223). Site 3 exceeded this objective in 2015, just as it had in 2013 and 2014, indicating habitat conditions at this site are particularly suitable for the growth of extensive macrophyte beds (e.g., fine sediment stream bed, slower water velocities, deeper water, little channel shading).

4.3 Aquatic Invertebrates

The invertebrate communities of the three sites were dominated by taxa such as the snail *P. antipodarum*, the amphipod crustacean *P. fluviatilis*, Ostracoda seed-shrimps, and oligochaete worms that prefer, or are typical of sluggish, soft-bottomed streams with abundant macrophyte growth in agricultural and urban catchments. The overall macroinvertebrate community is also typical of that found in low gradient, lowland streams impacted by agricultural and/or urban development throughout Canterbury. Of the EPT taxa that are associated with clean water (mayflies, stoneflies and caddisflies), only caddisflies were recorded from the three monitoring sites. In 2015 eight caddisfly taxa were recorded, with six of these taxa actually considered 'cleanwater' species: *Hudsonema amabile*, *Hydrobiosis parumbripennis*, *Triplectides*, *Psilochorema*, *Oecetis unicolor* and *Polyplectropus* (*O. albiceps* and *Paroxyethira* are pollution-tolerant caddisfly taxa). These 'cleanwater' caddisfly taxa can, nevertheless, tolerate some suspended sediment and can live in soft-bottomed streams provided that there is some suitable habitat to live on (such as submerged woody debris or macrophytes) (Winterbourn *et al.*, 2006; McMurtrie & James, 2013). All these taxa are previously known from Cashmere Stream and in 2015, as in previous years, were a relatively minor component of the macroinvertebrate community contributing no more than 5% of total invertebrate abundance.

Any between-site differences in 2015 were largely the result of relatively subtle differences in the relative abundance of dominant taxa rather than any major changes in macroinvertebrate community structure. Such subtle differences are probably 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 overall taxa richness in 2015 was significantly lower than that of 2014 and similar to that observed in 2013, while EPT taxa richness (both including and excluding Hydoptilidae caddisflies) was particularly low at Site 3 in 2015. Variability in these metrics (and others) may be related to the timing of macrophyte removal or alternately be natural variation. With only three years of data and without a control site free from the potential effects of macrophyte removal and stormwater discharges, it is not possible to determine any trends. Additional invertebrate data from Cashmere Stream is available from previous aquatic ecology surveys undertaken as part of the CCC's long-term monitoring programme (James, 2010) and as part of ecological monitoring related to the Aidanfield development (James & Taylor, 2010). Please refer to Drinan (2014) for coverage of this data.

All sites fall within the “poor” quality class for MCI and QMCI in 2014 and 2015, with Site 3 consistently having lower QMCI scores in all years. The low QMCI scores have meant all sites do not meet the QMCI surface water quality objective of a minimum score of 4–5 (from Consent CRC120223) in 2014 and 2015.

Despite the health of the sites in the study area being categorised as ‘poor’ by the QMCI, Cashmere Stream, in general, is considered the best quality sub-catchment of the Heathchote River (James, 2010). It retains populations of freshwater crayfish/kōura and freshwater mussels/kakahi, two notable mega-invertebrate species that are rare in urban or peri-urban waterways in Christchurch. In addition, Cashmere Stream 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).

5 ASSESSMENT OF STORMWATER EFFECTS

Due to the limitations of the current study design, it is not possible to determine if stormwater discharges are having an impact on the receiving environment. As the three sites are essentially ‘impact’ sites, there is no control/reference site (i.e.,a site that is not influenced by stormwater discharges) to compare against to determine if there are any stormwater-mediated temporal or spatial trends. With the limitations of the study design, all that can be taken from the monitoring results is that the ‘quality’ of the macroinvertebrate communities at the three monitoring sites (as inferred from the MCI/QMCI scores) is currently ‘poor’. Such designations, however, should be interpreted with caution, as we have no knowledge of the invertebrate community of Cashmere Stream prior to land use change.

Any observed changes in macrophyte cover have nothing to do with stormwater effects. Given this part of Cashmere Stream undergoes regular channel maintenance (macrophyte and sometimes sediment removal), fluctuations in macrophyte cover result from the interplay between growing conditions (i.e., season, sunshine, water temperature, nutrient availability) and the timing of channel maintenance. There have been some differences in the period between the macrophyte removal activities and the ecological surveys in the three years (i.e., macrophyte removal in 2014 was one month closer to the sampling date than in 2013, with 2015 having a similar gap as 2013). However, without knowledge of how fast macrophyte beds re-establish over the summer period, if this is constant every year, and without any control site that is not impacted by macrophyte removal, it is impossible to determine how significant one month versus two months of macrophyte regrowth truly is when in comes to interpreting the results of the ecological survey. Additionally, given macrophytes represent the only stable habitat in this primarily soft-sediment system, it is also likely that the periodic macrophyte removal is having an impact on the macroinvertebrate communities, and these effects could potentially mask any of the more subtle effects of stormwater discharges under the current sample design.

6 RECOMMENDATIONS

The recommendations given in Drinan (2014) are still relevant and all of these will not be repeated here. However, there are some key recommendations that relate directly to the aims and management outcomes of undertaking such resource consent monitoring. These are outlined below.

1. 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. The details of these limitations are fully described in Drinan (2014). Alteration to the study design is required if there is a desire to isolate the effects of stormwater discharges from other temporal variability.

2. While the three chosen sites are located downstream of tributaries draining the northern (lowland) side of the catchment where developments are (or will be) occurring, there are developments on the southern (hill) side of the catchment that are not accounted for. These discharges are currently located both upstream and downstream of the monitoring sites in this report, and have involved large amounts of sediment discharged into Cashmere Stream (based on monitoring and observations of sediment discharges by the local Cashmere Stream Care Group that undertake community-based water quality monitoring throughout the catchment). While I acknowledge that they technically are outside of the South-West Christchurch Area covered by the current consent monitoring, considering the higher risk of sediment inputs during hillside development of erosion-prone loess soils, it would be pertinent to account for these developments in any ecological monitoring.

3. 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 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/freshwater crayfish, give 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.

7 ACKNOWLEDGEMENTS

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9 APPENDICES

9.1 Site Photographs

Site photographs of each of the three monitoring sites, in 2013, 2014 and 2015.

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