Kaputone Creek Realignment

Baseline Conditions of Kaputone Creek
Prepared for the Christchurch City Council

6 July 2016

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Cover photograph: Realigned channel of Kaputone Creek, © Ground Services Limited, 2016

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Executive Summary

The Northern Arterial Motorway is a new four-lane, median-separated motorway that will cross Kaputone Creek in Belfast. In order to avoid two, long box culverts being installed, the Christchurch City Council has realigned a section Kaputone Creek to the west of the yet to be constructed motorway.

As part of this work, the Christchurch City Council commissioned Boffa Miskell Ltd to undertake an assessment of the freshwater ecology of four sites along Kaputone Creek. The sites included a site upstream and downstream of the realignment, and two sites within the oxbow, the area of Kaputone Creek to be retired as a result of the realignment works.

Investigations of the riparian and in-stream habitat conditions, and macroinvertebrate and fish communities showed that the current health of these parts of Kaputone Creek was generally poor, with probable severe pollution.

This information will provide the Christchurch City Council with robust information on the existing ecological condition of Kaputone Creek serving as a baseline for comparison after the realignment works have been completed.

Scope

The New Zealand Transport Agency (NZTA) is planning a new four-lane, median-separated motorway, the Northern Arterial Motorway. The alignment of this new motorway crosses a number of waterways in the north of Christchurch, including at three locations along Kaputone Creek. In particular, the new motorway will cross Kaputone Creek twice between Belfast and Radcliffe Roads, within a distance of approximately 250 m.

Four main options were proposed for the treatment of Kaputone Creek between Belfast and Radcliffe Roads, including the construction of two, long box culverts along the existing alignment of Kaputone Creek, immediately above and below an area known as the 'oxbow'.

It was recognised that the installation of these two culverts, and particularly due to their close proximity, would likely have permanent, detrimental effects on in-stream and riparian habitat and may have significant adverse effects on the passage of in-stream fauna.

The Christchurch City Council (CCC), in collaboration with NZTA, was granted consent to realign Kaputone Creek along the western side of the motorway. This eliminated the need for these major culverts and instead required the installation of only one small-diameter culvert to drain the retired 'oxbow' area.

The CCC designed approximately 350 m of waterway, modelled on the Kaituna River, a forested lowland waterway in Canterbury. The new section of Kaputone Creek included important ecological features, such as pool: riffle: run sequences, low-lying *Carex* dominated floodplains, and large-diameter woody debris, boulders, and overhanging banks to provide complex riparian and in-stream habitat for terrestrial and freshwater fauna.

Following construction, planting, and initial stabilisation of the realigned section of Kaputone Creek, base flows will be directed along the new section of creek, while any storm flows will for some time continue to discharge along the original oxbow section of Kaputone Creek. Once it is deemed that the new creek bed and margins have been stabilised, the oxbow will be fully retired and the dry creek bed planted with native sedges and rushes. It is likely that this area will become a wetland, which will be hydraulically connected to Kaputone Creek.

As part of this wider project, the CCC commissioned Boffa Miskell Ltd to conduct an ecological survey of Kaputone Creek in April 2016. This work was conducted prior the 'livening' of the newly realigned section, which will eventually retire the oxbow section of Kaputone Creek.

The purpose of this brief report was to:

- Describe the existing ecological values found at the survey sites along Kaputone Creek, with respect to riparian and in-stream physical habitat conditions, and macroinvertebrate and fish communities.

The above then provides the baseline information for these sites, which can be used to determine if the ecological values of the new creek are improving over time and after the diversion works have been completed.

Survey Methods

Site Locations

In consultation with Dr Belinda Margetts (CCC), Boffa Miskell Ecologists selected and surveyed four sites along Kaputone Creek (Table 1; Figure 1).

In addition to GPS co-ordinates, and for easier relocation of sites in future surveys, both the upstream and downstream extent at all sites were marked with wooden pegs with orange dazzle spray paint (Figure 2).

Sites 1 and 4 were located upstream and downstream, respectively, of the realignment works, while Sites 2 and 4 were located within the oxbow. The oxbow is the area of Kaputone Creek that is to be retired and replaced by the new channel constructed by the CCC.

Table 1. Site number, location, and co-ordinates (NZMG) for each of the four sites surveyed in this study.

Site number	Location	Upstream extent		Downstream extent	
		Easting	Northing	Easting	Northing
Site 1	Upstream of the realignment	5187879	1570708	5187911	1570740
Site 2	Upstream oxbow	5188093	1571095	5188081	1571147
Site 3	Downstream oxbow	5188228	1571125	5188255	1571085
Site 4	Downstream of the realignment	5188517	1570974	5188542	1570956

The riparian and in-stream ecology, including surveying of the macroinvertebrate community, was undertaken at each site on 14 April 2016. The fish community was assessed on 19 April 2016. All field assessments were conducted during baseflow conditions.

Water Quality

Spot measures of basic water chemistry (pH, dissolved oxygen, conductivity) and temperature were collected at each site using a hand-held Horiba multi-parameter water-quality meter.

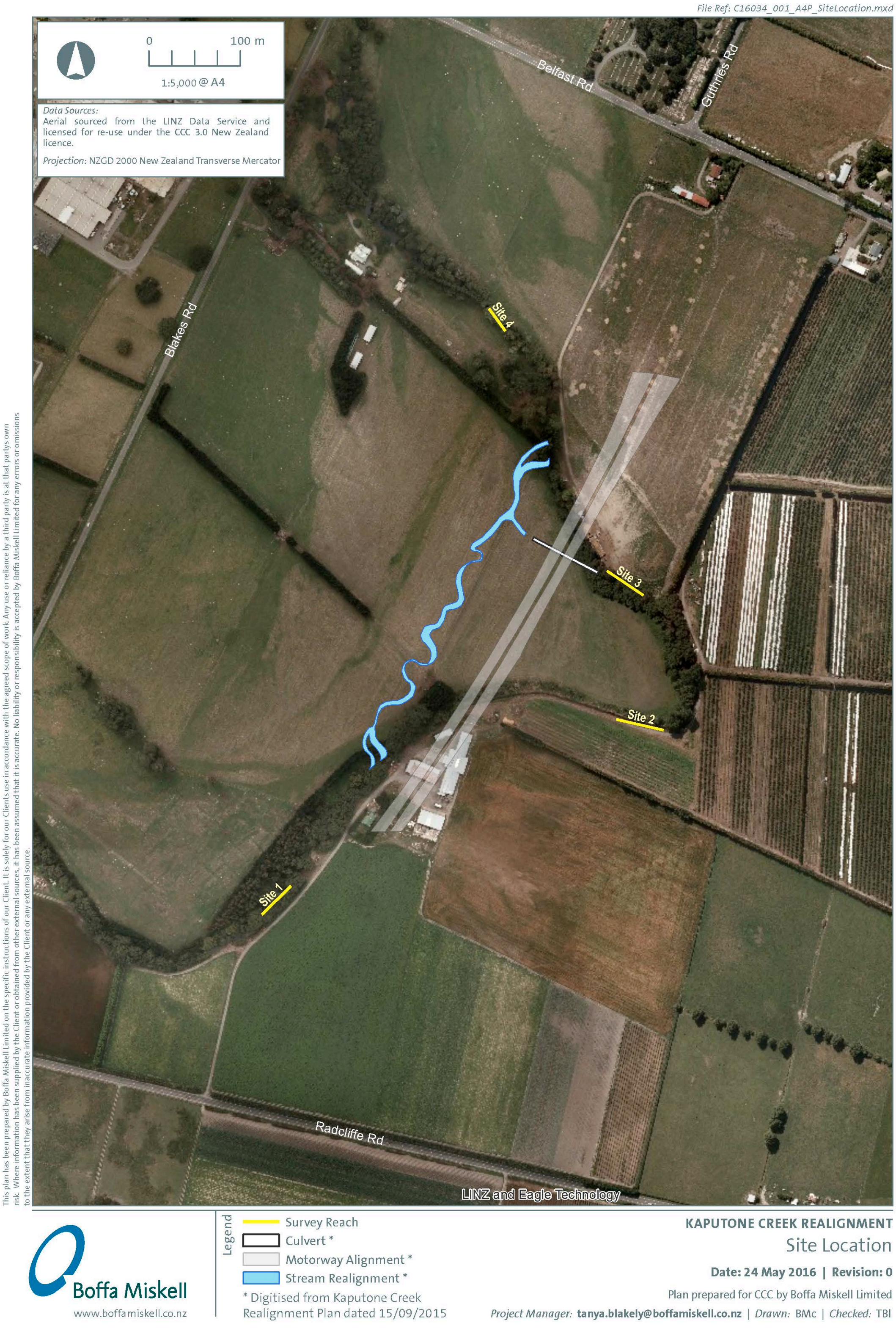

Figure 1. Locations of the four sites surveyed in Kaputone Creek in April 2016, above, below and within the oxbow, as part of the Kaputone Creek Realignment project.

Figure 2. The upstream and downstream extent of the four survey sites were marked with wooden stakes painted with orange dazzle spray paint, to allow for easier relocation during future surveys.

Habitat Assessment

A variety of riparian and in-stream habitat parameters were assessed at each site using the following standard protocols of Harding et al. (2009) and Clapcott et al. (2011):

- Protocol 3 (P3) Quantitative protocol of Harding et al. (2009):
  - P3b: Hydrology and morphology procedure;
  - P3c: In-stream habitat procedure; and
  - P3d: Riparian procedure.
- Sediment Assessment Methods of Clapcott et al. (2011):
  - Sediment Assessment Method 2 (SAM2) – in-stream visual estimate of % sediment cover; and
  - Sediment Assessment Method 6 (SAM6) – sediment depth.

Full details of P3, SAM2, and SAM6, including field-sheet templates, are provided in Appendix 1.

These habitat assessment methods involved measuring a range of in-stream and riparian physical habitat conditions at various distances across 6 equally spaced cross-sections established across the waterway every 10 m. The first (downstream most) and last (upstream most) cross-sections were located at the co-ordinates provided in Table 1.

The 3D modelling programme, Sketchup, was used to graphically present the 6 'stream profiles' measured at each site.

It's important to note that Protocol 3 of Harding et al. (2009) specifies that two cross-sections should be located in each of riffle, run, and pool habitat. However, in the sections surveyed, Kaputone Creek is dominated by slow-flowing run habitat, with riffles and pools being largely absent. Therefore, all six cross-sections at each site were established within run habitat.

Photographs of the upstream and downstream views of each site were also taken.

Macroinvertebrate Community

Macroinvertebrates (e.g., insects, snails and worms that live on the stream bed) can be extremely abundant in streams and are an important part of aquatic food webs and stream functioning. Macroinvertebrates vary widely in their tolerances to both physical and chemical conditions, and are therefore used regularly in biomonitoring, providing a long-term picture of the health of a waterway.

The macroinvertebrate community was assessed at each site within the same 50 m reach where in-stream habitat was surveyed[1].

Five replicate Surber samples (0.3 m^2, 500 μm mesh) were collected from each of the 4 sites following Protocol C3 of Stark et al. (2001). Surber samples were randomly collected from the most appropriate habitat available[2] at each site and disturbed to an approximate depth of 5 cm.

All macroinvertebrate samples were preserved, separately, in 70% ethanol prior to sending to Biolive Invertebrate Identification Service for identification and counting in accordance with protocol P3 of Stark et al (2001). Macroinvertebrates were identified to species level, where possible.

Fish Community

Each site was revisited on 18 April 2016 during which time the fish community was surveyed[3] from within the same 50 m reach that habitat and macroinvertebrate community were assessed. Each survey reach included the variety of habitats typically present at that site (e.g. stream margin, mid channel, undercut banks, macrophytes, silt).

Due to the nature of the waterway, with deep and slow-flowing run-dominated habitat, it was deemed that electric fishing was not safe, nor an appropriate method for sampling in Kaputone Creek. A combination of fyke nets and Gee minnow traps was used at each site.

Two fyke nets (baited with tinned cat food) and five Gee minnow traps (baited with Marmite) were set within each of the 50 m survey reaches late in the afternoon (18 April 2016) and left overnight. The following morning (19 April 2016), all fish captured were identified and measured before being returned alive to the stream.

[1] The macroinvertebrate community was sampled at each site on the same day that the habitat assessment was conducted (i.e. prior to habitat assessments, but after basic water chemistry and temperature parameters were measured).

[2] Protocol C3 of Stark et al. (2001) recommends the use of a Surber sampler for quantitative sampling. However, the use of the Surber sampler can be ineffective in deep, low velocity areas as this sampling method relies on flow to wash organisms dislodged from the substrate into the net.

[3] Boffa Miskell holds the required permits and approvals to *take* (i.e. capture & handle) aquatic life. In this case, a Special Permit issued by the Ministry for Primary Industries pursuant to Section 97(1) of the Fisheries Act 1996 allowed us to *take* aquatic life (macroinvertebrates and fish) from Kaputone Creek.

Data Analyses

Riparian and in-stream habitat assessments

The multiple measures across cross-sections for the various riparian and in-stream habitat variables recorded at each site were averaged to give an average value for each parameter per cross-section. Cross-sections within a site were used as replicates in statistical analyses.

Analyses of variance (ANOVAs) were used to test for differences in mean habitat conditions among sites. Response variables were *log* (x+1) transformed where necessary to meet assumptions of normality and homogeneity of variances. ANOVAs were performed in R version 3.0.2 (The R Foundation for Statistical Computing 2013).

Macroinvertebrate community

The following macroinvertebrate metrics and indices were calculated to describe the community and provide an indication of stream health:

- **Macroinvertebrate abundance** – the average number of individuals (per 1m^2) calculated from those collected in the five replicate Surber samples from each site. Comparisons of abundance of macroinvertebrates among sites can be useful as abundance tends to increase in the presence of organic enrichment, particularly for pollution-tolerant taxa.
- **Taxonomic richness** – the average number of macroinvertebrate taxa recorded from the five Surber samples collected at each site. Streams supporting high numbers of taxa generally indicate healthy communities, however, the pollution sensitivity / tolerance of each taxon needs to also be considered.
- **EPT taxonomic richness** – the average number of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) recorded from the five Surber samples collected at each site. These three insect orders (EPT) are generally sensitive to pollution and habitat degradation and therefore the numbers of these insects present provide a useful indicator of degradation. High EPT richness suggests high water quality, while low richness indicates low water or habitat quality.
- **EPT taxonomic richness (excl. hydroptilids)** – the average number of EPT taxa excluding caddisflies belonging to the family Hydroptilidae, which are generally more tolerant of degraded conditions than other EPT taxa.
- **%EPT richness** – the percentage of macroinvertebrates that belong to the pollution-sensitive EPT orders found in the five Surber samples collected at each site, i.e. relative to total richness of all macroinvertebrates at each site. High %EPT richness suggests high water quality.
- **%EPT (excl. hydroptilids)** – the percentage of EPT taxa at each site, excluding the more pollution-tolerant hydroptilid caddisflies.
- **Macroinvertebrate Community Index (MCI-hb[4])** – this index is based on the tolerance scores of Stark and Maxted (2007) for individual macroinvertebrate taxa found in the five

[4] The hard-bottom versions of the MCI and QMCI were used for Kaputone Creek as, although the bed of the waterway is now generally dominated by soft, fine sediments, it would once have been a gravel-pebble-cobble dominated, hard-bottom system. When using the MCI and QMCI for assessing ecosystem health, it's important to use the version (hard bottom versus soft bottom) most appropriate to the study system prior to human modification.

Surber samples collected at each site. Tolerance scores, which indicate a taxon's sensitivity to in-stream environmental conditions, are summed for the taxa present at a site, and multiplied by 20 to give MCI-hb values ranging from 0 – 200.

- **Quantitative Macroinvertebrate Community Index (QMCI-hb[4])** – this is a quantitative variant of the MCI-hb, which instead uses abundance data of the five replicate Surber samples. The QMCI-hb provides information about the dominance of pollution-sensitive species at a site.

Table 2 provides a summary of how MCI-hb and QMCI-hb scores were used to evaluate stream health.

Table 2. Interpretation of MCI-hb and QMCI-hb scores for hard-bottomed streams (Stark & Maxted 2007).

Stream health	Water quality descriptions	MCI	QMCI
Excellent	Clean water	>119	>5.99
Good	Doubtful quality or possible mild enrichment	100-119	5.00-5.90
Fair	Probable moderate enrichment	80-99	4.00-4.99
Poor	Probable severe enrichment	<80	<4.00

ANOVAs were used to test for differences in means (where the five Surber samples collected from each site were treated as replicates) among sites in macroinvertebrate abundance (per m^2), taxonomic richness, EPT richness, and MCI and QMCI values. Response variables were *ln* (x+1) transformed to meet assumptions of normality and homogeneity of variances. ANOVAs were performed in R version 3.0.2 (The R Foundation for Statistical Computing 2013).

A non-metric multidimensional scaling (or NMDS) ordination[5], with 1000 random permutations, using abundance data was used to determine if the macroinvertebrate community found was similar among the four sites surveyed in April 2016.

NMDS ordinations rank sites such that distance in ordination space represents community dissimilarity (in this case using the Bray-Curtis metric). Therefore, an ordination score (an *x* and a *y* value) for the entire macroinvertebrate community found at any site can be presented on an *x-y* scatterplot to graphically show how similar (or dissimilar) the community at a site is from that found at another site. Ordination scores that are closest together are more similar in macroinvertebrate community composition, than those further apart (Quinn and Keough 2002).

An analysis of similarities (ANOSIM), with 100 permutations, was then used to test for significant differences in macroinvertebrate community composition among sites. It is essential to view ANOSIM results when interpreting an NMDS ordination as an NMDS ordination may show that communities appear to be quite distinct (i.e. when shown graphically, sites might appear to be quite distinct from one another in ordination space), but ANOSIM results show whether these differences are in fact statistically significantly different[6].

[5] Goodness-of-fit of the NMDS ordination was assessed by the magnitude of the associated 'stress' value. A stress value of 0 indicates perfect fit (i.e. the configuration of points on the ordination diagram is a good representation of actual community dissimilarities). It is acceptable to have a stress value of up to 0.2, indicating an ordination with a stress value of <0.2 corresponds to a good ordination with no real prospect of misleading interpretation (Quinn & Keough 2002).

[6] ANOSIM is a non-parametric permutation procedure applied to the rank similarity matrix underlying the NMDS ordination and compares the degree of separation among groups (i.e. sites) using the test statistic, R. When R equals 0 there is no distinguishable difference in community composition, whereas an R-value of 1 indicates completely distinct communities (Quinn & Keough 2002).

If ANOSIM revealed significant differences in macroinvertebrate community composition (i.e. $R \neq 0$ and $P \leq 0.05$) among sites, similarity percentages (SIMPER) were calculated[7] to show which macroinvertebrate taxa were driving these differences.

NMDS, ANOSIM and SIMPER analyses were performed in PRIMER version 6.1.13 (Clarke and Warwick 2001; Clarke and Gorley 2006).

Fish community

The fish capture data were expressed as 'catch per unit effort' (CPUE), to enable any future comparisons of fish community information that may use different methods or sampling effort. CPUE was calculated by dividing the number of fish captured by the total number of traps and nets deployed at a site. CPUE was, therefore, expressed as number of fish per trap per night.

Existing Environment

Water Quality

pH was similar across sites, with circum-neutral pH recorded in all four sites surveyed (pH range: 7.45-7.86; Table 3). These spot measures (i.e. a single measurement on one occasion) of pH also met Environment Canterbury's Land and Water Regional Plan (LWRP) water quality standard for receiving waters of pH between 6.5 and 8.5.

Dissolved oxygen (DO) was slightly more variable across sites, with the lowest DO recorded downstream of the realignment at Site 4 (Table 3).

Conductivity, which is often used to indicate the level of pollutants in the water column, was relatively similar across the four sites, ranging between 189 μS / cm and 221 μS / cm (Table 3). These values fall within the normal range of conductivity expected for lowland rivers (ANZECC 2000). The highest recorded conductivity was downstream of the realignment at Site 4.

Spot water temperature measured at each site ranged from 10.7-13.2°C, with the highest temperature recorded downstream of the realignment at Site 4 (Table 3). However, differences in water temperatures within this range are likely to be of little biological relevance to the in-stream fauna.

It is important to note that these water quality parameters were measured only once during the daytime, and at different times of the day across the four sites. Moreover, all of these parameters can vary both diurnally and seasonally.

[7] The SIMPER routine computes the percentage contribution of each macroinvertebrate taxon to the dissimilarities between all pairs of sites among groups.

Table 3. Average velocity, Substrate Index, embeddedness, compactness, fine substrate depth, water temperature, pH, and conductivity recorded at each site. Standard error is shown in parentheses. Note, temperature, pH and conductivity were only measured once at each site.

Parameter	Upstream of realignment Site 1	Upstream oxbow Site 2	Downstream oxbow Site 3	Downstream of realignment Site 4
Velocity (m / s)	Negligible	Negligible	Negligible	Negligible
Temperature (°C)	11.1	12	10.7	13.2
pH	7.83	7.62	7.45	7.86
Conductivity (μS / cm)	189	214	210	221
Dissolved oxygen (mg / l)	8.24	9.39	8.1	6.52
Embeddedness	3.9 (0.1)	3.9 (0.1)	4.0 (0.0)	4.0 (0.0)
Compactness	4 (0)	4 (0)	4 (0)	4 (0)
Soft sediment depth (cm)	8 (1.8)	35 (5.1)	96 (13.4)	35 (1.6)
Soft sediment cover (%)	95 (2.8)	98 (1.3)	100 (0.0)	100 (0.0)
Canopy cover (%)	76.5 (4.0)	28.4 (3.3)	88.0 (2.0)	90.2 (2.6)
Macrophytes (cm)	3 (1.7)	3 (1.1)	58 (50.5)	0 (0.0)
Algae (cm)	5 (3)	21 (16)	64 (42)	0 (0)
Leaf packs (cm)	6 (2.4)	6 (0.8)	719 (252.9)	32 (14.5)
Woody debris (cm)	22 (7.7)	4 (0.5)	163 (42.4)	33 (15.2)
Boulders and log jams	0 (0.2)	0 (0.2)	13 (1.7)	3 (1.6)
Overhanging vegetation (cm)	0 (0.0)	0 (0.1)	0 (0.0)	3 (3.3)

General Habitat Conditions

Many of the habitat conditions measured were generally similar at the four sites surveyed along Kaputone Creek. While the section of creek surveyed was a natural waterway, it has been heavily modified and degraded, and largely lies within an agricultural catchment with grazed pasture grasses and limited riparian vegetation dominated by exotic species. Canopy cover, or stream shading, was variable across the four survey sites. Site 2, upstream oxbow, was found to have significantly less shading due to, on average, a lower canopy cover than the other three sites (ANOVA: $F_{3, 76} = 77.27$; $P < 0.001$) (Table 3).

The substrates of all sites along Kaputone Creek were dominated by soft, fine substrates, and while once gravel-pebble-cobble substrates would have been common, the bed was dominated by silt / sand, and organic matter in April 2016.

The high degree of embeddedness and compactness of the substrates indicated interstitial spaces (the open spaces between substrate particles, important for in-stream fauna) were limited at all sites. Similarly, the total cover of soft sediments was estimated between 95% and 100% for all sites (Table 3). However, the amount (depth) of soft sediment covering the creek bed varied across sites (Figure 3; ANOVA: $F_{3, 20} = 28.79$; $P < 0.001$), with the downstream in the oxbow (Site 3) having the greatest soft sediment depth, while upstream of the realignment (Site 1) had the least soft sediment (Figure 3).

Substrate size was also significantly different among sites, with the two upstream sites (Site 1, upstream of the realignment; and Site 2, upstream oxbow) having significantly larger-sized substrate, on average, than the two most downstream sites (Site 3, downstream oxbow; and Site 4, downstream of the realignment) (Figure 4). However, it's noteworthy that all sites had relatively small substrate overall (Figure 4).

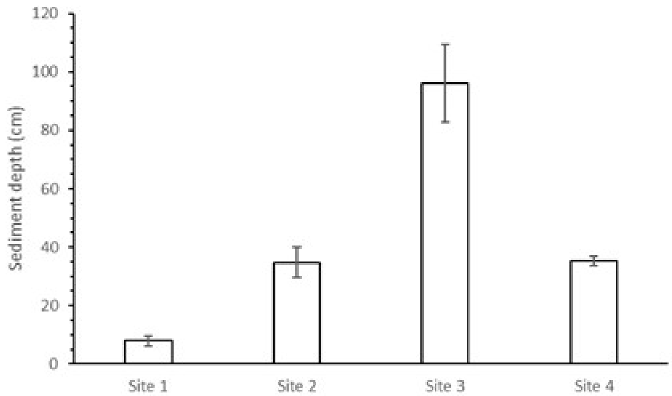

Figure 3. Average depth of soft sediment (cm) measured at four locations across five cross-sections at each site, in April 2016. Error bars are 1±SE.

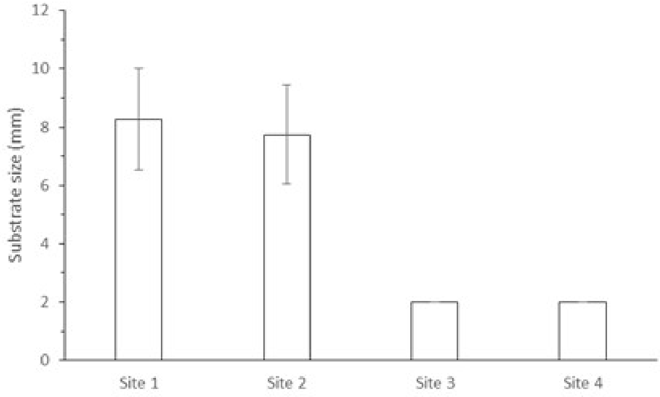

Figure 4. Average substrate size (mm) of ten substrates measured at each of six cross-sections at each site, in April 2016. Error bars are 1±SE.

A brief summary of the general habitat conditions encountered at each site is given in Table 3 and the text below. Stream profiles, of each of the six cross-sections measured at each site, are provided in Appendix 2.

Site 1: Upstream of the realignment

The upper most site was located in Kaputone Creek, upstream of the realignment and of the oxbow (Figure 1), which is to be retired at completion of the diversion works. Here the creek was approximately 2.5 m wide (average wetted width) and on average 19 cm deep (see Appendix 2 for cross-section profiles). The velocity was very low and could not be measured on the day of sampling. The riparian vegetation was dominated by willow and exotic understory species (Figure 5). The true right was mixed-use agricultural land, with potato growing dominating the nearby surrounding area. There was only a very narrow riparian buffer (approx. 5-7 m) on the true right before an unsealed farm road and potato fields. The true left, however, had a slightly wider riparian buffer between the creek and pasture. Macrophytes were largely absent from the site and the bed substrates were dominated by fine silt and sand. While leaf packs and coarse woody debris were present, neither were particularly abundant at this site.

Figure 5. Kaputone Creek at Site 1: Upstream of the realignment, looking upstream (left) and downstream (right).

Site 2: Upstream oxbow

Site 2 was located at the upstream end of the oxbow (Figure 1), approximately 500 m downstream of Site 1, and 400 m downstream of the upper end of the diversion. Here Kaputone Creek was approximately 3.5 m wide (wetted width) and on average 23 cm deep (see Appendix 2 for cross-section profiles). Again, velocity was negligible and unable to be measured on the day of sampling. Grass and a farm track extended right up to the water's edge on the true right bank, creating an extremely unstable bank in some areas, with no buffer between the creek and an apple orchard. A line of poplars with an exotic understory lined the true left bank, providing some buffer between the creek and pasture (Figure 6). Macrophytes were largely absent from the site and the bed substrates were dominated by fine silt and sand. While leaf packs and coarse woody debris were present, neither were particularly abundant at this site. Few macrophytes were present, however, algal was visible on around 20% of the creek bed. Generally, in-stream habitat variability, suitable for a range of aquatic fauna, was very limited.

Figure 6. Kaputone Creek at Site 2: Upstream oxbow, looking upstream (left) and downstream (right).

Site 3: Downstream oxbow

The third site was located at the downstream end of the oxbow, approximately 250 m downstream of site 2 (Figure 1). Kaputone Creek was much wider, than the upstream sites, with an average wetted width of around 12 m. However, much of this width was due to a wetland area clogged with willows on the true right of the main channel (Figure 7). The average depth at site 3 was 33 cm deep (see Appendix 2 for cross-section profiles). There was no noticeable flow at this site, and velocity was not able to be measured on the day of sampling. The riparian margins were limited to mature, well-spaced gum and willows along the true left bank, providing a narrow and intermittent buffer from the surrounding pasture. Macrophytes and algae were relatively sparse at the site, but there was an abundance of leaf litter and log jams in the creek and adjoining wetland, providing more in-stream habitat availability compared to the upstream sites.

Figure 7. Kaputone Creek at Site 3: Downstream oxbow, looking upstream (left) and downstream (right).

Site 4: Downstream of the realignment

The downstream most site (Site 4) was located downstream of the realignment and approximately 300 m downstream of site 3 (Figure 1). Here the creek narrowed again, with an average wetted width of 3.4 m, more similar to the upper two sites (Figure 8). The creek was very homogenous, with a straightened channel lined by poplar and willows, and little in-stream habitat variability; there was very little leaf litter, macrophytes and algae were almost entirely absent, and log jams were relatively sparse. The average water depth was 58 cm deep (see Appendix 2 for cross-section profiles). There was no noticeable flow at this site, and velocity was not able to be measured on the day of sampling. Both sides of the creek were fenced, which appeared to exclude the sheep from entering the true left of channel.

Figure 8. Kaputone Creek at Site 4: Downstream of the realignment, looking upstream (left) and downstream (right).

Macroinvertebrate Community

Overview

A total of 15,115 macroinvertebrates, belonging to 30 taxonomic groups, was collected from the four Kaputone Creek sites surveyed in April 2016. The most diverse groups were the true flies (or two-winged flies; Diptera; 9 taxa), freshwater snails and bivalves (Mollusca; 4 taxa), crustaceans (Crustacea; 4 taxa), and the caddisflies (Trichoptera; 4 taxa). Damselflies (Odonata; 1 taxon), worms and leeches (Annelida; 2 taxa), *Hydra* (Cnidaria; 1 taxon), springtails (Collembola; 1 taxon), and flatworms (Platyhelminthes; 1 taxon) were also present. No mayfly (Ephemeroptera) or stonefly (Plecoptera) taxa were found in any of the Kaputone Creek sites.

Crustaceans and molluscs numerically dominated the macroinvertebrate community found in the four Kaputone Creek sites, together making up nearly 80% of all the macroinvertebrate collected from the four sites (i.e. the total macroinvertebrate catch from all Surber samples collected from all sites). Of these, the ostracod *Herpetocypris pascheri*, the ubiquitous native mud snail *Potamopyrgus antipodarium*, and the aquatic worms (Oligochaeta) were the most abundant.

Although caddisflies were one of the most diverse taxonomic groups, they comprised less than 1% of the total number of macroinvertebrates collected from Kaputone Creek.

Seed shrimp ostracods, oligochaete worms, and *Potamopyrgus antipodarium* were common at all of the sites, as were the tiny freshwater clam (Sphaeriidae) and freshwater *Hydra*.

A full list of macroinvertebrate taxa collected from the four Kaputone Creek sites is presented in Appendix 3.

Abundance and richness

Macroinvertebrate abundance varied across the four sites, ranging from 1,859 to 17,138 individuals per square metre collected in the Surber samples. However, there was no difference in the average number of macroinvertebrates / m^2 collected at each site (ANOVA: $F_{3, 16} = 0.176$; $P = 0.911$; Figure 9).

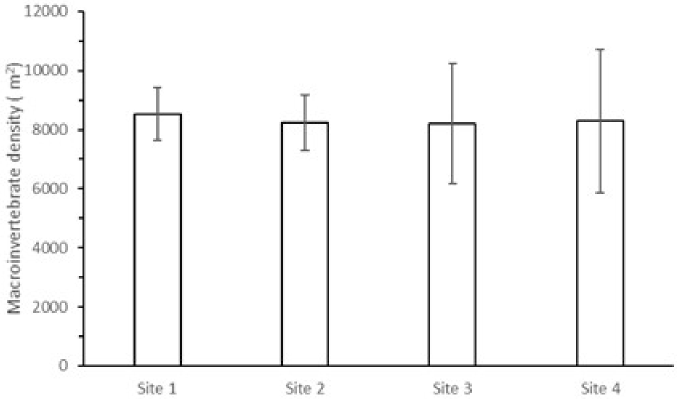

Figure 9. Average macroinvertebrate abundance (per m^2) collected in five Surber samples from at each site, in April 2016. Error bars are 1±SE.

Significantly more macroinvertebrate taxa were collected from upstream of the realignment (Site 1) with an average of 18 macroinvertebrate taxa collected in the five Surber samples, compared to only 12 collected from Site 4, downstream of the realignment (ANOVA: $F_{3, 16} = 7.98$; $P = 0.002$; Figure 10).

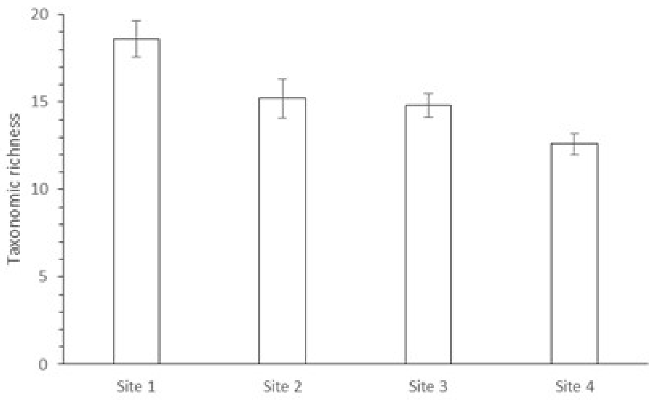

Figure 10. Average macroinvertebrate taxonomic richness collected in five Surber samples from at each site, in April 2016. Error bars are 1±SE.

EPT richness

THE EPT orders (Ephemeroptera, mayflies; Plecoptera, stoneflies; and Trichoptera, caddisfies), which are generally sensitive to pollution and habitat degradation, are useful indicators of stream health. High EPT richness suggests high water and habitat quality, while low EPT richness suggests low water and habitat quality, and degraded stream health. Caddisflies were the only group of the clean-water EPT taxa present in the Kaputone Creek; mayflies and stoneflies were not found in the Surber samples collected.

While caddisflies were found at all sites, EPT richness varied across the sites, with the greatest richness recorded upstream of the realignment at Site 1, compared to the other three sites (ANOVA: $F_{3, 16} = 10.97$; $P < 0.001$; Figure 11). Caddisflies were present in all of the macroinvertebrate (Surber) samples collected from Site 1, albeit in very low numbers, while they were only encountered in one or two of the Surber samples collected from the other sites.

The caddisflies collected included the stick-cased caddis *Hudsonema amabile* and *Triplecides* sp., the algal-piercing hydroptilid *Oxyethira albiceps*, and the stony-cased *Pycnocentria evecta*. *Pycnocentria evecta* was only found upstream of the realignment at Site 1, which is probably reflective of the slightly coarser substrate found upstream.

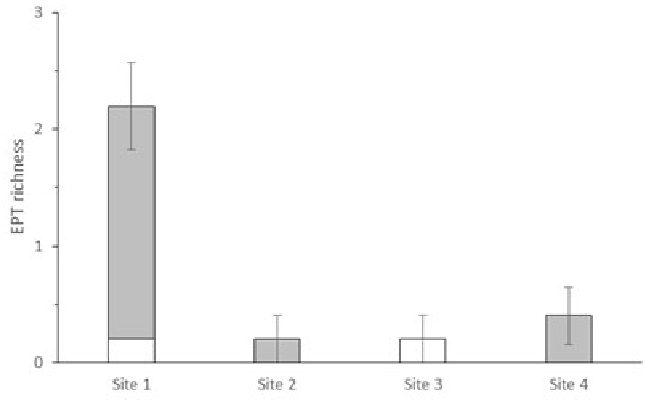

Figure 11. Average richness of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) collected in five Surber samples from at each site, in April 2016. Error bars are 1±SE. Grey bars indicate total EPT richness; white bars indicates richness of the pollution-tolerant hydroptilid caddisflies (*Oxyethira albiceps*).

Community composition

While all sites were generally dominated by crustaceans (e.g. the freshwater amphipod *Paracalliope*) and snails and bivalves (e.g. the ubiquitous mud snail *Potamopyrgus*), subtle differences in macroinvertebrate community composition among sites were observed (Figure 9). Caddisflies were present at all sites, but made up only a very small proportion of the community (Figure 12). Overall, macroinvertebrate community composition was similar across sites.

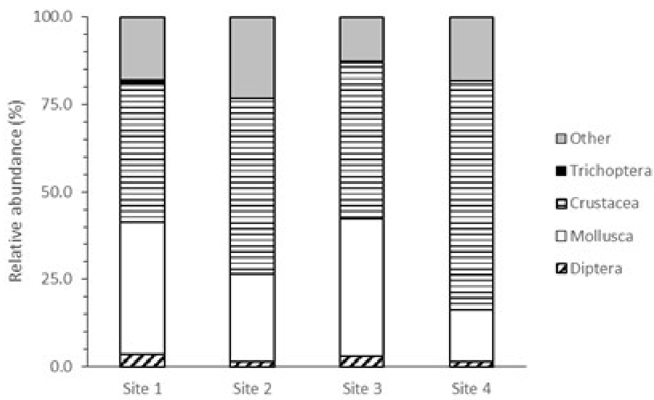

Figure 12. Relative abundance (%) of macroinvertebrates collected in five Surber samples from each of four sites along Kaputone Creek, April 2016. Other = aquatic mites, oligochaete worms and leeches, *Hydra*, springtails, waterboatmen, damselflies, and flatworms.

The NMDS ordination further indicated this, where there were only slight differences in macroinvertebrate community composition among sites (Figure 13). The ANOSIM results confirmed this, indicating only weak, albeit statistically significant differences in macroinvertebrate community composition among sites (ANOSIM: R = 0.34; P = 0.001).

SIMPER indicated that these weak, yet significant, differences among sites were due to variation in abundances, rather than the absence of certain taxa at some sites. For example, the freshwater amphipod *Paracalliope*, the mud snail *Potamopyrgus*; oligochaete worms, flatworms

(Platyhelminthes), and seed shrimp ostracods were present at all sites, but slightly more abundant at some sites than others.

See Appendix 3 for full SIMPER results.

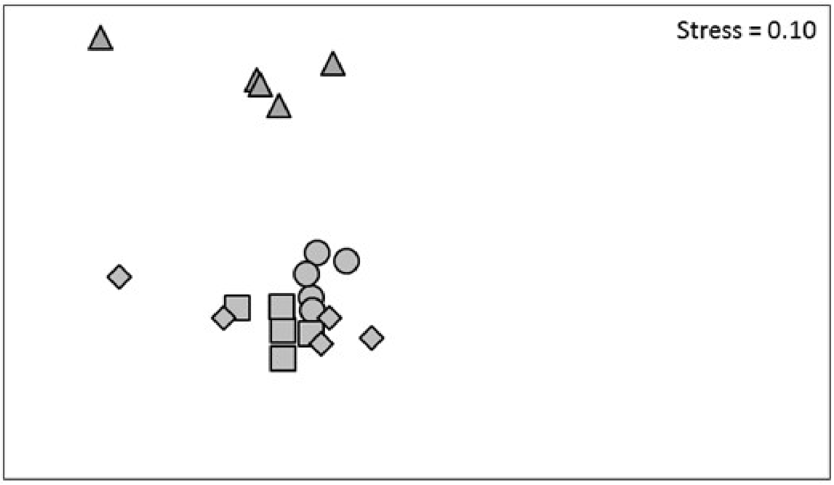

Figure 13. Non-metric multidimensional scaling (NMDS) ordination based on a Bray-Curtis matrix of dissimilarities calculated from macroinvertebrate abundance data collected in five Surber samples at each of four sites along Kaputone Creek. Circles = Site 1; squares = Site 2; diamonds = Site 3; triangles = Site 4. Note, the NMDS gave a good representation of the actual community dissimilarities among sites (two-dimensional stress = 0.10). Axes are identically scaled so that the sites closest together are more similar in macroinvertebrate community composition than those further apart.

Stream health indicators

MCI and QMCI scores are a measure of stream or ecological health, with higher scores indicating generally greater water-quality conditions and ecological, or stream, health.

MCI scores were significantly different among sites (ANOVA: $F_{3, 16}$ = 17.83; P < 0.001), with upstream of the realignment (Site 1) having a greater MCI score than the other three sites (Figure 14). However, the MCI scores of all sites fell below 80, indicating poor stream health with probable severe enrichment (based on the water-quality categories of Stark and Maxted 2007; Figure 14).

QMCI scores showed a similar pattern, with a slightly greater QMCI at Site 1, compared to the other sites, however, this difference was not statistically significantly different (ANOVA: $F_{3, 16}$ = 2.66; P = 0.083).

All sites fell within the “poor” water-quality category indicating probable severe enrichment (Figure 14).

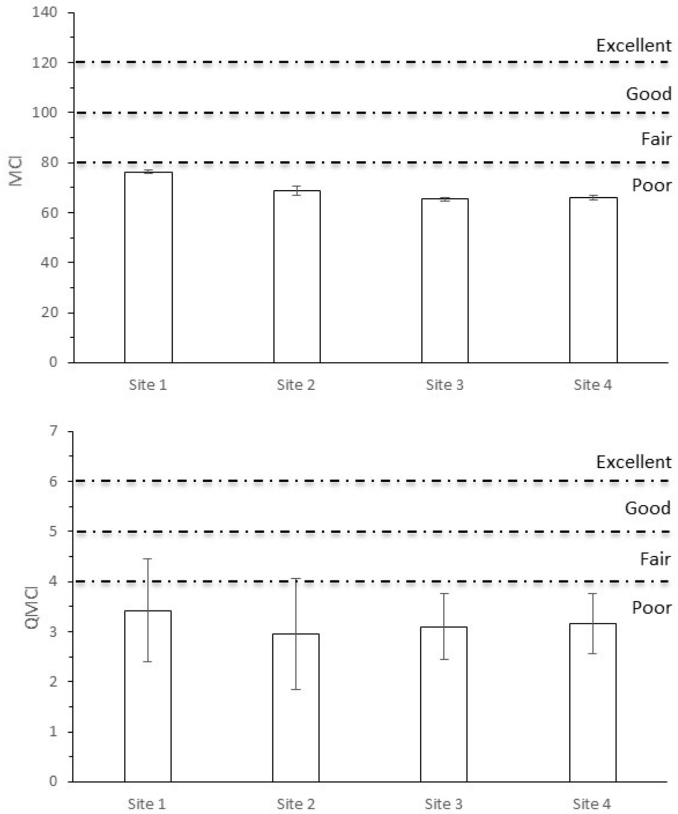

Figure 14. Average MCI and QMCI values for each of the four sites surveyed along Kaputone Creek in April 2016. Error bars are 1±SE.

Fish Community

Overview

A total of 93 fish, belonging to six species, were captured from the four Kaputone Creek sites in April 2016. The six species, in descending order (i.e. across all sites), were: inanga (*Galaxias maculatus*), shortfin eel (*Anguilla australis*), common bully (*Gobiomorphus cotidianus*), longfin eel (*A. dieffenbachii*), upland bully (*G. breviceps*), and giant bully (*G. gobioides*).

Longfin eel and inanga have a conservation status of "at risk, declining", while the remaining four freshwater fish species are currently listed as "not threatened" (Goodman et al. 2013).

Abundance and richness

The fish community was depauperate, with species richness ranging from 4 upstream of the realignment (Site 1), to only 6 upstream oxbow (Site 2). Five freshwater fish species were captured at sites 3 and 4 (Figure 15). The two species of greatest conservation interest, inanga and longfin eel, were encountered at all sites. Shortfin eels were also found at all four survey sites, while giant bullies were only found at Site 2 (upstream oxbow) and Site 4 (downstream of the alignment) (Figure 15).

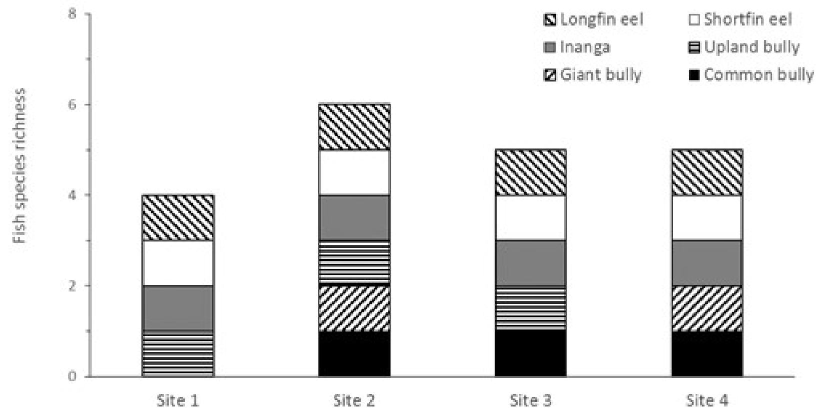

Figure 15. Species richness of fish captured in fyke nets and Gee minnow traps set at four sites in Kaputone Creek, in April 2016.

The total number of fish captured (expressed as number of fish caught per trap, per night) varied across the sites, with the greatest number of fish caught upstream of the realignment (Site 1) (Figure 16). The fewest fish were caught at Site 2, upstream oxbow. Figure 16 shows these fish catches categorised by the different species found at each site.

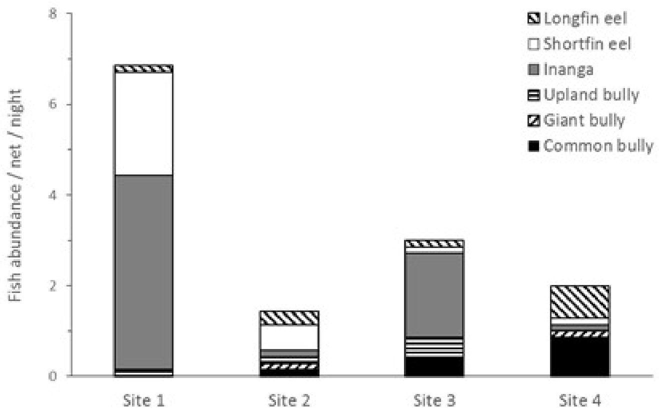

Figure 16. Fish abundance, expressed as number of fish captured per net, per night fished at each of the four sites along Kaputone Creek, in April 2016.

Size distribution of fish

Table 4 summarises the size of fish captured at the four sites surveyed along Kaputone Creek, in April 2016. Four very large longfin eels ("at risk – declining" species) (900 mm – 1020 mm) were captured at Sites 2, 3, ad 4. Smaller longfin eels were captured at Site 1.

Inanga were detected at all sites, including some large adult fish (90 – 110 mm) at Site 3.

Table 4. Total number, and size range (mm in parentheses), of fish caught at each of the four sites surveyed in Kaputone Creek, April 2016. Where the minimum and maximum size were the same, only one value is shown.

	Common bully	Upland bully	Giant bully	Longfin eel	Shortfin eel	Inanga
Site 1: Upstream of the realignment	0 (-)	1 (40)	0 (-)	1 (600)	16 (120-550)	30 (55-85)
Site 2: Upstream oxbow	1 (105)	1 (45)	1 (125)	2 (1000-1020)	4 (450-600)	1 (85)
Site 3: Downstream oxbow	3 (35-45)	3 (50-60)	0 (-)	1 (1000)	1 (220)	13 (70-110)
Site 4: Downstream of the realignment	6 (15-115)	0 (-)	1 (125)	5 (450-900)	1 (450)	1 (70)

Community composition

The relative abundances of fish species found was variable across sites, with the community being dominated by inanga and shortfin eels upstream of the realignment (Site 1), while longfin eels made up a greater proportion of the community found at Site 2 (upstream oxbow) and Site 4 (downstream of the alignment) (Figure 17).

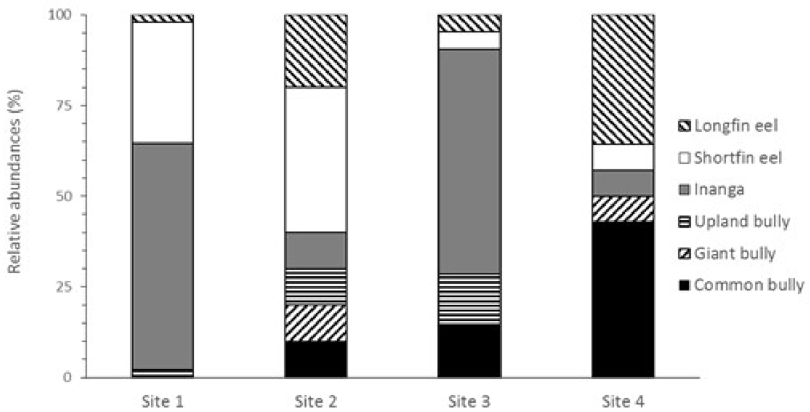

Figure 17. Community composition (% abundance) of fish captured in the four sites surveyed using fyke nets and Gee minnow traps along Kaputone Creek, April 2016.

Summary

This ecological assessment of Kaputone Creek upstream and downstream of the realignment, and within the oxbow, indicates that the waterway is of low, or poor, ecological health. The riparian habitat was dominated by exotic weeds including a number of willow trees encroaching on and constricting the waterway. The in-stream habitat conditions were generally degraded with small substrates dominating the bed, and a thick layer of fine soft sediment covering much of the creek bed. Coarse substrates such as cobbles and boulders, and large woody debris, were limited throughout four sites surveyed. Macrophytes (aquatic plants) and algae were uncommon throughout Kaputone Creek, which was likely due to both high canopy cover at some sites, and the abundance of highly mobile (easily disturbed) fine substrates. Although there were some subtle differences in habitat conditions among the four sites, there were few marked differences in overall habitat conditions, with the exception of slightly larger substrates upstream of the realignment (Site 1), compared to the other, downstream sites.

These poor riparian and in-stream physical characteristics were also reflected by the macroinvertebrate community and ecological health of the creek. The fauna was representative of a slow-flowing, modified system with (unnaturally) high levels of soft fine sediments covering the stream bed. All sites were dominated by taxa tolerant of degraded conditions, such as crustaceans, snails, bivalves, and aquatic worms. The more pollution-sensitive caddisflies, while present, were a less numerically abundant component of the macroinvertebrate community (less than 1% to the community composition). Moreover, the Macroinvertebrate Community Index, and the quantitative variant (QMCI) showed that all sites were of poor water quality and ecosystem health, with probable severe pollution.

The fish community was considered depauperate with just 4-6 species of freshwater fish encountered at the survey sites. Nevertheless, two “at risk – declining” species, inanga and longfin eel, were found at all four sites surveyed. This is noteworthy given that all sites were also classified as having “poor” water quality (based on the macroinvertebrate community present [QMCI]), yet still supported species of conservation interest.

This ecological assessment provides important information on the baseline conditions for four sites along Kaputone Creek, which will be valuable information when assessing ecological change as a result of the diversion works and retirement of the oxbow.

Future monitoring works will need to reassess these four sites in addition to sites within the realignment.

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Appendix 1: Habitat Assessment Methods

P3b field form

Site code		Site name	
Assessor		Date	

Reach assessment

Wetted width (m)		
Reach length (m)		
	Easting	Northing
Reach start		
Reach end		

Pool	Maximum depth(m)	Sediment depth (m)	Crest depth (m)
1			
2			
3			
4			
5			
6			

Meso-habitat length (m)					
Rapid	Run	Riffle	Pool	Backwater	Other

Plan diagram of the site (include significant land marks, access points, N direction, direction of stream flow, location of roads, rough scale)

Notes/comments

Cross sections

Run	Location⁺									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				
Velocity	0	0	0	0	0											0	0	0	0	0

⁺ 'head', 'middle' or 'tail' of run
LBF = left bank full, LB = left bank (for bank offsets record distance between ground and transect line in depth row), WE = water's edge

Run	Location⁺									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				
Velocity	0	0	0	0	0											0	0	0	0	0

Run	Location⁺									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				
Velocity	0	0	0	0	0											0	0	0	0	0

Riffle	Location+									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				
+ 'head', 'middle' or 'tail' of run																				
Riffle	Location+									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				
Riffle	Location+									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				

Pool	Location⁺									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				

⁺ 'head', 'middle' or 'tail' of run
LBF = left bank full, LB = left bank (for bank offsets record distance between ground and transect line in depth row), WE = water's edge

Pool	Location⁺									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				

Pool	Location⁺									Water depth below staff gauge										
	LBF	LB_1	LB_2	LB_3	WE	1	2	3	4	5	6	7	8	9	10	WE	RB_3	RB_2	RB_1	RBF
Offset (m)																				
Depth (m)																				

P3c field form

Site name		Site code	
Assessor		Date	

Riffle 1	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

Riffle 2	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

Run 1	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

Run 2	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

Pool 1	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

Pool 2	Cross-section	Wetted width (m)									
		1	2	3	4	5	6	7	8	9	10
	Substrate size										
	Embeddedness										
	Compactness										
	Depositional & scouring (cm)										
	Macrophytes (cm)										
	Algae (cm)										
	Leaf packs (cm)										
	Woody debris (cm)										
	Large boulders & log jams (count)										
	Bank cover (m)	Left bank					Right bank				

P3d field form

Site name		Site code	
Assessor		Date	

	Buffer width (m)		Land slope		Distance to stopbank (m)		Distance to floodplain (m)	
Cross-section	LB	RB	LB	RB	LB	RB	LB	RB
1								
2								
3								
4								
5								

Riparian vegetation	Distance from LB (m)				Distance from RB (m)			
Cross-section 1	0.5	3	7.5	20	0.5	3	7.5	20
Native vegetation	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Veg tier height								
0 - 0.3 m								
0.3 - 1.9 m								
2.0 - 4.9 m Shrubs								
5 - 12 m Subcanopy								
>12 m Canopy								
Cross-section 2								
Native vegetation	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Veg tier height								
0 - 0.3 m								
0.3 - 1.9 m								
2.0 - 4.9 m Shrubs								
5 - 12 m Subcanopy								
Cross-section 3								
Native vegetation	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Veg tier height								
0 - 0.3 m								
0.3 - 1.9 m								
2.0 - 4.9 m Shrubs								
5 - 12 m Subcanopy								
Cross-section 4								
Native vegetation	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Veg tier height								
0 - 0.3 m								
0.3 - 1.9 m								
2.0 - 4.9 m Shrubs								
5 - 12 m Subcanopy								
Cross-section 5								
Native vegetation	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N	Y/N
Veg tier height								
0 - 0.3 m								
0.3 - 1.9 m								
2.0 - 4.9 m Shrubs								
5 - 12 m Subcanopy								
>12 m Canopy								

	Left bank	Right bank
Gaps in buffer		
Wetland soils		
Stable undercuts		
Livestock access		
Bank slumping		
Raw bank		
Rills/Channels		
Drains (count)		

Shading of water				

Notes

Sediment Assessment Method 2 – In-stream visual estimate of % sediment cover

Rationale	Semi-quantitative assessment of the surface area of the streambed covered by sediment. At least 20 readings are made within a single habitat
Equipment required	• Underwater viewer - *e.g.*, bathyscope (www.absolutemarine.co.nz) or bucket with a Perspex bottom marked with four quadrats • Field sheet
Application	Hard-bottomed streams
Type of assessment	Assessment of effects
Time to complete	30 minutes
Description of variables	
% sediment	A visual estimate of the proportion of the habitat covered by deposited sediment (<2 mm)
Useful hints	Work upstream to avoid disturbing the streambed being assessed. Mark a four-square grid on the viewer to help with estimates – determine the nearest 5% cover for each quadrat. Calculate the average of all quadrats as a continuous variable following data entry. More than five transects may be necessary for narrow streams, to ensure 20 locations are sampled.

Field procedure

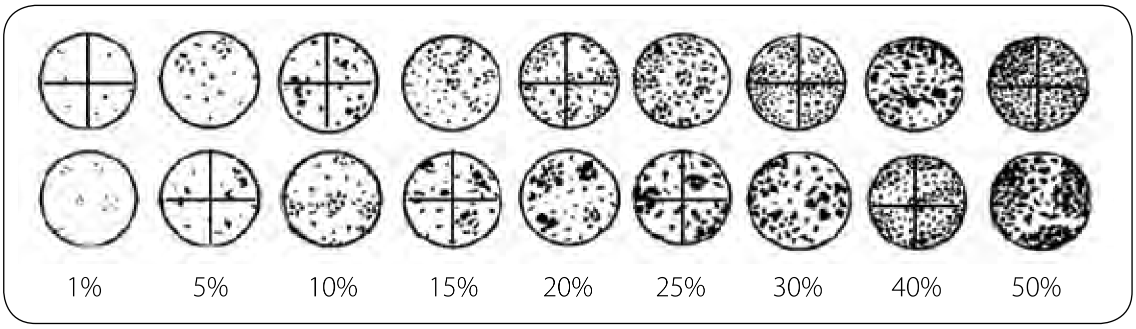
- Locate five random transects along the run.
- View the streambed at four randomly determined locations across each transect, starting at the downstream transect.
- Estimate the fine sediment cover in each quadrat of the underwater viewer in increments (1, 5, 10, 15, 20 …100%).
- Record results in the table below.
- Repeat for four more transects so that 20 locations are sampled in total.

Note: Estimation of cover in each quadrat is important during training but may not be necessary for experienced viewers – instead one measurement per location could be recorded.

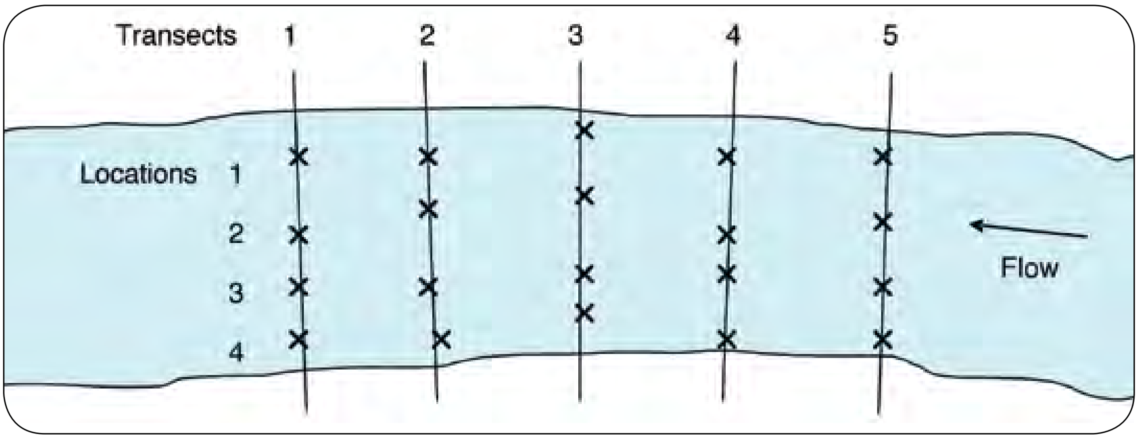
% sediment	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
Location 1	Q1	Q2								
	Q3	Q4								
Location 2										
Location 3										
Location 4										

Useful images

Digital examples of percent cover of sediment on the streambed as seen through an underwater viewer.



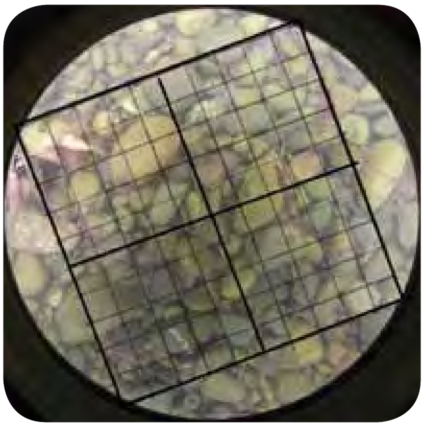
An example of viewer locations (x) for the in-stream visual assessment of sediment.



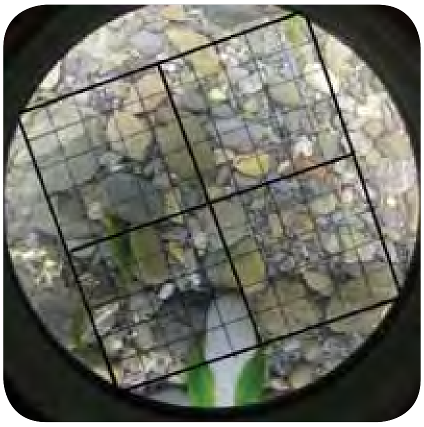
Real examples of percent cover of sediment on the streambed as seen through an underwater viewer.

1%

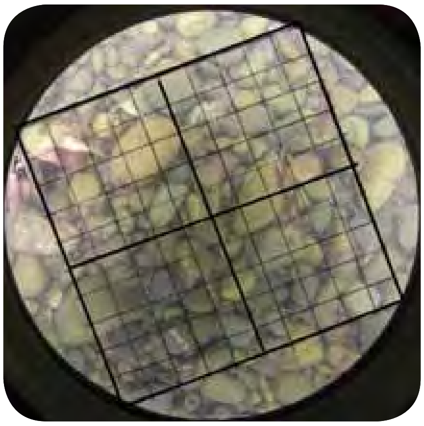
1%



5%



5%



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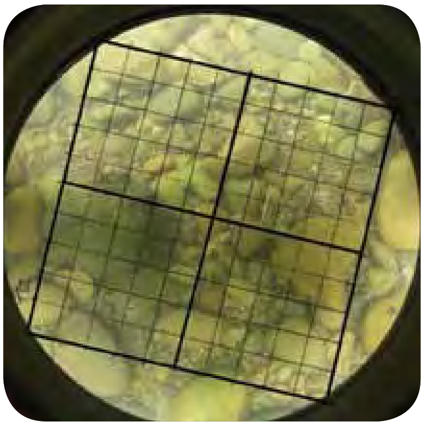

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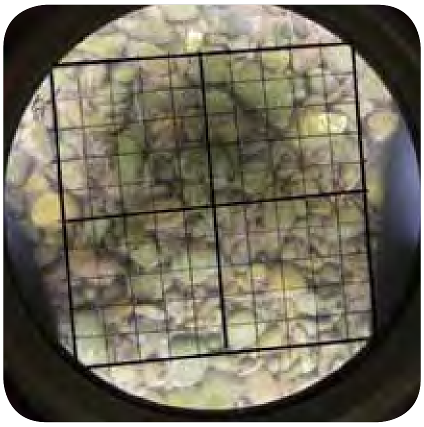

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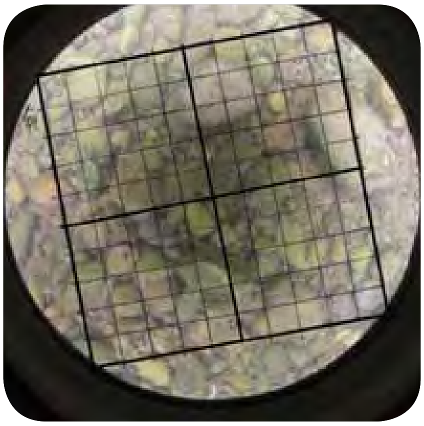

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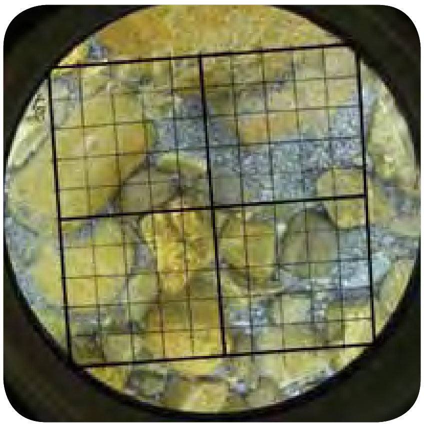

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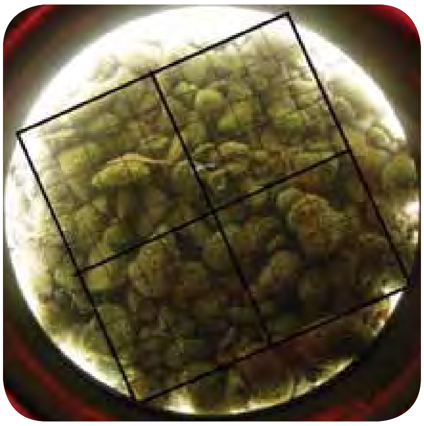

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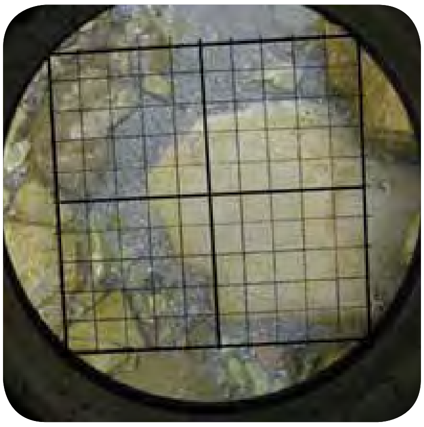

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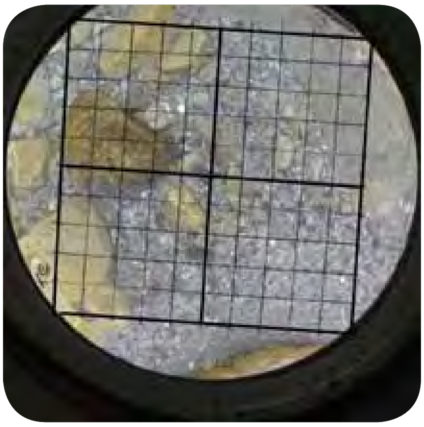

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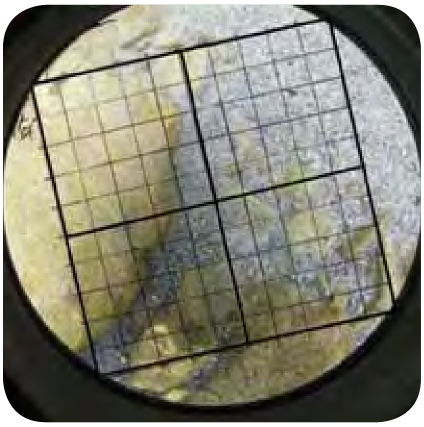

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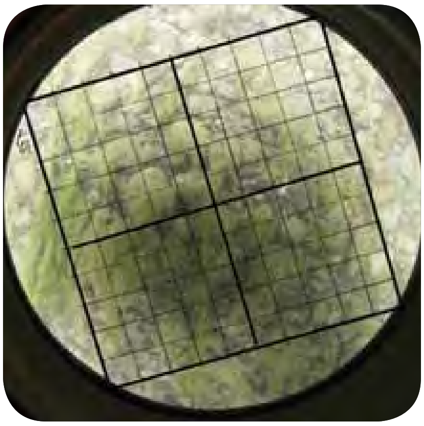

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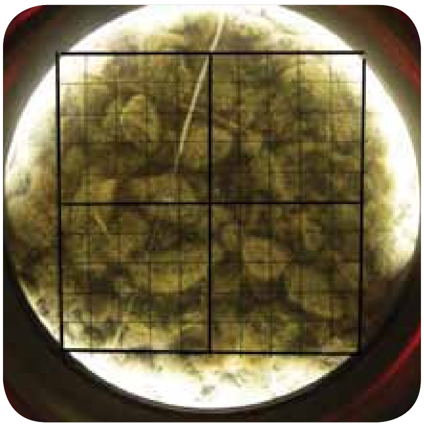

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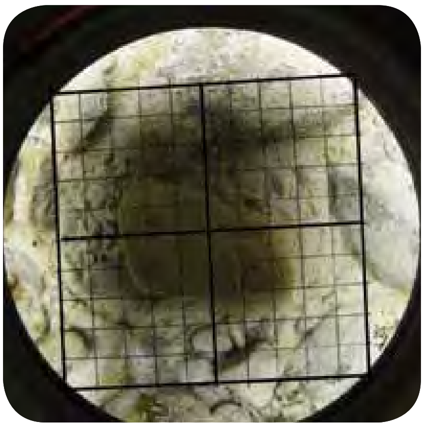


Sediment Assessment Method 6 –Sediment depth

Rationale	Quantitative assessment of the depth of sediment in a run habitat. At least 20 readings are made within a single habitat
Equipment required	• Ruler or ruled rod • Field sheet
Application	Hard-bottomed streams
Type of assessment	Assessment of effects
Time to complete	30 minutes
Description of variables	
Sediment depth (mm)	A measure of the depth of sediment (mm).
Useful hints	Determine the sampling grid first to ensure an even cover of edge and midstream locations. Move upstream to avoid disturbing the streambed being assessed. Calculate the average depth for each site. This method is usually only suitable when fine sediment is visible from the stream bank.

Field procedure

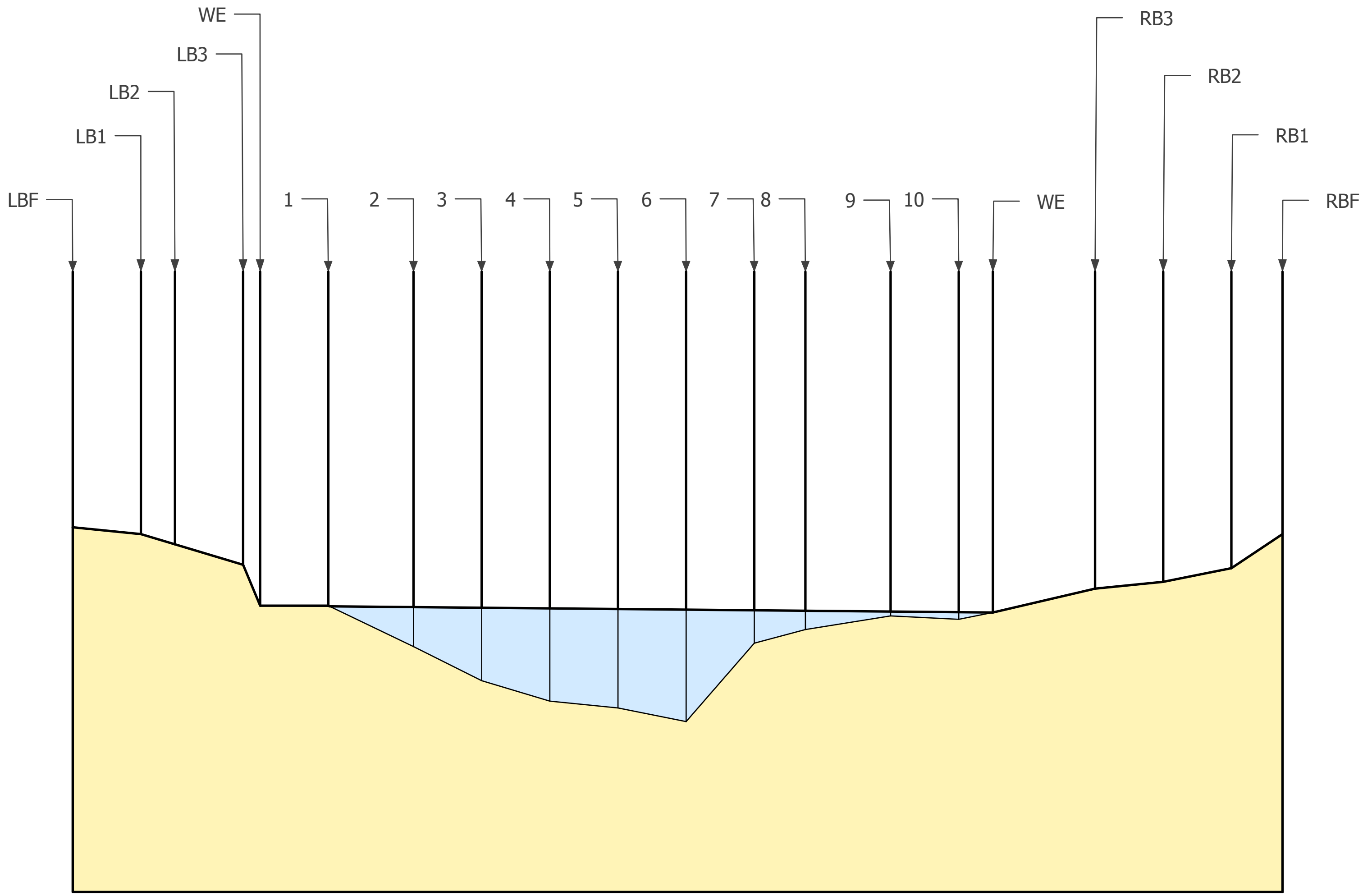
- Start downstream and randomly locate five transects along the run.
- Measure the sediment depth (mm) at four randomly determined locations across each transect and record depth in the table below.

Depth (mm)	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5
Section 1					
Section 2					
Section 3					
Section 4					

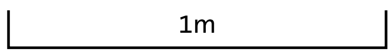
Appendix 2: Stream profiles

Site 1: Cross-section 1

File ref: C16034_profiles_LASC.layout



Legend
LBF: left bankfull height
LB1 – LBF3: left bankfull 1 - 3
WE – water's edge
1 – 10 – offset 1 - 10
RB1 – RB3: right bankfull 1 - 3
RBF – right bankfull height



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Site 1: Cross-section 2

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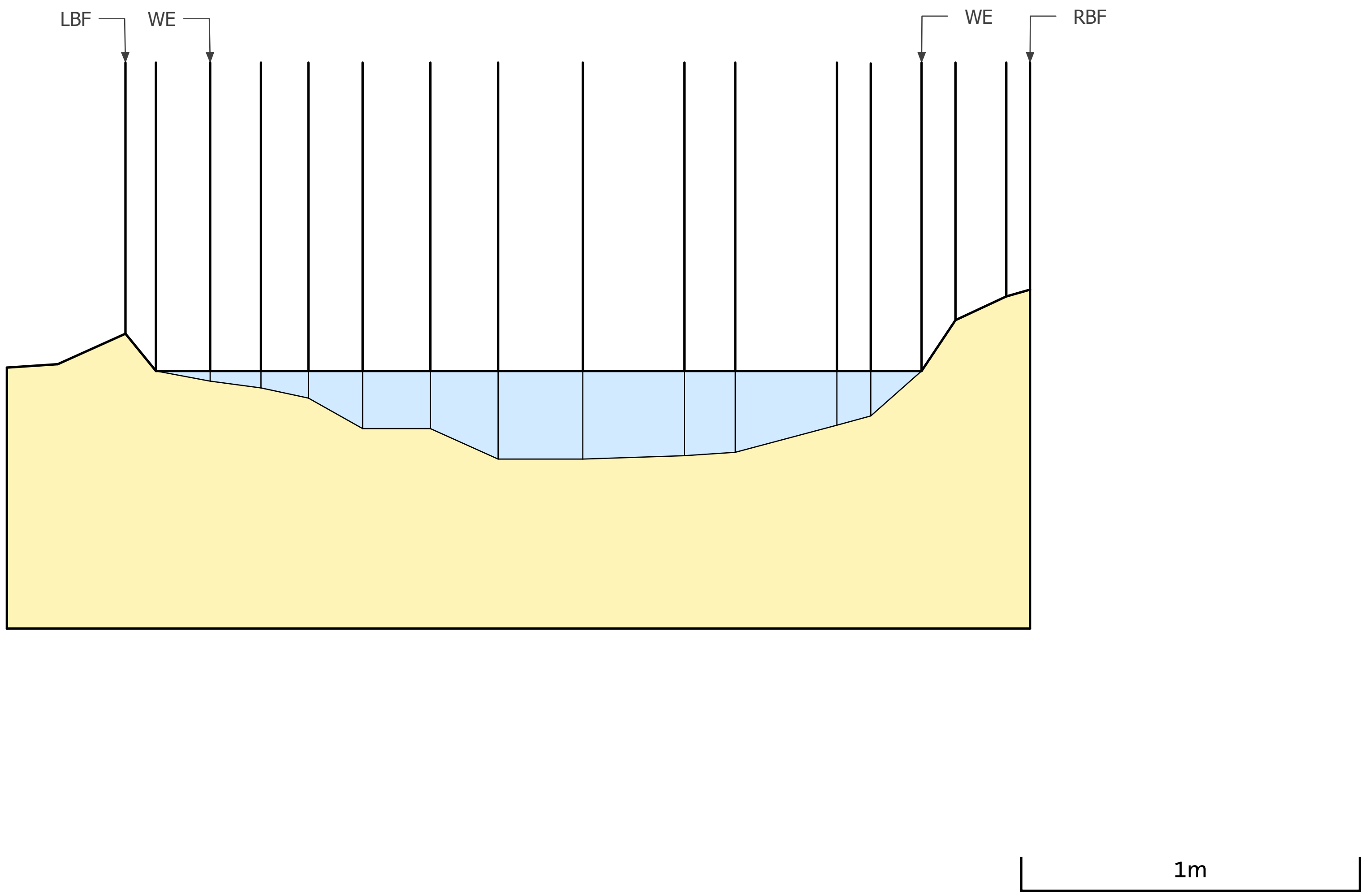

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Site 1: Cross-section 3

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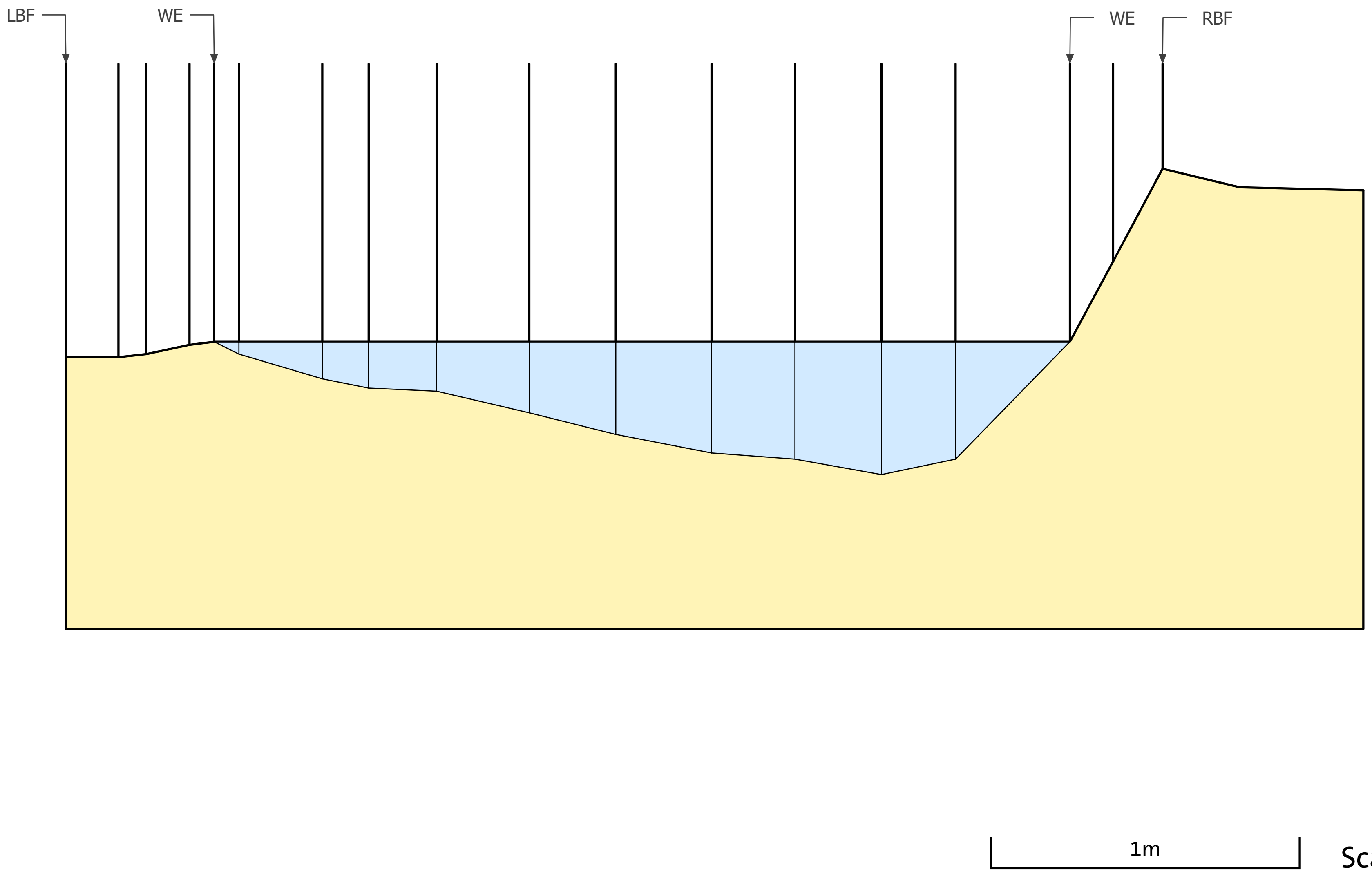

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Site 1: Cross-section 4

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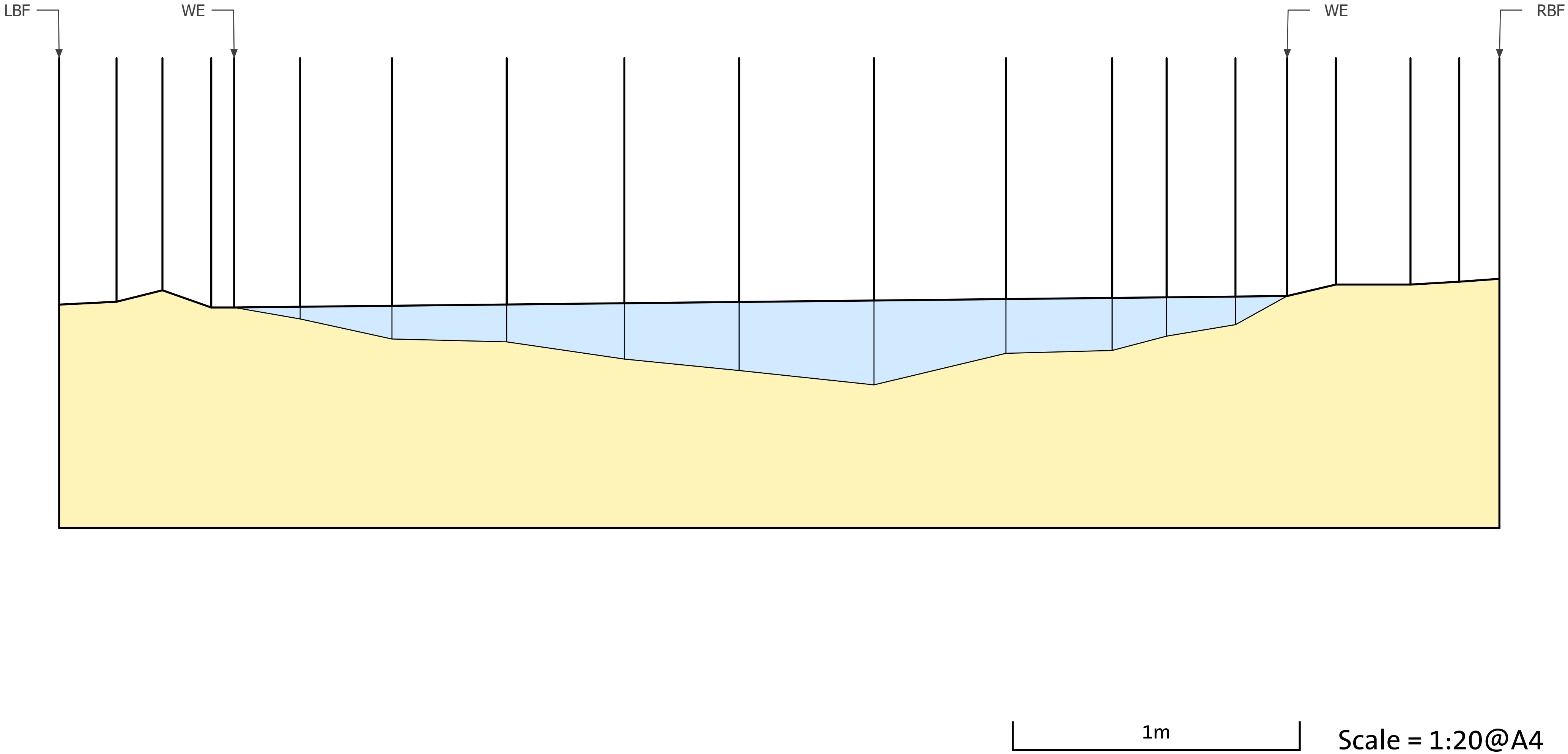

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Site 1: Cross-section 5

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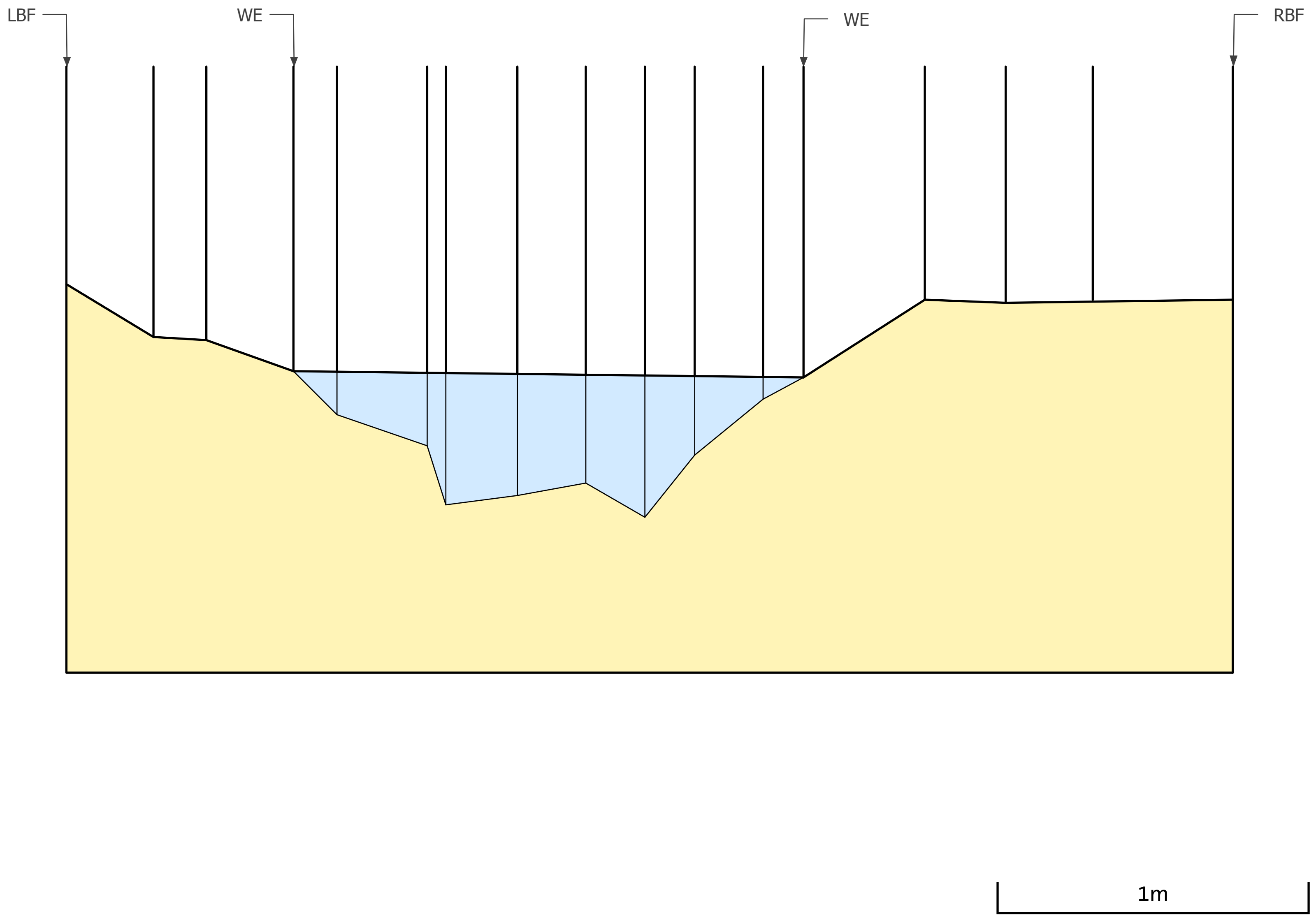

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Site 1: Cross-section 6

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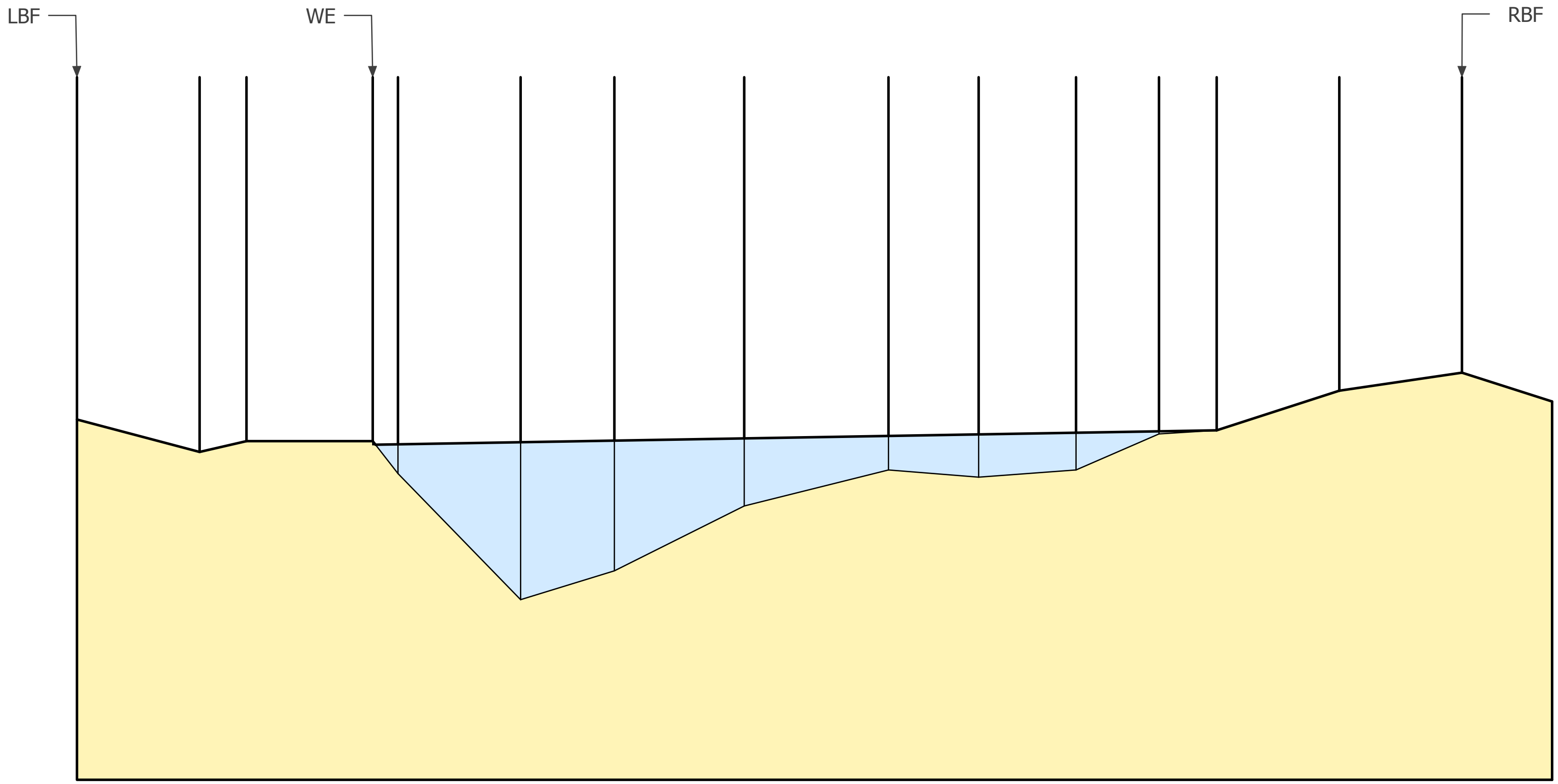

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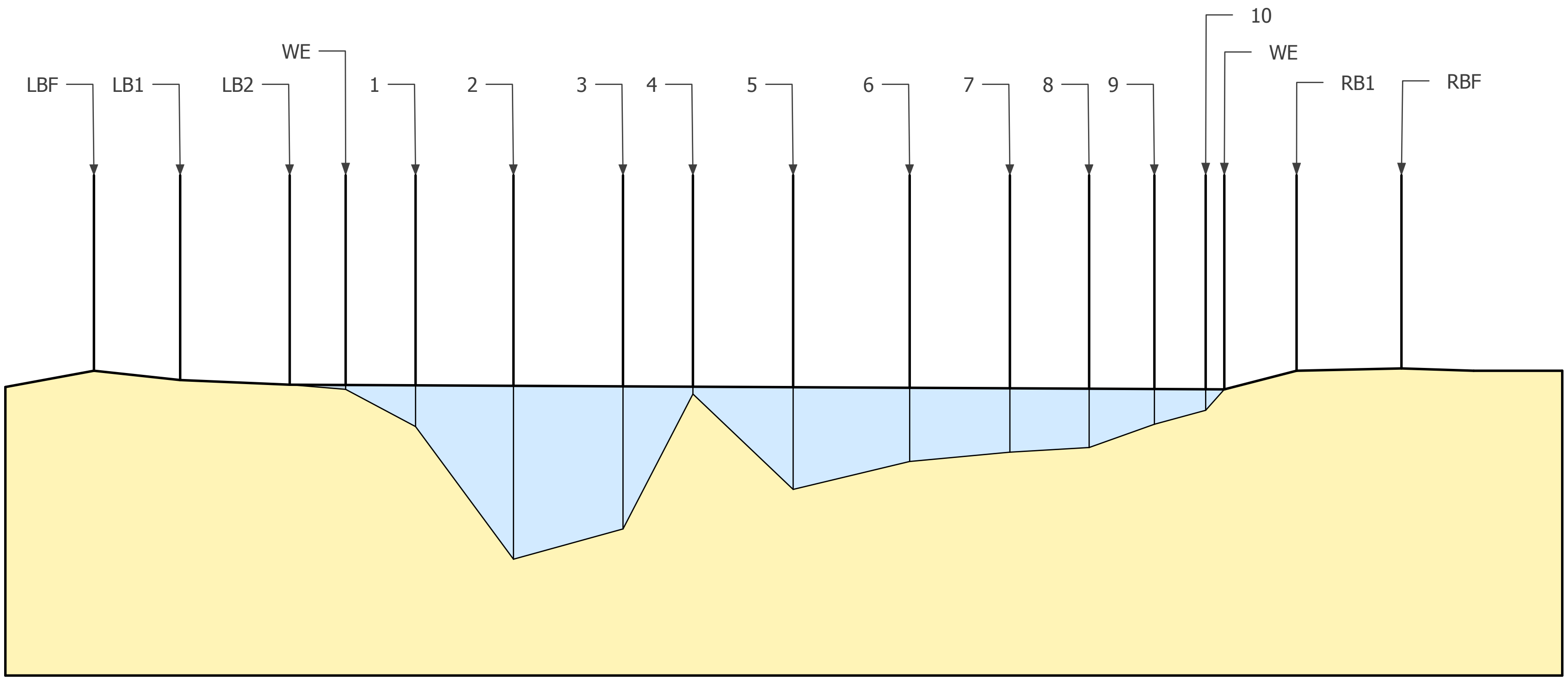
Scale = 1:20@A4

Site 2: Cross-section 1

File ref: C16034_profiles_LASC.layout



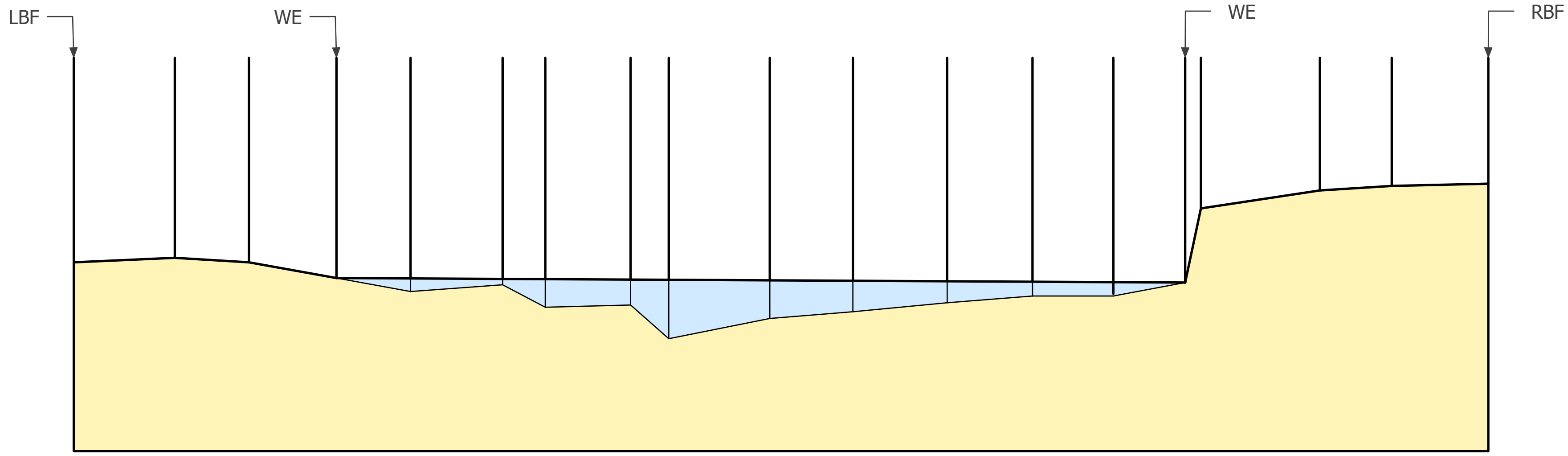
Legend
LBF: left bankfull height
LB1 – LBF3: left bankfull 1 - 3
WE – water's edge
1 – 10 – offset 1 - 10
RB1 – RB3: right bankfull 1 - 3
RBF – right bankfull height

1m

Scale = 1:30@A4

Site 2: Cross-section 2

File ref: C16034_profiles_LASC.layout



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Site 2: Cross-section 3

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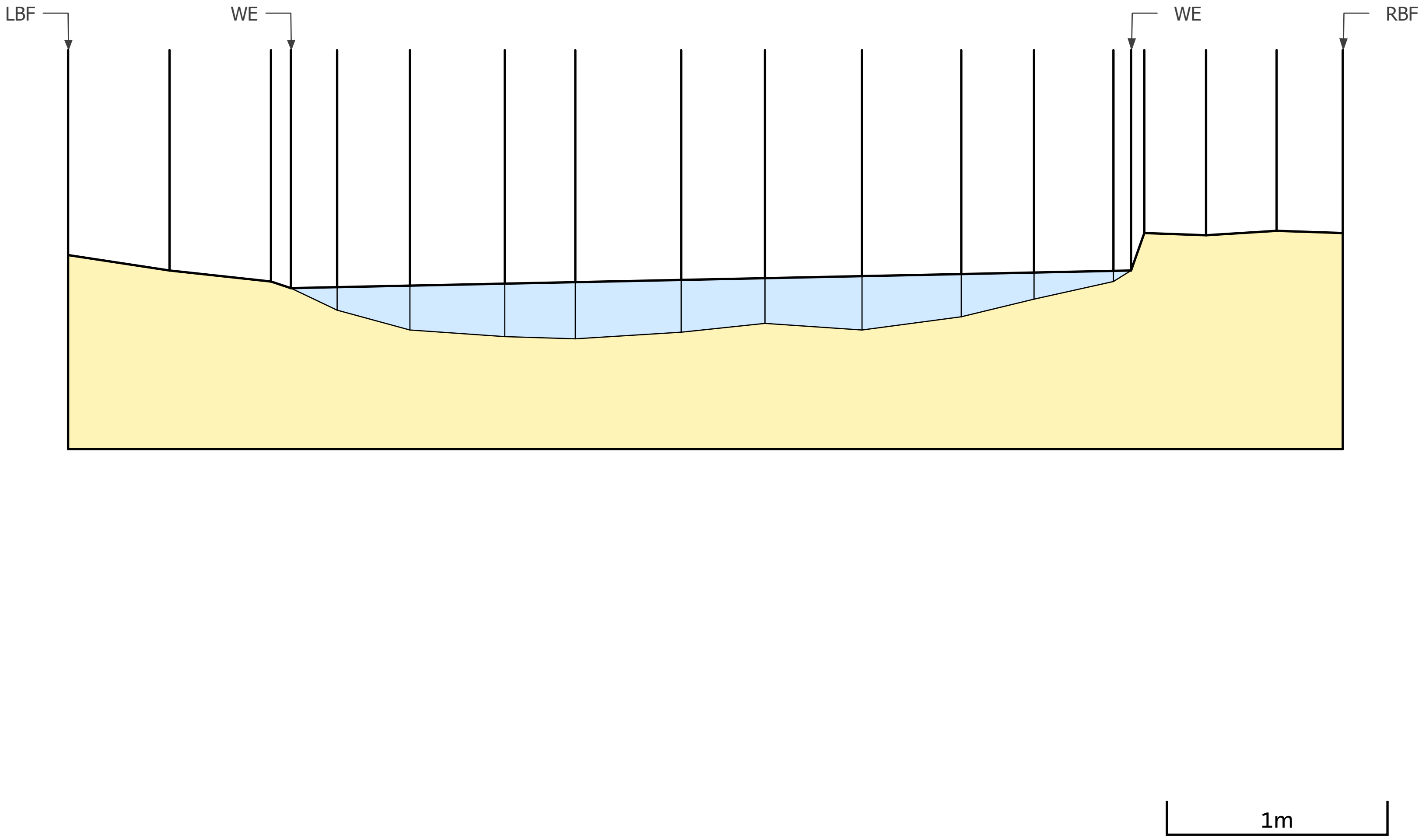

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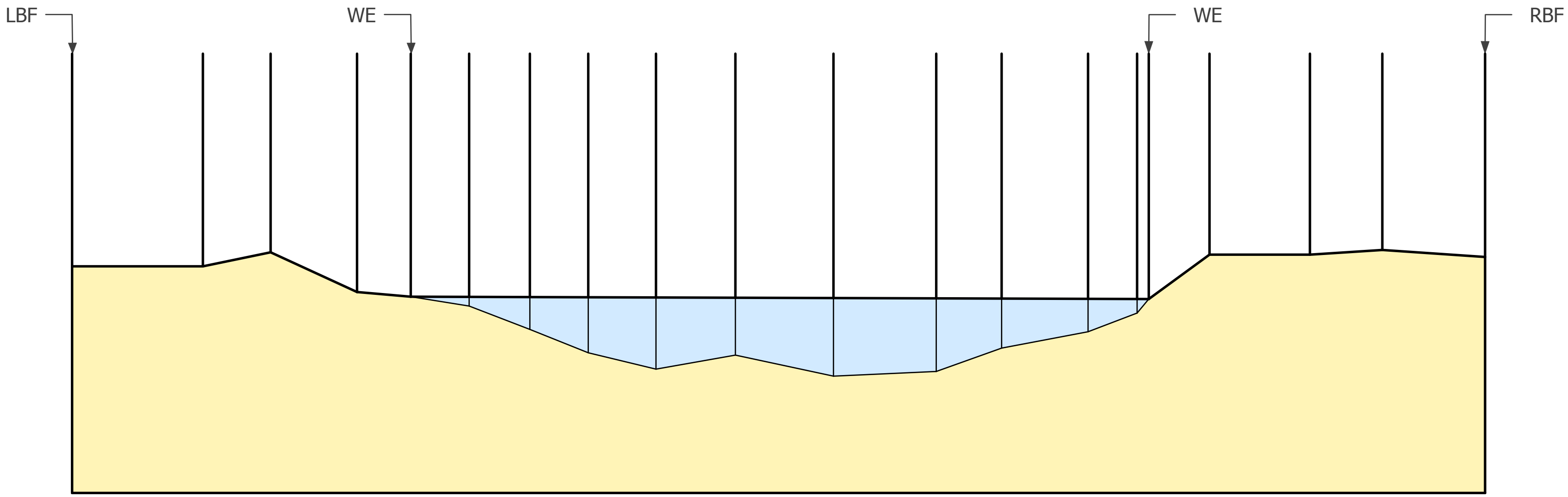
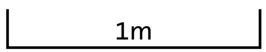
Site 2: Cross-section 4





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Site 2: Cross-section 5

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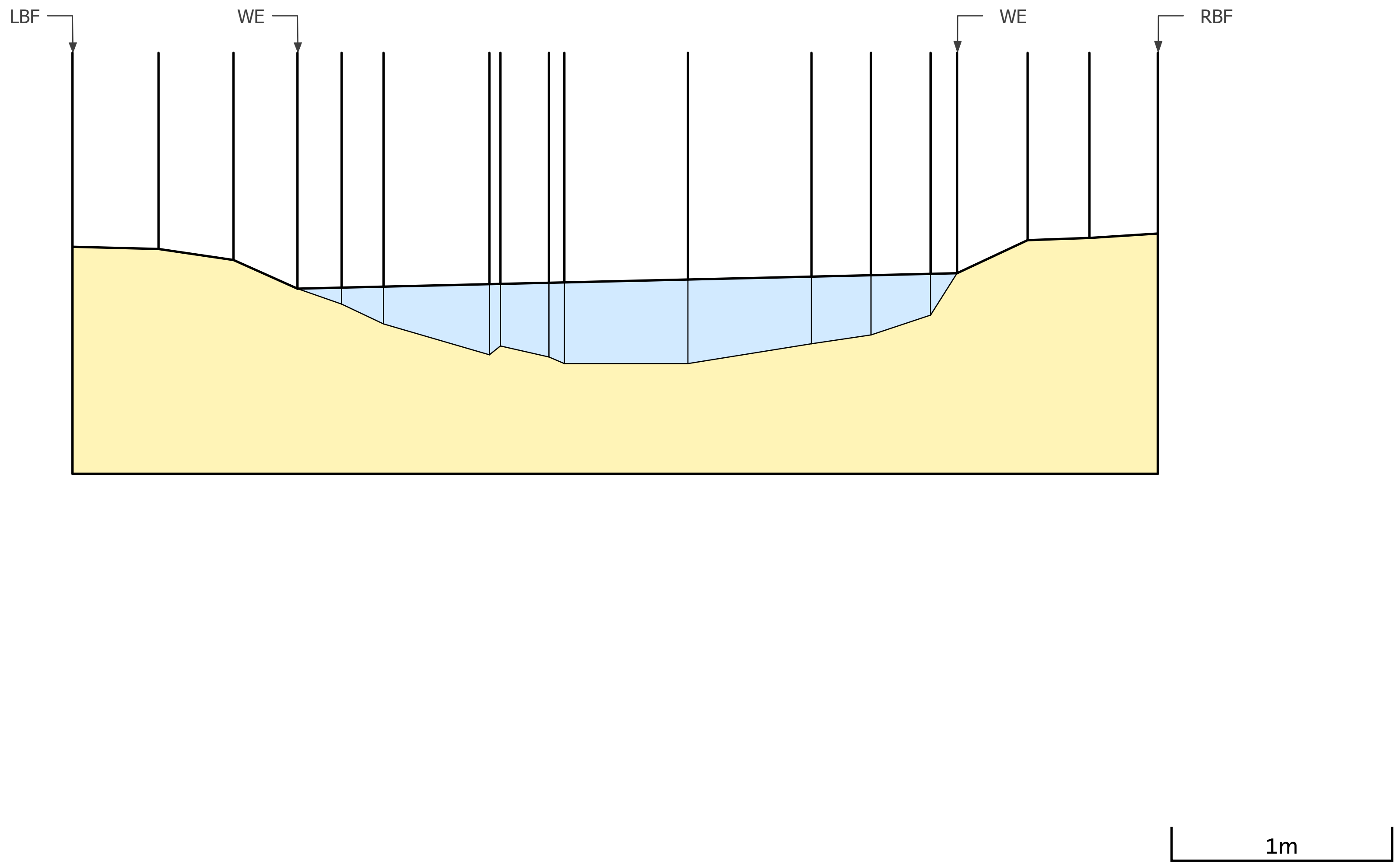

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Site 2: Cross-section 6

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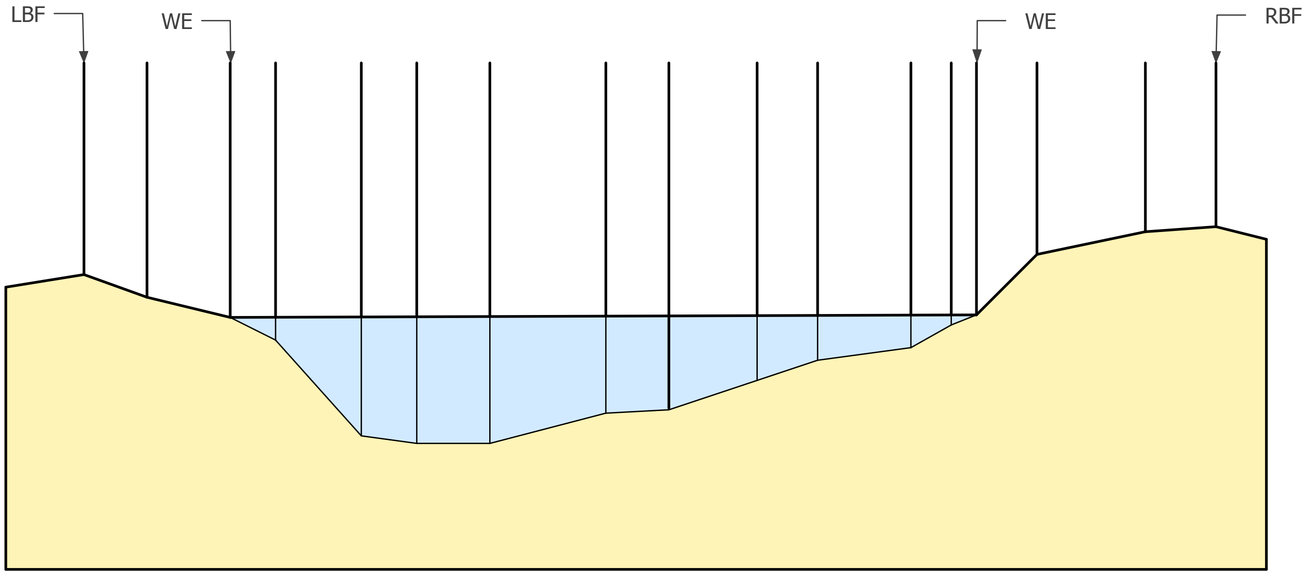

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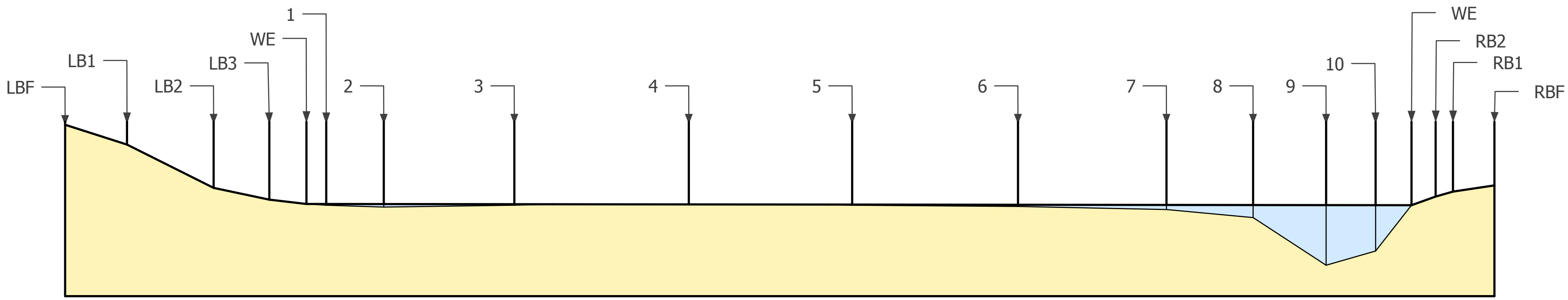
Scale = 1:30@A4

Site 3: Cross-section 1

File ref: C16034_profiles_LASC.layout



Legend

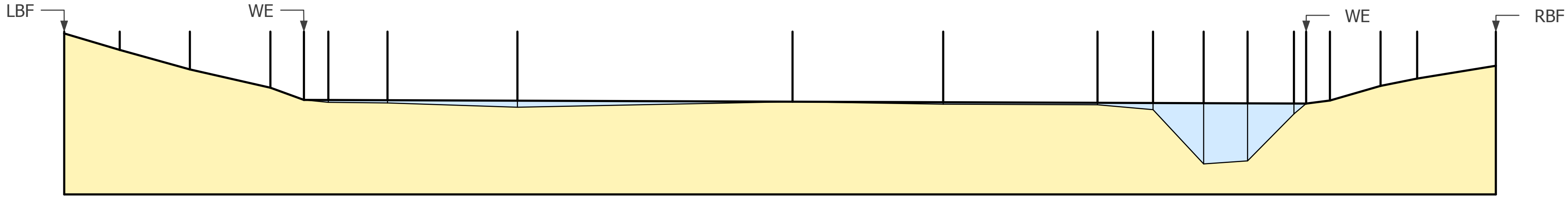
LBF: left bankfull height
LB1 – LBF3: left bankfull 1 - 3
WE – water's edge
1 – 10 – offset 1 - 10
RB1 – RB3: right bankfull 1 - 3
RBF – right bankfull height

1m

Scale = 1:100@A4

Site 3: Cross-section 2

File ref: C16034_profiles_LASC.layout

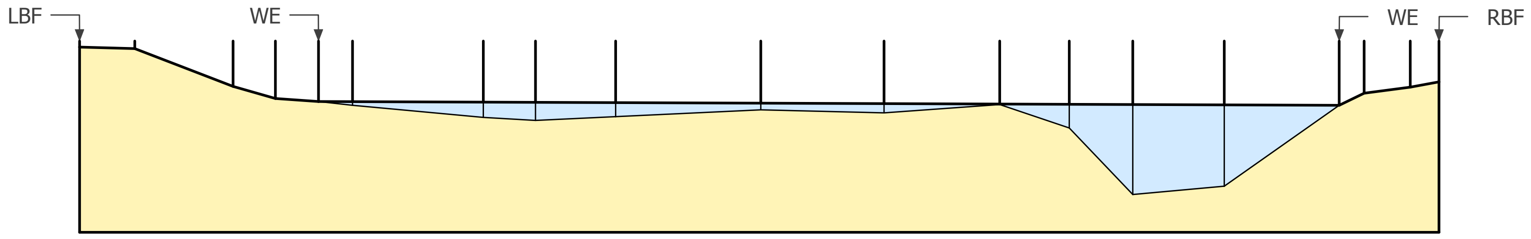


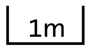
1m

Scale = 1:100@A4

Site 3: Cross-section 3

File ref: C16034_profiles_LASC.layout





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Site 3: Cross-section 4

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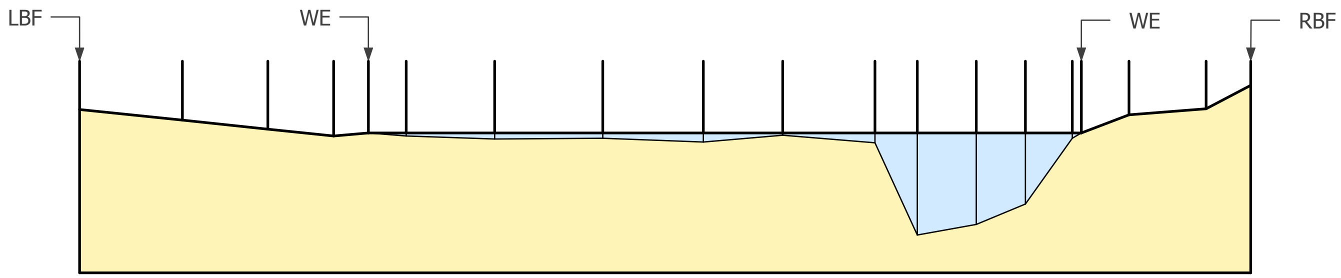

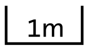

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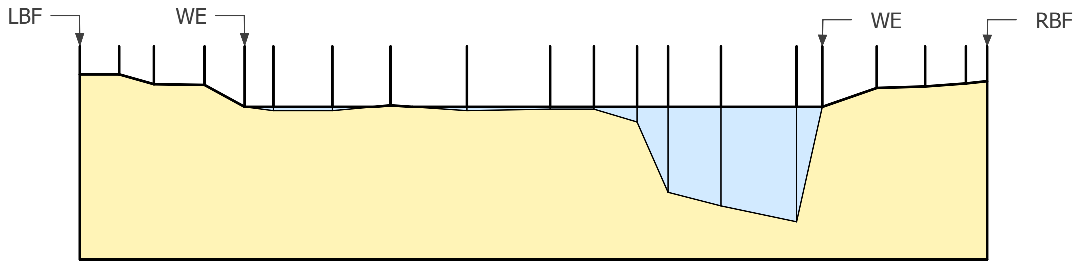
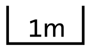
Site 3: Cross-section 5





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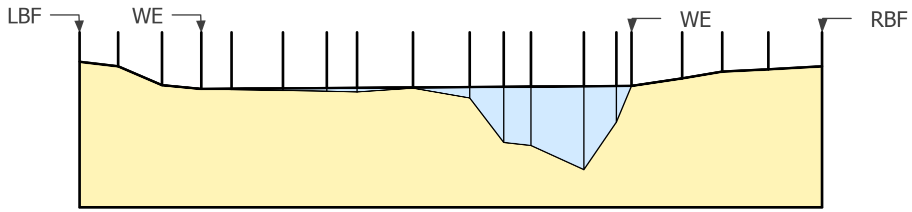

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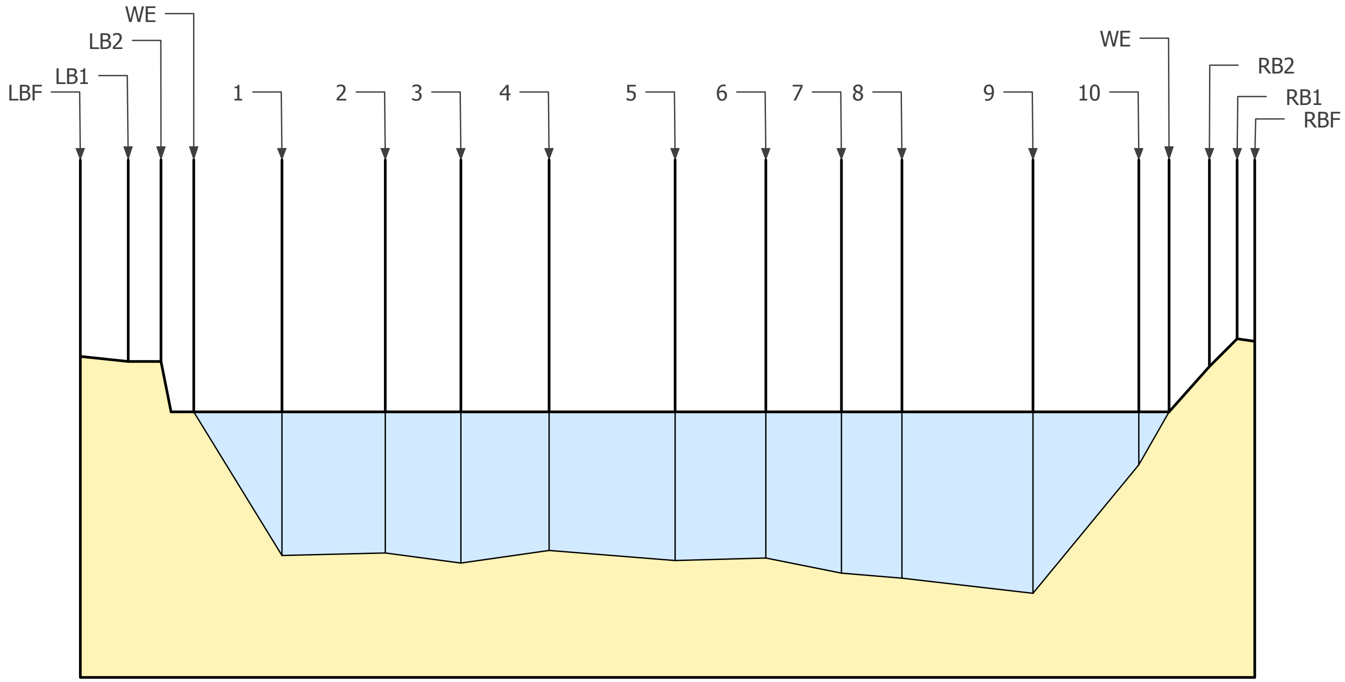
Site 4: Cross-section 1

File ref: C16034_profiles_LASC.layout



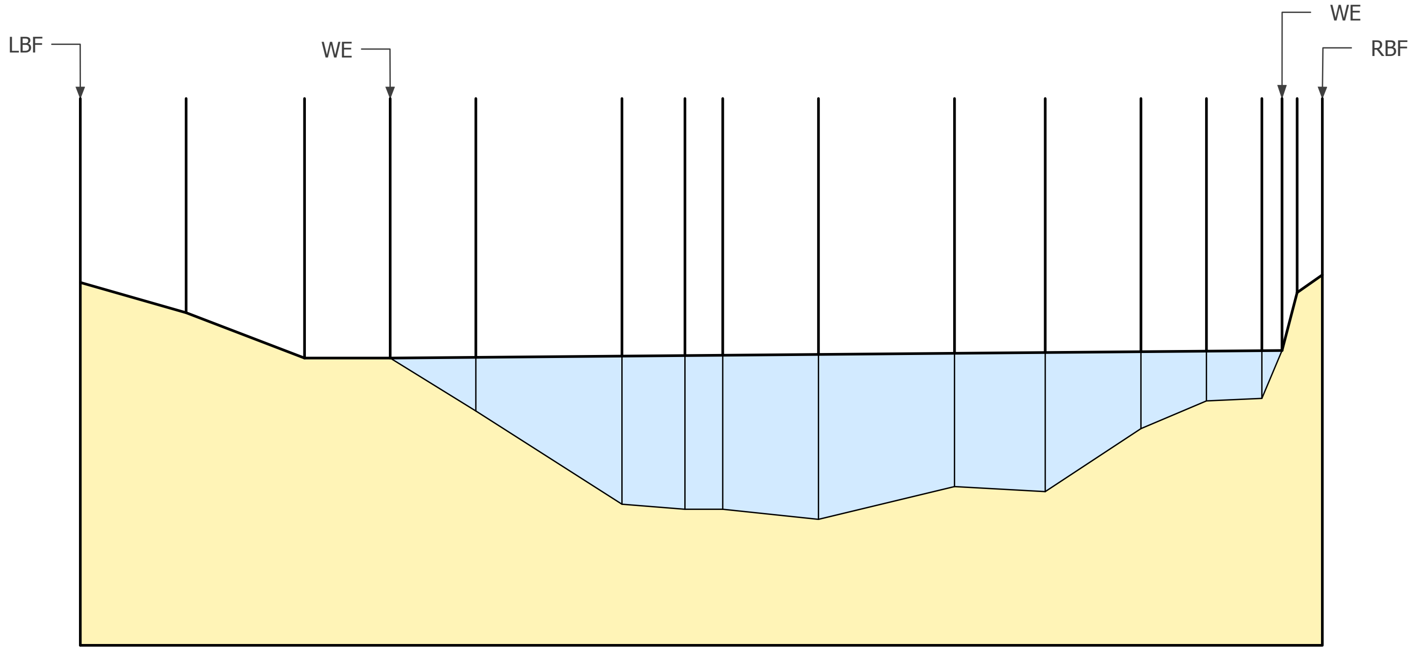
<u>Legend</u>
LBF: left bankfull height
LB1 – LBF3: left bankfull 1 - 3
WE – water's edge
1 – 10 – offset 1 - 10
RB1 – RB3: right bankfull 1 - 3
RBF – right bankfull height

1m

Scale = 1:30@A4

Site 4: Cross-section 2

File ref: C16034_profiles_LASC.layout



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Site 4: Cross-section 3

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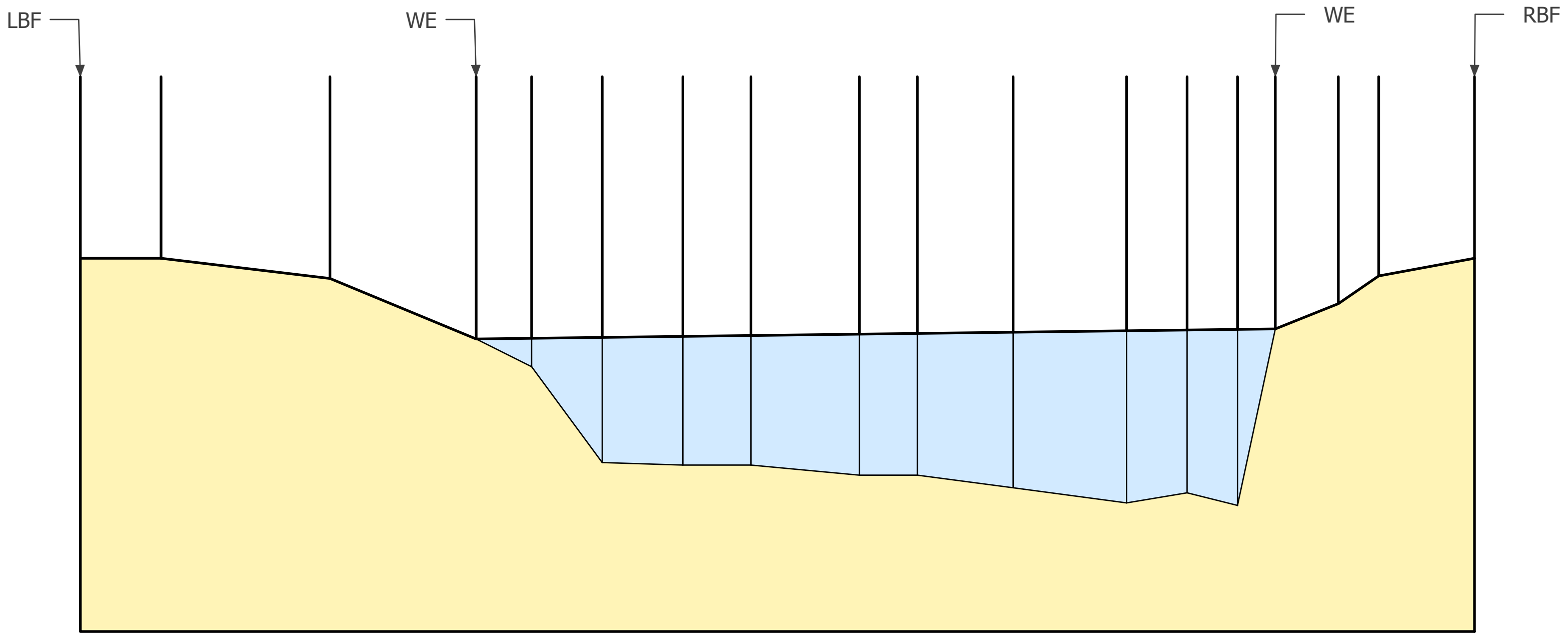

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Site 4: Cross-section 4

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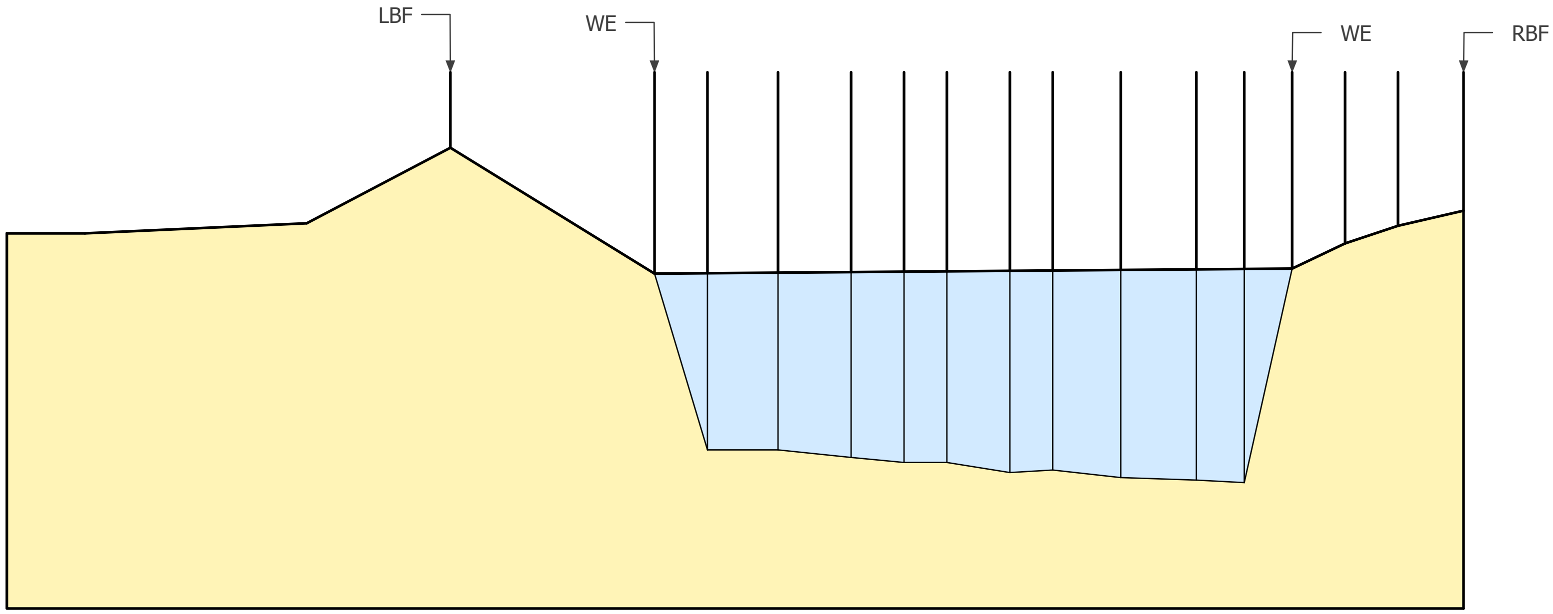

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Site 4: Cross-section 5

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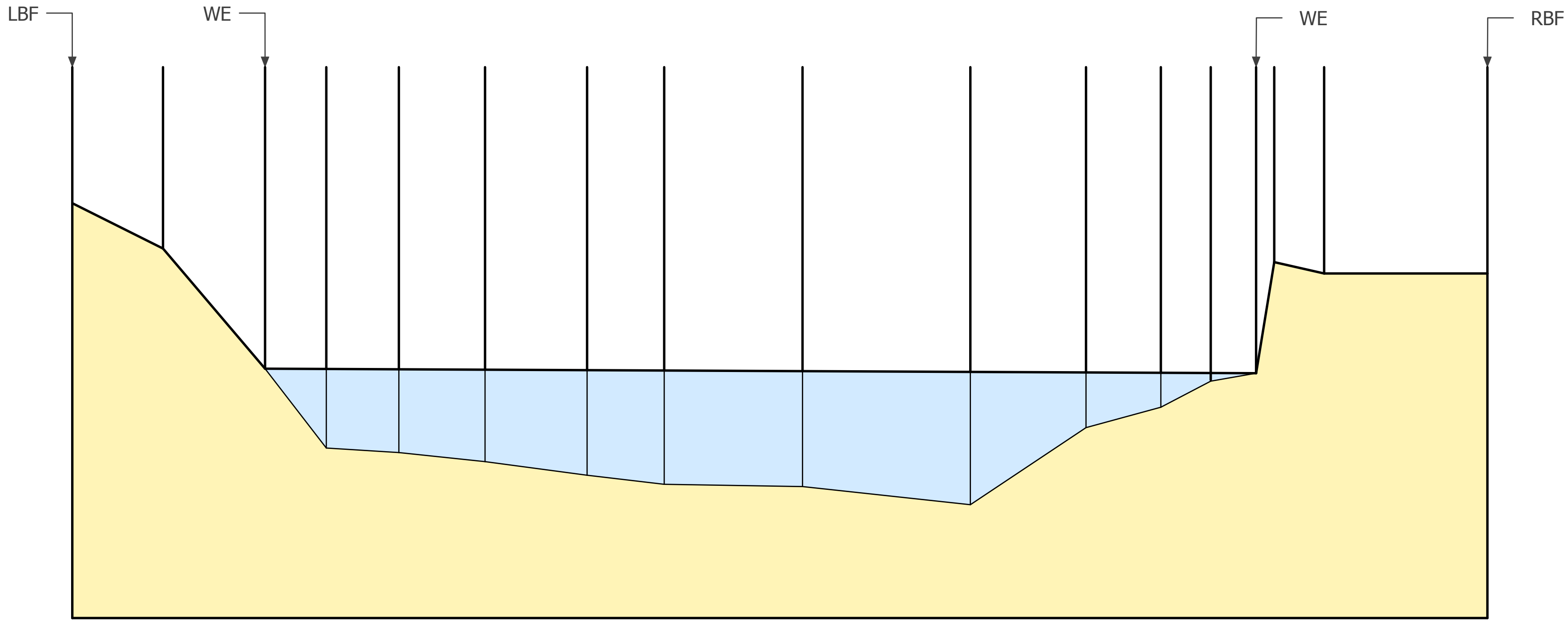

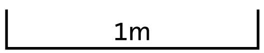

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Site 4: Cross-section 6

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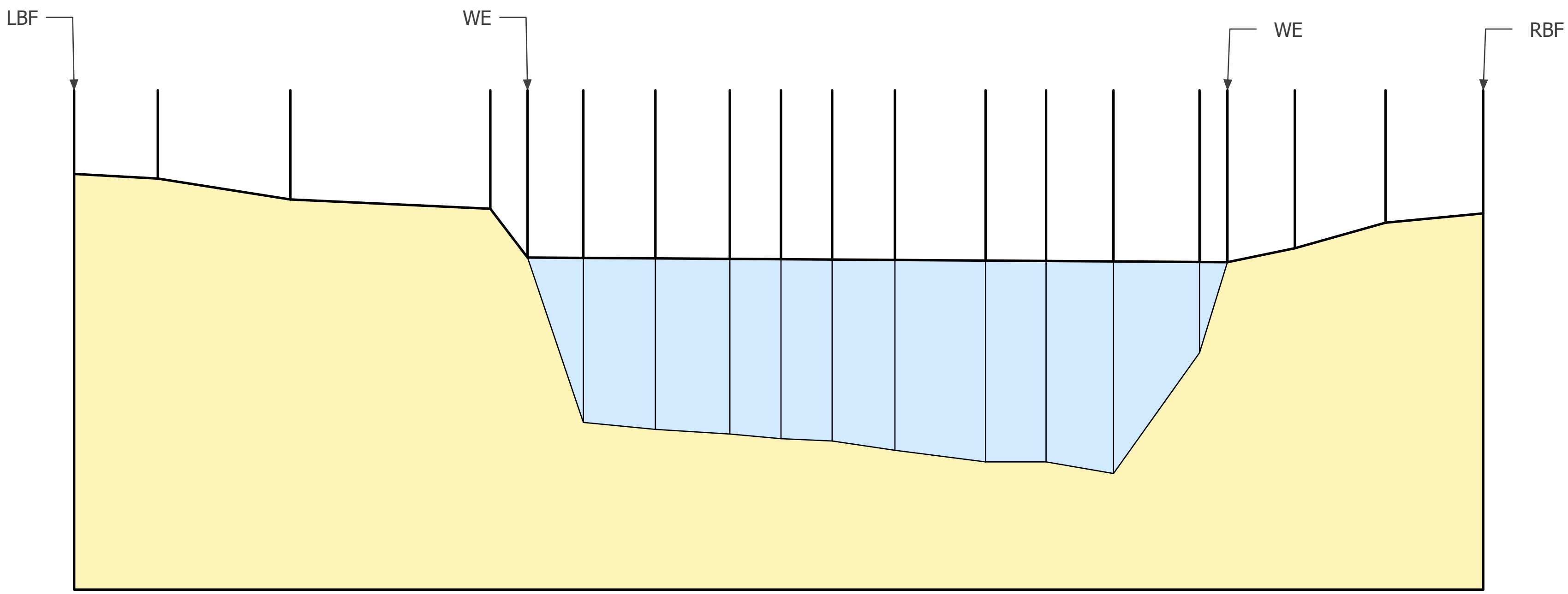

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Appendix 3: Macroinvertebrate taxa

		Site 1				
		Surber 1	**Surber 2**	**Surber 3**	**Surber 4**	**Surber 5**
ACARINA	Acarina	6	4	0	2	1
ANNELIDA	Hirudinea	0	1	1	3	9
	Oligochaeta	90	62	42	181	165
CNIDARIA	*Hydra*	34	2	8	30	5
COLLEMBOLA	Collembola	0	0	0	0	0
CRUSTACEA	Cladocera	29	14	5	30	3
	Copepoda	4	6	5	8	0
	Ostracoda (*Herpetocypris pascheri*)	250	110	155	334	145
	Paracalliope	54	138	12	37	206
DIPTERA	Ceratopogonidae	2	0	3	5	2
	Chironomus	42	4	3	48	0
	Corynoneura	1	0	0	0	0
	Orthocladiinae	0	0	2	0	3
	Paradixa	0	0	0	0	0
	Paralimnophila skusei	1	0	0	0	0
	Polypedilum	6	0	2	2	0
	Tanypodinae	3	2	0	8	1
	Tanytarsini	2	0	0	0	1
HEMIPTERA	*Sigara*	0	6	2	2	6
MOLLUSCA	*Gyraulus*	0	0	0	0	0
	Physa / Physella	10	0	1	0	4
	Potamopyrgus antipodarum	264	260	293	254	329
	Sphaeriidae	3	1	16	28	1
NEMERTEA	Nemertea	0	1	0	0	0
ODONATA	*Xanthocnemis*	4	0	1	2	0
PLATYHELMINTHES	Platyhelminthes	19	0	0	6	4
TRICHOPTERA	*Hudsonema amabile*	1	0	0	0	1
	Oxyethira albiceps	0	0	0	1	0
	Pycnocentria evecta	5	1	5	1	4
	Triplectides sp.	0	0	2	1	4
TOTAL		**830**	**612**	**558**	**983**	**894**

		Site 2				
		Surber 1	**Surber 2**	**Surber 3**	**Surber 4**	**Surber 5**
ACARINA	Acarina	3	5	1	1	1
ANNELIDA	Hirudinea	0	0	0	0	0
	Oligochaeta	67	190	167	118	102
CNIDARIA	*Hydra*	36	27	80	26	20
COLLEMBOLA	Collembola	1	1	0	0	0
CRUSTACEA	Cladocera	60	140	5	15	33
	Copepoda	0	1	0	0	2
	Ostracoda (*Herpetocypris pascheri*)	433	402	338	218	192
	Paracalliope	8	8	2	2	12
DIPTERA	Ceratopogonidae	3	0	5	3	1
	Chironomus	0	0	2	22	2
	Corynoneura	2	2	0	0	1
	Orthocladiinae	3	0	0	1	0
	Paradixa	0	0	0	0	0
	Paralimnophila skusei	0	0	0	0	0
	Polypedilum	2	0	4	1	1
	Tanypodinae	1	0	0	1	0
	Tanytarsini	1	0	0	0	0
HEMIPTERA	*Sigara*	1	0	0	1	0
MOLLUSCA	*Gyraulus*	0	0	0	0	0
	Physa / Physella	14	8	2	3	3
	Potamopyrgus antipodarum	225	66	114	192	71
	Sphaeriidae	72	37	63	44	27
NEMERTEA	Nemertea	0	0	0	0	0
ODONATA	*Xanthocnemis*	0	0	0	0	0
PLATYHELMINTHES	Platyhelminthes	2	7	8	7	2
TRICHOPTERA	*Hudsonema amabile*	0	0	0	0	0
	Oxyethira albiceps	0	0	0	0	0
	Pycnocentria evecta	0	0	0	0	0
	Triplectides sp.	1	0	0	0	0
TOTAL		**935**	**894**	**791**	**655**	**470**

		Site 3				
		Surber 1	**Surber 2**	**Surber 3**	**Surber 4**	**Surber 5**
ACARINA	Acarina	2	2	7	6	0
ANNELIDA	Hirudinea	0	0	2	0	0
	Oligochaeta	82	39	6	48	48
CNIDARIA	*Hydra*	48	30	12	4	2
COLLEMBOLA	Collembola	0	0	0	0	0
CRUSTACEA	Cladocera	33	48	38	14	13
	Copepoda	4	47	4	69	4
	Ostracoda (*Herpetocypris pascheri*)	178	265	459	371	72
	Paracalliope	3	19	5	18	1
DIPTERA	Ceratopogonidae	0	0	0	0	0
	Chironomus	10	5	34	23	8
	Corynoneura	1	0	5	10	0
	Orthocladiinae	0	4	5	4	0
	Paradixa	0	0	0	0	0
	Paralimnophila skusei	0	0	0	0	0
	Polypedilum	1	0	1	0	0
	Tanypodinae	0	0	1	0	0
	Tanytarsini	0	0	0	0	0
HEMIPTERA	*Sigara*	0	0	0	0	0
MOLLUSCA	*Gyraulus*	1	0	0	0	0
	Physa / Physella	26	45	38	83	1
	Potamopyrgus antipodarum	56	246	426	137	3
	Sphaeriidae	54	85	172	87	10
NEMERTEA	Nemertea	0	0	0	1	1
ODONATA	*Xanthocnemis*	0	0	0	0	1
PLATYHELMINTHES	Platyhelminthes	14	64	24	26	5
TRICHOPTERA	*Hudsonema amabile*	0	0	0	0	0
	Oxyethira albiceps	0	6	0	0	0
	Pycnocentria evecta	0	0	0	0	0
	Triplectides sp.	0	0	0	0	0
TOTAL		**513**	**905**	**1239**	**901**	**169**

		Site 4				
		Surber 1	**Surber 2**	**Surber 3**	**Surber 4**	**Surber 5**
ACARINA	Acarina	1	2	2	3	1
ANNELIDA	Hirudinea	0	0	0	0	0
	Oligochaeta	26	51	128	39	32
CNIDARIA	*Hydra*	11	14	158	3	28
COLLEMBOLA	Collembola	0	0	0	0	0
CRUSTACEA	Cladocera	44	67	266	46	72
	Copepoda	2	0	0	1	0
	Ostracoda (*Herpetocypris pascheri*)	25	305	794	408	420
	Paracalliope	2	10	9	0	1
DIPTERA	Ceratopogonidae	0	0	0	0	0
	Chironomus	3	23	10	16	3
	Corynoneura	2	0	0	0	0
	Orthocladiinae	0	1	1	0	0
	Paradixa	1	0	0	0	0
	Paralimnophila skusei	0	0	0	0	0
	Polypedilum	0	0	0	0	0
	Tanypodinae	0	0	0	0	0
	Tanytarsini	0	0	0	0	0
HEMIPTERA	*Sigara*	0	0	0	0	0
MOLLUSCA	*Gyraulus*	0	0	0	0	0
	Physa / Physella	8	35	28	7	2
	Potamopyrgus antipodarum	14	115	32	10	6
	Sphaeriidae	40	72	86	53	39
NEMERTEA	Nemertea	0	0	1	0	0
ODONATA	*Xanthocnemis*	0	0	0	0	0
PLATYHELMINTHES	Platyhelminthes	21	16	42	15	91
TRICHOPTERA	*Hudsonema amabile*	0	0	0	0	0
	Oxyethira albiceps	0	0	0	0	0
	Pycnocentria evecta	0	0	0	0	0
	Triplectides sp.	0	0	1	1	0
TOTAL		**200**	**711**	**1558**	**602**	**695**

Appendix 4: SIMPER results

Sites 1 & 2

Average dissimilarity = 39.86

	Site 1	Site 2				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Potamopyrgus antipodarum	280	133.6	10.04	1.83	25.2	25.2
Ostracoda (*Herpetocypris pascheri*)	198.8	316.6	9.5	1.59	23.83	49.03
Paracalliope	89.4	6.4	5.47	1.12	13.72	62.75
Oligochaeta	108	128.8	4.13	1.42	10.37	73.13
Cladocera	16.2	50.6	2.6	0.95	6.53	79.66
Sphaeriidae	9.8	48.6	2.54	2.09	6.37	86.03
Hydra	15.8	37.8	1.73	1.16	4.33	90.37

Site 1 & 3

Average dissimilarity = 48.12

	Site 1	Site 3				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Potamopyrgus antipodarum	280	173.6	13.18	1.23	27.39	27.39
Ostracoda (*Herpetocypris pascheri*)	198.8	269	9.55	1.58	19.85	47.24
Paracalliope	89.4	9.2	5.78	1.03	12.01	59.25
Sphaeriidae	9.8	81.6	4.37	1.77	9.08	68.33
Oligochaeta	108	44.6	4.36	1.32	9.06	77.38
Physa / *Physella*	3	38.6	2.24	1.42	4.66	82.05
Platyhelminthes	5.8	26.6	1.42	1.18	2.95	85
Copepoda	4.6	25.6	1.38	0.86	2.88	87.87
Chironomus	19.4	16	1.31	1.38	2.73	90.6

Sites 2 & 3

Average dissimilarity = 41.67

	Site 2	Site 3				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Ostracoda (*Herpetocypris pascheri*)	316.6	269	11.04	1.19	26.5	26.5
Potamopyrgus antipodarum	133.6	173.6	9.17	1.42	22.02	48.52
Oligochaeta	128.8	44.6	5.89	1.77	14.13	62.65
Sphaeriidae	48.6	81.6	3.3	1.53	7.91	70.56
Cladocera	50.6	29.2	2.62	0.93	6.29	76.85
Physa / *Physella*	6	38.6	2.19	1.42	5.25	82.09
Hydra	37.8	19.2	1.99	1.16	4.77	86.86
Copepoda	0.6	25.6	1.57	0.92	3.76	90.62

Site 1 & 4
Average dissimilarity = 61.34

	Site 1	Site 4				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Potamopyrgus antipodarum	280	35.4	17.75	2.41	28.94	28.94
Ostracoda (*Herpetocypris pascheri*)	198.8	390.4	16.62	1.98	27.1	56.04
Paracalliope	89.4	4.4	6.02	1.08	9.81	65.85
Cladocera	16.2	99	4.69	1.39	7.65	73.5
Oligochaeta	108	55.2	4.68	1.25	7.63	81.13
Sphaeriidae	9.8	58	3.2	2.75	5.22	86.35
Platyhelminthes	5.8	37	2.15	1.04	3.51	89.86
Hydra	15.8	42.8	2.04	0.91	3.32	93.18

Sites 2 & 4
Average dissimilarity = 42.25

	Site 2	Site 4				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Ostracoda (*Herpetocypris pascheri*)	316.6	390.4	14.85	1.32	35.15	35.15
Potamopyrgus antipodarum	133.6	35.4	7.72	1.44	18.26	53.42
Oligochaeta	128.8	55.2	6.27	1.49	14.83	68.25
Cladocera	50.6	99	4.53	1.37	10.72	78.97
Hydra	37.8	42.8	2.62	1.21	6.21	85.17
Platyhelminthes	5.2	37	2.18	1.05	5.16	90.33

Sites 3 & 4
Average dissimilarity = 48.10

	Site 3	Site 4				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Ostracoda (*Herpetocypris pascheri*)	269	390.4	17.8	1.37	37.01	37.01
Potamopyrgus antipodarum	173.6	35.4	9.75	1.24	20.26	57.27
Cladocera	29.2	99	4.26	1.07	8.86	66.13
Sphaeriidae	81.6	58	3.44	1.32	7.15	73.28
Hydra	19.2	42.8	2.42	1.01	5.04	78.31
Oligochaeta	44.6	55.2	2.35	1.21	4.89	83.2
Physa / Physella	38.6	16	2.14	1.26	4.44	87.64
Platyhelminthes	26.6	37	2.1	0.91	4.36	92