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Development of a Reference Site Network for Invertebrate Monitoring of Wadeable Streams in the Waikato

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1 Introduction

Every year Environment Waikato carries out state of the environment monitoring at over 100 stream and river sites throughout the Region, referred to as the Regional Ecological Monitoring of Streams (REMS) programme. Most of the sites in this network are considered “wadeable”, defined as those where more than half of the sampling reach can be safely accessed at summer low flow so that representative samples can be collected from benthic and/or other stable, productive habitats. These sites typically have mean depth of ≤1 m and occur on 1st- through to 4th-order streams, although some larger sites within this range may be non-wadeable. Monitoring of wadeable streams entails assessment of habitat and collection of macroinvertebrate samples using methodologies outlined in Collier & Kelly (2005), and more recently has included assessments of periphyton (2002 onwards with protocol modified in 2005) and macrophyte cover and type (2005 onwards).

A review of the REMS programme (Kingett Mitchell Ltd 2001) highlighted significant inadequacies in the number, geographic spread and selection process of reference sites, short-comings that impeded comparisons of similar types of streams within and between ecoregions. Previously there has been only seven sites sampled that drained unmodified catchments entirely in native forest out of a total of over 120 sites sampled annually. The following report describes the steps taken to identify accessible sections of wadeable streams suitable for the REMS reference site network. Identification of these sections of stream was undertaken with Environment Waikato’s GIS environment coupled where appropriate with local knowledge, followed by ground-truthing, field sampling and data analysis.

2 Methods

2.1 Background

Protocols were recently developed by the Ministry for the Environment (MfE) to provide guidance on reference site selection for environmental monitoring of streams (Boothroyd et al. 2002). These protocols identified four categories of reference site condition:

- **A+** – Pristine sites where the upstream catchment is essentially unmodified natural area;
- **A** – Near-pristine sites where sufficient unmodified natural area exists, but some minor upstream catchment modifications may be present;
- **B** – Best management sites which display the best environmental condition locally or regionally for that stream type; and
- **C** – Local benchmark sites which do not meet the above criteria, but nevertheless represent a site type against which other sites can be compared (e.g., restored streams, long-term records available).

Potential category “A+” or “A” wadeable stream (order ≥4) reference sites in the Waikato were identified by formulating criteria based around the definitions described above. For category “A” sites, the only “minor upstream catchment modifications” allowed were 1-15% non-natural landcover (i.e., >85% of upstream catchment area in unmodified landcover). In addition, all candidate sites were required to have adjacent native vegetation cover and no upstream roads (including bridges, culverts, sealed and unsealed roads), mines, quarries, dams, reservoirs or other structures that alter water flow. Accessibility was used as a constraint on reference site identification (see Section 2.3) as all sites needed to be reached by foot.

A five-stage process was applied to identify potential references sites (see Figure 1), involving:

1. identification of all potential sites based on pre-selected condition and access criteria;
2. selection of sites for further investigation using a random allocation process based around stream type, zone, and further assessments of condition and access;
3. verification involving the use of aerial photos and site visits;
4. field sampling to collect samples from reference sites;
5. data analysis to determine patterns and identify site redundancies.

Steps 1 and 2 above, and the aerial photograph assessment in step 3, were carried out in the GIS environment described in detail below.

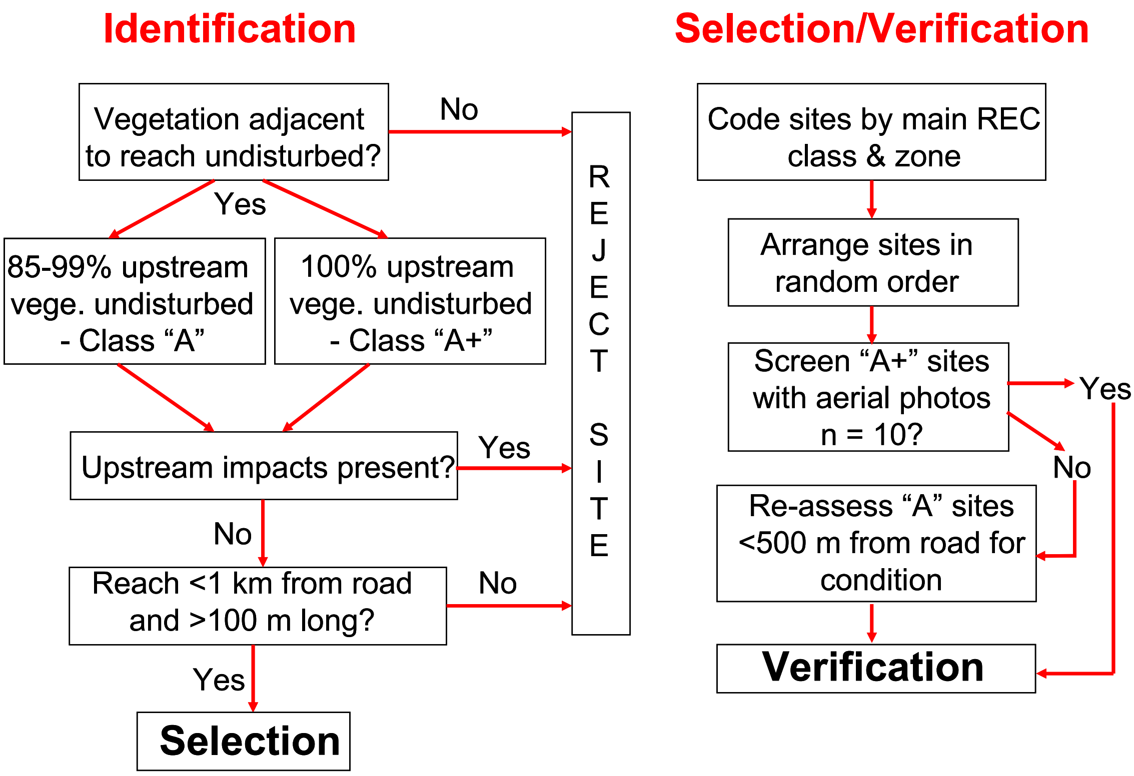


Figure 1: Process used to identify, select and verify potential reference sites for wadeable stream monitoring in the Waikato Region.

2.2 Representing geographic spread and stream type

We used the River Environment Classification (REC; Snelder & Biggs (2002)) to identify regionally dominant stream classes based on natural combinations of climate, source of flow and underlying geology. This level of classification was used because it was considered to represent the range of natural variation in key variables likely to influence macroinvertebrate communities at large spatial scales, without the anthropogenic pressure of land cover change which was to be addressed in the study design for impact site selection.

This analysis identified four main wadeable stream classes that, in the absence of human pressures, collectively comprised almost three-quarters (73%) of the 35,886 km of mapped wadeable stream length in the Waikato Region (Figure 2):

- Cool-wet climate/Hill-country source of flow/Volcanic acidic geology (CW/H/VA) – 24% of mapped regional stream length;

- Warm-wet climate/Low-elevation source of flow/Hard sedimentary geology (WW/L/HS) – 9% of mapped regional stream length;
- Warm-wet climate/Low-elevation source of flow/Soft-sedimentary geology (WW/L/SS) – 10% of mapped regional stream length;
- Warm-wet climate/Low-elevation source of flow/Volcanic acidic geology (WW/L/VA) – 30% of mapped regional stream length.

With the possible exception of WW/L/SS streams where <3% of stream length potentially occurs in A+ reference site conditions, the other three main REC classes seemed to be well represented (each >16% of contemporary stream length; Figure 2). Since the principal aim of the REMS wadeable stream reference sites is to enable the condition and biodiversity of impacted streams to be placed in context of comparable representative stream types unimpacted by human activities, it was decided to focus reference site selection primarily on the four REC main classes. However, based on local knowledge representatives of other classes were included, where practical, because less common stream classes are also of potential interest, particularly in terms of biodiversity assessment.

To ensure that the reference site network had a good geographic spread throughout the region, we nested dominant stream class within a zone layer modified from Environment Waikato's Asset Management Zone Boundaries. This layer comprised Coromandel, Lower Waikato, Hauraki, Waipa, West Coast, Middle/Upper Waikato, and Taupo. These zone boundaries have no biogeographic basis, but were used to provide consistency with other analyses carried out at Environment Waikato while achieving a good geographic spread of sites. The four dominant stream classes nested within the seven zones yielded a design with 28 potential sites if one unmodified site could be found in all combinations. As noted above, additional sites of special interest or sites representing less common stream types were also included in the field sampling stage based on local knowledge. Other REC types that were well-represented as potential reference sites were CX/H/VA (9 and 6% of regional wadeable stream length for A+ and A sites, respectively), WW/H/VA (6 and 2%), and WX/L/VA (4% for each), although overall stream length for each of these classes was less than 5% of the regional total (Figure 2).

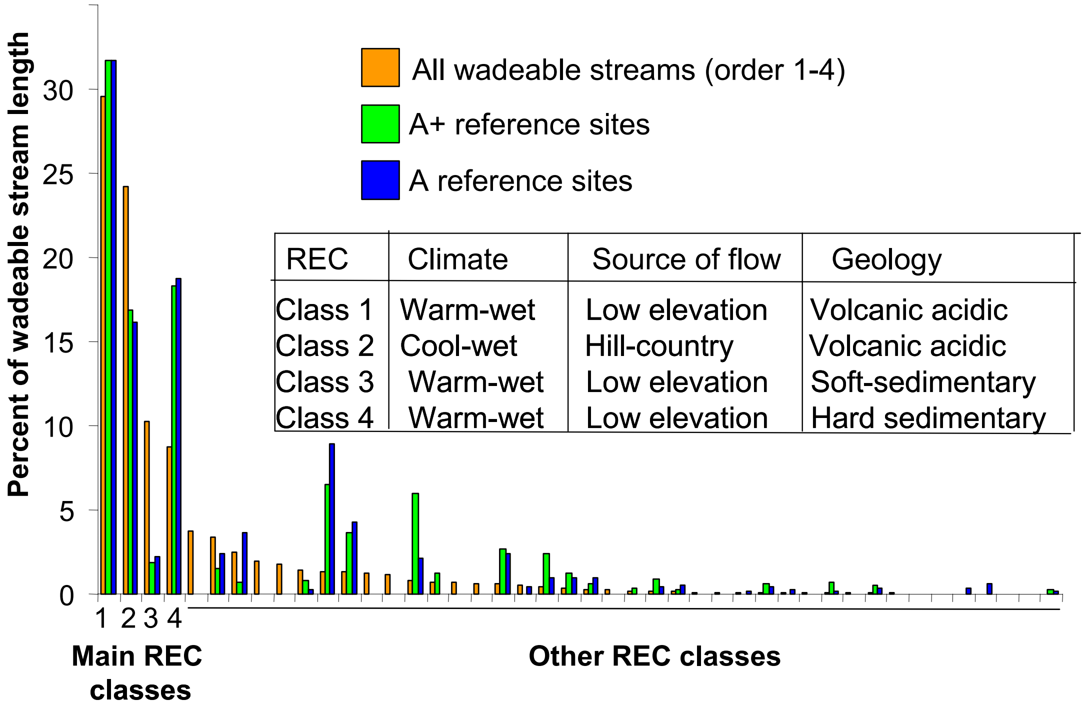


Figure 2: Percent of wadeable (order ≤4) stream length throughout the Waikato Region falling into REC classes based on differences in climate, source of flow and geology. Stream lengths are broken down by all wadeable streams, and segments that were identified as potentially falling into A+ or A reference site conditions.

2.3 Site identification

Potential reference sites were identified using GIS performed on Intergraph's Geomedia Professional with a range of databases and spatial layers. The GIS component described below was designed to provide a range of possible sites that meet specific criteria, within the limitations of the data available.

Stream network and watersheds
The drainage network layer of the REC was used in all analyses for stream orders 1-4 (i.e. wadeable streams). The REC system is a synthetic river network derived from a 30 m-pixel digital elevation model using the 20 m contour data from the NZMS260 map series. The synthetic river network is split into segments at points of confluence. This forms the WATERCOURSES_REC layer. The watercourse layer was queried to remove lengths that intersected NZMS260 series Lakes (primarily removing watercourses mapped as going through Lake Taupo), and also intersected with the Regional boundary to eliminate segments falling outside the Region.

The WATERSHEDS_REC layer was simultaneously delineated with the WATERCOURSES_REC. The watershed layer was used to calculate the area of landcover type upstream of a particular stream segment, allowing the % of upstream catchment landcover type to be calculated for any watercourse segment. The raw data underlying the REC were used with permission of NIWA to identify the percent catchment area unmodified (i.e., indigenous forest or tussock) upstream of REC river segment nodes.

Data processing

1. Determining category A+ and A stream segments - In order to identify WATERCOURES_REC segments classified as "A+" or "A" category streams, LCDB1 classes were combined where appropriate to standardise classes with the REC land use classes. Thus, areas for Inland Wetlands and Coastal Wetlands were combined to form Wetlands; Pasture and Horticulture formed Pastoral; Urban and Urban open space formed Urban; and Mangrove, Riparian Willows and Coastal Sands formed Miscellaneous. Bare Ground, Indigenous Forest, Scrub and Tussock were retained, and Indigenous Forest and Tussock were combined to identify unmodified vegetation cover (UNMOD_PC). Inland Waters, Coastal Dune Vegetation or Mines/Quarries were not considered as Landcover types for this purpose.

Within Geomedia Professional, a join was performed between the modified landcover layer and the WATERCOURSE_REC feature using the REACH_ID attribute to create a new feature WATERCOURSE_CAT. A query was then done to identify WATERCOURSE_CAT segments with UNMOD_PC values of 100% (A+), and those between 85 and 99% (A). The two queries are then output as the feature WATERCOURSE_A. The feature was given a new column CATEGORY_RANK populated by 'A+' or 'A'. Figure 3 illustrates the distribution of these areas throughout the Region.

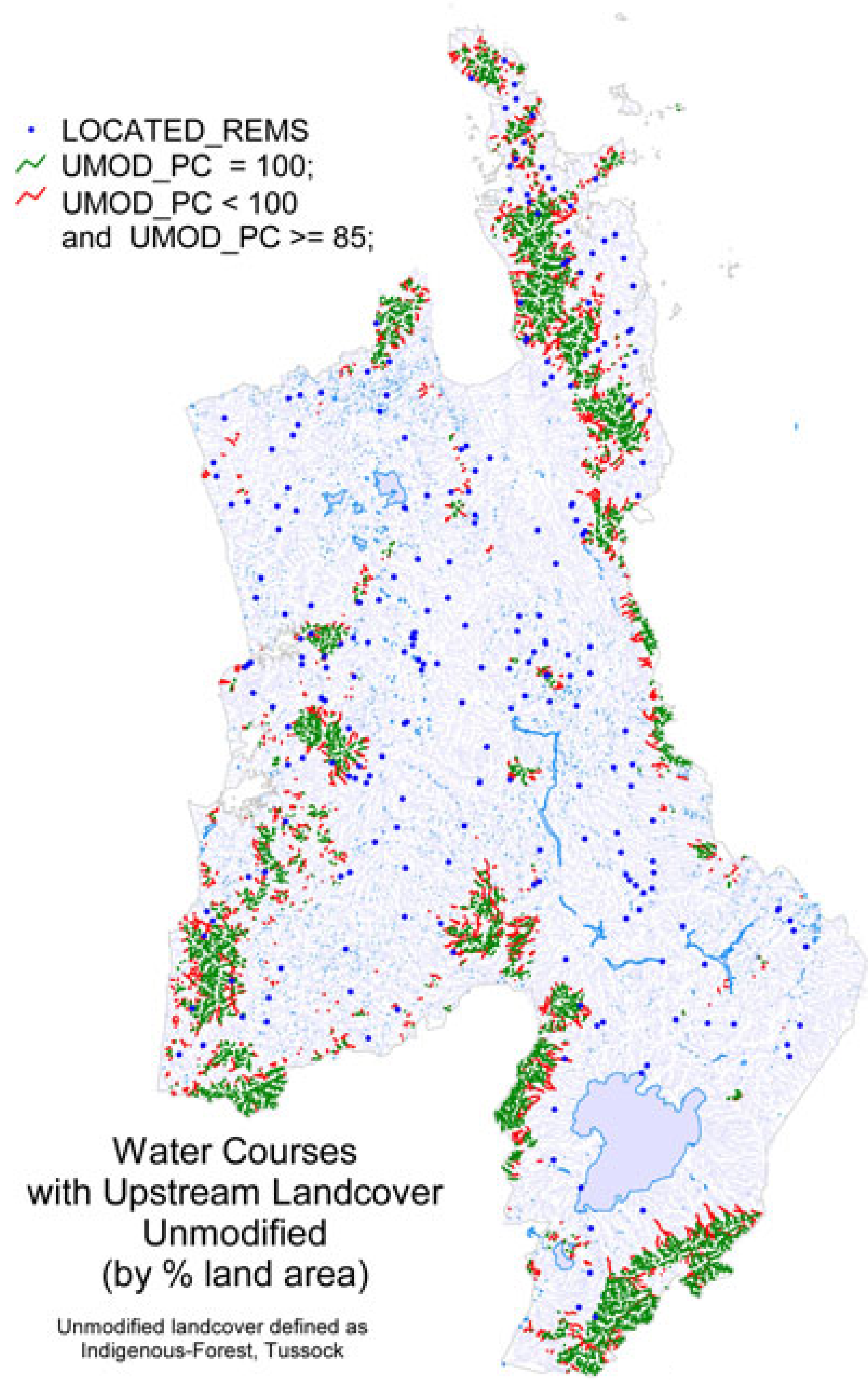


Figure 3: Distribution of 'A+' (100% unmodified upstream landcover) and 'A' (85-99% unmodified) REC stream segments throughout the Region.

2. Finding stream segments surrounded by native vegetation - For category “A” sites (85-99% indigenous vegetation) the above analysis did not guarantee that the actual stream segments identified would be surrounded by native vegetation. Two possible datasets were investigated as a means of identifying segments filling this criterion: the Landcover Database and the Indigenous Vegetation (1992) Database (LCDB1). The Indigenous Vegetation (1992) Database was considered to be at an inappropriate scale (i.e., to detailed) for this analysis, so the LCDB1 was used for this purpose.

A query was performed to identify all areas of LCDB1 classes labelled Indigenous Forest or Tussock, and these were combined to form Unmodified vegetation. A spatial intersection of WATERCOURSE_A and this merged LCDB1 attribute was performed to generate a feature called WATERCOURSE_NV_VEG which identified stream segments surrounded by unmodified vegetation.

3. Finding segments within 1 km of a road - All sites >1 km from a mapped road were dropped to ensure that identified sites were readily accessed by foot. This was done by using the Terralink supplied CRS_ROAD layer stored in Environment Waikato’s GIS database. A query was run to find all river segments in WATERCOURSE_NV_VEG within 1km of a road. This query found 1515 segments and the output was saved as WATERCOURSE_ROAD. Two more buffer zones were created around the CRS_ROAD feature, one for 100 m and another for 500 m, to complement the original 1000 m. A column labelled ACCESS_ROAD was added, and through a selection of queries, each watercourse segment was given the attributes ‘<100 m’ or ‘101 – 500 m’ or ‘>500 m’ (i.e., 501-1000 m) to identify different levels of potential accessibility.

4. Eliminating streams with potential upstream impacts - An approach for eliminating segments was experimented with by visually identifying and removing segments with potential upstream ‘interference objects’. This approach worked well for roads by copying WATERCOURSE_ROAD to WATERCOURSE_CLEAN, and then removing watercourses with CRS_ROAD features crossing upstream. Where the majority of the stream segment was below a road-crossing the whole segment and all those downstream were deleted.

The same approach was applied for upstream mines and quarries. Three candidate datasets were evaluated to identify these features:
1. 1:50000 NZMS topographic data;
2. Environment Waikato’s Resource Use Authorisations Management System (RUAMS) database;
3. Mineral prospecting licence locations as supplied by the Ministry of Economic Development.

Crown mineral permits only represented broad areas where companies have prospecting permits, and the topographic sheets did not seem to reliably represent mining/quarry sites. We investigated the AUTHORISATIONS feature in RUAMS in the GIS using STATUS = ‘Current’ or ‘Application’. There are a number of consent types and subtypes of potential interest which were eventually used for this analysis:
- Culvert (road)
- Discharge permit Discharge to water
- Land use consent Bed - deposit
- Land use consent Bed - disturbance
- Land use consent Bed - metal
- Land use consent Bed - reclamation
- Land use consent Bed - structure
- Land use consent Bed - whitebait
- Water permit Dam
- Water permit Diversion

Using these consent types, 13,315 points of potential interference were identified. Watercourses with any consent points upstream were identified, and any watercourse (i.e., the affected segment and all those downstream) with a consent considered to potentially contribute to a lessening of quality was removed from WATERCOURSE_CLEAN (Figure 4).

Reservoirs were identified as a feature on the current NZMS260 series topographic sheets which was available as a feature in Environment Waikato's GIS. WATERCOURSE_CLEAN was checked to ensure that none of the remaining segments had reservoirs upstream.

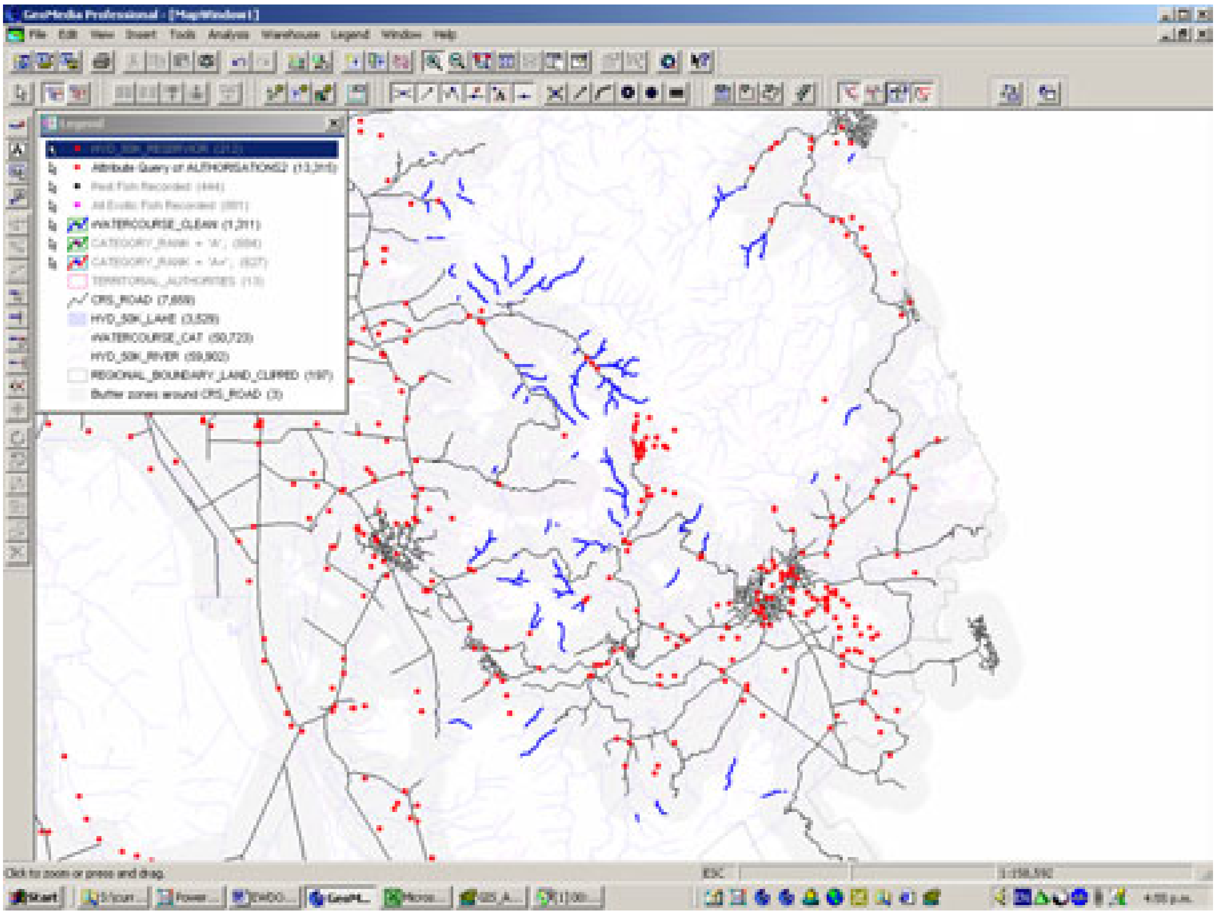


Figure 4: Example of RUAMS data (red points) with the WATERCOURSE_CLEAN data (blue) used to eliminate sites with potential upstream interferences that might have compromised reference site status.

5. Removing short stream segments - Remaining watercourse sections shorter than 100 m were removed, as mapped segments less than this length were considered marginal for REMS monitoring in terms of edge effects. To do this, Geomedia Professional's Functional-Attributes-GEOMETRIES tool was used to return the input geometries by expanding collections (discontiguous geometries – i.e., where one REC reach has been split into 2 or more sections). The output was then saved as WATERCOURSE_FINAL and a column was populated called GIS_LENGTH_M (Double, Fixed, 0dp) to replace the original LENGTH column values which were no longer valid as they were the lengths of the original segments prior to chopping. All sections of WATERCOURSE_FINAL GIS_LENGTH_M less than 100 m long were removed.

2.4 Site selection and verification

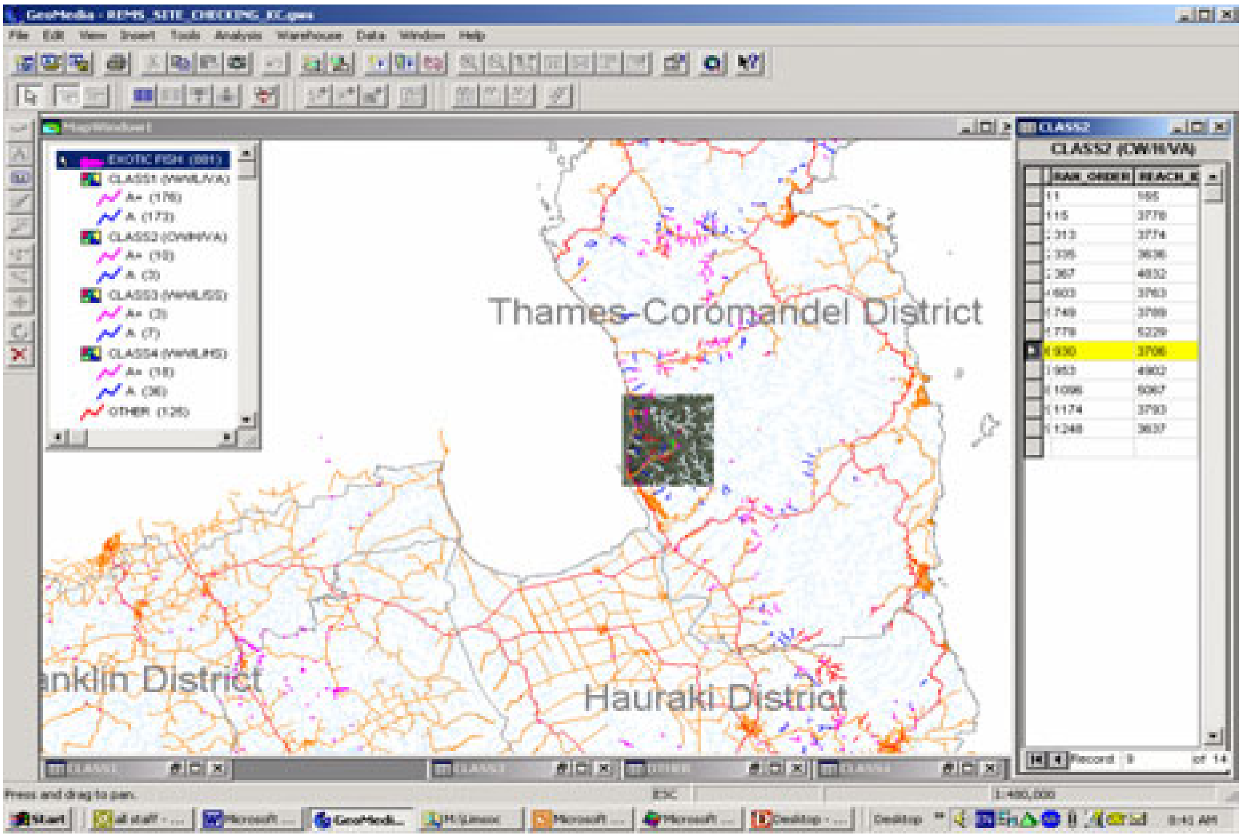
Candidate stream segments identified in the above GIS procedure were randomised for each category (A+ and A) within the main stream classes and zones using Excel, and joined back via the REACH_ID code in Geomedia Professional. Any existing REMS sites that met A+ criteria were assessed (identified by Located Key 125.4, 458.1, 477.14, 234.28, 33.16, 4.2, 1414.1); three sites (234.28 – CW/H/VA Coromandel; 4.2 – WW/L/VA Coromandel; 125.4 WW/L/HS Middle/Upper Waikato) fitted into the dominant stream class and zone layers (although following site verification site 125.4 was moved c. 300 m upstream to more naturally shaded conditions to generate site 125.15, and a calibration sample was collected at the downstream site). The remainder of existing REMS reference sites were retained as sites of special interest.

Candidate A+ reference sites were evaluated in sequential randomised order for each stream type and zone using aerial photos with 1 m pixel resolution (flown in 2002-2003) in the workflow environment shown in Figure 5. Sites where the integrity of upstream vegetation was confirmed and where access seemed reasonable were retained, with the intention of developing a short-list with up to 10 sites in each unallocated stream class/zone combination. If ten A+ sites could not be located, category A sites within 500 m of a road were evaluated to determine the accuracy of upstream landcover assessments, and any sites that appeared to have intact catchment vegetation and suitable access were retained in the short-list (see Figure 1).

A visual check of potential short-listed sites was carried out to identify any with known populations of pest fish using a regional snapshot extracted from the New Zealand Freshwater Fish Database. This analysis identified two potential reference sites in the Lower Waikato where goldfish (*Carassius auratus*) had been recorded in the near vicinity, and these were subsequently dropped from the list of candidate sites. There were several records of trout around Taupo and the southern West Coast in the near vicinity of potential sampling sites, but this was not considered a significant interference since numbers were likely to be low in upstream sampling reaches and the presence of salmonids is generally indicative of high water quality and habitat conditions.

Following finalisation of randomly selected short-listed sites, the first three candidate sites in each stream class/zone combination were selected for field verification. Any one of these was visited on a first-encounter basis, and if suitable in terms of integrity and accessibility it was selected for the reference site network; if the first-visited site was unsuitable, then the other sites were visited, and if neither of these proved suitable additional sites on the short list were assessed until a suitable site was located. If no suitable sites were located by this process, the original GIS workflow was revisited in an attempt to locate other candidate sites. This scenario was uncommon but did occur in the Middle/Upper Waikato region where few forest remnants remain, and for WW/L/SS sites, undisturbed examples of which were regionally uncommon.

A.



B.

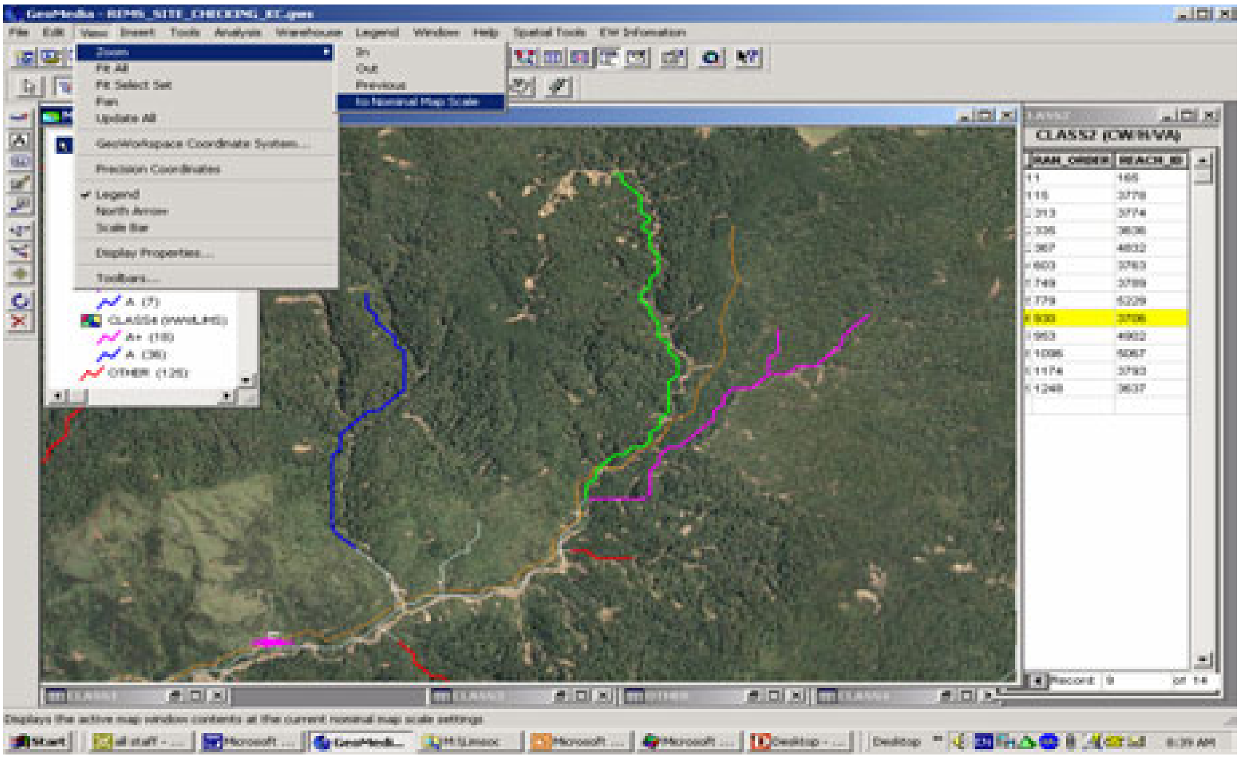


Figure 5: GIS workflow environment used in the selection and remote verification of potential reference sites for wadeable stream monitoring.

2.5 Field sampling

Physico-chemical features

Reference site reaches (maximum length 100 m) were selected at locations that appeared to have natural lighting regimes and minimal impact from mammals. In some places, reference sites were not fenced and there was obvious cattle damage to understorey vegetation near the forest-pasture boundary (e.g., sites 1966.1 and 1969.1); in these situations sampling reaches were located upstream where there was no sign of cattle damage. Wetted and channel widths were measured at five transects evenly spaced along the sampling reach, and depths were measured at five evenly-spaced points across each transect.

Qualitative assessments of habitat quality were made using Environment Waikato's standard habitat assessment field data sheet for wadeable hard-bottomed (<50% bottom substrates sand/silt/clay) and soft-bottomed (≥50% bottom substrates sand/silt/clay) streams (see Collier & Kelly 2005). This procedure provides an integrated score for riparian, bank, channel and instream conditions by evaluating nine attributes on a scale of 1 (lowest habitat value) to 20 (highest habitat value). Estimates were also made of the percentage of bed covered by large wood (<10 cm diameter), coarse particulate organic matter (CPOM; ≥1 mm diameter), fine particulate organic matter (FPOM; <1 mm diameter), and of surface water velocity. Shade was assessed on a scale of 1 (open) to 3 (significantly shaded).

Visual assessments were made of streambed compaction after Pfankuch (1975) (1 = no packing/loose assortment easily moved; 2 = mostly a loose assortment with little overlap; 3 = moderately packed with some overlap; 4 = assorted sizes tightly packed &/or overlapping), and embededness after Platts et al. (1983) according to the percentage of gravel-boulder particles covered by fine sediment (1 = <5%; 2 = 5-24%; 3 = 25-49%; 4 = 50-75%; 5 = >75%). Substrate size distribution along the sampling reach was also assessed based on the middle axis dimension of substrate particles using the size classes bedrock, boulder (>256 mm), cobble (64-256 mm), gravel (2-64 mm) and sand/silt/clay (<2 mm).

Spot measurements of water temperature and conductivity (WTW Cond 340i) were taken on site or measured on samples kept in the fridge (conductivity only). Ambient conductivity values were converted to 25^{o}C. Dissolved oxygen (concentration and percent saturation) was measured at all sites using calibrated WTW Oxi340 meters.

Periphyton and macrophyte assessments

Periphyton and macrophyte cover were assessed at the five transects described above. We used MfE protocol Rapid Assessment Method 2 (RAM2; Biggs & Kilroy (2000)). This procedure involved dividing the width of the stream into five equally spaced points and "randomly" removing a substrate particle >4 cm across at each point (i.e., total of 25 substrate elements per reach). Periphyton cover was recorded for each stone based on the thickness categories of thin mat/film (<0.5 mm), medium mat (0.5-3 mm), thick mat (>3 mm thick), short filaments (<2 cm long), and long filaments (>2 cm long).

Macrophyte cover was assessed at the same five transects by estimating percent streambed cover (plan view) over a 1 m swathe upstream. Total cover was broken down by dominant native and alien species of submerged (surface-reaching or below surface) or emergent macrophytes.

Aquatic invertebrate collection

Stream macroinvertebrates were collected from productive stable habitats in flowing water using MfE protocols C1 and C2 for hard- and soft-bottomed streams, respectively, as outlined in Collier & Kelly (2005). These protocols involved the use of a D-frame net (0.5 mm mesh) to sample riffles in hard-bottomed streams and macrophytes, wood and edges in proportion to their significance in soft-bottomed streams. Non-productive habitats (e.g., pools and fine substrates) are avoided using these protocols. Duplicate hard-bottomed and soft-bottomed samples were collected at 4 sites (1965.1, 1971.1, 522.2, 414.26) where a sufficient range of substrate types was available. Over all sites combined, most sampling was conducted in stony riffle habitats (c. 95% of sampling effort), followed by wood in run habitats.

Samples were preserved in c. 70% isopropynol, and later processed using MfE protocol P2, which involves a count of at least 200 invertebrates (excluding pupae) from randomly selected sub-samples followed by a search of the entire sample for rare taxa. The level of taxonomic resolution detailed in Appendix 2 of Collier & Kelly (2005) was used in subsequent analyses.

2.6 Data analysis

A range of measures of habitat characteristics and variability was derived from the data collected to assess relationships with reference stream invertebrate community composition. These derived variables included the ratio of channel:wetted width and wetted width:depth, the coefficient of variation (CV) of wetted width, channel width, mean transect depth and overall depth, as well as substrate diversity (calculated as Simpson's diversity) and a size index (following Jowett & Richardson 1990) (see Appendix 1).

Invertebrate taxa recorded as "Rare" were allocated a value of 0.5. Each invertebrate removed from the sample and returned to the stream (koura only) was given a value of 0.5 for each specimen removed. Non-metric multidimensional scaling (NMS) analyses were conducted in Primer 5 (version 5.2.9; Primer-E Ltd, 2002) using the Bray Curtis similarity measure on percent abundance (square root transformed) and presence-absence data. Analysis of Similarities (ANOSIM) was used to investigate differences between substrate type (soft versus hard), zone and REC class.

Spearman rank correlations were used to explore relationships between NMS axes scores for percent abundance ordinations and environmental variables (see Appendix 1). Correlations with probabilities < 0.01 were deemed significant to balance the need to protect against the possibilities of making Type I or II errors (Scarsbrook et al. 2000). Where paired hard and soft substrate samples were collected, the hard substrate data were used in correlation analyses.

NMS analysis was performed on a range of invertebrate community metrics that had been standardised by the maximum value of each metric to generate values ranging from >0 to 1. Where appropriate the inverse of maximum values was taken to ensure that higher values of all metrics indicated high potential ecological condition (e.g., 1 – Hydroptilidae richness and % dominant taxon, Hydroptilidae, Elmidae, Coleoptera, Diptera, Oligochaeta, Mollusca). A hypothetical reference site with values of 1 for all metrics was inserted into the NMS analysis to indicate the best achievable reference site condition as a benchmark. The NMS analysis was conducted on all metrics and on a subset of metrics that displayed low variation (CV <50%; see Table 5) and were independently-derived (e.g., total taxa richness, EPT* taxa richness, % EPT*, % *Deleatidium*, % Elmidae, % Diptera were dropped because they formed part of other indices). This left the following subset of metrics: Margalef diversity, Shannon diversity, Pielou eveness, Simpson diversity, Ephemeroptera taxa richness, Plecoptera taxa richness, Trichoptera* taxa richness, % EPT richness, % Ephemeroptera, % Trichoptera*, % dominant taxon (inverse), MCI and QMCI.

Comparisons of key metrics likely to be used in assessments of impacts (total sample taxa richness, Margalef diversity, EPT* richness, % EPT*, % dominant taxon, MCI and QMCI) were analysed using univariate statistics to enable comparisons among substrate types where paired samples were collected (paired t-test; Systat), and among REC classes and zones (2-way ANOVA, Datadesk v.6). For these analyses the distributions of variables were examined using normal probability plots and transformations (log) were made where appropriate (% dominant taxon only).

3 Results

3.1 Representativeness of sites

A total of 1260 potential A and A+ reference sites within 1 km of a road were identified by the initial GIS identification process, with around half of these being A+ (47%) sites. The four REC classes that comprised 73% of total wadeable stream length in the Waikato (orange bars in Figure 2) were generally well-represented by these potential reference sites (green and blue bars in Figure 2), with 71% or 890 of the potential reference sites falling into one of these stream types (33% for A+ sites). Most were identified as 1^{st}-order streams (62%), followed by 2^{nd}- (27%), 3^{rd}- (9%) and 4^{th}- (2%) order. Almost half of the sites were on Coromandel Peninsula (43%), followed by West Coast (25%) or Waipa (13%), with other regions comprising 3-6% (Taupo - 6%, Hauraki - 5%, Lower Waikato - 4%, Middle/Upper Waikato - 3%). This pattern reflects the combined effects of roading network density and the distribution of areas of remnant forest throughout the region.

Aerial photo verification of catchment condition and access for A+ sites and, where required, for A sites <500 m from a road, yielded 119 potential reaches that had no nearby pest fish records and appeared suitable for reference site monitoring (Table 1). Potential sites were well-represented on the Coromandel, West Cost, Hauraki and Waipa zones, but poorly represented in Lower Waikato, Middle/Upper Waikato and Taupo (Table 1). Stream types WW/L/VA, CW/H/VA and WW/L/HS were relatively common but WW/L/SS sites were poorly represented overall.

Field verification resulted in the random selection of 16 sites conforming to the stream class/zone design (Table 1). An additional six sites that were current REMS sites or of special interest (e.g., long-term monitoring sites used by other organisations) were added to this design to yield 22 sites. A further eight special interest sites belonging to other REC stream classes were added to yield at total of 30 reference sites that were sampled between 11/1/05 through to 3/3/05 (Table 1).

Table 1: Breakdown of numbers of sites in different zones and REC classes identified initially by the GIS identification process, aerial photo verification when a maximum of 10 sites in each combination was selected, and finally sites that were incorporated into the REMS field sampling programme for 2005.

	REC stream type															
	WW/L/VA			CW/H/VA			WW/L/SS			WW/L/HS			TOTAL			Additional sites sampled
Zone	GIS	Photo	Field	GIS	Photo	Field	GIS	Photo	Field	GIS	Photo	Field	GIS	Photo	Field	
Coromandel	348	10	1†	12	4	1†	9	5	1	53	10	1	422	29	4	WX/L/VA
Hauraki	21	7	1	21	9	1	0	0	0	8	3	1	50	19	3	CX/H/VA
Lower Waikato	0	0	0	0	0	0	1	1	1	49	10	1	50	11	2	
Middle/Upper Waikato	5	1	1	28	9	3‡	0	0	0	1	1	2† ‡	34	11	6	
Waipa	18	6	0	83	5	1	3	2	0	25	7	1	129	20	2	CX/H/VA†
West Coast	36	10	2‡	3	0	0	19	3	1	123	10	1	181	23	4	CX/H/HS†; WW/L/M; CX/H/VA†
Taupo	0	0	0	22	8	1	0	0	0	0	0	0	22	8	1	CX/H/VA; CX/M/VA†
TOTAL	428	34	5	169	35	8	32	11	3	261	41	7	890	119	22	Total sampled = 30

†, existing site
‡, augmented with special interest site(s)

Table 2: Details of individual reference sites incorporated into the 2005 REMS field sampling programme.

Greyed sites were dropped from the reference site network because they were not considered typical of regional wadeable stream reference site conditions (indicated by "*", although site 4.2 was retained as a "long-term" monitoring site in the REMS programme) or reach length was considered too short (<50 m; 414.26).

Sample number	Located site number	Site name	Zone	REC Class	NZMS260 map reference
3	373.5	Mangaiti	Hauraki	CW/H/VA	T13:554-993
4*	1224.2*	Wairere	Hauraki	CX/H/VA	T14:630-811
7	125.15	Firewood trib.	Up/Mid Waikato	WW/L/HS	S14:973-888
8	1961.1	Mangatea	Lower Waikato	WW/L/HS	S13:175-112
9	1962.1	Waiwhata	Hauraki	WW/L/HS	S13:221-199
12	1051.4	Tongariro trib.	Taupo	CX/H/VA	T19:527-226
14	458.1	Mangatawai	Taupo	CX/M/VA	T19:489-238
15*	1963.1*	Otara trib.	Taupo	CW/H/VA	T19:422-400
28	1888.4	Otautora	Up/Mid Waikato	CW/H/VA	T15:366-460
29	477.14	Mangauika	Waipa	CX/H/VA	S15:977-503
45*	1964.1*	Wentworth trib.	Coromandel	WX/L/VA	T12:597-349
48	234.28	Kaueranga	Coromandel	CW/H/VA	T12:478-564
60	33.16	Awakino trib.	West Coast	CX/H/HS	R17:671-962
64	1132.66	Waikato River trib.	Lower Waikato	WW/L/SS	R13:658-233
66	471.2	Mangatoa	West Coast	WW/L/HS	R16:591-064
74,75	1965.1	Waikuku	West Coast	WW/L/M	R15:842-461
76	1966.1	Purangirangi	Waipa	WW/L/HS	S16:900-386
78,79	1971.1	Mangapohue	West Coast	WW/L/VA	R16:788-242
85	754.2	Piakonui trib.	Hauraki	WW/L/VA	T14:422-735
86	1232.13	Waitakaruru trib.	Up/Mid Waikato	WW/L/VA	T14:347-752
94	1414.1	Omanawa trib.	West Coast	CX/H/VA	S15:910-515
107	481.14	Mangawara	Up/Mid Waikato	CW/H/VA	S15:992-571
108	1513.3	Te Rekereke	West Coast	WW/L/VA	R15:659-690
109	1968.1	Whakakai	Up/Mid Waikato	WW/L/HS	S14:926-785
110,111	552.2	Mokaihaha	Up/Mid Waikato	CW/H/VA	U16:747-320
118	1969.1	Mangawhata	West Coast	WW/L/SS	S17:969-924
120,121	414.26	Mangaokewa	Waipa	CW/H/VA	S17:145-017
134	9.4	Ahirau	Coromandel	WW/L/HS	T10:313-094
136	474.2	Mangatu	Coromandel	WW/L/SS	T10:372-009
138*	4.2*	Five Mile	Coromandel	WW/L/VA	T11:656-681

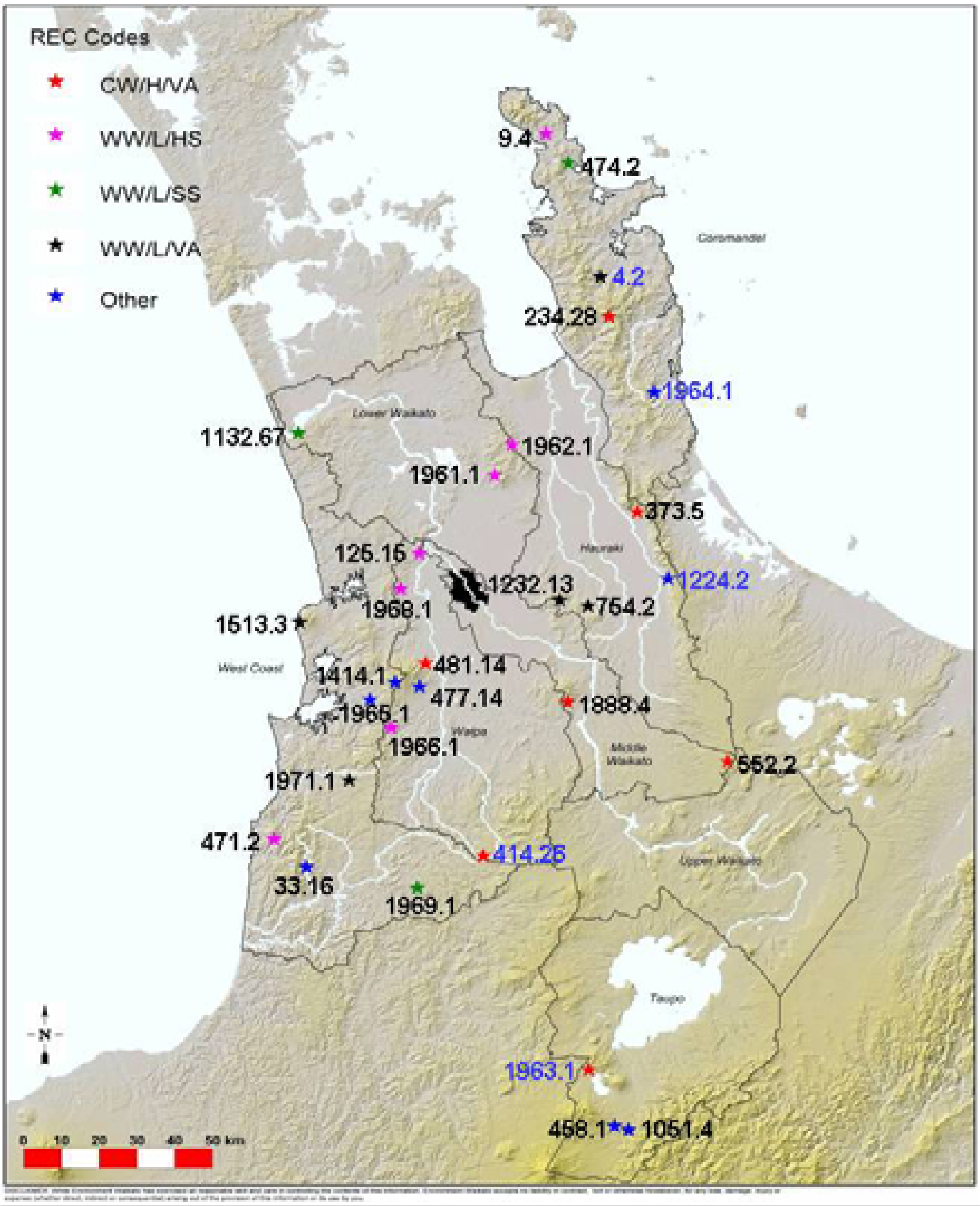


Figure 6: Location of potential reference sites (stars) sampled in summer 2005 in each zone coloured by REC class.

Middle Waikato and Upper Waikato zones were combined for the reference site selection process. Sites indicated by black numbers were retained in the reference site network for subsequent sampling; sites indicated by blue numbers were dropped because of short available reach lengths (<50 m; 414.26) or because they were outliers and deemed atypical of regional wadeable stream reference site conditions based on the analysis presented in Figure 8.

3.2 Physico-chemical characteristics

Although the initial GIS analysis aimed to identify reaches at least 100 m long, our field sampling found that some reaches were shorter than this due to the small size of some catchments (e.g., site 1964.1), sections of subterranean flow (e.g., site 414.26), streams emanating from previously unknown springs (e.g., site 1963.1), and the presence of tributary confluences which were avoided during sampling. Thus two sites had reach lengths ≤40 m and six sites had reach lengths of 50-80 m, with the remainder (73%) being 100 m long. The two sites with reach lengths <50 m were dropped from the reference site network.

Elevation of the sites sampled varied from 20 to 810 m a.s.l. (Table 3). Channel widths averaged 5.8 m (range 1.1-22.2 m), but wetted widths were considerably less (mean = 3.7 m, 0.6-8.9 m). This difference was reflected in a mean channel:wetted width ratio ranging from around 2 and up to 4. Most streams were shallow and well within the working definition of "wadeable" (mean depth <1.0 m). Depths averaged 0.2 m and ranged from <0.1 to 0.4 m. Width:depth ratios averaged 21 and were as high as 48, reflecting shallow water relative to wetted width. The mean of habitat quality scores was 88% of the maximum possible, and all potential reference sites scored >70% of the maximum.

On average, most sites were significantly shaded although some larger sites had partial shade where canopy closure over channels was not achieved, and very large sites (e.g., site 234.28) were rated as open. Visually estimated surface velocities averaged 0.3 $m.s^{-1}$ and were as high as 0.7 $m.s^{-1}$. Mean spot water temperature was 14.9 ^{o}C, and values exceeded 20 ^{o}C only at the widest site (e.g., 234.28) in late afternoon. Conductivity averaged 112 $\mu S.cm^{-1}$ but varied by an order of magnitude, being lowest (≤40 $\mu S.cm^{-1}$) at sites 1224.2 and 552.2, and highest (363 $\mu S.cm^{-1}$) at a soft-bottomed sandstone site (site 1965.1, WW/L/M). Spot dissolved oxygen measurements were always >8 $g.m^{-3}$ and 80% saturation, and averaged 9.6 $g.m^{-3}$ and 96%.

Streambed substrates were dominated by boulder, cobble and gravel particles (24-29%) on average, although there was considerable variability in substrate composition among sites. Four sites had >50% sand/silt and were designated "soft-bottomed", but overall these fine inorganic particles averaged 16% of substrate particles across all sites. The dominance of coarse inorganic particles was reflected in the mean substrate size index score of 5.5 and the variability of particles size distributions among sites resulted in a moderately high mean substrate diversity score (range of Simpson's index = 0.2-0.8). Compaction was generally high on average (moderately packed with some overlap) and embededness averaged 5-25% of gravel-boulder particles covered by fine sediment, although this was skewed by high values for a few "soft-bottomed" sites. Streambed area covered by wood, CPOM and FPOM averaged 6, 11 and 6%, respectively, but the range was highly variable.

Macrophytes were below detection levels at all sites (i.e., none were located at the 5 transects). Bryophytes were present at several sites and covered up to 38% of streambed area (mean = 3%). Periphyton cover averaged 21% of the upper surface area of stones examined and most of this was thin films, although some large, open sites had appreciable amounts of filamentous algae (e.g., site 234.28).

Table 3: Summary statistics of physico-chemical variables measured directly or derived from measured data at potential wadeable stream reference sites. *n* = 30 (see Appendix 1 for raw data).

	Mean	S.E.	Median	Min.	Max.	CV (%)
Elevation (m a.s.l.)	216.3	36.0	160	20.0	810.0	91
Shade score (1=low, 3=high)	2.7	0.1	3	1.0	3.0	19
Velocity ($m.s^{-1}$)	0.3	0.0	0.3	0.2	0.7	50
Temperature (^oC)	14.9	0.5	14.7	10.2	22.8	19
Conductivity ($\mu S.cm^{-1}$@25^{o}C)	111.6	13.2	86	39.0	363.0	64
Dissolved oxygen ($g.m^{-3}$)	9.6	0.1	9.7	8.4	11.4	8
Dissolved oxygen (% sat.)	96.3	1.1	96.7	82.0	114.7	6
Compaction (1=low, 5=high)	2.1	0.2	2	1.0	5.0	49
Embededness (1=low; 5=high)	2.0	0.2	2	1.0	4.0	53
% Large wood (>10 cm diam.)	5.9	1.2	5	0.0	30.0	110
% CPOM (≥1 mm)	10.5	1.8	7.5	1.0	40.0	92
% FPOM (<1 mm)	5.7	1.2	5	0.0	20.0	119
% Bedrock	7.5	2.2	0	0.0	35.0	159
% Boulder (>256 mm)	23.7	3.9	20	0.0	90.0	89
% Cobble (64-256 mm)	29.0	2.9	25	5.0	60.0	54
% Gravel (2-64 mm)	23.8	3.5	20	0.0	80.0	80
% Sand/silt/clay (<2 mm)	16.0	2.8	10.0	0.0	50.0	94
Substrate size index	5.5	0.1	5.6	3.9	6.9	12
Substrate diversity	0.6	0.0	0.7	0.2	0.8	20
Channel width (m)	5.8	0.8	3.9	1.1	22.2	77
Wetted width (m)	3.7	0.5	2.5	0.6	8.9	75
Channel:wetted width ratio	1.9	0.1	1.6	1.1	3.9	35
Depth (m)	0.2	0.0	0.2	<0.1	0.4	62
Width:depth ratio	20.8	1.8	17.6	7.3	47.8	47
% Periphyton cover – thin film/mat	18.0	3.5	13.1	0.0	75.0	108
% Periphyton cover – medium mat	2.2	1.0	0.0	0.0	21.6	258
% Periphyton cover – thick mat	0.1	0.1	0.0	0.0	3.2	515
% Periphyton cover – filamentous	0.8	0.7	0.0	0.0	22.0	528
% Total periphyton cover	21.0	4.1	13.6	0.0	75.0	107
% Bryophyte cover	2.9	1.6	0.0	0.0	38.0	306
Habitat score (% of maximum)	86.8	1.0	88.2	70.6	96.7	6

3.3 Invertebrate communities

Composition and environmental relationships

A total of 150 taxa was recorded from the 34 samples collected at 30 sites. Percent composition of the fauna for each sample is given in Appendix 2. NMS plots had stress values of 0.17 and 0.22 for percent abundance and presence-absence analyses, respectively. These values did not change when soft-bottomed samples were removed and the analysis was rerun. The stress value for the presence-absence analysis was considered too high to provide a reliable representation of the data, so this analysis was not considered further (but see Figure 7).

"Soft-bottomed" sites clustered towards the right of axis 1 on the percent abundance NMS plots. Paired samples collected from soft-bottomed or hard-bottomed substrates at the same sites occurred close together in ordination space indicating similar invertebrate community composition. When all samples were considered together, soft -bottomed samples differed significantly from hard-bottomed samples in terms of community composition (percent abundance; Global R = 0.313, P = 0.013).

Significant differences were detected among zones for percent abundance comparisons (Global R = 0.17, P = 0.016) with differences occurring between Upper/Middle Waikato and Taupo, Coromandel and Upper/Middle Waikato, and Coromandel and West Coast (Table 4). Significant differences were also detected among dominant REC classes for percent abundance comparisons (Global R = 0.110, P = 0.033) with differences occurring between WW/L/HS and WW/L/SS, and WW/L/HS and WW/L/VA (Table 4), although given the number of multiple comparisons relative to the probability values the ecological significance of these differences is not clear.

A range of variables reflecting stream size, current velocity and instream organic matter type and abundance was significantly ($P < 0.01$) correlated with axis 1 of the percent abundance ordination. Shade class and cover by wood, coarse particulate organic matter and bryophytes (r_s = 0.65, 0.56, 0.53, 0.57, respectively) were positively correlated with axis 1 so that higher shade and organic matter cover were present at sites towards the right of the ordination (Figure 7). Water velocity and frequency of riffles (r_s = -0.73 and -0.75), stream wetted and channel width (r_s = -0.69 and -0.73), water depth (r_s = -0.61) and total periphyton cover (r_s = -0.52) were all inversely correlated with axis 1 indicating that wider and deeper sites with faster flowing water and more periphyton tended to occur towards the left of axis 1. No significant correlations were detected for axis 2 of the percent abundance ordination.

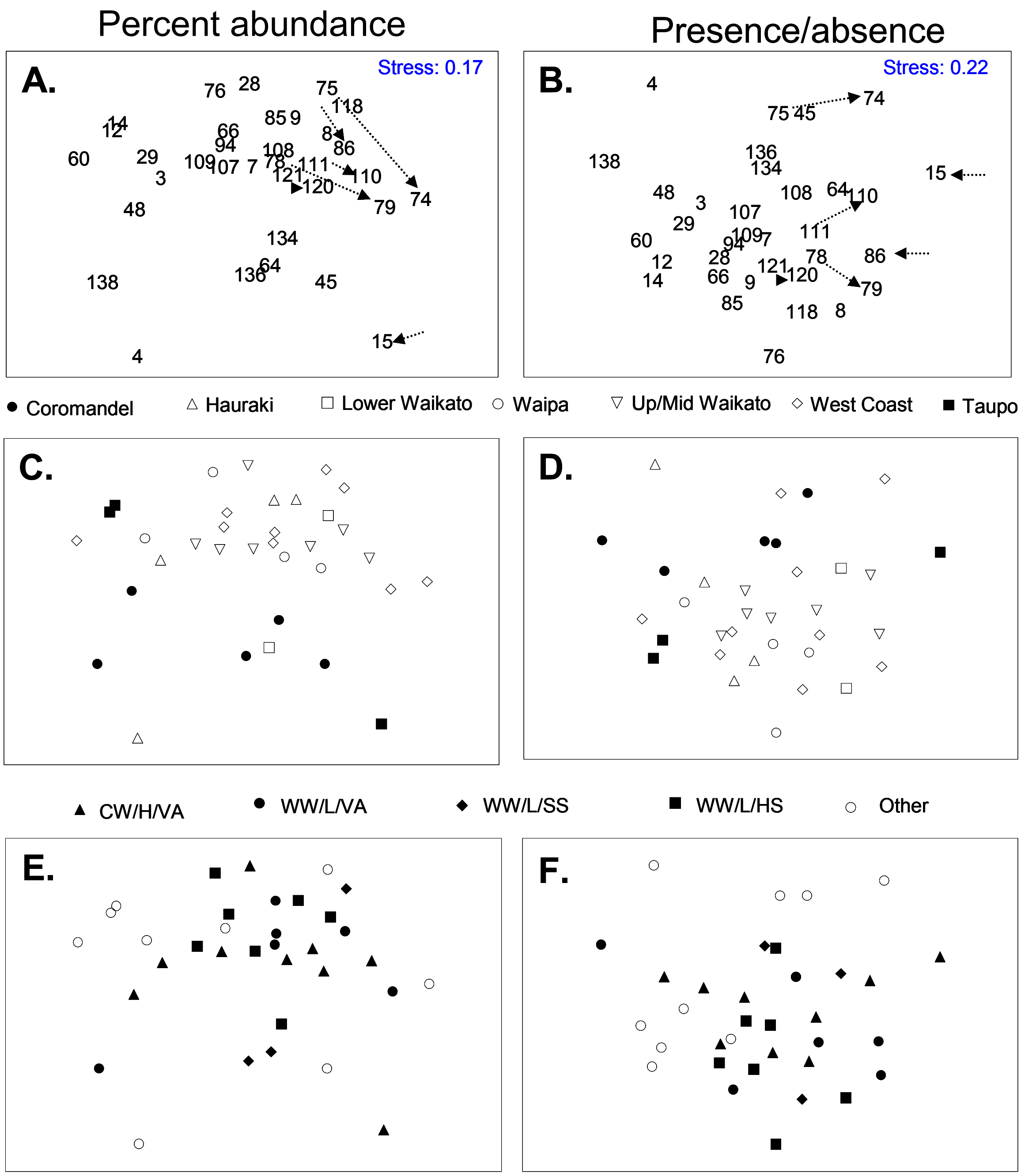


Figure 7: Non-metric multi-dimension scaling plot (Bray-Curtis similarity on square root transformed data) using percent abundance (A, C, E) and presence-absence (B, D, F) data from potential reference sites.

Sample numbers in A and B correspond to those in Table 2. Arrows connect paired hard- and soft-bottomed samples collected from the same sites, with arrowheads pointing towards soft-bottomed samples, or indicate sites where only soft-bottomed samples were collected. Zone (C, D) and REC class (E, F) comparisons are also presented (see Table 4 for ANOSIM results).

Table 4: ANOSIM results of comparisons among zones and REC classes for invertebrate community composition (percent abundance). Statistically significant differences are indicated in bold

Comparison	Percent abundance	
	R statistic	P
Zone		
Hauraki, Up/Mid Waikato	0.071	0.309
Hauraki, Lower Waikato	0.000	0.467
Hauraki, Taupo	-0.037	0.429
Hauraki, Waipa	-0.094	0.714
Hauraki, Coromandel	0.225	0.127
Hauraki, West Coast	0.062	0.324
Up/Mid Waikato, Lower Waikato	0.110	0.333
Up/Mid Waikato, Taupo	**0.647**	**0.008**
Up/Mid Waikato, Waipa	-0.077	0.661
Up/Mid Waikato, Coromandel	**0.530**	**0.001**
Up/Mid Waikato, West Coast	-0.009	0.477
Lower Waikato, Taupo	0.000	0.400
Lower Waikato, Waipa	0.179	0.200
Lower Waikato, Coromandel	0.273	0.190
Lower Waikato, West Coast	0.012	0.455
Taupo, Waipa	0.111	0.343
Taupo, Coromandel	0.313	0.107
Taupo, West Coast	0.339	0.059
Waipa, Coromandel	0.181	0.183
Waipa, West Coast	-0.104	0.731
Coromandel, West Coast	**0.355**	**0.014**
REC class		
CW/H/VA, Other	0.107	0.083
CW/H/VA, WW/L/HS	0.049	0.213
CW/H/VA, WW/L/SS	0.181	0.173
CW/H/VA, WW/L/VA	0.026	0.325
Other, WW/L/HS	0.142	0.079
Other, WW/L/SS	0.003	0.459
Other, WW/L/VA	0.081	0.201
WW/L/HS, WW/L/SS	**0.337**	**0.030**
WW/L/HS, WW/L/VA	**0.153**	**0.046**
WW/L/SS, WW/L/VA	0.093	0.321

Condition and biodiversity metrics

NMS analysis of all standardised community metrics and a subset of non-derived metrics indicated a core set of closely related sites that encompassed most hard-bottomed and soft-bottomed samples (Figure 8). Four outliers were distinguished; two large sites, a spring-fed site and a very small headwater stream site. These sites were dropped from the reference network because they were considered atypical of dominant wadeable stream reference conditions in the Waikato based on the multivariate metric analysis (sites 1224.2, 1963.1, 1964.1, 4.2; see Table 2). The sites retained in the network still covered a wide range of sizes and sources of flow, including spring-fed.

A summary of various diversity and condition metrics derived from the macroinvertebrate communities at sites retained in the reference site network is presented in Table 5 (see Appendix 3 for metric values for all samples). Variability was <50% for all biodiversity metrics evaluated, most condition richness metrics, several compositional condition metrics (% Ephemeroptera, % Trichoptera*, % EPT*, % Dominant taxon), and < 10% for MCI and QMCI (Table 5). Metrics with high variability among reference sites are unlikely to provide robust baselines to compare with impacted systems.

Where soft- and hard-substrate samples were collected at the same site, most metrics were higher at the hard-bottomed sites, but many were nevertheless very similar for both substrate types. Total taxa richness was on average 5 taxa higher at the hard-bottomed sites, and % *Deleatidium*, Trichoptera, EPT*, Chironomidae, Diptera, Mollusca, Crustacea and dominant taxon differed by more than 5% (Table 5). MCI was very similar on average for invertebrate communities on both substrate types, whereas QMCI was over one unit higher on hard substrates (Table 5). Paired t-tests were conducted on total sample taxa richness, Margalef diversity, EPT* richness, % EPT*, % Dominant taxon (log transformed), MCI and QMCI as these were considered key metrics that would typically be used in assessments of impact. This analysis indicated significant differences among substrates for total taxa richness, Margalef diversity and QMCI (t = 4.44, 5.22 and 6.81, respectively; P = 0.021, 0.014 and 0.009). Spearman correlations indicated that taxa richness, EPT* richness, % EPT*, % Dominant taxon and QMCI could be considered independent using a significance level of r_s = 0.7, following Barbour et al. (1992). However, it should be noted that taxa richness may not decline with low-intermediate levels of disturbance and may in fact increase if tolerant and sensitive taxa co-occur, so total taxa richness may not provide a useful indication of condition if used in isolation at less disturbed sites (Collier et al. 2000).

The key metrics listed above were all unaffected by REC class or by zone when all data were considered together, except for % EPT* where a significant effect of zone was detected (ANOVA, F = 4.13, P = 0.043). This analysis indicated lower mean % EPT* values at Coromandel, Lower Waikato and Taupo sites (63-71%) compared to other zones (83-89%). No significant interactions between zone or REC class were detected. The analysis of main factors (zone and REC class) was repeated using a balanced design by randomly eliminating sites until a sample size of n = 3 was achieved. This analysis similarly showed no effect of the four main REC classes on any of the key metrics. An effect of zone (only Coromandel, Hauraki, Upper/Middle Waikato, Waipa and West Coast could be compared using a balanced design) was detected on QMCI values (F = 6.48, P = 0.008), which were lower in the Coromandel (mean = 6.6) compared to Hauraki, Upper/Middle Waikato and Waipa (means = 7.9-8.1) (Bonferroni post-hoc test, P < 0.05). However, the balanced ANOVA did not indicate a statistically significant effect of zone on % EPT* (F = 3.32, P = 0.056).

A breakdown of mean regional values for key metrics is presented in Table 6, along with zone averages. These averages differ from those presented in Table 5 in some cases (e.g., % EPT*) because they represent the average of zone mean values rather than the average of all sites retained in the reference site network. However, caution needs to be exercised at this stage in interpreting whether zone means are applicable as sampling was conducted over an extended time (17/1/05 to 16/3/05) during a low flow recession period, with Coromandel samples collected towards the end of this period. Future sampling should include index reference sites that are sampled at the beginning and end of the REMS programme to determine any temporal effects on metric values. Similarly, caution should be exercised if applying metric means derived over this summer period as baseline data for other studies conducted at other times of year as we do not have data on reference site metric values for other seasons. This gap highlights the need to incorporate appropriate reference site sampling with site-specific impact assessments.

Another issue that warrants further investigation is determining whether the scale of sampling conducted (single reaches 50-100 m long) adequately represents average conditions at the segment scale, as defined in the REC. A pilot study is proposed in 2006 to address this question by collecting multiple samples at selected sites to assess meso-scale variation in metric values, and a temporal study involving quarterly sampling is currently underway at three reference sites (125.15, 754.2 and 1888.4). This information will provide added confidence in metric values when applying them as a benchmark for assessing impacts on wadeable stream ecosystems throughout the Waikato.

Table 5: Summary of diversity and condition metrics derived from a range of reference sites.

The final site average is for sites considered typical of Waikato wadeable stream reference conditions (i.e., excluding sites 1224.2, 4.2, 1963.1, 1964.1); where paired samples were taken, hard substrate data was used.

Invertebrate community metric	All soft substrate sample average (n = 6)	Paired soft substrate sample average (n = 4)	Paired hard substrate sample average (n = 4)	Final site average** (n = 25)	2SD**	CV** (%)
Diversity						
Total taxa richness (100) ‡	17.95	17.81	21.67	17.70	6.17	17
Total taxa richness (200) ‡	23.28	22.79	27.69	22.71	8.27	18
Total sample taxa richness†	24.50	24.25	29.50	25.35	7.80	15
Margalef diversity (d)	4.38	4.34	5.34	4.54	1.47	16
Pielou eveness (J')	0.66	0.67	0.75	0.69	0.18	13
Shannon diversity (H'(log_e))	2.14	2.16	2.55	2.23	0.72	16
Simpsons (1-λ)	0.77	0.78	0.85	0.81	0.20	12
Condition						
Ephemeroptera taxa richness	4.33	4.75	5.00	4.88	3.12	32
Plecoptera taxa richness	3.83	3.75	4.75	3.69	3.34	45
Trichoptera* taxa richness	6.50	6.75	7.75	7.65	4.45	29
Hydroptilidae taxa richness	0.33	0.00	0.00	0.04	0.39	510
EPT* taxa richness†	14.67	15.25	17.50	16.23	5.55	17
% EPT* taxa richness	59.97	62.95	58.85	64.36	16.61	13
% Ephemeroptera	39.68	45.42	48.83	51.87	22.99	22
% *Deleatidium*†	0.54	0.60	5.39	18.93	39.77	105
% Plecoptera	7.37	7.18	8.92	8.03	10.03	62
% Trichoptera*	16.06	15.53	22.86	19.86	14.89	37
% Hydroptilidae	1.14	0.00	0.00	0.02	0.19	510
% EPT*†	63.11	68.12	80.61	79.77	23.88	15
% Coleoptera	1.21	1.48	5.18	5.55	11.34	102
% Elmidae†	0.15	0.00	2.65	3.46	9.74	141
% Chironomidae	12.07	13.36	7.35	4.82	7.27	75
% Diptera other	1.27	1.53	2.17	2.83	4.74	84
% Diptera total†	13.34	14.89	9.52	7.64	7.89	52
% Mollusca	15.48	8.54	2.11	4.58	15.63	171
% Crustacea	4.73	6.27	0.82	0.57	1.67	147
% Oligochaeta	0.40	0.35	0.00	0.00	0.00	
% Dominant taxon	36.69	35.30	26.98	32.18	28.64	44
MCI	126.45	129.32	132.02	136.57	17.80	7
QMCI	6.29	6.38	7.48	7.62	1.30	9

†, not considered in independently-derived metric NMS analysis (see Fig. 8b)
‡, not considered in any NMS metric analysis (see Fig. 8)
**, where duplicate samples were taken at a site hard substrate data were used.

Table 6: Zone averages of key invertebrate community metrics measured in summer 2005 at reference stream sites based on invertebrate data derived from 200+ fixed counts and searches for rare taxa.

	Total taxa richness	Margalef diversity	EPT* sample richness	% EPT*	% Dominant taxon	MCI	QMCI
Coromandel *n* = 3	28	5.0	17.0	63.3	25.2	127.1	6.6
Hauraki *n* = 3	25	4.5	17.0	88.8	26.8	142.3	8.1
Lower Waikato *n* = 2	27	4.8	16.0	67.1	24.6	136.9	6.9
Waipa *n* = 2	23	4.1	14.7	83.9	37.1	134.8	8.0
Upper/Middle Waikato *n* = 6	25	4.5	16.8	84.5	29.8	137.5	8.0
Taupo *n* = 2	22	3.9	14.0	70.7	50.4	137.8	7.3
West Coast *n* = 7	26	4.6	16.4	83.4	34.4	137.6	7.7
Zone average	**25**	**4.5**	**16.0**	**77.4**	**32.6**	**136.3**	**7.5**

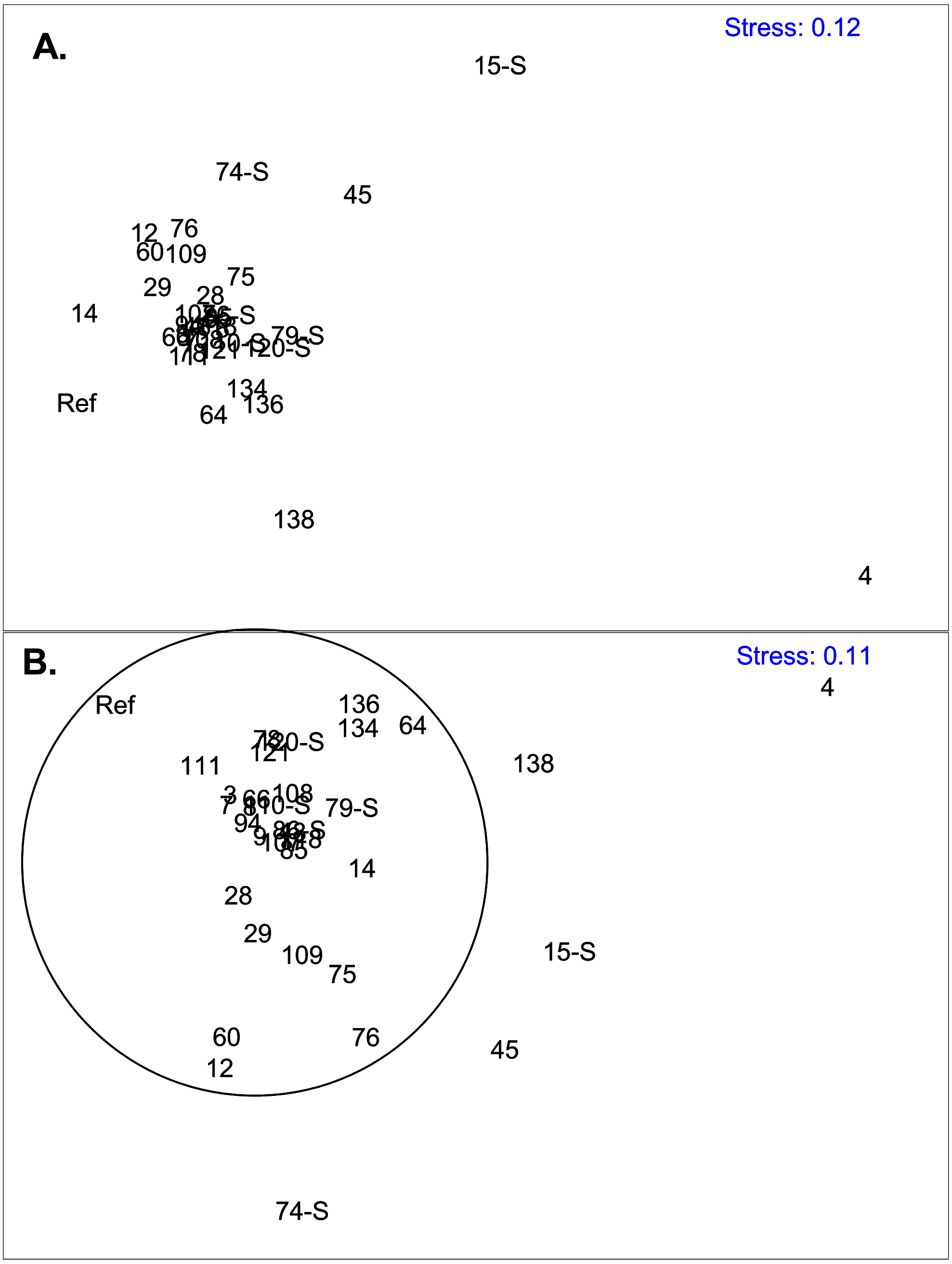


Figure 8: Non-metric multi-dimension scaling plot (Bray-Curtis similarity on data standardised by the maximum and square root transformed) for a range of invertebrate community metrics (standardised by the maximum) from potential reference sites.

A, all metrics (see Table 5); **B**, independently-derived (i.e., not directly used to derive other metric values) and stable (CV <50%) metrics. “S” after sample codes indicates soft-bottomed samples.

Conclusions

- Use of GIS coupled with stream typology, available spatial databases and aerial photography greatly enhanced the objectivity and efficiency of potential reference site selection. Field verification indicated that this process provided a high level of accuracy in identifying suitable reference site locations.

- Significant differences were detected in invertebrate community composition between some zones and stream classes indicating that the typology and spatial framework adopted were appropriate for identifying the range of reference conditions typically present in Waikato streams.

- A total of 25 wadeable stream sites with suitable reach lengths were identified as typical of reference conditions throughout the Waikato for inclusion in future REMS monitoring (see Table 2). This network represents approximately 20% of the total REMS sites currently sampled.

- Invertebrate community metrics with low variability are most suitable to provide baseline data for measuring impact magnitude in other wadeable streams. A range of diversity metrics along with EPT* taxa richness, % EPT*, MCI and QMCI all had coefficients of variation below 20% indicating little variability among the reference sites sampled in late summer 2005.

- Key metrics did not differ significantly among the four REC stream classes dominating regional wadeable stream length (CW/H/VA, WW/L/HS, WW/L/VA, WW/L/SS), indicating that similar baseline metric values for reference conditions can be applied across a range of stream types.

- There was evidence of zonal variation in some metrics (e.g., % EPT*, QMCI), indicating that benchmark values may need to be applied zonally for SOE monitoring and AEE purposes. However, further work needs to be conducted to assess this to account for variations in sampling times.

- Caution should be exercised if applying metric means derived over this summer period as baseline data for other studies conducted at other times of year as we do not have data on reference site metric values for other seasons. This gap highlights the need to incorporate appropriate reference site sampling with site-specific impact assessments.

- An assessment of spatial and temporal variability in metric values is required to understand how representative the current scale of sampling is.

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Appendix 1

Details of physico-chemical variables, habitat quality scores, and habitat sampled at the reference sites. "S" denotes sample collected from soft substrates (wood, macrophytes edges); ND = no data.

	3	4	7	8	9	12	14	15	28	29	45	48	60	64	66	74-S	75	76	78	79-S	85	86	94	107	108	109	110-S	111	118	120-S	121	134	136	138
Variables measured																																		
Elevation (m asl)	100.0	100.0	20.0	180.0	160.0	670.0	810.0	570.0	240.0	200.0	60.0	190.0	150.0	80.0	120.0	90.0	90.0	150.0	160.0	160.0	120.0	220.0	480.0	160.0	190.0	90.0	520.0	520.0	250.0	290.0	290.0	50.0	20.0	50.0
Shade (1-3)	2.0	2.0	3.0	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	1.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0
Velocity ($m.s^{-1}$)	0.7	0.7	0.3	0.2	0.3	0.5	0.7	0.2	0.4	0.5	0.2	0.3	0.4	0.2	0.3	0.2	0.2	0.5	0.2	0.2	0.2	0.2	0.3	0.5	0.2	0.3	0.2	0.2	0.2	0.6	0.6	0.2	0.2	0.4
Temperature (^oC)	12.5	12.8	13.5	14.0	14.1	12.6	11.2	10.2	12.4	12.4	18.9	22.8	16.8	18.3	15.8	16.1	16.1	14.8	13.8	13.8	14.7	15.8	11.7	20.0	15.8	16.3	11.2	11.2	14.6	13.4	13.4	16.1	17.8	16.0
Conductivity ($\mu S.cm^{-1}$)	64.0	39.0	75.0	87.0	84.0	54.0	57.0	125.0	113.0	74.0	110.0	52.0	86.0	268.0	132.0	363.0	363.0	102.0	121.0	121.0	81.0	85.0	98.0	80.0	227.0	139.0	40.0	40.0	ND	71.0	71.0	187.0	137.0	86.0
D.O. ($g.m^{-3}$)	10.5	10.3	10.2	9.8	9.9	9.8	9.9	8.8	9.8	10.3	8.4	8.4	9.2	9.0	9.0	ND	ND	8.7	11.4	11.4	9.7	8.5	10.1	ND	ND	ND	10.3	10.3	9.4	9.9	9.9	9.3	8.9	9.7
D.O. (%)	98.9	98.7	96.5	95.3	102.1	99.3	96.6	82.0	94.7	97.4	89.8	97.7	96.8	95.6	95.6	ND	ND	91.0	114.7	114.7	97.3	89.3	98.5	ND	ND	ND	98.6	98.6	94.6	98.0	98.0	94.0	93.0	98.0
Compaction (1-4)	4.0	4.0	2.0	3.0	3.0	3.0	3.0	1.0	3.0	4.0	3.0	3.0	4.0	3.0	3.0	3.0	2.0	3.0	3.0	2.0	4.0	4.0	3.0	2.0	2.0	1.0	4.0	3.0	2.0	4.0	1.0	2.0	3.0	1.0
Embeddedness (1-5)	1.0	1.0	2.0	2.0	2.0	2.0	1.0	3.0	2.0	1.0	2.0	1.0	1.0	2.0	3.0	4.0	4.0	4.0	3.0	3.0	2.0	1.0	3.0	4.0	4.0	3.0	1.0	1.0	1.0	4.0	4.0	4.0	3.0	4.0
Wood (%)	0.0	0.0	2.0	10.0	0.0	2.0	2.0	10.0	10.0	0.0	10.0	0.0	5.0	10.0	10.0	15.0	15.0	5.0	5.0	5.0	5.0	10.0	2.0	5.0	0.0	2.0	30.0	30.0	5.0	15.0	15.0	0.0	5.0	1.0
CPOM (%)	2.0	2.0	5.0	30.0	15.0	10.0	1.0	2.0	30.0	5.0	20.0	2.0	5.0	20.0	20.0	15.0	15.0	5.0	10.0	10.0	10.0	10.0	10.0	5.0	5.0	5.0	40.0	40.0	10.0	5.0	5.0	10.0	5.0	1.0
FPOM (%)	0.0	0.0	0.0	20.0	20.0	2.0	0.0	5.0	20.0	5.0	10.0	2.0	5.0	5.0	10.0	5.0	5.0	1.0	10.0	10.0	5.0	10.0	10.0	0.0	0.0	0.0	20.0	20.0	0.0	0.0	0.0	0.0	5.0	0.0
Bedrock (%)	10.0	0.0	20.0	25.0	25.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	30.0	0.0	30.0	30.0	10.0	0.0	0.0	0.0	0.0	5.0	35.0	35.0	0.0	0.0	0.0	30.0	0.0	0.0
Boulder (%)	60.0	90.0	0.0	30.0	20.0	30.0	40.0	5.0	20.0	40.0	20.0	30.0	40.0	20.0	0.0	0.0	0.0	0.0	5.0	5.0	20.0	10.0	40.0	40.0	20.0	10.0	5.0	5.0	0.0	60.0	60.0	20.0	10.0	25.0
Cobble (%)	20.0	10.0	20.0	20.0	15.0	50.0	40.0	15.0	40.0	30.0	50.0	40.0	40.0	50.0	60.0	15.0	15.0	10.0	10.0	10.0	30.0	20.0	40.0	40.0	30.0	20.0	5.0	5.0	10.0	20.0	20.0	20.0	50.0	50.0
Gravel (%)	10.0	0.0	50.0	20.0	20.0	10.0	15.0	70.0	20.0	20.0	20.0	20.0	10.0	25.0	20.0	5.0	5.0	80.0	35.0	35.0	10.0	20.0	10.0	20.0	40.0	55.0	5.0	5.0	40.0	5.0	5.0	25.0	25.0	10.0
Sand+silt+clay (%)	0.0	0.0	10.0	5.0	20.0	5.0	5.0	10.0	20.0	10.0	10.0	10.0	10.0	5.0	20.0	50.0	50.0	10.0	20.0	20.0	30.0	50.0	10.0	0.0	10.0	10.0	50.0	50.0	50.0	15.0	15.0	5.0	15.0	15.0
Substrate size index	6.7	6.9	5.4	6.4	5.8	6.1	6.0	4.7	5.3	5.8	5.6	5.7	6.0	5.7	5.1	5.0	5.0	4.5	5.5	5.5	5.4	4.3	6.0	6.1	5.3	5.1	5.2	5.2	3.9	6.1	6.1	6.3	5.3	5.7
Substrate diversity (1-λ)	0.6	0.2	0.7	0.8	0.8	0.7	0.7	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.3	0.7	0.7	0.8	0.7	0.7	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.7	0.7
Mean channel width (m)	10.8	12.2	3.9	1.9	2.7	7.0	8.5	4.7	3.7	10.7	2.4	22.2	8.8	3.9	3.5	2.3	2.3	3.8	1.6	1.6	2.8	2.4	4.6	8.7	3.8	3.4	7.2	7.2	1.1	3.6	3.6	3.1	5.9	11.6
Mean wetted width (m)	7.0	8.9	2.7	0.9	1.1	6.0	7.1	4.3	3.5	8.9	1.4	8.9	5.5	1.5	1.6	1.3	1.3	2.1	1.2	1.2	1.3	1.8	3.2	5.5	1.4	1.9	5.5	5.5	0.6	2.3	2.3	1.2	3.3	7.8
Wetted width CV (%)	24.5	23.7	18.1	52.4	18.0	39.5	18.1	26.9	28.4	19.5	34.6	8.1	16.8	32.5	19.3	26.7	26.7	27.2	17.7	17.7	31.0	43.0	11.0	23.3	56.2	24.5	37.2	37.2	27.9	16.2	16.2	42.9	24.5	17.4
Mean channel:wetted width	1.6	1.4	1.5	2.8	2.4	1.2	1.2	1.1	1.1	1.2	2.0	2.5	1.6	2.8	2.4	1.8	1.8	2.0	1.4	1.4	2.2	1.4	1.5	1.6	3.9	2.0	1.3	1.3	2.0	1.6	1.6	2.8	1.8	1.5
Channel width CV (%)	28.3	22.0	31.3	68.5	42.0	14.5	21.0	13.6	8.7	5.6	59.8	10.1	8.0	31.9	49.9	21.3	21.3	57.8	24.0	24.0	46.0	18.2	19.0	18.8	65.6	38.4	7.0	7.0	24.1	40.3	40.3	35.6	26.6	23.3
Mean depth (m)	0.4	0.4	0.1	0.0	0.1	0.4	0.2	0.2	0.1	0.3	0.2	0.2	0.3	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.0	0.1	0.1	0.1	0.2	0.2
Transect depth CV (%)	71.3	9.1	64.8	63.7	73.9	70.3	29.9	82.2	28.5	26.7	44.3	54.3	25.4	34.7	12.8	62.3	62.3	74.6	29.1	29.1	25.0	60.8	51.7	6.9	62.1	40.7	46.3	46.3	87.2	25.3	25.3	57.7	40.2	15.7
Overall depth CV (%)	69.0	63.6	88.3	79.3	100.1	69.7	56.1	79.3	49.8	34.0	53.6	68.4	43.6	70.9	32.1	80.0	80.0	89.2	63.6	63.6	60.0	61.8	55.4	38.4	77.9	52.3	72.3	72.3	107.4	69.1	69.1	77.1	61.1	46.7
Width:depth	15.8	21.8	23.4	17.6	7.3	15.4	30.8	28.8	23.7	29.8	9.1	47.5	15.8	18.5	15.6	22.9	22.9	13.3	20.3	20.3	14.9	9.9	14.5	29.3	17.6	12.4	32.5	32.5	15.6	16.0	16.0	18.3	17.2	47.8
Thin_periphyton (%)	75.0	31.0	18.0	14.0	4.0	24.8	20.4	51.0	3.0	36.8	11.0	58.0	12.2	0.0	19.2	0.0	0.0	10.0	3.0	3.0	0.0	0.0	1.2	20.0	6.0	36.0	0.0	0.0	0.0	0.0	0.0	23.0	20.0	41.0
Medium periphyton (%)	0.0	21.0	0.0	0.0	0.0	12.0	21.6	1.6	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	4.0
Thick_periphyton (%)	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filamentous algae (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.0
Total_periphyton (%)	75.0	52.0	18.0	14.0	4.0	36.8	45.2	52.6	4.0	36.8	11.0	58.8	13.2	0.0	19.2	0.0	0.0	10.2	3.0	3.0	0.0	0.0	1.2	20.0	6.0	36.0	0.0	0.0	0.0	0.0	0.0	23.0	24.0	67.0
Bryophyte (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.4	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	38.0	1.0	0.2	0.0	0.0	2.0	28.0	28.0	0.0	0.0	0.0	0.0	0.0	0.0

Habitat form scores																																		
Riparian zone width (1-20)	19.0	19.0	19.0	19.0	19.0	19.5	19.0	20.0	20.0	19.0	19.0	18.0	18.5	16.0	19.0	19.0	19.0	20.0	19.0	19.0	19.0	19.0	18.0	20.0	20.0	20.0	20.0	20.0	18.0	20.0	20.0	18.0	19.0	19.0
Vegetation protection (1-20)	19.0	19.0	19.5	19.0	20.0	20.0	20.0	20.0	19.0	20.0	19.0	18.0	17.0	15.0	19.0	19.0	19.0	20.0	20.0	20.0	19.0	18.0	18.0	20.0	20.0	18.0	20.0	20.0	19.0	19.0	19.0	20.0	19.0	20.0
Bank stability (1-20)	19.0	19.0	16.5	15.0	15.0	18.5	18.5	20.0	20.0	19.0	19.0	17.0	17.0	14.0	17.0	17.0	17.0	16.0	18.0	18.0	17.0	18.0	18.0	18.5	18.0	14.0	18.0	18.0	18.0	20.0	20.0	17.0	19.0	20.0
Riffle frequency (1-20)	19.0	19.0	18.0	18.0	17.0	12.0	18.0	9.0	19.0	19.0	17.0	18.0	19.0	18.0	19.0	6.0	6.0	17.0	16.0	16.0	16.0	13.0	18.0	19.0	17.0	13.0	5.0	5.0	18.0	19.0	19.0	19.0	14.0	20.0
Channel alteration (1-20)	20.0	20.0	19.0	19.0	19.0	20.0	20.0	20.0	20.0	20.0	19.0	18.0	19.0	20.0	19.0	20.0	20.0	20.0	20.0	20.0	18.0	18.0	18.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Sediment deposition (1-20)	20.0	19.0	15.0	17.0	16.0	17.0	19.0	16.0	19.0	19.0	19.0	18.0	19.0	18.0	15.0	11.0	11.0	15.0	18.0	18.0	14.0	13.0	18.0	18.0	19.0	15.0	20.0	20.0	16.0	19.0	19.0	19.0	18.0	19.0
Velocity/depth regimes (1-20)	18.0	19.0	15.0	10.0	10.0	14.0	14.0	10.0	18.0	18.0	10.0	17.0	19.0	10.0	14.0	5.0	5.0	15.0	15.0	15.0	15.0	12.0	17.0	14.0	10.0	14.0	10.0	10.0	15.0	13.0	13.0	15.0	15.0	20.0
Abundance/diversity of habitat (1-20)	19.0	20.0	18.0	17.0	17.0	18.0	17.0	12.0	20.0	18.0	16.0	14.0	17.0	17.0	18.0	12.0	12.0	18.0	18.0	18.0	17.0	15.0	17.0	18.0	18.0	19.0	15.0	15.0	18.0	16.0	16.0	18.0	17.0	16.0
Periphyton (1-20)	16.0	15.0	16.0	14.0	14.0	10.0	13.0	13.0	19.0	15.0	17.0	9.0	19.0	20.0	19.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	17.0	18.0	20.0	15.0	20.0	20.0	20.0	20.0	20.0	15.0	15.0	7.0
% of maximum possible score	93.9	93.9	86.7	82.2	81.7	82.8	88.1	77.8	96.7	92.8	86.1	81.7	91.4	82.2	88.3	70.6	70.6	88.3	90.0	90.0	85.0	80.0	88.3	91.9	90.0	82.2	82.2	82.2	90.0	92.2	92.2	89.4	86.7	89.4
Sampling details																																		
Stones	100.0	100.0	100.0	100.0	100.0	100.0	100.0	20.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	20.0	100.0	100.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0
Wood	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	90.0	0.0	50.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Edge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Macrophyte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Riffle	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	100.0	100.0	100.0	0.0	100.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0
Run	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0

Appendix 2

Percent composition of invertebrate communities in the potential reference sites sampled, mean composition for paired soft-bottomed (74-S, 79-S, 110-S, 120-S) and hard-bottomed (75, 78, 111, 121), and mean composition of final sites retained in the reference site network (hard-bottomed data used where paired samples collected; see Table 2).

Taxa	3	4	7	8	9	12	14	15 -S	28	29	45	48	60	64	66	74 -S	75	76	78	79 -S	85	86-S	94	107	108	109	110 -S	111	118	120 -S	121	134	136	138	Paired SB average	Paired HB average	Final site average
Acanthophlebia	0.2	0.0	1.5	1.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4
Ameletopsis	0.0	0.0	0.5	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.5	0.0	0.4	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Austroclima	10.8	0.0	17.2	8.1	9.6	0.0	0.0	0.5	21.8	0.9	5.9	1.0	0.0	0.5	8.1	0.0	0.0	0.0	5.5	1.0	31.8	15.8	3.7	7.5	1.0	0.5	2.0	4.4	2.4	8.3	18.7	0.0	0.9	0.0	2.8	7.2	6.2
Austronella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coloburiscus	15.5	0.0	21.2	18.6	14.1	2.0	2.2	0.0	37.4	6.4	7.8	28.5	0.0	0.2	18.0	3.8	6.9	44.2	7.8	2.9	9.5	17.1	22.4	20.7	3.5	6.3	8.4	10.8	4.4	10.1	11.8	6.7	20.8	9.2	6.3	9.3	13.6
Deleatidium	22.4	0.0	8.9	1.0	2.8	65.5	35.2	0.0	1.6	48.5	0.0	17.4	65.4	27.3	14.9	0.0	0.0	24.8	14.2	1.0	3.5	0.9	23.8	27.8	20.4	50.2	1.0	5.9	2.9	0.4	1.5	5.6	0.0	2.4	0.6	5.4	19.6
Icthybotus	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Neozephlebia	0.4	0.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	0.0	1.0	2.3	0.0	0.0	0.0	0.0	0.4	0.0	0.0	2.0	0.0	2.0	2.5	0.0	0.0	0.0	4.1	4.6	0.0	0.7	1.2	1.0
Nesamaletus	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0	0.0	3.4	1.0	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.3	0.8
Rallidens	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Zephlebia	0.9	0.0	4.4	19.5	26.1	0.0	0.0	1.0	4.3	0.0	0.0	0.0	0.0	3.4	3.6	69.7	55.9	2.0	11.9	21.6	14.4	20.7	1.4	0.9	17.4	0.0	32.7	19.1	35.4	14.0	5.4	16.0	2.3	0.0	34.5	23.1	9.8
Acroperla	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Austroperla	0.0	0.0	9.9	1.0	0.8	1.0	2.6	3.9	1.6	1.7	0.2	0.2	1.0	0.0	5.4	5.3	3.2	7.4	0.9	3.8	1.5	0.4	3.3	6.2	2.0	1.4	3.0	2.5	0.2	6.6	5.9	0.4	0.5	0.0	4.7	3.1	2.4
Megaleptoperla	0.4	0.0	0.0	0.0	0.0	1.0	4.3	0.5	3.1	1.7	0.0	0.2	0.0	0.0	0.2	1.0	1.4	0.0	1.8	0.2	0.0	0.0	1.4	0.2	0.0	1.0	1.0	4.4	0.5	0.4	0.2	0.0	0.0	0.0	0.7	1.9	0.9
Nesoperla	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spaniocera	0.0	0.0	0.0	3.3	3.6	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	1.9	0.0	0.4	0.5	0.0	0.0	0.0	0.0	0.0	2.9	0.9	0.5	0.0	0.0	0.0	0.7	0.1	0.5
Stenoperla	0.9	0.0	0.2	1.0	0.4	1.5	1.3	0.0	0.4	1.3	0.0	0.0	1.0	0.0	0.5	0.0	0.0	0.0	2.3	0.0	3.5	0.0	0.2	0.4	0.0	0.2	0.0	2.0	0.5	0.4	0.5	0.0	0.0	0.0	0.1	1.2	0.7
Zelandobius	0.4	0.0	0.5	0.0	0.0	2.0	0.4	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	2.3	2.4	0.5	3.5	5.1	0.0	0.0	0.0	0.0	2.5	4.8	0.9	2.0	0.0	0.0	1.5	0.8	1.7	0.8
Zelandoperla	9.5	21.2	0.0	0.5	0.4	1.0	1.3	0.0	3.1	17.6	0.5	15.5	6.2	0.0	0.5	0.0	0.0	0.0	1.8	0.0	2.5	0.0	4.2	4.0	1.5	0.0	0.0	0.0	0.0	0.4	1.0	0.0	0.0	1.9	0.1	0.7	2.8
Taraperla	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0
Aoteapsyche	4.3	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	15.9	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	3.2	21.4	0.0	0.0	1.1
Beraeoptera	3.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	1.3	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.2
Costachorema	0.0	3.8	0.5	0.0	0.4	3.4	7.4	0.0	0.8	1.3	0.0	1.0	0.5	0.0	1.4	0.0	0.9	0.0	1.4	0.0	0.5	0.0	0.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.7	0.2	0.5	0.0	0.7	0.9
Economidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1
Helicopsyche	4.7	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	2.4	1.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.5	0.0	1.5	6.9	0.0	0.0	0.0	9.7	9.7	0.0	0.4	1.7	1.4
Hudsonema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.2	0.0	0.1
Hydrobiosella	0.9	0.0	0.2	1.0	2.4	0.0	0.0	0.0	3.1	3.0	6.3	0.5	0.2	1.0	5.0	0.0	7.4	1.5	5.9	2.9	0.0	0.0	1.4	2.6	5.5	0.0	0.2	0.5	0.5	0.0	3.9	3.3	0.0	0.0	0.8	4.4	2.0
Hydrobiosis	0.0	0.0	0.2	0.0	0.2	1.5	1.3	0.0	0.0	0.4	0.0	1.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.5	0.0	0.5	0.0	0.0	0.5	0.0	1.0	1.0	0.9	1.0	0.0	0.2	0.0	0.3	0.5	0.4
Hydrochorema	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.5	0.2	0.0	0.0	0.1	0.1	0.1
Neurochorema	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	1.0	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.1	0.0	0.1
Oeconesus	0.0	0.0	0.0	0.2	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	0.0	0.4	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0
Olinga	12.1	0.0	3.4	0.0	0.0	1.0	0.0	0.0	0.0	3.0	0.0	1.0	3.8	3.9	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.4	1.4	0.0	0.0	0.0	1.5
Orthopsyche	2.2	0.5	8.4	21.9	24.9	0.5	2.2	0.0	10.9	1.3	6.8	0.0	0.0	5.4	21.2	0.5	6.9	5.5	14.2	1.0	15.9	23.3	15.4	8.8	24.9	7.7	6.4	5.9	27.1	13.2	17.2	1.1	0.5	0.0	5.3	11.1	10.0
Oxyethira	0.0	0.9	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0
Paroxyethira	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Philorheithrus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Polyplectropus	0.0	0.0	0.0	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.1
Psilochorema	0.2	0.5	1.0	0.0	0.4	0.5	0.4	0.5	0.0	0.2	0.0	0.0	0.2	0.5	0.5	0.0	0.0	0.0	0.0	2.4	0.0	1.8	0.5	0.9	0.5	0.0	1.0	1.0	1.0	1.3	0.5	1.9	0.2	0.0	1.2	0.4	0.4
Pycnocentrella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pycnocentria	0.0	0.0	0.5	0.5	0.0	0.5	0.0	1.5	0.0	0.0	2.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.9	1.0	1.0	0.0	0.0	0.0	0.0	0.0	10.9	3.4	0.0	1.8	0.0	1.9	0.5	0.0	3.4	1.1	0.4
Pycnocentrodes	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.4	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.7	4.6	30.2	0.0	0.0	0.4
Triplectides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	1.4	1.9	0.0	0.0	0.0	0.0	0.0	0.0	8.4	2.0	0.5	0.4	0.0	0.2	0.5	0.0	2.8	0.9	0.2
Zelolessica	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	3.9	0.0	0.0	0.0	0.0	1.2	0.2
Plectrocnemia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Alloecentrella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Archichauliodes	1.3	0.5	3.0	2.4	2.0	0.2	0.0	0.0	5.4	0.4	0.0	1.0	0.2	1.9	2.7	0.0	3.7	3.0	0.0	0.0	0.0	0.4	0.9	0.9	2.0	2.9	0.0	1.5	0.5	0.0	0.0	1.5	1.4	1.0	0.0	1.3	1.6
Kempynus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Microvelia	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elmidae	0.0	8.5	0.5	0.0	0.8	7.4	23.0	0.5	1.2	3.0	0.5	1.0	2.4	0.2	8.6	0.0	2.8	6.0	7.3	0.0	0.0	0.4	0.5	2.2	3.5	4.8	0.0	0.0	1.0	0.0	0.5	5.2	7.9	1.9	0.0	2.6	3.6

Hydraenidae	2.2	0.0	4.4	0.5	0.4	3.9	3.5	0.0	0.2	0.0	1.0	0.5	2.4	0.0	4.1	0.0	0.0	0.0	1.8	1.4	0.5	0.0	1.4	0.0	0.5	5.3	0.0	0.5	0.0	3.1	3.0	0.0	0.9	0.0	1.1	1.3	1.4
Hydrophilidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.2	0.1	0.0
Ptilodactlidae	0.0	0.0	0.5	1.4	0.8	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9	0.0	0.0	1.0	0.9	0.0	1.5	0.0	0.0	0.4	0.0	0.2	0.0	2.0	1.0	0.4	1.5	1.1	0.5	0.2	0.1	1.1	0.6
Scirtidae	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.1
Aphrophila	3.0	5.7	0.0	0.0	0.0	3.4	5.2	0.0	0.8	3.9	0.0	4.8	7.6	0.0	0.0	0.0	0.2	0.0	0.0	0.0	1.5	0.0	0.5	1.8	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	6.8	0.0	0.2	1.3
Austrosimulium	0.0	9.4	1.5	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.4	0.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	1.3	0.5	0.4	2.8	0.0	0.7	0.4	0.3
Ceratopogonidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
Empididae	0.0	0.5	0.0	0.0	0.0	0.0	0.4	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.5	0.0	1.5	0.7	0.2	1.9	0.2	0.4	0.1
Eriopterini	0.0	0.0	0.0	0.5	0.8	1.0	2.2	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.2	0.0	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.0	0.0	0.4	0.0	0.0	0.0	0.1	0.3
Hexatomini	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.5	0.0	0.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.2	0.5	0.0	0.2	0.4	0.1
Limonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Muscidae	0.0	0.9	0.0	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Neocurupira	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Paradixa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sciomyzidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Tabanidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
Psychodidae	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Orthocladiinae	0.2	3.3	0.0	0.0	0.0	1.5	4.8	4.4	0.0	0.4	0.5	3.4	0.5	3.9	0.9	1.0	0.5	1.5	1.4	0.0	1.5	1.3	2.8	0.4	0.0	1.4	2.0	1.0	1.5	15.4	5.9	3.3	3.7	8.8	4.6	2.2	1.6
Maoridiamesa	0.0	14.6	0.0	0.0	0.0	0.5	0.2	0.0	0.0	0.2	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.1
Tanytarsini	0.0	4.2	2.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.0	5.4	0.0	1.9	0.5	0.0	0.5	0.0	0.5	0.9	0.0	0.9	0.5	2.9	0.5	1.5	0.0	7.5	4.9	8.2	3.2	1.5	2.5	1.8	1.3
Tanypodinae	0.2	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	1.5	0.5	0.5	0.9	0.0	0.0	0.0	0.0	0.6	0.1	0.2
Podominae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.1	0.0
Harrisius	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Polypedilum	0.0	20.3	2.5	2.9	3.6	0.0	0.0	7.8	0.2	0.4	0.5	0.0	0.5	1.9	0.0	1.4	0.9	0.5	4.6	3.4	2.5	2.6	1.9	3.1	4.5	0.5	12.9	3.9	1.5	4.8	3.0	1.1	0.9	0.0	5.6	3.1	1.6
Nothodixa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.5	0.0	0.0	0.0	0.0	1.8	1.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.2
Stratiomyidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Molophilus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Antipodochlora	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hemicordulia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Latia	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Potamopyrgus	0.9	4.2	3.4	9.5	0.8	0.0	0.0	55.6	0.4	0.9	61.5	1.4	0.5	27.3	0.0	9.1	0.9	0.0	5.0	21.1	1.0	3.1	0.9	2.2	4.5	5.8	0.5	0.0	0.0	3.5	2.5	23.0	24.0	1.9	8.5	2.1	4.6
OLIGOCHAETA	0.0	0.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	3.9	0.3	0.0	0.0
PLATYHELMINTHES	0.0	0.0	0.0	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.2	1.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.2	0.2
Amphipoda	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.8	23.5	0.5	1.3	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.5	0.0	0.0	0.0	5.9	0.6	0.2
Paranephrops	0.0	0.0	0.0	0.5	1.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	1.0	1.5	0.0	0.0	0.0	0.5	0.2	0.0	0.5	1.3	0.0	0.0	0.0	0.0	0.4	0.1	0.2
Paratya	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.1	0.0
Isopoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0
ACARINA	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
COLLEMBOLA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.2	0.0	0.0

Appendix 3

Details of individual metrics derived from invertebrate communities sampled at potential reference sites. EPT = Ephemeroptera+Plecoptera+Trichoptera; “*” denotes Hydroptilidae excluded from calculation; “S” denotes sample collected from soft substrates (wood, macrophytes edges).

Sample	Total sample taxa richness	Margalf diversity d	Pielou eveness J'	Shannon diversity (H'(loge))	Simpson Diversity (1-λ)	Ephem-eroptera richness (sample)	Plecop-tera richness (sample)	Trichop-tera* richness (sample)	EPT* sample richness	% EPT* richness	% Ephem-eroptera	% *Deleatidium*	% Plecoptera	% Trichoptera*	% EPT*	% Coleoptera	% Elmidae	% Chironomidae	% Diptera other	% Diptera total	% Mollusca	% Crustacea	% Oligochaeta	% Dominant taxon	MCI	QMCI
3	25	4.4	0.8	2.4	0.9	7	4	9	20	80.0	50.6	22.4	11.2	27.8	89.7	2.2	0.0	0.4	5.6	6.0	0.9	0.0	0.0	22.4	149.2	8.3
4	18	3.2	0.8	2.3	0.9	0	1	4	5	27.8	0.0	0.0	21.2	4.7	25.9	8.5	8.5	42.5	16.5	59.0	4.5	0.0	0.5	21.2	92.6	5.1
7	29	5.3	0.8	2.6	0.9	7	3	10	20	69.0	54.7	8.9	10.6	15.0	80.3	5.9	0.5	4.4	2.5	6.9	3.4	0.5	0.0	21.2	134.0	7.9
8	28	5.1	0.7	2.3	0.9	8	4	6	18	64.3	49.3	1.0	5.7	24.0	79.0	1.9	0.0	4.3	0.5	4.8	9.5	0.5	0.0	21.9	146.2	7.7
9	23	4.0	0.7	2.2	0.8	6	4	6	16	69.6	56.0	2.8	5.2	28.3	89.6	2.0	0.8	3.6	0.8	4.4	0.8	1.0	0.0	26.1	148.3	8.0
12	21	3.8	0.5	1.5	0.6	2	5	8	15	71.4	67.5	65.5	6.4	7.9	81.8	11.3	7.4	2.0	4.7	6.7	0.0	0.0	0.0	65.5	139.1	7.6
14	23	4.0	0.7	2.2	0.8	2	5	6	13	56.5	37.4	35.2	10.0	12.2	59.6	26.7	23.0	5.0	8.7	13.7	0.0	0.0	0.0	35.2	136.5	7.1
15-S	25	4.5	0.6	1.9	0.7	2	4	7	13	52.0	1.5	0.0	10.2	8.3	20.0	0.5	0.5	14.1	1.5	15.6	55.6	0.0	1.0	55.6	116.8	4.5
28	21	3.6	0.6	2.0	0.8	5	5	6	16	76.2	66.9	1.6	8.4	16.3	91.6	1.4	1.2	0.2	0.8	1.0	0.4	0.2	0.0	37.4	149.1	8.7
29	24	4.2	0.6	1.9	0.7	3	4	11	18	75.0	55.8	48.5	22.3	12.2	90.3	3.0	3.0	1.1	4.3	5.4	0.9	0.0	0.0	48.5	138.4	8.2
45	20	3.6	0.5	1.6	0.6	3	2	4	9	45.0	13.9	0.0	0.7	17.6	32.2	1.5	0.5	1.0	2.2	3.2	62.4	0.7	0.0	61.5	129.0	5.6
48	24	4.3	0.7	2.2	0.8	5	3	8	16	66.7	47.8	17.4	15.9	21.3	85.0	1.4	1.0	5.3	5.3	10.6	1.4	0.0	0.0	28.5	135.2	7.4
60	24	4.3	0.5	1.5	0.6	4	4	9	17	70.8	68.3	65.4	8.4	8.4	85.0	4.8	2.4	1.0	8.6	9.5	0.5	0.0	0.0	65.4	136.7	7.7
64	25	4.5	0.7	2.2	0.8	6	0	8	14	56.0	41.6	27.3	0.0	13.6	55.2	0.5	0.2	11.7	1.7	13.4	27.3	0.2	0.0	27.3	127.7	6.1
66	23	4.1	0.7	2.4	0.9	5	5	7	17	73.9	45.0	14.9	7.0	29.7	81.8	13.5	8.6	0.9	1.1	2.0	0.0	0.0	0.0	21.2	153.3	8.3
74-S	18	3.2	0.5	1.3	0.5	4	2	5	11	61.1	74.9	0.0	6.2	3.1	84.2	0.5	0.0	4.3	1.4	5.7	9.1	0.0	0.5	69.7	118.9	6.7
75	25	4.5	0.5	1.8	0.6	4	2	7	13	52.0	65.6	0.0	4.6	17.1	87.3	2.8	2.8	1.8	2.8	4.6	0.9	0.7	0.0	55.9	123.1	7.3
76	15	2.7	0.6	1.7	0.7	4	1	4	9	60.0	71.5	24.8	7.4	7.2	86.1	6.9	6.0	2.0	1.0	3.0	0.0	0.5	0.0	44.2	130.0	8.2
78	31	5.6	0.8	2.8	0.9	4	6	7	17	54.8	39.4	14.2	8.7	24.7	72.8	10.1	7.3	6.4	3.0	9.4	5.0	1.8	0.0	14.2	129.0	7.3
79-S	26	4.7	0.7	2.4	0.9	4	4	8	16	61.5	26.4	1.0	8.4	11.5	46.3	1.9	0.0	3.4	2.4	5.8	21.1	23.5	0.5	23.5	130.0	5.9
85	28	5.1	0.7	2.3	0.8	4	4	7	15	53.6	59.2	3.5	8.0	19.9	87.1	2.0	0.0	5.0	3.0	8.0	1.0	1.5	0.0	31.8	129.3	8.1
86-S	25	4.4	0.7	2.2	0.8	5	4	5	14	56.0	54.9	0.9	5.3	25.9	86.2	0.9	0.4	4.8	0.0	4.8	3.1	3.3	0.0	23.3	124.6	7.7
94	26	4.7	0.7	2.4	0.9	5	6	8	19	73.1	56.4	23.8	14.7	19.1	90.2	1.9	0.5	4.7	0.9	5.6	0.9	0.5	0.0	23.8	143.0	8.1
107	23	4.1	0.7	2.4	0.9	4	4	7	15	65.2	56.8	27.8	10.8	19.8	87.4	2.6	2.2	4.4	2.2	6.6	2.2	0.0	0.0	27.8	142.5	8.2
108	23	4.2	0.7	2.3	0.9	6	2	8	16	69.6	44.8	20.4	3.5	32.8	81.1	4.0	3.5	6.5	1.0	7.5	4.5	0.0	0.0	24.9	145.8	7.6
109	22	4.0	0.6	1.9	0.7	6	3	4	13	59.1	61.4	50.2	2.7	10.1	74.2	10.4	4.8	4.8	0.5	5.3	6.8	0.5	0.0	50.2	134.8	7.5
110-S	25	4.5	0.7	2.3	0.8	6	3	9	18	72.0	47.0	1.0	4.5	30.0	81.4	0.0	0.0	16.8	1.0	17.8	0.5	0.2	0.0	32.7	138.4	6.6
111	32	5.8	0.8	2.9	0.9	8	5	10	23	71.9	52.9	5.9	12.3	22.1	87.3	2.5	0.0	6.9	1.0	7.8	0.0	0.0	0.0	19.1	140.0	7.7
118	29	5.3	0.7	2.2	0.8	5	5	6	16	55.2	46.5	2.9	9.0	30.0	85.5	3.4	1.0	3.4	4.8	8.2	0.0	2.4	0.0	35.4	132.7	7.4
120-S	28	5.0	0.8	2.7	0.9	5	6	5	16	57.1	33.3	0.4	9.6	17.5	60.5	3.5	0.0	28.9	1.3	30.3	3.5	1.3	0.4	15.4	130.0	6.3
121	30	5.5	0.8	2.7	0.9	4	6	7	17	56.7	37.4	1.5	10.1	27.6	75.1	5.4	0.5	14.3	2.0	16.2	2.5	0.7	0.0	18.7	136.0	7.6
134	28	4.8	0.8	2.6	0.9	4	1	12	17	60.7	32.3	5.6	0.4	21.2	53.9	6.3	5.2	12.6	2.4	15.1	23.0	0.2	0.0	23.0	126.2	6.2
136	32	5.8	0.7	2.5	0.9	4	1	13	18	56.3	28.6	0.0	0.5	21.9	51.0	10.6	7.9	7.9	4.4	12.2	24.0	0.2	0.0	24.0	120.0	6.3
138	19	3.4	0.8	2.2	0.8	2	2	6	10	52.6	11.7	2.4	3.4	55.0	70.1	2.2	1.9	10.7	8.8	19.5	1.9	0.0	3.9	30.2	106.0	4.9