

Review of Environment Waikato's Regional Ecological Monitoring of Streams (REMS) Programme

Past Practices and Future Directions

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1 Introduction

Since 1994, Environment Waikato has been carrying out rapid assessments of invertebrate community composition and habitat quality annually (Regional Ecological Monitoring of Streams – REMS) as part of its Environmental Indicators Programme to document the condition of streams and rivers in the region (<http://www.ew.govt.nz/enviroinfo/indicators/inlandwater/riversandstreams/riv3/report.htm>). Monitoring the composition of aquatic invertebrate communities provides a measure of the ecological condition of their habitats. This condition reflects a range of interacting factors thereby providing an holistic and cumulative understanding of ecosystem health that augments non-integrative measures such as water quality. Other factors shaping biological condition include the hydrological regime, quality of available habitat and the nature of biological interactions occurring at a site. Information on invertebrate community composition is condensed into metrics that can be used to report on changes in stream ecological health over time.

Similar approaches are widely used among other regional councils in New Zealand and territorial authorities internationally for monitoring ecological condition. If data on biology can be linked to landscape factors (e.g., upstream land use, geology), local habitat and water quality, hydrology, and alien species impacts, then it may be possible to identify factors and practices that are related to ecological integrity, although broadscale sampling programmes do not allow definitive cause-effect links to be made. In addition to understanding spatial patterns and temporal trends in ecosystem health, this information may enable the development of predictive models that have broad-scale application for planning and management purposes throughout the region.

This report:

1. Reviews the history of REMS from its commencement in 1994/95;
2. Re-defines the objectives of the REMS programme based on past recommendations and planned future directions;
3. Recommends changes to refine and refocus the programme; and
4. Describes a new sampling design for wadeable streams that was implemented in 2005.

2 Scope and Objectives of REMS

2.1 Scope

Permanently flowing waterways in the Waikato regions can be broadly classified into four groups for environmental monitoring purposes:

- groundwater dependent ecosystems - e.g., seeps, springs, cave systems;
- wadeable streams – typically 1st-4th order, although some larger sites within this range can be non-wadeable;
- non-wadeable streams and rivers – typically 5th order, although some large 3rd-4th sites may be considered non-wadeable if it is unsafe to enter the waterway or dominant substrates can not be sampled using wadeable stream protocols (<http://www.ew.govt.nz/publications/technicalreports/documents/tr05-02.pdf>);
- large rivers – lower Waikato, Waipa, Piako, Waihou, and Mokau rivers.

In the past the REMS program has sampled wadeable and non-wadeable streams and rivers (as defined above), although no distinction in terms of sampling protocols has been made between these waterways.

Recommendation 1: Clarify the distinction wadeable and non-wadeable streams by developing separate monitoring and assessment procedures.

Status: Wadeable stream protocols based on recommended MfE practices were implemented in 2002 and refined for local conditions in 2004 (see <http://www.ew.govt.nz/publications/technicalreports/tr0502.htm>). Non-wadeable stream sampling protocols are currently under development.

2.2 Objectives

The initial objectives of the REMS programme were to (see Edgar et al. 1994 - DOCs#921952):

1. Characterise regional stream habitat quality and biotic components;
2. Characterise the existence and severity of environmental impairment in stream ecosystems;
3. Aid in the identification of the sources and causes of environmental degradation;
4. Evaluate the effectiveness of actions designed to avoid, remedy or mitigate degradation;
5. Support water use classification investigations.

Boothroyd (2001) reviewed Environment Waikato's REMS programme and concluded that, although current objectives seem appropriate at the broad, multi-programme scale, no clear objectives had been developed for REMS as a single resource information gathering programme. He concluded that "REMS would benefit from the establishment of concise, specific and clear objectives aimed at clearly identifying what REMS can achieve...to provide a more precise understanding of the purpose of REMS". He went on to suggest that the objectives be revised as follows:

- To assess trends over time for ecological health, including habitat, of selected river and stream types in the Waikato Region and the delineation of water bodies into respective quality classes;
- To collect aquatic biota, habitat data and information to assess the water and habitat quality of the major freshwater habitats (or selected habitats, major waterways, or major geographic regions etc) of waterways in the Waikato Region;
- To assess the performance of policy 1 and 2 of Environment Waikato policies and rules in representative river and stream types;
- To assess the impact of specific land use activities on the ecological health of selected river and stream types in the Waikato region;
- To identify the characteristics and where possible the locations of water bodies at risk, conflicting uses and degradation;
- To prioritise the types and characteristics, and where possible the locations, of streams and rivers identified for restoration initiatives that will improve the ecological health of the streams and rivers. Priorities will include the identification of stream types and characteristics that will benefit from improvements to the riparian margins;
- To assess the performance of restoration initiatives applied to selected rivers and streams in the Waikato region;
- To distinguish and characterise waterbodies (and/or stream types) of exceptional water and habitat quality in the Waikato region, as indicated by their aquatic biota and habitat attributes;
- To contribute information to the development of best management practices and options and restoration guidelines for rivers and streams in the Waikato region.

More recently, Kelly (2003) summarised the contemporary objectives of the REMS programme as:

- To report on the current state of, and trends within, aquatic habitats in representative sites within the region;
- To report on the effects of landuse activities in representative sites within the region;

- To report on the effectiveness of restoration initiatives undertaken at representative sites within the region;
- To distinguish and characterise outstanding waterbodies within the region.

Recommendation 2: The following objectives are proposed for wadeable sites in the REMS programme for 2005 onwards:

- To report on the current condition and biodiversity of dominant wadeable stream types at representative sites in their natural condition and in relation to dominant landcover throughout the region (note the intention is not to report on the condition of “all” wadeable streams) ;
- To determine trends over time in ecological condition at representative long-term monitoring sites;
- To identify environmental factors related to stream ecological condition, and assist with developing policies that mitigate adverse effects on stream ecosystems;
- In association with existing initiatives (e.g., Clean Streams), to provide a context for assessing the effectiveness of restoration activities undertaken at representative sites within the region;
- To satisfy the Council’s RMA section 35 responsibilities for State of the Environment reporting and assess the performance of policies 1, 2 and 3 of Environment Waikato’s Regional Policy Statement for representative stream types (see below);
- To contribute to a national monitoring overview and international understanding of wadeable stream ecosystems.

Status: These objectives were adopted for the REMS programme in 2005.

2.3 Relevance to the Regional Policy Statement and Regional Plan

Measuring and monitoring changes in biological condition of streams and rivers has direct relevance to Policies 1, 2 and 3 and associated anticipated results of the Regional Policy Statement, along with several outcomes of the Regional Plan (version at 6/7/04).

- **Regional policy statement Policy 1 (Water Quality)** - “Ensure protection of significant characteristics of the quality of outstanding waterbodies”
Aquatic invertebrate communities respond to a range of environmental variables including large-scale factors such as geology and climate, and local-scale factors such as water chemistry, flow and habitat quality. The inclusion of undisturbed reference sites in the monitoring program provides a baseline against which to measure degradation and change, and will enable the identification characteristics typical of high quality wadeable streams.
- **Regional policy statement Policy 2 (Other water bodies)** - “Determine the characteristics for which other water bodies are valued and manage those water bodies to ensure that any adverse effects are avoided, remedied or mitigated”
Documenting the range of variation in biological communities in waterbodies throughout the region will enable the biological potential of sites to be recognised and assist with identifying key management practices that cause degradation or can be used to avoid, remedy or mitigate adverse impacts (e.g., degree of upstream landuse, extent of riparian protection).
- **Regional policy statement Policy 3 (Riparian management)** - “Ensure that the adverse effects of land use on water quality and aquatic habitats are avoided, remedied or mitigated “
Annual monitoring of aquatic invertebrates provides an integrated measure of ecosystem health as the community present at a particular time reflects the cumulative effects of both local and upstream activities over an extended period

prior to sampling. Due to their ability to reflect cumulative and proximate conditions, aquatic invertebrates can be used as indicators to detect whether adverse effects are being avoided, remedied or mitigated. Integration of REMS methodologies with those used in the Clean Streams and Project Watershed programmes can assist with identifying the long-term success of restoration methods such as riparian replanting.

By using aquatic invertebrate communities as indicators of ecosystem health and integrating biodiversity metrics into the analyses of REMS data, Environment Waikato will be able to monitor over the long term the following key anticipated results with respect to wadeable streams:

- Surface and groundwaters maintained and enhanced
- Biodiversity maintained and enhanced.

Sections 3.1.2a and b of the Regional Plan state that waterbodies will be managed in such a way as to ensure net improvement of water quality across the Region and the avoidance of significant adverse effects on aquatic ecosystems. The REMS programme contributes to both of these goals by providing ecological condition indicators and contributing to biodatabases, as detailed for several objectives in Section 3.1.4 of the Regional Plan. In addition, through its ability to integrate cumulative effects of landcover, water quality, and localised habitat condition into indicators, REMS contributes to policies identified in Sections 3.2 and 3.9 of the Regional Plan to identify water management classes (Section 3.2.3 Policy 1), manage degradation (Policy 8), maintain or enhance existing values (Policies 3, 7, 9), recognise characteristics of natural character (Policy 10), and reduce adverse effects of land use (Section 3.9.2 Policy 1).

3 Sampling sites

A total of 340 sites has been sampled over 1994 to 2005, with the number of sites sampled in each summer varying between 47 (1994/95) and 147 (2005; including Clean Streams and Project Watershed sites; see Appendices 1 - 3). Over this time there have been variations in the timing of sample collection (although most sampling has been conducted sometime over early to late summer; see Appendix 2), field protocols and laboratory processing procedures, as summarised in Table 1. Taylor et al. (1998) analysed 251 sites sampled prior to 1998 and used a cluster analysis to identify 125 that were considered representative of various hydroregions throughout the Region; these sites have formed the core set of REMS sampling sites since that time with few changes occurring until 2005 (see Taylor 2001 and Kelly 2003 for updates).

Originally, around one-quarter of sampling sites was intended to be the same as those monitored for the RERIMP (Regional River Monitoring Programme) water quality monitoring programme (Edgar et al. 1994). In 2005, 17 REMS sites coincided with RERIMP sites. One REMS site (421-19) has been sampled in every year, although it is not considered suitable for analysis of long-term trends due to changes in sampling protocols (see below). Sixty-eight sites have been sampled for 8-10 years, but only 49 of these are considered to have consistent sampling suitable for analysis of long-term trends. Thirteen of the 68 sites sampled for ≥ 8 years coincide with RERIMP sites, although not all these are considered suitable for long-term monitoring (see Appendix 3).

With respect to reference sites, Boothroyd (2001) noted that existing narrative reference site definition is contradictory, referring to both “natural state” and “best attainable ecological condition”. He considered that an appropriate number of reference sites for such a programme would be 10-20% of total site numbers. Subsequently, guidelines for selecting reference sites for environmental monitoring of streams and rivers have been released (Boothroyd et al. 2002).

Table 1: Details of REMS sampling and processing protocols used over 11 years.

Year	No. sites	Sampling period	Sampling protocol	Preceding flow criteria applied?	Habitat assessment method	Net mesh size (µm)	Sample sorter	Min. count	Rare taxa recorded separately?	Chironomids identified?
1994/95	47	Dec-Mar	EW	no	SHAM	250	EW	100	no	no
1995/96	119	Nov-Feb	EW	no	SHAM	250	EW	100	no	no
1996/97	122	Nov-Feb	EW	no	SHAM	250	EW*	100	no	no
1997/98	112	Nov-Feb	EW	no	SHAM	250	EW	100	no	no
1999	116	Jan-May	EW	no	HAT	250	EW	100	no	no
1999/00	123	Nov-Feb	EW	no	HAT	250	Goodwin/Taylor	100	no	no
2000/01	122	Nov-Feb	EW	no	HAT	250	NIWA	100	no	no
2002	121	Jan-Feb	MfEC1&2	yes	HAT	500	Landcare**	200	yes	no
2003	121	Jan-Feb	MfEC1&2	yes	HAT	500	Landcare**	200	yes	yes
2004	121	Jan-Feb	MfEC1&2	yes	HAT	500	Landcare	200	yes	yes
2005	146 ¹	Jan-Mar	MfEC1&2/ EW ²	yes	HAT	500	Landcare**	200	yes	yes

*, QA by NIWA; ** = QA by Kate Senner.

¹, Included Clean Streams and Project Watershed sites and comprised 130 wadeable and 16 non-wadeable (refer to Appendix 3); duplicate hard-bottomed and soft-bottomed samples were collected at 9 sites.

², Collier & Kelly (2005).

Recommendation 3: Revise the REMS network giving priority to continued sampling of long-term monitoring sites (i.e., ≥ 8 years of data, ≥ 100 invertebrates in a sample) with consistent sampling approaches.

Status: Implemented 2005 (see Appendix 3)

Recommendation 4: Other non-reference sampling sites should be identified to (i) represent a land-use optima design based on pastoral and upstream indigenous forest landcover, (ii) investigate emerging issues such as urban-peri-urban development, and (iii) assess the effects of restoration activities (e.g., Clean Streams and Project Watershed sites).

Status: Implemented 2005 (see Section 5 and Appendix 3)

Recommendation 5: Identify up to 20% of wadeable stream sites as reference sites that reflect variations in geographic distribution and dominant hydrogeological conditions using Level 3 of the River Environment Classification (combination of climate, source of flow and geology).

Status: Implemented 2005 (see Collier et al. 2005)

4 Methodologies

4.1 Invertebrate sampling

Boothroyd (2001) noted the following issues of concern regarding the current sampling and processing procedures:

- Lack of criteria to assess antecedent flow conditions prior to field sampling;
- Use of a single sampling method for all stream habitat types;
- Extended sampling period from November to March;
- Lack of conformity to national protocols (Stark et al. 2001), notably net mesh size and fixed-count number.

These issues were all addressed in the 2002 sampling year, and a consistent set of macroinvertebrate data in line with MfE protocols (Stark et al. 2001) was subsequently collected from 2002-2005 (Table 1). Over that period (i) a net mesh size of 500 μm was used following MfE sampling protocols C1 or C2 (but see below), (ii) at least 200 invertebrates have been identified by the same consultant with data from scans for rare taxa recorded separately, and (iii) a stand-down period of at least 2-weeks has been applied following large floods with estimated capacity of mobilise streambeds at index sites scattered throughout the region, following procedures outlined in Clausen & Plew (2004). These sampling methods as applied in the REMS programme are summarised by Collier & Kelly (2005).

Prior to 2002, the field sampling protocol broadly followed the methods outlined by Edgar et al. (1994). This procedure involved collecting “**representative**” samples from “comparably productive habitat types” at all sites, supplemented with separate samples from coarse particulate organic matter (CPOM). The CPOM sample was stored but was not analysed. The comparable habitats focussed on were runs/riffles (2 x 1 m^2 areas) with the inclusion of pools in proportion to their abundance in the 100 m sampling reach (B. Moore. pers. comm.). Where stony riffles were not available, submerged boulders, soft sediments, logs and macrophytes were sampled in proportion to abundance (B. Moore, pers. comm.).

The high-gradient technique for stony streams was probably broadly comparable to the hard-bottomed C1 method employed since 2002, because most taxa and individuals

would have been collected from riffles. However, there appear to be marked differences in protocols for wadeable, low-gradient streams dominated by fine or hard substrates (but without riffles) before and after 2002 which would compromise analysis of long-term trends. Non-wadeable, low-gradient streams dominated by fine substrates are probably comparable over the long term because sampling would have been done only on accessible substrates, which would have been mostly channel edges and submerged macrophytes.

In effect four types of stream can be recognised to date in terms of sampling strategies in the REMS programme:

1. **Wadeable high gradient/hard-bottomed streams** – runs and riffles were probably the primary habitat sampled for invertebrates prior to 2002 with riffles sampled after that date using the MfE C1 approach. These sites are considered suitable for analysis of long-term trends in invertebrate metrics.
2. **Wadeable low gradient/hard-bottomed streams** - >50% of substrates dominated by stony substrates but no riffles were present. These sites would have been sampled over the full range of habitats including stony runs and pools prior to 2002, but edges, wood and macrophytes would have been sampled after that using MfE protocol C2. These sites are not considered suitable for analysis of long-term trends in invertebrate metrics.
3. **Wadeable low gradient/soft-bottomed streams** - >50% of substrates sand/silt/mud. MfE soft-bottomed protocol C2 has been used since 2002 (mainly macrophytes, wood, edges) but prior to this soft substrates may have been included in the sample. These sites are not considered suitable for analysis of long-term trends in invertebrate metrics.
4. **Non-wadeable low gradient/soft-bottomed streams** - >50% of substrates sand/silt/mud and mean depth >1 m or unable to be safely waded. Sampling would most likely have consisted of edges and macrophytes over the entire sampling period. These sites are considered suitable for analysis of long-term trends in invertebrate metrics.

Based on this classification, 10 non-wadeable and 39 wadeable/hard-bottomed sites sampled for ≥ 8 years, with more than 100 invertebrates in a sample, and consistent sampling protocols are considered suitable for analysis of long-term trends (see Appendix 3).

Sample processing has been conducted on a fixed count basis since the start of the REMS programme (minimum fixed-count = 100 + scan for rare taxa). From 2002 the count was increased to at least 200 plus a scan for rare taxa following MfE protocol P2. From 2002, rare taxa data were kept separate from the fixed count data so they can be differentiated in analyses, but prior to this they appear to have been lumped with the count data and cannot be differentiated. All taxa counted are identified to the MCI level of taxonomy where possible, although prior to 2002 Chironomidae were not differentiated (see Collier & Kelly 2005 for accepted level of resolution and approaches to sample identification). Sample sorting QA procedures were implemented in 2002, 2003 and 2005 (see DOCs#773579, 824908 and 1007381). In all years, the samples examined (10% of total) were within the QA guidelines recommended by the MfE protocols (Stark et al. 2001).

As part of the transition from the initial Environment Waikato sampling protocol to the MfE wadeable streams protocol, validations were carried out to account primarily for changes in mesh size, as recommended by Boothroyd (2001). Analysis of these data indicate that, although community composition in terms of the relative abundance of dominant taxa was reasonably consistent among samples collected with different net meshes at a particular site (see Figure 1), several of the indices derived from these data were highly variable (see Tables 2 and 3). Rarified richness, Margalef diversity, % dominant taxon and MCI had mean change between two methods of $\leq 25\%$ and no site had >50% change in these metrics. However, it is not clear to what extent observed variability reflects differences in habitats sampled using the two methods, or the effect

of mesh size per. se. Given this caveat these figures probably represent a worse case scenario and other metrics are also worth incorporating into long-term analyses.

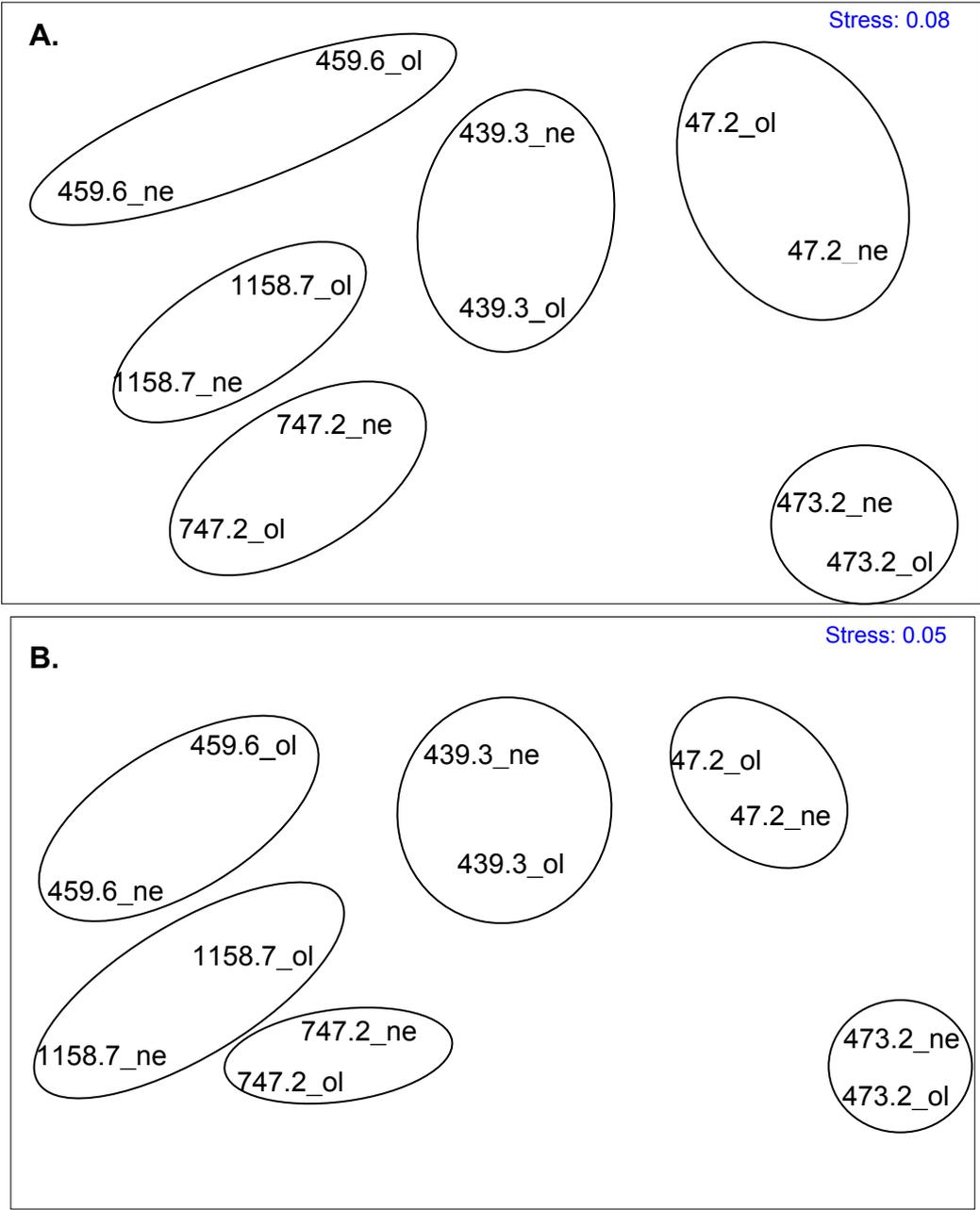


Figure 1: Non-metric multidimensional scaling plot based on presence absence (A) and relative abundance (B) of invertebrates in streams sampled using 0.25 mm mesh (“ol”) and 0.5 mm mesh (“ne”) nets at 6 sites.

Table 2: Invertebrate community metrics calculated for 6 sites sampled using 0.25 mm mesh (old) and 0.5 mm mesh (new).

Metric	1158.7 old	1158.7 new	439.3 old	439.3 new	459.6 old	459.6 new	47.2 old	47.2 new	473.2 old	473.2 new	747.2 old	747.2 new
Taxa richness	22	21	15	13	8	10	15	18	9	14	24	26
Rarified taxa richness (200-count)	20.9	19.0	14.2	11.8	7.5	8.8	14.0	15.9	9.0	12.8	23.1	23.8
Margalef diversity (d)	3.81	3.47	2.58	2.19	1.26	1.59	2.52	3.03	1.50	2.19	4.22	4.43
Pielou evenness (J')	0.82	0.75	0.58	0.48	0.42	0.60	0.64	0.50	0.45	0.69	0.76	0.72
Shannon diversity (H'(log _e))	2.52	2.27	1.56	1.24	0.87	1.38	1.72	1.46	0.99	1.82	2.42	2.35
Simpson diversity (1- Lambda)	0.90	0.86	0.67	0.57	0.37	0.69	0.70	0.64	0.42	0.77	0.87	0.85
Ephemeroptera taxa	3	3	1	2	1	2	0	0	0	0	5	2
Plecoptera taxa	2	3	0	0	0	0	0	0	0	0	1	2
Trichoptera* taxa	6	6	2	2	2	4	2	3	0	0	5	5
EPT* taxa	11	12	3	4	3	6	2	3	0	0	11	9
%Ephemeroptera	21.77	24.61	0.44	2.08	4.18	35.89	0.00	0.00	0.00	0.00	7.33	8.13
%Plecoptera	5.24	3.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.71
%Trichoptera*	11.29	33.12	0.88	0.83	6.08	12.20	1.17	1.46	0.00	0.00	30.17	12.72
%EPT*	38.31	61.20	1.32	2.92	10.27	48.08	1.17	1.46	0.00	0.00	37.93	21.55
Dominant taxon (%)	22.18	27.76	54.19	62.92	79.09	41.46	50.39	50.73	75.12	39.16	27.16	30.39
MCI	105.45	113.33	80.00	83.08	92.50	114.00	74.67	91.11	57.78	68.57	113.33	100.77
QMCI	5.29	6.11	3.01	3.03	4.25	5.71	2.67	2.56	1.44	2.68	4.62	3.67

*, (excl. Hydroptilidae)

Table 3: Percent change in a range of community metrics calculated from samples collected using 0.5 mm and 0.25 mm mesh nets (see Table 2). Values in bold have >50% change in metric values.

Metric	1158.7	439.3	459.6	47.2	473.2	747.2	Mean
Taxa richness	4.5	13.3	-25.0	-20.0	-55.6	-8.3	-15.2
Rarified richness (n=200)	9.2	16.7	-16.4	-13.1	-42.4	-2.8	-8.2
Margalef diversity	8.8	15.2	-26.6	-20.0	-46.0	-4.9	-12.2
Pielou evenness	8.5	16.1	-43.5	20.6	-52.7	5.4	-7.6
Shannon diversity	9.9	20.5	-59.0	15.3	-83.3	3.0	-15.6
Simpson diversity	4.4	14.8	-87.6	8.5	-81.0	2.7	-23.0
Ephemeroptera taxa	0.0	-100.0	-100.0	0.0	0.0	60.0	-23.3
Plecoptera taxa	-50.0	0.0	0.0	0.0	0.0	-100.0	-25.0
Trichoptera* taxa	0.0	0.0	-100.0	-50.0	0.0	0.0	-25.0
EPT* taxa	-9.1	-33.3	-100.0	-50.0	0.0	18.2	-29.0
%Ephemeroptera	-13.0	-372.9	-758.1	0.0	0.0	-10.9	-192.5
%Plecoptera	33.8	0.0	0.0	0.0	0.0	-64.0	-5.0
%Trichoptera*	-193.4	5.4	-100.5	-24.6	0.0	57.8	-42.5
%EPT*	-59.8	-120.7	-368.4	-24.6	0.0	43.2	-88.4
Dominant taxon (%)	-25.2	-16.1	47.6	-0.7	47.9	-11.9	6.9
MCI	-7.5	-3.8	-23.2	-22.0	-18.7	11.1	-10.7
QMCI	-15.4	-0.5	-34.4	4.2	-86.4	20.5	-18.7

*, (excl. Hydroptilidae)

Recommendation 6: Create a new field in the HYDROL database that identifies the sample collection method used for wadeable stream samples (C1 hard-bottom, C2 high gradient, C2 low gradient).

Status: Implemented May 2005

Recommendation 7: Maintain the existing sampling and processing protocols (MfE sampling protocols C1 and C2 and processing protocol P2 as outlined in Collier & Kelly 2005), but randomly select 100-invertebrate counts for analysis of combined data (e.g., for long-term trends).

Recommendation 8: Include rarified richness, Margalef diversity, % dominant taxon and MCI in analysis of long-term trends, but other metrics should not be discounted given that observed differences between mesh sizes may also reflect small-scale habitat variations.

4.2 Assessing habitat quality

Instream and riparian habitat are qualitatively assessed at each site in every year so that changes in habitat quality can be documented over time and habitat quality can be related to observed biotic patterns. Two habitat assessment approaches have been used in the REMS programme (see Table 1). From 1995 to 1998, an assessment form (SHAM) based on Riparian, Channel and Environment Inventory (Petersen et al. 1992) was used. From 1999 to 2005 a form (HAT) modified from the USEPA approach has been used following the conclusion by Taylor et al. (1998) that the SHAM method was not sensitive enough to detect changes in stream communities, particularly among streams in pastoral catchments. The HAT approach differentiates high gradient and low

gradient sites, and the distinction between two classes seems to have been based on the availability of riffles. Only two variables differ between the high and low gradient datasheets; in the low gradient form “Channel sinuosity” and “Pool Variability” are used whereas in the high gradient form “Frequency of riffles and bends” and “Velocity/Depth Regimes” are used instead. Total possible scores sum to the same number, and excluding the variables named above, high and low gradient habitat assessment variables can be directly compared.

In 2002, high gradient and low gradient habitat assessment forms were applied to hard-bottomed and soft-bottomed streams, respectively, following the change to MfE protocols. Similar issues to changes in invertebrate sampling protocols apply to habitat assessment, but these should not be problematic if long-term analyses of habitat quality are applied only to those sites where invertebrate sampling protocols have been consistent through time. In 2005, some of the wording of the HAT form was clarified, zero scores were excluded, variables were re-ordered into a more logical flow, and scales of variables evaluating right and left bank conditions were changed and mean scores used; these changes would have had little, if any, direct effect on HAT scores, and the 2005 data are considered directly comparable with HAT scores from other years. The Field Assessment Cover Form used until 2004 was considered useful but there was scope for expansion to include more information (see Collier & Kelly 2005).

The review by Boothroyd (2001) noted that habitat data would benefit from more rigorous and frequent analysis and integration with the macroinvertebrate data so that habitat quality can be reported along with ecological health indicators. Although a calibration exercise is conducted between field parties each year prior to the start of the REMS surveys, it needs to be recognised that habitat assessment is qualitative and there can potentially be considerable variation in variable scores between operators evaluating different sites (which may account for some inter-site variability). Nevertheless, total habitat scores have the potential to be a valuable reporting tool once sufficient long-term data have been acquired; at 2005 seven years of consistent data had been collected at sites monitored appropriately every year.

Recommendation 9: Re-name the REMS “high-gradient” and “low-gradient” habitat assessment forms to “hard-bottomed” and “soft-bottomed” to bring them in line with MfE protocols (noting hard-bottomed, low gradient sites that have been assessed with the soft-bottomed protocol in the past), clarify variables and develop a new Field Assessment Cover Form for wadeable streams.

Status: Implemented 2005 (see Collier & Kelly 2005)

Recommendation 10: Develop HYDROL database codes for new habitat measures.

Status: Implemented in May 2005 (see DOCs #1007537).

4.3 Data storage and analysis

Invertebrate taxa counts, total counts, and from 2002 the presence of rare species were recorded separately on Environment Waikato’s HYDROL database. Rare species are designated a “P” in a separate field and a “1” in the count field; data with “P” + “1” do not form part of the original 200+ count dataset. Prior to 2002, when 100+ counts were done, a scan for rare taxa was also carried out and values were given a “1” without an associated “P” in the HYDROL database so they can not be differentiated from the rest of the sample.

Prior to 2005, metric scores (see below) derived from invertebrate raw count data were calculated by an external Excel spreadsheet, and then imported and saved back into HYDROL. The metrics used for this purpose were taxa richness (“species diversity N”), EPT taxa richness (“EPT index”; including and excluding *Oxyethira* and *Paraoxyethira*), Shannon-Weaver diversity, MCI, QMCI, % Ephemeroptera, % EPT density (including

and excluding *Oxyethira* and *Paraoxyethira*), EPT/Chironomidae ratio (including and excluding *Oxyethira* and *Paraoxyethira*), and % dominant taxon.

Habitat data are also stored in HYDROL with a separate field for each variable assessed; total habitat scores are also stored on this database but the method used (SHAM, HAT high gradient, HAT low gradient) was not recorded prior to 2005.

Recommendation 11: Delete metric values from HYDROL as a quality assurance check indicated that some of these have been calculated incorrectly.

Status: Implemented July 2004.

Recommendation 12: Taxa codes should be corrected on HYDROL so that the level of taxonomy used reflects that recommended for MCI calculation, and a standardised taxonomic datasheet should be sent for use by the consultant responsible for sample processing.

Status: Implemented July 2004

5 A new study design

5.1 The GIS process used to identify impact sites

To achieve the revised objectives based around defining land cover optima (see Section 2.2), a GIS process was implemented to identify existing and new wadeable sites (REC order 1-4) on stream segments that met pre-defined upstream landcover criteria within seven zones and four dominant REC classes. The landcover classes used focussed on sites with pastoral adjacent land use, but with varying degrees of upstream catchment area in unmodified vegetation (predominantly native forest but also tussock were applicable), as follows:

- PP – adjacent pasture with <10% upstream catchment area unmodified
- PFL - adjacent pasture with 11-50% unmodified headwaters
- PFH - adjacent pasture with 51-90% unmodified headwaters

A similar process to that described for identifying potential reference sites (see Collier et al. 1995) was used to identify new impact sites for sampling in 2005 based on the landcover criteria described above. All GIS analyses were performed on Intergraph's Geomedia Professional. 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 30m-pixel DEM using the 20m contour data from the NZMS260 map series. The synthetic river network is split into segments at points of confluence (i.e. when a watercourse is joined by another, or when it joins another). A watersheds layer was used to calculate the area of landcover type upstream of a particular stream segment, allowing the % of landcover type upstream for any water course segment to be calculated. The raw data underlying the REC were used with permission of NIWA to identify the percent catchment area unmodified (i.e., in indigenous forest and/or tussock) upstream of REC river segments.

Candidate stream segments classified in the above GIS procedure as PP, PFL or PFH, and not currently available from existing sites, were randomised for each category within main stream type and zone classes using Excel, and joined back via the REACHID code in Geomedia. Any existing REMS sites that met upstream landcover criteria were assessed according to whether they fitted into the dominant stream type and zone layers, and where this was the case representative sites were retained (see Appendix 3). Over 17,000 REC segments were identified as belonging to one of the landcover optima classes across all zones, with 65-82% of these represented by the four dominant REC classes (Table 4). There were 84 sites possible if one of each

treatment was found for each REC class and zone (3 impact treatments x 4 REC classes x 7 zones).

Candidate sites were then evaluated in sequential randomised order for each stream type and zone using aerial photos with 1 m pixel resolution (flown in 2002-2003). Sites where access seemed reasonable were retained, with the intention of developing a short-list with up to 3 sites in each stream type/sub-region combination. Following finalisation of randomly selected short-listed sites (n = 81), the sites in each stream type/zone combination were selected for field verification. Any one of the three sites was visited on a first-encounter basis, and if suitable it was selected for the impact site network; if the first-visited site was unsuitable one of the other three sites was visited and if none of these proved suitable additional sites on the short list were visited until a suitable site was located if possible. Added to these impact sites are the 25 reference sites selected using the same design based around REC class and zone, as outlined in Collier et al. (2005).

Table 4: Number (percent) of REC segments identified using the GIS selection process. PP = pasture with ≤10% upstream catchment unmodified; PFL = pasture with 11-50% headwaters unmodified; PFH = pasture with 51-90% headwaters unmodified.

REC class	PP	PFL	PFH
CW/H/VA	617 (7.5)	888 (13.8)	310 (13.3)
WW/L/HS	296 (3.5)	1149 (17.8)	677 (29.1)
WW/L/SS	1480 (18.0)	595 (9.2)	121 (5.2)
WW/L/VA	2939 (35.7)	2651 (41.2)	707 (30.4)
Total (all REC classes)	8240	6441	2326

5.2 Additional sites

Other existing sites were retained in 2005 where they met the following criteria (see Appendix 3):

- All suitable sites monitored over the long-term (≥100 invertebrates for ≥8 years with consistent sampling approaches);
- Non-wadeable sites (order >4 or <4 but unable to access) that have been sampled for 7 years, including the last 3 years (NB: 1249.32 was dropped even though it had been sampled for 8 years because there was a duplicate site on that stream - 1249.15). These sites are currently under review and non-wadeable sampling protocols are under development.
- Wadeable sites sampled for at least seven years, including the last three years, and with supporting RERIMP information.

A number of existing sites that do not adhere to the above criteria were continued or new sites were added in 2005 to address topical issues (see Appendix 3):

- Monitoring restoration activities;
- Assessing the impacts of peri-urban intensification around Hamilton;
- Assessment instream values for flow allocation studies (one site only).

Existing sites were dropped if (i) they did meet any of the above criteria (e.g., were in different land uses (e.g., exotic forestry) or not in a main REC class, (ii) there were duplicate sites on the same stream (typically in this case shaded sites in pastoral or urban settings were dropped to minimise variance in on-site conditions), (iii) sampling approaches were deemed invalid (e.g., hard-bottomed streams sampled using soft-bottomed protocols or variable sampling approaches), although long-term sites falling into this category but with supporting RERIMP data were retained in 2005 until their value could be reviewed in the future.

6 Future sampling

During to course of the 2005 sampling, a number of observations and issues arose that led to the following recommendations for implementation in 2006.

Recommendation 13: Prioritise areas sampled so that streams most at risk from flooding are sampled early in the programme (e.g., Coromandel, West Coast, Kaimais);

Recommendation 14 Identify index sites that are sampled at the start and end of the programme to account for variations in flow regime over the summer sampling period;

Recommendation 15: Assess spatial and temporal variability among reaches on the same REC segment to determine how representative the current scale of sampling is (seasonal sampling is currently underway at three reference sites – 125.15, 754.2 and 1888.4).

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Appendix 1 – Locations and REC class of sampling sites.

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
4-2	5 Mile	Off Tapu Coroglen Rd	2745600	6467900	Coromandel	WW/L/VA
23-2	Apakura	Puriri Valley Rd	2747300	6439300	Coromandel	WW/H/VA
9-4	Ahirau (Coromandel)	Port Charles Rd 2 - 5 Km from Colville Rd	2731300	6509400	Coromandel	WW/L/HS
1009-3	Te Pahu trib.	Off main farm track downstream	2695200	6359300	Waipa	WW/L/VA
1012-3	Te Puru	Te Puru Rd	2735500	6458800	Coromandel	WW/H/VA
1029-1	Tererengaongaio	SH32 bridge	2753200	6289700	Up/Mid Waikato	CW/H/VA
1043-1	Toenepi	Tahuroa Rd	2735200	6385500	Hauraki	WD/L/VA
1045-3	Tokaanu	Off SH41 Turangi	2751700	6242300	Taupo	CW/L/VA
1051-3	Tongariro trib	Tree Trunk Gorge Rd	2752700	6221600	Taupo	CX/H/HS
1051-4	Tongariro trib	Off Tree Trunk Gorge Rd	2752722	6222659	Taupo	CX/H/VA
1053-11	Topehahae	Waterworks Rd	2738600	6377100	Hauraki	WW/L/VA
1053-12	Topehahae	Waterworks Rd	2737300	6374700	Hauraki	WW/L/VA
1053-3	Topehahae	Bell Rd	2734600	6382000	Hauraki	WW/L/VA
1055-2	Torehape	Torehape West Rd	2722800	6425300	Hauraki	WW/L/HS
1055-3	Torehape	Torehape West Rd	2721600	6424500	Hauraki	WW/L/HS
1056-3	Toreparu	Off main farm track downstream	2672800	6367600	West Coast	WW/L/VA
1072-3	Tui	Tui Rd	2750600	6405300	Hauraki	CW/H/VA
1076-5	Tunakohoia	Hamilton St Te Aroha	2750000	6404500	Hauraki	WW/H/VA

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
1090-1	Umangawha	Farm track ford	2732100	6504300	Coromandel	WW/L/VA
1092-3	Upper Waikato	Upstream SH1 bridge	2746602	6210015	Taupo	CW/M/VA
1098-3	Waerenga	Waipuna Gorge Rd	2714200	6421800	Lower Waikato	WW/L/HS
1105-1	Waiau	Below Waiau Falls	2737600	6482300	Coromandel	WW/L/VA
1105-3	Waiau	E309 Rd ford	2735676	6486578	Coromandel	WW/L/VA
1105-5	Waiau	Castle Rock Rd	2737200	6484000	Coromandel	WW/L/VA
1110-1	Waiharakeke	SH25	2765700	6433300	Coromandel	WX/L/VA
1110-4	Waiharakeke	Upstream of SH25	2763621	6435248	Coromandel	WW/L/VA
1113-11	Waihekau	SH26 Curtins bridge	2743700	6397700	Hauraki	WW/L/SS
1121-1	Waihora	Lakeside Lake Taupo	2747306	6281806	Taupo	CW/H/VA
1121-4	Waihora	Off Tihoi Rd	2745600	6282000	Taupo	CW/H/VA
1122-41	Waihou	Whites Rd	2757200	6350000	Hauraki	WW/L/VA
1122-44	Waihou	Scorpion Rd	2761200	6345700	Hauraki	WW/L/VA
1127-3	Waikanae	Off Waikawau Beach Rd	2734600	6506400	Coromandel	WW/L/VA
1132-66	Waikato River trib.	Tuakau/Port Waikato Road	2664936	6423011	Lower Waikato	WW/L/SS
1132-67	Waikato River trib.	Tuakau/Port Waikato Rd 2-2 Km East Port	2665837	6423399	Lower Waikato	WW/L/SS
1132-68	Waikato River trib.	Unnamed trib at River Rd just South Kay	2706788	6384476	Up/Mid Waikato	WD/L/SS
1132-69	Waikato River trib.	Unnamed trib at Lake Rd	2704958	6387722	Up/Mid Waikato	WW/L/SS
1132-70	Waikato River trib.	Unnamed trib at River Rd Sth Patterson	2705919	6386420	Up/Mid Waikato	WD/L/SS
1150-8	Waikoha	Waikoha Rd, Pirongia	2697500	6369800	Waipa	WW/L/SS
1157-2	Waimai	Waimai Valley Rd	2674700	6394500	West Coast	WW/L/SS

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
1158-7	Waimakariri	Off end of Waimakariri Rd	2761500	6350700	Hauraki	CW/H/VA
116-1	Eastern Drain (Aka Aka)	Eastern Drain Rd, Waiuku	2671800	6433300	Lower Waikato	WW/L/AI
1164-5	Waimata	Off main farm track downstream	2763000	6413600	Coromandel	WW/L/VA
1167-8	Waingaro	Ngaruawahia Rd	2686400	6388100	West Coast	WW/L/HS
1172-1	Wainui	Wainui Rd bridge	2670881	6373637	West Coast	WW/L/VA
1172-3	Wainui	Wainui Rd	2671700	6374300	West Coast	WW/L/VA
1172-6	Wainui	Wainui Stm (Raglan) at Wainui Reserve bridge	2672300	6374700	West Coast	WW/L/VA
1174-10	Waiomou	Waiomou Rd	2759900	6358600	Hauraki	WW/H/VA
1174-19	Waiomou	Off Old Te Aroha Rd - Keane Property	2763225	6368927	Hauraki	WW/L/VA
1184-1	Waiotahi	Downstream of mine	2736600	6449900	Coromandel	WW/L/VA
1184-5	Waiotahi	Downstream of mine	2736900	6450400	Coromandel	WW/L/VA
1184-8	Waiotahi	Waiotahi Rd	2737000	6450500	Coromandel	WW/L/VA
1191-31	Waipa	Between Mangawhero Stm and water intake	2705400	6332600	Waipa	WW/L/AI
1191-5	Waipa	Mangaokewa Rd	2723300	6302800	CW/H/VA	Waipa
1193-4	Waipa	Off Wiltsdown Rd	2750400	6333400	Up/Mid Waikato	WW/L/VA
1202-7	Waipapa	Tirohanga Rd bridge	2768500	6304700	Up/Mid Waikato	CW/H/VA
1206-10	Waipari	Ngaroma Rd upstream of bridge	2734605	6319451	Waipa	CW/H/VA
1206-11	Waipari	Unnamed trib Ngaroma Rd upstream of bridge	2734539	6319530	Waipa	CW/H/VA
1217-3	Wairakau	Wairakau Road	2756217	6397934	Hauraki	WW/L/SS
1224-2	Wairere	DOC Wairere Falls track	2763083	6381150	Hauraki	CX/H/VA

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
1231-17	Waitakaruru	Eureka Rd	2722500	6383300	Hauraki	WD/L/M
1231-41	Waitakaruru trib.	Tahuroa Rd	2728169	6380544	Hauraki	WW/L/HS
1231-42	Waitakaruru trib.	Unnamed trib at Te Miro Road	2731682	6373044	Up/Mid Waikato	WW/L/HS
1232-13	Waitakaruru trib.	Gray Rd	2734726	6375249	Up/Mid Waikato	WW/L/VA
1235-6	Waitawheta	Franklin Rd upstream of bridge	2756438	6413584	Coromandel	CW/H/VA
1236-2	Waitawhiriwhiri	Edgecumbe St	2710100	6378500	Up/Mid Waikato	WW/L/M
1236-4	Waitawhiriwhiri	U/S Maeroa Rd (above Saleyard inflow)	2708200	6377200	Up/Mid Waikato	WW/L/M
1239-2	Waitekauri	20m upstream Grace Darling Stm	2756600	6416800	Coromandel	WX/L/VA
1241-2	Waitekuri	Rd 41 ford	2740638	6490382	Coromandel	WW/L/VA
1243-6	Waitete Stm	Clean Streams downstream monitoring site	2760362	6419241	Coromandel	WX/L/VA
1243-7	Waitete	Unnamed trib at Umutawa Rd	2738739	6345727	Up/Mid Waikato	WW/L/VA
124-4	Firewood	Waingarō @ Ngaruawahia Rd	2697800	6388700	Waipa	WW/L/HS
1247-3	Waitetuna	Ohautira Rd	2684200	6374300	West Coast	WW/L/HS
1247-4	Waitetuna	Waitetuna Valley Rd	2689600	6365800	West Coast	WW/L/HS
1249-15	Waitoa	Landsdowne Rd bridge	2752100	6378600	Hauraki	WW/L/VA
1249-32	Waitoa	Station Rd Matamata	2751700	6372100	Hauraki	WW/L/VA
1249-42	Waitoa	Buckland Rd	2742200	6365500	Hauraki	WW/L/VA
1249-47	Waitoa	SH29	2748500	6364500	Hauraki	WW/L/VA
1252-3	Waitoki	Rawhiti Rd	2747400	6411300	Hauraki	WW/L/VA
1253-11	Waitomo	Waitomo Valley Rd	2695400	6325600	Waipa	WW/L/VA
1253-8	Waitomo	Waitomo Valley Rd	2701300	6332700	Waipa	WW/L/VA

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
1253-9	Waitomo	Tumutumu Rd	2693300	6324700	Waipa	WW/L/VA
125-4 {-15}	Firewood trib.	Off Walkway (Hakarimata Scenic Reserve)	2697200	6389300	Waipa	WW/L/HS
1257-4	Waiwawa	Upstream Toranoho Stm	2746600	6468500	Coromandel	WW/L/VA
1271-1	Wentworth	Upstream Wentworth Valley Rd	2761000	6436000	Coromandel	WX/L/VA
1279-1	Whakanekeneke	Buffalo Rd	2734600	6492600	Coromandel	WW/L/VA
128-11	Firth of Thames trib.	Unnamed trib flowing into Firth of Thames	2727581	6509600	Coromandel	WW/L/HS
1282-2	Whakapipi	Barnaby Rd	2683900	6437300	Lower Waikato	WW/L/VA
1284-1	Whakarautawa	Mangati Rd	2695200	6348200	Waipa	CX/H/VA
1287-3	Whakauru	Mossop Rd Tokoroa	2766500	6325500	Up/Mid Waikato	CW/H/VA
1293-8	Whangamarino	Jefferies Rd	2708400	6427200	Lower Waikato	WW/L/HS
1300-1	Whangamata	Whangamata Rd	2764900	6280400	Taupo	CW/H/VA
1300-2	Whangamata	Kinloch	2763700	6278700	Taupo	CW/H/VA
1307-10	Whangarahi	100m upstream Coromandel discharge Hauraki Rd	2733200	6490800	Coromandel	WW/L/VA
1307-11	Whangarahi	Upstream from Coromandel township	2733701	6490604	Coromandel	WW/L/HS
1307-4	Whangarahi	100m downstream of sewage discharge	2733100	6490600	Coromandel	WW/L/HS
1312-10	Wharekawa	Upstream Adams Farm bridge	2762300	6447400	Coromandel	WW/L/VA
1312-9	Wharekawa	Taungatara Rd	2759800	6443900	Coromandel	WW/L/VA
1317-2	Whareroa	Kennedy Bay Rd	2738400	6502400	Coromandel	WW/L/VA
1321-13	Whenuakite	SH25 upstream of road	2759737	6469131	Coromandel	WW/L/VA
1321-6	Whenuakite	SH25 bridge	2759700	6469100	Coromandel	WW/L/VA

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
1323-1	Whirinaki	Corbett Rd	2795700	6317100	Up/Mid Waikato	CW/H/VA
1406-1	Central Drain	Central drain at River Rd	2702300	6389300	Up/Mid Waikato	WW/L/SS
1407-1	Mangakawau	Henry Rd	2711400	6398800	Lower Waikato	WD/L/SS
1408-1	Mangakowhitiwhiti	Kiko to Hingapo Rds	2763900	6246500	Taupo	CW/H/VA
1414-1	Omanawa trib.	Pirongia West Rd	2691400	6351300	West Coast	CX/H/VA
1427-1	Ngakoahia	Mangati Rd	2696700	6347600	Waipa	WW/L/VA
1428-1	Te Hukui	Downstream of road culvert Tram Rd	2779100	6290200	Up/Mid Waikato	CW/H/VA
1435-1	Akeake	SH25	2753200	6487700	Coromandel	WW/L/VA
1513-3	Te Rekereke	Karioi at Papanui	2665920	6368952	West Coast	WW/L/VA
155-5	Harataunga	Kennedy Bay Rd	2736400	6496300	Coromandel	WW/L/HS
164-1	Hauwai trib	Orange Rd	2778400	6304000	Up/Mid Waikato	CW/H/VA
168-3	Hikuai	Snooks Farm	2758200	6456500	Coromandel	WW/L/VA
171-5	Hinemaia	SH1	2772200	6256700	Taupo	CW/H/VA
180-2	Hospital	Graham Park upper	2711500	6375200	Up/Mid Waikato	WW/L/M
180-3	Hospital	Graham Park lower	2711500	6375400	Up/Mid Waikato	WW/L/M
1825-1	Sheehan	Old Te Aroha Rd	2761775	6382524	Hauraki	WW/L/SS
1862-2	Mangatia	Off main farm track downstream	2681000	6415600	Lower Waikato	WW/L/VA
1873-1	Otupoto	Holland trib downstream	2745785	6276423	Taupo	CW/H/VA
1882-3	Otupoto	SH32 upstream from road	2744165	6277799	Taupo	CW/H/VA
1888-4	Otautara	Inside Maungatautari enclosure	2736668	6346017	Up/Mid Waikato	CW/H/VA
195-1	Huriwai	Waikaretu Rd	2664300	6418300	West Coast	WW/L/SS

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
1957-1	Waipakipaki	Tram Road, Te Pouwhakatutu	2778700	6293800	Upper Waikato	CW/H/VA
1958-1	Mangatara (Naike)	Off Matira Rd	2678300	6404700	Lower Waikato	WW/L/HS
1960-1	Ahirau (Ngaruawahia)	Elgood Rd upstream of culvert	2694714	6391520	Waipa	WW/L/HS
1961-1	Mangatea	Tate property	2717500	6411200	Lower Waikato	WW/L/HS
1962-1	Waiwhata	4-3 km from SH27 on Ohinewai Road	2722111	6419970	Hauraki	WW/L/HS
196-3	Huruhurutakimo	Purangi Rd	2757700	6474600	Coromandel	WW/L/VA
1963-1	Otara trib.	Upstream SH27	2742260	6240059	Taupo	CW/H/VA
1964-1	Wentworth trib.	Off DOC walkway	2759726	6434988	Coromandel	WX/L/VA
1965-1	Waikuku	Te Kauri Lodge	2684264	6346113	West Coast	WW/L/M
1966-1	Purangirangi	Oamaru Rd	2690000	6338600	Waipa	WW/L/HS
1967-1	Oamaru	Oamaru Rd upstream of bridge	2689974	6337580	Waipa	WW/L/HS
1968-1	Whakakai	Whatawhata Research Station	2692600	6378500	Up/Mid Waikato	WW/L/HS
1969-1	Mangawhata	Puhunga Rd	2696944	6292447	West Coast	WW/L/SS
1970-1	Paratikona	Ohiria Rd	2715091	6296775	West Coast	CW/H/VA
1971-1	Mangapohue	Waitomo/Marakopa Rd, opposite Marae Rd	2678898	6324200	West Coast	WW/L/VA
201-1	Kaawa	Waikaretu Rd	2667800	6411700	West Coast	WW/L/SS
201-2	Kaawa	Baker Rd	2671500	6412500	West Coast	WW/L/SS
205-1	Kaikai	Kawhia Kauroa Rd	2677400	6364400	West Coast	WW/L/HS
216-1	Kaituna	Kopu-Hikuai Rd	2755200	6449200	Coromandel	WW/L/VA
218-1	Kaiwhitiwhiti	Broadlands Rd	2797800	6285600	Upper Waikato	CW/H/VA
220-1	Kaiwhitiwhiti	Tiverton Downs Farm	2798200	6282500	Up/Mid Waikato	CW/H/VA

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
220-2	Kaiwhitwhiti	Upstream of Broadlands Rd	2797700	6285200	Up/Mid Waikato	CW/H/VA
224-1	Kapowai	Kapowai Rd (Anstiss Bridge)	2752400	6470300	Coromandel	WW/L/VA
227-7	Kaniwhaniwha	French Pass Rd bridge	2693900	6365000	Waipa	WW/L/VA
230-4	Karapiro		2736400	6366800	Up/Mid Waikato	WW/L/VA
230-5	Karapiro	Hickey Rd bridge	2733200	6363800	Up/Mid Waikato	WW/L/VA
234-14	Kauaeranga	Pinnacles Hut upstream of dam	2751500	6458700	Coromandel	CX/H/VA
234-28	Kauaeranga	Upstream from road end	2747900	6456700	Coromandel	CW/H/VA
240-5	Kawaunui	SH5 bridge	2802100	6308100	Up/Mid Waikato	CW/H/VA
240-6	Kawaunui	Ngapouri Rd	2799200	6311900	Up/Mid Waikato	CW/H/VA
246-1	Kerikeri	Ruakiwi Rd	2680300	6386000	West Coast	WW/L/SS
250-4	Kirikiri	SH25A	2741800	6445000	Coromandel	WW/L/VA
253-5	Kirikiroa	Glen Lynn Ave	2710400	6381600	Up/Mid Waikato	WD/L/SS
253-6	Kirikiroa	Huntington Dr	2710700	6381700	Up/Mid Waikato	WD/L/SS
256-2	Kiritihere	Mangatoa Rd	2661900	6316500	West Coast	WW/L/HS
258-8	Komakorau	Sainsbury Rd	2713700	6386900	Lower Waikato	WD/L/SS
262-5	Kopakorahi	Wawa Rd	2763100	6316700	Upper Waikato	CW/H/VA
262-9	Kopakorahi	Wawa Rd	2763100	6316800	Up/Mid Waikato	CW/H/VA
266-3	Kopuku	Coalfields Rd	2702700	6433400	Lower Waikato	WW/L/HS
268-2	Korakonui	Lichfield Rd bridge	2726000	6346700	Waipa	WW/L/VA
272-6	Koteruato	Monument Rd	2709400	6436800	Lower Waikato	WW/L/HS
279-6	Kuhatahi	Waimakariri Rd	2761500	6350800	Hauraki	WW/H/VA

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
282-4	Kuratau	SH41 Moerangi	2735600	6253700	Taupo	CW/H/VA
33-11	Awakino	Gribbon Rd upstream	2667700	6300300	West Coast	CX/H/HS
33-14	Awakino	SH 3 Gorge (NIWA)	2661000	6285200	West Coast	WX/L/HS
33-16	Awakino	Gribbon Rd	2667600	6298500	West Coast	CX/H/HS
33-6	Awakino	Gribbon Rd	2670200	6291800	West Coast	CX/L/HS
346-5	Mahakirau	E309 Road	2739600	6479600	Coromandel	WW/L/VA
353-1	Maire	Bothwell Rd	2678500	6411300	Lower Waikato	WW/L/SS
355-3	Makomako	Makomako Rd	2681000	6359700	West Coast	WW/L/HS
359-2	Mangaharakeke	SH30 bridge	2773300	6312900	Up/Mid Waikato	CW/H/VA
36-1	Awaroa	Awaroa Rd	2680400	6337600	West Coast	WW/L/HS
365-1	Mangahoanga	Moerangi Rd	2680900	6350800	West Coast	WW/L/SS
370-1	Mangahouhounui	Lake Rotoaira Rd	2751500	6231900	Taupo	CX/M/VA
37-2	Awaroa	SH22 bridge	2683000	6410200	Lower Waikato	WW/L/SS
373-3	Mangaiti	Rawhiti Rd	2748500	6407800	Hauraki	WW/L/VA
373-5	Mangaiti	Above water intake	2755300	6400700	Hauraki	CW/H/VA
379-2	Mangakara	Grey Rd bridge	2700800	6358900	Waipa	CW/H/VA
389-1	Mangakino	Titiraupenga Rd	2749300	6294400	Up/Mid Waikato	CW/H/VA
392-1	Mangakokopu	Pomarangi Rd	2663300	6314300	West Coast	WW/L/HS
398-1	Mangakotukutuku	Peacockes Rd	2712700	6374200	Up/Mid Waikato	WW/L/M
398-6	Mangakotukutuku	Rural trib "Waterford" (Sandford Park)	2712200	6372900	Up/Mid Waikato	WW/L/SS
407-1	Mangamingi	Paraonui Rd bridge	2758800	6330200	Up/Mid Waikato	CW/L/VA

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
410-3	Manganui	Manganui Rd	2655700	6283800	West Coast	WW/L/HS
410-5	Manganui	Manganui Rd	2658500	6293800	West Coast	WX/L/HS
410-6	Manganui	Manganui Rd	2655400	6283100	West Coast	WW/L/HS
411-25	Mangaohoi	Monkton Rd	2725800	6346500	Waipa	WW/L/VA
411-8	Mangaohoi	Maru Rd	2732900	6347200	Waipa	CW/H/VA
413-2	Mangaokahu	Cogswell Rd (upper)	2689500	6376100	West Coast	WW/L/HS
413-3	Mangaokahu	Cogswell Rd (lower)	2689900	6373500	West Coast	WW/L/HS
413-4	Mangaokahu	Cogswell Rd	2690141	6373450	West Coast	WW/L/HS
414-25	Mangokewa	Mangaokewa Scenic Reserve	2701800	6313700	Waipa	WW/L/VA
414-26	Mangaokewa	Unnamed trib Waipa Valley Rd upstream of road	2714373	6301600	Waipa	CW/H/VA
417-7	Mangaone	Annebrooke Rd bridge	2715900	6374400	Up/Mid Waikato	WD/L/SS
41-1	Awaroa	Culvert downstream tributary	2663900	6435600	Lower Waikato	WW/L/VA
41-9	Awaroa	Otaua Rd bridge opposite Moseley Rd	2666100	6432000	Lower Waikato	WW/L/VA
421-19	Mangaonua	Victoria Rd bridge	2726300	6373500	Up/Mid Waikato	WW/L/SS
421-24	Mangaonua	Te Miro Rd	2732700	6373200	Up/Mid Waikato	WW/L/VA
42-3	Awaroa	Wade Rd	2743332	6485393	Coromandel	WW/L/VA
425-7	Mangaorongo	Off Kiokio Station Rd	2706400	6336200	Waipa	WW/L/VA
425-8	Mangaorongo	Maihihi Rd	2718500	6328000	Waipa	WW/L/VA
428-3	Mangaotaki	SH3 bridge	2676400	6296300	West Coast	WW/L/VA
428-5	Mangaotaki	Mangaotaki Rd	2679200	6303200	West Coast	WW/L/VA

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
429-3	Mangaotama	Ryburn Rd	2708200	6360400	Waipa	WW/L/SS
429-4	Mangaotama	Tributary at Forkett Rd	2708800	6360800	Waipa	WW/L/SS
430-2	Mangaotama	Karakaraiki Rd	2696300	6380500	Waipa	WW/L/HS
430-3	Mangaotama	Karakariki Valley Rd	2693300	6379000	Waipa	WW/L/HS
433-2	Mangapapa	Henry Watson Rd	2747000	6371500	Hauraki	WW/L/VA
433-6	Mangapapa	Morgan Rd	2746500	6376400	Hauraki	WW/L/VA
438-17	Mangapiko	Robinson Rd	2728300	6354800	Waipa	WW/L/VA
438-25	Mangapiko	Kairangi Rd	2727500	6354900	Waipa	WW/L/VA
439-2	Mangapiko	Mangapiko Valley Rd	2719200	6414500	Lower Waikato	WW/L/HS
439-3	Mangapiko	Storey Rd	2713600	6413700	Lower Waikato	WW/L/VA
441-8	Mangapiko	Rahiri Road on Garland property	2732643	6351298	Waipa	WW/L/SS
445-3	Mangarata	Thickpenny Ln	2699127	6391026	Up/Mid Waikato	WW/L/HS
446-8	Mangare	Pukewhau Rd	2739900	6330800	Up/Mid Waikato	WW/L/VA
451-1	Mangatahae	Ropiha Rd	2746000	6305200	Up/Mid Waikato	CW/H/VA
452-2	Mangataheke	Waitetuna Valley Rd	2688700	6366300	West Coast	WW/L/HS
453-8	Mangatangi	Stubbs Rd	2704900	6445200	Lower Waikato	WW/L/HS
458-1	Mangatawai	Off SH1 upstream bridge	2749000	6223900	Taupo	CX/M/VA
459-13	Mangatawhiri	Mangatawhiri weir downstream of dam	2701800	6454000	Lower Waikato	WW/Lk/HS
459-16	Mangatawhiri	Lyons Road, Mangatawhiri	2700500	6443200	Lower Waikato	WW/L/HS
459-6	Mangatawhiri	Lyons Rd at Buckingham bridge	2699700	6442600	Lower Waikato	WW/L/HS
463-1	Mangatete	Broadlands Rd	2801100	6297100	Upper Waikato	CW/H/VA

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
467-2	Mangati	Te Aku Rd	2673500	6389900	West Coast	WW/L/SS
47-1	Bankwood	Donny Park, River Rd	2710000	6380500	Up/Mid Waikato	WD/L/M
471-2	Mangatoa	Awakino/Marakopa road	2659105	6306494	West Coast	WW/L/HS
47-2	Bankwood	Emerald Tce	2710500	6380300	Up/Mid Waikato	WD/L/M
473-2	Mangatoketoke	Kerie Rd	2705800	6394700	Lower Waikato	WW/L/SS
474-1	Mangatu	Bolt Rd	2737675	6501212	Coromandel	WW/L/SS
474-2	Mangatu	End of Mangatu Rd	2737236	6500987	Coromandel	WW/L/SS
476-1	Mangatutu	Lethbridge Rd	2722300	6336600	Waipa	CW/L/VA
476-12	Mangatutu	Unnamed trib @ Lethbridge Rd	2720304	6342029	Waipa	WW/L/VA
477-14	Mangauika	Upstream weir [A]	2697700	6350300	Waipa	CX/L/VA
477-16	Mangauika	Te Tahi Rd downstream of water take	2697600	6350400	Waipa	CX/H/VA
477-5	Mangauika	Mangauika Rd bridge	2703100	6352600	Waipa	WW/L/VA
481-11	Mangawara	Mangawara Rd	2723300	6414800	Lower Waikato	WW/L/HS
481-13	Mangawara	Mangawara side road	2724800	6409100	Lower Waikato	WW/L/HS
481-14	Mangawara	Grays Rd in DOC estate	2699200	6357100	Up/Mid Waikato	CW/H/VA
481-9	Mangawara	Tahuna Rd	2724700	6407300	Lower Waikato	WW/L/HS
485-1	Mangawhara (Tokoroa)	Poaka Rd	2771600	623700	Up/Mid Waikato	CW/H/VA
488-1	Mangawhero	Cambridge-Ohaupo Rd	2721700	6365300	Up/Mid Waikato	WD/L/SS
489-2	Mangawhero	Mangawara Rd	2724900	6419500	Hauraki	WW/L/HS
489-6	Mangawhero	Mangawhero Rd	2728300	6422500	Hauraki	WW/L/HS

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
492-2	Mangawhero	Te Kawa Rd	2707700	6342800	Waipa	WW/L/VA
493-1	Mangawhero trib.	Mangawhero Rd	2708400	6326600	Waipa	WW/L/VA
494-4	Mangawhio	Wairehi Rd	2738500	6322700	Up/Mid Waikato	CW/H/VA
495-1	Mangawhio trib.	Taupaki Rd	2739700	6323400	Up/Mid Waikato	CW/L/VA
498-1	Mangotutu	Smythe Rd bridge	2760000	6314700	Up/Mid Waikato	CW/H/VA
503-2	Mapara	Mapara South Rd	2706500	6293500	West Coast	CW/H/VA
504-2	Mapara	Off Mapara Rd (Whakaipo Reserve)	2768100	6275000	Taupo	CW/H/VA
506-4	Mapiu	Tikitiki Rd	2695500	6297700	West Coast	CW/L/VA
508-1	Maraetai	Waikaretu Rd	2663600	6421500	Lower Waikato	WW/L/SS
510-3	Maramarua River	SH2 bridge	2704200	6437200	Lower Waikato	WW/L/HS
514-1	Marokopa	Te Anga Rd	2675500	6325700	West Coast	WW/L/VA
516-5	Matahuru	Waiterimu Rd below confluence	2708300	6410900	Lower Waikato	WW/L/HS
516-6	Matahuru	Trib drain off Tahuna Rd above Waiterimu	2708400	6410800	Lower Waikato	WW/L/HS
529-13	Matarawa	SH1 bridge or reserve	2764100	6320700	Up/Mid Waikato	CW/H/VA
529-17	Matarawa	Kinleith Rd	2762300	6322500	Up/Mid Waikato	CW/H/VA
529-18	Matarawa	Matarawa Rd	2766100	6321800	Up/Mid Waikato	CW/H/VA
529-20	Matarawa	Arawa St	2760000	6325000	Up/Mid Waikato	CW/H/VA
529-4	Matarawa	Campbell Rd	2760800	6323700	Up/Mid Waikato	CW/H/VA
531-3	Matatoki	Quarry Rd - upstream Matatoki Quarry	2742800	6441400	Coromandel	WW/L/VA
531-4	Matatoki	Matatoki Rd	2741200	6439800	Hauraki	WW/L/VA
539-1	Maunurima	SH22	2684300	6375900	West Coast	WW/L/SS

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
552-2	Mokaihaha	Miranda Rd	2774776	6332059	Up/Mid Waikato	CW/H/VA
556-4	Mokau	Eight Mile Junction	2694400	6307700	West Coast	WW/L/VA
556-9	Mokau	Totoro Rd recorder	2675800	6290800	West Coast	WW/L/VA
557-6	Mokauiti	Corner Mokauiti & Dunphy Roads	2699700	6286800	West Coast	WW/L/SS
56-2	Boom	SH25	2760900	6451900	Coromandel	WW/L/VA
56-4	Boom	Duck Creek Rd	2761400	6452400	Coromandel	WW/L/VA
56-7	Boom	Hickson Downstream	2760283	6450189	Coromandel	WW/L/VA
572-1	Naike	Matira-Naike Rd Woodleigh	2678800	6405800	Lower Waikato	WW/L/VA
574-10	Ngakoaohia	Pirongia Ngutunui Rd	2699300	6346500	Waipa	WW/L/VA
574-3	Ngakoaohia	Mangati Rd	2700000	6348200	Waipa	WW/L/VA
582-12	Ngutunui	SH3 Pirongia	2696400	6342800	Waipa	WW/L/VA
612-12	Ohaeroa	Parsons Rd	2682200	6427900	Lower Waikato	WW/L/VA
612-9	Ohaeroa	SH22 bridge	2683400	6430300	Lower Waikato	WW/L/VA
613-2	Ohaeroa trib.	Hunt Rd bridge	2684200	6427900	Lower Waikato	WW/L/VA
613-8	Ohaeroa trib.	Parsons Rd	2682500	6427700	Lower Waikato	WW/L/SS
614-1	Ohahukura	Waipa Valley	2719600	6306900	Waipa	CW/H/VA
616-1	Ohautira	Waingaro Te Uku Rd	2684200	6380300	West Coast	WW/L/HS
616-2	Ohautira	Waingaro Te Uku Rd - off farm track	2686400	6381500	West Coast	WW/L/HS
617-1	Ohine	Wisemans Rd	2739400	6405500	Hauraki	WD/L/SS
619-20	Ohinemuri	SH25 bridge	2764100	6421300	Coromandel	WW/L/VA
619-4	Ohinemuri	Corbett Rd bridge	2765100	6423100	Coromandel	WW/L/VA

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
624-5	Ohote	Whatawhata/Horotiu Rd	2699700	6379300	Waipa	WW/L/SS
641-1	Omanawa	Pirongia West Rd	2691200	6351200	West Coast	CX/H/VA
645-2	Omori	Omori Rd	2749400	6251800	Taupo	CX/Lk/VA
651-2	Ongarahu	D/S Of Mokai Oruanui Rd bridge	2771600	6291100	Up/Mid Waikato	CW/H/VA
658-1	Oparau	Langdon Rd (off Okupata Rd)	2679902	6349334	West Coast	WW/L/SS
658-3	Oparau	Pirongia West Rd	2684400	6352400	West Coast	CW/L/HS
660-5	Opitonui	Off Opitonui Rd	2742200	6488000	Coromandel	WW/L/VA
665-5	Opuatia	Ponganui Rd	2677300	6424600	Lower Waikato	WW/L/SS
668-3	Orahiri	McCready Rd upstream from bridge	2702815	6332322	Waipa	WW/L/SS
669-23	Oraka	Waione Rd bridge	2766300	6337700	Hauraki	CW/H/VA
672-2	Orakonui	Orakeikorako Rd	2785200	6290000	Up/Mid Waikato	CW/H/VA
676-1	Oruapuraho	SH32	2743300	6270000	Taupo	CW/H/VA
677-2	Otahu	Quarry Rd	2762100	6434600	Coromandel	WX/L/VA
683-1	Otamakokore	Corbett Rd	2798400	6314200	Up/Mid Waikato	CW/H/VA
683-4	Otamakokore	Hossack Rd	2795500	6316600	Up/Mid Waikato	CW/H/VA
686-1	Otarua	Western Bay Rd	2743000	6258200	Taupo	CW/H/VA
704-4	Ounoura	Off Mill Creek Rd	2746700	6475300	Coromandel	WW/L/VA
708-1	Owawenga	Owawenga Rd	2716600	6313600	Waipa	CW/H/VA
727-2	Parakau	SH25 bridge	2755200	6473200	Coromandel	WW/L/VA
734-2	Paratawa	Old Mountain Rd	2696500	6371400	Waipa	WW/L/HS
747-2	Pepe	Laycocks property	2762000	6462600	Coromandel	WW/L/VA

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
749-10	Piako	Kiwitahi	2739800	6385600	Hauraki	WW/L/VA
749-29	Piako	Kopuatai Peat Dome	2734519	6417017	Hauraki	WD/L/M
753-10	Piakonui	Upstream of Paku Rd bridge	2741300	6379000	Hauraki	WW/L/VA
753-4	Piakonui	Piakonui Rd	2741700	6371700	Hauraki	WW/L/VA
753-7	Piakonui	Downstream of Paku Rd bridge	2741200	6379600	Hauraki	WW/L/VA
753-9	Piakonui	Te Tapui Reserve	2741400	6371500	Hauraki	WW/L/VA
753-11	Piakonui	Piakonui Rd, Richmond Downs	2741500	6371800	Hauraki	WW/L/VA
754-2	Piakonui trib.	Hyndmans Quarry consent	2742200	6373500	Hauraki	WW/L/VA
784-2	Pokaiwhenua	Jamieson Rd	2713200	6427400	Lower Waikato	WW/L/HS
786-2	Pokaiwhenua	Arapuni - Putaruru Rd	2749100	6345800	Up/Mid Waikato	CW/L/VA
786-22	Pokaiwhenua	Wiltsdown Rd	2757900	6334800	Up/Mid Waikato	WW/L/VA
786-31	Pokaiwhenua	500m downstream of bridge on Baldwin property	2751047	6341911	Up/Mid Waikato	CW/L/VA
786-32	Pokaiwhenua	500m upstream of bridge on Baldwin property	2751902	6341673	Up/Mid Waikato	CW/L/VA
786-5	Pokaiwhenua	Crown Rd bridge	2766300	6328100	Up/Mid Waikato	CW/H/VA
796-3	Pouraureroa	Pendergrast Rd	2695700	6441800	Lower Waikato	WW/L/HS
82-2	Central Drain	Piako Rd	2718400	6389800	Lower Waikato	WD/L/M
864-3	Rangihau	Rangihau Rd end	2749600	6465800	Coromandel	WW/H/VA
869-1	Dip	Rangitoto Rd	2708200	6315200	Waipa	WW/L/VA
872-11	Rapurapu	Taylor property off Rapurapu Rd	2764618	6362253	Hauraki	CW/H/VA
873-1	Rararimu	Mangatoa Rd	2661300	6310800	West Coast	WW/L/HS

Located number	Stream/river name	Location name	Easting	Northing	Zone	REC class
878-1	Rautawiri	Off Allen Rd	2800700	6289700	Up/Mid Waikato	CW/H/VA
887-1	Romaru	Wright Rd	2747600	6411800	Hauraki	WW/L/VA
931-1	Swampy	SH32 bridge	2754600	6290500	Up/Mid Waikato	CW/H/VA
934-3	Tahunaatra	Under bridge Southern End Apirana Rd	2786849	6321970	Up/Mid Waikato	CW/L/VA
94-1	Coromandel harbour trib	SH25 Te Kouma	2733100	6485200	Coromandel	WW/L/HS
941-3	Tairua trib	Fourth branch	2753700	6447700	Coromandel	WW/L/VA
945-1	Takatakahia	Kopu-Hikuai Rd	2750800	6446500	Coromandel	WW/H/VA
951-3	Taniwha	McGovern Road, Te Kauwhata	2714900	6419200	Lower Waikato	WW/L/HS
954-5	Tapu	Tapu-Coroglen Rd	2733364	6465803	Coromandel	WW/L/VA
966-7	Tauhei	Whitikahu Rd	2718800	6398200	Lower Waikato	WD/L/M
976-2	Tawarau	Speedies Rd	2671700	6324600	West Coast	WW/L/VA
990-5	Te Kaka	Martin Rd	2709363	6421378	Lower Waikato	WW/L/HS

Appendix 2 – Numbers of macroinvertebrates identified in each sample, and total number of years sampled.

All samples were collected in 1st quarter (January-March) of the year except where indicated - () = sampled in April-June; [] = sampled in October-November. Samples with less than 100 individuals were not included in subsequent analyses. * = duplicate samples collected concurrently in 2002 (for validation of change in net mesh sizes) or in 2005 (to compare soft- and hard-substrates).

Located number	1994/95	1995/96	1996/97	1997/98	1999	1999/2000	2000/01	2002	2003	2004	2005	Total years
4-2			116		105	192	[136]	220	212	202	205	8
9-4											267	1
33-16										210	207	2
33-14		122		100						203		3
23-2		104	115		110	[173]	[114]	286	236	210	205	9
33-11		135		110	112	175	[131]	206	203			7
33-6		135		113								2
41-10	100											1
41-9		121				88	[157]	208	203	208	85	7
36-1		112		127	119	116	139	300	203	(40)	267	9
37-2		100		127								2
42-3				119								2
			110									
			128									
47-2			[123]		110	167	[162]	275*	204	225	205	8
			108									
47-1			[103]		118	139	[118]	171	205	202		7
56-7										212	213	2
56-4			[101]		101	[154]	[121]	225	201	205		7
56-2				122	109	[192]	[134]	281	237	204		7
82-2				150								1
94-1			142									1
116-1	10											1
128-11											226	1
124-4		[115]			127	157	[122]	208	205	203	218*	8
125-4												
{125-15}			[114]		104	168	[143]	208	205	209	{201}	7 {8}
155-5				101								1

Located number	1994/95	1995/96	1996/97	1997/98	1999	1999/2000	2000/01	2002	2003	2004	2005	Total years
164-1			138			133						2
168-3				100	127	[126]	[127]	225	202	204		7
171-5										203		1
180-3			124 [108]		119	147	[144]	246	204	217		7
180-2			[117]		100	135	[108]	206	201			6
196-3			117									1
195-1		100		100	109	86	[137]	215	202	204	214	9
201-2		101		154	126	156	[136]	210	206	202	220	9
201-1		100		189								2
205-1		101		[115]								2
234-28										202	206	2
216-1			[112]									1
222-7	105											1
218-1	100											1
220-2		108	101									2
220-1		106	106		113	134	112	205	205	202	214	9
234-14				67		128						2
224-1				129		127	[140]	206	203	200		6
230-5		100	121		116	120	[139]	205	206	(208)	205	9
230-4			145									1
240-6			106									1
240-5			121		133	137	111	219	202	205	245	8
246-1		117		120								2
250-4			[120] 114									1
253-6			[108] 105		135	115	[131]	230	203	205	241	8
253-5			[107]		99	102	[125]	220	202	204		7
258-8			[109]			50	[134]	262	207			5
262-9		100										1
256-2		122		130	115	118	122	202	205	205	202	9
262-5	[100]											1
266-3			106		40	125	[129]	207	207	206		7
268-2		121		[112]		160	[140]	231	207	(234)		7
272-6	100											1

Located number	1994/95	1995/96	1996/97	1997/98	1999	1999/2000	2000/01	2002	2003	2004	2005	Total years
279-6	[100]											1
282-4	104											1
346-5				110								1
353-1		112		111								2
355-3		100		[106]							215	3
359-2			100									1
365-1		130		[105]	128	141	122	291	208	(208)	203	9
373-5											230	1
370-1			100		107							2
373-3		125	109	122								3
379-2	[100]											1
411-25		128		[145]								2
414-26											228*	1
389-1			118									1
414-25									200			1
392-1		134		118								2
398-6			136									
421-24	[100]	[100]	[113]	100	115	121	[123]	248	206	203		7
398-1			[134]									4
421-19	[100]	[133]	[102]	142	125	122	[123]	228	206	210	240	8
411-8		100	[104]		110	137	[142]	219	213	(207)	215	11
410-6		123		103	103		[145]	236	203	(205)	212	7
410-5		100		107								2
407-1		100			110	240	[148]	270	202	202	208	2
410-3	100											8
413-4	100											1
413-3		[102]	105	123								1
417-7		[128]		115	172	207	[133]	200	201			3
413-2		[109]	111	125	113	134	[132]	211	216	225	235	7
438-25		107		[100]								10
425-8			[116]	[131]								2
425-7		[111]		[121]								2
438-17	[100]											1
428-5		118			117	129	[150]	203	202	201	206	8

Located number	1994/95	1995/96	1996/97	1997/98	1999	1999/2000	2000/01	2002	2003	2004	2005	Total years
428-3		139		105	108	145	[137]	206	202	201	222	9
429-4			[118]	[130]								2
429-3			[106]	[128]	108	122	[147]	271	203	207	219	9
430-3			100									1
433-6		111		123								2
430-2		[121]										1
433-2		103		121	124	129	[124]	291	207	220	310	9
441-8											235	1
439-3		[105]		117	117	220	[134]	240	206	208	229	9
439-2	100	[106]		108								3
446-8			[106]									1
445-3											216	1
459-16	106											1
453-8	104	101			127	156	[126]	265	211	203	238	9
459-13		100										1
451-1			[119]		125	124	127	225	205	250		7
452-2		111	129	119	107	136	121	208	203	201		9
459-6		100			121	132	[144]	287*	250	210		7
458-1			100		102	130	135	218	201		229	7
477-16									225		236	2
463-1	100											1
477-14		[118]		[142]	112	128	136	202	211	204	232	9
467-2		109		101								2
481-14											226	1
481-13			141									1
471-2											221	1
476-7									204			1
481-11			100		133	182	[168]	230	204	208	211	8
473-2				140	112	135	[75]	383*	202	203	201	8
474-2											214	1
477-5	[95]	[100]		[110]	105	127	114	153	209	216	204	10
481-9			124		125	183	[157]	226	207	202		7
474-1											200	1
476-1			[111]	[115]	(284)	132	[141]	239	213	(226)	226	9
489-6		101	115	104								3
485-1									203			1

Located number	1994/95	1995/96	1996/97	1997/98	1999	1999/2000	2000/01	2002	2003	2004	2005	Total years
488-1			[110]		(161)	124	138	214	210	(201)	202	8
489-2		111	128	112							224	4
492-2			[125]									1
494-4			[108]									1
493-1			[116]	[102]	(251)	132	125	213	209	219	260	9
495-1			[112]		(471)*	123	[164]	261	205	(201)	216	8
498-1		108			121	142	[113]	221	206	214		7
503-2		102		106							257	3
504-2	100											1
506-4		105			(159)	122	[118]	226	210	205		7
508-1		100		113							263	3
510-3			121									1
529-20			100									1
516-6				94		140	[120]	248	204	204	212	7
529-18		105	118		102	114	[128]	365	229	205	202	9
516-5		[105]		102								2
529-17			104									1
514-1		142		123	115	180	125	219	219	210	221	9
529-13			124									1
529-4			108									1
531-4		107	112		119	[139]	[136]	234	233	204	237	9
531-3		111										1
539-1		[99]	119	101	101	230	[169]	203	212	203	252	10
556-9	100	157			110	154	[142]	228	201	200	206	9
552-2											201*	1
557-6		102		103								2
556-4	100	115		113								3
574-10		100		125								2
582-12	[100]											1
572-1		100		108	118	168	[117]	209	200	208		8
574-3				[128]	(389)*	121	143	247	205	205		7
619-20		[100]	100		111	127	[137]	226	211	203	221	9
612-12		100		127								2
612-9		113		86							207	3
613-8	107											1
613-2	100											1

Located number	1994/95	1995/96	1996/97	1997/98	1999	1999/2000	2000/01	2002	2003	2004	2005	Total years
614-1			[127]		(191)	130	128	255	205	205		7
616-2		116		127								2
616-1	100	111		100	133	163	[143]	265	235	215	256*	10
619-4	[100]											1
617-1			121									1
624-5			100		112	200	[118]	208	201	205	226	8
641-1				[114]								1
645-2			101		103	118	120	213	200	203		7
669-23	[100]	[107]										2
651-2			101									1
658-3		122		[143]								2
660-5	89		116									2
658-1											222	1
665-5		142		112								2
668-3											229	1
672-2			117		104							2
676-1			108		106	141	136	204	202	201		7
677-2	111			100								2
683-4	73		100		40	132	124	220	212	209		8
683-1			1									1
686-1			121		114	130	137	214	201	203		7
704-4			130		71	104	[137]	202	209	204		7
708-1			[127]	[104]								2
749-29									210			1
727-2				112								1
734-2			100								214	2
749-10		[118]		124	125	166	[181]	206	202	206	296	9
753-11	[100]											1
753-10			[101]	123								2
753-9		[101]		130								2
747-2				114	107	125	[134]	283*	203	203		7
753-7		[114]		142	128	119	[131]	235	210	211	210	9
753-4		[106]		107								2
754-2											201	1
786-32									(202)		239	2
786-31									201		221	2

Located number	1994/95	1995/96	1996/97	1997/98	1999	1999/2000	2000/01	2002	2003	2004	2005	Total years
786-22		100			126	118	[140]	305	202	213	207	8
786-5		101										1
784-2	103											1
786-2	[100]	136		100	121	135	[138]	225	204	215	217	10
796-3	100											1
864-3				100	104	132	[119]	246	207	209		7
872-11											200	1
869-1			[132]	[161]								2
873-1		135		116		144	137	232	204	210		7
878-1		112	114		79	119	136	200	207	201		8
887-1		101	141	133								3
931-1			108		111	135		287	211	201	210	7
934-3										226	201	2
941-3				127	112	[113]	[107]	254	206	228		7
945-1				104	105	[123]	[126]	174	213	220		7
951-3	92											1
954-5	100											1
966-7			[103]									1
976-2		142			101	138	133	201	208	203	210	8
990-5											209	1
1009-3									204	206	203	3
1012-3					55							1
1029-1			103									1
1053-12		100		118								2
1043-1		[115]		109	104	102	[170]	223	216	214	218	9
1045-3			118		128	112	144	252	200	215	465	8
1053-11		103		138								2
1051-4											202	1
1051-3			100		105	129	135	272	204	201		7
1053-3		[106]		116								2
1055-3		118	118	123	123	159	[143]	279	205	225	209	10
1055-2		118	15	128	126	185	[156]	208	210	209	207	10
1056-3								217				1
1132-70											204	1
1132-69											203	1
1132-68											217	1

Located number	1994/95	1995/96	1996/97	1997/98	1999	1999/2000	2000/01	2002	2003	2004	2005	Total years
1132-67											203	1
1132-66											234	1
1072-3		7	8	101	104	115	[69]	42	3			8
1076-5		30	121	30	102	122	[121]	192	105			8
1122-44		[110]										1
1122-41		102		106								2
1090-1				109								1
1092-3											24	1
1098-3	101											1
1105-5			120									1
1105-3	100											1
1113-11		[120]		172							282	3
1105-1				123								1
1110-4											201	1
1110-1				100								1
1121-1											206	1
1121-4			114		117	143	133	202	206	213		7
1127-3				113								1
1150-8	100											1
1158-7		101		116	120	144	[115]	317*	202	201	207	9
1174-19											207	1
1157-2		114		142	111	277	[134]	223	203	212	200	9
1164-5									208	205	206	3
1167-8		[116]		100	135	211	[159]	202	210	206	200*	9
1191-31										213		1
1174-10		100		127	109	107	[127]	261	213	203	233	9
1172-6		[104]	104	131	129	163	[112]	226	204	217	229	10
1172-3		[117]	104	117	105	161	[149]	212	205	209		9
1172-1		[104]		112								2
1184-8			15		86	106		236	17	66		6
1184-5							[88]					1
1184-1		10	2		105	[13]	[134]	188	63	21		8
1191-5	100											1
1231-42											202	1
1193-4			117									1
1231-41											204	1

Located number	1994/95	1995/96	1996/97	1997/98	1999	1999/2000	2000/01	2002	2003	2004	2005	Total years
1202-7			21									1
1206-11											214	1
1206-10											229	1
1249-47		100		126							216	3
1239-32	[109]											1
1249-42		104										1
1231-17				112								1
1217-3											214	1
1224-2											212	1
1249-32		109		137	124	150	[165]	237	203	206		8
1232-13											226	1
1235-6											203	1
1236-4			103 [107]		109	164	[123]	211	204	207		6
1249-15		[107]		145	118	150	[139]	236	212	201	234	9
1236-2			113 [100]		107	124	[120]	217	200		73	7
1243-7											232	1
1243-6											208	1
1241-2				109								1
1253-11		110	100	[113]								3
1247-4		100	125	102								3
1247-3		109	107	107	101	124	[100]	262	215		(207)	9
1253-9			119 [103]		(226)	133	120	285	205	212	248	8
1253-8		116	105	[115]	(151)	136	123	227	214		271	9
1252-3		113	131	105	111	113	[128]	253	207	202	222	10
1257-4	90			117	126	156	[143]	201	204	203	209	9
1271-1			[103]									1
1279-1				117	119	123	[134]	243	202	219		7
1282-2		120										1
1284-1		130		[120]	104	155	139	316	209	207	230	9
1287-3		100			108	126	[131]					4
1293-8		[100]		107	130	467	[147]	251	221	209	217	9
1307-11											225	1
1307-10			118		114	113	[143]	258	203	204		7

Located number	1994/95	1995/96	1996/97	1997/98	1999	1999/2000	2000/01	2002	2003	2004	2005	Total years
1300-2			103		98	145	115	217	204	203	241	8
1300-1			109		33	118	117	298	201	204		7
1312-10		[112]	112		120	[122]	[129]	219	254	211	224*	9
1307-4			126		109							2
1312-9			[103]									1
1321-13											203	1
1317-2					105	122	[115]	305	209	205		6
1321-6				109								1
1323-1	108		39		107	136	115	203	202	202	203	9
1406-1				106							202	2
1407-1				121								1
1408-1			101									1
1414-1		100		[132]	100	113	126	279	221	(208)		8
1427-1						121	153	228	207	215		5
1428-1						113	99	95	148			4
1435-1				102								1
1513-3											201	1
1825-1	100										203	2
1862-2								207	207	202		3
1873-1									201	200		2
1882-3										200*		1
1888-4										255		1
1957-1	102											1
1958-1	95											1
1960-1											232	1
1961-1											209	1
1962-1											247	1
1963-1											205	1
1964-1											203	1
1965-1											215*	1
1966-1											201	1
1967-1											232	1
1968-1											205	1
1969-1											205	1
1970-1											202	1
1971-1											208*	1

Appendix 3 – Details of sites sampled in 2005

For landcover optima codes, PFH = pasture with 51-85% upstream catchment area unmodified; PFL = pasture with 11-50% upstream catchment area unmodified; PP = pasture with ≤10% upstream catchment area unmodified. For status, “Long-term” = sampled ≥8 years; “Existing” = sampled prior to 2005 but record <8 years; “New” = selected randomly and first sampled in 2005; “***” = Long-term record but not used for trend analysis as data may have been compromised by change in sampling protocols.

Located number	Type	Landcover optima code	Restoration?	RERIMP?	Status	Comment
Wadeable streams						
4-2					Long term	
23-2	Landcover optima				Long term	
9-4	Reference Landcover optima				New	
1009-3	Landcover optima	PFL	Clean Streams		Existing	
1043-1	Landcover optima	PP			**	
1045-3	Landcover optima	PFL		RERIMP	**	Spring-fed - drop in 2006 due to access issues??
1051-4	Reference Landcover optima				New	
1055-2	Landcover optima	PFL			Long term	
1055-3					Long-term	
1092-3	Reference Landcover optima				New	Drop in 2006 due to lack of invertebrates
1110-4	Landcover optima	PP			New	
1113-11	Landcover optima	PP			Existing	
1121-1	Landcover optima	PFH			New	
1132-66	Landcover optima	PFH			New	
1132-67	Reference				New	
1132-68	Peri-urban				New	
1132-69	Peri-urban				New	
1132-70	Peri-urban				New	

Located number	Type	Landcover optima code	Restoration?	RERIMP?	Status	Comment
1157-2	Landcover optima	PP			**	
1158-7	Landcover optima	PFL			Long-term	
1164-5			Clean Streams		Existing	
1167-8	Landcover optima	PFL			**	
1172-6			Riparian planting		Long-term	
1174-10	Landcover optima	PFL			Long-term	
1174-19			Clean Streams		Existing	
1206-10	Landcover optima	PFL			New	
1206-11	Landcover optima	PP			New	
1217-3	Landcover optima	PFL			New	
1224-2	Reference				New	Drop in 2006; reference outlier
1231-41	Landcover optima	PP			New	
1231-42	Landcover optima	PP			New	
1232-13	Reference				New	
1235-6	Landcover optima	PFH			New	
1236-2	Peri-urban			RERIMP	Existing	
1243-6	Landcover optima	PFH	Clean Streams		New	
1243-7	Landcover optima	PFH			New	
1249-47	Landcover optima	PP			Long-term	
125-15	Reference				Long-term	Site moved a few hundred meters upstream in 2005; previous site number 125-4
1252-3	Landcover optima	PFL			Long-term	
1257-4	Landcover	PFH			Long-term	

Located number	Type	Landcover optima code	Restoration?	RERIMP?	Status	Comment
128-11	optima Landcover optima Landcover	PFL			New	
1284-1 1300-2	optima	PFH	Restoration		Long-term Existing	
1307-11 1321-13	Landcover optima Flow allocation	PFH			New New	Drop in 2006; one-off sampling
1323-1	Landcover optima Landcover	PFL		RERIMP	Long-term	
1406-1 1414-1 1513-3	optima Reference Reference	PP			Existing Long-term New	
1825-1	Landcover optima	PFH			New	
1862-2	Landcover optima Landcover	PP	Clean Streams		Existing	
1873-1	optima Landcover	PP	Clean Streams		Existing	
1882-3 1888-4	optima Reference	PFH			Existing New	
195-1	Landcover optima Landcover	PFL			Long-term	
1960-1 1961-1 1962-1 1963-1 1964-1 1965-1 1966-1	optima Reference Reference Reference Reference Reference Reference	PP			New New New New New New New	Drop in 2006; reference outlier Drop in 2006; reference outlier
1967-1 1968-1	Landcover optima Reference	PFH			New New	

Located number	Type	Landcover optima code	Restoration?	RERIMP?	Status	Comment
1969-1	Reference				New	
1970-1	Landcover optima	PP			New	
1971-1	Reference				New	
201-2					**	Drop in 2006
220-1	Landcover optima				Long-term	
230-5	Landcover optima	PP		RERIMP	**	
234-28	Reference				Existing	
240-5	Landcover optima	PFL		RERIMP	Long-term	
33-16	Reference				Existing	
355-3	Landcover optima	PP			Existing	
36-1	Landcover optima				Long-term	
365-1	Landcover optima				Long-term	
373-5	Reference				New	
398-1	Peri-urban			RERIMP	**	
407-1				RERIMP	Long-term	Order 5 but wadeable
411-8	Landcover optima	PFH			Existing	
413-2	Landcover optima	PFH			Long-term	
414-26	Reference				New	Drop in 2006; reference outlier
421-19	Landcover optima	PFL			**	
428-3				RERIMP	Long-term	Order 5 but wadeable
428-5	Landcover optima	PP			Long-term	
433-2	Landcover optima	PFL			Long-term	
439-3	Landcover optima	PP			**	
441-8	Landcover optima	PFH			New	

Located number	Type	Landcover optima code	Restoration?	RERIMP?	Status	Comment
445-3	Landcover optima	PFH			New	
453-8	Landcover optima	PFH			Long-term	
458-1	Reference				Existing	
471-2	Reference				New	
47-2	Peri-urban Landcover optima				**	Drop in 2006
473-2	Landcover optima	PP			Existing	
474-1	Landcover optima	PFH			New	
474-2	Reference				New	
476-1	Landcover optima	PFH			Long-term	
476-12	Landcover optima	PFL	Project Watershed		Existing	
477-14	Reference				Long-term	
477-16	Landcover optima				Existing	
477-5	Landcover optima	PFH			Long-term	
481-11	Landcover optima	PFL			Long-term	
481-14	Reference				New	
489-2	Landcover optima	PFH		RERIMP	Existing	
493-1	Landcover optima	PP			Long-term	
495-1	Landcover optima	PFL			Long-term	
503-2	Landcover optima	PFH			Existing	
508-1	Landcover optima	PFH			Existing	
514-1					Long-term	Order 5 but wadeable
529-18	Landcover optima				**	Drop in 2006
531-4	Landcover	PFH			Long-term	

Located number	Type	Landcover optima code	Restoration?	RERIMP?	Status	Comment
539-1	optima Landcover optima				Long-term	
552-2	Reference				New	
556-9					Long-term	Order 5 but wadeable
56-7			Clean Streams		Existing	
612-9	Landcover optima	PFL		RERIMP	Existing	
616-1	Landcover optima	PFH		RERIMP	**	
619-20	Landcover optima	PFL			Long-term	
624-5	Landcover optima	PP		RERIMP	**	
658-1	Landcover optima	PFH			New	
668-3	Landcover optima	PFL			New	
734-2	Landcover optima	PFL			Existing	
754-2	Reference				New	
786-2				RERIMP	Long-term	Order 5 but wadeable
786-22					Long-term	Order 5 but wadeable
786-31			Project Watershed		Existing	Order 5 but wadeable
872-11	Landcover optima	PFH			New	
931-1	Landcover optima	PP			Existing	
934-3			Project Watershed		Existing	
976-2					Long-term	Order 5 but wadeable
990-5	Landcover optima	PP			New	
Non-wadeable streams						
124-4					Long-term	
1247-3					Long-term	

Located number	Type	Landcover optima code	Restoration?	RERIMP?	Status	Comment
1249-15				RERIMP	Long-term	
1253-8			Restoration?		Long-term	
1253-9					Long-term	
1293-8					Long-term	
1312-10					**	Drop in 2006
253-6					**	Drop in 2006
256-2					Long-term	
41-9				RERIMP	Existing	
429-3					Long-term	
488-1				RERIMP	**	
516-6					Existing	
749-10				RERIMP	Long-term	
753-7					Long-term	
786-32			Project Watershed		Existing	