greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

Macroinvertebrate outcomes for aquatic ecosystem health in rivers and streams

Technical report to support the draft Natural Resources Plan

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Contents

Executive summary

This report presents technical background to macroinvertebrate indicators of river and stream ecosystem health recommended for inclusion in the draft Natural Resources Plan (dNRP) for the Wellington region. It was originally drafted prior to the release of the Regional Plan Working Document for Discussion (WDFD) in September 2013 (GWRC 2013) but was not completed due in part to uncertainty about changes that might be made in response to the release of the National Objectives Framework (NOF) under the National Policy Statement for Freshwater Management (NPS-FM). Although the outcomes recommended in this report differ from the final recommendations for the dNRP documented in Greenfield (2014a) this report presents relevant background analysis and a record of the evolution of outcomes for the dNRP.

The relationship between macroinvertebrate data collected from Rivers State of the Environment (RSoE) monitoring sites between 2004 and 2009 and environmental data such as water quality variables and land use was analysed to assess the suitability macroinvertebrate community health indicators for use in the dNRP (where they are referred to as ‘attributes’). A number of macroinvertebrate metrics were highly correlated with environmental factors across the RSoE site network. While the recommended approach is to assess macroinvertebrate community health using a range of metrics from the four main types (composition/abundance, richness/diversity, sensitivity/tolerance and functional) there is currently a lack of data, particularly reference data, to enable this approach to be used. In the interim, the Macroinvertebrate Community Index (MCI) has been chosen as the sole attribute to represent macroinvertebrate community health. MCI is highly correlated with environmental factors across the RSoE site network.

Predicted reference MCI scores from a national model (Clapcott et al. 2011) along with measured MCI scores from RSoE sites and sites sampled for a range of studies in the Wellington region between 1999 and 2010 were used to identify numeric thresholds to represent the desired levels of ecosystem health (referred to as ‘outcomes’). Outcomes representing two levels of ecosystem health were identified – a default ‘healthy’ level which applies to all rivers and streams in the region and a higher level which applies to rivers and streams identified as supporting ‘significant indigenous ecosystems’ in Table 16 of the Regional Policy Statement (GWRC 2013). Identification of numeric outcomes was based around the Freshwater Environments of New Zealand (FENZ) classification to account for natural variability in river and stream ecosystems across the region.

Recommended MCI outcomes for ‘significant aquatic ecosystem’ and ‘healthy aquatic ecosystem’ levels of protection for FENZ classes in the Wellington region

FENZ class	Significant aquatic ecosystem outcome (Chl. *a* mg/m^2)	Healthy aquatic ecosystem outcome (Chl. *a* mg/m^2)
C7, C6a, C10 and UR	130	115
C5, C8, C6b and C1	130	105
C6c	120	100
A,B	125	105

In addition, a standard of no more than 20% change in Quantitative Macroinvertebrate Index (QMCI) score is recommended to apply to specific consented activities such as point source discharges or water abstractions.

1. Introduction

Objective 13 of the Regional Policy Statement (RPS) for the Wellington region (GWRC 2013) states that the region's rivers must support healthy functioning ecosystems as a bottom line. Policy 17 of the RPS states that the Regional Plan should include policies and rules that protect the significant indigenous ecosystems[1] associated with rivers listed in Appendix 1 of the RPS. In order to implement the RPS the regional plans for the Wellington region are currently under review and a draft Natural Resources Plan (dNRP) will be released later in 2014. The dNRP will include numeric objectives or 'outcomes' for a range of river and stream health indicators (referred to as 'attributes' in the planning sense). As a default, numeric outcomes will be set at a level that will support 'healthy functioning ecosystems'. Outcomes representing a higher level of protection to support 'significant indigenous ecosystems' will also be identified for those rivers and streams identified in Table 16 of the RPS. Numeric outcomes must take into account natural variation in rivers and streams in the region.

This report was originally drafted prior to the release of the Regional Plan Working Document for Discussion (WDFD) in September 2013 but was not completed due in part to uncertainty about changes that might be made in response to the release of the National Objectives Framework (NOF) under the National Policy Statement for Freshwater Management (NPS-FM). Although the outcomes recommended in this report differ from the final recommendations for the dNRP documented in Greenfield (2014a), this report presents relevant background analysis and a record of the evolution of outcomes for the dNRP.

Ecological indicators used to represent the ecological health of rivers and streams in the Wellington region include:

- Instream macrophytes and periphyton
- Macroinvertebrates
- Native fish

This report identifies attributes and, where sufficient data are available, numeric outcomes for macroinvertebrate community health. Selection of attributes and outcomes is based on assessment of the relationship between macroinvertebrate community health metrics and environmental factors in the Wellington region. Key supporting environmental variables that will need to be managed in order to achieve macroinvertebrate outcomes are also briefly discussed.

1.1 Report outline

The river classification used as the basis for river and stream ecosystem health outcomes is outlined in Section 2. Section 3 provides information on the relationship between macroinvertebrate metrics and environmental variables in

[1] Significant river ecosystems were identified as having high value for general aquatic ecosystems (based on the proportion on indigenous forest or scrub in the upstream catchment or for native fish (based on the number of species recorded in the NZ Freshwater Fish Database, the presence of nationally threatened species and/or the presence of inanga spawning habitat) (Warr et al. 2009).

the Wellington region while proposed numeric outcomes for macroinvertebrate community health are presented in Sections 4 and 5. Section 6 outlines the supporting environmental factors that will need to be managed in order to achieve the recommended outcomes.

2. River classification

As stated by Barbour et al. (1999) the identification of a classification framework to partition natural ecosystem variability is a key first step in the development of biological indicators for ecological assessment. The Freshwater Environments of New Zealand (FENZ) classification has been selected as the classification that best represents natural variability in river and stream ecosystems in the Wellington region (Warr 2009) and has been modified to better suit the region (Warr 2010). Amendments involved amalgamating various 100-level classes to reduce the number of classes to allow their use in a resource management context and spitting of class C6 into three classes to better represent differences within this river type. The amended FENZ classification partitions rivers and streams in the Wellington region into 11 classes (Table 2.1, Figure 2.1) and is used as the basis for selection of macroinvertebrate community indicators and numeric outcomes.

Table 2.1: Extent and description of each class in the amended FENZ classification for the Wellington region

GW FENZ class	Stream length (km)	Description
A	3,299	A combination of 100-level classes A4 and A2. These are small streams occurring in inland or coastal locations with very low frequency of days with significant rainfall. Gradients of these streams are very gentle to gentle and substrates are predominantly silty or sandy. Predominant location: Central Wairarapa Valley and Kapiti Coast.
C5	3,076	Small streams occurring in moderately coastal locations with mild, maritime climates and low frequency of days with significant rainfall. Stream gradients are generally moderate and substrates are predominantly coarse gravels. Predominant location: Wellington south coast, eastern Wairarapa coast and western Tararua foothills.
C8	1,869	Small inland streams with mild climates and low frequency of days with significant rainfall. Stream gradients are moderate and substrates are generally coarse gravels. Predominant location: Eastern Wairarapa hill country and northern foothills of Tararua Range.
C7	1,729	Small to medium-sized streams occurring in inland locations with mild climates and low frequency of days with significant rainfall. Stream gradients are generally steep and substrates are generally coarse gravels. Predominant location: Lowland hills of the Tararua, Rimutaka and Aorangi ranges.
C10	924	Small streams occurring in inland locations with cool climates and moderate frequency of days with significant rainfall. Gradients of these streams are generally very steep and substrates are generally cobbly. Predominant locations: Small, mid-elevation streams in the Tararua, Rimutaka and Aorangi ranges
C6a	426	This class is a variant of 100-level class C6 and includes C6 rivers that have an upstream catchment dominated by C7 rivers. These are larger rivers occurring in moderately inland locations with warm climates and low frequency of days with significant rainfall and a predominance of coarse gravelly substrates. Stream gradients are gentle. Predominant location: Lower reaches of larger rivers draining the Tararua Range.
UR	356	A combination of 23 100-level classes that occur entirely within the upper Tararua or Rimutaka ranges.
C1	279	Small coastal streams with mild maritime climates and low frequency of days with significant rainfall. Stream gradients are generally very steep and substrates are predominantly coarse gravels. Predominant location: South Wairarapa coast, Rimutaka Range and Kapiti Island.
C6c	198	A variant of 100-level class C6 and includes C6 rivers that have an upstream catchment dominated by class A and/or C8 rivers and streams. Predominant location: Larger rivers draining eastern Wairarapa hill country and lowland areas of the Kapiti Coast.
C6b	17	A variant of 100-level class C6 and includes C6 rivers that have an upstream catchment dominated by class C5 streams. Location: Horokiri and Pauatahanui streams as well as some stream segments on the eastern Wairarapa coast.
B	3	A combination of 100-level classes B1 and B3 of very limited extent in the Wellington region but has been retained due to the peat-dominated nature of the catchments which is likely to result in unique ecological characteristics. Location: Mangaroa Valley, Lake Wairarapa, Paraparaumu.

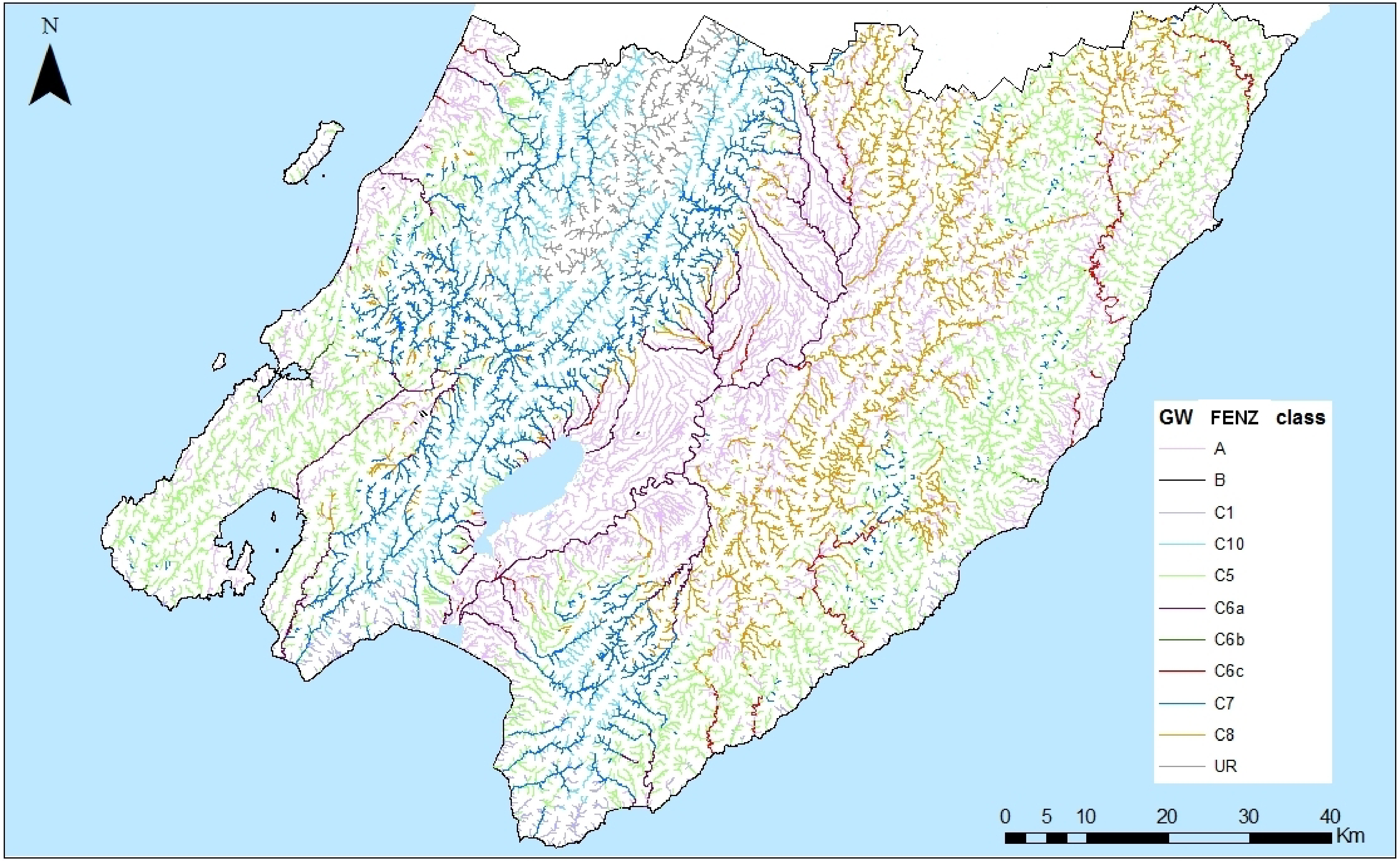

Figure 2.1: Map of the amended FENZ classification for the Wellington region (adapted from Warr 2010)

3. Macroinvertebrate attribute selection

Assessment of the health of macroinvertebrate communities should incorporate as many different aspects of the community as possible such as taxa richness, diversity, proportion of sensitive and tolerant taxa, and trophic structure (Hering et al. 2006, Barbour et al. 1999). A similar range of macroinvertebrate metric types are suggested by Schallenberg et al. (2011) as suitable for measuring ‘ecological integrity’ of rivers and streams in New Zealand. Hering et al. (2006) set out the process for selection of macroinvertebrate metrics as follows:

- Identification of a river classification system that accounts for natural variation in river/stream communities.
- Metric selection – candidate metrics should include at least one from each of the four main types; composition/abundance, richness/diversity, sensitivity/tolerance and functional metrics.
- Correlation of each metric with a stressor gradient – within each stream type the relationship between candidate metrics and environmental stressors should be assessed across sites within a range of conditions from reference to heavily impacted.
- Selection of core metrics by assessing those that have the strongest relationship with the stressor gradient but excluding those that are highly correlated.

Macroinvertebrate and environmental data from GWRC’s 56 Rivers State of the Environment (RSoE) monitoring sites (Figure 3.1) are used to assess the relationship between macroinvertebrate metrics and the environmental gradient across all stream types. Although there are macroinvertebrate data available from a number of other sites in the region many of these do not have accompanying water quality and other environmental data.

3.1 Relationship between macroinvertebrate community composition and environmental stressors

Clapcott and Olsen (2010) used a BIOENV routine to explore which environmental variables best explained patterns in the macroinvertebrate communities in RSoE samples. BIOENV is a permutation-based analysis that explores how all possible combinations of variables correlate with macroinvertebrate community data.

The five-variable solution with the highest correlation to invertebrate data (r=0.772) included conductivity, total nitrogen, turbidity, minimum dissolved oxygen saturation, and percentage of streambed silt cover. Percentage of silt cover was the single variable with the highest correlation with invertebrate community composition (r=0.653), reflecting the difference in macroinvertebrate community composition between soft and hard bottomed streams (Clapcott & Olsen 2010).

Figure 3.1: Location of GWRC's 56 River State of the Environment (RSoE) monitoring sites

Although these correlations do not represent a direct cause and effect, they suggest that silt cover, nutrient concentrations (in particular nitrogen), turbidity and dissolved oxygen content of the water, either directly or indirectly, affect macroinvertebrate community composition.

3.2 Correlation between macroinvertebrate community metrics and stressor gradient

Principal Components Analysis (PCA) was undertaken on environmental data (landuse data from the River Environment Classification database and annual summary statistics for 14 water quality variables for the period 2004–2009) for each RSoE site (Clapcott & Olsen 2010). The first principal component of this analysis (axis 1) explained 36% of the variation in environmental data while the second accounted for 11%. Low scores on axis 1 of the PCA were associated with sites with high water clarity, high dissolved oxygen concentration and high percentage of indigenous forest cover in the catchment above the site (Table 3.1). High scores on axis 1 of the PCA were associated with sites with a high proportion of high producing pasture[2] in the upstream catchment as well as high turbidity and high concentrations of ammoniacal nitrogen, total organic carbon and total phosphorus (Table 3.1).

Table 3.1: Eigenvectors from PCA analysis of environmental variables from RSoE monitoring sites
(Source: Clapcott & Olsen 2010, Table 8)

Variable	PC1	PC2
Black disc (visual clarity)	-0.28	0.218
DO ppm	-0.28	-0.027
DO satmin	-0.279	0.021
Indigenous forest %	-0.261	0.201
pH	-0.164	-0.437
Scrub %	-0.048	0.071
Exotic forest %	-0.011	-0.276
Low producing pasture %	0.018	-0.144
Other %	0.056	0.019
Urban %	0.137	0.281
Cropping %	0.151	0.121
Conductivity	0.17	-0.448
NOx	0.185	0.147
E. coli	0.201	0.221
DRP	0.214	0.239
TN	0.217	0.124
Water temperature	0.224	-0.13
High producing pasture %	0.24	-0.202
NH_4N	0.27	0.2
TOC	0.275	-0.17
Turbidity	0.278	-0.197
TP	0.304	0.122

2 High producing pasture is pasture with a medium to high dry matter production and includes rye grass and white clover (Ministry of Works and Development, Water and Soil Division 1979).

PCA axis 1 scores were then used to represent the range of environmental variables at each site and the relationship between these and macroinvertebrate metrics assessed (based on six annual macroinvertebrate samples collected at each RSoE site between 2004 and 2009).

There was a significant linear relationship (p<0.001) between environmental variables and all macroinvertebrate metrics apart from Qworms[3] (Table 3.2).

The macroinvertebrate indicators exhibiting the strongest relationship with environmental variables were the proportion of EPT[4] taxa in the sample (%EPT*), Macroinvertebrate Community Index (MCI)[5] score and the proportion of gastropod taxa (%gastropods). However, all three of these metrics were highly correlated (Clapcott & Olsen 2010).

Table 3.2: Linear regression output for the relationships between macroinvertebrate metrics and scores that summarise environmental variability (PCA axis 1) at RSoE sites (n=56) based on data collected between 2004 and 2009 (Source: Clapcott & Olsen 2010, Table 11)

Metric	F	r^2	p
Taxa	17.91	0.25	<0.001
MCI	156.05	0.74	<0.001
MCIsb	195.73	0.78	<0.001
%small	92.81	0.63	<0.001
%large	83.92	0.61	<0.001
%EPT*	214.24	0.80	<0.001
EPT richness	105.79	0.66	<0.001
%worms	15.90	0.23	<0.001
%predators	21.13	0.28	<0.001
%gastropods	115.33	0.68	<0.001
QMCI	73.47	0.58	<0.001
QMCIsb	128.34	0.70	<0.001
Qsmall	58.38	0.52	<0.001
Qlarge	61.07	0.53	<0.001
QEPT*	197.49	0.79	<0.001
Qworms	4.39	0.08	0.041
Qpredators	17.29	0.24	<0.001
Qgastropods	81.98	0.60	<0.001

3.3 Metric selection

The availability of reference data is a key aspect to setting numeric outcomes for biological indicators. Currently, MCI is the only macroinvertebrate metric for which there are sufficient reference data available across all river types. These reference data have been obtained from a model that predicts both current and reference MCI scores for each segment of the New Zealand river

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[3] Quantitative percent of individuals that are worms.

[4] Ephemeroptera, plecoptera and trichoptera taxa.

[5] The MCI is a biotic index that uses tolerance scores assigned to macroinvertebrate taxa based on their sensitivity to organic pollution to calculate a stream health score (Stark 1985). Although the MCI was originally formulated to represent the effects of organic pollution in hard-bottomed streams it has been shown to adequately represent a range of water quality and habitat impacts (apart from the effect of heavy metals).

network based on environmental variables (Clapcott et al. 2011). It is hoped that this model will be extended to other macroinvertebrate metrics in the near future and that these can also be used in the Regional Plan either as stand-alone metrics or as part of a multi-metric index. In the interim, MCI will be used as the sole indicator of macroinvertebrate community health. As noted earlier, there is a strong linear relationship between MCI scores and the environmental stressor gradient across RSoE sites. Non-linear regression analysis of the relationship between MCI scores and the environmental stressor gradient shows an even stronger relationship (Figure 3.2).

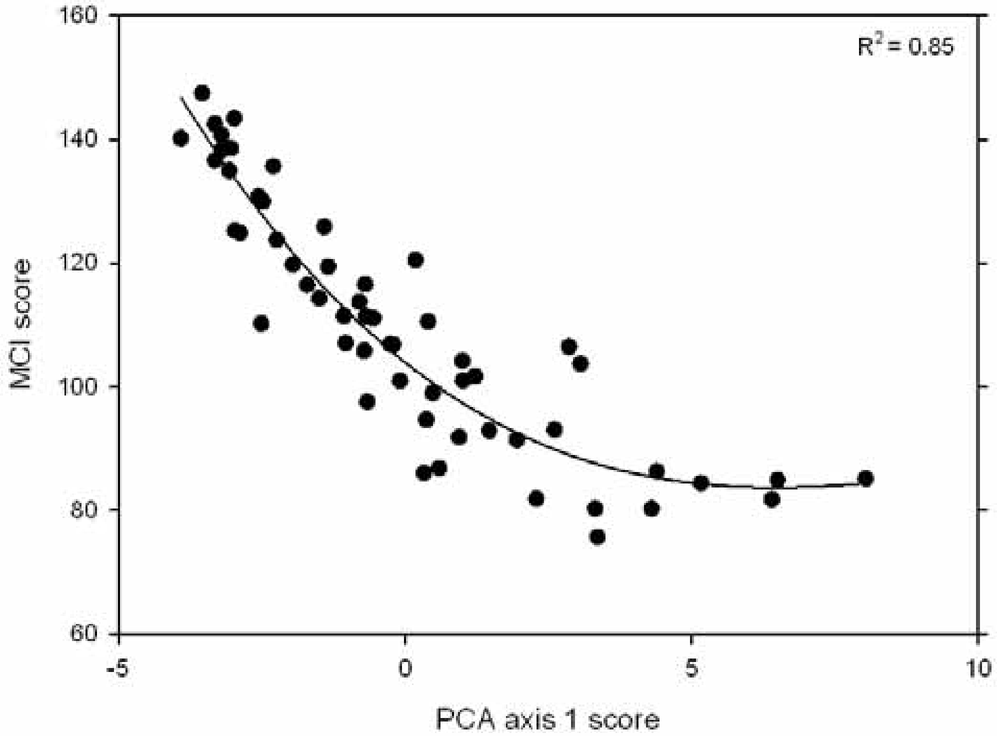


Figure 3.2: Non-linear regression relationship between environmental variables (summarised by PCA axis 1 score) and mean MCI (based on annual samples from 2004–2009, *n*=6 for each site) for 56 RSoE sites
(Source: After Clapcott and Olsen 2010, Figure 13)

Note that only the hard bottomed variant of the MCI has been used here. The soft bottomed variant of the MCI developed by Stark and Maxted (2007a) should only be used in streams that are known to be naturally soft bottomed. Although there are many soft bottomed streams[6] in the Wellington region it is unknown whether any of these would occur naturally.

[6] Collier and Kelly (2005) use a working definition of a soft bottomed stream of "*a stream in which ≥50% of the stream bed is composed of sand, silt or pumice*".

4. Identification of numeric outcomes for MCI

For each FENZ class the distribution of MCI scores available was used to identify thresholds for four categories of macroinvertebrate community health: excellent, good, fair and poor.

It is intended that the ‘excellent’ threshold be used as the numeric outcome for rivers and streams identified as “significant aquatic ecosystems” in Appendix 1 of the RPS (GWRC 2013) and that the ‘good’ threshold be used as the numeric outcome for all other rivers and streams in the Wellington region. Although not required by the RPS (GWRC 2013), the ‘fair’ and ‘poor’ thresholds have been identified to assist with the identification of the most degraded rivers and streams in the region.

4.1 Methods

MCI scores were calculated from macroinvertebrate community data collected from 270 sites across the Wellington region as part of historic and current RSoE monitoring, riparian rehabilitation-related monitoring and a number of one-off studies (Table 4.1, Figure 4.1).

Table 4.1: Details of macroinvertebrate samples collected from 270 sites across the Wellington region

Data source	No. of sites	Sampling date	Sampling methods	Sample analysis
RSoE monitoring	56	Annual samples between 2004–2009	3 replicates, protocols C1 and C2, 0.5 mm mesh	200 fixed count with scan for rare taxa
Historic RSoE monitoring	16	Annual samples between 1999–2003	3 replicates, 1 minute kick sample from riffle habitat, 0.5 mm mesh	Coded abundance
Riparian monitoring programme	3	Annual samples between 2002–2007	3 replicates, protocols C1 and C2, 0.5 mm mesh	200 fixed count with scan for rare taxa
Project Mangatarere study	9	One off samples taken in summer 2010	Single sample, protocol C1, 0.5mm mesh	200 fixed count with scan for rare taxa
Urban streams study	79	One off samples taken between 2001–2008	Single sample, 1–2 minute kick sample from all habitats, 0.5 mm mesh	Full count with subsampling option
REC verification study	29	One-off samples taken in 2001	3 replicates, 1 minute kick sample in run/riffle, 0.3 mm mesh	Full count with subsampling option
Massey University samples	78	One-off samples taken in 2001	Single sample, 1 minute kick sample from riffle habitat, 0.5 mm mesh	100 fixed count

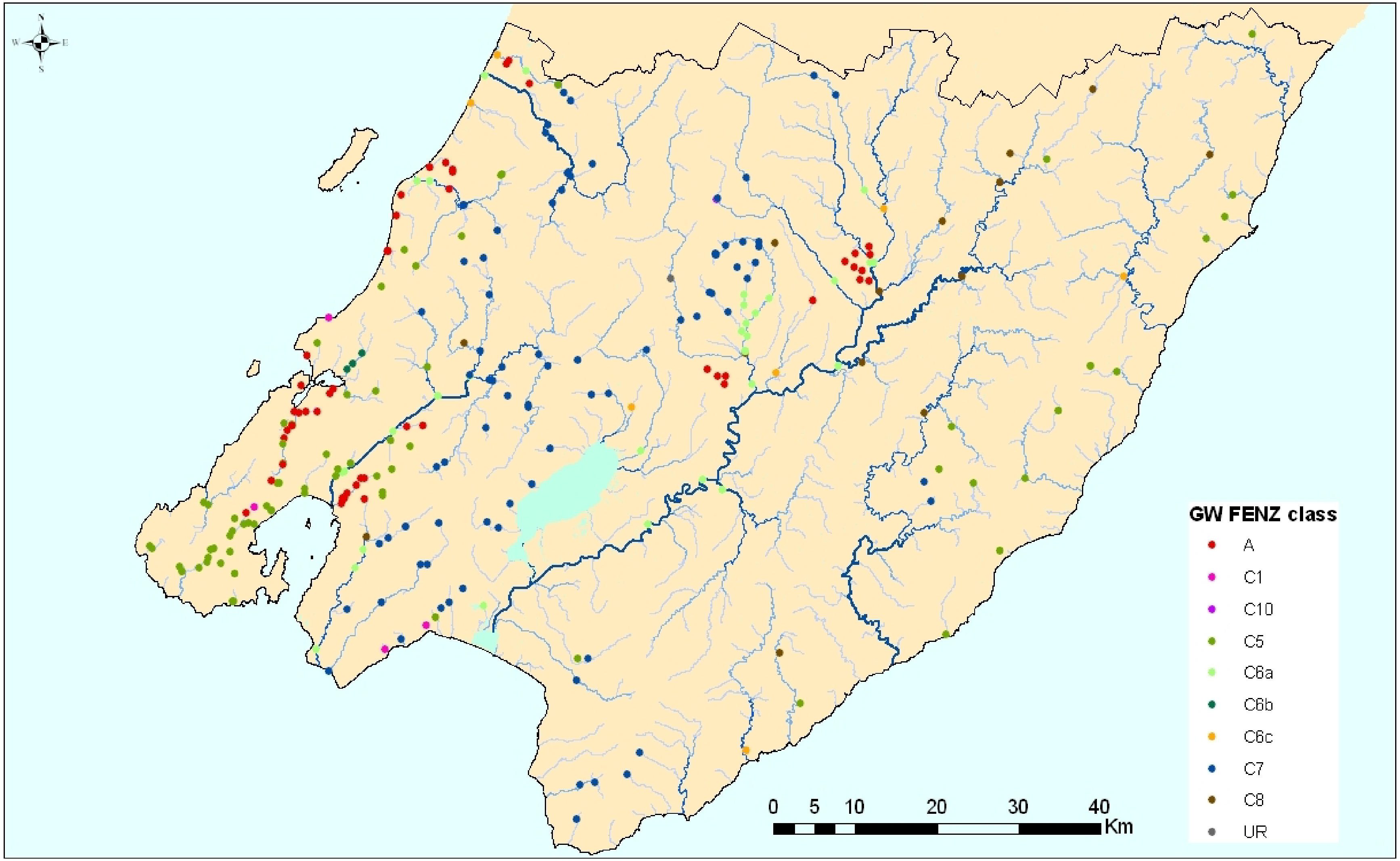


Figure 4.1: Location and FENZ class of 270 sites used to calculate MCI thresholds for the Wellington region

Despite differences in sample collection and analysis methods (Table 4.1), all available data were used to cover the widest possible range of river types and degrees of impact. It was considered that for a non-quantitative metric such as MCI these differences would not have a significant effect on the results.

Each site was assigned a FENZ class and one of two impact categories:

- Reference – sites with ≥ 95% indigenous forest and scrub cover in the upstream catchment based on REC raw data (Snelder et al. 2004)
- Non-reference/Impacted – all other sites

4.1.1 Identification of MCI range for each FENZ class

Hering et al. (2006) set out a method for identifying thresholds for a multi-metric macroinvertebrate index using the concept of upper and lower anchors. The upper anchor corresponds to the upper threshold of the metric's value under reference conditions while the lower anchor corresponds to the lower threshold of the metric's value under the worst attainable conditions. Although Hering et al. (2006) intended that this method be used to establish thresholds for a multi-metric index, here it has been be used to establish MCI thresholds for specific river classes.

Where sufficient (>30–40 sample sites) reference site data were available the upper anchor of the MCI score range was calculated from the 95th percentile of reference site data. Where there were insufficient reference site data, the 75th percentile of predicted reference values from a national model of MCI scores (Clapcott et al. 2011) was used. The 75th percentile was used because although predictions of contemporary MCI values were highly correlated with measured MCI values (Pearson correlation coefficient r=0.886), the model over-predicted MCI values by on average 5 units for the Wellington region (Clapcott & Olsen 2010).

The lower anchor of MCI scores for each class was identified using the 5th percentile of data from impacted sites. The 5th percentile was used instead of the minimum recorded value to take into account uncertainty over classification and sampling methods for some samples.

Where multiple MCI results were available for a single site, maximum and minimum scores were used for reference and impacted sites, respectively, in calculation of upper and lower anchors for each FENZ class.

4.1.2 Identification of MCI thresholds

For each FENZ class with insufficient measured reference data (all but C7) the MCI score range between the upper and lower anchor values was divided by four to delineate thresholds for four classes: 'excellent', 'good', 'fair' and 'poor'. Results were rounded to the nearest 5 MCI points for simplicity.

For FENZ class C7 the 'excellent' threshold was calculated as the 25th percentile of reference MCI scores for that class (n=50). The MCI range between the 'excellent' boundary and the lower anchor was then divided by three to give the 'good' and "fair" thresholds.

4.1.3 Identification of confidence around thresholds

An understanding of variability in macroinvertebrate metrics associated with measurement error is necessary to ensure that sites that are near a threshold are rated with known precision (Barbour et al. 1999).

Stark (1998) used an ANOVA procedure to determine detectable differences for kick net samples based on MCI values from replicate samples. These analyses suggested that MCI values calculated from single samples, collected according to Protocol C1 (Stark et al. 2001), would need to differ by 10.83 MCI units to be considered significantly different. If the assessment is based on two samples the buffer is reduced to ±7.66 MCI points (and to ±6.25 points based on three samples). This suggests that if assessment of a site is based on a single sample then results within ±10 MCI points of the threshold could fall into either category. Between 2004 and 2009 three replicate macroinvertebrate samples were collected at each RSoE site but from 2009/10 onwards, only a single sample has been collected at each site.

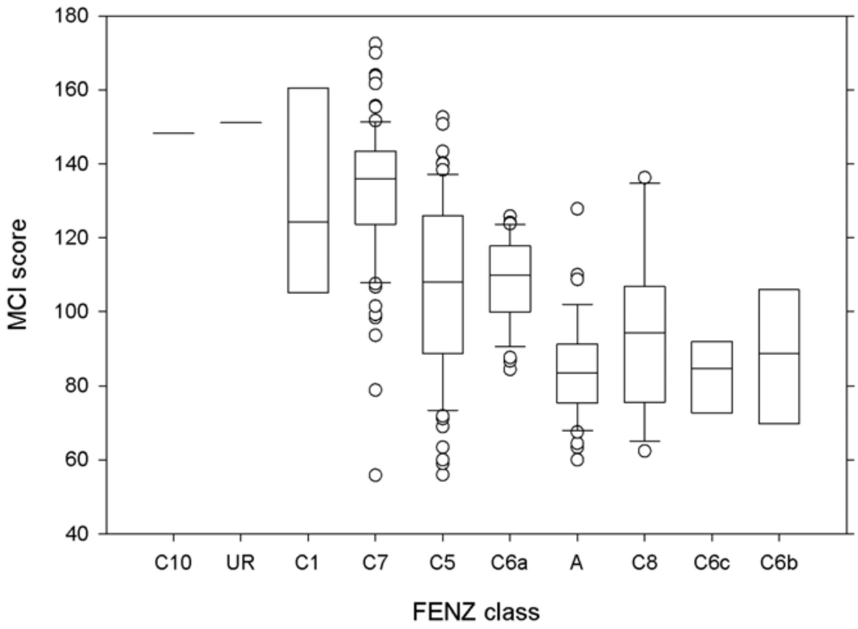
It is recommended that analysis of the precision of MCI score results at RSoE sites be undertaken either using existing data or by collecting additional replicate samples at selected sites. Depending on the precision required this will identify the number of replicate samples required. Given that RSoE sites are likely be graded on a five-yearly basis, this analysis should include assessment of the precision of an MCI score estimate from five years of results.

4.2 Macroinvertebrate health across FENZ classes

A Kruskal-Wallis ANOVA showed that there was a significant (p<0.001) difference in MCI scores collected from the 270 sites across FENZ classes in the Wellington region. However, the difference in scores is likely to be primarily driven by the varying degree of impact from human activities within these classes rather than natural differences. To check this, estimates of the proportion of natural vegetation cover in the upstream catchment (on a scale from 0 to 1 where 1 represented 100% natural cover) from the FENZ database were collated for each site. These were then compared against median MCI scores for each FENZ class (Figure 4.2).

Highest median MCI values were found at sites belonging to classes C10, UR, C1 and C7 (note only one result was available for classes C10 and UR). Sites in these classes tended to have a high proportion of natural vegetation cover in the upstream catchment with the median proportion ranging from 0.75 to 1. Lowest median MCI values were found at sites belonging to classes A, C8, C6c and C6b. Sites representing these classes tended to have a low proportion of natural vegetation cover in the upstream catchment with the median proportion ranging from 0.1 to 0.28.

The range of natural vegetation cover at sites sampled in each FENZ class was similar to the range of natural cover across all river segments within the class in the Wellington region.



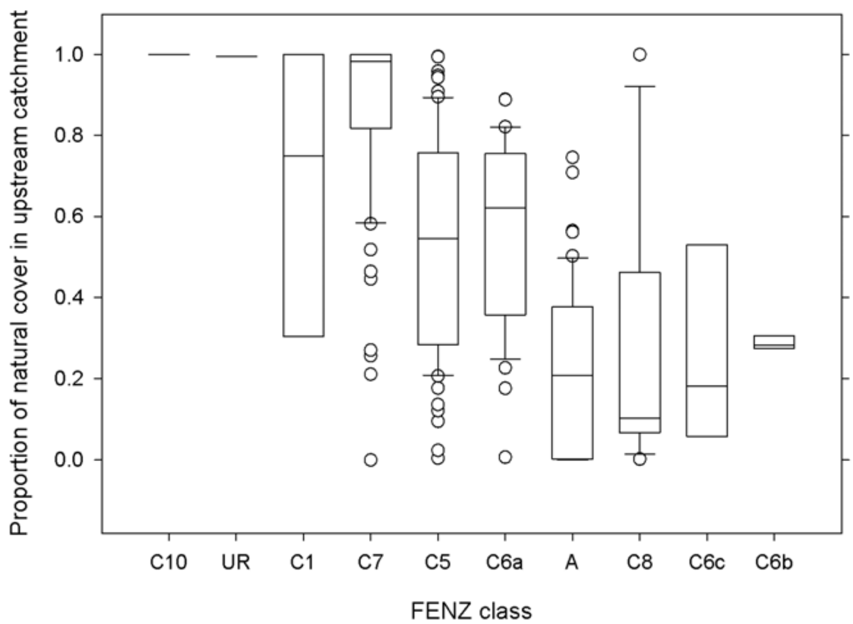


Figure 4.2: Box plots showing (top) range of MCI scores recorded across each FENZ class and (bottom) the proportion of natural cover in the upstream catchment of each macroinvertebrate sampling site. Where multiple MCI results exist for a single site the average was used. C10 *n*=1, UR *n*=1, C1 *n*=4, C7 *n*=83, C5 *n*=74, C6a *n*=38, A *n* 48, C8 *n*=13, C6c *n*=7, C6b *n*=4

4.3 Thresholds for FENZ types C7, C10 and UR

Class C7 was the only class for which there were sufficient reference site data to identify the 'excellent'/'good' threshold from the 25th percentile of reference site scores. Due to their upland location and associated lower intensity of human impacts, C7 streams show a narrow range of MCI scores (Figure 4.3). Accordingly, thresholds identified have a range of 30 MCI units from the 'excellent'/'good' boundary of 130 to the 'fair'/'poor' boundary of 100 (Table 4.2).

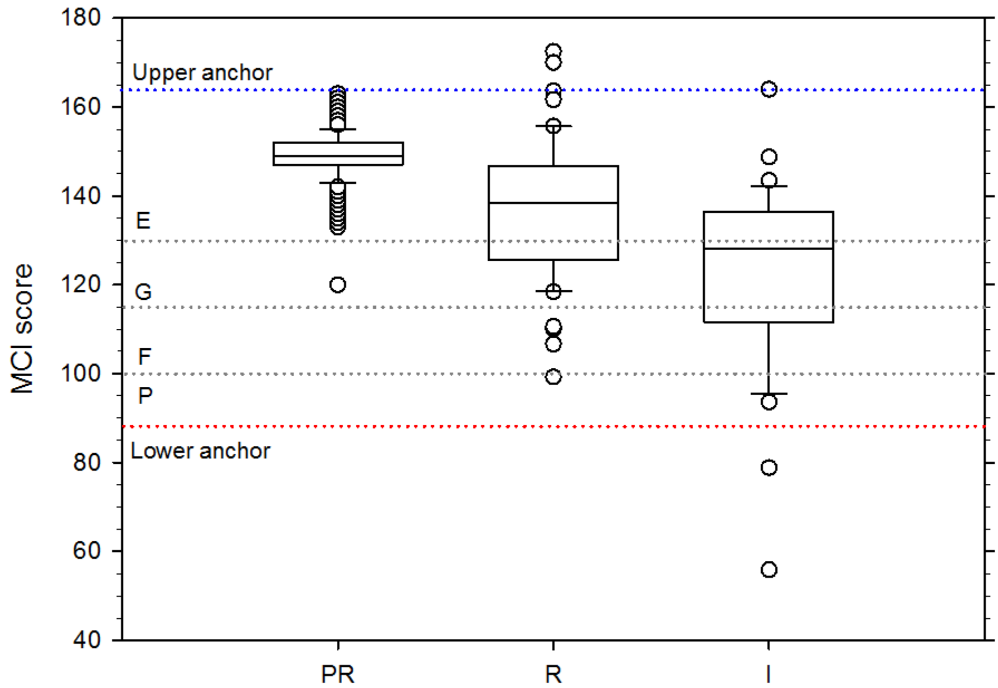


Figure 4.3: The range of MCI scores predicted for class C7 rivers in their natural state (PR, *n*=2,978) and measured at both reference sites (R, *n*=50) and impacted sites (I, *n*=33). Upper and lower anchor thresholds are shown as well as proposed thresholds for 'excellent' (E), 'good' (G), 'fair' (F) and 'poor' (P) categories

Table 4.2: Recommended MCI thresholds for FENZ classes C7, C10 and UR

Macroinvertebrate health class	Threshold
Excellent	≥130
Good	115–129
Fair	100–114
Poor	<100

There were insufficient data to identify thresholds for rivers and streams in classes C10 and UR. However, as these classes are limited to the upper Tararua, Rimutaka and Aorangi ranges the thresholds identified for class C7 (which streams in classes C10 and UR flow into) are likely to provide sufficient protection.

4.4 Thresholds for FENZ type C6a

There are no reference data available for rivers and streams in class C6a as all stream and river segments in this class are significantly affected by human activities and land use. Therefore, the upper anchor for this class was estimated from predicted natural MCI scores.

Rivers in class C6a show a relatively narrow range of MCI scores (Figure 4.4). Thresholds identified for this class are the same as those for class C7 (Table 4.3).

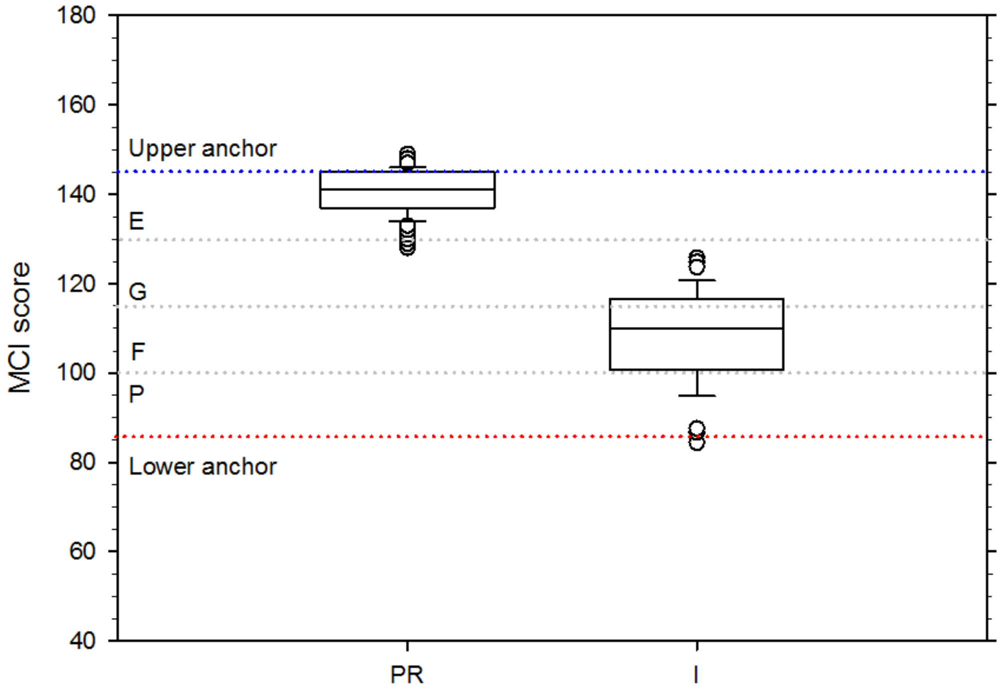


Figure 4.4: The range of MCI scores predicted for C6a rivers and streams in their natural state (PR, *n*=433) and measured at impacted sites (I, *n*=38). Upper and lower anchor thresholds are shown as well as proposed thresholds for 'excellent' (E), 'good' (G), 'fair' (F) and 'poor' (P) categories

Table 4.3: Recommended MCI thresholds for FENZ class C6a

Macroinvertebrate health class	Threshold
Excellent	≥130
Good	115–129
Fair	100–114
Poor	<100

4.5 Thresholds for FENZ classes C5, C1 and C6b

Data were available from only five reference sites belonging to class C5 and consequently the upper anchor for this class was estimated from predicted natural MCI scores.

Streams in class C5 showed a wide range of MCI scores (Figure 4.5). Accordingly, thresholds range over 45 MCI units from an 'excellent'/'good' threshold of 130 to a 'fair'/'poor' threshold of 85 (Table 4.4).

There were insufficient data to calculate thresholds for rivers and streams in classes C1 and C6b. However, because their physical characteristics are similar to those in class C5 the thresholds identified for this class should provide sufficient protection.

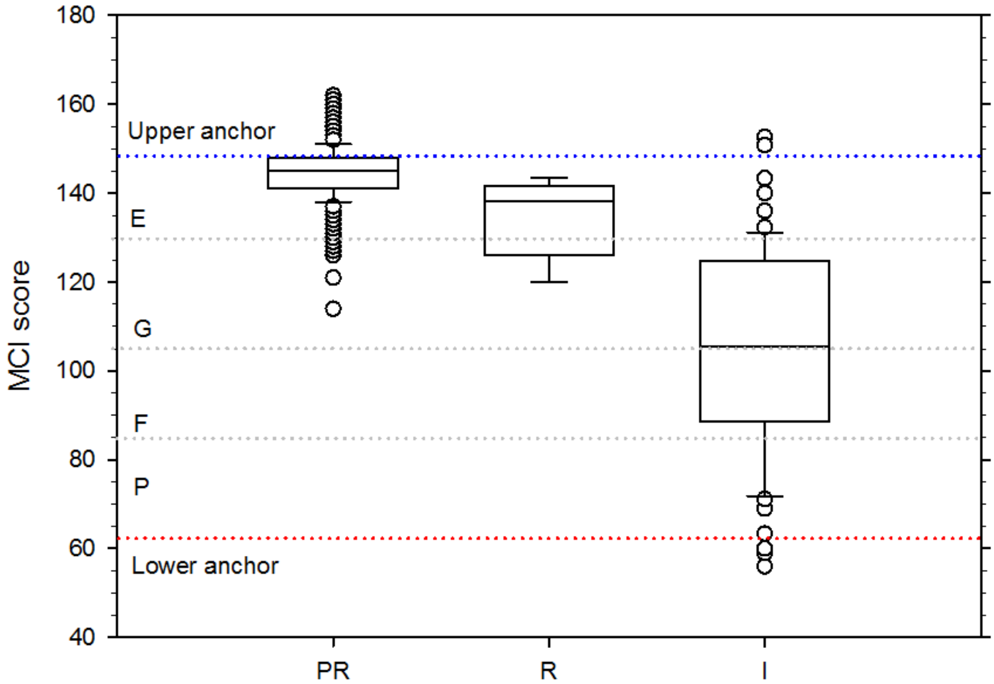


Figure 4.5: The range of MCI scores predicted for rivers and streams in class C5 in their natural state (PR, *n*=4,538) and measured at both reference sites (R, *n*=5) and impacted sites (I, *n*=69). Upper and lower anchor thresholds are shown as well as proposed thresholds for 'excellent' (E), 'good' (G), 'fair' (F) and 'poor' (P) categories

Table 4.4: Recommended MCI thresholds for FENZ classes C5, C1 and C6b

Macroinvertebrate health class	Threshold
Excellent	≥130
Good	105–129
Fair	85–104
Poor	<85

4.6 Thresholds for FENZ class C8

The lack of reference site data from rivers and streams in class C8 makes identification of thresholds difficult. There is one small stream in the eastern Wairarapa hill country that, based on GIS information, would meet the reference site criteria. However, due to the inaccessibility of this area, this stream has not yet been sampled. All other streams and rivers in this class are impacted by human activities and land use to some extent.

Based on the limited data available (*n*=13), streams and rivers in class C8 show a similar range in MCI scores to those in class C5 (Figure 4.6). Accordingly, the thresholds for these two classes are the same (Table 4.5).

Further sampling of rivers and streams in class C8 should be a high priority. Sampling is required across an impact gradient to enable greater confidence in the thresholds derived for this stream class.

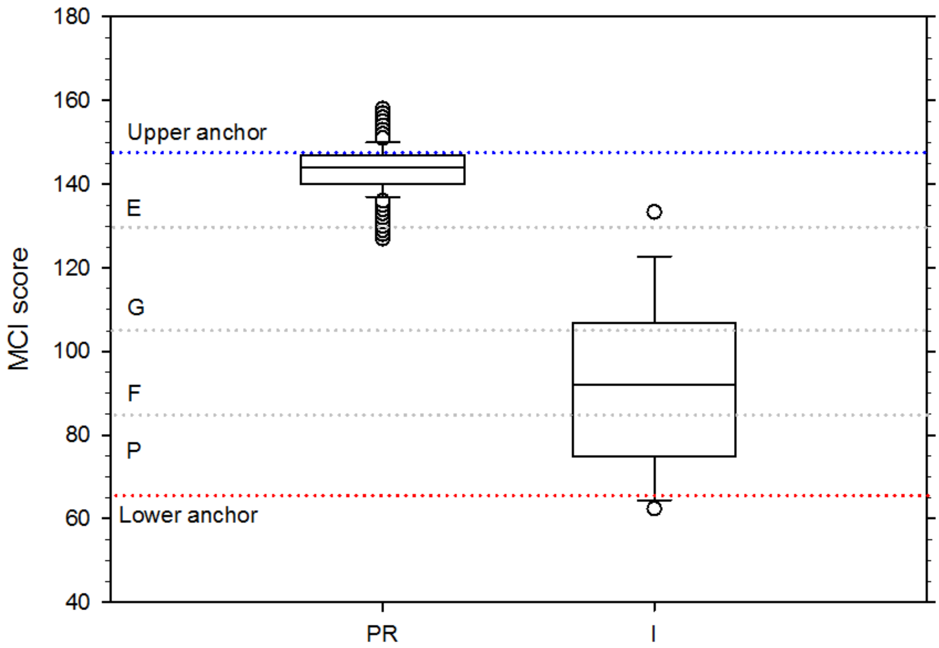


Figure 4.6: The range of MCI scores predicted for C8 rivers and streams in their natural state (PR, *n*=2,684) and measured at impacted sites (*n*=13). Upper and lower anchor thresholds are shown as well as proposed thresholds for 'excellent' (E), 'good' (G), 'fair' (F) and 'poor' (P) categories

Table 4.5: Recommended MCI thresholds for FENZ class C8

Macroinvertebrate health class	Threshold
Excellent	≥130
Good	105–129
Fair	85–104
Poor	<85

4.7 Thresholds for FENZ class C6c

There are no reference data for sites in class C6c as all examples of this stream type are significantly affected by human activities or land use. In addition, few data have been collected from impacted sites in this category.

Based on the limited data available, streams and rivers in class C6c show a relatively narrow range in MCI score with thresholds ranging across 35 MCI units from the 'excellent'/'good' boundary of 120 to the 'fair'/'poor' boundary of 85 (Figure 4.6, Table 4.6).

Collection of additional data from streams in this class should be a high priority to enable refinement of these thresholds.

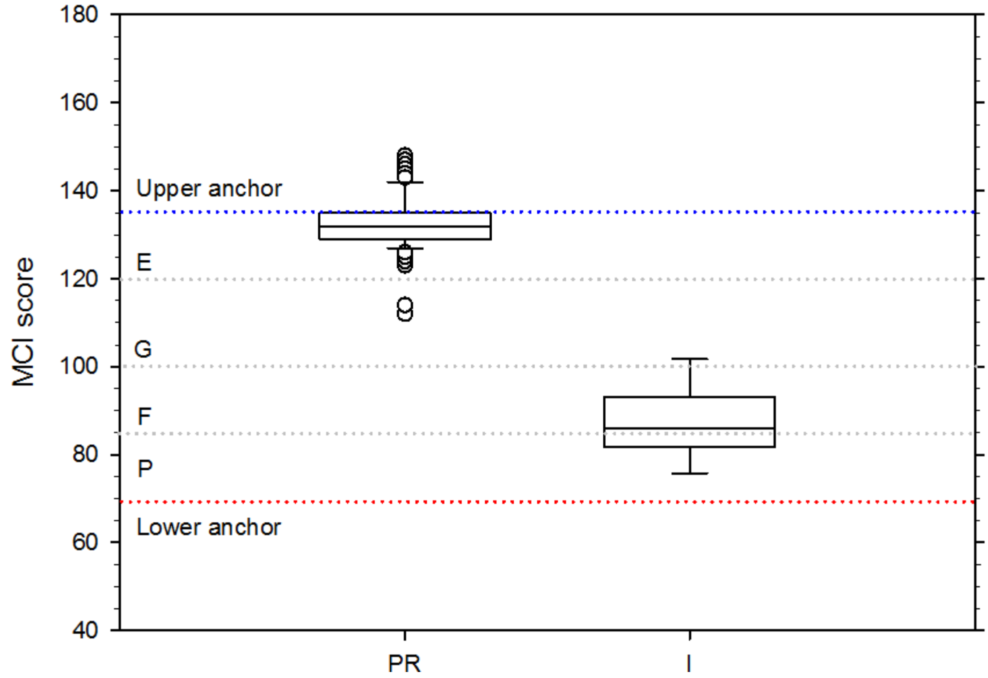


Figure 4.7: The range of MCI scores predicted for rivers in class C6c in their natural state (PR, *n*=289) and measured at impacted sites (I, *n*=7). Upper and lower anchor thresholds are shown as well as proposed thresholds for 'excellent' (E), 'good' (G), 'fair' (F) and 'poor' (P) categories

Table 4.6: Recommended MCI thresholds for FENZ class C6c

Macroinvertebrate health class	Threshold
Excellent	≥120
Good	100–119
Fair	85–99
Poor	<85

4.8 Thresholds for FENZ classes A and B

No reference site data are available for rivers and streams in class A. Based on GIS data there may be some sites that meet the criteria for reference condition in the western foothills of the Aorangi Range. However, these sites have yet to be sampled. In the meantime, the upper anchor for class A streams has been estimated from the 75th percentile of predicted natural MCI scores.

A high proportion of river and stream segments in class A are surrounded by intensive agricultural or urban land use and consequently the MCI scores measured at impacted sites in this class are typically low (Figure 4.8). Thresholds range over 40 MCI units from the 'excellent'/'good' boundary of 125 to the 'fair'/'poor' boundary of 85 (Table 4.7).

There are no data with which to identify MCI thresholds for streams in FENZ class B. However, as these streams are likely to be most physically similar to those in class A, the same thresholds are recommended until further information becomes available.

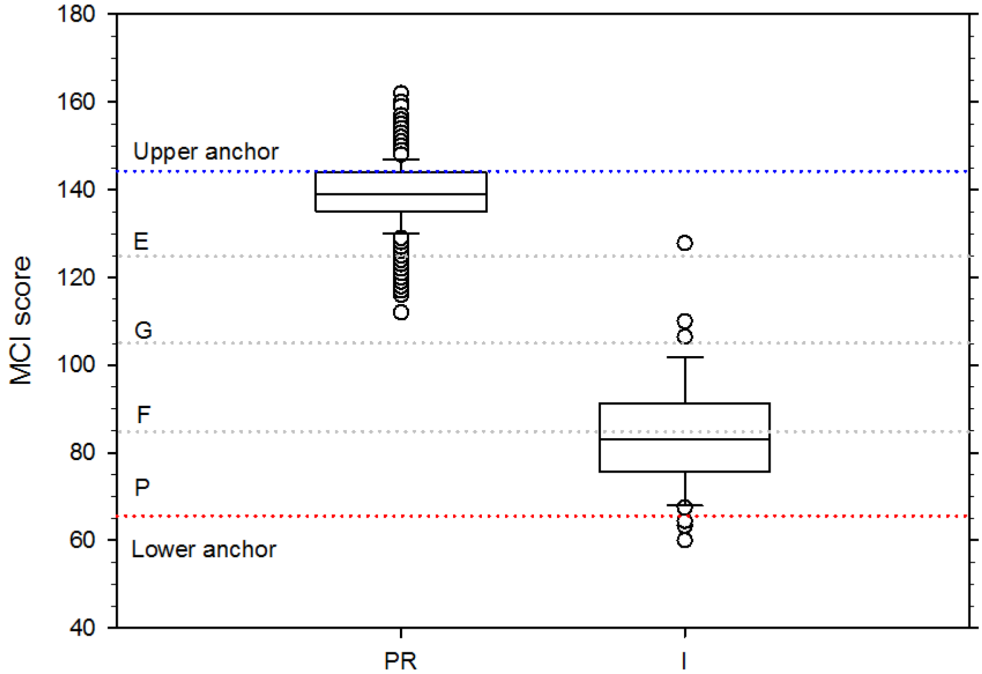


Figure 4.8: The range of MCI scores predicted for rivers in class A in their natural state (PR, *n*=4,248) and measured at impacted sites (*n*=48). Upper and lower anchor thresholds are shown as well as proposed thresholds for 'excellent' (E), 'good' (G), 'fair' (F) and 'poor' (P) categories

Table 4.7: Recommended MCI thresholds for FENZ classes A and B

Macroinvertebrate health class	Threshold
Excellent	≥125
Good	105–124
Fair	85–104
Poor	<85

4.9 Numeric outcomes for MCI

Using the 'excellent' and 'good' thresholds identified above as the numeric outcomes for 'significant' and 'healthy' levels of protection respectively the outcomes for MCI in Table 4.8 are recommended.

Table 4.8: Recommended MCI outcomes for 'significant aquatic ecosystem' and 'healthy aquatic ecosystem' levels of protection for FENZ classes in the Wellington region

FENZ class	Significant aquatic ecosystem outcome (Chl. *a* mg/m²)	Healthy aquatic ecosystem outcome (Chl. *a* mg/m²)
C7, C6a, C10 and UR	130	115
C5, C8, C6b and C1	130	105
C6c	120	100
A,B	125	105

5. Macroinvertebrate standards

Specific activities, such as point-source discharges, water abstraction or works in the bed of rivers and streams, can have a direct detrimental impact on macroinvertebrate communities. In this context, it is recommended that the Regional Plan define numeric thresholds relating to percent change in macroinvertebrate metrics that can be used to assess the effects of specific activities.

Whilst MCI is well suited to SoE reporting and the setting of management objectives or targets, QMCI is considered better adapted to direct comparisons between different sets of data collected to assess the effects of a specific activity, such as upstream/downstream comparisons. Because it is a quantitative rather than a qualitative index, the QMCI is considered less likely to be influenced by upstream macroinvertebrate communities[7], and more able to detect changes in community composition (Quinn 2009). Stark and Maxted (2007b) also maintain that QMCI (and SQMCI) are more suited to compliance monitoring than SoE monitoring.

A change of 20% in QMCI corresponds to a degree of change that is generally ecologically significant, can be statistically detected with an acceptable level of sampling effort and can be tested using relatively simple statistical methods (Stark 2010). This threshold is recommended as a maximum change that may occur as a result of an activity or a group of activities, either in space (eg, upstream/downstream comparison) or in time (before/after comparison). Because it is directly associated with the potential effects of identifiable activities, this threshold is well suited to be used as a standard in the Regional Plan.

Although good practice requires that macroinvertebrate communities be sampled following stable flow conditions, macroinvertebrate and trout live in the streams and rivers year-round, and at all flow conditions. Thus, this maximum change standard should apply at all times.

[7] In the context of upstream/downstream comparisons, downstream MCI is easily influenced by small numbers of macroinvertebrate species that may drift from the upstream site.

6. Supporting factors for macroinvertebrate health

In order for the macroinvertebrate metric outcomes proposed in Section 4 to be achieved GWRC's Regional Plan must include measures to manage the key environmental variables that affect macroinvertebrate community health. These are summarised in this section.

6.1 Instream temperature and dissolved oxygen

Water temperature is a fundamental variable in aquatic ecosystems which affects all facets of aquatic insect life-history and distribution. Sub-lethal increases in temperature can influence stream invertebrates by increasing growth rates, reducing longevity, and altering size and fecundity at emergence (Scarsbrook 2000). A national survey of invertebrates in New Zealand rivers found that stoneflies and mayflies were scarce where the maximum river temperatures exceeded 19 and 21.5°C, respectively (Quinn & Hickey 1990).

Dissolved oxygen is vital for life in rivers and streams. Low concentrations of dissolved oxygen can be a major stressor on aquatic life, including macroinvertebrates which depend on oxygen for their efficient functioning.

6.2 Nutrient concentration and periphyton biomass

The effect of nutrients on river and stream macroinvertebrate communities is largely indirect[8]. Nitrogen and phosphorus may stimulate instream plant growth where light, substrate and flow regime conditions are suitable. The presence of aquatic plant proliferations then acts to reduce the quality of instream habitat for macroinvertebrates. A change in benthic invertebrate community structure with increasing periphyton biomass has been a common observation in New Zealand streams (Biggs 2000). A significant (p<0.001) negative relationship was found between MCI score and periphyton biomass (as indicated by chlorophyll *a* concentration) data collected from RSoE sites between 2004 and 2012 (Greenfield 2014b).

The major sources of nutrient inputs to rivers and streams in the Wellington region are intensive agriculture and horticulture in rural areas (through both overland runoff and leaching through the soil profile into groundwater and streams) and sewer-stormwater cross connections in urban areas (Perrie et al. 2012).

6.3 Toxicants

There are a wide range of substances that are directly toxic to aquatic invertebrates including nitrate, ammonia, heavy metals, polycyclic aromatic hydrocarbons (PAHs), pesticides and herbicides. The major sources of toxicants to rivers and streams in the Wellington region include urban stormwater, agricultural runoff and municipal sewage discharges (Perrie et al. 2012).

Toxicants can have a range of sub-lethal effects on macroinvertebrates such as inhibition of growth or reproduction and can be lethal in high concentrations. Of the relatively few native macroinvertebrate species for which toxicological

[8] Nitrate-nitrogen can be directly toxic to some macroinvertebrate taxa at concentrations of 1 mg/L or higher (Hickey & Martin 2009).

sensitivity studies have been undertaken the crustacean *Paracalliope*, gastropod *Potamopyrgus* and the mayfly *Deleatidium* appear to be the most sensitive to ammonia and heavy metals (Hickey 2000). At the community level, metal pollution in streams has been shown to reduce abundance and species richness of mayflies, the number of EPT taxa and total taxonomic richness (Hickey 2000).

6.4 Habitat quality

Stream habitat quality is a critical factor in macroinvertebrate community health. The diversity of flow conditions such as riffles, runs and pools can affect the diversity and type of macroinvertebrate taxa present in a stream reach. Streambed particle size is another strong driver of the macroinvertebrate community in streams, with macroinvertebrate diversity and abundance greatest on cobble and boulder sized substrate (Death 2000). Fine sediments such as sand and silt are considered unsuitable for the majority of invertebrates apart from worms, molluscs, some midges and the burrowing mayfly *Ichthybotus hudsoni* (Parkyn et al. 2010). In their analysis of macroinvertebrate data from RSoE sites, Clapcott and Olsen (2010) found that the percentage of silt in the substrate was the single variable that was most highly correlated with macroinvertebrate community composition.

The amount of stream side vegetation and shade are also critical for macroinvertebrate community health; vegetation and shade regulate stream temperature and light availability and the vegetation provides a source of organic food for macroinvertebrates.

6.5 Water quantity and flow

Water depth and velocity are important predictors of macroinvertebrate species distribution with basic life-function requirements often driving preferences for particular flow conditions (Jowett 2000). Flow also affects macroinvertebrates indirectly by influencing substrate composition, water chemistry, the delivery rate of nutrients and organic particles, and habitat availability and suitability (Dewson et al. 2007a). Invertebrate community composition often changes in response to low or reduced flow. These changes probably are a result of increased habitat suitability for some species and decreased suitability for others (Dewson et al 2007a).

Dewson et al. (2007b) found that the effect of reducing instream width, velocity and depth on macroinvertebrate communities varied depending on water quality. The greatest effect occurred in pristine streams while no effect was observed in streams with poor water quality. This is likely to be due to the different sensitivity to changes in physical habitat of the invertebrate communities involved.

Climate and water abstraction are the main factors that affect flow and water velocity in rivers and streams. In the Wellington region, water is abstracted from rivers, streams and associated groundwater primarily for drinking water supply or irrigation (Keenan et al. 2012).

7. Summary and recommendations

The recommended approach for identification of attributes and numeric outcomes for macroinvertebrate community health is to select at least one metric from each of the four main types (composition/abundance, richness/diversity, sensitivity/tolerance and functional) based on correlation with key environmental variables that reflect the degree of human impact. Ideally relationships between macroinvertebrate metrics and the environmental gradient should be undertaken individually for each of the 11 FENZ classes in the Wellington region. Numeric outcomes for each FENZ class should then be identified by dividing the range of results available in each class evenly to identify thresholds for the ‘excellent’, ‘good’, ‘fair’ and ‘poor’ categories.

Currently, a lack of data across almost all FENZ classes, particularly reference data, means that it is not possible to use this approach to its full extent. In the interim, MCI is recommended as the sole attribute to represent macroinvertebrate community health based on its high correlation with environmental factors across the RSoE site network. Predicted reference MCI scores from a national model were used along with measured scores from across the region to estimate the range of MCI scores within each FENZ class and to identify MCI thresholds for the four categories. It is recommended that the ‘excellent’ threshold be used as the numeric outcome for rivers and streams identified as having significant indigenous ecosystem values in the RPS (GWRC 2013) and that the ‘good’ threshold should be used as the numeric outcome for all other rivers and streams in the region.

7.1 Recommendations for future work

The following work should be undertaken to allow greater representation of all main FENZ classes and to develop numeric outcomes for additional macroinvertebrate attributes:

- Collect macroinvertebrate samples from additional sites in FENZ classes C5, C8, C6c, A and B. Additional sampling from streams in class C5 should focus on reference sites while sampling in all other classes should be across the entire impact gradient. Enough additional sites should be sampled to bring the total number of sites sampled in each class to 30 (apart from class B where 5 sites will be sufficient as streams are of limited extent).

- Investigate the possibility of using macroinvertebrate data from sites in the Hawke’s Bay and Manawatu/Wanganui regions where FENZ classes are shared. Data sharing would be particularly useful where reference site data are available.

- Where available, use estimates of reference condition for additional macroinvertebrate indicators from national models to allow inclusion of a greater range of macroinvertebrate indicators. If multiple macroinvertebrate indicators are identified the possibility of a single multi-metric index should be investigated.

- Undertake further assessment to identify which streams in the Wellington region have naturally soft substrate. Streams with naturally soft substrate should then be assessed using the soft bottomed variant of the MCI.

- Undertake further analysis of the precision of the methods for macroinvertebrate sampling and analysis methods to identify confidence limits around the thresholds identified for each macroinvertebrate indicator. This analysis should be undertaken either using existing data or by collecting additional replicate samples at selected sites.

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Appendix 1: Macroinvertebrate sampling sites

Project ID	Site ID	Site name	FENZ class	Site type	NZTM Easting	NZTM Northing
RSoE	RS01	Mangapouri Stream at Rahui Rd	A	I	1783373	5484901
RSoE	RS02	Mangapouri Stream at Bennetts Rd	A	I	1780903	5487645
RSoE	RS03	Waitohu Stream at Forest Park	C7	R	1787593	5483689
RSoE	RS04	Waitohu Stream at Norfolk Crescent	C6c	I	1779537	5488304
RSoE	RS05	Otaki River at Pukehinau	C7	R	1785426	5478749
RSoE	RS06	Otaki River at Mouth	C6a	I	1777982	5485886
RSoE	RS07	Mangaone Stream at Sims Road Bridge	C6c	I	1776242	5482407
RSoE	RS08	Ngarara Stream at Field Way	A	I	1771180	5474620
RSoE	RS09	Waikanae River at Mangaone Walkway	C5	I	1779974	5473638
RSoE	RS10	Waikanae River at Greenaway Rd	C6a	I	1771223	5472915
RSoE	RS11	Whareroa Stream at Waterfall Rd	C5	I	1768074	5464532
RSoE	RS12	Whareroa Stream at QE Park	A	I	1765976	5464400
RSoE	RS13	Horokiri Stream at Snodgrass	C6b	I	1761804	5450653
RSoE	RS14	Pauatahanui Stream at Elmwood Bridge	C5	I	1761097	5446783
RSoE	RS15	Porirua Stream at Glenside Overhead Cable	C5	I	1753289	5438364
RSoE	RS16	Porirua Stream at Milk Depot	C5	I	1754366	5443031
RSoE	RS17	Makara Stream at Kennels	C5	I	1743530	5433635
RSoE	RS18	Karori Stream at Makara Peak Mountain Bike Pk	C5	I	1744212	5426874
RSoE	RS19	Kaiwharawhara Stream at Ngaio Gorge	C5	I	1749069	5431077
RSoE	RS20	Hutt River at Te Marua Intake Site	C7	I	1780071	5450158
RSoE	RS21	Hutt River Opposite Manor Park Golf Club	C6a	I	1766679	5442285
RSoE	RS22	Hutt River at Boulcott	C6a	I	1760858	5437486
RSoE	RS23	Pakuratahi River 50m Below Farm Creek	C7	I	1784607	5451677
RSoE	RS24	Mangaroa River at Te Marua	C7	I	1778543	5448643
RSoE	RS25	Akatarawa River at Hutt Confluence	C7	I	1776183	5449184
RSoE	RS26	Whakatiki River at Riverstone	C6a	I	1772256	5446747
RSoE	RS27	Waiwhetu Stream at Wainui Hill Bridge	A	I	1760565	5434141
RSoE	RS28	Wainuiomata River at Manuka Track	C7	R	1768242	5430634
RSoE	RS29	Wainuiomata River Upstr of White Bridge	C6a	I	1757316	5415724
RSoE	RS30	Orongorongo River at Orongorongo Station	C7	I	1758930	5413094
RSoE	RS31	Ruamahanga River at McLays	C7	R	1818149	5485809
RSoE	RS32	Ruamahanga River at Te Ore Ore	C6a	I	1825574	5463019
RSoE	RS33	Ruamahanga River at Gladstone Bridge	C6a	I	1821208	5450327
RSoE	RS34	Ruamahanga River at Pukio	C6a	I	1797832	5431010
RSoE	RS35	Mataikona tributary at Sugar Loaf Rd	C5	I	1871844	5490906
RSoE	RS36	Taueru River at Castlehill	C8	I	1852300	5484198
RSoE	RS37	Taueru River at Gladstone	C8	I	1824148	5450815
RSoE	RS38	Kopuaranga River at Stewarts	C6c	I	1826761	5469569
RSoE	RS39	Whangaehu River at 250m from Confluence	C8	I	1826267	5459407
RSoE	RS40	Waipoua River at Colombo Rd Bridge	C6a	I	1825018	5462890
RSoE	RS41	Waingawa River at South Rd	C6a	I	1820716	5460649
RSoE	RS42	Whareama River at Gauge	C6c	I	1856090	5461229
RSoE	RS43	Motuwaireka Stream at headwaters	C5	I	1852017	5450302
RSoE	RS44	Totara Stream at Stronvar	C5	I	1848025	5444916
RSoE	RS45	Parkvale tributary at Lowes Reserve	A	I	1818094	5458352
RSoE	RS46	Parkvale Stream at weir	C6c	I	1813515	5449469
RSoE	RS47	Waiohine River at Gorge	C7	R	1801889	5455995
RSoE	RS48	Waiohine River at Bicknells	C6a	I	1810615	5448099
RSoE	RS49	Beef Creek at headwaters	C7	R	1803963	5456398
RSoE	RS50	Mangatarere Stream at State Highway 2	C6a	I	1809768	5452160
RSoE	RS51	Huangarua River at Ponatahi Bridge	C6a	I	1807009	5435213
RSoE	RS52	Tauanui River at Whakatomotomo Rd	C7	R	1790648	5414515
RSoE	RS53	Awhea River at Tora Rd	C6c	I	1809951	5403289
RSoE	RS54	Coles Creek tributary at Lagoon Hill Rd	C8	I	1814020	5415217
RSoE	RS55	Tauherenikau River at Websters	C6a	I	1797082	5439942

Project ID	Site ID	Site name	FENZ class	Site type	NZTM Easting	NZTM Northing
RSoE	RS56	Waiorongomai River at Forest Park	C7	R	1779604	5430559
HRSoE	FB23	Hutt River at Birchville Canoe Club	C6a	I	1776180	5449084
HRSoE	FB18	Karori Stream Below Confluence With Sth Mak	C5	I	1740951	5425286
HRSoE	FB27	Mangaroa River at Kalcoolies Corner	C7	I	1773093	5438557
HRSoE	FB21	Ngauranga Stream 400m Above Mouth	C5	I	1751929	5432617
HRSoE	FB14	Ohariu Stream 50m above Makara Stream	C5	I	1744117	5433321
HRSoE	FB19	Owhiro Stream at Mouth	C5	I	1747104	5421529
HRSoE	FB37	Ruamahanga River at Double Bridges	C6a	I	1824387	5471781
HRSoE	FB40	Ruamahanga River at Waihenga Bridge	C6a	I	1804671	5436467
HRSoE	FB33	Wainuiomata River at Golf Course	C6a	I	1762084	5425649
HRSoE	FB32	Wainuiomata River at Leonard Wood Park	C6a	I	1763060	5427853
HRSoE	FB10	Horokiri Stream at Ongly	C6b	I	1761188	5449882
HRSoE	FB25	Hutt River u/s Melling Bridge	C6a	I	1760579	5437286
HRSoE	FB36	Ruamahanga River at Mt Bruce	C7	I	1820931	5483375
HRSoE	FB08	Waikanae River at Oxbow Boat Ramp	C6a	I	1769682	5472885
HRSoE	FB06	Waikanae River at Reikorangi Bridge	C7	I	1775382	5469985
HRSoE	FB01	Waitohu Stream at Water Supply Intake	C7	I	1786883	5484686
PM	PM1	Mangatarere Stream at Road End	C7	R	1806170	5464053
PM	PM2	Mangatarere Stream at Gorge	C7	I	1811484	5465442
PM	PM3	Mangatarere Stream at Belvedere Road	C6a	I	1811047	5456808
PM	PM4	Hinau Stream at Hinau Gully Road	C7	I	1810120	5461005
PM	PM5	Enaki Stream at Belvedere Road	C6a	I	1809643	5457736
PM	PM6	Kaipaitangata Stream at Dalefield Road	C6a	I	1809327	5454528
PM	PM7	Mangatarere Stream at Dalefield Road	C6a	I	1810012	5453960
PM	PM8	Mangatarere Stream at State Highway 2	C6a	I	1809779	5452134
PM	PM9	Beef Creek at State Highway 2	C8	I	1809836	5451891
RIP	RIP1	Enaki downstream	C6a	I	1809931	5455465
RIP	RIP2	Kakariki Downstream	A	I	1773211	5475132
RIP	RIP3	Kakariki reference	A	I	1774047	5474257
REC	ABB	Akatarawa River	C7	I	1777415	5452199
REC	BM1	Mangatarere Trib	C7	R	1806220	5463978
REC	BM2	Mangatarere stream	C7	I	1809465	5465531
REC	BM3	Kaipaitangata	C7	I	1805673	5459189
REC	BM4a	Kaipaitanga Stream	C6a	I	1809345	5454487
REC	BO1	Pukeatua Stream	C7	R	1788153	5474066
REC	BO2	Waiatapia Stream	C7	R	1788465	5473488
REC	BO3	Waiotauru River	C7	R	1787378	5471832
REC	BO4	Otaki Stream	C7	I	1786156	5478084
REC	WBA	Wainuiomata River	C7	R	1768301	5430758
REC	PG5	Wainuioru	C8	I	1831679	5444591
REC	TGC2	Waipawa Stream Trib	C8	I	1836268	5461267
REC	WGA	Whangaehu River	C8	I	1833898	5468058
REC	PM1	Hinau Rd Stream	C7	I	1808779	5462387
REC	PM2	Hururua Rd Stream	C7	I	1811036	5462934
REC	PM3	Mangatarere Stream	C7	R	1806260	5463926
REC	PM4	Mangatarere Stream	C7	R	1807381	5465031
REC	PM5	Mangatarere Stream	C7	R	1811413	5464950
REC	PM6	Kaipaitangata Trib	C7	I	1807633	5456866
REC	HRC	Horokiri stream	C6b	I	1762980	5451807
REC	MRD	Mangaroa River	C7	I	1772134	5437988
REC	PR1	Rockhill Rd Stream	C5	I	1833489	5437711
REC	PR2	Opunake Stream	C7	I	1831612	5436193
REC	PR5	Oamukura Trib	C7	I	1832468	5433802
REC	RM1	Mangatarere Stream	C6a	I	1812751	5458559
REC	RM2	Tea Creek	C8	I	1813442	5465350
REC	RM3	Enaki Stream	C6a	I	1809652	5459036
REC	WRA	Waitohu Stream	C5	I	1787001	5484721

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REC	WRB	Waikane River	C7	I	1775354	5469906
Urban	ARSL	Airlie Road Stream	A	I	1756180	5451586
Urban	BL	Black Stream lower	C8	I	1763577	5429374
Urban	BU	Black Stream upper	A	I	1763253	5434120
Urban	CH	Charthouse St Stream	A	I	1758962	5446980
Urban	CSL	Collins Stream lower	C7	I	1778980	5448484
Urban	CSU	Collins Stream upper	C7	R	1780726	5446749
Urban	DCL	Duck Creek	A	I	1759480	5447486
Urban	FS2	Porirua Stream mid	A	I	1753816	5442500
Urban	GRE	Grenada Stream at Seton Nossit	C5	I	1752538	5436093
Urban	GRE1	Grenada Stream tributary	C5	I	1752842	5435969
Urban	HAR	Harbourview Stream	C5	I	1759769	5436833
Urban	ITI	Wainuiomataiti Stream	C5	I	1765444	5434549
Urban	ITI1	Wainuiomataiti tributary	C5	I	1765423	5434879
Urban	K1	Kaiwharawhara Stream lower	C5	I	1749760	5430934
Urban	K2	Kaiwharawhara Stream lower	C5	I	1748466	5431045
Urban	K3	Kaiwharawhara Stream mid	C5	I	1747040	5430167
Urban	K4	Kaiwharawhara Stream mid	C5	I	1746779	5429553
Urban	K5	Kaiwharawhara Stream upper	C5	I	1746821	5427625
Urban	K6	Kaiwharawhara Stream upper	C5	R	1745694	5426213
Urban	KAR1	Karori Stream upper	C5	I	1744865	5428053
Urban	KAR2	Karori Stream upper	C5	I	1744377	5427937
Urban	KAR3	Karori Stream mid	C5	I	1744080	5426291
Urban	KEN	Kenepuru tributary	A	I	1757493	5444727
Urban	Ken1	Kenepuru Stream	A	I	1755231	5444592
Urban	Ken2	Kenepuru Stream	A	I	1756020	5444758
Urban	KM1	Korimako Stream	C5	I	1747418	5431713
Urban	KOR1	Korokoro Stream upper	C5	I	1758570	5439525
Urban	KOR2	Korokoro Stream lower	C5	I	1755985	5435261
Urban	KOR3	Korokoro Stream lower	C5	I	1756005	5434797
Urban	KSW	Kakariki Stream	A	I	1774082	5474085
Urban	KT1	Kaiwharawhara (upper) tributar	C1	I	1749765	5433139
Urban	Mit1	Mitchell Stream	C5	I	1753381	5443363
Urban	Mit2	Mitchell Stream	C5	I	1754406	5443133
Urban	MSO	Mangapouri Stream	A	I	1780683	5487186
Urban	N1	Ngauranga Stream upper	C5	I	1751333	5433178
Urban	N2	Ngauranga Stream lower	C5	I	1751928	5432706
Urban	OWH1	Owhiro Stream upper	C5	I	1747426	5424948
Urban	OWH2	Owhiro Stream lower	C5	I	1747254	5421631
Urban	P1	Porirua Stream lower	A	I	1754686	5444669
Urban	P1A	Porirua Stream lower	A	I	1754343	5443058
Urban	P3	Porirua Stream mid	A	I	1753371	5441490
Urban	P4	Porirua Stream mid	C5	I	1753329	5440795
Urban	P5	Porirua Stream upper	A	I	1753283	5438304
Urban	P6	Porirua Stream upper	A	I	1751927	5436311
Urban	PHU	Pinehaven Stream	C5	I	1768850	5440493
Urban	SC	Skerrets Creek	C7	R	1765018	5428658
Urban	SP1	Speedys Stream	C5	I	1761585	5438451
Urban	SSL	Silverstream lower	A	I	1768379	5442885
Urban	SSU	Silverstream upper	A	I	1770379	5443085
Urban	SVL	Stokes Valley Stream lower	C5	I	1766486	5441257
Urban	SVU	Stokes Valley Stream upper	C5	I	1766585	5437728
Urban	TCP	Tikotu Creek	A	I	1767782	5471185
Urban	TIR	Tirohanga Stream at Avonlea St	C5	I	1760068	5437736
Urban	Train1	Kaiwharawhara (mid) tributary	A	I	1748841	5432330
Urban	W1	Waiwhetu Stream lower	A	I	1760498	5433574
Urban	W2	Waiwhetu Stream lower	A	I	1760595	5433936

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Urban	W3	Waiwhetu Stream lower	A	I	1760894	5434252
Urban	W4	Waiwhetu Stream mid	A	I	1761128	5434708
Urban	W5	Waiwhetu Stream mid	A	I	1762207	5435729
Urban	W6	Waiwhetu Stream upper	A	I	1762833	5436559
Urban	W7	Waiwhetu Stream upper	A	I	1763208	5436560
Urban	W8	Waiwhetu Stream upper	C5	I	1764826	5436898
Urban	WS	Wainuiomata River	C7	R	1766141	5429278
Urban	WPB	Waimapehi Stream	C1	I	1758859	5456242
Urban	WSP	Wharemauku Stream	A	I	1767190	5468775
Urban	MK1	Makoura Stream 1	A	I	1823240	5464139
Urban	MK2	Makoura Stream 2	A	I	1824123	5461918
Urban	MK3	Makoura Stream 3	A	I	1825008	5460730
Urban	KP1	Kuripuni Stream 1	A	I	1822000	5463038
Urban	KP2	Kuripuni Stream 2	A	I	1823054	5462416
Urban	KP3	Kuripuni Stream 3	A	I	1823840	5460843
Urban	LH1	Landsdown Stream 1	A	I	1824982	5464854
Urban	LH2	Landsdown Stream 2	A	I	1825057	5463897
Urban	T1	Tilson Creek	A	I	1807414	5449128
Urban	PW1	Papawai Stream 1	A	I	1805143	5449966
Urban	PW2	Papawai Stream 2	A	I	1806428	5449100
Urban	PW3	Papawai Stream 3	A	I	1807236	5448034
Urban	B1	Boat Creek	C6c	I	1795944	5445303
Urban	A1	Abbots Creek	C7	R	1793127	5447007
Massey	Well1	Waitohu	C7	R	1788483	5482785
Massey	Well2	Waitohu	C6a	I	1782983	5486386
Massey	Well3	Otaki River	C7	I	1785661	5479806
Massey	Well4	Otaki River	C7	R	1786182	5470184
Massey	Well5	Otaki River	C7	R	1791160	5475009
Massey	Well6	Tauwera River	C5	I	1846643	5475529
Massey	Well7	Wainuiomapu Stream/Tauweru River	C8	I	1842192	5476280
Massey	Well8	Tauweru River/Raumahanga R	C8	I	1840991	5472779
Massey	Well12	Mangaterere/Waipoua River/Raumahanga R	C7	R	1805423	5459281
Massey	Well13	Raumahanga R	UR	R	1800683	5460982
Massey	Well15	Waiohine/Raumahanga R	C7	R	1809885	5473383
Massey	Well16	Otaki River	C7	R	1788083	5473884
Massey	Well17	Karori	C5	I	1740979	5425189
Massey	Well18	South Makara/Karori	C5	I	1740679	5425789
Massey	Well19	South Makara/Karori	C5	I	1742978	5425689
Massey	Well20	Oteranga Stream	C5	I	1737279	5427989
Massey	Well21	Oteranga Stream	C5	I	1736979	5428289
Massey	Well22	Puatahanui Stream	C5	I	1764680	5447185
Massey	Well23	Te Oneopoto Bay	A	I	1755580	5447886
Massey	Well24	Akatarawa/Hutt	C8	R	1775445	5453084
Massey	Well25	Waikanae	C5	R	1780082	5473785
Massey	Well26	Waikanae	C5	I	1769481	5462485
Massey	Well27	Hutt/Akatarawa/Whakaitikei	C7	R	1770281	5456985
Massey	Well28	Wareroa stream	A	I	1766231	5464368
Massey	Well29	Wainui Steam	C5	I	1765381	5459985
Massey	Well30	Taupo Stream	C5	I	1757481	5453086
Massey	Well31	Tauherenikau River	C7	R	1789280	5450983
Massey	Well32	Pakuratahi/Hutt	C7	I	1785680	5450283
Massey	Well33	Whakatikei/Hutt	C5	R	1771005	5450238
Massey	Well34	Mangaroa/Hutt	C7	I	1778079	5442784
Massey	Well35	Tauherenikau River	C7	R	1797681	5452282
Massey	Well36	Orongorongo	C7	R	1770957	5426105
Massey	Well37	Orongorongo	C7	R	1770077	5426085
Massey	Well38	Orongorongo	C7	R	1772377	5431185

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Massey	Well39	Lake Wairarapa	C7	R	1790980	5446782
Massey	Well40	Lake Wairarapa	C7	R	1778177	5431221
Massey	Well41	Ngakauau Stream	C5	I	1866198	5465972
Massey	Well42	Whareama River	C8	I	1866600	5476176
Massey	Well43	Whakataki River	C5	I	1869400	5471173
Massey	Well44	Castlepoint Stream	C5	I	1868399	5468573
Massey	Well45	Wainuioru River	C5	I	1834984	5442873
Massey	Well46	Pahaoa/Wainuioru	C5	I	1837683	5436032
Massey	Well47	Huatokitoki Stream	C5	I	1840981	5427769
Massey	Well48	Waihingaia Stream	C5	I	1834277	5417570
Massey	Well49	Kaiwhata River	C5	I	1843984	5436570
Massey	Well50	Motuwaireka Stream	C5	I	1855190	5449670
Massey	Well51	Pounui/Onoke	C7	R	1775276	5423184
Massey	Well52	Pounui/Onoke	C6a	I	1777775	5420984
Massey	Well53	Mukamukaiti	C1	I	1765775	5415722
Massey	Well54	Wharepapa River	C7	R	1773676	5421385
Massey	Well55	Wharepapa River	C7	R	1772686	5420811
Massey	Well56	Mukamuka Stream	C7	I	1767775	5416986
Massey	Well57	Corner reek	C1	I	1770775	5418685
Massey	Well58	Otakaha Stream	C7	R	1791370	5399481
Massey	Well59	Otakaha Stream	C7	R	1789570	5399082
Massey	Well60	Mangatoetoe stream	C7	R	1789169	5394982
Massey	Well61	Poley Stream	C7	R	1796871	5403080
Massey	Well62	Whawanui	C7	R	1795375	5400370
Massey	Well63	Oterei -unnamed trib	C5	R	1816473	5409074
Massey	Well64	Waikanae River	C7	R	1779482	5466884
Massey	Well65	Hutt River	C7	I	1775481	5463081
Massey	Well66	Waikanae/Reikorangi Stream	C5	I	1775181	5466185
Massey	Well67	Bull/Akatarawa/Hutt	C7	R	1777781	5463584
Massey	Well68	Akatarawa/Hutt	C7	I	1778481	5458984
Massey	Well69	Orongorongo River	C7	R	1765276	5421486
Massey	Well70	Catchpool stream	C7	I	1761087	5420574
Massey	Well71	Burlings stream	C7	I	1780978	5433483
Massey	Well72	Motuwaireke River	C5	I	1851989	5450348
Massey	Well73	Atiwhakatu/Waingawa/Ruamahanga	C10	R	1806348	5470613
Massey	Well74	Waingawa/Ruamahanga	C7	R	1806450	5470783
Massey	Well75	Wharekauhau stream	C5	I	1771875	5419585
Massey	Well76	Bocketts stream	C7	R	1783678	5435883
Massey	Well77	Cross Creek	C7	R	1785979	5440183
Massey	Well78	Turanganui River	C7	I	1789226	5411882
Massey	Well79	Putangirua Stream	C5	I	1789274	5414582
Massey	Well84	Ngarara Creek	A	I	1773582	5471885
Massey	Well85	unnamed trib	C7	R	1783279	5445283
Massey	Well86	Pakuratahi River	C7	I	1783237	5445631

R = reference, I = impacted.