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HAWKE'S BAY REGIONAL COUNCIL

SAFEGUARDING YOUR ENVIRONMENT + KAITIAKI TUKU IHO

Aropaoanui and Waikari Catchments

Surface Water Quality and Ecology State of the Environment Report

4 September 2009
EMT 09/28
HBRC Plan No 4156

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SAFEGUARDING YOUR ENVIRONMENT + KAITIAKI TUKU IHO

Resource Management Group
Technical Report

Environmental Science

Aropaoanui and Waikari Catchments State of the Environment Report 2009

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EXECUTIVE SUMMARY

Hawke's Bay Regional Council (HBRC) monitors water quality and river flow at a number of points across the Aropaoanui and Waikari Catchments of the Hawke's Bay Region and has produced a comprehensive report on the state and trends of water quality for sites within these catchments, based on data collected between 1998 and 2003 using the river environment classification (REC) (Stansfield 2004).

The present report provides a further update of the Aropaoanui and Waikari River catchments. Unlike the previous state of the environment report this report does not investigate water quality and ecology of historical sites, rather it only investigates the four sites that are currently monitored (Aropaoanui and Waikari Rivers and Mahiaruhe Stream and Sandy Creek). Furthermore the 2009 reporting is based on a catchment by catchment basis as opposed to the previous report that grouped sites according to the river environment classification only. This report forms part of a series of reports that have been prepared for Council's 2009 state of the environment summary.

The Aropaoanui and Waikari River catchments have been grouped together owing to their similar REC type (warm low elevation pastoral streams) and close proximity to each other. All sites are from a warm wet climate type except the Waikari River which is a warm dry type. Three sites fall within the Aropaoanui Catchment (Aropaoanui River, Sandy Creek and Mahiaruhe Stream) while the remaining site (Waikari) is in a separate catchment of its own.

The aim of this study is to analyse the water quality and biomonitoring data collected by HBRC between 1983 and 2008. In particular, the study aims to investigate the following points:

- the state of the rivers and streams
- compliance of the sites with relevant guidelines that are stipulated in either the regional resource management plan (RRMP), the resource management act (RMA) or ANZECC (Australia and New Zealand Environment and Conservation Council) guidelines
- temporal trends, *i.e.* are the water quality or the ecological indicators getting better or worse over time?;

This report also makes recommendations for future water quality monitoring and management in these catchments.

Mean macroinvertebrate community index (MCI) values for the Aropaoanui River, Sandy Creek and Waikari River all reflect possible mild enrichment while the Mahiaruhe Stream reflects poor water quality. The Mahiaruhe Stream also shows poor habitat quality. Unique features of this site that give rise to the poor habitat include bank instability, channel instability and lack of complexity and stable bottom substrate availability. It is likely that these habitat variables play some role in giving rise to poor quality macroinvertebrate communities at this site. Interestingly it is likely that these same habitat variables are also responsible for providing a mobile silty substrate which has resulted in this site having the lowest periphyton biomass. Compliance with the periphyton chlorophyll a guideline is generally good to excellent at all sites.

Compliance with environmental guidelines is excellent at all sites for DIN, pH for native fish and trout tolerance, ammoniacal nitrogen, suspended sediments, *E. coli* (for bathing river sites) and water temperature.

For the contact recreation sites (the Aropaoanui and Waikari rivers) compliance is generally excellent with the *E. coli* and clarity guidelines. Faecal coliform concentrations also show excellent compliance at the river sites but is poor at Sandy Creek.

For many variables compliance is better at the larger volume sites this is particularly so for DRP (average compliance at Rivers, poor compliance at Sandy Creek), faecal coliforms (excellent compliance at rivers, poor compliance at Sandy Creek) and % saturation dissolved oxygen (excellent compliance at river sites, good compliance at Sandy Creek and Mahiaruhe Stream). It is likely that the smaller water courses provide less dilution to the contaminants they receive which results in higher concentrations of nutrients and bacteria, and lower dissolved oxygen concentrations.

Water clarity readings show poor compliance with the 3.5 m guideline for trout foraging which could indicate that these guidelines are either too stringent or possibly not suitable for these stream types. Further research of trout energetic modelling is likely to refine these guidelines to meet river types more accurately in the future.

DRP concentrations show a slight decline with lower flows however the concentrations are relatively stable irrespective of flow category. It is possible that nutrient rich groundwater inputs may be playing a role in these rivers and streams that ensures that nutrient concentrations remain stable for this variable. All sites show increasing DIN concentrations with increased flow suggesting that nutrient mobilisation during storm events plays a large role in elevating nutrient concentrations at these sites.

As indicated earlier nutrient concentrations are generally higher in the smaller streams, which could be a result of less nutrient attenuation from incoming contaminants. This is because nutrient yields at source are higher than they are further down the catchment due to nutrient attenuation (e.g. Uptake and removal of nutrient by plants, dentification and phosphorus binding in the sediments and removal, etc). The DRP and DIN yield analysis certainly supports this hypothesis showing that Sandy Creek has significantly higher yield than the river sites when examined on a year by year basis (see Appendix 4).

The nutrient limitation analysis shows that the sites are often phosphorus limited, colimited or in a state where it could be either nitrogen or phosphorus limitation. The general pattern of the data suggests that N limitation is more likely to occur during lower flow events (i.e. summer), which possibly suggests some seasonality of nutrient limitation. Nutrient limitation analysis using nutrient agar bioassays would help confirm this.

E. coli concentrations are generally stable irrespective of flow category at most sites. The reason for this pattern is unclear. *E. coli* concentrations are generally higher at the stream sites while water clarity at these sites is generally lower when compared to the river sites. It is likely that higher sediment concentrations in the smaller streams provide for higher bacteria concentrations. Water clarity declines with increasing flows at all sites suggesting that both runoff and streambed mobilisation contribute to raising suspended sediments and decreasing clarity.

TOC concentrations are generally higher at higher flows indicating that much of the organic matter within these catchments is derived from runoff inputs received during storm events. Concentrations are generally higher at the Sandy Creek and Waikari River sites. The reason for this is unclear and may warrant further investigation. Percent saturation dissolved oxygen concentrations at the river sites is generally good to excellent indicating that current levels of organic matter entering these streams is insufficient to degrade oxygen concentrations in them.

Comparison with national median values indicates that all sites compare favourably in terms of DIN and water clarity while comparison with the national DRP median and *E. coli* 95^{th} percentile indicates that only the smaller streams (Sandy Creek and Mahiaruhe Stream) have higher concentrations.

Temporal trend analysis suggests that DRP concentrations are increasing at Sandy Creek and Aropaoanui River. *E. coli* concentrations are also increasing at Sandy Creek. The reason for these temporal trends is currently unclear. Further research into the catchment sensitivities of land use pressures using computer modelling would enable us to understand why these patterns are emerging. No temporal trends have been observed in terms of the in-stream biology as measured by the MCI and Chl a concentrations.

The contaminant loading analysis shows that while DRP loadings are highest at the Aropaoanui River and Waikari Rivers, DRP yield is comparatively high at Sandy Creek particularly when examined on a year by year basis (see Appendix 4).

DIN loading analysis shows that while loadings are highest at the Waikari and Aropaoanui Rivers, the yields are comparatively high at Sandy Creek particularly when examined on a year by year basis. Again the reason for this is unclear and further research of land use and sensitivity of catchments using computer models would help determine why these patterns are occurring.

There are number of spatial and temporal trends that have been presented in this state of the environment report and further research would be required to help elucidate why some of these trends are occurring. More research is required on land use pressures and catchment sensitivities to them using computer modelling using CLUES (catchment land use for environmental sustainability) to help elucidate these trends.

Table of Contents

1.0 **Introduction**

Hawke's Bay Regional Council (HBRC) monitors water quality and river flow at a number of points across the the Hawke's Bay Region and has produced a comprehensive report on the state and trends of water quality for sites within these catchments, based on data collected between 1998 and 2003 using the river environment classification (REC) (Stansfield 2004).
The present report provides a further update of the Aropaoanui and Waikare Catchments.

1.1 **Aim and scope of the study**

The aim of this study is to analyse the water quality and biomonitoring data collected by HBRC between 1978 and 2008. In particular, the study aims at investigating the following points:

- the state of the rivers and streams
- compliance of the sites with relevant guidelines that are stipulated in either the regional resource management plan (RRMP), the resource management act (RMA) or ANZECC (Australia and New Zealand Environment and Conservation Council) guidelines
- temporal trends, *i.e.* are the water quality or the ecological indicators getting better or worse over time?;
- the annual contaminant loadings within these rivers and streams

This report also makes recommendations for future water quality monitoring and management in these catchments.

2.0 METHODS

2.1 **Original dataset**

A complete extract of HBRC's water quality data for the sites were obtained from HBRC's PUDDLE water quality database. There are currently 3 sites within the Aropaoanui Catchment, namely Sandy Creek monitored since 1995, the Mahiaruhe Stream monitored since 2000 and the Aropaoanui River monitored since 1995. North of Tutira lies the Waikare River, which has been monitored since 2000 at Glenbrook Road in the lower catchment.

Average daily flow at each site for each day of sampling was obtained, either by direct measurement or by correlation with a flow recorder site.

2.2 **Water quality data preparation**

The dataset contained a small proportion of "less than detection limit" results. To conduct statistical analysis, such "censored" data should be replaced by numerical values. The "less than" values represented less than 10% of the total dataset for each parameter and were replaced by half of the detection limit, consistent with the recommendations of Scarsbrook and McBride (2007).
Dissolved Oxygen (DO) saturation were calculated from DO concentration and temperature data. Because atmospheric pressure and elevation were not being part of the dataset, it was considered that all samples were taken at sea level and at normal atmospheric pressure (1013 mbar)
The dataset contains two indicators of bacteriological water quality: faecal coliforms (FC) and *Escherichia coli* (*E. coli*). Generally speaking, FC has been used in the SOE monitoring programme since 1990, and to test compliance with the provisions of the RRMP. *E. coli* has more recently been used as it is considered a better indicator of potential pathogen presence in freshwater. A synthetic *E. coli* data set was generated for analysis for some sites provided good correlations were obtained with FC data. Compliance with the Ministry for the Environment microbiological water quality guidelines (MfE, 2002) have been made at some sites (Arpaoanui

River and Waikari River), that are considered suitable for swimming (i.e provide adequate accesibilty, safety and depth).

2.2.1 Monthly vs Quarterly series

The state of the environment monitoring programme has by and large been based around a quarterly series of data, however there were years (Sandy Creek and Aropaoanui River 1995-1996) in which monthly sampling was undertaken to gain a better understanding of trends and seasonal patterns in water quality determinants. To conduct temporal trends analysis, a number of adjustments were made to prepare the dataset for this analysis:

- when several results were available for a parameter in one given month, the result taken on the day the river flow was closest to the average flow for that month was used in the analysis;
- on rare occasions, some sites had two samples in 1 month, but none the preceding or following month. When considered appropriate (e.g. when one sample was taken very close to the beginning or end of the month), and for the temporal trends analysis only, one of the samples was considered taken a few days earlier or later (i.e. in a different month), to obtain a more consistent dataset.
- Temporal trend analysis was conducted by selecting 4 seasons and selecting median value per season. This ensures that if the data set has sections of data series that are monthly then it will select the median value per season in the analysis.

The Mahiaruhe Stream and Waikari River have been monitored quarterly since August 2000 therefore temporal analysis has not been conducted on them because the datasets are currently too small (n= 33).

2.3 **Flow data**

All flow data used in this report was provided by HBRC’s Hydrology team. Continuous (15 min interval) flow data is available from the Esk River at Waipunga Rd (table 1), which was used to make correlations with Sandy Creek, and the Aroapaoanui and Waikare Rivers (table 2). All correlated flow data used in this report was based on daily average flow.

Table 1: Flow statistics calculated from data collected at the Esk @ Waipunga Rd flow recorder.

Flow (L/s)	Esk @ Waipunga Rd
3× Median	10971
Median	3657
Lower Quartile	2744
7-day MALF	2137
Minimum	1633
Data record	1961-2008

Table 2: Flow statistics calculated from Esk River flow recorder data (table 1).

Flow (L/s)	Sandy Creek	Aropaoanui River	Waikari River
3× Median	519	6966	5370
Median	173	2322	1790
Lower Quartile	112	1491	1252
7-day MALF	73	947	900
Minimum	40	494	607
Calculated by:	Correlated with Esk @ Waipunga Rd	Correlated with Esk @ Waipunga Rd	Correlated with Esk @ Waipunga Rd

Note flow data could only be generated for Mahiaruhe Stream by correlation with the Esk River Q site. This was considered inappropriate therefore flow statistics were not generated for Mahiaruhe Stream.

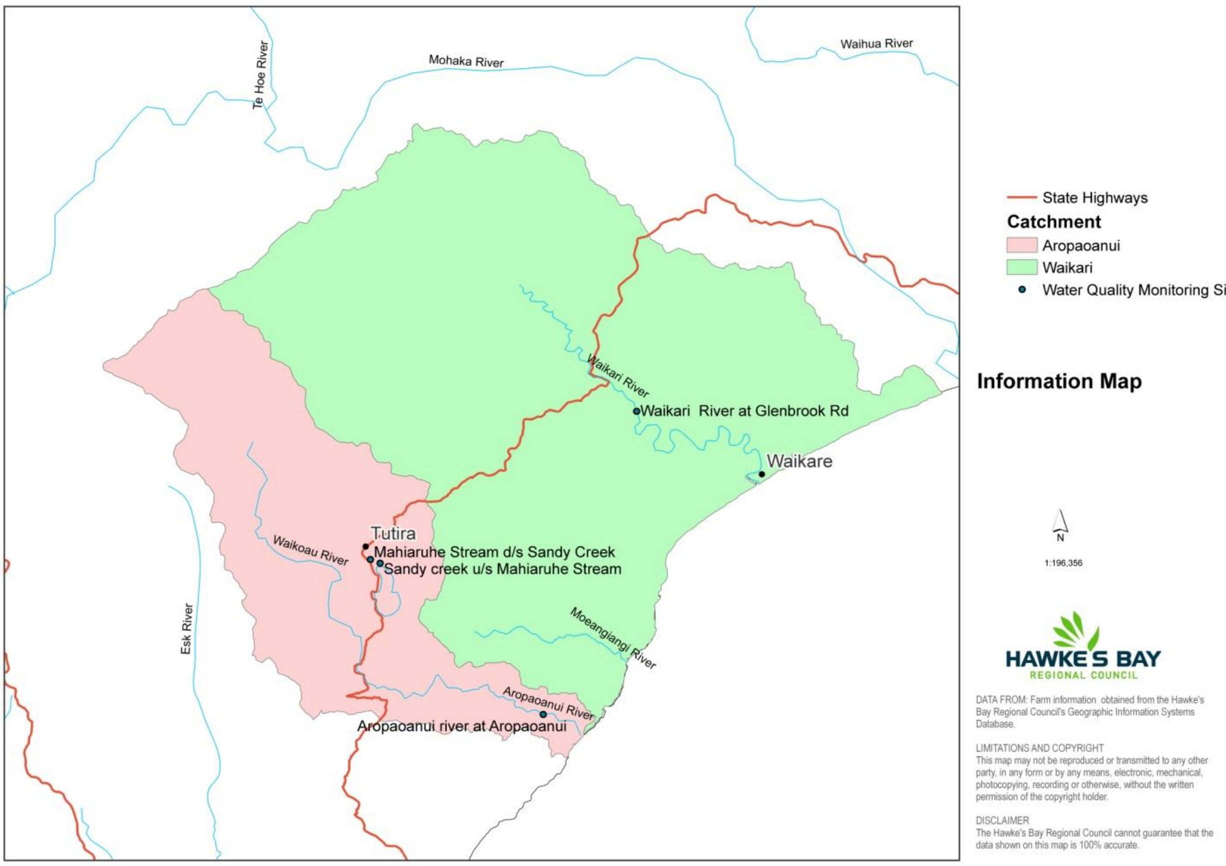


Figure 1: Tutira and Waikare River Catchment Water Quality Monitoring Sites.

Photo 1: Sandy Creek u/s of Mahiaruhe Steam

Photo 2: Mahiaruhe Stream d/s of Sandy Creek

Photo 3: Aropaoanui River

Photo 4: Waikari River

Table 3: Summary of the water quality and flow data used in this study for the Aropaoanui and Waikari Catchments. Phy-Chem: Physico-chemical parameters (temperature, pH, conductivity and dissolved oxygen). Nutrients comprise dissolved reactive phosphorus (DRP) and dissolved inorganic nitrogen (DIN). Bacto: bacteriological data (*E. coli* and faecal coliforms). Biom: Biomonitoring (macroinvertebrate and periphyton data

Monitoring site	HBRC Site ID	Water quality data						Flow data	Comments
		Record Period	Parameters						
			Phy-Chem	Nutrients	Bacto	Biom.			
Sandy Creek u/s of Mahiaruhe Stream	316	1995-2008	✓	✓	✓	✓		✓	Flow correlation with Esk @ Waipunga Rd
Mahairuhe Stream d/s of Sandy Creek Confluence	593	2000-2008	✓	✓	✓	✓		-	Flow data not available
Aropaoanui River @ Aropaoanui	317	1995-2008	✓	✓	✓	✓		✓	Flow correlation with Esk @ Waipunga Rd
Waikari River @ Glenbrook Rd	594	2000-2008	✓	✓	✓	✓		✓	Flow correlation with Esk @ Waipunga Rd

2.4 Data analysis

Descriptive statistics (mean, percentiles, confidence intervals etc), in this report were calculated using Statistica version 8. It was found that most sites were sampled at less than 3* median flow. To provide more in-depth analysis, water quality data was generally analysed:

- under 3* median flow, to remove the potential influence of flood flows;
- under median flow
- under the lower quartile (25^{th} percentile) flow, to reflect low river flow conditions;

Temporal trend analysis (including Kendall seasonal test) was carried out using NIWA's water quality trends software. All statistical tests involving pairwise comparisons were reconfirmed using the False Discovery Rate test recommended in McBride (2005).

2.5 Annual Contaminant loads

Contaminant loads are the amount of contaminant carried by the river through one point, or more correctly one transversal section of the river in a given length of time. Calculation methods generally assume that the contaminant concentration is homogenous across the section of river. When both continuous river flow and contaminant concentration data are available, instantaneous contaminant flux can be calculated at any point in time, and an estimate of the contaminant load during a given period of time can be calculated by simply summing up the instantaneous flux:

$$Load(year_i) = \int_{01/01/year_i}^{31/12/year_i} [Pollut](t) \cdot Flow(t) \cdot dt$$

Contaminant loadings and catchment yields were displayed using the average and 95% confidence intervals calculated from all flow data. Contaminant loadings and catchment yields were displayed using the average and 95% confidence intervals calculated from all flow data.

When contaminant concentrations are known only at regular time intervals (e.g. monthly or quarterly), the above formula can be approximated using a number of approaches. The averaging approach was used in this report. The nutrient loading and yields analysis in this report should be treated with caution firstly because the sample size is considered quite low to estimate loadings with much accuracy, secondly because the sites have been monitored at different times (and in some cases dates) some sites may have greater variance than others. The prime purpose of these analyses is to demonstrate pattern amongst the sties rather than obtain highly accurate estimates of flow and yield.

The other point being that with only one sample per season the uncertainties of annual loads and yields is extremely high.

2.5.1 Averaging approach

This method uses the monthly average river flow and the monthly average contaminant concentration to estimate monthly loads. The annual load is then calculated by summing up the monthly loads. This method is particularly applicable when the contaminant concentration and river flow are independent variables (Richards, 1998).

Monthly load:
$$Load(month_i) = [Pollut](month_i) \cdot \int_{01/month_i}^{31/month_i} Flow(t) \cdot dt$$

Annual load:
$$Load(year_i) = \sum_{i=1}^{12} Load(month_i)$$

Quarterly loads and annual loads were also calculated when data series contained quarterly data.

2.6 Habitat Assessments

On each occasion that a biological sample is taken from the stream site, a stream habitat assessment was completed which entailed completing a series of questions on the quality of the in-stream and riparian habitat. Since 2000 the questionnaire has grown such that some questions were divided into two for a left bank and right bank assessment. Furthermore, additional questions have been added. To give the habitat assessments some context for the 2000-2008 period, sites have been compared using only those questions that were in common to all years of sampling. Mean bar charts have been plotted without confidence intervals owing to the data being interval data and also owing to a small sample size.

3.0 SPATIAL TRENDS OF WATER QUALITY IN THE AROPAOANUI AND WAIKARI CATCHMENTS

3.1 The Aropaoanui and Waikari Catchments

Sandy Creek joins the Mahiairuhe Stream approximately 200m west of Lake Tutira, the stream then joins the Waikoau River approximately 2 km south of Lake Tutira, which them becomes the Aropaoanui River to the east of SH2 and then flows out to the Pacific Ocean. The Waikare River is located approximately 15 km north east of Lake Tutira and flows to the Pacific Ocean.

The Aropaoanui Catchment sites (Sandy Creek, Mahiaruhe Stream and Aropaoanui River) are classified as warm wet low elevation miscellaneous geology pastoral streams while the Waikari River is classified as a warm dry low elevation stream of soft sedimentary geology with pastoral landcover. It is highly likely that the geologies of the two catchments are similar however the river environment classification to date has not classified the geology of the Aropaoanui Catchment (Snelder 2002). These catchments provide a number of social and economic values that are outlined below.

The Mahiaruhe Stream and Sandy Creek are spring fed systems with slow water velocities that are usually dominated by a muddy bottom substrate. Sandy Creek contains aquatic macrophyte communities while the Mahiaruhe Stream has little growing in it at all. Alternatively, the Aropaoanui and Waikare Rivers are run-off fed systems with moderate water velocities that are usually dominated by a cobble/gravel bottom substrate. Both rivers contain periphyton growth with aquatic macrophytes occasionally appearing at the edges during low flow periods.

All sites have extensive stream bank erosion caused by stock access and freshes that may occur during storm events. Landuse within these catchments is predominantly sheep and beef farming.

The river environment classification for the sites analysed are provided in the table below.

Table 4: River Environment Classification of Sites

Site ID)	Site Name	Climate	Source of Flow	Geology	Landcover
316	Sandy Creek u/s of Mahiaruhe Stream	WW	L	M	P
593	Mahairuhe Stream d/s of	WW	L	M	P
317	Aropaoanui River @ Aropaoanui	WW	L	M	P
594	Waikari River @	WD	L	SS	P

Key: WD = Warm Dry, WW= Warm Wet, L = Low Elevation, SS = Soft Sedimentary, M= Miscellaneous, P = Pastoral,

3.1.1 Values

The Aropaoanui and Waikari Catchments support many native fish species including longfin eel, shortfin eel, koura (freshwater crayfish), inanga, torrent fish, blue gill bully, and common bully. In addition to this the Aropaoanui River also supports the redfin bully, banded kokopu and patiki (black flounder) while the Waikari River supports giant bully, yellow eyed mullet, and estuarine triple fin. Both catchments support an average stock of rainbow trout and while not considered a regionally significant fishery, they are assessed against criteria for 'fisheries of lesser significance'. These catchments do have value as an eel fishery.

The cultural value of these catchments is largely unknown.

3.1.2 Landcover, landuse and habitat value

The Aropaoanui and Waikari Catchments are characterised by having extensive pastoral farming with riparian margins predominated by pastoral grasses and weeds that are grazed to the stream edge with patchy trees that offer some shading. Sandy Creek of the Aropaoanui Catchment used to flow into Lake Tutira until 1991 when it was diverted from the lake. This diversion was undertaken on the belief that the stream was providing nutrient rich water to the lake, which was adversely affecting its water quality and ecology.

Habitat value of these streams is poor for Sandy Creek and Mahiaruhe Stream and average for the river sites for most reaches (see section 3.4.1).

3.2 Water quality Standards and Guidelines

Hawke's Bay Regional Council's Regional Resource Management Plan (RRMP) defines a number of surface water quality guidelines applying to most river catchments. These have primarily a regulatory purpose, particularly in relation to resource consents for activities having a potential or actual effect on water quality. All environmental guidelines except those for suspended solids apply to flowing surface water bodies when the flow of water is at or less than the median flow.

Although they may not be directly applicable to a regulatory context, environmental guidelines are commonly used in describing the general state of a natural resource. In particular, this report makes extensive use of indicators based on the percentage of samples which comply with environmental guidelines or standards. The 2000 ANZECC Guidelines, the 2002 MfE guidelines for microbiological water quality and the NZ periphyton guidelines (Biggs, 2000) are three documents that were used here as references sources in relation to surface water quality.

Compliance for nutrient variables which have a less than criteria have been assessed against the 95^{th} percentile of the data while other variables have been assessed against the maximum value (*E. coli*, Faecal coliforms, water temperature and suspended solids). Conversely, compliance for variables that have a "greater than" criterion (eg. water clarity, % saturation dissolved oxygen) have been assessed using the minimum value of the data.

The paragraphs below briefly discuss water quality guidelines and standards for the main physical, chemical, microbiological and biological parameters commonly used in assessing the "health" of a river system, and their appropriateness for the Aropaoanui and Waikari Catchments.

Table 5 summarises the reference values used in this report.

3.2.1 Water Temperature

The RRMP defines a maximum water temperature of 25°C which by and large is an adequate guideline for warm dry or warm wet low elevation streams that have a relatively tolerant fauna, such as the Aropaoanui or Waikari Catchments described in this report. However both these catchments support trout that are likely to be the most temperature sensitive fish within these catchments.

Water temperatures above 19°C are likely to cause behavioural disturbances of trout, such as cessation of feeding (Hay *et al*. 2007), and may exclude stoneflies (Quinn and Hickey, 1990). The incipient lethal temperature of brown trout increases with acclimation to a plateau at 24.7°C (Hay *et al*. 2007). A number of field and laboratory studies indicate that a maximum daily temperature of 21 to 23°C will adequately protect most common macroinvertebrate and native fish species (Ausseil and Clark, 2007). Recent research also indicates that stoneflies (an important food source for trout) may be present at occasional temperatures of 22-23°C if other water quality and habitat parameters are suitable for these sensitive species (Dr. John Quinn, pers. comm.).
A maximum water temperature of 19°C is therefore recommended for the Aropaoanui and Waikari Catchments to avoid behavioural disturbances of trout and the exclusion of sensitive invertebrate taxa (such as stoneflies) observed at higher temperatures

3.2.2 Water pH

Background information on the effects of pH on New Zealand native aquatic biota is scant. One study indicates that a number of native fish species show a definite avoidance of pH values below 6.5, and that pH range of 7 to 9.5 should not be toxic to most NZ fish species (West *et al.*, 1997). Raleigh *et al.* (1986) suggest the tolerable range of water pH for brown trout is 5 to 9.5, with an optimal range of 6.7 to 7.8. Both the tolerable and optimal pH ranges for trout have been used as benchmark values for the Aropaoanui and Waikari Catchments.

3.2.3 Dissolved oxygen (DO)

The RRMP sets a minimum dissolved oxygen concentration of 80% saturation, applying at all river flows. This is consistent with the RMA S69 standard for waters being managed for fishery purposes. This guideline is used in this report.
It should be noted however that instantaneous measurement taken as part of the SOE monitoring programme may have limited value in terms of assessing compliance with the guideline. DO concentration varies diurnally, with maximum values generally late afternoon and minimum values at dawn. Thus, only measurements taken early in the morning, or continuous monitoring, can provide some useful measure of the daily minimum DO concentration actually occurring in the river.

3.2.4 Organic load

A common cause of deleterious DO depletion is the in-stream degradation of organic matter by heterotrophic bacteria. Biochemical oxygen demand (BOD) and total organic carbon (TOC) are commonly used indicators of the organic load carried by the water.
TOC is routinely measured as part of HBRC's state of the environment monitoring programme. This indicator was selected by HBRC to provide better information in waterways with relatively low organic enrichment.
There is no general formula to directly link BOD or TOC with DO. Only site-specific modelling can assist in understanding how the dissolved oxygen concentration reacts to in-stream organic loads. For this reason, it is difficult to define acceptable TOC concentration thresholds, and this indicator was only used as an indicator of spatial and temporal trends in this report.

3.2.1 Water clarity and suspended solids

There is a suspended solids guideline of 50 mg/l in the RRMP for the Aropaoanui Catchment, which is to be assessed at all flows, yet nothing is specified for the Waikari Catchment. In light of the two catchments being of a similar river environment class and being in close proximity to each other it is recommended that the Waikari River also be assessed against the 50 mg/l suspended sediment guideline.

A recent Tukituki report has assessed this guideline against concentrations at less than 3* median flows (Ausseil 2008). This is the most appropriate method of measuring background concentrations of suspended sediments as it is widely accepted that flows above 3 * median can result in river bed movement which raises suspended sediment concentrations further. The lower Aroapoanui and Waikari River catchments are considered suitable water bodies for contact recreation; therefore the 1.6 m guideline for swimming is used. Compliance with the ANZECC Guidelines of 0.6 m for protection of aquatic ecosystems at lowland rivers is used in this report as is a guideline recommended by Hay et al (2007) of a minimum clarity of 3.5m for trout fisheries of lesser importance than “regionally significant”. This latter guideline only applies at less than median flow.

3.2.2 Ammonia

Ammonia can be toxic to many aquatic species, and is a common pollutant in treated domestic, agricultural and industrial wastewater discharges. In aqueous solution, ammonia exists in two chemical forms: the ammonium cation (NH_4^+) and un-ionised ammonia (NH_3). In the laboratory, total ammonia (i.e. NH_3 plus NH_4^+) is determined and reported, and is signified as NH_4. The respective proportion of these forms is determined by a chemical equilibrium governed by pH and temperature. The higher the pH and temperature, the higher the proportion of unionised ammonia. Because unionised ammonia is by far the most toxic form to aquatic life, the toxicity of ammonia increases with pH and temperature.

The 2000 ANZECC guidelines define a maximum unionised concentration of 0.035 mg/L (35 ppb) for the 95% protection level. The guidelines also provide tables and formulas to calculate the concentration of total ammonia (NH_4) corresponding to this threshold under different pH conditions.

The approach taken in this report was to use the 95th percentile of the pH data observed at different monitoring sites to calculate the total ammonia concentration corresponding to the ANZECC 95% protection level (35 ppb unionised ammonia). The results are summarised in table 4.

Table 5: Maximum total ammonia-nitrogen (NH_4-N) concentration recommended by the ANZECC (2000) guidelines for the protection of 95% of aquatic species. Calculations based on ANZECC Guidelines table 8.3.7, 95% protection level (0.035 mg N/l un-ionised ammonia), and 95th percentile of water pH data recorded at monitoring sites.

Site ID	Site Name	pH 95th %ile	Total Ammonia 95th %ile	% Compliance with standard	ANZECC Guideline
316	Sandy Creek u/s of Mahiaruhe Stream	8.0	0.165	100	0.9
593	Mahairuhe Stream d/s of Sandy Creek Confluence	8.4	0.065	100	0.42
317	Aropaoanui River @ Aropaoanui	8.4	0.065	100	0.42
594	Waikari River @ Glenbrook Rd	8.8	0.061	100	0.2

3.2.1 Bacteriological water quality

Two indicators of the microbiological water quality have been routinely monitored in the Aropaoanui and Waikari Catchments, faecal coliforms (FC) and *Escherichia coli* (*E. coli*). Both are used as indicators for the potential presence of pathogens of faecal origin in the water, in turn linked with the level of health risk to water users.

The RRMP defines a guideline value of 200 faecal coliforms/100mL for the Aroapaoanui River but nothing is specified for the Waikari Catchment. The initial intent of this guideline was not for contact recreation, rather it was set as an achievable goal provided land uses within the catchment were best practice. For the purposes of this report we will assume the same standard for the Waikari River. The guideline applies at river flows at or below median flow.

The MFE contact recreational guidelines are applicable to the Waikari and Aropaoanui River sites as they are the only sites considered suitable for contact recreation owing to their larger size.

Periphyton biomass, DRP and DIN

Periphyton is the brown or green slime or filaments coating stones, wood or any other stable surfaces in streams and rivers. In some situations, periphyton can proliferate and form thick mats of green or brown filaments on the river bed. The proliferation of periphyton can affect a number of water body values, including life-supporting capacity, recreational and aesthetic values and trout fishery.

Periphyton biomass in a stream or river is forever changing, as result of a dynamic equilibrium between periphyton growth and biomass loss (chiefly through hydrological influence, light levels and invertebrate grazing). Generally speaking, floods re-set periphyton biomass at a low level. The recession and low flow periods following a flood are termed “accrual period” during which periphyton biomass increases to reach a “peak biomass”. Both the peak biomass and the speed at which it is reached can be increased by high available nutrient concentration in the water. Periphyton cover in Hawke’s Bay rivers are predominantly diatoms. A biomass guideline of 120 mg/m^2 is recommended for the streams in this report (Ausseil pers. comm. 2009).

The RRMP defines a maximum DRP concentration of 0.015 mg/l when flow in the river is at or below median flow. This guideline was used in this report. The RRMP does not set maximum concentrations for the other macronutrient, nitrogen. As default values, the ANZECC guidelines for dissolved nitrogen oxides (NO_x – nitrate + nitrite)-N are recommended for soluble inorganic nitrogen (SIN): of 0.444 mg/l for middle to lower elevation catchments, applying when the flow in the river is at or below median flow. This assumes that NH_4-N concentrations are negligible by comparison with NO_x-N (see Table 9)

These nutrient criteria were used for the control of periphyton growths.

3.2.2 Macroinvertebrate communities

Macroinvertebrate communities are commonly used as an indicator of water quality and ecosystem health. A macroinvertebrate community index (MCI) guideline of 100 (indicative of possible mild pollution) for the Aropaoanui and Waikari Catchments is recommended. Caution should be exercised in assessing compliance of macroinvertebrate community results as sampling done prior to 2001 may not have been in accordance with the Macroinvertebrate Community Sampling Protocols (Stark et al 2001)

Table 6: Summary of recommended guidelines for the Aropaoanui and Waikari Catchments for physical, chemical and biological parameters.

Parameter	River flow	Sandy Creek & Mahiaruhe Stream	Waikari and Aropaoanui River
Temperature (°C)	All	25	19
pH (tolerance range) native fish	All	7.0 - 9.5	7.0 - 9.5
pH (tolerance range) trout	All	5.0-9.5	5.0-9.5
pH (optimal range) trout	All	6.7-7.8	6.7-7.8
DO (% saturation)	All	80	80
Clarity – aquatic ecosystems (m)	All	0.8	0.8
Clarity – contact recreation	All	n/a	1.6
Clarity – trout foraging	< median	n/a	3.5m
SS (mg/l)	< 3* median	50	50
Ammonia-N (mg/l)	All	See table 4	See table 4
Periphyton biomass (mg *Chlo a*/m^2)	All	120	120
SIN (mg/l)	< Median	0.444	0.444
DRP (mg/l)	< Median	0.015	0.015
E. coli		n/a	550
Faecal coliforms (/100mL)	< Median	200	200
Chl a (angling)	< 3* Median	n/a	200
MCI	< 3* Median	>100	>100

3.3 Water Quality

3.3.1 Temperature

Water temperature at all sites generally shows excellent compliance with the water temperature guideline of less than 19 °C.

Table 7: Summary of water temperature (°C) for the Aropaoanui and Waikari Catchments

Parameter	Monitoring Site	Average	Median	90th percentil	95th percentil	N. of Samples	% Compliance with standard	Standard/ Guideline
Water Temperature	Sandy Creek u/s of	12.67	13.0	18.0	18.0	52	100	< 19 C
	Mahiaruhe Stream d/s	13.63	12.5	19.0	19.5	33	90.9	
	Aropaoanui River @	13.23	13.0	19.0	19.5	65	93.8	
	Waikari River @	13.54	13.0	19.8	20.5	34	82.3	

3.3.2 pH

The sites show excellent compliance with the guidelines for the tolerance range of native fish and trout; however the sites tend to show poor compliance for the optimal range for trout.

Table 8: Summary of water quality state at monitoring sites on the Aropaoanui and Waikari catchments pH: two corresponding to (a) tolerable and range for native fish species (b) tolerable range for trout and (c) optimal range for trout.

Parameter	Monitoring Site	Average	Median	90th percentile	95th percentile	N. of Samples	% Compliance with standard	Standard/ Guideline
pH	Sandy Creek u/s of	7.77	7.8	8.0	8.0	24	91.7	7.5-9 (tolerance, native fish)
	Mahairuhe Stream d/s	7.78	7.8	8.0	8.1	33	93.4	
	Aropaoanui River @	8.18	8.2	8.4	8.4	40	100	
	Waikari River @	8.27	8.2	8.7	8.8	34	100	
pH	Sandy Creek u/s of	Summary Statistics As Above					100	5-9.5 (tolerance range trout)
	Mahairuhe Stream d/s						100	
	Aropaoanui River @						100	
	Waikari River @						100	
pH	Sandy Creek u/s of	Summary Statistics As Above					75	6.7-7.8 (optimal range trout)
	Mahairuhe Stream d/s						36.4	
	Aropaoanui River @						2.5	
	Waikari River @						2.9	

3.3.3 Ammonia

Ammonia concentrations are well below guideline concentrations at all sites. These concentrations are not expected to cause any chronic or acute toxic affects on the aquatic biota.

Table 9: Summary of ammoniacal nitrogen concentrations (mg/l) at monitoring sites on the Aropaoanui and Waikari catchments

Parameter	Monitoring Site	Average	Median	90th percentile	95th percentile	N. of Samples	% Compliance with standard	Standard/ Guideline
Ammonia N (g/m3)	Sandy Creek u/s of	0.051	0.0495	0.078	0.165	40	100	0.9
	Mahairuhe Stream d/s	0.0388	0.0340	0.070	0.088	33	100	0.42
	Aropaoanui River @	0.0278	0.0170	0.041	0.065	64	100	0.42
	Waikari River @	0.023	0.0200	0.050	0.061	34	100	0.2

3.3.4 Total Organic Carbon (TOC) and Dissolved Oxygen

TOC provides an indication of the amount of organic matter in the water column. Whilst relatively low levels are a normal, natural part of the ecosystem, elevated levels are a likely indicator of organic enrichment, either as a result of direct input of organic matter (e.g. from a discharge) or as a result of accelerated primary production (e.g. algal growth). Figure 2 shows that TOC concentrations are higher at higher flow categories for most sites which means that most organic matter within the stream is derived from allochthonous(derived from outside of the stream) input. Alternatively the Waikari River site tends to show little change in TOC concentrations amongst the flow categories. The reason for this latter trend is unclear.

Compliance with the 80% DO Saturation guideline is generally about 70-90% of the guideline value at the smaller stream sites (Sandy Creek and Mahiaruhe Stream) and excellent at the river sites. This indicates that the current levels of organic matter entering the rivers have not been at a level that would degrade oxygen levels such that aquatic life is harmed. Alternatively the TOC concentrations in the smaller streams may be affecting dissolved oxygen concentrations within them. Further diurnal water quality monitoring is recommended at Sandy Creek and Mahiaruhe Stream to gauge how low DO concentrations do become to give greater weight to this assumption.

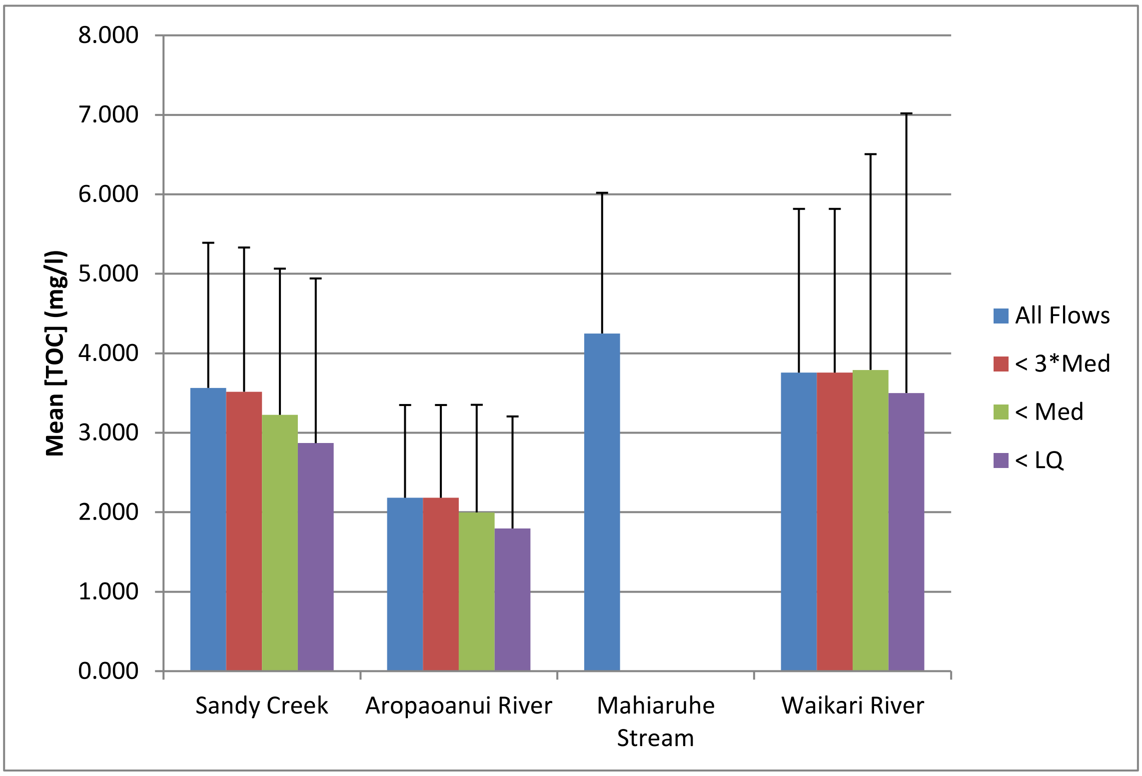


Figure 2: Mean total organic carbon (TOC) (mg/l) ± 95% confidence interval under different flow conditions: at all river flows (all flow), below three times median flow (<3* Med), below median flow (< Med) and below the lower quartile flow.

Table 10: Percent dissolved oxygen concentrations (%) at the Aropaoanui and Waikari Catchment Sties

Parameter	Monitoring Site	Average	Median	5th percentile	10th percentile	N. of Samples	% Compliance with standard	Standard/ Guideline
% Saturation Dissolved Oxygen	Sandy Creek u/s of	86.124	86.9	66.1	73.5	29	68.9	➢ 80
	Mahairuhe Stream d/s	86.5938	85.8	68.9	72.5	32	68.7	
	Aropaoanui River @	92.4238	91.6	75.5	77.3	42	88	
	Waikari River @	97.759	95.9	73.4	81.2	34	91.2	

3.3.5 Water Clarity and Suspended Solids

All sites show increasing water clarity at lower flow categories. In general water clarity is highest at Aropaoanui followed by Waikari River while water clarity is lowest at the smaller stream sites (Sandy Creek and Mahiaruhe Stream). The Waikari and Aropaoanui Rivers are larger water bodies and are therefore considered suitable for swimming. Both sites show above 80% compliance with the water clarity guideline of 1.6 m for swimming. All sites show poor compliance with the trout foraging guideline of 3.5 m for trout foraging (see table 11).

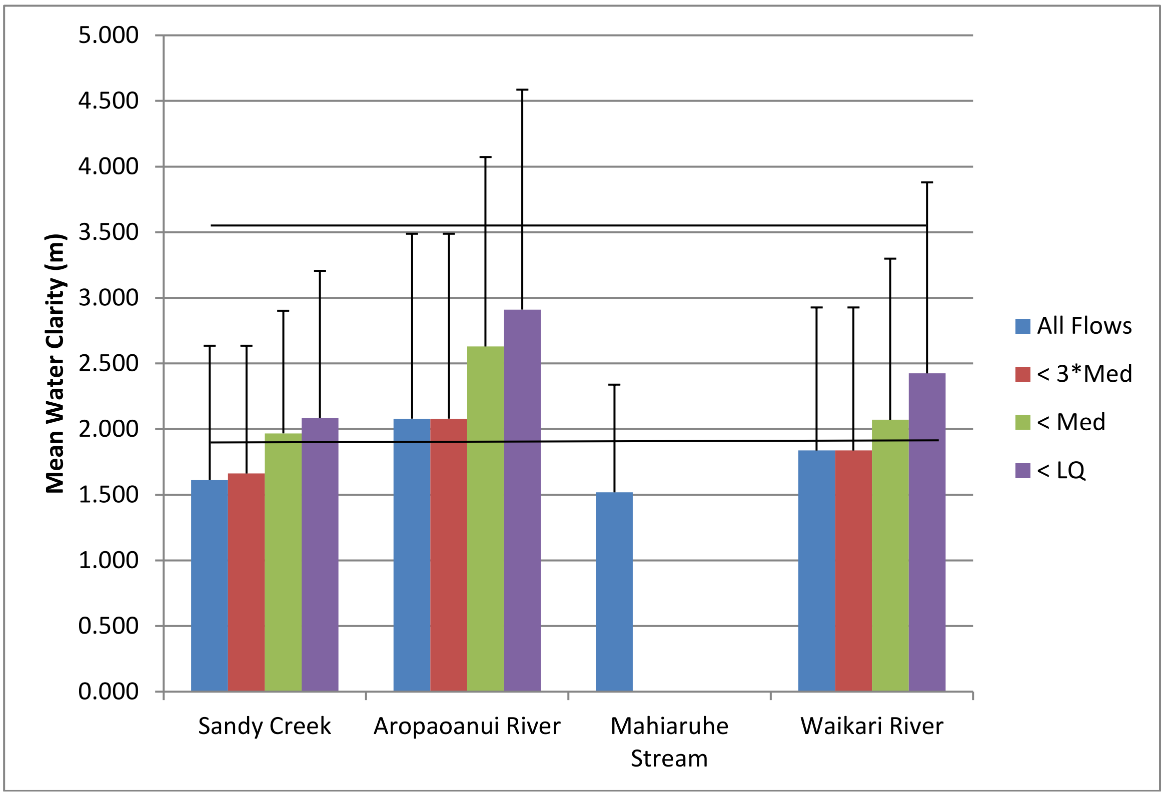


Figure 3: Mean water clarity) ±95% confidence interval under different flow conditions: at all river flows (all flow), below three times median flow (<3* Med), below median flow (< Med) and below the lower quartile flow. The threshold lines indicate the contact recreation guideline (>1.6m) and trout foraging (>3.5m).

All sites shows excellent compliance with the RRMP suspended solids guideline and the ANZECC guideline for low elevation streams.

Table 11: Summary of water quality and suspended solids concentrations at the Aropaoanui and Waikari Catchments

Parameter	Monitoring Site	Average	Median	5th percentile	10th percentile	N. of Samples	% Compliance with standard	Standard/ Guideline
Water Clarity (m) < Median Flow	Sandy Creek u/s of	1.968	1.9500	1.23	1.25	19	5.2	3.5 m (trout foraging)
	Mahiaruhe Stream d/s						n/a	
	Aropaoanui River @	2.629	2.525	0.68	1.26	38	18.4	
	Waikari River @	2.071	1.950	0.55	1.38	21	9.5	
Water Clarity (m) < Median Flow	Sandy Creek u/s of	n/a					n/a	1.6 m (Contact Recreation)
	Mahiaruhe Stream d/s	n/a					n/a	
	Aropaoanui River @	2.629	2.525	0.68	1.26	38	86.8	
	Waikari River @	2.071	1.950	0.55	1.38	21	85.7	
Water Clarity (m) All Flow	Sandy Creek u/s of	1.612	1.64	0.10	0.75	32	90.6	0.6 m (Lowland Streams)
	Mahiaruhe Stream d/s	1.5188	1.65	0.37	0.56	33	87.8	
	Aropaoanui River @	2.0800	1.93	0.57	0.75	64	93.8	
	Waikari River @	1.837	1.87	0.36	0.55	34	88.2	
		Average	Median	90th percentil	95th percentil			
Suspended Solids (mg/l) < 3* Median Flow	Sandy Creek u/s of	3.239	2.0000	6.700	11.000	28	96.4	< 50
	Mahiaruhe Stream d/s							
	Aropaoanui River @	3.1718	2.0000	6.000	11.000	39	94.9	
	Waikari River @ Glenbrook Rd	4.038	1.500	7.000	11.000	21	100	

3.3.6 Microbiological water quality

Microbiological water quality is generally good across all sites. Only the Aropaoanui and Waikari River sites are considered suitable for contact recreation owing to their larger size. Both sites show 100% compliance with the MFE guideline for contact recreation (< 550 *E. coli*/100ml). All sites show increased *E. coli* concentrations with increased flow. This indicates that storm events provide a lot of bacterial runoff to these catchments. In general *E. coli* concentrations are highest at Sandy Creek followed by Mahiaruhe Stream and are lowest at the river sites. This trend is expected as smaller streams have less capacity for diluting the bacterial inputs they receive.

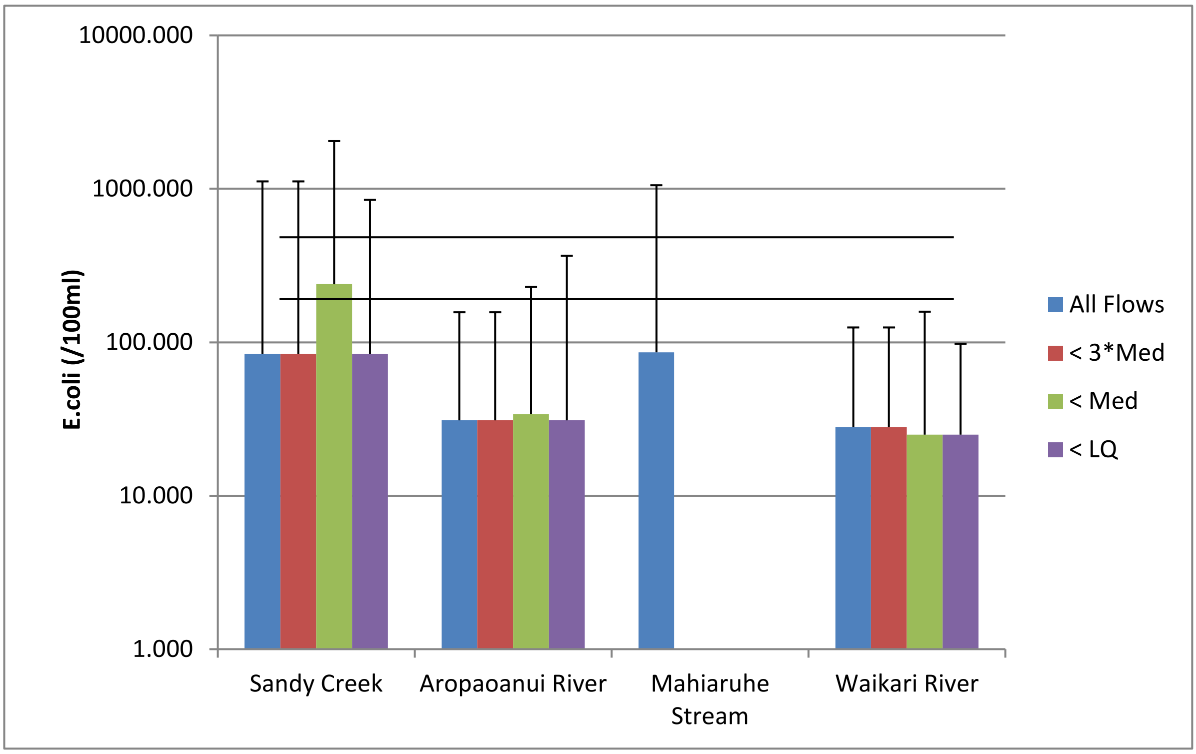


Figure 4: Median *E. coli* concentrations (/100ml)±95% confidence interval under different flow conditions: at all river flows (all flow), below three times median flow (<3* Med), below median flow (< Med) and below the lower quartile flow. The threshold lines indicate the threshold between green and amber modes (260 *E. coli*/100ml), amber and red (550 *E. coli*/10ml).

Table 12 Summary of *E. coli* and Faecal coliform concentrations (cfu/100ml) at the Aroapaoanui and Waikari Catchment sites

Parameter	Monitoring Site	Average	Median	90th percentile	95th percentile	N. of Samples	% Compliance with standard	Standard/ Guideline
E. coli (/100ml) All Flows	Sandy Creek u/s of	n/a					n/a	550 *E. coli* (/100ml) (Contact Recereation)
	Mahiaruhe Stream d/s	n/a					n/a	
	Aropaoanui River @	59.6	31.0	160.0	360.0	18	100	
	Waikari River @	55.5	28.0	120.0	260.0	18	100	
Faecal coliforms (/100ml) < Median Flow	Sandy Creek u/s of	927.2	580.0	3000.0	4200.0	18	33.3	< 200
	Mahiaruhe Stream d/s							
	Aropaoanui River @	84.5	56.50	130.0	340.0	28	92.8	
	Waikari River @ Glenbrook Rd	87.0	59.0	174.0	360.0	17	94.1	

3.3.7 Nutrients and Nutrient Limitation

The differences in DRP concentrations between flow categories is not considered significantly different in these streams. Unfortunately flow data was not available for the Mahiaruhe Stream so flow nutrient concentration patterns cannot be displayed for this site.

All sites show extreme variability at all flow categories indicating more sampling at these sites is needed to gain a better understanding of the true variance surround the mean DRP concentrations at these sites.

In general the Sandy Creek and Mahiaruhe stream sites show higher concentrations at all flows, while the Aropaoanui River shows the lowest DRP concentrations.

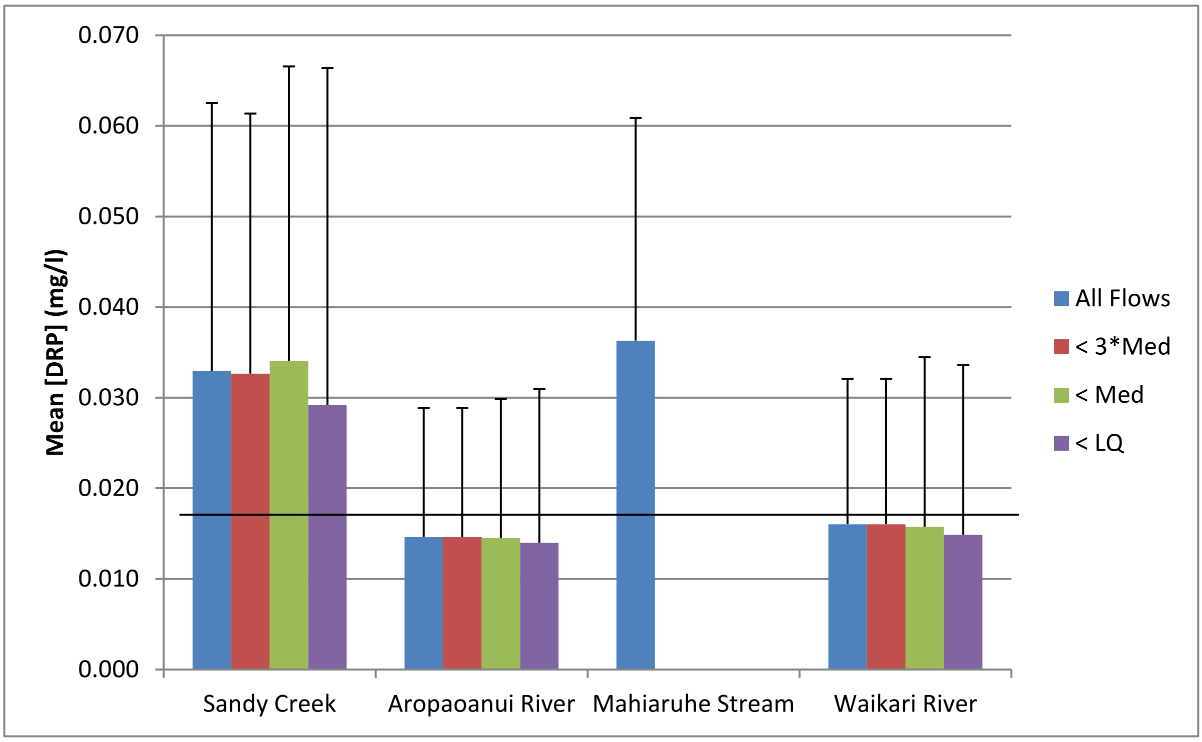


Figure 5: Mean DRP concentrations (mg/l) ±95% at all river flows (All flow), below three times the median flow (<3*Med), below median flow (< Med) and below the lower quartile flow (<LQ). The 0.015 mg/l line marks the RRMP guidleine for the control of periphyton growth measured at less than median flow.

Dissolved Inorganic Nitrogen

DIN concentrations in all catchments are generally elevated at higher flow categories, indicating that mobilisation of DIN during storm events contributes to elevated nutrient concentrations in these streams. The variance surrounding the mean values is high indicating that more sampling would help better determine the differences between flow categories.

In general Sandy Creek, followed by the Waikari River had higher DIN concentrations when compared to the Aropaoanui River. Note for most sites measurements nutrient sampling has not been undertaken above 3* median flow, this is why the all flow and 3* median flow bars are the same.

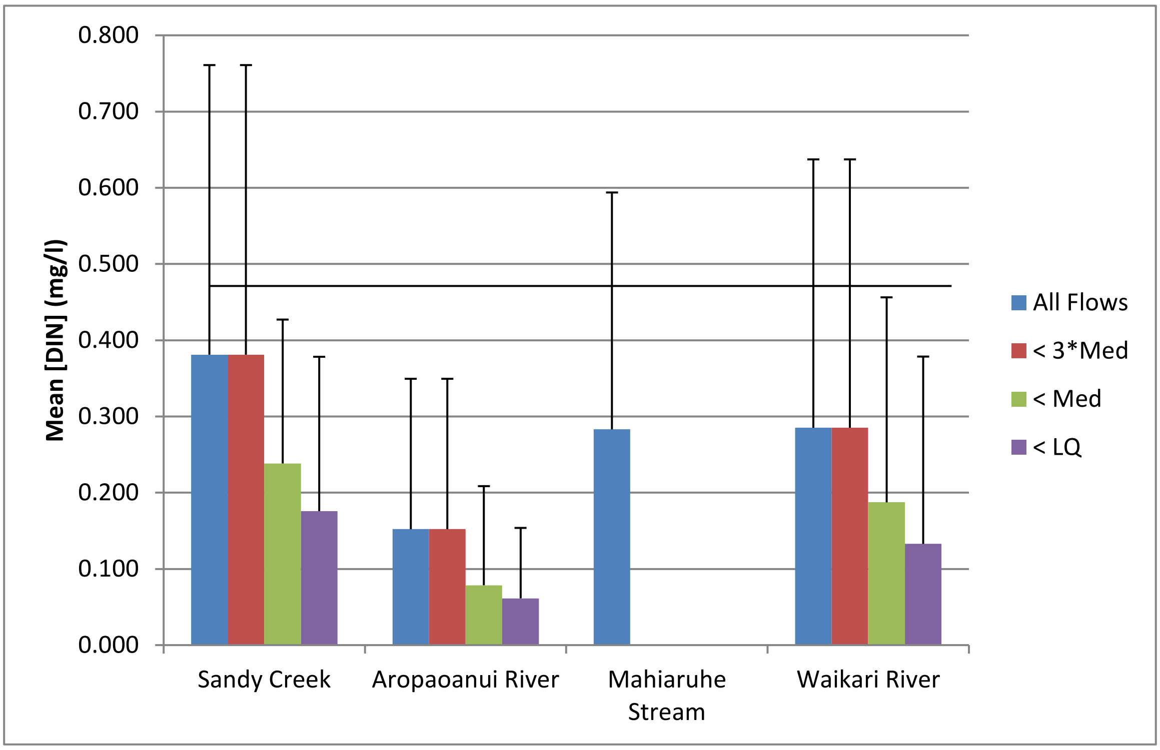


Figure 6: Mean DIN concentrations (mg/l) ± 95% confidence intervals under different flow conditions: at all river flows (all flow), below three times median flow (<3* Med), below median flow (< Med) and below the lower quartile flow. The threshold line indicates the RRMP guideline for DIN for control of periphyton growth.

The DRP concentrations indicate very poor quality at Sandy Creek and average quality at the Aropaoanui and Waikari Rivers, however the DIN concentrations indicate good water quality at all sites. The reason for this result could be that these systems are nitrogen limited, i.e. algae and aquatic macrophytes within the system are actively taking up DIN to maintain and enhance their growth while DRP is needed in lesser quantity to maintain and enhance their growth.

Table 13: Summary of dissolved Reactive phosphorus (DRP) and soluble inorganic nitrogen (SIN) at monitoring sites of the Aropaoanui and Waikari River Catchments. Sites are presented in the upstream to downstream order. Spelling of Mahiaruhe, different font types

Parameter	Monitoring Site	Average	Median	90th percentile	95th percentile	N. of Samples	% Compliance with standard	Standard/ Guideline
DRP (g/m^3) Under median flow	Sandy Creek u/s of	0.034	0.037	0.061	0.073	28	28.6	0.015
	Mahiaruhe Stream d/s							
	Aropaoanui River @	0.014	0.012	0.032	0.041	39	56.4	
	Waikari River @	0.016	0.011	0.030	0.036	21	52.4	
SIN (g/m^3) Under median flow	Sandy Creek u/s of	0.238	0.243	0.359	0.535	17	94.1	0.444
	Mahiaruhe Stream d/s							
	Aropaoanui River @	0.078	0.046	0.227	0.235	27	96.3	
	Waikari River @	0.187	0.123	0.487	0.622	19	89.5	

Note: the Mahiaruhe site did not have flow values to determine < median flow

Nutrient Limitation

Both nitrogen and phosphorus are needed for periphyton growth in an average weight ratio of 7.5:1, as defined in the Redfield equations (Stumm and Morgan, 1996 in Wilcock *et al.*, 2007). A ratio of approximately 7.5 is the theoretical limit between N-limited (ratio<7.5) and P-limited (Ratio >7.5) conditions.

The SIN/DRP ratio can be a useful indicator of which of SIN or DRP is the likely limiting nutrient for periphyton growth. Generally, elevated SIN/DRP ratios (above 20) are indicative of P-limited conditions, and low ratios (<4) indicate of N-limited conditions. Ratios between 4 and 20 are generally inconclusive or may indicate that the nutrient limitation may "switch" between the two nutrients at different times of the year/ flows. It is important to note that nutrient limitation may only occur when other factors controlling periphyton growth, such as sunlight, hydrological regime and biological activity are favourable and nutrient concentrations (at least one of them) are sufficiently low to limit periphyton growth. When both nutrients are in sufficient supply, nutrient concentration is unlikely to limit algal growth. For this study, this meant using the SIN:DRP ratios only outside flood flows (i.e. below three times median) and when the DRP concentration was below the RRMP standard (0.015 mg/l) or the SIN concentration was below 0.444 mg/l.

It should be stressed that, although a useful indicator, SIN:DRP ratios do not provide a definite answer, and bioassays, such as nutrient diffusing substrates, are generally viewed as a more reliable method to determine nutrient limitation.

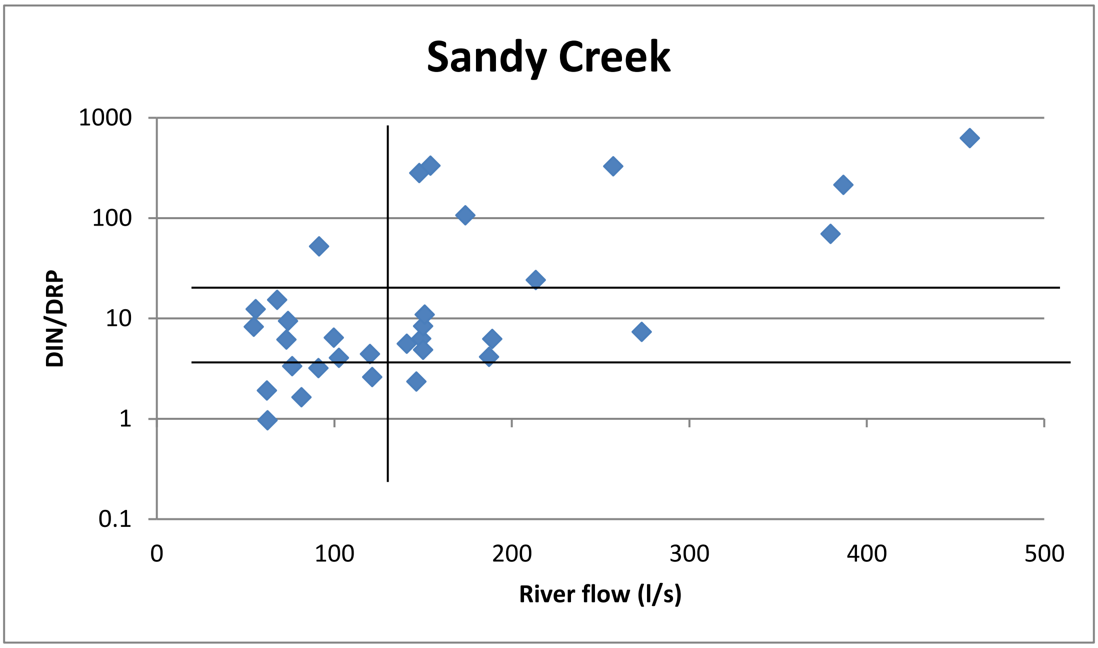
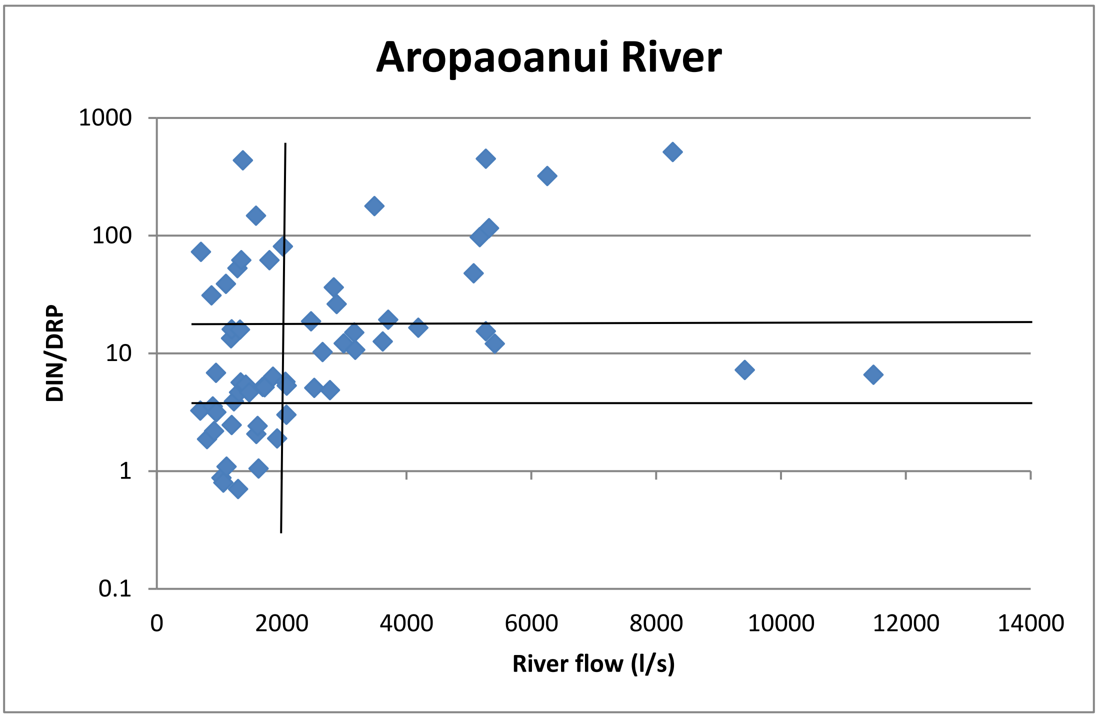


Figure 7: DIN:DRP ratio for Sandy Creek. Data is for river flows below 3* median flow and when either DIN or DRP concentrations are below guideline levels (0.015 mg/l for DRP or 0.444 mg/l for DIN). The vertical line indicates the lower quartile flow. Points above and below the upper horizontal line are indicative of P limited conditions. Points below the lower horizontal line are indicative of N limited conditions.



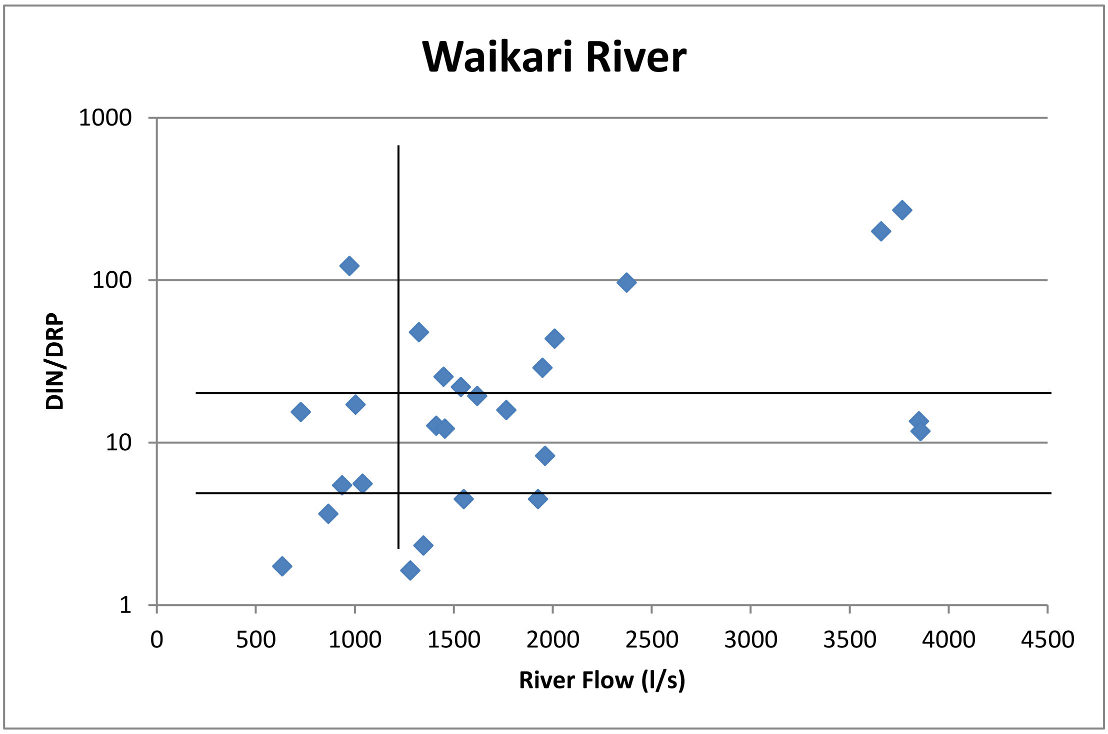


Figure 7 continued: DIN:DRP ratio at monitoring sites. Data for river flows below 3* median flow and when either DIN or DRP concentrations are below guideline levels (0.015 mg/l for DRP or 0.444 mg/l for DIN). The vertical line indicates the lower quartile flow. Points above and below the upper horizontal line are indicative of P limited conditions. Points below the lower horizontal line are indicative of N limited conditions.

Figure 7 shows that the sites are often P limited or in a state that cannot be easily determined (i.e DIN/DRP ratio between 4 and 20). Sandy Creek and Aroapaoanui River tend to show N limitation towards lower flows (i.e at less than lower quartile).

3.3.8 Biological Monitoring

The Chlorophyll a results show that all sites have excellent compliance with the amended MFE guidelines for the protection of benthic biodiversity (see table 14). Most sites show high variability as indicated by the broad confidence intervals.

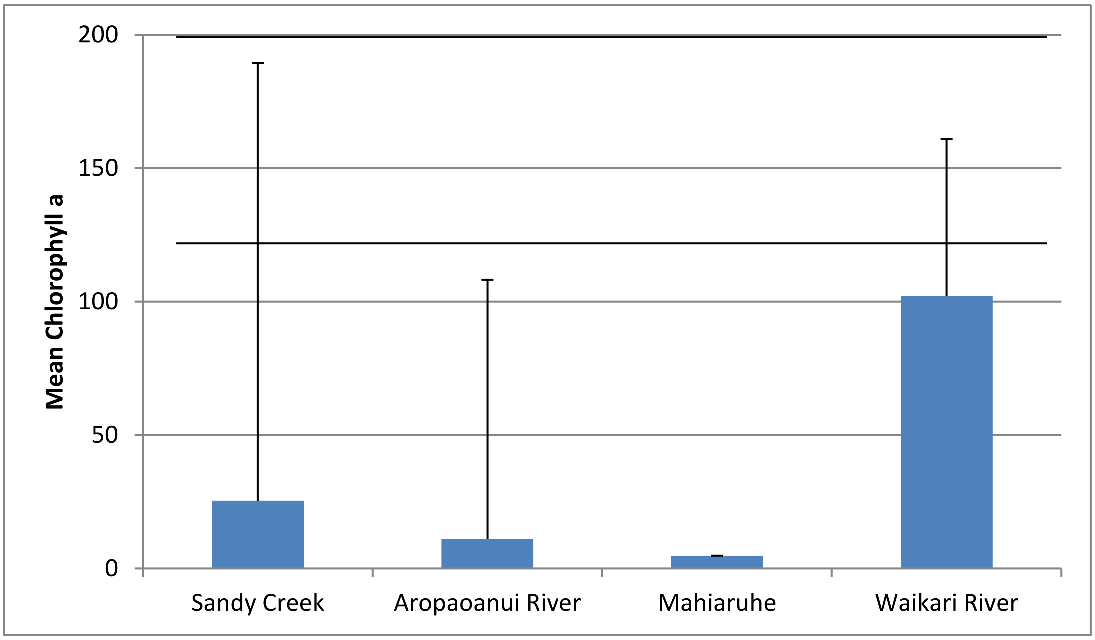


Figure 8: Mean Chlorophyll a concentrations ± 95% confidence intervals. The solid threshold lines represent the recommended guideline for aquatic ecosystem protection (120) and trout angling (200).

MCI

Macroinvertebrate community index results show that the Mahiaruhe Stream has the poorest MCI value while the remaining sites have similar mean MCI's. The Mahiaruhe Stream is the only site to fall well short of the desired biological state of water quality (MCI > 100). No confidence interval has been shown for the Mahiaruhe Stream owing to the small sample size (n=2).

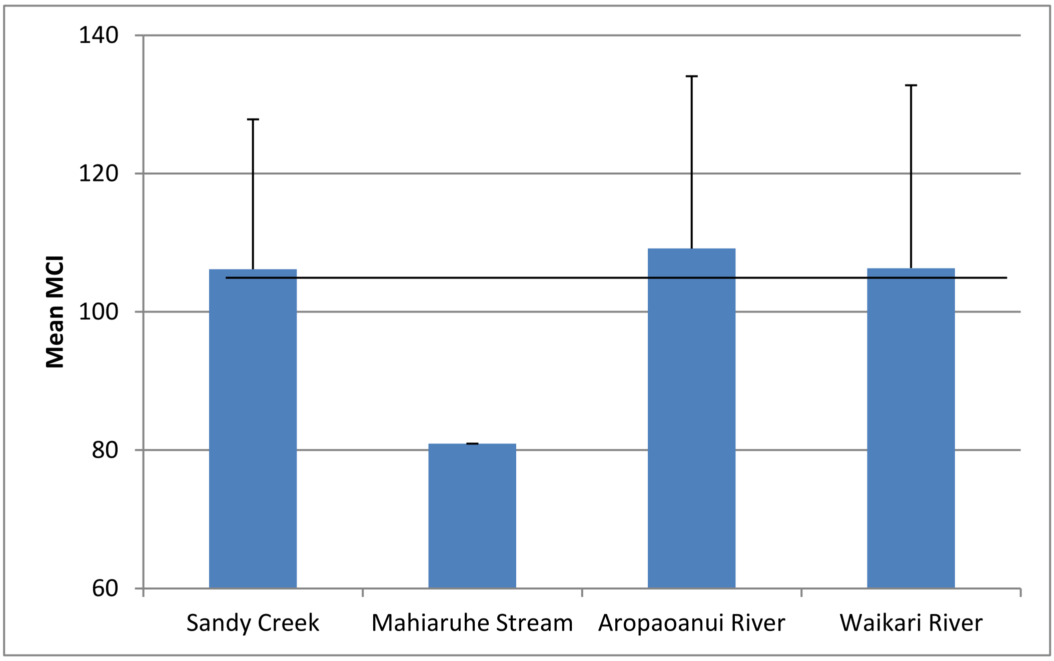


Figure 9: Mean macroinvertebrate index (MCI)± 95% confidence intervals. The solid threshold line represents the recommended guideline for these streams

Table 14: Summary of biomonitoring results at four sites of the Aroapaoanui and Waikari Catchments. Sites are presented in the upstream to downstream order for the Aropaoanui River. Spelling of Mahiaruhe (100 lines!)

Parameter	Monitoring Site	Average	Minimum	Maximum	N. of Samples	% Compliance with standard	Standard/ Guideline
Periphyton biomass Chl a (mg/m^2)	Sandy Creek u/s of	110.0	2.0	610.5	7	85.7	< 120
	Mahiaruhe Stream	8.9	4.8	13.0	2	100	
	Aropaoanui River @	77.7	2.0	420.0	8	87.5	
	Waikari River @	76.5	11.0	289.1	8	87.5	
Macroinvertebrate Community Index (MCI)	Sandy Creek u/s of	106.16	95.0000	120.00	6	83.3	100
	Mahiaruhe Stream	80.9	74	87.9	8	0	
	Aropaoanui River @	109.16	93.0000	124.000	8	75.0	
	Waikari River @	106.33	89.5000	126.000	8	62.5	

Table 14 shows that compliance with the chl a guideline is excellent at all sites. The desired ecological state as measured by the MCI is good at Sandy Creek and the Aropaoanui River, average at Waikari River and poor at the Mahiaruhe Stream site.

Habitat Value

Figure 10 shows that the habitat quality at the Mahiaruhe Stream is significantly lower than the remaining sites. Habitat features that give rise to the poor habitat include bank instability, channel instability and complexity, and stable bottom substrate availability. The Waikari River shows the best habitat score. Features that give rise to the good habitat include channel stability and complexity, river bottom habitat diversity, stable bottom substrate availability, riparian vegetation width and embeddedness of substrate.

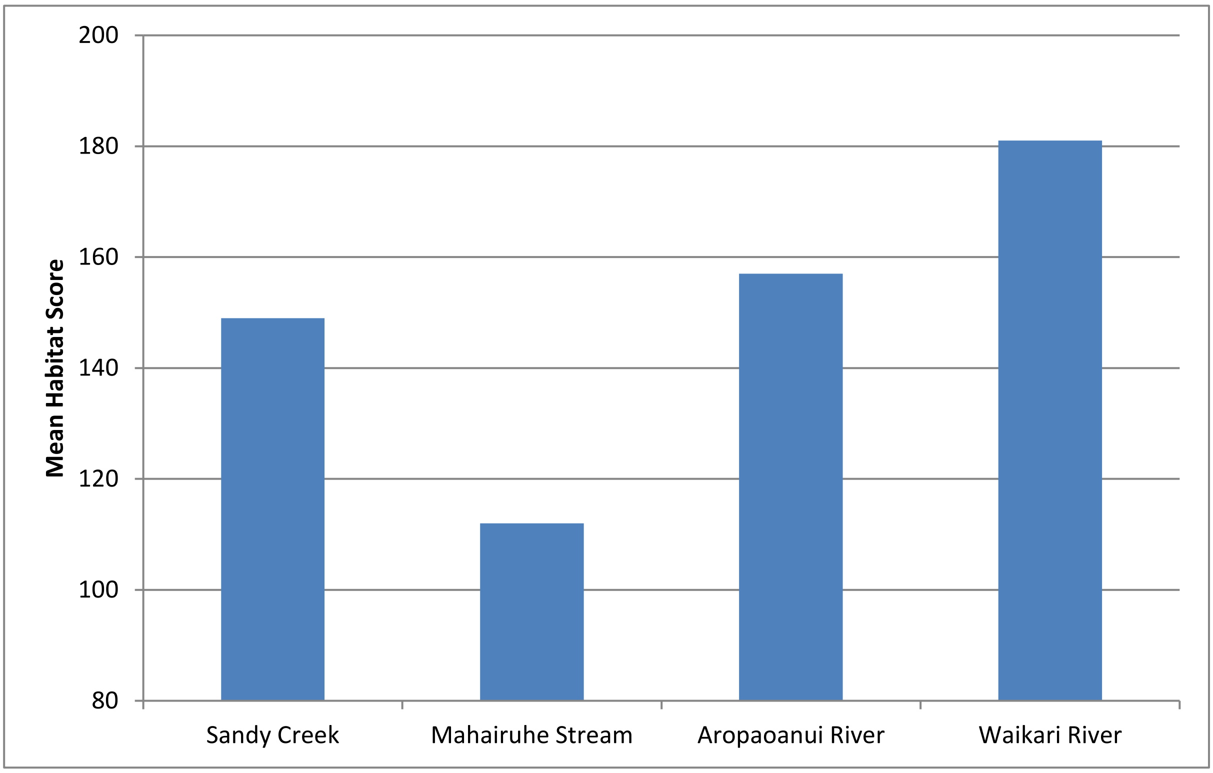


Figure 10: Mean habitat score from stream habitat assessments

3.4 Comparison with national figures

A 2008 report prepared by NIWA for the ministry for the Environment to support the 2007 national state of the environment report presents a national summary of regional council data. In particular, the report provides national median values for some key water quality variables, recorded at sites classified in 5 broad categories, based on the source of flow (upland/lowland) and the dominant land cover (natural/pastoral), the fifth category being urban streams (NIWA 2008).
The results obtained for the Aropaoanui and Waikari Catchments were compared to national figures, to provide a national perspective. All sites were compared to lowland/pastoral sites (NIWA 2008).

In general the sites show favourable water quality when compared to the national median values for DIN and water clarity. The river sites compare favourably when compared to national median values of DRP and *E. coli* while the smaller stream sites (Sandy Creek and Mahiaruhe) do not.

Table 15: Comparison of water quality statistics for the Aropaoanui and Waikari catchments with national figures (1997-2002). Green shading indicates better or equivalent to water quality of the national median, red shading indicates worse water quality than the national median.

Site Type	Site	DRP (mg/l, median)		SIN (mg/l, median)		*E. coli* (/100ml,) 95th %ile		Clarity (m, median)	
		National median	Site median	National median	Site median	National median	Site 95th %ile	National median	Site median
Lowland pastoral streams	Sandy Creek u/s of tream	0.016	0.037	0.55	0.305	1542	2500	1.2	1.64
	Mahiaruhe Stream d/s of Sandy Creek Confluence		0.035		0.247		2000		1.65
	Aropaoanui River @ Aropaoanui		0.012		0.073		360		1.93
	Waikari River @ Glenbrook Rd		0.016		0.224		260		1.87

3.5 Temporal Trends

The results of the seasonal Kendall trend tests performed on the data collected at the Aropaoanui and Waikari Catchments are presented in tables 16 and 17.
Water quality variables analysed include MCI,Chl a, DRP, DIN *E. coli* and water clarity.

Table 16: Summary of macroinvertebrate community index score and Chl a temporal trend analysis.

		MCI				
	Site	Period analysed	N. of samples	Trend	p	Slope (%/year)
MCI	Sandy Creek u/s of Mahiaruhe Stream	2000-2007	6	-	NS	-
	Mahiaruhe Stream d/s of Sandy Creek Confluence	n/a	2			
	Aropaoanui River @ Aropaoanui	2001-2008	8	-	NS	-
	Waikari River @ Glenbrook Rd	2001-2008	8	-	NS	-
Chl a	Sandy Creek u/s of Mahiaruhe Stream	2000-2007	6	-	NS	-
	Mahiaruhe Stream d/s of Sandy Creek Confluence	n/a	2			
	Aropaoanui River @ Aropaoanui	2001-2008	8	-	NS	-
	Waikari River @ Glenbrook Rd	2001-2008	8	-	NS	-

Table 17 Summary of water physicochemistry temporal trend analysis.

	Site	Sandy Creek	Aropaoanui River	Waikari River
DRP	Period Analysed	1995-2008	1995-2008	2000-2008
	Trend	↗	↗	-
	P	0.007	0.001	ns
	Slope (%/yr)	6.06	6.8	-
SIN	Period Analysed	1995-2008	1995-2008	2000-2008
	Trend	-	-	-
	P	ns	ns	ns
	Slope (%/yr)	-	-	-
E. coli	Period Analysed	1997-2008	1997-2008	2000-2008
	Trend	↗	-	-
	P	0.05	ns	ns
	Slope (%/yr)	6.75	-	-
Water Clarity	Period Analysed	1995-2008	1995-2008	2000-2008
	Trend	-	-	-
	P	ns	ns	ns
	Slope (%/yr)	-	-	-

Table 16 shows that no significant trends were observed with respect to MCI or Chl a concentrations. Table 17 shows significant increasing trends with respect to dissolved reactive phosphorus concentrations at all sites except the Waikari River. Table 17also shows *E. coli* concentrations are increasing at Sandy Creek.

3.6 **Contaminant loads analysis**

This section of the report presents the results of an analysis of the contaminant loads of the Sandy Creek, Aropaoanui River and Waikari River catchments. The Mahiaruhe Stream has not been analysed because of insufficient reliable flow data being available.

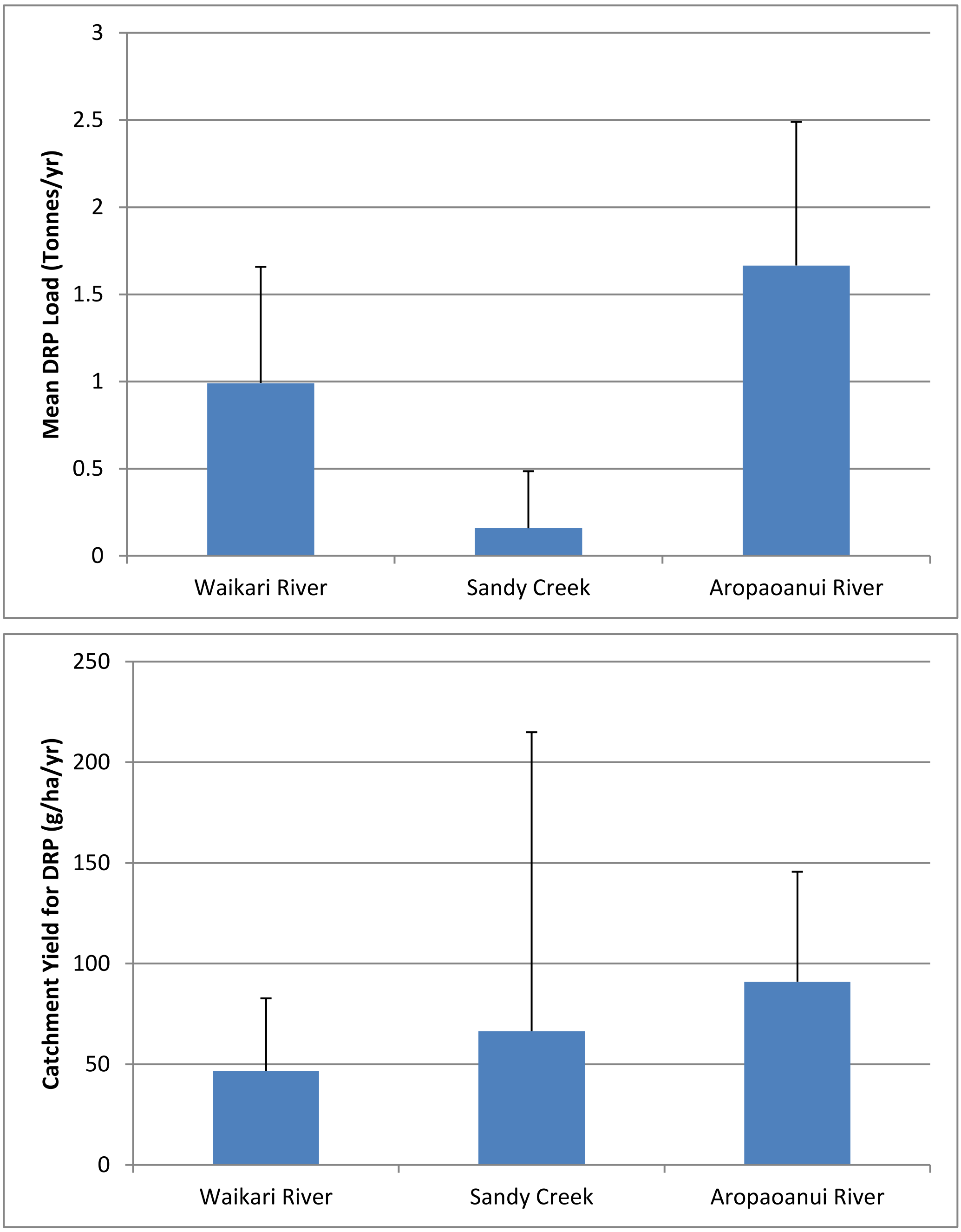


Figure 11: DRP loading and yield analysis for the Aropaoanui and Waikari Catchments

Figure 11 shows that DRP loadings are highest in the Aropaoanui River followed by the Waikari River and lowest in Sandy Creek. The yields analysis shows the Aropaoanui River as highest which is followed by Sandy Creek. A year by year analysis showed that Sandy Creek had significantly higher yields than the remaining catchments (see Appendix 4).

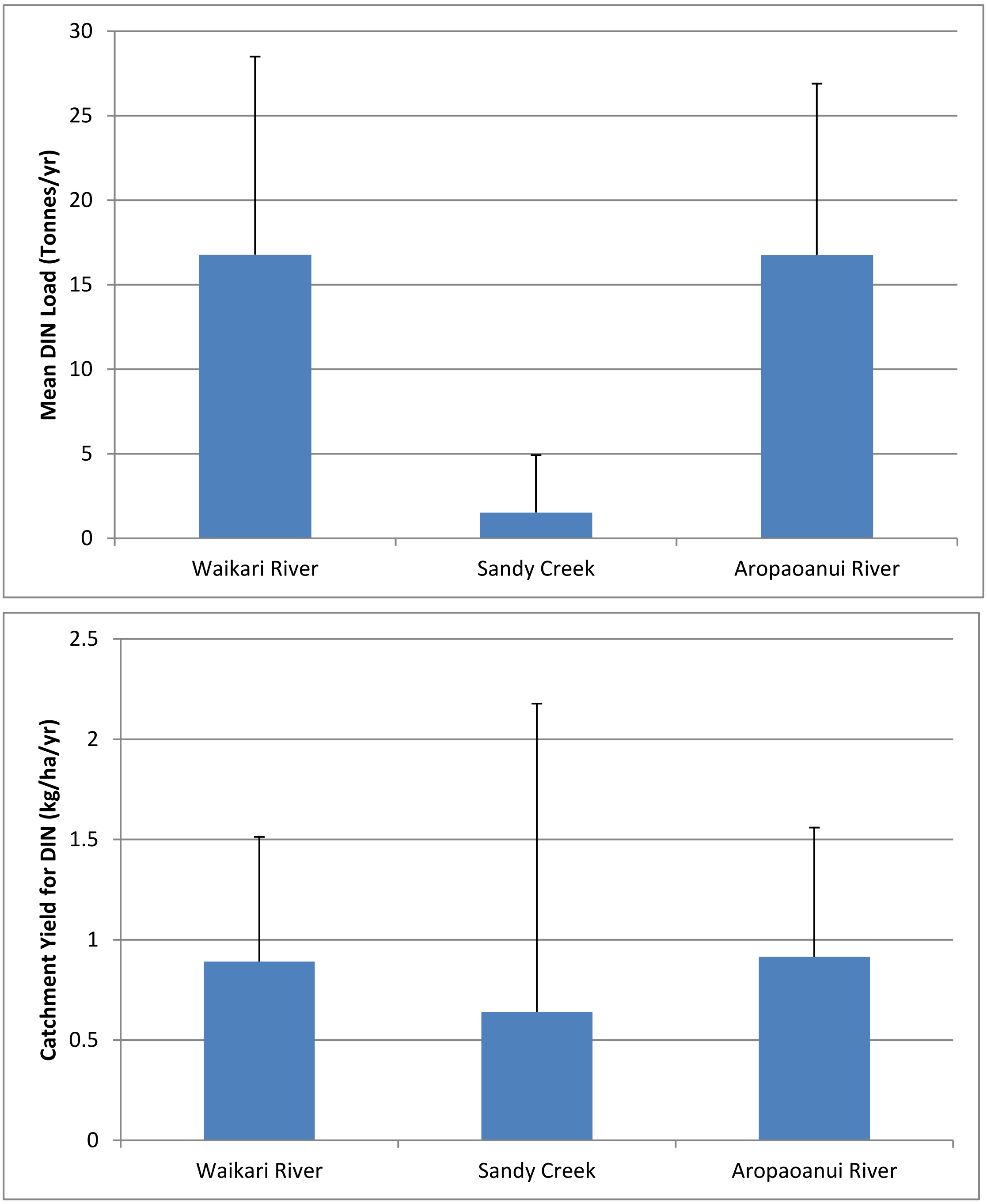


Figure 12: DIN loadings and yields for the Aropaoanui and Waikari Catchments.

Figure 12 shows that DIN loadings and yields are generally higher in the Wiakari and Aropaoaonui Catchments and lowest at Sandy Creek.

4.0 DISCUSSION AND CONCLUSIONS

The Aropaoanui and Waikari River Catchments have been grouped together because they have a similar river environment classification (warm low elevation pastoral streams) and are in close proximity to each other near Tutira.

Mean MCI values for the Aropaoanui River, Sandy Creek and Waikari River all reflect possible mild enrichment while the Mahiaruhe Stream reflects poor water quality. The Mahiaruhe Stream also shows poor habitat quality. Unique features of this site that give rise to the poor habitat include bank stability, channel stability and complexity and stable bottom substrate availability. It is likely that these habitat variables play some role in giving rise to poor quality macroinvertebrate communities at this site. Interestingly it is likely that these same habitat variables are also responsible for providing a mobile silty substrate which has resulted in this site having the lowest periphyton biomass. Compliance with the periphyton chlorophyll a guideline is generally excellent at all sites.

Compliance with environmental guidelines is excellent at all sites for DIN, pH for native fish and trout tolerance, ammoniacal nitrogen, suspended sediments, *E. coli* (for bathing river sites) and water temperature.

For the contact recreation sites (the rivers) compliance is generally excellent for *E. coli* and clarity guidelines. Faecal coliform concentrations also show excellent compliance at the river sites but are poor at Sandy Creek.

For many variables compliance is better at the larger volume sites this is particularly so for DRP (average compliance at Rivers, poor compliance at Sandy Creek), faecal coliforms (excellent compliance at rivers, poor compliance at Sandy Creek) and % saturation dissolved oxygen (excellent compliance at river sites, good compliance at Sandy Creek and Mahiaruhe Stream). It is likely that the smaller water courses provide less dilution to the contaminants they receive which results in higher concentrations of nutrients and bacteria resulting in lower dissolved oxygen concentrations.

Water clarity readings show poor compliance with the 3.5m guideline for trout foraging which could indicate that these guidelines are either too stringent or possibly not suitable for these stream types. Further research of trout energetic modelling is likely to refine these guidelines to meet river types more accurately in the future.

DRP concentrations show a slight decline with lower flows however the concentrations are relatively stable irrespective of flow category. It is possible that nutrient rich groundwater inputs may be playing a role in these rivers and streams that ensures that nutrient concentrations remain stable for this variable. All sites show increasing DIN concentrations with increased flow suggesting that nutrient mobilisation during storm events plays a large role in elevating concentrations at these sites.

As indicated earlier nutrient concentrations are generally higher in the smaller streams, which could be a result of inadequate dilution to incoming contaminants. The DRP and DIN yield analysis certainly supports this hypothesis showing that Sandy Creek has significantly higher yield than the river sites when examined on a year by year basis (see appendix 4).

The nutrient limitation analysis shows that the sites are often P limited, co-limited or in a state where the limitation could be either N or P limitation. The general pattern of the data suggests that N limitation is more likely to occur during lower flow events, which possibly suggests some seasonality of nutrient limitation. Nutrient limitation analysis using nutrient agar bioassays would help confirm if this is so. Nitrate is water soluble and tends to be most mobile on land when soils are wet (winter) and practically immobile during summer droughts. DRP, by contrast is mostly mobilised in surface runoff events and is related to land loadings from superphosphate and animal dung. Land loadings of DRP to waterways are not generally seasonal, or are weakly associated with fertiliser applications in spring and autumn. This means that streams in pasture catchments commonly have high N/P ratios in winter and low ratios in summer.

E. coli concentrations are generally stable irrespective of flow category at most sites. The reason for this pattern is unclear. *E. coli* concentrations are generally higher at the stream sites while water clarity at these sites is generally lower when compared to the river sites. The smaller sites generally have less dilution capacity and easier stock access to the waters edge than larger rivers. This may account for the higher E. Coli and sediment concentrations in these streams. Water clarity declines with increasing flows at all sites suggesting that both runoff and streambed mobilisation contribute to raising suspended sediments and decreasing clarity.

TOC concentrations are generally higher at higher flows indicating that much of the organic matter within these catchments is derived from runoff inputs received during storm events. Concentrations are generally higher at the Sandy Creek and Waikari River sites. The reason for this is unclear and may warrant further investigation. % saturation dissolved oxygen concentrations at the river sites is generally good to excellent indicating that current levels of organic matter entering these streams is insufficient to degrade oxygen concentrations in them.

Comparison with national median values indicates that all sites compare favourably in terms of DIN, and water clarity while comparison with the national DRP median and *E. coli* 95th percentile indicates that only the smaller streams (Sandy Creek and Mahiaruhe Stream) have higher concentrations.

Temporal trend analysis suggests that DRP concentrations are increasing at Sandy Creek and Aropaoanui River. *E. coli* concentrations are also increasing at Sandy Creek. The reasons for these temporal trends are currently unclear. Further research into the catchment sensitivities of land use pressures occurring within these catchments using computer modelling would help better understand why these patterns are emerging. No temporal trends have been observed in terms of the in-stream biology as measured by the MCI and Chl a concentrations.

The contaminant loading analysis shows that while DRP loadings are highest at the Aropaoanui and Waikari Rivers, DRP yield at Sandy Creek is comparatively higher than the Waikari River.

DIN loading analysis shows that while loadings are highest at the Waikari and Aropaoanui Rivers, the yields at Sandy Creek are comparatively high when considered on a year by year basis. Again the reason for this is unclear and further research of land use and sensitivity of catchments using computer models would help determine why these patterns are occurring.

To conclude there are number of spatial and temporal trends that have been presented in this state of the environment report and further research would be required to help elucidate why some of these trends are occurring. With this in mind I would recommend the following:

- More research is required on land use pressures and catchment sensitivities to them using computer modelling using CLUES (catchment land use for environmental sustainability).

ACKNOWLDEGEMENTS

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Appendix 1: Summary Statistics – All Flow

Sandy Creek	Mean	Median	Minimum	Maximum	90th Percentile	95th Percentile	Valid N	Std.Dev.	95% C.I	S.E
AFDW (mg/L)	1846.935	261.12	1.50000	6864.00	6864.000	6864.000	4	3353.211	10603.05	838.3027
BD (m)	1.612	1.64	0.07000	3.60	2.250	3.450	32	0.770	0.406169	0.02405
CHLA (mg/m2)	100.851	0.03	0.00200	610.52	610.522	610.522	7	226.232	352.3951	32.31883
DIN (mg/L)	0.381	0.31	0.03000	1.21	0.799	0.927	27	0.277	0.161599	0.010268
ECOLI (cfu/100mL)	383.938	84.00	6.00000	2500.00	1400.000	2500.000	16	668.102	540.4854	41.75638
FC (cfu/100mL)	1199.852	540.00	37.00000	10000.00	3100.000	4200.000	27	2060.956	1201.362	76.33169
MCI (Unit)	106.167	105.50	95.00000	120.00	120.000	120.000	6	8.841	16.16529	1.473532
NH3 (mg/L)	0.051	0.05	0.00500	0.20	0.078	0.165	40	0.043	0.020038	0.001078
PH ()	7.612	7.65	6.86000	8.12	7.890	7.900	27	0.284	0.165832	0.010537
PHLAB ()	7.771	7.80	7.20000	8.10	8.000	8.000	24	0.210	0.131059	0.00873
SDO (%)	86.124	86.90	60.10000	122.60	99.300	122.600	29	13.663	7.635609	0.471122
SRP (mg/L)	0.033	0.04	0.00100	0.08	0.061	0.073	49	0.024	0.009848	0.000484
SS (mg/L)	11.704	3.00	1.00000	260.00	15.500	40.000	50	37.313	15.32829	0.746267
TKN (mg/L)	0.366	0.30	0.02500	1.50	0.530	1.200	32	0.289	0.15278	0.009046
TN (mg/L)	0.672	0.60	0.13000	1.66	1.180	1.580	27	0.385	0.224555	0.014268
TOC (mg/L)	3.564	3.30	1.80000	7.50	5.400	6.500	39	1.417	0.66803	0.036326
WATEMP (celcius)	12.679	13.00	6.00000	19.00	18.000	18.000	52	3.950	1.588111	0.075957

Aropaoanui River	Mean	Median	Minimum	Maximum	90th Percentile	95thPercentile	Valid N	Std.Dev.	95% C.I	S.E
AFDW (mg/L)	343.3620	24.69	2.10000	1084.000	1084.000	1084.000	5	486.3689	1106.208	97.27379
BD (m)	2.0800	1.93	0.08000	5.510	3.760	4.100	64	1.1628	0.417811	0.018168
CHLA (mg/m2)	8.3844	0.06	0.00200	35.519	35.519	35.519	8	15.4014	21.16306	1.925178
DIN (mg/L)	0.1521	0.07	0.01200	0.520	0.430	0.451	41	0.1542	0.070701	0.003761
ECOLI (cfu/100mL)	59.6667	31.00	8.00000	360.000	160.000	360.000	18	83.9902	62.8882	4.666122
FC (cfu/100mL)	214.2857	61.00	18.00000	3800.000	260.000	420.000	42	624.6893	282.5848	14.87355
MCI (Unit)	109.1625	108.65	93.00000	124.000	124.000	124.000	8	12.2467	16.82822	1.530843
NH3 (mg/L)	0.0278	0.02	0.00250	0.370	0.041	0.065	64	0.0524	0.018831	0.000819
PH ()	7.9400	7.99	7.30000	8.420	8.230	8.280	27	0.2745	0.159998	0.010166
PHLAB ()	8.1800	8.20	7.80000	8.500	8.400	8.400	40	0.1620	0.075327	0.004051
SDO (%)	92.4238	91.60	55.50000	118.200	107.200	113.000	42	12.1226	5.483769	0.288632

SRP (mg/L)	0.0146	0.01	0.00050	0.045	0.031	0.033	65	0.0118	0.004193	0.000181
SS (mg/L)	8.4152	3.70	0.50000	170.000	14.000	23.000	66	22.4334	7.928842	0.3399
TKN (mg/L)	0.2457	0.20	0.02500	1.200	0.420	0.850	48	0.2191	0.09204	0.004564
TN (mg/L)	0.3627	0.35	0.09300	1.298	0.619	0.730	42	0.2491	0.112671	0.00593
TOC (mg/L)	2.1811	1.75	0.59000	5.800	3.500	3.800	64	0.9640	0.346398	0.015063
WATEMP (celcius)	13.2338	13.00	5.50000	22.000	19.000	19.500	65	4.4949	1.601746	0.069153

Mhiaruhe Stream	Mean	Median	Minimum	Maximum	90thPercentile	95thPercentile	Valid N	Std.Dev.	95% C.I	S.E
AFDW (mg/L)	2.5900	2.59	2.59000	2.590	2.590	2.590	1		0	0
BD (m)	1.5188	1.65	0.10000	2.700	2.120	2.580	33	0.6200	0.321487	0.018789
CHLA (mg/m2)	2.4065	2.41	0.01300	4.800	4.800	4.800	2	3.3849	106.5032	1.69246
DIN (mg/L)	0.2830	0.25	0.02300	1.288	0.504	0.553	32	0.2338	0.123375	0.007305
DO (mg/L)	8.8394	8.92	5.35000	11.040	10.190	10.400	32	1.2373	0.653012	0.038665
ECOLI (cfu/100mL)	366.1765	86.00	17.00000	2000.000	2000.000	2000.000	17	637.1521	495.1685	37.47953
FC (cfu/100mL)	506.9259	250.00	36.00000	2700.000	1200.000	2600.000	27	688.5267	401.3527	25.50099
MCI (Unit)	80.9500	80.95	74.00000	87.900	87.900	87.900	2	9.8288	309.253	4.914392
NH3 (mg/L)	0.0388	0.03	0.00500	0.120	0.070	0.088	33	0.0230	0.011921	0.000697
PHLAB ()	7.7848	7.80	7.20000	8.500	8.000	8.100	33	0.2502	0.129704	0.00758
SDO (%)	86.5938	85.80	57.60000	114.400	101.800	103.100	32	12.2762	6.479101	0.383632
SRP (mg/L)	0.0363	0.04	0.00700	0.077	0.063	0.071	33	0.0186	0.009636	0.000563
SS (mg/L)	11.5939	4.00	1.00000	185.000	12.000	53.000	33	32.4471	16.82394	0.983245
TKN (mg/L)	0.4120	0.30	0.02500	1.100	0.720	1.100	33	0.2494	0.129327	0.007558
TN (mg/L)	0.6678	0.61	0.21000	1.920	1.012	1.240	32	0.3306	0.1745	0.010332
TOC (mg/L)	4.2485	3.80	1.80000	7.600	6.000	7.000	33	1.3384	0.693968	0.040558
WATEMP (celcius)	13.6303	12.50	6.00000	20.500	19.000	19.500	33	4.3542	2.257669	0.131945

Waikari River	Mean	Median	Minimum	Maximum	90thPercentile	95thPercentile	Valid N	Std.Dev.	95% C.I	S.E
AFDW (mg/L)	1223.456	66.26	18.07000	3195.000	3195.000	3195.000	5	1625.574	3697.241	325.1147
BD (m)	1.837	1.87	0.28000	3.750	2.950	3.560	34	0.828	0.422141	0.024359
CHLA (mg/m2)	11.620	0.20	0.04600	49.254	49.254	49.254	8	18.582	25.534	2.322797
DIN (mg/L)	0.285	0.22	0.01400	1.161	0.622	0.725	32	0.265	0.139745	0.008274
ECOLI (cfu/100mL)	55.556	28.00	1.00000	260.000	120.000	260.000	18	64.646	48.40399	3.591436

Waikari River	Mean	Median	Minimum	Maximum	90thPercentile	95thPercentile	Valid N	Std.Dev.	95% C.I	S.E
FC (cfu/100mL)	90.750	59.00	9.00000	360.000	178.000	330.000	28	85.671	48.87678	3.05968
MCI (Unit)	106.338	105.10	89.50000	126.000	126.000	126.000	8	12.992	17.85254	1.624024
NH3 (mg/L)	0.023	0.02	0.00500	0.090	0.050	0.061	34	0.020	0.010313	0.000595
PHLAB ()	8.274	8.20	7.70000	8.900	8.700	8.800	34	0.276	0.140464	0.008105
SDO (%)	97.759	95.90	65.70000	136.700	118.700	135.300	34	15.283	7.789667	0.449494
SRP (mg/L)	0.016	0.02	0.00050	0.053	0.030	0.036	34	0.012	0.006216	0.000359
SS (mg/L)	3.988	1.50	0.50000	31.000	7.300	12.000	34	5.510	2.808442	0.162058
TKN (mg/L)	0.316	0.28	0.02500	1.500	0.500	0.660	34	0.251	0.128116	0.007393
TN (mg/L)	0.584	0.49	0.17000	1.680	0.930	1.650	32	0.359	0.189396	0.011214
TOC (mg/L)	3.756	3.20	1.80000	8.500	5.700	7.400	34	1.565	0.797877	0.046041
WATEMP (celcius)	13.544	13.05	5.90000	21.000	19.800	20.500	34	4.820	2.457007	0.141779

Appendix 2: Stream Habitat Assessment Form

STREAM/RIVER……..…………..

EASTING……………..……………...

NORTHING……………..…………

SITE- ID ……………………………..

DATE…………………………………

ASSESSOR………………………….

WIDTH of the stream………………

STREAM HABITAT ASSESSMENT

Determine the condition of the stream channel and riparian zone at which you are standing and up to 100m upstream and downstream. Estimate the average condition over that distance and select ONE of the scoring categories for each characteristic.

I. Adjacent landuse

Q1 Dominant land-use pattern beyond the immediate streamside vegetative buffer zone.

	L	R	
Undisturbed native forest, wetland			40
Disturbed native forest, Tussock grassland			30
Non production exotic forest			25
Production forest			20
Retired Pasture			15
Extensive pastoral farming e.g. Beef, sheep and deer on hill country			10
Intensive pastoral farming e.g. Dairy on easy contour			5
Horticultural /Urban / Industrial			1

II. Vegetation

Q2 Width of stream and bankside vegetation on both sides that buffers the effect of deleterious land use patterns (average riparian zone)

>30 m wide		30
5-30m		20
1-5m		5
0m		1

Q3 Structure of streamside vegetation

	L	R	
Trees with dense groundcover e.g. Tussock, toetoe, ferns, flax, rushes			20
Trees with no or light groundcover			15
Tall grasses with patchy trees and groundcover scrub			10
Patchy trees, groundcover grazed			5
Grazed Pasture, grasses to stream edge			1

Q4 Type of streamside vegetation

	L	R	
Native trees like, Manuka, Kowhai, Hebe, Cabbage Tree etc., wetland			30
Native trees with different exotic species			25
Willows, Poplars, Rank, tall native grass			15
Pinus Radiata, Conifers in general >10 years			10
Gorse, Blackberry, Broome, high grasses, plantation forests< 10 years			5
Pasture grasses and weeds			1

Q5 Age of the trees and the vegetation

	L	R	
High > 60			10
Medium 21-60			5
Low 0.1-20			1

Q6 Streamside shading

50% or more		20
30 – 49%		10
10 – 29%		5
Little or no shading		1

Q7 Completeness of bank and streamside vegetative buffer

Completely intact		30
Occasional breaks i.e. 1-10 gaps in reach		20
Breaks common i.e. 11-20 gaps in reach		10
Breaks frequent i.e. 20+ gaps in reach		5
Buffer absent		1

Q8 Periphyton cover on suitable substrates (as filamentous or mat forming growths >3mm thick). This excludes bryophytes and mosses.

Periphyton not visible on hand held stones		20
Visible on bed covering few surfaces, <20% cover		10
Visible on bed covering many surfaces, 20-50% cover		5
Visible on bed covering most surfaces, >50% cover		1

Q9 Macrophyte abundance

Macrophytes generally absent and stony substrate and / or low growing chara/bryophyte. Moss communities dominant		20
Submerged and or emergent macrophytes		10

present		
Submerged macrophytes abundant		5
Emergent macrophytes abundant		1

III. Stability (Bank, Channel)

Q10 Bank Stability

Bank stable, no evidence of erosion or bank failure Infrequent, small areas of erosion (10%)		20
Moderate frequency of erosion areas (11-30%)		10
Unstable, many eroded areas (>30% eroded)		1

Q11 Channel stability and complexity

Stable natural stream width little or no enlargement of islands, point bars (sediment movement), and/or no channelisation		20
Some new increase in sediment movement mostly from coarse gravel and/or some channelisation present.		10
Moderate movement of gravel, coarse sand, pools partially filled with silt and/ or channelisation obvious.		5
Heavy deposits of fine material, most pools filled with sediment and/or extensive channelisation		1

IV. Disturbances caused by stock management

Q12 Stock Access

Stock do not have access to the stream or it's banks		20
Stock only have access to a small part of the stream		10
Stock have access to most of the stream		5
Stock have access to the entire stream		1

Q13 Stock damage

None		20
Low		10
Modest		5
High		1

V. Other external disturbances

Q14 What is the potential for the **input of sediments** to your stream e.g. from stock trampling, stock crossings, surface runoff, farm roads, slips erosion, gravel extraction?

No potential		20
Low potential		10
Moderate potential		5
High potential		1

Q15 What is the potential for the **input of contaminants** to your stream e.g. from spray drift, sprayer washings, sheep dips, effluent ponds, silage pits dumps, oil and foam, dead animals etc.?

No contamination		20
Low contamination		10
Moderate contamination		5
High contamination		1

Q16 Is there any **artificial drainage** entering the stream e.g. tile, mole, storm water & open drains which have the vegetation dredged?

No artificial drainage		20
Sparse artificial drainage		10
Moderate amount of drainage		5
Extensive drainage networks		1

Q17 Are there any **natural drainage pathways within 200m** of you (e.g. where run-off is directed into a gully or ephemeral type channel and then into a stream- a large amount of run-off enters the stream at one point)

No natural drainage pathways within 100m		20
1 natural drainage pathway within 100m		10
2-3 natural drainage pathways within 100 m		5
> 3 natural drainage pathways within 100m		1

VI. Stream/Riverbottom habitat diversity

Q18 Hydraulic indicators of in-stream macrohabitat diversity measured by different frequency of flow types.

Frequent occurrence of riffle/ bends/pools. Excellent diversity of habitat.		20
Common occurrence of riffle/bend/pools. Good diversity of habitat.		10
Occasional occurrence of riffle/ bends/ pools. Moderate diversity.		5
Infrequent or absence of riffle/ bends/ pools. Essentially a straight run. Poor diversity of habitat		1

Q19 Stable bottom substrate availability.

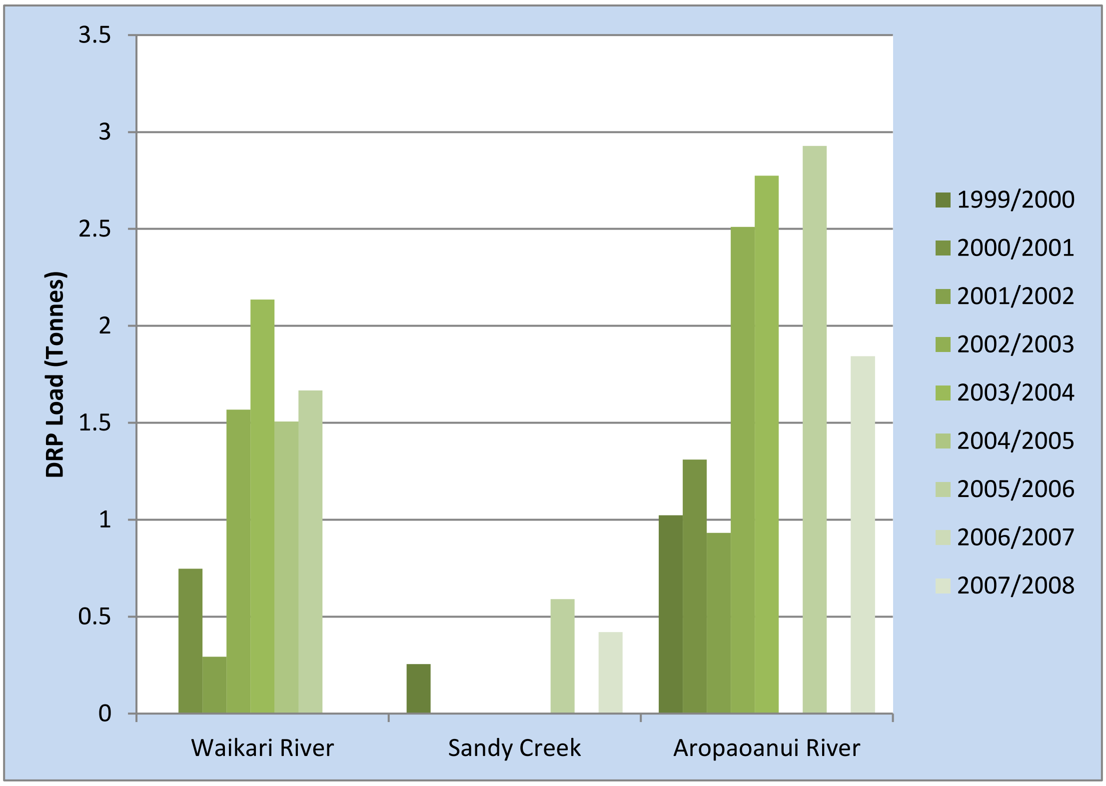
> 50% cobble, gravel, submerged logs, undercut banks, bedrock or other stable habitat (diverse and		20

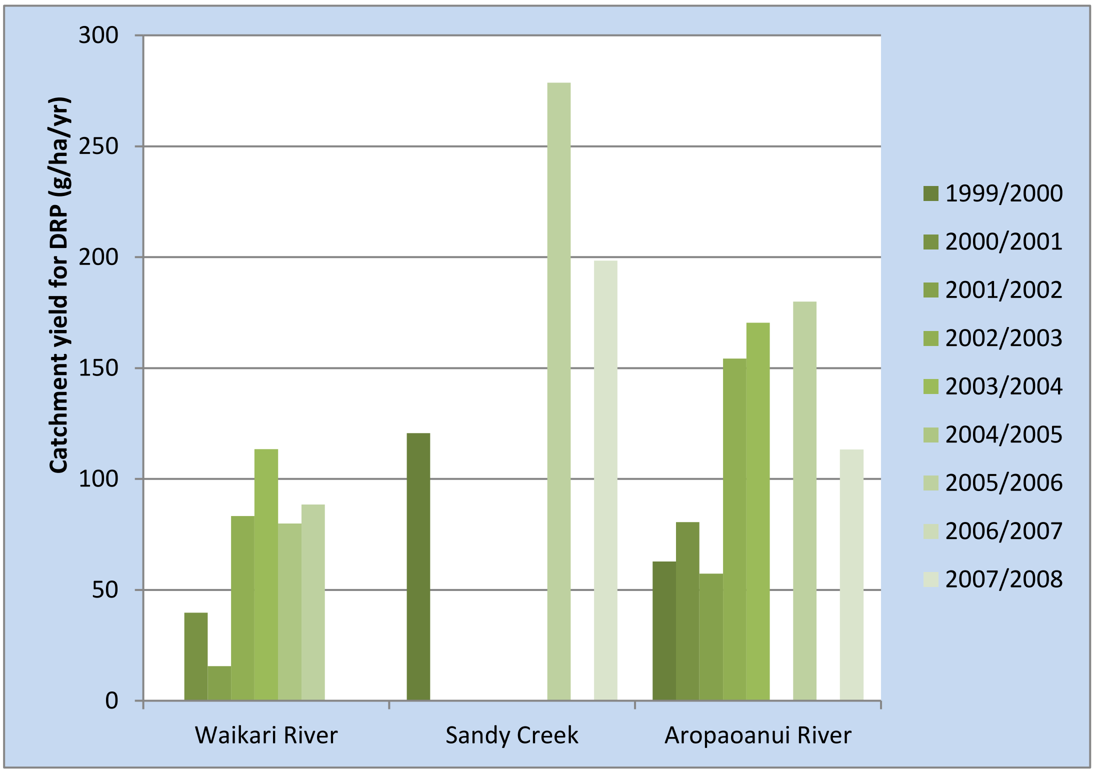
stable)		
30-50% cobble, gravel or other stable habitat (adequate habitat)		10
10-30% cobble, gravel or other stable habitat. Habitat availability less than desirable		5
< 10% cobble, gravel or other stable habitat. Lack of habitat is obvious		1

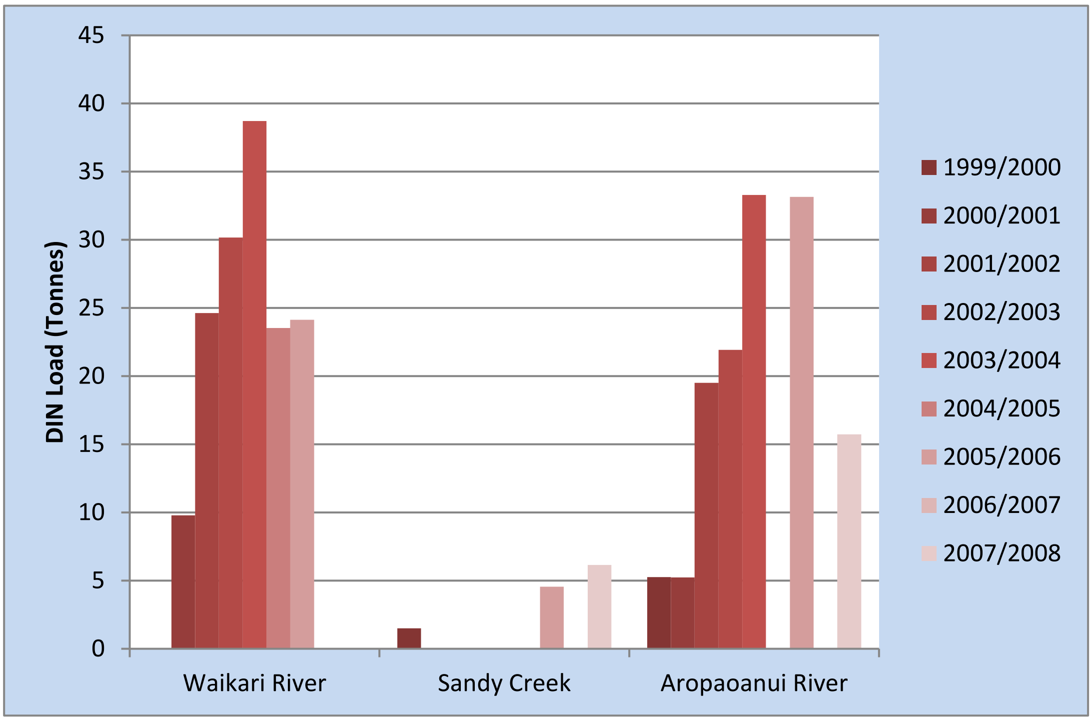
Q20 Embeddedness of dominant coarse substrate

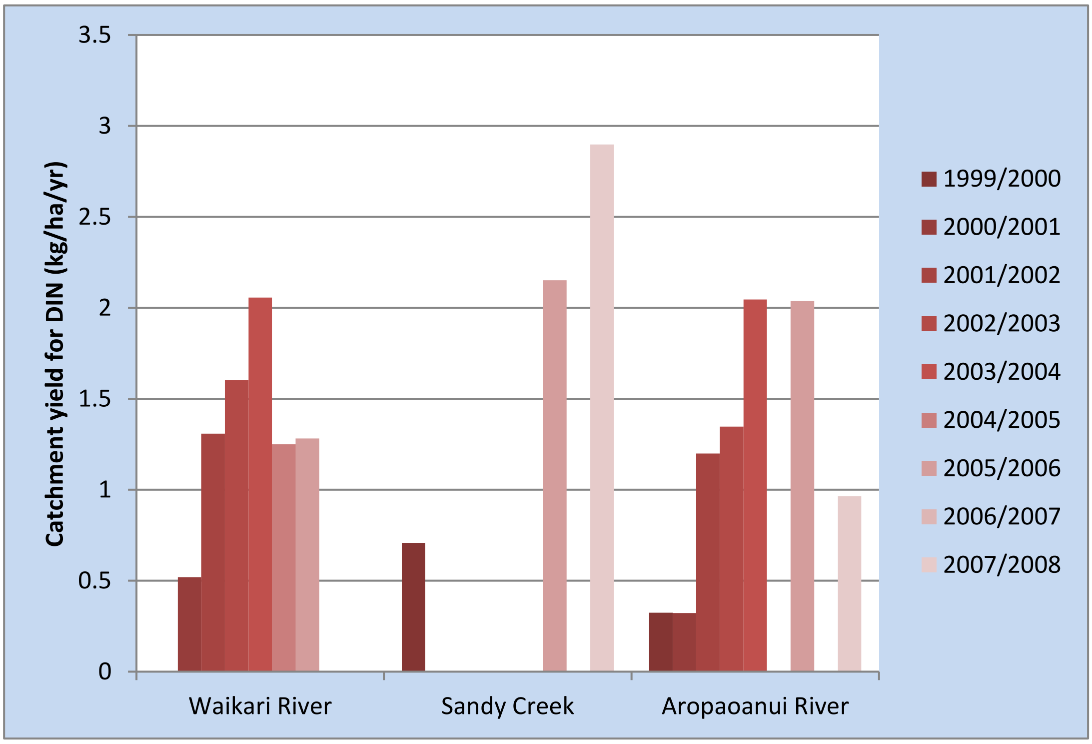
Difficult to move		20
Moderate amount of effort		10
Easy to move		1

Appendix 4: Catchment loading and yield analysis by year






DIN Load (Tonnes)
45
40
35
30
25
20
15
10
5
0
Waikari River
Sandy Creek
Aropaoanui River
1999/2000
2000/2001
2001/2002
2002/2003
2003/2004
2004/2005
2005/2006
2006/2007
2007/2008


Catchment yield for DIN (kg/ha/yr)
3.5
3
2.5
2
1.5
1
0.5
0
Waikari River
Sandy Creek
Aropaoanui River
1999/2000
2000/2001
2001/2002
2002/2003
2003/2004
2004/2005
2005/2006
2006/2007
2007/2008