State of the Environment Surface Water Quality Monitoring Report, 2010

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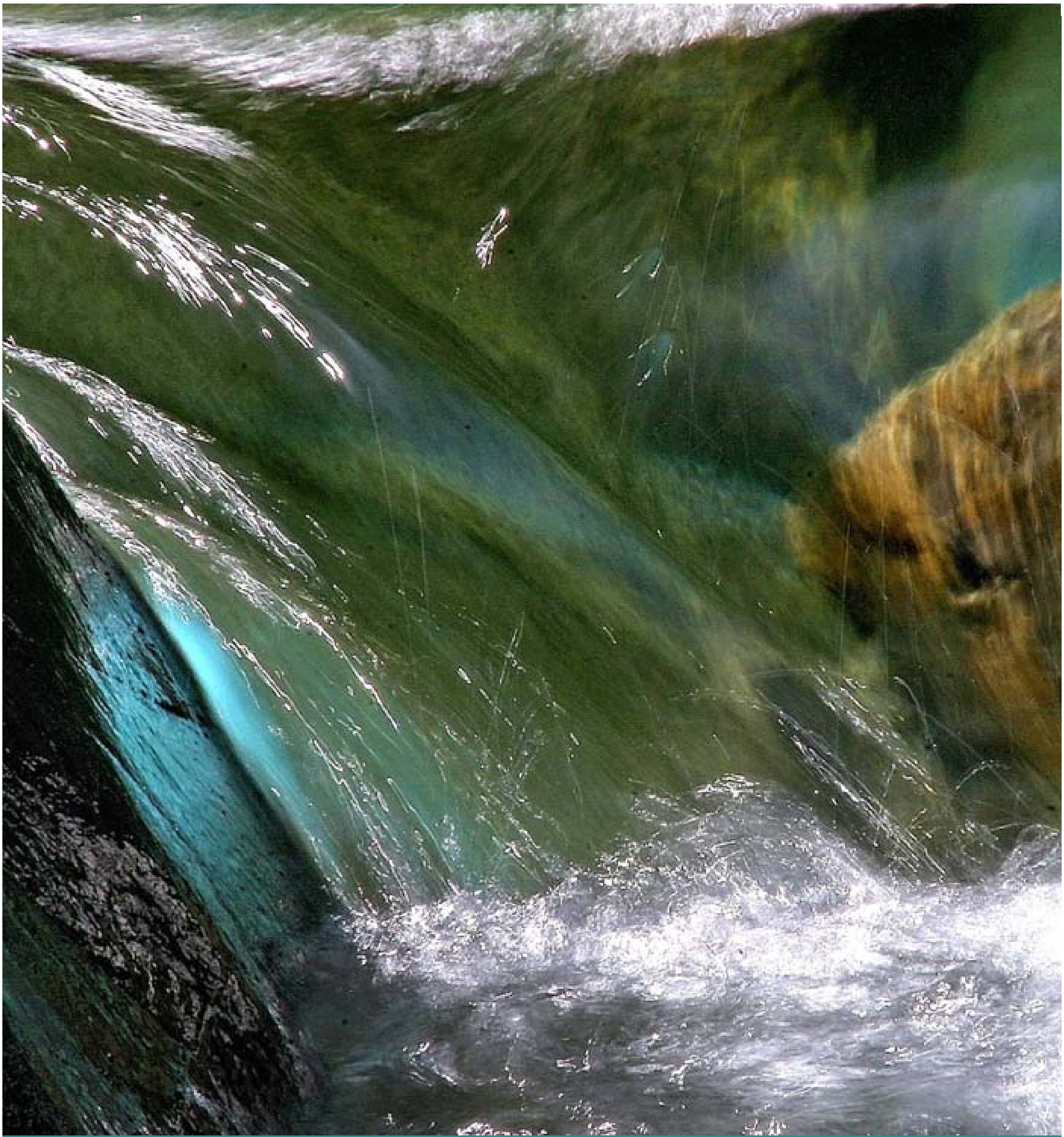

MARLBOROUGH
DISTRICT COUNCIL

State of the Environment Surface Water Quality Monitoring Report, 2010

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Executive Summary

Marlborough's Surface Water Quality monitoring programme for state of the environment reporting was revised in 2007. The revision incorporated a catchment management approach to water quality monitoring. The core objectives of this report are to:

1. Elucidate the current surface water quality monitoring strategy.

2. Analyse surface water quality (2007-2009) with a view to establishing baseline water quality for the regions sites which are monitored on a monthly basis.

72 Water Resource Units (WRU's) have been created based on hydrological catchment boundaries. The creation of a WRU implies the need to establish baseline water quality for that unit. A variety of parameters, including chemical, biological and physical are used to establish baseline water quality for each unit. Currently there are 34 sites which are monitored on a monthly basis for a range of physical and chemical parameters; the majority of these also have biological (macroinvertebrate) monitoring carried out on an annual basis. Twenty of the sites have flow monitoring. Of the 72 WRU's 50 have either biological or phys/chem parameters measured at annual and monthly frequencies respectively. The remainder have no routine monitoring carried out due to their remote locations and current low risk with regard to pressures on water quality. However, baseline water quality is still required for these units by 2012 (Marlborough District Council Long Term Plan, 2009-2019). Biological monitoring will be carried out at these sites by 2012 in order to establish baseline water quality, 3 yearly monitoring will occur thereafter; the frequency of monitoring can be increased if pressures within the WRU increase.

The current Water Resource Units have been created with a view to managing Marlborough's surface water quality; however it is envisaged that these units will remain flexible to allow for a more holistic sustainable approach to water management.

In 2007 SoE surface water monitoring comprised of 18 sites, further sites have been added since then. A total of 34 sites are currently monitored on a monthly basis. A minimum of 3 years of data is preferable in order to establish baseline water quality for these sites; therefore many sites will not have a complete picture of baseline water quality until 2012.

Water quality is generally poorer in areas which have been intensively modified either for agriculture, horticulture or urbanisation. Very few point source discharges exist in the region and therefore the biggest threat to maintaining good water quality comes from diffuse pollution. Water quality is intrinsically linked with land use and development, therefore having the ability to track changes in water quality with changes in land use is essential in order to develop sustainable management practices for our water resources.

Water quality grades have been developed for the region based on current guidelines and current water quality. Grades range from excellent to very poor. 33 sites have been graded with grades being categorised as complete or interim depending on the number of samples used to calculate the grade. Of these 42% are graded as excellent or good whilst 21% are graded as poor or very poor; the remainder are graded as fair. Nearly 60% of sites have a complete grade.

Contents

1. Introduction

Currently there are three monitoring programmes which assess surface water quality in Marlborough, these are;

1. State of the Environment (SoE) surface water quality monitoring
2. Recreational water quality monitoring
3. Clean streams accord water quality monitoring

Each of these programmes have been set up with specific objectives. These objectives determine the frequency, type and location of monitoring that is required. This report discusses the objectives and analyses the results of the State of the Environment (SoE) surface water quality monitoring programme. Details of the recreational water quality monitoring programme and the clean streams accord water quality monitoring programme can be found in the reports 'Marlborough's Freshwater Recreational Water Quality 2008-09' and 'Rai River Catchments Monitoring Report for the Dairying and Clean Streams Accord, 2008'.

The two core objectives of SoE monitoring are:

1. to define the state of water quality for the region; and
2. to detect changes in water quality for the region.

Monitoring of surface water quality in Marlborough for SoE reporting first began in 1996. The number of sites and the parameters measured has varied from year to year resulting in very few sites having long term data from which to identify trends in water quality for the region. Sampling frequency varied from monthly, quarterly and annually with monthly sampling of some river catchments occurring for one year, with a change in catchment the following year. Historic monitoring provides for some baseline information on water quality for much of the region but the frequency of the monitoring doesn't allow for trend analysis. A period of three years of monthly monitoring is usually required to determine baseline water quality; this period of time allows for seasonal variation and inter-annual variation (to include droughts and floods) to be taken into account. A period of five years or longer of monthly monitoring is most appropriate for determining trends in water quality (Scarsbrook and McBride, 2007).

In 2007 the surface water quality monitoring strategy changed to focus on catchment scale analysis across the region. Water quality of rivers and streams is largely determined by the landuse, geology and soils of the hydrological catchment. Changes in landuse can have dramatic effects on water quality. Water quality in upland areas is generally of better quality than that found in lowland areas of a catchment. In order to determine changes in water quality within a hydrological catchment from upland to lowland, monitoring sites need to be located in the upper and lower part of the catchment.

Catchments vary in size from 1st order to 7th order in Marlborough. Stream order refers to the size of the river where the smallest order numbers refer to the smallest streams and the highest order number refer to the largest rivers e.g. the Amazon is a 12th order river, the highest rank possible in the stream order system. Stream order increases when smaller tributaries join up to produce larger tributaries (Figure 1) until the eventual outlet to the sea.

There are 11,720 1st order catchments recorded under the River Environment Classification (REC) system devised by NIWA for the Ministry for the Environment; 2,500 2nd order catchments, 533 3rd order catchments, 105 4th order catchments, twenty three 5th order catchments, six 6th order catchments and one 7th order catchment (Snelder *et al*., 2004). The size of the catchment does not necessarily denote the value or importance of the catchment e.g. the small 2nd order catchments of Murphys Creek and other urban springs in Blenheim are highly valued for their natural character and ecological values. It is not feasible or desirable to monitor water quality in all catchments or to only choose catchments of a certain size and therein lies the challenge of devising a water quality monitoring strategy based on catchments.

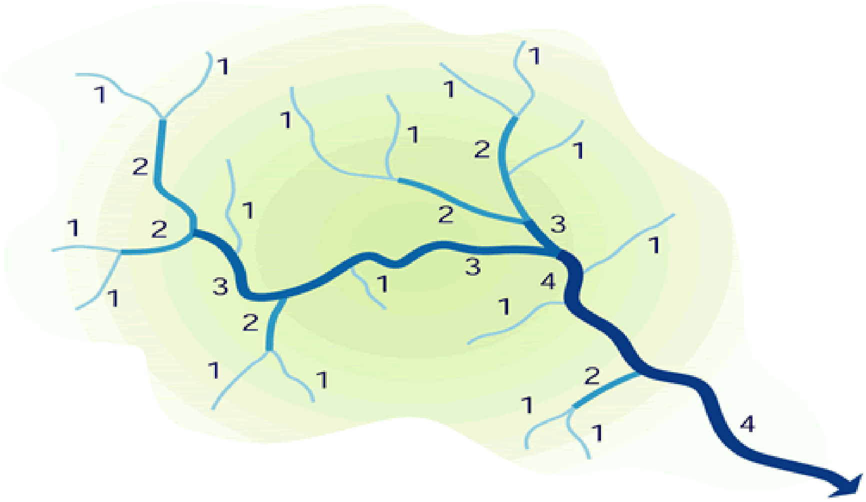


Figure 1: Increasing stream order number showing the increase in stream size from source to sea (from: www.fgmorph.com).

The choice of water quality standard for a particular water body is dependent on a number of factors including the values of the water body, the current water quality and the water quality which can be expected from such a water body. Each of these has to be carefully measured and assessed in order to arrive at a relevant set of standards. An underlying value which can be attributed to most if not all water bodies is that of ecological integrity, the value and sensitivity of which needs to be assessed for each water body depending on the flora and fauna present. Other values include fish spawning, contact recreation, iwi values, industrial, commercial or domestic supply of water, stock drinking water etc.

Current water quality can be good or bad, depending on the standards which it is expected to achieve. Water quality in this report is assessed against both national and international guidelines and refers primarily to the protection of aquatic life values. Water quality standards need to consider both current water quality and the values allocated to that water body. If the values of the water body are not protected by the current water quality then standards should be imposed to ensure that these values are protected, the result of which can be that the water body is classed as degraded (i.e. water quality is not of a standard which protects its values). Identifying degraded water bodies allows for a programme of action to be set up to rehabilitate these water bodies. Water quality is inherently better in upper catchments and often standards are set for ‘upland’ and ‘lowland’ rivers and streams on this basis (ANZECC, 2000); the expectation is that water quality is better and therefore water quality standards are more stringent in upland areas.

1.1. Objectives of the Report

1. Establish ‘water resource units’ (WRU’s) within Marlborough based on hydrological catchment areas for the purpose of defining and managing surface water quality.

2. Devise a surface water quality monitoring programme relevant for the whole of Marlborough for State of the Environment reporting.

3. Analyse surface water quality with a view to establishing baseline water quality.

4. Categorise the state of water quality by assimilating results to date from different water quality parameters to determine ‘grades’ for each monitored site.

2. Water Resource Units (WRU's)

The water quality of river and streams is primarily a function of the geology and soils from which they arise and flow through and the climate in which they exist. Changes in water quality are primarily attributed to changes in land use within the catchment. The management of the water quality of rivers and streams needs to consider the catchment from which they arise and the associated land uses within that catchment. It is widely acknowledged that upland rivers and streams have better water quality than lowland rivers and streams, and as a general rule upland catchments are less modified than lowland catchments. When assessing the water quality of rivers and streams, the water at the bottom of the catchment will generally be of poorer quality in relation to water quality from the upper catchment. From a management point of view a decline in water quality at the bottom of the catchment can be reflective of a degradation of water quality in the catchment as a whole.

Water quality monitoring based on a catchment management approach requires that all catchments be monitored. However the decision as to which catchments to monitor arises. A decision could be made to monitor only 4th order catchments of which there are 105 in Marlborough, however this approach would preclude smaller catchments with intrinsic values in their own right and might focus resources in areas where there is currently a low risk. Including 3rd order catchments would increase this to 533, therefore it is neither feasible nor desirable to monitor water quality in all catchments in Marlborough. Therefore an approach which allows for the amalgamation of similar catchments (either contiguous or non-contiguous) but which is flexible enough to allow for the addition of further catchments should risks or values to those catchments change is favoured. Such catchments are more appropriately termed water resource units and are used in this context for the purpose of managing water quality within each unit.

The WRU's take into account the hydrological catchment, land use pressures, existing monitoring data, homogeneity of the catchment or catchments, unique ecological values and groundwater linkages. The water resource units allow for the division along the hydrological boundaries of existing WRU's to create new WRU's should issues arise in future which would necessitate the creation of new WRU's. The delineation along hydrological catchments allows for the effects of landuse or changes in land use on water quality to be measured over time.

2.1. Hydrological Catchment Boundaries

NIWA has delineated hydrological catchments from 1st order streams to 7th order rivers for the whole of New Zealand. These catchments are based on the hydrological boundaries and have been mapped using computer models. However there are some inherent problems with the modelling. Catchments in low lying or flat areas are difficult to model and incorrect catchment boundaries have been drawn. The maintenance of this database is with NIWA and periodically updates will be made to account for regional and local discrepancies. As and when the database is updated by NIWA, these updates will be incorporated into the WRU boundaries as necessary.

2.2. Land Use Pressures

Approximately 50% of the Marlborough land region is under native forest or native vegetation (MDC, 2008). Pressures from land use on water quality will be minimal in these areas as the rivers and streams will be at pristine or near pristine states, however the climatic and geological character of these areas will differ across Marlborough thus the aquatic flora and fauna within these areas will differ depending on their adaptations to the differing climates, geology, altitudes etc. and consequently any landuse change within these areas will affect the aquatic flora and fauna and water quality in different ways.

The lower Wairau catchments, the Rai, Kaituna, and Linkwater catchments are amongst the catchments where water quality is under increasing risk of deterioration due to landuse pressures within the catchment. Increased intensification of viticulture and dairying in these catchments have put pressure on the water quality with increasing nitrates and bacteria numbers being recorded in these catchments. Catchments which are deemed 'high risk' with regard to land use pressure have been designated a WRU.

2.3. Existing Monitoring data

The creation of WRU's requires that water quality within the units be monitored to establish baseline water quality and to monitor trends over time. The boundaries of the WRU's take account of existing data i.e. water quality data, biological data and/or hydrological data. The existence of monitoring data is usually a reflection of land use pressure as monitoring generally takes place when there is an issue or a need for it. By taking into account existing data within a WRU a longer time period can be used from which to establish baselines and trends in water quality.

2.4. Homogeneity of Catchment

The degree of homogeneity within a catchment can reflect the degree of homogeneity of the water quality. Where catchments are similar with regard to climate, geology, soils, values and land use pressure they can be amalgamated as one WRU. Should future land use pressures or values change within the WRU then the WRU can be further subdivided along catchment boundaries to allow for this distinction.

2.4.1. River Environmental Classification (REC) of New Zealand

The REC system for New Zealand was published in 2004 by the Ministry for the Environment and NIWA (Snelder *et al.*, 2004). The REC system classifies rivers on a hierarchy of six levels which shape, form and define a river with a view to being able to group similar rivers types together across the entire country. This hierarchy is broadly divided at two scales, the catchment and local scale and the processes that occur within these scales. Catchment scale processes include climate, topography, geology and land-cover; local scale processes include network-position (i.e. stream order) and valley-landform. Figure 2 depicts the hierarchy of each of these processes when determining the physical and biological properties of a water body according to the REC classification (Snelder *et al.*, 2004).

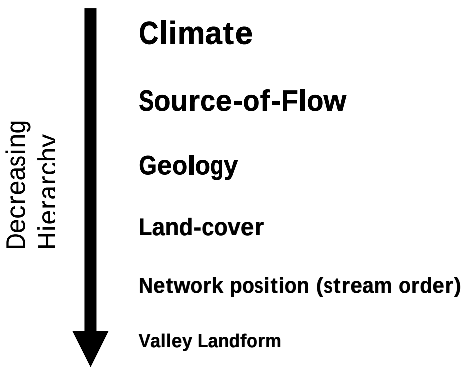


Figure 2: Processes which shape the physical and biological form of rivers, in decreasing order of hierarchy (from Snelder *et al*., 2004).

The REC classification of rivers is a useful means of defining water resource units as it allows for sub-catchments with similar climate, geology and terrain to be grouped together to create a single unit. Such units can be further sub-divided into sub-units should specific issues arise in the catchment to create pressures on water quality which creates the need for specific management practices within that sub-unit.

2.4.2. River Environmental Classification (REC) in Marlborough

The REC for Marlborough was analysed to determine the major river 'types' for the region. The three major 'processes' which shape river systems (climate, geology and source of flow) were analysed to determine how many different river types there were i.e. how many combination of the above (climate, geology and source of flow) exist for Marlborough's rivers. There are 46 river types in Marlborough based on the REC system (using and taking account of climate, geology and source of flow). 21 of these types each make up less than 1% of the total river stretch in Marlborough. The 15 major river types are listed in Table 1 below. The areas of Marlborough in which each of these occur are shown in Appendix 1 where each river type is highlighted in bold.

Table 1: Description and examples of river types based on the River Environment Classification (REC) system (Snelder *et al*., 2004)

RIVER TYPE	Climate	Source of Flow	Geology	Typical Examples
A	Cool wet	Mountain	Hard sedimentary	Branch, Hodder
B	Cool wet	Hill	Hard sedimentary	Saltwater Stream, Cullens Creek
C	Cool wet	Lowland	Hard sedimentary	Are Are Creek, Small Sounds Streams
D	Cool dry	Hill	Hard sedimentary	Omaka, Blairich
E	Cool dry	Mountain	Hard sedimentary	Upper Awatere
F	Cool dry	Lowland	Hard sedimentary	Lower Opawa, Needles
G	Cool extremely wet	Hill	Hard sedimentary	Wakamarina
H	Cool extremely wet	Mountain	Hard sedimentary	No catchment
I	Warm dry	Lowland	Alluvium	Lower Wairau 'trib' complex, Grovetown Lagoon
I_{sp}	Warm dry	Lowland	Alluvium	Blenheim Springs, Spring Creek
J	Warm dry	Lowland	Soft sedimentary	East coast 'complex', Wairau Lagoon 'complex'
K	Cool dry	Lowland	Soft sedimentary	Seventeen Valley Stream 'complex'
L	Cool dry	Hill	Soft sedimentary	Waima
M	Cool dry	Lowland	Alluvium	Lower Waihopai
N	Cool extremely wet	Lowland	Hard sedimentary	Opouri
O	Cool Dry	Hill	Alluvium	No catchment

2.5. Unique Ecological Values

Catchments which have been identified as having unique ecological values have been delineated as separate WRU's e.g. the Anakoha catchment in the outer Marlborough Sounds.

2.6. Groundwater Linkages

Some catchments in low lying areas, such as the Wairau plains have strong groundwater linkages with the water quality of the streams being heavily influenced by groundwater quality and vice versa. In such cases the WRU has been delineated to encompass the area known or thought to influence surface water quality in that area. These units are subject to change to take account of existing or potential groundwater areas.

2.7. Marlborough's Water Resource Units

Based on information outlined in sections 2.1 to 2.6 seventy two water resource units (WRU's) were defined for the Marlborough region. These WRU's fall into 9 geographical regions as shown in Table 2. Appendix 2 lists each of the water resource units and describes the percentage of each river type (as described in section 2.4.2) in each unit. The dominant river type is then used to describe the river type for that catchment.

Table 2: **Geographical regions of Marlborough based on water resource units.**

Geographic Region	Description
Pelorus	High rainfall area, large areas of native forest. Dairying is main land use activity.
Marlborough Sounds	High rainfall, small order streams. Large areas of native forest. Pastoral and exotic forests.
Wairau	High rainfall and large areas of native forest in upper catchment. Pastoral farming, exotic forests and vineyards.
Waihopai	Dry, hill country, predominance of pastoral farmland, vineyards on the increase.
Omaka	Dry lowland area, dominated by vineyards.
Awatere	Dry mountain and hill country. Pastoral farming predominates.
South East Marlborough	Dry lowland areas, low order streams, sparse vegetation.
Clarence	Mountainous area, pastoral farming.
Small Coastal Catchments	No water catchments have been described in NIWAs database. Most likely ephemeral waterways predominate.

3. Surface Water Quality Monitoring Strategy

3.1. Devising the Monitoring Strategy

In 2007 the surface water quality monitoring programme was revised in line with the revision of the objectives of state of the environment reporting for the region. The core objectives of state of the environment reporting for surface water quality are:

1. Defining the current state of surface water quality in water bodies for the whole of the region.

2. Detecting changes in water quality over time for the region.

3. Correlating changes over time in water quality with pressures/improvements from land management practices (including point source discharges).

These objectives allow for the accurate reporting of the state of our natural resources and how our natural resources can be best used whilst also managing them to ensure degradation does not occur which would impact on the values of these resources. Detecting declining trends in a timely manner allows for improvements in land management practices to be initiated to ensure the integrity of our water resources.

Objective 1: Many water quality parameters display seasonal variations. Water quality monitoring data needs to account for these variations. Quarterly monitoring for a period of a year is the minimum sampling frequency required in order to define the state of water quality. It is also advantageous to include monitoring data from more than one year to allow for changes from year to year in seasonal patterns.

The selection of which water bodies will be monitored requires careful consideration if the objective of defining the water quality of water bodies for the whole of the region is to be achieved. A catchment based approach to monitoring allows for the general assessment of all water bodies through the monitoring of one representative site at the bottom of the catchment. Ideally two sites within a catchment would be monitored, one representing upstream water quality and one representing downstream water quality. However when cost is an issue a downstream site is seen as being more beneficial as it will reflect the water quality of the wider catchment. Land use and therefore water quality will change within any given catchment and therefore the scale at which the catchment is defined is important. The selection and definition of the catchments or water resource units is described more fully in section 2.

Objective 2: The ability to detect trends in water quality over time is dependent on the frequency of sampling and the number of samples over a time period. Quarterly (seasonal) monitoring will require a longer time period of monitoring (up to 10 years (Scarsbrook and McBride, 2007)) with which to accurately detect trends, more frequent monitoring, such as monthly, will allow for trends to be detected in a shorter time period. It is recommended that in order to assess trends over a five year period monthly monitoring be undertaken.

Objective 3: The ability to track changes in water quality with changes in land management practices relies on an adequate dataset with which to compare water quality with land use practices. As already described monthly monitoring over a five year period is required in order to 1. define current water quality 2. detect trends over time, this can then be correlated with land use and/or changing land use practices within a catchment.

To achieve these objectives the water quality monitoring programme was structured in such a way as to allow for the above objectives to be achieved and reported on in Councils comprehensive State of the Environment Reporting of Natural Resources on a five yearly basis.

Monitoring is based on a catchment analysis approach. Monitoring sites are located in the bottom of catchments were possible, were flow monitoring is currently being measured or where it is anticipated that flow will be measured by Council. Water quality is inherently linked with flow. Flow information is vital when assessing trends in water quality over time. Flow measurement coupled with water quality monitoring also allows for contaminant loads generated within a system to be calculated and their subsequent impact on estuaries and other water bodies to be assessed. Historic monitoring at a site was also considered when selecting a site for the state of the environment surface water quality monitoring programme.

Perceived pressures on water quality and the values associated with a water body were also considered when selecting monitoring sites for state of the environment water quality monitoring.

3.2. The Current Surface Water Quality Monitoring Programme

The current water quality monitoring programme consists of 34[1] sites monitored on a monthly basis for a range of physical/chemical parameters. It is not possible or desirable to monitor all water quality parameters, therefore a set of parameters which best define waterways and the health of waterways and which reflect human influence on water quality are chosen. A full list of the parameters analysed for on a routine basis is shown in Appendix 3. Temperature, conductivity and dissolved oxygen measurements are carried out on site at all sites using a YSI meter; dissolved oxygen is calibrated each day whilst temperature and conductivity are calibrated monthly. A core set of water quality parameters (numbers 1 – 11, Appendix 3) are measured at all sites whilst a sub-set (numbers 12 – 17, Appendix 3) are measured at a selection of sites where the risk of contamination is seen as moderate to high.

In addition macroinvertebrate sampling is carried out on an annual basis at 50 sites. The majority of these sites coincide with the 34 monthly monitored sites. Macroinvertebrate sampling is a low cost method of assessing water quality based on the ecological integrity of a site. In particular it allows for water quality to be assessed in catchments which are remote and/or low risk in terms of human pressures and which would otherwise incur a substantial cost in characterising the water quality status based on monthly monitoring of physical/chemical parameters. A combination of physical, chemical and biological parameters are necessary to accurately define the state of water quality and to assess the effects of land use and land use change on water quality.

Twenty of the 34 monthly monitored sites also have flow measured at the site or in the vicinity of the site such that flow measurements can be used when assessing flow adjusted data for trends. Figure 3 shows the locations of the 34 monthly monitored sites.

A full list of the sites, their ID and grid reference is shown in Table 3. Monitoring of two sites on the Wairau River (WRR-2 and WRR-6) is undertaken by NIWA as part of their National River Quality Monitoring Network (NRQMN).

[1] Black Birch Stream is monitored on a monthly basis by the Assets and Services section of Council for a number of parameters, including pH and turbidity and assessed against drinking water standards. Additional environmental parameters will be monitored at this site from 2010-11 to tie in with parameters monitored at other SoE sites. Because of this no analysis has been made of existing information at this site in this report.

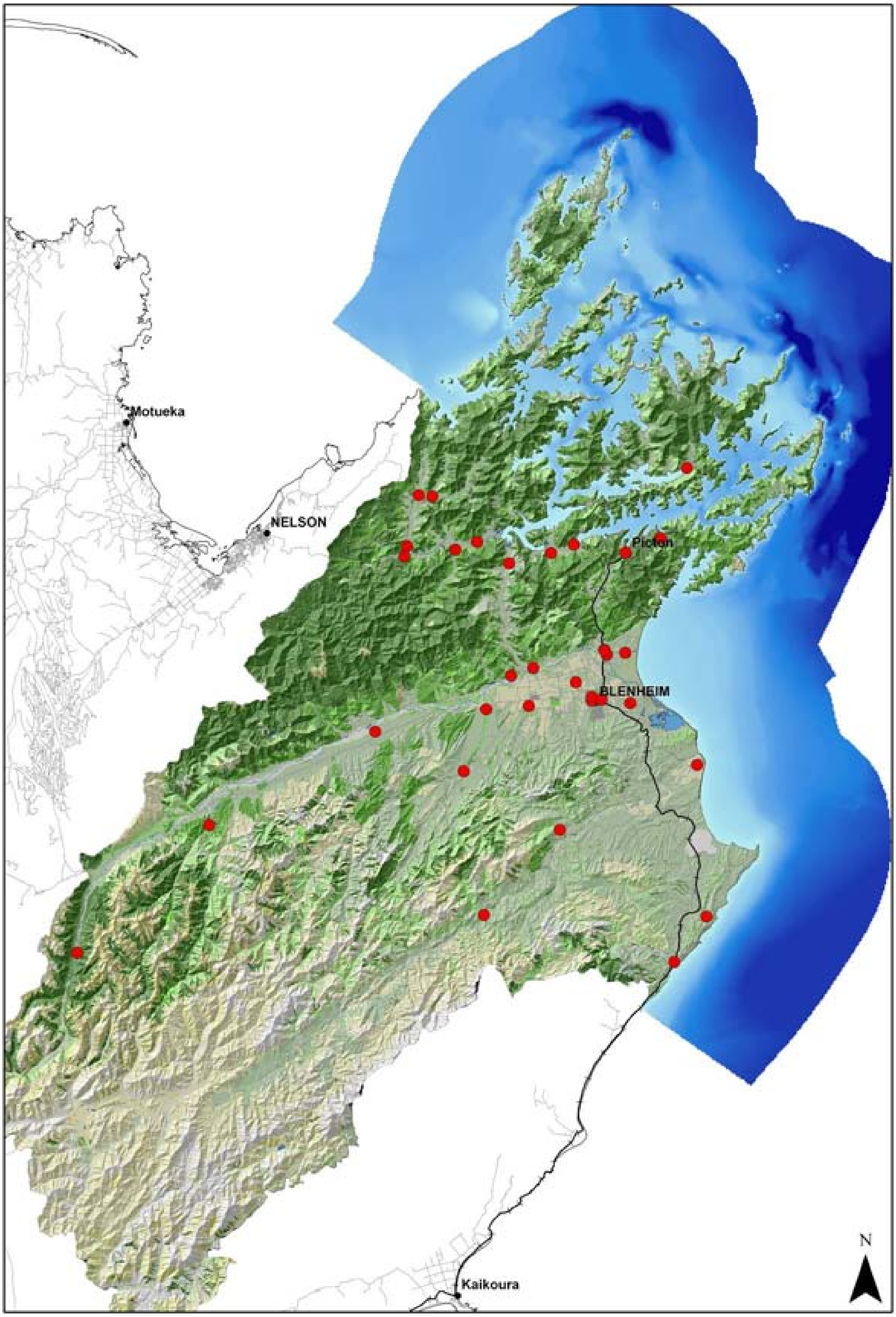


Figure 3: Locations of the 34 state of the environment surface water quality monitoring sites.

Table 3: State of the Environment surface water quality monitoring sites.

Site ID	Site Name	Easting (NZTM)	Northing (NZTM)
ARE-3	Are Are Creek	1668891	5409150
AWR-1	Awatere (lower)	1695945	5393096
AWR-3	Awatere at Awapiri	1660707	5368307
BBS-001	Black Birch Stream	1673268	5382346
BNR-1	Branch River upstream of Hydroelectric dam	1615310	5383200
CUL-3	Cullens Creek	1671802	5428178
DNC-002	Duncan Stream (Linkwater)	1675552	5429552
DRC-1	Doctors Creek	1678538	5403700
FLX-1	Flaxbourne at limestone quarry	1697479	5368033
GRR-001	Graham River at road bridge	1689949	5430629
KNR-1	Kenepuru upstream of NIWA flow site	1694287	5442220
KTR-005	Kaituna at Readers Road	1664877	5426463
MST-21	Mill Stream at flow site	1642747	5398630
MUR-1	Murphys Creek	1678585	5404340
OMR-1	Omaka River at Hawkesbury Road	1668150	5402871
ONR-1	Onamalutu	1665221	5407894
OPO-1	Opouri	1652204	5437502
OPR-1	Opawa at Swamp Road	1684887	5403319
OPR-3	Opawa at Hammerichs Road	1675898	5406769
PLR-4	Pelorus at Fishermans Flat	1659571	5430016
PLR-5	Pelorus at Kahikatea Flat	1647585	5427613
RAR-1	Rai at Rai Falls	1648018	5429266
RON-4	Ronga	1649966	5437711
SPC-1	Spring Creek at flood gates	1681052	5411335
TMR-1	Tuamarina at Wairau confluence	1680588	5412144
TYR-1	Taylor River at Riverside	1680148	5403948
WaiM	Waima upstream of SH bridge	1692178	5360509
WDV-1	Wairau Diversion at Neals Road	1684047	5411651
WHR-1	Waihopai at SH bridge	1661086	5402329
WHR-5	Waihopai at flow site	1657397	5392054
WKR-1	Wakamarina upsteam of SH bridge	1656011	5428720
WRR-2	Wairau at Dip Flat	1680623	5412041
WRR-6	Wairau at SH6 Bridge	1593486	5362089
WTS-009	Waitohi at SH1 bridge	1684133	5428227

4. Current Water Quality

4.1. State

Water quality data for 33 of the 34 state of the environment sites from 2007 to 2009 (inclusive) was analysed using STATISTICA 7.0. Monthly monitoring takes place at Black Birch Stream (BBS-001), however only a limited number of parameters are measured at this site, for this reason and because of the limited amount of data the site was not included in the analysis. For each parameter measured at each site the mean, median, 10^{th}, 25^{th}, 75^{th} and 90^{th} percentiles were calculated. The results are shown in Appendix 4. The number of samples per site ranges from 5 to 48 due to the addition of new sites since the revision of the SoE monitoring strategy in 2007. The greater the number of samples available when determining the summary statistics the greater the confidence in the results, 12 samples, over a years period at monthly intervals, is the minimum number deemed necessary in order to obtain accurate statistics for a site as this will take account of seasonal variations. As of 31 December 2009, not all sites have this minimum requirement. Three years is ideal as it takes account of weather patterns from year to year which can influence results (e.g. floods and droughts). In the absence of water quality standards the results are compared with various appropriate guidelines (Table 4) in order to place the values in context. An exceedance of a guideline does not always imply an effect; rather they are thresholds at which management options need to be considered to prevent further degradation of water quality.

Table 4: Guideline values used to assess the state of surface water quality in Marlborough.

Parameter	Guideline Value	Purpose	Reference
Nitrate	1.7mg/L	Aquatic ecosystem toxicity	Hickey and Martin (2009)
	0.444mg/L	Prevent nuisance algal growth in lowland rivers	ANZECC (2000)
	0.167mg/L	Prevent nuisance algal growth in upland rivers	ANZECC (2000)
DRP	0.01mg/L	Prevent nuisance algal growth in lowland rivers	ANZECC (2000)
	0.009mg/L	Prevent nuisance algal growth in upland rivers	ANZECC (2000)
Ammonia	0.9mg/L*	Aquatic ecosystem toxicity	ANZECC (2000)
	0.021mg/L**	Lowland river ecosystem health	ANZECC (2000)
	0.01mg/L**	Upland river ecosystem health	ANZECC (2000)
E. coli	550 n/100mL	Contact recreation (action level)	MfE (2003)
	260 n/100mL	Contact recreation (alert level)	MfE (2003)
	126 n/100mL	Contact recreation (median level for surface waters)	McBride *et al*. (1991)
Turbidity	5.6 NTU	Lowland rivers	ANZECC (2000)
	4.1 NTU	Upland rivers	ANZECC (2000)
Suspended Solids	10 mg/L	Ecological guideline	CCREM (1991)
Copper	0.0014mg/L	95% protection of freshwater aquatic life (slightly to moderately disturbed systems)	ANZECC (2000)
Zinc	0.008mg/L	95% protection of freshwater aquatic life (slightly to moderately disturbed systems)	ANZECC (2000)
Arsenic	0.013mg/L	95% protection of freshwater aquatic life (slightly to moderately disturbed systems)	ANZECC (2000)

* The ANZEEC guidelines specify a toxic guideline level of 0.9mg/L for total ammonia (NH_3 plus NH_4^+)
** In addition the guidelines give a limit for ionised ammonia ($NH4^+$) of 0.01mg/L for upland rivers and 0.021mg/L for lowland rivers for the protection of ecosystem health

4.1.1. Nitrate

Nitrogen is found in several different forms in surface waters, one of which is nitrate. Nitrate is a compound of nitrogen and oxygen ($NO3^-$). In well oxygenated waters nitrate is the dominant form of nitrogen. In soils and water nitrate is transformed naturally from other forms of nitrogen with the help of bacteria. The nitrogen cycle is complex, where nitrogen and its different forms undergo a sequence of changes between land and water. Factors such as oxygen availability, bacteria types present and pH all play a role in the nitrogen cycle. Figure 4 shows the different forms of nitrogen as analysed by Environmental Laboratory Services Ltd (ELS).

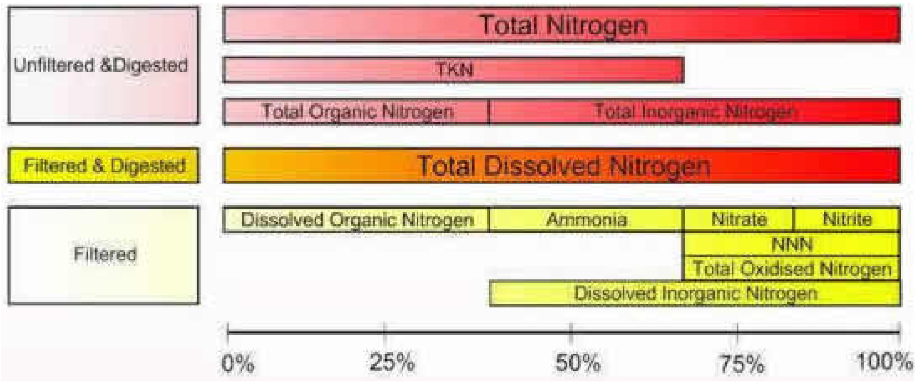


Figure 4: The different forms of nitrogen commonly analysed for in the environmental monitoring of surface waters (from www.els.co.nz/)

Nitrate enters waterways directly through atmospheric deposition. Excess nitrate can enter waterways from agricultural (e.g. fertiliser run-off, animal effluent), residential (e.g. septic tanks) and industrial sources (e.g wastewater treatment plants). Nitrate does not bind to soils or particles in the water and is therefore easily transported along with water through overland or subsurface (leaching) flows. During rainy periods, excess nitrate not used by plants will move downwards through the soil to groundwater or will be carried overland to surface waters. Nitrate concentrations in rivers typically show strong seasonal trends, being low in summer and high in winter. Typically nitrate concentrations are greater during times of high runoff after a dry summer when nitrogen has built up in the soil from fertiliser, deposition from the air and nitrogen fixing plants.

Nitrogen is an important nutrient for plant growth and nitrate is the form in which it is most readily available to plants. This can be a problem when excess nitrate enters waterways causing excessive plant and algae growth which can choke waterways and lead to algal blooms. Excessive plant growth can lead to reduced oxygen levels in the water. In large enough concentrations nitrate can be directly toxic to fish and other organisms. The ANZEEC guidelines identify 0.167mg/L as the concentration above which nuisance plant growth will occur in upland rivers and 0.444mg/L as the concentration above which nuisance plant growth will occur in lowland rivers. Recent research has shown that nitrate toxicity for aquatic organisms can occur at levels above 1.7mg/L (Hickey and Martin, 2009).

The median, interquartile range and 5-95 percentile range for nitrate are shown in Figure 5. The relevant guideline values are shown to the right of the boxplot.

Doctors Creek and Mill Stream have the highest nitrate concentrations. Mill Stream and Doctors Creek are also two of the longest spring fed streams in Marlborough. Nitrate concentrations at these sites are consequently heavily influenced by groundwater nitrate concentrations. Nitrate concentrations in groundwater are influenced by the age and thereby the redox potential of groundwater in addition to past and present human influences which can result in elevated groundwater nitrate concentrations. Groundwater in the Wairau Plains is important as a drinking water supply and thus must comply with the New Zealand Drinking Water Standards (NZDWS, 2005). The drinking water standard for nitrate is 11.3mg/L; the groundwaters of the Wairau plains generally comply with this standard. Groundwater nitrate concentrations within the drinking water standards but above the threshold for ecological toxicity (1.7mg/L) (Hickey and Martin, 2009) are a concern where groundwater quality determines the water quality of spring fed streams thereby influencing their life supporting capacity. Spring fed streams support a sensitive ecological community as water quality (in particular temperature and conductivity) tends to remain very stable; small changes in water quality can stress the aquatic life of spring fed streams.

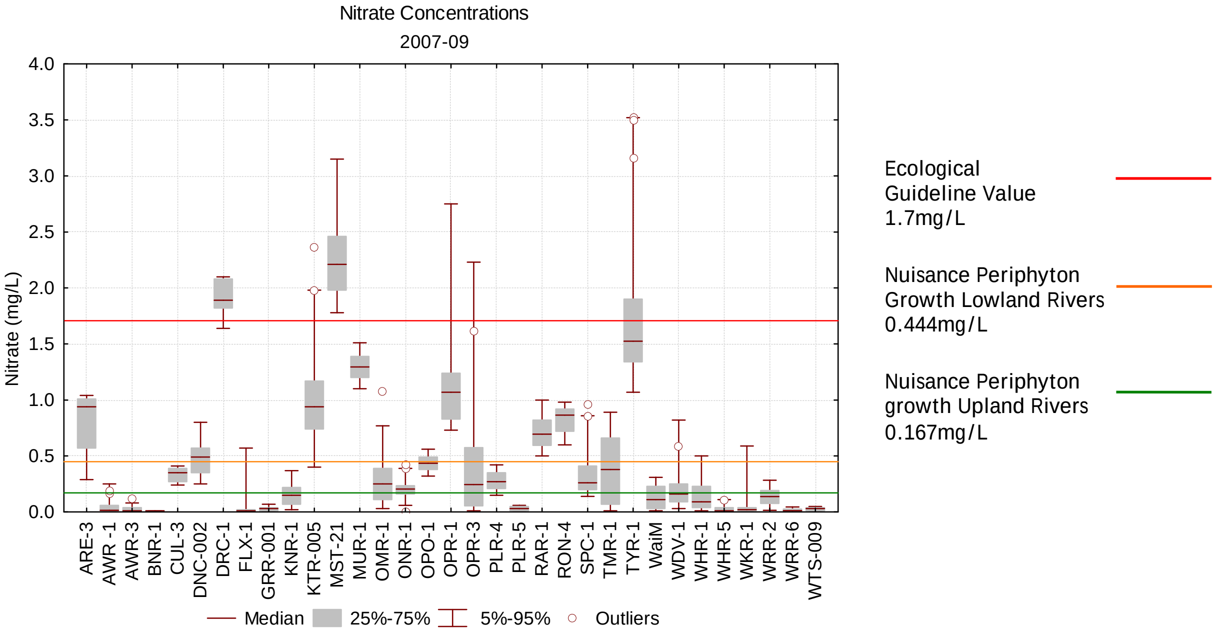


Figure 5: Boxplot showing the summary statistics for nitrate for the 33 monthly monitored SoE sites in relation to the relevant guideline values. Table 3 gives the reference for each of the site IDs.

Several rivers and streams, mainly in lowland heavily cultivated land areas, have median nitrate concentrations above the concentration which results in nuisance algal growth (0.444mg/L). These river include: Are Are Creek, Duncan Stream, the Kaituna River, the Rai River, the Ronga River and the Taylor River.

The lowest nitrate concentrations are found in the Branch River (BRN-1) and the Wairau River at Dip Flat (WRR-6).

4.1.2. Dissolved Reactive Phosphorus (DRP)

Phosphorus is an essential nutrient for plant growth and is commonly applied to crops as a fertiliser. In rivers and streams dissolved reactive phosphorus (DRP) is the most bioavailable form of phosphorus available to plants and algae and is the dominant form of phosphorus found in the water column. Whilst phosphorus is an essential nutrient for plant growth an excess of it will lead to increased plant growth, reduced plant diversity and increased algal growth leading to algal blooms and eutrophication. Excessive macrophyte growth can clog streams and slow flows which can reduce the oxygen content of the water and reduce habitat and feeding areas for aquatic life. Phosphorus is usually the limiting nutrient in riverine systems, which means that plant growth is limited by the amount of available phosphorus, other nutrients may be available in abundance but if phosphorus is near background levels then plant and algal growth will be kept in check, however the processes that control this are complex (McDowell *et al*., 2009).

The amount of phosphorus in a riverine system is largely determined by the geology of the area. Rock weathering produces most of the natural phosphorus entering waterways. In soils phosphorus will absorb to clay particles and organic material, thereby retarding its movement through the subsurface. Phosphorus enrichment of rivers and streams commonly occurs through diffuse sources such as fertiliser runoff from agricultural land and point sources such as wastewater treatment works and stormwater runoff.

The median, interquartile range and 5-95 percentile range for DRP are shown in Figure 6. The relevant guideline values are shown to the right of the boxplot.

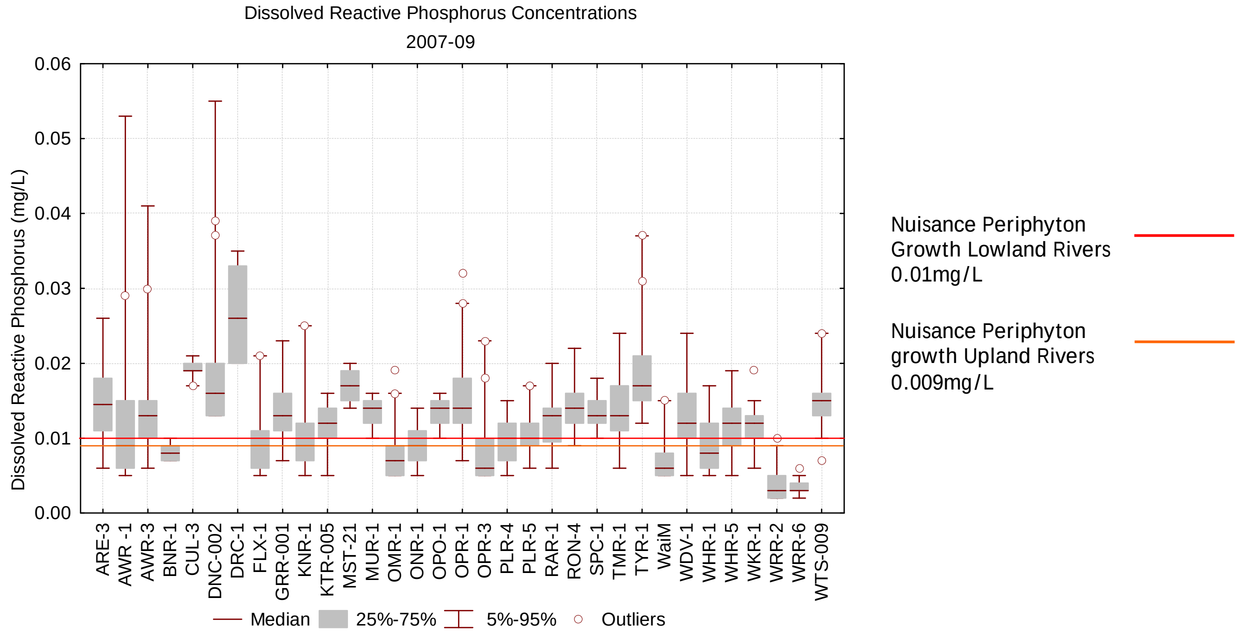


Figure 6: Boxplot showing the summary statistics for DRP for the 33 monthly monitored SoE sites in relation to the relevant guideline values. Table 3 gives the reference for each of the site IDs.

Doctors Creek has the highest median DRP concentration, being approximately twice as high as the next highest concentration. 26 of the 33 sites had median concentrations above one or both of the guideline values (0.01mg/L and 0.009mg/L). Despite this it is difficult to say if all of these rivers experience nuisance algal growth as periphyton is not routinely monitored at the sites. Lack of instream shading allowing more sunlight on the streams will also help drive plant and algal growth and therefore nutrient (nitrate and DRP) concentrations need to be correlated with other factors that contribute to algal growth (such as sunlight) in order to determine the real impact of elevated DRP concentrations at nearly 80% of monitored sites. As with nitrate, the lowest DRP concentrations are measured in the upper the Wairau at Dip Flat (WRR-6).

4.1.3. Ammonia Nitrogen

The term 'ammonia' or 'total ammonia' refers to two chemical forms of ammonia that are present in water; the un-ionised ammonia (NH_3) form and the ionised ammonium form (NH_4^+). Un-ionised ammonia (NH_3) is very soluble in water at low pH. At low pH and temperatures, ammonia combines with water to produce the ammonium ion (NH_4^+) and a hydroxide ion (OH^-); the ammonium ion is non-toxic to aquatic organisms. Un-ionised ammonia levels in surface water increase with increasing pH and temperature (Figure 7). River waters typically have a stable pH range of 6.5 to 8.5 whilst temperature increases from winter to summer and can range from 2°C to 22°C. The table below shows the percentage of the toxic un-ionised form available as part of total ammonia at changing temperature and pH. At the temperature and pH range typical of most rivers and lakes, ammonia exists predominantly in the ionised form (NH_4+). As pH and temperature increase, the ionised ammonia changes to un-ionised ammonia gas (NH_3). In well oxygenated waters ammonia is quickly converted by nitrifying bacteria to nitrite and nitrate, nitrate is the dominant form of nitrogen in surface waters.

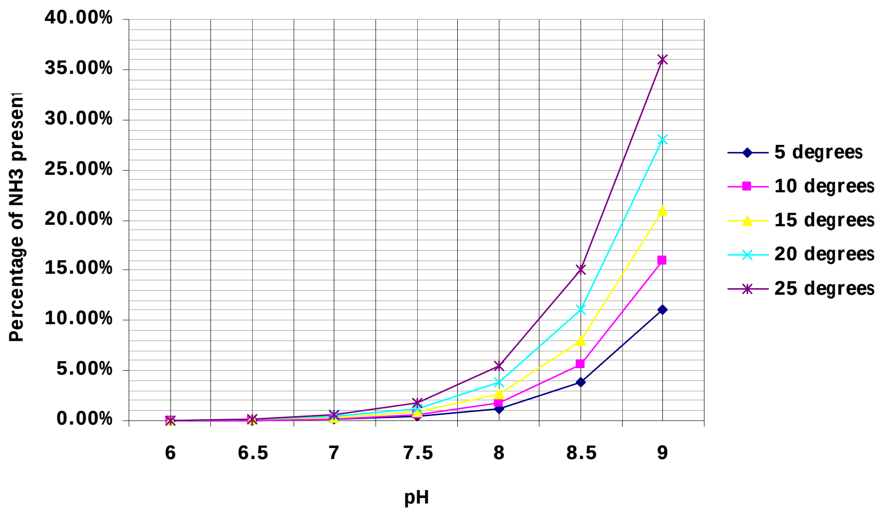


Figure 7: Percentage of un-ionised ammonia (NH_3) present at varying temperatures (°C) and pH, (USEPA, 1987).

Ammonia is excreted by animals and is produced during the decomposition of plants and animals. Ammonia is also present in sewage, agricultural fertilisers, landfill leachate, storm water runoff, industrial wastewaters and runoff from animal feed areas.

The ANZEEC guidelines specify a toxic guideline level of 0.9mg/L for total ammonia (NH_3 plus NH_4^+). In addition the guidelines give a limit for ionised ammonia ($NH4^+$) of 0.01mg/L for upland rivers and 0.021mg/L for lowland rivers for the protection of ecosystem health. At normal river pH and temperature the majority of total ammonia will be in the ionised ($NH4^+$) form of ammonia and thus these upland and lowland river levels can be used for state of the environment purposes when assessing rivers against guideline values for the protection of aquatic life. The median, interquartile range and 5-95 percentile range for ammonia are shown in Figure 8. The relevant guideline values are shown to the right of the boxplot.

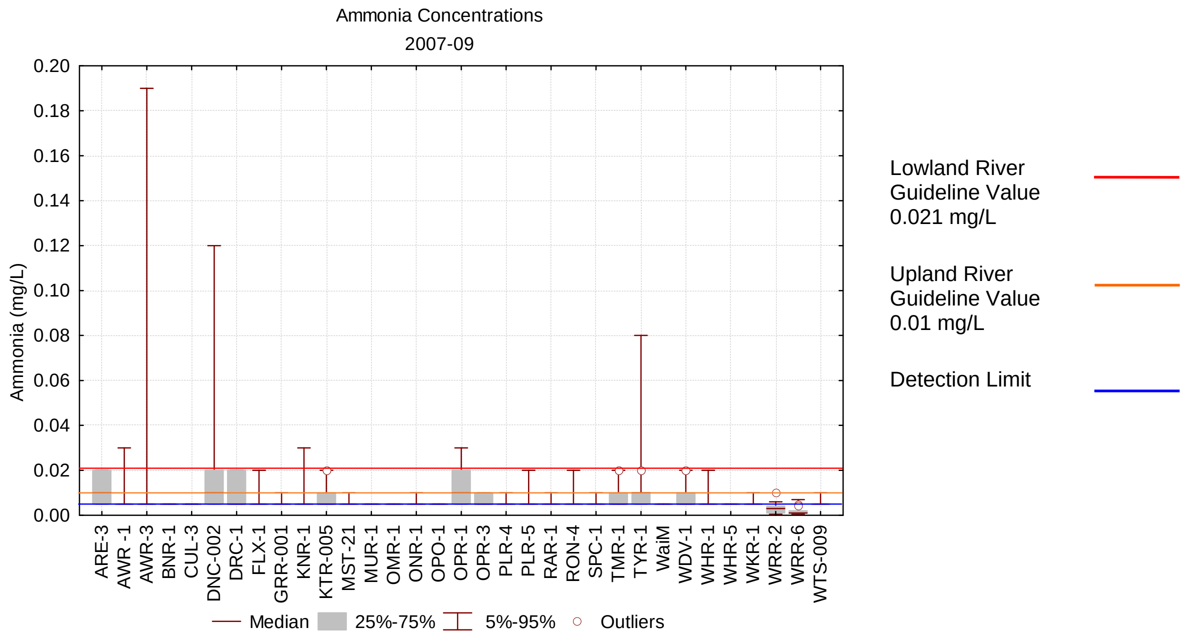


Figure 8: Boxplot showing the summary statistics for total ammonia for the 33 monthly monitored SoE sites in relation to the relevant guideline values. Table 3 gives the reference for each of the site IDs.

Ammonia concentrations are low throughout the region and rarely exceed the relevant guideline standards. In most cases ammonia concentrations are recorded as being below the detection limit. This is as a consequence of very few point source discharges of effluent to rivers and streams. Ammonia is generally not associated with diffuse sources of pollution as it readily degrades in the environment. Ammonia, in high concentrations (0.9mg/L), is highly toxic to aquatic life, however concentrations this high have not been recorded during state of the environment monitoring. Ammonia is a soluble form of nitrogen used by plants and algae for growth. The lowland river guideline (0.021mg/L) is rarely exceeded. High ammonia concentrations have been recorded from the Awatere at Awapiri, Duncan Stream, Kenepuru, the Opawa and the Taylor River. High ammonia concentrations are associated with very heavy rainfall and are typically (but not always) associated with urban and intensive agricultural areas.

4.1.4. E. coli

E. coli is a bacterium found in the gut of all warm blooded animals (including humans, mammals and birds). Its presence in water indicates the recent contamination of the water by faecal matter. *E. coli* is used as an indicator organism when assessing the quality of water for the suitability of swimming and other contact recreational activities. *E. coli* by itself may not necessarily cause illness or infection as a result of coming in contact with it but high numbers are an indicator of an increased risk of other pathogens being present alongside it in the water. *E. coli* will survive for a period of time outside the gut of warm blooded animals but cannot multiply in numbers, UV rays from sunlight will reduce their numbers over time.

The median, interquartile range and 5-95 percentile range for *E. coli* are shown in Figure 9. The relevant guideline values are shown to the right of the boxplot.

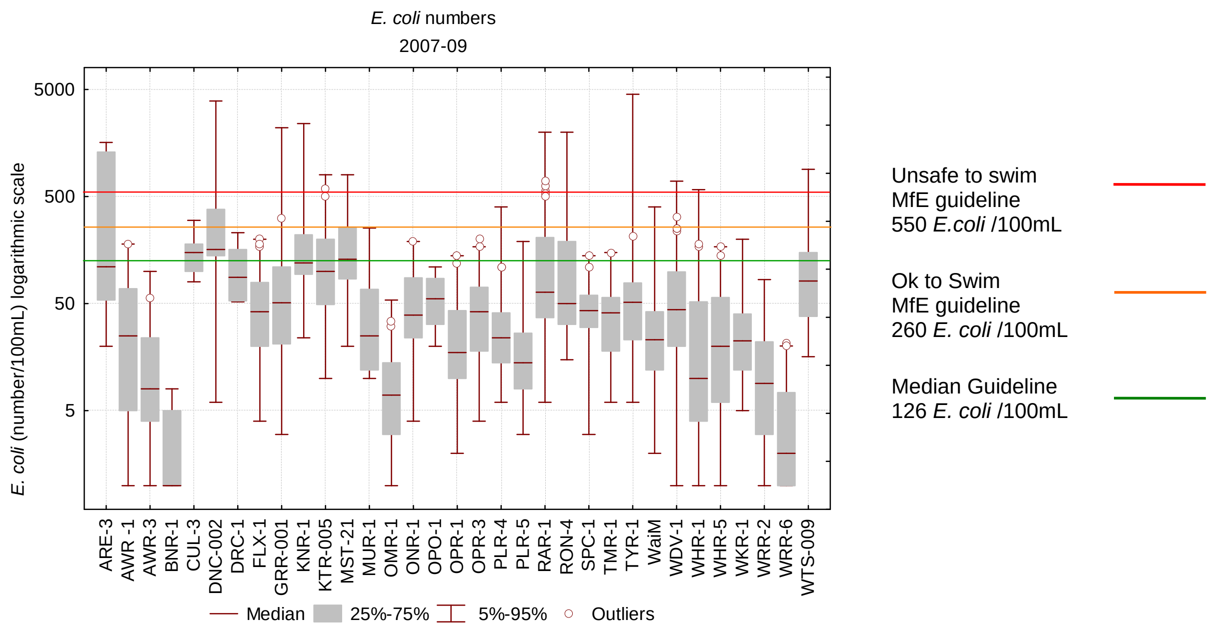


Figure 9: Boxplot showing the summary statistics for *E. coli* for the 33 monthly monitored SoE sites in relation to the relevant guideline values. Table 3 gives the reference for each of the site IDs.

Rivers in lowland farmed areas and urban areas have the poorest water quality in terms of bacteria numbers, with numbers being particularly high during and after heavy rainfall (MDC, 2008b, 2009). Rivers that exceed the median guideline of 126 *E. coli*/100mL include: Cullens Creek, Duncan Stream and Mill Stream.

E. coli is the water quality parameter used to assess the suitability of a river for swimming and contact recreation. Annual reports are prepared by MDC which assess swimming and popular recreational river locations against the Ministry for the Environments contact recreation guidelines. In 2009 69% of swimming sites were graded[2] as poor or very poor (MDC, 2009), this percentage is similar to what was reported by Scarsbrook and McBride (2004) in their assessment of 410 river sites in New Zealand.

Dairying has a long history in the Rai River catchment. In recent years much work has been done in the catchment to reduce the number of stream crossings. In 2003 there were 112 stream crossings in the Rai catchment, by 2009 this had reduced to 36 (MDC, 2009b). The Rai is a popular river for contact recreation with kayaking, swimming, drift diving and trout fishing being popular pursuits in the area. Figure 10 shows that the median *E. coli* number for the Rai shows an overall decline from 1999 to 2009.

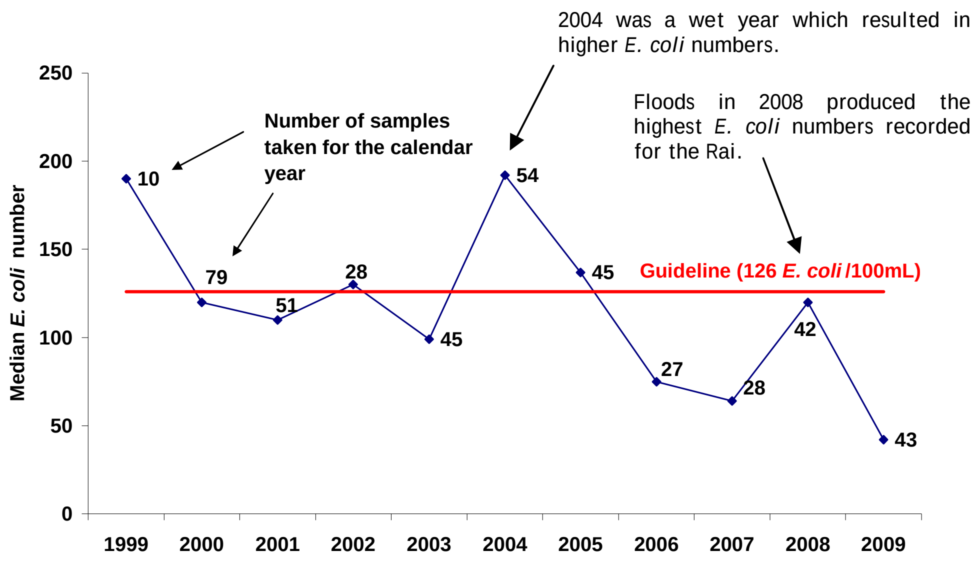


Figure 10: Median *E. coli* numbers at Rai Falls from 1999 to 2009. The number of samples from which the median is derived varies from year to year is shown beside the median result for each year e.g. 10 samples in 1999, 79 samples in 2000 etc.

4.1.5. Turbidity

Turbidity is a measure of water clarity or murkiness. It is an optical property that shows the amount in which light is scattered and absorbed by particles in the water. Turbidity levels are a measure of water clarity with low levels reflecting good water clarity and higher levels indicating poor water clarity. Turbidity results from the presence of coloured dissolved organic matter (CDOM) e.g. humic acids and tannins and suspended particulate matter e.g. clay, silt, detritus and microorganisms in the water. Turbidity in rivers can result from the input of fine sediments as a result of stream bank erosion. Algal blooms, often indicative of excessive nutrient loads, can also be an important cause of turbidity. Some rivers have naturally high turbidity e.g. rivers draining alpine or glacial wash areas where large amount of fine sediment is eroded from the land and washed into the river. Increased turbidity can have a significant effect on aquatic ecosystems. The most obvious effect is a reduction in light available for photosynthesis. This reduces the amount of plant growth and in turn limits the number of aquatic organisms that feed on these plants and finally fish communities that rely on aquatic organisms as a food source are affected.

The median, interquartile range and 5-95 percentile range for turbidity are shown in Figure 11. The relevant guideline values are shown to the right of the boxplot.

[2] Suitability for Recreation Grades (SFRG's) as defined in Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE, 2003).

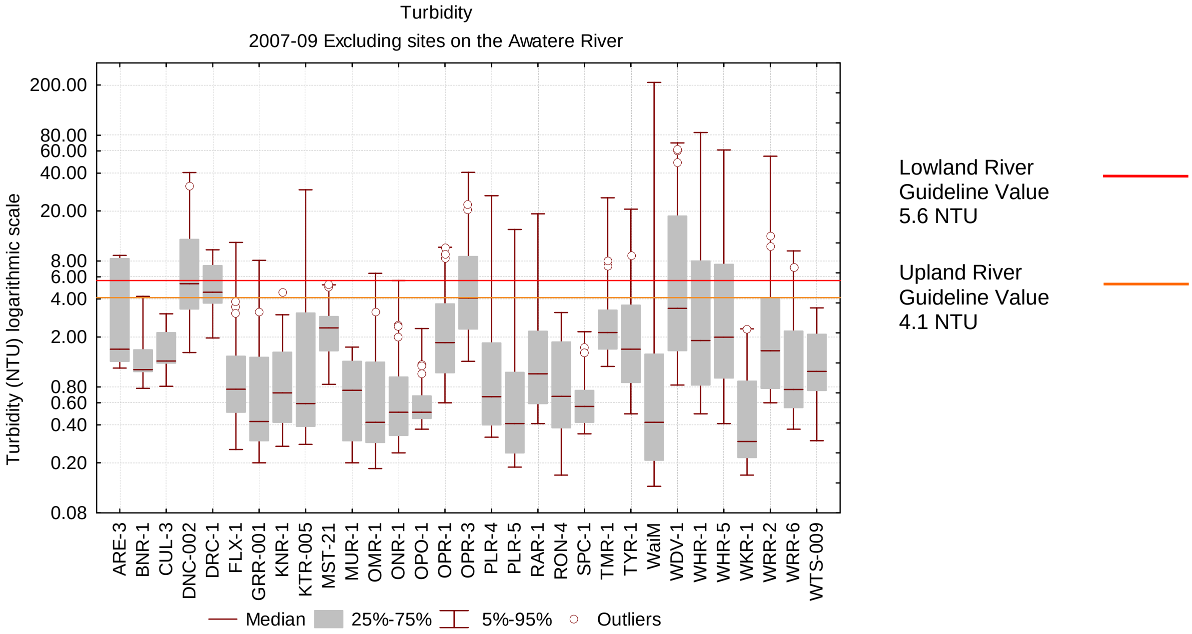


Figure 11: Boxplot showing the summary statistics for turbidity for 31 monthly monitored SoE sites in relation to the relevant guideline values. The Awatere sites have been excluded from analysis, results for the Awatere are shown in Appendix 4. Table 3 gives the reference for each of the site IDs.

Rivers and streams in Marlborough generally have low levels of turbidity with median levels for approximately 90% of monitored sites within the ANZECC guidelines for upland rivers. The Awatere has high background levels of turbidity and is characterised by a milky white/blue colour (Photo 1). The high turbidity is due to the high levels of suspended sediment eroded from the surrounding catchment. Turbidity levels in the Awatere are naturally high and therefore the guideline values shown above are not applicable. The highest median turbidity levels (excluding the Awatere River) are recorded at Duncan Stream and Doctors Creek, however the median is still within the lowland river guideline. The lowest (90%ile < 2NTU) turbidity levels have been recorded from the Opouri River, the Wakamarina River, Spring Creek and Murphys Creek.

Photo 1: The Awatere at Awapiri**.** High turbidity levels due to the high suspended sediment load from the catchment, resulting in the characteristic blue/grey colour of the river.

4.1.6. Suspended Solids

Total suspended solids (TSS) are a measure of the mass of suspended material in a given volume of water. It is can be comprised of mineral matter (sediment or soil), phytoplankton, plant and animal debris. Excess suspended solids can smother aquatic organisms and reduce the habitat available for fish spawning as well as smothering fish eggs and larvae. It can cause mechanical and abrasive damage to the gills of fish reducing growth rates and decreasing their resistance to disease. Suspended solids also transports contaminants, such as metals and other toxicants and pathogens and waterborne diseases in rivers. High concentrations of suspended solids will absorb light and consequently increase water temperature. The higher the water temperature the less oxygen it can hold.

The median, interquartile range and 5-95 percentile range for total suspended solids concentrations are shown in Figure 12. The relevant guideline values are shown to the right of the boxplot.

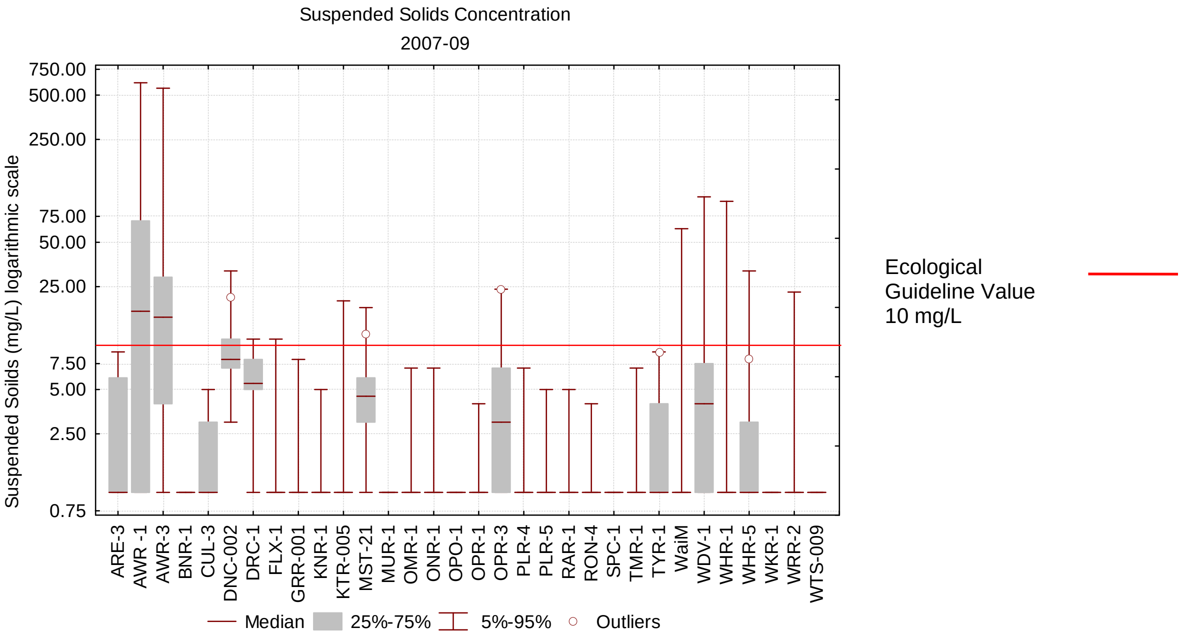


Figure 12: Boxplot showing the summary statistics for total suspended solids for 32 monthly monitored SoE sites in relation to the relevant guideline values. Total suspended solids are not routinely monitored by NIWA and therefore there is no data for suspended solids for the Wairau at Dip Flat (WRR-6). Table 3 gives the reference for each of the site IDs.

Suspended solids concentrations are generally low in the rivers and streams of Marlborough, with the exception of the Awatere, where levels are naturally high due to the geology of the catchment. Suspended solids concentrations are relatively high for the Duncan Stream, Doctors Creek, Mill Stream, Are Are Creek, the Opawa River, the Taylor River, the Wairau Diversion and the Waihopai River.

4.1.7. pH

pH is a measure of the acidity or alkalinity of a water sample. pH is measured on a scale of 0 to 14 and is a measure of the free hydrogen ion concentration. A pH of 7 is considered to be neutral, less than 7 is considered acidic and greater than 7 is considered alkaline. Rain water is naturally acidic at about 5.6. Stream water usually ranges from a pH of 6.5 to a pH of 8.5; this range is considered to be an optimal range for most aquatic life. The natural pH of a river will vary from river to river but the pH range of a river will generally remain stable. The natural pH range of a river is largely determined by the geology and soils of the area, for example limestone areas will result in rivers and streams having naturally higher pH levels and peat areas will have naturally low pH levels. Carbon dioxide from the atmosphere can also affect the pH of a river; when it mixes with the water it increases its acidity. The pH of a stream affects the organisms living there. Large fluctuations in pH outside of a rivers natural pH range can lead to stresses on aquatic life in that river. Low pH levels (below optimal) can result in fish kills by stressing their systems causing physical damage, which in turn can make them more vulnerable to disease, similarly high pH particularly in combination with high water temperature, can increase the amount of unionized ammonia which is highly toxic to fish. Low pH also mobilises otherwise bound heavy metals, an increase in which can be toxic to aquatic life. A high or low pH can also adversely affect the availability of nutrients in the water for use by plants. External factors or human factors that can cause fluctuations in the pH of a river include agricultural runoff (pesticides, fertilisers, soil leachates) acidic mine drainage and fossil fuel emissions such as carbon, sulphur and nitrogen oxides. pH has a diurnal cycle i.e. it fluctuates between night and day as a result of plant respiration and photosynthesis. Photosynthesis in plants, especially during algal blooms, can drive pH to high levels. Peak pH levels normally coincide with peak oxygen levels during mid afternoon when plant photosynthesis is at its highest and similarly the lowest levels are typically recorded at night when photosynthesis is at its minimum and when plant respiration is high.

The median, interquartile range and 5-95 percentile range for pH are shown in Figure 13. Guideline values for pH have not been shown on the plot as guidelines for pH are specific to individual water bodies i.e. some water bodies have a naturally high pH e.g. the Waima, Awatere and Flaxbourne rivers due to the geology of the area (e.g. limestone), whilst other water bodies can have a low pH e.g. some areas of the west coast have naturally low pH values, as low as 4 due to humic acids or young sedimentary geologies with a pyrite component (WCRC, 2005).

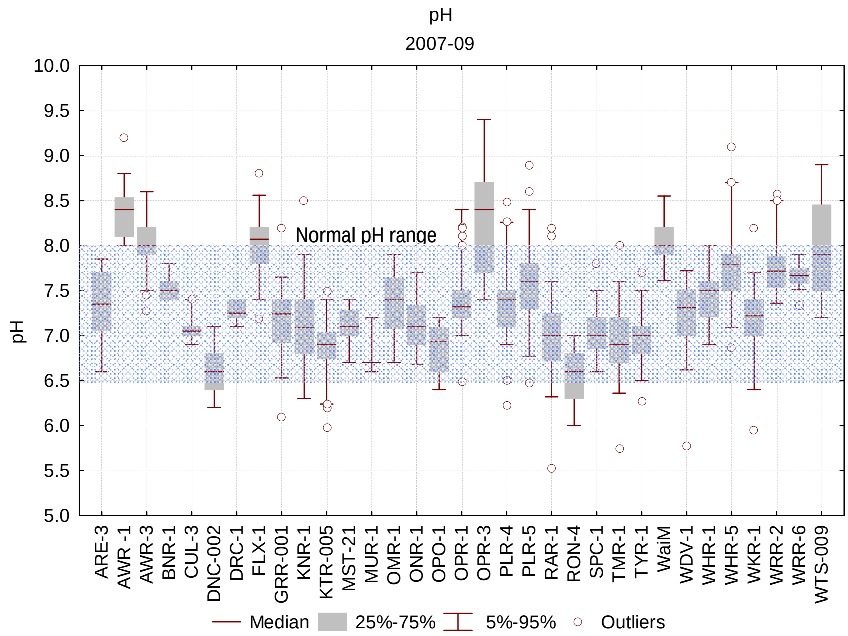


Figure 13: Boxplot showing the summary statistics for pH for 33 monthly monitored SoE sites in relation to the relevant guideline values. Table 3 gives the reference for each of the site IDs. The blue band depicts the 'normal' range for rivers as defined by the ANZECC guidelines.

The ANZECC guidelines give recommended trigger levels of 7.2 to 8 for New Zealand rivers, however from the results above it can be seen that this range is too narrow and therefore these trigger levels are not appropriate. The ANZECC guidelines further state that a more appropriate way of setting pH limits involves the use of the 20th and 80th percentiles based on seasonal medians of reference sites; changes of more than 0.5 from the seasonal minimum and maximums should be investigated (ANZECC 2000).

Surface waters commonly fall between a pH range of 6.5 to 8 (ANZECC, 2000) as shown by the blue zone in Figure 13. The Awatere, Flaxbourne and Waima have naturally high pH values due to the geology of the catchments. High pH values recorded from the Opawa and the Waitohi can not be completely explained by the underlying geology and anthropogenic influences may be influencing the pH of these rivers. In addition these rivers have the largest pH range of the 33 monitored sites.

4.1.8. Specific Conductivity

Specific conductivity is conductivity measured at 25°C. Conductivity is a measure of the ability of water to conduct an electrical current. The temperature of water influences the conductivity values with warmer waters having lower conductivity values; this is why conductivity is commonly measured at a standard temperature of 25°C; to allow for comparisons throughout the year and between different water bodies. Conductivity gives an estimate of the amount of dissolved inorganic solids such as chloride, sulphate, sodium, calcium etc. present in the water. The conductivity of a river will principally be determined by the geology and soils of the catchment through which the river flows. Catchments comprised of 'hard' rocks such as granite will have rivers with low conductivity values whilst catchments with 'soft' rocks such as limestone and clay soils will have higher conductivity values. The conductivity of a river will tend to remain within a specified range. Conductivity is often used as a surrogate for water pollution as a gradual increase in conductivity over time can be an indication of pollution. Urban runoff and industrial pollution are characterised by high conductivity. Organic compounds such as oil are not good electrical conductors and thus oil spills will tend to lower the conductivity of water. The median, interquartile range and 5-95 percentile range for specific conductivity are shown in Figure 14.

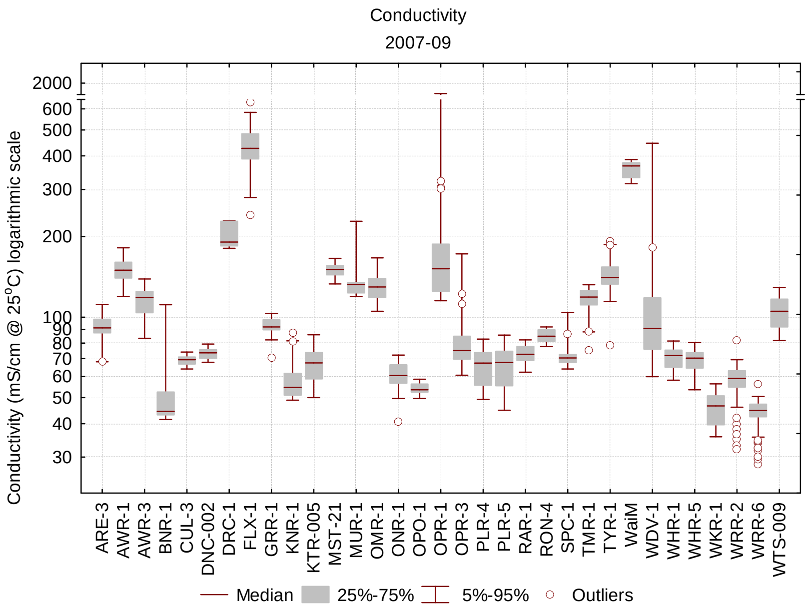


Figure 14: Boxplot showing the summary statistics for specific conductivity for 33 monthly monitored SoE sites in relation to the relevant guideline values. Table 3 gives the reference for each of the site IDs.

Conductivity is primarily a function of the surrounding geology. There are no guidelines for conductivity in surface waters as conductivity is specific to each water body however increases in conductivity over time can be an indication of pollution within the catchment as a result of inputs from anthropogenic sources such as fertilisers, effluents etc. Figure 14 shows that the lower Opawa and the Wairau Diversion have the highest variability in conductivity, this is due to the sites being influenced by the saline water from the coast.

4.1.9. Dissolved Oxygen

Healthy aquatic ecosystems depend on a good supply of oxygen being dissolved in the water column. Faster flowing sections of rivers and streams and sections that flow through riffles or small waterfalls will have better oxygenated waters than slow flowing sections of rivers or rivers that have been modified as straight channels. The amount of dissolved oxygen in the water is also dependent on temperature, with cooler waters having more dissolved oxygen than warmer waters. Aquatic plants will add oxygen to the water but their overabundance can lead to oxygen super saturation during the day and consequently very low levels at night when photosynthesis ceases but respiration (which uses oxygen) continues. This fluctuation in oxygen can stress the aquatic communities living there. A common cause of low oxygen waters is where organic material (from wastewater treatment works, agricultural runoff etc.) is added to the water. Bacteria break down this material and in so doing use up the available oxygen in the water to the extent that waters can become severely depleted of oxygen or anoxic. Whilst most species require well oxygenated waters in order to survive (e.g. stoneflies are only found in cool, well oxygenated waters (Photo 2)) some species thrive in low oxygen waters. The presence or the abundance of these species can be an indicator of organic enrichment. Chironomids, (non-biting midges that resemble mosquitoes) are a good example of a group of species adapted to living in low oxygen environments (Photo 3).

Photo 2

The stonefly *Stenoperla prasina*, found in pristine stony rivers and streams, is one of the most pollution sensitive species found. It requires very high concentrations of dissolved oxygen to thrive

Photo 3

The non-biting midge larvae *Chironomus*, also called a blood worm because of the bright red colour, is one of the most pollution tolerant species, found in polluted and highly enriched waterways.

The median, interquartile range and 5-95 percentile range for dissolved oxygen are shown in Figure 15. The normal range for dissolved oxygen in healthy ecosystems lies between 80 and 120%. Surface waters in Marlborough are predominately within this range, however some sites fall outside this range. The Tuamarina shows the largest dissolved oxygen range. Factors such as salinity, temperature, groundwater inflow, the presence of organic matter and plant life all have an influence on dissolved oxygen concentrations. Dissolved oxygen exhibits diurnal and seasonal variations in concentrations. In order to accurately assess the health of a river with regard to dissolved oxygen, continuous monitoring during the critical summer months when dissolved oxygen is likely to be at its lowest, should be carried out. Spot measurements, such as those carried out for the analysis in Figure 15 are a useful way of identifying where dissolved oxygen levels are likely to have a detrimental effect on aquatic life and where further more intensive monitoring can be carried out.

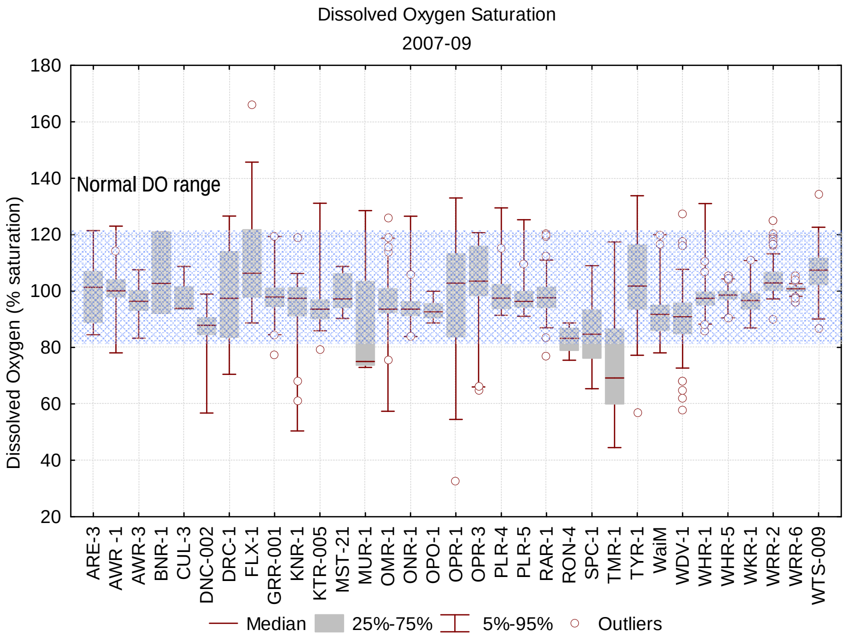


Figure 15: Boxplot showing the summary statistics for dissolved oxygen for 33 monthly monitored SoE sites in relation to the relevant guideline values. Table 3 gives the reference for each of the site IDs. The blue band depicts the dissolved oxygen range expected for normal healthy rivers.

A narrow dissolved oxygen range such as that seen for the Waihopai River, the Wairau, the Wakamarina and the Opouri is a good indication that oxygen levels within the river are stable and thus unlikely to have a negative impact on aquatic life. Large dissolved oxygen ranges as seen for Doctors Creek, the Opawa and the Taylor for example indicate the potential for the ecosystem to become stressed due to low oxygen levels, even though for the most part the concentrations lie within the normal range.

4.1.10. Temperature

The median, interquartile range and 5-95 percentile range for temperature are shown in Figure 16. Temperature changes from season to season with warmer temperatures occurring in the summer months and colder temperatures during the winter months. Some of the factors that influence the degree to which temperatures increase in surface waters during the summer months include:

- Altitude; upland rivers and streams are generally cooler than lowland rivers and streams
- Degree of shading e.g. from riparian vegetation, cliffs, tall buildings etc.
- Groundwater inflow
- Substrate type and degree of exposure to sunlight e.g. gravels within a braided rivers system absorb and retain heat thereby acting as radiators heating up the surrounding water, fine sediment within a river or stream will act in much the same way.

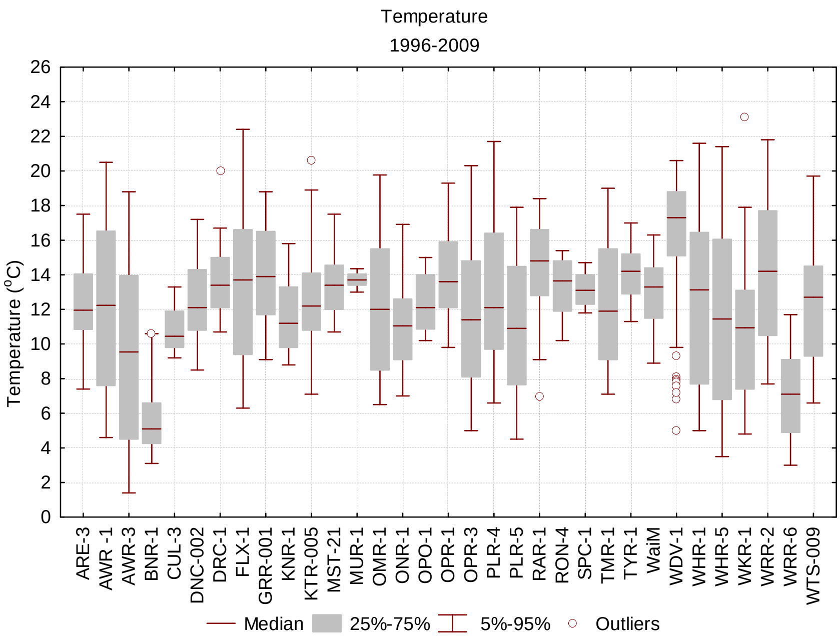


Figure 16: : Boxplot showing the summary statistics for temperature for 33 monthly monitored SoE sites in relation to the relevant guideline values. Table 3 gives the reference for each of the site IDs.

The narrowest temperature range is observed in spring fed system where the temperature of the water largely reflects the temperature of groundwater e.g. Murphys Creek and Spring Creek. Some aquatic organisms such as stone flies, some mayflies and trout are sensitive to elevated temperatures and can become stressed or disappear completely where elevated temperatures persist. Elevated temperatures (above 20°C) are generally not a problem in Marlborough's rivers and streams.

4.1.11. Metals

Copper, lead and zinc are three of the most common metal pollutants from runoff in urban areas of New Zealand (Zander, 2005), however lead concentrations are in decline due to the phasing out of lead based paints and petrol (Suren and Elliott, 2004). Vehicle brake emissions and buildings account for sources of copper whilst tyre wear and catchment roof run-off are common sources for zinc. Copper is also commonly used in horticulture as a pesticide. Arsenic has been found in some groundwaters in the Wairau plains and is mainly associated with current or historic wetlands where redox conditions cause it to become soluble. These same reducing conditions exist in deep aquifer systems beneath the Wairau Plains and it is likely that arsenic exists naturally in these groundwaters also (Callander and Loomer, 2002; Robinson *et al.*, 2004). Arsenic is also commonly used for the treatment of vineyard posts. Vineyards now account for just less than 24,000 hectares of the Marlborough region. Copper, zinc and arsenic are analysed for at the following surface water monitoring sites:

- Are Are Creek ARE-3
- Doctors Creek DRC-1
- Murphys Creek MUR-1
- Opawa (upper) OPR-3
- Opawa (lower) OPR-1
- Taylor River TYR-1
- Waitohi River WTS-009

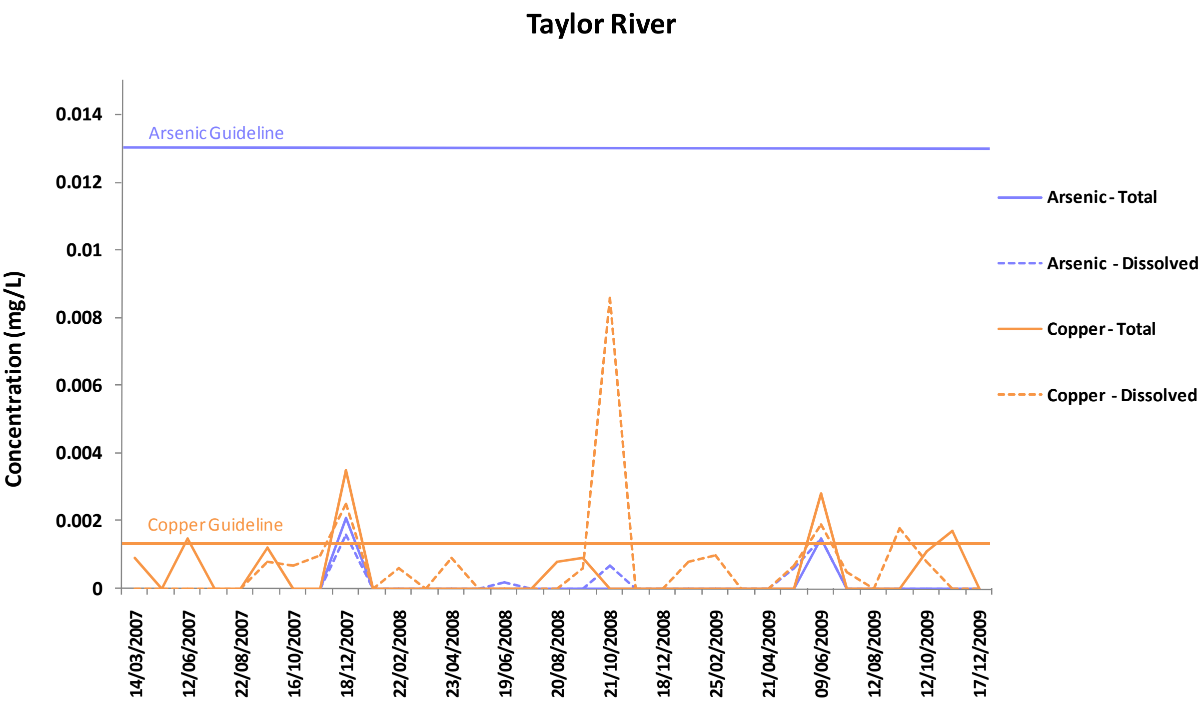
Both total and dissolved metals are analysed for completeness. The ANZECC guidelines do not specify the form (whether dissolved or total) to which the guidelines refer to, commonly it is the dissolved phase of a metal which can have the greater ecological impact, however measuring the total metal concentration gives a more complete picture of metal concentrations.

Arsenic has not been recorded above the guidelines at any of the sites (Figures 17 to 23). Low concentrations have been recorded from the Taylor River (Figure 17); the upper and lower Opawa (Figures 18 and 19) and Are Are Creek (Figure 20).

Copper has been recorded above the guideline at all monitored sites with the exception of Murphys Creek (Figure 22). The highest recorded copper concentration (0.064mg/L) was from Doctors Creek on the 17th November 2009 (Figure 21). This coincided with a peak in zinc concentrations in Doctors Creek and also with a peak in copper concentration in Murphys Creek. There was a minor peak in concentrations of copper and zinc in the Taylor, however there is not enough record to determine if peak metal concentrations in Doctors Creek and Murphys Creek reflect peak metal concentrations in the Taylor River.

The zinc guidelines are regularly exceeded in the Taylor River, the upper and lower Opawa and the Waitohi. Doctors Creek has exceeded the guidelines on one occasion. There have been no exceedances of the zinc guideline in Are Are Creek or Murphys Creek.

On occasion the dissolved metal concentration is higher than the total metal concentrations. In most cases this is due to the different detection limits for the two test methods (detailed in Appendix 3) and the error associated with each test (approx. ± 10%). However there are occasions when the above explanation does not fit; these include: Taylor River Copper 21/10/08; Taylor River Zinc 20/8/08; Taylor River Zinc 18/12/08; Opawa (upper) Zinc 20/8/08; Opawa (upper) Zinc 12/3/09; Opawa (upper) Zinc 12/3/09; Opawa (lower) Zinc 23/4/08; Opawa (lower) Zinc 20/8/08; Opawa (lower) Zinc 18/12/08; Opawa (lower) Zinc 17/11/09. Discussions with the laboratory to investigate these anomalies were inconclusive, it is possible that the samples could have been contaminated somewhere between taking the sample and analysing the sample at the laboratory. Filtering during the testing for dissolved metal concentrations can contaminate samples and may have been responsible for some of the anomalous results.



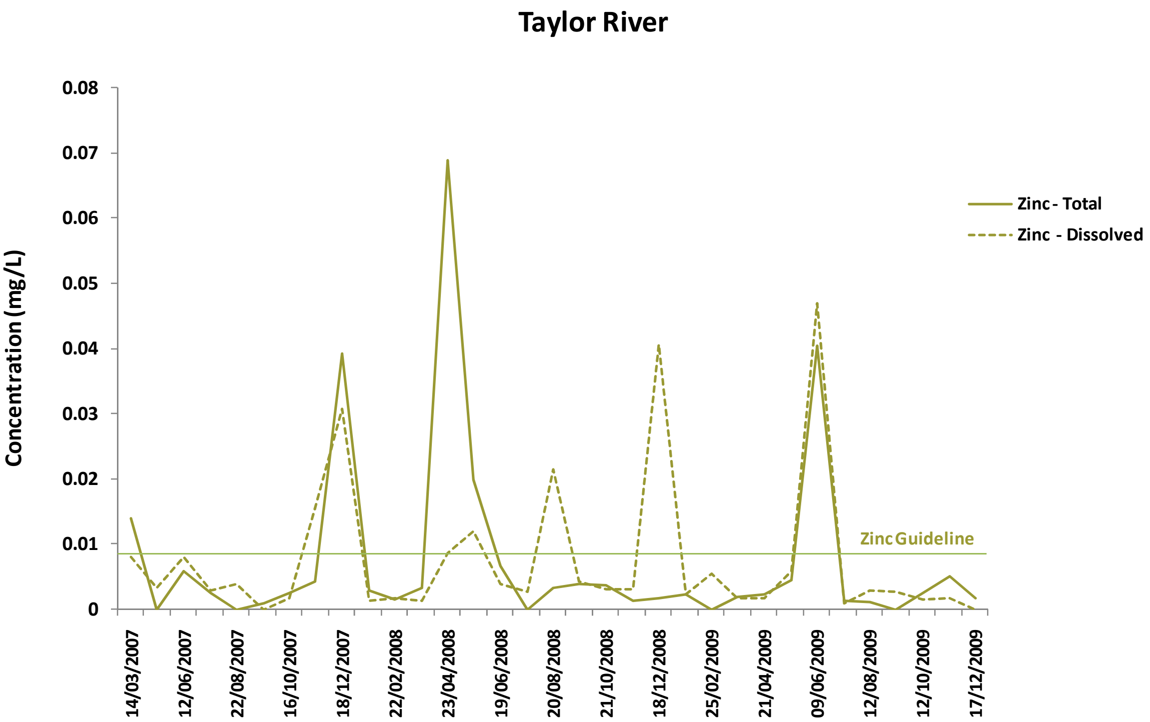
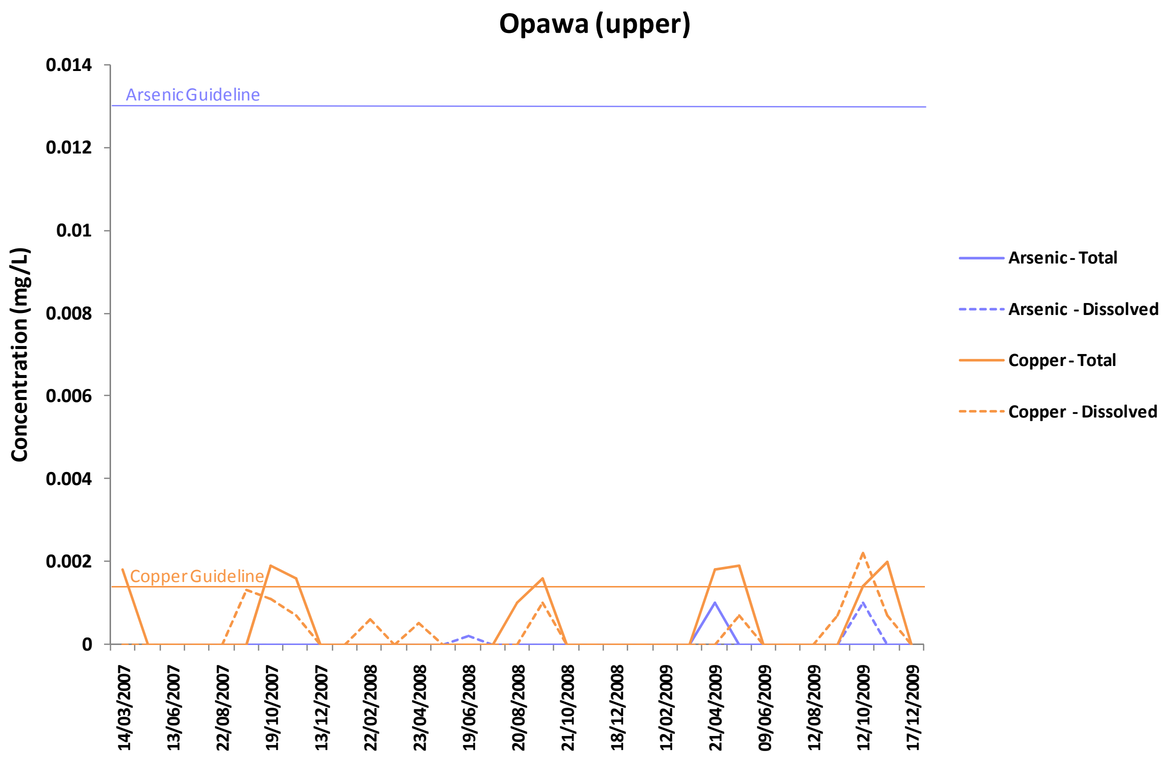


Figure 17: Arsenic, copper and zinc concentrations for the Taylor River (TYR-1). Both total and dissolved concentrations are measured. The guidelines refer to the ANZECC trigger values for slightly to moderately disturbed systems for the protection of 95% of species in freshwater. The ANZECC guidelines do not differentiate between total and dissolved concentrations.



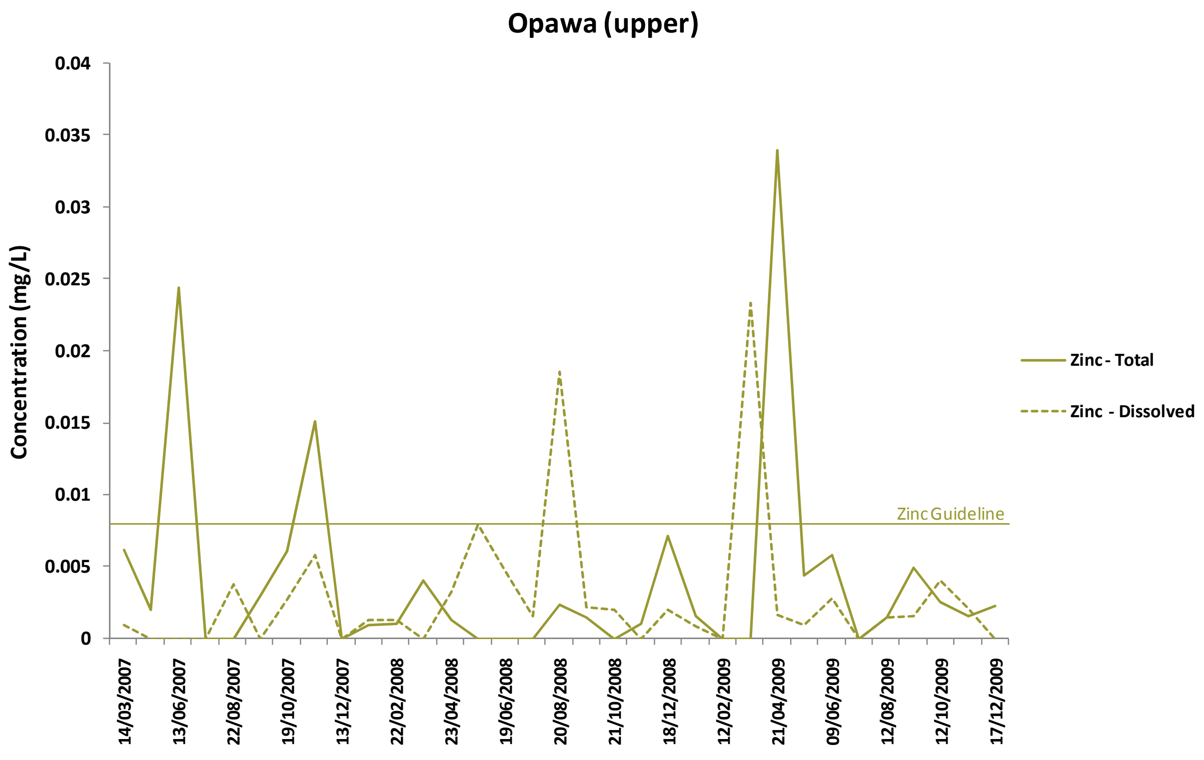
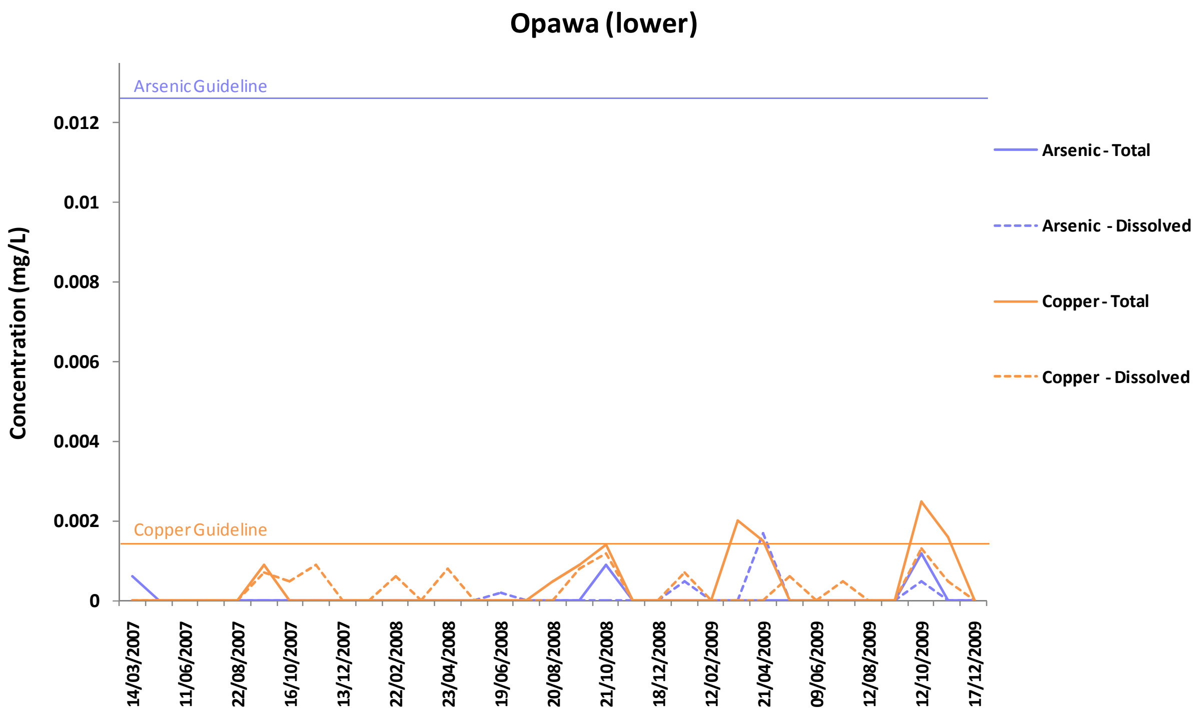


Figure 18:: Arsenic, copper and zinc concentrations for the upper Opawa (OPR-3). Both total and dissolved concentrations are measured. The guidelines refer to the ANZECC trigger values for slightly to moderately disturbed systems for the protection of 95% of species in freshwater. The ANZECC guidelines do not differentiate between total and dissolved concentrations.



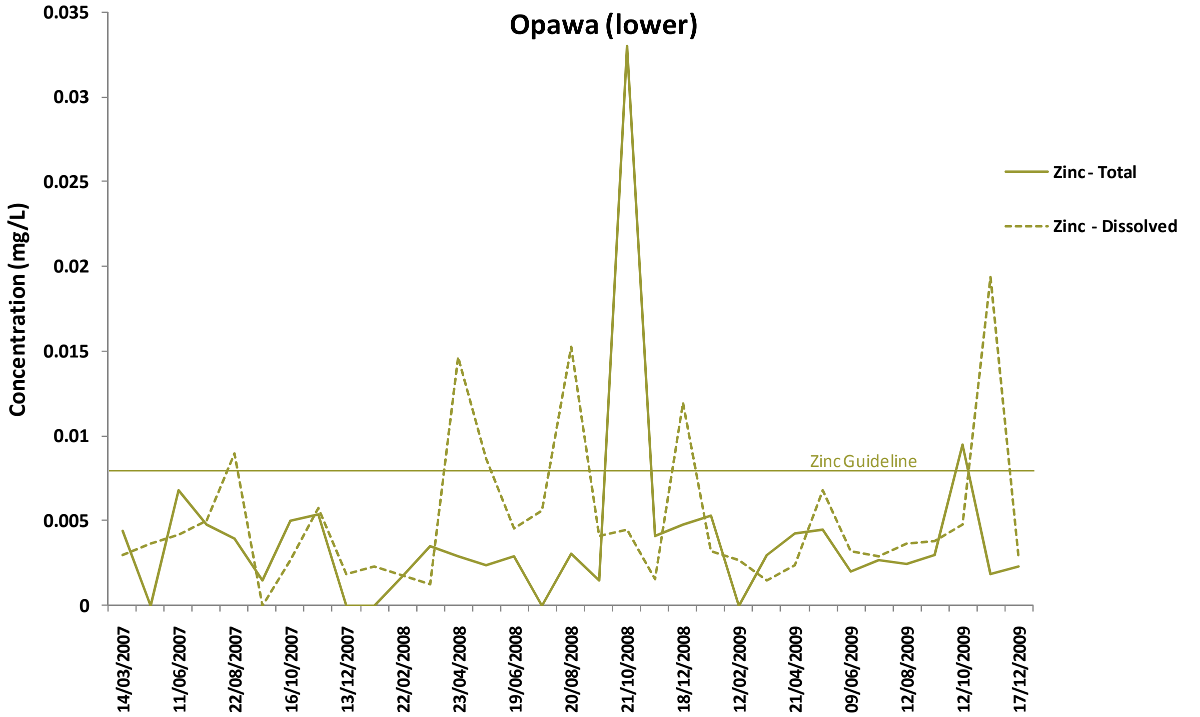
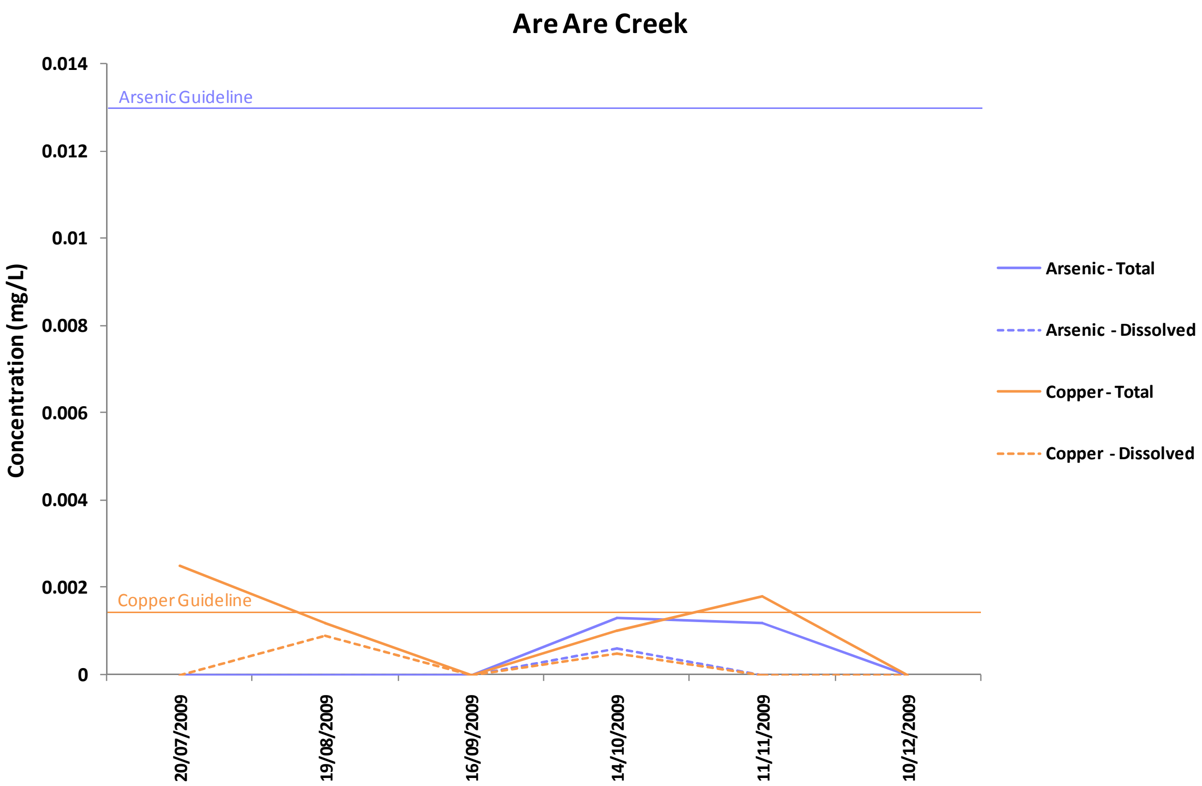


Figure 19: Arsenic, copper and zinc concentrations for the lower Opawa (OPR-1). Both total and dissolved concentrations are measured. The guidelines refer to the ANZECC trigger values for slightly to moderately disturbed systems for the protection of 95% of species in freshwater. The ANZECC guidelines do not differentiate between total and dissolved concentrations.



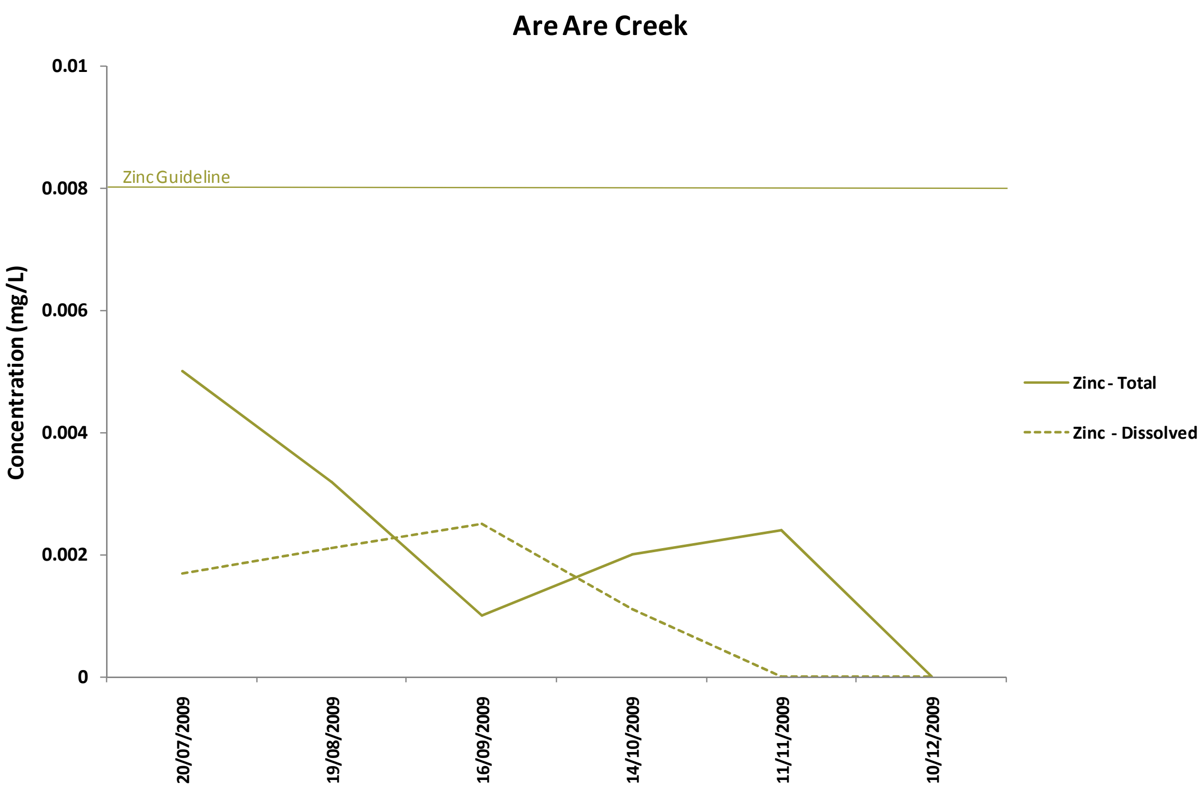
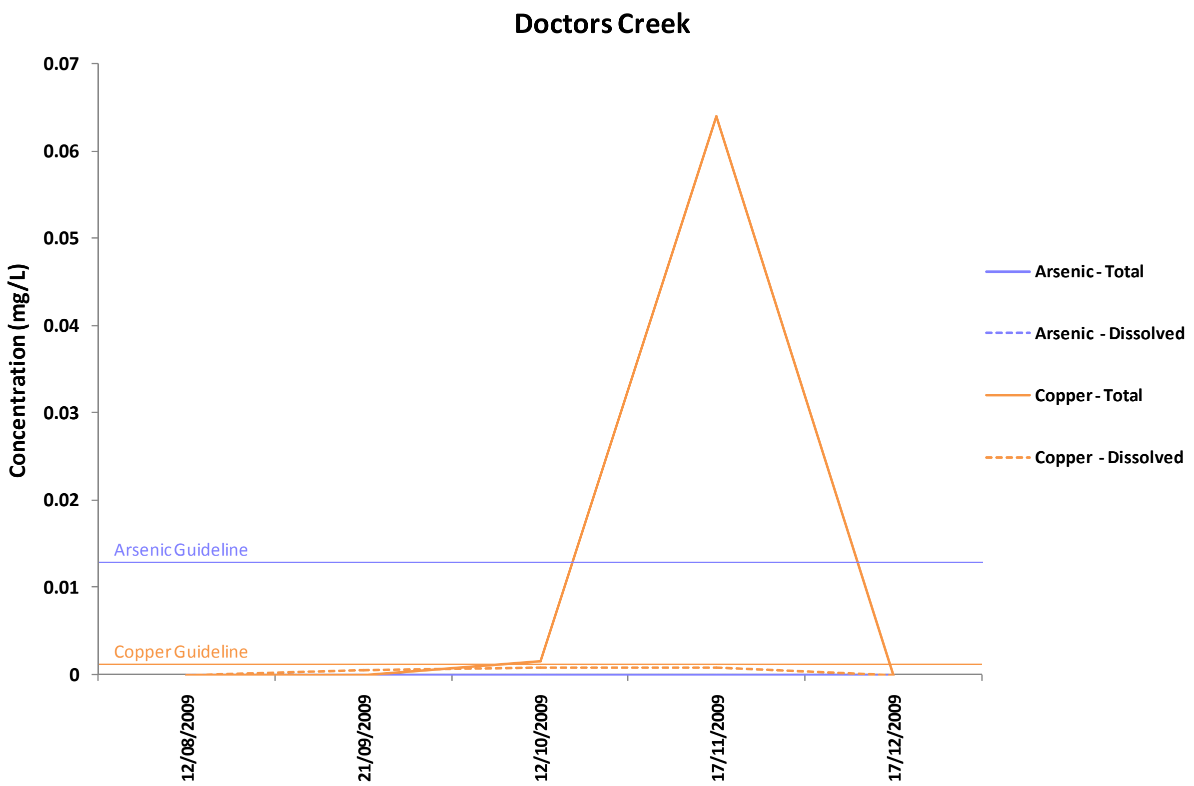


Figure 20: Arsenic, copper and zinc concentrations for Are Are Creek (ARE-3). Both total and dissolved concentrations are measured. The guidelines refer to the ANZECC trigger values for slightly to moderately disturbed systems for the protection of 95% of species in freshwater. The ANZECC guidelines do not differentiate between total and dissolved concentrations.



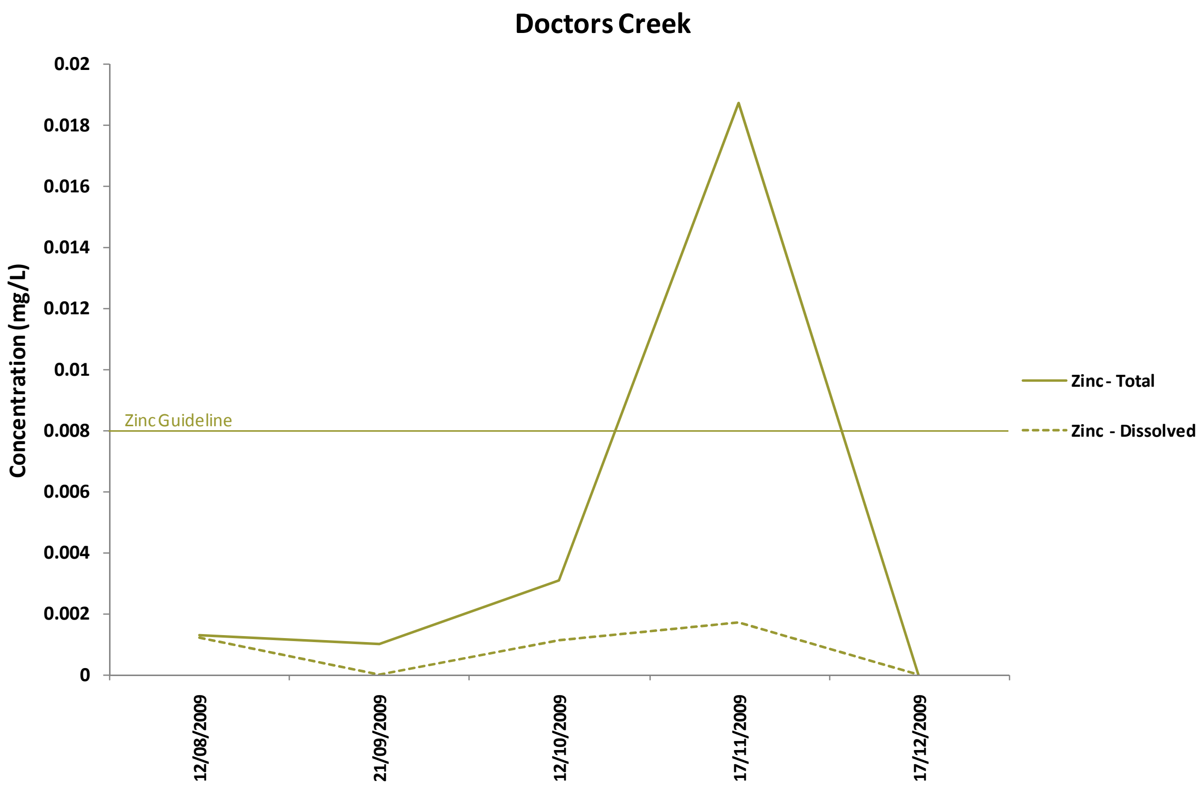
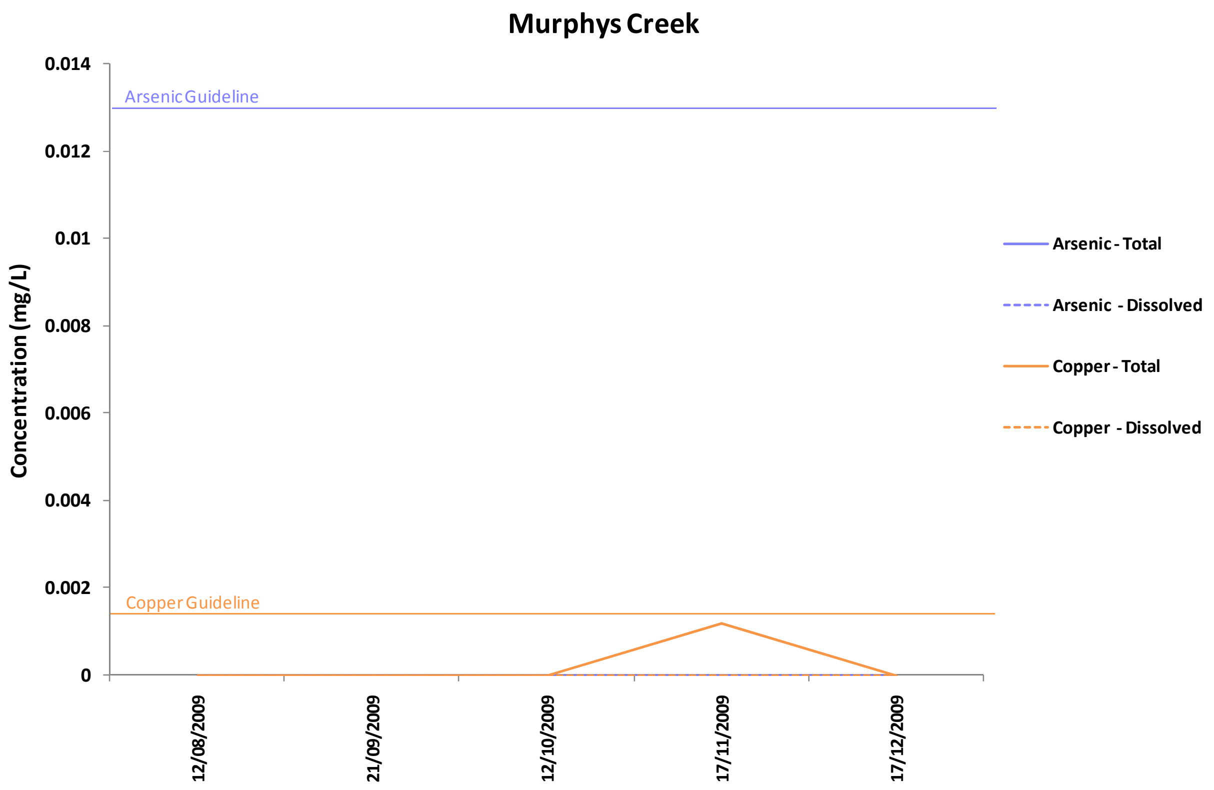


Figure 21: Arsenic, copper and zinc concentrations for Doctors Creek (DRC-1). Both total and dissolved concentrations are measured. The guidelines refer to the ANZECC trigger values for slightly to moderately disturbed systems for the protection of 95% of species in freshwater. The ANZECC guidelines do not differentiate between total and dissolved concentrations.



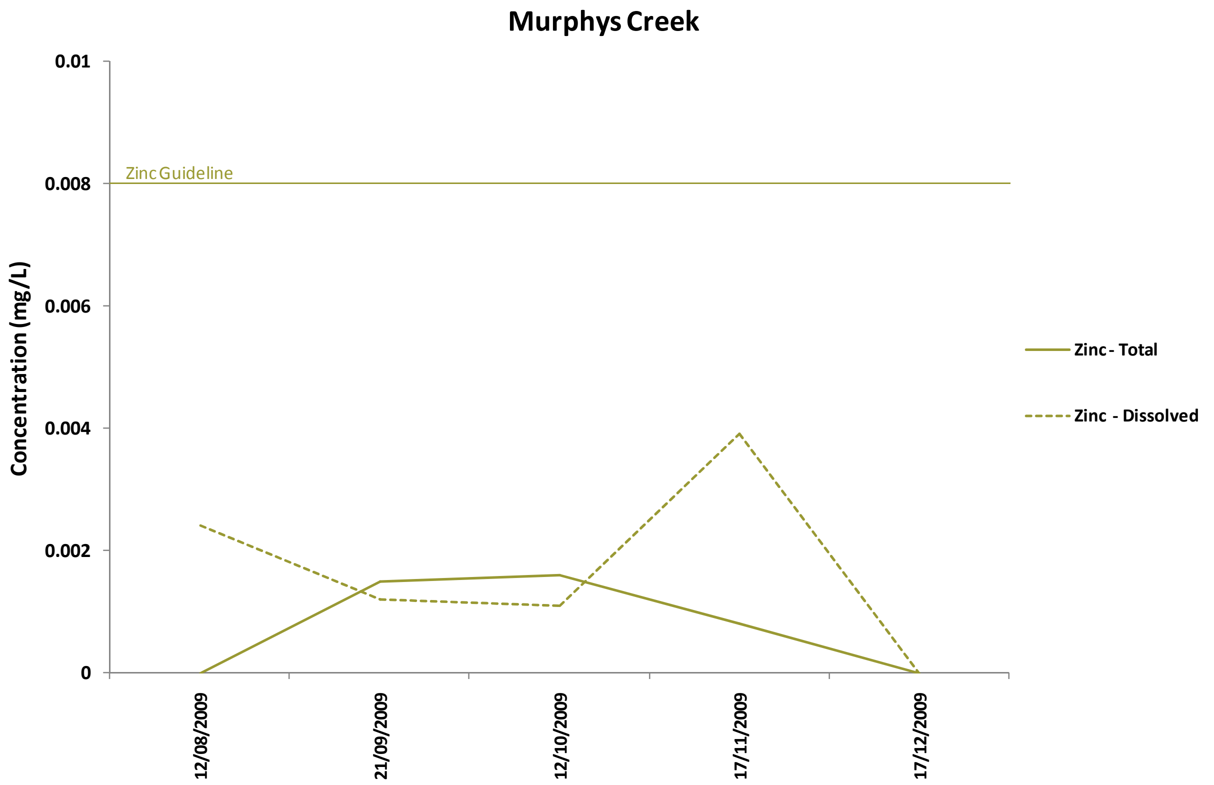
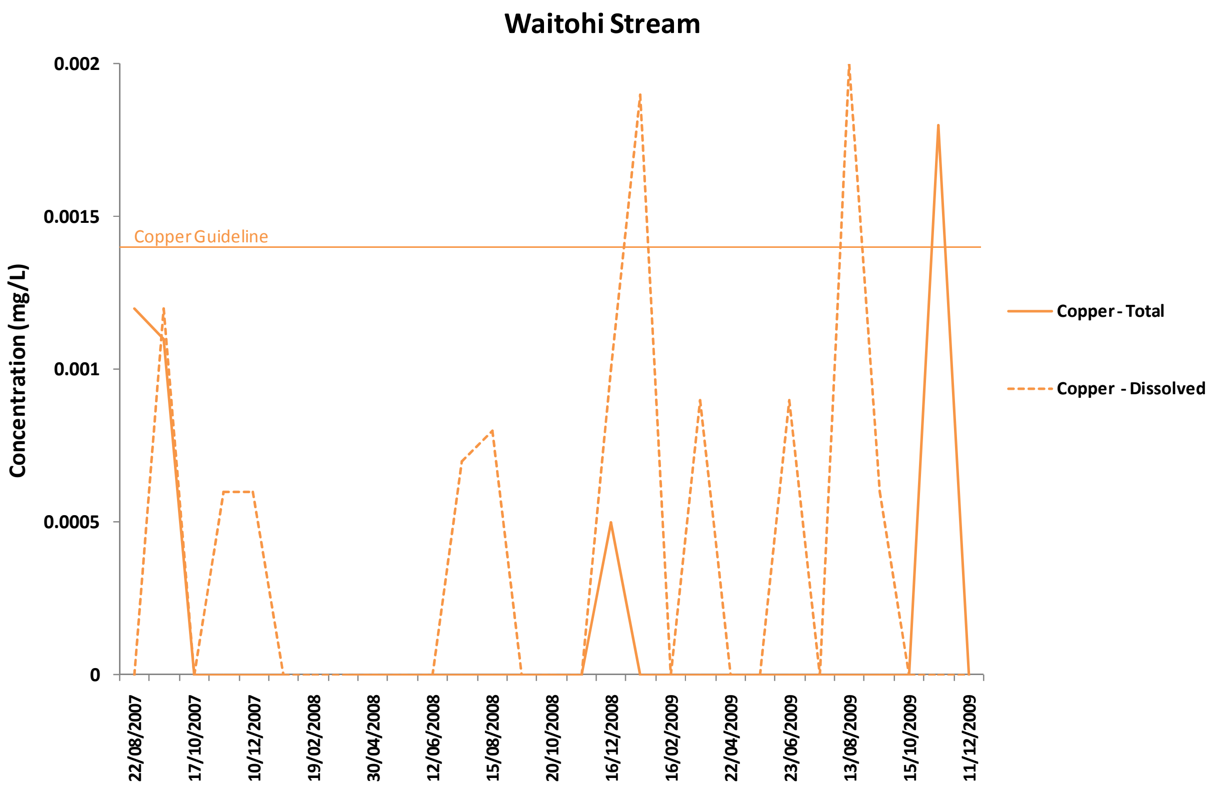


Figure 22: Arsenic, copper and zinc concentrations for Murphys Creek (MUR-1). Both total and dissolved concentrations are measured. The guidelines refer to the ANZECC trigger values for slightly to moderately disturbed systems for the protection of 95% of species in freshwater. The ANZECC guidelines do not differentiate between total and dissolved concentrations.



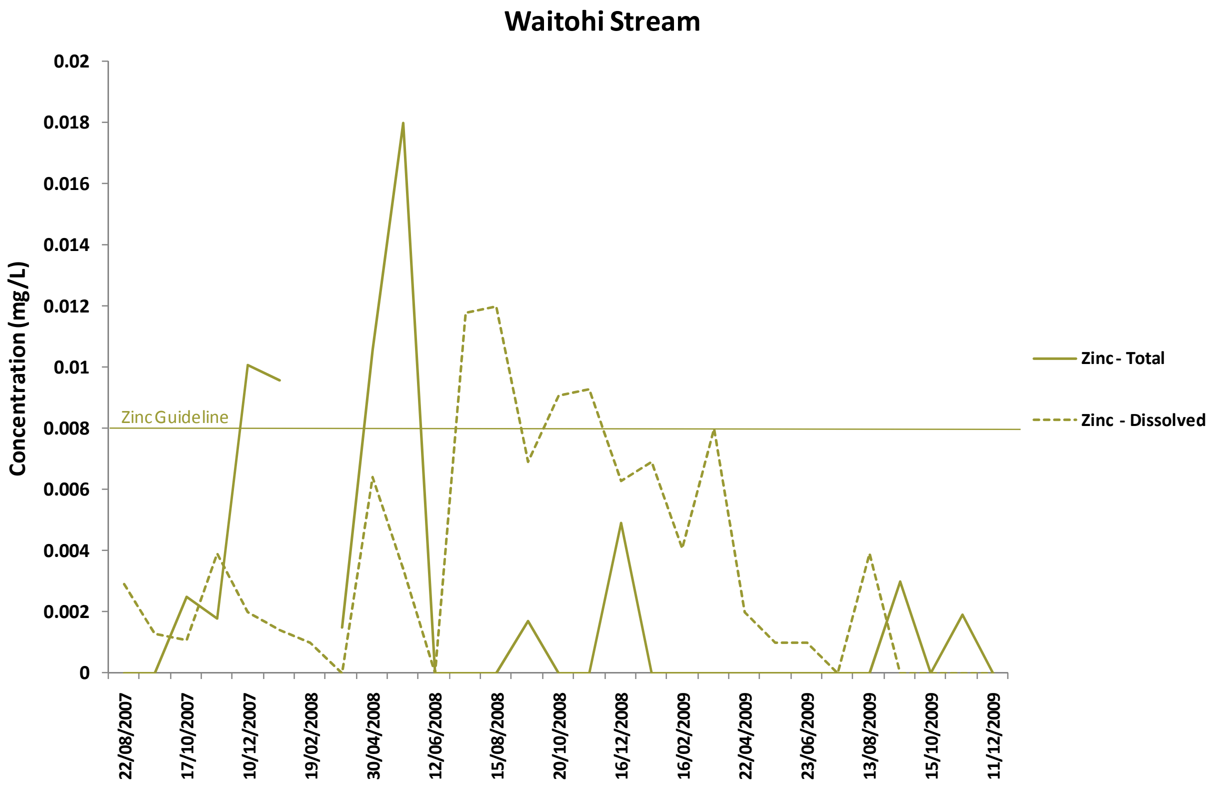


Figure 23: Arsenic, copper and zinc concentrations for the Waitohi Stream (WTS-009). Both total and dissolved concentrations are measured. The guidelines refer to the ANZECC trigger values for slightly to moderately disturbed systems for the protection of 95% of species in freshwater. The ANZECC guidelines do not differentiate between total and dissolved concentrations.

5. Water Quality Index

A water quality index is a way of summarising differing amounts and types of water quality data into a single score. By their nature the score is somewhat subjective and without units but the derivation of the score is based on actual data and assessed against known quality (guidelines) criteria. Deriving water quality indices for river sites help to summarise a vast amount of data collected over time for a range of parameters.

The health and values of a river can be affected by a range of physical and chemical stressors. Different types of physical and chemical stressors can have either a direct or indirect effect on aquatic life. Other water quality parameters such as *E. coli* will not directly affect the aquatic health of a stream but may impinge on the values associated with a stream (e.g. recreational or cultural). Figure 24, taken from the ANZECC guidelines (2000), summarises some examples of physical and chemical stressors and their effects on aquatic stream health.

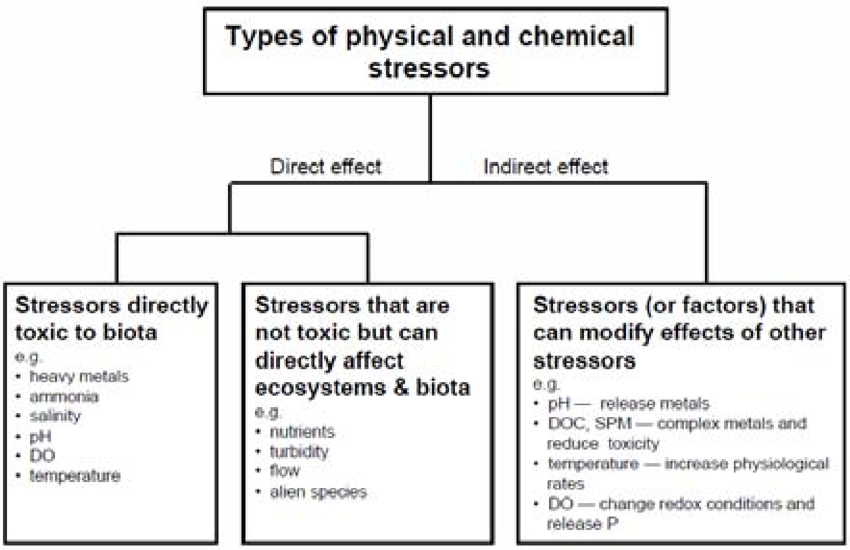


Figure 24: Physical and chemical stressors in surface waters which can affect the aquatic ecosystem health (from ANZECC, 2000).

Results for ammonia, dissolved oxygen, nitrate, dissolved reactive phosphorus, *E. coli* and turbidity for the sampling period 2007-09 were used to derive a water quality score for each site. These parameters were weighted depending on whether they produced a direct or indirect effect on aquatic ecosystem health and whether they were directly or indirectly toxic to aquatic ecosystem health as prescribed in the ANZECC guidelines. Weighting was as follows:

Ammonia	DO	Nitrate	DRP	Turbidity	*E. coli*
1.5	1.5	1	1	0.5	0.2

For data collected from 2007 -2009 the 90%ile was used for nitrate, dissolved reactive phosphorus and *E. coli*, the quartile range was used for dissolved oxygen and the mean was used for turbidity. The selection of what statistic to use for each parameter was based on what most appropriately described the parameter over a period of time and the impact it was deemed to have on aquatic ecosystem health. Results were assessed against existing guidelines and best estimate. A score from 1 to 5 was derived for each parameter, with 1 equating to excellent and 5 equating to very poor. An overall score was then calculated for each site. Table 5 details the derivation of each score.

Table 5: Derivation of the water quality index score.

Water Quality Weighting

Ammonia	DO	Nitrate	DRP	Turbidity	E. coli
1.5	1.5	1	1	0.5	0.2

Water Quality Guidelines

WQ Class	Ammonia	DO	Nitrate	DRP	Turbidity	E. coli	SCORE
Very Poor	0.9	20	1.7	0.05	5.6	550	5
Poor	0.021	15	0.444	0.021	4.1	260	4
Fair	0.01	10	0.167	0.01	2	126	3
Good	0.005	5	0.05	0.005	1	50	2
Excellent	<.005	<5	<0.05	<.005	<1	<50	1

Water Quality Grades

5.7	The lowest possible score if all parameters scored '1' according to their water quality assessed against the guidelines
28.5	The highest possible score if all parameters scored '5' according to their water quality assessed against the guidelines

The difference between 28.5 and 5.7 is **22.8**

22.8 divided by 5 WQ classes is 4.56
The lowest score (5.7) plus the difference between classes (4.56) gives the width band for the excellent class and so forth for the 5 classes

All scores are subsequently divided by 5.7 to give a band width from 1 to 5.

A	Excellent	1 - 1.8
B	Good	1.9 - 2.6
C	Fair	2.7 - 3.4
D	Poor	3.5 - 4.2
E	Very Poor	4.3 - 5

Finally, the scores from 1 to 5 were assigned to one of five categories or grades; Excellent, Good, Fair, Poor and Very Poor (appendix 5).

The number of samples taken from each site varies from as little as 5 to as many as 48 depending on the frequency of sampling and the time at which the site was added to the regions surface water quality monitoring programme. Ideally monthly monitoring for at least 3 years should be used in order to have a degree of confidence in the final water quality grade. This would result in 36 samples being used to assess a ‘complete’ grade, however circumstances such as dry stream beds during drought years or time constraints etc. can result in less than the desired number of 36 samples being taken over a three year period, therefore an arbitrary number of 30 was used as the minimum for which to calculate a complete water quality grade. The status of the water quality grade is either described as ‘complete’ or ‘interim’ depending on the number of samples used for the assessment (Appendix 6).

Figure 25 shows the water quality index score for the 33 state of the environment surface water quality monitoring sites. Just over half of the monitored sites have complete grades. The Taylor River has the poorest score and is the only site to be graded as ‘very poor’. The best score was for the Wairau at Dip Flat which was the only site to be graded as ‘excellent’.

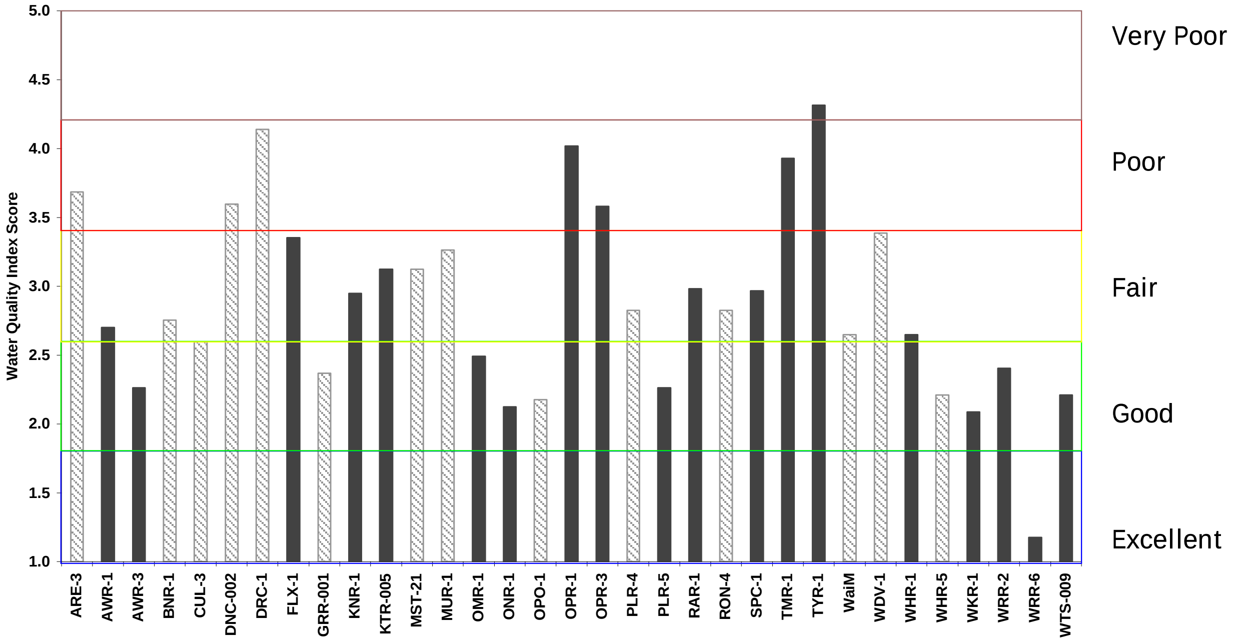


Figure 25: Water quality scores for the state of the environment monitoring sites. The colours denote the grade from Excellent to Very Poor. The hatched columns denote an incomplete grade (i.e. less than 30 samples taken from 2007-2009). Turbidity is not included in the WQ score for the Awatere sites (AWR-1 and AWR-3) as naturally high turbidity in the catchment would skew results.

Figure 26 shows the spatial locations of the water quality grades. It is apparent that the majority of poor to very poor sites are located in the lower Wairau plains where arguably the greatest intensification of land use occurs. The only exception is Duncan Stream at the head of the Queen Charlotte Sound which is graded as 'poor'. Dairy farming is the dominant land use in this catchment. The Marlborough Sounds, due to their low flushing rate and enclosed nature are particularly sensitive to poor water quality from the rivers and tributaries draining into them.

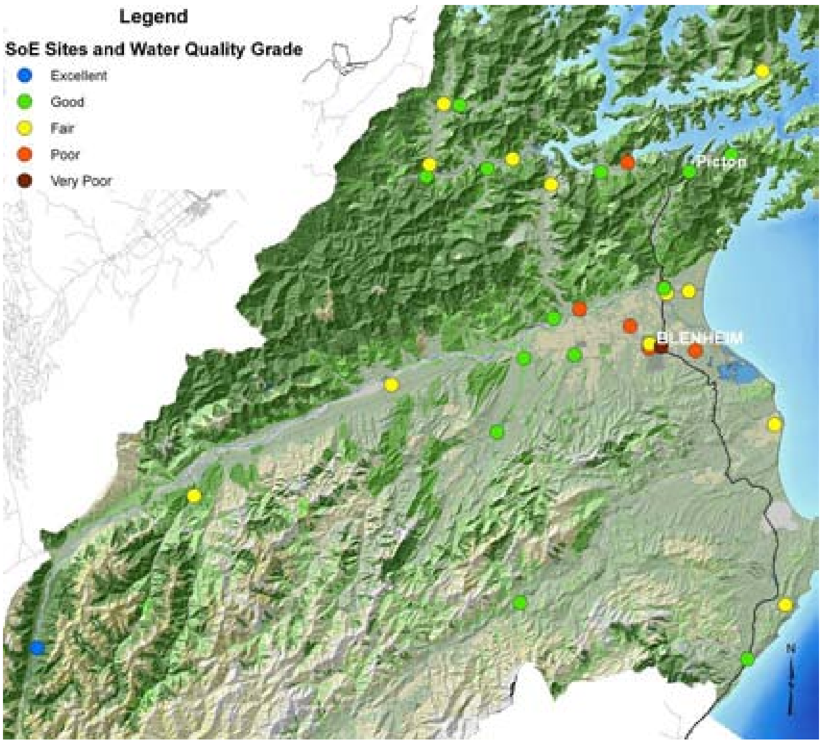


Figure 26: Water Quality Grades for the State of the Environment surface water quality monitoring sites in Marlborough

6. Discussions and Conclusions

Taking a catchment management approach to water quality management allows for the ability to assess land use and land use change with water quality trends over time. There are very few point source discharges to surface waters in Marlborough and thus the biggest threat to surface water quality comes from diffuse pollution from land use, including urban development. The ability to track changes in water quality with changes in land use is essential in order to allow for the development of appropriate land management practices to prevent degradation of water bodies and to enhance and maintain water bodies where appropriate.

State of the Environment reporting requires that the state and trends of surface waters are assessed on a timely basis. Comprehensive State of the Environment reports are produced by Council at five year intervals. The frequency of monitoring and the longevity of monitoring need to be considered in order to satisfy the requirements of state of the environment reporting. Three years of monthly monitoring is considered a minimum to assess the state or baseline water quality. Five years of monthly monitoring is considered the minimum to detect trends in water quality.

The values of Marlborough's surface waters need to be accurately defined to allow for appropriate water quality standards to be set, from which to assess the status of surface water bodies. These standards can then be incorporated into the calculation of water quality grades and reported on, on an annual basis.

Poorer water quality is found in areas of intensive land use, either agricultural or urban. Land management practices, such as those introduced in the Rai Valley as part of the Clean Streams Accord have shown that improvements in water quality can be achieved. The ability to assess the effectiveness of land management practices and/or water quality management initiatives is essential in order to ensure that resources and funds are managed in a sustainable way.

7. References

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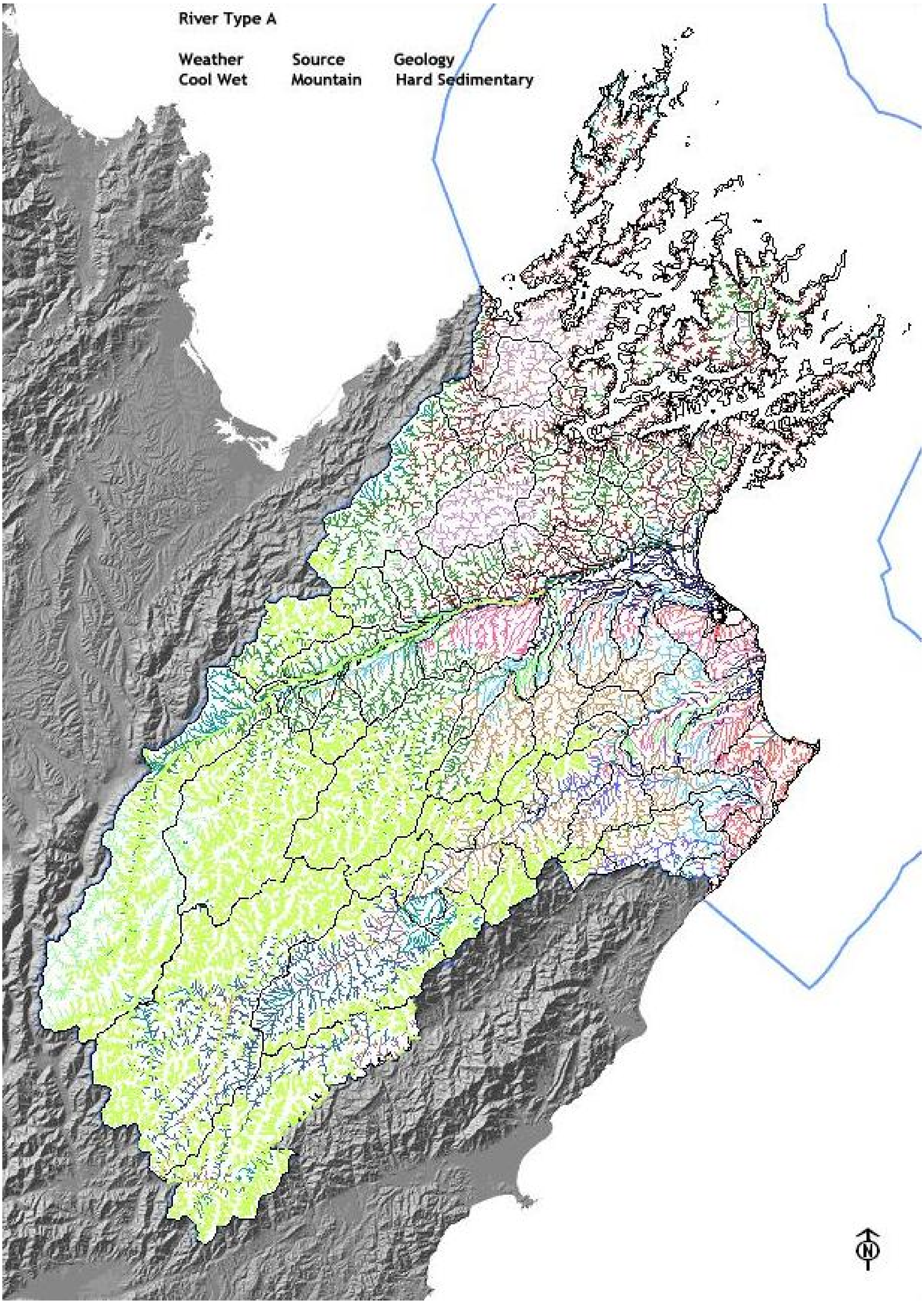
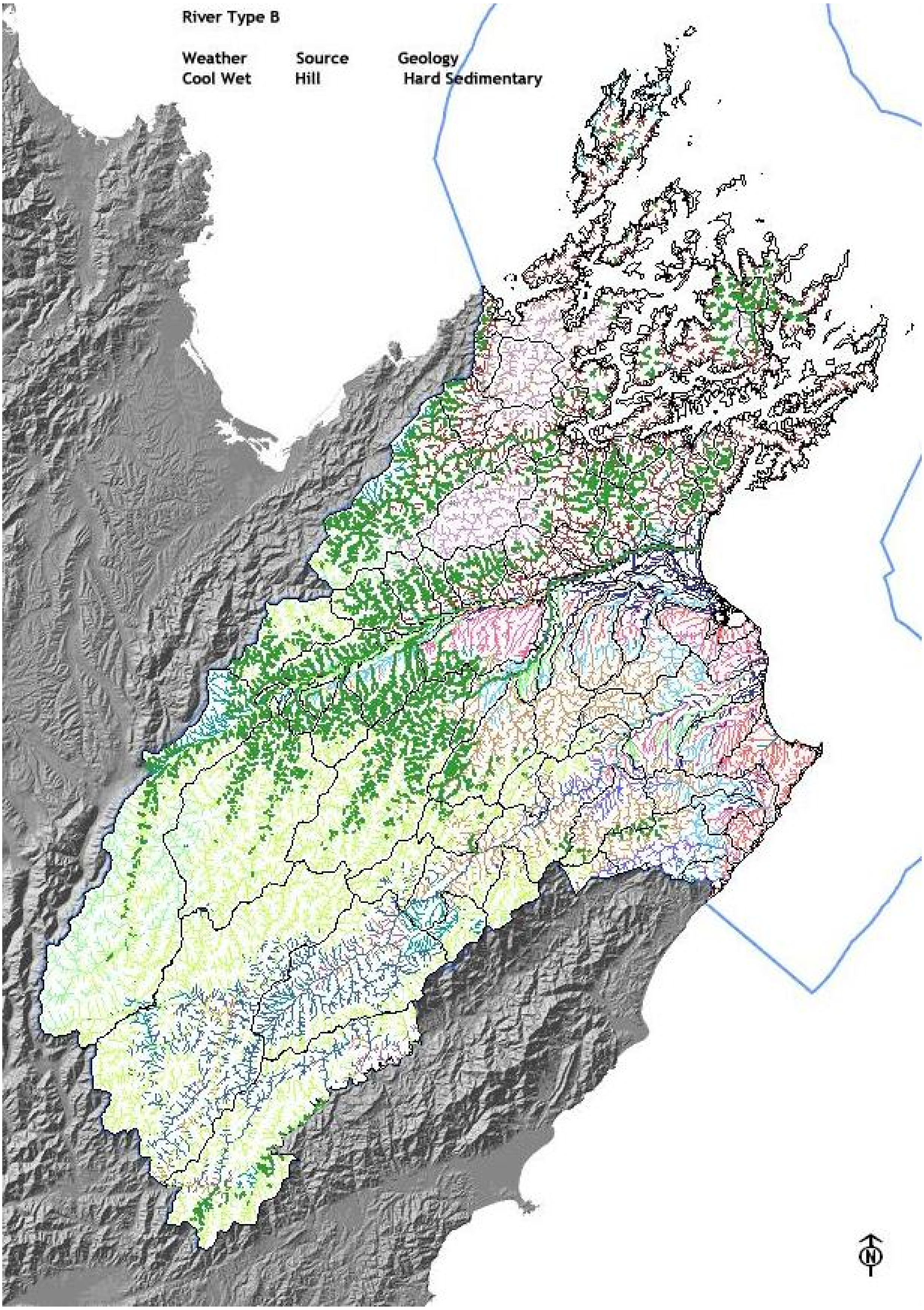
Appendix 1: River 'types' in Marlborough according to the River Environment Classification. Water Resource Units boundaries are shown in black and the river type is shown in bold in each map.

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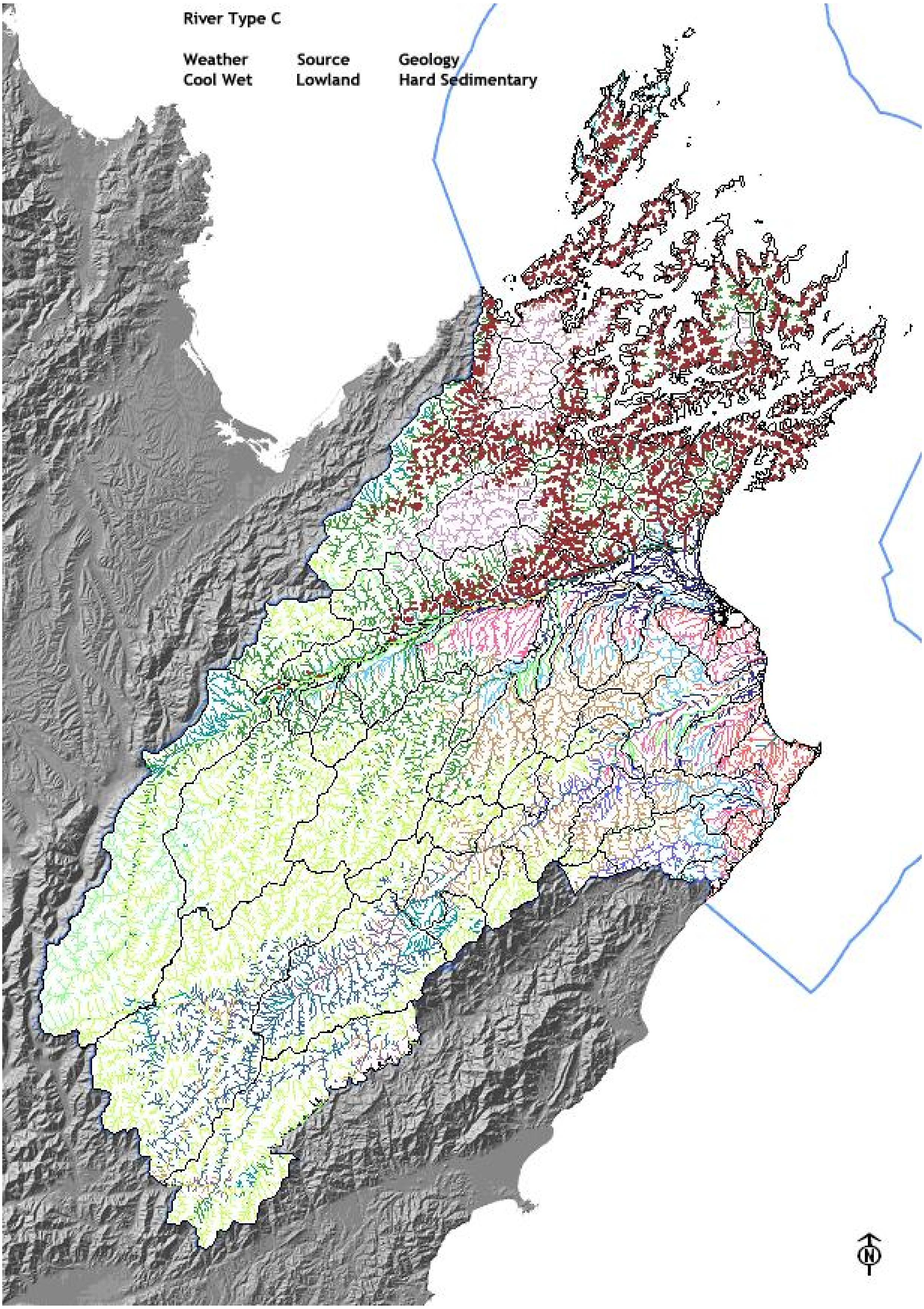
Cool Wet
Source
Hill
Geology
Hard Sedimentary
N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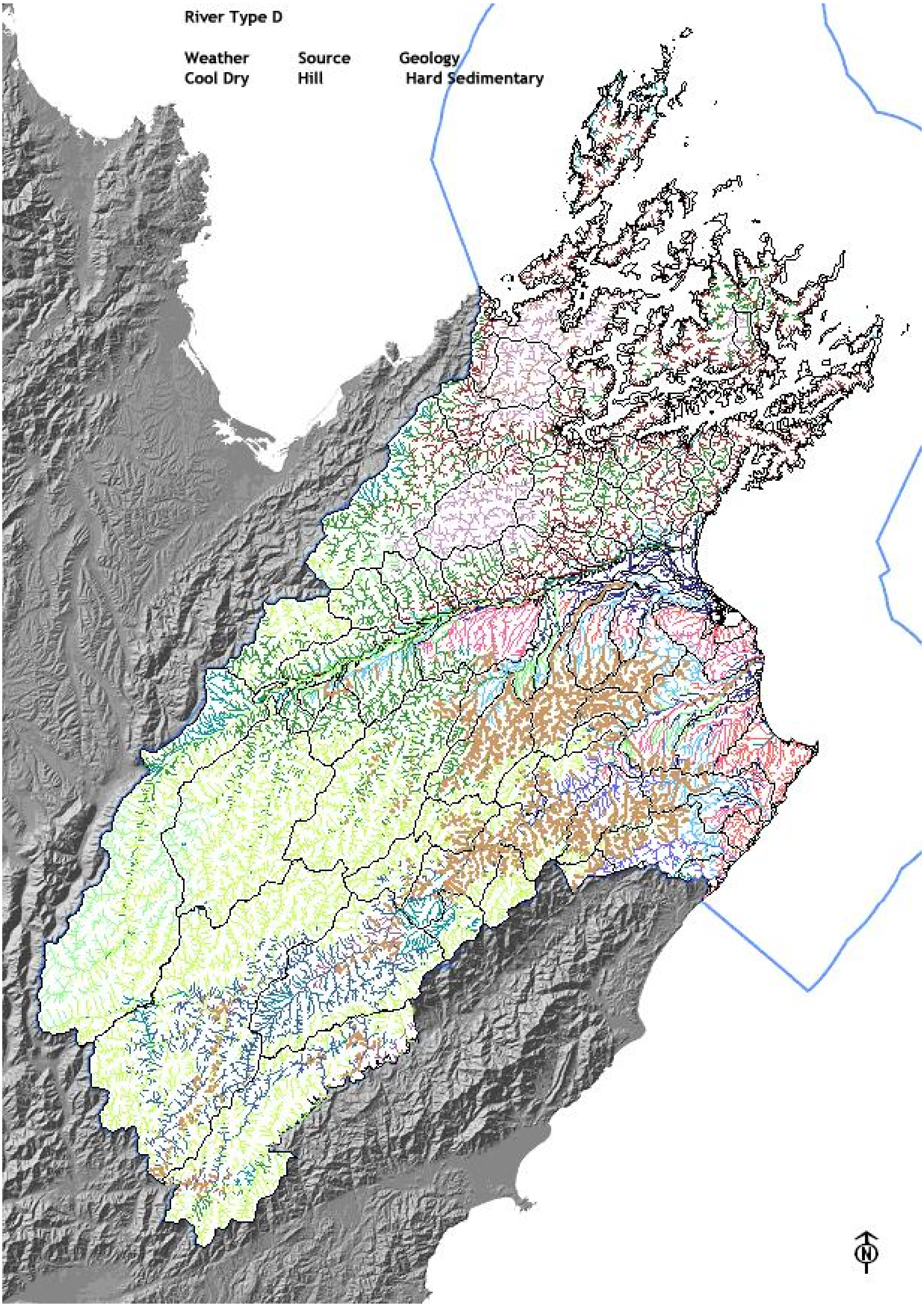
Source
Lowland
Geology
Hard Sedimentary
N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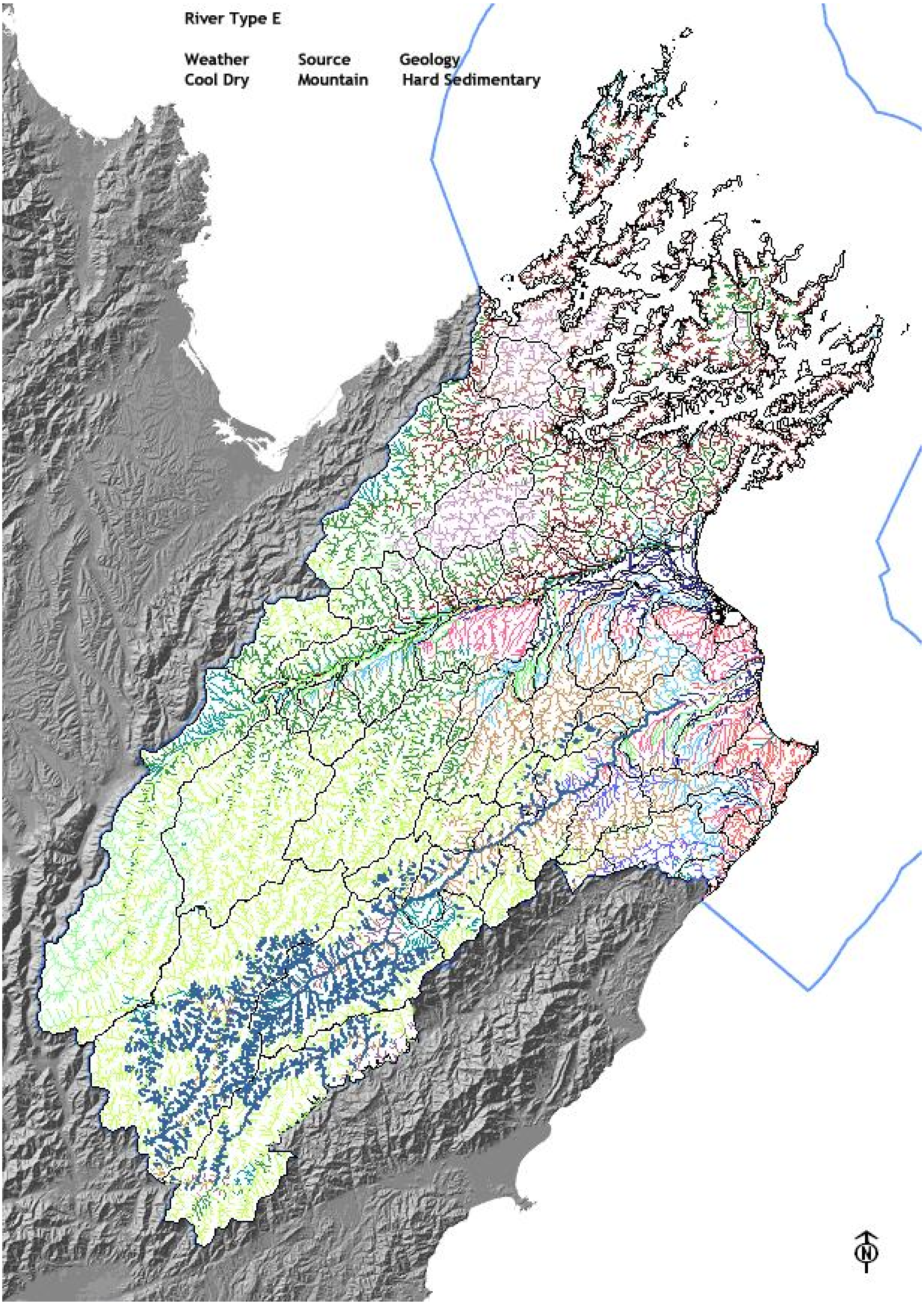
Source
Hill
Geology
Hard Sedimentary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Mountain
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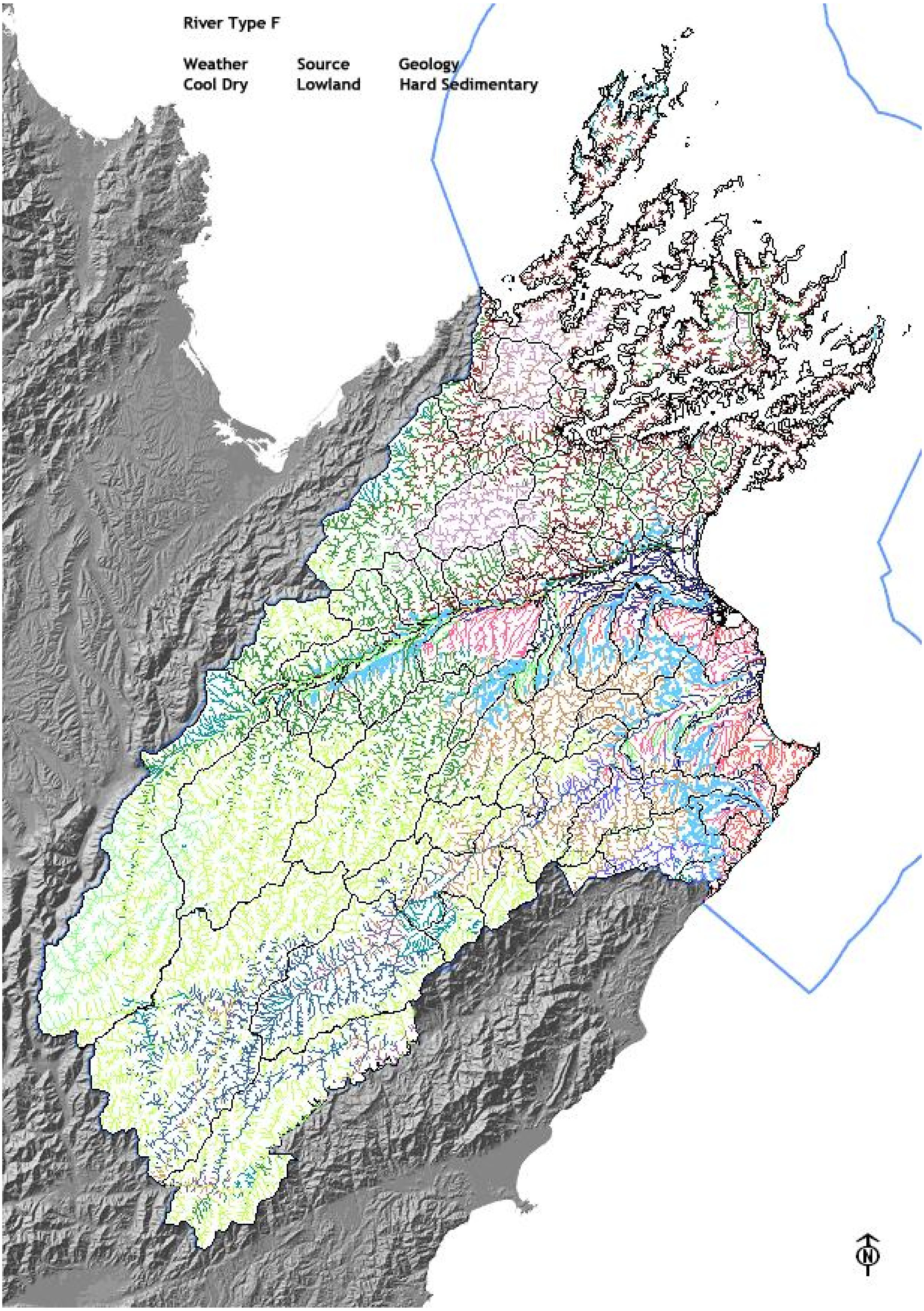
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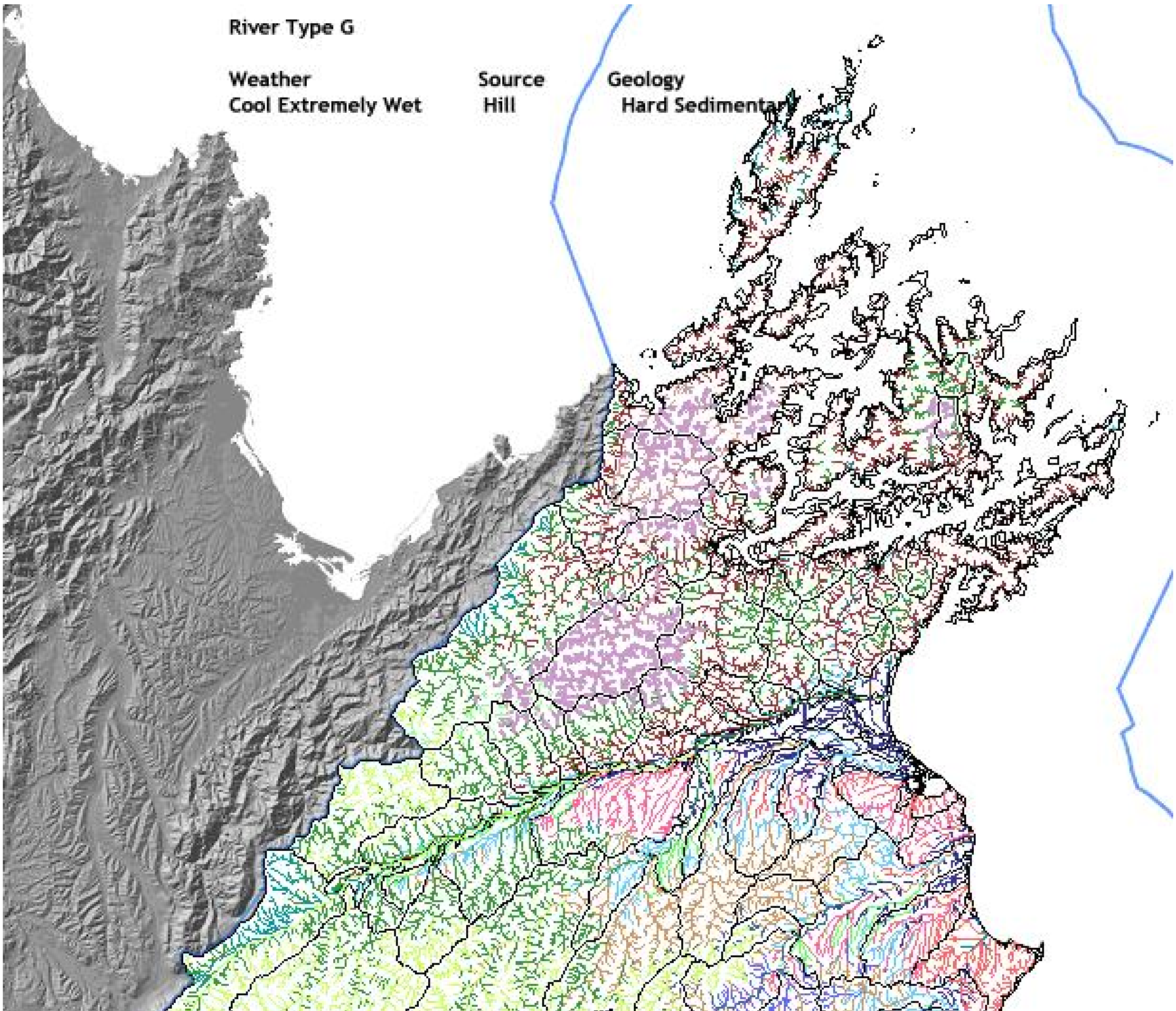
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Geology
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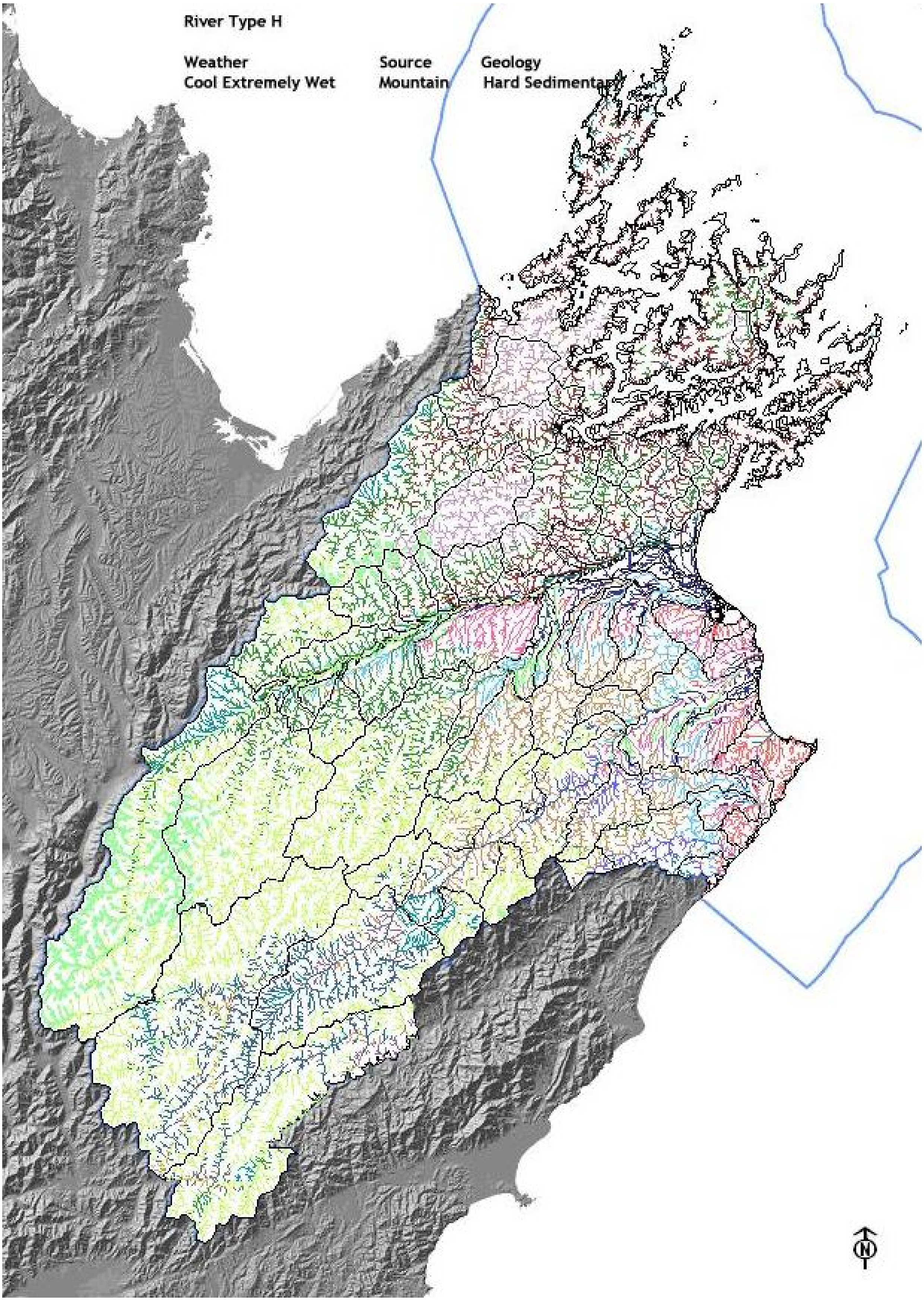
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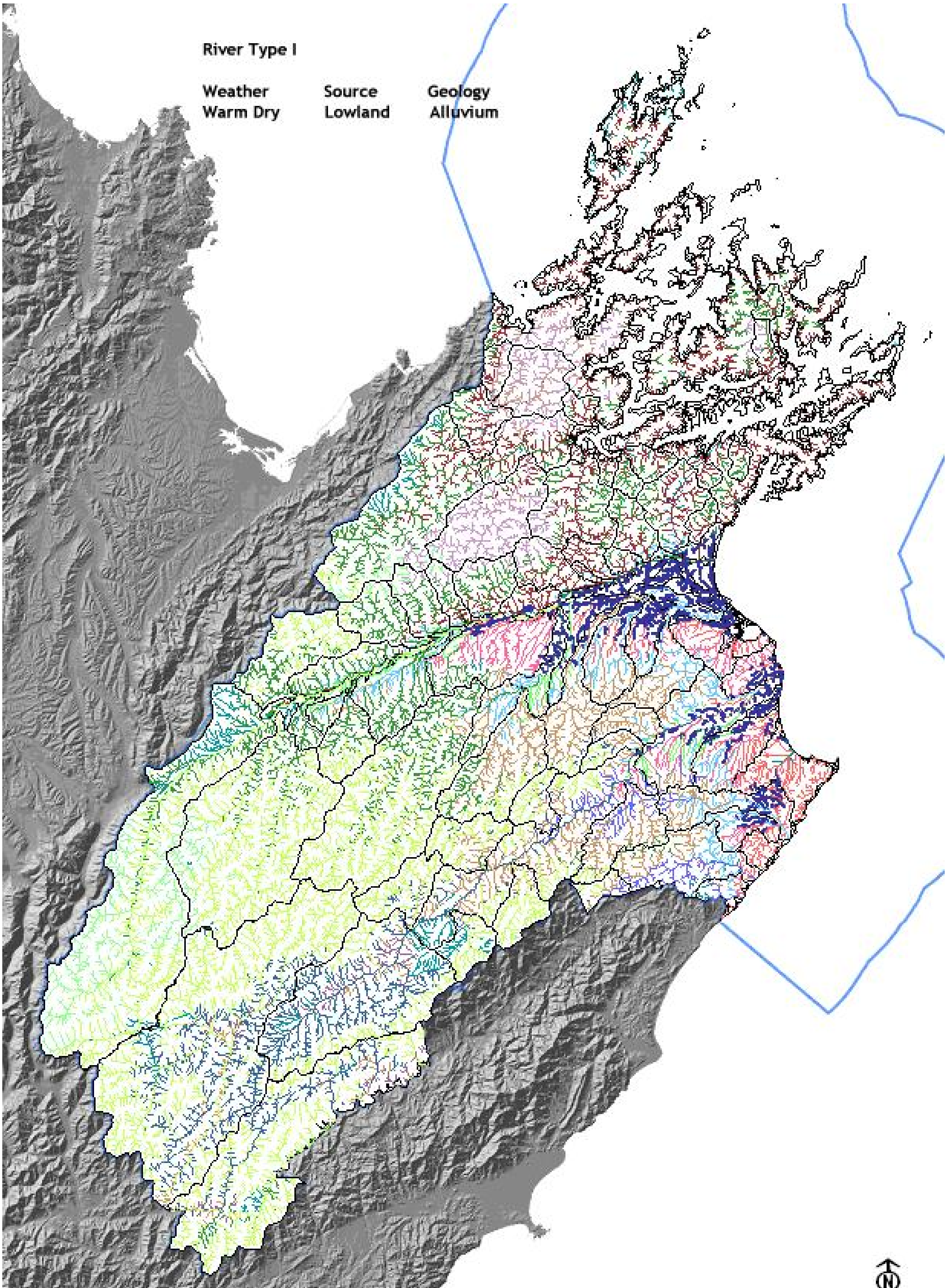
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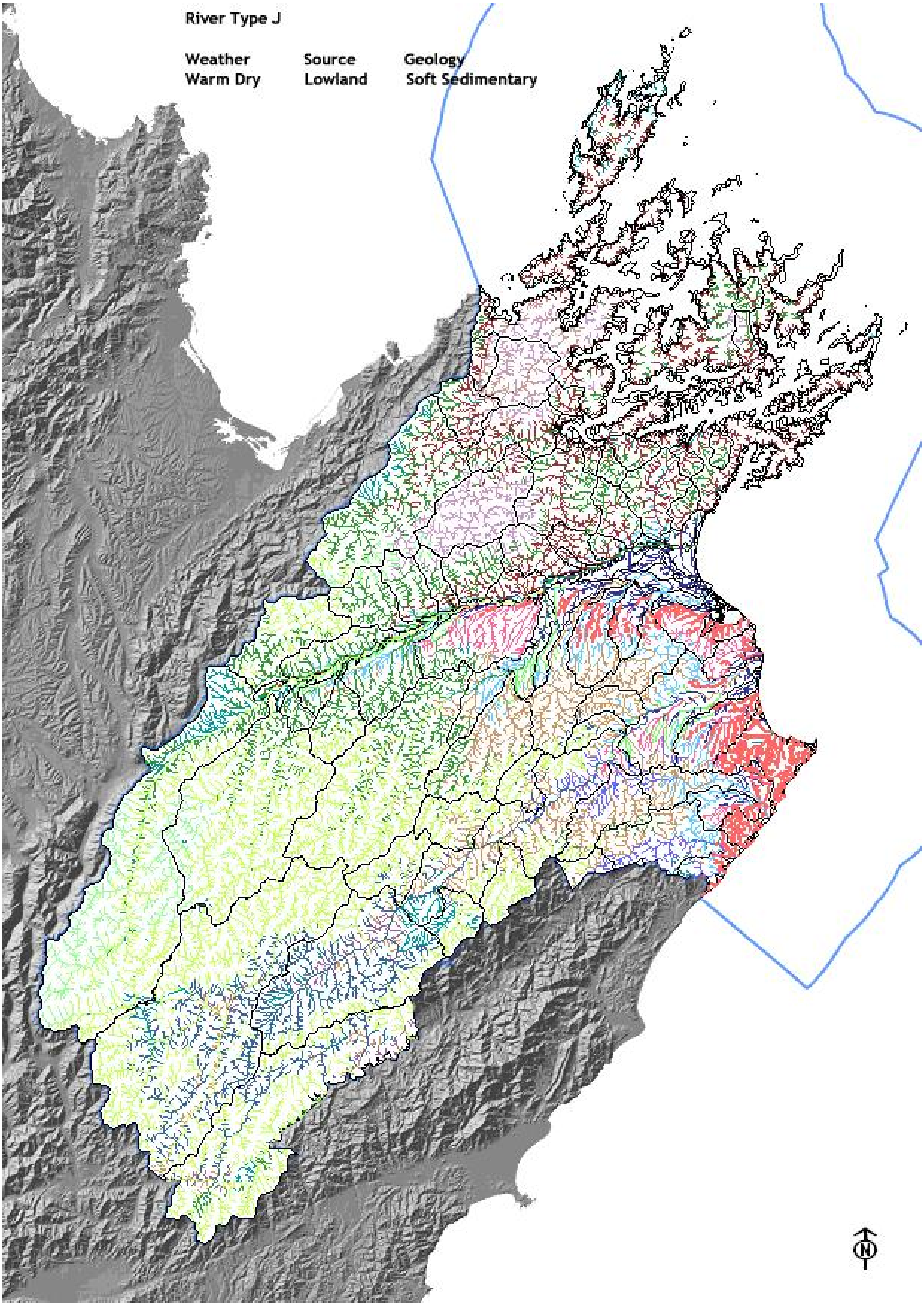
Weather
Warm Dry
Source
Lowland
Geology
Alluvium
N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Source
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Geology
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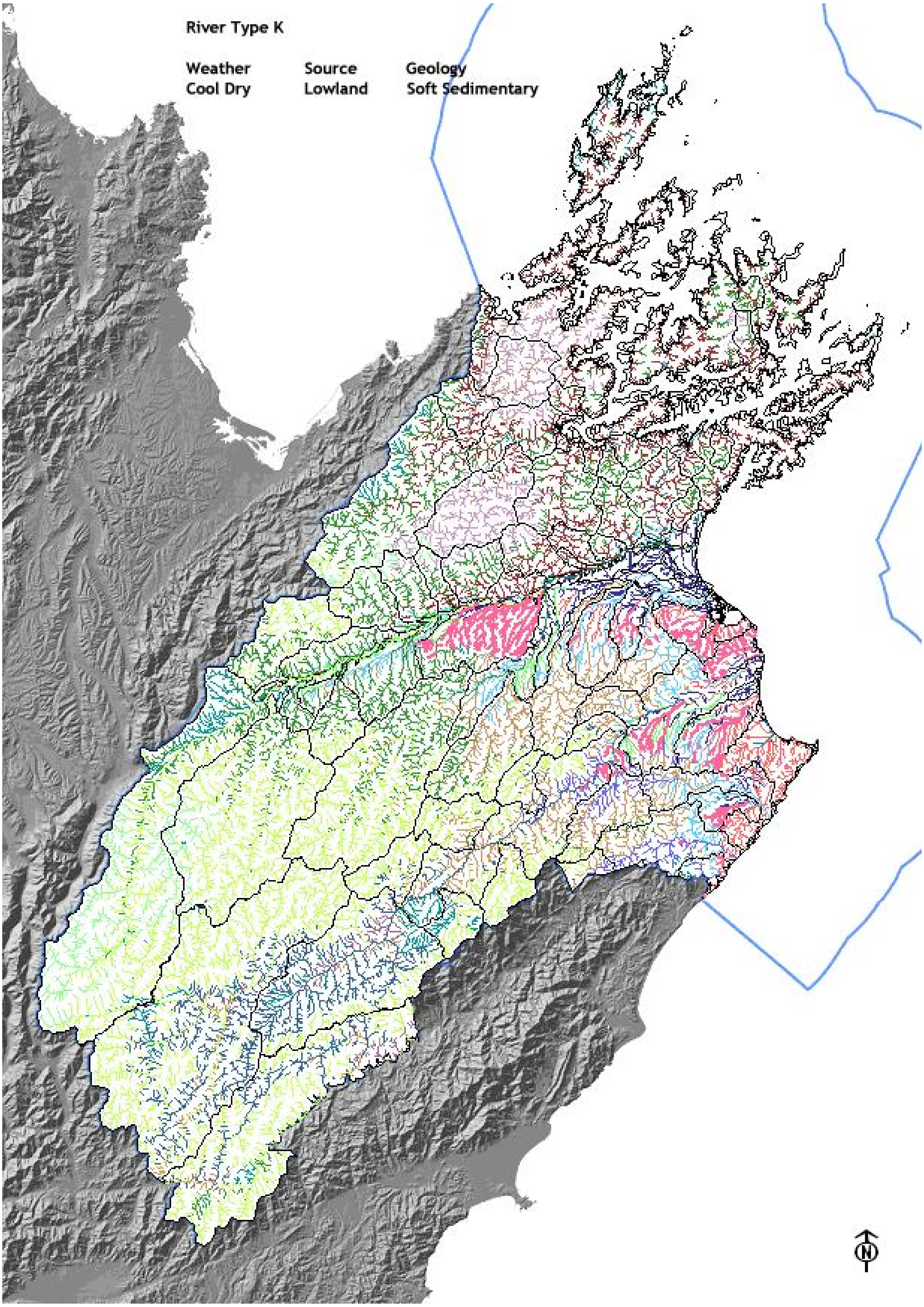
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Geology
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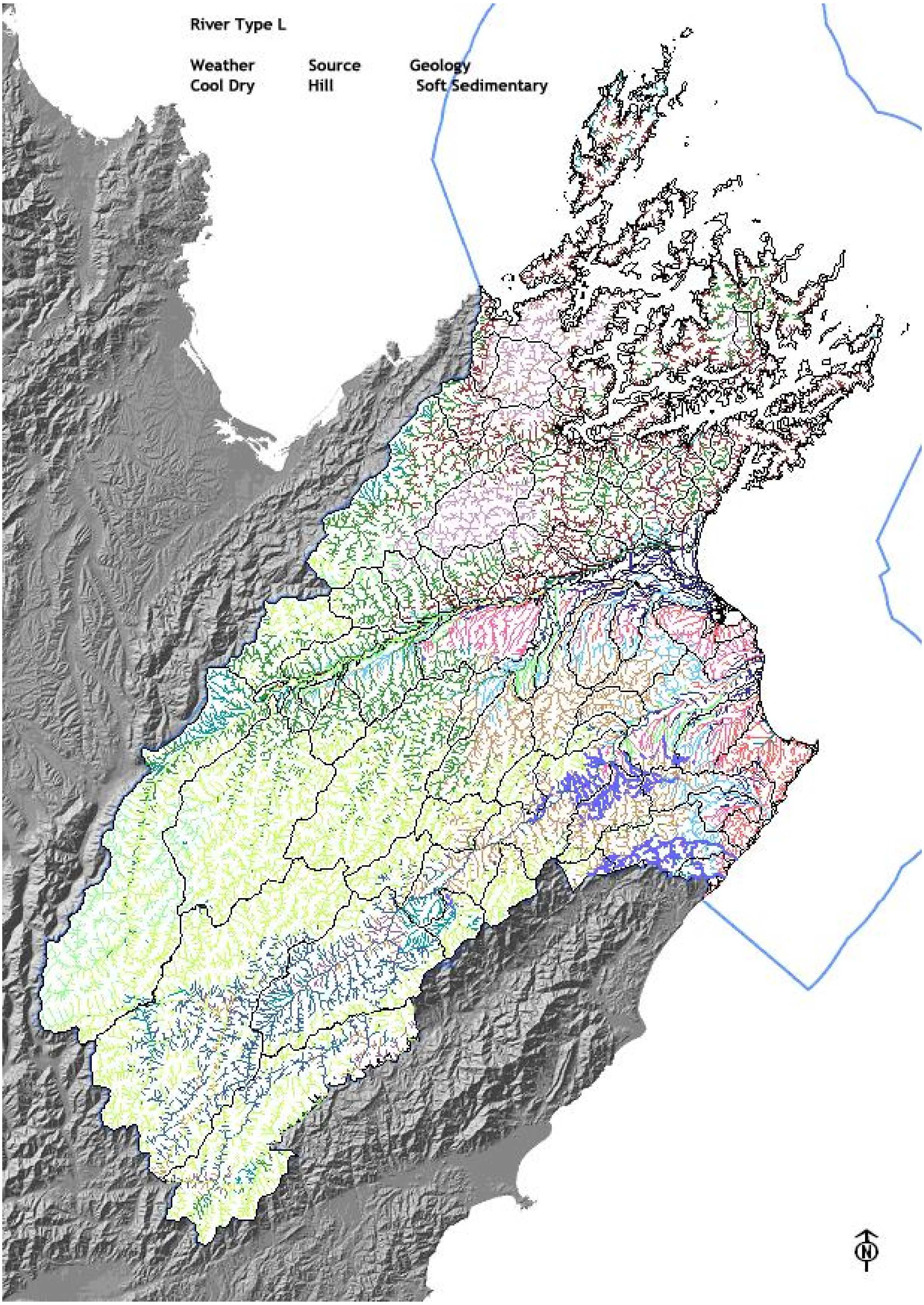
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Weather
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Source
Hill
Geology
Soft Sedimentary
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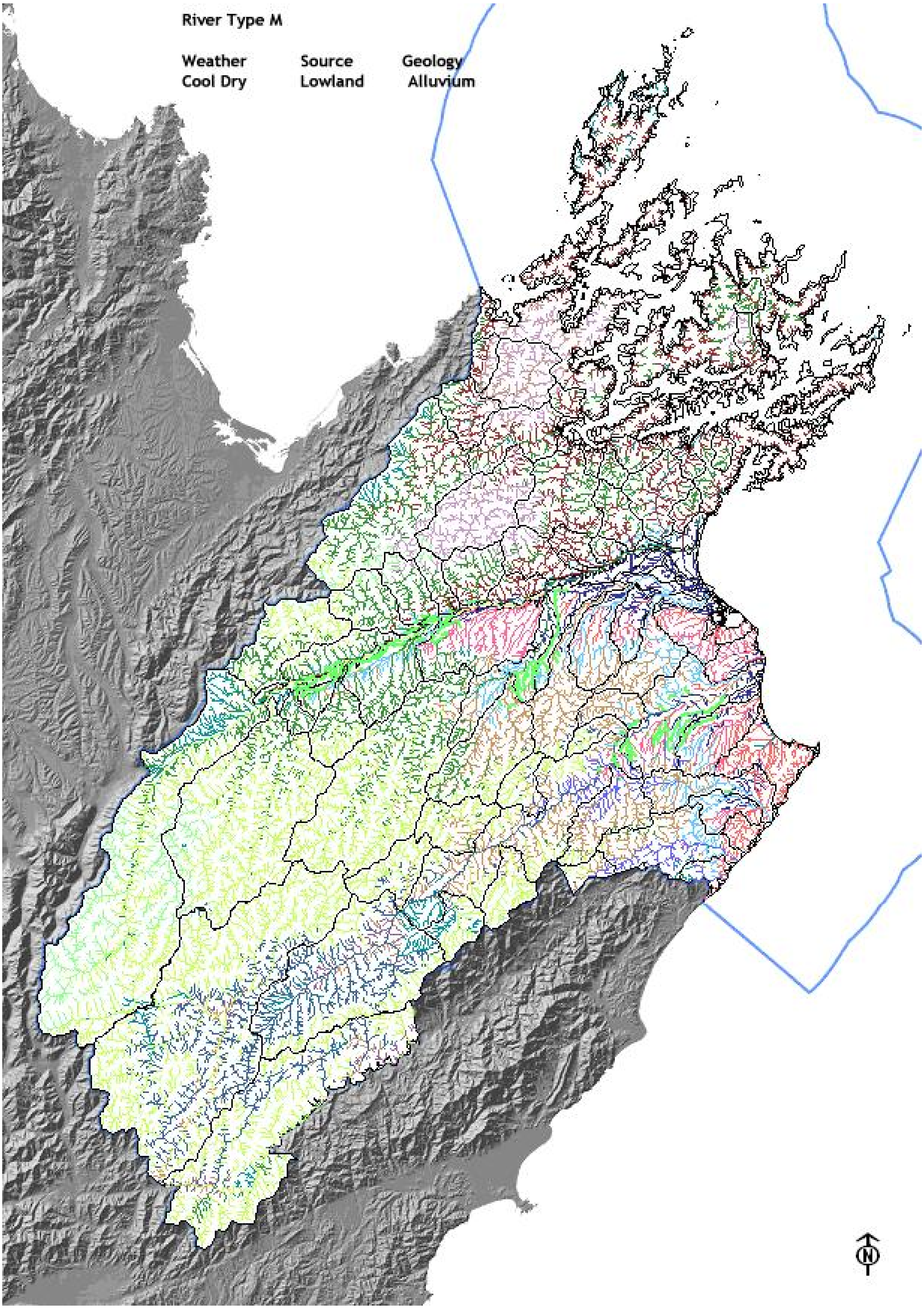
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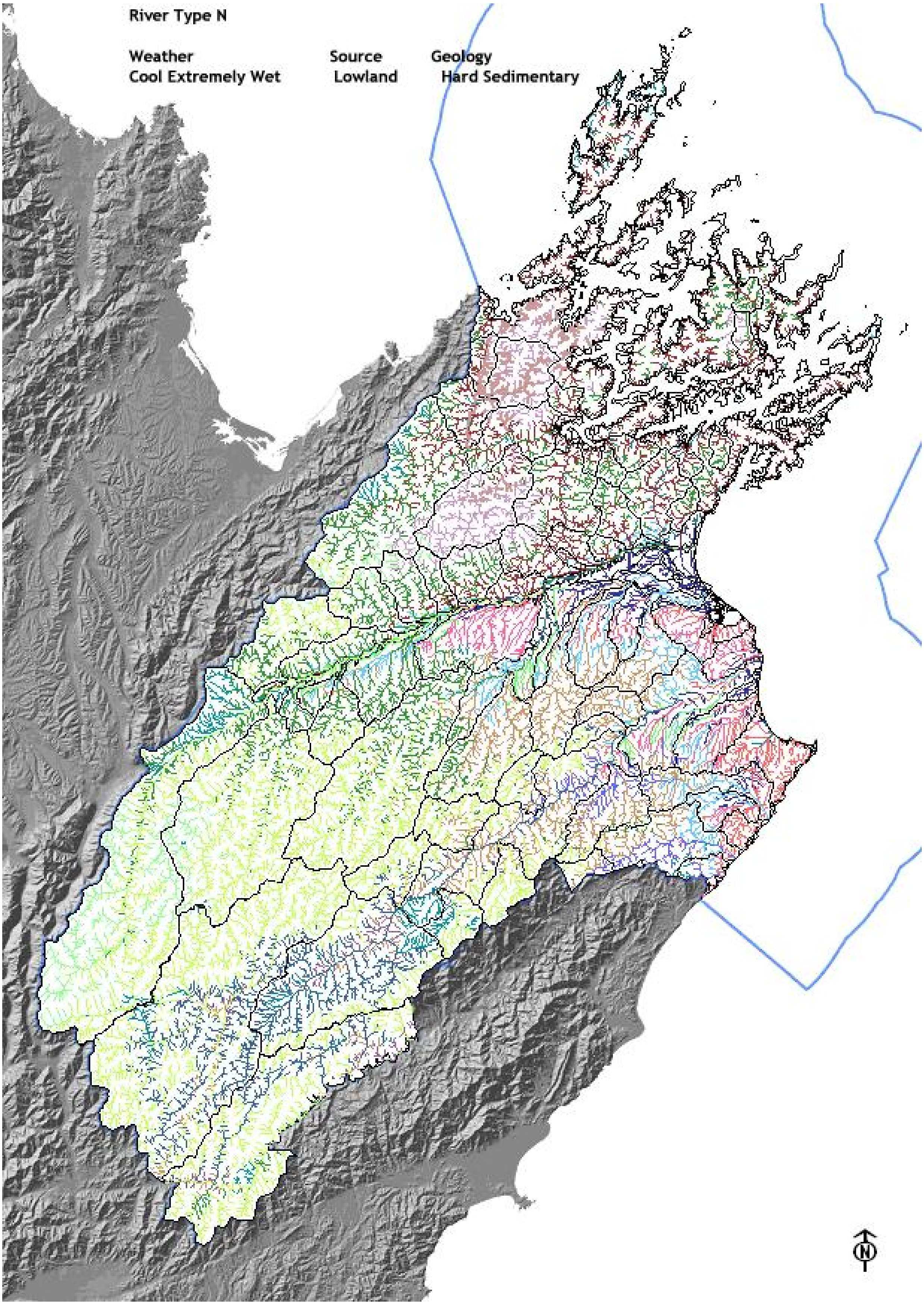
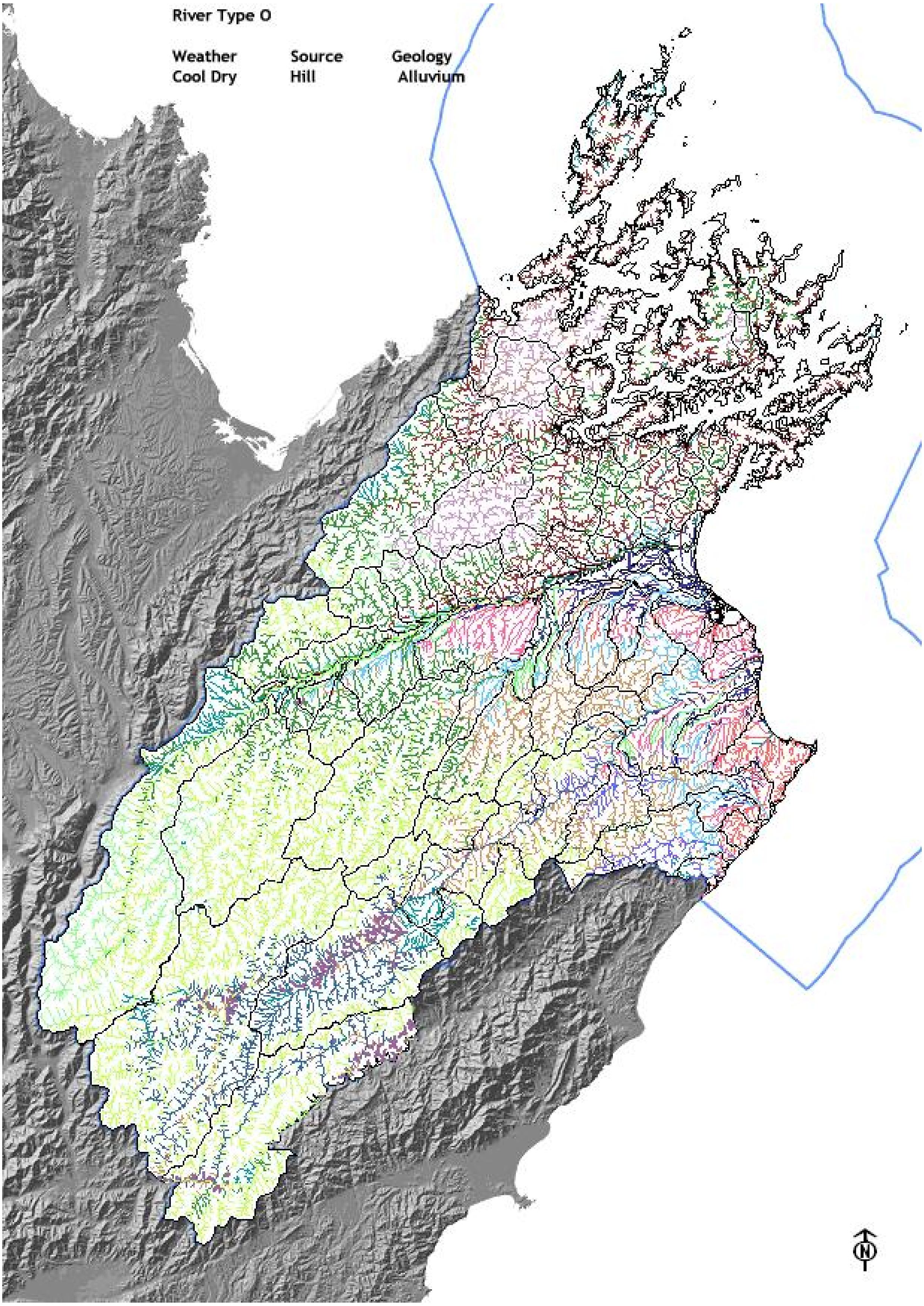
Geology
Alluvium
N


River Type N
Weather
Cool Extremely Wet
Source
Lowland
Geology
Hard Sedimentary
N


River Type O
Weather
Cool Dry
Source
Hill
Geology
Alluvium
N

Appendix 2: The Water Resource Units (WRU's) for the purpose of assessing surface water quality for the Marlborough Region.

Region	Unit	% River Type (based on REC)															Final River Type
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
Pelorus	Ronga	0	9	47	0	0	0	9	0	0	0	0	0	0	31	0	**C**
	Opouri	0	0	1	0	0	0	50	0	0	0	0	0	0	49	0	**N**
	Rai	0	23	53	0	0	0	1	0	0	0	0	0	0	17	0	**C**
	Upper Pelorus	5	54	17	0	0	0	7	6	0	0	0	0	0	0	0	**B**
	Wakamarina	0	4	11	0	0	0	76	2	0	0	0	0	0	7	0	**G**
	Lower Pelorus	0	24	52	0	0	0	16	0	0	0	0	0	0	5	0	**C**
Marlborough Sounds	Small Sounds streams	0	15	65	0	0	0	8	0	0	0	0	0	0	5	0	**C**
	Anakoha	0	61	37	0	0	0	0	0	0	0	0	0	0	0	0	**B**
	Kenepuru	0	28	43	0	0	0	24	0	0	0	0	0	0	0	0	**C**
	Kaiuma	0	17	72	0	0	0	11	0	0	0	0	0	0	0	0	**C**
	Kaituna	0	34	49	0	0	0	14	0	0	0	0	0	0	0	0	**C**
	Cullens Creek	0	80	18	0	0	0	0	0	0	0	0	0	0	0	0	**B**
	Ada Creek 'complex'	0	31	60	0	0	0	0	0	0	0	0	0	0	0	0	**C**
	Waitohi	0	21	70	0	0	0	0	0	0	0	0	0	0	0	0	**C**
	Graham River	0	54	46	0	0	0	0	0	0	0	0	0	0	0	0	**B**
Wairau	Upper Wairau	44	12	0	0	0	0	0	31	0	0	0	0	0	0	0	**A**
	Branch River	73	16	0	0	0	0	0	0	0	0	0	0	0	0	0	**A**
	Goulter	54	43	0	0	0	0	0	2	0	0	0	0	0	0	0	**A**
	Patriarch 'complex'	10	74	1	0	0	7	0	0	0	0	0	0	7	0	0	**B**
	Argyle Pond	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**Other**
	Saltwater Stream	0	89	0	0	0	0	0	0	0	0	0	0	0	0	1	**B**
	Cabbage Tree Gully Stream	0	41	0	12	0	21	0	0	0	0	0	0	23	0	3	**B**
	Wye River	42	54	0	3	0	1	0	0	0	0	0	0	0	0	0	**B**
	Top Valley Stream	11	74	3	0	0	3	0	7	0	0	0	0	2	0	0	**B**
	Boundary Creek 'complex'	0	62	0	4	0	28	0	0	0	0	0	0	6	0	0	**B**
	Timms Creek	0	54	14	0	0	4	13	12	0	0	0	0	3	0	0	**B**
	Centre Valley Stream 'complex'	0	17	0	6	0	2	0	0	5	2	62	1	4	0	0	**K**
	Pine Valley Stream	0	47	19	0	0	6	15	11	0	0	0	0	2	0	0	**B**
	Bartletts Creek	0	58	25	0	0	2	13	1	0	0	0	0	1	0	0	**B**
	North Bank 'complex'	0	9	76	0	0	6	0	0	5	0	0	0	0	0	0	**C**
	Onamalutu	0	19	54	0	0	0	26	0	0	0	0	0	0	0	0	**C**
	Are Are Creek	0	7	89	0	0	3	0	0	0	0	0	0	0	0	0	**C**
	Waikakaho	0	47	46	0	0	6	0	0	0	0	0	0	0	0	0	**C**
	Tuamarina	0	23	58	0	0	8	0	0	1	0	0	0	0	0	0	**C**
	Pukaka Stream	0	53	46	0	0	1	0	0	0	0	0	0	0	0	0	**C**
	Spring Creek	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	**I_{sp}**
	Grovetown Lagoon	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	**I**

Region	Unit	% River Type (based on REC)															Final River Type
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
	Coastal Wairau 'complex'	0	0	7	0	0	0	0	0	78	0	0	0	0	0	0	**I**
	Wairau River	44	24	0	0	0	0	0	0	13	0	2	0	10	0	0	**A**
	Lower Wairau Trib 'complex'	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	**I**
Waihopai	Upper Waihopai	59	36	0	4	0	1	0	0	0	0	0	0	0	0	0	**A**
	Avon	18	23	0	53	0	4	0	0	0	0	0	0	1	0	0	**D**
	Mid Waihopai	1	32	0	29	0	38	0	0	0	0	0	0	0	0	0	**D**
	Lower Waihopai	0	21	0	9	0	19	0	0	20	0	0	0	31	0	0	**M**
Omaka	Omaka River	6	0	0	80	3	6	0	0	2	1	0	0	1	0	0	**D**
	Gibsons Creek	0	0	0	1	0	12	0	0	45	13	0	0	29	0	0	**I**
	Fairhall River	0	0	0	28	0	38	0	0	13	18	2	0	0	0	0	**F**
	Doctors Creek	0	0	0	1	0	14	0	0	38	21	21	0	0	0	0	**I**
	Blenheim Springs	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	$\mathbf{I_{SP}}$
	Taylor River	0	0	0	52	0	38	0	0	1	6	3	0	0	0	0	**D**
	Opawa River	0	0	0	0	0	32	0	0	68	0	0	0	0	0	0	**I**
	Lower Opawa	0	0	0	0	0	59	0	0	38	0	0	0	0	0	0	**F**
	Seventeen Valley Stream 'complex'	0	0	0	0	0	4	0	0	12	33	50	0	0	0	0	**K**
	Wairau Lagoon 'complex'	0	0	0	0	0	0	0	0	23	59	18	0	0	0	0	**J**
Awatere	Upper Awatere	22	0	0	4	52	0	0	0	0	0	0	0	0	0	11	**E**
	Castle River	81	0	0	4	14	0	0	0	0	0	0	0	0	0	1	**A**
	Winterton River	58	0	0	2	3	0	0	0	0	0	0	3	0	0	0	**A**
	Grey River	67	8	0	25	0	0	0	0	0	0	0	0	0	0	0	**A**
	Mid Awatere	22	1	0	36	17	0	0	0	0	0	4	10	1	0	0	**D**
	Hodder River	84	0	0	12	1	0	0	2	0	0	0	0	0	0	0	**A**
	Penk River	63	1	0	19	13	0	0	0	0	0	0	5	0	0	0	**A**
	Medway River	8	5	0	56	0	0	0	0	0	0	2	29	0	0	0	**D**
	Black Birch Stream	36	0	0	41	16	5	0	0	0	0	0	0	2	0	0	**D**
	Blairich Stream	0	0	0	84	3	11	0	0	0	0	0	0	3	0	0	**D**
	Lower Awatere	0	0	0	21	5	20	0	0	14	3	15	4	18	0	0	**D**
South East Marlborough	Blind River	0	0	0	5	0	20	0	0	12	33	22	2	6	0	0	**J**
	East coast complex	0	0	0	1	0	2	0	0	12	63	15	0	0	0	0	**J**
	Flaxbourne	0	0	0	29	0	29	0	0	15	16	1	9	1	0	0	**F**
	Needles/Tachalls	0	0	0	0	0	44	0	0	16	15	25	0	0	0	0	**F**
	Waima	2	5	0	32	0	0	0	0	0	5	20	33	0	0	0	**L**
Clarenece	Acheron	53	2	5	3	30	0	1	0	0	0	0	0	0	0	2	**A**
	Upper Clarence	46	7	8	6	17	0	2	0	0	0	0	1	0	3	6	**A**
Small Coastal Catchments	Small Coastal Catchments	No catchments defined under NIWAs catchment database, therefore no REC values given to the streams.															

Appendix 3: **Water quality parameters measured for state of the environment surface water monitoring; the test method used for analysis and the detection limit for each parameter. All analysis carried out by Environmental Laboratories Services (ELS) Ltd to IANZ accredited standards.**

No.	Test Code	Test Name	Test Method	Detection Limits
1	1	pH	Dedicated pH meter following APHA 21st Edition Method 4500 H. LAS official test 5.03.	<0.1
2	2	Suspended Solids - Total	APHA 21st Edition Method 2540 D	<3 g/m³
3	55	Conductivity at 25°C	APHA 21st Edition Method 2510 B. LAS official test 5.02.	<0.1 mS/m
4	84	Turbidity	Turbidity Meter following APHA 21st Edition Method 2130 B. LAS official test 5.04.	<0.01 NTU
5	89	Faecal Coliforms	Membrane Filtration following APHA 21st Edition Method 9222 D	<1 cfu/100mL
6	98	*E. coli*	APHA 21st Edition 9222 G.	<1 cfu/100mL
7	125	Inorganic Nitrogen	By Calculation - NNN plus Ammonia	<0.01 g/m³
8	515	Nitrite Nitrate Nitrogen	Flow Injection Autoanalyser following APHA 21st Edition Method 4500-NO3 I. LAS official tests 5.13 and 5.14.	<0.005 g/m³
9	605	Nitrate - Nitrogen	Ion Chromatography following USEPA 300.0 (modified). LAS official test 5.13.	<0.01 g/m³
10	760	Ammonia Nitrogen	Flow Injection Autoanalyser following APHA 21st Edition Method 4500 NH3 H. LAS official test 5.10.	<0.01 g/m³
11	2088	Dissolved Reactive Phosphorus	Flow Injection Autoanalyser following APHA 21st Edition Method 4500-P G. Official LAS test 5.15.	<0.005 g/m³
12	6603	Arsenic - Total	ICP-MS following APHA 21st edition method 3125 (modified)	<0.002 g/m³
13	6613	Copper - Total	ICP-MS following APHA 21st edition method 3125 (modified)	<0.002 g/m³
14	6638	Zinc - Total	ICP-MS following APHA 21st edition method 3125 (modified)	<0.005 g/m³
15	6703	Arsenic - Dissolved	ICP-MS following APHA 21st edition method 3125 (modified). LAS official test 5.18	<0.001 g/m³
16	6713	Copper - Dissolved	ICP-MS following APHA 21st edition method 3125 (modified). LAS official test 5.23	<0.0005 g/m³
17	6738	Zinc - Dissolved	ICP-MS following APHA 21st edition method 3125 (modified). LAS official test 5.33	<0.002 g/m³
18	P1855	Aqueous Total Metal Digestion	Follows APHA 21st Edition Method 3030E (modified) using nitric acid.	
19	P1859	Sample Filtration	Sample filtered through 0.45 micron filter following APHA 21st Edition Method 3030B.	

'<' means that no analyte was found in the sample at the level of detection shown. Detection limits are based on a clean matrix and may vary according to individual sample.

g/m^3 is the equivalent to mg/L and ppm

Appendix 4: Summary statistics for each water quality parameters for 33 of the 34 state of the environment water quality monitoring sites. Black Birch is monitored quarterly and for a limited number of parameters and is not included in this analysis.

Descriptive Statistics Nitrate (mg/L) 2007-2009										
	Valid Number	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	10%ile	90%ile	Standard Deviation.
ARE-3	7	0.790000	0.940000	0.290000	1.040000	0.570000	1.010000	0.290000	1.040000	0.275923
AWR -1	34	0.067059	0.015000	0.010000	0.880000	0.010000	0.060000	0.010000	0.170000	0.155008
AWR-3	35	0.025429	0.010000	0.010000	0.120000	0.010000	0.040000	0.010000	0.060000	0.025245
BNR-1	5	0.010000	0.010000	0.010000	0.010000	0.010000	0.010000	0.010000	0.010000	0.000000
CUL-3	6	0.335000	0.350000	0.240000	0.410000	0.270000	0.390000	0.240000	0.410000	0.071484
DNC-002	19	0.479474	0.490000	0.250000	0.800000	0.350000	0.570000	0.290000	0.770000	0.154362
DRC-1	6	1.903333	1.890000	1.640000	2.100000	1.820000	2.080000	1.640000	2.100000	0.171659
FLX-1	35	0.067143	0.010000	0.010000	0.870000	0.010000	0.020000	0.010000	0.110000	0.176061
GRR-001	29	0.028966	0.030000	0.010000	0.070000	0.010000	0.040000	0.010000	0.060000	0.017797
KNR-1	34	0.152353	0.150000	0.010000	0.370000	0.070000	0.220000	0.020000	0.270000	0.096517
KTR-005	34	1.012647	0.940000	0.380000	2.360000	0.740000	1.170000	0.560000	1.520000	0.421522
MST-21	14	2.295714	2.210000	1.780000	3.150000	1.980000	2.460000	1.900000	2.800000	0.397099
MUR-1	6	1.298333	1.295000	1.100000	1.510000	1.200000	1.390000	1.100000	1.510000	0.143863
OMR-1	34	0.290000	0.250000	0.020000	1.080000	0.110000	0.390000	0.040000	0.560000	0.244763
ONR-1	36	0.205972	0.205000	0.005000	0.420000	0.160000	0.235000	0.130000	0.320000	0.081142
OPO-1	22	0.435909	0.435000	0.290000	0.560000	0.380000	0.490000	0.330000	0.540000	0.077131
OPR-1	35	1.229714	1.070000	0.380000	3.190000	0.830000	1.240000	0.780000	2.500000	0.623442
OPR-3	36	0.461806	0.245000	0.005000	3.610000	0.055000	0.575000	0.010000	0.880000	0.716860
PLR-4	29	0.281379	0.270000	0.140000	0.430000	0.210000	0.350000	0.170000	0.390000	0.081228
PLR-5	34	0.031176	0.030000	0.010000	0.080000	0.010000	0.050000	0.010000	0.060000	0.019658
RAR-1	48	0.712500	0.695000	0.480000	1.060000	0.595000	0.820000	0.500000	0.950000	0.158645
RON-4	24	0.822083	0.865000	0.580000	1.060000	0.720000	0.920000	0.630000	0.970000	0.131842
SPC-1	35	0.321429	0.260000	0.130000	0.960000	0.200000	0.410000	0.180000	0.530000	0.189056
TMR-1	35	0.376000	0.380000	0.010000	1.030000	0.070000	0.660000	0.020000	0.780000	0.300325
TYR-1	34	1.747941	1.525000	0.910000	3.740000	1.340000	1.900000	1.100000	3.160000	0.718967
WaiM	27	0.132593	0.110000	0.010000	0.380000	0.030000	0.230000	0.010000	0.280000	0.106828
WDV-1	29	0.243103	0.160000	0.020000	1.050000	0.090000	0.250000	0.050000	0.770000	0.249157
WHR-1	35	0.158000	0.090000	0.010000	0.990000	0.040000	0.230000	0.010000	0.400000	0.193418
WHR-5	27	0.031481	0.010000	0.010000	0.220000	0.010000	0.040000	0.010000	0.080000	0.045801
WKR-1	36	0.094028	0.020000	0.005000	1.980000	0.010000	0.040000	0.010000	0.060000	0.337154
WRR-2	36	0.140944	0.137000	0.012000	0.365000	0.076000	0.192000	0.035000	0.283000	0.084705
WRR-6	36	0.016722	0.012000	0.002000	0.048000	0.006000	0.026000	0.003000	0.038000	0.013253
WTS-009	30	0.033000	0.030000	0.010000	0.240000	0.010000	0.040000	0.010000	0.050000	0.041202

Descriptive Statistics DRP (mg/L) 2007-2009										
	Valid Number	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	10%ile	90%ile	Standard Deviation.
ARE-3	6	0.015000	0.014500	0.006000	0.026000	0.011000	0.018000	0.006000	0.026000	0.006928
AWR -1	33	0.013879	0.009000	0.005000	0.067000	0.006000	0.015000	0.006000	0.026000	0.013364
AWR-3	34	0.015765	0.013000	0.005000	0.081000	0.010000	0.015000	0.009000	0.021000	0.013276
BNR-1	5	0.008200	0.008000	0.007000	0.010000	0.007000	0.009000	0.007000	0.010000	0.001304
CUL-3	6	0.019167	0.019000	0.017000	0.021000	0.019000	0.020000	0.017000	0.021000	0.001329
DNC-002	19	0.020105	0.016000	0.013000	0.055000	0.013000	0.020000	0.013000	0.039000	0.011274
DRC-1	6	0.026667	0.026000	0.020000	0.035000	0.020000	0.033000	0.020000	0.035000	0.007062
FLX-1	35	0.009686	0.009000	0.005000	0.028000	0.006000	0.011000	0.005000	0.014000	0.004807
GRR-001	29	0.014586	0.013000	0.006000	0.048000	0.011000	0.016000	0.008000	0.019000	0.007514
KNR-1	34	0.010441	0.009000	0.005000	0.033000	0.007000	0.012000	0.005000	0.015000	0.005642
KTR-005	34	0.011500	0.012000	0.005000	0.020000	0.010000	0.014000	0.008000	0.015000	0.003250
MST-21	14	0.016857	0.017000	0.014000	0.020000	0.015000	0.019000	0.015000	0.020000	0.002070
MUR-1	6	0.013500	0.014000	0.010000	0.016000	0.012000	0.015000	0.010000	0.016000	0.002168
OMR-1	33	0.007758	0.007000	0.005000	0.019000	0.005000	0.009000	0.005000	0.012000	0.003410
ONR-1	35	0.009171	0.009000	0.005000	0.014000	0.007000	0.011000	0.006000	0.013000	0.002738
OPO-1	22	0.013545	0.014000	0.010000	0.017000	0.012000	0.015000	0.012000	0.015000	0.001765
OPR-1	35	0.015657	0.014000	0.005000	0.032000	0.012000	0.018000	0.010000	0.024000	0.005667
OPR-3	35	0.008743	0.006000	0.005000	0.038000	0.005000	0.010000	0.005000	0.014000	0.006532

PLR-4	29	0.009966	0.010000	0.005000	0.016000	0.007000	0.012000	0.005000	0.014000	0.003213
PLR-5	34	0.010235	0.010000	0.005000	0.017000	0.009000	0.012000	0.006000	0.014000	0.002818
RAR-1	48	0.014042	0.013000	0.005000	0.080000	0.009500	0.014000	0.007000	0.017000	0.011066
RON-4	22	0.015364	0.014000	0.009000	0.043000	0.012000	0.016000	0.010000	0.018000	0.006911
SPC-1	35	0.013200	0.013000	0.009000	0.018000	0.012000	0.015000	0.011000	0.016000	0.002180
TMR-1	35	0.014086	0.013000	0.006000	0.025000	0.011000	0.017000	0.008000	0.021000	0.004598
TYR-1	35	0.019571	0.017000	0.009000	0.064000	0.015000	0.021000	0.013000	0.028000	0.009605
WaiM	27	0.007296	0.006000	0.005000	0.023000	0.005000	0.008000	0.005000	0.011000	0.003911
WDV-1	29	0.017621	0.012000	0.005000	0.162000	0.010000	0.016000	0.007000	0.018000	0.028063
WHR-1	35	0.013029	0.008000	0.005000	0.154000	0.006000	0.012000	0.005000	0.015000	0.024765
WHR-5	27	0.011778	0.012000	0.005000	0.020000	0.009000	0.014000	0.007000	0.019000	0.003816
WKR-1	35	0.011371	0.012000	0.006000	0.019000	0.010000	0.013000	0.008000	0.014000	0.002486
WRR-2	36	0.003958	0.003000	0.000500	0.010000	0.002000	0.005000	0.002000	0.007000	0.002218
WRR-6	36	0.003361	0.003000	0.002000	0.006000	0.003000	0.004000	0.002000	0.004000	0.000961
WTS-009	30	0.014833	0.015000	0.007000	0.029000	0.013000	0.016000	0.010500	0.018000	0.004103

Descriptive Statistics Ammonia (mg/L) 2007-2009										
	Valid Number	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	10%ile	90%ile	Standard Deviation.
ARE-3	7	0.011000	0.010000	0.005000	0.020000	0.005000	0.020000	0.005000	0.020000	0.006733
AWR -1	34	0.008088	0.005000	0.005000	0.040000	0.005000	0.005000	0.005000	0.020000	0.007883
AWR-3	35	0.030857	0.005000	0.005000	0.720000	0.005000	0.005000	0.005000	0.005000	0.123916
BNR-1	5	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.000000
CUL-3	6	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.000000
DNC-002	19	0.018684	0.010000	0.005000	0.120000	0.005000	0.020000	0.005000	0.030000	0.025595
DRC-1	6	0.010000	0.005000	0.005000	0.020000	0.005000	0.020000	0.005000	0.020000	0.007746
FLX-1	35	0.006429	0.005000	0.005000	0.020000	0.005000	0.005000	0.005000	0.010000	0.004300
GRR-001	29	0.006379	0.005000	0.005000	0.040000	0.005000	0.005000	0.005000	0.005000	0.006532
KNR-1	34	0.008529	0.005000	0.005000	0.060000	0.005000	0.005000	0.005000	0.020000	0.010627
KTR-005	34	0.007794	0.005000	0.005000	0.020000	0.005000	0.010000	0.005000	0.020000	0.004953
MST-21	14	0.005357	0.005000	0.005000	0.010000	0.005000	0.005000	0.005000	0.005000	0.001336
MUR-1	6	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.000000
OMR-1	34	0.005147	0.005000	0.005000	0.010000	0.005000	0.005000	0.005000	0.005000	0.000857
ONR-1	35	0.005286	0.005000	0.005000	0.010000	0.005000	0.005000	0.005000	0.005000	0.001178
OPO-1	22	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.000000
OPR-1	35	0.011571	0.010000	0.005000	0.040000	0.005000	0.020000	0.005000	0.020000	0.008726
OPR-3	35	0.010857	0.005000	0.005000	0.170000	0.005000	0.010000	0.005000	0.010000	0.027772
PLR-4	29	0.007069	0.005000	0.005000	0.050000	0.005000	0.005000	0.005000	0.010000	0.008400
PLR-5	34	0.006765	0.005000	0.005000	0.050000	0.005000	0.005000	0.005000	0.005000	0.008061
RAR-1	48	0.010729	0.005000	0.005000	0.240000	0.005000	0.005000	0.005000	0.010000	0.033896
RON-4	22	0.009318	0.005000	0.005000	0.080000	0.005000	0.005000	0.005000	0.010000	0.016132
SPC-1	35	0.005714	0.005000	0.005000	0.020000	0.005000	0.005000	0.005000	0.005000	0.002750
TMR-1	35	0.010429	0.005000	0.005000	0.070000	0.005000	0.010000	0.005000	0.020000	0.011781
TYR-1	35	0.014714	0.010000	0.005000	0.110000	0.005000	0.010000	0.005000	0.030000	0.022194
WaiM	27	0.005556	0.005000	0.005000	0.020000	0.005000	0.005000	0.005000	0.005000	0.002887
WDV-1	29	0.009310	0.005000	0.005000	0.030000	0.005000	0.010000	0.005000	0.020000	0.006908
WHR-1	35	0.021571	0.005000	0.005000	0.560000	0.005000	0.005000	0.005000	0.010000	0.093728
WHR-5	27	0.006296	0.005000	0.005000	0.040000	0.005000	0.005000	0.005000	0.005000	0.006736
WKR-1	35	0.005571	0.005000	0.005000	0.020000	0.005000	0.005000	0.005000	0.005000	0.002649
WRR-2	36	0.002889	0.003000	0.000500	0.010000	0.001000	0.004000	0.001000	0.006000	0.001979
WRR-6	36	0.001958	0.001000	0.000500	0.009000	0.001000	0.002000	0.001000	0.004000	0.001786
WTS-009	30	0.006167	0.005000	0.005000	0.030000	0.005000	0.005000	0.005000	0.007500	0.004676

Descriptive Statistics *E. coli* (number/100mL) 2007-2009										
	Valid Number	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	10%ile	90%ile	Standard Deviation.
ARE-3	6	532.5000	110.5000	20.00000	1600.000	54.0000	1300.000	20.00000	1600.000	718.512
AWR -1	34	50.5000	25.0000	1.00000	390.000	5.0000	69.000	3.00000	120.000	75.017
AWR-3	35	18.8857	8.0000	1.00000	140.000	4.0000	24.000	1.00000	50.000	28.940
BNR-1	5	3.2000	1.0000	1.00000	8.000	1.0000	5.000	1.00000	8.000	3.194
CUL-3	6	160.0000	150.0000	80.00000	300.000	100.0000	180.000	80.00000	300.000	77.974
DNC-002	19	472.3684	160.0000	6.00000	3900.000	140.0000	380.000	34.00000	1800.000	916.740
DRC-1	6	111.8333	88.0000	52.00000	230.000	53.0000	160.000	52.00000	230.000	69.970

FLX-1	35	62.8000	42.0000	1.00000	300.000	20.0000	79.000	10.00000	170.000	64.938
GRR-001	29	257.6897	51.0000	1.00000	2600.000	21.0000	110.000	7.00000	1000.000	623.698
KNR-1	33	333.2121	120.0000	1.00000	3500.000	94.0000	220.000	50.00000	400.000	706.368
KTR-005	34	359.0294	100.0000	10.00000	7000.000	49.0000	200.000	25.00000	500.000	1186.946
MST-21	14	208.0714	130.0000	20.00000	800.000	85.0000	260.000	32.00000	500.000	211.390
MUR-1	7	59.8571	25.0000	10.00000	254.000	12.0000	68.000	10.00000	254.000	87.747
OMR-1	33	12.9394	7.0000	1.00000	81.000	3.0000	14.000	1.00000	31.000	17.128
ONR-1	35	66.6857	39.0000	2.00000	300.000	24.0000	87.000	8.00000	170.000	66.019
OPO-1	22	62.7727	55.5000	13.00000	140.000	32.0000	86.000	28.00000	110.000	33.580
OPR-1	34	32.2059	17.5000	1.00000	180.000	10.0000	43.000	6.00000	57.000	39.991
OPR-3	34	54.1765	42.0000	1.00000	200.000	18.0000	71.000	5.00000	110.000	47.420
PLR-4	29	59.7586	24.0000	1.00000	400.000	14.0000	41.000	8.00000	160.000	100.771
PLR-5	32	29.8125	14.0000	1.00000	200.000	8.0000	26.500	5.00000	53.000	46.933
RAR-1	114	337.1491	64.0000	1.00000	8900.000	37.0000	207.000	20.00000	624.000	989.267
RON-4	22	418.0000	50.0000	1.00000	5300.000	32.0000	190.000	24.00000	250.000	1166.168
SPC-1	35	50.1429	43.0000	1.00000	190.000	30.0000	60.000	18.00000	80.000	36.604
TMR-1	35	66.7429	41.0000	3.00000	900.000	18.0000	57.000	8.00000	70.000	147.963
TYR-1	34	468.2941	51.5000	6.00000	9400.000	23.0000	78.000	14.00000	210.000	1753.025
WaiM	27	64.0741	23.0000	1.00000	500.000	12.0000	42.000	2.00000	240.000	120.586
WDV-1	94	118.5213	44.0000	1.00000	1100.000	20.0000	99.000	6.00000	324.000	205.066
WHR-1	36	76.6667	10.0000	1.00000	740.000	4.0000	52.000	2.00000	180.000	170.191
WHR-5	27	63.7778	20.0000	1.00000	831.000	6.0000	57.000	2.00000	140.000	158.928
WKR-1	34	46.1176	22.5000	2.00000	500.000	12.0000	40.000	8.00000	60.000	88.595
WRR-2	65	38.9262	9.0000	1.00000	1203.300	3.0000	22.000	1.00000	40.000	154.871
WRR-6	35	4.7571	2.0000	1.00000	21.100	1.0000	7.400	1.00000	10.900	5.368
WTS-009	30	163.6667	81.5000	13.00000	1500.000	38.0000	150.000	26.00000	200.000	298.657

Descriptive Statistics Turbidity (NTU) 2007-2009										
	Valid Number	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	10%ile	90%ile	Standard Deviation.
ARE-3	6	3.8100	1.60000	1.130000	8.870	1.280000	8.38000	1.130000	8.8700	3.7395
AWR -1	47	154.1557	17.10000	1.020000	2600.000	3.830000	90.60000	1.610000	344.0000	421.5832
AWR-3	49	117.8259	17.20000	0.530000	1320.000	5.620000	48.10000	1.090000	493.0000	271.9298
BNR-1	5	1.7420	1.10000	0.780000	4.190	1.060000	1.58000	0.780000	4.1900	1.3984
CUL-3	6	1.6383	1.28500	0.810000	3.050	1.240000	2.16000	0.810000	3.0500	0.8197
DNC-002	20	9.8090	5.29500	1.410000	49.300	3.325000	11.90000	1.710000	25.0500	11.8203
DRC-1	6	5.3200	4.53000	1.960000	9.830	3.710000	7.36000	1.960000	9.8300	2.8231
FLX-1	40	2.9265	0.77000	0.230000	52.300	0.505000	1.40500	0.290000	4.3750	8.4435
GRR-001	32	2.1147	0.42500	0.050000	35.900	0.300000	1.37500	0.230000	2.3000	6.3439
KNR-1	38	1.0371	0.72000	0.270000	4.500	0.420000	1.51000	0.310000	2.1700	0.9197
KTR-005	41	5.6410	0.59000	0.270000	51.300	0.390000	3.10000	0.310000	21.6000	11.4160
MST-21	15	2.4893	2.36000	0.840000	5.180	1.550000	2.90000	1.370000	4.9300	1.2172
MUR-1	6	0.8250	0.75500	0.200000	1.660	0.300000	1.28000	0.200000	1.6600	0.5669
OMR-1	37	1.6092	0.42000	0.160000	24.000	0.290000	1.26000	0.200000	3.1600	4.0047
ONR-1	38	1.2774	0.50500	0.200000	13.500	0.330000	0.96000	0.260000	2.4500	2.3447
OPO-1	22	0.7836	0.50500	0.320000	3.290	0.450000	0.68000	0.390000	1.2100	0.7157
OPR-1	45	3.5544	1.80000	0.500000	23.400	1.040000	3.66000	0.700000	9.0100	4.5961
OPR-3	46	9.6204	4.06500	1.030000	86.500	2.310000	8.70000	1.650000	22.3000	15.8010
PLR-4	34	4.8209	0.67000	0.300000	47.400	0.400000	1.79000	0.340000	17.9000	10.0492
PLR-5	40	2.8817	0.41000	0.150000	50.400	0.240000	1.04500	0.200000	7.4450	8.4438
RAR-1	57	3.2247	1.02000	0.360000	38.400	0.590000	2.22000	0.510000	7.9300	6.6363
RON-4	22	1.8068	0.67500	0.160000	17.800	0.380000	1.82000	0.290000	2.7100	3.6790
SPC-1	37	0.9465	0.56000	0.290000	10.300	0.420000	0.75000	0.360000	1.5000	1.6325
TMR-1	40	5.0678	2.16500	0.790000	48.200	1.605000	3.26000	1.300000	10.4000	9.2711
TYR-1	43	3.9730	1.60000	0.450000	32.100	0.870000	3.57000	0.630000	7.6000	6.5087
WaiM	31	18.9632	0.42000	0.110000	224.000	0.210000	1.46000	0.150000	47.5000	54.9335
WDV-1	36	14.6222	3.36500	0.800000	92.800	1.555000	18.20000	1.020000	60.7000	23.4995
WHR-1	41	21.6485	1.87000	0.230000	260.000	0.830000	8.02000	0.680000	47.6000	57.0139
WHR-5	32	11.3316	1.99000	0.270000	91.300	0.945000	7.52500	0.670000	41.3000	21.7942
WKR-1	38	0.6476	0.29500	0.130000	4.370	0.220000	0.89000	0.170000	1.5000	0.7928
WRR-2	36	9.8094	1.55000	0.400000	174.000	0.780000	4.07500	0.610000	12.5000	30.1825
WRR-6	36	3.4433	0.76500	0.350000	62.000	0.550000	2.22500	0.380000	7.1000	10.2658
WTS-009	32	1.5116	1.06500	0.170000	6.510	0.750000	2.10000	0.610000	3.0000	1.2773

Descriptive Statistics Suspended Solids (mg/L) 2007-2009										
	Valid Number	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	10%ile	90%ile	Standard Deviation.
ARE-3	6	3.1667	1.00000	1.000000	9.000	1.000000	6.00000	1.000000	9.0000	3.4881
AWR -1	33	132.0909	17.00000	1.000000	2270.000	1.000000	70.00000	1.000000	291.0000	405.2132
AWR-3	34	112.1176	15.50000	1.000000	1630.000	4.000000	29.00000	1.000000	390.0000	306.1793
BNR-1	5	1.0000	1.00000	1.000000	1.000	1.000000	1.00000	1.000000	1.0000	0.0000
CUL-3	6	2.0000	1.00000	1.000000	5.000	1.000000	3.00000	1.000000	5.0000	1.6733
DNC-002	17	10.1765	8.00000	3.000000	32.000	7.000000	11.00000	4.000000	21.0000	7.0466
DRC-1	6	6.0000	5.50000	1.000000	11.000	5.000000	8.00000	1.000000	11.0000	3.3466
FLX-1	35	2.0571	1.00000	1.000000	12.000	1.000000	1.00000	1.000000	4.0000	2.6115
GRR-001	29	6.5172	1.00000	1.000000	141.000	1.000000	1.00000	1.000000	5.0000	25.9197
KNR-1	34	1.3824	1.00000	1.000000	6.000	1.000000	1.00000	1.000000	3.0000	1.1551
KTR-005	33	5.0303	1.00000	1.000000	98.000	1.000000	1.00000	1.000000	5.0000	17.0468
MST-21	14	5.4286	4.50000	1.000000	18.000	3.000000	6.00000	1.000000	12.0000	4.6362
MUR-1	6	1.0000	1.00000	1.000000	1.000	1.000000	1.00000	1.000000	1.0000	0.0000
OMR-1	34	1.5882	1.00000	1.000000	9.000	1.000000	1.00000	1.000000	1.0000	1.9403
ONR-1	34	1.5000	1.00000	1.000000	12.000	1.000000	1.00000	1.000000	1.0000	2.1213
OPO-1	22	1.1364	1.00000	1.000000	4.000	1.000000	1.00000	1.000000	1.0000	0.6396
OPR-1	35	1.5714	1.00000	1.000000	4.000	1.000000	1.00000	1.000000	4.0000	1.0924
OPR-3	34	5.4412	3.00000	1.000000	42.000	1.000000	7.00000	1.000000	11.0000	7.9475
PLR-4	29	1.7931	1.00000	1.000000	12.000	1.000000	1.00000	1.000000	5.0000	2.3812
PLR-5	34	1.8235	1.00000	1.000000	25.000	1.000000	1.00000	1.000000	1.0000	4.1522
RAR-1	48	1.5833	1.00000	1.000000	11.000	1.000000	1.00000	1.000000	4.0000	1.7361
RON-4	22	1.5909	1.00000	1.000000	11.000	1.000000	1.00000	1.000000	1.0000	2.1965
SPC-1	35	1.1429	1.00000	1.000000	6.000	1.000000	1.00000	1.000000	1.0000	0.8452
TMR-1	35	2.1429	1.00000	1.000000	16.000	1.000000	1.00000	1.000000	5.0000	2.8814
TYR-1	35	3.1143	1.00000	1.000000	31.000	1.000000	4.00000	1.000000	6.0000	5.2902
WaiM	27	15.2222	1.00000	1.000000	309.000	1.000000	1.00000	1.000000	8.0000	59.8706
WDV-1	28	13.2857	4.00000	1.000000	144.000	1.000000	7.50000	1.000000	34.0000	32.1649
WHR-1	35	13.6000	1.00000	1.000000	282.000	1.000000	1.00000	1.000000	18.0000	49.5457
WHR-5	27	7.4074	1.00000	1.000000	114.000	1.000000	3.00000	1.000000	16.0000	22.2853
WKR-1	34	1.2647	1.00000	1.000000	10.000	1.000000	1.00000	1.000000	1.0000	1.5435
WRR-2	28	4.5000	1.00000	1.000000	63.000	1.000000	1.00000	1.000000	10.0000	12.2912
WTS-009	30	1.1333	1.00000	1.000000	5.000	1.000000	1.00000	1.000000	1.0000	0.7303

Descriptive Statistics pH 2007-2009										
	Valid Number	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	10%ile	90%ile	Standard Deviation.
ARE-3	12	7.351333	7.350000	6.600000	7.850000	7.055500	7.700000	7.000000	7.800000	0.384876
AWR -1	50	8.361400	8.400000	7.630000	9.200000	8.100000	8.530000	8.000000	8.780000	0.314221
AWR-3	51	8.037647	8.000000	7.280000	9.300000	7.900000	8.200000	7.800000	8.290000	0.309222
BNR-1	5	7.540000	7.500000	7.400000	7.800000	7.400000	7.600000	7.400000	7.800000	0.167332
CUL-3	6	7.083333	7.050000	6.900000	7.400000	7.000000	7.100000	6.900000	7.400000	0.172240
DNC-002	25	6.615200	6.600000	6.100000	7.300000	6.400000	6.800000	6.300000	7.100000	0.310109
DRC-1	6	7.266667	7.250000	7.100000	7.400000	7.200000	7.400000	7.100000	7.400000	0.121106
FLX-1	51	8.017647	8.070000	7.190000	8.800000	7.800000	8.200000	7.500000	8.400000	0.350300
GRR-001	40	7.172350	7.240000	6.100000	8.200000	6.925000	7.400000	6.750000	7.500000	0.368397
KNR-1	47	7.119957	7.090000	6.080000	8.500000	6.800000	7.400000	6.400000	7.800000	0.492315
KTR-005	52	6.885962	6.900000	5.980000	8.000000	6.750000	7.035000	6.500000	7.200000	0.329850
MST-21	17	7.087647	7.100000	6.700000	7.400000	7.000000	7.280000	6.800000	7.400000	0.220554
MUR-1	6	6.766667	6.700000	6.600000	7.200000	6.700000	6.700000	6.600000	7.200000	0.216025
OMR-1	50	7.348980	7.400000	6.370000	8.000000	7.080000	7.639000	6.770000	7.900000	0.402590
ONR-1	51	7.120980	7.100000	6.600000	7.900000	6.900000	7.330000	6.700000	7.600000	0.325031
OPO-1	26	6.856846	6.935000	6.300000	7.300000	6.600000	7.088000	6.400000	7.200000	0.278067
OPR-1	49	7.421224	7.320000	6.490000	8.570000	7.200000	7.500000	7.000000	8.200000	0.437096
OPR-3	49	8.271224	8.400000	7.100000	9.600000	7.700000	8.700000	7.400000	9.280000	0.647854
PLR-4	44	7.356591	7.400000	6.220000	8.700000	7.100000	7.500000	6.900000	7.700000	0.437003
PLR-5	53	7.531283	7.600000	6.470000	8.900000	7.300000	7.800000	7.000000	7.820000	0.439067
RAR-1	91	6.980088	7.000000	5.520000	8.200000	6.720000	7.244000	6.580000	7.400000	0.403840
RON-4	26	6.544846	6.600000	5.800000	7.200000	6.300000	6.800000	6.100000	6.900000	0.321085

SPC-1	50	7.042000	7.000000	6.350000	7.800000	6.860000	7.200000	6.700000	7.400000	0.281432
TMR-1	50	6.963500	6.900000	5.740000	8.000000	6.700000	7.200000	6.595000	7.470000	0.395480
TYR-1	49	7.000612	7.000000	6.270000	8.100000	6.800000	7.100000	6.640000	7.400000	0.314135
WaiM	38	8.043421	8.000000	7.600000	8.600000	7.900000	8.200000	7.730000	8.340000	0.248120
WDV-1	60	7.248500	7.310000	5.770000	7.900000	7.000000	7.505000	6.735000	7.640000	0.376522
WHR-1	49	7.469592	7.500000	6.790000	9.100000	7.210000	7.600000	6.950000	7.900000	0.378225
WHR-5	37	7.742297	7.790000	6.860000	9.100000	7.500000	7.900000	7.200000	8.100000	0.432009
WKR-1	53	7.186604	7.220000	5.950000	8.200000	7.000000	7.400000	6.800000	7.570000	0.405818
WRR-2	36	7.751667	7.715000	7.320000	8.570000	7.535000	7.875000	7.390000	8.240000	0.308818
WRR-6	36	7.670278	7.665000	7.330000	7.900000	7.585000	7.745000	7.520000	7.840000	0.125913
WTS-009	42	7.996429	7.900000	6.900000	9.400000	7.500000	8.450000	7.380000	8.630000	0.577770

Descriptive Statistics Conductivity (µS/cm @ 25^{o}C) 2007-2009										
	Valid Number	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	10%ile	90%ile	Standard Deviation.
ARE-3	8	91.5625	91.1500	68.1000	111.400	87.2500	98.1000	68.1000	111.4000	12.4229
AWR-1	34	149.3441	149.8500	118.0000	183.300	140.0000	160.4000	126.8000	166.4000	16.2422
AWR-3	35	113.9457	118.5000	79.2000	139.600	103.9000	124.7000	92.4000	134.5000	15.7997
BNR-1	8	54.1000	44.4500	41.4000	111.300	43.1000	52.5000	41.4000	111.3000	23.6907
CUL-3	8	68.9875	69.3000	64.0000	74.000	66.7500	70.9000	64.0000	74.0000	3.2428
DNC-002	20	73.1300	73.5500	67.2000	80.900	70.3000	75.5000	68.5000	77.1500	3.5379
DRC-1	7	199.1571	190.7000	180.9000	229.000	184.6000	228.0000	180.9000	229.0000	20.4032
FLX-1	37	433.3514	427.0000	241.0000	638.000	390.0000	484.0000	336.0000	545.0000	84.6067
GRR-1	31	93.6032	91.9000	70.4000	142.000	89.6000	97.8000	86.5000	99.2000	10.9219
KNR-1	36	57.8722	54.6500	48.8000	87.600	51.0500	61.6500	49.2000	74.1000	9.6857
KTR-005	37	66.8676	67.4000	48.4000	86.400	58.8000	73.7000	54.6000	77.6000	9.6479
MST-21	16	149.7813	150.5000	133.0000	165.800	143.8500	155.8000	138.5000	163.7000	8.9321
MUR-1	7	142.3429	132.4000	119.3000	228.000	123.2000	134.7000	119.3000	228.0000	38.2147
OMR-1	34	130.1882	129.7000	104.4000	170.200	118.4000	139.5000	106.1000	148.2000	16.4328
ONR-1	37	60.3514	60.5000	40.8000	72.400	56.6000	66.3000	50.5000	70.5000	7.4741
OPO-1	23	54.0957	53.5000	48.4000	59.600	52.4000	56.2000	49.9000	57.3000	2.8809
OPR-1	36	263.6361	151.6500	75.3000	1953.000	124.9500	187.3000	120.1000	322.0000	405.4783
OPR-3	37	84.3622	74.9000	57.4000	182.800	69.7000	84.8000	62.9000	122.6000	29.3844
PLR-4	31	65.5839	67.3000	46.1000	85.400	55.7000	73.8000	52.1000	77.9000	10.5030
PLR-5	37	66.4351	67.7000	41.7000	87.300	55.4000	74.5000	47.6000	81.0000	12.1133
RAR-1	43	72.8465	72.6000	58.9000	88.100	68.8000	77.7000	63.4000	80.7000	6.3944
RON-4	23	86.8870	84.8000	76.9000	136.300	81.2000	89.6000	77.6000	91.7000	11.6866
SPC-1	37	72.9973	70.4000	63.4000	113.100	67.6000	72.5000	65.6000	86.9000	10.2572
TMR-1	37	116.4162	118.8000	75.1000	136.000	111.1000	125.6000	102.0000	131.3000	13.1284
TYR-1	36	143.6750	140.5000	78.2000	192.600	132.8500	153.8000	122.8000	180.5000	21.5589
WaiM	29	357.2069	367.0000	311.0000	394.000	332.0000	377.0000	321.0000	385.0000	24.6669
WDV-1	31	135.4839	90.7000	51.0000	1001.000	75.9000	118.1000	64.7000	163.2000	175.0023
WHR-1	38	70.6395	71.8500	54.9000	82.700	65.0000	75.3000	61.9000	78.8000	6.6420
WHR-5	27	68.6407	70.3000	53.4000	80.600	64.5000	73.6000	56.9000	76.8000	7.4633
WKR-1	37	45.9027	46.6000	34.1000	60.100	39.6000	50.8000	36.4000	54.3000	6.6534
WRR-2	257	58.6778	59.0000	32.0000	81.800	54.8000	63.0000	50.5000	67.0000	7.0587
WRR-6	257	44.3669	44.8000	21.7000	56.400	42.4000	47.3000	38.6000	49.1000	4.6341
WTS-009	31	104.2710	105.1000	73.3000	134.900	91.8000	116.7000	84.7000	122.9000	15.7699

Descriptive Statistics Temperature (^{o}C) 1996-2009										
	Valid Number	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	10%ile	90%ile	Standard Deviation.
ARE-3	12	12.15833	11.95000	7.40000	17.50000	10.85000	14.05000	7.70000	15.00000	2.876380
AWR -1	64	12.32828	12.23500	3.90000	24.10000	7.60000	16.52000	5.70000	19.40000	5.282959
AWR-3	60	9.21333	9.55000	0.40000	19.80000	4.50000	13.95000	2.10000	16.35000	5.340150
BNR-1	8	5.70000	5.10000	3.10000	10.60000	4.25000	6.60000	3.10000	10.60000	2.343380
CUL-3	4	10.85000	10.45000	9.20000	13.30000	9.80000	11.90000	9.20000	13.30000	1.736855
DNC-002	17	12.46471	12.10000	8.50000	17.20000	10.80000	14.30000	8.60000	17.00000	2.846476
DRC-1	47	13.65979	13.40000	10.40000	20.00000	12.10000	15.00000	10.90000	16.42000	2.004505
FLX-1	35	13.45057	13.70000	4.80000	23.70000	9.40000	16.60000	7.30000	21.10000	4.948863
GRR-001	28	13.98571	13.90000	6.90000	21.30000	11.70000	16.50000	9.50000	18.70000	3.336189
KNR-1	29	11.64828	11.20000	8.10000	16.30000	9.80000	13.30000	8.90000	14.80000	2.243979

KTR-005	38	12.40158	12.20000	6.80000	20.60000	10.80000	14.10000	8.10000	16.70000	3.189272
MST-21	12	13.42500	13.40000	10.70000	17.50000	12.00000	14.55000	11.50000	15.40000	1.913172
MUR-1	13	13.67769	13.70000	13.00000	14.35000	13.40000	14.05000	13.00000	14.33000	0.484031
OMR-1	55	12.35600	12.00000	4.00000	22.00000	8.50000	15.50000	7.00000	18.20000	4.346078
ONR-1	42	11.29571	11.05000	6.30000	17.60000	9.10000	12.60000	7.60000	16.10000	3.053029
OPO-1	22	12.37591	12.10000	8.80000	15.40000	10.87000	14.00000	10.50000	14.50000	1.796135
OPR-1	65	14.03646	13.60000	8.50000	21.50000	12.10000	15.90000	10.00000	18.70000	3.066958
OPR-3	49	11.71286	11.40000	2.70000	22.20000	8.10000	14.80000	5.50000	19.60000	5.013065
PLR-4	33	12.88970	12.10000	5.40000	22.90000	9.70000	16.40000	7.20000	19.80000	4.717438
PLR-5	36	11.02639	10.90000	3.20000	20.90000	7.65000	14.48000	5.70000	17.30000	4.360303
RAR-1	255	14.45522	14.80000	7.00000	22.20000	12.80000	16.60000	10.30000	17.80000	2.794867
RON-4	22	13.25455	13.65000	10.10000	15.40000	11.90000	14.80000	10.50000	15.20000	1.870250
SPC-1	53	13.13208	13.10000	10.00000	15.40000	12.30000	14.00000	12.00000	14.50000	1.058259
TMR-1	44	12.46205	11.90000	6.30000	21.20000	9.10000	15.50000	7.50000	18.20000	4.010589
TYR-1	62	14.12903	14.20000	10.30000	17.80000	12.90000	15.20000	11.80000	16.07000	1.718389
WaiM	27	12.99037	13.30000	8.30000	16.70000	11.50000	14.40000	10.20000	15.80000	2.234481
WDV-1	227	16.61960	17.30000	5.00000	22.40000	15.10000	18.80000	12.70000	19.80000	3.130916
WHR-1	52	12.90192	13.13000	4.90000	25.90000	7.70000	16.45000	6.00000	20.60000	5.526086
WHR-5	24	11.72083	11.45000	3.30000	23.00000	6.80000	16.05000	3.70000	19.80000	5.867003
WKR-1	35	10.67429	10.94000	4.10000	23.10000	7.40000	13.10000	6.30000	15.60000	4.088585
WRR-2	429	14.23263	14.20000	5.00000	23.90000	10.50000	17.70000	8.30000	20.20000	4.439932
WRR-6	386	7.09378	7.10000	0.40000	13.30000	4.90000	9.10000	3.60000	11.00000	2.785605
WTS-009	29	12.65172	12.70000	5.90000	21.20000	9.30000	14.50000	6.70000	19.00000	4.290406

Descriptive Statistics Dissolved Oxygen (% sat) 2007-2009										
	Valid Number	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	10%ile	90%ile	Standard Deviation.
ARE-3	7	101.1000	101.3000	84.50000	121.4000	88.9000	106.9000	84.50000	121.4000	12.22770
AWR -1	37	100.0297	100.1000	37.90000	133.0000	98.0000	103.9000	92.20000	108.8000	13.77030
AWR-3	31	94.7097	96.4000	37.00000	108.8000	93.2000	100.1000	90.10000	101.4000	11.90704
BNR-1	3	105.2667	102.7000	92.10000	121.0000	92.1000	121.0000	92.10000	121.0000	14.61996
CUL-3	4	97.4750	93.8500	93.50000	108.7000	93.5000	101.4500	93.50000	108.7000	7.49061
DNC-002	16	86.5375	87.8500	56.80000	98.9000	84.6000	90.5000	82.30000	94.2000	9.06869
DRC-1	22	100.1682	97.4000	70.10000	155.3000	83.6000	113.9000	76.60000	123.8000	21.43418
FLX-1	31	110.7065	106.3000	74.20000	166.0000	97.9000	121.7000	95.10000	131.8000	18.12071
GRR-001	26	98.6923	97.8500	77.20000	139.7000	94.6000	101.0000	89.50000	107.4000	11.29400
KNR-1	26	91.9692	97.4000	39.90000	119.0000	91.2000	101.2000	61.20000	104.1000	17.67355
KTR-005	32	96.5875	93.5500	79.10000	142.2000	90.2000	96.8500	87.80000	102.7000	12.98445
MST-21	11	98.3000	97.2000	90.30000	108.7000	94.2000	106.1000	90.70000	107.9000	6.57510
MUR-1	9	88.5667	75.0000	72.90000	128.5000	73.7000	103.4000	72.90000	128.5000	20.79435
OMR-1	39	94.3154	93.6000	52.80000	125.8000	92.4000	100.8000	75.50000	113.9000	14.08845
ONR-1	35	95.2571	93.6000	56.80000	128.8000	91.3000	96.2000	87.10000	106.1000	12.22587
OPO-1	22	92.9318	92.6000	69.50000	113.5000	90.6000	95.5000	89.40000	97.8000	7.36332
OPR-1	41	97.4515	102.8000	32.50000	137.4000	83.8000	113.2000	65.10000	127.1000	24.14449
OPR-3	38	102.9842	103.5000	65.00000	124.1000	98.4000	115.9000	84.20000	117.8000	13.86172
PLR-4	31	100.1774	97.5000	87.60000	133.4000	93.8000	102.3000	92.10000	106.7000	10.06895
PLR-5	30	99.4133	96.3500	91.10000	130.0000	94.3000	99.8000	91.75000	114.4000	9.54838
RAR-1	153	97.9281	97.6000	76.80000	120.4000	94.2000	101.3000	90.90000	105.3000	6.78565
RON-4	22	82.5727	83.2500	74.50000	90.4000	79.0000	86.8000	75.80000	88.6000	4.81369
SPC-1	41	83.5876	84.7000	8.79000	115.0000	76.2000	93.3000	66.90000	98.5000	17.37626
TMR-1	31	72.5419	69.2000	39.60000	123.8000	60.0000	86.5000	48.30000	96.4000	20.34920
TYR-1	41	104.4588	101.8000	56.70000	142.7000	93.7000	116.3000	79.90000	132.0000	19.29215
WaiM	25	94.1480	91.7000	78.00000	148.8000	86.0000	95.0000	81.10000	116.4000	15.09782
WDV-1	133	90.6277	90.9000	58.00000	127.4000	84.9000	95.7000	78.20000	103.0000	10.65832
WHR-1	33	100.0485	97.4000	85.70000	150.0000	95.1000	99.6000	92.10000	107.0000	11.74803
WHR-5	24	98.3958	98.6000	85.70000	105.5000	97.1500	99.9000	95.50000	104.1000	4.07393
WKR-1	29	97.7552	96.6000	85.60000	136.1000	93.7000	99.2000	91.60000	103.9000	8.93303
WRR-2	415	103.6961	102.9000	75.60000	124.9000	100.3000	106.6000	98.40000	110.8000	5.41677
WRR-6	369	100.5488	100.8000	80.00000	107.0000	100.0000	101.4000	99.00000	102.0000	1.99817
WTS-009	29	107.1069	107.4000	86.70000	134.1000	102.3000	111.6000	96.70000	120.4000	9.49056

Appendix 5: Calculation of the water quality index scores and assessment of water quality grades.

SITE ID	AMMONIA Input Value	Score Concentrations 2	3	4	5	Score	Weight	Weighted Score
ARE-3	0.02	0.005	0.01	0.021	0.9	3	1.5	4.5
AWR-1	0.02	0.005	0.01	0.021	0.9	3	1.5	4.5
AWR-3	0.005	0.005	0.01	0.021	0.9	2	1.5	3
BNR-1	0.005	0.005	0.01	0.021	0.9	2	1.5	3
CUL-3	0.005	0.005	0.01	0.021	0.9	2	1.5	3
DNC-002	0.03	0.005	0.01	0.021	0.9	4	1.5	6
DRC-1	0.02	0.005	0.01	0.021	0.9	3	1.5	4.5
FLX-1	0.01	0.005	0.01	0.021	0.9	3	1.5	4.5
GRR-001	0.005	0.005	0.01	0.021	0.9	2	1.5	3
KNR-1	0.02	0.005	0.01	0.021	0.9	3	1.5	4.5
KTR-005	0.02	0.005	0.01	0.021	0.9	3	1.5	4.5
MST-21	0.005	0.005	0.01	0.021	0.9	2	1.5	3
MUR-1	0.005	0.005	0.01	0.021	0.9	2	1.5	3
OMR-1	0.005	0.005	0.01	0.021	0.9	2	1.5	3
ONR-1	0.005	0.005	0.01	0.021	0.9	2	1.5	3
OPO-1	0.005	0.005	0.01	0.021	0.9	2	1.5	3
OPR-1	0.02	0.005	0.01	0.021	0.9	3	1.5	4.5
OPR-3	0.01	0.005	0.01	0.021	0.9	3	1.5	4.5
PLR-4	0.01	0.005	0.01	0.021	0.9	3	1.5	4.5
PLR-5	0.005	0.005	0.01	0.021	0.9	2	1.5	3
RAR-1	0.01	0.005	0.01	0.021	0.9	3	1.5	4.5
RON-4	0.01	0.005	0.01	0.021	0.9	3	1.5	4.5
SPC-1	0.005	0.005	0.01	0.021	0.9	2	1.5	3
TMR-1	0.02	0.005	0.01	0.021	0.9	3	1.5	4.5
TYR-1	0.03	0.005	0.01	0.021	0.9	4	1.5	6
WaiM	0.005	0.005	0.01	0.021	0.9	2	1.5	3
WDV-1	0.02	0.005	0.01	0.021	0.9	3	1.5	4.5
WHR-1	0.01	0.005	0.01	0.021	0.9	3	1.5	4.5
WHR-5	0.005	0.005	0.01	0.021	0.9	2	1.5	3
WKR-1	0.005	0.005	0.01	0.021	0.9	2	1.5	3
WRR-2	0.006	0.005	0.01	0.021	0.9	2	1.5	3
WRR-6	0.004	0.005	0.01	0.021	0.9	1	1.5	1.5
WTS-009	0.0075	0.005	0.01	0.021	0.9	2	1.5	3

SITE ID	DISSOLVED OXYGEN Input Value	Score Concentrations 2	3	4	5	Score	Weight	Weighted Score
ARE-3	18	5	10	15	20	4	1.5	6
AWR-1	5.9	5	10	15	20	2	1.5	3
AWR-3	6.9	5	10	15	20	2	1.5	3
BNR-1	28.9	5	10	15	20	5	1.5	7.5
CUL-3	7.95	5	10	15	20	2	1.5	3
DNC-002	5.9	5	10	15	20	2	1.5	3
DRC-1	30.3	5	10	15	20	5	1.5	7.5
FLX-1	23.8	5	10	15	20	5	1.5	7.5
GRR-001	6.4	5	10	15	20	2	1.5	3
KNR-1	10	5	10	15	20	3	1.5	4.5
KTR-005	6.65	5	10	15	20	2	1.5	3
MST-21	11.9	5	10	15	20	3	1.5	4.5
MUR-1	29.7	5	10	15	20	5	1.5	7.5
OMR-1	8.4	5	10	15	20	2	1.5	3
ONR-1	4.9	5	10	15	20	1	1.5	1.5
OPO-1	4.9	5	10	15	20	1	1.5	1.5
OPR-1	29.4	5	10	15	20	5	1.5	7.5
OPR-3	17.5	5	10	15	20	4	1.5	6
PLR-4	8.5	5	10	15	20	2	1.5	3
PLR-5	5.5	5	10	15	20	2	1.5	3
RAR-1	7.1	5	10	15	20	2	1.5	3
RON-4	7.8	5	10	15	20	2	1.5	3
SPC-1	17.1	5	10	15	20	4	1.5	6
TMR-1	26.5	5	10	15	20	5	1.5	7.5
TYR-1	22.6	5	10	15	20	5	1.5	7.5
WaiM	9	5	10	15	20	2	1.5	3
WDV-1	10.8	5	10	15	20	3	1.5	4.5
WHR-1	4.5	5	10	15	20	1	1.5	1.5
WHR-5	2.75	5	10	15	20	1	1.5	1.5
WKR-1	5.5	5	10	15	20	2	1.5	3
WRR-2	6.3	5	10	15	20	2	1.5	3
WRR-6	1.4	5	10	15	20	1	1.5	1.5
WTS-009	9.3	5	10	15	20	2	1.5	3

SITE ID	NITRATE Input Value	Score Concentrations 2	3	4	5	Score	Weight	Weighted Score
ARE-3	1.04	0.05	0.167	0.444	1.7	4	1	4
AWR-1	0.17	0.05	0.167	0.444	1.7	3	1	3
AWR-3	0.06	0.05	0.167	0.444	1.7	2	1	2
BNR-1	0.01	0.05	0.167	0.444	1.7	1	1	1
CUL-3	0.41	0.05	0.167	0.444	1.7	3	1	3
DNC-002	0.77	0.05	0.167	0.444	1.7	4	1	4
DRC-1	2.1	0.05	0.167	0.444	1.7	5	1	5
FLX-1	0.11	0.05	0.167	0.444	1.7	2	1	2
GRR-001	0.06	0.05	0.167	0.444	1.7	2	1	2
KNR-1	0.27	0.05	0.167	0.444	1.7	3	1	3
KTR-005	1.52	0.05	0.167	0.444	1.7	4	1	4
MST-21	2.8	0.05	0.167	0.444	1.7	5	1	5
MUR-1	1.51	0.05	0.167	0.444	1.7	4	1	4
OMR-1	0.56	0.05	0.167	0.444	1.7	4	1	4
ONR-1	0.32	0.05	0.167	0.444	1.7	3	1	3
OPO-1	0.54	0.05	0.167	0.444	1.7	4	1	4
OPR-1	2.5	0.05	0.167	0.444	1.7	5	1	5
OPR-3	0.88	0.05	0.167	0.444	1.7	4	1	4
PLR-4	0.39	0.05	0.167	0.444	1.7	3	1	3
PLR-5	0.06	0.05	0.167	0.444	1.7	2	1	2
RAR-1	0.95	0.05	0.167	0.444	1.7	4	1	4
RON-4	0.97	0.05	0.167	0.444	1.7	4	1	4
SPC-1	0.53	0.05	0.167	0.444	1.7	4	1	4
TMR-1	0.78	0.05	0.167	0.444	1.7	4	1	4
TYR-1	3.16	0.05	0.167	0.444	1.7	5	1	5
WaiM	0.28	0.05	0.167	0.444	1.7	3	1	3
WDV-1	0.77	0.05	0.167	0.444	1.7	4	1	4
WHR-1	0.4	0.05	0.167	0.444	1.7	3	1	3
WHR-5	0.08	0.05	0.167	0.444	1.7	2	1	2
WKR-1	0.06	0.05	0.167	0.444	1.7	2	1	2
WRR-2	0.283	0.05	0.167	0.444	1.7	3	1	3
WRR-6	0.038	0.05	0.167	0.444	1.7	1	1	1
WTS-009	0.05	0.05	0.167	0.444	1.7	2	1	2

Contd. ➦

DRP								E. COLI								TURBIDITY							
Input Value	Score Concentrations 2	3	4	5	Score	Weight	Weighted Score	Input Value	Score Concentrations 2	3	4	5	Score	Weight	Weighted Score	Input Value	Score Concentrations 2	3	4	5	Score	Weight	Weighted Score
0.026	0.005	0.01	0.021	0.05	4	1	4	1600	50	126	260	550	5	0.2	1	3.81	1	2	4.1	5.6	3	0.5	1.5
0.026	0.005	0.01	0.021	0.05	4	1	4	120	50	126	260	550	2	0.2	0.4	154.156	1	2	4.1	5.6	1	0.5	0.5
0.021	0.005	0.01	0.021	0.05	4	1	4	50	50	126	260	550	2	0.2	0.4	117.826	1	2	4.1	5.6	1	0.5	0.5
0.01	0.005	0.01	0.021	0.05	3	1	3	8	50	126	260	550	1	0.2	0.2	1.742	1	2	4.1	5.6	2	0.5	1
0.021	0.005	0.01	0.021	0.05	4	1	4	300	50	126	260	550	4	0.2	0.8	1.6383	1	2	4.1	5.6	2	0.5	1
0.039	0.005	0.01	0.021	0.05	4	1	4	1800	50	126	260	550	5	0.2	1	9.809	1	2	4.1	5.6	5	0.5	2.5
0.035	0.005	0.01	0.021	0.05	4	1	4	230	50	126	260	550	3	0.2	0.6	5.32	1	2	4.1	5.6	4	0.5	2
0.014	0.005	0.01	0.021	0.05	3	1	3	170	50	126	260	550	3	0.2	0.6	2.9265	1	2	4.1	5.6	3	0.5	1.5
0.019	0.005	0.01	0.021	0.05	3	1	3	1000	50	126	260	550	5	0.2	1	2.1147	1	2	4.1	5.6	3	0.5	1.5
0.015	0.005	0.01	0.021	0.05	3	1	3	400	50	126	260	550	4	0.2	0.8	1.0371	1	2	4.1	5.6	2	0.5	1
0.015	0.005	0.01	0.021	0.05	3	1	3	500	50	126	260	550	4	0.2	0.8	5.641	1	2	4.1	5.6	5	0.5	2.5
0.02	0.005	0.01	0.021	0.05	3	1	3	500	50	126	260	550	4	0.2	0.8	2.4893	1	2	4.1	5.6	3	0.5	1.5
0.016	0.005	0.01	0.021	0.05	3	1	3	254	50	126	260	550	3	0.2	0.6	0.825	1	2	4.1	5.6	1	0.5	0.5
0.012	0.005	0.01	0.021	0.05	3	1	3	31	50	126	260	550	1	0.2	0.2	1.6092	1	2	4.1	5.6	2	0.5	1
0.013	0.005	0.01	0.021	0.05	3	1	3	170	50	126	260	550	3	0.2	0.6	1.2774	1	2	4.1	5.6	2	0.5	1
0.015	0.005	0.01	0.021	0.05	3	1	3	110	50	126	260	550	2	0.2	0.4	0.7836	1	2	4.1	5.6	1	0.5	0.5
0.024	0.005	0.01	0.021	0.05	4	1	4	57	50	126	260	550	2	0.2	0.4	3.5544	1	2	4.1	5.6	3	0.5	1.5
0.014	0.005	0.01	0.021	0.05	3	1	3	110	50	126	260	550	2	0.2	0.4	9.6204	1	2	4.1	5.6	5	0.5	2.5
0.014	0.005	0.01	0.021	0.05	3	1	3	160	50	126	260	550	3	0.2	0.6	4.8209	1	2	4.1	5.6	4	0.5	2
0.014	0.005	0.01	0.021	0.05	3	1	3	53	50	126	260	550	2	0.2	0.4	2.8817	1	2	4.1	5.6	3	0.5	1.5
0.017	0.005	0.01	0.021	0.05	3	1	3	624	50	126	260	550	5	0.2	1	3.2247	1	2	4.1	5.6	3	0.5	1.5
0.018	0.005	0.01	0.021	0.05	3	1	3	250	50	126	260	550	3	0.2	0.6	1.8068	1	2	4.1	5.6	2	0.5	1
0.016	0.005	0.01	0.021	0.05	3	1	3	80	50	126	260	550	2	0.2	0.4	0.9465	1	2	4.1	5.6	1	0.5	0.5
0.021	0.005	0.01	0.021	0.05	4	1	4	70	50	126	260	550	2	0.2	0.4	5.0678	1	2	4.1	5.6	4	0.5	2
0.028	0.005	0.01	0.021	0.05	4	1	4	210	50	126	260	550	3	0.2	0.6	3.973	1	2	4.1	5.6	3	0.5	1.5
0.011	0.005	0.01	0.021	0.05	3	1	3	240	50	126	260	550	3	0.2	0.6	18.9632	1	2	4.1	5.6	5	0.5	2.5
0.018	0.005	0.01	0.021	0.05	3	1	3	324	50	126	260	550	4	0.2	0.8	14.6222	1	2	4.1	5.6	5	0.5	2.5
0.015	0.005	0.01	0.021	0.05	3	1	3	180	50	126	260	550	3	0.2	0.6	21.6485	1	2	4.1	5.6	5	0.5	2.5
0.019	0.005	0.01	0.021	0.05	3	1	3	140	50	126	260	550	3	0.2	0.6	11.3316	1	2	4.1	5.6	5	0.5	2.5
0.014	0.005	0.01	0.021	0.05	3	1	3	60	50	126	260	550	2	0.2	0.4	0.6476	1	2	4.1	5.6	1	0.5	0.5
0.007	0.005	0.01	0.021	0.05	2	1	2	40	50	126	260	550	1	0.2	0.2	9.8094	1	2	4.1	5.6	5	0.5	2.5
0.004	0.005	0.01	0.021	0.05	1	1	1	10.9	50	126	260	550	1	0.2	0.2	3.4433	1	2	4.1	5.6	3	0.5	1.5
0.018	0.005	0.01	0.021	0.05	3	1	3	200	50	126	260	550	3	0.2	0.6	1.5116	1	2	4.1	5.6	2	0.5	1

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WQ SCORE									
					Grade Classes				
Sum weig. Scores	min Score	**WQ Score**	max Score	Class Diff.	Good	Fair	Poor	V.Poor	**WQ Grade**
21	5.7	**3.7**	28.5	4.56	1.9	2.7	3.5	4.3	**Poor**
15.4	5.7	**2.7**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
12.9	5.7	**2.3**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
15.7	5.7	**2.8**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
14.8	5.7	**2.6**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
20.5	5.7	**3.6**	28.5	4.56	1.9	2.7	3.5	4.3	**Poor**
23.6	5.7	**4.1**	28.5	4.56	1.9	2.7	3.5	4.3	**Poor**
19.1	5.7	**3.4**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
13.5	5.7	**2.4**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
16.8	5.7	**2.9**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
17.8	5.7	**3.1**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
17.8	5.7	**3.1**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
18.6	5.7	**3.3**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
14.2	5.7	**2.5**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
12.1	5.7	**2.1**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
12.4	5.7	**2.2**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
22.9	5.7	**4.0**	28.5	4.56	1.9	2.7	3.5	4.3	**Poor**
20.4	5.7	**3.6**	28.5	4.56	1.9	2.7	3.5	4.3	**Poor**
16.1	5.7	**2.8**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
12.9	5.7	**2.3**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
17	5.7	**3.0**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
16.1	5.7	**2.8**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
16.9	5.7	**3.0**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
22.4	5.7	**3.9**	28.5	4.56	1.9	2.7	3.5	4.3	**Poor**
24.6	5.7	**4.3**	28.5	4.56	1.9	2.7	3.5	4.3	**Very Poor**
15.1	5.7	**2.6**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
19.3	5.7	**3.4**	28.5	4.56	1.9	2.7	3.5	4.3	**Fair**
15.1	5.7	**2.6**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
12.6	5.7	**2.2**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
11.9	5.7	**2.1**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
13.7	5.7	**2.4**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**
6.7	5.7	**1.2**	28.5	4.56	1.9	2.7	3.5	4.3	**Excellent**
12.6	5.7	**2.2**	28.5	4.56	1.9	2.7	3.5	4.3	**Good**

Appendix 6: **Summary statistics for the water quality parameters used to calculate the water quality score and assess the water quality grade.**

WATER QUALITY RESULTS (2007-2009)
WATER QUALITY GRADE CALCULATIONS

Site ID	Ammonia (90%ile)	DO (Quartile Range)	Nitrate (90%ile)	DRP (90%ile)	E. coli (90%ile)	Turbidity (mean)	Number of Samples	WQ Score	WQ Grade	Grade Status
ARE-3	0.02	18.0	1.04	0.026	1600	3.8	7	3.7	Poor	Interim
AWR-1	0.02	5.9	0.17	0.026	120	154.2	34	2.7	Fair	Complete
AWR-3	0.005	6.9	0.06	0.021	50	117.8	35	2.3	Good	Complete
BNR-1	0.005	28.9	0.01	0.01	8	1.7	5	2.8	Fair	Interim
CUL-3	0.005	8.0	0.41	0.021	300	1.6	6	2.6	Good	Interim
DNC-002	0.03	5.9	0.77	0.039	1800	9.8	19	3.6	Poor	Interim
DRC-1	0.02	30.3	2.1	0.035	230	5.3	6	4.1	Poor	Interim
FLX-1	0.01	23.8	0.11	0.014	170	2.9	35	3.4	Fair	Complete
GRR-001	0.005	6.4	0.06	0.019	1000	2.1	29	2.4	Good	Interim
KNR-1	0.02	10.0	0.27	0.015	400	1.0	34	2.9	Fair	Complete
KTR-005	0.02	6.6	1.52	0.015	500	5.6	34	3.1	Fair	Complete
MST-21	0.005	11.9	2.8	0.02	500	2.5	14	3.1	Fair	Interim
MUR-1	0.005	29.7	1.51	0.016	254	0.8	6	3.3	Fair	Interim
OMR-1	0.005	8.4	0.56	0.012	31	1.6	34	2.5	Good	Complete
ONR-1	0.005	4.9	0.32	0.013	170	1.3	36	2.1	Good	Complete
OPO-1	0.005	4.9	0.54	0.015	110	0.8	22	2.2	Good	Interim
OPR-1	0.02	29.4	2.5	0.024	57	3.6	35	4.0	Poor	Complete
OPR-3	0.01	17.5	0.88	0.014	110	9.6	36	3.6	Poor	Complete
PLR-4	0.01	8.5	0.39	0.014	160	4.8	29	2.8	Fair	Interim
PLR-5	0.005	5.5	0.06	0.014	53	2.9	34	2.3	Good	Complete
RAR-1	0.01	7.1	0.95	0.017	624	3.2	48	3.0	Fair	Complete
RON-4	0.01	7.8	0.97	0.018	250	1.8	24	2.8	Fair	Interim
SPC-1	0.005	17.1	0.53	0.016	80	0.9	35	3.0	Fair	Complete
TMR-1	0.02	26.5	0.78	0.021	70	5.1	35	3.9	Poor	Complete
TYR-1	0.03	22.6	3.16	0.028	210	4.0	34	4.3	Very Poor	Complete
WaiM	0.005	9.0	0.28	0.011	240	19.0	27	2.6	Good	Interim
WDV-1	0.02	10.8	0.77	0.018	324	14.6	29	3.4	Fair	Interim
WHR-1	0.01	4.5	0.4	0.015	180	21.6	35	2.6	Good	Complete
WHR-5	0.005	2.8	0.08	0.019	140	11.3	27	2.2	Good	Interim
WKR-1	0.005	5.5	0.06	0.014	60	0.6	36	2.1	Good	Complete
WRR-2	0.006	6.3	0.283	0.007	40	9.8	36	2.4	Good	Complete
WRR-6	0.004	1.4	0.038	0.004	10.9	3.4	36	1.2	Excellent	Complete
WTS-009	0.0075	9.3	0.05	0.018	200	1.5	30	2.2	Good	Complete

Number of complete grades = 19

Turbidity results for AWR-1 and AWR-3 excluded from calculations