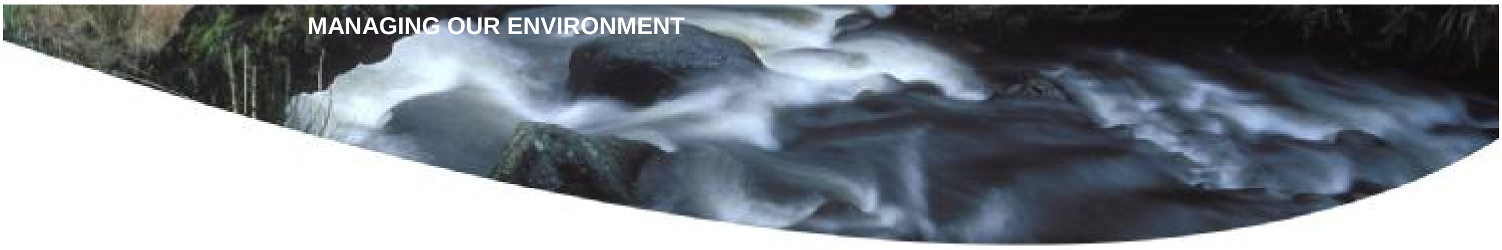

Recommended Water Quality Standards for the Manawatu-Wanganui Region :

Technical Report to Support Policy Development

horizons regional council

one plan MOTE ITI MOTE RAHI

Recommended Water Quality Standards for the Manawatu-Wanganui Region : Technical Report to Support Policy Development

horizons
regional council

June 2007

Author
Dr Olivier Ausseil
Senior Scientist – Water Quality

Maree Clark
Research Associate

Internally Reviewed and Approved by
Dr Jon Roygard, Science Manager
Jeff Watson, Manager Resource Data
Alistair Beveridge, Manager Water Quality and Biodiversity

External Review by
Dr John Quinn, Principal Scientist – River Ecosystems, NIWA
Dr Bob Wilcock, Principal Scientist - Group Manager Aquatic Chemistry, NIWA
Dr Roger Young, Aquatic Ecologist, Cawthron Institute
Dr Barry Biggs, General Manager Environmental Information and International NIWA (review of the nutrient standards, section 6 of this report)

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CONTACT	**24hr Freephone 0508 800 800**		help@horizons.govt.nz		www.horizons.govt.nz
SERVICE CENTRES	**Kairanga** Cnr Rongotea & Kairanga-Bunnythorpe Rds Palmerston North **Marton** Cnr Hammond & Hair Sts **Taumarunui** 34 Maata Street **Woodville** Cnr Vogel (SH2) & Tay Sts	**REGIONAL HOUSES**	**Palmerston North** 11-15 Victoria Avenue **Wanganui** 181 Guyton Street	**DEPOTS**	**Levin** 11 Bruce Road **Taihape** Torere Road Ohotu
POSTAL ADDRESS	Horizons Regional Council, Private Bag 11025, Manawatu Mail Centre, Palmerston North 4442 | **F** 06 9522 929				

EXECUTIVE SUMMARY

Horizons Regional Council is currently developing a new combined Regional Plan and Regional Policy Statement: the One Plan. This Plan will propose an improved water and catchment management regime for the Manawatu-Wanganui Region.

The central component of this proposed management regime is the clear definition and identification of the values our regional community places on our rivers and lakes. A total of 23 different values, applying to all or parts of the Region's rivers, lakes and coastal waters and their margins have been identified, and classed into four groups:

- the Ecosystem Values group includes five individual values recognising the intrinsic value of freshwater and coastal ecosystems for the living communities and natural processes they sustain;
- the Recreational and Cultural Values group includes nine individual values, associated with the spiritual and cultural values and the recreational (ie. non-consumptive or non-commercial) use of the waterbodies;
- the Consumptive Use Values group refers to the value of abstracted surface water in supporting the regional communities (eg. community water supply) and economy (ie. irrigation). It includes four individual values; and
- the Social and Economic Values Group includes five individual values identifying that rivers and their margins provide services and uses that support and protect the regional communities and assets.

The definition of the waterbody values is the subject of a separate technical report, and the reader is invited to refer to (Ausseil and Clark, 2007a) for more details.

A key goal for the proposed new water and catchment management regime will be to ensure the values associated with the waterbodies are maintained or improved. To cover the different aspects of water, river and aquatic biodiversity, different policy streams are recommended for the One Plan.

One key policy stream recommended to protect the values associated with the Region's waterbodies is the setting of water quality standards. This report summarises the information and process used to define recommended water quality standards in the One Plan.

In this report, the need to translate each value into WQ standards is examined. Seven of the 23 proposed values were translated into numerical water quality standards. These were the Life-Supporting Capacity (LSC), Contact Recreation (CR), Amenity (A), Trout Fishery (TF), Trout Spawning (TS), Shellfish Gathering (SG) and livestock drinking water (SW). Narrative standards are recommended in relation to a further two values (Natural State and Mauri). The translation of the remaining values into water quality standards was not recommended, as they were considered better protected by:

- standards attached to other values, and/or
- policies/rules exerting control over the cause of potential, and/or
- policies/rules relating to other aspects of aquatic ecosystems (eg. aquatic habitat).

The underlying philosophy guiding the "translation" of values into water quality standards is to represent the environmental bottom line beyond which the value would be compromised, in other words the "good state" of the water in relation to that value.

The recommended standards cover a number of water quality aspects, to ensure that each value is adequately protected, including:

- physicochemical parameters to ensure conditions are adequate for aquatic life and water users: pH, dissolved oxygen, temperature, water clarity, biochemical oxygen demand (BOD), particulate organic matter (POM), toxicants;
- parameters relating to the recreational use of the waterbodies and the protection of public health, including indicators of faecal contamination, water clarity and algal biomass and cover;
- biological parameters, directly linked with the integrity of aquatic ecosystems: quantitative macroinvertebrate communities index (QMCI) and periphyton biomass; and
- nutrient (nitrogen and phosphorus) standards to control algal growth.

Water Management Zones (WMZs) are the fundamental geographic units in the integrated water management regime recommended for the One Plan. A number of waterbody values have been associated with each waterbody and/or water management zones. A set of water clarity standards was defined for each water management sub-zone, to ensure all the values identified are adequately maintained or protected.

By comparing the recommended standards to the current state of the water quality, one can identify the waters that

- clearly meet the standards;
- are close to the standards (on either side of the standards); and
- clearly do not meet the standards (degraded waters).

The strategic approach to the management of these different categories of waters, particularly the prioritisation of non-regulatory resources and strategies, should be markedly influenced by these results. For example, the waters that meet the standards by only a small margin may be at risk of breaching the standards in the near future and may require closer monitoring and management. Conversely, waters that only just breach the standards may be able to be restored at lower cost and more quickly than more heavily degraded waters.

The project aimed to use the best and most up-to-date scientific information and expertise available at the time, and has identified a number of areas requiring further research. A number of recommendations are made in this report, ranging from improvements to Horizons' monitoring and research programmes to the development of tools and guidelines to better manage the water resource.

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1 Planning Context

1.1 Introduction

Horizons Regional Council has commenced the process of simplifying its current suite of resource management policy documents. Horizon's operative Regional Policy Statement and six regional plans are being reviewed, simplified and where necessary new policy drafted. These provisions will then be combined into a single second generation planning document – the One Plan. The One Plan will be arranged into chapters around the key resource themes of:

- Land
- Water
- Air
- Coastal Environment
- Iwi Issues
- Living Heritage (including biodiversity and cultural/historic heritage)
- Waste and Contaminated Sites
- Natural Hazards

As well as being a one-stop-shop for all planning provisions to do with resource management in the Manawatu-Wanganui Region, the One Plan aims to be more prescriptive and give greater certainty to resource users around the constraints being imposed on resource use. Consequently it is intended that the One Plan will define water quality management policies and rules that differ substantially from those in existing plans.

As per the RMA, these planning provisions must guide the sustainable management of surface water, allowing for reasonable use of the resource whilst safeguarding its life-supporting capacity and avoiding, remedying or mitigating any adverse effect of use.

In the light of sustained and increasing water quality issues in the Manawatu-Wanganui Region (Horizons, 2005; Gibbard *et al*., 2006), a new water quality approach is proposed for the One Plan (Figure 1). This report is part of a series of technical reports produced by the Science Team at Horizons Regional Council to support the development of this new water quality management framework. The definition of water quality standard is one of the policy streams that give effect to the definition of waterbody values and water management zones. Thus, this report should be read in conjunction with the Values report (Ausseil and Clark, 2007a) and the Water Management Zones report (McArthur *et al.* 2007a)

- Section 1 of this report describes the planning framework and the proposed water management approach.
- Section 2 presents the general principles and methodologies, and defines the key water quality parameters used to define the standards recommended in this report.
- Sections 3 to 5 describe the recommended water quality standards in relation to each of the waterbody values.

- Section 6 specifically deals with the definition of water quality standards relating to nutrients (nitrogen and phosphorus) concentrations in the water.
- Section 7 compiles the recommended standards by water management sub-zone, and includes detailed recommendations for inclusion in the One Plan Schedule D.
- Section 8 compares the current state of the water quality with the proposed water quality standards for each management sub-zone.
- Section 9 presents some recommendations for future research, monitoring and resource management tools.

1.2 State of the water quality in the Manawatu-Wanganui Region

The recent State of the Environment Report (Horizons 2005) identifies four water quality issues significantly affecting a number of the Region's river and lakes systems:

- Nutrient enrichment of the water, causing nuisance biological growth, generally observed as green filamentous algae growing on the riverbed and algal blooms in lakes.
- Too much sediment in the waterways, causing muddy-looking water and impacting on aquatic life.
- Faecal contamination of the water, posing a health risk to swimmers and other water users.
- Stressors or toxicants that can have direct detrimental effects on aquatic life. Stressors may include high water temperatures or low dissolved oxygen, and toxicants like ammonia are common in the region's waters.

All these issues do not affect all the catchments, but many streams and rivers are affected by at least one.

A statistical analysis of long-term water quality data indicates that water quality is improving in some areas that were historically impacted by point source pollutions (ie. discharge of domestic or industrial effluent) (Gibbard *et al.* 2005). However, the same analysis also clearly indicates that water quality is degrading in many rivers, generally in areas of intensive farming (dairying, cropping, high density drystock farming), hinting at the significance of non-point source pollution in our Region. Further studies have shown that agricultural non-point source pollution was a key contributor to nutrient pollution of waterways (Ledein *et al.*, 2007; Roygard, 2007).

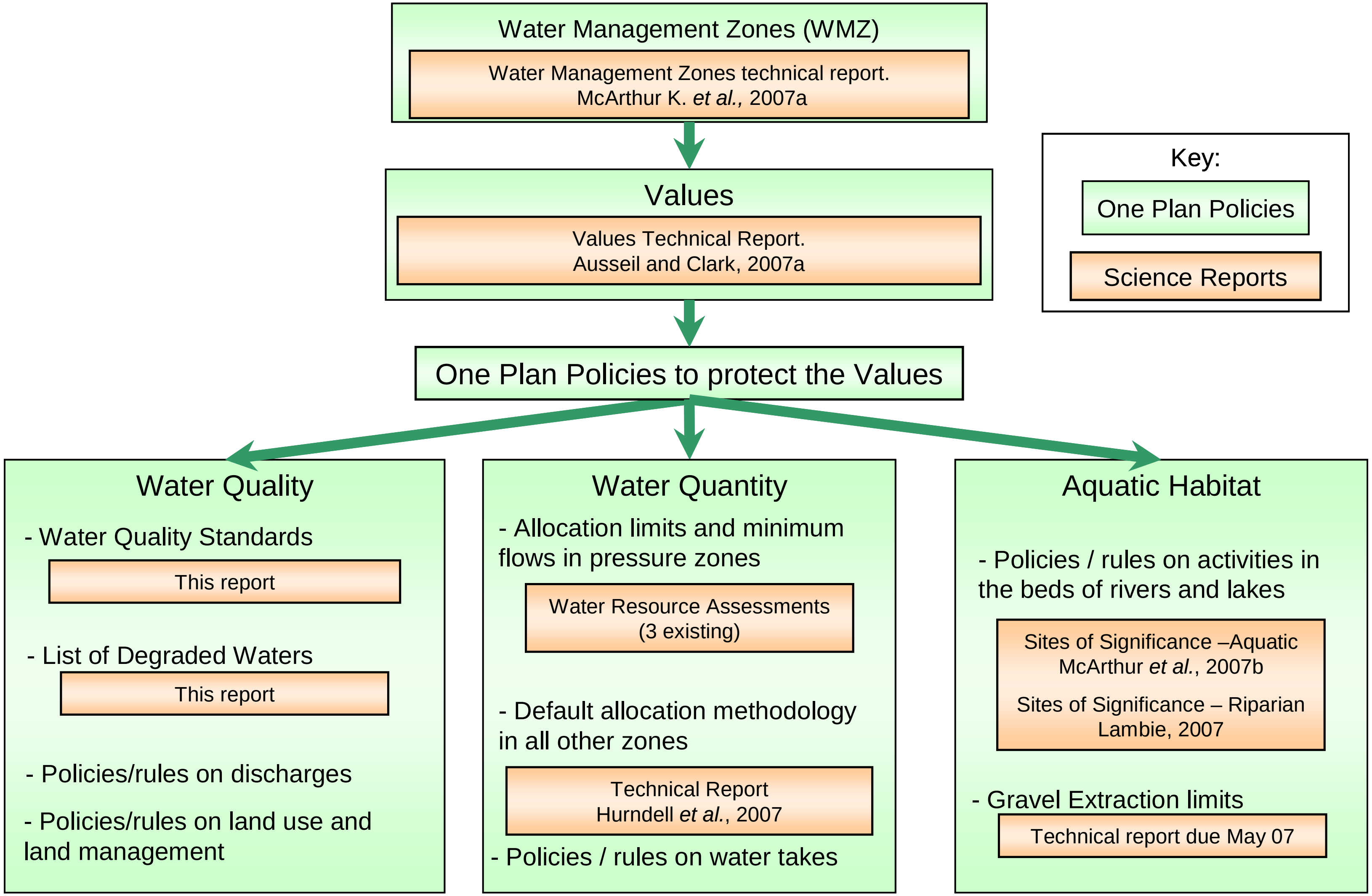


Figure 1: Overview of the proposed water management regime and structure of the Technical Report series to support policy development.

1.3 Current Planning framework

1.3.1 Water quality standards in the RMA

The purpose of the RMA (1991) is to promote the sustainable management of the natural and physical resources. This particularly includes “safeguarding the life-supporting capacity of […] water […] and ecosystems” and “avoiding, remedying or mitigating any adverse effect of activities on the environment”. Some sections of the Act relate specifically to the management of the water resource and the protection of aquatic ecosystems. Section 69 of the Act defines rules relating to water quality. In particular:

- Section 69(1) defines 11 water classes, corresponding to management objectives. It also defines a suite of numerical or narrative water quality standards for each class. Section 69(1) also gives mandate to the Regional Councils to use and apply these classes and narrative water quality standards in Regional Plans. Where the Council is of the opinion that these standards are not adequate or appropriate, it may define more stringent or specific water quality standards.
- Section 69(2) allows the Regional Council to define new classes where it is not satisfied that the classes/standards defined in Schedule 3 provide for certain management purposes.
- Section 63(3) prohibits the setting of standards in a plan which result or may result in a reduction of the quality of the water in any waters at the time of the public notification, unless it is consistent with the purpose of the Act to do so.

Sections 70(1) and 107(1) set five narrative standards in relation with permitted and consented discharges to water or to land. These standards relate to different potential impacts of a discharge, ranging from visual impact to adverse effects on aquatic life.

1.3.2 Water quality standards in the National Water Conservation Orders

There are two **National Water Conservation Orders** (NWCOs) that apply in the Region, covering the Upper and Middle Rangitikei River and the Manganui O Te Ao River. The specific values these orders seek to protect are: Aesthetic (scenic), Trout Fishery, and Wildlife (blue duck) Habitat.

Both Orders define numerical and narrative water quality standards to protect the outstanding features of both waterways from the effects of discharges. These standards are summarised in Table 1.

In defining water quality standards for these waterbodies already covered by a NWCO, the Regional Council must ensure both sets of standards are consistent. In other words, the water quality standards defined in the Regional Plans must be at least as stringent as the NWCO standards.

Table 1: Water quality standards associated with National Water Conservation Orders (NWCOs) in the Manawatu-Wanganui Region.

NWCO	Standard
Manganui O Te Ao River	"The water temperature shall be less than 25^{o}C in the months of October to April and shall be less than 13^{o}C in the months of May to September, and within that range the natural water temperature shall not be changed by more than 3^{o}C"
	"The […] pH shall be within the range 6.0 to 9.0, and within that range the natural pH of the water shall not be changed by more than 1.0 units."
	"The water shall not be tainted so as to be unpalatable or unsuitable for consumption by humans or farm animals"
	"The water shall not emit an objectionable odour"
	"There shall be no adverse effect on the aquatic community attributable to pollutants"
	"Aquatic organisms shall not be rendered unsuitable for human consumption by accumulation of excessive concentrations of pollutants"
	"The natural colour and clarity of the waters shall not be changed to a conspicuous extent"
	"There shall be no visible oil or grease films or conspicuous floating or suspended waste materials"
	"The concentration of dissolved oxygen shall exceed 80% saturation"
	"There shall be no undesirable biological growths attributable to pollutants"
Rangitikei River	"The natural water temperature shall not be changed by more than 3^{o}C"
	"The […] pH shall be within the range 6.0 to 9.0, and within that range the natural pH of the water shall not be changed by more than 1.0 units."
	"The concentration of dissolved oxygen shall not be less than 80% saturation"
	"There shall be no undesirable biological growths attributable to pollutants"

1.3.3 National Environmental Standards (NES) Programme

Currently there are no national environmental standards for river or lake water quality. Through its Water Programme of Action, MfE is consulting on the relevance of developing national water quality standards or a national framework to define water quality standards.

It is also noted the Ministry for the Environment is working with the Ministry of Health to develop and implement a NES for raw drinking-water sources. Although no final document has been made public at the time of writing, the latest public consultation documents hints on the likely outcomes, including:

- the identification of all public water sources, and catchments or parts of catchment above the water take; and
- a review of the effects of permitted activities on the suitability of the water as a raw drinking water source may be imposed on the Regional Councils.

At the time of writing, it seems very unlikely the raw drinking water source NES will set numerical water quality standards, or propose/impose a framework to define numerical water quality standards.

1.3.4 Water Quality Standards in Horizons Regional Council Regional Policy Statement and Regional Plans

Horizons Regional Council's suite of planning documents relevant to water quality and aquatic habitat include:

- The regional Policy Statement (RPS) 1998;
- The Manawatu Catchment Water Quality Regional Plan (MCWQRP), operative October 1998;
- The Land and Water Regional Plan (LWRP), operative in September 2003;
- The Regional Coastal Plan (January 2002); and
- The Beds of Rivers and Lakes Regional Plan (BRL), operative March 2001.

As explained in section 1.3.1 of this report, a Regional Council may choose to set standards for water quality in a regional plan, but it is not mandatory to do so. Currently, two of Horizons' regional plans contain water quality management provisions:

- Manawatu Catchment Water Quality Regional Plan 1998 (MCWQRP) and
- Land and Water Regional Plan 2003 (LWRP).

The **LWRP** covers the whole Region with the exception of the Manawatu catchment. It defines discharges to surface water as a discretionary activity, but **does not impose water quality standard**s except the RMA section 107 narrative standards for receiving waters.

Although developed prior to the LWRP, the **MCWQRP**, which applies to the Manawatu catchment, **imposes general water quality standards** based on an interpretation of the RMA s.107 **and additional standards for five classes of waters**:

- contact recreation (CR) (covering most streams and rivers);
- fishery waters (F);
- fish spawning FS);
- Water supply (WS); and
- Natural State (NS).

It is noted that the MCWQ Rule 1 and 2 standards are the same for all streams and rivers within the Manawatu catchment. Whilst providing clear and useful guidance, this "one size fits all" approach may fail to recognise the different types of waterbodies in the catchment.

Table 2: Summary of the Manawatu Catchment Water Quality Regional Plan water quality standards.

Rule	Standards
Rule 1: General Water Standards for Water Quality (apply to all surface waters, at all flows)	1(a) Change in horizontal visibility shall not be greater than 30%.
	1(b) Change in hue shall not be greater than 10 points on the Munsell scale.
	1(c) Change in euphotic depth shall not be greater than 10% or 20% (location dependent).
	1(d) The daily average concentration of ammonia (NH_4-N) in water i. shall not exceed 1.1 g/m^3 at water temperatures equal to or less than 15°C; or ii. shall not exceed 0.8 g/m^3 at water temperatures greater than 15°C.
	1(e) The daily average carbonaceous BOD_5 concentration due to dissolved organic compounds (that is, material passing through a GF/C filter), shall not exceed 2 g/m^3.

Rule	Standards
Rule 2: Contact Recreation Water Quality Standards (apply to all surface waters at flows under half median flow)	(a) The water shall not be rendered unsuitable for bathing by the presence of contaminants.
	(b) The horizontal visibility in rivers shall be greater than 1.6 metres, unless existing physical and/or biological factors cause the visibility to be less than 1.6 metres at the point of discharge.
	(c) Bacterial and/or fungal slime growths shall not be visible to the naked eye as plumose growths or mats.
	(d) The daily average concentration of particulate organic matter shall not exceed 5 g/m^3.
	(e) The median concentration of enterococci of at least 20 samples taken throughout the bathing season shall not exceed 33 per 100 ml nor shall any sample exceed 107 enterococci per 100 ml. The bathing season is defined as the period of 1 November to 1 May inclusive.
	(f) The seasonal maximum cover of stream or river beds by periphyton as filamentous growths or mats (more than 3 mm thick) shall not exceed 40%, and the biomass on the bed shall not exceed 100 mg chlorophyll *a*/m^2 over a representative reach. Existing discharges shall comply with this Standard by 1 June 2009.
	(g) The daily average concentration of dissolved reactive phosphorus (DRP) shall be less than 15 mg/m^3. Existing discharges shall comply with this Standard by 1 June, 2009.
Rule 3: Fishery Water Quality Standards (apply to the Manawatu River upstream of the Manawatu Gorge, the Mangatainoka catchment and the Makuri catchment, at all river flows)	3(a) The natural temperature of the water shall not be changed by more than 3° Celsius; and shall not exceed 25° Celsius.
	(b) The concentration of dissolved oxygen shall exceed 80% of saturation concentration.
	(c) Fish shall not be rendered unsuitable for human consumption by the presence of contaminants.
Rule 4: Fish Spawning Water Quality Standards (applies to a number of specified streams)	4(a) The natural temperature of the water shall not be changed by more than 3° Celsius
	4(b) The concentration of dissolved oxygen shall exceed 80% of saturation concentration.
	(c) There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water.
	(d) There shall be no significant deposition of sediment or particulate organic matter on the bed of the river.
Rule 5: Water Supply Water Quality Standards (applies to a number of specified streams)	(a) The pH of surface waters shall be within the range 6.0-9.0 units.
	(b) The concentration of dissolved oxygen in surface waters shall exceed 5 grams per cubic metre (5 g/m^3).
	(c) The water shall not be rendered unsuitable for treatment (equivalent to coagulation, filtration, and disinfection) for human consumption by the presence of contaminants
	(d) The water shall not be tainted or contaminated so as to make it unpalatable or unsuitable for consumption by humans after treatment (equivalent to coagulation, filtration, and disinfection), or unsuitable for irrigation
Rule 5a: Natural State Water Quality Standards (apply to sections of rivers within Ruahine or Tararua Forest Park)	5(a) the natural quality of the water shall not be altered. Note: the NS standard does not apply to sections of the Mangahao and Tokomaru Rivers and Mangaore Stream that are downstream of hydroelectricity dams

1.3.5 Conclusions on current policy framework

Issue 1: Lack of clarity between management objectives, policies and supporting information.

The current policy framework contains a number of values/management objectives. However there are not always very clear links between the values and the policies and rules (including standards) intended to protect them. Further, the information that supports the policies is not always clearly identified. This report is part of a process that will allow a clearer link between the values and the policies, and a clearer identification and recording of the technical information and the consultation process which led to the decisions made in the One Plan.

Issue 2: Lack of water quality standards in most of the Region.

Experience has shown that narrative water quality standards as defined in the RMA (Schedule 3) are too general to be of real practical value in the resource consent process. They usually require translation into well defined numerical limits so they can be enforced.

The current policy framework does not define water quality standards outside the Manawatu catchment, causing a lack of clear environmental bottom-line and management goals for the water quality in the Region's waterways.

In the absence of clear, numerical, standards, the assessment of effects in relation to resource consent applications is left to the discretion of the reporting officer. This is dependent on the officer's knowledge and expertise; and may result in a lack of consistency and fairness for the applicant in the way Horizons imposes conditions on discharge permits.

Issue 3: Inadequacy of some of the MCQW standards

Some of the MCWQRP water quality standards have never been monitored (eg. 1.b, 1.c, 3.3c), or are obsolete (2.4e). Some major (nitrogen) or potential (in our Region) contaminants (heavy metals, pesticides) are not covered. Furthermore, Rule 1 and 2 standards apply to all rivers in the catchment. As a result they may not be stringent enough to preserve water quality in some rivers (eg. headwater streams) and/or at some flows, or they are never achieved (and are therefore of limited use) at other flows/rivers.

1.4 The proposed approach

To address the gaps and deficiencies identified in the current plans and policies, it is proposed to develop and implement the following policy framework:

- Define water management zones
- Define the community values associated with the waterbodies
- Define water quality standards
- Identify the waters that meet the standards, and those that don't meet the standards
- Develop water quality management plans to maintain or improve water quality.

1.4.1 Step 1: Define water management zones

Water Management Zones (WMZs) are the fundamental geographic units in the integrated water management regime being developed by Horizons. The spatial framework provided by the WMZs will allow Horizons to implement integrated surface water quantity and quality and catchment management policies at the catchment or sub-catchment scale. The possibility to bring the management of the groundwater resource into this framework is also being explored.

Horizons' desire to make use of this type of spatial framework recognises that different rivers and lakes have different environmental values and resource uses, and have different capacities to yield flow and assimilate contaminants – all of which are controlled by the catchment's physical characteristics and location.

The definition of Water Management Zones is the subject of a separate technical report (McArthur *et al.*, 2007a). The outline of the Region's water management zones and sub-zones is presented in Map 1 and Map 2.

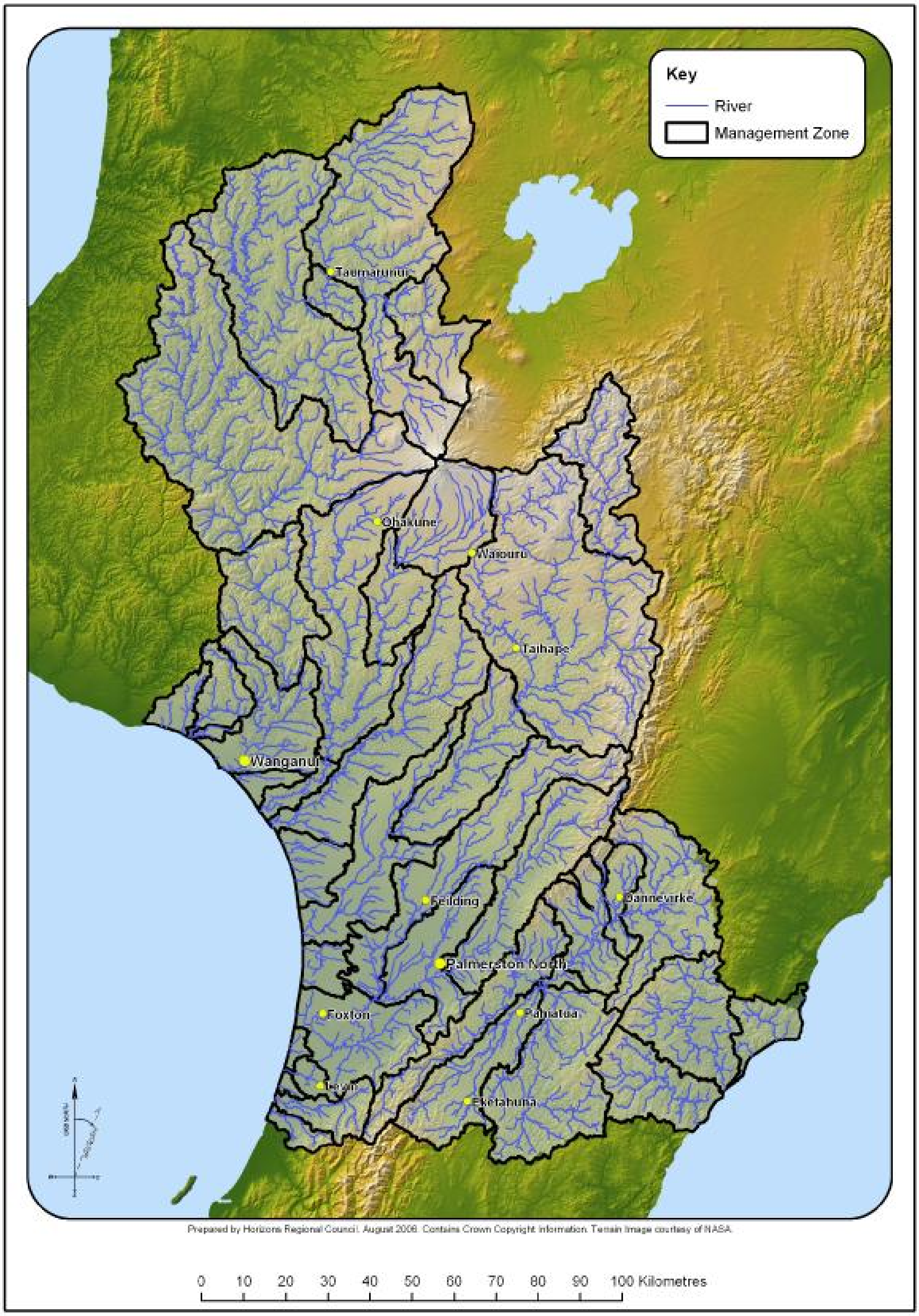
1.4.2 Step 2: Define the values (management objectives) associated with the waterbodies in each zone

The definition of the waterbody values is the subject of a separate technical report (Ausseil and Clark, 2007a, often referenced as the "Values Report" in this document), and the reader is invited to refer to it for further detail. The waterbody values are also summarised in Table 3.

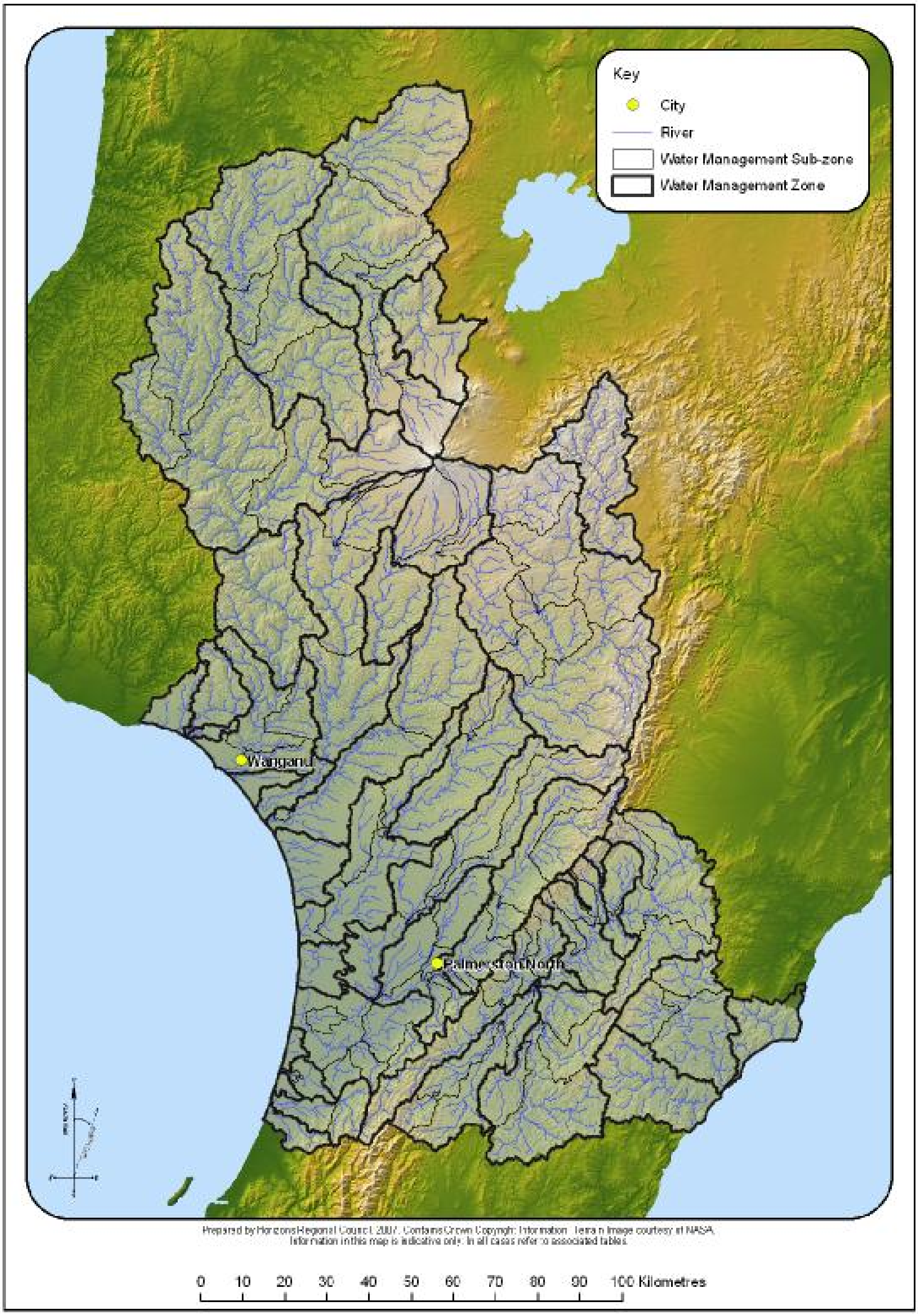
The waterbody values aim at reflecting the community's aspirations for the waterways in our Region. They define what Horizons must look to protect when managing water allocation, water quality and activities on land and in the beds of rivers and lakes. Determination of these values must accurately reflect, via consultation, stakeholder and community aspirations.

A total of 23 different values, applying to all or parts of the Region's rivers and lakes and their margins have been identified, and classed into four groups:

- the Ecosystem Values group includes five individual values recognising the intrinsic value of freshwater and coastal ecosystems for the living communities and natural processes they sustain;
- the Recreational and Cultural Values group includes nine individual values, associated with the spiritual and cultural values and the recreational (ie. non-consumptive or non-commercial) use of the waterbodies;
- the Consumptive Use Values group refers to the value of abstracted surface water in supporting the regional communities (eg. community water supply) and economy (ie. irrigation). It includes four individual values; and
- the Social and Economic Values Group includes 5 individual values identifying that rivers and their margins provide services and uses which support and protect the regional communities and assets.



Map 1: Water Management Zones



Map 2: Water Management Sub-zones

1.4.3 Step 3: Translation of the Community Values into relevant policy and standards

It is anticipated the One Plan will use the community values defined in the Values report (Ausseil and Clark, 2007a) as overarching management goal for the Region's rivers and catchments.
Once defined, the values should be translated into policies that will seek the protection of each value to a satisfactory level. To cover the different aspects of water, river and aquatic biodiversity, policies should be inserted in the relevant One Plan chapter, including:

- the Water chapter to cover both water quality and water allocation,
- the activities in beds of rivers and lakes (BRL) chapter, in relation to the protection of aquatic and riparian habitat,
- the Living Heritage chapter, in relation to both biodiversity and landscape protection
- the Land chapter for catchment management, and
- the Coast chapter.

It is recommended the One plan includes:

- **Standards**, that will define the environmental bottom line beyond which values will be lost or compromised. In other words, the standards will define the bounds within which an activity can occur without compromising the values. They will represent one aspect of the **regulatory** translation of the values into policies. The definition of water quality standards is the subject of this report,
- **Non regulatory methods**, including riparian management in priority catchment, incentives for restoration work, education, support of community initiatives. As any other environmental management agency, Horizons Regional Council has limited resources, and needs to prioritise its activities. It is recommended that the waterbody values and standards are incorporated in the prioritisation process through which Horizons' future environmental management programmes will run.

The clear definition of the values applying to each waterbody (or section of waterbody), and the translation of these values into water quality standards allows much greater transparency and certainty about the management objectives and water quality targets associated with each waterbody. It also enables the tailoring of the water quality standards to the natural characteristics and community expectations specific to each waterbody. As such it represents a significant step forward compared to the current "one size fits all" approach of the Manawatu Catchment Water Quality Regional Plan[1].

The definition of water quality standards in relation to the protection of the different waterbody values is described in sections 2 to 6 of this report.

[1] The main sets of MCWQ standards – General and Contact Recreation - are unique for the whole catchment. The standards recommended for the One Plan are specific to each water management subzone.

1.4.4 List of degraded waters

By comparing the recommended standards to the current state of the water quality, one can identify the waters that :

- clearly meet the standards
- are close to the standards (on either side of the standards)
- clearly do not meet the standards (degraded waters).

The strategic approach to the management of these different categories of waters, particularly the prioritisation of non-regulatory resources and strategies, should be markedly influenced by these results. For example, the waters that meet the standards by only a small margin may be at risk of breaching the standards in the near future, and may require closer monitoring and management. Conversely, waters that only just breach the standards may be able to be restored at lower cost and more quickly than more heavily degraded waters.

Specific methodologies and results relating to the establishment of a list of degraded waters are documented in section 8 of this report.

1.5 Scope of this report

As explained in section 1.1, this report is part of a series of technical reports documenting recommendations for the One Plan's water and catchment management framework. It specifically presents and documents the water quality standards recommended for the protection of the waterbody values defined in the "values report" (Ausseil and Clark 2007). Whilst supporting policy development, this is a technical report, and it does not deal with the definition of actual policies.

The definition of water quality standard is one of the policy streams that give effect to the definition of waterbody values and water management zones. Policies associated with water allocation, activities in the beds of rivers and lakes (BRL) and biodiversity/living heritage are also required to protect the different values. Although it contains some general recommendations, this report does not attempt to cover these aspects, and the reader should refer to the relevant technical reports for detailed recommendations (eg. Maseyk, 2007; McArthur *et al.* 2007b, Hurndell *et al.*, 2007).

The water quality standards defined in this report aim to be based on the best available scientific evidence, monitoring data and expert advice, as documented in this report. In some instances, the current state of the waters is also incorporated in the decision-making process leading to the definition of the standards. The wide peer review panel offers further assurance the standards are at the same time relevant and realistic. This report also presents an assessment of which waterbodies currently meet and do not meet the recommended standards.

This report does not however explore the feasibility of maintaining or restoring the recommended standards. In particular, considerations relating to the costs (both social and economic) and time required are outside the scope of this report.

This report primarily deals with the definition of water quality standards for the Region's freshwater environments. Although some recommendations are made in relation to the protection of the shellfish gathering (SG) and contact recreation (CR) values in coastal waters, not all aspects of the protection of coastal water quality are covered in this report. In particular, due to a lack of supporting data and information, including a coastal ecosystem classification, no water quality standards are defined in relation to the protection of the life-supporting capacity (LSC) value in coastal waters.

2 Protection of the waterbody values by water quality standards.

2.1 Principles and goals

This chapter presents the general principles and methodologies used to define the water quality standards for the protection of the waterbody values. The definition of the actual standards in relation to each value group is documented in sections 3 to 5 of this report.

Protecting water quality through standards and other management tools is only one component of the package required to protect the defined values. Policies associated with water allocation, activities in the beds of rivers and lakes and biodiversity/living heritage are also required to protect the different values. Conversely, not all values require translation into water quality standards. It is recommended only 7 of the 23 proposed values will require direct translation into water quality standards (Table 3). The translation of the remaining values into water quality standards is not recommended, as they are better protected by:

- standards attached to other values, and/or
- policies/rules exerting control over the cause of potential effects (eg. policies relating to the discharge of human effluent in relation to its effects on the Mauri value), and/or
- policies / rules relating to other aspects of aquatic ecosystems (eg. aquatic habitat).

The underlying philosophy guiding the "translation" of values into water quality standards is to represent the environmental bottom line beyond which the value would be compromised, in other words the "good state" of the water in relation to that value.

Wherever possible, the approach taken was to define numerical (as opposed to narrative) water quality standards, to provide greater certainty for all water resource users, the community and the Regional Council.

It is noted none of the Values in the Social / Economic group has recommended water quality standards associated with it. This group of values is therefore not dealt with in this report.

Once water quality standards in relation to each value have been defined, the next step is to define the standards that apply to each waterbody. The process comprises three basic steps:

- identify all the values associated with this particular waterbody;

- compile all the water quality standards recommended for the protection of these values; and
- identify for each water quality parameter the most stringent numerical standard (ie. the standard that will protect all the values associated with the waterbody).

As defined in the Values report (Ausseil and Clark, 2007a), some values apply to whole management sub-zones ("zone-wide values"), and the others are "site-specific values". The set of "zone-wide values" allows the determination of a unique set of water quality standards for each management sub-zone. The standards associated with site-specific values are additional to these.

2.2 Methodology

The general methodology used to define water quality standards that will protect the waterbody values followed four basic steps:

1. Define how the value can be translated in terms of water quality, ie. what aspects of the value:
   - are associated with water quality, or
   - can be protected by water quality standards, or
   - can be compromised by degraded water quality.
2. Define how and when the water is used in relation to this value (eg. CR occurs mostly in summer, while Water Supply occurs year round).
3. Define the water quality parameters relevant to the value (eg. *E. coli* for contact recreation).
4. Define, for each parameter, the numerical level (eg. concentration, count) beyond which the value would be compromised/at which the value is protected to a good level.

These steps are detailed for each value in the following sections of this chapter. For more convenience, the first three steps are summarised in Table 4.

Table 3: Summary of the waterbody values requiring protection by Water Quality Standards.

Value Groups	Values		Translation into Water Quality Standards?	Notes
Ecosystem Values	NS	Natural State	ü	Narrative standard only
	LSC	Life-Supporting Capacity	ü	10 LSC classes. Standards apply to all natural waterbodies
	SOS-A	Sites of Significance-Aquatic		Protected by LSC standards Recommended BRL Policies
	SOS-R	Sites of Significance-Riparian		
	NF	Native Fish Spawning		
Recreational And Cultural Values	CR	Contact recreation	ü	Standards relating to primary and secondary contact recreation and visual use
	A	Amenity	ü	Covered by the CR standards
	SG	Shellfish Gathering	ü	Standards apply to the Coastal marine area
	NF	Native Fishery		Protected by LSC standards
	SOS-C	Sites of significance-Cultural		Some aspects covered by LSC and CR standards. Policies relating to discharges of human sewage and mixing of water bodies are recommended. Site-specific protection may be required once the sites are clearly identified.
	TF	Trout Fishery	ü	3 trout fishery
	TS	Trout Spawning	ü	Site-specific value and standards
	Ae	Aesthetics		Covered by the CR standards
	Mau	Mauri	ü	Some aspects covered by LSC and CR standards. Policies relating to discharges of domestic sewage (ie. narrative standards)
Water Use Values	WS	Water Supply		Awaiting National Environmental Standards
	IA	Industrial Abstraction		Industry specific. General requirement covered by other standards
	I	Irrigation		Crop- specific. General requirement covered by other standards
	HG	Hydroelectricity Generation		General requirement covered by other standards
	S	Stockwater	ü	Standards recommended
Social and Economic Values	CAP	Capacity to Assimilate Pollution		No water quality standards required.
	FC	Flood Control		
	EI	Existing Infrastructure		
	D	Drainage		
	GE	Gravel Extraction		

Table 4: Water quality parameters relevant to each Value. (Note the Natural State value is translated into a narrative standard only – see section 3.1).

Value	Step 1: translate value in water quality	Step 2: Use of water in relation to the value	Step 3: Parameters relevant to the value	
Life-Supporting Capacity (LSC)	The water supports the basic vital functions of plants, invertebrates and fish	Year round	Physico-chemical parameters	pH Dissolved Oxygen Temperature Clarity
			Biological indicators	QMCI Periphyton biomass
	The ecosystem's good health is not compromised by waterborne contaminants potentially toxic to aquatic life or affecting habitat quality	Year round	Nutrients	Nitrogen and Phosphorus
			Deposited sediments	See section 2.3.2.3
			Toxicants	Ammonia Other toxicants
Contact Recreation (CR) and Amenity	The health risk to water users due to waterborne contaminants is acceptable.	Bathing season for primary contact. Year round for secondary contact	Indicators of faecal contamination	E. coli in freshwater Enterococci in marine waters
			Biotoxins	See section 2.3.6
			Physico-chemical parameters	pH
			Toxicants	Toxicants
	The visual/aesthetic values of the water bodies are not compromised	Year round	Unsightly biological growths	Sewage fungus
				Periphyton biomass
				Filamentous algae cover
			Water clarity	Horizontal/vertical visibility (Black/Secchi Disc)
Shellfish Gathering (SG)	The health risk to people eating shellfish is acceptable	Year round	Indicators of faecal contamination	Faecal coliforms
Trout Fishery (TF)	The water supports the basic vital functions of trout	Year round	Physico-chemical parameters	pH Dissolved Oxygen Temperature Clarity
			Biological indicators	QMCI Periphyton Biomass
	The trout fishery is not compromised by waterborne contaminants potentially toxic to aquatic life or affecting habitat quality	Year round	Nutrients	Soluble Inorganic Nitrogen (SIN) and Dissolved Reactive Phosphorus (DRP)
			Deposited sediments	See section 2.3.2.3
			Toxicants	Ammonia Other toxicants
Trout Spawning (TS)	The water supports the vital functions of trout egg and fry	Trout Spawning season	Physico-chemical parameters	Dissolved Oxygen Water Temperature
	The survival of trout egg and fry is not compromised by waterborne contaminants potentially affecting trout spawning habitat quality or toxic to trout egg/fry		Deposited sediments	See section 2.3.2.3
			Toxicants	Ammonia Other toxicants
Stock Water (SW)	The water does not pose unacceptable health risk to livestock drinking it	Year round	Indicators of faecal contamination	Faecal coliforms
			Toxicants	Nitrate and nitrite Other toxicants

2.3 The different water quality parameters

This section introduces the physical, chemical and biological parameters used to define the water quality standards recommended in this report. For each parameter, the following points are detailed:

- definition of the parameter, including its natural variations, ranges, and interactions with other parameters;
- how the parameter relates to/affects the values;
- the type of standard required in relation to this parameter (max, min, etc…), and when the standard should apply; and
- a list of values the parameter is relevant to, ie. a list of values that will require the definition of a water quality standard relating to this parameter.

2.3.1 Physico-chemical parameters

2.3.1.1 Water pH

pH is a measure of water acidity or alkalinity, measured on a scale from 0 (extremely acidic) to 14 (extremely alkaline). Pure distilled water is neutral at pH 7. Most natural freshwater have a pH in the range 6.5 – 8.5, while the pH of most marine waters is close to 8.2.

pH is a major determinant in natural waters, and interacts with (ie. influences and or is influenced by) other major physico-chemical and biological parameters (respiration/photosynthesis rates, water hardness). It also influences the bioavailability, and hence the toxicity of a number of toxicants, including ammonia and heavy metals (ANZECC, 2000).

During the day, the algal production uses CO_2 faster than it can be replaced from the atmosphere, causing the dominant CO_2/HCO_3^- equilibrium[2] to be displaced so that the pH is increased. As a result, the highest pH observed in a river usually occurs during summer low flows conditions, towards the end of the afternoon. It is important to note that these are also the periods of time when the water temperature is likely to be at or near its daily or seasonal maximum.

The range of pH values in marine waters is considerably less than in most fresh waters, typically being 8.0 – 8.3, although this range can be extended in coastal waters with high biological activity (ANZECC, 2000).

In marine and fresh waters, both very acidic or very alkaline pH values can be directly toxic to aquatic life and compromise a number of recreational and water use values. For this reason, the recommended standards for water pH are a range of values (ie. the water pH shall remain within a defined range). The pH standards should apply at all times when the value it seeks to protect applies (ie. year round for LSC and trout spawning season for TS).

Water pH being a major determinant of aquatic ecosystem processes, a major unnatural change may have direct or indirect effect on aquatic communities. A

[2] $HCO_3^- + H^+ \leftrightarrow CO_2 + H_2O$

water quality standard relating to water pH change is therefore recommended (ie. “the water pH shall not be changed by more than…“).

Water pH is directly relevant to the protection of the following values:

- Life-Supporting Capacity (LSC);
- Contact Recreation (CR);
- Trout Fishery (TF); and
- Trout Spawning (TS).

2.3.1.2 Water Temperature

Aquatic ecosystem functioning is very closely regulated by temperature. Biota and physical and chemical processes (eg. oxygen solubility) are sensitive to temperature changes. An organism’s growth, metabolism, reproduction, mobility and migration patterns may all be altered by changes in ambient water temperature (ANZECC, 2000). Water temperature and its variation has a direct influence on the suitability of a habitat for aquatic organisms (Davies-Colley and Wilcock, 2004). Temperature changes occur naturally as part of normal diurnal and seasonal cycles, or as a consequence of human activities. Temperatures typically fluctuate diurnally around a (seasonal) mean, usually with a faster rise to the mid-afternoon maximum temperature than fall to the minimum near dawn (Davies-Colley and Wilcock, 2004).

Excess heat or cold are considered to be forms of thermal pollution. Anthropogenic point sources of thermal pollution can include discharges of relatively warm (eg. industrial cooling water) or cold (bottom water from dams) water. Loss of riparian vegetation, water abstraction and global warming may also lead to temperature increases in streams, representing the non-point source component of thermal pollution.

The effects of excessively high water temperature on fish and aquatic invertebrates found in New Zealand have been relatively well studied and documented (Richardson *et al.* 1994, Cox and Rutherford 2000, Quinn *et al.* 1994). The effects of cold water discharge on aquatic ecosystems have received very little attention from the New Zealand scientific community. Thus, the inclusion of water quality standards to protect aquatic life from the discharge of unnaturally cold water is not recommended at this stage, due to the lack of supporting information.

For these reasons the recommended water temperature standards are based on a maximum daily temperature value (ie. “the water temperature shall not exceed…”), to protect aquatic life from the known effects of too high temperatures.

Water temperature being a major determinant of most fundamental processes of aquatic ecosystems, a major unnatural change in water temperature, even within the tolerance ranges of key species, could cause significant changes in ecosystem processes and communities. A water quality standard relating to water temperature change is therefore recommended (ie. “the water temperature shall not be changed by more than…“).

The temperature standards should apply whenever the value they seek to protect applies (eg. year round for Life-Supporting Capacity, May to September for Trout Spawning).

Water temperature is directly relevant to the protection of the following values:

- Life-Supporting Capacity (LSC);
- Trout Fishery (TF); and
- Trout Spawning (TS).

2.3.1.3 Dissolved oxygen and biochemical oxygen demand

Dissolved oxygen (DO) is essential for aerobic forms of river life, including most plants and animals. As explained by Davies-Colley and Wilcock (2004), the oxygen concentration at any point in time will be a resulting balance between a number of processes:

- Oxygen-consuming respiration by aquatic life (bacteria, plants and animals);
- Oxygen-producing photosynthesis by aquatic plants and cyanobacteria;
- Exchanges between the water and the atmosphere that tend to re-establish equilibrium at “saturation” level (in turn largely dependant on the water temperature). This process (re-aeration) is mostly controlled by the degree of turbulent mixing occurring. Thus, a swift-flowing river is well re-aerated, whereas a sluggish stream has poor uptake of atmospheric oxygen.

The DO concentration in the water is subject to diurnal variations governed by the three processes above, leading to maximum levels (which can be significantly higher than the equilibrium 100% saturation) in mid-afternoon when photosynthesis is at maximum intensity, and minimum levels at dawn (after a whole night of oxygen-consuming respiration, and no photosynthesis).

Low levels of DO can be a major stressor to aquatic life, including fish, invertebrates and micro-organisms, which depend upon oxygen for their efficient functioning. It is also known that many toxic compounds, including heavy metals and ammonia, become increasingly toxic at reduced DO concentrations (EIFAC, 1973; Davis, 1975 in ANZECC, 2000).

The 2000 ANZECC Guidelines define an upper default trigger value of 103% DO saturation for upland rivers, and 105% for lowland rivers. An upper DO limit is relevant as an indicator of potentially excessive primary production (photosynthesis) due to eutrophication. As such, DO concentration above the theoretical saturation is not a direct stressor, but an indicator of potential eutrophication issues. The set of water quality standards recommended in this report addresses the eutrophication issues through biological (periphyton biomass and macroinvertebrate communities) and chemical (nutrient concentration) standards. For this reason, a DO standard based on maximum saturation levels is not recommended in this report.

The quantity of oxygen in the water can be expressed directly as a concentration (eg. mg/L or ppm). However, oxygen solubility is dependent on temperature, and the percentage of saturation is often considered a better, more integrated, impact measure (ie. provides an estimate of oxygen depletion/saturation).

Table 5 provides concentration/saturation correspondence as a function of water temperature.

For the reasons outlined above, the recommended DO standards will be expressed as a minimum % of saturation (ie. the DO saturation shall not be less than…).

Because DO is essential to aquatic life, the recommended DO standards apply :

- at all river flows;
- whenever the value they seeks to protect applies (eg. year round for Life-Supporting Capacity, May to September for Trout Spawning

Table 5: Oxygen saturation (%) as a function of water temperature and dissolved oxygen concentration.

DO concentration (mg/L)	Temperature (°C)													
	5	10	14	18	19	20	21	22	23	24	25	26	28	30
1	8	9	10	11	11	11	11	11	12	12	12	12	13	13
2	16	18	19	21	22	22	22	23	23	24	24	25	26	26
3	23	27	29	32	32	33	34	34	35	36	36	37	38	40
4	31	35	39	42	43	44	45	46	47	48	48	49	51	53
5	39	44	49	53	54	55	56	57	58	59	61	62	64	66
6	47	53	58	63	65	66	67	69	70	71	73	74	77	79
7	55	62	68	74	75	77	79	80	82	83	85	86	89	93
8	63	71	78	85	86	88	90	91	93	95	97	99	102	106
9	70	80	87	95	97	99	101	103	105	107	109	111	115	119
10	78	89	97	106	108	110	112	114	117	119	121	123	128	132
11	86	97	107	116	119	121	123	126	128	131	133	136	141	146

A common cause of undesirable DO depletion is the instream degradation of organic matter by heterotrophic bacteria, as a result of natural processes (eg. decomposition of tree leaves, or algal biomass[3]) or discharges of effluent. The organic load, or strength of an effluent is typically measured by its biochemical oxygen demand (BOD) or chemical oxygen demand (COD).

For this reason, although DO (or rather the lack of it) is the actual stressor, it is recommended to also define BOD standards that will help maintain the DO at satisfactory levels (in the same fashion nutrient standards are defined to control algal growth). Although there is no well defined direct relationship between BOD concentrations in the river and observed DO levels, BOD standards are recommended to facilitate the resource consent process, as BOD is able to be measured directly in the discharges, and maximum daily BOD loads can be defined as consent conditions. BOD measures are also relatively inexpensive compared to continuous DO monitoring.

DO and BOD standards are directly relevant to the protection of the following values:

- Life-Supporting Capacity (LSC);
- Trout Fishery (TF); and
- Trout Spawning (TS).

2.3.2 Parameters relating to water clarity, colour, and sediments

Catchment geology and landforms have a major influence on the type (eg. chemical composition and size distribution) and quantity of solid materials in,

[3] It is noted that severe oxygen depletions caused by the degradation of algal biomass is usually a result of excessive algal growth, in turn often caused by anthropogenic sources of nutrients.

and being transported by, the rivers and streams. The nature and load of solid material exerts fundamental control on channel form and behaviour, and influences the type and diversity of the river ecosystems (Hicks *et al.*, 2004).

Different geologies will lead to different particle size distribution. For example, greywacke will produce gravel of different size, but a relatively small amount of very fine particles, whilst mudstone will comparatively produce much more fine sediment.

While erosion is a natural process, recent deforestation of major parts of river catchments has caused accelerated erosion, particularly in catchments dominated by soft sedimentary rock types. The Life-Supporting Capacity classification accounts for the influence of catchment geology on river morphology and water quality (Ausseil and Clark, 2007b).

While large-sized material will determine river morphology and habitat type, the fine particles will influence water clarity and colour (sediments suspended in the water column) and habitat quality (fine sediment deposited on the riverbed).

Both suspended and deposited fine sediment can have detrimental effects on aquatic life. Sediments suspended in the water column can have detrimental on fish, invertebrates and plants. The effects on fish include disruptions of the migration movements (Richardson *et al.*, 2001), reduction of the sight feeding range (Hay *et al.*, 2006), or direct abrasion of the gills (Wood & Armitage in Hay *et al.*, 2006). Effects on invertebrates include clogging of gills and food catching ability. Suspended sediments also have an effect on photosynthetic depth (depth at which there is enough light to allow plants and algae to grow), thus affecting plant and algal communities.

Sediments deposited on, and in, the riverbed can have a major effect on aquatic micro-habitat quality, particularly by filling the interstitial space between rocks, cobble and gravel, where many invertebrates live (Ryan, 1991). It can also reduce survival and development success of trout egg and larvae by reducing the interstitial flow of water and oxygen concentration. Substantial deposition of sediment can also affect macro-habitat. For example it can reduce water depth, and thus cover for fish, in pools.

2.3.2.1 *Sediments in the water column*

Three parameters are commonly used in relation to the amount of solids suspended in the water column: turbidity, water clarity and total suspended sediments (TSS). Provided a sufficient dataset is available, excellent site-specific, correlations can be drawn between the three parameters. Examples of clarity/turbidity correlations are provided in Appendix 2. For consistency, only one parameter should be used to define water quality standards for the One Plan. The paragraphs below detail the matters considered in making a recommendation.

TSS is a direct measurement of the concentration of the amount of suspended sediments in the water column. As such, it is the best parameter to estimate the sediment loads transported by the waterway. TSS is not measured routinely as part of Horizons' SOE monitoring programme.

Visual clarity (measured as Secchi or black disc visibility) is monitored regularly as part of Horizons SOE programme and NIWA's National Network. The Manawatu Catchment Water Quality Regional Plan defines standards relating to minimum water clarity (1.6 m in recreational waters) and water clarity change (30% change in black disc measurement), and this parameter is often used in resource consent conditions. Black disc visibility is inter-convertible with beam attenuation, a fundamental optical quantity that can be monitored continuously by beam transmissometry (Davies-Colley and Smith, 2001), although it is noted Horizons does not currently own or use continuous transmissometry equipment. Black disc measurement is often considered the best indicator of water clarity in the "clear water" end of the spectrum, down to a clarity of about 0.35 m when using black discs of different size, as recommended by Davies-Colley (1988). Contrary to common perception, black disc measurement is not particularly subjective or imprecise (Davies-Colley and Smith, 2001). However, black disc measurement also has a number of limitations. In particular, physical conditions at the monitoring site can prevent measurement. For example, measurements cannot be made at night or in very small/shallow streams.

Turbidity is an index of light scattering by suspended particles that is widely used in scientific monitoring and research. Turbidity is a better indicator than black disc in the "muddy water" end of the spectrum (when water clarity <0.5 m). It can be measured in a water sample, which means physical conditions at the site (poor light conditions, small streams) do not prevent measurement. It can be measured continuously, and portable equipment allows measurements on the field. Samples can also be taken and analysed in an accredited laboratory, the analysis being rather inexpensive.

In a review of the available scientific literature, Davies-Colley and Smith (2001) have assessed the suitability of the three indicators for use in water quality applications, including environmental standards. The use of TSS is not recommended in the context of water quality values protection, as much of the impact, while sediment remains suspended, is related to its light attenuation, which reduces visual range in water and light availability for photosynthesis. Thus measurement of the optical attributes of suspended matter in many instances is more relevant than measurement of its mass concentration. Turbidity is a widely used, simple, cheap instrumental surrogate for suspended sediments, that also relates more directly than mass concentration to optical effects of suspended matter. However, turbidity is only a relative measure of scattering that has no intrinsic environmental relevance until calibrated to a "proper" scientific quantity. The authors conclude that visual clarity or beam attenuation should supplant Nephlometric turbidity in many water quality applications, including environmental standards.

For these reasons, the following recommendations are made for the One Plan and Horizons monitoring programmes:

- Water clarity is the actual environmental parameter that requires control in relation to the protection of a number of values (LSC, TF, CR). It is therefore the recommended parameter for the definition of water quality standards for the One Plan,
- The protocol for measuring water clarity needs to be fully adhered to (see section 9 for further recommendations on this aspect),

- Monitoring of the three parameters (water clarity, turbidity and TSS) is strongly recommended as part of Horizons' SOE monitoring programme, to allow a refinement of the turbidity/ clarity / TSS correlations.
- In situations where physical conditions prevent the measurement of water clarity, or continuous monitoring is required, turbidity should be used as a surrogate. Statistical relationships (preferably site-specific) between turbidity and clarity will allow comparison with the standard. Thus, if the situation warrants, resource consent conditions could be based on turbidity.

It is noted that a water clarity standard is also recommended in lake waters (vertical visibility of a Secchi disc), although this standard is defined in relation to eutrophication issues rather than erosion/sediment issues (refer to section 3.2.3.7).

2.3.2.2 Change in water clarity or colour

Section 107(1)(d) of the Resource Management Act 1991 (RMA) prohibits the granting of resource consents to activities that are likely to give rise to "any conspicuous change in the colour or visual clarity" of the receiving waters.

Water clarity

Reduction of visual clarity has considerable effects on human perception of recreational waterbodies and their fishability (Davies-Colley and Smith, 2001). A significant change in water clarity may also alter sunlight penetration and be associated with sediment deposition on the riverbed, in turn affecting ecosystem processes and communities.

The Manawatu Catchment Water Quality Regional Plan defines a water quality standard setting a maximum water clarity change of 30%, and resource consents for discharges to water in the Region commonly have conditions relating to change in water clarity. These conditions are relatively simple to understand, monitor and enforce, and are usually considered useful and workable. Problems associated with limitations of the black disc measurement method should be addressed by the recommendations provided in section 2.3.2.1 above.

Based on these considerations, water quality standards relating to changes in water clarity are recommended for the One Plan.

The translation of a "conspicuous change" in water clarity into numerical terms was studied by Davies-Colley and Smith (1990). The results indicate that most people are able to detect a change of 30% in visual clarity. Based on these results, Davies-Colley (1991) and the 2000 ANZECC guidelines recommend that visual clarity should not be reduced by more than 20% to avoid conspicuous change in water clarity.

The recommended approach for the One Plan is to set a maximum clarity change of 20% where protection of water clarity is particularly important (eg. naturally clear waters, presence of sensitive species, highly valued trout fisheries, etc.) and 30% elsewhere.

Water colour

The 2000 ANZECC Guidelines contain recommendations relating to change in water colour caused by an activity, and the Manawatu Catchment Water Quality Plan sets standards relating to acceptable change in hue and euphotic depth. However, these standards were not widely implemented in the Manawatu-Wanganui Region in the SOE monitoring programme or resource consent conditions. At this stage, water quality standards relating to these parameters are not recommended for the One Plan. It is noted that this does not preclude the definition of specific consent conditions in relation to a specific discharge, giving direct effect to section s107(1)(d) of the Act relating to conspicuous change in water clarity or colour.

2.3.2.3 Sediments on the river bed

The amount of fine sediment deposited on the stream or river bed can be evaluated by the level of embeddedness. Embededness is "the degree to which fine sediments surround coarse substrates (gravel, cobbles, etc) on the surface of the streambed" (Sylte and Fischenich, 2002). However, embeddedness measurements are usually considered quite subjective (Phillips and Basher, 2005), in any case too subjective to be of real use in a regulatory framework.

The percentage of fine sediment from a "Wolman pebble count" provides a simple, rapid, quantitative measure for quantifying streambed characteristics and the amount of sediment of the streambed surface. However, setting standards for this parameter would be difficult, due to the natural differences in the percentage of fine sediments in relation to stream slope and geology (Dr John Quinn, pers. comm.).

Another method, the "Quorer" method, measures the amount of re-suspendable (ie. fine) sediment per volume unit of bed material. This method is particularly promising but more work is required to test and validate it before numerical guidelines or standards are defined. In particular, more research in trying to link the levels measured with biological effects is necessary before acceptable/unacceptable levels can be defined. This tool can be used to assess the effect point source discharges (upstream versus downstream measurements), provided the streambed slope is consistent amongst such sites (Dr. John Quinn, pers. comm.).

For all three methods, the relationships between the measures of sedimentation and ecological effects is an area of active research by a number of New Zealand research institutes and universities.

In conclusion, at this stage, no numerical standard can be recommended in relation to the deposition of fine particles on the stream and river beds. However, the Quorer method is considered promising, and further research is strongly recommended to develop this research tool into a robust resource management tool (see section 9).

2.3.3 Parameters related to the trophic status of the waterbody

The trophic status of a waterbody is a general term to represent the degree of organic enrichment of a system. Broad classes of trophic status commonly used are oligotrophic (extremely low level of organic enrichment), mesotrophic and eutrophic (high level of organic enrichment). With higher levels of enrichment, usually as a result of human influence, some systems may become hypertrophic.

Different types of waterbodies have different natural trophic status. For example, upland streams in catchments dominated by nutrient-poor geology (eg. greywacke) are generally naturally oligotrophic, while some lowland systems may be naturally richer, ie. mesotrophic to eutrophic.

A number of human activities, such as point source discharges or nutrient loss from intensively farmed landscape, can modify (generally increase) the trophic status of waterbodies, causing increased primary production by algae, cyanobacteria and plants.

Periphyton is the brown or green slime or filaments coating stones, wood, or any other stable surfaces in streams and rivers. In streams and rivers, periphyton have long been a primary tool for assessing the degree of enrichment and pollution in waterways (Biggs, 2000). In some situations, periphyton can proliferate and form mats of green or brown filaments on the river bed. The proliferation of periphyton can affect a number of waterbody values, including life-supporting capacity, recreational and aesthetic values and trout fishery. As a result, maximum periphyton biomass and/or cover standards are recommended for the protection of the following values:

- Life-Supporting Capacity (LSC);
- Contact Recreation (CR);
- Trout Fishery (TF); and
- Trout Spawning (TS).

In some streams with soft bed material, and some lakes, plant growth is likely to be dominated by macrophytes rather than algae. Excessive macrophyte growth may threaten a number of waterbody values, by for example, slowing down the stream flow, trapping fine sediments, causing oxygen depletion at times. Although some of these effects are documented in the scientific literature, it remains difficult to determine maximum acceptable macrophyte biomass in relation to the protection of river values, and no standards relating to macrophyte biomass are recommended.

A key cause and controlling factor of periphyton, macrophyte and planktonic algae growth is the amount of two major nutrients (nitrogen and phosphorus) available. Nutrient standards are recommended where periphyton and/or planktonic algae biomass standards are recommended. These are detailed in section 6 of this report.

The trophic status of **lakes** is commonly assessed using a combination of four parameters, as recommended in the Protocol for Monitoring New Zealand Lakes and Reservoirs (Burns *et al.* 1999):

- planktonic algal biomass (as mg chlorophyll a/m^3);
- water clarity, measured as the vertical visibility range of a black and white 200 mm disc (Secchi depth); and
- total phosphorus (TP) and total nitrogen (TN) concentration in the water column.

Standards relating to these parameters are relevant to the protection of the Life-Supporting Capacity (LSC) and contact recreation (CR) values in lakes.

2.3.4 Biological Indicators

The composition of the aquatic macroinvertebrate communities can be used as a biomonitoring tool to assess the likely level of ecosystem degradation or enrichment (Stark, 1985). Because they are permanently present in the streams, macroinvertebrate communities are often seen as an excellent integrated indicator of water quality and ecosystem health. For example, “spikes” of contaminants occurring as a result of a discharge or a heavy rain are unlikely to be adequately captured by a monthly sampling programme, whilst the macroinvertebrate communities may show signs of effects. Macroinvertebrate communities can also be a good indicator of the combined effects of several stressors or toxicants (eg. temperature, periphyton growth, sedimentation). Macroinvertebrate communities are commonly used as an indicator of pollution impact, both through time (eg. recovery after an accidental pollution) and space (eg. recovery downstream of a discharge).

As a result, a number of experts have recommended the inclusion of macroinvertebrate communities standards for the protection of several waterbody values, particularly the life-supporting capacity (LSC) and trout fishery (TF) values (Dr. Barry Biggs, Dr. Russell Death and Dr. John Stark, personal communications).

A number of macroinvertebrate communities indices relating to water quality have been developed: the Macroinvertebrate Community Index (MCI) (Stark, 1985), the Quantitative Macroinvertebrate Community Index (QMCI), the semi-quantitative MCI (SQMCI), the percentage of Ephemeroptera, Plecoptera and Trichoptera taxa or individuals, etc… For consistency of approach and simplicity, it is recommended only one index is used in the One Plan.

Whilst experts in the field agree on the fact macroinvertebrate communities should be used to define One Plan standards, there does not seem to be a consensus as to which index should be used:

- Dr. Barry Biggs recommends the use of %ETP taxa, as the index that seem to correlate best with observed organic and sediment enrichment, (Biggs, 2000 and pers. comm.). However, acceptable levels (ie. acceptable scores in relation to the protection of the different values) cannot easily be defined at this stage, and this indicator is not recommended for the One Plan.
- Dr. John Stark, from Cawthron Institute recommends using the MCI in relation to the protection of the TF value (Hay *et al.*, 2006) and the LSC value (pers. comm.).
- Dr. Russell Death recommends using the QMCI, as being the index that seems to best correlate with water quality and habitat degradation in the Horizons Region. Dr. Death’s observations are based on a wealth of specific knowledge of the Region’s streams and rivers. In particular, Dr. Death (through Massey University) has been commissioned to undertake Horizons’ periphyton and macroinvertebrate state of the environment monitoring programme for the last nine years (1999-2007).

Based on the considerations above, the recommended index to define standards for the One Plan is the **QMCI**. It is recommended however that the different macroinvertebrate community indices are calculated and used as part of the SOE monitoring and reporting programme.

It is noted that predictive modelling approaches, in which site data are compared with regionally-relevant reference condition, via a predictive model, and reported using a single index, are particularly relevant to assess ecosystem health (ANZECC, 2000). The predictive modelling approach also offers the advantage of being applicable to all types of ecosystems found in a Region. Massey University has developed such a predictive model (Joy & Death, 2003), and its use was considered for the One Plan. However, the model is still a research tool and further development and validation are needed before the tool can be considered for use in a regulatory framework (Dr. Russell Death, pers. comm.). This has been identified as an area requiring further attention, as detailed in section 9 of this report.

In a study of sites located upstream and at various distances downstream of point source discharges, Quinn and Hickey (1993) identified a relationship between the concentration of particulate organic matter (POM) and deleterious effects on aquatic macroinvertebrate communities. The study was done in relation to discharges of oxidation pond effluents, so the parameter is particularly relevant to this context. POM is considered a useful parameter to control the effects of point source discharges on benthic invertebrate communities (Dr. John Quinn, pers. com.), and is recommended for the set of water quality standards in the One Plan.

Indicators based on fish communities' health have been considered and rejected for inclusion in the set of recommended standards, as too many factors (habitat quality, barriers to migration, introduced predators) may have a greater influence on fish communities than water quality. It is recommended however that indicators based on fish communities (diversity, presence of indicator/sensitive species) are used in Horizons' state of the environment monitoring and reporting programmes, as well as in monitoring programmes associated with site restoration programmes (eg. indicators of restoration success).

It is noted that macroinvertebrates and fish are representative of the ecosystem they live in, and are often used as indicator organisms to determine environmental limits for parameters such as water temperature, dissolved oxygen and pH. In other words, it is often assumed that if the water quality requirements of representative organisms such as fish and invertebrates are met, the conditions should be satisfactory for the rest of the living communities.

2.3.5 Toxicants

2.3.5.1 Ammonia

Ammonia can be toxic to many aquatic species, and is a common pollutant in many treated agricultural, domestic and industrial discharges. Ammonia is a toxicant but also a nutrient (part of SIN). This paragraph deals only with ammonia as a toxicant.

When in solution in the water, ammonia occurs under two main chemical forms: the ammonium cation (NH_4^+) and unionised ammonia (NH_3). The respective proportion of these two forms is determined by a chemical equilibrium governed by pH and temperature. The higher the pH and temperature, the higher the proportion of unionised ammonia. Unionised ammonia being much more toxic to aquatic life, the toxicity of total ammonia (being the sum of unionised and ionised forms) increases with pH and/or temperature.

Ammonia being a very common contaminant, a standard setting maximum acceptable concentrations of ammonia is recommended for the One Plan. In setting ammonia standards, the pH and temperature dependency of ammonia toxicity must be carefully considered.

It is noted the 1999 USEPA update on ammonia criteria defines acute and chronic criterion. To adequately protect aquatic life, the USEPA recommends the one-hour average total ammonia nitrogen does not exceed the acute criterion, and the thirty-day average concentration does not exceed the chronic criterion more than once every three year (USEPA 1999). This option was considered, but judged impractical given the frequency sampling of SOE monitoring (monthly) and most compliance monitoring programmes (weekly to quarterly). The option judged most practical, and recommended for the One Plan, is to set a unique water quality standard based on chronic exposure effects.

2.3.5.2 Other toxicants

A very large number of other **toxicants** are potentially found in the environment, and listing them and defining a numerical water quality standard for each of them is outside the scope of this report. The 2000 ANZECC Guidelines provide an extensive list of relevant parameters and numerical acceptable limits.

Ammonia (as a toxicant) and other toxicants are relevant to the following values (Table 4):

- Life Supporting Capacity (LSC);
- Trout Fisheries (TF); and
- Trout Spawning (TS).

2.3.6 Parameters related to human and livestock health.

Water contaminated by human or animal faecal material or containing toxins can pose a health risk to recreational users of the water. The risk of illness to water users can be due to the presence of toxins (eg. biotoxins produced by blue-green algae) or pathogenic (ie. that can cause illness) organisms (eg. bacteria, viruses, protozoa).

However, there is an immense variety of pathogens, and it would be difficult and impractical to measure them all, or even the most common (MfE, 2002). Rather, the level of health risk associated with faecal contamination is generally assessed with bacteriological indicators. These bacteria (eg. *Escherichia coli*), or bacteria types (faecal coliforms), are generally not pathogenic (ie. will generally not cause illness), but are indicative of the potential presence of actual pathogens (eg. campylobacter).

The better indicator (ie. the indicator that correlates best with the presence of actual pathogens) depends on the media (freshwater, marine waters, industrial wastewater), the source of contamination (diffuse/animal dominated, treated sewage, treated industrial wastewater) and the use of the waterbody (drinking water, contact recreation, shellfish gathering).

For recreational waters, the 2002 MfE guidelines recommend the use of the following indicator bacteria to assess the level of faecal contamination and associated health risk to water users:

- *Escherichia coli*, commonly called ***E. coli***, is a bacteria species that lives exclusively in the gut of warm-blooded animals (mammals and birds). It is the recommended indicator organism for **freshwaters**[4];
- **Enterococci** have been identified as having the best relationship with health effects in **marine** waters, in relation to contact recreation use of the waterbody[5];
- **Faecal coliforms** is the recommended indicator in relation to the health risk to people **gathering** (and eating) **shellfish** form the waterbody.

Faecal coliforms is also the recommended indicator in relation to the health risk to livestock drinking water (ANZECC, 2000).

Cyanobacteria (blue-green algae) are a common and naturally occurring component of most aquatic ecosystems. They can occur singly or grouped in colonies and can increase to such large numbers that they colour the water (a "bloom") and form highly visible thick scums (NHMRC, 2005). Cyanobacteria are of public health concern because some types produce toxins that have harmful effects on tissues, cells or organisms. The identification of the toxicity of waters is rendered very difficult by a number of factors:

- a number of cyanobacteria species can potentially produce toxins;
- at least eight cyanotoxins belonging to three groups have been identified (NHMRC, 2005). Testing is relatively time consuming and expensive, making the routine monitoring of all these toxins largely impractical;
- the production of cyanotoxins is unpredictable, and there seems to be no direct relationship between the cell density in the water and the concentration of toxins; and
- the occurrence of cyanobacteria blooms is relatively unpredictable, and it is generally difficult to identify a direct cause.

For these reasons, it is considered that water quality standards are not the best tool to manage the public health risk associated with cyanotoxins, and no water quality standards are recommended in relation to cyanobacteria cell density or cyanotoxin concentration. Rather, it is recommended that a proper management framework and associated monitoring programme are developed and implemented (see section 9 of this report).

[4] Although there may be exceptions, eg. in close proximity to large waste stabilisation pond outfalls (MfE 2002).

[5] Enterococci may also be derived from other than faecal sources in some conditions, such as warm temperatures and mangrove swamps or freshwater runoff from dense vegetation (MfE 2002). High numbers of Enterococci have also been identified in some warm industrial waste streams.

3 Definition of water quality standards in relation to the Ecosystem Values

The "Ecosystem Values" group recognises the intrinsic value of freshwater and coastal ecosystems for the living communities and natural processes they sustain. It contains five individual values:

- Natural State (NS);
- Life-Supporting Capacity (LSC);
- Sites of Significance – Aquatic (SoS-A);
- Sites of Significance – Riparian (SoS-R); and
- Native Fish Spawning.

Due to difficulties in adequately defining the natural state of each river and stream associated with this value, it is recommended the NS value is protected by a narrative standard, as described in section 3.1 of this report.

Numerical standards in relation to each parameter relevant to the LSC value defined in Table 4 are defined in section 3.2. These standards aim at providing for the water quality requirements of the native aquatic species found in each LSC category.

The protection of the other three values (SOS-A, SOS-R and NFS) requires to provide for both the water quality and the aquatic/riparian habitat requirements of the species relevant to these values. As explained above, the water quality standards associated with the LSC value aim at providing for the requirements of aquatic species, thus covering the need to translate these values into specific water quality standards. Water quality standards specifically associated with the SOS-A, SOS-R and NFS values are not developed in this report, as they would be similar to the LSC standards. It is noted the specific requirements of aquatic species relating to aquatic and riparian habitat should be addressed by specific policies relating, for example, to activities in the beds of rivers and lakes. Recommendations are detailed in a separate technical report (McArthur *et al.*, 2007b).

3.1 Definition of water quality standards in relation to the Natural State value

The Natural State (NS) value is defined as follows: "The waterbody is maintained in its natural state". This value applies where the water is currently at or near natural state, ie. within National and Forest Park boundaries.

Section 63(3) of the Act prohibits the setting of standards in a plan which result or may result in a reduction of the quality of the water in any waters at the time of the public notification.

Some data is available immediately downstream of Forest and National Park, providing some indication of the natural water quality of some streams. However, defining numerical water quality standards in relation to the NS value would require to be able to perfectly characterise the natural state of the water in each stream.

For this reason, it is not recommended that an attempt be made to define numerical water quality standards in relation to the NS value.

Instead, the **narrative standard** defined in the Third Schedule of the Act is recommended for the One Plan: "**The natural quality of the water shall not be altered**".

As a direct consequence, in the case of an activity (eg. discharge, abstraction), the onus will on the Applicant to define what the natural state of the water is and prove the activity does not alter it.

It is important to note that the Natural State value and associated narrative standard is an additional protection coming on top of the standards associated with the Life-Supporting Capacity value.

3.2 Definition of water quality standards in relation to the Life-Supporting Capacity value

3.2.1 Guiding principle

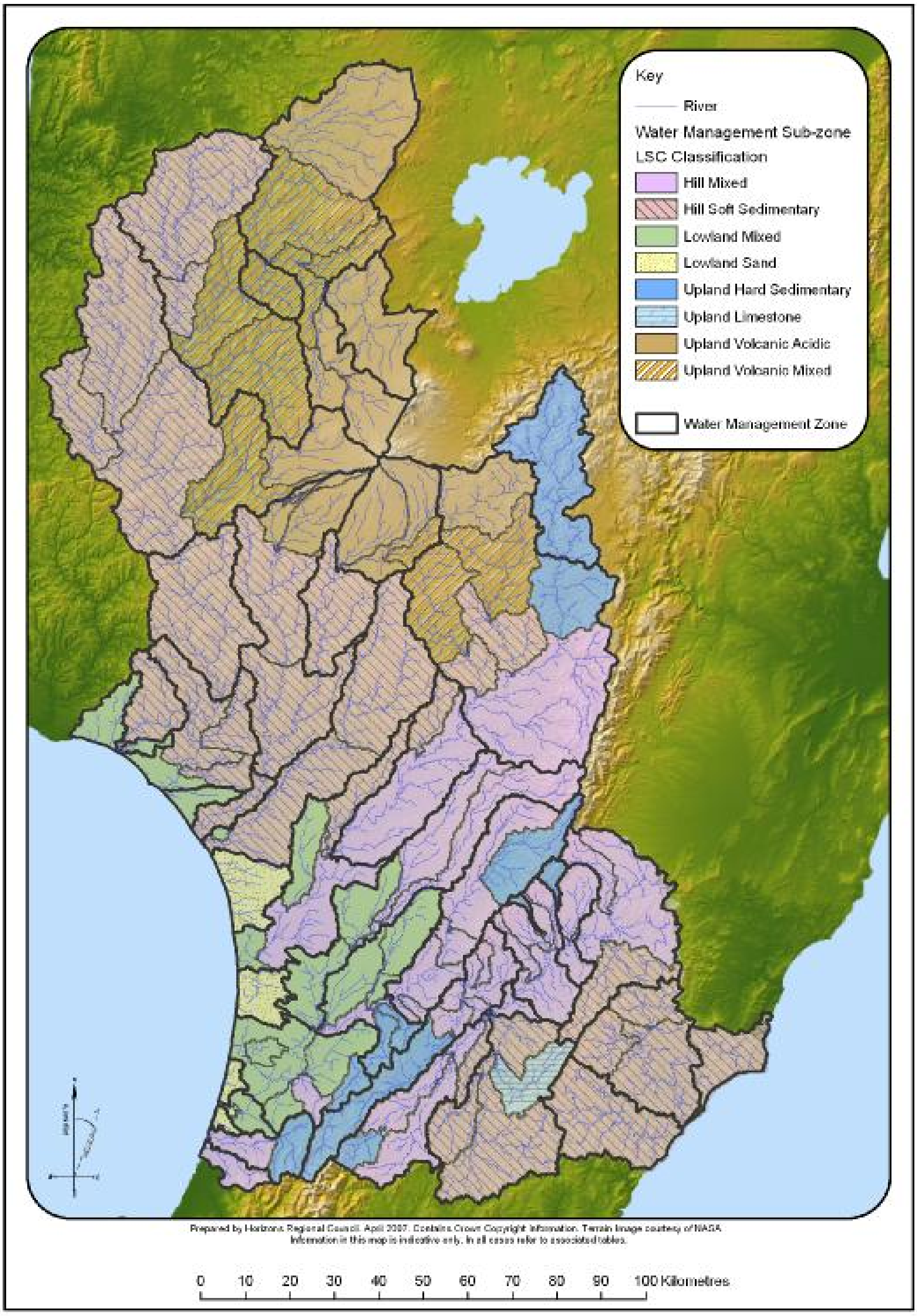
The Life-Supporting Capacity (LSC) value has a management goal of: "the waterbody supports healthy aquatic life/ecosystems" (Ausseil and Clark, 2007a). This value specifically recognises the water quality requirements of native aquatic ecosystems, including, but not restricted to, fish and aquatic macroinvertebrates. Most importantly, this value seeks to safeguard the life-supporting capacity of the waterbodies to a satisfactory (ie. healthy) level. It is not intended to support a return to a pristine or natural state.

As a consequence, the proposed water quality standards associated with the LSC category aim to represent a healthy ecosystem. In other words they aim to represent the environmental benchmark, or bottom-line, against which ecosystem health will be assessed.

Ten categories of aquatic ecosystems have been defined, including eight riverine freshwater categories, one for freshwater lakes and one for coastal marine waters (Ausseil and Clark, 2006b) (Map 3 and Table 6).

It is noted that the 2000 ANZECC guidelines recommend assigning one of three levels of protection when considering the management of aquatic ecosystems: high conservation/ecological value ecosystems; slightly to moderately modified ecosystems; and highly modified ecosystems. Whilst it is recognised some systems are currently highly modified, maintaining them in a degraded state is contrary to the purpose of the LSC value as defined above. Generally, the LSC value as defined above corresponds to either high ecological value ecosystems or slightly to moderately modified ecosystems.

No water quality standards are defined in relation to the protection of the life-supporting capacity (LSC) value in coastal waters. It was considered that more supporting monitoring data, information and research, including a marine and coastal ecosystem classification, were necessary steps before water quality standards could be defined (see section 9 of this report).



Map 3: Life Supporting Capacity Classification in the Manawatu-Wanganui Region.

Table 6: Description and typical examples of the different LSC freshwater river classes, adapted from (Ausseil and Clark, 2007b).

WMZ class	Source of flow	Geology	Typical river type	Examples
Lowland Sand (LS)	Lowland	Windblown sand dominant.	Western coastal streams. A large proportion of these streams flow either into or out of coastal lakes.	West coast zones.
Lowland Mixed (LM)	Lowland	No dominant geology, generally a mix of sand, loess, alluvium and soft sedimentary.	Medium to slow flowing streams/rivers. Bed material a mix of gravel and soft sediments.	Mangaone Stream, lower Manawatu and lower Rangitikei.
Hill Mixed (HM)	Predominantly Hill	Hill country zones with no dominant geology class. Geology is generally a mix of alluvium, SS, HS and loess.	Typically rivers with a gravel/cobble bed, receiving base flow from the Tararua or Ruahine Ranges, but also influenced by soft sedimentary geology, impacting on water clarity/bed siltation.	Upper and middle Manawatu, Pohangina, Mangatainoka, Middle Rangitikei and some tributaries.
Upland Hard Sedimentary (UHS)	Predominantly Hill with some Mountain	Predominantly greywacke.	Typically streams flowing from the Tararua and Ruahine Ranges.	Tamaki, Turitea, Kahuterawa, Mangahao, upper zones of the Rangitikei, Mangatainoka, Pohangina and Oroua.
Upland Limestone (UL)	Hill	Predominantly limestone.	Streams flowing off parts of the Puketoi Range.	Makuri River
Upland Volcanic Acidic (UVA)	Predominantly Mountain with some Hill	Volcanic acidic soils (ash, pumice) over mostly hard sedimentary (greywacke) or hard volcanic rocks (ignimbrite, lavas).	Rivers flowing off the Ruapehu/Tongariro area, Kaimanawa and Hauhungaroa Ranges. Typically cold, clear, fast flowing rivers on rock/boulder/cobble bed.	Upper zones of: Moawhango, Whangaehu, Mangawhero, Manganui o Te Ao, Whanganui, Whakapapa and Ongarue.
Upland Volcanic Mixed (UVM)	Predominantly Hill with some Mountain	Volcanic acidic soils (ash, pumice) over mostly soft sedimentary (sandstones, mudstones).	Rivers flowing off the Central Plateau area. Often transitions zones between UVA and HSS zones.	Upper Hautapu, lower Manganui O Te Ao, lower Ongarue, Retaruke, and Whanganui to the confluence with the Retaruke.
Hill Soft Sedimentary (HSS)	Hill	Predominantly soft sedimentary	Zones dominated by soft sedimentary geology.	East coast rivers, Tiraumea, Turakina, middle and lower Whangaehu, and middle and lower Whanganui and tributaries.

3.2.2 Methodology

To define water quality standards in relation to the protection of the Life-Supporting Capacity value, three methods were used, in the following order of priority:

- When known from available scientific literature, the water quality requirements of key species (eg. native fish, invertebrates) representative of the ecosystem type can be used to derive water quality standards. This method allows a direct link between the numerical water quality standards and their primary purpose, the protection of aquatic biota. Massey University's Institute of Natural Resources was commissioned to compile the fish and invertebrate species occurring in each LSC class, and some of their water quality requirements (Death, 2006). However, only a very limited number of scientific studies provide information relevant to New Zealand species. Further, the significance of some studies is limited by the fact that they relate to short-term, small scale experiments, and are unable to reliably represent the effects of long-term exposure or inter-species interactions. Table 7 summarises the known water quality requirements of aquatic biota occurring in each LSC class.
- When available, the data collected at reference (undisturbed or slightly disturbed) sites can also be used to estimate the natural range of relevant water quality parameters. This method has the advantage of using actual, site-specific data. It was used to determine some water quality standards and/or to validate the results of the method above. This approach is consistent with the recommendations of the ANZECC Guidelines to determine trigger values for physical and chemical stressors: "*Where there is insufficient information on ecological effects to determine an acceptable change from the reference condition, use an appropriate percentile of the reference data distribution to derive the trigger value*" (ANZECC, 2000). The sites where water quality and flow data are available are shown in Appendix 1.
- National or international guidelines and standards are based on the requirements of a wide range of species (plants, invertebrates, vertebrates) living in a wide range of ecosystems. Provided appropriate consideration is given to the transferability of such results to the Manawatu-Wanganui Region's ecosystems, these guidelines can provide an excellent tool to define or support water quality standards. They also constitute the best fall-back position when there is not sufficient information to use any of the two methods above.

The final choice of the most appropriate method, or mix of methods, was based on availability and quality of data. As a consequence it varied with the river or lake class and/or the water quality parameter considered, and is justified on a case by case basis in the relevant paragraph. Wherever possible, the results of all three methods outlined above were reported and used to cross-validate the standards recommended in this report.

It is important to note the approach outlined above is very consistent with the recommendations of the 2000 ANZECC guidelines: to determine appropriate trigger values for physical and chemical stressors and toxicants for the protection of aquatic ecosystems, the Guidelines recommend to follow the

order: "*use of biological effects data, then local reference data, and finally (least preferred) the tables of default values provided in the Guidelines*".
Water quality parameters that were judged to be relevant to the LSC value are summarised in Table 4.

Instream nutrients concentrations are relevant to the protection of the LSC category in rivers as a controlling factor of periphyton growth (a biological stressor). However, the determination of water quality standards relating to nutrient concentrations in rivers is also a scientifically complex issue, and is the subject of a separate section of this report (section 6).Water quality requirements of aquatic biota relevant to the LSC value
A large number of invertebrate and fish species are known to occur in the Region's waterbodies (Death, 2006). However, only a relatively small number of these species have been studied for their water quality requirements. Table 7 summarises the information available in the scientific literature. The table also includes information relating to the occurrence of each species in the different classes, both actual (ie. known from data) and potential (ie. extrapolated from the habitat preference and migratory habits of each species). As an example, banded kokopu is currently known from only a very limited number of sites in the Region. Whilst the reasons for its demise remain unproven, a combination of factors, including the removal of riparian habitat, degraded water quality and instream habitat, are likely to be involved. In a more favourable context, this species would be expected in most lowland and low to moderate elevation hill country streams (Dr. Russell Death, pers. comm.).

Table 7: Temperature, dissolved oxygen, pH and water clarity/turbidity requirements of aquatic biota known to occur in the different life-supporting capacity (LSC) classes of waterbodies. Temp: temperature; DO: dissolved oxygen; LT_{50} : Lethal Temperature 50%; CTM: Critical Thermal Temperature.

Biota			Found in LSC classes	Estimated natural occurrence in LSC classes	Parameter	Value	Effect	Reference
	Bullies (Eleotridae)	common bully (*Gobiomorphus cotidianus*)	UHS, HM, HSS, LM,	All	Temp (ºC)	32.7 to 34.0	CTM	Simons, 1984
						30.9	96h LT_{50}	Richardson *et al.*, 1994
						20.2	Preferred Temp	
					pH	6.2 - 10.1	Preferred range (adult)	West *et al.*, 1997
						6.1 – 10.6	Preferred range (juv.)	
					Turbidity	160 NTU	Reduction in feeding rate	Rowe and Dean, 1998
					DO	0.91 mg/L at 15 ºC	48h LC_{50}	Landman *et al.*, 2005
		cran's bully	UHS, UVA, UVM, HM, HSS, LM	All	Temp (ºC)	32.3 to 33.9	CTM	Simons, 1984
						30.9	96h LT_{50}	Richardson *et al.*, 1994
						21	Preferred Temp	
		upland bully	UHS, UVA, UVM, HM, HSS, LM	All but LS	Temp (ºC)	32.8	CTM	Teale, 1986 in Richardson *et al.*, 1994
		redfin bully	UHS, HM, HSS, LM	All but LS	pH	6.1 – 10.4	Preferred range	West *et al.*, 1997
	Mugiloididae	torrentfish	UHS, UVM HM, HSS, LM	All but LS and lakes	Temp (ºC)	30	LT_{50}	Richardson *et al.*, 1994
						21.8	Preferred T	
	Galaxids (Galaxiidae)	Inanga (*Galaxias maculatus*)	UHS, UVM, HSS, LM, LS	UHS, UVM, HSS, LM, LS	Temp (ºC)	31.7 to 35.4	CTM (juvenile)	Simons, 1986
						30.8	LT_{50} (adult)	Richardson *et al.*, 1994
						18.8	Preferred T (whitebait)	
						18.7	Preferred T (juvenile)	
						18.1	Preferred T (adult)	
					pH	5.2 – 10.9	Preferred range (adult)	West *et al.*, 1997
						5.9 to 9.7	Preferred range (juvenile)	
					DO	1 mg/l at 15 ºC (10% sat)	36h LC_{50}	Dean & Richardson, 1999
						2.65 mg/L at 15ºC	48h LC_{50} (whitebait)	Landman *et al.*, 2005
					Turbidity	640 NTU	Reduction in feeding rate	Rowe and Dean, 1998
						420 NTU	Avoidance response	Boubée *et al.*, 1997
		banded kokopu	LM	LM, LS, HM, HSS,	Temp	30.6 to 34.0	CTM (whitebait)	Simons, 1986

Biota			Found in LSC classes	Estimated natural occurrence in LSC classes	Parameter	Value	Effect	Reference
		(*Galaxias fasciatus*)		UHS, Lakes	(ºC)	29.0	LT_{50}	Main, 1988 in Richardson *et al.*, 1994
						30.0	CTM	
						16.1	Preferred Temp (whitebait)	Richardson *et al.*, 1994
						17.3	Preferred Temp (adult)	
					pH	5.9 – 10.9	Preferred range (juvenile)	West *et al.* 1997
					Turbidity	20 NTU	Reduction in feeding rate	Rowe and Dean, 1998
						25 NTU	Modification of migration direction and rate	Richardson *et al.*, 2001
						17 NTU	Avoidance response	Boubée *et al.*, 1997
		shortjaw kokopu (galaxias	UHS, UVM, HM, HSS, LM	All	Temp (ºC)	30	CTM	Main, 1988 in Richardson *et al.*, 1994
						29	LT_{50}	
					pH	6.6 – 10.4	Preferred range (juvenile.)	West *et al.* 1997
Fish		koaro (*Galaxias brevipinnis*)	UHS, UVA, HM, LM	All	Temp (ºC)	28	CTM	Main, 1988 in Richardson *et al.*, 1994
						27	LT_{50}	
					pH	5.7 – 10.7	Preferred range (juvenile)	West *et al.* ,1997
					Turbidity	70 NTU	Avoidance response	Boubée *et al.*, 1997
	Retropinnidae	smelt (*Retropinna retropinna*)	LS	LM, LS, HM, HSS, Lakes	Temp (ºC)	31.8 to 33.4	CTM	Simons, 1984
						28.3 to 31.9	LT_{50}	Richardson *et al.*, 1994
						16.1	Preferred T	Richardson *et al.*, 1994
					pH	7.2 – 9.8	Preferred range	West *et al.*, 1997
					DO	1.83 mg/L at 15 ºC	48h LC_{50}	Landman *et al.*, 2005
	Eels (Anguillidae)	longfin eel	All	All	Temp (ºC)	25	LT_{50} (elvers)	Jellyman, 1974 in Richardson *et al.*, 1994
						34.8	LT_{50} (elvers)	Richardson *et al.*, 1994
						24.4	Preferred Temp (elver)	
						37.3	LT_{50} (adult)	
					pH	5.6 – 10.3	Preferred range (elvers)	West *et al.*, 1997
		shortfin eel (*Anguilla australis*)	All	All	Temp (ºC)	28	LT_{50} (glass eel)	Jellyman, 1974 in Richardson *et al.*, 1994
						30.5 to 38.1	CTM (elver)	Simmons, 1986
						35.7	LT_{50} (elver)	Richardson *et al.*, 1994
						39.7	LT_{50} (adult)	
						26.9	Preferred Temp (elver)	
					pH	3.3 – 9.8	Preferred range (elver)	West *et al.*, 1997

Biota			Found in LSC classes	Estimated natural occurrence in LSC classes	Parameter	Value	Effect	Reference
					DO	0.54 mg/L at 15 ºC	48h LC_{50} (elvers)	Landman *et al.*, 2005
Crustaceans	Decapods	koura (*Paranephrops planifrons*)	UHS, UVA, UVM, HM, HSS, LM,	All	DO	0.77 mg/L at 15 ºC	48h LC_{50}	Landman *et al.*, 2005
		freshwater shrimp *(Paratya curvirostris)*	HM, LM, LS	HM, LM, LS, HSS	Temp (ºC)	25.7	96h LT_{50}	Quinn *et al.*, 1994
					DO	0.82 mg/L at 15 ºC	48h LC_{50}	Landman *et al.*, 2005
	Amphipods	*Paracalliope fluviatilis*	UHS, HM, HSS, LM, LM, LS		Temp (ºC)	24.1	96h LT_{50}	Quinn *et al.*, 1994
Insects	Stoneflies (*Plecoptera*)	stoneflies	UHS, UVA, UVM, HM	UHS, UVA, UVM, HM, HSS	Temp (ºC)	19	Maximum temperature for presence (88 rivers field observations)	Quinn and Hickey, 1990
		Zelandobius sp.	UVA, HM	UHS, UVA, UVM, HM, HSS	Temp (ºC)	25.5	48h LT_{50}	Quinn *et al.*, 1994
	Mayflies (*Ephemeroptera*)	*Ephemeroptera*	All	All	Temp (ºC)	21.5	Decrease in Ephemeroptera biomass (88 rivers field observations)	Quinn and Hickey, 1990
		Deleatidium sp.	UHS, UVA, UVM, HM, HSS, LM, LS	All	Temp (ºC)	22.6	96h LT_{50}	Quinn *et al.*, 1994
						24.2	96h LT_{50} (constant T)	Cox and Rutherford, 2000
						21.9	96h LT_{50} (daily mean)	
						26.9	96h LT_{50} (daily max)	
		Zephlebia sp.	UHS, UVA, UVM, HM, HSS	All	Temp (ºC)	23.6	96h LT_{50}	Quinn *et al.*, 1994
	Caddisflies (*Trichoptera*)	*Aoteapsyche sp.*	UHS, UVA, UVM, ULi, HM, HSS, LM	All	Temp (ºC)	25.9	96h LT_{50}	Quinn *et al.*, 1994
		Pycnocentrodes sp.	UHS, UVA, UVM, ULi, HM, HSS, LM	All	Temp (ºC)	32.4	96h LT_{50}	Quinn *et al.*, 1994

Biota			Found in LSC classes	Estimated natural occurrence in LSC classes	Parameter	Value	Effect	Reference
		Pycnocentria sp.	UVA, UVM, HM, HSS, LM	All	Temp (ºC)	25	96h LT_{50}	Quinn *et al.*, 1994
	Beetles (*Coleoptera*)	Elmidae (*Hydora sp.*)	UHS, UVA, UVM, ULi, HM, HSS, LS		Temp (ºC)	32.6	96h LT_{50}	Quinn *et al.*, 1994
Other invertebrates	Worms (Oligochaetea)	*Lumbriculus variegatus*	UHS, UVA, ULi, HM, LM		Temp (ºC)	26.7	96h LT_{50}	Quinn *et al.*, 1994
	Mollusca	Freshwater fingernail clam *(Sphaerium sp.)*		All	Temp (ºC)	30.5	96h LT_{50}	Quinn *et al.*, 1994
	Snails (Gastropoda)	*Potamopyrgus antipodarum*	UVA, ULi, UVM, HSS, LM, LM	All	Temp (ºC)	32.4	96h LT_{50}	Quinn *et al.*, 1994
						31	96h LT_{50} (constant Temp)	Cox and Rutherford, 2000
						28.6	96h LT_{50} (daily mean)	
						33.6	96h LT_{50} (daily max)	

3.2.3 Recommended water quality standards for protection of the LSC value.

3.2.3.1 Water pH

As explained in section 2.3.1.1 of this report, the recommended pH standards should be a pH range, ie. defining both a daily maximum and a daily minimum, applying at all times.

Changes of pH can be a direct stressor to aquatic biota. As a result, the pH standard should provide for the requirements of representative aquatic biota. However, background information on the effects of pH changes on New Zealand aquatic biota is scant. One publication indicates a pH range of 7 to 9.5 should not be toxic to most New Zealand fish species (West *et al.*, 1997). This short-term study does not however include the potential long-term effects of pH change, nor does it not account for the effects of pH on the toxicity of other parameters, eg. ammonia and heavy metals.

The information on biota requirement is considered insufficient to confidently derive water quality standards. As explained in section 3.2.2, the use of reference data is the next preferred approach. The ANZECC guidelines also provide some trigger values for upland and lowland rivers.

Table 8 summarises the data collected as part of Horizons' monitoring programmes and NIWA's national network programme, the pH ranges recommended in the 2000 ANZECC Guidelines for upland and lowland rivers, as well as the pH range standards recommended for each LSC class for the One Plan (LSC classes are described in Table 6).

UHS class
The 2000 ANZECC guidelines for upland rivers is a pH range of 7.3 to 8.0. However, the reference data available indicates natural pH range of 6.7 to 8.2 for UHS rivers, based on 95th percentile of the data. The reference data represents the natural pH for these classes of water, and was used to define the water quality standards. It is noted that this approach (ie. the use of reference data) is consistent with the ANZECC guidelines recommendations. **The recommended water pH standard for UHS waters is a range of 6.7 to 8.2.**

UVA class
The 2000 ANZECC guidelines for upland rivers is a pH range of 7.3 to 8.0. However, the reference data available indicates natural pH range of 7 to 8.2 for UVA rivers, based on 95th percentile of the data. The reference data represents the natural pH for these classes of water, and was used to define the water quality standards. It is noted that this approach (ie. the use of reference data) is consistent with the ANZECC guidelines recommendations. **The recommended water pH standard for UVA waters is a range of 7 to 8.2.** It is recommended that . the Whangaehu River mainstem is excluded from this standard due to the natural influence of Mt Ruapehu's crater lake on the river's pH.

UVM, HSS, and HM classes
These classes are considered upland rivers under the ANZECC criteria (>150m in elevation). The ANZECC guidelines for upland rivers is a pH range

of 7.3 to 8.0. Although there is only limited reference or slightly modified systems data available for waters in these classes (one site in UVM and 2 in HM), it indicates the ANZECC trigger values may not adequately represent the natural pH range for these classes of waters.

The data collected at reference and slightly disturbed sites provide some indication of the natural pH range of rivers and streams in each of these classes, but the data is insufficient to confidently recommend a different pH standard for each class. When considered together, the data collected at reference and slightly disturbed sites indicates the natural pH range of waters in all three classes is within the range 7 to 8.5. It is noted this pH range is consistent with what is known of the requirements of aquatic biota living in these LSC classes.

In the absence of sufficient reference data, it is recommended to define the standard as a relatively wide pH range, encompassing the reference data for all three classes. **A pH range standard of 7 to 8.5 is therefore recommended.**

It is noted this standard may need to be refined in the future, if results of monitoring undertaken at reference sites indicate a different natural range of pH.

It is also noted that a number of sites have pH occasionally outside this range., but these sites[6] are known to be impacted by point source and/or non-point source pollution. As explained in section 2.3.1.1, occurrences of high pH during daytime may be caused by accelerated primary production (photosynthesis).

ULi class
Only one site (Makuri River at Tuscan Hills) is monitored in this LSC class. Data indicates the water quality at this site may be moderately impacted (nutrient levels in particular are relatively elevated), so it cannot be used as reference data. Rivers in limestone catchments are known to have slightly alkaline pH. Until reference data is available, and/or further investigation is conducted, **a pH range standard of 7 to 8.5 is recommended** for consistency with the other moderate elevation (hill country classes HM, HSS, UVM) classes.

LM and LS classes
There is no reference data for streams and rivers in these classes. This has been identified as a significant information gap in section 9 of this report. The only datasets available are from sites moderately to heavily modified, and it would be inappropriate to use this data to derive water quality standards. The recommended approach is to use the same **pH range standard** as was defined for the UVM, HM and HSS classes: **7 to 8.5.**

In addition to the above proposed standards, discharges should not cause pH changes of more than 0.5 in all freshwaters, including lakes. This standard should apply immediately outside of a reasonable mixing zone. This standard relating to pH change is consistent with the recommendations of the 1992 ANZECC guidelines (ANZECC, 2000).

[6] eg. Manawatu at Opiki and Hopelands, Mangatera Stream at Timber Bay, Oroua River at Awahuri.

Table 8: Observed pH ranges observed at monitoring sites, typical biota requirements, ANZECC guidelines recommendations and recommended pH standard for each LSC class. (ND: No data; N/A: not applicable).

LSC category	Data	Reference sites	Other sites	Biota Tolerance range	ANZECC Guideline	Recommended Standard
UHS	5 %ile	6.7 to 7.3	6.7 to 7.2	5.9 to 9.7	7.3 to 8.0	6.7 to 8.2
	10 %ile	7.1 to 7.6	6.9 to 7.3			
	Median	7.4 to 7.9	7.4 to 7.5			
	90 %ile	7.8 to 8.1	7.5 to 8.0			
	95 %ile	7.9 to 8.2	7.5 to 8.1			
UVA [a]	5 %ile	7.2 to 7.3	7.1 to 7.4	7 to 9	7.3 to 8.0	7 to 8.2 [d]
	10 %ile	7.3 to 7.4	7.1 to 7.5			
	Median	7.6 to 7.5	7.5 to 7.9			
	90 %ile	7.8 to 7.9	7.7 to 8.3			
	95 %ile	7.9 to 8.2	7.8 to 8.4			
UVM[b]	5 %ile	7.9	7.0 to 7.6	5.9 to 9.7	7.3 to 8.0	7 to 8.5
	10 %ile	8.0	7.1 to 7.7			
	Median	8.2	7.3 to 8.0			
	90 %ile	8.3	7.5 to 8.3			
	95 %ile	8.4	7.6 to 8.5			
ULi[c]	5 %ile	ND	8.1	5.9 to 9.7	7.3 to 8.0	7 to 8.5
	10 %ile		8.1			
	Median		8.3			
	90 %ile		8.4			
	95 %ile		8.4			
HM[d]	5 %ile	6.6 to 7.5	7.0 to 7.9	5.9 to 9.7	7.3 to 8.0	7 to 8.5
	10 %ile	6.9 to 7.6	7.0 to 7.9			
	Median	7.2 to 7.7	7.1 to 8.1			
	90 %ile	7.5 to 7.9	7.2 to 8.6			
	95 %ile	7.5 to 8	7.3 to 8.9			
HSS[a]	5 %ile	ND	7.3 to 8.0	5.9 to 9.7	7.3 to 8.0	7 to 8.5 [d]
	10 %ile		7.3 to 8.0			
	Median		7.6 to 8.3			
	90 %ile		7.8 to 8.7			
	95 %ile		7.8 to 8.8			
LM	5 %ile	ND	6.1 to 7.4	5.9 to 9.7	7.2 to 7.8	7 to 8.5
	10 %ile		6.2 to 7.5			
	Median		6.5 to 7.6			
	90 %ile		6.7 to 7.9			
	95 %ile		6.8 to 7.9			
LS		ND	ND	7.2 -9.8	7.2 to 7.8	7 to 8.5
Lakes		ND	ND	5.9 to 9.7	N/A	No recommended Standard

(a) The Whangaehu River is excluded from this analysis due to the natural impact of the Ruapehu Crater Lake on the river pH.
(b) Only one monitored reference/slightly disturbed site in the UVM class (Whanganui at Cherry Grove)
(c) Only one monitored site in the ULI class (Makuri at Tuscan Hills)
(d) Data from the monitoring sites “Ohau at Haines Farm” and “Pohangina at Raumai Reserve” was used as reference/slightly disturbed data.

3.2.3.2 Water temperature

As explained in section 2.3.1.2, the recommended approach is to set daily maximum temperature standards and maximum temperature change, that apply whenever the LSC value applies, ie. at all river flows and year round. These standards should be defined for each LSC class based on reference data and/or on the tolerance/preferred temperature range of species expected to live in this given LSC class. For example, the upland temperature standard should provide for the requirements of stoneflies and mayflies, as these species would be expected to not only exist but also be predominant. Conversely, it would be inappropriate to expect lowland stream communities to be dominated by stoneflies, and the standards may not need to provide for the requirements of these species.

Monitoring data available

The monitoring data available is summarised in Table 10. Two types of temperature monitoring data are available:

- Continuous temperature recording has been conducted since 2000 at approximately 33 sites across the Region. Continuous monitoring provides a complete picture of temperature in rivers, including seasonal and diurnal variations. As such, it is the most meaningful monitoring data. Unfortunately, there is a considerable backlog of unprocessed data, and only a small fraction of the data (one 12-month period at most sites) was available in a usable form at the time of writing.
- "spot" temperature measurements are taken during Horizons' State of the Environment and NIWA's national network monitoring. This data only provides a snapshot of water temperature at the time of sampling. The sampling is generally undertaken during hours of daylight (generally between 9 am and 4 pm), so the data has some relevance in relation to maximum temperatures (this is confirmed by the fact that the 95 percentile and maximum temperature from continuous and spot monitoring are usually comparable).

Thermal tolerance limits of aquatic organisms

The 2000 ANZECC Guidelines provide guidance on how to manage and set limits on unnatural changes to water temperature, but do not define numerical guidelines. Such an approach is, to some extent, adapted to dealing with significant point source discharges of relatively (to the river temperature) hot or cold water/effluent. However, this approach fails to recognise the influence of the diffuse temperature changes, such as those caused by the absence of riparian vegetation or the reduction in flow due to water abstraction on water temperature.

The preferred water temperature and tolerance limits of a number of New Zealand native fish and invertebrates species reported in the scientific literature are summarised in Table 7.

Fish are extremely sensitive to temperatures and will select those temperatures where physiological functions operate at maximum efficiency (Crawshaw 1977). The physiological preference of eight common New Zealand native fish species was found to vary from 16^{o}C (smelt) to 26.9^{o}C (shortfin eel elver), with most species between 18 and 22^{o}C (Richardson *et al.* 1994). The temperatures fish species can tolerate for a short period of time are significantly higher: the 96h LT_{50}[7] calculated for the same fish species varied from 27°C (koaro) to 39 °C (adult shortfin eel), with most species around 30 °C. These results are consistent with two previous studies (Teale, 1986 in Richardson *et al.*, 1994; Simons, 1986).

Studies on common invertebrate species show that some invertebrate species (stoneflies and mayflies) are more sensitive to elevated temperatures than others (eg. worms and snails). The most sensitive stoneflies and mayflies species have been found to have 96h LT_{50} ranging from 22 to 25°C.
In a study of 88 New Zealand rivers, Quinn and Hickey (1990) found that water temperature (both mean annual temperature and maximum temperature) was particularly important in determining the distribution of Plecoptera (stoneflies) and Ephemeroptera (mayflies). Stoneflies were found to be largely restricted to rivers with a maximum temperature of 19°C, while Ephemeroptera biomass was lower at sites with a maximum temperature of 21.5°C.

How to translate these results into recommended temperature regimes for waterways ?
Whilst aquatic organisms can survive, within limits, in temperatures outside their optimal ranges, resulting physiological or behavioural changes can decrease their chances of survival and reproductive success (Reynolds, 1977 in Richardson *et al.*, 1994). Therefore, the acute tolerance data obtained in short-term laboratory experiments should be used with caution. They provide an estimate of maximum temperatures that can be tolerated by the different species, but do not necessarily correspond to temperature conditions allowing the long-term survival of the same species.

One approach commonly used is to derive long-term upper thermal limits to allow a safety margin (typically 3°C) below the LT_{50} to set the maximum acceptable temperature for protecting a particular species (Simons, 1986; Cox and Rutherford, 2000).

Another aspect to consider is the fact that laboratory studies usually use constant temperature conditions, that hardly reflect the natural pattern of diurnal temperature variations. Cox and Rutherford (2000) studied the upper thermal tolerances of the freshwater snail *Potamopyrgus antipodarum* and the mayfly *Deleatidium autumnale* under both constant and diurnally varying temperature. The results indicate that the LT_{50} derived from constant temperature experiments should be applied to a temperature midway between the daily average and the daily maximum of a diurnal profile. That is to say that, in a situation with significant diurnal temperature variation, acute effects of high temperatures are likely to occur at higher daily maximum temperature than the LT_{50} derived from constant temperature experiment.

A different approach to incorporate the acute thermal tolerance data obtained from laboratory studies into environmental limits for natural waterbodies was developed by the USEPA[8], and also recommended in the 1992 ANZECC Guidelines. This method uses the following formula to determine the maximum permissible temperature for long-term exposure (USEPA, 1986):

$$T_{lt} = T_{og} + ((T_i - T_{og})/3))$$

[7] The temperature at which 50% of individuals die in a 96h (4 days) period.
[8] United States Environmental Protection Agency

With: T_{lt} = maximum permissible temperature for long-term exposure
T_{og} = temperature for optimum growth
T_i= incipient lethal temperature

When applying this formula to Richardson *et al.*'s (1994) results, assuming the preferred temperature is close to the growth optimum, the permissible long term temperatures for common species of native fish would be as shown in Table 9. It is noted this formula was originally developed to set limits for acceptable effects of discharges of heated effluent, not to set background environmental limits. Preference temperature data is not available for invertebrates.

Table 9: Long-term acceptable temperature for six common native fish species, based on Richardson *et al.* (1994) results applied to the maximum permissible temperature for long-term exposure (USEPA, 1986b).

Species	96h LT_{50}	Preferred temperature	Long-term maximum temperature
common bully	30.9 ^oC	20.2 ^oC	23.7 ^oC
cran's bully:	30.9 ^oC	21 ^oC	24.3 ^oC
torrentfish	30 ^oC	21.8 ^oC	24.5 ^oC
inanga	30.8 ^oC	18.1 ^oC	22.3 ^oC
smelt	28.3 ^oC	16.1 ^oC	20.2 to 21.4 ^oC
banded kokopu	29 ^oC	17.3	21.2 ^oC
longfin eel (elver)	34.8 ^oC	24.4 ^oC	27.8 ^oC
shortfinned eel (elver)	35.7 ^oC	26.9 ^oC	29.8 ^oC

Field studies and observations, such as Quinn and Hickey's (1990), provide an excellent indication of the long-term thermal tolerance range of different species, although a confounding factor is the multitude of other factors potentially influencing the distribution of species.

On the other hand, laboratory studies are conducted in an extremely controlled environment, allowing an excellent discrimination of the actual effects of one individual stressor. However, laboratory studies are generally short-term studies, and better suited to determine the acute, short-term, rather than the long-term, effects of the stressor.

The approach taken is to use both type of studies to narrow down a range of acceptable values, and, where possible, to cross-validate it with reference data. Accordingly, for each LSC class, the following considerations are factored in the decision-making process:

- the level of acceptable effect of high temperatures on aquatic biota;
- typical species present in each LSC classes;
- indications from field studies;
- 96h LT_{50} from laboratory studies;
- inclusion of Cox and Rutherford's conclusions: the application of constant temperature LT_{50} to the midpoint between daily average and daily maximum;
- the 3 ^oC safety margin as per Simons (1986);
- the acceptable long-term limits for fish, as calculated in Table 9; and
- reference and non-reference data.

Recommended standards for each LSC class

UHS (Upland Hard Sedimentary) and **UVA** (Upland Volcanic Acidic) waters are naturally cold mountain streams. The macroinvertebrate communities in these streams are expected to be dominated by stoneflies, mayflies and caddisflies. The maintenance of the QMCI standard for these zones (QMCI of 6, see section 3.2.3.6) requires the temperature standard to avoid any significant effect on the most sensitive species.

Quinn and Hickey (1990)'s results suggest that temperatures above 19^{o}C are likely to exclude stoneflies, and temperatures above 21.5^{o}C are linked with a decrease in Ephemeroptera (mayflies) biomass.

The 96h LT_{50} (constant temperature) for the *Deleatidium* and *Zephlebia* mayflies vary from 22.6 to 24^{o}C (Quinn *et al.*, 1990; Cox and Rutherford, 2000). When applying the 3^{o}C safety margin, this provides maximum temperature limits of 19.6 to 21^{o}C. Cox and Rutherford (2000) found that constant temperatures LT50 should be applied to a point midway between daily average and daily maximum temperature. Not factoring this consideration in the calculation provides an additional safety margin, which is well aligned with avoiding any significant effect on macroinvertebrates communities.

Both field observations and laboratory studies concur to indicate that temperatures should be maintained under 19-20^{o}C to avoid significant temperature-induced effects on stonefly and mayfly populations.

Monitoring data indicates the 95th percentiles of the reference datasets is below 18^{o}C, with absolute maximum recorded just above 20^{o}C. These reference sites also have excellent macroinvertebrate communities, characterised by QMCI values typically above 6, further confirming the adequacy of a 19^{o}C maximum temperature.

It is noted a maximum temperature standard of 19^{o}C also provides for the known long-term requirements of native fish species.

Due to the typical presence of temperature sensitive species in the UHS and UVA streams, a maximum temperature change standard of 2^{o}C is recommended, applying within the bounds of the maximum temperature standard.

The recommended temperature standards for the UVA and UHS classes are : The water temperature shall not be changed by more than 2^{o}C <u>and</u> shall not exceed 19^{o}C.

UVM (Upland Volcanic Mixed) waters are also upland streams, although generally at lower altitude than UHS and UVA waters.

Only limited reference data is available (one site) but together with non-reference data it suggests the temperature in UVM streams is expected to be similar to what is recorded in UVA sites, suggesting a similar standard should adequately protect the values of these streams.

The recommended temperature standards for the UVM class is: The water temperature shall not be changed by more than 2°C <u>and</u> shall not exceed 19°C.

ULi (Upland Limestone) waters are in effect the streams and rivers in the Makuri River catchment. Monitoring results at the Makuri at Tuscan Hills site, located near the downstream end of the catchment, indicate the water temperature should comply easily with a 19 °C temperature standard (when compliance is assessed at the 95th percentile of the data). This temperature should also adequately protect the macroinvertebrate and fish communities.

The recommended temperature standards for the ULi class are: The water temperature shall not be changed by more than 2°C <u>and</u> shall not exceed 19°C.

HM (Hill Mixed) and **HSS** (Hill Soft Sedimentary) are hill country streams and rivers, typically between 200 and 600 m altitude. Very little reference data is available for streams in these classes.

LM (lowland mixed) and **LS** (lowland sand) streams are lowland streams, typically flowing in the west coastal plains of the Region. No reference data (and very little non-reference data) is available for these classes. This has been identified as a significant knowledge gap that should be addressed by Horizons' future monitoring and research programmes (see section 9 of this report.

The recommended QMCI standard in all four classes is 5 (see section 3.2.3.6), indicating that a moderate level of disturbance may be acceptable. The macroinvertebrate communities are expected to be dominated by mayflies and caddisflies, with the presence of stoneflies in HM and HSS classes.

Quinn and Hickey (1990)'s results suggest that temperatures above 21.5°C are linked with a decrease in Ephemeroptera (mayflies) biomass.

The 96h LT_{50} (constant temperature) for the *Deleatidium* and *Zephlebia* mayflies vary from 22.6 to 24°C, and from 25 to 25.9°C for *Pycnocentria* and *Aoteapsyche* caddisflies (Table 7).

In HM and HSS rivers, diurnal thermal amplitude during summer low flow is typically between 3 and 8°C (Appendix 2). In this situation, based on Cox and Rutherford's (2000) conclusions, the 96h LT_{50} (based on maximum temperature) would be between 0.75 and 2 °C higher than found in the laboratory under constant temperature conditions[9]. The 96h LT_{50} (maximum temperature) for *Deleatidium* and *Zephlebia* mayflies becomes approximately 23.5 to 26°C, and from 25.8 to 27.9°C for *Pycnocentria* and *Aoteapsyche* caddisflies.

When applying the empirical 3°C safety margin (Simons, 1986), the acceptable temperature maximum ranges to protect *Deleatidium* is 20.5 to 22.5; 21.5 to 22.6 for *Zephlebia*; 22.8 to 24.9 for *Pycnocentria* and

9 This is based on the assumption that the maximum daily temperature approximately equals the daily average temperature plus half the daily amplitude.

Aoteapsyche caddisflies. It is noted that the 96h LT_{50} (constant temperature) for the *Zelandobius* stonefly was not calculated in Quinn *et al.* 1994, but the 48h LT_{50} was similar to that of the *Deleatidium* mayfly, indicating similar acute thermal sensitivity for the two species.

Both field and laboratory studies suggest that a maximum daily temperature of 21 to 23^{o}C will avoid acute effects of thermal maximum and, based on the empirical 3^{o}C safety margin, should appropriately protect all macroinvertebrate species known to occur in HM and HSS classes. Although this temperature may not be ideal for stoneflies (Quinn and Hickey, 1990), occasional excursions above 19^{o}C are unlikely to exclude stoneflies. Recent research indicates stoneflies may be present at occasional maximum temperatures of 22-23^{o}C if other water quality and habitat parameters are suitable for these sensitive species (Dr John Quinn, pers. comm.).

A 21 to 23^{o}C maximum temperature limit also provides for the long-term requirements of all fish species found in these classes (Table 9). It is noted that although the long-term temperature requirements of smelt as calculated with the USEPA formula are quite low (20.5^{o}C), smelt is a lowland species and should be relatively well adapted to relatively high summer temperatures. It is also noted that records in the national freshwater fish database indicate that smelt are present only in the LM class, but this species has been collected in the Manawatu River at the Manawatu Gorge; therefore its natural range would be expected to extend to all lowland and hill country LSC classes (Dr Russell Death, pers. comm.).

Based on the considerations above, a range of maximum daily temperatures of 21 to 23^{o}C seem to provide adequate protection for most species found in all four HM, HSS, LM and LS classes. To recognise the fact that lowland streams are likely to experience warmer temperatures than hill country streams, it is recommended to use the lower end of this range to define the HM and HSS standard, and the upper end to define LM and LS standards.

The recommended temperature standard for the HM and HSS classes class is: The water temperature shall not be changed by more than 3^{o}C and shall not exceed 21^{o}C.

The recommended temperature standard for the LM and LS classes class is: The water temperature shall not be changed by more than 3^{o}C and shall not exceed 23^{o}C.

Lakes

Very little water temperature monitoring data is available for lakes in the Region. The ability to influence water temperature in these waterbodies is also very limited. For these reasons, no daily maximum water temperature standards are recommended for lakes.

To provide for the management of warm or cold effluent discharge, a temperature change standard is recommended. Due to the lack of information on the natural temperature ranges and the potential effects of temperature change on these ecosystems, a relatively precautionary standard – a maximum temperature change of 1^{o}C - is recommended. This standard should apply immediately outside a zone of reasonable mixing defined through the resource consent process.

Notes on compliance with the temperature standard
Shade provided by riparian vegetation plays a vital role in maintaining cool, headwater, stream habitat for benthic invertebrate communities. Small shallow streams are particularly prone to heating if riparian vegetation is removed (Quinn *et al.*, 1992). As an example reported in Davies-Colley and Wilcock (2004), maximum daily temperature in an unshaded pasture stream has been shown to be 7 to 8 degrees more than in a nearby stream shaded by native forest.

When the temperature standards are regularly breached in small streams, the best method to improve compliance with the standard is restoring riparian vegetation to provide shading of the stream bed. In larger rivers, the ability to control temperature may be limited to the temperature and flow (which may be influenced by water abstraction) of smaller tributary streams.

Assessing compliance with the standard also has significant challenges, and further research is required, as identified in section 9 of this report.

Table 10: Temperature (^oC) ranges observed at monitoring sites and recommended temperature standard for each LSC class. (ND: No data).

LSC category	Data	Reference sites	Other sites	Recommended Standard	
				Maximum daily	Change
UHS(c)	Median	9.0 to 12.3(a) 12.3(b)	9.6 to 11.9 (a) 11.1 to 14.1(b)	19	2
	90 %ile	13.0 to 17.1(a) 15.2(b)	16.8 to 18.9 (a) 16.7 to 19.8(b)		
	95 %ile	14.3 to 17.8(a) 16.1(b)	17.0 to 19.6 (a) 17.7 to 21.1(b)		
	Max	15.6 to 20.4(a) 19(b)	17.6 to 23.8 (a) 21.0 to 24.8(b)		
UVA(d)	Median	8.4 to 11.0 (a) 9.9 (b)	11.2 to 12.3 (a)	19	2
	90 %ile	11.1 to 15.0(a) 15 (b)	15.0 to 16.9(a)		
	95 %ile	11.8 to 16.0(a) 16.4 (b)	15.6 to 17.3(a)		
	Max	11.3 to 20 (a) 20.8 (b)	10.3 to 17.8(a)		
UVM(e)	Median	8.9 (a)	10.5 to 13.0(a)	19	2
	90 %ile	14.1 (a)	16.3 to 18.7(a)		
	95 %ile	14.7 (a)	17.9 to 19.6(a)		
	Max	15.2 (a)	17.3 to 23.3 (a)		
ULi(f)	Median	ND	10.8 (a) /12.2(b)	19	2
	90 %ile		15.0 (a) /16.7(b)		
	95 %ile		15.8 (a) /17.6 (b)		
	Max		16.9 (a) /20.7 (b)		
HM(g)	Median	11.7(a)	11.2 to 16.4a) 11.5 to 14.3(b)	21	3
	90 %ile	17.8(a)	16.4 to 21.4 (a) 18.1 to 20.9(b)		
	95 %ile	18.1 (a)	18.8 to 22.1(a) 19.6 to 22.8(b)		
	Max	18.1 - 19.2 (a)	18.1 to 26.6 (a) 23.3 to 30.5(b)		
HSS	Median	ND	11.1 to 15.0(a)	21	3

LSC category	Data	Reference sites	Other sites	Recommended Standard	
				Maximum daily	Change
			12.9 to 15.4(b)		
	90 %ile		16.4 to 21.0(a) 18.4 to 22.4b)		
	95 %ile		17.7 to 22.1(a) 19.3 to 23.7(b)		
	Max		10.1 to 25(a) 21.7 to 29.6(b)		
LM	Median	ND	12.0 to 16.0(a) 15.1 to 15.9 (b)	23	3
	90 %ile		16.5 to 21.7(a) 20.1 to 21.5 (b)		
	95 %ile		16.8 to 22.3(a) 21.1 to 22.5 (b)		
	Max		18.4 to 25.1 (a) 24.1 to 25.4 (b)		
LSC	Median	ND	14.6 to 18.0 (a)	23	3
	90 %ile		19.7 to 20.6(a)		
	95 %ile		21.5 to 22.5(a)		
	Max		27		

(a) from spot measurement
(b) from continuous monitoring. All continuous monitoring temperature information used in this table from (Horizons, 2001)
(c) UHS Reference sites: Kumeti at Te Rehunga, Mangatainoka at Putara, Tamaki at Reserve. Mangahao at Kakariki and Tokomaru at Horseshoe Bend are not taken as reference sites as the water temperature may be influenced by upstream dams (cold water from bottom of dams). Rangitikei at Pukeokahu not included in the reference sites, as a significant area of the catchment is deforested, leading to potential higher than natural temperatures in summer.
(d) UVA reference sites: Mangawhero at Hagleys, Manganui O Te Ao at Hoihenga Rd, Mangawhero at DoC Headquarters, Whangaehu at Tangiwai.
(e) UVM: Hautapu at Mulvays as reference site.
(f) Mangapapa at Troop Road was used as a reference site for small streams in this category as most of the mainstem above the sampling site is fenced off and has good riparian cover. It is noted that this site does not constitute a good reference site for the larger rivers in this class (eg. Manawatu and Rangitikei rivers)

3.2.3.3 Dissolved Oxygen

Dissolved oxygen (DO) is essential for aerobic forms of river life, including most plants and animals. Low levels of DO can be a major stressor to aquatic life, including fish, invertebrates and micro-organisms, which depend upon oxygen for their efficient functioning. As explained in section 2.3.1.3 of this report, the recommended DO standard is based on a minimum dissolved oxygen saturation (ie. “The dissolved oxygen concentration shall exceed …% saturation”). DO being necessary to most complex life forms, the standard should apply at all times (ie. year-round, at all river flows). Although having some value as an indicator of prolific photosynthetic activity, a maximum DO saturation standard is not recommended for the One Plan.

The oxygen requirements of aquatic biota have been the subject of numerous scientific investigations overseas (USEPA, 1986b), although only few studies specifically relate to New Zealand native fish and invertebrate. Most of the studies have focused on fish, but from the little evidence available, it appears that provided all life stages of fish are protected, freshwater invertebrate communities should also be adequately protected (ANZECC, 2000). Generally, adult fish are more tolerant than other life stages, particularly egg and larvae (USEPA, 1986b).

There is only limited supporting information relating to the tolerance of New Zealand aquatic biota to low levels of dissolved oxygen in the scientific literature.

Dean and Richardson (1999) report on the tolerance of seven native fish and one freshwater shrimp species to low levels of oxygen. Two parameters were studied: survival and change in behaviour (surfacing). Results indicate a relatively good tolerance of native fish to relatively low levels of oxygen. Rainbow trout was also tested as a comparison in the same study, and was the most sensitive species tested. The authors acknowledge that the significance of these results is limited by the absence of information on the tolerances of early life stages, particularly egg and larvae, and recommend a precautionary approach. The authors conclude the native fish species and life stages tested appear to be less sensitive than rainbow trout to low levels of oxygen, and recommend the adoption of the USEPA water quality criteria for salmonid waters, as it should adequately protect New Zealand aquatic fauna and flora (Table 11).

Landman *et al.* (2005) further studied the sensitivity of common fish and invertebrate species to acute hypoxia. The results indicate that inanga whitebait was the most sensitive species, and smelt and rainbow trout were similar in their sensitivities. The other fish species were less sensitive than rainbow trout (results are summarised in Table 7).

Similarly to Dean and Richardson‘s study, these result suggest that DO levels suitable for trout should also adequately provide for the requirements of common native fish and invertebrate species. The sensitivity of inanga whitebait should be further studied, as contradictory results in the two studies – inanga whitebait was found to be one of the most tolerant species by Dean and Richardson (1999) - do not allow firm conclusions to be drawn.

Table 11: Dissolved Oxygen concentrations (mg/l) recommended by the U.S. Environmental Protection Agency to confer five levels of protection for waters containing “other life stages” (ie. not early life stages) of salmonids (adapted from Dean and Richardson 1999), and corresponding DO saturation at different temperatures.

Degree of impairment acceptable	DO (mg/L)	Saturation (^{o}C)				
		10	16	19	22	24
None	8	71	81	86	91	95
Slight	6	53	61	65	69	71
Moderate	5	44	51	54	57	59
Severe	4	35	41	43	46	48
Acute	3	27	30	32	34	36

Horizons’ state of the environment monitoring results generally indicate high to very high dissolved oxygen saturation at most monitoring sites (typically around or above 100% saturation). However, this monitoring is usually done during daytime and does not provide a good estimate of the daily minimum oxygen levels (usually occurring at dawn), which are the most relevant measurement with regard to the effects on aquatic life. Horizons recently acquired a limited number of oxygen probes which will allow continuous monitoring of dissolved oxygen concentrations at selected sites. By capturing the full range of diurnal variations, continuous monitoring will provide a much more complete and meaningful picture of instream DO levels (see also section 9 of this report).

Due to the scarcity of robust information on the effects of low dissolved oxygen concentrations on New Zealand native aquatic biota (particularly chronic studies), and the absence of relevant reference monitoring data, the third approach - the use of national and international guidelines - is fully warranted and recommended. It is also noted Dean & Richardson (1999) recommend the use of the USEPA dissolved oxygen criteria. Table 12 summarises the USEPA DO criteria for salmonid waters.

The ANZECC guidelines recommend default trigger values of 99 to 103% saturation for upland rivers (above 150m altitude) and 99 to 105% saturation for lowland rivers. These DO saturation levels are based on statistical distribution of measurements taken at reference sites and do not have a physiological or biological basis. It is also noted that the ANZECC guidelines also recommend that in no case should the DO concentration be allowed to fall under 60% saturation.

The results of the two studies on acute sensitivity of New Zealand species suggest that acceptable DO levels for trout should also adequately protect the requirements of native fish and invertebrate species. The USEPA criteria provide useful guidance in the sense that they link the degree of acceptable impairment with minimum oxygen concentration, and it was used in the decision process summarised in Table 12 (as was also recommended by Dean and Richardson, 1999).

Table 12: Recommended DO saturation (%) standard in the different Life-Supporting Capacity classes.

LSC category	USEPA criteria				ANZECC guideline	Recommended standards	
	Degree of impairment	DO mg /L	Temperature standard	Corresponding DO saturation (%)		DO (%)	BOD_5 (g/m^3)
UHS	None	8	19	86	99	80	1
UVA	None	8	19	86	99	80	1
UVM	None / Slight	7	19	75	99	80	1
ULi	None / Slight	7	19	75	99	80	1
HM	Slight	6	22	69	99	70	2
HSS	Slight	6	22	69	99	70	2
LM	Moderate	5	24	59	99	60	2
LS	Moderate	5	24	59	99	60	2

3.2.3.4 Biochemical Oxygen Demand

As explained in section 2.3.1.3, low levels of oxygen are often caused by the instream degradation of organic matter. Biochemical Oxygen Demand (BOD) is a way to measure the amount of biodegradable organic matter present in the water. BOD standards are recommended to help maintain the dissolved oxygen at or above the standard. The recommended BOD standard applies at all times.

There is no general formula to directly link DO and BOD. Site-specific modelling can assist in understanding how the dissolved oxygen concentration reacts to instream BOD concentration. The base data usually requires continuous DO monitoring, unavailable at the time of writing. This has been identified as a area requiring further work in section 9 of this report.

The Manawatu Catchment Water Quality Regional Plan defines a filtered carbonaceous BOD_5 standard of 2 g/m^3, applying year round at all flows. This standard was primarily set to control the effects of the discharges of domestic and industrial treated waste on sewage fungus growth and oxygen depletion, and maintain the dissolved oxygen concentrations above 5 mg/m^3.

Until further investigation, in the form of continuous oxygen monitoring and modelling, is completed, the recommended approach is to maintain the MCWQ Plan standard in water management zones and sub-zones where the recommended standard is 60 or 70% saturation (5 or 6 mg/L at 24^oC). For zones where the recommended DO standard is higher, it is recommended to halve that BOD_5 standard (Table 12). It is however acknowledged that these values are provisional, and site-specific monitoring and/r modelling is strongly recommended in relation to discharges to water resource consent applications and reviews.

3.2.3.5 Water clarity

As discussed in section 2.3.2, **water clarity** is the recommended indicator of the amount of sediment in the water column, and is also the recommended default indicator of the risk of fine sediment deposition. It is noted that water clarity and turbidity are usually well correlated, and that specific relationships between clarity and turbidity have been determined at a number of sites to support the decision making process (Appendix 2).

Scientific literature
Low water clarity/high water turbidity levels affect the ability to feed and the migratory behaviour of several native fish species.

Boubée *et al.* (1997) studied the avoidance response of the migratory stage of six New Zealand diadromous native fish species to different levels of suspended sediments. The banded kokopu (*Galaxias maculatus*) was found to be the most sensitive species, displaying avoidance behaviour to turbidity levels as low as 17 and 25 NTU. The authors conclude a limit of about 15 NTU in otherwise clear waterways should ensure that the upstream migration of some of the most common New Zealand native freshwater species is not affected. These findings were confirmed by Richardson *et al.* (2001), who found that the migration rate and direction were affected at turbidities in excess of 25 NTU.

The sensitivity of juvenile banded kokopu to suspended sediments was further confirmed by Rowe and Dean (1998), who studied the effects of suspended sediments on the feeding ability of the juvenile migrant stage of six native fish species. Again, banded kokopu was found to be the most sensitive species, with feeding rates significantly lower at turbidity levels of 20 NTU and over. It is noted that, in the same study, decreased feeding rates were also observed at 10 NTU, although the results should be taken with caution due to a problem in the experimental protocol (significant difference in fish length between the control and the 10 NTU treatment).

Rowe *et al.* (2000) studied the distribution of native fish in the North Island's rivers, and found that the mean occurrence of banded kokopu was reduced by nearly 90% in turbid rivers compared to clear rivers. The occurrence of redfinned bullies, inanga and shortfinned eel was also significantly lower in turbid rivers, although the decrease was less dramatic than for the banded kokopu.

NIWA has published a decision support system (DSS) for setting maximum turbidity for riverine fish at base and peak flows (Rowe, 2006). The model correlates the percentage of occurrence of banded kokopu and inanga with the amount of time the turbidity exceeds 20 NTU.

The 2000 ANZECC guidelines define default trigger values of 4.1 NTU for upland rivers and 5.6 NTU for lowland rivers. However, The ANZECC Guidelines also recommend that interim trigger values should only be used where data from an appropriate reference system is not available (ANZECC, 2000). Low-risk trigger value should be determined as the 80th percentile of the reference system[10]. It is noted that the general approach recommended by the ANZECC Guidelines is to then compare the trigger value to the statistical distribution of data collected at the study site.

Monitoring data
The water clarity data from Horizons' state of the environment and NIWA's national network monitoring programmes is presented in Table 13.

Methodology
The natural water clarity in a stream or river is not season dependent, but will vary according to the river flow/level and the dominant geology in the catchment. For this reason, the recommended water clarity standards apply year round, but some river flow conditions (variable with the river type) are excluded.

Banded kokopu was found to be the most sensitive native fish species to suspended sediment, both in laboratory and field studies. Although banded kokopu has only been recorded in a handful of sites in the Horizons Region (McArthur *et al.*, 2007b), its expected natural range is much wider, covering rivers in the LM, LS, HM, HSS, ULi and UHS classes (Dr. Russell Death, pers. comm.). The results of the different scientific studies described above suggest that water turbidity above 15 NTU is likely to negatively impact on the banded kokopu's ability to feed and migrate. 15 NTU generally corresponds to a water clarity of 0.5m (Appendix 2). The DSS published by NIWA predicts a low level of effects on banded kokopu migration if the turbidity is maintained below 20 NTU 80 to 90% of the time. Three time the median flow generally corresponds to a point between the 80th and the 90th percentile of the flow distribution (Henderson and Diettrich, 2007). A water clarity standard of 0.5m applying when the river flow is at or below three times the median flow should prevent significant effects on banded kokopu and other native fish.

10 80th percentile of the turbidity data or 20th percentile of the black disc data.

It is noted however, that the information relating to aquatic biota requirements has significant limitations. The studies that associate an identified effect (eg. feeding rate) with a quantified measure of sediment (eg. turbidity) relate only to the effects of sediments suspended in the water column over a relatively short period of time, and the more insidious effects of long term exposure to low water clarity, or the effects of deposited sediment on aquatic habitat, are not accounted for. The standard derived directly from these studies may not be sufficient to protect the habitat values across the whole range of LSC classes, and should therefore be regarded as an environmental bottom-line, ie. a minimum requirement.

In setting reasonable expectations, the recommended standards should account for the specific physical characteristics of the different river types. For example, rivers in catchments dominated by hard sedimentary geology would be expected to run clear most of the time, except during floods. Conversely, the rivers in catchments dominated by easily erodible geology would be expected to run clear only when the river flow is low.

The river classification underpinning the definition of the different river LSC classes was based on source of flow elevation and catchment geology. Different sets of standards are recommended for the different LSC classes, to account for the influence of catchment geology.

To reflect the differences between the different LSC classes, the methodology used to derive the recommended water quality standards makes extensive use of reference and near-reference data where available. In accordance with the ANZECC guidelines, the approach taken was to use the 20th percentile of the data collected at reference sites. The standards were derived as being the lowest value observed at the reference sites. Standards were defined at different flow categories, to protect base-flow (under median flow) and other conditions (under 3*median flow). Base flow standards are considered necessary to protect clearer water under these conditions; fine sediment deposition on the riverbed is also more likely during base-flow conditions. Flood flows (above 3*median flow) were not included in the standard, as most rivers experience turbid waters during floods.

From a state of the environment point of view, compliance with the water clarity standard will be assessed against the 20th percentile of the data distribution. It is noted that this differs from the approach taken for other parameters, such as water temperature or pH, where compliance is assessed against the 5th/95th percentile of the reference data (section 8 of this report). Low water clarity is not a direct toxicant, and regular breaches of the standard are expected as direct result of the natural variability in flow events. For example, water clarity on a rising, but still low, flow can be poor, and conversely, satisfactory water clarity may be observed during periods of relatively high, but stable flows.

Table 13: Water clarity measured at monitoring sites in the Horizons Region. Data percentiles within the specified range of river flows.

LSC Class	River	Site	Black Disc (m)																				
			Under ½ Median Flow				Under Median Flow				Under 3* Median Flow				All Flows				All Data				
			10	20	50	N	10	20	50	N	10	20	50	N	10	20	50	N	10	20	50	N
UHS	Tamaki	Reserve	3.1	3.5	4.7	3	2.7	2.7	3.2	6	1.1	1.3	3.3	17	0.6	1.2	3.1	20	0.4	0.8	3	44
	Kumeti	Te Rehunga	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		1.7	1.9	2.5	3
	Mangatainoka	Putara	3	3.6	5.5	7	3.2	3.7	5.5	15	1.6	2.8	4.7	22	1.6	2.9	4.5	23	1.6	2.9	4.5	23
	Mangatainoka	Larsons Rd	3.4	3.8	5	3	2.7	2.9	4.5	5	2.1	2.5	3.5	10	2.3	2.5	3.3	12	1.1	2.3	3.3	22
	Mangahao	Ballance	3.8	3.9	4.9	8	2.4	3.3	4.1	14	1	1.5	3.4	20	0.7	1.2	2.8	23	0.6	1	2	44
	Mangahao	Kakariki	2.5	2.9	5.7	8	2.7	3	4.6	15	1.7	2.7	4	21	1	2.3	3.8	24	1.5	2.3	3.6	29
	Pohangina	Piripiri	1.1	2.2	3.5	4	0.7	1.7	3.1	8	0.3	0.6	1.1	24	0.3	0.4	1	26	0.2	0.5	1.1	36
	Tokomaru	Horseshoe Bend	2.3	2.8	3.1	7	1..7	2.1	3	15	1.6	2	2.4	25	1.6	2	2.3	26	1.2	1.6	2.2	43
	Rangitikei	Pukeokahu	2	3.3	5.2	19	2.2	3.4	5	45	1.5	2.1	3.8	75	1.3	1.9	3.6	81	1.2	1.9	3.6	107
	Ohau	Gladstone	2.5	3	3.9	4	2.2	2.9	4.8	12	2.3	2.8	4.2	23	2.1	2.7	4.2	24	2.1	2.7	4.2	24
UVA	Whakapapa	Below TPD Intake	10.1	10.1	10.1	1	4.1	6.2	10.6	6	3	5.2	6.7	13	3.5	5.3	6.7	15	3.5	5.3	6.7	15
	Piopiotea	Bullians Rd	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.3	0.4	1.1	22
	Manganui o te Ao	Hoihenga Rd	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		1.5	1.8	3.8	22
	Whangaehu	Tangiwai Rail Bridge	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.1	0.2	30
	Tokiahuru	Above Confluence	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.6	0.7	1.2	11
	Makotuku	SH49A	3.6	3.6	3.6	1	1	1.5	2	5	1.1	1.5	2.4	8	1.1	1.6	2.3	9	1.3	1.6	2.3	15
	Makotuku	U/s Raetihi	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.9	1.1	2.1	9
	Mangawhero	DoC Headquarters	2.5	2.9	3.6	8	2	3	3.8	40	1.6	2.3	3.3	86	1.5	2.1	3.2	84	1.5	2	3.1	94
	Mangawhero	Pakahi Rd Bridge	2	2	2	1	0.7	0.8	1.3	2	0.7	0.8	1.3	2	0.7	0.8	1.3	2	0.8	1	1.8	21
	Mangawhero	Downstream Makotuku	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.6	1.1	2.1	82
UVM	Hautapu	Rest Area	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		3.6	3.7	3.8	2
	Hautapu	Mulvays	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.8	1.3	2.3	19
	Hautapu	Taihape	1.7	1.8	2.3	7	1.4	1.5	1.7	14	0.5	0.6	1.4	28	0.3	0.5	1.3	32	0.4	0.5	1.3	36
	Whanganui	Cherry Grove	2.1	2.4	3	18	1.2	1.8	2.9	35	0.5	0.7	1.8	67	0.5	0.7	1.8	69	0.5	0.7	1.8	106
	Pungapunga	Kirton Rd Bridge	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.4	0.7	1.5	15
	Ongarue	Cherry Grove	1.8	2	2.1	6	0.8	1.1	1.9	16	0.3	0.5	1.1	27	0.3	0.4	1.1	28	0.3	0.4	1.1	28
	Whanganui	Te Maire	1.5	1.9	2.5	23	0.8	1.1	2	50	0.4	0.8	1.6	71	0.4	0.6	1.4	75	0.4	0.5	1.1	96
	Retaruke	Above Confluence	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.3	1	24
	Whanganui	D/s Retaruke	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.3	0.8	80
	Manganui o te Ao	Above Confluence	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.4	0.6	2.1	23
ULi	Makuri	Tuscan Hills	3.1	3.1	3.1	1	0.8	1.1	1.9	10	0.3	0.5	1.2	19	0.2	0.4	1.1	20	0.2	0.3	0.9	24
HM	Mangarangiora	U/s Norsewood Oxponds	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.6	0.8	1	19
	Manawatu	Weber Road (NIWA)	1.2	1.4	1.9	28	0.9	1.1	1.6	52	0.3	0.5	1.1	89	0.1	0.3	1	101	0.1	0.3	1	101
	Mangatera	U/s Dannevirke Oxponds	1.7	1.8	2.2	17	1.2	1.6	1.9	27	0.7	1.2	1.8	34	0.7	1.2	1.3	34	0.5	0.8	1.8	42
	Mangatera	Timber Bay	0.4	1	1.2	21	0.4	0.6	1.1	49	0.3	0.5	0.9	76	0.2	0.4	0.9	81	0.2	0.3	0.9	105
	Manawatu	Hopelands	1	1.5	2	19	0.8	1	1.6	53	0.3	0.6	1.1	87	0.2	0.3	1	98	0.1	0.3	1	119

LSC Class	River	Site	Black Disc (m)																			
			Under ½ Median Flow				Under Median Flow				Under 3* Median Flow				All Flows				All Data			
			10	20	50	N	10	20	50	N	10	20	50	N	10	20	50	N	10	20	50	N
	Tamaki	SH2	2.7	2.8	4.1	4	1.8	2.5	3.3	9	1.5	1.7	2.7	21	0.4	1.2	2.6	24	0.3	0.8	2.5	46
	Kumeti	SH2	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		1.3	1.4	2	3
	Oruakeretaki	Oringi	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.3	0.4	2.6	10
	Raparapawai	Jacksons Rd	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.3	0.8	2.8	12
	Makakahi	Konini	1.1	1.4	1.6	33	1.1	1.4	1.7	45	0.9	1	1.5	72	0.5	0.8	1.4	85	0.4	0.8	1.4	95
	Makakahi	Hamua	ND	ND	ND		1.1	1.1	1.1	1	1.1	1.1	1.1	1	0.6	0.6	0.8	2	0.8	0.9	1.8	22
	Mangatainoka	SH2 Bridge	1.6	2.1	3.5	32	1.6	2.1	3.4	61	1	1.5	2.4	92	0.4	0.9	2.2	112	0.5	1	2.2	137
	Manawatu	Upper Gorge	1.6	1.6	1.6	1	1.6	1.6	1.6	1	0.1	0.2	0.3	4	0.1	0.2	0.3	4	0.1	0.2	0.4	26
	Mangapapa	Troup Rd Bridge	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.7	0.9	2.4	23
	Mangapapa	SH2	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.6	0.7	1.4	24
	Mangaatua	U/s Woodville Oxponds	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.6	0.8	1.7	36
	Manawatu	Teachers College (NIWA)	1	1.3	2.1	28	0.6	0.9	1.3	55	0.2	0.2	0.9	87	0.1	0.1	0.6	101	0.1	0.1	0.6	101
	Pohangina	Mais Reach	ND	ND	ND		ND	ND	ND		0.4	0.5	0.8	2	0.4	0.5	0.8	2	0.2	0.3	1.4	22
	Pohangina	Raumai Reserve	2.8	3	3.8	4	2.5	2.9	3.4	8	0.4	0.8	1.5	22	0.2	0.5	1.3	24	0.2	0.5	1.3	24
	Manawatu	42 Mile Hydro Station	1.6	1.6	2	20	0.9	1.2	1.7	34	0.4	0.5	1.4	52	0.2	0.5	1.2	56	0.2	0.5	1.3	59
	Manawatu	Opiki Bridge (NIWA)	1	1.2	1.6	25	0.6	0.8	1.2	53	0.1	0.3	0.9	87	0.1	0.1	0.7	101	0.1	0.1	0.7	101
	Oroua	Apiti Gorge Bridge	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		1.3	1.5	3.3	16
	Oroua	Almadale Slackline	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.3	0.6	18
	Oroua	Nelson Street	2.2	2.6	3.5	25	1	1.7	3	48	0.4	0.7	1.8	84	0.2	0.3	1.5	97	0.2	0.3	1.5	100
	Rangitikei	Mangaweka (NIWA)	3.2	4.5	4.5	21	1.2	3.2	3.2	49	0.2	1.6	1.6	93	0.1	0.3	1.3	101	0.1	0.3	1.3	101
	Rangitikei	Vinegar Hill	2.1	2.3	3.3	15	1	1.3	2.2	32	0.4	0.9	1.8	41	0.4	0.9	1.8	42	0.3	0.5	1.5	49
	Rangitikei	Onepuhi	ND	ND	ND		ND	ND	ND		1.8	1.8	1.8	1	1.8	1.8	1.8	1	0.2	0.2	0.8	19
	Rangitikei	Kakariki (NIWA)[11]	1.3	2	3.5	27	0.9	0.9	1.7	60	0.1	0.2	1	96	0.1	0.2	0.9	101	0.1	0.2	0.9	101
	Ohau	Haines Farm	3.3	3.4	3.7	3	3.2	3.3	3.8	11	1.1	1.6	3.3	22	1	1.3	3.3	23	0.6	1.1	3.3	35
	Waikawa	D/s Manukau	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.5	0.6	0.9	22
HSS	Mangatoro	Mangahei Rd	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.3	0.5	2	11
	Tiraumea	Katiawa Bridge	0.4	0.5	0.8	5	0.2	0.3	0.5	15	0.2	0.3	0.5	16	0.1	0.2	0.3	23	0.1	0.2	0.3	33
	Hautapu	U/s Rangitikei	1.4	1.7	2.1	22	1.2	1.4	1.7	42	0.5	0.5	1.3	71	0.3	0.5	1.2	82	0.3	0.5	1.1	105
	Makohine	Viaduct	0.9	0.9	1.3	9	0.8	0.9	1.2	13	0.4	0.4	0.9	20	0.1	0.2	0.4	31	0.1	0.2	0.4	34
	Porewa	Onepuhi Rd	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.3	0.4	1.3	34
	Ohura	Above Confluence	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.1	0.4	24
	Ohura	Tokorima	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.2	0.2	7
	Whanganui	Pipiriki	0.7	1	1.6	20	0.5	0.7	1.3	55	0.2	0.3	0.7	97	0.2	0.2	0.6	104	0.2	0.2	0.6	104
	Tangarakau	Above Confluence	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.2	0.6	23
	Whangamomona	Above Confluence	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.2	0.8	23
	Whanganui	Paetawa	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.3	0.6	18
	Matarawa	Above Confluence	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.2	0.3	23
	Whangaehu	Aranui	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.1	0.3	8

[11] Flow Statistics for Kakariki are based on Onepuhi Flow Site

LSC Class	River	Site	Black Disc (m)																			
			Under ½ Median Flow				Under Median Flow				Under 3* Median Flow				All Flows				All Data			
			10	20	50	N	10	20	50	N	10	20	50	N	10	20	50	N	10	20	50	N
	Whangaehu	Kauangaroa	0.05	0.1	0.2	5	0.1	0.2	0.3	10	0.1	0.1	0.2	18	0.1	0.1	0.2	22	0.1	0.1	0.2	32
	Mangawhero	Raupiu Rd	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.1	0.7	9
	Turakina	Otairi	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.2	0.4	9
	Turakina	SH3	0.4	0.4	0.9	12	0.3	0.4	0.8	16	0.1	0.3	0.5	23	0.1	0.1	0.4	32	0.1	0.1	0.4	34
	Owahanga	Branscombe Bridge	0.3	0.5	0.8	10	0.3	0.3	0.6	12	0.2	0.3	0.5	16	0.1	0.1	0.3	23	0.1	0.1	0.3	23
	Akitio	Weber Rd	0.6	0.9	1.7	4	0.7	1.2	1.7	6	0.7	1.2	1.7	6	0.1	0.2	0.7	10	0.1	0.2	0.6	22
	Akitio	Above Estuary	0.5	0.8	1.3	4	0.2	0.3	1	6	0.2	0.3	1	6	0.1	0.1	0.1	10	0.1	0.1	0.2	24
	Kai Iwi	SH3 Bridge	ND	ND	ND		0.5	0.6	1	7	0.2	0.3	0.5	12	0.2	0.2	0.5	13	0.2	0.2	0.5	21
	Kai Iwi	Handley Rd	ND	ND	ND		0.5	0.7	0.9	6	0.2	0.3	0.8	8	0.1	0.2	0.5	10	0.1	0.2	0.4	15
	Makino	Boness Rd	1.8	1.9	2	3	1.5	1.6	1.8	7	1.4	1.5	1.8	8	0.9	1	1.5	12	0.7	0.9	1.6	22
	Mangaone West	All Sites	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.6	0.7	1.1	13
	Manawatu	Whirokino Boat Ramp	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.2	0.3	116
	Manawatu	Foxton Loop Boat Ramp	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.2	0.4	24
	Rangitawa	U/s Halcombe Oxponds	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.8	1	1.2	18
LM	Rangitikei	McKelvies	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.2	0.5	7
	Rangitikei	Scotts Ferry	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.2	0.8	79
	Tutaenui	Curls Bridge	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.3	0.4	0.7	74
	Whanganui	Aramoho Rail Bridge	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.2	0.4	43
	Whanganui	Estuary Opposite Marina	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.2	0.4	97
	Mowhanau	Mowhanau	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.2	0.4	8
LS	Hokio Stream	All Sites	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.3	0.9	9

The eight LSC river classes were grouped into three categories, depending on the expected level of effect by the catchment geology on water clarity:

- Upland hard sedimentary (UHS) and upland volcanic acidic (UVA) catchments have very little soft sedimentary rock, and have naturally clear water. Good reference data exists for these classes, which was used to derive water quality standards.
- Mixed geology catchments (UVM, HM, LM and ULi): these water classes are expected to be moderately influenced by the proportion of soft geology in their catchment. Dominant pastoral land cover in these classes also means that undisturbed reference sites are rare and true reference data is scarce. A number of UVM and HM rivers are downstream sections of UHS and UVA rivers. Monitoring sites located near the transition between LSC classes can provide acceptable reference data. A number of other sites within the HM class are considered to be only slightly to moderately disturbed, and can also provide acceptable reference data.
- Water clarity in hill country streams and rivers flowing in catchments dominated by soft sedimentary geology (HSS) is expected to be moderately to heavily impacted by land erosion.

Practically no water quality data is available for the lowland sand country streams (LS class). Water in these streams is expected to be reasonably clear, and the recommended default position is to define the same water clarity standards as for the mixed geology waters. It is recommended Horizons' monitoring programme addresses this lack of data (section **Error! Reference source not found.**).

The recommended standards define a minimum water clarity for the different LSC classes. A number of rivers have water clarity that is significantly better than the recommended standards. A significant sediment load increase in clear water systems is likely to affect ecosystem processes and aquatic habitat, and standards relating to change in water clarity are recommended. Water clarity change standards also give direct effect to section 107(1)(d) of the Act. As explained in section 2.3.2.2 of this report, the recommended standards set a maximum water clarity change of 20% in sensitive areas (UVA and UHS) and 30% in all other classes.

The paragraphs below document the decision-making process followed in making recommendations for each LSC class:

UHS and UVA waters

Excellent reference data exists for these classes. Reference sites in the UHS class are: Mangatainoka at Putara; Ohau at Gladstone; Tamaki at Reserve; Tokomaru at Horseshoe Bend; and Rangitikei at Pukeokahu. Reference sites in the UVA class are: Mangawhero at DoC Headquarters, Whakapapa below TPD intake and Manganui o Te Ao at Hoihenga Road.

The approach taken, as per the 2000 ANZECC guidelines recommendations, was to use the 20^{th} percentile of the data distribution at each reference site.

The recommended standards for the UHS and UVA waters are:

- **The water clarity shall exceed 3 metres when the river flow is at or below median flow, and**

- **The water clarity shall exceed 2 metres when the river flow is at or below three times the median flow, and**
- **The water clarity shall not be changed by more than 20% at all flows.**

Mixed geology waters (HM, UVM, LM, Uli, LS)

Two reference sites have been monitored in these classes: Oroua at Apiti Gorge Bridge (HM) and Hautapu at Rest Area (UVM). This data is however of limited use, due to the very limited amount of data and the absence of river flow data at these sites.

Two sites are considered to have a relatively low level of disturbance and can be used as reference: Rangitikei at Mangaweka and Ohau at Haines farm.

A number of other sites are located in UHS or UVA zones, but immediately upstream of UVM or HM zones and it is considered they can be used as reference sites: Mangatainoka at Larsons Road; Manganui o te Ao at Hoihenga Road; Mangahao at Balance; and Tamaki at Reserve.

The approach taken, as per the 2000 ANZECC guidelines recommendations, was to use the lowest 80th percentile of the data distribution at each reference site.

The recommended standards for the HM, UVM, LM, Uli and LS waters are:

- **The water clarity shall exceed 2.5 metres when the river flow is at or below median flow, and**
- **The water clarity shall exceed 1.6 metres when the river flow is at or below three times the median flow, and**
- **The water clarity shall not be changed by more than 30% at all flows**

Hill country soft sedimentary geology (HSS)

No reference data is available for HSS waters.

As explained above, a minimum water clarity of 0.5 m when the river flow is at or under 3* median flow is a minimum requirement to avoid direct effects on banded kokopu migratory and feeding behaviours. It is also noted that the contact recreation standard set a minimum water clarity of 1.6 m when the flow is at or below median flow. This is considered a reasonable clarity level to protect a number of ecosystem processes dependent on light penetration and limit fine sediment deposition during base flow conditions.

Accordingly, the recommended water clarity standards for the HSS class waters are:

- **The water clarity shall exceed 1.6 metres when the river flow is at or below median flow, and**
- **The water clarity shall exceed 0.5 metres when the river flow is at or below three times the median flow, and**
- **The water clarity shall not be changed by more than 30% at all flows.**

Notes on the water clarity standard

The recommended standards define a minimum water clarity for the different classes. A number of rivers in each class have water clarity that is significantly better than the recommended standards. A significant sediment load increase in clear water systems is likely to affect ecosystem processes and aquatic habitat, and it is recommended naturally clear waters are recognised and protected. In other words, the recommended water clarity standards define a bottom-line under which the LSC value may be compromised, and should not be used to justify a significant degradation of naturally clear waters.

3.2.3.6 QMCI and Particulate Organic Matter

As explained in section 2.3.4, the Quantitative Macroinvertebrate Community Index (QMCI) is the selected indicator of the state of the macroinvertebrate communities in rivers and streams. Although good practice for macroinvertebrate communities sampling requires certain flow conditions (ie. several weeks without significant flood prior to sampling), macroinvertebrates live in rivers year round and at all flow conditions, so the standard should apply at all times.

The composition of the aquatic macroinvertebrate communities can be used as a biomonitoring tool to assess the likely level of ecosystem degradation or enrichment (Stark 1985). A QMCI score of :

- 6 is indicative of “clean water”
- 5 is indicative of “possible mild degradation”
- 4 is indicative of “probable moderate degradation”
- 3 is indicative of “probable severe degradation”.

UVA and UHS classes represent upland, oligotrophic streams, where the degree of organic enrichment is expected to be very low. The degree of impact by sedimentation is also expected to be low, and the macroinvertebrate communities at reference sites are dominated by pollution-sensitive taxa (stoneflies, mayflies and caddisflies). **The recommended standard is a QMCI score of 6**.

Other water classes (hill country and lowland classes) are expected to have a naturally higher trophic status, more elevated temperatures, and, in some classes, naturally higher levels of fine sediment in the water column and deposited on the riverbed. With these considerations in mind, a QMCI score of 5 can be considered indicative of a healthy ecosystem. This is further confirmed by data collected at reference sites (although no reference data is available for the lowland classes). **The recommended standard is a QMCI score of 5.**

It is noted that some streams are naturally not suitable for QMCI (eg. tidal zones and streams with a naturally soft bed material). The LS, LM, HSS are particularly likely to contain such streams. It is recommended these sites can be exempted from the QMCI standard on a case per case basis[12]. Other methods of assessing the macroinvertebrate communities, such as the soft-bottom MCI (Stark and Maxted, 2004) and predictive modelling (Joy and Death, 2003), may be useful in this context, although more validation is required, as explained in section 9 of this report.

Elevated concentration of particulate organic matter (POM), particularly downstream of some point source discharges, can cause detrimental effects to macroinvertebrate communities (Quinn and Hickey 1993). Setting a POM standard, applying at all times is recommended for the One Plan. The determination of the POM standard is based on the findings of Quinn and Hickey (1993), and should be linked with the QMCI standards for each LSC class. In a study of sites located upstream and at various distances downstream of point source discharges, Quinn and Hickey identified that:

- the background levels were generally in the order of 1 g/m^3;
- a POM concentration increase below 1.5 to 2 g/m^3 had no significant effect on the different macroinvertebrate community indices; and
- a POM concentration increase of more than 4 g/m^3 had significant effect on the macroinvertebrate community indices.

Based on these considerations, the recommended POM standards are:

- **2.5 g/m^3 in classes where the QMCI standard is 6,**
- **g/m^3 in classes where the QMCI standard is 5.**

Table 14: Observed QMCI (Quantitative Macroinvertebrate Index) values in the different LSC classes, and recommended QMCI and POM (particulate Organic Matter) standards for the One Plan.

LSC category	Observed QMCI values				Recommended QMCI standard	Recommended POM standard (g/m^3)
	Reference sites		Other sites			
	Mean	Max	Mean	Max		
UHS	5.62 – 7.49	6.05 – 8.01	4.27 – 7.87	4.27 - 8.01	6	2.5
UVA	5.4 – 7.76	5.96 – 8.51	2.62	3.12	6	2.5
UVM	ND	ND	2.96 – 6.78	4.03 – 6.78	5	5
ULi	ND	ND	4.23	4.4	5	5
HM	7 -7.58	7 - 7.58	1.14 – 6.98	1.14 – 7.08	5	5
HSS	ND	ND	1.38 – 5.49	1.38 – 6.58	5	5
LM	ND	ND	2.98 – 5.38	3.27 – 6.82	5	5
LS	ND	ND	ND	ND	5	5
Lakes	N/A	N/A	N/A	N/A	N/A	N/A
Coastal waters	N/A	N/A	N/A	N/A	N/A	N/A

3.2.3.7 Parameters related to the waterbody's trophic status.

Rivers and Streams

Excessive periphyton biomass has well documented detrimental effects on aquatic biodiversity values (Biggs, 2000). Although excessive periphyton biomass is more likely to occur during extended summer low flow conditions, the detrimental effects on aquatic biodiversity will occur, regardless of the time

[12] One need to be particularly cautious to exclude from the standard only the streams that are naturally unsuitable for assessment by QMCI (ie. the standard should apply to streams that have soft bed material only as a result of human activities).

of the season or river flow. For this reason the recommended periphyton biomass standards should apply year round, under all river flow conditions.

Nutrients are key controllers of periphyton biomass, and nutrient concentration standards are recommended in section 6 of this report.

The 2000 New Zealand periphyton guidelines (Biggs, 2000) define two levels of protection:

- 50 mg chlorophyll a/m^2 for the protection of aquatic biodiversity. It is important to note that this is a very low level of biomass, and this guideline should only be applied to streams and rivers where high invertebrate biodiversity can reasonably be expected (Dr. Barry Biggs, pers. comm.). For this reason, **a standard of 50 mg chlorophyll a/ m^2 is** only **recommended** for the protection of aquatic biodiversity in the LSC classes that also have a QMCI standard of 6 (refer to Table 14), namely the **UHS and UVA classes**. It is noted that this level of periphyton biomass is very stringent, and temporary, moderate, exceedances of the standard can be expected, even in systems close to their natural state. For this reason, compliance with this standard should be based on 80% of monthly samples (ie. up to two-monthly samples exceeding the standard per year is acceptable) (Dr Barry Biggs, pers. comm.).
- 120 mg chlorophyll a/m^2 for the protection of angling and aesthetic/ recreation values. This biomass level is also suitable to protect a wide range of biodiversity values in slightly more enriched systems (Dr. Barry Biggs, pers. comm.). **120 mg chlorophyll a/ m^2 is the recommended standard for the ULi, UVM and HM classes**.

In catchments dominated by tertiary soft-sedimentary geology (**HSS class**) and in lowland areas (**LM and LS classes**), the periphyton biomass are likely to reach higher values, even if best practice were implemented in the catchments. Due to the catchment characteristics, particularly the natural sources of DRP, the high sediment loads, and/ or the very low summer flows, high invertebrate biodiversity should not be expected. **A maximum periphyton biomass standard of 200 mg chlorophyll a/m^2** is appropriate to protect these streams' biodiversity values (Dr. Barry Biggs, pers. comm.).

Physical conditions (eg. silty/sandy bed material, high turbidity) in some rivers and streams may preclude significant growth of periphyton, particularly in the lower/tidal reaches of the larger rivers, and in streams in the LS (Lowland Sand) class. It is however unlikely this would happen uniformly across whole water management zones. For example, although the Manawatu River downstream of Opiki has a silty bed material, some of its tributaries (eg. the Mangaore Stream) have a gravel bed and should be subject to periphyton standards. It is therefore recommended to maintain the periphyton standards as recommended in Table 15. At sites where periphyton growth is unlikely to be significant, it will only mean the standards are unlikely to be breached.

Table 15: Recommended periphyton biomass standards for streams and rivers in the different LSC classes, and observed values at monitoring sites.

LSC category	Observed periphyton biomass values (mg *Chlorophyll a* /m^2)				Recommended periphyton biomass standard (mg *Chlorophyll a* /m^2)
	Reference sites		Other sites		
	Mean	Max	Mean	Max	
UHS	4.2 – 25.1	5.6 – 47.8	5.7 – 31.1	8.9 – 35.9	50
UVA	9.9 – 27.3	15.9 – 33.8	10.8 – 89.5	10.8 – 157.7	50
UVM	ND	ND	13.4 – 189.4	13.4 – 355.7	120
ULi	ND	ND	90.7	119	120
HM	19.7 – 89	19.7 – 89	3 – 126.5	3 – 373.3	120
HSS	ND	ND	9.9 – 133.9	9.9 – 268.8	200
LM	ND	ND	25 – 118.9	27.6 – 136.6	200
LS	ND	ND	ND	ND	200

Lakes

Standards relating to algal biomass, water clarity, total phosphorus (TP) and total Nitrogen (TN) are recommended, and should apply year round.

Very limited data exists on the current water quality of the Region's coastal lakes. This has been identified as a knowledge gap, that should be addressed by Horizons' future monitoring and research programme, as recommended in section 9 of this report. Whilst little data exists on the current trophic status of the coastal lakes, it is estimated the lakes without a surface water inflow are naturally oligotrophic, and the lakes with a surface water inflow are naturally oligo- to mesotrophic (Dr Brian Sorrell, pers. comm.).

The recommended approach is to define water quality standards corresponding to the limit between mesotrophic and eutrophic status, as defined in Burns *et al.* (2000). These standards should adequately protect the naturally mesotrophic lakes. It is acknowledged that naturally oligotrophic lakes may not be adequately protected by these standards, and refinement of the recommended standards may be necessary once suitable information is gained.

The recommended standards for lake waters are:

- **Algal biomass: 5 mg/m^3 as annual mean and a maximum of 15 mg/m^3;**
- **Secchi depth: 2.8 m;**
- **Mean annual TN: 337 mg N/m^3; and**
- **Mean annual TP: 20 mg P/m^3.**

3.2.3.8 Ammonia

Ammonia can be toxic to many aquatic species, and is a common pollutant in treated agricultural, domestic and industrial discharges. The ammonia standard should apply at all times (ie. year round at all river flows).

As explained in section 2.3.5, the toxicity of ammonia is mostly due to unionised ammonia, the percentage of which is in turn determined by pH and temperature. The ammonia standards should therefore account for the expected pH and temperature range in the different classes of water. For ease of use, the recommended ammonia standard is expressed as total ammoniacal Nitrogen (NH_4-N) concentration.

Bibliography

In a study of the acute toxic effects of ammonia on eight New Zealand native species, Richardson (1997) found the 96h LC_{50}[13] ranged from 0.77 to 2.35 mg NH_3/L (expressed as unionised ammonia, temperature = 15 ^oC and pH = 7.5 to 8.1). In a previous study, Richardson (1991) reported a 96h LC_{50} range of 1.47 – 1.73 mg NH_3/L for juvenile inanga. The sublethal toxic effects of ammonia concentrations were not reported in either study, although the 96h LC_{10} values, which may provide an indication of the thresholds for toxic effects (Richardson, 1997), were reported to range 0.45 to 1.37 NH_3/L (expressed as unionised ammonia, temperature = 15 ^oC and pH = 7.5 to 8.1).

Hickey and Vickers (1994) studied the toxic effects of ammonia on nine New Zealand aquatic invertebrate species. The results indicate that some New Zealand invertebrate species are more sensitive to ammonia toxicity than fish species. A final acute value (FAV), incorporating the results for the four most sensitive species, of 0.15 mg NH_3/L (as unionized ammonia) was calculated. This FAV compares to the 0.52 mg NH_3/L criteria set by the USEPA to protect aquatic communities, including mature rainbow trout. Chronic exposure criteria cannot be determined in the absence of suitable studies on New Zealand species, but using acute-to-chronic ratios available in the scientific literature would result in calculated chronic criteria of 0.011 mg NH_3/L to 0.044. The authors concluded that the USEPA chronic criteria of 0.035 mg/L may not provide adequate protection for all New Zealand species, and recommended chronic studies should be conducted.

Existing national and international guidelines.

Both the USEPA 1984 Ammonia criteria (USEPA, 1985) and ANZECC 2000 guidelines are based on unionised ammonia concentrations.

The 1985 USEPA ammonia criteria is:

- 35 ppb[14] for pH >=8 and temperature = 15^oC, or
- 50 ppb for temperatures 20^oC and above when salmonids are not present.

The 2000 ANZECC guidelines incorporate published results relating to the ammonia toxicity on New Zealand native fish and invertebrate species, and compare them with international literature. ANZECC recommends the adoption of a trigger value of 35 ppb of unionised ammonia nitrogen for a protection level of 95% of species. This corresponds to a total ammonia nitrogen concentration of 900 mg NH_4-N/m^3 at pH 8 and 20^oC, recommended as default trigger value in the absence of site-specific temperature and pH data. This threshold value is estimated to adequately protect most New Zealand species (protection level of 95% species), except the freshwater clam *Sphaerium novaezelandiae,* common in lowland rivers. In cases where it is

[13] 50% lethal concentration: Concentration of contaminant at which 50 % of the test organisms die within the stipulated time – in this case 96h.

[14] Part per billion, which equates to µg/L or g/m^3.

judged important to protect the fingernail clams or related species, the Guidelines recommend halving the 95% trigger value, or adopting the 99% protection level (320 ppb at pH 8 and 20^{o}C). It is noted the ANZECC guidelines are based on a chronic exposure situation, typically longer than 4-5 days.
In the absence of new information, particularly chronic exposure studies on New Zealand fish and invertebrate studies, the proposed approach is to follow the recommendations of the ANZECC guidelines, ie. a maximum unionised ammonia nitrogen concentration of 35 ppb.

pH and temperature dependency

1. As explained in section 2.3.5, the toxicity of ammonia is mostly due to unionised ammonia, the percentage of which is in turn determined by pH and temperature. Therefore the ammonia standards, based on a maximum concentration of total ammoniacal Nitrogen (NH_4-N) for ease of use, should account for the expected pH and temperature range in the different classes of water. Generally, the higher the pH and temperature, the higher the percentage of unionised ammonia, so the higher the toxicity to aquatic life. However, the ANZECC Guidelines do not provide useful guidance with regards to the choice of temperature or pH used to derive the final standard value (eg. what percentile of the pH and temperature distributions should be selected).

2. Water pH and temperature will vary diurnally and seasonally in all natural waterbodies. High pH are likely to occur at times of high algal growth (section 2.3.1.1), which in turn generally occur during low/ stable river flows. The pH/ river flow graphs presented in Appendix 2 confirm that high pH nearly always occurs during low river flow. The monthly “spot sampling” data does not provide any indication of the duration of the high pH events (ie. how many days in a row high daily maximum pH values are reached).

One example of a pH/ temperature plot chart in Appendix 2 also indicates that there is a weak positive correlation between pH and temperature at the Manawatu at Teachers College site (ie. high temperature and high pH are reasonably likely to occur at the same time).

3. Due to the natural or induced variations in pH and temperature occurring in all waterbodies, the total ammonia-N concentrations corresponding to 35 ppb of unionised ammonia will depend significantly on which value of the pH and temperature data distribution is used. Table 16 provides an example of the range of total ammonia-N concentrations corresponding to 35 ppb of unionised ammonia-N under pH and temperature conditions recorded at the Mangatainoka River at SH2 Bridge monitoring site. The total ammonia-N concentrations vary from less than 180 to 7,800 mg NH_4-N/m^3.

Table 16: Range of total ammonia nitrogen (mg NH4-N /m^3) corresponding to the recommended 35 mg/m3 unionised ammonia recommended by the 2000 ANZECC guidelines for the protection of 95% of aquatic species, under different temperature and pH conditions. Temperature and pH are a real data example from the Mangatainoka at SH2 Bridge monitoring site. N.D. not determined – outside the range of values covered by the ANZECC guidelines.

			Temperature					
			Percentile of data					Standard (22 ^{o}C)
			50th (13.3 ^{o}C)	75th (16.9 ^{o}C)	90th (19 ^{o}C)	95th (20.2 ^{o}C)	Max (22.6 ^{o}C)	
pH	Percentile of data	50th (7.3)	7,800	7,600	6,800	6,300	5,300	5,500
		75th (7.6)	5,500	2,800	2,400	2,240	1.880	1,940
		90th (8.2)	950	731	636	591	499	515
		95th (8.4)	613	472	411	390	327	372
		Max (9.2)	N.D.	N.D.	<180	<180	<180	<180
		Standard (8.5)	494	385	333	313	267	270

The use of median temperature and pH values is not recommended, as a standard derived from these values would protect aquatic biota from toxic effect less than 50% of the time.

The 180 mg NH_4-N/m^3 value is based on a worst-case scenario where maximum observed pH and temperature occur at the same time, for several days in a row. The key question to answer is, how likely to occur is this scenario? As discussed in point 2 above, although maximum temperature and pH are unlikely to be observed at exactly the same time, high (relatively to the data distribution) temperature and pH do occur jointly. Based on this observation, recommendations based on the 90 to 95th percentile of the temperature and pH distribution is considered the most sensible approach.

For the Mangatainoka at SH2 example, this would translate into maximum recommended total ammonia-N concentrations of approximately 400 to 600 mg NH_4-N/m^3.

4. Another approach is to base the calculations of the pH and temperature dependency on the pH and temperature standards for each LSC class. The maximum ammonia concentration corresponding to 95% protection would then be:

- 636 mg NH_4-N/m^3 for UHS and UVA classes (pH 8.2, 19 ^{o}C)
- 333 mg NH_4-N/m^3 for ULi and UVM classes (pH 8.5, 19 ^{o}C)
- 313 mg NH_4-N/m^3 for HM and HSS classes (pH 8.5, 21 ^{o}C)
- 258 mg NH_4-N/m^3 for LM and LS classes (pH 8.5, 23 ^{o}C)

Based on pH standard alone, the maximum ammonia concentration corresponding to 95% of species protection level would be 660 for UHS and UVA classes and 400 mg NH_4-N/m^3 for all classes.

Recommended standards:

- For UHS and UVA waters: the ANZECC guidelines recommend that the 95% protection level should adequately protect most ecosystems that are slightly to moderately disturbed. The UHS and UVA systems are mostly undisturbed systems, with invertebrate communities characterised by pollution-sensitive taxa. The 99% protection level is also consistent with the recommended level of protection for other toxicants for these LSC classes.
  The recommended ammonia standard for UVA and UHS waters is: 320 mg NH_4-N/m^3 (expressed as total ammonia-nitrogen).

- For all other classes of waters (HM, UVM, ULi, LM, LS, Lake waters)
  The recommendations detailed in the "pH and temperature dependency" paragraph above range from 240 to 600 ppb (mg NH_4-N/m^3).
  The recommended standard for the HM, UVM, ULi, LM, LS and Lake waters is a mid-point value of **400 mg NH_4-N/m^3** (expressed as total ammonia-nitrogen).

Note on the recommended ammonia standards in relation to the nutrient standards

It is important to note that ammonia nitrogen is one of the soluble inorganic nitrogen (SIN) and total nitrogen (TN) forms. SIN is directly available to plant growth and the recommended nitrogen-related standards are based on SIN concentrations. The SIN standards apply to all waterways in the Region when the river flows are at or below 3*median flow. The SIN standards recommended for rivers in the Region range from 70 to 444 ppb. Any ammoniacal nitrogen limit imposed on a consented discharge will have to ensure both the ammoniacal nitrogen standard relating to ammonia toxicity and the SIN standard (incorporating ammonia- and nitrate- nitrogen) are complied with. The recommended SIN standards apply year round when the river flows are at or below 3*median flow, representing between 75% and 95% of the time depending on the hydrogeological characteristics of the river system. In the recommended framework, the ammonia standard will therefore be superseded by the SIN standard 75% to 95% of the time.

3.2.3.9 Other toxicants

The 2000 ANZECC guidelines incorporated the best scientific information available at the time of development. To the best of our knowledge, there are no further comprehensive studies justifying a significant departure from the ANZECC recommendations on acceptable levels of waterborne toxicants.

With the exception of cadmium, which has been monitored at a very few sites, toxicants are not routinely monitored in Horizons' monitoring programmes. In the absence of monitoring data, the approach taken is to base the definition of the recommended standards on the tolerance/requirements of typical aquatic biota.

The ANZECC guidelines recommend several levels of protection, depending on the level of disturbance acceptable at the site. These levels of protection correspond to the percentage of species likely to be adequately protected by the corresponding guideline level: 99% is the recommended level for systems of high biodiversity value, 95% for slightly to moderately disturbed ecosystems, and 90% for highly disturbed ecosystems.

It is recommended that the level of protection defined in the ANZECC guidelines be linked with the likely pollution sensitivity level of the aquatic biota characteristic of each LSC class. Generally speaking, the biota present in the UHS and UVA classes are particularly sensitive to disturbance and pollution.

The recommended level of protection for the zones with a LSC classification of UHS or UVA is 99%. The 95% protection level is recommended for all other LSC classes. These standards should apply at all times.

The recommended levels of protection for each LSC class are summarised in Table 21.

It is noted that some toxicants, particularly some heavy metals, may naturally occur at relatively high levels (sometimes exceeding guideline levels), for example in areas of strong volcanic/geothermal activity. If future monitoring demonstrates it to be the case in any of the Region's waters, the recommended approach is to modify the relevant water quality standard to account for these natural levels.

3.3 Definition of water quality standards in relation to the SOS-A, SOS-R and NFS Values.

When known, the requirements of all species of fish and invertebrates, including rare and threatened species, were incorporated in the decision-making process leading to the definition of the Life-Supporting Capacity (LSC) standards.

The requirements of the whio, or blue duck, were not specifically considered in the definition of the LSC standards. The SoS-A sites defined for the protection of existing blue duck populations occur along streams and rivers classified as either NS (natural state), UHS (upland hard sedimentary), UVA (upland volcanic acidic) and/or TF1 (outstanding trout fishery). Outside its riparian habitat requirements (including low predator density), one key requirement of whio is the presence of aquatic invertebrate communities dominated by large stonefly, mayfly and caddisfly species. Water classified as UVA, UHS and TF1 have all a recommended QMCI standard of 6, indicative of clean water, and generally indicative of large invertebrate species. The other water quality requirements of the whio should also be provided for by the relatively stringent standards associated with HS, UVA and TF1 waters.

It is therefore considered the LSC standards will adequately cover the water quality requirements associated with the protection of the SoS-A value. In the same fashion, it is considered the LSC standards will adequately cover the water quality requirements associated with the protection of the NFS value.

The protection of the SoS-R value will primarily require protection of roosting, nesting and feeding habitats at critical times (Lambie, 2007). The water quality requirements associated with this value should be adequately covered by the LSC standards.

4 Definition of water quality standards in relation to the Recreational and Cultural Values.

The "Cultural and Recreational Values" group recognizes the non-commercial values and uses of the waterbodies and their margins. Nine individual values have been identified in this group (Ausseil and Clark 2007):

- Contact Recreation (CR)
- Amenity (Am);
- Native Fishery (NF)
- Mauri (M)
- Shellfish Gathering (SG)
- Sites of Significance – Cultural (SoS-C)
- Trout Fishery (TF)
- Trout Spawning (TS)
- Aesthetics (Ae)

Whilst all of these values have a direct link with water quality, they do not all require translation into specific water quality standards, because the protection of their water quality aspects is either or both:

- covered by water quality standards associated with other values, or
- better addressed by narrative policies and methods.

Further, most of these values also include considerations that are not directly linked with water quality, or cannot be addressed by water quality standards. An example of this is the maintenance of safe public access to sites where the Amenity value is recognised.

The CR value requires translation into water quality standards relating to the protection of public health and the visual "use" of waterbodies. These are detailed in section 4.1 below.

Both the Am and Ae values include considerations that do not require translation into water quality standards (such as public access), but also considerations relating to the visual aspect of the waterbody, which are covered by the water quality standards associated with the CR value.

The water quality requirements of native fish species are covered by the Life-Supporting Capacity (LSC) standards described in section 3.2. For this reason, it is considered the NF value does not require additional water quality standards.

The Mauri value includes considerations relating to the life-supporting capacity of waterbodies, the protection of which is covered by the LSC standards. Considerations relating to swimming in, and gathering food from, lakes, streams and rivers are covered by the CR and SG standards. The spiritual aspects are probably better addressed by specific policies. For example, the inclusion of specific policies relating to the mixing of waterbodies and the direct discharge of effluent of human origin, is recommended for the One Plan, but is not addressed in this report.

The protection of the SoS-C value may, in some cases, require specific water quality standards. However, the SoS-C sites have not yet been identified and it is recommended the protection of the sites of cultural significance be addressed as required on a case by case basis.

Consuming shellfish taken from contaminated water may pose a significant health risk to people, and specific water quality standards are necessary to protect the SG value, as detailed in section 4.2.

The water quality requirements of trout are not specifically considered in the development of water quality standards associated with other values. The LSC standards are developed to provide for the water quality requirements of native fish and invertebrates, and may not cover adequately all the requirements of rainbow and brown trout. The protection of the TF and TS values therefore requires the development of specific water quality standards (sections 4.3 and 4.4 of this report).

4.1 Definition of water quality standards in relation to the Contact Recreation value

4.1.1 Methodology and definition

The Contact Recreation (CR) value covers activities in which the user enters in contact with the water (contact recreation), such as swimming and boating. It also includes considerations relating to the visual use, or visual aspect of the waterbody. The CR value is recognised in all natural waterbodies, including streams, rivers, lakes and coastal waters (Ausseil and Clark, 2007a).

It is noted that the physical characteristics of some streams, rivers and lakes may preclude contact recreation. For example, first or second order streams are generally too small for swimming; other rivers may be flowing through inaccessible gorges. However, these streams and rivers usually flow into larger river systems, or directly into the sea, potentially affecting water quality at sites where contact recreation may occur. Recent research has indicated that faecal indicator bacteria and associated pathogens may survive for several weeks in stream bed sediment and be transported downstream (Sinton *et al.*, 2002). The potential for streams and rivers to adversely affect downstream water quality is high, and, on this basis, it is recommended the water quality standards for contact recreation applies to all natural waterbodies.

The 2000 ANZECC guidelines define three categories of water-based recreational activities:

- the activities in which the user comes into frequent direct contact with water, such as swimming and waterskiing (Primary Contact);
- the activities that generally have less frequent body contact with the water, such as boating and fishing (Secondary Contact); and
- activities occurring in close proximity to the waterbody but that do not involve direct contact with the water, such as walking (Visual Use).

The ANZECC guidelines provide a list of water quality parameters relevant to the CR value and useful guidance on numerical acceptable limits for some of these parameters (Table 17). It is noted however that some parameters (eg.

nuisance organisms) are only described in general terms, and require significant refinement in order to define numerical water quality standards. Further, two more recent documents also provide numerical guidelines for recreational waters:

- the 2002 Microbiological Water Quality Guidelines for Marine and Freshwater Recreational areas, published by the Ministry of Health and the Ministry for the Environment (MfE, 2002),
- the New Zealand Periphyton Guidelines (Biggs, 2000) provide acceptable levels of periphyton in relation to the recreational use of rivers and streams.

These documents incorporate the latest research findings and should be used to refine or supersede altogether the ANZECC Guidelines.

4.1.2 Time of the year and river flow conditions relevant to the protection of the CR value

Primary Contact Recreation, such as swimming, is most likely to occur during the warmest months of the year. The 2003 Microbiological Water Quality Guidelines, define the bathing season as follows: "the bathing season will vary according to location, but will generally extend from 1 November to 31 March." The Manawatu Catchment Water Quality Regional Plan (MCWQRP) defines the bathing season as "the period of 1 November to 1 May inclusive" (MCWQ Rule 2.e).

Since the 2004-05 summer, Horizons Regional Council has conducted a weekly monitoring at more than 30 recognised river and coastal swimming sites across the Region. The weekly monitoring begins early November and ends when the river flow and temperature conditions become unsuitable for swimming, usually between mid and end of April.

In rivers, primary contact Recreation is much less likely to occur during high river flow. The MCWQRP contact recreation standards apply when the river flow is at or below half median flow. However, there is ample anecdotal evidence that the rivers are used for primary contact recreation when the river flow is significantly higher than half median flow up to about median flow.

In accordance with the considerations above, it is recommended that the water quality standards relating to primary contact recreation (swimming) apply during the period 1 November to 31 April. For rivers, these standards should apply when the river flow is at or below median flow.

Secondary Contact Recreation, such as boating, kayaking or fishing, may (and does) occur year round in many rivers and lakes, although the intensity of use is generally lower in winter. In rivers, secondary contact usually occurs at all river flows except during floods. A commonly used cut-off value to define a flood flow is three times the median flow (Biggs, 2000).

Based on the considerations above, it is recommended the water quality standards relating to secondary contact recreation apply year round. For rivers, these standards should apply when the river flow is at or below three times the median flow.

Visual “use” of the waterbodies is likely to occur year round, regardless of river flows. However, the general community’s expectations are likely to vary depending on the location and conditions. For example, one would expect relatively clear water during low river flows, while it would be unreasonable to expect clear waters during a flood, and the water quality standards should account for this.

4.1.3 Recommended water quality standards for the protection of the CR value

The 2000 ANZECC guidelines define three groups of water quality characteristics relevant to recreational use of the water for Primary and Secondary Contact and Visual use, as well as the relevant water quality parameters and a number of numerical or narrative guidelines, as summarised in Table 17.

Table 17: Water quality characteristics relevant to the Contact Recreation value, water quality parameters and recommended guidelines, as adapted and compiled from the 2000 ANZECC guidelines. (N/A: not applicable).

<table>
<tr><th>Characteristic</th><th>Parameter</th><th>Primary contact</th><th>Secondary contact</th><th>Visual use</th></tr>
<tr><td rowspan="3">Microbiological</td><td>Faecal coliforms (median value)</td><td>150/ 100mL</td><td>1000/100mL</td><td>N/A</td></tr>
<tr><td>Enterococci (median value)</td><td>35/100mL</td><td>230 /100mL</td><td>N/A</td></tr>
<tr><td>Pathogenic free-living protozoans</td><td>Absent</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="3">Nuisance organisms</td><td colspan="4">“Macrophytes, phytoplankton scums, filamentous algal mats, sewage fungus, leeches, etc. should not be present in excessive amounts”</td></tr>
<tr><td>Algae</td><td colspan="2">15 - 20, 000 cells /mL</td><td>N/A</td></tr>
<tr><td>Midges and aquatic worms</td><td colspan="3">Large numbers should be avoided</td></tr>
<tr><td rowspan="8">Physical and chemical</td><td></td><td colspan="3">1.6m
(horizontal visibility of black disc)</td></tr>
<tr><td rowspan="3">Water clarity and colour</td><td colspan="3">The natural visual clarity should not be changed by more than 20%</td></tr>
<tr><td colspan="3">The natural hue of the water should not be changed by more than 10 points on the Munsell Scale</td></tr>
<tr><td colspan="3">The natural reflectance of the water should not be changed by more than 50%</td></tr>
<tr><td>pH</td><td>5 to 9</td><td>5 to 9</td><td>N/A</td></tr>
<tr><td>General chemicals and pesticides</td><td colspan="3">An extensive list of chemicals and acceptable maximum concentrations is defined in tables 5.2.3 and 5.2.4</td></tr>
<tr><td>Surface films</td><td colspan="3">“Oil and petrochemicals should not be noticeable as a visible film on the water nor should they be detectable by odour”</td></tr>
</table>

The following paragraphs provide the rationale for the recommended water quality standards in relation to the CR value, as also summarised in Table 21.

4.1.3.1 Microbiological water quality

The recommended approach is to follow the 2002 MfE guidelines, which recommend the use of the following indicator bacteria to assess the level of faecal contamination and associated health risk to water users:

- *Escherichia coli*, commonly called *E. coli*, is a bacteria species that lives exclusively in the gut of warm-blooded animals (mammals and birds). It is the recommended indicator organism for freshwaters[15].
- Enterococci have been identified as having the best relationship with health effects in marine waters[16].

It is noted the Manawatu Catchment Water Quality Regional Plan (MCWQ) sets microbiological water quality standards based on Enterococci, which was the recommended/preferred indicator for freshwaters at the time the MCWQ was developed. As explained above, the MfE guidelines now recommend the use of *E. coli* in freshwater environments. Accordingly, Horizons has used *E. coli* in its SOE and compliance monitoring and reporting programmes and resource consent conditions for a number of years.

The 2002 MfE guidelines define a three-mode management system for recreational beaches: Acceptable/Green mode, Alert/Amber mode and Action/Red mode. The green mode indicates a low level of health risk, the Amber mode is indicative of a slightly more elevated, although still acceptable, health risk, and the red mode indicates the health risk to swimmers is unacceptable and the site/beach is unsuitable for swimming.

Most Regional Councils in New Zealand follow the recommendations of the MfE guidelines and report their monitoring result within the three mode framework.

To minimise the health risk to water users whilst avoiding unnecessarily stringent limits, the recommended approach is to maintain the waters within:

- the “green” category when primary contact recreation is most likely (summer and relatively low river flows), and
- the orange category when secondary contact is predominant (the rest of the time except during river floods).

Accordingly, the recommended standards are as follows:

- for freshwater lakes, 260 *E. coli* /100 mL during the bathing season, 550 *E. coli* /100 mL outside the bathing season,
- for freshwater rivers and streams, 260 *E. coli* /100 mL when the river flow is at or below median flow during the bathing season, and 550 *E. coli* /100 mL the rest of the time when the river flow is at or under three times the median flow.
- For the coastal marine area, 140 enterococci /100 mL during the bathing season and 280 enterococci /100 mL the rest of the year.

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[15] Although there may be exceptions, eg. in close proximity to large waste stabilisation pond outfalls (MfE 2002).

[16] Enterococci may also be derived from other than faecal sources in some conditions, such as warm temperatures and mangrove swamps or freshwater runoff from dense vegetation (MfE 2002). High numbers of Enterococci have also been identified in some warm industrial waste streams.

4.1.3.2 Nuisance organisms

Rivers and streams

The 2000 New Zealand periphyton guidelines (Biggs, 2000) define two key parameters to assess the level of impact of periphyton growth on the recreational and visual values of streams and rivers: periphyton biomass (expressed as mg chlorophyll a/m^2) and periphyton cover (expressed as percentage cover of the stream bed).

- A maximum biomass of 120 mg chlorophyll a /m^2, and
- A maximum of 30% bed cover by filamentous algae more than 2 cm long.

The percentage of bed cover is a visual measurement and is directly relevant to the protection of the visual use of the rivers, and the maximum bed cover of 30% by filamentous algae is recommended for the One Plan.

Periphyton biomass standards have been defined in relation to the LSC value. As explained in section 3.2.3.7 of this report, the natural geology settings in some catchments cause naturally elevated levels of nutrients, phosphorus in particular. In a predominantly deforested landscape, relatively high periphyton biomass levels are expected to occur in these streams and rivers, and maintaining low periphyton biomass in these streams may be an unreasonable expectation (Dr. Barry Biggs, pers. comm.). The water quality standards associated with the Life Supporting Capacity value vary from 50 to 200 mg chlorophyll a/m^2, depending on the ecosystem type. Rather than relying on a unique maximum biomass value, it is recommended that the LSC standards be adopted for the protection of the CR value.

The presence of other nuisance organisms, including sewage fungus[17], is generally adequately covered by the water quality standards set in sections 105 and 107 of the Act.

Lakes

In lakes, nuisance algae (green algae or cyanobacteria) usually occur as planktonic blooms, the intensity of which is measured by the algal biomass, expressed as mg chlorophyll a /m^3 (Burns *et al.* 1999).

An algal biomass standard has been recommended in relation to the protection of the LSC value in lakes, and the same standard is recommended for the protection of the CR value (refer to section 3.2.3.7 of this report).

4.1.3.3 Water clarity

Minimum water clarity standard

In rivers and streams, water clarity is usually measured as the horizontal visibility range of a black disc. This parameter is recommended for the One Plan. Water clarity is of considerable importance in relation to the CR value, because it affects the recreational and aesthetic quality of the water. In addition, visual clarity is also important so that swimmers can estimate depth and see sub-surface hazards (ANZECC, 2000).

[17] BOD and nutrient standards set in relation to other values, such as the LSC and TF values will ensure sewage fungus growth (visible as plumose mats) does not occur outside the zone of reasonable mixing.

The 2000 ANZECC guidelines recommend the water clarity of recreational waters should exceed 1.6 m, and this threshold value is recommended for the One Plan.

Water clarity affects all aspects of recreational use of waterways: primary and secondary contact and visual use. To protect the visual use of lakes and coastal waters, the recommended standard should apply year round. It is noted however, that the standards associated with the LSC value define a minimum water clarity of 2.8 m in lakes, that will supersede the recommended 1.6 m CR standard.

In rivers, the standard should apply under median flow during the bathing season to protect primary contact. Visual use of the waterbodies occurs year round, at all river flows. However, most rivers are naturally turbid during high river flows, and would be expected to breach the 1.6 m limit at least occasionally.

It is suggested that relatively clear water during periods of base flow constitutes a reasonable expectation, and it is recommended that the minimum water clarity standard of 1.6m apply year-round, when the river flow is at or below the median flow.

Water clarity change standard
A sudden, conspicuous change in water clarity due to an activity or discharge is likely to affect the visual use of a waterway. Section 107(1)(d) of the Act also prohibits the granting of resource consents to activities likely to cause a conspicuous change in water clarity or colour. A standard setting a maximum allowable water clarity change as a result of an activity is recommended for the One Plan.

As explained in section 2.3.2.2 of this report, most people can detect a change of 30% in visual clarity (Davies-Colley and Smith, 1990). A maximum water clarity change of 30% is recommended as a standard for the One Plan.

4.1.3.4 pH

This parameter is considered very relevant to the protection of the CR value and is recommended for the One Plan. The ANZECC Guidelines recommend a pH range of 5 to 9 for recreational waters to avoid irritation of the eyes. This is the recommended range for the One Plan standard, although it is noted this standard will be superseded by the more stringent LSC pH standard.

4.1.3.5 Surface films and odours

These parameters are considered very relevant to the protection of the CR value. However their exact nature and origin can be very varied and they are best covered by the general narrative standards set in Sections 105 and 107 of the Act, and no further water quality standards in relation to surface films and odours are recommended for the One Plan.

4.1.3.6 Other chemicals

A large number of chemicals can impact on the CR value. However, they are not routinely monitored as part of Horizons' monitoring programmes, and defining water quality standards relating to these parameters was judged outside the scope of this work, and no water quality standards are recommended for the One Plan. The 2000 ANZECC Guidelines provide an extensive list of relevant parameters and numerical acceptable limits. It is recommended that the ANZECC guidelines be used as/if required on a case by case basis.

4.2 Definition of water quality standards in relation to the Shellfish Gathering (SG) Value

The SG value recognises the requirement that the shellfish collected along the Region's coasts be safe for human consumption. It applies to all waters within the Coastal Marine Area (Ausseil and Clark, 2007a).

Two documents, the 2000 ANZECC Guidelines and the 2002 microbiological water quality guidelines (MfE, 2002), provide guidance on the microbiological water quality requirements to minimise health risk to human consumers of aquatic food species. It is noted that the ANZECC guidelines relate to water quality for both commercial and recreational shellfish aquaculture/gathering, while the MfE guidelines refer only to recreational shellfish gathering.

Both documents recommend that the concentration of faecal coliforms in the water as the indicator of the presence of pathogenic bacteria, viruses and protozoans.

The ANZECC and MfE guidelines define the same numerical values for the protection of the SG value, and it is recommended to use them as standards for the One Plan:

- a maximum median value of 14 faecal coliforms /100 mL, and
- a maximum 90% percentile value of (ie. no more than 10% of the samples over) 43 faecal coliforms /100 mL.).

Shellfish gathering occurs year round on both the Region's east and west coasts; the SG standards should therefore apply year round.

It is noted the gathering of shellfish may involve direct, prolonged, contact with water. The minimisation of health risks related to this aspect of the SG value is addressed by the CR standards.

A number of waterborne chemical contaminants (toxicants) may render the flesh of aquatic organisms unsuitable for human consumption. The food standards developed by ANZFA and published in the Food Standards Code (ANZFA 1996, and updates) aims to protect consumers from chemically contaminated foods, including aquatic species. These standards are measured directly in the flesh of aquatic organisms, rather than in the water, and are not recommended for inclusion in the One Plan (although their use is recommended if required).

4.3 Definition of water quality standards in relation to the Trout Fisheries (TF) value.

4.3.1 Methodology / definition

Although other salmonid species have been recorded[18], only two species have significant, self-sustaining populations in the Horizons Region: the brown trout (*Salmo trutta*) and the rainbow trout (*Onchorhyncus mykiss*). The standards associated with the TF value were therefore primarily defined to provide for the requirements of sub-adult and adult brown and rainbow trout, as well as one of their main food sources - macroinvertebrates. Trout egg and fry development are also necessary to sustain good trout fisheries, and their requirements are covered by the Trout Spawning (TS) standards.

Three categories of trout fisheries have been defined in (Ausseil and Clark, 2007b), as summarised by Map 4. The guiding philosophy for defining the TF water quality standards is to provide different levels of protection to these three TF categories:

- The Outstanding Trout Fishery value (TF1) applies to the Region's two internationally significant trout fisheries that are protected by National Water Conservation Orders: the Upper Rangitikei River and the Manganui o te Ao River. The recommended standards aim to protect optimum or near-optimum conditions for trout, whilst remaining consistent with the NWCOs standards.
- The Regionally Significant Trout Fishery value (TF2) applies to the Upper Hautapu, the Upper Manawatu, Makuri and Mangatainoka Rivers. The recommended standards were designed to protect, as much as practicable, conditions that could be deemed "good to excellent" for trout.
- The Other Trout fisheries value (TF3) applies to all other locally significant trout fisheries. The TF3 standards aim to maintain "tolerable to good" conditions for trout.

The different trout species are generally considered sensitive to environmental conditions, particularly to a wide range of human-induced environmental degradations, including physical habitat degradation, water chemistry, toxicants, sediment and temperature.

The water quality requirements of both brown and rainbow trout have been quite extensively studied, and a wealth of information is available in both New Zealand and international scientific literature, some of which is summarised and incorporated in the ANZECC guidelines.

The Cawthron Institute was commissioned to produce a report summarising recommendations for water quality standards to protect the TF and TS values (Hay *et al.* 2006). For ease of reading, the "Hay *et al.* 2006" report is sometimes referred to in the text of this report as "the Cawthron report".

[18] Quinnat salmon (*Oncorhynchus tshawytscha*) have also been reported in a number of the Region's rivers, but they are considered isolated stragglers, and no sizeable population with significant established spawning is known in the Manawatu-Wanganui Region and small populations of brook trout (*Salvelinus fontinalis*) can be found in small streams in the headwaters of the Moawhango River (McDowall, 1990).

The recommendations of the Cawthron report were largely used to define the TF water quality standards recommended in this report, supplemented where required with monitoring data, information from scientific literature and national and international guidelines.

4.3.2 Recommended water quality standards for protection of the TF value.

As summarised in Table 4, the parameters relevant to the protection of the trout fishery value include parameters of direct relevance to the trout's physiological requirements, aquatic macroinvertebrates (which trout largely prey upon) and their habitat.

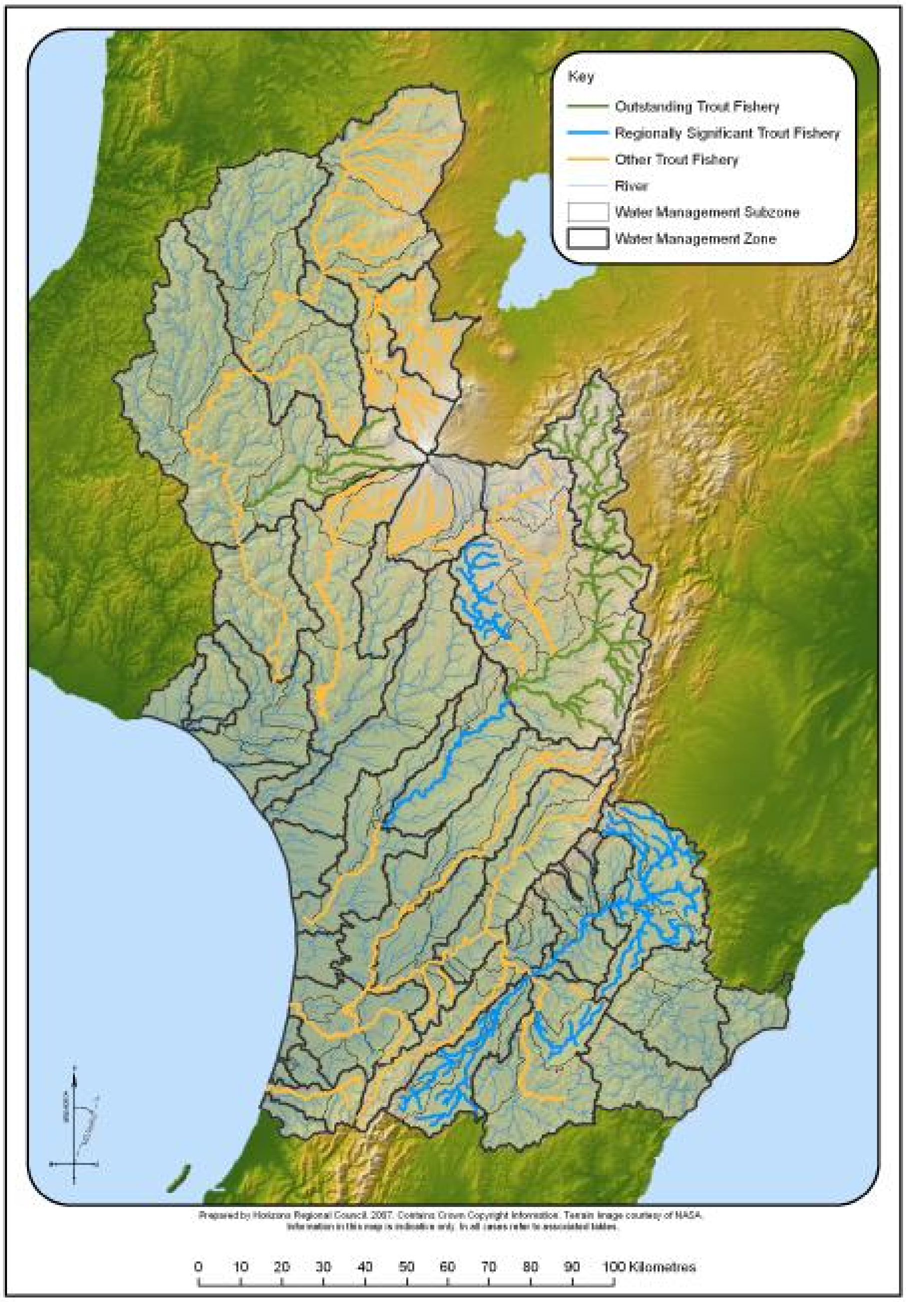
4.3.2.1 Water pH

As explained in section 2.3.1.1 of this report, the recommended pH standards should be a pH range, ie. defining both a daily maximum and a daily minimum, applying at all times.

Raleigh *et al.* (1986) suggest the tolerable range of pH for brown trout is 5 to 9.5, with an optimal range of 6.7 to 7.8. Kwak and Waters (1997, in Hay *et al.* 2006) found a positive correlation between salmonid production and alkalinity in North American streams (ie. trout production is lower in streams with acidic water).

The Cawthron report recommends that maintaining the pH within a circum-neutral range should avoid any adverse effect on trout, although it may be necessary to adapt these guidelines.

The LSC pH standard takes into account the natural pH of the different classes of waters, as well as the pH requirements of native fish and invertebrates. The reported pH tolerance range for trout are similar to those of native fish, thus it is considered the LSC standards should provide adequately for the pH requirement of trout. This approach is considered to be in agreement with the Cawthron report's recommendations.



Map 4: Recommended trout fishery Classification in the Manawatu - Wanganui Region (Ausseil and Clark, 2007a).

4.3.2.2 Water Temperature

As explained in section 2.3.1.2, the recommended approach is to set daily maximum temperature standards and maximum temperature change, that apply whenever the TF value applies, ie. at all river flows and year round.

The water temperature requirements of trout are discussed at length in the Cawthron report, and the recommended standards follow its conclusions:

- A maximum temperature of 19°C for TF1 and TF2 waters. The first deleterious effects of temperature on trout are observed at temperatures of 19°C and above.
- A maximum temperature of 24°C for TF3, to maintain temperature below the incipient lethal temperature, ie. to avoid trout death as a result of too high water temperature.

Due to the sensitivity of trout to temperature change, a maximum temperature change standard is also recommended. Both the Rangitikei and Manganui o te Ao National Water conservation orders impose a maximum water temperature change standard of 3°C. For consistency with the NWCOs, the same temperature change standard (3°C) is recommended for the One Plan for the three classes of trout fisheries. It is noted this standard applies within the bounds of the maximum temperature standard. The exact recommended spelling of the temperature standard is provided in section 7 of this report.

4.3.2.3 Dissolved Oxygen and BOD

Dissolved oxygen (DO) is essential for aerobic forms of river life, including trout and macroinvertebrates. As explained in section 2.3.1.3 of this report, the recommended DO standard is based on a daily minimum dissolved oxygen saturation. The standard should apply at all times (ie. year round, at all river flows).

The DO requirements of trout are discussed in the Cawthron report. Although the incipient lethal concentration of DO for rainbow and brown trout is about 3 mg/L, the minimum oxygen concentration tolerated by trout is about 5 to 5.5 mg/L for short-term exposure and about 6 mg/L for extended periods of time. A concentration of 8 mg/L should ensure a very low level of effects (ie. a high level of protection) to trout populations. Table 5 provides the corresponding DO saturation corresponding to these concentrations at different temperatures.

The 1986 USEPA DO criteria associate minimum DO concentrations with an acceptable level of impairment of the trout fishery (Table 18). This is particularly useful guidance in the context of this work, as different levels of protection (equivalent to acceptable impairment) are associated with different trout fishery classes (TF1, TF and TF3).

Table 18: Dissolved Oxygen concentrations (mg/l) recommended by the U.S. Environmental Protection Agency to confer five levels of protection for waters containing "other life stages" (ie. not early life stages) salmonids (adapted from Dean and Richardson 1999), and corresponding DO saturation.

Degree of impairment acceptable	DO (mg/L)	Saturation (°C)			
		10	16	19	24
None	8	71	81	86	95
Slight	6	53	61	65	71
Moderate	5	44	51	54	59
Severe	4	35	41	43	48
Acute	3	27	30	32	36

Based on the above considerations, the recommended DO standards for the protection of the trout fishery value in the One Plan are:

TF1

Following the USEPA and BCME recommendations, a minimum DO concentration of 8 mg/L corresponds to high level of protection. At 19 °C (the maximum temperature standard for TF1 waters), this corresponds to a DO saturation of 86%. This appears to be a logical recommendation for the One Plan. However, both Rangitikei River and Manganui O Te Ao National Water Conservation Orders (NWCO) set a minimum DO standard of 80% saturation. To ensure consistency with the NWCOs, **the recommended DO standard for TF1 waters is 80% saturation**. It is noted this is also consistent with the Cawthron report recommendations.

TF2

The Cawthron report recommends a minimum DO saturation for the protection of TF2 waters. At 19°C, 80% DO saturation corresponds to 7.5 mg/L. In the USEPA criteria, 7.5 mg/L is between "no impairment" and "slight impairment", which in turn corresponds well to the level of protection sought for TF2 waters defined in section 4.3.1 of this report.

Accordingly, the recommended DO standard for TF2 waters is 80% saturation.

TF3

A DO concentration of 6 mg/L is acceptable to trout in the short term, even though long term exposure may lead to sublethal effects, such as decreased growth rate (Hay *et al.*, 2006).

At 24°C (the maximum water temperature standard for TF3 waters), 6 mg/L corresponds to 70% saturation. At lower temperatures, 70% saturation would ensure DO concentration above 6 mg/L. At temperatures above 24°C, 70% saturation will correspond to DO concentration below 6 mg/L, potentially leading to detrimental effects on trout. This example re-emphasizes the importance of the temperature standard, and more generally the interdependency of the different standards.

As justified in section 3.2.3.4, **the following BOD_5 standards are recommended:**

- **1 g/m^3 where the DO standard is 80% saturation (TF1 and TF2)**
- **2 g/m^3 where the DO standard is 70% saturation (TF3).**

4.3.2.4 Water clarity

Sediments in the water column and/or deposited on the riverbed can have serious detrimental effects on fish and invertebrates. Water clarity and turbidity are particularly important for trout, since they rely heavily on eyesight for predation, and drift feeding is the predominant foraging behaviour in most rivers. Increased turbidity/lower clarity is expected to have an adverse effect on trout because it reduces their foraging radius and efficiency (Hay *et al.*, 2006).

High levels of suspended sediments can also have a direct detrimental effect on trout, through direct physical abrasion effect of gill rakers and gill filaments. Deposited fine sediment may also impact on the availability of suitable benthic habitat for trout spawning and macroinvertebrates, which generally represent a significant proportion of trout diet in rivers.

As discussed in section 2.3.2, water clarity is the recommended indicator of the amount of sediment in the water column, and is also the recommended default indicator of the risk of fine sediment deposition.

General approach

The Cawthron report recommends a minimum water clarity of 5 m for TF1 and TF2 and 3.5 m for TF3 under base flow conditions to protect the sight feeding ability of trout, although the authors recognise there will be cases where the underlying geology may render these guidelines unattainable. The alternative recommendation is to use the 10th percentile of existing data[19]. It is noted this recommendation is based on the assumption that the current situation is satisfactory and should be maintained. The Cawthron report also recommends the setting of water clarity standards under base flow conditions, as a surrogate for a direct measure of deposited sediment, to protect macroinvertebrate habitat.

The visual quality of the river in relation to the trout fishery also needs to be considered. Water clarity is particularly important for sight fishing, an angling approach extensively used in New Zealand trout fisheries. It is generally considered sight fishing opportunities are severely limited when the water clarity is less than 2 m. A 3 m clarity is generally considered acceptable, and a 4 to 5 m clarity does not restrict sight fishing (Peter Taylor, pers. comm.)

The approach taken is to define water clarity standards that will apply under median flow (ie. base flow conditions). The standards aim to protect the sight-feeding of trout, the visual/aesthetic value for the anglers and limit the deposition of fine sediment during base flow conditions.

Standards in relation to the three trout fisheries classes

The water clarity requirements for an outstanding trout fishery, both to protect the requirements of trout and to satisfy the anglers' expectations, are higher than for a less significant fishery. Accordingly, the standards associated with

19 The Cawthron report refers to the 90th percentile of existing turbidity data. Water clarity a minimum standard (ie. a high water clarity is "good"), and turbidity is a maximum standard (ie. high turbidity is "bad"). The 90th percentile of the turbidity data and the 10th percentile of the clarity data correspond to the "bad" end of the spectrum. The 10th or 20th percentile of the clarity data is used when the 80th or 90th percentile of the turbidity data is recommended.

the TF1 value should logically be more stringent than the TF2 standards, in turn more stringent than TF3 standards.

The standards should also account for the natural limitations of some catchments to have clear water. When available, reference data is particularly useful in this context. Reference data can be used in different ways to provide appropriate levels of protection to the different TF classes.

- TF1 waters are expected to be at, or very near to, reference level. Accordingly, TF1 standards were based on the 20th percentile of reference data. This way, reference sites comply with the standard[20], but a degradation of the reference sites, or a degradation compared to the reference site will translate into a breach of the standard.
- For TF2 waters, a slight level of degradation compared to reference conditions is acceptable. One approach was to define standards based on the 10th percentile of the reference data. Because compliance with the standard should use the 20th percentile of the clarity data, a site with water clarity slightly worse than reference condition would still comply. Another approach was to use near reference data from slightly degraded TF1 sites.
- TF3 waters are too variable in their catchment characteristics to allow an appropriate use of reference data. The approach taken was to base the standard on acceptable clarity for fishing.

As explained in section 2.3.2.2 of this report, a water clarity change standard is a useful tool to limit the effects of an activity on both the ecological and visual values of a waterbody. The recommended approach is to standard set a maximum water clarity change of 20% in nationally and regionally significant trout fisheries (TF1 and TF2) and 30% in other trout fisheries.

The following paragraphs summarise the information considered in making a recommendation:

TF1

The Cawthron report's recommendation for TF1 waters is a water clarity of 5 m during base flow conditions.

Monitoring data is available at four sites in the TF1 class. Two sites can be considered as reference: Rangitikei at Pukeokahu and Manganui o te Ao at Hoihenga Rd. However, no flow data is available for the Manganui o te Ao River, so only the Rangitikei at Pukeokahu provides useful reference data. The Rangitikei at Mangaweka and Manganui o te Ao above confluence monitoring sites are moderately impacted by land erosion, and should not be used as reference data for TF1.

The 20th percentile of the water clarity measured at the Rangitikei at Pukeokahu monitoring site when the flow is at or under median flow is 3.4 m. The data at all flows from Rangitikei at Pukeokahu and Manganui o te Ao at Hoihenga Rd indicates the distribution of the water clarity data is very similar at the two sites (Table 19). Assuming that the distribution of the data in relation to river flow is similar for the two sites, a minimum water clarity of 3.4

[20] To assess compliance with the clarity standard, the recommended approach is to compare the standards with the 20th percentile of the water clarity data measured at the site.

m under median flow should be a good representation of the water clarity in the Manganui o te Ao at Hoihenga Rd.

It is noted that the 5m water clarity standard recommended in the Cawthron report corresponds to the median value of measurements taken at or under median flow. Compliance with the water clarity standard will be assessed against the 20th percentile of the water clarity data (ie. at least 80 % of the samples must comply with the standard). A standard of 5m would be inappropriate, as even the reference sites would breach it.

The recommended standards for the TF1 waters are:

- **The water clarity shall exceed 3.4 metres when the river flow is at or below median flow, and**
- **The water clarity shall not be changed by more than 20%. The water clarity change standard applies at all river flows.**

TF2

Water clarity data is available for 13 monitoring sites in the TF2 category. Of these sites, two can be considered as reference sites: Mangatainoka at Putara and Hautapu at Rest area. However, no flow data is available for the Hautapu at Rest area site, so only the Mangatainoka at Putara provides true reference data. The Mangatainoka at Larsons Road and the Rangitikei at Mangaweka are taken as acceptable near-reference sites, representative of satisfactory conditions for TF2 fisheries.

The 10th percentile of the black disc data distribution at the Mangatainoka at Putara monitoring sites is 3.2 m. The 20th percentile at the two near-reference sites are 2.9 m at Mangatainoka at Larsons Rd and 3.2 m at Rangitikei at Mangaweka.

A water clarity of 3 m maintains a good sight feeding range for drift-feeding trout (Hay et al. 2007), and also maintains good angling conditions, particularly for sight fishing (Peter Taylor, pers. comm.).

The recommended standards for the TF2 waters are:

- **The water clarity shall exceed 3 metres when the river flow is at or below median flow, and**
- **The water clarity shall not be changed by more than 20%. The water clarity change standard applies at all river flows.**

TF3

The Cawthron report's recommendation for TF3 waters is a water clarity of 3.5 m during base flow conditions. As for TF2, the report also specifies that catchment geology may render these guidelines unattainable. A large number of rivers are classified in TF3, and their catchments have diverse dominant geology types, making difficult the determination of a sensible standard based on monitoring data.

As explained above, the TF3 standard is expected to be less stringent than the TF2 standard while maintaining reasonable conditions for trout and angling. Angling opportunities, particularly sight fishing, are considerably reduced when the water clarity is less than 2 m (Peter Taylor, pers. comm.). A water clarity of 2 m should also maintain the foraging area of trout when they are feeding on average-sized preys (12 mm or less) (Hughes and Dill's, 1990 in Hay *et al.*, 2006).

The recommended standards for the TF3 waters are:

- **The water clarity shall exceed 2 metres when the river flow is at or below median flow, and**
- **The water clarity shall not be changed by more than 30%. The water clarity change standard applies at all river flows.**

4.3.2.5 Biological indicators

The composition of the aquatic macroinvertebrate communities can be used as a biomonitoring tool to assess the likely level of ecosystem degradation or enrichment (Stark 1985). The macroinvertebrate species that score highly in the different community indices are usually also good quality prey for drift feeding trout; the indices have therefore the potential to provide an indication of the relative availability of trout food (Hay *et al.*, 2006).

As explained in section 2.3.4. of this report, several indices indicative of the macroinvertebrate communities' health exist, each presenting pros and cons. Although the Cawthron report (Hay *et al.,* 2006) recommends using the MCI as the standard for the TF value, it was decided to use the QMCI to maintain consistency of the recommended standards across the different values[21].

The approach taken was to follow the Cawthron report's recommendations in relation to the degree of acceptable impairment, and translate it into the corresponding QMCI score.

Although good practice for macroinvertebrate communities sampling requires certain flow conditions (ie. several weeks without significant flood prior to sampling), macroinvertebrates live in rivers year round and at all flow conditions, so the standard should apply at all times.

For both TF1 and TF2 waters, the Cawthron report recommend a minimum MCI score of 120, which corresponds to "Clean Water". The corresponding **QMCI score** is **6**.

For TF3 waters, a minimum MCI score of 100 was recommended, which is "indicative of possible mild pollution". The corresponding **QMCI score** is **5**.

Elevated concentration of particulate organic matter (POM), particularly downstream of some point source discharges, can cause detrimental effects to macroinvertebrate communities (Quinn and Hickey 1993). Setting a POM standard, applying at all times is recommended for the One Plan. As explained in section 3.2.3.6, the recommended approach is to set **POM standards** at:

- **2.5 g/m^3 in classes where the QMCI standard is 6,**
- **5 g/m^3 in classes where the QMCI standard is 5.**

[21] The QMCI is the macroinvertebrate communities indicator selected to define water quality standards in relation to the Life-Supporting Capacity value.

Table 19: Summary of the statistical distribution (10th, 20th and 50th percentiles) of water clarity (m) recorded at sites classified for the three Trout Fishery classes, under different river flow categories. "All flow" data is the water clarity data at dates when river flow data is also available (ie. the same dataset as used to determine the "under 1/2 median flow", "under median flow" and "under 3* median flow" statistics). All data encompasses all data available, regardless of river flow data availability. N: Number of samples.

TF Class	River	Site	Black Disc (m)																			
			Under ½ Median Flow				Under Median Flow				Under 3* Median Flow				All Flows				All Data			
			10	20	50	N	10	20	50	N	10	20	50	N	10	20	50	N	10	20	50	N
1	Rangitikei	Pukeokahu	2	3.3	5.2	19	2.2	3.4	5	45	1.5	2.1	3.8	75	1.3	1.9	3.6	81	1.2	1.9	3.6	107
	Rangitikei	Mangaweka (NIWA)	3.2	4.5	4.5	21	1.2	3.2	3.2	49	0.2	1.6	1.6	93	0.1	0.3	1.3	101	0.1	0.3	1.3	101
	Manganui o te Ao	Hoihenga Rd	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		1.5	1.8	3.8	22
	Manganui o te Ao	Above Confluence	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.4	0.6	2.1	23
2	Manawatu	Weber Road (NIWA)	1.2	1.4	1.9	28	0.9	1.1	1.6	52	0.3	0.5	1.1	89	0.1	0.3	1	101	0.1	0.3	1	101
	Mangatoro	Mangahei Rd	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.3	0.5	2	11
	Manawatu	Hopelands	1	1.5	2	19	0.8	1	1.6	53	0.3	0.6	1.1	87	0.2	0.3	1	98	0.1	0.3	1	119
	Makuri	Tuscan Hills	3.1	3.1	3.1	1	0.8	1.1	1.9	10	0.3	0.5	1.2	19	0.2	0.4	1.1	20	0.2	0.3	0.9	24
	Mangatainoka	Putara	3	3.6	5.5	7	3.2	3.7	5.5	15	1.6	2.8	4.7	22	1.6	2.9	4.5	23	1.6	2.9	4.5	23
	Mangatainoka	Larsons Rd	3.4	3.8	5	3	2.7	2.9	4.5	5	2.1	2.5	3.5	10	2.3	2.5	3.3	12	1.1	2.3	3.3	22
	Mangatainoka	SH2 Bridge	1.6	2.1	3.5	32	1.6	2.1	3.4	61	1	1.5	2.4	92	0.4	0.9	2.2	112	0.5	1	2.2	137
	Makakahi	Hamua	ND	ND	ND		1.1	1.1	1.1	1	1.1	1.1	1.1	1	0.6	0.6	0.8	2	0.8	0.9	1.8	22
	Hautapu	Rest Area	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		3.6	3.7	3.8	2
	Hautapu	Mulvays	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.8	1.3	2.3	19
	Hautapu	Taihape	1.7	1.8	2.3	7	1.4	1.5	1.7	14	0.5	0.6	1.4	28	0.3	0.5	1.3	32	0.4	0.5	1.3	36
	Rangitikei	Vinegar Hill	2.1	2.3	3.3	15	1	1.3	2.2	32	0.4	0.9	1.8	41	0.4	0.9	1.8	42	0.3	0.5	1.5	49
	Rangitikei	Kakariki (NIWA)[22]	1.3	2	3.5	27	0.9	0.9	1.7	60	0.1	0.2	1	96	0.1	0.2	0.9	101	0.1	0.2	0.9	101
3	Tiraumea	Katiawa Bridge	0.4	0.5	0.8	5	0.2	0.3	0.5	15	0.2	0.3	0.5	16	0.1	0.2	0.3	23	0.1	0.2	0.3	33
	Manawatu	Upper Gorge	1.6	1.6	1.6	1	1.6	1.6	1.6	1	0.1	0.2	0.3	4	0.1	0.2	0.3	4	0.1	0.2	0.4	26
	Mangahao	Ballance	3.8	3.9	4.9	8	2.4	3.3	4.1	14	1	1.5	3.4	20	0.7	1.2	2.8	23	0.6	1	2	44
	Mangahao	Kakariki	2.5	2.9	5.7	8	2.7	3	4.6	15	1.7	2.7	4	21	1	2.3	3.8	24	1.5	2.3	3.6	29
	Manawatu	Teachers College (NIWA)	1	1.3	2.1	28	0.6	0.9	1.3	55	0.2	0.2	0.9	87	0.1	0.1	0.6	101	0.1	0.1	0.6	101
	Pohangina	Piripiri	1.1	2.2	3.5	4	0.7	1.7	3.1	8	0.3	0.6	1.1	24	0.3	0.4	1	26	0.2	0.5	1.1	36
	Pohangina	Mais Reach	ND	ND	ND		ND	ND	ND		0.4	0.5	0.8	2	0.4	0.5	0.8	2	0.2	0.3	1.4	22
	Pohangina	Raumai Reserve	2.8	3	3.8	4	2.5	2.9	3.4	8	0.4	0.8	1.5	22	0.2	0.5	1.3	24	0.2	0.5	1.3	24
	Manawatu	42 Mile Hydro Station	1.6	1.6	2	20	0.9	1.2	1.7	34	0.4	0.5	1.4	52	0.2	0.5	1.2	56	0.2	0.5	1.3	59

[22] Flow Statistics for Kakariki are based on Onepuhi Flow Site

TF Class	River	Site	Black Disc (m)																			
			Under ½ Median Flow				Under Median Flow				Under 3* Median Flow				All Flows				All Data			
			10	20	50	N	10	20	50	N	10	20	50	N	10	20	50	N	10	20	50	N
	Manawatu	Opiki Bridge (NIWA)	1	1.2	1.6	25	0.6	0.8	1.2	53	0.1	0.3	0.9	87	0.1	0.1	0.7	101	0.1	0.1	0.7	101
	Oroua	Almadale Slackline	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.3	0.6	18
	Oroua	Nelson Street	2.2	2.6	3.5	25	1	1.7	3	48	0.4	0.7	1.8	84	0.2	0.3	1.5	97	0.2	0.3	1.5	100
	Tokomaru	Horseshoe Bend	2.3	2.8	3.1	7	1..7	2.1	3	15	1.6	2	2.4	25	1.6	2	2.3	26	1.2	1.6	2.2	43
	Whanganui	Cherry Grove	2.1	2.4	3	18	1.2	1.8	2.9	35	0.5	0.7	1.8	67	0.5	0.7	1.8	69	0.5	0.7	1.8	106
	Whakapapa	Below TPD Intake	10.1	10.1	10.1	1	4.1	6.2	10.6	6	3	5.2	6.7	13	3.5	5.3	6.7	15	3.5	5.3	6.7	15
	Piopiotea	Bullians Rd	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.3	0.4	1.1	22
	Pungapunga	Kirton Rd Bridge	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.4	0.7	1.5	15
	Ongarue	Cherry Grove	1.8	2	2.1	6	0.8	1.1	1.9	16	0.3	0.5	1.1	27	0.3	0.4	1.1	28	0.3	0.4	1.1	28
	Whanganui	Te Maire	1.5	1.9	2.5	23	0.8	1.1	2	50	0.4	0.8	1.6	71	0.4	0.6	1.4	75	0.4	0.5	1.1	96
	Whanganui	D/s Retaruke	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.3	0.8	80
	Whanganui	Pipiriki	0.7	1	1.6	20	0.5	0.7	1.3	55	0.2	0.3	0.7	97	0.2	0.2	0.6	104	0.2	0.2	0.6	104
	Whanganui	Paetawa	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.2	0.3	0.6	18
	Tokiahuru	Above Confluence	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.6	0.7	1.2	11
	Makotuku	SH49A	3.6	3.6	3.6	1	1	1.5	2	5	1.1	1.5	2.4	8	1.1	1.6	2.3	9	1.3	1.6	2.3	15
	Makotuku	U/s Raetihi	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.9	1.1	2.1	9
	Mangawhero	DoC Headquarters	2.5	2.9	3.6	8	2	3	3.8	40	1.6	2.3	3.3	86	1.5	2.1	3.2	84	1.5	2	3.1	94
	Mangawhero	Pakahi Rd Bridge	2	2	2	1	0.7	0.8	1.3	2	0.7	0.8	1.3	2	0.7	0.8	1.3	2	0.8	1	1.8	21
	Mangawhero	Downstream Makotuku	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.6	1.1	2.1	82
	Mangawhero	Raupiu Rd	ND	ND	ND		ND	ND	ND		ND	ND	ND		ND	ND	ND		0.1	0.1	0.7	9
	Ohau	Gladstone	2.5	3	3.9	4	2.2	2.9	4.8	12	2.3	2.8	4.2	23	2.1	2.7	4.2	24	2.1	2.7	4.2	24
	Ohau	Haines Farm	3.3	3.4	3.7	3	3.2	3.3	3.8	11	1.1	1.6	3.3	22	1	1.3	3.3	23	0.6	1.1	3.3	35

4.3.2.6 Periphyton biomass

Excessive periphyton biomass and cover has detrimental effects on benthic habitat quality and macroinvertebrate communities. It also impacts negatively on the angling experience, as clumps of algae tangle in fishing line/lures, and excessive algae growth is unsightly (Biggs, 2000).

Although excessive periphyton biomass is more likely to occur during extended summer low flow conditions, the detrimental effects on the fishery will occur regardless of the time of the season or river flow. For this reason the recommended periphyton biomass standards should apply year round, under all river flow conditions. The maintenance of periphyton biomass and cover under acceptable levels requires the implementation of nutrient standards. These are defined in section 6 of this report.

The New Zealand Periphyton Guidelines (Biggs, 2000) recommend a **maximum periphyton biomass of 120 mg chlorophyll a/m^2** for the maintenance of trout fishery values, and this is the recommended standard for the One Plan.

It is noted that some thought was given to setting a maximum periphyton biomass standard of 50 mg chlorophyll a/m^2 for outstanding and regionally significant trout fisheries (TF1 and TF2). However, some of the best trout fisheries in the country regularly experience algal biomass of 100 to 120 mg chlorophyll a /m^2, and setting a maximum biomass at 50 may not necessarily enhance the trout fishery (Dr. Barry Biggs, pers. comm.).

4.3.2.7 Ammonia

Ammonia can be toxic to many aquatic species, including trout and macroinvertebrates, and is a common pollutant in many treated agricultural, domestic and industrial discharges. Because it is a direct pollutant, the ammonia standard should apply at all times (ie. year round at all river flows).
As explained in section 2.3.5, the toxicity of ammonia is mostly due to unionised ammonia, the percentage of which is in turn determined by pH and temperature. The ammonia standards should therefore account for the expected pH and temperature range in the different classes of water. For ease of use, the recommended ammonia standard is a maximum concentration of total ammonia nitrogen (NH_4-N).

The 2000 ANZECC Guidelines' 99% protection level (**320 mg NH_4-N/m^3**) is recommended **for TF1 waters**, to remain consistent with the high level of protection sought for these waters.

The 2000 ANZECC guidelines 95% protection level is based on a unionised ammonia concentration of 35 mg-N/ m^3. This is also the basis for the USEPA 1999 ammonia criteria for salmonid waters (USEPA, 1999). It is therefore considered that this guideline should adequately protect trout from the toxic effects of ammonia. Similarly to the ammonia standard defined for the protection of the LSC value, the inclusion of pH and temperature dependency leads to a recommended standard of **400 mg NH_4-N /m^3** (expressed as total ammonia nitrogen) **for TF2 and TF3 waters**.

4.3.2.8 Other toxicants

A very large number of toxicants are potentially found in the environment, and defining a numerical water quality standard for each of them is outside the scope of this report. The 2000 ANZECC Guidelines provide an extensive list of relevant parameters and numerical acceptable limits.

The ANZECC guidelines also recommend several levels of protection, depending on the level of disturbance acceptable at the site: 99% is the recommended level for systems of high biodiversity value, 95% for slightly to moderately disturbed ecosystems, and 90% for highly disturbed ecosystems. The approach taken was to link the level of protection defined in the ANZECC guidelines with the level of protection sought for each TF class.

As explained in the Cawthron report, trout are generally located toward the more sensitive end of the continuum of sensitivity to toxic substances in the environment. Accordingly, the ANZECC **99% protection level** is recommended **for TF1 and TF2 waters** .

The **95% protection level** is recommended **for TF3 waters**, corresponding to a slightly lower level of protection than recommended for TF1 and TF2 waters.

4.4 Definition of water quality standards in relation to the Trout Spawning Value

4.4.1 Methodology/definition

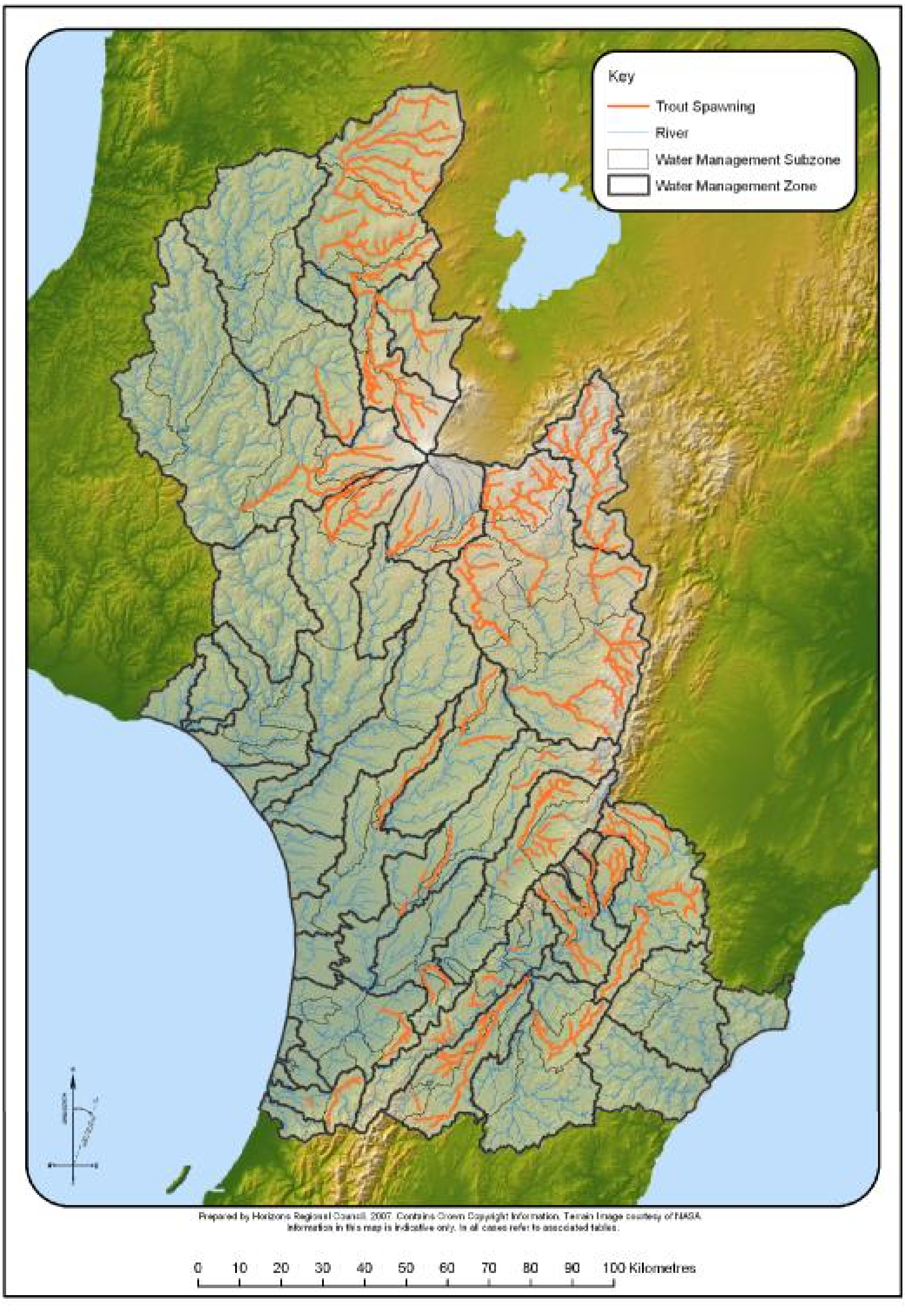
The location of significant trout spawning streams and rivers is identified in the Vaues report (Ausseil and Clark, 2007a), and summarised in Map 5.

The Cawthron Institute was commissioned to produce a report summarising recommendations for water quality standards to protect the TF and TS values (Hay *et al.* 2006). The approach taken is to largely follow the recommendations of the Cawthron report.

Trout eggs and larvae are known to be sensitive to a number of water quality parameters, including (summarised from Hay *et al.*, 2006):

- Elevated **water temperature** may result in increased mortality.
- Low intra gravel **dissolved oxygen** concentration can result in asphyxiation of embryos and alevins.
- Deposited fine **sediments**, that may block the interstices between the gravel grains thus preventing water flow which in turn prevents adequate intra-gravel oxygenation of the egg and larvae.

Trout spawning is highly seasonal. The spawning and incubation period may vary from year to year and is slightly different for brown and rainbow trout, but it is generally inside the May to October period (Hay *et al.*, 2006). Controls on activities in the beds of rivers and lakes (BRL) have been recommended for the One Plan in relation to the protection of the trout spawning value (McArthur *et al.*, 2007b). These controls apply from 1 May to 30 September. To maintain consistency between the different parts of the One Plan, **it is recommended the TS water quality standards apply during the period 1 May to 30 September.**



Map 5: Recommended Trout Spawning value in the Manawatu-Wanganui Region.

4.4.2 Recommended water quality standards for protection of the TS value

4.4.2.1 Water Temperature

The effect of water temperature on the success of brown and rainbow trout spawning is extensively discussed in Hay *et al.* (2006). The abundant supporting information in the scientific literature is based on both laboratory and field observations, suggesting a very good reliability. It is recommended that the Cawthron report's conclusion be followed: that the water temperature in streams managed for trout spawning should be maintained below 11 ^{o}C to avoid any significant effect of the water temperature on trout spawning success.

Temperature being a key factor controlling trout egg and alevin development, a temperature change standard is also recommended.

Accordingly, the recommended temperature standard for the protection of the Trout Spawning value is:
"The water temperature shall not exceed 11^{o}C, and shall not be changed by more than ^{o}C, during the period 1 May to 30 September."

4.4.2.2 Dissolved Oxygen

As discussed in Hay *et al.* (2006), intra-gravel dissolved oxygen concentration is a key parameter for the successful development and of trout egg and larvae. It can be influenced by:

- the dissolved oxygen concentration in the water column, and
- deposited fine sediment preventing water flow in the substrate interstitial space.

The U.S. Environmental Protection Agency (USEPA, 1986) recommends minimum water column DO concentrations of 9 mg/L to maintain near optimum conditions (slight impairment) and of 11 mg/L for optimum conditions (Table 20). The British Columbia Ministry of Environment (BCME, 1997) has similar guideline. Accordingly, Hay *et al.* suggest the DO concentration should exceed 9 mg/L, which in turn approximately corresponds to 80% saturation at 11^{o}C. Eighty percent saturation corresponds to higher (than 9 mg/L) DO concentrations at temperatures below 11^{o}C, and should therefore adequately protect the egg and larvae development.

Accordingly, the recommended DO standard for the protection of the Trout Spawning value is:
"The Dissolved Oxygen concentration in the water shall not be less than 80% saturation during the period 1 May to 30 September."

Table 20: Dissolved Oxygen concentrations (mg/L) recommended by the U.S. Environmental Protection Agency to confer five levels of protection for waters containing early life stages of salmonids (adapted from Dean and Richardson, 1999).

Degree of impairment acceptable	Early life stages	
	Water column	Intra-gravel
None	11	8
Slight	9	6
Moderate	8	5
Severe	7	4
Acute	6	3

4.4.2.3 Sediment-related parameters

In relation to sediments, two parameters are critical for the success of trout spawning.

First, the availability of suitable spawning beds, which require gravel of the right size and depth. This can be affected by gravel extraction and works in the river bed, issues better addressed by BRL[23] policies than water quality standards.

Secondly, the deposition of fine particles on, and in, the riverbed substrate can clog the interstitial space and reduce the flow of water through the top layer of gravel. As explained in Section 2.3.2 of this report, and also discussed in Hay *et al.*, reliable methods of measuring substrate embeddedness, such as the Quorer method, are still under development, and no numerical water quality standard can be confidently defined in relation to the protection of the TS value (Dr. John Quinn, pers. comm.). The Manawatu Catchment Water Quality Plan defines a narrative standard to protect TS waters during the spawning season.

This seems the most pragmatic approach, and **the recommended standard is:**
"There shall be no measurable increase in sediment or particulate organic matter deposited on the bed of the river or stream during the period 1 May to 30 September inclusive".

5 Definition of water quality standards in relation to the Consumptive Water Use Values

Four consumptive water use values have been identified in the Values report (Ausseil & Clark, 2007a):

- (drinking) Water Supply (WS)
- Stockwater (SW)
- Irrigation (I)
- Industrial abstraction (IA).

The Ministry for the Environment is working with the Ministry of Health to develop and implement a National Environmental Standard (NES) for raw

[23] Policies controlling the activities in the Beds of Rivers and Lakes

drinking water sources. Although no final document has been made public at the time of writing, the NES would possibly supersede any relevant Regional Plan provisions. For this reason, no specific water quality standards are recommended in relation to the WS value, and it is recommended the situation is reassessed once the NES are in force.

The water quality requirements for irrigation use vary widely depending on the crop, the soil, and the use of the crop. Similarly, different industries will have different water quality requirements. Thus, the definition of specific water quality standards in relation to these values is not recommended. It is anticipated however that, if the standards defined in relation to all the other values are met, the waterbodies should generally be suitable as a raw water source (ie. some level of treatment may be required) for irrigation and/or industrial use.

Water quality standards are recommended for the protection of the Stock drinking water value.

5.1 Definition of water quality standards in relation to the livestock drinking water Value.

The livestock drinking water (SW) value applies to all waterbodies in the Region, at all times (Ausseil and Clark, 2007a).

The 2000 ANZECC Guidelines define a number of parameters of relevance for the protection of the livestock drinking water quality, including:

- cyanobacteria density and cyanotoxin concentration;
- pathogens and parasites, and indicators of faecal contamination;
- major ions, such as calcium, magnesium, nitrate and nitrite, etc; and .
- heavy metals and metalloids and pesticides and other organic contaminants.

As explained in section 2.3.6, the health risk associated with the presence of cyanobacteria is considered to be better managed by a specific monitoring and reporting framework rather than by water quality standards.

The presence of pathogens and parasites may affect stock health, causing morbidity and reduced growth, and possibly mortality (ANZECC, 2000). The 2000 ANZECC guidelines recommend a maximum median value of 100 faecal coliforms /100 mL, and an 80th percentile of 400 /100 mL.

The recommended approach for the One Plan is to follow the recommendations of the 2000 ANZECC guidelines. To simplify, it is recommended to use only one of the trigger values, the 400 faecal coliforms /100 mL upper limit, and assess a site's compliance with this standard against the 80th percentile of the data collected at the site.

The ANZECC recommendations relating to major ions are dependent on the feed or dietary supplement of livestock. Such considerations are judged outside the scope of this report and no standards are recommended for the One Plan. It is also noted that the ANZECC recommendations relating to nitrate and nitrite concentrations are between two and three orders of magnitude greater than the SIN standards recommended in this report; the livestock requirements in relation to these parameters are therefore adequately covered by the nutrient standards.

A large number of metals, pesticides and organic chemicals can cause toxic effects in livestock. However, they are not routinely monitored as part of Horizons' monitoring programmes, and defining water quality standards relating to these parameters was judged outside the scope of this work. Rather, it is recommended to use the ANZECC guidelines as/if required on a case by case basis.

Table 21: Summary of the recommended water quality standards for the protection of the different waterbody values. This does not define the final recommended standards by management zone, as several waterbody values may apply in each zone. Consolidated standards are presented in Table 23. Note the nutrient standards are not included (see section 6).

Value	Parameter	Standard	River Flow	Time of the year
NS (Natural State)	Narrative standard	The rivers shall be managed in their natural state	All	Year round
Life-Supporting Capacity UHS	pH	6.7 to 8.2	All	Year round
		Shall not be changed by more than 0.5	All	Year round
	Temperature	19°C as daily maximum	All	Year round
		Shall not be changed by more than 2°C *	All	Year round
	Dissolved Oxygen	80% saturation	All	Year round
	BOD_5	1 g/m³	All	Year round
	POM	2.5 g/m³	All	Year round
	Periphyton Biomass	50 mg *Chlorophyll a* /m²	All	Year round
	QMCI	6	All	Year round
	Ammonia N	320 mg-N/m³	All	Year round
	Toxicants	ANZECC Guidelines 99%	All	Year round
	Clarity	3 m	< median	Year round
	Clarity	2 m	< 3 x median	Year round
	Clarity (Change)	20%	All	Year round
Life-Supporting Capacity UVA	pH	7 to 8.2	All	Year round
		Shall not be changed by more than 0.5	All	Year round
	Temperature	19°C as daily maximum	All	Year round
		Shall not be changed by more than 2°C	All	Year round
	Dissolved Oxygen	80% saturation	All	Year round
	BOD_5	1 g/m³	All	Year round
	POM	2.5 g/m³	All	Year round
	Periphyton Biomass	50 mg *Chlorophyll a* /m²	All	Year round
	QMCI	6	All	Year round
	Ammonia N	320 mg-N/m³	All	Year round
	Toxicants	ANZECC Guidelines 99 %	All	Year round
	Clarity	3 m	< median	Year round
	Clarity	2 m	< 3 x median	Year round
	Clarity (Change)	20%	All	Year round
Life-Supporting Capacity UVM	pH	7 to 8.5	All	Year round
		Shall not be changed by more than 0.5 pH	All	Year round
	Temperature	19°C as daily maximum	All	Year round
		Shall not be changed by more than 2°C *	All	Year round
	Dissolved Oxygen	80 % saturation	All	Year round
	BOD_5	1 g/m³	All	Year round
	POM	5 g/m³	All	Year round

Value	Parameter	Standard	River Flow	Time of the year
	Periphyton Biomass	120 mg *Chlorophyll a* /m²	All	Year round
	QMCI	5	All	Year round
	Ammonia N	400 mg-N/m³	All	Year round
	Toxicants	ANZECC Guidelines 95%	All	Year round
	Clarity	2.5 m	< median	Year round
	Clarity	1.6 m	< 3 x median	Year round
	Clarity (Change)	30%	All	Year round
Life-Supporting Capacity Uli	pH	7 to 8.5	All	Year round
		Shall not be changed by more than 0.5 pH	All	Year round
	Temperature	19°C	All	Year round
		Shall not be changed by more than 2°C *	All	Year round
	Dissolved Oxygen	80 % saturation	All	Year round
	BOD_5	1 g/m³	All	Year round
	POM	5 g/m³	All	Year round
	Periphyton Biomass	120 *Chlorophyll a* /m²	All	Year round
	QMCI	5	All	Year round
	Ammonia N	400 mg-N/m³	All	Year round
	Toxicants	ANZECC Guidelines 95%	All	Year round
	Clarity	2.5 m	< median	Year round
	Clarity	1.6 m	< 3 x median	Year round
	Clarity (Change)	30%	All	Year round
Life-Supporting Capacity HM	pH	7 to 8.5	All	Year round
		Shall not be changed by more than 0.5 pH	All	Year round
	Temperature	21°C as daily maximum	All	Year round
		Shall not be changed by more than 3°C *	All	Year round
	Dissolved Oxygen	70% saturation	All	Year round
	BOD_5	2 g/m³	All	Year round
	POM	5 g/m³	All	Year round
	Periphyton Biomass	120 *Chlorophyll a* /m²	All	Year round
	QMCI	5	All	Year round
	Ammonia N	400 mg-N/m³	All	Year round
	Toxicants	ANZECC Guidelines 95%	All	Year round
	Clarity	2.5 m	< median	Year round
	Clarity	1.6 m	< 3* median	Year round
	Clarity (Change)	30%	All	Year round
Life-Supporting Capacity HSS	pH	7 to 8.5	All	Year round
		Shall not be changed by more than 0.5 pH	All	Year round
	Temperature	21°C as daily maximum	All	Year round
		Shall not be changed by more than 3°C *	All	Year round
	Dissolved Oxygen	70% saturation	All	Year round
	BOD_5	2 g/m³	All	Year round
	POM	5 g/m³	All	Year round
	Periphyton Biomass	200 *Chlorophyll a* /m²	All	Year round
	QMCI	5	All	Year round
	Ammonia N	400 mg-N/m³	All	Year round
	Toxicants	ANZECC Guidelines 95%	All	Year round
	Clarity	1.6 m	< median	Year round
	Clarity	0.5 m	< 3 x median	Year round
	Clarity (Change)	30%	All	Year round
Life-Supporting Capacity LM	pH	7 to 8.5	All	Year round
		Shall not be changed by more than 0.5 pH	All	Year round
	Temperature	23°C as daily maximum	All	Year round

Value	Parameter	Standard	River Flow	Time of the year
		Shall not be changed by more than 3°C *	All	Year round
	Dissolved Oxygen	60% saturation	All	Year round
	BOD_5	2 g/m³	All	Year round
	POM	5 g/m³	All	Year round
	Periphyton Biomass	200 *Chlorophyll a* /m²	All	Year round
	QMCI	5	All	Year round
	Ammoniacal N	400 mg/m³	All	Year round
	Toxicants	ANZECC Guidelines 95%	All	Year round
	Clarity	2.5 m	< median	Year round
	Clarity	1.6 m	< 3 x median	Year round
	Clarity (Change)	30%	All	Year round
Life-Supporting Capacity LS	pH	7 to 8.5	All	Year round
		Shall not be changed by more than 0.5 pH	All	Year round
	Temperature	23°C as daily maximum	All	Year round
		Shall not be changed by more than 3°C *	All	Year round
	Dissolved Oxygen	60% saturation	All	Year round
	BOD_5	2 g/m³	All	Year round
	POM	5 g/m³	All	Year round
	Periphyton Biomass	200 *Chlorophyll a* /m²	All	Year round
	QMCI	5	All	Year round
	Ammonia N	400 mg-N/m³	All	Year round
	Toxicants	ANZECC Guidelines 95 %	All	Year round
	Clarity	2.5 m	< median	Year round
	Clarity	1.6 m	< 3 x median	Year round
	Clarity (Change)	30%	All	Year round
Life-Supporting Capacity Lake waters	pH	Shall not be changed by more than 0.5 pH	N/A	Year round
	Temperature	Shall not be changed by more than 1°C		
	Algal biomass	Annual mean: 5 mg *Chlorophyll a*/m³ Max: 15 mg *Chlorophyll a*/m³		
	TP	20 mg/m³ (annual average)		
	TN	337 mg/m³ (annual average)		
	Ammoniacal N	400 mg/m³		
	Clarity (Secchi Depth)	2.8 m		
	Clarity	20% change		
Contact Recreation and Aesthetics - River waters	*Escherichia coli*	260 /100 mL	< median	1 November to 30 April
	Escherichia coli	550 /100 mL	< 3 x median	Year round
	Filamentous algae cover	30 % bed cover by filamentous algae more than 2 cm long.	All	Year round
	pH	5.0 to 9.0	All	Year round
	Water clarity	1.6 m	< median	Year round
Contact Recreation and Aesthetics - Lake waters	*Escherichia coli*	260 /100 mL	N/A	1 November to 30 April
	Escherichia coli	550 / 100 mL	N/A	1 May to 30 October
	Clarity (Secchi Disc)	1.6 m	N/A	1 November to 30 April
	pH	5.0 to 9.0		
	Toxic chemicals	Refer to ANZECC Guidelines		
Contact Recreation and Aesthetics	Enterococci	140 /100 mL	N/A	1 November to 30 April

Value	Parameter	Standard	River Flow	Time of the year
- Coastal marine waters	Enterococci	280 / 100 mL		1 May to 30 October
	Clarity (Secchi Disc)	1.6 m		Year round
	pH	5.0 to 9.0		Year round
Stockwater	Faecal coliforms	400 /100 mL	All	Year round
TF (Trout Fisheries) Class I - Outstanding	Temperature (max)	19°C as daily maximum	All	Year round
	Temperature (change)	Shall not be changed by more than 3°C	All	Year round
	Dissolved Oxygen	80% saturation	All	Year round
	BOD_5	1 g/m^3	All	Year round
	POM	2.5 g/m^3	All	Year round
	Periphyton Biomass	120 mg *Chlorophyll a* /m^2	All	Year round
	QMCI	6	All	Year round
	Ammonia	320 mg-N/m^3	All	Year round
	Other Toxicants	Refer to table 3.4.1. ANZECC guidelines at 99% protection level	All	Year round
	Water Clarity	3.4 m	< median	Year round
	Water Clarity	20 % change	All	Year round
TF (Trout Fisheries) Class II – Regionally significant	Temperature (max)	19°C as daily maximum	All	Year round
	Temperature (change)	Shall not be changed by more than 3°C	All	Year round
	Dissolved Oxygen	80 % saturation	All	Year round
	$cBOD_5$	1 g/m^3	All	Year round
	POM	2.5 g/m^3	All	Year round
	Periphyton Biomass	120 mg/m^2	All	Year round
	QMCI	6	All	Year round
	Ammonia	400 mg-N/m^3	All	Year round
	Other Toxicants	Refer to table 3.4.1. ANZECC guidelines at 99% protection level	All	Year round
	Water Clarity	3 m	< median	Year round
	Clarity	20 % change	All	Year round
TF (Trout Fisheries) Class III Other significant fisheries	Temperature (max)	24°C as daily maximum	All	Year round
	Temperature (change)	Shall not be changed by more than 3°C *	All	Year round
	Dissolved Oxygen	70% saturation	All	Year round
	$cBOD_5$	2 g/m^3	All	Year round
	POM	5 g/m^3	All	Year round
	Periphyton Biomass	120 mg/m^2	All	Year round
	QMCI	5	All	Year round
	Ammonia	400 mg-N/m^3	All	Year round
	Other Toxicants	Refer to table 3.4.1. ANZECC guidelines at 95% protection level	All	Year round
	Water Clarity	2 m	< median	Year round
	Clarity	20% change	All	Year round
TS (Trout Spawning)	Dissolved Oxygen	80%	All	1 May to 30 September
	Deposited material	There shall be no significant increase in sediment or particulate organic matter deposited on the bed of the river or stream	All	
	Temperature (max)	11°C as daily maximum	All	
	Temperature (change)	Shall not be changed by more than 2°C *	All	
	Toxicants	Refer to ANZECC guidelines 99% level	All	
SG (Shellfish gathering)	Faecal Coliforms	14 /100 mL (Median value)	N/A	Year round
		43 / 100 mL (90 percentile)		

Value	Parameter	Standard	River Flow	Time of the year
Mau (Mauri)	No direct discharge of treated effluent to a natural waterbody No discharge of untreated of human effluent to a waterbody			

6 Nutrient standards for rivers and streams

6.1 Introduction

Periphyton is the brown or green slime or filaments coating stones, wood, or any other stable surfaces in streams and rivers. It is composed of a large number of different algae species, forming a living community. Being the main primary producers in streams and rivers, periphyton communities are fundamental to the functioning of the aquatic ecosystem.

The biomass (ie. quantity) of periphyton in a stream is forever changing. At any given time, it is the result of a dynamic equilibrium between:

- the speed at which the periphyton is growing (in turn determined by sunlight, temperature, nutrient concentration in the water column and water velocity[24]);
- the physical sloughing caused by water velocity; and
- the grazing by macroinvertebrates that feed on periphyton[25].

Floods and freshes play a major role in the dynamics of periphyton biomass, by suddenly “resetting” the biomass at lower levels. When the river flow rises during a fresh, the water velocity and the quantity and size of particles transported by the flow increase, causing increased physical sloughing and abrasion of the periphyton mats. In a larger flood, the bed material (gravel, stones) itself starts being rolled downstream, which physically removes most of the living periphyton biomass. As a result, periphyton biomass usually peaks during periods of extended stable flow, between two “resetting” flood events (Biggs, 2000).

In some situations, periphyton can proliferate and form mats of green or brown filaments on the river bed. The proliferation of periphyton can affect a number of waterbody values, including life-supporting capacity, recreational and aesthetic values and trout fishery. As a result, periphyton biomass standards have been defined in this report in relation to the protection of waterbody values (see sections 3.2.3.7, 4.1.3.2 and 4.3.2.6 of this report).

The bed of some streams and rivers is dominated by fine material (eg. silt or sand); these streams are often called “soft bottom streams”. Unless the flow is extremely stable or slow, significant periphyton blooms do not tend to occur in these streams and rivers, simply due to the lack of solid surface to grow on. In some of these streams, plant growth is often dominated by macrophytes, which are either submerged or emergent flowering plants. In the same fashion as periphyton, macrophyte play an essential role in aquatic ecosystems.

[24] Water velocity is an important parameter as it determines the flux of nutrient that come in contact with the growing algal mats or filaments.

[25] A large proportion of macroinvertebrate species are “grazers”, meaning they feed on the algae growing on the river bed material.

However, macrophyte growth can also reach nuisance levels, particularly if invasive introduced weeds are present.

In lakes and ponds, plant growth tends to be dominated by planktonic microscopic algae and cyanobacteria (“blue-green algae”), and macrophytes. Both can reach nuisance levels. Blue-green alga can form massive blooms, affecting water clarity and being potentially toxic to recreational users of the lakes. Invasive macrophytes tend to be confined to shallow ponds and the margins of larger lakes. In eutrophied (ie. enriched) systems, invasive macrophytes such as hornwort (*Ceratophyllum demersum),* can completely choke the shallow habitats, affecting habitat quality for a number of species and displacing native macrophyte communities.

6.2 Why nutrient standards are recommended

Three levels of periphyton biomass standards have been recommended in relation to the protection of the different waterbody values:

- 50 mg/m^2 in upland areas;
- 120 mg/m^2 in hill country and / or trout fisheries; and
- 200 mg/m^2 in lowland areas and naturally phosphorus-enriched systems.

Algal biomass standards have also been recommended for lowland lakes.

The relationship between increased nutrients in the waterbodies and increased occurrence of excessive periphyton growth and algal blooms has been clearly demonstrated, and setting controls on the amount of nutrients is a logical option to control algal growth in streams, rivers and lakes.

However, before setting standards on nutrient concentration in the water, and imposing controls on the sources of nutrients (ie. on discharges and land use, to address point- and non point sources), a number of questions need answering:

1. Do all aquatic systems need controls on nutrients to control algal and plant growth? And as a corollary to this, are the two following questions: Are there systems that will not be affected by nutrient enrichment? Are there other methods to control algae and plant growth ?
2. How do we include effects on downstream systems (ie. larger rivers, lakes, estuaries and sea)?
3. What are the best water quality parameter(s) to impose control on (ie. TN, NO_3, SIN, DRP, TP)?
4. Can management efforts concentrate on one nutrient only (ie. N or P)?
5. When do nutrient standards and controls need to apply (in relation to river flow and season)?

A panel of leading experts from NIWA and Massey University on the questions of periphyton growth and control was tasked with making recommendations in response to the series of questions above. A report summarises the panel’s recommendations (Wilcock *et al.*, 2007). Whilst the main conclusions are summarised below, readers should refer to the report for further details.

1. Different strategies may be successful at the local scale[26], and some systems are not prone to periphyton growth. However **nutrient management is strongly recommended in most systems** to mitigate local (eg. macrophyte growth) and downstream effects, particularly on lakes and coastal waters, including estuaries. The only areas that potentially do not require any form of nutrient control are systems that are not suitable for periphyton growth and do not discharge in a system prone to periphyton growth, an estuary or a lake, and has no nuisance macrophyte growth.
2. For estuaries and coastal areas, specific studies are necessary to determine a “safe” level of nutrients. Until such studies are done, a precautionary approach is strongly recommended. The nutrient levels that are likely to be imposed on the riverine systems to control periphyton growth are considered to provide adequate interim protection.
3. In **rivers and streams**, the controls should be exerted on the chemical forms of both nitrogen and phosphorus that plants can directly assimilate for their growth (ie. bioavailable). For nitrogen, this includes oxides (nitrate: NO_3-N and nitrite: NO_2-N), and ammonia (NH_4-N), the sum of which is called soluble inorganic nitrogen (**SIN**). Bioavailable phosphorus is taken as dissolved reactive phosphorus (**DRP**). Although this specific point was not addressed in the report, it may be useful to add that Total Nitrogen (**TN**) and Total Phosphorus (**TP**) are usually the metrics of choice in enclosed systems where nutrient recycling may be significant, such as **lakes and estuaries** (Burns *et al.*, 1999)
4. **Control of both nutrients is necessary**. Where there is a clear indication that one nutrient may be limiting[27], it may be sensible to focus on managing that nutrient without neglecting the controls on the other macronutrient. Spatial variability and effects on downstream environments should also be considered carefully: a river may generally be P-limited, but parts of its catchment and/or the downstream environments (estuary, coastal waters) may be N-depleted.
5. Periphyton can grow to nuisance levels in winter. The **nutrient controls** should apply **year round**. In particular, nutrient standards applying only during the summer period are inadequate to protect biodiversity values. Periphyton growth and vigour is influenced by antecedent water quality. Only flood flow conditions may be excluded from nutrient standards. Nutrient standards applying only at low flows are inadequate to reach the periphyton biomass targets.

6.3 Methodology applied to nutrient standards determination for rivers

Considering the advice received was based on the best scientific expertise available in the country, decision was made to closely follow the panel’s recommendations:

[26] For example, shading provided by overhanging riparian vegetation can be a very effective way of controlling periphyton growth in small streams. However, the nutrients that are not used locally by periphyton growth are exported downstream, potentially causing increased effects on the downstream receiving systems.

[27] The method for determining the limiting nutrient are also dealt with in the NIWA report. The most reliable methods include NDS (nutrient diffusing substrate) and calculation of the N:P ratios at different times of the year.

- Recommend **both SIN and DRP standards in rivers**. The standards should apply **year round, at all river flows except flood flows** (under 3*median or a percentile of the flow distribution).
- The **standards should be based on avoiding detrimental effects**, **either locally or in the downstream receiving environments**.

The process of determining these standards was based on four main sources of information and recommendations, as detailed in sections 6.3.1.1 to 6.3.1.4.

Note on the flow dependency of the recommended nutrient standards

The recommended nutrient standards for rivers in lake catchments apply year round at all river flows.

For rivers outside lake catchments, the recommended nutrient standards should apply at all river flow, except flood flows. Flood flows may be characterised in a number of different ways.

One commonly used method is to use 3*median flow as a threshold for flood flows.

Another method is to define a percentile of the flow distribution above which the nutrient standard does not apply. Horizons is developing a framework to manage and allocate point source (PS) and non-point source (NPS) pollution in rivers (Roygard, 2007). This framework is based on 10 different flow categories (0 to 10^{th} percentile, 10^{th} to 20^{th}, etc…). Inside each of these flow categories, the total allowable contaminant load will be different, as well as the proportional allocation to PS and NPS. To align on this framework, it may be useful to link the nutrient standards' flow dependency to the 80^{th} or 90^{th} percentile of the flow distribution.

6.3.1.1 New Zealand Periphyton Guidelines

The New Zealand Periphyton Guidelines (Biggs 2000) is a key reference document. Further to developing useful guidance on the acceptable levels of periphyton biomass in relation to different river values, the document provides recommendations on the determination of nutrient standards to control periphyton growth. The recommendations are based on a model predicting the maximum periphyton biomass based on descriptors of the hydrological regime and nutrient availability.

The hydrological regime is represented in the model by a parameter called "mean days of accrual" (MDA in this report), which is in essence the average time between two flood events. The flood events are characterised as a river flow over three times the median flow (3* median). This flow level is a general indicator of a flood that will start to initiate "periphyton scour", ie. that can reset the periphyton biomass to a very low level. The calculation of the MDA variable requires a significant record of flow data. It is generally considered that a strict minimum five years of continuous flow data is required to determine basic flow statistics, such as median flow and 3*median (Jeff Watson, pers. comm.).

There are different ways of calculating the MDA variable. Key parameters include:

- the type of basic flow statistics, or averaging interval: “instantaneous” (every 15 min) data may be used, or averaged over a certain period of time, eg. daily average flow;
- the minimum time between two separate flood events, or interflood spacing. Flood events/periods often contain several episodes, characterised by peaks. If the time between two major (> 3* median) flow peaks is too short, periphyton will not have time to develop significantly, and the whole period should be considered a unique flood event. In other words, after the flow recedes below 3* median, a new accrual phase is not calculated to begin until the flow has remained below 3* median for at least a certain number of days (defining the interflood spacing).

As demonstrated in Henderson and Diettrich (2007), the details of the MDA calculation are particularly critical to the result. There can be differences of 50% or more between FRE3s calculated at the same site, with the same data, but with different methods (daily average flow/7 days vs. instantaneous flow/5 days).

Although details were not included in the document, information provided by NIWA (Roddy Henderson, pers. comm.) clarified the calculation methods used to develop the periphyton guidelines model: 5 days interflood spacing and daily average flow.

As part of a larger flow statistics compilation project, FRE3 and MDA were calculated according to this methodology at all sites in the Manawatu-Wanganui Region where sufficient data was available (Henderson and Diettrich, 2007).

The MDA variable calculated and the periphyton biomass standard specific to each site / water management sub-zone were fed into the NZ periphyton guidelines model.

Table 22 presents the mean monthly DRP and SIN concentrations produced by the model, (ie. the concentrations predicted by the model as being the maximum concentration acceptable to maintain the periphyton biomass under standard levels) for each water management zone where sufficient flow data was available. The model’s outputs provided figures that varied between rivers belonging to the same values classification. To help the decision process, the table also provides the range and median values of DRP and SIN predictions for each LSC class.

A number of limitations were identified in relation to the model’s results:

- the model was not developed to work with the very particular hydrological regime of the central plateau’s streams, and should not be used in these situations. (Dr. Barry Biggs, pers. comm.). No results are therefore provided for these streams.
- The model is based on idealised conditions for periphyton growth, and does not take all parameters into consideration, such as grazing by macroinvertebrates and physical abrasion by suspended particles. As a result, the model’s nutrient concentrations predictions are usually at the lower end of the spectrum and can generally be considered as environmentally conservative figures (Dr. Barry Biggs, pers. comm.).

- The model was developed on a set of data collected nationally. Calibration of the model on a regional dataset was identified as a useful step to validate and/or refine the model's recommendations for the Horizons Region. The periphyton biomass data held by Horizons is based on annual sampling. Although useful to identify some areas with periphyton issues, annual monitoring is very unlikely to capture maximum periphyton biomass (Dr. Barry Biggs, pers. comm.). For this reason, whilst hydrological data of sufficient quality and quantity is available, the periphyton biomass data was judged insufficient to calibrate a predictive model. This has been identified as a data and knowledge gap in section 9 of this report.

6.3.1.2 Expert opinion from Dr Barry Biggs

As explained above, the periphyton guideline model has some limitations. Whilst the model should still be used as a key element of the decision-making process, further information and expertise were required. Advice from NIWA's leading expert on periphyton issues Dr. Barry Biggs' was sought to:

- recommend appropriate maximum periphyton biomass standards in relation to the different waterbody values identified (as detailed in sections 3.2.3.7, 4.1.3.2 and 4.3.2.6 of this report);
- recommend standards for the areas where the periphyton model cannot be applied (central plateau area); and
- recommend nutrient standards to maintain periphyton biomass at or below target (standard) levels.

Dr. Biggs' recommendations are provided for each water management sub-zone in Table 22. The general guiding principles were:

- For UHS and UVA waters, 50 mg/m^2 is the appropriate periphyton biomass standard for zones where a high macroinvertebrate biodiversity, with communities dominated by pollution-sensitive taxa, are expected. Recommended ranges for nutrient standards are: DRP 5 to 6 mg/m^3, SIN 55 to 70 mg/m^3. For DRP, there may be instances where DRP standards are naturally locally exceeded, and the standard should account for this.
- For UVM, HM, ULi and TF waters, a periphyton biomass of 120 mg/m^2 is recommended to protect biodiversity and trout fishery values in these slightly more enriched systems. Recommended nutrient standards are 10 mg/m^3 for DRP and 110 mg/m^3 for SIN.
- For HSS, LM, and LS waters a periphyton biomass of 200 mg/m^2 is recommended to protect the lower expected biodiversity in these systems. Recommended nutrient standards are 15 mg/m^3 for DRP and 165 mg/m^3 for SIN.
- The nutrient standards should apply year round at all but flood flows (defined as at or above three times the median flow).

All nutrient standards relate to monthly mean concentration, that is to say the annual average concentration based on monthly monitoring.

6.3.1.3 ANZECC Guidelines

The 2000 ANZECC Guidelines provide default trigger values for nutrient concentration in upland and lowland (defined as <150m altitude) rivers in New Zealand:

- for upland rivers, the default trigger values are 9 mg/m^3 for DRP and 167 mg/m^3 for NOx (ie. nitrate + nitrite),
- for lowland rivers, the default trigger values are 10 mg/m^3 for DRP and 444 mg/m^3 for NOx (ie. nitrate + nitrite)

It is noted that the trigger values are based on statistical analysis of a limited dataset from reference and slightly disturbed New Zealand rivers, and are not based on any objective biological criteria. For this reason, the ANZECC guidelines emphasise that the default trigger values should only be used until site-specific values can be generated.

In spite of these limitations, the default trigger values are very widely used by Regional Councils in New Zealand for SOE reporting, resource consent decisions and Regional Plans.

6.3.1.4 Monitoring data

Nutrient concentration results from Horizons' monitoring programmes and NIWA's national network are summarised in Table 22.

Horizons does not currently have a regular monitoring programme of lakes or coastal waters that incorporates nutrient concentration measurements. It is recommended future monitoring and research programs address this information gap (section 9 of this report).

6.4 Recommended Nutrient standards

6.4.1 General principles

The recommended standards generally follow Dr. Biggs' recommendations, although some changes were incorporated to include:

- the effects on the downstream/receiving environments. Generally, the downstream standards take precedence over the upstream standards. For example, if a tributary where Dr. Biggs's recommended standards are 15/165 (mg/m^3 DRP/SIN) flows into a river where the recommended standards are 10/110, then the recommended standards in the tributary are 10/110; and
- the priority nutrient and the current state of the water quality, as measured at the monitoring sites. In some instances, significant relaxation of Dr. Biggs's recommended standards was recommended. These changes were made only in situations where there was a clear indication of one nutrient likely to be currently limiting (eg. P) and a very significant gap between the recommended standard and the current water quality for the other nutrient (eg. N).

It is noted both these modifications are very much in accordance with the recommendations of the expert panel, who specifically recommended that downstream effects must be considered and that "where there is a key indication of a single, limiting nutrient (eg. P), it would be sensible to focus onmanaging that nutrient without neglecting controls on the other macronutrient (eg. N)" (Wilcock *et al.*, 2007). The standards were consolidated to recommend a unique set of standards per water management sub-zone, as summarised in Table 22, Map 6 and Map 7

The paragraphs below document the decision-making process for the different catchments.

6.4.2 Manawatu catchment

The current Manawatu Catchment Water Quality plan defines a DRP standard of 15 mg/m^3, applying only when the flow is under half median flow, but no standard relating to nitrogen as a nutrient.

Regular exceedances of the recommended periphyton biomass standard (120 mg/m^2) have been measured at several sites in the Manawatu mainstem (Hopelands, and Opiki), and tributaries (eg. Mangatainoka, Makakahi, Mangatera, Oroua).

To date, no specific limiting nutrient study has been conducted in the Manawatu catchment. The N:P ratio at reference sites varies between 8 (Upper Pohangina) and 11 (Upper Tamaki), suggesting that there is no marked pattern, and that, naturally, both N and P are likely to be limiting at different times of the year.

At sites influenced by land use (eg. lower Mangatainoka, Makuri, Manawatu at Hopelands), the N:P ratios are high, typically between 40 and 100. This suggests that, currently, DRP is likely to be the limiting nutrient in many parts of the catchment. However, the comparison with the reference data suggests that this is due to the very high levels of nitrogen measured in many parts of the catchment, rather than a reflection of a natural situation.

In accordance with the expert panel's recommendations:

- both nutrients should be managed and nutrient concentration standards relating to both nutrients are recommended
- phosphorus seemingly being the limiting nutrient, the focus should be on this nutrient, while also implementing controls on nitrogen.

Accordingly, the approach taken was to follow Dr. Biggs's recommendations with regards to the DRP standards, and to allow some relaxation of the SIN standards where it was justified by the current state of the water quality.

The average SIN concentrations in many parts of the Manawatu catchment are very elevated, often between 5 and 10 times higher than the 110 mg SIN/L recommended for most of the catchment (Table 22). Recent studies indicate that SIN in the Manawatu catchment comes predominantly from non-point source pollution (Ledein *et al.,* 2007; McArthur *et al.*, 2007c), and that, even if current best farming management practices were implemented, the 110 mg SIN/L standard may not be achieved (Roygard, 2007). The recommended standards aim to balance the need for a significant improvement in water quality with the requirement of defining a demonstrably achievable target (Roygard, 2007). Accordingly, where there was sufficient evidence to suggest phosphorus limitation <u>and</u> the current average SIN concentration was elevated, the recommended SIN standard was set at :

- 167 mg/m^3 if the mean monthly SIN concentration in the water was 220 to 550 mg/m^3, or
- 444 mg/m^3 if the mean monthly SIN concentration in the water was over 550 mg/m^3.

The paragraphs below document the decisions for the Manawatu catchment.

Upper Manawatu except the Mangatoro Stream (Mana_1a and Mana_1b)
- Classification: HM/TF2
- Periphyton biomass standard: 120 mg/m^2
- SIN <500 mg/m^3
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 167 mg/m^3

Mangatoro Stream (Mana_1c)
- Classification: HM/ TF2
- Periphyton biomass standard: 120 mg/m^2
- No water quality data
- Geology: the upper catchment is dominated by limestone and the lower catchment by mudstone, which both provide natural sources of P. The Mangatoro Stream is likely to be naturally N limited. No relaxation of the standard is recommended.
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 110 mg/m^3

Upper Tamaki and Upper Kumeti (Mana_3 and Mana_4)
- Classification: UHS
- Periphyton biomass standard: 50 mg/m^2
- Recommended DRP standard: 6 mg/m^3 or natural levels
- Recommended SIN standard: 70 mg/m^3

Manawatu mainstem from Weber Rd to Tiraumea confl. (Mana_2a, 5a, and 6)
- Classification: HM/TF2
- Periphyton biomass standard: 120 mg/m^2
- SIN = 850 mg/m^3
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 444 mg/m^3

Tributaries Weber to Tiraumea confl. (Mana_2b, 5b, 5c, and 5e)
- Classification: HM
- Periphyton biomass standard: 120 mg/m^2
- SIN = 700 to 1,000 mg/m^3
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 444 mg/m^3

Tiraumea catchement excluding Makuri, and Mangaramarama (Mana_7a, 7b, 7c and 8e)
- Classification: HSS/TF3
- Periphyton biomass standard: 200 mg/m^2
- SIN = 600 mg/m^3
- DRP standard recommended by Barry Biggs: 15 mg/m^3
- The Tiraumea is a major tributary of the Upper Manawatu River, where the recommended DRP standard is 10 mg/m^3
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 444 mg/m^3

Makuri (Mana_7d)
- Classification: ULi/TF2
- Periphyton biomass standard: 120 mg/m^2

- SIN = 850 mg/m^3
- Geology: the catchment is dominated by limestone and tertiary soft sedimentary rocks, both natural sources of P. The Makuri River is likely to be naturally N limited. No relaxation of the standard is recommended.
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 110 mg/m^3

Upper Mangatainoka (Mana_8a)
- Classification: UHS/TF2
- Periphyton biomass standard: 50 mg/m^2
- Recommended DRP standard: 6 mg/m^3 or natural levels
- Recommended SIN standard: 70 mg/m^3

Middle and lower Mangatainoka and Makakahi (Mana_8b, 8c and 8d)
- Classification: HM/TF2
- Periphyton biomass standard: 120 mg/m^2
- SIN = 800 to 1,100 mg/m^3
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 444 mg/m^3

Upper Mangahao (Mana_8a)
- Classification: UHS/TF3
- Periphyton biomass standard: 50 mg/m^2
- SIN = 300m g/m^3
- Recommended DRP standard: 6 mg/m^3 or natural levels
- Recommended SIN standard: 167 mg/m^3

Manawatu mainstem from Tiraumea confluence to Opiki Bridge, including lower Mangahao (Mana_9a, 9e, 10a, 11a)
- Classification: HM/TF3
- Periphyton biomass standard: 120 mg/m^2
- SIN = 600 to 1,800 mg/m^3
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 444 mg/m^3

Manawatu mainstem from Tiraumea confluence to Opiki Bridge, including lower Mangahao (Mana_9a, 9e, 10a, 11a)
- Classification: HM/TF3
- Periphyton biomass standard: 120 mg/m^2
- SIN = 600 to 1,800 mg/m^3
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 444 mg/m^3

Mangaatua and Mangapapa (Mana_9b and 9c)
- Classification: HM
- Periphyton biomass standard: 120 mg/m^2
- SIN = 300 to 1,100 mg/m^3
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 444 mg/m^3

Upper Pohangina, Turitea, Kahuterawa and Upper Tokomaru (Mana_10b, 11b and 11c)
- Classification: UHS/TF3
- Periphyton biomass standard: 50 mg/m^2

- SIN = 90 mg/m^3
- Recommended DRP standard: 6 mg/m^3 or natural levels
- Recommended SIN standard: 70 mg/m^3

Middle and Lower Pohangina (Mana_10c and 10d)
- Classification: HM/ TF3
- Periphyton biomass standard: 120 mg/m^2
- SIN = 140 mg/m^3
- Relatively low SIN, no relaxation of the standard recommended
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 110 mg/m^3

Mangaone Stream (Mana_11d and 11e)
- Classification: LM
- Periphyton biomass standard: 200 mg/m^2
- SIN = 1200 mg/m^3
- DRP standard recommended by Barry Biggs: 15 mg/m^3
- Flows into the Manawatu upstream of Opiki Bridge, where the recommended DRP standard is 10 mg/m^3
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 444 mg/m^3

Upper Oroua and Kiwitea (Mana_12a and 12d)
- Classification: HM/TF3
- Periphyton biomass standard: 120 mg/m^2
- SIN =400 mg/m^3 (Upper Oroua), no data for Kiwitea and Mangaore,
- Sin<500, recommended relaxation of the SIN standard to 167
- In the absence of data for the Mangaore and Kiwitea, relaxation to 444 is not recommended,
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 167 mg/m^3

Middle Oroua (Mana_12b)
- Classification: HM/TF3
- Periphyton biomass standard: 120 mg/m^2
- SIN =1,500 mg/m^3
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 444 mg/m^3

Makino (Mana_12e)
- Classification: LM
- Periphyton biomass standard: 200 mg/m^2
- DRP standard recommended by Barry Biggs: 15 mg/m^3
- Flows into the Middle Oroua where the DRP standard is 10 mg/m^3
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 444 mg/m^3

Lower Oroua (Mana_12c)
- Classification: LM/TF3
- Periphyton biomass standard: 120 mg/m^2
- No water quality data.
- The Oroua has a soft material bed downstream of Kopane, so is not prone to periphyton growth.

- It is estimated the few km of river between Awahuri Bridge and Kopane should be adequately protected by the standards at Awahuri Bridge.
- The Oroua flows into the Manawatu downstream of Opiki Bridge, where the recommended DRP standard is 15 mg/m^3
- Recommended DRP standard: 15 mg/m^3
- Recommended SIN standard: 444 mg/m^3

Coastal Manawatu, Koputaroa, and Foxton Loop
- Classification: LM/TF3
- Periphyton biomass standard: 200 mg/m^2
- The Manawatu and Foxton Loop have soft bed material downstream of Opiki Bridge, so are not prone to periphyton growth,
- Lowland standards are recommended to protect the downstream ecosystems (estuary and coastal waters),
- Recommended DRP standard: 15 mg/m^3
- Recommended SIN standard: 444 mg/m^3

6.4.3 Rangitikei catchment

The current Land and Water Regional Plan applies to the Rangitikei catchment, but does not define numerical water quality standards.

Regular exceedance of the recommended periphyton biomass standard (120 mg/m^2) have been measured at some sites in the catchment, particularly in tributaries (Tutaenui Stream, Porewa River, Hautapu River) and the lower mainstem (downstream of Bulls).

A nutrient diffusing substrate (NDS) study was undertaken in 2005 at 11 sites within the Rangitikei catchment, indicating a general nitrogen limitation of periphyton growth, except at sites heavily impacted by point source discharges, where no nutrient limitation was apparent. This result is generally confirmed by relatively low N:P ratios. (Death & Death, 2005).

In accordance with the expert panel's recommendations:
- both nutrients should be managed and nutrient concentration standards relating to both nutrients are recommended
- nitrogen being the likely limiting nutrient, the management focus should be on this nutrient, while also implementing controls on phosphorus.

Accordingly, the approach taken was to follow Dr. Biggs's recommendations with regard to the SIN standards for the Rangitikei River mainstem:
- 70 mg-N/m^3 in the upper part of the catchment classified UHS or UVA (Rang_1, Rang_2a and Rang_2c); and
- 110 in the rest of the catchment, to maintain the periphyton biomass under 120 mg/m^2.

Nitrogen being the likely limiting nutrient, relaxation of the standard for the Rangitikei mainstem is strongly not recommended.

The levels of DRP measured in the Rangitikei mainstem comply with (Middle and Lower Rangitikei), or are near complying with, (Coastal Rangitikei) the DRP standard recommended by Dr. Biggs. In accordance with the general principles explained in section 6.4.1, no relaxation of the DRP standard is recommended.

In some tributaries classified HSS or LM and not classified as trout fisheries (eg. Makohine, Porewa, Tutaenui), the recommended periphyton standard was set at 200 mg/m^2. Dr Biggs' general recommendations for these systems were 15 mg/m^3 for DRP and 165 mg/m^3 for SIN. However, the expert panel also recommended that effects on downstream systems are carefully considered. As a consequence, and in accordance with the general principles explained in section 6.4.1, the recommended standards for these tributaries were dictated by the Rangitikei River mainstem standards (10/110).

6.4.4 Whanganui catchment

The Land and Water Regional Plan currently applies to the Whanganui catchment, but does not define water quality standards.

To date, no exceedance of the proposed periphyton standards has been recorded, although anecdotal evidence suggests that excessive periphyton growth occurs on the middle Whanganui River (eg. at Pipiriki) margins during periods of low flow (Dr Russell Death, pers. comm.).

To date, no specific limiting nutrient study has been conducted in the Whanganui catchment. The only reference data available in the Whanganui catchment (Manganui o te Ao at Hoihenga Rd) presents typical N:P ratios between 8 and 9, providing no clear indication of one nutrient being limiting. N:P ratios at other sites throughout the catchment vary between 20 and 37, indicating that phosphorus may be limiting. The N:P imbalance is not marked enough to draw firm conclusions, and further investigating of the nutrient limitation status of the Whanganui River and its tributaries is recommended. Based on the information currently available, SIN and DRP standards with a N:P ratio of 11, as recommended by Dr Biggs, are proposed.

Whanganui River Headwaters and tributaries - Whakapapa, Piopiotea, Upper Ongarue and upper Manganui o te Ao
- Classification: UVATF1 or TF3
- Periphyton biomass standard: 50 mg/m^2
- Recommended DRP standard: 6 mg/m^3 or natural levels
- Recommended SIN standard: 70 mg/m^3

Whanganui River from Whakapapa confluence to Retaruke, Pongaponga, Retaruke, lower Ongarue and lower Manganui o te Ao.

- Classification: UVM/TF1 or TF3
- Periphyton biomass standard: 120 mg/m^2
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 110 mg/m^3

Whanganui River from Retaruke to Paetawa
- Classification: HSS/TF3
- Periphyton biomass standard: 120 mg/m^2
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 110 mg/m^3

Middle Whanganui River tributaries: Ohura, Tangarakau, Whangamomona

- Classification: HSS
- Periphyton biomass standard: 200 mg/m^2
- Flow into Whanganui River, where DRP/SIN standards are 10/110
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 110 mg/m^3

Lower Whanganui River from Paetawa to mouth and tributaries

- Classification: HSS or LM
- Periphyton biomass standard: 200 mg/m^2
- Recommended DRP standard: 15 mg/m^3
- Recommended SIN standard: 167 mg/m^3

6.4.5 Whangaehu catchment

Upper Whangaehu (Whau_1a)

- Classification: UVA
- Periphyton biomass standard: 50 mg/m^2
- Very uncommon ecosystem due to the influence of the Ruapehu crater lake (very acidic water at times)
- More research is required to understand the nutrient sensitivity of this very special environment (section 9). Until this research is conducted, a precautionary approach is recommended
- Recommended DRP standard: 6 mg/m^3 or natural levels
- Recommended SIN standard: 70 mg/m^3

Upper Mangawhero, Makotuku, Tokiahuru (Whau_1c, Whau 3b and Whau_3c)

- Classification: UVA/TF3
- Periphyton biomass standard: 50 mg/m^2
- It is noted that natural phosphorus levels can be relatively elevated (eg. in the Upper Mangawhero, see Table 22), and nutrient management should focus on nitrogen
- Recommended DRP standard: 6 mg/m^3 or natural levels
- Recommended SIN standard: 70 mg/m^3

Waitangi Stream (Whau_1b)

- Classification: UVM/TF3
- Periphyton biomass standard: 120 mg/m^2
- It is noted that natural phosphorus levels may be relatively elevated and nutrient management should focus on nitrogen
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 110 mg/m^3

Middle, lower and coastal Whangaehu (Whau_2, Whau_3a and Whau_4)

- Classification: HSS
- Periphyton biomass standard: 200 mg/m^2
- Recommended DRP standard: 15 mg/m^3
- Recommended SIN standard: 167 mg/m^3

Middle and lower Mangawhero (Whau_3e and Whau_3a)

- Classification: HSS/TF3
- Periphyton biomass standard: 120 mg/m^2
- Recommended DRP standard: 10 mg/m^3

- Recommended SIN standard: 110 mg/m^3

It is noted that the Whangaehu mainstem in the Whau_3a zone is not classified as a trout fishery, and the same standard as for the Whau_2 zone should apply

6.4.6 Turakina catchment

Upper and lower Turakina (Tura_1a and Tura_1b)
- Classification: HSS
- Periphyton biomass standard: 200 mg/m^2
- Recommended DRP standard: 15 mg/m^3
- Recommended SIN standard: 167 mg/m^3

Ratana/ Lake Waipu (Tura_1c)
- Classification: LM/lake catchments
- Lake standards apply to lake tributaries
- Recommended TP standard: 20 mg/m^3
- Recommended TN standard: 337 mg/m^3

6.4.7 East coast catchments (Owha_1, East_1, Akit_1)

- Classification: HSS
- Periphyton biomass standard: 200 mg/m^2
- Recommended DRP standard: 15 mg/m^3
- Recommended SIN standard: 167 mg/m^3

6.4.8 Ohau River catchment

Upper Ohau(Ohau_1a)
- Classification: UHS/TF3
- Periphyton biomass standard: 50 mg/m^2
- Recommended DRP standard: 6 mg/m^3 or natural levels,
- Recommended SIN standard: 70 mg/m^3

Lower Ohau (Ohau_1b)
- Classification: HM/TF3
- Periphyton biomass standard: 120 mg/m^2
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 110 mg/m^3

6.4.9 Waikawa catchment

Waikawa Stream (West_9)
- Classification: HM/ TF3
- Periphyton biomass standard: 120 mg/m^2
- N:P ratios typically >40, indicating a likely phosphorus limitation
- Average SIN concentration is approximately 1,400 mg N/ m^3,
- In a similar fashion to the Manawatu catchment, a relaxation of the SIN standard to 444 mg/m^3 is recommended.
- Recommended DRP standard: 10 mg/m^3
- Recommended SIN standard: 444 mg/m^3

6.4.10 Western coastal zones

- Classification: LM
- Periphyton biomass standard: 200 mg/m^2
- No data available
- Recommended DRP standard: 15 mg/m^3
- Recommended SIN standard: 165 mg/m^3

6.4.11 Lake waters and lake catchments

Nutrient standards for lake waters have been defined in section 3.2.3.7 of this report:

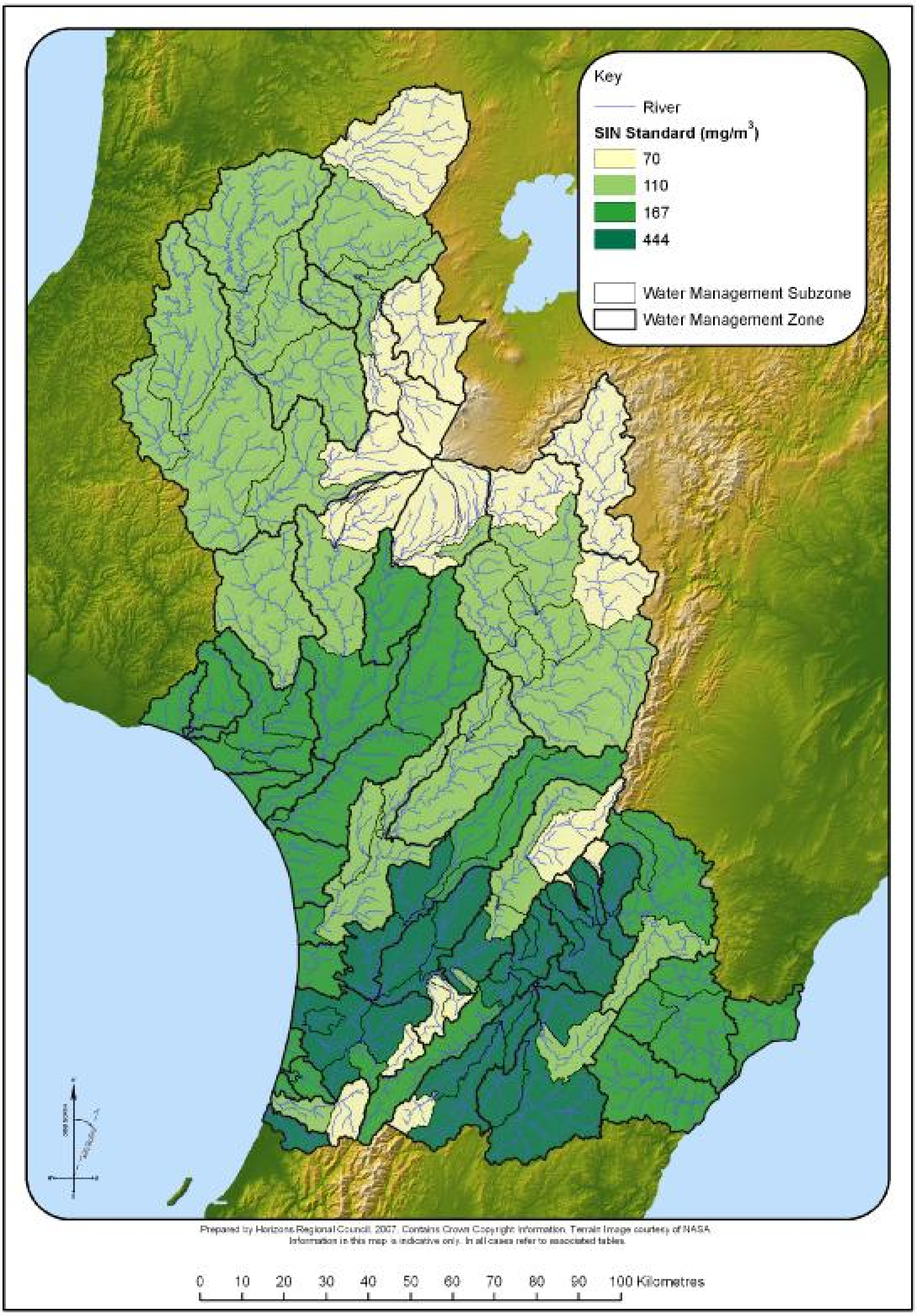
- annual average total phosphorus (TP): 20 mg/m3
- annual average total nitrogen (TN): 337 mg/m3

Further monitoring and research is required to better qualify the state of the Region's coastal lakes and define appropriate management regimes to protect these sensitive environments (see section 9 of this report).

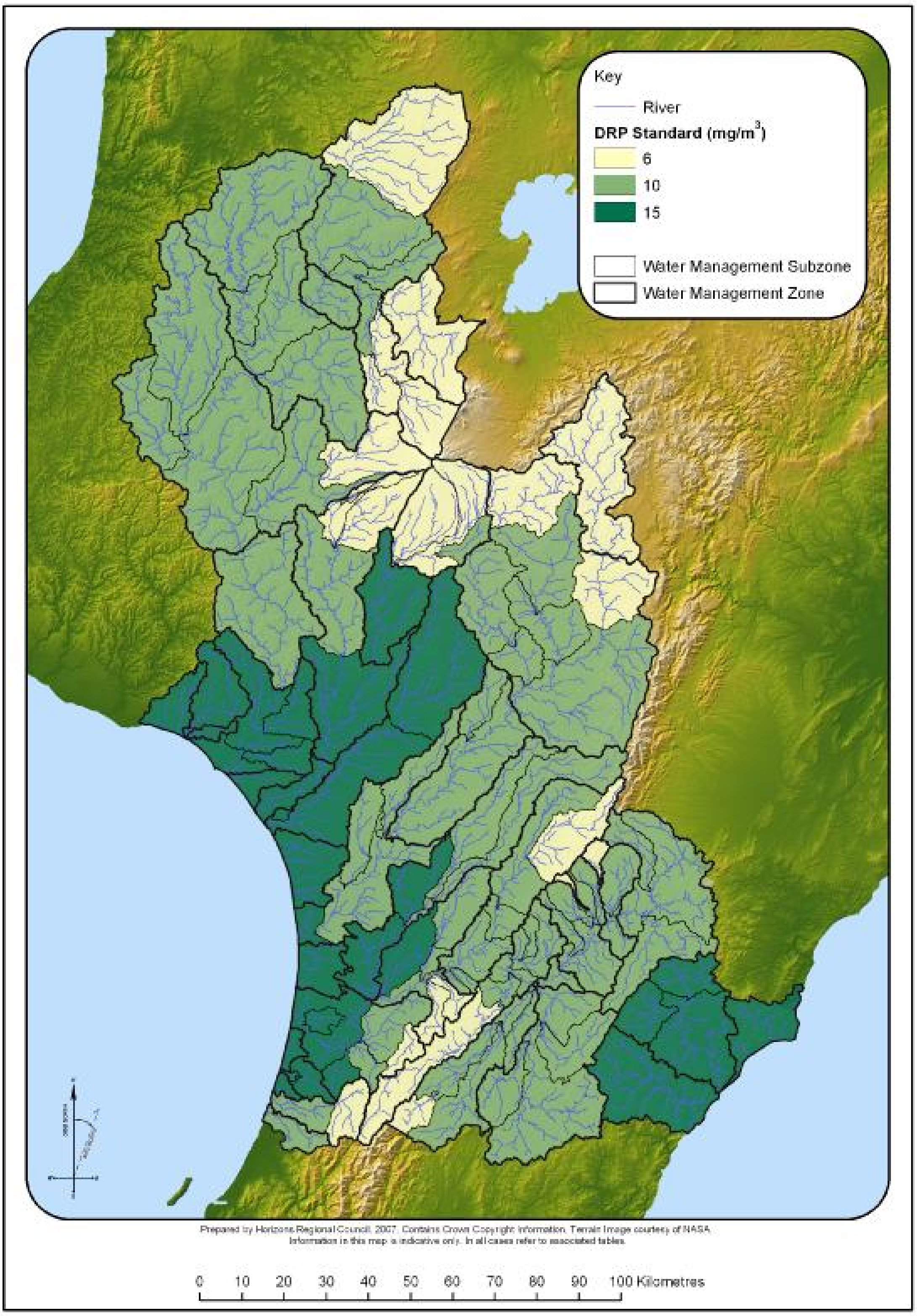
Until such research is conducted it is recommended the standards for lake waters also apply to tributaries of these lakes. These standards are set to control the nutrient loadings added to the lakes, therefore they apply year round, at all river flows.

These standards apply to all lake tributaries within the following zones: Mana_13, Whai_7, Whau_4, Tura_1, West_1, West_4, West_5, West_6, West_7, West_8 and Hoki_1.

Streams and rivers within these water management sub-zones that do not flow into a natural lake are subject to the DRP and SIN standards defined in sections 6.4.2 to 6.4.10 above.



Map 6: Recommended Soluble Inorganic Nitrogen (SIN) standard (mg/m^3) by water management sub-zone.



Map 7: Recommended Dissolved Reactive Phosphorus (DRP) standard (mg/m^3) by water management sub-zone.

Table 22: Nutrient standards- summary by water management sub-zone of the New Zealand Periphyton Guidelines' model predictions, Dr. Biggs's recommendations, ANZECC Guidelines trigger values for upland and lowland rivers, observed mean monthly concentrations in summer (1st October – 31st April) and year-round (NIWA data for the following sites : Manawatu at Weber Road, Manawatu at Teachers College, Manawatu at Opiki Bridge, Whanganui at Te Maire), and recommended standards for the One Plan (as mean monthly concentration, expressed in mg/m^3).

Management Zone	Zone Code	Sub-zone	Biomass Target	Periphyton Guidelines model (for site)		Periphyton guidelines (for LSC class)		Dr. Biggs's recommendations		ANZECC		Observed Summer (mg/m^3)		Observed Year round (mg/m^3)		Recommended One Plan Standard (mg/m^3)	
				DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN
Upper Manawatu	Mana_1a	Upper Manawatu	120	5.5	58	3 to 24 (7)	30 to 240 (70)	10	110	9	167	11	354	11	493	10	167
	Mana_1b	Mangatewainui	50	ND	ND	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	ND	ND	ND	ND	10	167
	Mana_1c	Mangatoro	120	ND	ND	3 to 24 (7)	30 to 240 (70)	10	110	9	167	ND	ND	ND	ND	10	110
Weber-Tamaki	Mana_2a	Weber-Tamaki	120	5.5	58	3 to 24 (7)	30 to 240 (70)	10	110	9	167	ND	ND	ND	ND	10	444
	Mana_2b	Mangatera	120	5.5	58	3 to 24 (7)	30 to 240 (70)	10	110	9	167	200	880	170	1080	10	444
Upper Tamaki	Mana_3	Upper Tamaki	50	0.3	3	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	9	109	11	120	6	70
Upper Kumeti	Mana_4	Upper Kumeti	50	0.1	1	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	ND	ND	ND	ND	6	70
Tamaki-Hopelands	Mana_5a	Tamaki-Hopelands	120	4.3	45	3 to 24 (7)	30 to 240 (70)	10	110	10	444	25	700	170	850	10	444
	Mana_5b	Lower Tamaki	120	0.3	3	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	12	560	13	710	10	444
	Mana_5c	Lower Kumeti	120	5.1	53	3 to 24 (7)	30 to 240 (70)	10	110	9	167	ND	ND	ND	ND	10	444
	Mana_5d	Oruakeretaki	120	ND	ND	3 to 24 (7)	30 to 240 (70)	10	110	9	167	ND	ND	ND	ND	10	444
	Mana_5e	Raparapawai	120	ND	ND	3 to 24 (7)	30 to 240 (70)	10	110	9	167	ND	ND	ND	ND	10	167
Hopelands-Tiraumea	Mana_6	Hopelands-Tiraumea	120	4.3	45	3 to 24 (7)	30 to 240 (70)	10	110	10	444	ND	ND	ND	ND	10	444
Tiraumea	Mana_7a	Upper Tiraumea	200	9.8	101	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	25	400	23	600	10	444
	Mana_7b	Lower Tiraumea	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	ND	ND	ND	ND	10	444
	Mana_7c	Mangaone River	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	ND	ND	ND	ND	10	444
	Mana_7d	Makuri	120	6.5	68	6.5	68	10	110	9	167	11	840	11	850	10	110
Mangatainoka	Mana_8a	Upper Mangatainoka	50	6.2	61	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	4	32	5	45	6	70
	Mana_8b	Middle Mangatainoka	120	22	224	4.4 to 83 (12)	46 to 785 (120)	10	110	9	167	14	1,060	13	1,130	10	444
	Mana_8c	Lower Mangatainoka	120	ND	ND	4.4 to 83 (12)	46 to 785 (120)	10	110	10	444	ND	ND	ND	ND	10	444
	Mana_8d	Makakahi	120	24	240	4.4 to 83 (12)	46 to 785 (120)	10	110	9	167	11	690	11	820	10	444
	Mana_8e	Mangaramarama	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	ND	ND	ND	ND	10	444
Upper Gorge	Mana_9a	Upper Gorge	120	11	112	3 to 24 (7)	30 to 240 (70)	10	110	10	444		710		740	10	444
	Mana_9b	Mangapapa	120	ND	ND	3 to 24 (7)	30 to 240 (70)	10	110	10	444	19	706	17	1100	10	444
	Mana_9c	Mangaatua	120	15	155	3 to 24 (7)	30 to 240 (70)	10	110	10	444	31	260	36	325	10	444
	Mana_9d	Upper Mangahao	50	2.2	23	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	8	200	8	300	6	167
	Mana_9e	Lower Mangahao	120	ND	ND	3 to 24 (7)	30 to 240 (70)	10	110	10	444	ND	ND	ND	ND	10	444
Middle Manawatu	Mana_10a	Middle Manawatu	120	9	90	3 to 24 (7)	30 to 240 (70)	10	110	10	444	10	445	11	613	10	444
	Mana_10b	Upper Pohangina	50	ND	ND	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	15	56	11	90	6	70

Management Zone	Zone Code	Sub-zone	Biomass Target	Periphyton Guidelines model (for site)		Periphyton guidelines (for LSC class)		Dr. Biggs's recommendations		ANZECC		Observed Summer (mg/m^3)		Observed Year round (mg/m^3)		Recommended One Plan Standard (mg/m^3)	
				DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN
	Mana_10c	Middle Pohangina	120	15	150	3 to 24 (7)	30 to 240 (70)	10	110	10	444	13	93	13	138	10	110
	Mana_10d	Lower Pohangina	120	ND	ND	3 to 24 (7)	30 to 240 (70)	10	110	10	444	ND	ND	ND	ND	10	110
	Mana_10e	Aokautere	120	ND	ND	3 to 24 (7)	30 to 240 (70)	10	110	10	444	ND	ND	ND	ND	10	110
Lower Manawatu	**Mana_11a**	Lower Manawatu	120	9	93	3 to 24 (7)	30 to 240 (70)	10	110	10	444	61	1630	52	1860	10	444
	Mana_11b	Turitea	50	0.6	7	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	13	130	13	220	6	70
	Mana_11c	Kahuterawa	50	ND	ND	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	ND	ND	ND	ND	6	70
	Mana_11d	Upper Mangaone Stream	200	ND	ND	2 to 14	20 to 150	15	165	10	444	172	60	150	1200	10	444
	Mana_11e	Lower Mangaone Stream	200	ND	ND	2 to 14	20 to 150	15	165	10	444	ND	ND	ND	ND	10	444
	Mana_11f	Main Drain	200	ND	ND	2 to 14	20 to 150	15	165	10	444	ND	ND	ND	ND	15	444
Oroua	**Mana_12a**	Upper Oroua	120	7	70	3 to 24 (7)	30 to 240 (70)	10	110	9	167	13	260	13	400	10	167
	Mana_12b	Middle Oroua	120	8.4	87	3 to 24 (7)	30 to 240 (70)	10	110	10	444	166	1840	134	1500	10	444
	Mana_12c	Lower Oroua	200	ND	ND	2 to 14	20 to 150	15	165	10	444	ND	ND	ND	ND	15	444
	Mana_12d	Kiwitea	120	6	62	3 to 24 (7)	30 to 240 (70)	10	110	9	167	ND	ND	ND	ND	10	167
	Mana_12e	Makino	200	6.6	70	3 to 24 (7)	30 to 240 (70)	15	165	10	444	ND	ND	ND	ND	10	444
Coastal Manawatu	**Mana_13a**	Coastal Manawatu	N/A	N/A	N/A	N/A	N/A	15	165	10	444	42	700	39	720	15	444
	Mana_13b	Upper Tokomaru	50	2.3	23	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	9	64	8	82	6	70
	Mana_13c	Lower Tokomaru	120	ND	ND	3 to 24 (7)	30 to 240 (70)	10	110	10	444	ND	ND	ND	ND	10	444
	Mana_13d	Mangaore	120	ND	ND	2 to 14	20 to 150	10	110	10	444	ND	ND	ND	ND	10	167
	Mana_13e	Koputaroa	200	ND	ND	2 to 14	20 to 150	15	165	10	444	ND	ND	ND	ND	15	444
	Mana_13f	Foxton Loop	N/A	N/A	N/A	N/A	N/A	15	165	10	444	63	301	61	409	15	444
Upper Rangitikei	**Rang_1**	Upper Rangitikei	50	0.4	4	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	ND	ND	ND	ND	6	70
Middle Rangitikei	**Rang_2a**	Middle Rangitikei	50	0.3	3	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	5	28	5	28	6	70
	Rang_2b	Pukeokahu - Mangaweka	120	4	40	3 to 24 (7)	30 to 240 (70)	10	110	9	167	7	90	8	102	10	110
	Rang_2c	Upper Moawhango	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	ND	ND	ND	ND	6	70
	Rang_2d	Middle Moawhango	120	ND	ND	0.4 to 21 (2.3)	4 to 210 (24)	10	110	9	167	ND	ND	ND	ND	10	110
	Rang_2e	Lower Moawhango	120	N/A	N/A	4.4 to 83 (12)	46 to 785 (120)	10	110	9	167	ND	ND	ND	ND	10	110
	Rang_2f	Upper Hautapu	120	N/A	N/A	N/A	N/A	10	110	9	167	10	138	10	195	10	110
	Rang_2g	Lower Hautapu	120	ND	ND	4.4 to 83 (12)	46 to 785 (120)	10	110	9	167	30	130	28	194	10	110
Lower Rangitikei	**Rang_3a**	Lower Rangitikei	120	6.5	67	3 to 24 (7)	30 to 240 (70)	10	110	10	444	21	10	20	11	10	110
	Rang_3b	Makohine	200	26	264	4.4 to 83 (12)	46 to 785 (120)	15	165	9	167	14	260	14	260	10	110
Coastal Rangitikei	**Rang_4a**	Coastal Rangitikei	120	ND	ND	4.4 to 83 (12)	46 to 785 (120)	10	110	10	444	16	110	17	176	10	110
	Rang_4b	Tidal Rangitikei	120	ND	ND	4.4 to 83 (12)	46 to 785 (120)	10	110	10	444	14	129	16	218	10	110
	Rang_4c	Porewa	200	14	147	2 to 14	20 to 150	15	165	10	444	32	260	31	570	10	110
	Rang_4d	Tutaenui	200	4	42	2 to 14	20 to 150	15	165	10	444	1160	1420	900	2200	10	110

Management Zone	Zone Code	Sub-zone	Biomass Target	Periphyton Guidelines model (for site)		Periphyton guidelines (for LSC class)		Dr. Biggs's recommendations		ANZECC		Observed Summer (mg/m^3)		Observed Year round (mg/m^3)		Recommended One Plan Standard (mg/m^3)	
				DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN
Upper Whanganui	**Whai_1**	Upper Whanganui	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	25	21	24	21	6	70
Cherry Grove	**Whai_2a**	Cherry Grove	120	4.6	48	0.4 to 21 (2.3)	4 to 210 (24)	10	110	9	167	10	130	9	186	10	110
	Whai_2b	Upper Whakapapa	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	ND	ND	ND	ND	6	70
	Whai_2c	Lower Whakapapa	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	6	83	5	124	6	70
	Whai_2d	Piopiotea	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	ND	ND	ND	ND	6	70
	Whai_2e	Pungapunga	120	ND	ND	0.4 to 21 (2.3)	4 to 210 (24)	10	110	9	167	ND	ND	ND	ND	10	110
	Whai_2f	Upper Ongarue	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	ND	ND	ND	ND	6	70
	Whai_2g	Lower Ongarue	120	2.3	24	0.4 to 21 (2.3)	4 to 210 (24)	10	110	9	167	10	215	10	250	10	110
Te Maire	**Whai_3**	Te Maire	120	6	60	0.4 to 21 (2.3)	4 to 210 (24)	10	110	9	167	12	177	12	254	10	110
Middle Whanganui	**Whai_4a**	Middle Whanganui	120	6	60	0.4 to 21 (2.3)	4 to 210 (24)	10	110	9	167	13	154	15	255	10	110
	Whai_4b	Upper Ohura	200	14	144	4.4 to 83 (12)	46 to 785 (120)	15	165	9	167	ND	ND	ND	ND	10	110
	Whai_4c	Lower Ohura	200	14	144	4.4 to 83 (12)	46 to 785 (120)	15	165	9	167	ND	ND	ND	ND	10	110
	Whai_4d	Retaruke	120	ND	ND	0.4 to 21 (2.3)	4 to 210 (24)	10	110	9	167	ND	ND	ND	ND	10	110
Pipiriki	**Whai_5a**	Pipiriki	120	14	144	4.4 to 83 (12)	46 to 785 (120)	15	165	9	167	7	160	10	300	10	110
	Whai_5b	Tangarakau	200	14	144	4.4 to 83 (12)	46 to 785 (120)	15	165	9	167	ND	ND	ND	ND	10	110
	Whai_5c	Whangamomona	200	14	144	4.4 to 83 (12)	46 to 785 (120)	15	165	9	167	ND	ND	ND	ND	10	110
	Whai_5d	Upper Manganui o te Ao	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	8	74	7	77	6	70
	Whai_5e	Lower Manganui o te Ao	120	N/A	N/A	N/A	N/A	10	110	9	167	ND	ND	ND	ND	10	110
Paetawa	**Whai_6**	Paetawa	120	13	130	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	ND	ND	ND	ND	10	110
Lower Whanganui	**Whai_7a**	Lower Whanganui	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	9	150	9	220	15	167
	Whai_7b	Coastal Whanganui	N/A	N/A	N/A	N/A	N/A	15	165	10	444	10	180	11	230	15	167
	Whai_7c	Upokongaro	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	ND	ND	ND	ND	15	167
	Whai_7d	Matarawa	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	ND	ND	ND	ND	15	167
Upper Whangaehu	**Whau_1a**	Upper Whangaehu	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	ND	ND	ND	ND	6	70
	Whau_1b	Waitangi	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	17	290	17	290	6	70
	Whau_1c	Tokiahuru	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	ND	ND	ND	ND	6	70
Middle Whangaehu	**Whau_2**	Middle Whangaehu	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	9	167	ND	ND	ND	ND	15	167
Lower Whangaehu	**Whau_3a**	Lower Whangaehu	200	4.4	46	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	12	172	13	282	15	167
	Whau_3b	Upper Makotuku	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	20	255	20	260	6	70
	Whau_3c	Lower Makotuku	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	42	490	35	520	6	70
	Whau_3d	Upper Mangawhero	50	N/A	N/A	N/A	N/A	5 to 6	55 to 70	9	167	14	46	14	60	6	70
	Whau_3e	Lower Mangawhero	120	9.7	100	4.4 to 83 (12)	46 to 785 (120)	10	110	9	167	ND	ND	ND	ND	10	110
Coastal Whangaehu	**Whau_4**	Coastal Whangaehu	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	ND	ND	ND	ND	15	167
Turakina	**Tura_1a**	Upper Turakina	200	11	110	4.4 to 83 (12)	46 to 785 (120)	15	165	9	167	ND	ND	ND	ND	15	167

Management Zone	Zone Code	Sub-zone	Biomass Target	Periphyton Guidelines model (for site)		Periphyton guidelines (for LSC class)		Dr. Biggs's recommendations		ANZECC		Observed Summer (mg/m^3)		Observed Year round (mg/m^3)		Recommended One Plan Standard (mg/m^3)	
				DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN	DRP	SIN
	Tura_1b	Lower Turakina	200	6.5	68	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	ND	ND	ND	ND	15	167
	Tura_1c	Ratana	N/A	N/A	N/A	N/A	N/A	20 (TP)	337 (TN)	10	444	ND	ND	ND	ND	20 (TP)	337 (TN)
Ohau	**Ohau_1a**	Upper Ohau	50	1.7	18	0.1 to 6.2 (0.9)	1 to 6.1 (9)	5 to 6	55 to 70	9	167	5	60	6	80	6	70
	Ohau_1b	Lower Ohau	120	ND	ND	3 to 24 (7)	30 to 240 (70)	10	110	10	444	11	240	14	300	10	167
Owahanga	**Owha_1**	Owahanga	200	18	190	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	10	80	10	80	15	167
East Coast	**East_1**	East Coast	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	ND	ND	ND	ND	15	167
Akitio	**Akit_1a**	Upper Akitio	200	9.3	96	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	11	140	10	218	15	165
	Akit_1b	Lower Akitio	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	17	138	15	232	15	167
	Akit_1c	Waihi	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	ND	ND	ND	ND	15	167
Northern Coastal	**West_1**	Northern Coastal	200	ND	ND	2 to 14	20 to 150	15	165	10	444	ND	ND	ND	ND	15	167
Kai Iwi	**West_2**	Kai Iwi	200	ND	ND	4.4 to 83 (12)	46 to 785 (120)	15	165	10	444	ND	ND	ND	ND	15	167
Mowhanau	**West_3**	Mowhanau	200	ND	ND	2 to 14	20 to 150	15	165	10	444	ND	ND	ND	ND	15	167
Kaitoke Lakes	**West_4**	Kaitoke Lakes	N/A	N/A	N/A	N/A	N/A	20 (TP)	337 (TN)	10	444	ND	ND	ND	ND	20 (TP)	337 (TN)
Southern Wanganui Lakes	**West_5**	Southern Wanganui Lakes	N/A	N/A	N/A	N/A	N/A	20 (TP)	337 (TN)	10	444	ND	ND	ND	ND	20 (TP)	337 (TN)
Northern Manawatu Lakes	**West_6**	Northern Manawatu Lakes	N/A	N/A	N/A	N/A	N/A	20 (TP)	337 (TN)	10	444	ND	ND	ND	ND	20 (TP)	337 (TN)
Waitarere	**West_7**	Waitarere	200	ND	ND	ND	ND	15	165	10	444	ND	ND	ND	ND	15	167
Lake Papaitonga	**West_8**	Lake Papaitonga	N/A	N/A	N/A	N/A	N/A	20 (TP)	337 (TN)	10	444	ND	ND	ND	ND	20 (TP)	337 (TN)
Waikawa	**West_9**	Waikawa	120	ND	ND	3 to 24 (7)	30 to 240 (70)	10	110	10	444	30	1396	31	1426	10	444
Lake Horowhenua	**Hoki_1a**	Lake Horowhenua	N/A	N/A	N/A	N/A	N/A	20 (TP)	337 (TN)	10	444	ND	ND	ND	ND	20 (TP)	337 (TN)
	Hoki_1b	Hokio	200	ND	ND	ND	ND	15	165	10	444	ND	ND	ND	ND	15	167

7 Recommended Water Quality Standards for each Management Zone

As explained in section 2.1 of this report, the process of defining water quality standards for each waterbody comprises three basic steps:

- identify all the values associated with this particular waterbody. This step is defined in the "Values report" (Ausseil & Clark 2007a);
- compile all the water quality standards recommended for the protection of these values. This step is described in the previous sections of this report; and
- identify, for each waterbody, the most stringent numerical standard for each water quality parameter. The final set of standards thus defined will protect all the values associated with the waterbody.

Some values, such as life-supporting capacity and contact recreation, apply to whole management zones ("zone-wide values"); the others, such as trout spawning (TS), are "site-specific values" (Ausseil & Clark, 2007a). The set of "zone-wide values" allows the determination of a unique set of water quality standards for each management sub-zone. The standards associated with site-specific values (eg. the TS standards) are additional to these.

The tables and schedules in section 7 are the water quality standards recommendations for inclusion in the One Plan.

7.1 Water Quality Standards for stream and rivers in Water Management Sub-zones

Table 23: Recommended wording for the water quality standards defined in Table 24 (Numerical values in Table 24 are indicated by [...])

Column in Table 24		Recommended standard wording
Header	Sub-header	
pH	Range	The pH of the water shall be within the range […] to […]
	Δ	The pH of the water shall not be changed by more than […]
Temp (°C)	<	The temperature of the water shall not exceed […] degrees Celsius.
	Δ	The temperature of the water shall not be changed by more than […] degrees Celsius.
DO (%SAT)	<	The concentration of dissolved oxygen shall exceed […]% of saturation
BOD_5 (g/m^3)	<	The five-days biochemical oxygen demand shall not exceed […] grams per cubic metre.
POM (g/m^3)	<	The concentration of particulate organic matter shall not exceed […] grams per cubic metre.
Periphyton	Chla (mg/m^2)	The algal biomass on the stream or river bed shall not exceed […] milligrams of chlorophyll a per square metre.
	% cover	The maximum cover of visible stream or river bed by periphyton (as filamentous algae more than 2 centimetres long) shall not exceed […]%
DRP (mg/m^3)	<	The annual average concentration of dissolved reactive phosphorus when the river flow is at or below three times the median flow shall not exceed […] milligrams per cubic metre, unless natural levels already exceed this standard.
SIN (mg/m^3)	<	The annual average concentration of soluble inorganic nitrogen when the river flow is at or below three times the median flow shall not exceed […] milligrams per cubic metre.
QMCI		The quantitative macroinvertebrate index shall exceed […], unless natural physical conditions are outside the scope of application of the QMCI.
Ammonia (mg/m^3)	<	The concentration of ammonia nitrogen shall not exceed […] milligrams per cubic metre.
Toxicants	<	For toxicants not otherwise defined in these standards, the concentration of toxicants in the water shall not exceed the trigger values defined in the 2000 ANZECC guidelines Table 3.4.1 with the level of protection of […]% of species.
Clarity (m)	<m	The clarity of the water when the river flow is at or below median flow shall exceed […] metres (m)
	<3 x m	The clarity of the water when the river flow is at or below three time the median flow shall exceed […] metres (m)
	Δ	The clarity of the water shall not be changed by more than […] %. This standard applies at all river flows.

Note: Soluble Inorganic Nitrogen (SIN) concentration is measured of the sum of nitrate nitrogen, nitrite nitrogen and ammonia nitrogen

Table 24: Water quality standards for rivers and streams in each Water Management Sub-zone (Note Refer to 7.2 for water quality standards applying to rivers and streams flowing into natural lakes).

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD_5 (g/m^3)	POM (g/m^3)	Periphyton		DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Ammonia (mg/m^3)	Tox.	**Clarity (m)**		
		Range	**Δ**	<	**Δ**	>	<	<	Chl *a* (mg/m^2)	% cover	<	<		<		< m	< 3 xm	**% Δ**
Upper Manawatu (Mana_1)	Upper Manawatu (Mana_1a)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	167	6	400	99	3	1.6	20
	Mangatewainui (Mana_1b)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	167	6	400	99	3	1.6	20
	Mangatoro (Mana_1c)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	110	6	400	99	3	0.5	20
Weber-Tamaki (Mana_2)	Weber-Tamaki (Mana_2a)	7 to 8.5	0.5	19	2	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
	Mangatera (Mana_2b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99	2.5	1.6	30
Upper Tamaki (Mana_3)	Upper Tamaki	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
Upper Kumeti (Mana_4)	Upper Kumeti	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
Tamaki-Hopelands (Mana_5)	Tamaki-Hopelands (Mana_5a)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
	Lower Tamaki (Mana_5b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99	2.5	1.6	30
	Lower Kumeti (Mana_5c)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99	2.5	1.6	30
	Oruakeretaki (Mana_5d)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99	2.5	1.6	30
	Raparapawai (Mana_5e)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	99	2.5	1.6	30
Hopelands-Tiraumea (Mana_6)	Hopelands-Tiraumea	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
Tiraumea (Mana_7)	Upper Tiraumea (Mana_7a)	7 to 8.5	0.5	23	3	70	2	5	120	30	10	444	5	400	95	2	0.5	30
	Lower Tiraumea (Mana_7b)	7 to 8.5	0.5	23	3	70	2	5	120	30	10	444	5	400	95	2	0.5	30
	Mangaone River (Mana_7c)	7 to 8.5	0.5	23	3	70	2	5	200	30	10	444	5	400	95	1.6	0.5	30

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD_5 (g/m^3)	POM (g/m^3)	Periphyton		DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Ammonia (mg/m^3)	Tox.	**Clarity (m)**		
		Range	**Δ**	<	**Δ**	>	<	<	Chl *a* (mg/m^2)	% cover	<	<		<		< m	< 3 xm	**% Δ**
	Makuri (Mana_7d)	7 to 8.5	0.5	19	2	80	1	2.5	120	30	10	110	6	400	99	3	1.6	20
Mangatainoka (Mana_8)	Upper Mangatainoka (Mana_8a)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Middle Mangatainoka (Mana_8b)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
	Lower Mangatainoka (Mana_8c)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
	Makakahi (Mana_8d)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	444	6	400	99	3	1.6	20
	Mangaramarama (Mana_8e)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	444	5	400	95	1.6	0.5	30
Upper Gorge (Mana_9)	Upper Gorge (Mana_9a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Mangapapa (Mana_9b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Mangaatua (Mana_9c)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Upper Mangahao (Mana_9d)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	167	6	320	99	3	2	20
	Lower Mangahao (Mana_9e)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
Middle Manawatu (Mana_10)	Middle Manawatu (Mana_10a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Upper Pohangina (Mana_10b)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Middle Pohangina (Mana_10c)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2.5	1.6	30
	Lower Pohangina (Mana_10d)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2.5	1.6	30
	Aokautere (Mana_10e)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2.5	1.6	30
Lower Manawatu (Mana_11)	Lower Manawatu (Mana_11a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Turitea (Mana_11b)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD5 (g/m³)	POM (g/m³)	Periphyton		DRP (mg/m³)	SIN (mg/m³)	QMCI	Ammonia (mg/m³)	Tox.	Clarity (m)		
		Range	Δ	<	Δ	>	<	<	Chl *a* (mg/m²)	% cover	<	<		<		< m	< 3 xm	% Δ
	Kahuterawa (Mana_11c)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Upper Mangaone Stream (Mana_11d)	7 to 8.5	0.5	24	3	60	2	5	200	30	10	444	5	400	95	2.5	1.6	30
	Lower Mangaone Stream (Mana_11e)	7 to 8.5	0.5	24	3	60	2	5	200	30	10	444	5	400	95	2.5	1.6	30
	Main Drain (Mana_11f)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	444	5	400	95	2.5	1.6	30
Oroua (Mana_12)	Upper Oroua (Mana_12a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	167	5	400	95	2.5	1.6	30
	Middle Oroua (Mana_12b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Lower Oroua (Mana_12c)	7 to 8.5	0.5	24	3	70	2	5	200	30	15	444	5	400	95	2.5	1.6	30
	Kiwitea (Mana_12d)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	167	5	400	95	2.5	1.6	30
	Makino (Mana_12e)	7 to 8.5	0.5	24	3	70	2	5	120	30	15	444	5	400	95	2.5	1.6	30
Coastal Manawatu (Mana_13)	Coastal Manawatu (Mana_13a)	7 to 8.5	0.5	24	3	70	2	5	200	30	15	444	5	400	95	2.5	1.6	30
	Upper Tokomaru (Mana_13b)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Lower Tokomaru (Mana_13c)	7 to 8.5	0.5	24	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
	Mangaore (Mana_13d)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	167	5	400	95	2.5	1.6	30
	Koputaroa (Mana_13e)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	444	5	400	95	2.5	1.6	30
	Foxton Loop (Mana_13f)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	444	5	400	95	2.5	1.6	30
Upper Rangitikei (Rang_1)	Upper Rangitikei	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3.4	2	20
Middle Rangitikei (Rang_2)	Middle Rangitikei (Rang_2a)	6.7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3.4	2	20

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD_5 (g/m³)	POM (g/m³)	Periphyton		DRP (mg/m³)	SIN (mg/m³)	QMCI	Ammonia (mg/m³)	Tox.	**Clarity (m)**		
		Range	**Δ**	<	**Δ**	>	<	<	Chl *a* (mg/m²)	% cover	<	<		<		< m	< 3 xm	**% Δ**
	Pukeokahu – Mangaweka (Rang_2b)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	110	6	320	99	3.4	1.6	20
	Upper Moawhango (Rang_2c)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Middle Moawhango (Rang_2d)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
	Lower Moawhango (Rang_2e)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2	0.5	30
	Upper Hautapu (Rang_2f)	7 to 8.5	0.5	19	2	80	1	2.5	120	30	10	110	6	400	99	3	1.6	20
	Lower Hautapu (Rang_2g	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2	0.5	30
Lower Rangitikei (Rang_3)	Lower Rangitikei (Rang_3a)	7 to 8.5	0.5	19	3	80	1	2.5	120	30	10	110	6	400	99	3	1.6	20
	Makohine (Rang_3b)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
Coastal Rangitikei (Rang_4)	Coastal Rangitikei (Rang_4a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2.5	1.6	30
	Tidal Rangitikei (Rang_4b)	7 to 8.5	0.5	24	3	70	2	5	200	30	15	167	5	400	95	2.5	1.6	30
	Porewa (Rang_4c)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
	Tutaenui (Rang_4d)	7 to 8.5	0.5	24	3	60	2	5	200	30	10	110	5	400	95	2.5	1.6	30
Upper Whanganui (Whai_1)	Upper Whanganui	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
Cherry Grove (Whai_2)	Cherry Grove (Whai_2a)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
	Upper Whakapapa (Whai_2b)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Lower Whakapapa (Whai_2c)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Piopiotea (Whai_2d)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD_5 (g/m^3)	POM (g/m^3)	Periphyton		DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Ammonia (mg/m^3)	Tox.	Clarity (m)		
		Range	Δ	<	Δ	>	<	<	Chl *a* (mg/m^2)	% cover	<	<		<		< m	< 3 xm	% Δ
	Pungapunga (Whai_2e)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
	Upper Ongarue (Whai_2f)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Lower Ongarue (Whai_2g)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
Te Maire (Whai_3)	Te Maire	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
Middle Whanganui (Whai_4)	Middle Whanganui (Whai_4a)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
	Upper Ohura (Whai_4b)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
	Lower Ohura (Whai_4c)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
	Retaruke (Whai_4d)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
Pipiriki (Whai_5)	Pipiriki (Whai_5a)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2	0.5	30
	Tangarakau (Whai_5b)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
	Whangamomona (Whai_5c)	7 to 8.5	0.5	22	3	70	2	5	200	30	10	110	5	400	95	1.6	0.5	30
	Upper Manganui o te Ao (Whai_5d)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3.4	2	20
	Lower Manganui o te Ao (Whai_5e)	7 to 8.5	0.5	19	2	80	1	2.5	120	30	10	110	6	320	99	3.4	1.6	20
Paetawa (Whai_6)	Paetawa	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2	0.5	30
Lower Whanganui (Whai_7)	Lower Whanganui (Whai_7a)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Coastal Whanganui (Whai_7b)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Upokongaro (Whai_7c)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD_5 (g/m³)	POM (g/m³)	Periphyton		DRP (mg/m³)	SIN (mg/m³)	QMCI	Ammonia (mg/m³)	Tox.	**Clarity (m)**		
		Range	**Δ**	<	**Δ**	>	<	<	Chl *a* (mg/m²)	% cover	<	<		<		< m	< 3 xm	**% Δ**
	Matarawa (Whai_7d)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
Upper Whangaehu (Whau_1)	Upper Whangaehu (Whau_1a)	7 to 8.2[(a)]	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Waitangi (Whau_1b)	7 to 8.5	0.5	19	2	80	1	5	120	30	10	110	5	400	95	2.5	1.6	30
	Tokiahuru (Whau_1c)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
Middle Whangaehu (Whau_2)	Middle Whangaehu	7 to 8.5[(a)]	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
Lower Whangaehu (Whau_3)	Lower Whangaehu (Whau_3a)	7 to 8.5[(a)]	0.5	22	3	70	2	5	200	30	15	167	5	400	95	2	0.5	30
	Upper Makotuku (Whau_3b)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Lower Makotuku (Whau_3c)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Upper Mangawhero (Whau_3d)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Lower Mangawhero (Whau_3e)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2	0.5	30
Coastal Whangaehu (Whau_4)	Coastal Whangaehu	7 to 8.5[(a)]	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
Turakina (Tura_1)	Upper Turakina (Tura_1a)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Lower Turakina (Tura_1b)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Ratana (Tura_1c)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Ohau (Ohau_1)	Upper Ohau (Ohau_1a)	7 to 8.2	0.5	19	2	80	1	2.5	50	30	6	70	6	320	99	3	2	20
	Lower Ohau (Ohau_1b)	7 to 8.5	0.5	22	3	70	2	5	120	30	10	110	5	400	95	2.5	1.6	30
Owahanga (Owha_1)	Owahanga	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
East Coast (East_1)	East Coast	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30

Management Zone	Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD_5 (g/m³)	POM (g/m³)	Periphyton		DRP (mg/m³)	SIN (mg/m³)	QMCI	Ammonia (mg/m³)	Tox.	**Clarity (m)**		
		Range	**Δ**	<	**Δ**	>	<	<	Chl *a* (mg/m²)	% cover	<	<		<		< m	< 3 xm	**% Δ**
Akitio (Akit_1)	Upper Akitio (Akit_1a)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Lower Akitio (Akit_1b)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
	Waihi (Akit_1c)	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
Northern Coastal (West_1)	Northern Coastal	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Kai Iwi (West_2)	Kai Iwi	7 to 8.5	0.5	22	3	70	2	5	200	30	15	167	5	400	95	1.6	0.5	30
Mowhanau (West_3)	Mowhanau	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Kaitoke Lakes (West_4)	Kaitoke Lakes	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Southern Wanganui Lakes (West_5)	Southern Wanganui Lakes	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Northern Manawatu Lakes (West_6)	Northern Manawatu Lakes	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Waitarere (West_7)	Waitarere	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Lake Papaitonga (West_8)	Lake Papaitonga	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
Waikawa (West_9)	Waikawa	7 to 8.5	0.5	22	3	70	2	5	120	30	10	444	5	400	95	2.5	1.6	30
Lake Horowhenua (Hoki_1)	Lake Horowhenua (Hoki_1a)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30
	Hokio (Hoki_1b)	7 to 8.5	0.5	24	3	60	2	5	200	30	15	167	5	400	95	2.5	1.6	30

7.2 Water quality standards for natural lakes and lake catchments

This part defines :

- water management sub-zones where water quality standards for lakes and lake catchments are defined in Schedule 1; and
- water quality standard for natural lake waters (**Error! Reference source not found.**), and
- water quality standard for streams and rivers that flow into lakes (Table 25 and Table 26).

Schedule 1: Management sub-zones where lake water and lake catchment water quality standards apply

- West_1;
- Whai_7b
- West_4;
- Whau_4;
- Tura_1c
- West_5
- West_6
- West_7
- Tura_1c
- West_5
- West_6
- West_7

Schedule 2: Lakes water quality standards. These standards apply year round to waters of all natural lakes within the water management sub-zones defined in **Schedule 1**

1. The pH of the water shall be within the range 7 to 8.5 and shall not be changed by more than 0.5 pH;
2. The temperature of the water shall not be changed by more than 1°C;
3. The five-days biochemical oxygen demand shall not exceed 1 g/m^3;
4. The annual average algal biomass shall not exceed 5 mg Chlorophyll a/m^3 and no sample shall exceed 15 mg Chlorophyll a/m^3;
5. The annual average total phosphorus concentration shall not exceed 20 mg/m^3;
6. The annual average total nitrogen concentration shall not exceed 337 mg/m^3;
7. The concentration of ammoniacal Nitrogen shall not exceed 337 mg/m^3;
8. For toxicants not otherwise defined in these standards, the concentration of toxicants in the water shall not exceed the trigger values defined in the 2000 ANZECC guidelines Table 3.4.1 with the level of protection of 95% of species;
9. The clarity of the water measured as Secchi depth shall not be less than 2.8 m and shall not be changed by more than 20%;
10. The concentration of Escherichia coli shall not exceed 260 per 100 millilitres. This standard applies during the period 1st November to 30th April inclusive;
11. The concentration of Escherichia coli shall not exceed 550 per 100 millilitres. This standard applies during the period 1st May to 31th October inclusive year round; and
12. No more than one out of five samples shall contain more than 400 faecal coliforms per 100 millilitres. This standard applies year round.

Table 25: Recommended wording for the Water quality standards defined in Table 26 (The numerical values in Table 26 are indicated by [...])

Column		Standard spelt out
header	sub-header	
pH	Range	The pH of the water shall be within the range […] to […]
	Δ	The pH of the water shall not be changed by more than
Temp (ºC)	<	The temperature of the water shall not exceed […] degrees Celsius .
	Δ	The temperature of the water shall not be changed by more than […] degrees Celsius.
DO (%SAT)	<	The concentration of dissolved oxygen shall exceed […]% of saturation
BOD_5 (g/m^3)	<	The five-days biochemical oxygen demand shall not exceed […] grams per cubic metre.
POM (g/m^3)	<	The concentration of particulate organic matter shall not exceed […] grams per cubic metre.
Periphyton	Chla (mg/m^2)	The algal biomass on the stream or river bed shall not exceed […] milligrams of chlorophyll a per square metre.
	% cover	The maximum cover of visible stream or river bed by periphyton (as filamentous algae more than 2 centimetres long) shall not exceed […]% between 1st November to 30th April inclusive.
TP (mg/m^3)	<	The mean monthly concentration of total phosphorus shall not exceed […] milligrams per cubic metre, unless natural levels already exceed this standard.
TN (mg/m^3)	<	The mean monthly concentration of total nitrogen shall not exceed […] milligrams per cubic metre.
Ammonia (mg/m^3)	<	The concentration of ammonia nitrogen reactive phosphorus shall not exceed […] milligrams per cubic metre.
Toxicants	<	For toxicants not otherwise defined in these standards, the concentration of toxicants in the water shall not exceed the trigger values defined in the 2000 ANZECC guidelines Table 3.4.1 with the level of protection of […] % of species.
Clarity (m)	<m	The clarity of the water when the river flow is at or below median flow shall exceed […] metres (m)
	<3 x m	The clarity of the water when the river flow is at or below three times the median flow shall exceed […] metres (m)
	Δ	The clarity of the water shall not be changed by more than […]%

Table 26: The following water quality standards apply to streams and rivers in natural lake catchments (ie. flowing directly or indirectly into a natural lake).

Management Zone	Management Sub-zone	pH		Temp (°C)		DO (%SAT)	BOD_5 (g/m³)	POM (g/m³)	Periphyton		TP (mg/m³)	TN (mg/m³)	Ammonia (mg/m³)	Toxicants	Water Clarity (m)		
		Range	Δ	<	Δ	>	<	<	Chla (mg/m²)	% cover	<	<	<		< m	< 3 xm	Δ
Coastal Manawatu Mana_13	Coastal Manawatu Mana_13a	7 to 8.5	0.5	24	3	70	2	5	200	30	20	337	337	95	2.5	1.6	30
Lower Whanganui Whai_7	Coastal Whanganui Whai_7b	7 to 8.5	0.5	24	3	60	2	5	200	30	20	337	337	95	1.6	0.5	30
Coastal Whangaehu Whau_4	Coastal Whangaehu Whau_4	7 to 8.5	0.5	22	3	70	2	5	200	30	20	337	337	95	1.6	0.5	30
Turakina Tura_1	Ratana Tura_1c	7 to 8.5	0.5	24	3	60	2	5	200	30	20	337	337	95	2.5	1.6	30
Northern Coastal West_1	Northern Coastal West_1	7 to 8.5	0.5	24	3	60	2	5	200	30	20	337	337	95	2.5	1.6	30
Kaitoke Lakes West_4	Kaitoke Lakes West_4	7 to 8.5	0.5	24	3	60	2	5	200	30	20	337	337	95	2.5	1.6	30
Southern Wanganui Lakes West_5	Southern Wanganui Lakes West_5	7 to 8.5	0.5	24	3	60	2	5	200	30	20	337	337	95	2.5	1.6	30
Northern Manawatu Lakes West_6	Northern Manawatu Lakes West_6	7 to 8.5	0.5	24	3	60	2	5	200	30	20	337	337	95	2.5	1.6	30
Waitarere West_7	Waitarere West_7	7 to 8.5	0.5	24	3	60	2	5	200	30	20	337	337	95	2.5	1.6	30
Lake Papaitonga West_8	Lake Papaitonga West_8	7 to 8.5	0.5	24	3	60	2	5	200	30	20	337	337	95	2.5	1.6	30
Lake Horowhenua Hoki_1	Lake Horowhenua Hoki_1a	7 to 8.5	0.5	24	3	60	2	5	200	30	20	337	337	95	2.5	1.6	30

Note: these water management sub-zones also contain streams and rivers that do not flow into a natural lake. For these waters, standards in table D-3 apply

7.3 Additional Water quality standards applying to all natural stream and river waters

1. The concentration of *Escherichia coli* when the river or stream flow is at or below median flow shall not exceed 260 per 100 millilitres. This standard applies during the period 1st November to 30th April inclusive, and
2. The concentration of *Escherichia coli* when the river or stream flow is at or below three times median flow shall not exceed 550 per 100 millilitres. This standard applies year round.
3. No more than one out of five samples shall contain more than 400 faecal coliforms per 100 millilitres. This standard applies year round

7.4 Additional water quality standards applying to the streams and rivers classified as Trout Spawning

The following standards apply to all streams where the TS (Trout Spawning) value is identified, from 1st May to 30th September inclusive.

1. The temperature of the water shall not be changed by more than 2°C, and
2. The temperature of the water shall not exceed 11 °C, and
3. The dissolved oxygen concentration shall not be less than 80% saturation, and
4. There shall be no measurable increase in sediment or particulate organic matter deposited on the bed of the river or stream, and
5. The concentration of toxicants in the water shall not exceed the trigger values defined in the 2000 ANZECC guidelines Table 3.4.1 with the level of protection of 99 % of species.

7.5 Water quality standards for the marine coastal waters.

The following standards apply year round to the waters within the coastal Marine area

1. The concentration of *Enterococci* shall not exceed 140 per 100 millilitres. This standard applies during the period 1st November to 30th April inclusive, and
2. The concentration of *Enterococci* shall not exceed 280 per 100 millilitres. This standard applies during the period 1st May to 31st October inclusive.
3. The median concentration of faecal coliforms shall not exceed 14 per 100 millilitres and the 90th percentile shall not exceed 43 per 100 millilitres. This standard applies year round.

8 List of degraded waters

8.1 Goals and principles

This section presents the methodology and results of the comparison between the recommended water quality standards and the water quality measured in rivers and streams across the Region.

The methodology described in section 8.2 below is the recommended method for assessing compliance with the water quality standards from a state of the environment monitoring and reporting point of view. It is noted this methodology may not always be directly transferable to resource consent conditions (ie. different resource consent conditions may be required to ensure the standard is complied with in the receiving environment).

The results presented in Table 27 summarises the compliance of the water quality in each water management sub-zone with the recommended water quality standards. This assessment is based on the monitoring information available and the methodology presented in this report. As such, it represents a “stock-take” at the time of writing, and its scope and limitations, presented in section 8.4, should be carefully considered. In particular, the list should be updated on a regular basis, to incorporate new data, or if/when methodologies to assess compliance with the standards are changed.

8.2 Methodology

8.2.1 Comparison with the standards

Most water quality parameters used to define water quality standards in this report are monitored monthly, with the exception of the biomonitoring parameters (periphyton biomass and cover and QMCI), that are monitored once every year.

For water quality parameters that are monitored monthly, the general recommended method is to compare a certain percentile of the data distribution with the water quality standard. The percentile used depends on the nature of the water quality parameter and the methodology used to define the standard, as detailed in sections 8.2.1.1 to 8.2.1.7 below.

For parameters monitored annually, the percentile method is not suitable due to the low number of samples. Biomonitoring by Horizons[28] started in 1999, making a maximum of 8 results per site, but most sites have less than 8 results, as some sites are monitored only every three years and a number of sites have been included in the monitoring programme post-1999.

8.2.1.1 Water pH, temperature, dissolved oxygen and ammonia

Water pH, temperature, dissolved oxygen and ammonia are direct stressors to aquatic life. In other words, a breach in the standards may cause direct toxic effects on plants, fish or invertebrates. It is therefore recommended the level of compliance with the standards should be very high.

[28] Macroinvertebrates and periphyton monitoring has been undertaken by Massey University’s Institute of Natural Resources on behalf of Horizons from 1999 to 2007.

The water quality standards were defined using either or both reference data (pH and temperature) and chronic exposure (ie. long-term) requirements of representative aquatic species. As such, short-term, moderate, breaches of the standard may be tolerable by aquatic life.

The recommended approach is to use the 95th percentile of the data collected at the site to assess compliance with the standard. In other words, at least 95 percent of the samples must comply with the standard for the site to be considered compliant. In practice, this approach has a number of limitations.

Monthly monitoring does not provide information on the duration of a standard breach: a standard breach could last a few hours, a few days, or a few weeks, or occur daily for a certain period of time. Continuous monitoring is the best approach to eliminate this limitation.

The 95th percentile approach allows standard breaches 5% of the time. Based on monthly samples, it translates into 1 sample a year. Based on continuous monitoring, it means the standards could be breached up to 18 days. The standards are generally based on chronic exposure requirements of representative species. This means that a short-term breach of the standard (within limits) should not cause detrimental effects on aquatic life, but longer term exposure may. A compliance assessment method based on the length of time a standard is breached seems better than the 95th percentile approach, and further research on these options is recommended in section 9 of this report.

8.2.1.2 Biochemical oxygen demand and particulate organic matter

Biochemical oxygen demand (BOD) and particulate organic matter (POM) are controlling factors, ie. these standards were defined to help maintain other parameters (DO and QMCI) at a satisfactory level. It is considered that compliance with these standards should be high, but occasional, moderate exceedances may be acceptable. It is recommended the compliance with this standard is assessed against the 90th percentile of the data distribution.

8.2.1.3 QMCI standards

As explained above, macroinvertebrate monitoring is currently undertaken on an annual basis. Due to natural variability, occasional, moderate breaches may occur. Table 27 presents the number of samples that complied with the standard compared with the total number of samples. Professional judgment, based on the proportion of samples that breach the standard and the gravity of the breaches, was used to propose an interim satisfactory/unsatisfactory rating. The general guiding rule is that a site complies with the standard if at least four out of five samples comply, and the samples that do not comply are not more than two points below the recommended standard.

8.2.1.4 Periphyton biomass and cover

Three standard levels are recommended in this report in relation to periphyton biomass:

- 50 mg chlorophyll a /m^2. As explained in section 3.2.3.7, this standard is very stringent and occasional breaches are expected, even in sites at or near reference level. The recommended method is to assess compliance at the 80th percentile level (Dr. Barry Biggs, pers. comm.).

In other words, up to two samples (based on monthly monitoring) per year may be in breach of the standard,

- 120 and 200 mg chlorophyll a /m^2. Some occasional breaches may be acceptable, and the recommended approach is to assess compliance at the 95th percentile level, ie. up to 1 sample every two years may not be compliant. This recommended methodology is based on monthly monitoring, as recommended in section **Error! Reference source not found.** of this report.

However, periphyton biomass monitoring is currently undertaken on an annual basis only, and periphyton cover is not currently regularly monitored by Horizons. Compliance with the periphyton standard cannot be fully assessed, and only an interim rating is proposed. Table 27 presents the number of periphyton biomass samples that complied with the standard compared with the total number of samples. Annual periphyton monitoring is very unlikely to capture maximum biomass/cover (Dr. Barry Biggs, pers. comm.). A sample that breaches the standard suggests that regular breaches of the standard may occur at the site. As a result, a site received an interim rating of compliant (green) only if all samples complied with the standards.

8.2.1.5 Nutrient standards

Nutrient standards were defined as being the annual average concentration, based on monthly monitoring. The recommended approach to assess compliance with the nutrient standards is to compare the annual average concentration measured at the site with the standard.

8.2.1.6 E. coli

The MfE microbiological guidelines compare the 95th percentile of the data collected at the site with the guideline levels to determine the Microbiological Assessment Category (MAC) of the site. To remain consistent with the MfE guidelines, it is recommended to assess compliance with the microbiological standards at the 95th percentile level.

However, due to the nature of the microbiological results, where an unsatisfactory result can commonly be several orders of magnitude greater than a satisfactory sample, the 95th percentile may be misleadingly high when it is calculated on a small number of samples (ie. one very high sample out of 20 samples can lead to a high 95th percentile even if the 19 other results are satisfactory). The 95th percentile approach is suitable (and recommended) when the number of sample is sufficient (eg. 50 samples). When the number of samples is less than 50, the recommended approach is to compare the 90th percentile of the data to the standard.

8.2.1.7 Faecal coliforms

The method recommended to assess compliance with the faecal coliforms standards is directly dependent upon the methodology used to define the standards:

- In freshwaters, the recommended standard requires four out of five (80%) samples to comply with the 400 faecal coliforms/100 mL limit, for the protection of the livestock drinking water value. The recommended approach is to compare the 80^{th} percentile of the data collected at the site with the water quality standard.

- In coastal waters, the recommended standard sets a limit for both the median value and the 90^{th} percentile. The recommended approach is to compare both the 50^{th} (median) and 90^{th} percentile of the data collected at the site with the water quality standard.

It is noted that very little monitoring data is available relating to faecal coliforms in freshwaters, and compliance with this standard is not presented in Table 27. Compliance with the faecal coliform standard in coastal waters is presented in section Table 28.

8.2.2 Data requirements

Flow data

A number of standards apply only at certain river flows. The water quality data was sorted according to the river flow at the time of sampling, and the appropriate subset of the water quality data was used to assess compliance with the standard.

Flow data was not available at a number of sites. Although compliance with the standard is difficult to assess for flow-dependent standards, the water quality data available still provides some indication of likely compliance with the standard. The data is presented in Table 27, but should be treated as indicative only and relevant cells in the table are identified by a dark diagonal pattern.

Season-dependent standards

A number of standards apply only at certain times of the year. The water quality data was sorted according to the date of sampling, and the appropriate subset of the water quality data was used to assess compliance with the standard.

Water quality data.

The assessment is based on data collected between January 1997 and January 2007. Older data was considered irrelevant to an assessment of current compliance with the standard. Consideration was given to shortening the period of record to better reflect the current situation, but this meant the number of samples at a number of sites/under some flow conditions became insufficient to determine compliance with the standard.

For most parameters, the standard was compared to a percentile of the data recorded at the site. For these parameters, a minimum of 12 samples was considered the minimum required to propose compliance rating (ie. compliant or non-compliant).

It is noted that the number of samples used to assess compliance with the standard is indicated in Table 27. The degree of certainty provided by the compliance assessment increases with the number of samples.

If less than 12 samples were available, data was judged insufficient (identified in Table 27 by “ID”). In some instances, a lower number of samples can provide some indication of the water quality. For example, if eight samples were taken, with seven of them breaching the proposed standard, more sampling is likely to confirm the water is not meeting this standard more than 10% of the time. In these cases, professional judgment was used and a compliance rating was provided. These are identified by grey shading in Table 27. It is recommended these results are confirmed by additional monitoring. It is noted that, in many cases, the new monitoring programme in place since 2006-2007 will address these information gaps.

8.3 Results

A double symbology was adopted to present the results in Table 27. Compliance with the standard is identified by a tick (**ü**), and non-compliance by a cross (**û**). The sites that meet (vs. do not meet) the standards by a reasonable margin (calculated by at least 10% of the standard) are identified by a green (vs. red) colour. The sites that only just (identified as inside the 10% of the standard margin) meet or do not meet the standard are identified by an orange colour.

As a result, a red cross indicates the standard is breached by a reasonable margin, and an orange tick indicates the standard is met, but only by a small margin.

The strategic approach to the management of these different categories of waters, particularly the prioritisation of non-regulatory resources and strategies, should be markedly influenced by these results. For example, the waters that meet the standards by only a small margin may be at risk of breaching the standards in the near future and may require closer monitoring and management. Conversely, waters that only just breach the standards may be able to be restored at lower cost and more quickly than more heavily degraded waters.

Compliance with the periphyton biomass and QMCI standards was assessed following the methodology outlined in sections 8.2.1.3 and 8.2.1.4. Compliance with the standard was indicated by a green font, and non-compliance by a red font.

8.4 Scope and Limitations

The assessment of compliance with the standard presented in Table 27 and Table 28 allows a quick grasp of the nature and locations of the water quality issues across the Horizons Region. The methodology used aimed to be robust and clearly defined. However, care should be taken to use this information within its intended scope and acknowledge its limitations.

The results presented in Table 27 and Table 28 are based on monitoring data from 1997 to 2007. Any significant improvement or degradation within this period may not be adequately captured.

Table 27 presents the assessment of compliance with the standard at monitoring sites. For greater ease of use and consistency with the rest of the report, the assessment is presented by water management sub-zone. This does not mean however, that the situation at the monitoring site necessarily reflects the whole water management zone. In other words, water quality standards breached at the monitoring site located at the downstream end of the zone may not be breached a few kilometres upstream the mainstem and/or tributaries.

There was insufficient data to fully assess compliance with certain standards (ie. periphyton biomass) and/or at certain sites, and some results presented have indicative value only.

The methodology to assess compliance with the direct stressors standards (pH, temperature, DO and ammonia) are currently based on the 95th percentile of the data. This method has some limitations and may require some further development, as outlined in section 9.2.3 of this report.

The methodology used in this report is a recommended methodology for state of the environment-type reporting. It is not intended to be used directly to define resource consent conditions nor for enforcement purposes.

Table 27: Current compliance with the recommended water quality standards. ü: The standard is met; û: the standard is not met. The number in brackets is the Standard and the number above is the recorded value at the site (ie. the 90th percentile of monitoring data for pH, temperature, DO, BOD, POM, Turbidity, Ammonia-N and *E. coli*, and the average concentration for Sin and DRP). For periphyton biomass and QMCI, the number of samples complying with the standard is provided, eg. 6/8 means that six out of eight samples taken complied with the standards (ie. two samples did not comply).

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble $cBOD_5$ (g/m^3)	POM (g/m^3)	Periphyton biomass (mg *Chloro a* $/m^2$)	DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Clarity (m)		Ammonia (mg $N\text{-}NH_3\text{-}/m^3$)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
Upper Manawatu	Upper Manawatu (assessed at Weber Rd[29])	ü 7.9 – 8.2 (7 – 8.5) n = 101	û 19.5 (19) n = 101	ND	ü 0.9 (1) n = 55	ND	ü 3/3	û 13 (10) n = 78	û 496 (167) n= 89	û 0/2	û 1.1 (3) n = 52	û 0.5 (1.6) n= 89	ü 37 (400) n = 189	ID	ID
	Mangatewainui (Assessed at Hardys)	ID	ID	ND	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	Mangatoro (Assessed at Mangahei Rd)[30]	û 8.3 – 8.9 (7 – 8.5) n = 12	û 21.5 (19) n = 12	ND	ND	ND	û 0/1	ü 10 (10) n= 12	ü 51 (110) n= 12	û 0/1	û 0.5 (3) n = 11	ü 0.5 (0.5) n = 11		û 512 (260) n = 8	ü 513 (550) n = 12
Weber-Tamaki	Weber-Tamaki	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Mangatera (Assessed at Timber bay)	û 7.4 – 8.8 (7 – 8.5) n = 71	ü 20.3 (22) n = 72	ND	û 3 (2) n = 59	ND	û 6/8	û 188 (10) n = 45	û 991 (444) n = 43	û 1/6	û 0.6 (2.5) n = 49	û 0.5 (1.6) n = 76	û 499 (444) n = 73	û 3750 (260) n = 18	û 3480 (550) n = 20
Upper Tamaki	Upper Tamaki (assessed at Reserve)	ü 7.1 – 7.7 (6.7 – 8.2) n = 48	ü 16.5 (19) n = 72	ND	ND	ND	ü 3/3	ü 7 (6 or nat. level) n = 20	û 120 (70) n = 21	ü 3/3	û 2.7 (3) n = 6	û 1.3 (2) n = 17	ü 50 (320) n = 48		ü 88 (550) n = 10
Upper Kumeti	Upper Kumeti[31] (Assessed at Te Rehunga)	ID	ID	ND	ID	ND	ND	ID	ID	ND	ID	ID	ID	ID	ID

29 Data has been acquired from NIWA for Manawatu at Weber Road.

30 No Flow data is available for Mangatoro at Mangahei Road for the sample dates. Data shown in columns requiring flow is all data for that time of the year and is indicative only

31 No Flow data is available for Kumeti at Te Rehunga Road for the *E. coli* samples. The data used is all data for that time of the year and is indicative only.

Management Zone	Sub-zone	pH Range	Temp. (°C) Max daily	DO (% Sat)	Soluble cBOD5 (g/m³)	POM (g/m³)	Periphyton biomass (mg *Chloro a* /m²)	DRP (mg/m³) Monthly Mean value, < 3* med	SIN (mg/m³) Monthly Mean value, < 3* med	QMCI	Clarity (m) < med	Clarity (m) < 3 * med	Ammonia (mg N-NH3 -/m³)	*E.coli* (N/100mL) Nov-April Flow < med	*E.coli* (N/100mL) < 3* med
Tamaki-Hopelands	Tamaki-Hopelands (Assessed at Hopelands)	û 7.5 – 8.8 (7 – 8.5) n = 127	û 20.8 (19) n = 138	ND	ü 1 (1) n = 28	ND	û 3/8	û 27 (10) n = 69	û 953 (444) n = 64	û 1/7	û 1 (3) n = 53	û 0.6 (1.6) n = 87	ü 70 (400) n = 71	û 598 (260) n = 27	û 1613 (550) n = 56
	Lower Tamaki (Assessed at SH2))	ü 7.1 – 7.7 (7 – 8.5) n = 46	ü 19.5 (22) n = 44	ND	ID	ND	ü 3/3	ü 9 (10) n = 21	û 644 (444) n = 21	ü 3/3	ü 2.5 (2.5) n = 9	ü 1.7 (1.6) N = 21	ü 65 (400) n = 46	ID	ü 532 (550) n = 10
	Lower Kumeti[32] (Assessed at SH2)	ID	ID	ND	ID	ND	ND	ID	ID	ND	ID	ID	ID	ID	ID
	Oruakeretaki[33] (Assessed at Oringi)	ü 7 – 7.8 (7 – 8.5) n = 10	ü 18.9 (22) n = 10	ND	ND	ND	ND	û 19 (10) n = 10	û 1338 (444) n = 10	ND	û 0.4 (2.5) n = 10	û 0.4 (1.6) N = 10	ü 27 (400) n = 10	û 362 (260) n = 6	û 1020 (550) n = 10
	Raparapawai[34] (Assessed at Jacksons Rd)	ü 7.1 – 8.4 (7 – 8.5) n = 11	ü 21 (22) n = 12	ND	ID	ND	1/1	û 20 (10) n = 12	û 565 (444) n = 12	ND	û 0.8 (2.5) n = 12	û 0.8 (1.6) n = 12	ü 20 (400) n = 12	û 1890 (260) n = 8	û 3570 (550) n = 12
Hopelands-Tiraumea	Hopelands-Tiraumea	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tiraumea	Upper Tiraumea (Assessed at Katiawa Bridge)	ü 7.1 – 7.8 (7 – 8.5) n = 34	ü 19 (22) n = 33	ND	ND	ND	1/1	û 26 (10) n = 16	ü 380 (444) n = 16	û 0/2	û 0.3 (2) n = 15	û 0.3 (0.5) n = 16	ü 110 (400) n = 34	ID	û 5245 (550) n = 8
	Lower Tiraumea	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Mangaone River	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

32 No Flow data is available for Kumeti at SH2 for the sample dates. Data shown in columns requiring flow is all data for that time of the year and is indicative only,

33 No Flow data is available for Oruakeretaki at Oringi. Data shown in columns requiring flow is all data for that time of the year and is indicative only

34 No Flow data is available for Raparapawai at Jacksons Road. Data shown in columns requiring flow is all data for that time of the year and is indicative only

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble cBOD5 (g/m³)	POM (g/m³)	Periphyton biomass (mg *Chloro a* /m²)	DRP (mg/m³)	SIN (mg/m³)	QMCI	Clarity (m)		Ammonia (mg N-NH3 -/m³)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
	Makuri (Assessed at Tuscan Hills)	ü 8.1 – 8.4 (7 – 8.5) n = 24	ü 15.8 (19) n = 39	ND	ND	ND	ü 3/3	û 11 (10) n = 19	û 887 (110) n = 19	û 0/3	û 1.1 (3) n = 10	û 0.5 (1.6) n = 19	ü 67 (400) n = 24	ID	ID
Mangatainoka	Upper Mangatainoka (Assessed at Putara)	ü 7 – 7.6 (6.7 – 8.2) n =24	ü 14.6 (19) n = 23	ND		ND	ü 3/3	ü 2.2 (6 or nat. level) n = 23	ü 44 (70) n = 18	ü 3/3	ü 3.7 (3) n = 15	ü 2.8 (2) n = 22	ü 53 (320) n = 18	ü 16 (260) n = 9	ü 20 (550) n = 11
	Upper Mangatainoka (Assessed at Larsons Rd)	û 6.6 – 7.9 (7 – 8.5) n = 22	û 19.4 (19) n = 23	ND	ND	ND	ND	ü 8 (6 or nat. level) n = 10	û 139 (70) n = 10	ND	ID	ü 2.5 (2) n = 10	ü 10 (320) n = 22	ID	ü 161 (550) n = 10
	Middle Mangatainoka	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Lower Mangatainoka (Assessed at SH2)	ü 7 – 8.2 (7 – 8.5) n = 141	û 20 (19) n = 146	ND	û 1.2 (1) n = 110	û 5 (2.5) n = 17	û 7/8	û 475 (10) n = 93	û 1253 (444) n = 93	û 2/7	û 2.1 (3) n = 61	û 1.5 (1.6) n = 92	ü 100 (400) N = 140	û 589 (260) n = 39	û 1080 (550) n = 69
	Makakahi (Assessed at Konini)	ü 7 – 7.8 (7 – 8.2) n = 99	û 19.8 (19) n = 97	ND	û 1.1 (1) n = 75	ND	û 5/8	û 9.4 (10) n = 76	û 920 (444) n = 76	û 0/6	ID	ID	ü 120 (400) n = 99	û 3812 (260) n = 15	û 2400 (550) n = 41
	Mangaramarama	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Upper Gorge	Upper Gorge[35] (Assessed at Upper Gorge)	ü 7.1 – 7.9 (7 – 8.5) n = 26	û 19.9 (22) n = 26	ND	ND	ND	ü 2/2	û 17 (10) n = 26	û 655 (444) n = 22	1/2	ID	ID	ü 10 (400) n = 22		û 5120 (550) n = 7

35 No Flow data is available for Manawatu at Upper Gorge for the SIN samples. The data used is all data for that time of the year and is indicative only.

Management Zone	Sub-zone	pH Range	Temp. (°C) Max daily	DO (% Sat)	Soluble $cBOD_5$ (g/m³)	POM (g/m³)	Periphyton biomass (mg *Chloro a* /m²)	DRP (mg/m³) Monthly Mean value, < 3* med	SIN (mg/m³) Monthly Mean value, < 3* med	QMCI	Clarity (m) < med	Clarity (m) < 3 * med	Ammonia (mg N-NH₃ -/m³)	*E.coli* (N/100mL) Nov-April Flow < med	*E.coli* (N/100mL) < 3* med
	Mangapapa[36] (Assessed at Troup Rd Bridge)	û 6.9 – 7.9 (7 – 8.5) n = 23	ü 20 (22) n = 23	ND	ND	ND	1/1	û 17 (10) N = 22	û 950 (444) n = 22	0/1	û 0.9 (2.5) n = 23	û 0.9 (1.6) n = 23	ü 68 (400) n = 22	û 2720 (260) n = 13	û 2720 (550) n = 23
	Mangaatua[37] (Assessed at Downstream Woodville Oxponds)	ü 7.1 – 8.4 (7 – 8.5) n = 34	û 22.4 (22) n = 34	ND	ü 1.1 (2) n = 34	ü 4.2 (5) n = 9	ND	û 82 (10) n = 34	û 7461 (444) n = 34	ND	û 0.7 (2.5) n = 36	û 0.7 (1.6) N = 36	û 398 (400) n = 34	û 13310 (260) n = 14	û 13310 (550) n = 14
	Upper Mangahao (Assessed at Kakariki)	û 6.6 – 7.7 (6.7 – 8.2) n = 29	ü 17.8 (19) n = 28	ND	ID	ND	ü 2/2	ü 3.9 (6) n = 20	ü 43 (167) n = 21	1/2	ü 3 (3) n = 15	ü 2.7 (2) N = 21	ü 56 (320) n = 29	ID	ü 38 (550) n = 10
	Lower Mangahao (Assessed at Ballance)	û 6.4 – 7.7 (7 – 8.5) n = 46	ü 20 (22) n = 28	ND	ID	ND	ü 3/3	ü 6 (10) n = 21	ü 282 (444) n = 21	ü 3/3	ü 3.3 (2.5) n = 14	û 1.5 (1.6) N = 20	ü 50 (400) n = 46	ID	ü 292 (550) n = 10
Middle Manawatu	Middle Manawatu[38] (Assessed at Teachers College)	ü 7.4 – 8.4 (7 – 8.5) n = 101	ü 21 (22) n = 101	ND	ü 1.3 (2) n = 67	ND	û 4/6	û 11.4 (10) n = 87	û 647 (444) n = 87	ü 2/3	û 0.9 (2.5) n = 55	û 0.2 (1.6) n = 87	ü 41 (400) n =	ID	ID
	Upper Pohangina (assessed at Piripiri)	ü 6.9 – 7.9 (6.7 – 8.2) n = 36	ü 17.5 (19) n = 35	ND	ID	ND	ü 2/2	ü 6.5 (6 or nat. level) n = 24	û 93 (70) n = 24	1/2	û 1.7 (3) n = 8	û 0.6 (2) n = 24	ü 62.5 (320) n = 36	ID	ü 36 (550) n = 13
	Middle Pohangina[39] (Assessed at Raumai Res and Mais Reach.)	ü 7.1 - 8 (7 – 8.5) n = 75	ü 19.3 (22) n = 62	ND	ID	ND	ü 3/3	û 13 (10) n = 24	û 160 (110) n = 24	ü 2/3	ü 2.9 (2.5) n = 8	û 0.6 (1.6) n = 24	ü 70 (400) n = 46	ü 147 (260) n = 7	ü 248 (550) n = 26

36 No Flow data is available for Mangapapa at Troup Road Bridge. Data shown in columns requiring flow is all data for that time of the year and is indicative only

37 No Flow data is available for Mangaatua Downstream Woodville Oxidation Ponds. Data shown in columns requiring flow is all data for that time of the year and is indicative only

38 Data for Manawatu at Teachers College is from NIWA

39 Previous to 2005 Water Quality monitoring was carried out at Raumai Reserve. The site has been moved to Mais Reach in order to align with the flow monitoring site. The data presented in the table is a consolidated dataset for both sites. Future compliance with the standards will be assessed at the Mais Reach Site.

Management Zone	Sub-zone	pH Range	Temp. (°C) Max daily	DO (% Sat)	Soluble cBOD$_5$ (g/m^3)	POM (g/m^3)	Periphyton biomass (mg *Chloro a* /m^2)	DRP (mg/m^3) Monthly Mean value, < 3* med	SIN (mg/m^3) Monthly Mean value, < 3* med	QMCI	Clarity (m) < med	Clarity (m) < 3 * med	Ammonia (mg N-NH$_3$ -/m^3)	*E.coli* (N/100mL) Nov-April Flow < med	*E.coli* (N/100mL) < 3* med
	Lower Pohangina	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Aokautere	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lower Manawatu	Lower Manawatu[40] (assessed at Opiki)	û 7.4 – 8.8 (7 – 8.5) n = 101	ü 21.7 (22) n = 62	ND	û 2.5 (2) n = 100	ND	û 3/4	û 34 (10) n = 82	û 664 (444) n = 82	û 0/3	û 0.8 (2.5) n = 53	û 0.3 (1.6) n = 87	ü 118 (400) n = 101	ID	ID
	Turitea	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Kahuterawa (assessed Above Confluence	ND	ND	ND	ND	ND	ND	ND	ND	0/1	ND	ND	ND	ND	ND
	Upper Mangaone Stream (assessed at Milson Line)[41]	ü 7.1 – 7.6 (7 – 8.5) n = 24	ü 19.7 (24) n = 24	ND	ü 2 (2) n = 23	ND	ü 3/3	û 150 (10) n = 24	û 1199 (444) n = 24	û 0/3	ND	ND	ü 79 (400) n = 24	û 2050 (260) n = 6	û 10320 (550) n = 12
	Lower Mangaone Stream	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Main Drain	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Oroua	Upper Oroua (Assessed at Nelson Street))	ND	ND	ND	ND	ND	ü 8/8	ND	ND	û 2/7	ND	ND	ND	ND	ND
	Middle Oroua (Assessed at Awahuri Bridge)	û 7.3 – 8.9 (7 – 8.5) n = 124	ü 21 (22) n = 122	ND	ü 1.4 (2) n = 45	ü 5 (5) n = 14	û 5/8	û 147 (10) n = 84	û 723 (444) n = 83	û 0/7	ND	ND	ü 307 (400) n = 123	û 1628 (260) n = 17	û 2855 (550) n = 38
	Lower Oroua	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Kiwitea (assessed at SH54)	ND	ND	ND	ND	ND	1/1	ND	ND	ND	ND	ND	ND	ND	ND

40 Data for Manawatu at Opiki is from NIWA

41 No Flow data is available for Mangapapa at Troup Road Bridge. Data shown in columns requiring flow is all data for that time of the year and is indicative only

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble cBOD5 (g/m³)	POM (g/m³)	Periphyton biomass (mg *Chloro a* /m²)	DRP (mg/m³)	SIN (mg/m³)	QMCI	Clarity (m)		Ammonia (mg N-NH3 -/m³)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
	Makino[42] (Assessed at Boness Road)	û 7.2– 9 (7 – 8.5) n = 22	ü 20.1 (24) n = 21	ND	ND	ND	ü 2/2	û 57 (15) n = 8	ü 90 (444) n = 8	û 0/2	û 1.6 (2.5) n = 7	û 1.5 (1.6) n = 8	ü 159 (137) n = 24	ID	û (700) (550) n = 8
Coastal Manawatu	Coastal Manawatu[43] (Assessed at Whirokino)	ü 7 – 8 (7 – 8.5) n = 123	ü 22.2 (24) n = 48	ND	ü 2 (2) n = 19	ID	ND	û 35 (15) n = 124	û 712 (444) n = 123	û 0/5	û 0.2 (2.5) n = 116	û 0.2 (1.6) n = 116	ü 150 (400) n = 123	û 2626 (260) n = 77	û 4900 (550) n = 111
	Upper Tokomaru (Assessed at Horseshoe Bend)	ü 6.8 – 8 (6.7 – 8.2) n = 45	û 19.5 (19) n = 122	ND	ND	ND	ü 3/3	ü 6.5 (6 or nat. level) n = 27	û 78 (70) n = 27	ü 1/2	û 2.1 (3) n = 15	ü 2 (2) n = 25	ü 65 (320) n = 46	ü 200 (260) n = 26	ü 329 (550) n = 54
	Lower Tokomaru	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Mangaore	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Koputaroa	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Foxton Loop[44] (Assessed at Foxton Loop Boat Ramp Wharf))	ü 7.1 – 7.6 (7 – 8.5) n = 24	ü 22.6 (24) n = 24	ND	ND	ND	ND	û 61 (15) n = 24	ü 409 (444) n = 24	ND	û 0.2 (2.5) n = 24	û 0.2 (1.6) n = 24	ü 170 (400) n = 24	ü 232 (260) n = 6	ü 517 (550) n = 12
Upper Rangitikei	Upper Rangitikei	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Middle Rangitikei	Middle Rangitikei (Assessed at Pukeokahu)	ü 7.6 – 8.1 (6.7 – 8.2) n = 106	ü 18.7 (19) n = 107	ND	ID	ID	ü 8/8	ü 9.2 (6 or nat. level) n = 77	ü 50 (70) n = 34	û 3/7	ü 3.4 (3.4) n = 45	ü 2.1 (2) n = 75	ü 40 (320) n = 60	ü 75 (260) n = 21	ü 83 (550) n = 48

42 Periphyton and QMCI for Makino are assessed at South Street
43 No Flow data is available for Manawatu at Whirokino Boat Ramp. Data shown in columns requiring flow is all data for that time of the year and is indicative only
44 No Flow data is available for Manawatu at Foxton Loop Boat Ramp (Wharf). Data shown in columns requiring flow is all data for that time of the year and is indicative only

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble $cBOD_5$ (g/m^3)	POM (g/m^3)	Periphyton biomass (mg *Chloro a* /m^2)	DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Clarity (m)		Ammonia (mg $N-NH_3$ -/m^3)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
	Pukeokahu – Mangaweka[45] (Assessed at Mangaweka)	ü 7.7 – 8.2 (7 – 8.5) n = 101	ü 17.6 (19) n = 101	ND	ü 0.7 (1) n = 67	û 10 (2.5) n = 6	ü 7/8	ü 4.8 (10) n = 93	û 87 (70) n = 89	û 3/6	û 3.2 (3.4) n = 49	ü 1.6 (1.6) n = 93	ü 10 (320) n = 97	û 454 (260) n = 63	û 673 (550) n = 108
	Upper Moawhango	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Middle Moawhango (Assessed at Moawhango)	ND	ND	ND	ND	ND	1/1	ND	ND	ND	ND	ND	ND	ND	ND
	Lower Moawhango (Assessed at Toaroa)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Upper Hautapu (Assessed at NIWA Station Taihape)	ü 7.8 – 8.2 (7 – 8.5) n = 37	ü 17.7 (19) n = 38	ND	ND	û 4.5 (2.5) n = 6	û 1/2	ü 8.1 (10) n = 31	û 143 (110) n = 21	û 0/2	û 1.5 (3) n = 14	û 0.6 (1.6) n = 28	ü 98 (400) n = 26	û 442 (260) n = 14	ü 481 (550) n = 28
	Lower Hautapu (Assessed at U/S Rangitikei)	û 7.8 – 8.7 (7 – 8.5) n = 99	ü 19 (22) n = 107	ND	ü 1.7 (2) n = 85	ID	û 3/8	û 25 (10) n = 73	û 156 (110) n = 72	û 0/7	û 1.4 (1.6) n = 42	ü 0.5 (0.5) n = 71	ü 70 (400) n = 107	û 980 (260) n = 16	û 2455 (550) n = 70
Lower Rangitikei	Lower Rangitikei[46] (Assessed at Kakariki)	ü 7.7 – 8.3 (7 – 8.5) n = 102	ü 20.5 (19) n = 101	ND	ND	ID	ü 5/5	ü 6.7 (10) n = 96	û 137 (110) n = 84	û 3/7	û 0.9 (3) n = 49	û 0.2 (1.6) N = 93	ü 17 (400) n = 97	û 1334 (260) n = 25	û 1014 (550) n = 49
	Lower Rangitike[47]i (Assessed at Onepuhi)	û 7.5 – 8.8 (7 – 8.5) n = 19	û 22 (19) n = 20	ND	ND	ND	ü 5/5	û 14 (10) n = 20	ü 11 (110) n = 20	ND	û 0.2 (3) n = 19	û 0.2 (1.6) n = 19	ü 21 (400) n = 20	û 3257 (260) n = 10	û 660 (550) n = 20
	Makohine (Assessed at Viaduct)	ü 7.7 – 8.3 (7 – 8.5) n = 35	ü 20.7 (22) n = 35	ND	ND		û 2/4	û 13 (10) n = 22	û 302 (110) n = 13	û 0/2	û 0.9 (1.6) n = 13	û 0.4 (0.5) n = 20	ü 126 (400) n = 24	û 485 (260) n = 6	û 690 (550) n = 11

45 Rangitikei at Mangaweka data except *E. coli* and POM is from NIWA
46 Rangitikei at Kakariki data is from NIWA except *E. coli* and POM. Periphyton data is from Rangitikei River at Vinegar Hill and flow percentiles are based on Onepuhi
47 No Flow data is available for Rangitikei at Onepuhi. Data shown in columns requiring flow is all data for that time of the year and is indicative only.

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble cBOD5 (g/m³)	POM (g/m³)	Periphyton biomass (mg *Chloro a* /m²)	DRP (mg/m³)	SIN (mg/m³)	QMCI	Clarity (m)		Ammonia (mg N-NH3 -/m³)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
Coastal Rangitikei	Coastal Rangitikei[48] (Assessed at McKelvies)	û 7.8 – 9 (7 – 8.5) n = 8	û 23.7 (22) n = 9	ND	ND	ND	ND	û 17 (10) n = 9	û 176 (110) n = 9	ND	û 0.2 (2.5) n = 7	û 0.2 (1.6) n = 7	ü 21 (400) n = 9	ID	û 5496 (550) n = 9
	Tidal Rangitikei[49] (Assessed at Scotts Ferry)	ü 7.5 – 8.1 (7 – 8.5) n = 84	ü 21.4 (24) n = 84	ND	ID	ID	ü 4/4	û 16 (15) n = 85	û 218 (167) n = 84	N/A	û 0.2 (2.5) n = 79	û 0.2 (1.6) N = 79	ü 108 (400) n = 85	û 1014 (260) n = 19	û 1320 (550) n = 37
	Porewa[50] (Assessed at Onepuhi Rd)	ü 7.5 – 8.2 (7 – 8.5) n = 36	ü 18.2 (22) n = 36	ND	ü 0.5 (2) n = 24	ID	û 3/4	û 30 (10) n = 38	û 521 (110) n = 38	1/2	û 0.4 (1.6) n =1.6	û 0.4 (0.5) n = 34	ü 112 (400) n = 37	û 1290 (260) n = 12	û 3060 (550) n = 24
	Tutaenui[51] (Assessed at Curls Bridge)	ü 7.2 – 8.3 (7 – 8.5) n = 107	ü 20.5 (24) n = 108	ND	û 5 (2) n =71	ID	û 2/4	û 905 (10) n = 107	û 2241 (110) n = 101	û 0/2	û 0.4 (2.5) n = 74	û 0.4 (1.6) n = 74	ü 294 (400) n = 107	û 4450 (260) n = 12	û 3345 (550) n = 24
Upper Whanganui	Upper Whanganui (assessed at Hohotaka Rd)	ND	ND	ND	ND	ND	1/1	ND	ND	ND	ND	ND	ND	ND	ND
Cherry Grove	Cherry Grove (Assessed at Cherry Grove)	ü 7.4 – 8.5 (7 – 8.5) n = 132	ü 18.2 (19) n = 126	ND	ü 1 (1) n =76	ü 5 (5) n =11	ü 7/8	ü 6 (10) n =86	û 155 (110) n =86	û 4/7	û 1.8 (2.5) n = 35	ü 1.7 (1.6) N = 67	ü 50 (400) n =132	ü 210 (260) n = 16	û 876 (550) n =48
	Upper Whakapapa (Assessed Below TPD)	ND	ND	ND	ND	ND	ü 2/3	ND	ND	ND	ü 6.2 (3) n = 6	ü 5.2 (2) n = 13	ND	ID	ID
	Lower Whakapapa	ND	ND	ND	ND	ND	1/1	ND	ND	ND	ND	ND	ND	ND	ND

48 No Flow data is available for Rangitikei at McKelvies. Data shown in columns requiring flow is all data for that time of the year and is indicative only

49 No Flow data is available for Rangitikei at Scotts Ferry. Data shown in columns requiring flow is all data for that time of the year and is indicative only

50 No Flow data is available for Porewa at Onepuhi Rd. Data shown in columns requiring flow is all data for that time of the year and is indicative only

51 No Flow data is available for Porewa at Onepuhi Rd. Data shown in columns requiring flow is all data for that time of the year and is indicative only

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble $cBOD_5$ (g/m^3)	POM (g/m^3)	Periphyton biomass (mg *Chloro a* /m^2)	DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Clarity (m)		Ammonia (mg N-NH_3 -/m^3)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
	Piopiotea[52] (Assessed at Bullians Rd)	û 6.7 – 8.2 (7 – 8.2) n = 7	ü 14.7 (19) n = 7	ND	ND	ND	ND	û 13.5 (6 or nat. level) n = 7	û 223 (70) n = 7	ND	û 0.4 (3) n = 22	û 0.4 (2) n = 22	ü 62 (320) n = 7	ID	û 7120 (550) n = 9
	Pungapunga[53] (Assessed at Kirtons Rd Bridge)	ND	ND	ND	ND	ND	1/1	ND	ND	ND	û 0.7 (2.5) n = 15	û 0.7 (1.6) n = 15	ND	ND	ID
	Upper Ongarue	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Lower Ongarue (Assessed at Cherry Grove)	ü 7.1 – 7.6 (7 – 8.5) n = 41	û 18.2 (19) n = 39	ND	ND	ID	ND	û 11 (10) n = 38	û 276 (110) n = 39	ND	û 1.1 (2.5) n = 16	û 0.5 (1.6) n = 27	ü 60 (400) n = 41	ND	ID
Te Maire	Te Maire (Assessed at Te Maire)	ü 7.2 – 8.5 (7 – 8.5) n = 119	ü 18.8 (19) n = 119	ND	ü 1 (1) n = 53	ID	û 7/8	û 11 (10) n = 90	û 227 (110) n = 90	û 1/7	û 1.1 (2.5) n = 50	û 0.6 (1.6) N = 71	ü 60 (400) n = 119	ID	û 1370 (550) n = 44
Middle Whanganui	Middle Whanganui (assessed at Downstream Retaruke)[54]	ü 7.2 – 8.3 (7 – 8.5) n = 83	û 20.3 (19) n = 73	ND	ID	ID	ND	û 15 (10) n = 83	û 249 (110) n = 40	û 0/6	û 0.3 (2.5) n = 80	û 0.3 (1.6) n = 80	ü 27 (400) n = 66	û 13840 (260) n = 53	û 9280 (550) n = 89
	Upper Ohura[55] (Assessed at Tokorima)	û 6.8 – 7.4 (7 – 8.5) n = 8	ü 19.7 (22) n = 15	ND	ND	ND	ND	û 13 (10) n =9	û 289 (110) n = 9	ND	û 0.2 (1.6) n = 7	û 0.2 (0.5) n = 7	ü 90 (400) n = 66	ID	û 12680 (550) n = 9
	Lower Ohura (Assessed above confluence)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

52 No Flow data is available for Piopiotea at Bullians Road. Data shown in columns requiring flow is all data for that time of the year and is indicative only

53 No Flow data is available for Pungapunga at Kirtons Road Bridge. Data shown in columns requiring flow is all data for that time of the year and is indicative only

54 No Flow data is available Whanganui D/s Retaruke. Data shown in columns requiring flow is all data for that time of the year and is indicative only

55 No Flow data is available Ohura at Tokorima for the DRP, SIN and *E. coli* parameters. Data shown in columns requiring flow is all data for that time of the year and is indicative only

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble cBOD$_5$ (g/m^3)	POM (g/m^3)	Periphyton biomass (mg *Chloro a* /m^2)	DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Clarity (m)		Ammonia (mg N-NH$_3$ -/m^3)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
	Retaruke[56] (Assessed above confluence)	ND	ND	ND	ND	ND	ü 2/2	ND	ND	ü 1/1	û 0.8 (1.6) n = 24	ü 0.8 (0.5) n = 24	ND	ND	ü 228 550 n =9
Pipiriki	Pipiriki (Assessed at Pipiriki)	ü 7.2 – 8.1 (7 – 8.5) n = 106	ü 21.1 (22) n = 90	ND	ID	ID	ü 8/8	ü 10 (10) n = 98	û 195 (110) n = 43	û 0/5	û 0.7 (2) n = 55	û 0.3 (0.5) n = 97	ü 50 (400) n = 48	û 484 (260) n = 43	û 776 (550) n = 78
Pipiriki	Tangarakau[57] (Assessed above confluence)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ID
Pipiriki	Whangamomona (Assessed above confluence)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ID
Pipiriki	Upper Manganui o te Ao [58] (Assessed at Hoihenga Rd)	ü 7.3 – 8.1 (7 – 8.2) n = 23	ü 15.7 (19) n = 22	ND	ND	ID	ü 3/4	ü 7.3 (6 or nat. level) n = 23	ü 77 (70) n = 23	ü 2/2	û 1.8 (3.4) n = 22	û 1.8 (2) N = 22	ü 50 (320) n = 23	ID	ü 489 (550) n =12
Pipiriki	Lower Manganui o te Ao[59] (Assessed above confluence)	ND	ND	ND	ND	ND	ND	ND	ND	ND	û 0.6 (3.4) n = 23	û 0.6 (1.6) n = 23	ND	ND	ü 113 (550) n =12
Paetawa	Paetawa[60] (Assessed at Paetawa)	ü 7.1 – 7.8 (7 – 8.5) n = 20	ü 21.3 (22) n = 21	ND	ND	ND	ND	û 18 (10) n = 21	û 201 (110) n = 21	ND	û 0.3 (2) n =184	û 0.3 (0.5) n = 18	ü 90 (400) n = 21	û 770 (260) n = 11	û 1500 (550) n = 23

56 No Flow data is available for Retaruke Above Confluence. Data shown in columns requiring flow is all data for that time of the year and is indicative only
57 No Flow data is available for Tangarakau Above Confluence. Data shown in columns requiring flow is all data for that time of the year and is indicative only
58 No Flow data is available for Manganui o te Ao at Hoihenga Road. Data shown in columns requiring flow is all data for that time of the year and is indicative only
59 No Flow data is available for Manganui o te Ao Above Confluence. Data shown in columns requiring flow is all data for that time of the year and is indicative only
60 No Flow data is available for Whanganui at Paetawa. Data shown in columns requiring flow is all data for that time of the year and is indicative only

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble $cBOD_5$ (g/m^3)	POM (g/m^3)	Periphyton biomass (mg *Chloro a* /m^2)	DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Clarity (m)		Ammonia (mg $N-NH_3$ -/m^3)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
Lower Whanganui	Lower Whanganui (Assessed at Aramoho Rail Bridge/ Kaiwhaiki)	ü 7.2 – 8 (7 – 8.5) n = 49	û 22.6 (22) n = 45	ND	ü 1 (5) n = 48	ID	ND	ü 8.4 (15) n = 49	û 197 (167) n = 40	û 2/5 (@ Kaiwhaiki)	û 0.7 (1.6) n = 43	ü 0.7 (0.5) n = 43	ü 91 (400) n = 40	ID	ID
	Coastal Whanganui[61] (Assessed at Estuary Opposite Marina)	ü 7.2 – 8.2 (7 – 8.5) n = 85	ü 21.5 (24) n = 95	ND	ID	û 14 (5) n = 8	N/A	ü 12 (15) n =85	û 259 (167) n = 7	N/A	û 0.2 (1.6) n =97	û 0.2 (0.5) n = 97	ü 44 (400) n = 7	û 1210 (260) n = 20	û 1990 (550) n = 41
	Upokongaro	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Matarawa[62] (Assessed above confluence)	ND	ND	ND	ND	ND	ND	ND	ND	ND	û 0.2 (1.6) n =23	û 0.2 (0.5) n =23	ND	ND	ID
Upper Whangaehu	Upper Whangaehu (Assessed at Karioi)	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Waitangi	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Tokiahuru[63] (Assessed above confluence)	û 7.1 – 7.9 (7 – 8.2) n = 10	ü 13 (19) n = 12	ND	ID		0/1	û 32 (6 or nat. level) n = 9	û 113 (70) n = 9	ND	û 0.7 (3) n =11	û 0.7 (2) n = 11	ü 16 (320) n = 9	ID	û 691 (550) n = 8
Middle Whangaehu	Middle Whangaehu[64] (Assessed at Aranui)	NA	ü 17.1 (22) n = 10	ND	ND	ND	ND	û 30 (15) n = 9	û 191 (167) n = 9	ND	û 0.1 (1.6) n =8	û 0.1 (0.5) n = 8	ü 72 (400) n = 9	ID	û 4735 (550) n = 8

61 No Flow data is available for Whanganui at Estuary Opposite Marina. Data shown in columns requiring flow is all data for that time of the year and is indicative only
62 No Flow data is available for Matarawa Above Confluence. Data shown in columns requiring flow is all data for that time of the year and is indicative only
63 No Flow data is available for Tokiahuru Above Confluence. Data shown in columns requiring flow is all data for that time of the year and is indicative only
64 No Flow data is available for Whangaehu at Aranui. Data shown in columns requiring flow is all data for that time of the year and is indicative only

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble $cBOD_5$ (g/m^3)	POM (g/m^3)	Periphyton biomass (mg *Chloro a* /m^2)	DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Clarity (m)		Ammonia (mg N-NH_3 -/m^3)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
Lower Whangaehu	Lower Whangaehu (Assessed at Kaungaroa)	NA	ü 21.3 (22) n = 37	ND	ID	ID	ND	ü 12 (15) n = 21	û 297 (167) n = 11	0/1	û 0.2 (1.6) n =10	û 0.1 (0.5) n =18	ü 80 (400) n = 24	ND	û 6990 (550) n = 10
	Upper Makotuku[65] (Assessed at SH49a)	ü 7 – 8 (7 – 8.2) n = 15	ü 14.5 (19) n = 15	ND	ND	ND	1/2	23 (6 or nat. level) n = 8	û 289 (70) n = 8	ü 2/2	ID	û 1.5 (2) n = 8	ü 33 (320) n = 15	ND	ü 170 (550) n = 6
	Lower Makotuku[66] (Assessed at Upstream Raetihi)	ü 7.1 – 8 (7 – 8.2) n = 9	ü 17 (19) n = 9	ND	ND	ND	0/1	û 13 (6 or nat. level) n = 9	ü 41 (70) n = 9	ND	û 1.1 (3) n = 9	û 1.1 (2) n = 9	ü 78 (320) n = 9	ID	û 1680 (550) n = 8
	Upper Mangawhero (Assessed at DoC Headquarters	ü 7.2 – 7.9 (7 – 8.2) n = 99	ü 11.8 (19) n = 94	ND	ü 0.8 (1) n = 93	ID	ü 8/8	ü 15 (Natural) n = 79	ü 51 (70) n = 78	ü 7/7	ü 3 (3) n = 40	ü 2.3 (2) N = 86	ü 60 (320) n = 97	ü 111 (260) n = 17	ü 71 (550) n = 45
	Upper Mangawhero[67] (Assessed at Pakihi Rd Bridge)	ü 7.2 – 7.9 (7 – 8.2) n = 21	ü 14.6 (19) n = 21	ND	ND	ND	1/1	ID	ID	û 0/7 (d/s makotoku)	ID	ID	ü 30 (320) n = 21	ND	ID
	Lower Mangawhero[68] (Assessed at Raupiu Rd)	ü 7.3 – 8.3 (7 – 8.5) n = 9	ü 19.6 (22) n = 9	ND	ND	ND	1/1	û 17 (10) n = 9	û 312 (110) n = 9	ND	û 0.8 (2) n = 8	ü 0.8 (0.5) n = 9	ü 26 (400) n = 9	ID	û 8000 (550) n =9
Coastal Whangaehu	Coastal Whangaehu	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

65 Upper Makotuku periphyton assessed at Railway Bridge
66 No Flow data is available for Makotuku Upstream Raetihi. Data shown in columns requiring flow is all data for that time of the year and is indicative only
67 QMCI Data is from Mangawhero Downstream Makotuku Confluence
68 No Flow data is available for Mangawhero at Raupiu Road. Data shown in columns requiring flow is all data for that time of the year and is indicative only

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble $cBOD_5$ (g/m³)	POM (g/m³)	Periphyton biomass (mg *Chloro a* /m²)	DRP (mg/m³)	SIN (mg/m³)	QMCI	Clarity (m)		Ammonia (mg N-NH_3 -/m³)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
Turakina	Upper Turakina[69] (Assessed at Otairi)	û 7.9 – 8.6 (7 – 8.5) n =8	ü 21.4 (22) n = 11	ND	ND	ND	1/1	û 18 (15) n = 9	û 201 (167) n = 9	ND	û 0.2 (1.6) n = 8	û 0.2 (0.5) n = 9	ü 54 (400) n = 9	û 19553 (260) n = 6	û 9220 (550) n =9
	Lower Turakina (Assessed at SH3 Bridge)	ü 7.7 – 8.4 (7 – 8.5) n = 36	û 23.2 (19) n = 36	ND	ND	ID	N/A	û 40 (15) n = 25	û 270 (167) n = 18	û 0/2	û 0.4 (1.6) n = 16	û 0.3 (0.5) n = 23	ü 110 (400) n = 24	ND	û 1325 (550) n = 16
	Ratana	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ohau	Upper Ohau (assessed from Gladstone)	ü 6.7 – 7.9 (6.7 – 8.2) n = 45	ü 19 (19) n = 49	ND	ND	ND	ü 3/3	ü 5.1 (6) n = 23	ü 68 (70) n = 23	ü 2/3	û 2.9 (3) n = 12	ü 2.8 (2) n = 23	ü 48 (320) n = 46	ü 140 (260) n = 21	ü 299 (550) n = 40
	Lower Ohau (assessed at Haines Farm)	û 6.8 – 7.5 (7 – 8.5) n =36	ü 19 (22) n = 36	ND	ND	ND	ü 3/3	ü 9 (10) n = 23	û 320 (167) n = 23	û 1/3	ü 3.3 (2.5) n = 11	ü 1.6 (1.6) n = 22	ü 73 (400) n = 36	ID	ü 290 (550) n = 11
Owahanga	Owahanga (assessed at Branscombe Bridge)	ü 8 – 8.3 (7 – 8.5) n = 24	ü 22 (22) n = 36	ND	ND	ND	ü 2/2	ü 9 (15) n = 16	ü 57 (167) n = 15	ü 1/2	û 0.3 (1.6) n = 12	û 0.3 (0.5) n = 16	ü 110 (400) n = 36	ID	û 3361 (550) n = 8
East Coast	East Coast	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Akitio	Upper Akitio[70] (assessed at Weber Rd)	û 8 – 8.8 (7 – 8.5) n =22	ü 21 (22) n = 22	ND	ND	ND	ü 2/2	ü 12 (15) n = 8	ü 112 (167) n = 6	ü 1/2	û 1.2 (1.6) n = 6	ü 1.2 (0.5) n = 6	ü 69 (400) n = 22	ID	û 1635 (550) n = 10

69 No Flow data is available for Turakina at Otairi. Data shown in columns requiring flow is all data for that time of the year and is indicative only

70 No Flow data is available for Akitio at Weber Rd for the *E. coli* parameter. Data shown in columns requiring flow is all data for that time of the year and is indicative only

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble $cBOD_5$ (g/m^3)	POM (g/m^3)	Periphyton biomass (mg *Chloro a* $/m^2$)	DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Clarity (m)		Ammonia (mg $N\text{-}NH_3$ $-/m^3$)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
	Lower Akitio[71] (assessed Above Estuary)	ü 7.8 – 8.1 (7 – 8.5) n = 24	ü 22 (22) n = 24	ND	ND	ND	ü 2/2	û 30 (15) n = 6	ü 158 (167) n = 6	û 0/2	û 0.3 (1.6) n = 6	û 0.3 (0.5) n = 6	ü 77 (400) n = 24	û 555 (260) n = 6	û 2055 (550) n = 12
	Waihi (assessed at SH2)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Northern Coastal	Northern Coastal	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Kai Iwi	Kai Iwi (Assessed at SH3 Bridge)	ü 7.3 – 7.9 (7 – 8.5) n = 21	ü 17 (22) n = 20	ND	ID	ND	ND	û 26 (15) n = 12	û 472 (167) n = 12	ND	û 0.6 (1.6) n = 7	û 0.3 (0.5) n = 12	ü 53 (400) n = 20	ND	û 2535 (550) n = 12
	Kai Iwi[72] (Assessed at Handley Rd)	ü 7.2 – 8.1 (7 – 8.5) n = 16	ü 17 (22) n = 16	ND	ND	ND	ND	û 27 (15) n = 9	û 337 (167) n = 9	ND	û 0.7 (1.6) n = 6	û 0.3 (0.5) n = 8	ü 90 (400) n = 16	ID	ID
Mowhanau	Mowhanau[73] (Assessed at Mowhanau)	ü 7.4 – 7.8 (7 – 8.5) n = 8	ü 18 (24) n = 8	ND	ND	ND	ND	û 37 (15) n = 8	û 336 (167) n = 8	ND	û 0.2 (2.5) n = 8	û 0.2 (1.6) n = 8	ü 89 (400) n = 8	ID	û 8150 (550) n = 8
Kaitoke Lakes	Kaitoke Lakes (Assessed at Lake Wiritoa)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ü 80 (260) n = 91	ND
	Kaitoke Lakes Tributaries	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

71 No Flow data is available for Akitio above Estuary for the *E. coli* parameter. Data shown in columns requiring flow is all data for that time of the year and is indicative only

72 No Flow data is available for Kai Iwi at Handley Road for the *E. coli* parameter. Data shown in columns requiring flow is all data for that time of the year and is indicative only

73 No Flow data is available for Mowhanau at Mowhanau. Data shown in columns requiring flow is all data for that time of the year and is indicative only

Management Zone	Sub-zone	pH	Temp. (°C)	DO (% Sat)	Soluble cBOD$_5$ (g/m^3)	POM (g/m^3)	Periphyton biomass (mg *Chloro a* /m^2)	DRP (mg/m^3)	SIN (mg/m^3)	QMCI	Clarity (m)		Ammonia (mg N-NH$_3$ -/m^3)	*E.coli* (N/100mL)	
		Range	Max daily					Monthly Mean value, < 3* med			< med	< 3 * med		Nov-April Flow < med	< 3* med
Southern Wanganui Lakes	S. Wanganui Lakes (Assessed at Lake Dudding)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ü 85 (260) n = 93	ND
	S. Wanganui Lakes Tributaries	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Northern Manawatu Lakes	N. Manawatu Lakes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	N. Manawatu Lakes Tributaries	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Waitarere	Waitarere	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lake Papaitonga	Lake Papaitonga	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Lake Papaitonga Tributaries	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Waikawa	Waikawa[74] (Assessed at Downstream Manakau)	ü 7– 7.8 (7 – 8.5) n = 24	ü 20 (22) n = 24	ND	ND	ND	ND	û 31 (10) n = 24	û 1426 (444) n = 24	ü 1/2	û 0.6 (2.5) n = 22	û 0.6 (1.6) n =22	ü 170 (400) n = 24	ID	û 980 (550) n = 11
Lake Horowhenua	Lake Horowhenua (Assessed at Lake Horowhenua)	û 7.6 – 9.9 (7 – 8.5) n = 42	ID	ND	ND	NA	ND	ND	û 3103 TN mg/m^3 (337) n = 10	ND	ND	ND	û 345 (337) n = 86	ü 40 (260) n = 16	ü 151 (550) n = 15
	Lake Horowhenua Tributaries	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Hokio Stream	ID	ID	ID	ID	ID	ND	ID	ID	ND	ID	ID	ID	ID	ID

74 No Flow data is available for Waikawa Downstream Manakau. Data shown in columns requiring flow is all data for that time of the year and is indicative only

Table 28: Assessment of compliance with the Enterococci and Faecal Coliforms Standards in Coastal Waters

Site	Enterococci Nov – April (MPN/100ml) Median value	Faecal Cloiforms	
		50^{th} percentile	90^{th} Percentile
Tasman Sea at Foxton Beach	ü 80 (140) n = 112	ü 8 (14) n = 81	û 500 (43) n = 81
Tasman Sea at Himitangi Beach	ü 116 (140) n = 108	û 22 (14) n = 76	û 415 (43) n = 76
Tasman Sea at Waitarere Beach	ü 130 (140) n = 110	û 23 (14) n = 79	û 558 (43) n = 79
Tasman Sea at Hokio Beach	û 300 (140) n = 42	û 90 (14) n = 12	û 293 (43) n = 12
Tasman Sea at Waikawa Beach	ü 125 (140) n = 42	û 35 (14) n = 12	û 472 (43) n = 12
Tasman Sea at Kai Iwi Beach	û 500 (140) n = 107	û 230 (14) n = 79	û 2520 (43) n = 79
Tasman Sea at Castlecliff Beach	ü 58 (140) n = 107	ü 11 (14) n = 79	û 300 (43) n = 79
Pacific Ocean at Herbertville Beach	ü 5.6 (140) n = 9	ID	ID
Pacific Ocean at Akitio Beach	ü 14 (140) n = 28	ü 2 (14) n = 22	û 122 (43) n = 22

9 Recommendations for further work

A number of information and research gaps have been identified during the development of the recommended water quality management framework for the One Plan. Whilst the work presented in the series of technical reports (Figure 1), and particularly the development of water quality standards, was aimed to be based on the best available information, science and expert advice, it is also recognised that the understanding and management of the water resource should benefit from further research and development.

It is recommended the following projects are incorporated in regional and national research and monitoring programmes. The findings should form part of a "feedback loop" to continuously incorporate the latest monitoring data and scientific findings into policy frameworks.

9.1 Improvements to Horizons' monitoring programmes

Horizons' current state of the environment (SOE) water quality monitoring programme was last reviewed in 2005, and covers a large number of sites (about 100 sites, 32 monitored monthly each year, 68 monitored monthly every three years). The development of the new water quality framework has allowed the following gaps and weaknesses to be identified; and recommended improvements are as follows:

- There is virtually no water quality data in the LS (Lowland Sand) class. Ideally, both reference and impacted sites should be identified and monitored. It is acknowledged that reference sites may be very hard to find in the LS class due to the dominant intensive land use in the Region's west coast sand country.
- There are very few or no reference (undisturbed or slightly disturbed) sites in the LS, LM, HM, HSS and ULi classes. At least two or three reference sites should be monitored in each LSC class for at least two years (regular monitoring after the initial period should not be necessary unless a higher level of disturbance occurs or is suspected in the catchment). Reference data is paramount to better understand the natural characteristics of each class of water.
- Very little recent water quality data exists on most of the Region's coastal lakes and lake tributaries. Recent data only includes the Lake Horowhenua monitoring programme and bacteriological and blue-green algae data in lakes that are part of the swimming spot programme. Some of these lakes are potentially under a considerable amount of pressure from non-point source pollution, and it is strongly recommended that lakes and lake tributaries be included in the SOE monitoring programme. A rolling programme allowing monitoring of all lakes every five years could help to optimise the programme's cost/benefit ratio.
- As explained in section 3.2.3.3, spot sampling of dissolved oxygen (DO) concentration during daytime does not measure (in fact it does not even provide an indication of) the daily minimum DO concentration. Such monitoring is therefore unlikely to highlight any issues related to low DO levels, unless the problem is extreme (day-long DO depletion). Horizons recently acquired a limited number of oxygen probes which allow continuous monitoring of dissolved oxygen concentrations at selected sites. By capturing the full range of diurnal variations, continuous monitoring will provide a much more complete and meaningful picture of instream DO levels. Due to the low number of DO probes currently operated by Horizons, a careful prioritisation of the sites monitored is recommended. The purchase and operation of additional DO probes are also recommended. Priority sites should include:
  - reference/slightly impacted sites, to establish a baseline,
  - sites impacted by land use to establish a comparison with the baseline, and
  - upstream and downstream of sites affected by point-source discharges. Recommended priorities in this category include the Manawatu immediately downstream of Palmerston North, the

Oroua downstream of Feilding, the Rangitikei downstream of Bulls and the Hautapu downstream of Taihape.

- Horizons' current periphyton monitoring programme is based on annual samples taken at 30 sites across the Region. This is largely insufficient to capture the key parameter, ie. the maximum annual periphyton biomass at each site. An increased periphyton monitoring programme is strongly recommended, to incorporate monthly monitoring. Cost will be an obvious limitation, and a satisfactory option would be to confine the monthly monitoring to the October to May period (ie. the most likely time of the year for excessive periphyton growth in the Horizons Region). Another option is to undertake actual sampling only when visual inspection reveals a significant periphyton biomass. To optimise the different monitoring programmes, it is also recommended that the periphyton sampling be undertaken at the same time and sites, and by the same staff, as the monthly water quality monitoring programme[75]. Appropriate training of Horizons staff will be necessary. It is also recommended that the periphyton monitoring programme cover more sites representative of all Life-Supporting Capacity classes.
- As explained in section 2.3.6, no water quality standards are recommended in relation to blue-green algae density and/or toxins. Although the presence of significant cyanobacterial blooms, and associated public health risks in a number of the Region's lakes - and potentially rivers - is of significant concern, a regulatory framework may not be the most appropriate response. Rather, a well established public health risk management framework, similar to the Australian Guidelines for Recreational Waters (Australian Government, 2005) system is recommended. It is recommended that Horizons engage the services of an expert organisation to review its monitoring, reporting and management response programmes. It is noted this type of service is likely to obtain Envirolink funding, if applied for.
- Horizons' SOE and compliance monitoring programmes currently use only one black disc size (200 mm). It is noted this is partly due to the Manawatu Catchment Water Quality Plan's standard that specifically applies to "the horizontal sighting range of a 200 mm black disc". However, black discs of different sizes should be used depending on the water clarity range observed at the site, as defined in (Davies-Colley, 1988). In particular, a 200 mm black disc is not appropriate when the water clarity is less than one metre, leading to a low reliability of the method in turbid waters. It is recommended that the proper black disc measurement protocol be followed in both SOE and compliance monitoring programmes. It is noted that turbidity should also be monitored to refine the turbidity/black disc correlations, particularly in the "turbid water" end of the spectrum; and that turbidity may be used as a surrogate to water clarity if required.
- Continuous monitoring of water clarity can be done by beam attenuation/ transmissometry (Davies-Colley & Smith 2001). Horizons currently has a network of continuous turbidity monitoring equipment, and compliance with the water clarity standards can be assessed by using site specific black disc/turbidity relationships. However, there may be some benefit for Horizons to continuously monitor water clarity at specific sites in response

[75] The yearly periphyton and invertebrates monitoring programme is currently outsourced to Massey university.

to specific issues, or for the whole monitoring network in the future. Accordingly, it is recommended that the suitability of transmissometry equipment for state of the environment or compliance monitoring programmes be assessed. Equipment cost, ease of installation and maintenance, data logging and processing should form part of the assessment.

9.2 Further research and tool development

9.2.1 Develop a region-specific periphyton/nutrient model

Following the implementation of the recommended improved periphyton monitoring programme, a region-specific periphyton model should be developed, to refine the predicted nutrient concentrations required to control periphyton biomass under acceptable levels. A review of the proposed nutrient standards may be required once the model is developed and validated.

9.2.2 Develop a method to assess the effects of fine sediment deposition

As explained in section 2.3.2.3, hill country erosion and associated sedimentation on the riverbeds is a major issue for the Region. However, there is currently no proven method to measure the degree of fine sedimentation on riverbeds, or, more importantly, to assess its effects on different river values (eg. LSC, TS). Further research is required in this area. It is noted NIWA is currently conducting a significant amount of applied research on the topic. It is also noted the Quorer method was tested in the 2007 Upper Manawatu low flow investigation, conducted in partnership with Massey University, Fish and Game and the Department of Conservation. The results, although not available at the time of writing, should form part of this tool development programme.

9.2.3 Improve the method to assess compliance with the DO, temperature and pH standards

Compliance with the temperature, DO and pH standards in this report is assessed against the 95th percentile of the data. This method is simple and provides a quick assessment of the general state of the water quality in relation to each water quality parameter. It cannot however account for the duration of standard breaches.

The temperature, DO and pH standards are based on the effects of chronic exposure on aquatic biota. As such, occasional, moderate exceedance of the standard should not cause deleterious effects on aquatic life, but regular daily maximum exceedance over the course of several days may have a significant effect.

A method based on the number of days in a row with daily breaches of the standard may be more appropriate to assess compliance with the standard. Further research is required to develop such methods, and assess their adequacy and feasibility. The data requirements (ie. monthly vs. continuous) of the different methods need to be incorporated in the decision-making process.

9.2.4 Further development of the macroinvertebrate predictive modelling tool

As explained in section 2.3.4, macroinvertebrate predictive models have a great potential as a resource management tool. The model developed by Massey University is currently a research tool, and it is recommended it is developed into a fully validated management tool that can be used by Horizons staff. Envirolink funding was sought and obtained. Delivery of test product expected by the end of 2007.

9.3 Further development of guidelines and technical guidance documents

The determination of the water quality standards presented in this report makes extensive use of the recommendations provided by national guideline documents, including the 2000 ANZECC guidelines and the New Zealand Periphyton Guidelines. Along the process, a number of areas that require more guidance have been identified, including:

- A review of the microbiological guidelines relating to livestock drinking water. The 2000 ANZECC guidelines do not clearly define acceptable and unacceptable thresholds (rather it defines different levels for further monitoring). A two-step approach similar to the microbiological guidelines for recreational waters is suggested.
- An update of the ammonia guidelines, and particularly how the temperature and pH dependency should be implemented (refer to section 3.2.3.8 of this report).
- The 2000 ANZECC guidelines trigger values for physical and chemical stressors guidelines defined in the are based on a statistical analysis of data collected at low/moderate-disturbance sites, but do not have biological basis. It is suggested these trigger values should be reviewed to be better aligned with the effects-based approach imposed by the legislation. It is also suggested these trigger values are reviewed to incorporate the latest research guidelines, and account for catchment geology rather than merely the elevation (lowland/upland).
- More guidance is required on the setting of nutrient standards in relation to acceptable levels of periphyton growth. As described above, the 2000 ANZECC guideline trigger values for nitrogen and phosphorus are based on statistical analysis of moderately disturbed sites, but are not effect-based (ie. not linked with a likely level of periphyton growth). Whilst a useful tool, the New Zealand Periphyton Guidelines' model was found to generally be very environmentally conservative. The model also does not work on all river types. It is suggested a risk-based model linking the likely occurrence and duration of high periphyton biomass event to nutrient concentration in the water would be a very useful tool. The development of national guidance on the use of limiting nutrient information and the resource management implications of prioritising one macronutrient over the other, building on the Wilcock *et al.* (2007) report, is also recommended.

It is noted that these projects relate to the review or further development of national guideline documents, and would be best addressed at a national rather than regional level. The Surface Water Interest Group[76] (SWIG) has recently identified a review of the 2000 ANZECC guidelines as a priority project for Envirolink tool funding.

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Personal communications

A number of personal communications are referenced in this report. A list of the persons quoted is provided, as well as their current title and position.

Dr Barry Biggs, General Manager Environmental Information and International, National Institute of Water and Atmospheric Research Ltd (NIWA).

Dr. Russell Death, Senior Lecturer, Institute of Natural Resources Massey University. Palmerston North.

Roddy Henderson, Hydrologist, National Institute of Water and Atmospheric Research Ltd (NIWA).

Dr. John Quinn, Principal Scientist – River Ecosystems, National Institute of Water and Atmospheric Research Ltd (NIWA) Hamilton.

Dr. Brian Sorrell, Principal Scientist National Institute of Water and Atmospheric Research Ltd (NIWA) Hamilton.

Peter Taylor, Senior Fisheries Officer, Fish and Game, Wellington Fish and Game Council.

Jeff Watson, Manager Environmental Information. Horizons Regional Council.

11 Appendices

Appendix 1: Water quality and quanity monitoring sites and summary of available monitoring data.

Table 1: Reference and impacted water quality site within each Life-Supporting Capacity (LSC) and Trout Fishery (TF) category. LU: Land-Use, D: Discharges, E: Erosion.

LSC	TF	River	Site	Reference / impacted	Existing data			Flow Statistic		
					Spot WQ sampling	Continuous Flow recording	Continuous Temp. Recording.	½ med (m^3/s)	Med (m^3/s)	3*med (m^3/s)
UHS	-	Tamaki	Reserve	Reference site	Extensive	Tamaki at Water Supply Weir July 1999 – June 2003		0.487	0.983	2.919
	-	Tamaki	Water Supply Weir	Slightly impacted (LU)	Limited	Tamaki at Water Supply Weir February 2000 - March 2000	July 2000 – June 2001	0.487	0.983	2.919
	-	Kumeti	Te Rehunga Rd	Impacted (LU)	Limited	Kumeti at Te Rehunga February 2000 - March 2000	July 2000 – June 2001	0.138	0.276	0.878
	2	Mangatainoka	Putara	Reference site	Fair	Mangatainoka at Larson's Bridge July 1999 – June 2003		1.065	2.13	6.39
	2	Mangatainoka	Larsons Road	Slightly impacted (LU)	Fair	Mangatainoka at Larson's Bridge March 2000 – June 2006	July 2000 – June 2001	1.065	2.13	6.39
	3	Mangahao	Kakariki	Potentially affected by the presence of hydroelectricity dams in the upper catchments	Good	Mangahao at Ballance July 1999 – June 2003	July 2000 – June 2001	3.683	7.366	22.098
	3	Mangahao	Ballance	Slightly impacted (LU, dams)	Extensive	Mangahao at Ballance July 1999 – June 2003	June 2000 – May 2001	3.683	7.366	22.098
	3	Pohangina	Piripiri	Slightly impacted (E)	Good	Pohangina at Mais Reach July 1999 – August 2005		5.006	10.012	30.036
	3	Tokomaru	Horseshoe Bend	Potentially affected by the presence of hydroelectricity dams in the upper catchments	Extensive	Tokomaru All July 1999 - November 2005		0.625	1.249	3.747
	3	Tokomaru	Darky's Hole		Limited	Tokomaru All January 2000 – February 2000	July 2000 – June 2001	0.625	1.249	3.747
	1	Rangitikei	Pukeokahu	Reference site	Extensive	Rangitikei at Pukeokahu[77] March 1999 – October 2005	May 2000 – April 2001	8.689	17.378	52.134
	3	Ohau	Gladstone Reserve	Reference site	Extensive	Ohau at Rongomatane July 1999 – April 2005		1.91	3.819	11.457
UVA	3	Whakapapa	Below TPD intake	Reference site	Fair	Whakapapa at Footbridge November 1997 – October 1999		3.433[78]	3.788	11.364
	3	Piopiotea	Bullians Road	Mod. impacted (LU)	Limited	No Flow Data				

[77] Due to Hydroelectricity schemes the flow statistic for this site is from the NIWA Flow Statistics Report: Rangitikei at Pukeokahu (32763), Jul 1999 to Jul 2005 (Post Diversion)

[78] The 25th percentile flow is used for Whakapapa at Footbridge due to Hydroelectricity schemes. Flow Statistics from NIWA Flow Statistics Report: Whakapapa at Footbridge (3320), Jul 1993 to Jul 2000 (Planning Tribunal 1990)

LSC	TF	River	Site	Reference / impacted	Existing data			Flow Statistic		
					Spot WQ sampling	Continuous Flow recording	Continuous Temp. Recording.	½ med (m³/s)	Med (m³/s)	3*med (m³/s)
	1	Manganui o te Ao	Hoihenga Rd	Slightly impacted (E)	Fair	No Flow Data				
	-	Whangaehu	Tangiwai	Naturally different and Mod. impacted (D)	Good	No Flow Data				
	3	Tokiohuru	Above Confluence		Limited	No Flow Data				
	3	Makotuku	SH49A		Fair	Makotuku at SH49A May 1998 – December 2005		0.223	0.446	1.338
	3	Makotuku	Upstream Raetihi	Slightly impacted (LU, E, WA)		No Flow Data				
	3	Mangawhero	DoC Headquarters	Reference Site	Extensive	Mangawhero at Ohakune All May 1998 – August 2005		0.93	1.859	5.577
	3	Mangawhero	Hagleys	Slightly impacted (LU, E, WA)	Extensive	Mangawhero at Ohakune All April 1999 – August 2005	July 2000 – June 2001	0.93	1.859	5.577
	3	Mangawhero	Pakihi Rd Bridge		Fair	Mangawhero at Ohakune All July 2005 – August 2005		0.93	1.859	5.577
	3	Mangawhero	D/s Makotuku	Mod. impacted (D, E, LU)	Extensive	No Flow Data				
	-	Whangaehu	Karioi recorder		Good	Whangaehu at Karioi January 1997 – February 2000		9.793[79]	11.746	35.238
UVM	2	Hautapu	Rest Area	Reference	Limited	No Flow Data				
UVM	2	Hautapu	Mulvays	Reference	Limited	No Flow Data				
UVM	2	Hautapu	Taihape	Mod impacted (LU, E)	Extensive	Hautapu at Taihape All July 1998 – June 2006		1.4	2.8	8.4
UVM	3	Whanganui	Cherry Grove	Slightly impacted (LU)	Extensive	Whanganui at Piriaka January 1997 – December 2003		16.62[80]	20.088	60.264
UVM	3	Ongarue	Cherry Grove	Mod. impacted (LU, E)	Extensive	Ongarue at Taringamotu January 1997 – May 2000		12.27	24.54	73.62
UVM	3	Whanganui	Te Maire		Extensive	Whanganui at Te Maire January 1997 – March 2005		32.767[81]	24.18	145.077
UVM	3	Pungapunga	Kirton Road Bridge		Limited	No Flow Data				
UVM	3	Whanganui	D/s Retaruke	Mod. (E))	Extensive	No Flow Data				
UVM	1	Manganui o te Ao	Above confluence	Slightly impacted (E)	Limited	No Flow Site				
ULi	2	Makuri River	Tuscan Hills	Mod. impacted (LU)	Extensive		July 2000 – June 2001	1.922	3.843	11.529
HM	2	Mangarangiora	U/s Norsewood Oxpond	Impacted (LU)	Fair	No Flow Data				

79 The 25th percentile flow is used for Whangaehu at Karioi due to Hydroelectricity schemes. Flow Statistics from NIWA Flow Statistics Report: Whangaehu at Karioi (33107) Jul 1979 to Jul 2003 (post Diversion)

80 The 25th percentile flow is used for Whanganui at Piriaka due to Hydroelectricity schemes. Flow Statistics from NIWA Flow Statistics Report: Whanganui at Piriaka (33356), Jul 1993 to Jul 2003 (Planning Tribunal 1990)

81 The 25th percentile flow is used for Whanganui at Te Maire due to Hydroelectricity schemes. Flow Statistics from NIWA Flow Statistics Report: Whanganui at Te Maire (33302), Jul 1993 to Jul 2004 (Planning Tribunal 1990)

LSC	TF	River	Site	Reference / impacted	Existing data			Flow Statistic		
					Spot WQ sampling	Continuous Flow recording	Continuous Temp. Recording.	½ med (m^3/s)	Med (m^3/s)	3*med (m^3/s)
	2	Manawatu	Weber Road	Mod. impacted (LU, E)	Extensive	Manawatu at Weber Road January 1997 – May 2005 (N)	May 1999 – April 2001	3.803	7.605	22.815
	-	Mangatera	U/s Dannevirke Oxpond	Mod. Impacted (LU)	Good	Mangatera at Dannevirke 1 January 1997 – April 2005		0.416	0.831	2.493
	-	Mangatera	Timber Bay	Impacted (D,LU)	Extensive	Mangatera at Dannevirke 1 January 1997 – April 2005		0.416	0.831	2.493
	-	Tamaki	SH2	Slightly impacted (LU)	Extensive	Tamaki at Water Supply Weir July 1999 – June 2003		0.487	0.983	2.919
	-	Kumeti	SH2		Limited	No Flow Data				
	-	Oruakeretaki	Oringi		Limited	No Flow Data				
		Raparapawai	Jacksons Rd		Limited	No Flow Data				
	2	Manawatu	Hopelands	Impacted (LU, D, E)	Extensive	Manawatu at Hopelands January 1997 – October 2005	July 1999 – June 2001	7.852	15.703	47.109
	2	Mangatainoka	Suspension Bridge	Mod. impacted (LU, D, E)			June 2000 – May 2001			
	2	Makakahi	Konini	Impacted (LU, D, E)	Extensive	Makakahi at Hamua January 1997 – June 2005		1.59	3.18	9.54
	2	Makakahi	Hamua	Impacted (LU, D, E)	Fair	Makakahi at Hamua July 2005 – August 2005	June 2000 – June 2001	1.59	3.18	9.54
	2	Mangatainoka	SH2 Bridge	Mod. impacted (LU, D, E)	Extensive	Mangatainoka at Pahiatua All January 1997 – July 2005		4.45	8.9	26.7
	3	Manawatu	Upper Gorge	Mod. impacted (LU, D, E)	Fair	Manawatu at Upper Gorge November 2003 – March 2004	June 2000 – May 2001	25.185	50.37	151.11
	-	Mangapapa	Troup Road Bridge		Fair	No Flow Data				
	-	Mangapapa	SH2	Impacted (LU, E)	Fair	No Flow Data				
	-	Mangaatua	u/s Woodville Oxpond	Mod. Impacted (LU, E)	Good	No Flow Data				
	-	Mangaatua	d/s Woodville Oxpond	Mod. Impacted (LU, E)	Good	No Flow Data				
	3	Manawatu	Teachers College	Mod. impacted (LU, D, E)	Extensive(N)	Manawatu at Teachers College[82] January 1997 – May 2005 (N)	July 2000 – July 2001	36.702	73.404	220.212
	3	Pohangina	Raumai Reserve	Slightly impacted (LU, E)	Good	Pohangina at Mais Reach December 1998 – June 2003		5.006	10.012	30.036
	3	Pohangina	Mais Reach	Slightly impacted (LU, E)	Extensive	Pohangina at Mais Reach July 1999 – August 2005	April 2000 – June 2001	5.006	10.012	30.036
	3	Manawatu	42 Mile Hydro Station	Impacted (D, LU, E)	Extensive	Manawatu at Palmerston North All January 1997 – October 2005		36.702	73.404	220.212
	3	Manawatu	Opiki Bridge	Impacted (D, LU, E)	Extensive(N)	Manawatu at Opiki January 1997 – May 2005 [83](N)		37.569	75.138	225.414
	3	Oroua	Apiti Road Bridge[84]	Reference	Extensive	No Flow Data				

[82] Manawatu at Palmerston North All Flow statistics are used for the NIWA teachers college data
[83] Manawatu at Opiki Flow Statistics provided by Marianne Watson

LSC	TF	River	Site	Reference / impacted	Existing data			Flow Statistic		
					Spot WQ sampling	Continuous Flow recording	Continuous Temp. Recording.	½ med (m^3/s)	Med (m^3/s)	3*med (m^3/s)
	3	Oroua	Almadale	Mod Impacted (LU, E)	Fair	Oroua at Almadale All August 2003 – January 2005	July 1994 – June 2001	3.552	7.104	21.312
	3	Oroua	Nelson Street	Mod Impacted (LU, E)	Extensive	Oroua at Kawa Wool All January 1997 – March 2005		3.486	6.971	20.913
	3	Oroua	Barrows Road	Mod Impacted (LU, E)			July 2000 – July 2001			
	3	Oroua	Awahuri Bridge	Impacted (D, LU, E)	Extensive	Oroua at Awahuri Bridge January 1997 – March 2005		3.908	7.816	23.448
	-	Kiwitea	Gun Club				July 2000 – June 2001			
	1	Rangitikei	Mangaweka	Slightly Impacted (LU, D, E)	Extensive(N)	Rangitikei at Mangaweka January 1997 – May 2005	July 2000 – June 2001	21.648	43.296	129.888
	3	Rangitikei	Vinegar Hill	Slightly Impacted (LU, D, E)	Extensive	Rangitikei at Mangaweka December 1998 - March 2005		21.648	43.296	129.888
	3	Rangitikei	Kakariki	Mod Impacted (E, LU, D)	Extensive(N)	Rangitikei at Kakariki[85] January 1997 – May 2005		26.637	53.274	159.822
	-	Waikawa	D/s Manakau Str.	Impacted (LU)	Fair	No Flow Data				
	3	Ohau	Haines Farm	Slightly impacted (LU)	Good	Ohau at Rongomatane July 1997 – June 2003		1.91	3.819	11.457
HSS	2	Mangatoro	Mangahei Road		Fair	No Flow Data				
	3	Tiraumea	Kaitiawa Bridge	Impacted (E, LU)	Good	Tiraumea at Ngaturi July 2000 – June 2004		3.606	7.211	21.633
	3	Tiraumea	Ngaturi	Impacted (E, LU)			July 2000 – June 2001			
	-	Hautapu	U/s Rangitikei	Impacted (D, E)	Extensive	Hautapu at Taihape All July 1998 – March 2005		1.4	2.8	8.4
	-	Makohine	Viaduct	Mod. Impacted (E, LU)	Extensive	Makohine at Viaduct July 1998 – March 2005		0.163	0.326	0.975
	-	Porewa	Onepuhi Rd	Impacted (LU, E)	Extensive	No Flow Data	No			
	-	Ohura	Above confluence	Impacted (E, LU)	Limited	Ohura at Tokorima November 1997 – October 1999		5.95	11.9	35.7
	-	Ohura	Tokorima		Limited	Ohura at Tokorima July 2001 – September 2005		5.95	11.9	35.7
	3	Whanganui	Pipiriki	Impacted (E) Slightly impacted (LU)	Extensive	Whanganui at Pipiriki Hydrotelrating[86] July 1998 – March 2007		65.1	130.2	390.6
		Whangamomona	Above Confluence		Limited	No Flow Data				
	3	Whanganui	Paetawa	Impacted (E) Slightly impacted (LU)	Fair	No Flow Data	July 2000 – June 2001			

84 The Upper Oroua zone is classified as Hill-Mixed geology but the Oroua at Apiti site is located in the upper Oroua catchment, heavily dominated by Hard sedimentary rocks (greywacke). Therefore the Oroua at Apiti site should be considered a UHS site, and due to its position (immediately downstream of the Forest Park boundary), can be regarded as a reference site for the UHS waters.

85 Flow statistics for Rangitikei at Kakariki are based on Rangitikei at Onepuhi Flow site

86 Whanganui at Pipiriki Statistics provided by Marianne Watson

LSC	TF	River	Site	Reference / impacted	Existing data			Flow Statistic		
					Spot WQ sampling	Continuous Flow recording	Continuous Temp. Recording.	½ med (m³/s)	Med (m³/s)	3*med (m³/s)
	-	Matarawa	City Branch	Impacted (LU, E)			July 2000 – June 2001			
	-	Matarawa	Above Confluence		Fair	No Flow Data				
	-	Whangaehu	Aranui		Limited	No Flow Data				
	-	Whangaehu	Kaungaroa	Impacted (E, LU)	Extensive	Whangaehu at Kauangaroa July 1998 – June 2002	July 2000 – June 2001	18.791[87]	26.722	80.166
	3	Mangawhero	Raupiu Road		Limited	No Flow Data				
	-	Turakina	Otairi		Limited	No Flow Data				
	-	Turakina	SH3	Impacted (E, LU)	Extensive	Turakina at Otairi July 1998 – April 2005		1.068	2.135	6.405
	-	Owahanga	Branscombe Bridge	Impacted (E) Slightly impacted (LU)	Good	Owahanga at Branscombe Bridge July 2000 – September 2005	July 2000 – June 2001	0.746	1.492	4.476
	-	Akitio	Weber Road		Fair	Akitio at Weber Road July 2000 – April 2001		0.313	0.626	1.878
	-	Akitio	Above Estuary		Fair	Akitio at Weber Road July 2000 – April 2001		0.313	0.626	1.878
	-	Kai Iwi	Handley Road		Fair	Kai Iwi at Handley Road July 1999 – June 2000		0.499	0.998	2.994
	-	Kai Iwi	Bridge	Impacted (LU, E)	Fair	Kai Iwi at Handley Road October 1999 – March 2004		0.499	0.998	2.994
LM	-	Mangaone	Milson Line	Mod impacted (LU, E)		No Flow Data				
	-	Makino	South Street	Mod impacted (LU, E)	Limited	Makino at Boness Road July 2002 – June 2003		0.122	0.244	0.732
	-	Makino	Boness Road		Fair	Makino at Boness Road July 2005 – June 2006		0.122	0.244	0.732
	-	Mangaone West	All Sites	Mod impacted (LU, E)	Fair	No Flow Data				
	3	Manawatu	Whirokino Boat Ramp	Impacted (LU, D, E)	Extensive	No Flow Data				
	3	Manawatu	Moutoa	Impacted (LU, D, E)	None	No Flow Data	June 2000 - May 2001			
	3	Manawatu	Foxton Wharf	Impacted (LU, D, E)	Fair	No Flow Data	July 2000 – June 2001			
	-	Foxton Loop	Boat Ramp	Impacted (LU, D, E)		No Flow Data				
	3	Rangitikei	McKelvies		Limited	No Flow Data				
	3	Rangitikei	Scotts Ferry	Mod Impacted (E, LU, D)	Extensive	No Flow Data				
		Tutaenui	Curls Bridge		Extensive	No Flow Data				
	-	Rangitawa	U/s Halcombe Oxpond	Mod Impacted (LU, E)	Fair	No Flow Data				
	-	Whanganui	Aramoho Railbridge	Impacted (E) Slightly impacted (LU)	Extensive	No Flow Data				
	-	Whanganui	Estuary		Extensive	No Flow Data				

87 The 25th percentile flow is used for Whangaehu at Kauangaroa due to Hydroelectricity schemes. Flow Statistics from NIWA Flow Statistics Report: Whangaehu at Kauangaroa (33101) Jul 1979 to Jul 2004 (post Diversion)

LSC	TF	River	Site	Reference / impacted	Existing data			Flow Statistic		
					Spot WQ sampling	Continuous Flow recording	Continuous Temp. Recording.	½ med (m^3/s)	Med (m^3/s)	3*med (m^3/s)
	-	Mowhanau	Mowhanau		Limited	No Flow Data				
	-	Arawhata	Hokio Beach Road		Limited	No Flow Data				
LS	-	Hokio	All sites	Impacted (LU, D)	Good	No Flow Data				
	-	Hokio	Lake Outlet	Impacted (LU, D)	Extensive	No Flow Data				
	-	Whitebait	All sites	Impacted (LU)	Limited	No Flow Data				

Appendix 2: Water quality correlations

A. pH- flow graphs

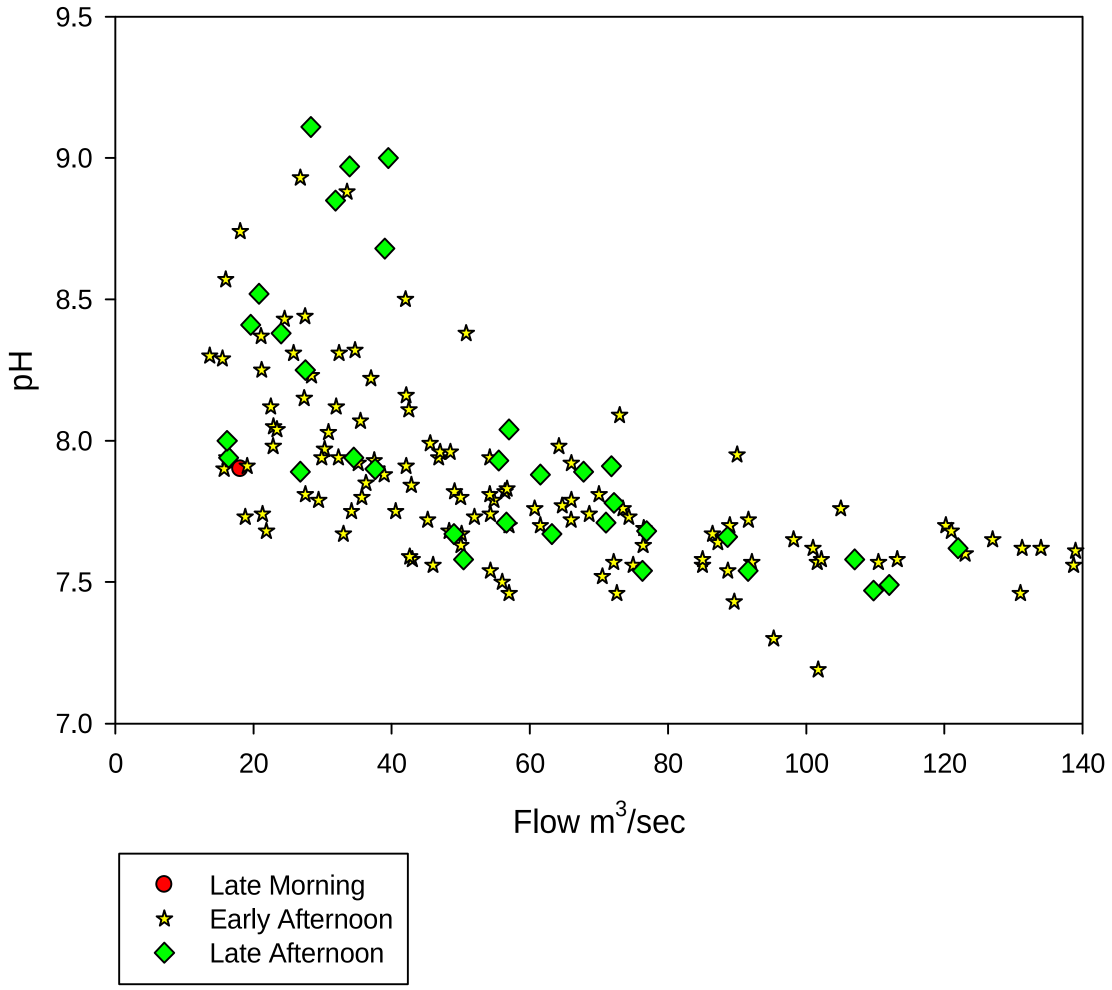

Figure 1: Manawatu at Teachers College pH vs Flow

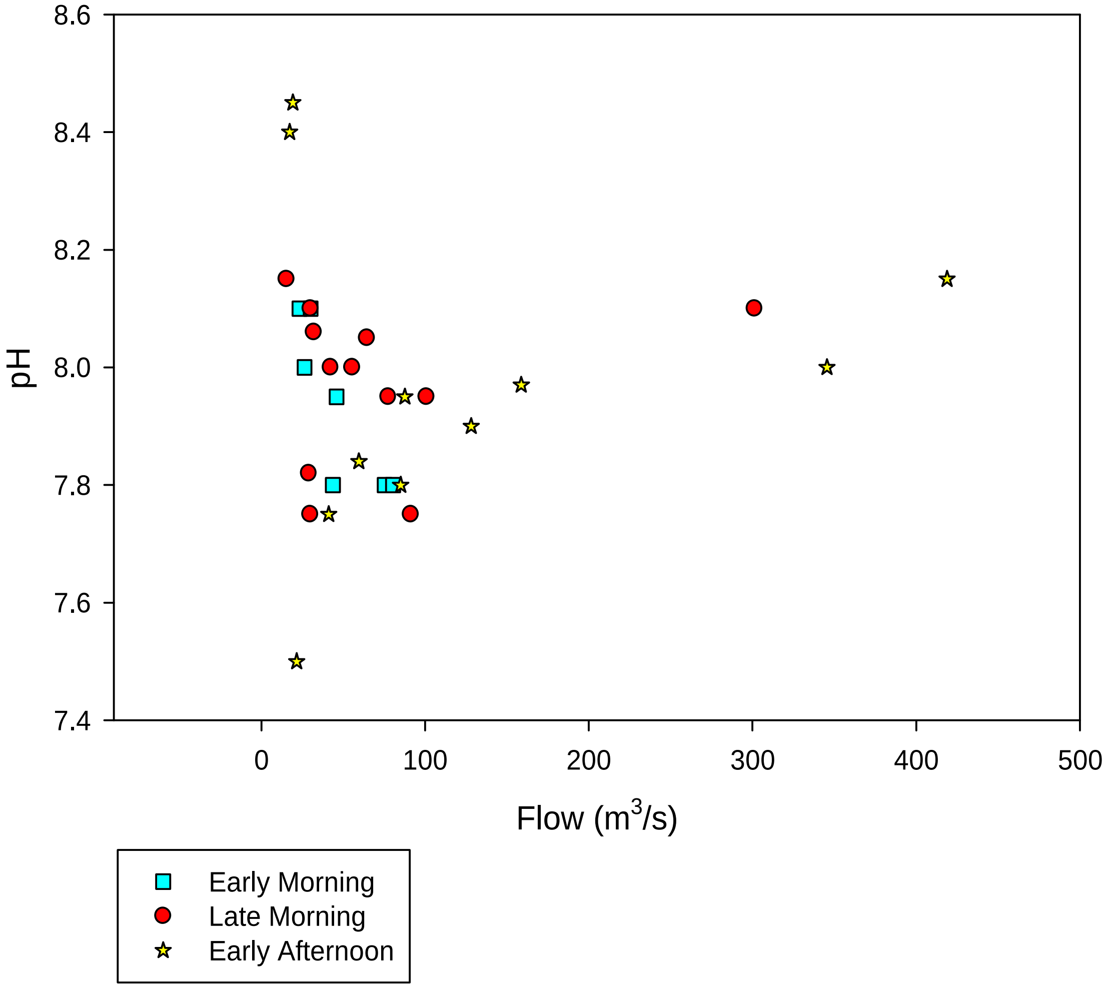

Figure 2: Rangitikei at Kakariki pH vs Flow

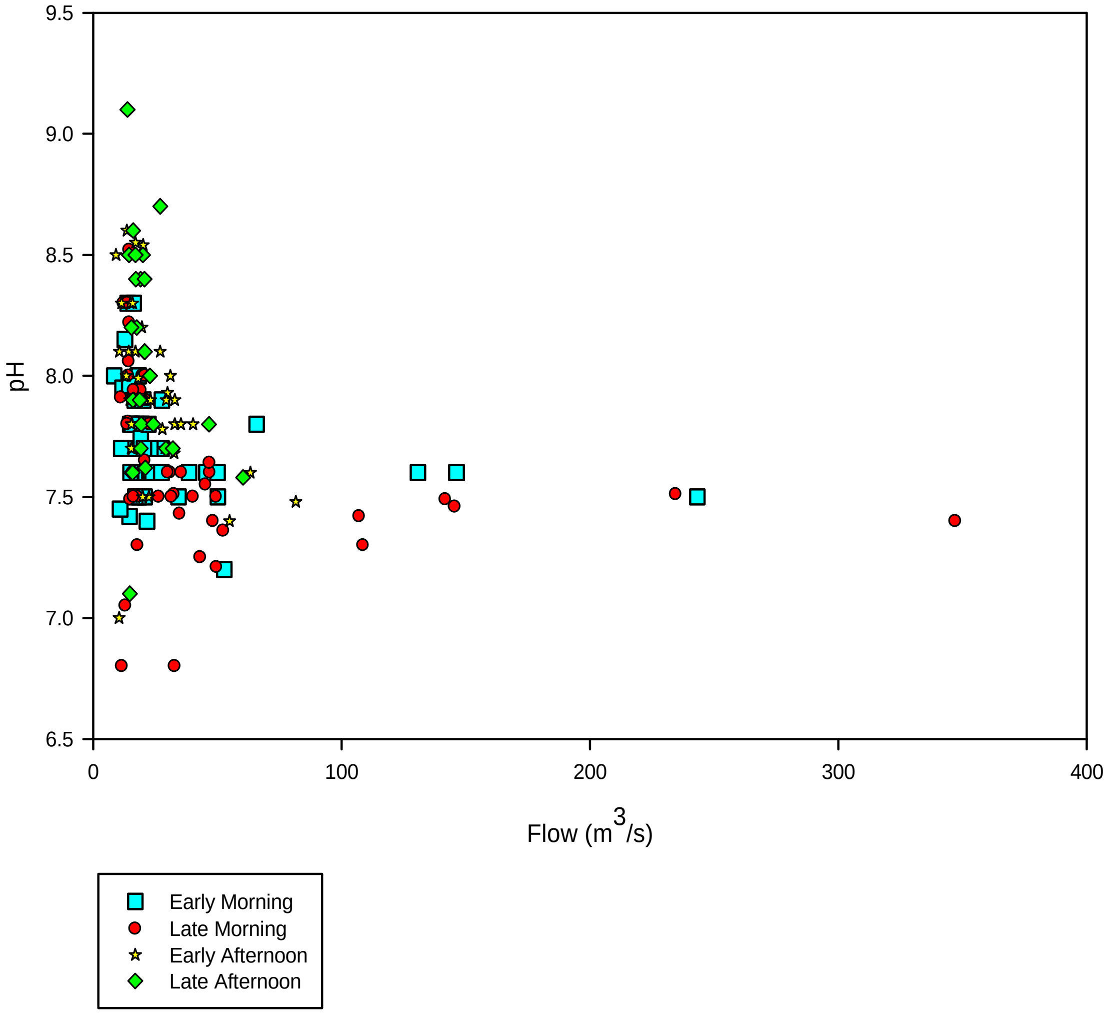

Figure 3: Whanganui at Cherry Grove pH vs Flow

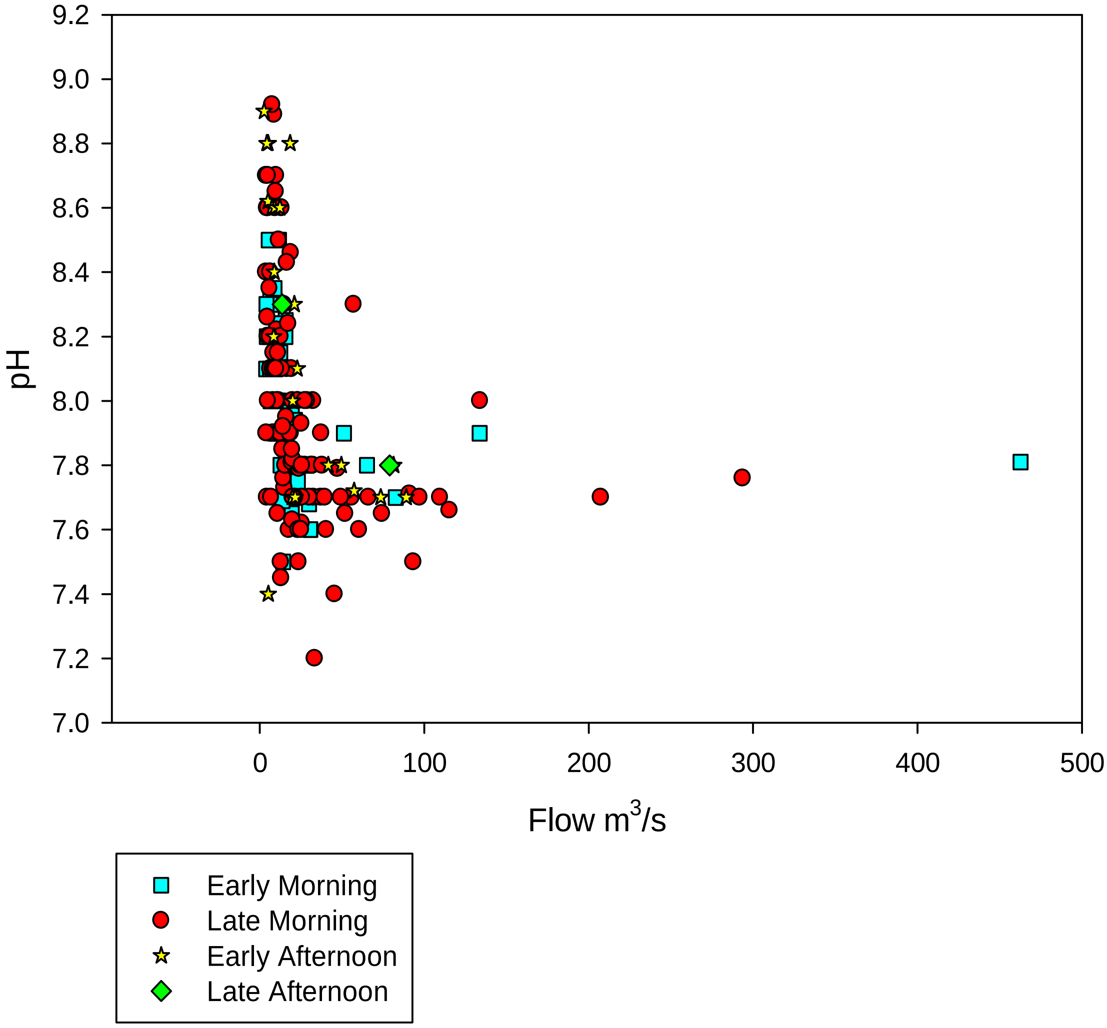

Figure 4: Manawatu at Hopelands pH vs Flow

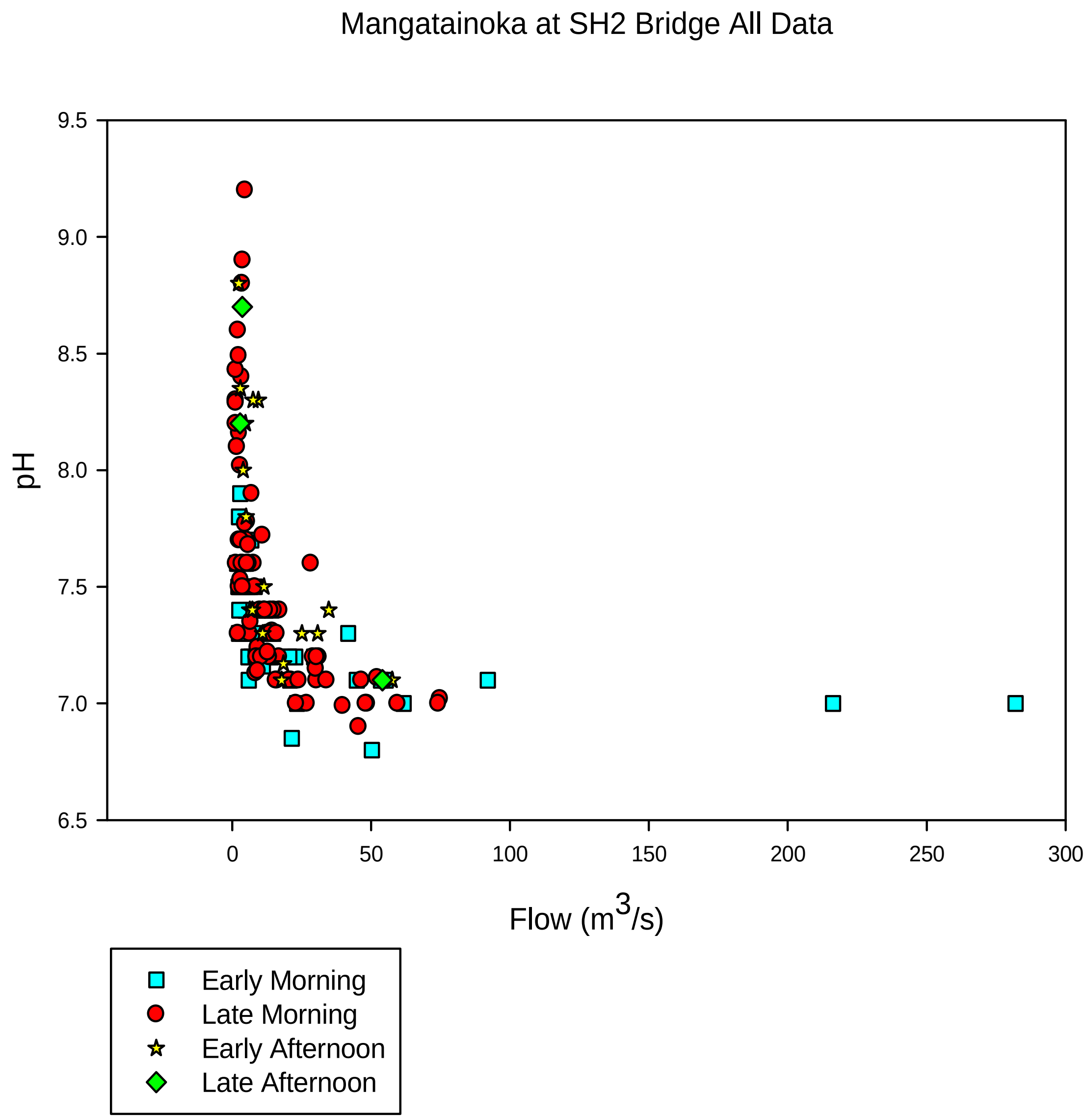

Figure 5: Mangataionka at SH2 pH vs Flow

B. Temperature / pH

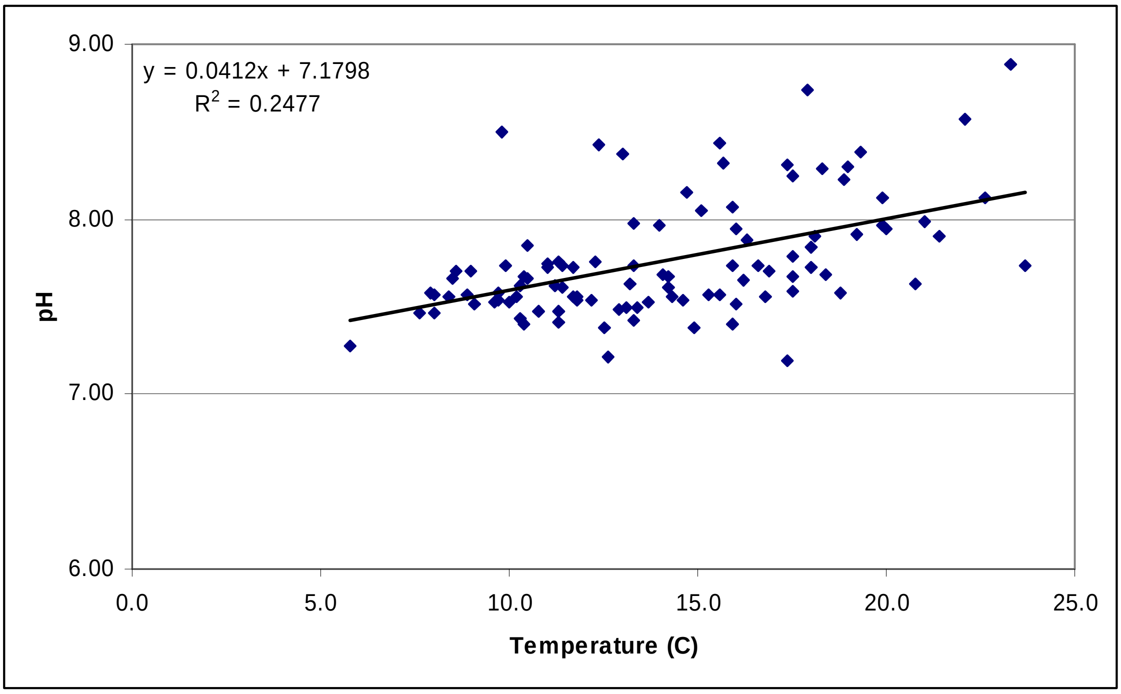

Figure 6: Relationship between pH and temperature at the Manawatu at Teachers College monitoring site.

C. Turbidity/ Black disc graphs and correlations

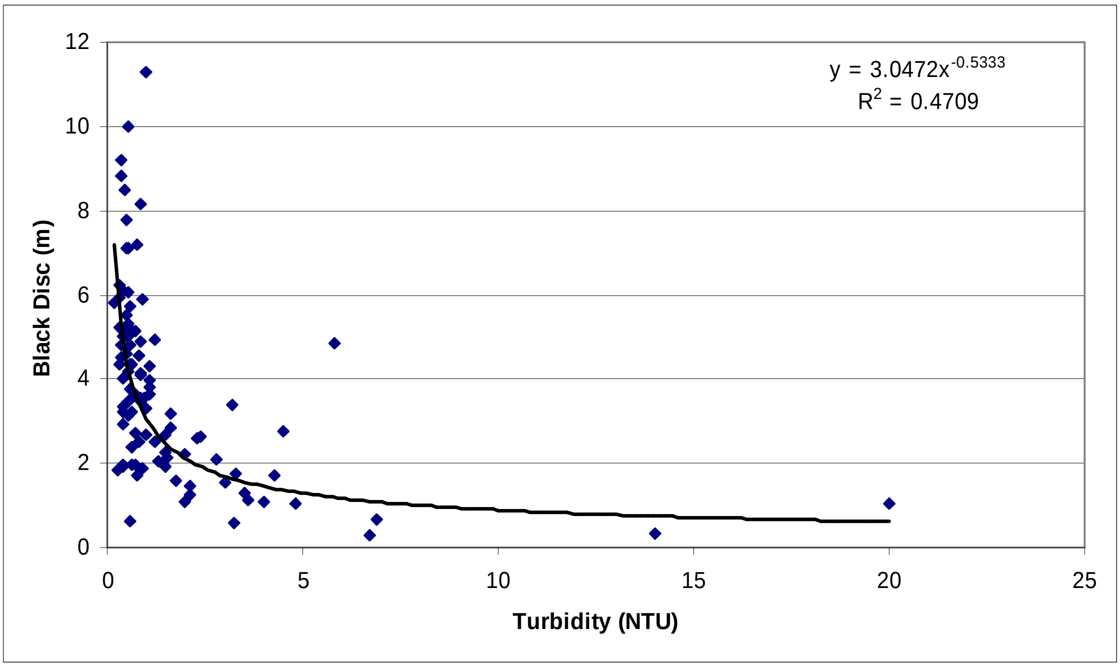

Figure 7: Rangitikei at Pukeokahu Turbidity vs. Black Disc

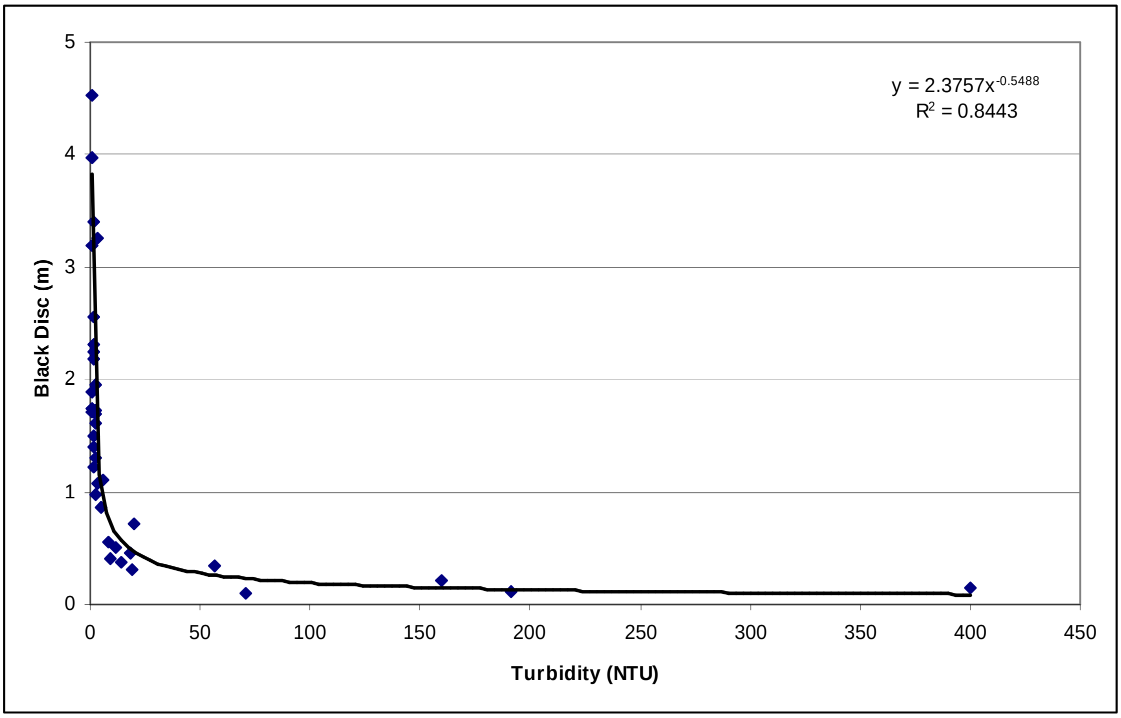

Figure 8: Rangitikei at Mangaweka Turbidity vs. Black Disc

Figure 9: Manganui o te Ao at Hoihenga Rd Turbidity vs. Black Disc

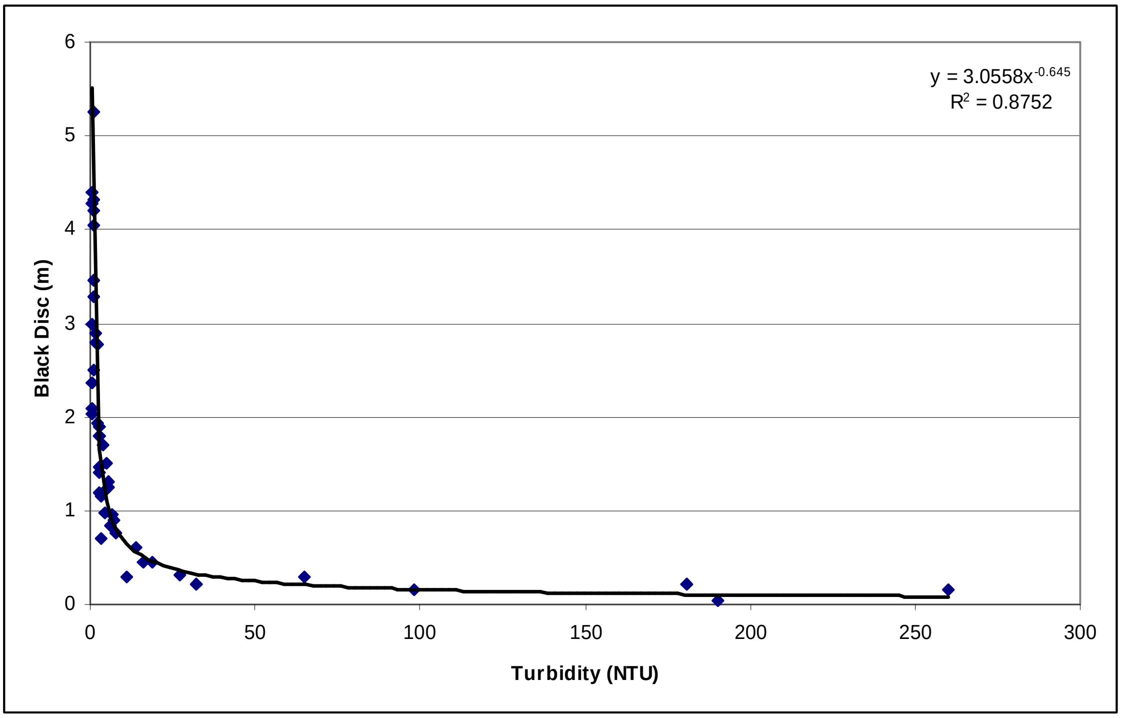

Figure 10: Rangitikei at Vinegar Hill Turbidity vs. Black Disc

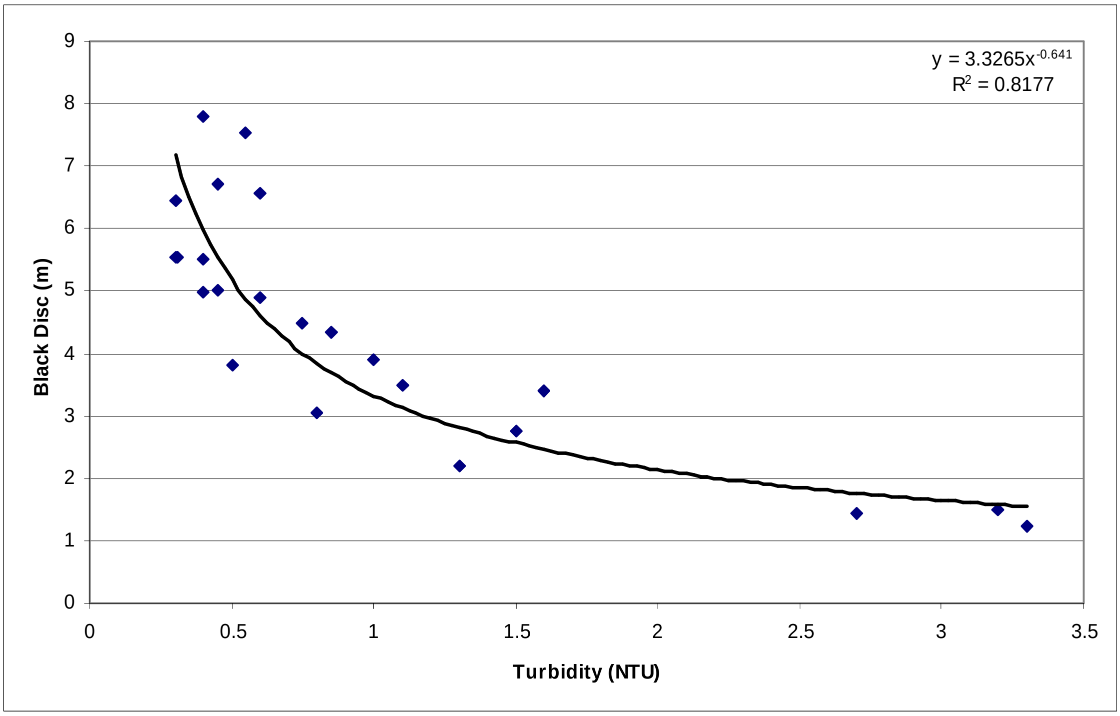

Figure 11: Mangatainoka at Putara Turbidity vs. Black Disc

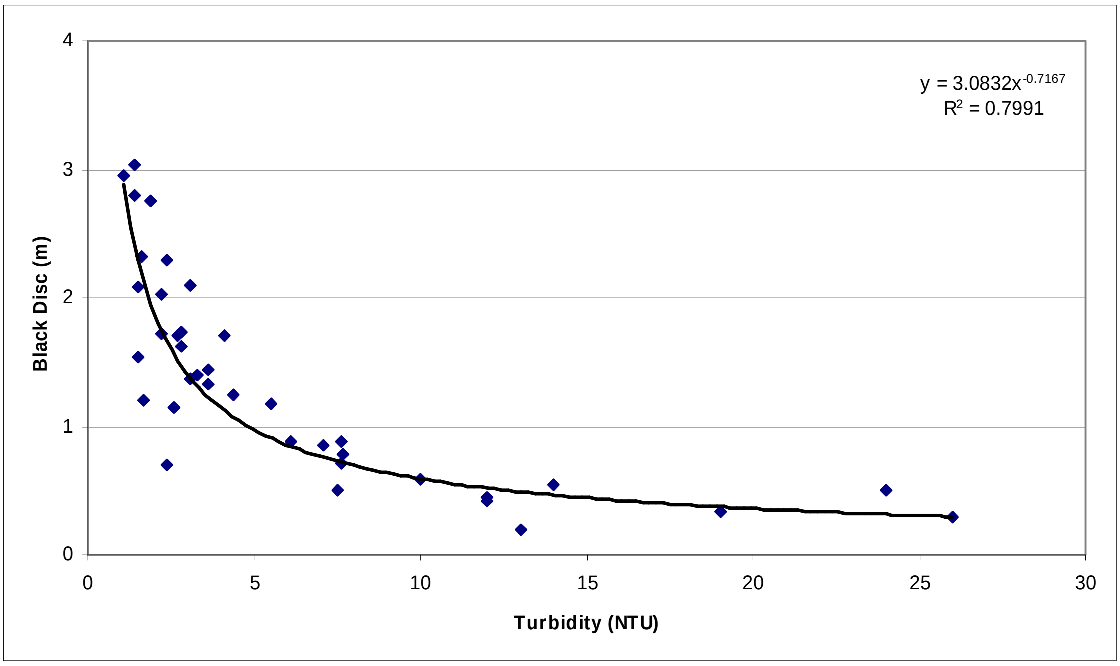

Figure 12: Hautapu at Taihape Turbidity vs. Black Disc

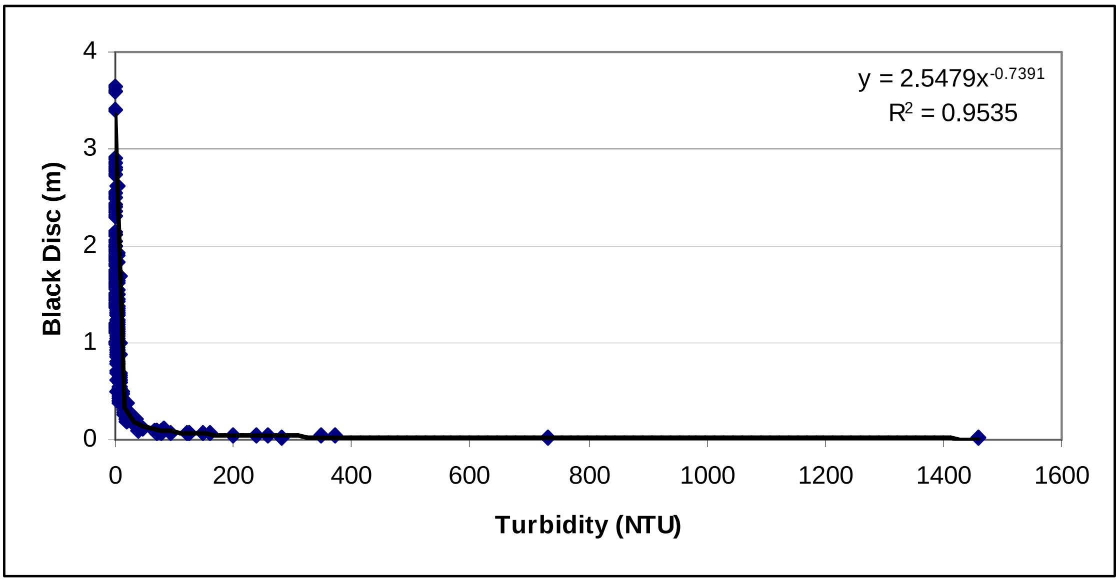

Figure 13: Manawatu at Weber Road Turbidity vs Black Disc

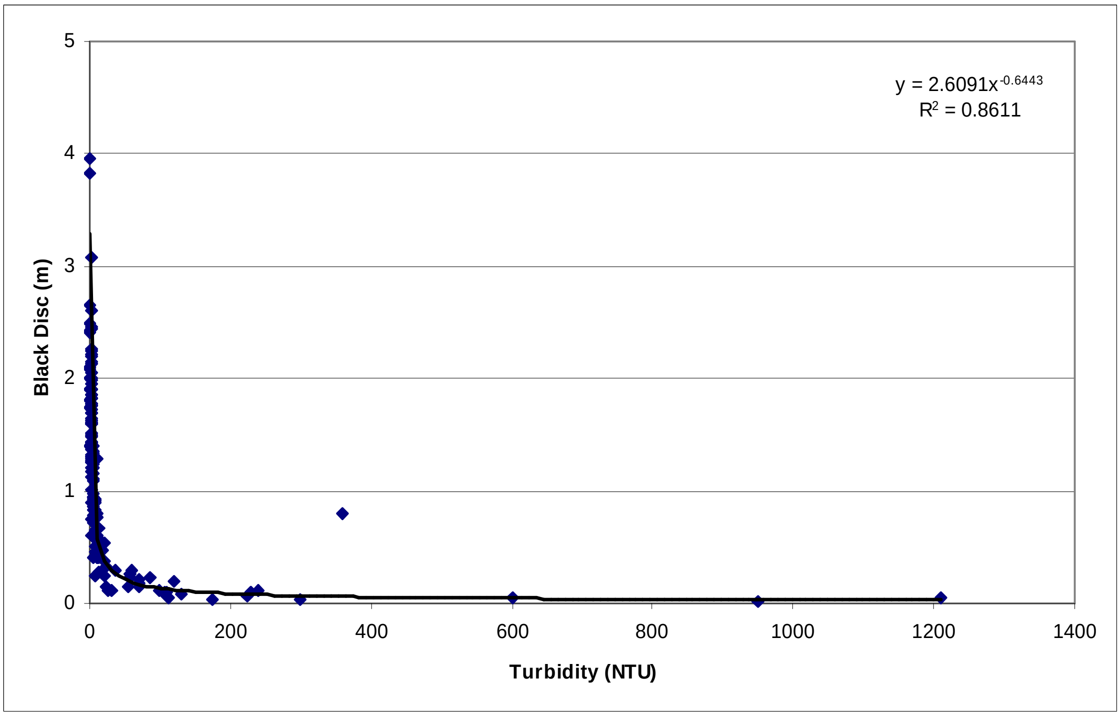

Figure 14: Manawatu at Hopelands Turbidity vs. Black Disc

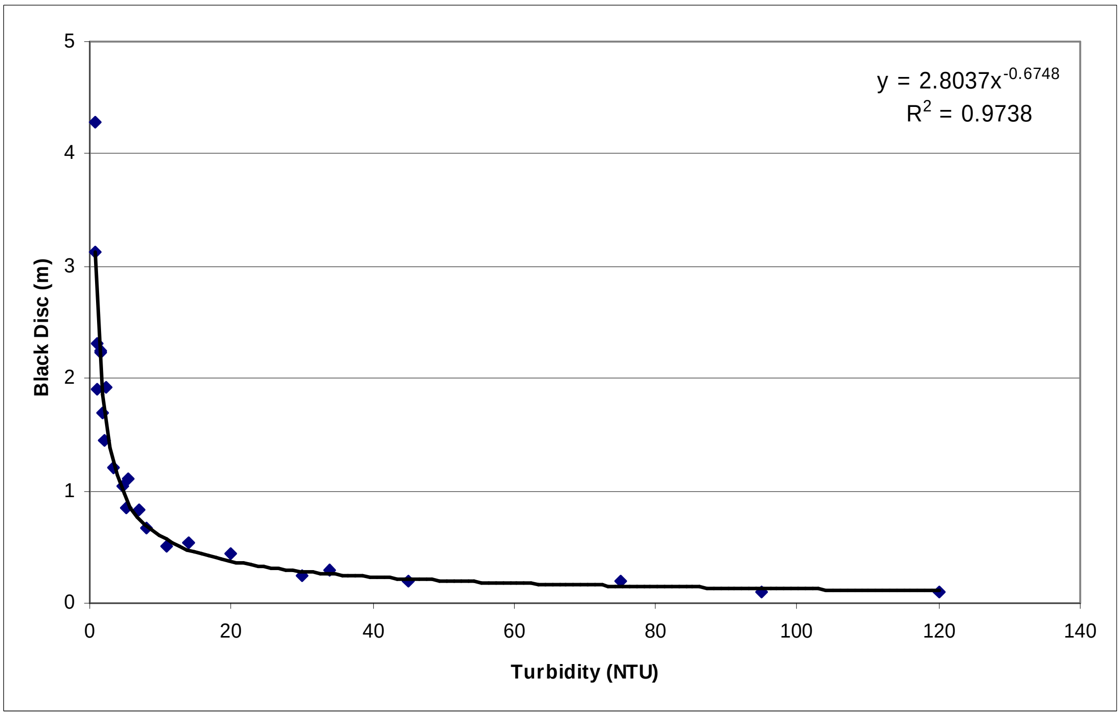

Figure 15: Makuri at Tuscan Hills Turbidity vs. Black Disc

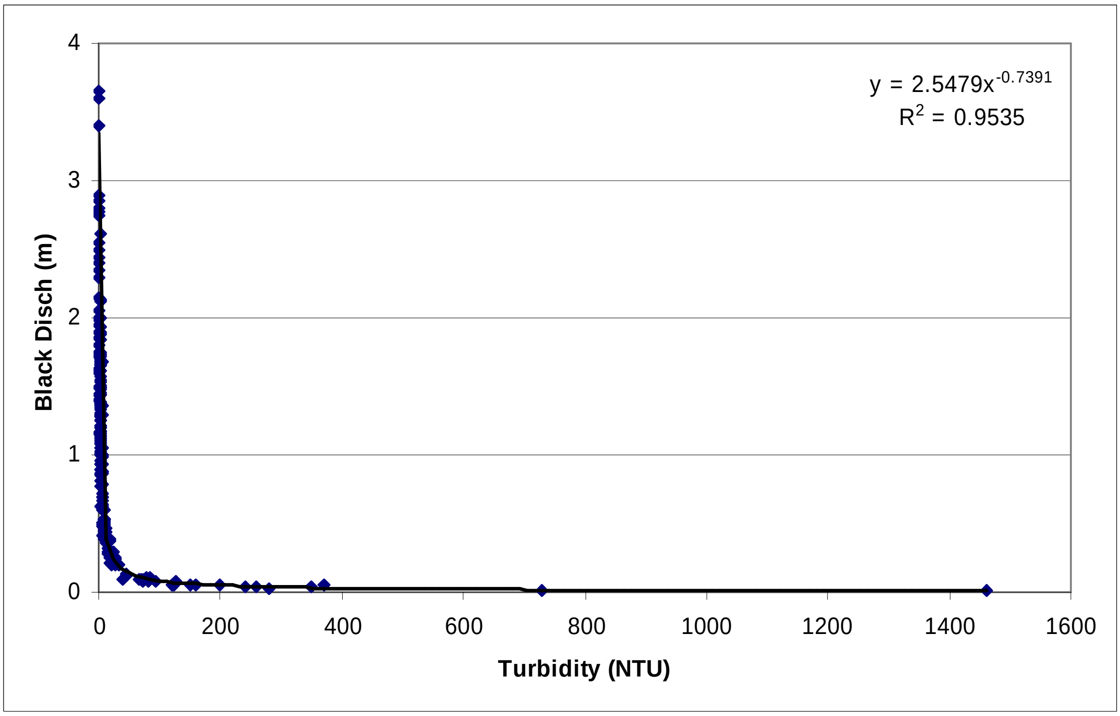

Figure 16: Manawatu at Teachers College (NIWA) Turbidity vs. Black Disc

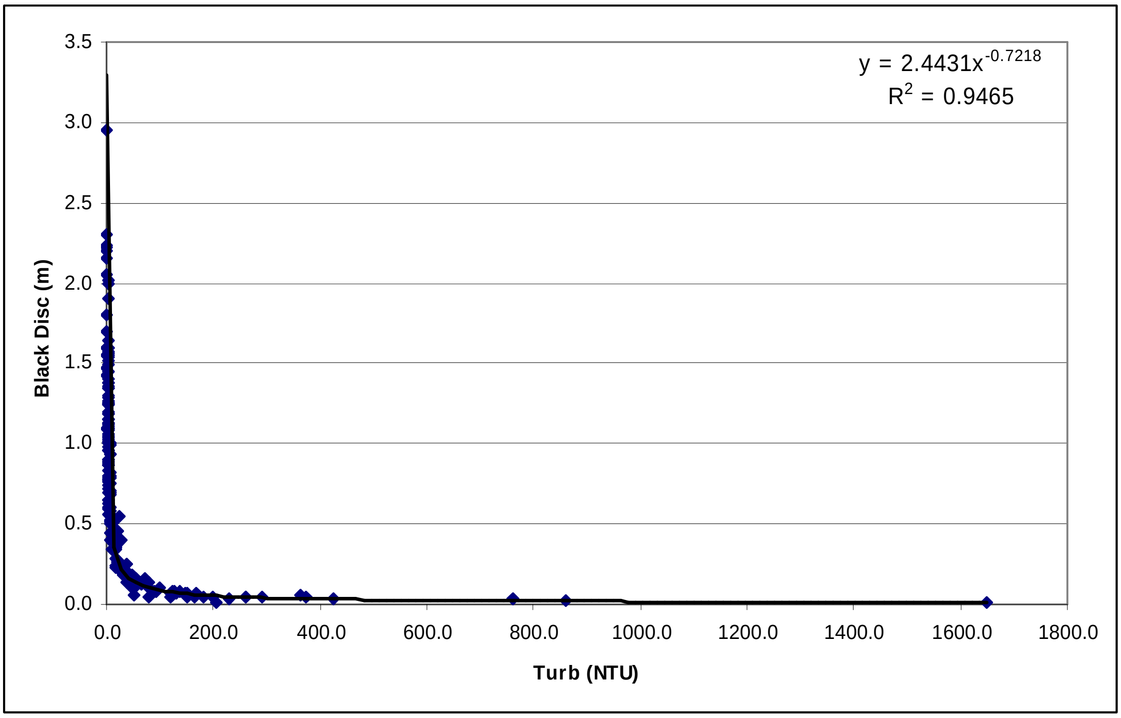

Figure 17: Manawatu at Opiki Bridge (NIWA) Turbidity vs. Black Disc

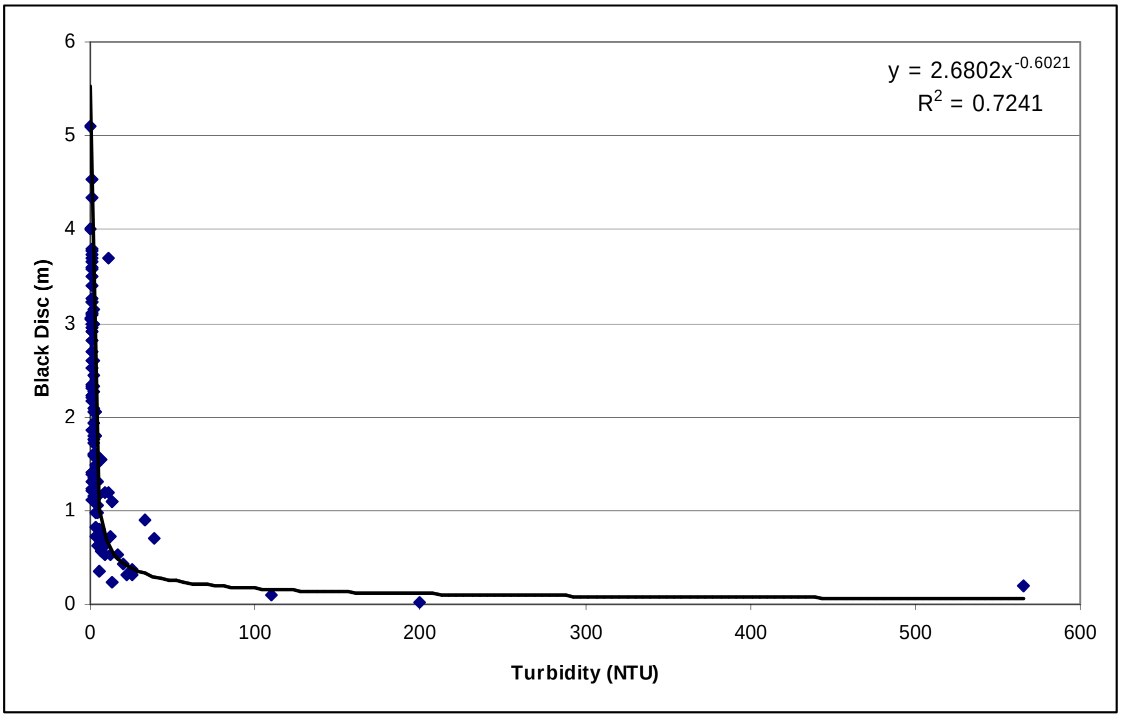

Figure 17: Whanganui at Cherry Grove Turbidity vs. Black Disc

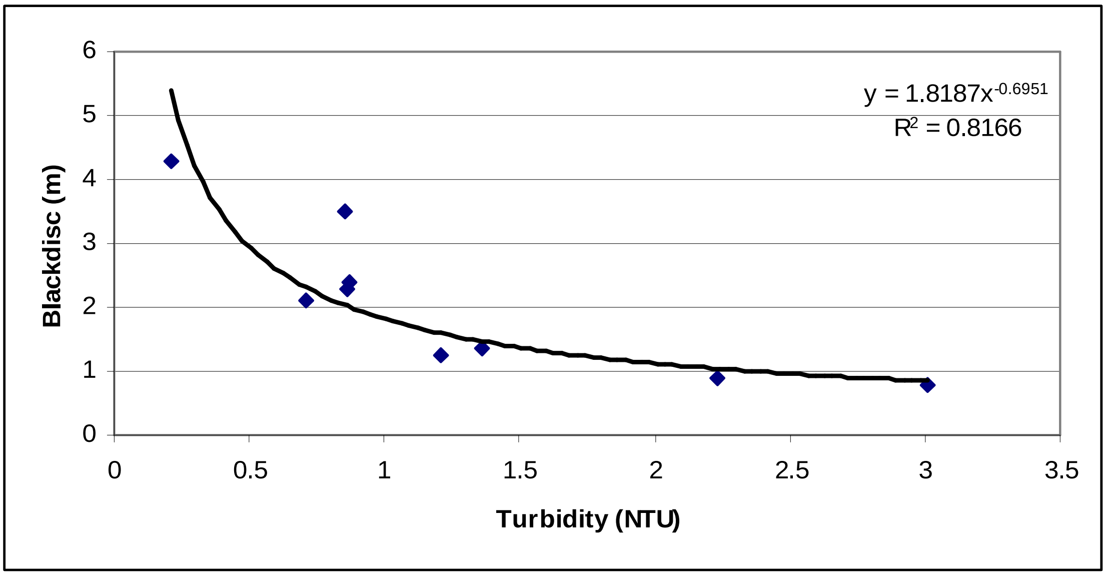

Figure 18: Makotuku u/s Raetihi Turbidity vs. Black Disc

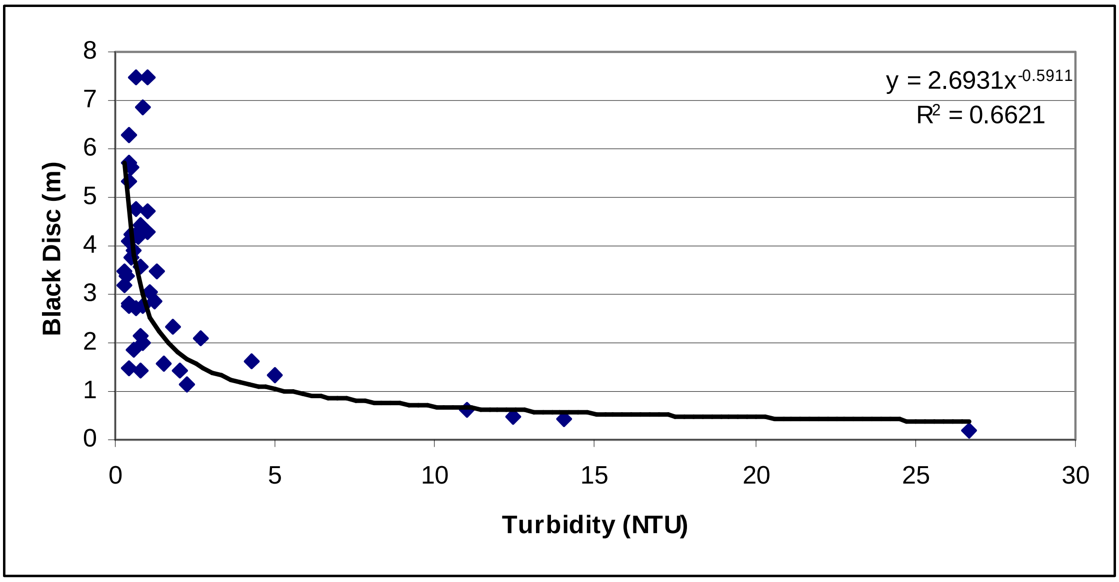

Figure 19: Ohau at Gladstone Reserve Turbidity vs. Black Disc

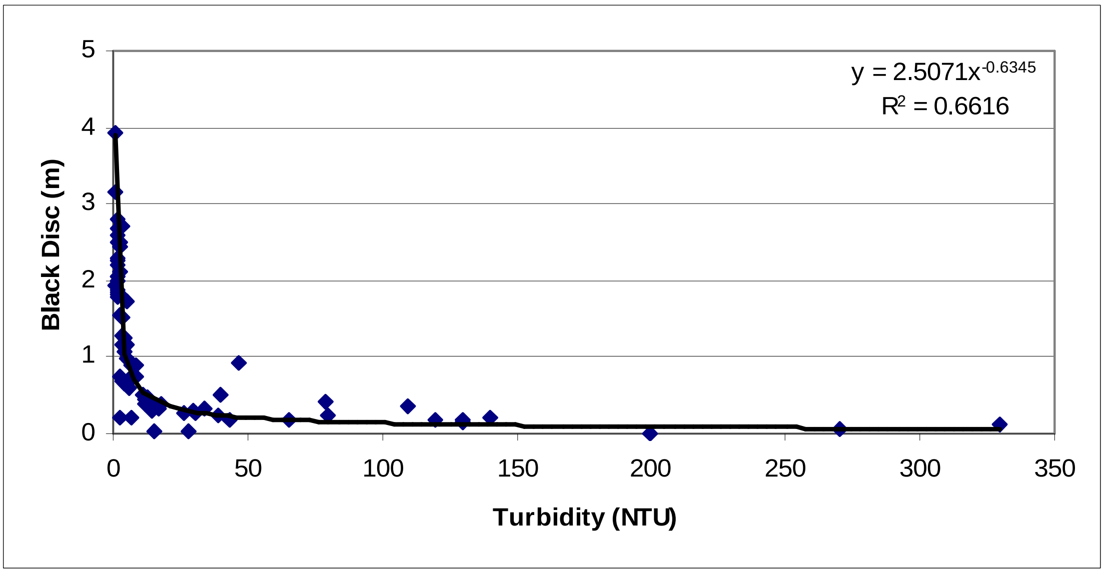

Figure 20: Whanganui d/s Retaruke Turbidity vs. Black Disc

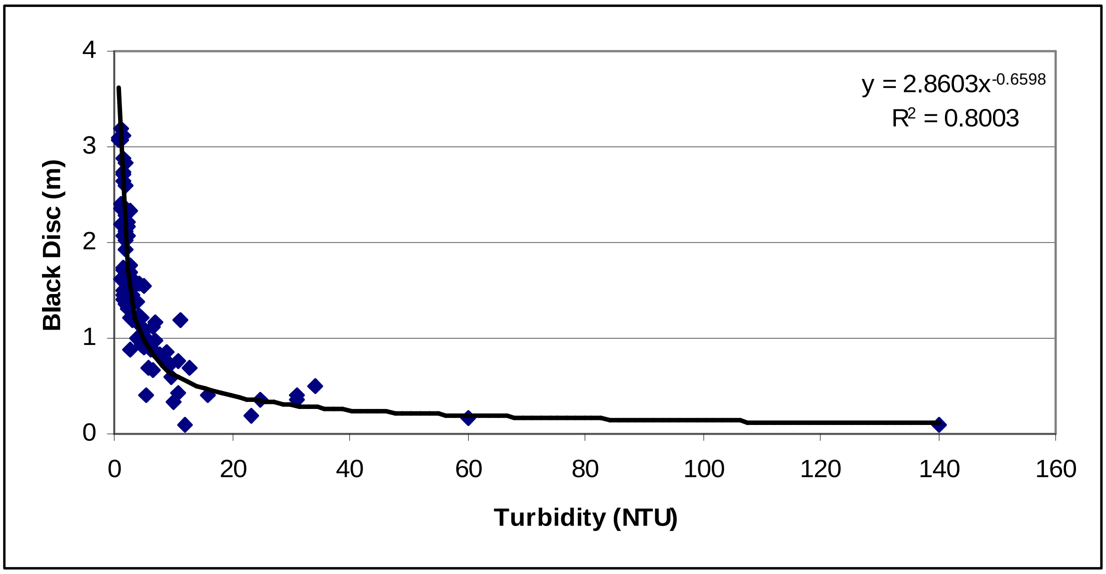

Figure 21: Makakahi at Konini Turbidity vs. Black Disc

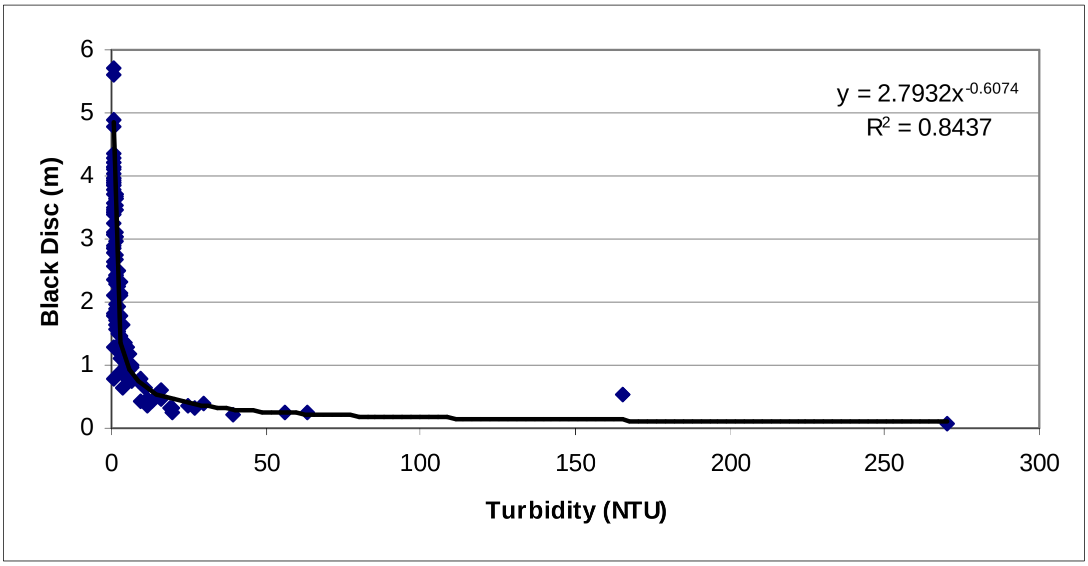

Figure 22: Mangatainoka at SH2 Turbidity vs. Black Disc

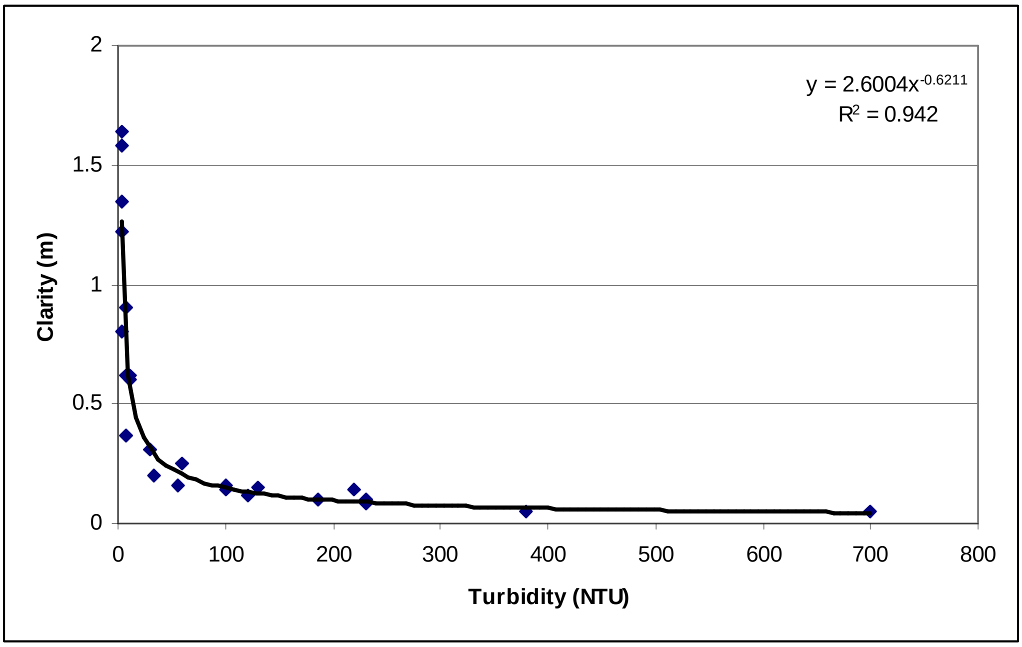

Figure 23: Akitio above Estuary Turbidity vs. Black Disc

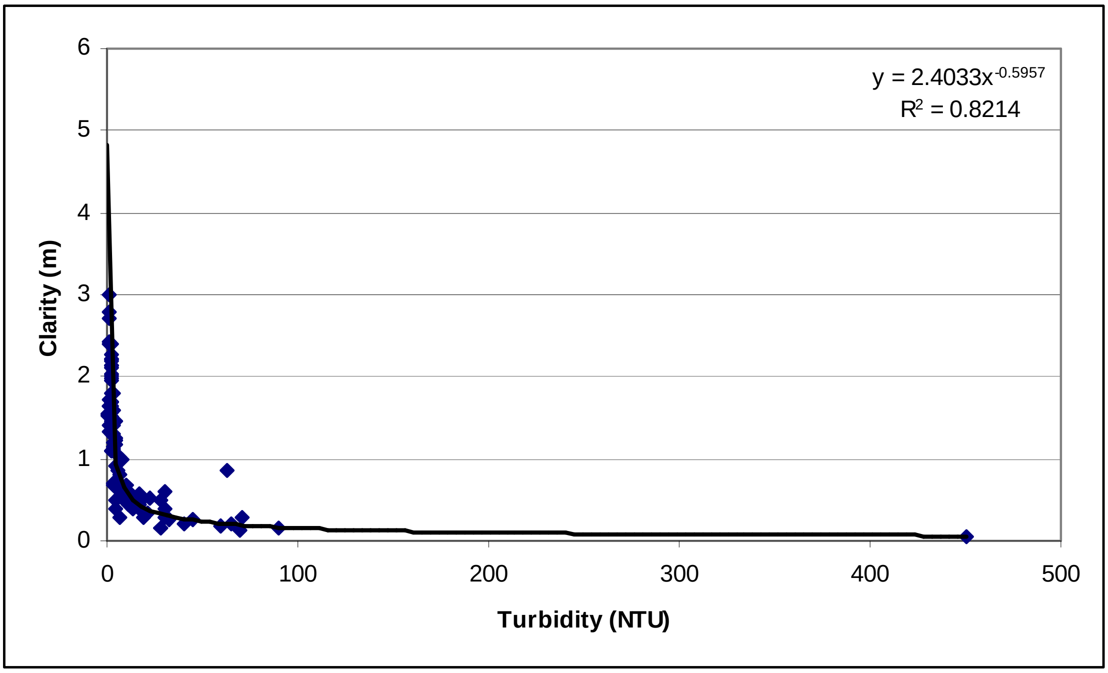

Figure 24: Hautapu upstream Rangitikei: Turbidity vs. Black Disc

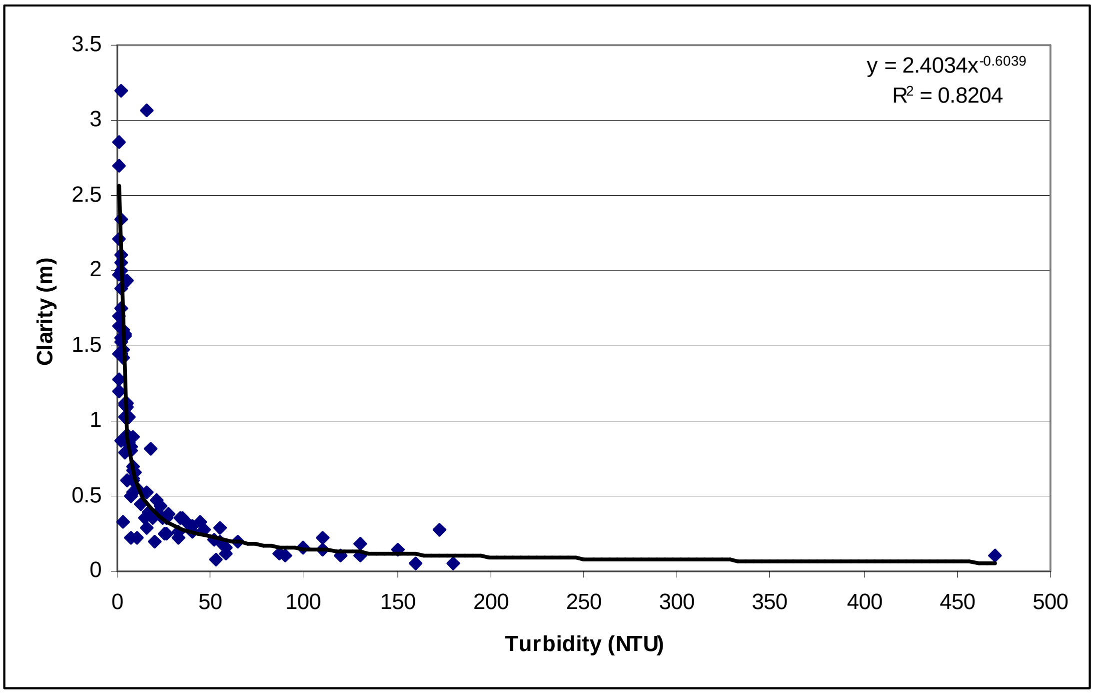

Figure 25: Whanganui at Pipiriki: Turbidity vs. Black Disc

D. Diurnal temperature variations during low river flows.

Table 1: Minimum and maximum diurnal temperature range during periods of low river flow (visually estimated from continuous temperature monitoring records)

LSC Class	Site	Min Change	Max Change
HM	Manawatu at Weber Rd	1	3.3
	Manawatu at Hopelands	1	6.8
	Oruakeretaki at SH2	0.9	7.2
	Raparapawai	1.8	12.7
	Makakahi at Hamua	1	3.1
	Manawatu at Upper Gorge	0.4	5.5
	Pohangina at Mais Reach	1.2	8
	Manawatu at Teachers College	0.7	4.8
	Kiwitea at Spur Rd Extn	2.1	9.1
	Rangitikei at Mangaweka	1.2	5.3
	Rangitikei at Onepuhi	1.4	5.4
HSS	Owahanga at Branscombe	1	5.5
	Akitio at Weber Rd	1.3	11.5
	Tiraumea at Ngaturi	1	3
	Whangaehu at Kauangaroa	0.7	3.5
LM	Makino at Boness Rd	2	4.8
	Manawatu at Foxton	1.7	7.2

Appendix 3: Periphyton biomass and QMCI values recorded at monitoring sites in the Manawatu–Wanganui Region

Table 1: Periphyton and QMCI values recorded at Monitoring Sites in the Manawatu – Wanganui Region

ND: No Data
NS: No Substrate

Site	Periphyton			QMCI		
	Mean (mg/m^2)	Max (mg/m^2)	No. of Samples	Mean	Max	No. of Samples
Manawatu at SH2	89	89	1	ND	ND	ND
Manawatu River at Weber Rd	30.4	38.7	2	4.86	5.22	2
Mangatoro at Mangahei Rd	126.5	126.5	1	4.97	4.97	1
Mangatera Confluence at Timber Bay	90	183.2	7	3.28	5.60	7
Tamaki at Reserve	5.7	8.9	3	7.87	8.01	3
Manawatu at Hopelands Reserve	126.5	239.7	7	4.49	6.33	7
Manawatu Above Oruakeretaki Confluence	19.2	19.2	1	ND	ND	ND
Tamaki at SH2	27.2	29.3	3	6.34	7.08	3
Raparapawai Stream at Jackson Rd	18	18	1	ND	ND	ND
Tiraumea at Katiawa Bridge	9.9	9.9	1	3.68	4.36	2
Makuri at Tuscan Hills	90.7	119	3	4.23	4.4	3
Mangatainoka at Putara	10.3	15.4	3	7.39	7.72	3
Mangatainoka at SH2	52.2	85.2	7	4.89	6.51	7
Makakahi at Konini	69	153.9	7	3.88	4.49	7
Makakahi at Hamua	64.8	64.8	1	3.19	3.19	1
Manawatu River at Ashhurst Domain	81.4	120	3	5.22	7.03	3
Manawatu at Upper Gorge	54.3	65.6	2	5.49	6.7	2
Mangapapa at Troop Rd Bridge	34.1	49.7	3	5.42	6.04	3
Mangahao at Kakariki	10.9	15.4	2	6.29	7.23	2
Mangahao at Ballance	20.9	35.9	3	5.73	6.43	3
Manawatu at Teachers College	27.4	50.6	3	5.31	5.89	3
Pohangina at Piripiri	10.2	16.6	2	6.3	7.24	2
Pohangina at Totara Reserve	8.3	8.3	1	7.49	7.49	1
Pohangina at Raumai Reserve	9.7	14.4	2	4.84	5.35	2
Pohangina at Mais Reach	10.6	10.6	1	6.65	6.65	1
Pohangina at Saddle Road Bridge	6.4	10.6	2	4.01	4.44	2
Manawatu at Maxwells Line up/s PNCC STP	77.7	137.2	4	4.74	5.84	4
Manawatu at Karere Rd	71.1	127.2	7	1.35	1.35	1
Manawatu at 42 Mile Hydro Station	ND	ND	ND	2.68	3.5	6
Manawatu at Opiki	32.8	59.5	3	2.32	3.27	3
Turitea Above Confluence	31.1	31.1	1	ND	ND	ND
Kahuterawa Above Confluence	19.2	19.2	1	4.27	4.27	1
Mangaone at Milson Line	79.8	120	3	3.95	4	3
Mangaone d/s landfill Higgins access Crossing	118.9	118.9	1	ND	ND	ND
Mangaone u/s Awapuni Landfill	87.9	87.9	1	ND	ND	ND
Oroua at Apiti Gorge Bridge	19.7	19.7	1	7.58	7.58	1
Oroua at Barrows Road	3	3	1	4.97	4.97	1
Oroua at Almadale	6.2	6.2	1	1.14	1.14	1
Oroua at Nelson St	37.2	56.7	7	4.58	6.55	7
Oroua at Main South Rd	9.4	9.4	1	6.98	6.98	1
Oroua at Awahuri Bridge	108.4	373.3	7	2.72	4.02	7
Kiwitea at SH54	28.7	28.7	1	3.16	3.16	1
Makino at South St	50.1	55.7	2	2.98	3.27	2
Makino at Reid Line	27.6	27.6	1	ND	ND	ND
Manawatu at Whirokino Boat Ramp	NS	NS	5	4.19	4.45	5
Tokomaru at Horseshoe Bend	25.1	28.5	3	5.83	6.65	2
Rangitikei at Springvale	4.2	5.6	2	4.50	4.93	2
Rangitikei at Pukeokahu	16.6	47.8	7	5.62	7.33	7

Site	Periphyton			QMCI		
	Mean (mg/m²)	Max (mg/m²)	No. of Samples	Mean	Max	No. of Samples
Rangitikei at Mangaweka	11.3	17.5	6	5.58	6.54	6
Moawhango and Moawhango	16.3	16.3	1	ND	ND	ND
Hautapu River at NIWA Station Taihape	ND	ND	ND	2.96	4.04	2
Hautapu at Taihape (motor camp)	189.4	355.7	2	ND	ND	ND
Hautapu at Alabasters	74.3	74.3	1	ND	ND	ND
Hautapu U/s Rangitikei Confluence	133.9	203.6	7	2.69	4.27	7
Rangitikei at Vinegar Hill	19.8	63.5	4	4.37	6.1	3
Makohine at Viaduct	98.8	268.8	3	2.61	2.89	2
Rangitikei at Onepuhi	15.9	15.9	1	ND	ND	ND
Rangitikei at Kakariki	25	53.9	7	5.38	6.82	7
Rangitikei at Scotts Ferry	60.6	92.3	4	4.06	4.39	5
Porewa U/s Hunterville Oxponds	75.7	75.7	1	ND	ND	ND
Porewa at SH1	73.6	73.6	1	ND	ND	ND
Porewa at Onepuhi Rd	128.2	212.5	3	5.29	6.06	2
Tutaenui at Curls Rd Bridge	95.2	136.6	2	4.14	4.62	2
Tutaenui at Parewanui Rd	67.3	67.3	1	ND	ND	ND
Whanganui at Headwaters	18.3	18.3	1	ND	ND	ND
Whanganui at Hohotaka Rd	10.8	10.8	1	ND	ND	ND
Whanganui at Cherry Grove	17.8	39.2	7	5.39	6.81	7
Whakapapa at Footbridge	ND	ND	ND	ND	ND	ND
Whakapapa Below TPD Intake	21.1	33.8	2	5.4	5.96	2
Whakapapa Below Te Rena Rd	27.3	27.3	1	ND	ND	ND
Piopiotea at Bullians Rd	ND	ND	ND	ND	ND	ND
Pungapunga at Kirton Rd Bridge	13.4	13.4	1	ND	ND	ND
Taringamotu at Oruaiwi Rd	17.3	17.3	1	6.78	6.78	1
Whanganui at Te Maire	34.8	67.1	7	3.99	5.37	7
Whanganui D/s Retaruke Confluence. (Wades Landing)	42.3	98.7	7	3.44	4.03	6
Retaruke U/s Whanganui Confluence	16.5	20.5	2	5.76	5.76	1
Whanganui at Pipiriki	54.9	82.6	7	2.97	3.63	7
Manganui o te Ao at Hoihenga Rd	24.5	27.8	3	7.35	7.35	2
Manganui o te Ao at Ruatiti Domain	51.6	51.6	1	ND	ND	ND
Whanganui at Kaiwhaiki	NS	NS	4	4.96	5.50	5
Upokongaro above confluence	20.7	20.7	1	ND	ND	ND
Matarawa Above Confluence	20.6	20.6	1	ND	ND	ND
Whanganui at Estuary	41.5	41.5	3 (2 NS)	5.27	4.96	5
Whanganui at Whakahoro	ND	ND	ND	4.04	4.04	1
Waitangi at Tangiwai	17.9	17.9	1	ND	ND	ND
Tokiahuru Above Confluence	78.5	78.5	1	ND	ND	ND
Whangaehu at Kaungaroa	NS	NS	1	1.38	1.38	1
Makotuku at Railway Bridge	9.9	15.9	2	7.42	7.69	2
Makotuku River U/s Raetihi Water Supply Take	16.2	16.2	1	ND	ND	ND
Makotuku River D/s Raetihi Water Supply Take	21.5	21.5	1	ND	ND	ND
Makotuku U/s NZ Energy Take	41.5	41.5	1	ND	ND	ND
Makotuku D/s NZ Energy Take	17.9	17.9	1	ND	ND	ND
Makara at SH4	36.2	36.2	1	ND	ND	ND
Makotuku U/s Raetihi	79.2	79.2	1	ND	ND	ND
Makotuku D/s Raetihi Oxpond	69.6	69.6	1	ND	ND	ND
Makotuku Above Confluence	15.6	15.6	1	ND	ND	ND
Mangawhero at DoC Headquarters	10.9	22.7	7	7.76	8.51	7
Taonui Stream at Old Mangarewa Rd	78.5	78.5	1	ND	ND	ND
Mangawhero Pakihi Rd Bridge	22.3	22.3	1	ND	ND	ND
Mangawhero D/s Makotuku Confluence	89.5	157.7	6	2.62	3.12	7
Mangawhero at Raupiu Rd	47.3	47.3	1	ND	ND	ND
Turakina at Otairi	79.8	79.8	1	ND	ND	ND
Turakina at SH3 Bridge	24.8	57.2	3	3.27	4.37	2
Ohau at Gladstone Reserve	15.9	24.7	3	5.18	6.05	3
Ohau at Haines Property	27.2	29.6	3	4.72	6.32	3
Owahanga at Branscombe Bridge	31.5	59.6	2	4.52	5.03	2

Site	Periphyton			QMCI		
	Mean (mg/m²)	Max (mg/m²)	No. of Samples	Mean	Max	No. of Samples
Akitio at Weber Rd Bridge	61.4	107.8	2	5.49	6.58	2
Akitio Above Estuary	21.4	34.3	2	3.8	4.10	2
Waikawa New Flow Site	ND	ND	ND	ND	ND	ND
Waikawa D/s Manukau	37.5	38.3	2	5.34	6.48	2

horizons regional council

11-15 Victoria Avenue
Private Bag 11 025
Manawatu Mail Centre
Palmerston North 4442

T 0508 800 800
F 06 952 2929
help@horizons.govt.nz
www.horizons.govt.nz