Recommended water quality limits for rivers and streams managed for Aquatic Ecosystem Health in the Wellington Region

June 2013

aquanet consulting ltd

Recommended water quality limits for rivers and streams managed for Aquatic Ecosystem Health in the Wellington Region

June 2013

Report prepared for Greater Wellington Regional Council by:

Dr Olivier Ausseil
Senior Water Quality Scientist
Aquanet Consulting Limited

Peer-review:

Dr Ned Norton, Resource management Consultant, NIWA

Dr Roger Young, Freshwater Ecologist, Cawthron Institute

Acknowledgments to:

Summer Greenfield, Senior Environmental Scientist, Water Quality & Freshwater Ecology;

Alton Perrie, Environmental Scientist, Water Quality & Freshwater Ecology

Juliet Milne, Team Leader, Environmental Science

Greater Wellington Regional Council

Revision Schedule:

Revision N.	Date	Description	Reviewed by
1	June 2011	First draft	Summer Greenfield
2	August 2012	Final draft	Dr Roger Young Dr Ned Norton
3	June 2013	Final Report	-

EXECUTIVE SUMMARY

Greater Wellington Regional Council (GWRC) is in the process of developing technical recommendations to support the Council's second generation Regional Plan. This report is one in a series of technical reports on the Wellington region's streams and rivers, destined to inform and support the policy development process.

This report makes recommendations relating to water quality limits for streams and rivers managed for aquatic ecosystem health. This specifically corresponds to the water quality requirements of New Zealand native aquatic ecosystems, including but not limited to, fish and aquatic macroinvertebrates. The Freshwater Environments of New Zealand (FWENZ) classification adapted for the Wellington region (Warr 2009, 2011) has been used as the spatial framework for this work, and the recommended water quality limits are designed to give effect to the biological limits defined by Greenfield (2013a, 2013b) for each of the eleven FWENZ river classes.

The biological limits defined by Greenfield (2013a, 2013b) relate to two levels of protection for ecosystem health: "healthy" and "significant" ecosystems. For the purpose of this report and the technical recommendations it contains, the "healthy" aquatic ecosystem is taken as the default management objective, applicable to all streams and rivers within each class. "Significant" aquatic ecosystems correspond to a higher level of protection.

The water quality limits recommended in this report for each river class are summarised in Table A below. Together with the biological limits recommended by Greenfield (2013a, 2013b) they provide a comprehensive set of limits for the maintenance of aquatic ecosystem values.

A number of other freshwater management purposes, such as contact recreation, amenity and trout fishery have also been identified in the Wellington Region. Separate technical reports make recommendations for biological and water quality limits in relation to these management purposes (Ausseil, 2013a and b). One should also refer to the report that recommends in-stream nutrient limits (Ausseil, 2013c) to give effect to the different periphyton limits defined in relation to the different management purposes mentioned above.

In order to present a comprehensive and consistent set of recommended biological and water quality limits for each water body, catchment or any other freshwater "management unit" that may be defined, for inclusion in the regional plan, the following steps are recommended:

- identify and compile the management purposes that apply to each "management unit";
- compile all biological and water quality limits that apply to each management purpose in each "management unit";
- for each biological and water quality determinand, identify a limit that will enable the maintenance of all management purposes (i.e. generally the most stringent limit for each determinand).

It is also recommended that existing stream and river monitoring data be compared with the limits recommended in the different reports in this series, to assess the current state of the region's streams and rivers in relation to the different management purposes.

Table A: Summary of water quality limits recommended for the Aquatic Ecosystem management purpose. (N/A: Not Applicable).

Water quality determinand	FWENZ class	Aquatic Ecosystem Value "Healthy"	Aquatic Ecosystem Value "Significant"	Limit application
Temperature (°C, Daily maximum)	A, B, C8	21°C	21°C	Year round, all river flows
	C5, C1, C6b	20°C	20°C	
	C7, C10, UR	19°C	19°C	
	C6a	21°C	20°C	
	C6c	23°C	21°C	
Temperature Change	A, B, C8, C6a, C6c	±3°C	±2°C	Year round, all river flows
	C5, C1, C6b, C7, C10, UR	±2°C	±2°C	
pH (range)	A	5.8-7.8	6.1-7.5	Year round, all river flows
	B	N/A	N/A	
	C5, C1, C6b	6.4-8.9	6.7-8.6	
	C8	6.8-8.7	7.1-8.4	
	C7, C6a, C10, UR	5.8-8.5	6.1-8.2	
	C6c	5.8-8.7	6.1-8.4	
pH Change	All	±0.5	±0.5	Year round, all river flows
Dissolved Oxygen (% Saturation, daily minimum)	A, C8, C6c, B	60%	70%	Year round, all river flows
	C5, C1, C6b	70%	70%	
	C7, C10, UR	80%	80%	
	C6a	70%	80%	
$ScBOD_5$ (mg/L, maximum daily average)	All	2 mg/L	2 mg/L	Year round, River flows < median
POM (mg/L, maximum average)	All	5 mg/L	5 mg/L	Year round, River flows< median
Visual clarity (m, minimum, default limit)	All	0.5m	0.5m	Year round, River flows< 3 × median
Visual clarity (m, minimum, class-specific limits)	A, B	1.3m	1.6m	Year round, River flows< median
	C5, C1, C6b	1.3m	1.9m	
	C8, C6c	0.5m	0.8m	
	C7, C10, UR	1.8m	2.2m	
	C6a	1.6m	2.2m	
Visual clarity change (% change, maximum)	C7, C10, UR	20%	20%	Year round, all river flows
	A, C8, C6c, B, C5, C1, C6a, C6b	33%	20%	
Total Ammonia-N (**Chronic**) (mg/L, maximum average concentration) At pH=8.0, Temp=20°C	C1, C10, UR, B	0.900	0.320	Year round, all river flows
	A, C5, C6a, C6b, C6c, C7 C8	0.320	0.320	
Total Ammonia-N (**Acute**) (mg/L, maximum concentration) At pH=8.0, Temp=20°C	C1, C10, UR, B	7.5	7.5	Year round, all river flows
	A, C5, C6a, C6b, C6c, C7 C8	4.3	4.3	Year round, all river flows
Other toxicants (protection level)	All	95%	99%	Year round, all river flows

CONTENTS

Table of Contents

1 Introduction 1
1.1 Background 1
1.2 Aim and scope 1
1.3 Policy context 3
1.3.1 RMA 3
1.3.2 National Policy Statement – Freshwater Management 2011 3
1.3.3 Existing Regional policy 5
1.3.4 Greater Wellington's proposed Regional Policy Statement 5
1.3.5 Other regional plans 5
1.3.6 Management purposes 6
2 Data and methods 10
2.1 River classes 10
2.2 Biological limits 10
2.3 Monitoring data 13
2.4 General principles and methodology 13
2.4.1 General guiding principles 13
2.4.2 General methodology 14
3 Recommended water quality limits 15
3.1 Water temperature 15
3.1.1 Background 15
3.1.2 Effects of temperature on aquatic life 15
3.1.3 Approaches to determining environmental temperature limits 15
3.1.4 Existing water temperature limits 18
3.1.5 Re commended water temperature limits 18
3.1.6 Notes on applicability and compliance assessment of temperature limits 21
3.2 Water pH 22
3.2.1 Background 22
3.2.2 Bibliography 22
3.2.3 Recommended water pH limits 23
3.2.4 Application of water pH limits 23
3.3 Dissolved Oxygen 24

3.3.1 Background ... 24
3.3.2 Bibliography ... 25
3.3.3 Recommended dissolved oxygen limits ... 25
3.3.4 Notes on applicability and compliance assessment of DO limits ... 28
3.4 Organic matter ... 29
3.4.1 Biochemical Oxygen Demand (BOD) ... 29
3.4.2 Particulate Organic Matter (POM) ... 29
3.5 Water clarity and colour ... 30
3.5.1 Background ... 30
3.5.2 Bibliography ... 31
3.5.3 Recommended visual clarity limits ... 32
3.5.4 Notes on water clarity monitoring methods and compliance assessment ... 36
3.5.5 Conclusions ... 36
3.6 Ammonia ... 37
3.6.1 Background ... 37
3.6.2 Bibliography ... 37
3.6.3 Recommended chronic limits ... 38
3.6.4 Recommended Acute limits ... 40
3.6.5 Application of ammonia limits ... 41
3.7 Nitrate ... 41
3.8 Other toxicants ... 42
3.8.1 Application of toxicant limits ... 42
4 Conclusions and recommendations ... 44

Tables

Table 1: Summary of determinands relevant to the Aquatic Ecosystem value. 2

Table 2: Summary of numerical water quality standard, guidelines or targets to protect ecological values in selected operative or proposed regional plans. 7

Table 3: Summary of biological limits recommended by Greenfield (2013a, 2013b) for rivers and streams to be managed for aquatic ecosystem purposes, for two levels of protection: "significant" and "healthy" aquatic ecosystems. 10

Table 4: Summary of FWENZ classification in the Wellington Region and typical characteristics of streams within each class (adapted from Greenfield, 2013a and Ausseil 2011). 11

Table 5: Calculated long-term maximum acceptable temperature for 11 common macroinvertebrate species, based on published 96h LT_{50}, corrected to account for diurnal temperature variations (3-6°C), based on Cox and Rutherford (2000) and a 3°C safety margin, as per Simons (1986). 17

Table 6: Long-term maximum acceptable temperature for 8 common native fish species, based on Richardson *et al.* (1994) results applied to the maximum permissible temperature for long-term exposure (USEPA, 1986a). Fish presence in the different classes is based on NZFFD records. 17

Table 7: Recommended water temperature limits for waters to be managed for "significant" and "healthy" aquatic ecosystems in the different stream and river classes in the Wellington Region. The "measured range" columns represent water temperature measured as part of the RSoE monitoring programme (95^{th} percentile of data measured at each site, July2204 to June 2009). 21

Table 8: Recommended water pH limits for waters to be managed for "significant" and "healthy" aquatic ecosystems in the different stream and river classes in the Wellington Region. The "measured range" columns represent the range of pH measured as part of the RSoE monitoring programme (5^{th} and 95^{th} percentile of data measured at each site, July2004 to June 2009). 24

Table 9: Dissolved Oxygen concentrations (mg/L) recommended by the USEPA (1986b) to confer five levels of protection for waters containing "other life stages" (i.e. not early life stages) salmonids (adapted from Dean and Richardson 1999), and corresponding DO saturation at different temperatures. 24

Table 10: Recommended DO limits for waters to be managed for "significant" and "healthy" aquatic ecosystems in the different stream and river classes in the Wellington Region. The "measured range" columns represent DO measured as part of the RSoE monitoring programme (5^{th} percentile of "spot measurement" data at each site, July2004 to June 2009). 26

Table 11: Recommended visual clarity and receiving visual clarity change limits for the different FWENZ river classes in the Wellington Region. Data in italics corresponds to sites where flow data were not available. The overall median visual clarity value is reported for these sites. 35

Table 12: Recommended visual clarity limits for the main rivers in the Wellington Region. 35

Table 13: Recommended chronic total ammonia-N concentration (mgN/L) limit for classes of water where *S. novaezelandiae* is absent, at different water pH and temperature. 39

Table 14: Recommended chronic total ammonia-N concentration (mgN/L) limit for classes of water where *S. novaezelandiae* is present, at different water pH and temperature. 39

Table 15: Indicative chronic total ammonia-N limits in the different river classes, based on the ranges of 95^{th} percentile of water temperature and pH data measured at RSoE sites in each river class (July 2004 to June 2009 period). N.D.: No data. 39

Table 16: Recommended acute total ammonia-N concentration (mgN/L) limit for classes of water where *S. novaezelandiae* is present, at different water pH and temperature. 40

Table 17: Recommended acute total ammonia-N concentration (mgN/L) limit for classes of water where *S. novaezelandiae* is absent, at different water pH and temperature. 41

Table 18: Recommended levels of protection for the use of the numerical trigger values in Table 3.4.1 of the ANZECC (2000) Guidelines to set water quality limits for toxicants in the different stream and river classes in the Wellington Region. 43

Table 19: Summary of recommended water quality limits for waters managed for Aquatic Ecosystems. 45

1 Introduction

1.1 Background

Greater Wellington Regional Council (GWRC) is in the process of developing technical recommendations to support its second generation Natural Resources Regional Plan. This report is one in a series of technical reports on the Wellington region's streams and rivers, destined to inform and support the policy development process.

The term "limit" is used in this report as a generic term to describe a numeric or narrative threshold that defines a particular state for a river or stream. The way in which these limits will be used in the Regional Plan is a policy decision and is outside the scope of this report. In particular, it is important to note that since this report was initiated, the form of GWRC's regional plan process has changed from a 'traditional' single stage plan process to a two-stage 'collaborative' process. It is expected the two-stage process will involve firstly a regional plan which will include river and stream objectives appropriate at a regional scale and secondly collaborative development of catchment or 'whaitua' based river and stream objectives and resource use limits. This means that some of the instream 'limits' identified in this report will be used to inform the first stage, i.e. the definition of regional scale river and stream objectives, while some will be considered during the collaborative 'whaitua' second stage. Identification of at what stage the limits proposed here will be considered is outside the scope of this report.

This report makes recommendations relating to water quality limits for streams and rivers managed for aquatic ecosystem health. The Freshwater Environments of New Zealand (FWENZ) classification adapted for the Wellington region (Warr 2009, 2011) has been used as the spatial framework for this work, and the water quality limits recommended in this report are designed to give effect to the biological limits defined by Greenfield (2013a, 2013b) for streams and rivers managed for two levels of aquatic ecosystem health.

This report should be read in conjunction with the other reports in the series, which recommend biological and water quality limits for waters managed for trout fishery and trout spawning (Ausseil, 2013a) and contact recreation, amenity and stock drinking water values (Ausseil, 2013b). Finally, one should refer to the report that recommends in-stream nutrient limits (Ausseil, 2013c) to give effect to the different periphyton limits defined in relation to each management purpose mentioned above.

1.2 Aim and scope

The aim of this report is to provide recommended water quality limits for streams and rivers[1] to be managed for the purpose of aquatic ecosystem health in the Wellington region. This specifically corresponds to the water quality requirements of New Zealand native aquatic ecosystems, including but not limited to, fish and aquatic macroinvertebrates. Exotic components of the stream and river ecosystems are not covered in this report – water quality limits for the protection of trout fisheries are recommended in a separate report (Ausseil 2013a).

The river classification exercise undertaken by Warr (2009, 2011), has identified 11 stream and river classes in the Wellington region. A key component of the project brief for this report was to provide recommended water quality limits for each of these classes.

Greenfield (2013a, 2013b) identified biological limits, namely numerical limits for macroinvertebrate community index (MCI) and periphyton biomass, for the protection of aquatic ecosystem health. The limits defined by Greenfield (2013a, 2013b) relate to two levels of protection of ecosystem health:

[1] This specifically excludes lakes, wetlands, estuaries and coastal waters.

"healthy" and "significant" ecosystems. For the purpose of this report and the technical recommendations it contains, the "healthy" aquatic ecosystem is taken as the default management objective, applicable to all streams and rivers within each class. "Significant" aquatic ecosystems correspond to a higher level of protection.

The key aim of this report is thus to provide recommended water quality limits for "healthy" and "significant" aquatic ecosystems within each of the 11 river classes.

This report covers the list of water quality determinands identified in Table 1. Biological determinands, such as macroinvertebrate communities and periphyton are relevant to the aquatic ecosystem values, but are covered in specific, separate reports, and are consequently not dealt with in this report. Dissolved nutrients are also relevant to aquatic ecosystem values, but are specifically considered in a separate report (Ausseil, 2013c).

The recommendations relating to water quality limits for deposited sediments and toxicants (other than ammonia) are kept general in this report. Detailed examination of toxicant guidelines is undertaken as part of a separate project (Pawson and Milne, 2011). Since this report was initiated in 2010 and primarily written in 2010/2011, guidelines published after that time have not been considered in this report. This concerns in particular the sediment assessment protocols (Clapcott *et al*. 2011), the review of the instream plant and nutrient guidelines (Matheson *et al.*, 2012) and some additional work undertaken by NIWA on nitrate toxicity (e.g. Hickey, 2013). Similarly this report does not reference or consider recent changes in Regional Plan provisions (such as summarised in Table 3) and/or recent technical work on water quality limits.

Table 1: Summary of determinands relevant to the Aquatic Ecosystem value.

Main issue	Water quality determinand	Notes
Physico-chemical stressors	pH	This report
	Temperature	This report
	Dissolved oxygen	This report
	Water clarity	This report
Sediment	Turbidity	This report
	Total Suspended Solids	This report
	Deposited fine sediments	This report
Toxicants	Ammonia	This report
	Nitrate	This report
	Other toxicants	This report, Pawson and Milne (2011)
Organic enrichment and Eutrophication	Algal biomass/cover	Covered in a separate report (Greenfield, 2013b)
	Heterotrophic growths	
	Organic matter (BOD, COD, TOC, DOC, etc…)	This report
	Dissolved nutrients (DIN, DRP)	Covered in a separate report (Ausseil, 2013c)
Macroinvertebrate communities	MCI/QMCI	Covered in a separate report (Greenfield, 2013a)
	MCI/QMCI change	

1.3 Policy context

1.3.1 RMA

The purpose of the Resource Management Act (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 RMA relate specifically to the management of the water resource and the protection of aquatic ecosystems.

Sections 70(1) and 107(1) set five narrative standards in relation to 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.

Section 69 enables the following approaches to rules relating to water quality:

- Section 69(1) refers to Schedule 3, which defines 11 water classes, corresponding to management purposes. Schedule 3 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;

In addition, Section 69(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.

The narrative standards for Aquatic Ecosystems in the Third Schedule to the RMA provide essential guidance for the definition of water quality limits in the context of this work. As indicated later in Section 1.3.4 of this report, Greater Wellington Regional Council's proposed RPS directs that the narrative standards for aquatic ecosystems will be used as the basis for establishing limits for water quality. The Third Schedule standards relative to the Aquatic Ecosystem Class read as follows:

"Class AE (being water managed for aquatic ecosystem purposes)

(1) The natural temperature of the water shall not be changed by more than 3 ^{o} Celcius

(2) The following shall not be allowed if they have an adverse effect on aquatic life:

(a) Any pH change;

(b) Any increase in the deposition of matter on the bed of the water body or coastal water;

(c) Any discharge of a contaminant into the water.

(3) The concentration of dissolved oxygen shall exceed 80% saturation concentration

(4) There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water"

1.3.2 National Policy Statement – Freshwater Management 2011

On 12th May 2011, a National Policy Statement (NPS) for freshwater management was gazetted. The NPS's preamble identifies values that:

"relate to recognising and respecting fresh water's intrinsic values for: safeguarding the life-supporting *capacity of water and associated ecosystems; and sustaining its potential to meet the reasonably foreseeable needs of future generations. Examples of these values include:*

- *the interdependency of the elements of the freshwater cycle*
- *the natural form, character, functioning and natural processes of water bodies and margins, including natural flows, velocities, levels, variability and connections*

- *the natural conditions of fresh water, free from biological or chemical alterations resulting from human activity, so that it is fit for all aspects of its intrinsic values*
- *healthy ecosystem processes functioning naturally*
- *healthy ecosystems supporting the diversity of indigenous species in sustainable populations […]"*

The NPS contains five main parts relating to: A. Water quality, B. Water Quantity, C. Integrated Management, D. Tangata whenua role and interests and E. Progressive implementation programme. In Part A. (Water quality), Objectives A1 and A2 set the overall objectives, whilst Policy A1 directs every regional council to establish freshwater objectives and set freshwater quality limits for all bodies of fresh water in their region. Policy A2 directs the regional councils to set targets where water bodies do not meet the freshwater objectives.

The text of Objectives A1 and A2 and Policies A1 and A2 is reproduced below for use of reference.

> *"Objective A1*
> *To safeguard the life-supporting capacity, ecosystem processes and indigenous species including their associated ecosystems of fresh water, in sustainably managing the use and development of land, and of discharges of contaminants.*
>
> *Objective A2*
> *The overall quality of fresh water within a region is maintained or improved while:*
> *a) protecting the quality of outstanding freshwater bodies*
> *b) protecting the significant values of wetlands and*
> *c) improving the quality of fresh water in water bodies that have been degraded by human activities to the point of being over-allocated.*
>
> *Policy A1*
> *By every regional council making or changing regional plans to the extent needed to ensure the plans:*
> *a) establish freshwater objectives and set freshwater quality limits for all bodies of fresh water in their regions to give effect to the objectives in this national policy statement, having regard to at least the following:*
> *i) the reasonably foreseeable impacts of climate change*
> *ii) the connection between water bodies*
> *b) establish methods (including rules) to avoid over-allocation.*
>
> *Policy A2*
> *Where water bodies do not meet the freshwater objectives made pursuant to Policy A1, every regional council is to specify targets and implement methods (either or both regulatory and non-regulatory) to assist the improvement of water quality in the water bodies, to meet those targets, and within a defined timeframe."*

1.3.3 Existing Regional policy

GWRC has an operative Regional Freshwater Plan (1999) with specific policies that manage the water quality of all surface water bodies for the following identified purposes:

- aquatic ecosystems (all water bodies)
- contact recreation (identified water bodies)
- natural state (identified water bodies)
- trout fishery and fish spawning (identified water bodies)
- water supply (identified water bodies).

Both narrative and prescriptive receiving water quality guidelines associated with each water quality purpose are identified in appendices that are linked to each relevant policy (although the guidelines are very limited, reflecting the date of the plan). Some water bodies that are known to be degraded are identified separately as needing enhancement, so that water quality guidelines for aquatic ecosystems, contact recreation or fishery and fish spawning purposes are met.

1.3.4 Greater Wellington's proposed Regional Policy Statement

GWRC's proposed Regional Policy Statement sets the proposed directions for the management of natural resources in the region, including freshwater quality (GWRC, 2010)[2]. Of particular relevance to this work is:

Policy 11

"Regional Plans will establish limits for water quality, flows and water levels that safeguard aquatic habitats and ecosystems in water bodies.
The narrative standard for aquatic ecosystems in the Third Schedule to the Resource Management Act will be used as the basis for safeguarding what is needed for aquatic ecosystem protection in terms of water quality."

Policy 11 also indicates that some water bodies may also be managed for other purposes, such as trout fishery, contact recreation, water supply, groundwater protection or cultural purposes. Where more than one management purpose is assigned to a waterbody, water quality "*shall not be less than the limits established for aquatic ecosystem health*".

Policy 17 requires the regional plan to include policies, rules and/or methods that protect significant indigenous ecosystems and habitats, rivers and lakes.

Appendix 1 lists the rivers and lakes with significant amenity and recreational values, and, of particular relevance to this report, the rivers and lakes with significant indigenous ecosystems.

1.3.5 Other regional plans

Most Regional Councils in New Zealand have produced regional policy statements and regional plans. Although most regional policy statements and regional plans identify management objectives and/or values associated with waterbodies, only a relatively small number of regions have operative or proposed instream numerical water quality limits. One of the first regional plans to contain numerical water quality standards was the Manawatu Catchment Water Quality Regional Plan, which became operative in 1998. It contains a number of "general" water quality standards, as well as standards relating to specific management purposes, including contact recreation, fishery and fish spawning, as summarised in Table 2.

---

[2] GWRC's Regional Policy Statement became operative in April 2013.

The Waikato Regional Plan (2007) also contains a small number of numerical water quality standards, although these primarily relate to the protection of recreational values (contact recreation and trout fishery).

More recently, Canterbury's Proposed Natural Resources Regional Plan (April 2011 version) contains numerical water quality and ecological objectives relating to the protection of a number of management purposes, including aquatic ecosystems of indigenous flora and fauna.

The Regional Water Plan for Southland (2010) contains water quality standards to ensure that the water bodies are suitable for a number of values, including native fish and healthy aquatic habitat. One of the objectives (Objective 4) of the Plan is to achieve measurable improvement in surface water quality in four of its stream/river classes. Objective 4 sets a minimum of 10 % improvement over 10 years in levels of four key water quality determinands: microbiological contaminants, nitrate, phosphorus and clarity.

The Manawatu-Wanganui combined Regional Policy Statement and Regional Plan, the Proposed One Plan, was notified in 2008. Submissions on the notified plan were heard and the panel decision released in August 2010. The Proposed One Plan (2010) includes a framework of 19 river values (ecological, recreational and cultural, consumptive use and social and economic values) and water quality targets, superimposed over a spatial framework constituted of 44 water management zones and 117 water management sub-zones. The Proposed One Plan values framework sets that the Life Supporting Capacity (LSC) numerical biological and water quality targets apply to all natural waterbodies in the region (Table 2). The One Plan is currently under appeal to the Environment Court.

1.3.6 Management purposes

Policy 11 in the Proposed RPS sets that water bodies shall be managed as a minimum for the purpose of maintaining or enhancing aquatic ecosystem health. Policy 11 also indicates that some water bodies may also be managed for other purposes, such as trout fishery, contact recreation, water supply, groundwater protection or cultural purposes. Where more than one management purposes is assigned to a waterbody, water quality "*shall not be less than the limits established for aquatic ecosystem health*". The proposed RPS (Appendix 1) also lists rivers with significant indigenous ecosystems.

For the purpose of this report and the technical recommendations it contains, aquatic ecosystem health is therefore considered as a "bottom line" management purpose, which applies to all streams and rivers in the Wellington Region. The "significant aquatic ecosystem" management purpose corresponds to a higher level of protection, applicable only to the waterbodies listed in the proposed RPS Appendix 1. The approach taken by Greenfield (2013a and 2013b) is consistent with the Proposed RPS.

Table 2: Summary of numerical water quality standard, guidelines or targets to protect ecological values in selected operative or proposed regional plans.

Region	Plan	Values/	Determinand	Limit	Comment
Manawatu-Wanganui	Manawatu Catchment Water Quality Regional Plan	"General" standards	Water clarity change	30%	MCWQ Rule 1 "general" standards are a numerical translation of Section 70(1) and 107(1) of the Act Standards apply at all times
			Colour change	10 points (Munsell scale)	
			Euphotic depth	20% reduction	
			Total Ammonia-N	0.8 mg/L at T ≥ 15°C 1.1 mg/L at T < 15°C	
			$ScBOD_5$	2 g/m^3	
		Contact recreation standards	Sewage Fungus	No visible growth	MCWQ Rule 2 Standards are primarily for the purpose of contact recreation, although the plan states that they have benefits for aquatic life. Standard apply at or below half median flows Standards apply at flows below half median flow
			(POM)	5 g/m^3	
			Periphyton cover	40% (mats + filam. >2cm)	
			Periphyton biomass	100 mg/m^2 (Chlorophyll *a*)	
			Water clarity	1.6m	
	One Plan (2010)	LSC (Life Supporting Capacity)	pH	[7 - 8.2] to [7 -8.5]	Applies at all times. Water management zone-specific target
			Temperature *(max daily)*	19°C to 24°C	
			DO *(min. daily)*	60% to 80%	
			$ScBOD_5$ (*monthly average*)	1.5 to 2 mg/L	Applies at flows below 20^{th} flow exceedence percentile. Water management zone-specific target
			POM (average)	5 mg/L	Applies at flows below median flow. Identical target for all water management zones
			QMCI	20% change	Applies at all times. Identical target for all water management zones
			MCI	100 to 120	Applies at all times. Water management zone-specific target
			Periphyton biomass	50 to 200 mg/m^2 (Chlorophyll *a*)	
			DRP	0.006 to 0.015 mg/L	Applies at flows below 20^{th} flow exceedence percentile. Water management zone-specific target
			DIN	0.070 to 0.444 mg/L	
			Total Ammonia-N	0.320 to 0.400 mg/L	Average concentration, applies at all times
				1.7 to 2.1 mg/L	Maximum concentration, applies at all times.
			Toxicants	95 to 99 %	2000 ANZECC Guidelines protection level
			Water clarity	1.6 to 3.4m	Applies at flows below median. Water management zone-specific target
			Water clarity change	20 to 30%	Applies at all times. Water management zone-specific target

Region	Plan	Values/	Determinand	Limit	Comment
Southland	Regional Water Plan for Southland	Native fish Aquatic habitat Trout	pH	[6.5 – 9.0] to [7.2 - 8.0]	Applies at all times. Class-specific standard
			Temperature *(max daily)*	21°C to 23°C	Applies at all times. Class-specific standard
			Temperature (change)	1 to 3°C	Allowable temperature changes depends on background temperature
			DO *(min. daily)*	80% to 99% 5 to 6 mg/L	Applies at all times. Class-specific standard
			Total Ammonia-N	0.32 to 0.9 mg/L	pH–dependant standard Applies at all times. Class-specific standard
			Periphyton biomass	50 to 120 mg/m^2 (Chlo *a*) 35 g/m^2 (AFDW)	Applies at all times. Class-specific standard
			Periphyton cover	30% (filamentous. >2cm)	Applies at all times. Class-specific standard
			Sewage Fungus	No visible growth	This standard applies to within the zone of reasonable mixing
			Water clarity	1.6 to 3 m	Applies at flows below median flow. Class-specific standard
			sQMCI	4.5 to 5.5	Applies at all times. Class-specific standard
			MCI	90 to 100	
Canterbury	Natural Resources Regional Plan (NRRP – October 2010)		pH	6.5 to 8.5	Standard, applicable to consented activities
			Temperature *(max daily)*	20°C	Objective
			Temperature (change)	2°C	Standard, applicable to consented activities
			DO *(min. daily)*	70% to 90%	Numerical objective depends on waterbody class
			Toxicants	90 to 99 %	2000 ANZECC Guidelines protection level, Class-specific standard applicable to consented activities
			Periphyton biomass	50 to 200 mg/m^2 (Chlorophyll *a*)	Numerical objective depends on waterbody class
			Periphyton cover	10 to 30% (filamentous >2cm)	Numerical objective depends on waterbody class
			Macrophyte cover	20 to 30% (emergent) 30 to 60% (total)	Numerical objective depends on waterbody class
			Deposited sediment	10 to 40% cover	Numerical objective depends on waterbody class
			QMCI	3.5 to 6	Numerical objective depends on waterbody class
			Water clarity change	20 to 35%	Class-specific standard, applicable to consented activities
			Water colour change	5 to 10 pts (Munsell Scale)	

Region	Plan	Values/	Determinand	Limit	Comment
Waikato	Waikato Regional Plan (2007)	"Waikato Region Surface Water class"	Temperature (change)	3°C	General "Surface Water Class". The Waikato regional Plan also defines a number of narrative standards relative to changes in pH, water clarity, DO, deposited sediment and biological growths "if they have any significant adverse effects on aquatic ecosystems"
			TSS increase	10%	
			TSS in discharge	100 mg/L	
		Indigenous fisheries	Tot. Ammonia-N	0.88 mg/L	In Indigenous fisheries waters
			TSS in receiving environment	80 mg/L	

2 Data and methods

2.1 River classes

The spatial framework for this work is defined by the river classification recently undertaken by GWRC (Warr, 2009, 2011). This classification, based on an adapted version of the Freshwater Environments of New Zealand (FWENZ) framework (Leathwick *et al.*, 2008), resulted in the definition of 11 river classes (Table 3 and Table 4).

2.2 Biological limits

Greenfield (2013a, 2013b) identified interim biological limits with which to measure whether objectives set for the protection/maintenance of Aquatic Ecosystems are being achieved. These consist of numerical thresholds for macroinvertebrate communities and periphyton indicators in relation to "healthy aquatic ecosystems" and "significant aquatic ecosystems" for each FWENZ class (Table 3).

Limits relating to native fish indicators are currently under development (Summer Greenfield, pers. comm.)

Table 3: Summary of biological limits recommended by Greenfield (2013a, 2013b) for rivers and streams to be managed for aquatic ecosystem purposes, for two levels of protection: "significant" and "healthy" aquatic ecosystems.

GW FWENZ class	Stream length (km) (% of regional stream network)	MCI (average score)		Periphyton biomass (maximum biomass, in mg/m^2)	
		Significant	Healthy	Significant	Healthy
A	3299 (27%)	125	105	120	200
C5	3076 (25%)	130	105	50	120
C8	1867 (15%)	130	105	120	200
C7	1729 (14%)	130	120	50	50
C10	924 (8%)	130	115	50	50
C6a	426 (3.5%)	130	115	50	120
UR	356 (2.9%)	130	115	50	50
C1	279 (2.3%)	130	105	50	120
C6c	198.48 (1.6%)	120	100	120	200
C6b	17.45 (0.1%)	130	105	50	120
B	3.42 (0.03%)	125	105	120	200

Table 4: Summary of FWENZ classification in the Wellington Region and typical characteristics of streams within each class (adapted from Greenfield, 2013a and Ausseil 2011).

GW FWENZ class	Stream length (km)	Typical characteristics
A	3299 (27%)	Mostly small streams in coastal or inland locations with gentle gradients and generally silty or sandy substrates, although hard substrates (bed rock, cobble and/or gravel) are present at some stream reaches in this class.
C5	3076 (25%)	Small streams occurring in moderately coastal locations with mild, maritime climates and low frequencies of days with significant rainfall. Stream gradients are generally moderate and substrates are predominantly coarse gravels.
C8	1867 (15%)	Small inland streams with mild climates and a low frequency of days with significant rainfall, moderate gradients and generally coarse gravels substrate. Located in the eastern Wairarapa hill country and northern Tararua Ranges.
C7	1729 (14%)	Predominantly contains streams and rivers occurring in the lowland hills of the Tararua, Aorangi and Rimutaka Ranges, with mild climates and low frequencies of days with significant rainfall. Stream gradients are generally steep and substrates are generally coarse gravels. Contains sites in the upper reaches of the Region's main rivers, including the Otaki, Hutt and Ruamahanga Rivers and their tributaries.
C10	924 (8%)	Streams in the C10 class are small streams occurring in inland locations with cool climates and moderate frequency of days with significant rainfall. Gradients are generally very steep and substrates are generally cobbly. Typically small, mid-elevation streams in the Tararua, Rimutaka and Aorangi Ranges
UR	356 (2.9%)	Stream reaches located in the upper Tararua and Rimutaka Ranges. Almost all stream segments fall within DoC estate, and are unlikely to be affected by human activities
C1	279 (2.3%)	Small coastal streams with mild maritime climates and low frequency of days with significant rainfall. Stream gradients are generally very steep and substrates are predominantly coarse gravels. Small streams draining the south Wairarapa coast, Rimutaka Range and Kapiti Island.
C6 (Sum of C6a, C6b and C6c)	642 (5.2%)	Class C6 includes the mid and lower reaches of most of the major rivers in the Wellington region. These include rivers draining the Tararua, Rimutaka and Aorangi Ranges as well as those draining lower elevation, more soft sedimentary catchments in Kapiti and eastern Wairarapa.
C6a	426 (3.5%)	River sections with an upstream catchment dominated by class C7 streams, or sometimes C5 streams (e.g. Waikanae River). This includes streams and rivers fed by the Tararua, Rimutaka and Aorangi Ranges. This class is primarily represented by the lower reaches of the region's larger rivers, such as the Otaki, Hutt and Ruamahanga Rivers. These rivers generally have an open channel with cobble and gravel substrate and gentle gradient.
C6b	17.45 (0.1%)	A subset of the C6 class and is represented by C6 stream segments with the upstream catchment dominated by class C5 streams. Includes the Horokiri and lower Pauatahanui Streams, and some stream segments on the Wairarapa coast. Reference conditions for this class should be sought in the class C5 reference sites.
C6c	198.48 (1.6%)	A subset of the C6 class. C6c streams are C6 stream segments with the upstream catchment dominated by streams in class A or class C8. This includes streams on the Wairarapa and Kapiti Coasts as well as streams in the central Wairarapa valley.
B	3.42 (0.03%)	Very limited extent in the Wellington region and are restricted to three short segments in the Mangaroa Valley, one segment near Lake Wairarapa and one in Paraparaumu. The key characteristic of B group streams is that they have catchments with a high cover of peat and as such are likely to have distinctive ecological characteristics.

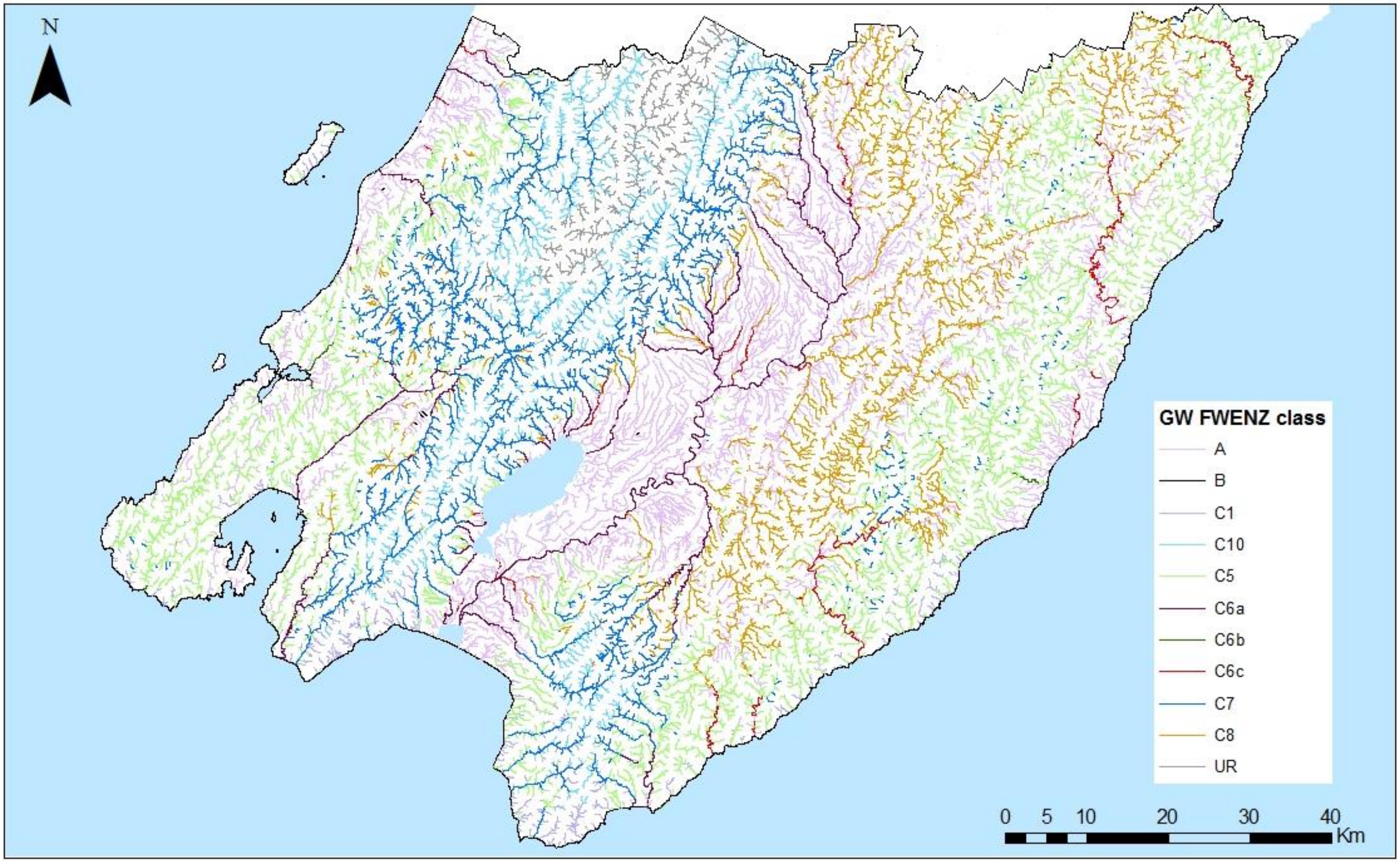

Figure 1: Spatial extent of the FWENZ classification in the Wellington Region (Source: Summer Greenfield, Greater Wellington regional Council.

2.3 Monitoring data

The development of water quality limits recommended in this report was supported by monitoring data summaries provided by GWRC. These monitoring data were collected as part of GWRC's RSoE monitoring programme during the period July 2004 to June 2009. GWRC's RSoE monitoring programme for this period included 56 river/stream sites across the Wellington region[3].

GWRC also continuously monitors river flow at 42 sites across the region. However, only 19 of these sites are directly associated with a SoE water quality monitoring site. GWRC has therefore undertaken work to provide flow estimates at many water quality sites. To provide an informative dataset for this work, GWRC have developed flow estimates for an extra 33 sites. The following data were made available for this study:

- Mean daily flow on each sampling day, available at 12 sites;
- A flow category estimate on each sampling day, given as one of four flow categories: below half median flow, half median flow to median flow, median flow to three times median flow and above three times median flow. Flow category data were available for 45 sites (including the 12 sites where mean daily flow data were available);

2.4 General principles and methodology

2.4.1 General guiding principles

As a general guiding principle, the water quality limits recommended in this report are designed to give effect to the macroinvertebrate community limits defined by Greenfield (2013a). They also need to take into account other components of the aquatic ecosystems, in particular native fish and plant communities. A summary of plant and macroinvertebrate community characteristics in each FWENZ class is provided in Appendix A. The current state, typical composition and desired state of native fish communities in the different FWENZ classes are being examined by GWRC and will be the focus of a future technical report.

Certain water quality limits may only need to apply in some places, at some times of the year, and/or under some river flow conditions. Where required, this report includes recommendations relating to the location and timing of their applicability.

Table 1 provides a list of water quality determinands that are relevant to the aquatic ecosystem health management purpose, and could potentially be used to define water quality limits. The relevance of each determinand to the management of aquatic ecosystems and the ability to define meaningful thresholds is examined in this report. Also relevant is Table 2, which provides a summary of water quality limits defined in operative or proposed regional plans in other regions of New Zealand.

As mentioned above, this report contains recommended water quality limits for "healthy" and "significant" aquatic ecosystems within each class. This basically corresponds to two different levels of protection within each stream/river type, with the "healthy" ecosystem limits corresponding to the "default" management objectives for the class, and the limits associated with "significant" ecosystems generally corresponding to a more stringent level of protection.

[3] Monitoring at RS01 (Mangapouri Stream at Rahui Rd) was discontinued in October 2009. As a result, the SoE water quality monitoring network currently comprises 55 sites.

2.4.2 General methodology

Three general methods or approaches were used to determine recommended water quality limits in this report:

- Where available in the scientific literature, the water quality requirements of key representative species were used. Appendix A summarises the typical physical habitat, macroinvertebrate communities and fish species in each FWENZ class. This generally appears the most appropriate method, as it allows a direct link between water quality determinand concentrations or levels and effects on aquatic life. Unfortunately, the number of studies directly relating to the tolerance of New Zealand native species to the different contaminants or stressors is very limited. Furthermore, the significance of some studies is limited by the fact they relate to short term, small scale experiments, and are unable to reliably represent the effects of long-term exposure or inter-species interactions. Appendix B summarises the known water quality requirements of some aquatic biota present in each FWENZ class for the Wellington region.
- 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 determinands. This is turn can be used to determine a natural baseline from which a degree of departure or change can be defined. This method has the advantage of using actual, site-specific data, and was used in this report to determine some water quality limits and/or to validate the results of the method above. In particular, the range of reference data is useful to check that the recommended limits are realistic in the context of each FWENZ class's natural characteristics. This approach is consistent with the recommendations of the ANZECC (2000) 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*".
- National and 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 Wellington Region's ecosystems, these guidelines can provide an excellent tool to define or support water quality limits. They also constitute the best fall-back position when there is not sufficient information to use either of the two methods above.

Generally speaking, all three approaches were considered for the determination of recommended water quality limits in this report. The final choice of the most appropriate method, or mix of methods, was made on the basis of information and data available for each water quality determinand. This approach is consistent with the recommendations of the ANZECC (2000) 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*".

3 Recommended water quality limits

3.1 Water temperature

3.1.1 Background

The functioning of aquatic ecosystems and their biological, chemical and physical processes are closely regulated by water temperature. An organism's growth, metabolism, reproduction, mobility and migration patterns may all be altered by changes in ambient water temperature (ANZECC, 2000). Temperature changes may occur as part of natural diurnal and seasonal cycles, or as a consequence of human activities. Water temperature in a stream or river typically fluctuates diurnally around a seasonal daily mean, with a faster rise to the mid-afternoon daily maximum temperature then fall to the daily 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 (e.g. 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.

3.1.2 Effects of temperature on aquatic life

It is well established that excessively elevated water temperatures can have detrimental effects on New Zealand stream fish and invertebrate communities (e.g. Richardson *et al.*, 1994; Quinn and Hickey, 1990). Parkyn *et al.* (2003) have also shown that the recovery of macroinvertebrate communities following riparian buffer planting was most strongly linked to decreases in water temperature.

The preferred water temperature and tolerance limits of a number of New Zealand native fish and macroinvertebrate species reported in the scientific literature are summarised in Appendix B. This table also contains an indication of the FWENZ classes each fish or invertebrate is typically found in.

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 NZ native fish species was found to vary from 16°C (smelt) to 26.9°C (shortfin eel elver), with most species between 18 and 22°C (Richardson *et al.* 1994). The temperatures fish species can tolerate for a short period of time are significantly higher: the 96h LT_{50}[4] calculated for the same fish species varied from 27 ^{o}C (koaro) to 39 ^{o}C (adult shortfin eel), with most species around 30 ^{o}C. These results are consistent with two previous studies (Teale, 1986 in Richardson *et al.*, 1994; Simons, 1986).

Some invertebrate species (particularly stoneflies and some mayflies) are more sensitive to elevated temperatures than others (e.g. worms and snails). The most sensitive stonefly and mayfly species have been found to have 96h LT_{50} ranging from 22 to 25°C (Quinn *et al.*, 1994)

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^{o}C, while *Ephemeroptera* biomass was lower at sites with a maximum temperature of 21.5°C.

3.1.3 Approaches to determining environmental temperature limits

Because of the established causal association between water temperature and the health of macroinvertebrate communities, recommended water quality limits defined in this report need to give effect to the macroinvertebrate limits defined for each FWENZ class by Greenfield (2013a). The

[4] The temperature at which 50% of individuals die in a 96h (4 day) period.

presence, or absence, of native fish species in each FWENZ class should also be taken into account when defining water quality limits.

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 an 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.

Acute tolerance data obtained in short-term laboratory experiments 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. Aquatic organisms can survive, within limits, at temperatures outside their optimal ranges, but physiological or behavioural changes may result and decrease their chances of survival and reproductive success (Reynolds, 1977 in Richardson *et al.*, 1994). For these reasons, it is not appropriate to directly use laboratory-obtained acute tolerance data to derive long-term environmental limits.

Another aspect to consider is the fact that laboratory studies usually use constant temperature conditions, which do not 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. Thus, where significant diurnal temperature variation occurs, acute effects of high temperatures are likely to only occur when the daily maximum temperature is higher than the LT_{50} derived from constant temperature experiments. Based on a typical summer diurnal temperature amplitude of 3 to 6°C[5], a correction of +0.75°C to +1.5°C should be applied to the LT_{50} to make them directly comparable with daily maximum values in a natural environment

There are several approaches available to determine water temperature thresholds. One approach commonly used to derive long-term upper thermal limits is 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). Table 5 provides a summary of long-term maximum acceptable temperatures for 11 common macroinvertebrate species calculated using this method.

A different approach incorporating the acute thermal tolerance data obtained from laboratory studies into environmental limits for natural waterbodies was developed by the USEPA[6], and also recommended in the ANZECC (2000) guidelines. This method uses the following formula to determine the maximum permissible temperature for long-term exposure (USEPA, 1986):

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

With: T_{lt} = maximum permissible temperature for long-term exposure

T_{og} = temperature for optimum growth

T_i= incipient lethal temperature

[5] Based on continuous temperature records available for sites RS05, RS10, RS20, RS24, RS34, RS38, RS45, RS46, RS47, RS50 and RS51.

[6] United States Environmental Protection Agency

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 6. It is noted that 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 5: Calculated long-term maximum acceptable temperature for 11 common macroinvertebrate species, based on published 96h LT_{50}, corrected to account for diurnal temperature variations (3-6°C), based on Cox and Rutherford (2000) and a 3°C safety margin, as per Simons (1986).

Taxon	Common name	Present in FWENZ classes	96h LT_{50} (°C)	Corrected 96h LT_{50} (Cox and Rutherford, 2000)	Long-term maximum temperature (3°c safety margin)
Zelandobius sp.	*Stonefly*	C5, C6a, C6b, C7, C8	25.5	26.3 – 27.0	23.3 – 24.0
Deleatidium sp.	*mayfly*	C5, C6a, C6b, C7, C8	24.2	25.0 – 25.7	22.0 – 22.7
Zephlebia sp.		A, C1, C5, C6a, C6b, C7, C8	23.6	24.4 – 25.1	21.4 – 22.1
Pycnocentria sp.	*caddisfly*	A, C5, C6a, C6b, C6c, C7, C8	25	25.8 – 26.5	22.8 – 23.5
Pycnocentrodes sp.		A, C5, C6a, C6b, C6c, C7, C8	32.4	33.2 – 33.9	30.2 – 30.9
Aoteapsyche sp.		A, C5, C6a, C6b, C6c, C7, C8, UR	25.9	26.7 – 27.4	23.7 – 24.4
Hydora sp.	*beetle*	A, C1, C5, C6a, C6b, C6c, C7, C8, C10, UR	32.6	33.4 – 34.1	30.4 – 31.1
Sphaerium sp.	*Fingernail clam*	A, C5, C6a, C6b, C6c, C7, C8	30.5	31.3 – 32.0	28.3 – 29.0
Potamopyrgus sp.	*snail*	A, C1, C5, C6a, C6b, C6c, C7, C8	31	31.8 – 32.5	28.8 – 29.5
Paracalliope sp.	*crustacean*	A, C1, C5, C6a, C6b, C7, C8	24.1	24.9 – 25.6	21.9 – 22.6
Paratya sp.		A, C1, C5, C6a, C6c	25.7	26.5 – 27.2	23.5 – 24.2

Table 6: Long-term maximum acceptable temperature for 8 common native fish species, based on Richardson *et al.* (1994) results applied to the maximum permissible temperature for long-term exposure (USEPA, 1986a). Fish presence in the different classes is based on NZFFD[7] records.

Species	Present in FWENZ classes	96h LT_{50}	Preferred temperature	Long-term maximum temperature
common Bully	A, B, C5, C6a, C6b, C6c, C7, C8	30.9°C	20.2°C	23.7°C
Cran's Bully:	A, C5, C6a, C6c, C7, C8	30.9°C	21°C	24.3°C
torrentfish	A, C5, C6a, C6b, C6c, C7, C8	30°C	21.8°C	24.5°C
inanga	A, C1, C5, C6a, C6b, C6c, C7, C8	30.8°C	18.1°C	22.3°C
smelt	A, B, C5, C6a, C6b, C6c, C7	28.3°C	16.1°C	20.2 to 21.4°C
banded kokopu	A, C1, C10, C5, C6a, C7, C8	29°C	17.3°C	21.2°C
longfin eel (elver)	A, C1, C10, C5, C6a, C6b, C6c, C7, C8, UR	34.8°C	24.4°C	27.8°C
shortfin eel (elver)	A, B, C1, C5, C6a, C6b, C6c, C7, C8	35.7°C	26.9°C	29.8°C

[7] New Zealand Freshwater Fish Database.

3.1.4 Existing water temperature limits

The Third Schedule of the RMA defines water temperature maximum (25°C) and maximum change (±3°C) for the protection of waters managed for fishery purposes, but not for waters managed for aquatic ecosystem purposes. The ANZECC Guidelines (2000) provide a framework to define water temperature limits, but do not provide numerical guidelines.

Water temperature limits for the protection of aquatic ecosystem values in existing and proposed Regional Plans in New Zealand are summarised in Table 2. Water temperature limits (as daily maximum temperature) range from 19 to 24°C, and temperature change limits range from 1 to 3°C.

3.1.5 Re commended water temperature limits

3.1.5.1 <u>Classes C7, C10 and UR</u>

Class C7 streams and rivers are upland rivers with macroinvertebrate communities characterised by high MCI scores, and a dominance of EPT taxa. The recommended MCI limit is a score of 115 for "healthy" ecosystems, and 130 for "significant" ecosystems. These are quite stringent limits, the highest limits of all FWENZ classes, which means that the recommended water temperature limits should correspond to a very low level of impairment.

The study conducted by Quinn and Hickey (1990) indicates that water temperatures above 19°C are likely to exclude stoneflies, and that temperatures in excess of 21.5°C are associated with losses 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.*, 1994; Cox and Rutherford, 2000). When applying the 3 ^{o}C safety margin, this provides maximum temperature limits of 19.6 to 21°C (Table 5). Cox and Rutherford (2000) found that constant temperatures LT_{50} 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 the very low level of impairment sought for this class.

Both field and laboratory observations point to thresholds between 19 and 20°C to avoid adverse effects on mayfly and stonefly populations. A temperature limit within this range would also provide for the requirements of most native fish species present in classes C7, C10 and UR (Table 6).

Monitoring data at C7 sites shows that 95th percentile temperature (based on spot measurements) at reference sites vary between 14.4°C and just below 19.0 °C. Non-reference sites present 95th percentile temperatures of 16.0 to 20.2°C.

Based on the above considerations, the recommended **daily maximum temperature limit** for C7 class streams and rivers is **19°C**. A lower temperature limit could be considered for "significant" aquatic ecosystems, but this would mean a limit more stringent than the temperature measured at some reference sites. It is considered that a daily maximum temperature of 19°C will provide sufficient protection to all ("healthy" and "significant") ecosystems within the C7 Class, and a different limit is not recommended for "significant" ecosystems.

Due to the dominance of temperature-sensitive families of invertebrates in typical C7 macroinvertebrate communities, a maximum **temperature change** limit of **2°C** is recommended.

No data are available on water temperature or macroinvertebrate communities in the C10 or UR Classes. A large proportion of both classes are located within conservation estate, and, as such, are expected to be covered by the "natural state" provisions of the Regional Plan, requiring that the water quality not be changed compared with its natural state. C7 streams are probably the closest type of streams with RSoE data available. For these reasons, it is recommended that the C7 water temperature limits also apply to C10 and UR Classes. This approach is consistent with that of other reports in the same series, which recommended the same macroinvertebrate and periphyton limits Greenfield (2013a, 2013b), and nutrient concentration limits (Ausseil 2011c) for the three classes.

3.1.5.2 Classes C5, C1 and C6b

Class C5 streams also have macroinvertebrate communities strongly dominated by EPT taxa, but have generally lower gradient and more coastal locations than C7 streams. The MCI limits for C5 streams are slightly lower than for C7 streams: 105 for "healthy" ecosystems and 130 for "significant" ecosystems.

The 95th percentiles of temperature data (spot measurements) at reference sites range from 15.3 to 19.1°C, and from 18.2 to 23.1°C in developed catchments.

A **daily maximum water temperature limit of 20°C** is recommended for C5 streams. This limit is consistent with protecting the temperature-sensitive taxa that are typically dominant in C5 macroinvertebrate communities, but also consistent with the reference data in this class. This limit should also provide for the requirements of native fish found in this class. Similarly to what was recommended for the C7 Class, the same limit should apply to both "significant" and "healthy" ecosystems within this class.

There are no reference temperature data available for C1 (no RSoE sites) and C6b (only one, non-reference RSoE site) Classes. Greenfield (2013a) recommended that C5 MCI limits should also be applied to C1 and C6b Classes, based on the fact that C1 and C6b streams' characteristics are most similar to those of C5 streams. A similar approach is recommended here.

Similarly to what was recommended for the C7 Class, and for the same reasons, a maximum **temperature change** limit of **2°C** is recommended.

3.1.5.3 Class C6a

The MCI limits recommended for the C6a Class "healthy" ecosystems are the same as for the C7 Class. However, Class C6a rivers and streams are generally located downstream of C7 Class stream segments, and are therefore expected to generally have higher water temperatures than C7.

A **daily maximum water temperature limit of 21°C** is recommended for "**healthy**" aquatic ecosystems in this class. This limit is set to be below the threshold temperature at which ephemeroptera biomass losses are likely (21.5°C, in Quinn and Hickey, 1990), and should also provide for the requirements of macroinvertebrate species present in this class (Table 5). Although this limit may not be ideal for stoneflies (Quinn and Hickey, 1990), occasional excursions above 19°C are unlikely to exclude stoneflies. This limit also provides for the requirements of all native fish species known to be present in this class of streams, whilst recognising that some temperature increases are expected between C6a and C7 stream segments.

The MCI limit recommended for "significant" aquatic ecosystems is the same for Classes C6a and C6b. A temperature limit of **20°C** is recommended for "**significant**" aquatic ecosystems in the C6a Class.

There are no monitored reference sites in this class, but there are 15 RSoE sites within developed catchments, three of which are classified as "significant aquatic ecosystems. The 95th percentile temperature (based on spot measurement) is below the above recommended limits at most (12 out of 15) sites. Two sites on the lower Ruamahanga River slightly exceed the 21˚C recommended threshold for "healthy" ecosystems (22.1˚C at Gladstone and 21.7˚C at Pukio). It is probable that these temperature are at least in part driven by the natural characteristics of the lower Ruamahanga River, and options to manage maximum summer temperatures, in the lower Ruamahanga River are probably very limited, supporting the recommendation that maximum water temperature limits should be seen as general benchmark values rather than "hard" enforceable limits (refer to section 3.1.6). The 95th percentile temperature at Tauherenikau River at Websters is the only "significant ecosystem" to exceed the above recommended temperature threshold, with a 95th percentile temperature of 23.6˚C. It is recommended that the reasons for these elevated high water temperatures be investigated for the Tauherenikau River.

Maximum **temperature change** limits of **2°C** and **3°C** are recommended for C6a "significant" and "healthy" aquatic ecosystems respectively.

3.1.5.4 Class A

Monitoring data shows that the only "best available" site within this class has consistently low water temperatures (95th percentile of 15.6°C), and even sites within developed catchments have 95th percentiles of temperature data between 16.0 and 20.6 °C.

Based primarily on available monitoring data, a **daily maximum** water temperature limit of **21°C** is recommended for both "healthy" and "significant" aquatic ecosystems in this class. This limit provides for the requirements of macroinvertebrate and fish species typical of this class, and appears realistic in the light of available information. A lower temperature limit for "significant" aquatic ecosystems is not considered necessary in this context, and is not recommended.

Similarly to other classes, maximum **temperature change** limits of **2°C** and **3°C** are recommended for Class A "significant and "healthy" aquatic ecosystems respectively.

3.1.5.5 Class B

There are no water temperature or macroinvertebrate monitoring data available for Class B streams. NZFFD records indicate that smelt, longfin eel and common bully have been found in Class B stream reaches. Greenfield (2013a) suggests that MCI limits defined for Class A streams would probably provide sufficient protection for Class B streams. Similarly, it is considered that the 21°C limit recommended for Class A streams would provide for the requirements of the fish species identified in Class B streams, and is recommended as a default value for this class.

Maximum **temperature change** limits of **2°C** and **3°C** are recommended for Class B "significant and "healthy" aquatic ecosystems respectively

3.1.5.6 Class C8

C8 streams are typically small streams, with extended periods of stable flows. The MCI limits recommended for Class C8 "healthy ecosystems" are the lowest of all classes, along with Classes A, B and C6c. Monitoring data shows that water temperatures at C8 "best available" sites remain below 19°C, and even sites within developed catchments have 95th percentiles of temperature data between 19 and 20.4°C.

A **daily maximum** water temperature limit of **21°C** is recommended for both "healthy" and "significant" aquatic ecosystems in this class. Similarly to the limit recommended for Class A, this limit is primarily based on the insights brought by available monitoring data into likely temperature ranges in this class of streams. This limit provides for the requirements of macroinvertebrate and fish species typical of this class (Table 5 and Table 6), and appears realistic in the light of available information. A lower temperature limit for "significant" aquatic ecosystems is not considered necessary in this context, and is not recommended.

3.1.5.7 Class C6c

Class C6c streams are lowland streams, located downstream of Class A or Class C8 stream segments. The recommended MCI targets for Class C6c are the same as for A and C8, i.e. the lowest of all classes. There are no reference or "best available" monitoring sites in this class, making it difficult to gain an appreciation of natural water temperature conditions in this class. Water temperature (95^{th} percentiles) at sites in developed catchments range from 18.3 to 22.6°C.

A temperature limit of 23°C is recommended for "healthy" ecosystems in C6c streams. This limit should provide for the requirements of invertebrate and fish species found in this class. It recognises that C6c streams are located downstream of Class A or C8 streams, thus are expected to experience higher water temperatures, even naturally. The recommendation is also consistent with that of Ausseil and Clark (2007b) for inland and coastal lowland catchments.

A temperature limit of 21°C is recommended for "significant" aquatic ecosystems in this class. This limit is the same as for the C8 and A class, which represent the upstream stream segments for C6c class.

Maximum **temperature change** limits of **2°C** and **3°C** are recommended for Class C6c "significant" and "healthy" aquatic ecosystems respectively.

Table 7: Recommended water temperature limits for waters to be managed for "significant" and "healthy" aquatic ecosystems in the different stream and river classes in the Wellington Region. The "measured range" columns represent water temperature measured as part of the RSoE monitoring programme (95^{th} percentile of data measured at each site, July2204 to June 2009).

GW FWENZ Class	MCI (minimum score)		Recommended Temperature limits (daily maximum in °C)		Measured range (95^{th} percentiles)		Temperature change (Maximum change in °C)	
	Significant	Healthy	Significant	Healthy	Reference/ Best Avail.	Impacted	Significant	Healthy
A	125	105	21	21	15.6	16.0 – 20.6	2	3
C5	130	105	20	20	15.3 – 19.1	18.2 – 23.1	2	2
C8	130	105	21	21	17.7 – 18.5	19.3 - 20.4	2	3
C7	130	115	19	19	14.4 – 19.0	16.0 – 20.2	2	2
C10	130	115	19	19	N.A.	N.A.	2	2
C6a	130	115	20	21	N.A.	16.5 – 23.6	2	3
UR	130	115	19	19	N.A.	N.A.	2	2
C1	130	105	20	20	N.A.	N.A.	2	2
C6c	120	100	21	23	N.A.	18.3 – 22.6	2	3
C6b	130	105	20	20	N.A.	20.6	2	2
B	125	105	21	21	N.A.	N.A.	2	3

3.1.6 Notes on applicability and compliance assessment of temperature limits

The maximum daily water temperature and water temperature change limits recommended above should apply at all times/all river flows.

As indicated previously in this report, a range of human activities can affect water temperatures in streams and rivers, including removal of riparian vegetation, modifications of the natural flow regimes and discharges. Generally speaking, small streams can be more sensitive to effects on water temperature, but there are also those where remediation by way of riparian shading is likely to be the most successful.

Options to manage water temperature, particularly maximum summer temperatures, in large rivers are much more limited, and the way water temperature limits are applied in the Regional Plan should account for this. The maximum daily water temperature limits are thus well suited for use as general objectives or benchmark values, particularly applicable to general State of the Environment reporting, rather than "hard" enforceable limits.

For general State of the Environment reporting, it is recommended that compliance with the daily maximum water temperature limits be assessed against the 95th percentile of continuous monitoring data.

Maximum temperature change limits of 2 or 3^{o}C (depending on river class) are recommended. These limits are well suited to use as standards in relation to specific activities such as discharges, and should in that case apply downstream, of the zone of reasonable mixing.

The recommended temperature change limits are primarily based on the general thermal sensitivity of typical macroinvertebrate and fish communities in each river class, but they do not account for other aspects of the aquatic ecosystems potentially affected by temperature changes, such as changes in primary productivity. For example, temperature increases due to increased water abstraction, could lead to increased periphyton growth. These potential effects should be considered on a case-by-case basis.

Both daily maximum water temperature and water temperature change limits are recommended. The way these two limits are intended to work is for the temperature change limit to apply within the bounds of the daily maximum temperature limit. In other words, if the background water temperature is, say, 19°C and the water temperature limits are 20°C (maximum daily) and ±3°C (change), then the temperature should be allowed to increase to 20°C, not 22°C, unless site/case-specific investigations show that the effects of doing so are acceptable.

3.2 Water pH

3.2.1 Background

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 fresh waters have a pH in the range 6.5 – 8.5 (ANZECC, 2000). pH is a major determinant in natural waters, and interacts with (i.e. 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[8] to be displaced so that the pH is increased. As a result, the highest pH observed in a river usually occurs during summer low flow conditions, towards the end of the afternoon. Daily and seasonal maximum water pH and temperature are therefore likely to coincide – an important point to remember when considering ammonia toxicity (section 3.6).

Both very acidic (low pH) and very alkaline (high pH) water can have direct or indirect toxic effects on aquatic life. For this reason, environmental limits relating to pH are generally defined as ranges (i.e. comprising a minimum and maximum).

3.2.2 Bibliography

Information on the effects of pH on New Zealand native biota is scant in the scientific literature. One publication (West *et al.*, 1997) reports that the preferred pH range of most native fish species is quite wide (generally around 6 to 10 or wider), although smelt had a much narrower preferred range (7.2 to 9.8) (refer to Appendix B for more detail).

---

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

The ANZECC (2000) Guidelines recommend default trigger pH ranges of 7.3 to 8.0 for upland rivers, and 7.2 to 7.8 for lowland rivers.

There is much more ample information on the pH requirements of exotic fish species, in particular rainbow and brown trout. pH ranges of 6 to 9 and 6.5 to 8.5 are recommended for locally and regionally significant trout fisheries (Ausseil, 2013a). Whilst not directly relevant to the protection of native fish or macroinvertebrate species, these limits may be useful in this context as a default reference point.

3.2.3 Recommended water pH limits

The RMA Third Schedule standard (2)(a) sets that no change in water pH shall be allowed if it has an adverse effect on aquatic life. Given the paucity of data regarding the pH tolerance of New Zealand native fish or macroinvertebrate species, it is difficult to give direct effect to this standard by defining effects-based pH limits. Rather, it is recommended that monitoring data be used to provide an indication of the natural range of pH in the different classes, and define an acceptable departure from this natural range.

This approach is consistent with the ANZECC (2000) Guidelines which recommend that either the 20th-80th percentile of reference data or default trigger values (as detailed in 3.2.2 above) be used as a trigger value for slightly to moderately disturbed ecosystems.

However, it is considered that using the 20th-80th percentile of reference data as default water quality limits is considered unnecessarily stringent in the context of recommended water quality limits for a Regional Plan, as it would place many reference sites outside this range a significant proportion of the time. Instead, the 5th-95th percentile of reference data is used as the basis for recommendations in this report (Table 8).

For the default "healthy" ecosystems, it is recommended that the pH range limit be set approximately 0.5 pH units on each side of the reference data range. This is consistent with the pH change limit recommended below. For waters managed for "significant" aquatic ecosystems, a limit more closely aligned with reference conditions is recommended, generally 0.2 pH units on either side of reference pH conditions. For classes where reference data are not available, the approach was to consider reference data in upstream classes (e.g. Class C7 as reference to C6a, and Classes A and C8 as reference for C6c), or use similar classes (e.g. C10 and UR limits based on C7 limits; C1 and C6b limits based on C5 limits). Class B streams are characterised by a high peat content in their catchment, which is likely to influence water pH in these streams. This influence is, however, unable to be quantified due to the lack of monitoring data for streams in this class. It was considered that this precluded robust recommendations to be developed and no pH limits are recommended for the B Class. Limits may be developed for this class once water quality monitoring information becomes available. Recommendations are summarised in Table 8.

Similarly to what is recommended for water temperature, it is recommended that numerical limits for maximum relative change in water pH as a result of an activity be established, in addition to the pH range limits as defined above. These would be particularly suited to be used as a standard. The ANZECC (2000) guidelines recommend that unnatural pH changes of more than 0.5 units be fully investigated. This is consistent with the recommendations of the previous set of ANZECC Guidelines (ANZECC, 1992), and is recommended for both healthy and significant ecosystems.

3.2.4 Application of water pH limits

The pH range and pH change limits recommended above should apply at all times/all river flows.

For general State of the Environment reporting, it is recommended that compliance with the pH range limits be assessed against the 5th-95th percentile of data collected year-round.

Similarly to water temperature, the pH change limits are intended to apply within the bounds of the pH range limits.

3.3 Dissolved Oxygen

3.3.1 Background

Dissolved oxygen (DO) is essential for aerobic forms of river life, including most plants and animals. As explained in Davies-Colley and Wilcock (2004), the dissolved 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 dependent 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.

Table 8: Recommended water pH limits for waters to be managed for "significant" and "healthy" aquatic ecosystems in the different stream and river classes in the Wellington Region. The "measured range" columns represent the range of pH measured as part of the RSoE monitoring programme (5th and 95th percentile of data measured at each site, July2004 to June 2009).

GW FWENZ Class	pH limit (range)		pH change limit (Maximum change)		Measured range			
	Significant	Healthy	Significant	Healthy	Reference/ best available		Impacted	
					5th %ile	95th %ile	5th %ile	95th %ile
A	6.1-7.5	5.8-7.8	0.5	0.5	6.3	7.3	6.3 - 6.7	7.1 - 7.7
C5	6.7-8.6	6.4-8.9	0.5	0.5	6.9 – 7.4	7.8 – 8.4	6.7 – 7.2	7.9 – 9.0
C8	7.1-8.4	6.8-8.7	0.5	0.5	7.3	7.9 – 8.2	6.8 - 7.5	7.9 - 8.5
C7	6.1-8.2	5.8-8.5	0.5	0.5	6.3 – 7.1	7.8 – 8.0	6.3 – 7.1	7.6 – 8.1
C10	6.1-8.2	5.8-8.5	0.5	0.5	N.A.	N.A.	N.A.	N.A.
C6a	6.1-8.2	5.8-8.5	0.5	0.5	N.A.	N.A.	6.3-7.7	7.7-9.1
UR	6.1-8.2	5.8-8.5	0.5	0.5	N.A.	N.A.	N.A.	N.A.
C1	6.7-8.6	6.4-8.9	0.5	0.5	N.A.	N.A.	N.A.	N.A.
C6c	6.1-8.4	5.8-8.7	0.5	0.5	N.A.	N.A.	6.4-7.6	7.2-8.7
C6b	6.7-8.6	6.4-8.9	0.5	0.5	N.A.	N.A.	6.8	7.9
B	-	-	0.5	0.5	N.A.	N.A.	N.A.	N.A.

Table 9: Dissolved Oxygen concentrations (mg/L) recommended by the USEPA (1986b) to confer five levels of protection for waters containing "other life stages" (i.e. not early life stages) salmonids (adapted from Dean and Richardson 1999), and corresponding DO saturation at different temperatures.

USEPA criteria		Calculated corresponding saturation at water temperature (°C)					
Degree of impairment acceptable	DO (mg/L)	10°C	16°C	19°C	20°C	21°C	23°C
None	8	71	81	86	91	90	94
Slight	6	53	61	65	69	68	70
Moderate	5	44	51	54	57	56	58
Severe	4	35	41	43	46	45	47
Acute	3	27	30	32	34	34	35

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.

3.3.2 Bibliography

There is only limited information in the published scientific literature about the DO requirements or tolerance of New Zealand native fish and macroinvertebrates.

Existing studies have generally concluded that New Zealand native fish species are relatively tolerant to low levels of DO when compared with rainbow trout, and that the USEPA water quality criteria for salmonids waters (1986b) should adequately protect New Zealand aquatic fauna and flora (Dean and Richardson, 1999; Landman *et al.* 2005[9]).

Table 9 above summarises the USEPA (1986b) DO criteria for the protection of salmonids waters, and lists the corresponding DO saturation at different water temperatures.

3.3.3 Recommended dissolved oxygen limits

As explained in Section 1.3.4 of this report, GWRC's proposed RPS sets that the narrative standards of the RMA Schedule 3 will be used as the basis for the definition of water quality limits in the proposed Regional Plan. Schedule 3 defines that "*The concentration of dissolved oxygen shall exceed 80% saturation concentration*" in Class AE waters.

This section of the report therefore examines the suitability of using the 80% threshold as the default environmental bottom-line for all river classes in the Wellington region, whilst still retaining considerations relating to the causing of environmental effects (are the recommended numbers effects-based?) and the natural characteristics of the waterbody (are these saturation levels naturally achieved?).

For consistency with the RMA standard, it is recommended to define DO limits as % saturation (rather than as a concentration expressed in mg/L). This is also consistent with proposed and operative regional plans for the Manawatu-Wanganui, Canterbury and Southland regions.

DO is essential for aerobic forms of river life, including most plants and animals, and it is suggested that the numerical limits relating to DO should apply at all times. Because DO is essential to aquatic life, a high level of compliance with the limits is recommended. For general SoE reporting purposes, it is recommended that the DO limits be compared to the 5th percentile of data collected at each site.

As explained in Section 2.4, the water quality limits recommended in this report are intended to give effect to the biological (macroinvertebrate and periphyton) limits defined by Greenfield (2013a, 2013b) for the different FWENZ classes. Macroinvertebrate and periphyton communities are both indicators of the system's general organic or trophic status, in turn narrowly associated with DO in the water column (Section 3.3.1 above). For this reason, both the macroinvertebrate communities (MCI) and periphyton biomass limits recommended for each river class were considered in the setting of corresponding DO limits in this report.

A significant point to note is that day-time instantaneous ("spot") measurements, as generally taken as part of GWRC's routine RSoE monitoring programme, only provide a snapshot of the DO concentration

[9] Landman *et al*. did conclude that inanaga whitebait was more sensitive to hypoxia than rainbow trout.. However, these results are contradictory with those of Dean and Richardson, who found that inanga whitebait was one of the most tolerant species. Apart from this uncertainty, the two studies are consistent in their findings.

in the river at the time of sampling, but provide little information on the daily minimum concentrations. As such, RSoE monitoring results can be useful in identifying existing issues associated with DO at some sites, but will not enable a thorough assessment at all sites. Basically daytime "spot" measurements below the saturation guideline strongly indicate the existence of a DO issue. The opposite is not true however, as high daytime DO readings are inconclusive. As a result the lower end of the range of values measured at each site (5th percentile) should be compared with the recommended limits and used as a trigger for further investigations. Sites with observed high periphyton or macrophyte biomass, or receiving point-source discharges should also be prioritised for investigations. These should ideally involve DO continuous monitoring records, although spot measurements taken at or near dawn can also provide a useful measure of daily minimum DO concentration/saturation. The monitoring results and limits presented in Table 10 should be understood and taken in this context.

3.3.3.1 Classes C7, C10 and UR

Rivers and streams in the C7, C10 and UR Classes are naturally fast flowing rivers with a high degree of re-aeration and relatively low productivity and biomass. DO saturation is expected to remain high throughout the diurnal and seasonal pattern. This is confirmed by reference data, showing 5th percentiles of daytime DO in excess of 86% at all sites. In this context, the RMA Third Schedule 80% saturation standard appears suitable and realistic and is recommended for these stream classes.

A more stringent limit could be recommended for waters to be managed for significant aquatic ecosystems, for example 90% saturation. However, data show that at least three of the reference sites[10] would likely not comply with a 90% saturation limit. The 80% limit is therefore recommended for all waters in the C7 Class, including those managed for "significant" aquatic ecosystems (Table 10).

Table 10: Recommended DO limits for waters to be managed for "significant" and "healthy" aquatic ecosystems in the different stream and river classes in the Wellington Region. The "measured range" columns represent DO measured as part of the RSoE monitoring programme (5th percentile of "spot measurement" data at each site, July2004 to June 2009).

GW FWENZ Class	MCI limits (minimum score)		Periphyton limits Max. biomass (mg *Chlo a*./m²)		DO limits (daily minimum saturation, in %)		Measured range (5th %ile, in % saturation)	
	Significant	Healthy	Significant	Healthy	Significant	Healthy	Reference / Best Available	Impacted
A	125	105	120	200	70	60	60	49-77
C5	130	105	50	120	70	70	80-91	80 - 93
C8	130	105	120	200	70	60	66-85	56-79
C7	130	115	50	50	80	80	86-94	88-97
C10	130	115	50	50	80	80	N.A.	N.A.
C6a	130	115	50	120	80	70	N.A.	81-98
UR	130	115	50	50	80	80	N.A.	N.A.
C1	130	105	50	120	70	70	N.A.	N.A.
C6c	120	100	120	200	70	60	N.A.	55-83
C6b	130	105	50	120	70	70	N.A.	93
B	125	105	120	200	70	60	N.A.	N.A.

[10] RS31, Ruamahanga at McLays; RS47, Waiohine at Gorge and RS52, Tauanui at Whakatomotomo Rd.

3.3.3.2 Class C6a

Class C6a contains river sections with an upstream catchment dominated by Class C7 streams. It includes the middle and lower reaches of the region's main rivers, such as the Hutt, Ruamahanga and Otaki Rivers and their tributaries. These river segments are expected to be more productive and organically enriched than their upstream C7 reaches, as illustrated by the higher periphyton biomass recommended by Warr (2013b). As a result, lower daily minimum DO saturation limit are recommended for this class: 70% for waters managed for "healthy" ecosystems, and 80% for waters managed for "significant" ecosystems.

A 70% DO saturation at 21°C (the recommended water temperature limit for C6a waters) corresponds to a DO concentration of 6.2 mg/L, i.e. between the "slight" and "none" impairment thresholds in the USEPA criteria (Table 9).

3.3.3.3 Classes C5, C1 and C6b

Class C5 streams are typically coastal or inland streams with moderate gradients. Similarly to C6a streams, C5 streams have a higher expected level of productivity and organic enrichment than the upland (C7, C10 and UR) classes, as illustrated by the higher periphyton biomass and lower MCI limits recommended by Greenfield (2013a, 2013b). Reference data in the C5 Class indicates that the daytime DO saturation can be around 80% saturation, indicating that a daily minimum of 80% may not be realistic for this class of streams. As a result, DO saturation limits of 70% saturation are recommended for all waters within this class (i.e. for waters managed for either "healthy" ecosystems and "significant" ecosystems). The same limits are recommended for C1 and C6b Classes.

A 70% DO saturation at 20°C (the recommended water temperature limit for C5, C1 and C6b waters) corresponds to a DO concentration of 6.3 mg/L, i.e. between the "slight" and "none" impairment thresholds (Table 9).

3.3.3.4 Class C8

Class C8 streams are typically small streams with moderate gradients, generally with gravel bed and long periods between floods. Ausseil (2011) identified that these characteristics made C8 streams particularly likely to experience nuisance periphyton growths. This is reflected in the periphyton biomass limits set by Greenfield (2013b) (200 mg/m^2 for "healthy" aquatic ecosystems, and 120 mg/m^2 for "significant" ecosystems).

No true reference data are available for C8 streams, but "best available" data indicate that relatively low DO concentrations can be expected, even at sites in relatively good condition: the 5^{th} percentile of daytime DO data at the Coles Creek Tributary (RS54) monitoring site is 66%. This is probably associated with the high periphyton cover and very low stream flows commonly observed at this site in summer.

A daily minimum DO limit of 60% saturation is recommended for Class C8 waters to be managed for "healthy" ecosystems. This limit should provide for the minimum requirements of native fish and macroinvertebrate communities typically found in this stream class, whilst remaining realistic in the context of the data available. A daily minimum limit of 70% saturation is recommended for waters to be managed for "significant" aquatic ecosystems, in recognition of the higher level of protection sought for these stream segments (Table 10).

3.3.3.5 Classes A and B

Class A and B streams have in common that they are generally slow moving lowland streams, often with soft substrate, and a plant biomass dominated by macrophytes.

The only "best available" site in Class A actually has elevated dissolved nutrient concentrations (Ausseil, 2011), and regularly presents significant macroalgae (*Nitella* sp.) growth (Alton Perrie, pers. comm.). The 5th percentile of the daytime DO concentration at this site is relatively low (60%) and is expected to be influenced by the high algal biomass generally observed at this site. It is considered that this site should not be used as a reference site for this class in relation to DO levels.

A daily minimum DO limit of 60% saturation is recommended for Class A waters to be managed for "healthy" ecosystems. This limit should provide for the minimum requirements of native fish and macroinvertebrate communities typically found in this stream class, whilst remaining realistic in the context of the data available. A daily minimum limit of 70% saturation is recommended for waters to be managed for "significant" aquatic ecosystems, in recognition of the higher level of protection sought for these stream segments. The same limits are recommended as default limits for Class B segments (Table 10).

A 60% DO saturation at 21°C (the recommended water temperature limit for C8, A, B and C6c waters) corresponds to a DO concentration of 5.4 mg/L, i.e. between the "moderate" and "slight" impairment thresholds (Table 9).

3.3.3.6 Class C6c

Class C6c stream segments are generally downstream of Classes A and C8 stream segments, and the same DO limits are recommended. A 60% DO saturation at 23°C (the recommended water temperature limit for C8, A, B and C6c waters) corresponds to a DO concentration of 5.1 mg/L, i.e. between the "moderate" and "slight" impairment thresholds (Table 9).

3.3.4 Notes on applicability and compliance assessment of DO limits

Since DO is indispensable to most superior forms of aquatic life, it is recommended that the DO saturation objectives apply at all times, at all river flows.

The limits recommended above are daily minima, and compliance against them should be assessed accordingly.

It should be noted however that inputs of low DO groundwater to spring-fed streams can cause naturally low DO levels. The stream classification used in this report does not specifically identify/differentiate spring-fed streams, or reaches of streams and rivers influenced by groundwater. It is suggested that Plan DO limits should account, possibly by way of exclusion from the DO limit or by way of application of a different limit, for the natural influence of groundwater on in-stream DO in some streams/stream reaches.

A significant point to note is that day-time instantaneous ("spot") measurements, generally taken as part of GWRC's routine SoE monitoring programme, only provide a snapshot of the DO concentration in the river at the time of sampling, but provide little information on the daily minimum concentrations. As such, they are of limited value in terms of SoE reporting or to assess compliance with the DO objectives. Although low daytime DO measurements do indicate a possible significant issue, reasonably high concentrations do not mean that the DO concentration remains acceptable at night.

Ideally, continuous monitoring records should be obtained at least during summer, although spot measurements taken at or near dawn can provide a useful measure of daily minimum DO concentration/saturation.

The existing SoE "spot measurement" DO data can still be useful in identifying existing issues associated with DO, although it will not enable a thorough assessment at all sites. Basically daytime "spot" measurements that regularly fall below the saturation guideline strongly indicate the existence of a DO issue. The opposite is not true however: high daytime DO readings are inconclusive. As a result the lower end of the range of values measured at each site (5^{th} percentile is recommended in this case) should be compared with the recommended limits and used as a trigger for further investigations.

3.4 Organic matter

3.4.1 Biochemical Oxygen Demand (BOD)

Heterotrophic growths are assemblages of heterotrophic bacteria and fungi attached to the substrate, and are commonly called "sewage fungus" when they become abundant enough to be visible as mats or plumose growths. The presence of abundant sewage fungus growths can adversely affect a number of ecological and recreational values. For this reason, narrative limits relating to heterotrophic growths were recommended by Greenfield (2013b) for water managed for aquatic ecosystem purposes, and by Ausseil (2013a, 2013b) in relation to waters to be managed for trout fishery and contact recreation/amenity purposes.

As indicated by their name, heterotrophic organisms need input of organic matter for their growth, and generally occur only in response to point-source inputs of organic matter. For this reason, water quality limits relating to BOD/COD are recommended for inclusion in the Regional Plan, but only in relation to point source discharges.

BOD is an expensive parameter to measure and it is not recommended that routine monitoring of BOD be undertaken across the region (e.g. as part of the RSoE monitoring programme) in response to including this limit in the Regional Plan.

Sewage fungus growth is particularly promoted by the low molecular weight fraction of the available organic matter (Quinn and Mcfarlane, 1988; Quinn and Gilliland, 1989). Like other types of periphyton growth, the growth of sewage fungus will primarily occur as a result of ambient concentration over a period of time during periods of stable flow and will get scoured, or reset to low levels following a significant fresh. As a result, it is recommended that the limit be termed as a daily average maximum concentration of soluble carbonaceous BOD_5 ($ScBOD_5$), applicable at flows below 3 times the median flow.

The studies cited above were the basis for the MCWQRP Rule 1.e. standard, which set a maximum daily average $ScBOD_5$ concentration of 2 mg/L in all surface water bodies in the Manawatu catchment. This limit is still considered relevant for the avoidance of nuisance sewage fungus growth (Quinn, 2009), and is recommended for waters managed for "healthy" aquatic ecosystem values across all FWENZ classes. A more stringent limit of 1.5 mg/L is recommended for waters managed for "significant" aquatic ecosystem values, and for upland classes that have naturally low levels of dissolved organic matter (Classes C7, C10 and UR). This recommendation is consistent with that of Quinn (2009) in relation to the Proposed One Plan water quality targets.

3.4.2 Particulate Organic Matter (POM)

Particulate organic Matter (POM) is a measure of the organic component of total suspended solids. Deposition of POM on the bed of streams and rivers downstream of point source discharges has been shown to cause detrimental effects on macroinvertebrate communities (Quinn and Hickey, 1993). The mechanism of effect is primarily the deposition of bacterial or algal cells downstream of oxidation pond (or other biological treatment processes) point-source discharges. Quinn and Hickey (1993) found a consistent reduction in the abundance of sensitive macroinvertebrate species where the average POM concentration increased by 6 mg/L or more downstream of point-source discharges. No significant adverse effects were observed at concentration increases below 4 mg/L. Background POM concentrations were in the order of 1 mg/L (McBride and Quinn, 1993).

A maximum POM concentration limit of 5g/m^3 after reasonable mixing is recommended in relation to point-source discharges to all streams and rivers. Because it directly relates to potential effects of point-source discharges, it is suggested that this limit is suitable for use as a standard.

The POM concentration in the receiving water column is used here as an indicator of the potential for this POM to settle on the stream/river bed and cause detrimental effects on benthic communities. The limit should therefore apply only when the stream/river is under base flow conditions (below median flow), i.e. when the potential for particulate matter to deposit is significant. To reflect the timeframes required for the deposited POM to cause effects, this limit should be expressed as an average concentration over base flow conditions (Quinn, 2009). This recommended limit is consistent with that of Horizons' One Plan (2010[11]).

Similarly to BOD it is not recommended that routine monitoring of POM be undertaken across the region (e.g. as part of the RSoE monitoring programme) in response to including this limit in the Regional Plan.

3.5 Water clarity and colour

3.5.1 Background

Water clarity refers to light transmission through water, and has two important aspects: visual clarity (sighting range for humans and aquatic animals) and light penetration for growth of aquatic plants (Davies-Colley and Smith, 2001; Davies-Colley *et al.*, 2003). Changes (generally reduction) of water clarity can affect a number of values associated with streams and rivers, including recreational, amenity, and, of relevance to this report, ecological values.

One measure of light penetration for growth of aquatic plants is euphotic depth. The MfE (1994) water quality guidelines No.2 recommend that euphotic depth should not be changed by more than 10%, or that lighting at the bed should not be reduced by more than 20% in waters shallower than half the euphotic depth. Although it might be an issue in lakes and coastal waters (which are outside the scope of this report), light penetration is seldom a constraint in rivers (Davies-Colley, 2009). Given the generally shallow nature of rivers in the Wellington region, it is considered that issues associated with light penetration will generally be adequately covered by the recommended visual clarity and visual clarity change limits recommended below. Consequently, water quality limits relating to euphotic depth in rivers are not recommended for inclusion in the Regional Plan. It is suggested that the MfE (1994) guidelines relating to euphotic depth can always be used if/when specific issues arise in the future.

The fundamental importance of water clarity is recognised in the RMA (S70/107 standards) and in operative and proposed regional plans (refer Table 2).

Three water clarity determinands are commonly monitored in relation to particles present in the water column: visual water clarity, turbidity and total suspended solids (TSS).

Visual clarity is generally measured using the "black disc" method, which determines the underwater horizontal sighting range of a black disc.

TSS is a direct measurement of the concentration of sediment suspended in the water column. As such, it is the best determinand to estimate sediment loads transported by a waterway.

Turbidity is an index of light scattering by suspended particles that is widely used in scientific monitoring and research. Turbidity can be measured in a water sample, which means physical conditions at the site (poor light conditions, small streams) do not prevent measurement. Importantly, turbidity probes allow continuous turbidity monitoring.

---

[11] 2010 version, as per the Hearing panel decision (under appeal)

Provided sufficient data are collected, robust site-specific correlations can be drawn between the three determinands. As a result, continuous turbidity probes are particularly useful monitoring tools, as they enable the indirect (i.e. via statistical correlations) continuous monitoring of TSS, in turn enabling the estimation of sediment loads transported by a waterway. Continuous turbidity monitoring also enables the indirect continuous monitoring of visual clarity.

In a review of the available scientific literature, Davies-Colley and Smith (2001) 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.

Visual clarity limits have also been defined (in preference to turbidity or TSS limits) in most recent regional plans that contain river water quality limits, including the Regional Water Plan for Southland, the Canterbury NRRP, and Manawatu-Wanganui's One Plan.

Based on these considerations, it is recommended that water quality limits relating to visual clarity be included in GWRC's Regional Plan.

Visual clarity is naturally variable across different types of waterways, and one must take the catchment's natural characteristics, in particular its underlying geology into account when setting visual clarity limits. Ausseil and Clark (2007c) undertook a river classification of the Manawatu Wanganui Region based on elevation and catchment geology, leading to the definition of 8 river classes, underpinning the definition of the Life-Supporting Capacity value in that region (Ausseil and Clark, 2007a). The natural catchment characteristics and the data available within each class were part of the process used to define different visual clarity limits for the different classes of waters (Ausseil and Clark, 2007b). This approach is consistent with that of Hayward *et al.* (2009) when making recommendations for visual clarity limits for the Canterbury Proposed NRRP. A similar approach is recommended for the GWRC Regional Plan.

Visual clarity also naturally varies depending on river flow conditions, with less clear water generally occurring at higher river flows. This natural relationship between river flow and visual clarity must be accounted for in the development of visual clarity limits, as reflected in the approaches taken by Ausseil and Clark (2007b) and Hayward *et al.* (2009). This relationship is also reflected in the wording of visual clarity limits in regional plans; for example visual clarity limits in both the Manawatu-Wanganui One Plan (2010) and the Southland Regional Water Plan apply only when the river flow is below median flow.

3.5.2 Bibliography

Ausseil and Clark (2007b) undertook a review of the scientific literature available at the time regarding the effects of low water clarity, high turbidity or high TSS on native fish and macroinvertebrates, and the reader is invited to refer to that report for more detail. The overall conclusion was that water turbidity above 17 to 25 NTU could cause behavioural changes in some native fish species (Boubée *et al.*, 1997; Richardson *et al.*, 2001; Rowe and Dean, 1998; Richardson *et al.* 2001), and that the occurrence of a number of native fish species was significantly reduced in highly turbid rivers (Rowe *et al.*, 2000). The most sensitive species appeared to be the banded kokopu (*Galaxias maculatus*), smelt and redfin bully.

In work more recently published, Rowe *et al.* (2009) found that most native fish were able to survive short-term exposure to high concentrations of suspended solids, in excess of 1,000 mg/L for smelt and in excess of 3,000 mg/L for all other species studied, suggesting that the mechanisms of effects of high suspended solids on sediment sensitive species may be species-specific.

3.5.3 Recommended visual clarity limits

3.5.3.1 Default limit

Based on the above scientific studies, a maximum turbidity of 15 NTU, roughly corresponding to 0.5m visual clarity was recommended to avoid significant effects on native fish migration by Ausseil and Clark (2007b). This limit is based on available scientific literature and directly relates to potential effects on native fish fauna, thus is very relevant to the protection of waters to be managed for aquatic ecosystems. This limit could apply as a region-wide bottom-line, applicable to all river classes, and at all flows except flood flows (i.e. below 3 × median flow).

3.5.3.2 Visual clarity change limits

The RMA Sections 70 and 107 standards set that discharges of contaminants into water shall not give rise to "*any conspicuous change in the colour or visual clarity in the receiving waters*". The Ministry for the Environment Water Quality Guidelines No. 2 (MfE, 1994) provide guidance as to what degree of water clarity change constitutes a "conspicuous change": 20% change in waters where visual clarity is an important characteristic of the waterbody, and 33% to 50% in other waters.

Consequently, the following limits setting maximum change in water clarity as a result of a given activity are recommended:

- 20% for upland classes with catchments dominated by hard sedimentary rocks, where clear water is a significant ecosystem attribute, namely in Classes C7, UR and C10; and
- 20% for significant ecosystems, regardless of river class; and
- 33% for the remainder.

Although these visual clarity change limits were originally defined for the protection of aesthetic values, in direct translation of the RMA S70/107 standards, such guidelines should also provide adequate protection for the habitat of sighted animals. Protection of the visual clarity of waters will also generally ensure that colour and light penetration (relevant to ecosystem values) are not degraded (MfE, 1994). For these reasons the above visual clarity change limits are considered appropriate for the protection of aquatic ecosystem values, and are recommended for GWRC's Regional Plan.

3.5.3.3 Changes in water colour

It is expected that these visual clarity change limits will adequately cover potential issues associated with changes in water colour, except in exceptional cases, for example as the result of a specific activity (Davies-Colley, 2009). It is expected that exceptional cases will be able to be assessed on their own merits, thus specific limits relating to changes in water colour are probably not absolutely necessary in GWRC's Regional Plan.

3.5.3.4 Class-specific limits

The "default" visual clarity limit recommended above (0.5m) corresponds to quite low visual clarity, and allowing a reduction in visual clarity to this level may have a detrimental effect on the natural appearance and functioning of some ecosystem types. An approach that determines the natural/expected clarity characteristics in each stream class and allows for a given acceptable degree of departure from the natural characteristics (as defined in Section 2.4.2) was used for the definition of class-specific visual clarity limits presented below.

The ANZECC (2000) guidelines define default trigger values for visual clarity in upland (0.8m) and lowland (0.6m) rivers. These trigger values were determined using a very limited dataset, particularly for the lowland trigger value, and their direct relevance for rivers in the Wellington region is questionable. Furthermore, these trigger values were derived using the 20th percentile of reference data from the National River Water Quality Network (NRWQN), for upland and lowland sites respectively. No flow partition of the data was apparently conducted, thus the 20th percentile of data is probably representative of high flow conditions, rather than base flow conditions.

It is recommended that the class-specific limits recommended in this report be applied outside periods when visual clarity is naturally reduced by high river flows, i.e. under median flow. The RSoE data used for the development of the class-specific visual clarity limits was thus partitioned according to flow. Table 11 below provides a summary of the lower 20th percentile of data collected at each RSoE site when the flow is at or below median flow. For sites where flow data were not available, the overall median water clarity value is used as a surrogate for the 20th percentile clarity at flows below median (Table 11).

3.5.3.5 Classes C7, C10 and UR

Reference data at C7 RSoE monitoring sites generally indicate relatively high visual clarity, with 20th percentiles of the <median flow data ranging from 2.2 to 4.1m. The recommended visual clarity change limit for these classes is 20%. Applying this amount of reduction to the bottom of the reference range leads to a class-wide water clarity limit of 1.8m. A limit of 2.2m, corresponding to the bottom of the range of reference conditions is recommended for the "significant" ecosystems.

3.5.3.6 Class C6a

Class C6a contains river sections with an upstream catchment dominated by Class C7 streams. It includes the middle and lower reaches of the region's main rivers, such as the Hutt, Ruamahanga and Otaki Rivers and their tributaries. Reference conditions for this class of river should be sought in the C7 Class. The recommended maximum visual clarity change in Class C6a is 33%, which leads to a class-wide visual clarity limit of 1.6m when applied to the bottom of the reference range. A limit of 1.8m is recommended for "significant" aquatic ecosystems in Class C6a. This limit corresponds to a 20% reduction from the bottom of the reference conditions, and also reflects the clarity limit recommended for Class C7 waters, which are upstream of Class C6a waters.

3.5.3.7 Classes C5, C1 and C6b

One reference site and three "best available" RSoE sites are available in the C5 Class. The reference site and two of the three best available sites present 20th percentiles of their water clarity in the 1.9-2.3m range. One of the "best available" sites (RS11, Whareroa Stream at Waterfall Road) presents significantly poorer water clarity (0.6m). Causes of this poorer water clarity should be investigated, and, in the meantime, this site should be excluded from the "reference" dataset for this class.

The recommended maximum visual clarity change in Class C5 is 33%, which leads to a class-wide visual clarity limit of 1.3m when applied to the bottom of the reference range. A limit of 1.9m, corresponding to the bottom of the range of reference conditions is recommended for the "significant" ecosystems. The same limits are recommended for Class C1 and C6b waters.

3.5.3.8 Class C8

No true reference data are available for C8 streams, however two "best available" sites are monitored as part of the RSoE programme. Flow data are available at only one of these two sites (RS54, Coles Creek Tributary). The 20th percentile of visual clarity measured at flows below median flow is 0.8m at this site.

The recommended maximum visual clarity change in Class C8 is 33%, which leads to a class-wide visual clarity limit of 0.5m when applied to measured reference conditions. A limit of 0.8m, corresponding to a 20% reduction from the reference conditions is recommended for the "significant" ecosystems.

3.5.3.9 Classes A and B

There are no true reference sites in the A Class. Flow data are not available at the only "best available" site (RS45, Parkvale Tributary at Lowes Reserve), which prevents the calculation of the 20th percentile of data collected below median flow. The overall median visual clarity, used as a surrogate, is 2.0m at this site. Application of 33% and 20% changes leads to the recommendation of visual clarity limits of 1.3 and 1.6m for "healthy" and "significant" ecosystems respectively.

It is noted however that this site is located near the source of a small, spring-fed site, that probably has naturally better water clarity than most larger, runoff-fed, streams within the same class. As a matter of fact, all other sites within this class present much lower visual clarity (0.2 to 0.75m), and a visual clarity of 2.0m may not be truly representative of a wide range of reference conditions within this class.

It is recommended that reference, or "best available" conditions be investigated across a number of class A stream systems. In the meantime, visual clarity limits of 1.3m for "healthy" ecosystems, and 1.6m for "significant" ecosystems is recommended, acknowledging that these limits may need to be refined.

The same limits are recommended for Class B streams, pending further investigations into the water quality characteristics of this class of streams.

Class C6c

There are no reference or "best available" monitoring site in this class, making it difficult to gain an appreciation of natural visual clarity conditions in this class. Visual clarity (20th percentiles at flows <median) at sites in developed catchments range from 0.6 to 1.3m.

Class C6c stream segments are generally downstream of Class A and C8 stream segments, and the same visual clarity limits as for the Class C8 waters are recommended.

3.5.3.10 River- specific limits

Regardless of the river classification, the visual water clarity in each major river is influenced by a range of catchment characteristics, including the geology, topography and land use. For this reason, this section examines the suitability of the class-wide visual clarity limits recommended above for each of the region's main rivers. These river-specific limits are based on reference data for each river, with an allowance for a 33% maximum clarity change for "healthy" ecosystems and 20% for "significant" ecosystems. This approach is consistent with that used to recommend water clarity limits for waters to be managed for trout fishery (Ausseil, 2013a).

Table 11: Recommended visual clarity and receiving visual clarity change limits for the different FWENZ river classes in the Wellington Region. Data in italics corresponds to sites where flow data were not available. The overall median visual clarity value is reported for these sites.

GW FWENZ Class	Current range (20th percentile, < median flow)		Default limit (<3×median flow)	Visual clarity limits (m) (<median flows)		Visual clarity change limits (at all flows)	
	Reference/ Best Avail.	Impacted		Significant	Healthy	Significant	Healthy
A	*(2.0)*	0.2-0.5 *(0.4-0.75)*	0.5	1.6	1.3	20%	33%
C5	(0.6) 1.9-2.3	1.0-1.9 *(2.2)*	0.5	1.9	1.3	20%	33%
C8	0.8 *(1.1)*	0.9 *(0.6)*	0.5	0.8	0.5	20%	33%
C7	2.2-4.1 *(2.0-2.7)*	0.6-3.3	0.5	2.2	1.8	20%	20%
C10	N.A.	N.A.	0.5	2.2	1.8	20%	33%
C6a	N.A.	0.4-2.7 (1.4-*2.4*)	0.5	2.2	1.6	20%	33%
UR	N.A.	N.A.	0.5	2.2	1.8	20%	20%
C1	N.A.	N.A.	0.5	1.9	1.3	20%	33%
C6c	N.A.	0.6-1.3	0.5	0.8	0.5	20%	33%
C6b	N.A.	1.6	0.5	1.9	1.3	20%	33%
B	N.A.	N.A.	0.5	1.6	1.3	20%	33%

Table 12: Recommended visual clarity limits for the main rivers in the Wellington Region.

River	Current water clarity (m) (20th percentiles at flows below median at individual RSoE sites)		Recommended water clarity objective (m)	
	Reference	Impacted	Significant	Healthy
Hutt River	2.7m (RS20)	1.8 – 1.9m (RS21-22)	2.1m	1.8m
Ruamahanga River	4.1m (RS31)	0.8 - 1.5m (RS32-34)	3.3m	2.9m
Waikanae River	2.3m (RS09)	1.5m (RS10)	1.8m	1.5m
Wainuiomata River	2.2m (RS28)	1.2m (RS28)	1.8m	1.5m
Otaki River	2.5m (RS05)	2.2m (RS06)	2.0m	1.7m
Waiohine River	3.1m (RS47)	0.4m (RS48)[a]	2.5m	2.1m
Waitohu River	2.5m (RS03)	0.6m (RS04)	2.0m	1.7m

[a] Visual clarity at Waiohine at Bicknells RSoE monitoring site is likely affected by river works and gravel extraction (Juliet Milne, pers. comm.)

3.5.4 Notes on water clarity monitoring methods and compliance assessment

The most common method of measuring visual clarity in rivers in New Zealand is by measuring the horizontal sighting range of a black disc (Davies-Colley, 1988). It is a simple field method that can be used to directly estimate the beam attenuation coefficient, the primary factor controlling underwater visual ranges for both humans and aquatic animals (Davies-Colley, 1988; Davies Colley *et al.*, 2003). The direct black disc measurement can be limited by high turbidity and/or physical conditions at the sites (e.g. very small, shallow streams). In these cases, visual clarity can be measured ex-situ in a steel trough. These measurements have been shown to be closely correlated with both in-situ measurements and the beam attenuation coefficient (Davies-Colley and Smith, 1992).

Another out-of-stream method uses a 1m long clear plastic tube, with a small black disc sliding inside the tube. This method was originally developed as part of the Stream Health Monitoring and Assessment Kit (SHMAK) (Biggs *et al.*, 2002). The clarity tube measurements have been shown to be correlated with in-situ clarity measurements, particularly in relatively low water clarity environments (Kilroy and Biggs, 2002).

Nephlometric turbidity provides a relative measure of light scattering and has no direct environmental relevance (Davies-Colley, 1991). Turbidity and water clarity and turbidity and total suspended solids are generally well correlated, although specific relationships vary between rivers. Turbidity probes can be directly installed on site and provide a continuous turbidity record. Turbidity monitoring, in particular continuous monitoring, can be a very useful way of providing a continuous (including at night) assessment of compliance with water clarity limits, provided that specific turbidity/water clarity relationships are established at each site.

All of the three methods above are acceptable as surrogates for direct visual clarity measurements, within their respective field of application, and it is recommended that any plan standard or objective allow for the use of these methods where dictated by conditions.

The recommended limits should apply year-round under base flow conditions, i.e. below median flow. Compliance should be assessed such that a site will be deemed to comply with the recommended objective if 80% or more of the measurements undertaken at this site when the flow is below median flow are better than the recommended objective. In practice, this means comparing the limit with the 20th percentile of the data collected at the site when the flow is at or below median flow.

RMA S107 and S70 relating to conspicuous change in water colour or clarity do not specify any acceptable frequency or duration of breach of these standards. The recommended water clarity change standards may thus be applied to single water clarity measurements. It is noted however, that specific situations may require a modification or relaxation of this standard. For example, in situations where a conspicuous change in water clarity is inevitable as the result of an activity (e.g. infrastructure works in the bed of a river), then a duration or frequency at which the standard may be breached may need to be defined (e.g. 8 hours in a row, or 2 hours after the cessation of the works).

3.5.5 Conclusions

A number of limits can be recommended in relation to visual clarity, each with its own justification and purpose. However, adopting all of these limits may result in an overly complicated and cumbersome Plan, and the policy makers will need to decide on an approach that will enable adequate management of streams and rivers for aquatic ecosystems purposes, whilst maintaining a workable Regional Plan.

3.6 Ammonia

3.6.1 Background

Ammonia is a common pollutant in raw or treated domestic, agricultural and industrial wastewater, and can be toxic to many aquatic species. Ammonia is a toxicant, but also a directly bioavailable nutrient[12]. This report only considers the potential effects of ammonia as a toxicant, aspects relating to ammonia as a nutrient are covered in a separate report (Ausseil, 2013c).

When in solution in the water, ammonia occurs as 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 is much more toxic to aquatic life than ionised ammonia, thus the toxicity of total ammonia (being the sum of unionised and ionised forms) increases with pH and/ or temperature.

In setting ammonia limits, the pH and temperature dependency of ammonia toxicity must be carefully considered.

3.6.2 Bibliography

Richardson (1997) found that the 96h LC_{50}[13] of unionised ammonia on eight New Zealand native fish species ranged from 0.77 to 2.35 mg NH_3/L. 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 96h LC_{10} values, which may provide an indication of the thresholds for toxic effects (Richardson, 1997), were reported to range from 0.45 to 1.37 NH_3/L (expressed as unionised ammonia, temperature = 15 ^{o}C and pH = 7.5 to 8.1).

Hickey and Vickers (1994) found 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 unionised ammonia) was calculated. Chronic exposure criteria cannot be determined in the absence of suitable studies on NZ species, however using acute-to-chronic ratios available in the scientific literature results in calculated chronic criteria of 0.011 to 0.044 mg NH_3-N/L (as unionised ammonia). 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.

In a study of three New Zealand native freshwater fish species and one macroinvertebrate species, Richardson *et al*. (2001) found that only one of the fish species actively avoided ammonia, whilst one was strongly attracted to it. These findings have implications with regards to the management of point source discharges, particularly within the mixing zone near the discharge outfall.

Studies have shown that freshwater fish (salmonids) were more tolerant to constant concentrations of ammonia than to fluctuating concentrations of ammonia (Thurston *et al.*, 1981). In this context, it is recommended that repetitive exposures to fluctuating levels of ammonia (e.g. nocturnal or tide-related discharge regimes) be, by default, considered as chronic exposures, unless case-specific studies show otherwise.

The recent Canadian water quality guideline for the protection of aquatic life is based on an unionised ammonia-N concentration of 0.016 mgN/L (CCME, 2010).

---

[12] Total ammonia-nitrogen is one of the components of Dissolved Inorganic Nitrogen (DIN), along with nitrate- and nitrite- nitrogen.

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

The ANZECC (2000) guidelines were based on the toxicity studies available at the time, and recommend a default trigger value based on a concentration of 0.035 mg/l (35 ppb) as unionised ammonia-N for the 95% protection level. This corresponds to approximately 0.900 mg/L as total ammonia-N at pH 8 and 20°C. The ANZECC (2000) guidelines also provide the corresponding total ammonia concentration at different water pH, as well as the percentage of unionised ammonia at different pH/temperature combinations.

The ANZECC (2000) guidelines recommend that the 95% protection level trigger value will adequately protect most New Zealand species, except *Sphaerium novaezelandiae*, a freshwater clam common in lowland rivers. *Sphaerium novaezelandiae* was found to be particularly sensitive to ammonia toxicity (Hickey and Martin, 1999). Where *Sphaerium novaezelandiae* is present and it is considered important to protect it, the ANZECC (2000) guidelines recommend halving the 95% trigger value or adopting the 99% protection level trigger value (0.320 mg/L as total ammonia-N at pH 8 and 20°C).

The sensitivity of freshwater bivalves to ammonia is also recognised in the most recent USEPA ammonia criteria (USEPA, 2009), which sets different chronic exposure criteria for waters containing freshwater mussels (0.354 mg N/L) and waters not containing freshwater mussels (2.54 mg N/L) (at pH =8 and temperature = 25˚C).

On this basis, the presence of *S. novaezelandiae* in the different FWENZ classes should be carefully assessed and become part of the recommendation-making process. Based on information provided by GWRC staff, *Sphaerium novaezelandiae* is known to be present at sites within the following classes: A, C5, C6c and C8 (Appendix B).

Although no specific information appears to be available on ammonia toxicity to other freshwater bivalves species, it may be prudent, as noted by Dr Roger Young in his peer-review of this report, to extend the application of the more stringent ammonia concentration limits recommended in Sections 3.6.3 and 3.6.4 below to waters containing other freshwater bivalve species, such as the freshwater mussel (Kakahi, *Echyridella menziesi*), given the general sensitivity of freshwater bivalves to ammonia.

3.6.3 Recommended chronic limits

As explained above, ammonia can cause both acute and chronic toxic effects. In situations with constant or variable and/or repetitive exposures (e.g. every day for a given period) to ammonia occurring for more than four days in a row, a limit based on chronic toxicity thresholds is recommended. This number should be compared with the average concentration of total ammonia nitrogen, calculated over a period exceeding four days. The following chronic concentration limits are recommended:

- the 99% protection level for both “healthy” and “significant” aquatic ecosystems in FWENZ classes where *S. novaezelandiae* is known to be present, and
- the 95% protection level for “healthy” aquatic ecosystems and the 99% protection level for “significant” aquatic ecosystems in other classes.

The recommended limit for stream classes where *S. novaezelandiae* is known to be present is based on unionised ammonia-N concentration of 0.012 mg/L, corresponding to approximately 0.320 mg/l as total ammonia-N at pH=8 and water temperature =20°C.

The limit recommended for “other” (i.e. *S. novaezelandiae* absent) is based on an unionised ammonia-N concentration of 0.035 mg/L, corresponding to approximately 0.916 mg/l as total ammonia-N at pH=8 and water temperature =20°C.

Because of the pH and temperature dependency of ammonia toxicity, the pH and temperature measured at the time and place of sampling should be used to calculate the percentage of unionised ammonia in the sample, and the result compared with the recommended limits. The ANZECC (2000) guidelines provide the necessary equations. Table 13, Table 14 and Table 15 provide examples of Total ammonia-N limits at different water pH and temperatures.

Table 13: Recommended chronic total ammonia-N concentration (mgN/L) limit for classes of water where *S. novaezelandiae* is absent, at different water pH and temperature.

		Temperature			
		15°C	20°C	25°C	30°C
pH	6.5	40	28	19	14
	7	13	8.8	6.2	4.4
	7.5	4.1	2.8	2.0	1.4
	8	1.314	0.916	0.649	0.469
	8.5	0.440	0.314	0.229	0.172
	9	0.163	0.123	0.096	0.078

Table 14: Recommended chronic total ammonia-N concentration (mgN/L) limit for classes of water where *S. novaezelandiae* is present, at different water pH and temperature.

		Temperature			
		15°C	20°C	25°C	30°C
pH	6.5	14	10	7	5
	7	4	3.1	2.2	1.5
	7.5	1.4	1.0	0.7	0.5
	8	0.459	0.320	0.227	0.164
	8.5	0.154	0.110	0.080	0.060
	9	0.057	0.043	0.034	0.027

Table 15: Indicative chronic total ammonia-N limits in the different river classes, based on the ranges of 95th percentile of water temperature and pH data measured at RSoE sites in each river class (July 2004 to June 2009 period). N.D.: No data.

GW FWENZ class	pH 95th %ile	Temperature (°C) 95th %ile	Chronic limit Total ammonia-N (mgN/L)	
			Significant	Healthy
A	7.1-7.7	15.6-20.6	0.600 - 3.405	1.718 - 9.745
C5	7.8-9.0	15.3-23.1	0.037 - 0.705	0.105 - 2.017
C8	7.9-8.5	17.7-20.4	0.107 - 0.472	0.306 - 1.350
C7	7.6-8.1	14.4-20.2	0.253 - 1.187	0.725 - 3.398
C10	N.D.	N.D.	N.D.	N.D.
C6a	7.7-9.1	16.5-23.6	0.031 - 0.809	0.089 - 2.314
UR	N.D.	N.D.	N.D.	N.D.
C1	N.D.	N.D.	N.D.	N.D.
C6c	7.2-8.7	18.3-22.6	0.063 - 2.214	0.181 - 6.337
C6b	7.9	20.6	0.383	1.097
B	N.D.	N.D.	N.D.	N.D.

3.6.4 Recommended Acute limits

It is recommended that the chronic exposure limit be considered the default limit, but it is also recommended that GWRC's Regional Plan provide for the use of a different limit, based on acute toxicity threshold in situations where the exposure to ammonia is of known short duration. This should be an absolute limit, that should not be exceeded for more than one hour (in effect, it means that it is applicable to individual samples, as it is very rare to have more than one sample taken in less than one hour). The recommended limits are based on the USEPA updated (2009) acute criteria.

The recommended limits (as total ammonia-N concentration in mg N/L) are based on the following formulae:

- Where *S. novaezelandiae* is known to be present:

$$0.811 \times \left(\frac{0.0489}{1 + 10^{7.204-pH}} + \frac{6.95}{1 + 10^{pH-7.204}}\right) \times MIN(12.09{,}3.539 \times 10^{0.036\times(25-T)}$$

- Where *S. novaezelandiae* is absent:

$$0.826 \times \left(\frac{0.0489}{1 + 10^{7.204-pH}} + \frac{6.95}{1 + 10^{pH-7.204}}\right) \times MIN(12.09{,}6.018 \times 10^{0.036\times(25-T)}$$

For easier reference, Table 16 and Table 17 below provide the recommended limits, expressed as total ammonia-N at a range of pH and temperatures.

Table 16: Recommended <u>acute</u> total ammonia-N concentration (mgN/L) limit for classes of water where *S. novaezelandiae* is <u>present</u>, at different water pH and temperature.

		Temperature			
		15°C	**20°C**	**25°C**	**30°C**
pH	**6.5**	38.2	25.2	16.7	11.0
	7	28.2	18.7	12.3	8.1
	7.5	15.6	10.3	6.8	4.5
	8	6.6	4.3	2.9	1.9
	8.5	2.5	1.7	1.1	0.7
	9	1.0	0.7	0.5	0.3

Table 17: Recommended acute total ammonia-N concentration (mgN/L) limit for classes of water where *S. novaezelandiae* is absent, at different water pH and temperature.

		Temperature			
		15°C	20°C	25°C	30°C
pH	6.5	58.0	43.7	28.9	19.1
	7	42.9	32.3	21.4	14.1
	7.5	23.6	17.8	11.8	7.8
	8	10.0	7.5	5.0	3.3
	8.5	3.8	2.9	1.9	1.3
	9	1.6	1.2	0.8	0.5

3.6.5 Application of ammonia limits

All ammonia concentration limits should apply year-round, at all river flows.

The chronic limit should be applied to situations with constant or variable and/or repetitive exposures (e.g. for a given duration every day) to ammonia occurring for extended periods (e.g. more than four days in a row). This number should be compared with the average concentration of total ammonia nitrogen, calculated over a period exceeding four days.

It is recommended that the chronic exposure limit be considered the default limit, but it is also recommended that the Regional Plan provide for the use of an acute limit, for situations where the exposure to ammonia is of known short duration. This limit should not be exceeded for more than one hour (in effect, it means that it is applicable to individual samples, as it is very rare to have more than one sample taken in less than one hour).

3.7 Nitrate

Nitrate can be toxic to aquatic species above certain concentrations. Similarly to ammonia, nitrate is a toxicant, but also a directly bioavailable nutrient[14]. This report only considers the potential effects of nitrate as a toxicant.

The ANZECC (2000) guidelines for nitrate toxicity to freshwater species were reviewed in 2009 by Hickey & Martin, based on the data available at that time. The authors recommended an acute trigger value of 20 mg NO_3-N/L, and chronic trigger values of 1.0 mg/L, 1.7 mg/L, 2.4 mg/L and 3.6 mg/L (as NO_3-N) for the 99%, 95%, 90% and 80% ecosystem protection levels, respectively.

As detailed in Section 3.8 below, the genera l recommendation is to apply the 95% protection to “healthy” aquatic ecosystems, and the 99% protection to “significant” aquatic ecosystems as the default limits.

It should be noted however, that additional nitrate toxicity data has recently become available for both exotic and New Zealand native species. It is the author’s understanding that these data will be incorporated in a revised set of chronic trigger values mid- to late- 2012. It is thus recommended that the outcomes of this review be considered for inclusion in the Regional Plan when they become available.

[14] Nitrate-nitrogen is one of the components of Dissolved Inorganic Nitrogen (DIN), along with total ammonia- and nitrite- nitrogen.

3.8 Other toxicants

A very large number of other toxicants, including metals and organic micro-contaminants (such as pesticides, hydrocarbons, etc.), may be released into the aquatic environment, and potentially cause toxic effects. Listing them and defining concentration limits for each of them is outside the scope of this report. The recommended approach is to use the trigger values provided in Table 3.4.1 of the ANZECC (2000) guidelines as water quality targets, with the level of protection recommended in Table 18 below. Detailed examination of toxicant guidelines is undertaken as part of a separate project (Pawson and Milne, 2011).

The ANZECC (2000) water quality guidelines define different protection levels, depending on the type of receiving environment. The approach is based on calculations of a probability distribution of aquatic toxicity end-points, and attempts to protect a pre-determined percentage of species. A percentage of species protected of 95% is generally used, but the approach enables quantitative alteration of protection levels.

The 95% protection level applies to "slightly to moderately disturbed" ecosystems, and is generally recommended as the default limit for waters to be managed for aquatic ecosystem health.

The ANZECC (2000) guidelines recommend the use of a higher (99%) protection level as the default trigger values for ecosystems with high conservation values. This protection level is recommended as the default limit for "significant" aquatic ecosystems.

Finally, the ANZECC (2000) guidelines recognise that it can be appropriate, depending on the state of the ecosystem, the management goals and in consultation with the community, to apply less stringent protection levels (90% or 80%), as intermediate targets for water quality improvement. For the purpose of this report, protection levels lower than 95% are not recommended as river class-wide water quality limits, but it is recognised that intermediate targets may need to be set on a case-by-case basis, for example in highly modified urban streams. The recommended levels of protection may also be able to be reviewed on a case-by-case basis, for example to provide for a lower protection for a given water body and/or in relation to a given toxicant level if information available allows one to determine that this would not result in a significant degradation of the aquatic communities at the site. It is recommended that the provisions of the Regional Plan allow for such flexibility.

3.8.1 Application of toxicant limits

It is essential to note that the numerical limits provided in Table 3.4.1 of the ANZECC (2000) Guidelines are "trigger values", and are not intended to be used as absolute water quality limits or standards. They "represent the best current estimates of the concentrations of chemicals that should have no significant adverse effects on the aquatic ecosystems" (ANZECC 2000, Section 3.4.3). The ANZECC (2000) guidelines provide a risk-based decision scheme for applying the guideline trigger values. The process is summarised in Figure 3.4.1, p 3.4-14 of the guidelines document. Basically the process recommends comparing the expected contaminant concentration with the default trigger guideline value. If the expected contaminant concentration is below the guideline, this indicates a low risk of significant adverse effects on the aquatic ecosystems. If the contaminant concentration exceeds the guideline, this indicates a potential risk, and the guideline trigger values should be reviewed in the light of site specific factors and/or a site-specific guideline should be calculated. If the site-specific guideline is still exceeded, the ANZECC framework recommends that either further investigation in the risk of effects (e.g. direct toxicity assessments) or remediation action be undertaken.

These considerations have direct implications when considering the translation of these trigger values into the policy framework, and into resource consent conditions.

The ANZECC (2000) guidelines could be used as thresholds helping the determination of an activity's status, with noncompliance with the trigger value leading to a change in activity status (e.g. from discretionary to non-complying as in the Canterbury Regional Plan), and the risk of environmental effects should be refined through the application process. Caution should be also exerted when considering translating ANZECC trigger values directly into resource consent conditions, to ensure that limits imposed through the consent conditions are consistent with the intent of the ANZECC (2000) guidelines. In particular:

- trigger concentrations should be applied to the bioavailable (not total) fraction of metals;
- most of ANZECC (2000) Table 3.4.1 trigger values are chronic exposure values, and should, as a first approach, be compared with the median value of monitoring results. Requiring an absolute compliance with a chronic toxicity threshold is likely to be inconsistent with its intended application.

The other important point to note is that the ANZECC (2000) guidelines are currently under review. The review, and the release of the updated guidelines are likely to be a relatively lengthy and staged (i.e. individual guidelines may be released as work is completed) process. It is recommended that sufficient flexibility be built into the Regional Plan to allow for the use of revised guidelines as they become available.

Table 18: Recommended levels of protection for the use of the numerical trigger values in Table 3.4.1 of the ANZECC (2000) Guidelines to set water quality limits for toxicants in the different stream and river classes in the Wellington Region.

GW FWENZ class	MCI		Recommended Level of protection	
	Significant	Healthy	Significant	Healthy
A	115	100	99 %	95%
C5	125	105	99 %	95%
C8	115	100	99 %	95%
C7	130	115	99 %	95%
C10	130	115	99 %	95%
C6a	125	115	99 %	95%
UR	130	115	99 %	95%
C1	125	105	99 %	95%
C6c	115	100	99 %	95%
C6b	125	105	99 %	95%
B	115	100	99 %	95%

4 Conclusions and recommendations

The water quality limits recommended in this report for waters to be managed for Aquatic Ecosystems in each FWENZ class in the Wellington Region are summarised in Table 19.

Together with the biological limits recommended by Greenfield (2013a, 2013b), they provide a comprehensive set of limits for the maintenance of aquatic ecosystem values.

A number of other freshwater management purposes, such as contact recreation, amenity and trout fishery have also been identified in the Wellington Region. Separate technical reports make recommendations for biological and water quality limits in relation to these management purposes.

In order to present a comprehensive and consistent set of recommended biological and water quality limits for each water body, catchment or any other freshwater "management unit" that may be defined, for inclusion in the regional plan, the following steps are recommended:

- identify and compile the management purposes that apply to each "management unit";
- compile all the biological and water quality limits that apply to each management purpose in each "management unit";
- for each biological and water quality determinand, identify a limit that will enable the maintenance of all management purposes (i.e. generally the most stringent limit for each determinand).

It is also recommended that existing stream and river monitoring data be compared with the limits recommended in the different reports in this series, to assess the current state of the region's streams and rivers in relation to the different management purposes.

Table 19: Summary of recommended water quality limits for waters managed for Aquatic Ecosystems.

Water quality determinand	FWENZ Class	Aquaticc Ecosystem Value "Healthy"	Aquaticc Ecosystem Value "Significant"	Limit application
Temperature (°C, Daily maximum)	A, B, C8	21°C	21°C	Year round, all river flows
	C5, C1, C6b	20°C	20°C	
	C7, C10, UR	19°C	19°C	
	C6a	21°C	20°C	
	C6c	23°C	21°C	
Temperature Change	A, B, C8, C6a, C6c	±3°C	±2°C	Year round, all river flows
	C5, C1, C6b, C7, C10, UR	±2°C	±2°C	
pH (range)	A	5.8-7.8	6.1-7.5	Year round, all river flows
	B	N/A	N/A	
	C5, C1, C6b	6.4-8.9	6.7-8.6	
	C8	6.8-8.7	7.1-8.4	
	C7, C6a, C10, UR	5.8-8.5	6.1-8.2	
	C6c	5.8-8.7	6.1-8.4	
pH Change	All	±0.5	±0.5	Year round, all river flows
Dissolved Oxygen (% Saturation, daily minimum)	A, C8, C6c, B	60%	70%	Year round, all river flows
	C5, C1, C6b	70%	70%	
	C7, C10, UR	80%	80%	
	C6a	70%	80%	
$ScBOD_5$ (mg/L, maximum daily average)	All	2 mg/L	2 mg/L	Year round, River flows < median
POM (mg/L, maximum average)	All	5 mg/L	5 mg/L	Year round, River flows < median
Visual clarity (m, minimum, default limit)	All	0.5m	0.5m	Year round, River flows< 3 × median
Visual clarity (m, minimum, class-specific limits)	A, B	1.3m	1.6m	Year round, River flows< median
	C5, C1, C6b	1.3m	1.9m	
	C8, C6c	0.5m	0.8m	
	C7, C10, UR	1.8m	2.2m	
	C6a	1.6m	2.2m	
Visual clarity change (% change, maximum)	C7, C10, UR	20%	20%	Year round, all river flows
	A, C8, C6c, B, C5, C1, C6a, C6b	33%	20%	
Total Ammonia-N (**Chronic)** (mg/L, maximum average concentration) At pH=8.0, Temp=20°C	C1, C10, UR, B	0.900	0.320	Year round, all river flows
	A, C5, C6a, C6b, C6c, C7 C8	0.320	0.320	
Total Ammonia-N (**Acute)** (mg/L, maximum concentration) At pH=8.0, Temp=20°C	C1, C10, UR, B	7.5	7.5	Year round, all river flows
	A, C5, C6a, C6b, C6c, C7 C8	4.3	4.3	Year round, all river flows
Other toxicants (protection level)	All	95%	99%	Year round, all river flows

REFERENCES

1. **ANZECC. (2000).** Australia and New Zealand Guidelines for Fresh and Marine Water Quality. *Australian and New Zealand Environment and Conservation Council. Agriculture and Resource Management Council of Australia and New Zealand. ISBN 09578245 0 5.*
2. **ANZECC. (1992).** Australian Water Quality Guidelines for Fresh and Marine Waters, National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council, Canberra.
3. **Ausseil O. and Clark M. (2007a)**. Identifying Community Values to guide Water Management in the Manawatu-Wanganui Region. Technical Report to Support Policy Development.. *Horizons Regional Council Report No. 2007/EXT/786. ISBN 1-877413-76-3..*
4. **Ausseil O and Clark M. (2007b)**. Recommended water quality standards for the Manawatu-Wanganui Region: technical report to support policy development. *Horizons Regional Council Report N. 2006/EXT/806. ISBN: 1-877413-89-5.*
5. **Ausseil O and Clark M. (2007c**). River classification of the Manawatu-Wanganui Region to support the definition of the life-supporting capacity value. *Horizons Regional Council Report N. 2006/EXT/752. ISBN: 1-877413-62-3*.
6. **Ausseil O. (2013a).** Recommended biological and water quality limits for trout fishery and trout spawning waters of the Wellington Region. *Technical report prepared by Aquanet Consulting Limited for greater Wellington Regional Council*. *Draft March 2011*.
7. **Ausseil O. (2013b).** Recommended biological and water quality limits for streams and rivers managed for contact recreation, amenity and stock drinking water in the Wellington Region. *Technical report prepared by Aquanet Consulting Limited for greater Wellington Regional Council. Draft June 2011*.
8. **Ausseil O. (2013c).** Recommended in-stream nutrient limits for rivers and streams in the Wellington Region. *Technical report prepared by Aquanet Consulting Limited for greater Wellington Regional Council. Draft June 2011*.
9. **Ausseil O. (2011).** Nutrient status of rivers and streams in the Wellington Region. An analysis of State of the Environment monitoring data. *Technical report prepared by Aquanet Consulting Limited for greater Wellington Regional Council*.
10. **Biggs B., Kilroy C., Mulcock C.M., Scarsbrook M.R. and Ogilvie S.C. (2002).** New Zealand Stream Health Monitoring and Assessment Kit. Stream Monitoring Manual. Version 2K – A tool for Kaitiaki. *NIWA Technical report 111-1*.
11. **Boubée J.A., Dean T.L., West D.W. and Barrier R.F.G. (1997).** Avoidance of suspended sediment by the juvenile migratory stage of six new Zealand native fish species. *New Zealand Journal of Marine and Freshwater Research, 2001, Vol. 31: 61-69*.
12. **Canadian Council of Ministers of the Environment. (2010)**. Canadian water quality guidelines for the protection of aquatic life: Ammonia. *In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.*
13. **Cox T. J. and Rutherford J.C. (2000)**. Thermal tolerances of two stream invertebrates exposed to diurnally varying temperature. *New Zealand Journal of Marine and Freshwater Research, Vol. 34:203-208.*
14. **Crawshaw L. (1977)**. Physiological and behavioural reactions of fishes to temperature change. *Journal of the fisheries Research Board of Canada 34: 730-734.*
15. **Davies-Colley R.J. (1988)**. Measuring water clarity with a black disc. *Limnology and oceanography 33(4): 616-623.*
16. **Davies-Colley R.J. (1991)**. Guidelines for optical quality of water and for protection from damage by suspended solids. Consultancy Report N. 6213/1. *Water Quality Centre, Hamilton, New Zealand.*
17. **Davies-Colley R.J. & Smith D.G. (1992)**. Offsite measurement of the visual clarity of waters. *Water Resources Bulletin 28:1-7.*

18. **Davies-Colley R.J. & Smith D.G. (2001)**. Turbidity, suspended sediment and water clarity: a review. *Journal of American Water Research association. 37: 1085 – 1101.*
19. **Davies-Colley, R.J.; Vant, W.N. and Smith, D.G. (2003).** Colour and clarity of natural waters. *Science and management of optical water quality. Blackburn Press, New Jersey, USA. 310 p.*
20. **Davies-Colley R. and Wilcock B. (2004)**. Water Quality and chemistry in running waters. *In Freshwaters of New Zealand, New Zealand Hydrological Society and New Zealand Limnological Society. ISBN 0-476-00708-9.*
21. **Davies-Colley R. (2009).** Section 42A report of Dr Robert James Davies-Colley on behalf of Horizons Regional Council. *In the matter of hearings on submissions concerning the Proposed One Plan notified by the Manawatu-Wanganui Regional Council*.
22. **Dean T. and Richardson J. (1999)**. Responses of seven species of native freshwater fish and a shrimp to low levels of dissolved oxygen. *New Zealand Journal of Marine and Freshwater Research, Vol. 33: 99-106.*
23. **Greenfield, S. (2013a).** River and stream macroinvertebrate indicators and limits for the protection of aquatic ecosystem health. *Unpublished internal report, document reference #816827. Greater Wellington Regional Council, Wellington.*
24. **Greenfield, S. (2013b).** River and stream plant and periphyton indicators and limits for protection of aquatic ecosystem health. *Unpublished internal report, document reference #808707. Greater Wellington Regional Council, Wellington*.
25. **Hayward S., Meredith A. and Stevenson M. (2009).** Review of proposed NRRP water quality objectives and standards for rivers and lakes in the Canterbury Region. *Environment Canterbury Report No. R09/16. ISBN 978-1-86937-932-2.*
26. **Hickey C. W. and Vickers M. L. (1994)**. Toxicity of ammonia to nine native New Zealand freshwater invertebrate species. *Arch. Environ. Contam. Toxicol. 26, 292-298.*
27. **Hickey C.W. and Martin (1999).** Chronic toxicity of ammonia to the freshwater bivalve *Sphaerium novaezealandiae*. *Arch. Environ Contam Toxicol 36:38-45*.
28. **Hickey C.W. and Martin M.L. (2009).** A review of nitrate toxicity to freshwater aquatic species. *Environment Canterbury report R09/57.*
29. **Hicks M., Quinn J. and Trustrum N. (2004)**. Stream sediment load and organic matter. *In Freshwaters of New Zealand, New Zealand Hydrological Society and New Zealand Limnological Society. ISBN 0-476-00708-9.*
30. **Kilroy C. and Biggs B. (2002).** Use of the SHMAK clarity tube for measuring water clarity: comparison with the black disc method. New Zealand Journal of Marine and Freshwater Research 36: 519-527.
31. **Landman M.J., Van Den Heuvel M.R. and Ling N. (2005)**. Relative sensitivities of common freshwater fish and invertebrates to acute hypoxia. *New Zealand Journal of Marine and Freshwater research 39: 1061-1067.*
32. **Leathwick, J., Julian K., Elith J., Chadderton L., Ferrier S. and Snelder T. (2008).** A biologically-optimised environmental classification of New Zealand rivers and streams; reanalysis excluding human impacts variables. *NIWA Client report: HAM2008-027. Prepared for Department of Conservation.*
33. **McBride, G.B.; Quinn, J.M. (1993).** Quantifying water quality standards in the Resource Management Act.
34. **MfE (1994).** Water Quality Guidelines No2: Guidelines for the Management of Water colour and Clarity. *Published by the Ministry for the Environment, Wellington, New Zealand. ISBN 0-477-05891-4.*
35. **Pawson R. and Milne J.R. (2011).** Stormwater toxicants Summary of Greater Wellington's Expert Panel Workshop, 2 May 2011. *GW Reference #920046-V1*.

36. **Parkyn S.M, Davies-Colley R.J., Halliday N.J., Costley K. J. and Croker G.F. (2003)**. Planted riparian buffer zones in New Zealand: do they live up to expectations? *Restoration Ecology Vol. 11 No 4, pp436-447*.
37. **Quinn J.M. and McFarlane P.N. (1988).** Control of sewage fungus to enhance recreational use of the Manawatu River, New Zealand. *Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie 23: 1572-1577.*
38. **Quinn J.M. and Gilliland, B.W. (1989)**. The Manawatu River cleanup: has it worked*? Transactions Institute of Professional Engineers of New Zealand 16(1): 22-26.*
39. **Quinn J. and Hickey, C. (1990).** Characterisation and classification of benthic invertebrate communities in 88 New Zealand rivers in relation to environmental factors. *New Zealand Journal of Marine and Freshwater Research, 1990, Vol. 24: 387 – 409.*
40. **Quinn J. and Hickey, C. (1993),** Effects of sewage waste stabilisation lagoon effluent on stream Invertebrates. *Aquatic Ecosystem Health 2: 205 –219.*
41. **Quinn J., Steele L., Hickey C. and Vickers M. (1994).** Upper thermal tolerances of twelve New Zealand stream invertebrate species. *New Zealand Journal of Marine and Freshwater Research, Vol. 28:391-397.*
42. **Quinn J.M. (2009).** Section 42A report of Dr John Martin Quinn on behalf of Horizons Regional Council. *In the matter of hearings on submissions concerning the Proposed One Plan notified by the Manawatu-Wanganui Regional Council.*
43. **Richardson J., Boubée J. and West D. (1994)**.Thermal tolerance and preference of some native New Zealand native fish. *New Zealand Journal of Marine and Freshwater Research, Vol. 28:399-407.*
44. **Richardson J. (1997)**. Acute ammonia toxicity for eight New Zealand indigenous freshwater species. *NZ Journal of Marine and Freshwater Research, Vol. 31: 185-190*
45. **Richardson J., Williams E.K. and Hickey C.W. (2001).** Avoidance behaviour of freshwater fish and shrimp exposed to ammonia and low dissolved oxygen separately and in combination. *New Zealand Journal of Marine and Freshwater Research, Vol. 35:625-633.*
46. **Richardson J., Rowe D.K. and Smith J. P. (2001)**. Effects of turbidity on the migration of juvenile banded kokopu (*Galaxias fasciatus*) in a natural stream. *New Zealand Journal of Marine and Freshwater Research, 2001, Vol. 35: 191-196*.
47. **Rowe D.K. and Dean T.L. (1998)**. Effects of turbidity on the feeding ability of the juvenile migrant stage of six New Zealand freshwater fish species. *New Zealand Journal of Marine and Freshwater Research, Vol. 28:399-407*.
48. **Rowe D., Hicks M. and Richardson J. (2000)**. Reduced abundance of banded kokopu (*Galaxias fasciatus*) and other native fish in turbid rivers of the North Island of New Zealand. *New Zealand Journal of Marine and Freshwater Research, 2000, Vol. 34: 547-558*.
49. **Rowe D. (2006)**. Decision Support System for setting maximum turbidity levels for riverine fish. *http://www.niwascience.co.nz/ncwr/toolss/turbidity. Accessed April 2007.*
51. **Rowe D.K., Hicks M., Smith J.P. and Williams E. (2009)**. Lethal concentrations of suspended solids for common native fish species that are rare in New Zealand rivers with high suspended solids loads. *New Zealand Journal of Marine and Freshwater Research, 2009, Vol. 43: 1029-1038.*
52. **Ryan P.A. (1991)**. Environmental effects of sediments on New Zealand streams: a review. *New Zealand Journal of Marine and Freshwater Research, 1991, Vol. 25: 207-221*.
53. **Simons M. (1984)**. Species-specific responses of freshwater organisms to elevated water temperatures. *Waikato Valley Authority technical publication 29.*
54. **Simons M. (1986)**. Effects of elevated temperatures and thermal shock on fish larvae. *Waikato Valley Authority technical publication 42.*
55. **Thurston R.**V.**, Chakoumakos C. and Russo R.C. (1981).** Effects of fluctuating exposures on the acute toxicity of ammonia to rainbow trout (*Salmo gairdneri*) and cutthroat trout (*S. clarki*). *Water Research Vol. 15:911-917.*

56. **USEPA (1986a)**. Quality criteria for water: 1986. *United States Environmental Protection Agency. EPA 440/5-86-001*.
57. **USEPA (1986b)**. Ambient water quality criteria for dissolved oxygen. *United States Environmental Protection Agency. EPA 440/5-86-003.*
58. **USEPA. (1999)**. 1999 Update of ambient water quality criteria for Ammonia. *U.S. Environmental Protection Agency.*
59. **USEPA. (2009)**. Draft 2009 Update Aquatic Life Ambient Water Quality Criteria For Ammonia – Freshwater. December 2009. Supersedes 1999 Update. *U.S. Environmental Protection Agency Office of Water. Office of Science and Technology. Washington, DC.*
60. **Warr S. (2009)**. River ecosystem classes for the Wellington region – Part 1. *Unpublished internal report, document reference #655606. Greater Wellington Regional Council, Wellington*.
61. **Warr, S. (2011).** River ecosystem classes for the Wellington region - Part two. *Unpublished internal report, document reference #792833. Greater Wellington Regional Council, Wellington*.
62. **West D. W., Boubée J. A., Barrier R. F. (1997).** Responses to pH of nine fishes and one shrimp native to New Zealand freshwaters. *New Zealand Journal of Marine and Freshwater Research 31: 461-468.*

APPENDICES

Appendix A: periphyton and macroinvertebrate communities in the different FWENZ class. Native fish community characteristics and limits for each FWENZ class have not yet been identified.

FWENZ class	Plants		Macroinvertebrates	
	Characteristic/ composition	Recommended Limits (as per Greenfield, 2013b)	Characteristic/ composition	Recommended Limits (as per Greefield, 2013a)
A	Often soft sedimentary, macrophyte dominated. Little data available for hard sedimentary sites but long accrual periods suggest that moderate periphyton growth may occur even at minimally impacted sites.	Significant aquatic ecosystems: <120 mg/m^2 chlorophyll *a* Healthy aquatic ecosystems: <200 mg/m^2	Characterised by *Paracalliope* and *Potamopyrgus* in impacted environments. Little information is available from minimally impacted environments but due to their low elevation and often long accrual periods these streams are likely to support a naturally tolerant macroinvertebrate community.	Significant aquatic ecosystems: MCI ≥ 125 Healthy aquatic ecosystems: MCI 105-124
C5	Generally hard substrate streams dominated by *Navicula, Synedra, Nitzschia, Gomphonema* and *Rhoicosphenia* species. Low elevation and moderate accrual periods mean that slightly elevated algal biomass may occur even at minimally impacted sites.	Significant aquatic ecosystems: <50 mg/m^2 chlorophyll *a* Healthy aquatic ecosystems: <120 mg/m^2	Characterised by *Deleatidium*, *Aoteapsyche*, *Potamopyrgus*, Orthocladiinae, Elmidae, *Archicaulioides*, Oligochaeta. Able to support sensitive stonefly, mayfly and caddisfly taxa at minimally impacted sites.	Significant aquatic ecosystems: MCI ≥ 130 Healthy aquatic ecosystems: MCI 105-129
C8	Often soft sedimentary, macrophyte dominated. Limited data available for hard sedimentary sites suggests dominance by *Cladophora, Navicula, Nitzschia, Cocconeis* and *Gomphonema* species. Long accrual periods suggest that moderate periphyton growth may occur even at minimally impacted sites.	Significant aquatic ecosystems: <120 mg/m^2 chlorophyll *a* Healthy aquatic ecosystems: <200 mg/m^2	Characterised by *Potamopyrgus, Paracalliope,* Orthocladiinae, Oligochaeta, *Austrosimulium, Oxyethira* and Elmidae at impacted sites. Limited data from minimally impacted sites suggests that these streams can support sensitive mayfly and caddisfly taxa.	Significant aquatic ecosystems: MCI ≥ 130 Healthy aquatic ecosystems: MCI 105-129
C7	Hard substrate streams dominated by *Gomphonema, Synedra, Navicula, Heteroleibleinia, Nitzschia* and *Cocconeis* species. Moderate elevation and short accrual periods mean that even at impacted sites algal biomass should be low.	Significant aquatic ecosystems: <50 mg/m^2 chlorophyll *a* Healthy aquatic ecosystems: <50 mg/m^2	Characterised by *Deleatidium*, Elmidae, *Zelandoperla*, *Aoteapsyche, Olinga, Hydrobiosis*. At minimally impacted sites a diverse range of sensitive stonefly, mayfly and caddisfly taxa occur.	Significant aquatic ecosystems: MCI ≥ 130 Healthy aquatic ecosystems: MCI 115-129
C10	No data available but high elevation and short accrual periods mean that even at impacted sites algal biomass should be low.	Significant aquatic ecosystems: <50 mg/m^2 chlorophyll *a* Healthy aquatic ecosystems: <50 mg/m^2	Very limited data suggests that these streams support a diverse range of sensitive stonefly, mayfly and caddisfly taxa.	Significant aquatic ecosystems: MCI ≥ 130 Healthy aquatic ecosystems: MCI 115-129
C6a	Hard substrate rivers dominated by *Gomphonema, Stigeoclonium, Nitzschia, Cymbella, Synedra,* and *Navicula* species. Low elevation and moderate	Significant aquatic ecosystems: <50 mg/m^2 chlorophyll *a*	Characterised by *Deleatidium*, Elmidae, Orthocladiinae, Tanytarsini, *Aoteapsyche* and *Hydrobiosis*. No data available from minimally impacted sites available.	Significant aquatic ecosystems: MCI ≥ 130 Healthy aquatic

FWENZ class	Plants		Macroinvertebrates	
	Characteristic/ composition	Recommended Limits (as per Greenfield, 2013b)	Characteristic/ composition	Recommended Limits (as per Greefield, 2013a)
	accrual periods mean that slightly elevated algal biomass may occur even at minimally impacted sites.	Healthy aquatic ecosystems: <120 mg/m^2		ecosystems: MCI 115-129
UR	No data available but high elevation and short accrual periods mean that even at impacted sites algal biomass should be low.	Significant aquatic ecosystems: <50 mg/m^2 chlorophyll *a* Healthy aquatic ecosystems: <50 mg/m^2	No data available but these streams all occur at high elevations within DoC forest parks and are likely to support a diverse range of sensitive stonefly, mayfly and caddisfly taxa.	Significant aquatic ecosystems: MCI ≥ 130 Healthy aquatic ecosystems: MCI 115-129
C1	No data available but low elevation and moderate accrual periods mean that slightly elevated algal biomass may occur even at minimally impacted sites.	Significant aquatic ecosystems: <50 mg/m^2 chlorophyll *a* Healthy aquatic ecosystems: <120 mg/m^2	Limited data available suggests that, when subject to minimal impacts, these streams should support a diverse range of sensitive stonefly, mayfly and caddisfly taxa.	Significant aquatic ecosystems: MCI ≥ 130 Healthy aquatic ecosystems: MCI 105-129
C6c	Both hard and soft substrate rivers. Limited data from hard substrate sites suggests dominance by *Gomphonema, Synedra, Cocconeis, Navicula, Nitzschia, Spirogyra* and *Cladophora* species. Low elevation and long accrual periods mean that moderate periphyton growth may occur even at minimally impacted sites.	Significant aquatic ecosystems: <120 mg/m^2 chlorophyll *a* Healthy aquatic ecosystems: <200 mg/m^2	Characterised by *Potamopyrgus, Paracalliope, Oxyethira* and Orthocladiinae. No data available from minimally impacted sites but due to their low elevation and long accrual periods these streams are likely to support a naturally tolerant macroinvertebrate community.	Significant aquatic ecosystems: MCI ≥ 120 Healthy aquatic ecosystems: MCI 100-119
C6b	No data available but low elevation and moderate accrual periods mean that slightly elevated algal biomass may occur even at minimally impacted sites.	Significant aquatic ecosystems: <50 mg/m^2 chlorophyll *a* Healthy aquatic ecosystems: <120 mg/m^2	Limited data available suggests that, when subject to minimal impacts, these streams should support a diverse range of sensitive stonefly, mayfly and caddisfly taxa.	Significant aquatic ecosystems: MCI ≥ 130 Healthy aquatic ecosystems: MCI 105-129
B	These are small streams with significant runoff from peat areas. No data are available on their characteristics. In the interim limits for Class A streams will be applied.	Significant aquatic ecosystems: <120 mg/m^2 chlorophyll *a* Healthy aquatic ecosystems: <200 mg/m^2	These are small streams with significant runoff from peat areas. No data are available on their characteristics. In the interim limits for Class A streams will be applied.	Significant aquatic ecosystems: MCI ≥ 125 Healthy aquatic ecosystems: MCI 105-124

Appendix B: Temperature, dissolved oxygen, pH and water clarity/turbidity requirements of aquatic biota known, or estimated, to occur in the different stream classes in the Wellington region. Temp: temperature; DO: dissolved oxygen; LT_{50} : Lethal Temperature 50%; CTM: Critical Thermal Temperature

Biota			Found in classes	Determinand	Value	Effect	Reference
Fish	Bullies (Eleotridae)	common bully (*Gobiomorphus cotidianus*)	A, B, C5, C6a, C6b, C6c, C7, C8	Temp (°C)	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 °C	48h LC_{50}	Landman *et al.*, 2005
		Cran's bully	A, C5, C6a, C6c, C7, C8	Temp (°C)	32.3 to 33.9	CTM	Simons, 1984
					30.9	96h LT_{50}	Richardson *et al.*, 1994
					21	Preferred Temp	
		upland bully	A, C5, C6a, C6c, C7, C8	Temp (°C)	32.8	CTM	Teale, 1986 in Richardson *et al.*, 1994
		redfin bully	A, C1, C10, C5, C6a, C6b, C6c, C7, C8, UR	pH	6.1 – 10.4	Preferred range	West *et al.* 1997
	Mugiloididae	torrentfish	A, C5, C6a, C6b, C6c, C7, C8	Temp	30	LT_{50}	Richardson *et al.*, 1994
					21.8	Preferred T	
	Galaxids (Galaxiidae)	Inanga (*Galaxias maculatus*)	A, C1, C5, C6a, C6b, C6c, C7, C8	Temp	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 (juv.)	
				DO	1 mg/l at 15 °C (10% sat)	36h LC_{50}	Dean & Richardson, 1999
					2.65 mg/L at 15 °C	48h LC_{50} (whitebait)	Landman *et al.*, 2005
				Turbidity	640 NTU	Reduction in feeding	Rowe and Dean, 1998

Biota			Found in classes	Determinand	Value	Effect	Reference
						rate	
					420 NTU	Avoidance response	Boubée *et al.*, 1997
		banded kokopu (*Galaxias fasciatus*)	A, C1, C10, C5, C6a, C7, C8	Temp	30.6 to 34.0	CTM (whitebait)	Simons, 1986
					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 (juv.)	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 postvectis*)	A, C1, C10, C5, C6a, C7	Temp	30	CTM	Main, 1988 in Richardson *et al.*, 1994
					29	LT_{50}	
				pH	6.6 – 10.4	Preferred range (juv.)	West *et al.* 1997
		koaro (*Galaxias brevipinnis*)	A, C1, C10, C5, C6a, C7, C8	Temp	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
Fish	Retropinnidae	smelt (*Retropinna retropinna*)	A, B, C5, C6a, C6b, C6c, C7	Temp	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 °C	48h LC_{50}	Landman *et al.*, 2005
	Eels (Anguillidae)	longfin eel (Anguilla dieffenbachii)	A, C1, C10, C5, C6a, C6b, C6c, C7, C8, UR	Temp	25	LT_{50} (elvers)	Jellyman, 1974 in Richardson *et al.*, 1994
					34.8	LT_{50} (elvers)	Richardson *et al.*, 1994
					24.4	Preferred T (elver)	
					37.3	LT_{50} (adult)	
				pH	5.6 – 10.3	Preferred range (elvers)	West *et al.*, 1997
		shortfin eel (*Anguilla australis*)	A, B, C1, C5, C6a, C6b, C6c,	Temp	28 °C	LT_{50} (glass eel)	Jellyman, 1974 in Richardson *et al.*, 1994

Biota			Found in classes	Determinand	Value	Effect	Reference
			C7, C8		30.5 to 38.1 °C	CTM (elver)	Simmons, 1986
					35.7 °C	LT_{50} (elver)	Richardson *et al.*, 1994
					39.7 °C	LT_{50} (adult)	
					26.9 °C	Preferred Temp (elver)	
				pH	3.3 – 9.8	Preferred range (elver)	West *et al.*, 1997
				DO	0.54 mg/L at 15 °C	48h LC_{50} (elvers)	Landman *et al.*, 2005
Crustaceans	Decapods	Koura (*Paranephrops planifrons*)	A, C1, C5, C6c, C7, C8	DO	0.77 mg/L at 15 °C	48h LC_{50}	Landman *et al.*, 2005
		Freshwater shrimp *(Paratya curvirostris)*	A, C5, C6c	Temp	25.7 °C	96h LT_{50}	Quinn *et al.*, 1994
				DO	0.82 mg/L at 15 °C	48h LC_{50}	Landman *et al.*, 2005
	Amphipods	*Paracalliope fluviatilis*	A, C1, C5, C6a, C6b, C6c, C7, C8	Temp	24.1 °C	96h LT_{50}	Quinn *et al.*, 1994
Insects	Stoneflies (*Plecoptera*)	Stoneflies	C5, C6a, C6b, C7, C8	Temp	19 °C	Maximum temperature for presence (88 rivers field observations)	Quinn and Hickey 1990
		Zelandobius sp.	C5, C6a, C6b, C6c, C7, C8	Temp	25.5 °C	48h LT_{50}	Quinn *et al.*, 1994
	Mayflies (*Ephemeroptera*)	*Ephemeroptera*	All	Temp	21.5 °C	Decrease in Ephemeroptera biomass (88 rivers field observations)	Quinn and Hickey 1990
		Deleatidium sp.	A, C1, C5, C6a, C6b, C6c, C7, C8, C10, UR	Temp	22.6 °C	96h LT_{50}	Quinn *et al.*, 1994
					24.2 °C	96h LT_{50} (constant T)	Cox and Rutherford, 2000
					21.9 °C	96h LT_{50} (daily mean)	
					26.9 °C	96h LT_{50} (daily max)	

Biota			Found in classes	Determinand	Value	Effect	Reference
		Coloburiscus humeralis	A, C1, C5, C6a, C6b, C6c, C7, C8, C10				
		Zephlebia sp.	A, C1, C5, C6a, C6b, C6c, C7, C8	Temp	23.6 °C	96h LT_{50}	Quinn *et al.*, 1994
	Caddisflies (*Trichoptera*)	*Aoteapsyche sp.*	A, C5, C6a, C6b, C6c, C7, C8, UR	Temp	25.9 °C	96h LT_{50}	Quinn *et al.*, 1994
		Pycnocentrodes sp.	A, C5, C6a, C6b, C6c, C7, C8	Temp	32.4 °C	96h LT_{50}	Quinn *et al.*, 1994
		Pycnocentria sp.	A, C5, C6a, C6b, C6c, C7, C8	Temp	25 °C	96h LT_{50}	Quinn *et al.*, 1994
	Beetles (*Coleoptera*)	Elmidae (*Hydora sp.*)	A, C1, C5, C6a, C6b, C6c, C7, C8, C10, UR	Temp	32.6 °C	96h LT_{50}	Quinn *et al.* 1994
Other invertebrates	Worms (Oligochaetea)	*Lumbriculus variegatus*		Temp	26.7 °C	96h LT_{50}	Quinn *et al.* 1994
	Mollusca	Freshwater fingernail clam *(Sphaerium sp.)*	A, C5, C6c, C8	Temp	30.5 °C	96h LT_{50}	Quinn *et al.* 1994
	Snails (Gastropoda)	*Potamopyrgus antipodarum*	A, C1, C5, C6a, C6b, C6c, C7, C8	Temp	32.4 °C	96h LT_{50}	Quinn *et al.* 1994
					31 °C	96h LT_{50} (constant T)	Cox and Rutherford 2000
					28.6 °C	96h LT_{50} (daily mean)	
					33.6 °C	96h LT_{50} (daily max)	

Appendix C:

Peer review comments from Dr Roger Young (Cawthron Institute) were received in the form of a letter dated 19th October 2012. The table below summarises the comments from Dr Young and the author's response. (Note that minor editorial comments are omitted).

Comments from Dr Roger Young			Response from author	
No.	**Reference**	**Comment**	**Comment**	**Action**
1	Executive Summary	The term 'limits' is widely used throughout the report. The NPS on Freshwater Management (2011) requires that regional councils establish freshwater objectives and set freshwater quality limits for all water bodies in their region. The Land & Water Forum reports also mention objectives and limits. It is not clear to me if all the numeric values given in this report are considered to be limits, or if some are likely to be numeric objectives. A paragraph clarifying this point early in the report would be useful	Agree	Paragraph added in Section
2	Executive Summary (Table A)	I think nitrate nitrogen should be included in Table A on page ii	Table A summarises specific numerical limits recommended in the report. Whilst nitrate nitrogen is acknowledged as a determinand of interest in relation to its potential toxic effects on aquatic life, the report does not recommend a specific numerical limit due to the on-going nature of the technical review work undertaken by NIWA at the time of writing this report (refer to Section 3.7 of the report)	No changes made to the report.
3	Section 1.2, Page 1, Third paragraph	This is the first mention of the 'healthy' and 'significant' levels. I think it would be useful to point out how/who defines what areas are 'significant'. I note that this is mentioned later in the report, but needs to be brought forward.	Agree	Mentions added in both Section 1.2 and the executive summary to add further clarification that the "healthy" and "significant" levels of protection were defined by Greenfield (2013a and 2013b)
4	Section 2.2	A map showing the distribution of the different classes throughout the region would be very helpful	Agree	Map added (Figure 1)
5	Section 3.1.3, para5	I am uncomfortable with the correction factor being applied for the LT50 measurements based on diurnal temperature amplitudes. I think the constant temperature LT50 values should be used without correction. Even though the assessments are over 96 hours, it is possible that the organisms died within just a few hours – therefore the maximum temperature is most relevant, not a lower value. At the very least, more rationale for why this correction is necessary is required.	The application of the temperature correction follows the recommendations of Cox and Rutherford (2000) who specifically studied the applicability/transferability of constant temperature laboratory assays to field conditions where some diurnal variations in temperature are generally present. It is noted that this method was only one of two	No change made to the report.

Comments from Dr Roger Young			Response from author	
No.	Reference	Comment	Comment	Action
			methods utilised to derive long-term temperature tolerance ranges for a ranges of New Zealand native species, and that, in some classes, this correction was ignored to provide additional safety margin. Actual data were then used to cross check the applicability of these numbers to the different classes of water in the Wellington region.	
6	Section 2.4.2	Last sentence of first bullet point: Appendix B summarises requirements of only SOME aquatic biota present in each class.	Agree	Changes made to text as per suggestion
7	Section 3.1.2, para 4	Need to specify that 95th percentile of monitoring data is based on spot measurements of temperature or continuous measurements. There's a big difference. This applies for the other class assessments too.	Agree	Text amended accordingly
8	Section 3.1.2, Class C6a	No comparison with monitoring data is provided for this class. Is there no data available, or was this an oversight??	No reference data, which is most useful in the derivation of limits, are available for this class. Class C7 can provide an indication of reference conditions for upland areas of Class c6a, although water temperature is expected to increase naturally in lower parts of catchments. Although a full assessment of compliance with the recommended limits is beyond the scope of this report, comparison with actual data still provides useful insight and was added	Comparison with actual data from the 15 RSoE sites in Class C6a was added.r
9	Throughout	For consistency 'Class' should have a capital letter when referring to a specific class.	Agree	Changes made throughout the report
10	Section 3.3.3 para 3	It might be useful to suggest whether monthly SOE data or continuous data is the preferred approach to guide investment in monitoring. Continuous data is more appropriate in my opinion.	Agree that continuous data is preferable. Para 4 contains the following sentence, which in the author's view is consistent with the suggestion: "These should ideally involve DO continuous monitoring records, although spot measurements taken at or near dawn can also provide a useful measure of daily minimum DO concentration/saturation"	No change made to report
11	Section 3.3.3	believe that the author is meaning that DO limits should be compared to the 5th percentile, not the 95th percentile as stated. The 5th percentile is used on the following page.	Agree	Changes made to text as per suggestion

Comments from Dr Roger Young			Response from author	
No.	Reference	Comment	Comment	Action
12	Table 10	It would be good to specify in the table that the measured range is based on spot measurements of DO, rather than continuous measures.	Agree	Changes made to text as per suggestion
13	Section 3.3.3, Class C8	Periods of accrual are mentioned. Accrual of what??	Agree this is unclear. The intention was to refer to periphyton accrual periods, i.e. the period between two floods.	Text changed to read " long periods between floods
14	Section 3.3.4	There are some spring-fed streams in the Wellington region that are fed by low-DO groundwater (e.g. in Wairarapa). Does the classification system take this into account? Some of these groundwater fed streams may not be able to meet these DO criteria naturally, because of their groundwater source. This should be acknowledged.	Agree, this is a useful suggestion. The FWENZ-based classes used in this report do not identify/differentiate spring-fed streams (or within these the reaches that receive some groundwater), but could possibly be refined.	Added comment in Section 3.3.4
15	Section 3.5.3	The way that the change limit is added to the observed percentile is a very different approach to that used for temperature, DO, pH etc. I can see why this might be sensible, but the rationale needs to be laid out more clearly, presumably in the section at the bottom of Page 31.	This is a useful comment. The method used for water clarity limits is essentially to use the reference data to determine a natural range of water clarity within each class, then to apply a degree of change (dictated by RMA provisions) over that natural range. The principles of the derivation of the limits are laid out in Section 2.4.2., which, in the author's view should explicitly document this process.	Added comment in Section 2.4.1 Also added a comment in Section 3.5.3
16	Section 3.5.4, last para	This is an appropriate consideration, as long as suitable efforts to reduce/mitigate effects of these short-term activities are taken too.	Agree, however, this should be specifically addressed in the Plan, not in this technical report	No change made to report
17	Section 3.6.2	Since there is evidence that one NZ bivalve is particularly sensitive to ammonia, and that bivalves in general are particularly sensitive to ammonia, I suggest that the 99% protection level is applied at sites where any bivalve is present, not just Sphaerium novaezelandiae. Given the concerns with the status of our freshwater mussel populations (e.g. Hannah Rainforth's MSc thesis) I think this is a suitably cautious approach.	This is a useful suggestion that may need to be taken into account by GWRC when developing the final limits. It is noted however, that to the author's knowledge, no information relative to ammonia toxicity on NZ freshwater mussels are available.	Added a comment in Section 3.6.2
18	Section 3.6.4, Table 17	The values in the last two rows of this table are incorrect and appear to have been accidently copied from the first two rows	Agree.	Table 17 corrected
19	Section 3.7, footnote	Needs to refer to nitrate, not ammoniacal nitrogen	Agree	Changes made to text as per suggestion
20	Appendix A	I don't understand why there's a MCI range limit for healthy aquatic ecosystems, and not just a minimum MCI value	The terminology used here could be causing confusion, the terms 'healthy aquatic ecosystems' and 'significant aquatic ecosystems' come from	No change made to report

Comments from Dr Roger Young			Response from author	
No.	**Reference**	**Comment**	**Comment**	**Action**
			GWRC's RPS which states that all rivers and stream must support healthy aquatic ecosystems and that significant aquatic ecosystems must be protected. These terms have been used here to represent different levels of ecosystem health, specifically 'good' for healthy aquatic ecosystems and 'excellent' for significant aquatic ecosystems. This then means that for biological indicators such as MCI there is a range of scores that fit into the 'good' range. These are what have been listed in this table	

Appendix D:

Peer review comments from Dr Ned Norton (NIWA) were received in the form of a draft letter dated 29th November 2012. The table below summarises the comments from Dr Norton and the author's response. It is noted that many of Dr Norton's comments were not able to be addressed as they stem from the outcomes of processes that occurred after the development of this report. (Note that minor editorial comments are omitted).

Comments from Dr Ned Norton			Response from author	
No.	**Reference**	**Comment**	**Comment**	**Action**
1	Overall	The reports are well written and technically thorough. They will, in combination with the other reports referenced, provide a very useful basis for a plan development process to set limits for water quality. I have no pressing concerns with any of the proposed numbers. Minor queries on the number tables in the executive summaries are listed in section 3 of this review. Therefore most of my comments relate to how these reports might be used to set limits in a plan process	Noted	No change made to report
2	Overall	I think the system of two different levels of protection (i.e. "significant" and "healthy") is a good pragmatic system. However it will be worth considering this 2-level system in light of the 3-level system ("Fair", "Good", "Excellent") suggested as part of a nationally consistent framework for water management in the Second LAWF Report (LAWF 2012). The LAWF (2012) report was released after the reviewed reports and so couldn't have been considered in them. There would be a benefit for national consistency if the same system was used across regional councils. It seems likely that the GWRC 2-level system could be converted to a 3-level system using the information already available, although it would be useful to await the outcome of the Government-led National Objectives Framework (NOF) process to see what decisions are made on the LAWF's proposed framework. One of the LAWF (2012) recommendations (Recommendation 4) was that Government should define minimum numeric "bottom lines" for a limited range of parameters and these would define the bottom of the "Fair" category. Obviously if this recommendation is implemented it would have implications for how GWRC uses its current 2-level system. The LAWF reports (and subsequent pending decisions by Government on a NOF) may also help GWRC to consider how to use terminology (e.g. objectives, limits etc) in the new regional plan, and this is discussed further in the bullet below	Noted and agreed. As noted in Section 1, this report was first developed before the release of the LAWF reports, and was finalised before the release of the NOF. The author agrees that it would be desirable to incorporate the outcomes of the NOF process when developing the final set of proposed objectives, limits and targets.	No change made to report

Comments from Dr Ned Norton			Response from author	
No.	**Reference**	**Comment**	**Comment**	**Action**
3	Overall	I generally agree with the pragmatic approach taken in both the Recreation Report and the Ecosystem Report. The Recreation Report defines various levels of protection for water bodies (or sites) having different levels of recreational use and the Ecosystem Report uses the 2-level ("healthy" and "significant") system. My only comment is again (as for the bullet above) to note that it may be useful to communicate several options for limits in the subsequent planning process in order to justify the single set of limits recommended in the executive summary tables of these two reports.	As per point 2 above	No change made to report
4	Overall	I think the spatial classification system used (i.e. by FWENZ class) is a good pragmatic system and allows limits to be assigned at more appropriate level than a "one-size-fits-all" approach. Again I note the LAWF (2012) recommendations for some consistency across regional councils on the use of spatial frameworks and Government decisions on implementation of LAWF recommendations will be of interest to GWRC in this regard. I have no view on which is the best spatial classification system. My view is that national consistency would be useful, or at least that the different regions have spatial classification systems that can be easily aggregated to a common format for national level analysis and reporting, but can then be disaggregated where appropriate for regional use	Agree that national consistency is highly desirable. The FWENZ classification was a fixed "input" to this report.	No change made to report
5	Overall	I agree with the recommendation (in the final paragraph in the executive summary of the Ecosystem Report) that it would be useful to assess the whole package of limits in all these reports against current monitoring data. This would allow an assessment of current compliance and could provide part of the information necessary to inform an assessment of cost implications of the limits (e.g. for s32 reporting).	Noted	No change made to report
6	Overall	The reports (executive summary tables of numbers) cover all the key water quality determinands that I would expect to be currently suitable for considering in a regional plan, with the exception of the following (which the reports themselves acknowledge): a) Not all toxicants are listed, but these are appropriately referenced to the ANZECC (2000) lists; b) Nitrate (toxicity), which could usefully refer to Hickey and	Agree. Section 1.2 now clarifies which of these recent documents were able to be incorporated in this report.	Clarification added to Section 1.2

Comments from Dr Ned Norton			Response from author	
No.	Reference	Comment	Comment	Action
		Martin (2009) and Hickey (2012); c) Cyanobacteria and biotoxins, which the reports appropriately refer to the interim cyanobacteria guidelines (MfE/MoH 2009); d) Deposited sediment, which would warrant some further consideration now that national sediment guidelines have been released (i.e. Clapcott et al. 2011); and e) Macroinvertebrate community index limits are also not dealt with in the scope of these reports but the Nutrient Report notes that GWRC intends to include these (e.g. MCI) in the new plan framework, which I agree with.		
7	Overall	I assume that flow-related limits (e.g. minimum flows and allocation limits) are covered elsewhere in the planning framework. I emphasise the need to integrate water quantity and quality planning, particularly if/when providing direction about consideration of catchment load limits in addition to concentration-based environmental limits. The latter concentration-based limits can apply whatever happens to flow, but catchment load limits (and therefore any associated NDAs) change with flow and must therefore be derived in tandem with water quantity plan provisions. For example, if a minimum flow or flow allocation changes, the catchment load limit must change too – the latter can't be set without prior knowledge or assumption about the former	The author also assumes that water quantity limits are covered elsewhere, and agrees that water quantity/flows are crucial to the development/setting of catchment load limits or resource use limits – although load or resource use limits are not covered in any of the series of technical reports.	No change made to report
8	Overall	There will be a need to consider the degree of compliance (in both time and space) with all the limits recommended in these reports. For example, will compliance be tested against a maximum, 95 percentile, median or some other statistic? An example of this is alluded to in the Nutrient Report in particular where it is noted that an acceptable degree and frequency of exceedence of periphyton limits should be defined rather than creating the (unrealistic) expectation that limits will never be exceeded. The need to be clear about the intended degree of compliance and monitoring statistics applies to all determinands, not just nutrients and periphyton. The NOF process mentioned above may provide some useful guidance on this when it is reported.	Agreed. The report provides guidance in relation to the application and compliance assessment of each recommended limit	No change made to report
9	Executive summary	I agree in general with the numbers in this table.		

Comments from Dr Ned Norton			Response from author	
No.	**Reference**	**Comment**	**Comment**	**Action**
	table A			
10	Executive summary table A	In the eighth row it is not clear what aspect of visual clarity (minimum, change or other?) this is referring to. There are three rows for clarity measures and this one isn't clear.	There are two rows relating to minimum water clarity. The first relates to an overall default limit, the second relates to class-specific limits.	Clarification added to table A and table 19
11	Executive summary table A	The final row (other toxicants). I assume that the 95% and 99% refers to the level of protection classes in ANZECC 2000 toxicant tables and some other guidelines (e.g. Hickey and Martin (2009) and Hickey (2012) for nitrate toxicity). It may be worth including nitrate toxicity limits explicitly in the table alongside ammonia, as the former is relevant for agricultural diffuse pollution management while the latter tends to be more a point source issue. I assume that by defining the 95 and 99 percentile levels of protection this implicitly points to the appropriate toxicant concentrations in these other guidelines – if this is the case it could be worth making this explicit in a table footnote. Because there are only 2 levels of protection ("Healthy" and "Significant") there is no space for a lower level of protection associated with 90 or 80%. GWRC may need to consider this in relation to the Fair, Good and Excellent category system promoted by LAWF. It may be that GWRC decides that a third (lower protection) category (e.g. ~"Fair") is not acceptable anywhere in the region in which case the 2-class system (plus the interim targets for degraded waters) suffices.	Yes, the intention is to define a default level of protection, then use the ANZECC guidelines (2000 or subsequent version given that a review is underway) to define specific concentrations in relation to each individual contaminant. Section 3.8 provides extensive comments relative to how these numbers should and importantly should not be used, including some comments that are very consistent with the reviewer's in relation to protection levels lower than 95%, and agrees that it will be desirable to ensure that any final proposed limit is consistent with the NOF.	No change made to report