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REGIONAL COUNCIL
Te Pane Matua Taiao

Technical guidance document: Aquatic ecosystem health and contact recreation outcomes in the Proposed Natural Resources Plan

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Contents

1. Introduction

This document provides technical guidance on the interpretation, measurement and assessment criteria of outcomes for aquatic ecosystem health and contact recreation in fresh and coastal waters set out in Tables 3.1–3.3 (Objective O24: Contact recreation and Māori customary use) and Tables 3.4-3.8 (Objective O25: Aquatic ecosystem health and mahinga kai) of the Proposed Natural Resources Plan for the Wellington Region (the proposed Plan) (GWRC 2015a). Depending on the state of knowledge the proposed Plan outcomes are either expressed in numbers (numeric outcome) or in words (narrative outcome). Guidance on outcomes relating specifically to mahinga kai and Māori customary use attributes of water, as described in the shared values approach of the proposed Plan Objective O5, is not provided here.

This document provides guidance separately for each of the following fresh and coastal water bodies:

- Rivers and streams
- Lakes
- Wetlands
- Groundwater, and
- Coastal waters

Each section describes the attributes and outcomes for each water body type and presents measurement and assessment methods for interpreting each outcome.

It is not possible to measure all attributes of aquatic ecosystem health and contact recreation. Instead, the outcomes in Tables 3.1–3.8 of the proposed Plan are indicators suitable for describing when the objectives of the proposed Plan for aquatic ecosystem health and contact recreation have been met. The rationale for the inclusion of the outcomes in Tables 3.1–3.8 and how they are given effect to through the proposed Plan provisions is set out in *Section 32 report: Water quality* (GWRC 2015b) and *Section 32 report: Aquatic ecosystem health* (GWRC 2015c).

Guidance on the measurement and assessment of other biological and water quality attributes of aquatic ecosystem health and contact recreation that are not included in the proposed Plan can be found in Greenfield et al. (2015). These attributes may be helpful in understanding further the state of a water body in relation to the outcomes in Tables 3.1–3.8 of the proposed Plan.

2. Aquatic ecosystem health

This section sets out guidance for interpretation and assessment of aquatic ecosystem health (aquatic ecosystem health) outcomes presented in Tables 3.4–3.8 of the proposed Plan.

Key principles of aquatic ecosystem health are introduced first along with brief comments on assessment and statistical considerations and the National Objectives Framework (NOF) of the National Policy Statement for Freshwater Management (NPS-FM, MfE 2014). Outcomes for each of the aquatic ecosystem health attributes in Tables 3.4–3.8 are then discussed separately for each of the five water body types: rivers and streams, lakes, wetlands, groundwater and coastal waters.

2.1 Introduction

2.1.1 What is aquatic ecosystem health?

In general, the outcomes in Tables 3.4–3.8 of the proposed Plan represent a ‘good’ level of aquatic ecosystem health. The exceptions are for ‘significant’, ‘regionally important’ or ‘outstanding’ water bodies where some outcomes are included to represent an ‘excellent’ state.

The work to develop the aquatic ecosystem health outcomes has drawn heavily on the work of Schallenberg et al. (2011) that applies the concept of ecological integrity to freshwater management in New Zealand. Schallenberg et al. (2011, p10) defined ecological integrity as:

> “*The degree to which the physical, chemical and biological components of an ecosystem and their relationships are present, functioning and maintained close to a reference condition reflecting negligible or minimal anthropogenic impacts*.”

Like ecosystem integrity, the aquatic ecosystem health outcomes in the proposed Plan are underpinned by the degree of departure of an attribute from a pre-human condition (often referred to as reference condition). Assessment relative to reference condition is essential as community structure, composition and diversity will vary naturally in aquatic ecosystems. This means that ‘good’ ecosystem health is generally represented by a range of conditions rather than an absolute condition (eg, different lakes may have different reference conditions due to their size and depth etc. and hence the good ecosystem referred in the aquatic ecosystem health outcomes will differ between these lakes). Table 2.1 defines some terms which are commonly used in relation to aquatic ecosystem health outcomes in the proposed Plan.

The characteristics of a ‘balanced’ community, a term used in many of the aquatic ecosystem health outcomes, will vary depending on the reference condition of the water body being assessed. However, in general, a balanced plant community will be dominated by a diverse range of indigenous species and be subject to only infrequent nuisance blooms. Invertebrate and fish communities will have a variety of feeding types, trophic associations, reproductive strategies and tolerances to stressors (Robertson & Stevens 2014).

Balanced communities will also typically be characterised by multiple age and size classes.

Table 2.1: Definition of terms commonly used in aquatic ecosystem health outcomes in the Proposed Natural Resources Plan

Term	Definition
Resilience	The ability of an ecosystem to exist into the future despite environmental fluctuation (Schallenberg et al. 2011). When an ecosystem is disturbed and can still remain within the natural range of variability it can be described as resilient (Alberta Water Council 2008).
Structure	A pattern of biological organisation necessary for an ecological function to operate (Myster 2001). For example, trophic organisation is an aspect of community structure related to energy transfer/nutrient cycling. Other important aspects of community structure are population age/size distribution and productivity (eg plant biomass).
Composition	The representation of different taxonomic groups (eg, family) in an assemblage (Whittier et al. 2007). Community composition is often expressed as a relative abundance and can refer to the occurrence of taxa which are sensitive or tolerant to an environmental stressor.
Diversity	Diversity comprises two components; the number of taxa (richness) and the distribution of individuals amongst taxa (evenness) (Schallenberg et al. 2011).

2.1.2 Assessment and statistics

To assess how a water body compares to the outcomes in Table 3.4–3.8 of the proposed Plan, statistically robust data sets will underpin assessment of attributes with numeric outcomes (eg, periphyton biomass). Narrative outcomes will be assessed using numeric measures where possible (eg, interpretation of nitrate toxicity for groundwater).

Guidance has been taken from McBride (2005) which illustrates that to balance confidence in determining a sample statistic and diminishing returns in sampling effort:

- Median values should be determined from around 12–20 data points; and
- 95th percentile values should be determined from around 30–50 data points.

Generating these sized data-sets will almost certainly require data collection over multiple years. We consider three years is the optimum period in most cases and is preferable to annual assessments of ecosystem health which can be unduly influenced by a particularly wet or dry summer (or year).

All percentile-based statistics should be derived using the Hazen method, which is considered a 'middle-of-the-road' option (McBride[1] pers. comm. 2014).[2]

For a number of attributes with narrative outcomes there are currently no sufficiently robust guideline values that can be used to assess aquatic ecosystem health (eg, for fish in rivers and streams). In addition standard

[1] Dr Graham McBride, Principal Scientist – Water Quality, NIWA.

[2] Other percentile methods include Blom, Tukey, Weibull and Excel (the standard formula used to calculate percentiles in Excel). The methods vary in the minimum number of data they require, the formula used to calculate the percentile and the actual result. For example, the Excel percentile method always gives the lowest percentile result, while the Weibull method always gives the highest.
Source: http://www.mfe.govt.nz/publications/water/microbiological-quality-jun03/hazen-calculator.html

protocols for measurement are lacking for some attributes. Development of measurement protocols and guidelines will require expert advice and additional data collection. In some cases, assessing if a particular outcome has been met may need to rely on expert opinion.

2.1.3 National Objectives Framework

The National Objectives Framework (NOF) under the NPS-FM came into effect on 1 August 2014. The NOF describes attributes of ecosystem and human health in fresh water bodies and sets for each a series of states describing excellent to poor health. The NOF contains some attributes in common with those in Tables 3.4–3.5 of the proposed Plan. While the NPS-FM only provides limited information on interpreting the attributes in the NOF (eg, data-set size and statistical calculations), guidance is currently under development and is anticipated to be similar to that recommended here.

It should be noted that the requirements to set freshwater objectives and limits for water quality under the NPS-FM are not implemented in the proposed Plan and instead will be implemented through the Wellington Regional Council's whaitua processes (GWRC 2015d). The whaitua processes will lead to subsequent and progressive whaitua-specific plan changes to the proposed Plan over the next ten years, including incorporation of the requirements of the NOF.

2.2 Rivers

2.2.1 Attributes and outcomes

Table 2.2 sets out the attributes and outcomes selected for aquatic ecosystem health in rivers (including streams) in the proposed Plan. The importance of each of these attributes and an explanation of their respective outcomes is summarised in Table 2.3.

Aquatic ecosystem health outcomes for rivers and streams are based around six river classes. These river classes are intended to be broadly representative of natural variation in river and stream ecosystems across the Wellington Region and are documented further in Greenfield et al. (2013) and Warr (2010). 'River class' is defined in the proposed Plan Interpretation section (section 2) and shown on Maps 21a to 21e.

'Significant' rivers are those with significant macroinvertebrate values, as identified in the second column of Schedule F1 of the proposed Plan and documented in Perrie et al. (2014). Aquatic ecosystem health outcomes in Table 2.2 for significant rivers represent an 'excellent' state.

Table 2.2: River aquatic ecosystem health and mahinga kai outcomes in Table 3.4 of the proposed Plan

River class[1]		Macrophytes	Periphyton[2] mg/m² chlorophyll *a*		Invertebrates[3] Macroinvertebrate Community Index		Fish	Mahinga kai species
			All rivers	Significant rivers[4]	All rivers	Significant rivers[4]		
1	Steep, hard sedimentary	Indigenous macrophyte communities are resilient and their structure, composition and diversity are balanced	≤ 50	≤ 50	≥ 120	≥ 130	Indigenous fish communities are resilient and their structure composition and diversity are balanced	Mahinga kai species, including taonga species, are present in quantities, size and of a quality that is appropriate for the area
2	Mid-gradient, coastal and hard sedimentary		≤ 120	≤ 50	≥ 105	≥ 130		
3	Mid-gradient, soft sedimentary		≤ 120*	≤ 50*	≥ 105	≥ 130		
4	Lowland, large, draining ranges		≤ 120	≤ 50	≥ 110	≥ 130		
5	Lowland, large, draining plains and eastern Wairarapa		≤ 120*	≤ 50*	≥ 100	≥ 120		
6	Lowland, small		≤ 120*	≤ 50*	≥ 100	≥ 120		

[1] Shown on Maps 21a to 21e of the proposed Plan.

[2] This value shall not be exceeded in more than 8% of samples; for river classes marked with an * this value should not be exceeded in more than 17% of samples based on a minimum of three years of monthly sampling.

[3] Rolling median based on a minimum of three years of annual samples collected during summer or autumn.

[4] Rivers or streams with high macroinvertebrate community health, identified in column 2 of Schedule F1 (rivers and lakes).

Table 2.3: Explanation of aquatic ecosystem health attributes for rivers
This table should be read in conjunction with the definitions in Table 2.1

Attribute	Explanation
Macrophytes	Macrophytes are a natural component of the biodiversity and functioning of stream and river systems – in particular those with stable, slow flows. However, an over-abundance can reduce water and habitat quality in rivers and streams. Excessive macrophyte growth is generally associated with introduced rather than indigenous species (Matheson et al. 2012).
Periphyton	Periphyton are primary producers and an important foundation of many river and stream food webs. Periphyton also stabilise substrata and serve as habitat for many other organisms. Because periphyton attach to substrate their characteristics are affected by physical, chemical and biological disturbances that occur in the stream reach during the time in which the assemblage developed (Barbour et al. 2009). An over-abundance of periphyton can reduce ecological habitat quality (Matheson et al. 2012).
Invertebrates	Benthic macroinvertebrates are one of the most widely used biological indicators of river and stream ecosystem health. Macroinvertebrates are a critical part of the food web and are affected by physical, chemical and biological conditions. In addition their sedentary nature and relatively long life span means that they represent local conditions and show the effects of both short and long-duration stressors (Boothroyd & Stark 2000).
Fish	Fish are a key component of river and stream ecosystems and a very useful indicator of ecosystem health because they respond to both local and catchment-scale impacts (David et al. 2010). The majority of indigenous fish species are diadromous (migratory) so require connectivity to and from the sea. A healthy indigenous fish community is also dependent on water quality and habitat quality. Some introduced fish species can negatively impact indigenous fish communities (eg, through direct predation and competition and indirectly through affecting food webs, water quality and habitat) (McDowall 2000; McQueen & Morris 2013).

2.2.2 Measurement and assessment methods

Table 2.4 sets out the methods to use to measure each aquatic ecosystem health attribute in Table 2.2 and the guidelines to be used to assess whether or not the outcomes are being met. Of the attributes for river aquatic ecosystem health in the proposed Plan, only periphyton biomass is included in the NOF. Measurement and assessment methods for the proposed Plan periphyton outcome identified here are consistent with those in the NOF.

Table 2.4: Methods for measuring aquatic ecosystem health attributes in rivers and assessing if outcomes have been met

Attribute	Outcome		Measurement method	Assessment method	Comments
	Numeric or narrative?	If narrative, suggested guidance			
Macrophytes	Narrative	≤50% cross-sectional volume or cover in soft bottomed streams (Matheson et al. 2012)	Monthly estimates of: • cross-sectional area/volume of the stream channel occupied by macrophytes using the method identified in Matheson et al. (2012); • macrophyte cover using the method identified in Collier et al. (2007); and • macrophyte native cover (MNC) using the method identified in Collier et al. (2007).	To be determined.	Provisional guidance only from Matheson et al. (2012) as there is currently no national protocol for measurement or assessment of macrophyte community health. In addition, lack of knowledge of macrophyte communities in pre-human condition lowland streams in New Zealand (ie reference condition) as well as their sensitivity to pressure gradients currently limits the use of macrophytes as ecological indicators for rivers and streams (Schallenberg et al. 2011).
Periphyton	Numeric	NA	Monthly biomass estimate based on chlorophyll *a* concentration using method QM-1a from Biggs and Kilroy (2000).	Sample statistic = Mean number of exceedances per year based on a minimum of 3 years data.	Also consider monthly estimates of stream bed periphyton cover using the method identified for benthic cyanobacteria in MfE/MoH (2009) and the growth categories identified in Kilroy (2011) because it may be possible to use periphyton cover as a surrogate for periphyton biomass where a relationship between the two has been identified.
Macroinvertebrates	Numeric	NA	Annual sampling during summer/autumn of macroinvertebrate community composition using Protocols C1 and C2 identified in Stark et al. (2001). Calculation of macroinvertebrate community index (MCI) using the method and tolerance values identified in Stark and Maxted (2007).	Sample statistic = 3-year rolling median.	Also consider calculation of other commonly used macroinvertebrate metrics including number of taxa, QMCI, %EPT taxa, % EPT individuals (see Appendix 1) and diversity indices such as Shannon or Simpson diversity.
Fish	Narrative	None available	Assessment of fish community composition using methods identified in Joy et al. (2013) for wadeable habitats on at least a 3-yearly basis. Methodology for non-wadeable habitats is to be developed but will likely include netting and trapping. Fishing effort will be quantified (eg, area fished or number of nets used) and species caught will be identified, counted and their lengths measured.	To be determined.	There are no national protocol for sampling of non-wadeable rivers and streams and no national guidance for assessing indigenous freshwater fish community health. Assessment is likely to include comparison against expected (based on expert opinion and predictive models) community composition, calculation of fish community indices such as IBI (Joy & Death 2004), abundance of key species and determination of size-frequency classes for key species.

2.3 Lakes

2.3.1 Attributes and outcomes

Table 2.5 sets out the attributes and outcomes selected for aquatic ecosystem health in lakes in Table 3.5 of the proposed Plan. The importance of each of these attributes and an explanation of their respective outcomes is briefly outlined below in Table 2.6. While these attributes apply to all lakes, they were developed with particular consideration of five lakes in the Wellington Region where information on aquatic ecosystem health exists: Lakes Waitawa, Kohangapiripiri, Kohangatera, Pounui and Wairarapa.

Table 2.5: Lakes aquatic ecosystem health and mahinga kai outcomes in Table 3.5 of the proposed Plan

Lake type	Macrophytes	Phytoplankton	Fish	Mahinga kai species	Nutrients
All lakes[1]	Submerged and emergent macrophyte communities are resilient and occupy at least one third of the lake bed that is naturally available for macrophytes, and are dominated by indigenous species	Phytoplankton communities are balanced and there is a low frequency of nuisance blooms	Indigenous fish communities are resilient and their structure, composition and diversity are balanced	Mahinga kai species, including taonga species, are present in quantities, size and of a quality that is appropriate for the area	Total nitrogen and phosphorus concentrations do not cause an imbalance in aquatic plant, invertebrate or fish communities

[1] Except for intermittently closed and open lakes or lagoons (ICOLLs), such as Lake Onoke. These should be treated as a lake when they are in a closed state. When open to the coast, they should be managed an estuary, in which case Table 3.8 applies.

Table 2.6: Explanation of aquatic ecosystem health attributes for lakes

This table should be read in conjunction with the definitions in Table 2.1

Attribute	Explanation
Macrophytes	Macrophytes (aquatic plants) provide food, refuge and habitat for a range of invertebrate and fish species and also help stabilise lakebed sediments (reducing re-suspension of these sediments and any associated effects on water clarity) and recycle nutrients. Loss of macrophyte communities, which can occur through eutrophication, sedimentation, changes in lake water levels, etc., can be detrimental to shallow lake ecosystems. Some exotic macrophyte species have the potential to outcompete and smother indigenous macrophytes, reducing biodiversity and habitat values (Vant 1987).
Phytoplankton	Phytoplankton are a critical part of lake food webs and in a balanced ecosystem they provide food for a wide range of aquatic life, including zooplankton and kakahi (freshwater mussel). When nutrient concentrations are too high phytoplankton blooms may occur. Blooms have the potential to cause ecological impacts through changes in water quality (eg, reduced water clarity) and food webs (ie, some bloom-forming species are unpalatable). Blooms of some types of phytoplankton (cyanobacteria) are also potentially toxic (Vant 1987).
Fish	Fish are a key component of lake ecosystems and a very useful indicator of ecosystem health because they respond to both local and catchment-scale impacts (David et al. 2010). The majority of indigenous species are diadromous (migratory) so require connectivity to and from the sea. A healthy indigenous fish community is also dependent on water quality and habitat quality. Some introduced fish species can negatively impact indigenous fish communities (eg, through direct predation and competition and indirectly through affecting food webs, water quality and habitat) (McDowall 2000; McQueen & Morris 2013).

Attribute	Explanation
Nutrients	Nutrients are essential for lake ecosystems but excessive nutrient inputs (principally nitrogen and phosphorus) can lead to nuisance blooms of phytoplankton, macro-algae/epiphytes and/or nuisance growths of macrophytes, all of which can alter the health of lake ecosystems by affecting water quality and habitat quality.

2.3.2 Measurement and assessment methods

The methods to use to measure each aquatic ecosystem health attribute for lakes and guidelines to be used to assess whether or not the outcomes listed are being met are shown in Table 2.7.

Suggested guidance values for the macrophytes, phytoplankton and nutrient attributes are currently limited to the lakes named in Table 2.7. Further work is required to develop guidance for other lakes in the region. Water sample collection for analysis of phytoplankton and nutrient samples will follow appropriate methodology determined for each individual lake (ie, may differ slightly between lakes due depths, size etc.). While protocols do exist for the collection of water samples from lakes (eg, Burns et al. 2000) these are generally considered more suitable for deeper lakes than the shallow lakes found in the Wellington Region.

Of the attributes presented in Table 2.7, both phytoplankton and nutrients are included in the NOF. The measurement and assessment methods identified for these attributes are generally consistent with those identified in the NOF though some additional guidance is required to confirm how lakes should be classified. For example, NOF describes different total nitrogen attribute states for lakes that are stratified or brackish versus those lakes that are mixed (polymictic). Some lakes in the Wellington Region fall into both categories (eg, Lake Wairarapa is a polymictic lake that is also at times brackish) and it is unclear how the NOF attributes should be applied to these lakes (Perrie & Milne 2014).

Table 2.7: Methods for measuring aquatic ecosystem health attributes in lakes and assessing if outcomes have been met

Attribute	Outcome		Measurement method	Assessment method	Comments
	Narrative or numeric?	If narrative, suggested guidance			
Macrophytes	Narrative	Two thirds of vegetation cover should be indigenous and the LakeSPI scores should not fall below: L Kohangapiripiri: 63 L Kohangatera: 88 L Pounui: 56	At least 5-yearly measurement of 11 submerged aquatic plant community metrics along selected transects in each lake following Lake Submerged Plant Index (LakeSPI) protocols developed by Clayton and Edwards (2006). These metrics are then condensed into indices of indigenous species condition, invasive species condition and an overall LakeSPI index (that synthesises the indigenous and invasive species condition indices).	Comparison of LakeSPI score against suggested guidance value, with a drop of 5 or more LakeSPI units interpreted as a decline in vegetation condition (de Winton 2014).	No official national guidelines exist, although LakeSPI is a nationally recognised method for assessing lake vegetation. For larger lakes broad-scale mapping of aquatic plant communities may also be undertaken to complement LakeSPI assessments.
Phytoplankton	Narrative	The median concentration of chlorophyll *a* should be: • <5 mg/m^3 in Lakes Kohangapiripiri, Kohangatera, Pounui and Waitawa; and • <12 mg/m^3 in Lakes Onoke[3] and Wairarapa AND Maximum concentrations of chlorophyll *a* should not exceed 60 mg/m^3 in any lake	• Laboratory determination of chlorophyll *a* content in lake water samples collected monthly at a representative site(s) and analysed using standard APHA methods; and • At least annual identification and relative abundance of the taxonomic composition of the phytoplankton community.	Sample statistics: • Median based on 3 years of data (with the median recalculated annually); and • Annual maximum	The chlorophyll *a* concentrations of 5 mg/m^2 and 12 mg/m^2 equate to the boundaries of the mesotrophic/eutrophic and eutrophic/supertrophic ranges provided in Burns et al. (2000) and the boundaries of the B and C bands of the NOF, respectively. The maximum concentration is an interim value based on the boundaries of the C/D bands in the NOF. Further work is required to develop a guidance value(s) for the region's lakes that relates to a *"…low frequency of nuisance blooms"* (see Table 2.4). No guidance currently exists for assessing lake phytoplankton community balance.

Attribute	Outcome		Measurement method	Assessment method	Comments
	Narrative or numeric?	If narrative, suggested guidance			
Fish	Narrative	None available	To be developed. Likely to be involve 3-yearly fish surveys using a variety of techniques (suited to the habitat(s) present), with surveys extending into selected adjacent connected wetlands and rivers/streams where appropriate. Fishing effort will be quantified (eg, area fished or number of nets used) and species caught will be identified, counted and their lengths measured.	To be developed. Likely to include comparisons of the fish community against expected fish distributions and abundances based on expert opinion.	There are no national protocols for sampling or assessing indigenous fish community health in lakes. Sampling will likely employ multiple methods (eg, trammel, fyke and seine nets, and backpack electric fishing and spotlighting where appropriate).
Nutrients	Narrative	The concentration of total nitrogen should be: • <0.337 mg/L in Lakes Kohangapiripiri, Kohangatera, Pounui and Waitawa; and • <0.725 mg/L in Lakes Onoke[3] and Wairarapa The concentration of total phosphorus should be: • <0.02 mg/L in Lakes Kohangapiripiri, Kohangatera, Pounui and Waitawa; and • <0.043 mg/L in Lakes Onoke[3] and Wairarapa	Laboratory determination of total nitrogen and total phosphorus concentrations in water samples collected monthly at a representative site(s) and analysed using standard APHA methods.	Sample statistic = median based on a minimum of 3 years of data (with the median recalculated annually).	The nutrient concentrations for Lakes Kohangapiripiri, Kohangatera, Pounui and Waitawa equate to the boundaries of the mesotrophic/eutrophic ranges provided in Burns et al. (2000) and are broadly consistent with the boundaries of the B/C bands in the NOF. The nutrient concentrations for Lakes Onoke[3] and Wairarapa equate to the boundaries of the eutrophic/ supertrophic ranges provided in Burns et al. (2000) and fall within band C of the NOF. Note that in some cases elevated nutrient concentrations may be associated with naturally occurring dissolved organic matter. Chlorophyll *a* concentrations should also be used to assess whether nutrient concentrations may be causing an imbalance in aquatic plant communities.

[3] Only applies when the lake mouth is closed.

2.4 Groundwater

2.4.1 Attributes and outcomes

The attributes and outcomes for aquatic ecosystem health in groundwater in the proposed Plan are set out Table 2.8. The importance of each of these attributes and an explanation of their respective outcomes are outlined in Table 2.9.

Aquatic ecosystem health outcomes are based around two principal types of groundwater:

- Groundwater that is directly connected to surface water (Category A), and
- Groundwater that is not directly connected to surface water (Category C).

For groundwater with a moderate degree of hydraulic connectivity to surface water (Category B), site-specific information on the location and nature of the adjacent surface water feature is needed to assign the groundwater type. It is possible that outcomes for both groundwater types may be applied. The groundwater categories are defined in the Interpretation (Section 2) and mapped in Figures 7.2–7.9, 8.1–8.2 and 10.1-10.2 of the proposed Plan. Information on how the categories were derived can be found in Thompson and Mzila (2015).

Table 2.8: Groundwater aquatic ecosystem health and mahinga kai outcomes from Table 3.6 of the proposed Plan

<table>
<tr><th>Groundwater type</th><th>Nitrate</th><th>Quantity</th><th>Salt water intrusion</th></tr>
<tr><td>Directly connected to surface water</td><td>Nitrate concentrations do not cause unacceptable effects on groundwater-dependent ecosystems or on aquatic plants, invertebrate or fish communities in connected surface water bodies</td><td rowspan="2">The quantity of water is maintained to safeguard healthy groundwater-dependent ecosystems</td><td rowspan="2">The boundary between salt and fresh groundwater does not migrate between freshwater and salt water aquifers</td></tr>
<tr><td>Not directly connected to surface water</td><td>Nitrate concentrations do not cause unacceptable effects on stygofauna communities or other groundwater ecosystems</td></tr>
</table>

Table 2.9: Explanation of aquatic ecosystem health attributes for groundwater
This table should be read in conjunction with the definitions in Table 2.1

Attribute	Explanation
Nitrate	Nitrate-nitrogen (nitrate) is highly mobile in water allowing the quick migration from land to groundwater and hydraulically connected surface waters. Elevated concentrations of nitrate in groundwater can contribute to eutrophication of surface waters and be detrimental or toxic to aquatic organisms (Freeze & Cherry 1979; Younger 2007). Unacceptable effects are defined as those that prevent outcomes identified for connected surface water bodies (ie, rivers and streams, lakes or wetlands) from being met. It is not possible to define unacceptable effects on groundwater ecosystems as information for these ecosystems is currently lacking.
Quantity	Groundwater provides base-flow to rivers, streams, lakes and wetlands, or forms natural springs or seeps where it discharges to the ground's surface. Provision of base-flow to surface waters therefore needs to be maintained to sustain groundwater-dependent ecosystems. Over-abstraction of groundwater can cause stress to, or collapse of, such ecosystems.
Salt water intrusion	Salt water intrusion is the migration of salt water into fresh groundwater aquifers. It occurs naturally to some degree where groundwater aquifers extend to the coast and/or out under the sea. However, salt water intrusion can also be induced through over-abstraction of groundwater, leading to water chemistry changes that adversely affect groundwater and groundwater-dependent aquatic ecosystems reliant on fresh water (Younger 2007).

2.4.2 Measurement and assessment methods

The methods to measure each groundwater aquatic ecosystem attributes and the guidelines to use to assess whether or not the outcomes are being met are set out in Table 2.10.

Table 2.10: Methods for measuring groundwater aquatic ecosystem health attributes and assessing if outcomes have been met

Attribute	Outcome		Measurement method	Assessment method	Comments
	Numeric or narrative?	If narrative, suggested guidance			
Nitrate	Narrative	Nitrate chronic toxicity thresholds defined by Hickey (2013): ≤2.4 mg/L (median) ≤ 3.5 mg/L (95th percentile)	At least six-monthly measurements of the concentration of nitrate-nitrogen in groundwater following national sampling protocols (MfE 2006) and APHA standard methods for sample analysis.	Samples statistics: median and 95th percentile values calculated from a minimum of 12 and 30 data points, respectively (with the statistics recalculated annually).	Currently there is no national guidance for assessing aquatic ecosystem health in groundwater that is directly or partially connected to surface water. The surface water nitrate chronic toxicity threshold, as defined by Hickey (2013), has been adopted to assess the potential of nitrate in groundwater to impact on hydraulically connected surface water ecosystems. There is also currently little understanding of the response of groundwater fauna (stygofauna) to elevated concentrations of nitrate. In the interim, the surface water nitrate chronic toxicity threshold is adopted as the closest relevant measure of protection.
Quantity	Narrative	Surface water allocation limits and groundwater allocation limits in the tables within Chapters 7, 8 and 10 of the proposed Plan	Calculation of total consented water allocation within each water management zone coupled with: • Review of resource consent water take data collected under the Resource Management Measurement and Reporting of Water Takes Regulations 2010; and • Ongoing groundwater level monitoring programme comprising automated (continuous) and manual (spot) measurements to track trends.	Assessment of new resource consent applications for water takes against the allocation limits specified in the proposed Plan.	Numeric allocation limits in the proposed Plan only exist for the principal groundwater resource areas in the region (Ruamāhanga Valley, Hutt Valley and Kāpiti Coast). Permitted activity water takes are excluded from allocation accounting. Possible periodic audits of resource consent holder water meters may also be carried out. Water level measurements should meet the National Environmental Monitoring Standards for Water Level Recording (NEMS 2013). It may also be necessary to develop a monitoring programme that specifically assesses the health of groundwater-dependent ecosystems.
Salt water intrusion	Narrative	Policy P121 of the proposed Plan	Continuous groundwater level and conductivity measurements from groundwater bores located in coastal areas where large scale groundwater abstractions occur.	Comparison of groundwater levels against aquifer management levels in Policy P121.	Policy P121 provides numeric guidance only for the Kāpiti Coast and Lower Hutt where large-scale groundwater abstractions occur. GWRC has existing telemetered systems in place for these areas. National guidelines also exist for managing monitoring and managing sea water intrusion risks on groundwater (Callander et al. 2011).

2.5 Wetlands

2.5.1 Attributes and outcomes

Attributes and outcomes selected for aquatic ecosystem health in the proposed Plan for natural wetlands are shown in Table 2.11 (below). The importance of each of these attributes and an explanation of their respective outcomes is outlined in Table 2.12.

The proposed Plan uses the term 'natural wetlands' to distinguish between naturally occurring wetlands and those that are constructed or areas where soil is boggy but no wetland ecosystem exists.[4] The four key natural wetland types described in Table 3.7 of the proposed Plan are based on classification work by Johnson and Gerbeaux (2004).

Table 2.11: Wetland aquatic ecosystem health and mahinga kai outcomes in Table 3.7 of the proposed Plan

<table>
<tr><th>Wetland type</th><th>Plants</th><th>Fish</th><th>Mahinga kai species</th><th>Nutrient status</th><th>Hydrology</th></tr>
<tr><td>Bog</td><td rowspan="4">Indigenous plant communities are resilient and their structure, composition and diversity are balanced</td><td rowspan="4">Indigenous fish communities are resilient and their structure composition and diversity are balanced</td><td rowspan="4">Mahinga kai species, including taonga species, are present in, or are migrating through, the wetland and are in quantities, size and of a quality that is appropriate to the area</td><td>Low or very low</td><td rowspan="4">Water table depth and hydrologic regime is appropriate to the wetland type</td></tr>
<tr><td>Fen</td><td>Low to moderate</td></tr>
<tr><td>Swamp</td><td>Moderate to high</td></tr>
<tr><td>Marsh</td><td>Moderate to high</td></tr>
</table>

Table 2.12: Explanation of aquatic ecosystem health attributes for wetlands
This table should be read in conjunction with the definitions in Table 2.1

Attribute	Explanation
Plants	Wetland plants form the basis of the food web by capturing energy from sunlight and making it available to other organisms in the wetland ecosystem via herbivory and decomposition (Begon et al. 2006). Decomposition of plant material also creates soils and peat, the structure and composition of which can influence wetland hydrology and chemistry. Plants also provide structurally complex habitats for other wetland organisms, including invertebrates, fish, lizards and birds. The different environmental conditions of the different wetland types drive the composition of the plant communities present. Natural wetland functioning is enhanced by the presence of indigenous species (Peters & Clarkson 2010). Introduced pest plant species can out-compete indigenous species, resulting in the depletion of biodiversity and alterations to ecosystem function.

[4] The proposed Plan defines natural wetlands as "a permanently or intermittently wet area, shallow water and land water margin that supports a natural ecosystem of plants and animals that are adapted to wet conditions, including in the beds of lakes and rivers, the coastal marine area (e.g. saltmarsh), and groundwater-fed wetlands (e.g. springs)…"

Attribute	Explanation
Fish	Fish are a key component of wetland ecosystems and a very useful indicator of ecosystem health because they respond to both local and catchment-scale impacts (David et al. 2010). Some species, such as the brown mudfish, are considered 'wetland specialists' and unlikely to be found in other types of freshwater habitats. The majority of indigenous species are diadromous (migratory) so require connectivity to and from the sea. A healthy indigenous fish community is also dependent on water quality and habitat quality. Some introduced fish species can negatively impact indigenous fish communities (e.g. through direct predation and competition and indirectly through affecting food webs, water quality and habitat) (McDowall 2000; McQueen & Morris 2013).
Nutrient status	The availability of nutrients has a strong influence on wetland plant community composition (e.g. mosses grow in bogs where nutrient concentrations are low while flaxes prefer higher nutrient concentrations (Johnson & Gerbeaux 2004)). It is important to maintain nutrient concentrations within the tolerance range of the plants characteristic of each wetland type.
Hydrology	Water levels and the frequency and duration of water fluctuations are important drivers of the biotic component of wetlands. Some plants can tolerate continually wet conditions (e.g. mosses) while others are adapted to changing water levels (e.g. flaxes). Fish and other animal species that use wetlands for habitat are affected by alterations in the water levels as this causes changes in food supply and habitat availability (Beca 2008).

2.5.2 Measurement and assessment methods

Methods to measure the attributes of aquatic ecosystem health in natural wetlands and guidelines to use to assess whether or not the outcomes are being met are set out in Table 2.13.

There is currently no official national guidance available for monitoring and assessment of wetland ecosystem health. The majority of the guidance presented in Table 2.13 is based on a wetland condition monitoring manual developed by Landcare Research (Clarkson et al. 2004). This manual is widely used across New Zealand. Although the manual provides methods and a scoring system for a range of wetland indicators (attributes), at present the overall wetland condition index is largely used for comparisons between wetlands or to assess change in an individual wetland through time rather than to describe a healthy state. As wetland monitoring is established more widely across various wetland types and across the country, it is expected that numerical guidance values may be developed for particular attributes (eg, nutrients).

Table 2.13: Methods for measuring wetland aquatic ecosystem health attributes and assessing if outcomes have been met

Attribute	Outcome		Measurement method	Assessment method	Comments
	Numeric or narrative?	If narrative, suggested guidance			
Plants	Narrative	None currently available	To be developed. Likely to involved two methods: • Five-yearly estimate of indigenous species cover relative to introduced species for each wetland determined by the use of aerial photography, infrared imagery and LIDAR, with ground-truthing of vegetation at selected sites; and • Five-yearly measurement and scoring (0–5) of selected vegetation-based indicators in plots at selected sites following the methods outlined in Clarkson et al. (2004).	To be developed but likely to involve comparison of indigenous species cover and vegetation condition indicator scores through time.	Although no guidance is available >50% indigenous plant cover recognises the importance of indigenous plants to healthy functioning wetlands. First measurement method is a GWRC-derived desk-top method. This method is too coarse to determine sub-canopy or some groundcover vegetation types. Second measurement method incorporates indicators such as percent cover of introduced species in the canopy and understory, vegetation damage from browsing animals and vegetation clearance.
Fish	Narrative	None currently available	To be developed. Likely to involve 3-yearly fish surveys using a variety of techniques (suited to the habitat(s) present). Fishing effort will be quantified (e.g. area fished or number of nets used) and species caught will be identified, counted and their lengths measured.	To be developed. Likely to include comparisons of the fish community against expected fish distributions and abundances based on expert opinion.	There are no national protocols for sampling or assessing indigenous fish community health in wetlands (although Ling et al. 2009 provides guidance for surveying mudfish populations). Sampling will likely employ multiple methods (e.g. trammel, fyke and seine nets, and minnow traps).
Nutrient status	Narrative	None currently available	To be developed. Likely to involve 5-yearly measurement of total nitrogen and phosphorus in substrate and foliage samples at selected plots following protocols developed by Clarkson et al. (2004). Where open water is present, assessments of algal bloom levels will also be made.	To be developed but likely to involve comparison of substrate and foliage nutrient scores through time.	
Hydrology	Narrative	None currently available	To be developed. Likely to involve a combination of: • Manual and continuous water level measurements on an ongoing basis in selected wetlands; • 5-yearly measurement and scoring (0–5) of hydrological integrity indicators in plots at selected sites following the methods outlined in Clarkson et al. (2004); and • 5-yearly determination of plant species composition and cover in selected plots to enable calculation of a Prevalence Index (Clarkson et al. 2014).	To be developed but likely to involve water level trend assessment and comparison of indigenous species cover and vegetation condition indicator scores through time.	Continuous water level measurements should meet the National Environmental Monitoring Standards for Water Level Recording (NEMS 2013). Work is underway nationally to determine appropriate water level fluctuations for different wetland types. There are three hydrological integrity indicators described in Clarkson et al. (2004): impact of man-made structures, evidence of change in water level, and dryland plant invasion.

2.6 Coastal waters

2.6.1 Attributes and outcomes

The attributes and outcomes for aquatic ecosystem health in coastal waters in the proposed Plan are set out in Table 2.14. The importance of each of these attributes and an explanation of their respective outcomes is outlined in Table 2.15.

Coastal waters have been separated into two main types: open coast, and estuaries and harbours. Estuaries and harbours are semi-enclosed, meaning they tend to act as depositional environments compared with more energetic open coastal waters. Semi-enclosed environments also support different aquatic ecosystems (eg, saltmarsh).

Table 2.14: Coastal water aquatic ecosystem health and mahinga kai outcomes from Table 3.8 of the proposed Plan

<table>
<tr><th>Coastal water type</th><th>Macroalgae</th><th>Seagrass and saltmarsh</th><th>Invertebrates</th><th>Mahinga kai species</th><th>Fish</th><th>Sedimentation rate</th><th>Mud content</th></tr>
<tr><td>Open coast</td><td rowspan="2">The algae community is balanced with a low frequency of nuisance blooms</td><td>NA</td><td rowspan="2">Invertebrate communities are resilient and their structure, composition and diversity are balanced</td><td rowspan="2">Mahinga kai species, including taonga species, are present in quantities, sizes and of a quality that is appropriate for the area</td><td colspan="3">NA</td></tr>
<tr><td>Estuaries and harbours[1]</td><td>Seagrass, saltmarsh and brackish water submerged macrophytes are resilient and diverse and their cover is sufficient to support invertebrate and fish communities</td><td>Indigenous fish communities are resilient and their structure, composition and diversity are balanced</td><td>The sedimentation rate is within an acceptable range of that expected under natural conditions</td><td>The mud content and areal extent of soft mud habitats is within a range of that found under natural conditions</td></tr>
</table>

[1] Intermittently closed and open lakes or lagoons (ICOLLs), such as Lake Onoke, should be treated as an estuary when they are in an open state. When closed to the coast, they should be managed as a lake, in which case Table 3.5 of the proposed Plan applies.

Table 2.15: Explanation of aquatic ecosystem health attributes for coastal waters
This table should be read in conjunction with the definitions in Table 2.1

Attribute	Explanation
Macroalgae	Macroalgae are an important component of all aquatic ecosystems, helping to stabilise bottom sediments and provide habitat for other species. However, mass blooms of green and red macroalgae, mainly of the genera *Ulva, Cladophora,* and *Gracilaria,* can present a significant nuisance problem, especially when loose mats accumulate and decompose. Algal blooms also have major ecological impacts on water and sediment quality, reducing water clarity and oxygen and smothering other resident species (Robertson & Stevens 2013).
Seagrass and saltmarsh	Saltmarsh, seagrass and submerged macrophytes are essential for healthy estuarine and harbour systems, providing essential food, refuge and nursery habitat for fish, invertebrates and birds. They also provide buffering from wave action and entrain nutrients and sediments. Loss of these habitats negatively affects fisheries, animal populations and filtering of water pollutants (Stevens & Robertson 2014a).

Attribute	Explanation
Invertebrates	Invertebrates are the primary indicator of sediment health and the abundance, diversity and biomass of invertebrate communities living within and on the sediment can be used as indicators of changing environmental conditions. A balanced community is represented by animals with a variety of feeding types, trophic associations, reproductive strategies and tolerances to different stressors such as mud content and organic enrichment (Robertson & Stevens 2014).
Fish	Fish are a key component of marine and estuarine ecosystems and a healthy indigenous fish community is dependent on water quality and habitat quality. Of significance for marine fish species, estuarine systems – including lake and river mouths – are also significant for freshwater fish species. The majority of freshwater fish species are diadromous (migratory) and utilise estuaries as migratory pathways between freshwater and oceanic environments. Inanga spawning also occurs within the tidal reaches of the estuarine habitat.
Sedimentation rate Mud content	Estuaries and harbours are natural 'sinks' for catchment-derived sediment and their natural cycle is to slowly infill with fine muds and clays. Historically, they were dominated by sandy sediments and had low sedimentation rates (<1 mm/yr). Human activities have accelerated sedimentation rates causing estuaries and harbours to infill quickly with muds, reducing biodiversity. Muddy sediments have a higher tendency to become anoxic and anoxic sediments contain toxic sulphides and very little aquatic life. Elevated sedimentation rates are likely to lead to significant and detrimental ecological changes within estuary areas that could be very difficult to reverse (Stevens & Robertson 2013).

2.6.2 Measurement and assessment methods

The methods to measure each aquatic ecosystem health attribute for coastal waters and the guidelines to use to assess whether or not the outcomes are being met are set out in Table 2.16.

There is very little national guidance available for either measurement or assessment methods, particularly for open coastal waters. As such, no measurement or assessment guidance is provided for open coastal waters in this document. Instead, the guidance presented in Table 2.16 relates to estuarine environments for which national monitoring protocol were established in 2002 (Robertson et al.). In the absence of national guidelines for assessing measures of estuarine ecological health, condition ratings have been developed for estuaries based on monitoring data from estuaries across many parts of New Zealand, including several estuaries in the Wellington Region (Robertson & Stevens 2012a & b; Stevens & Robertson 2013 & 2014c; Robertson & Stevens 2015a & b). These ratings require expert evaluation and assessment though time and will continue to be reviewed and updated as more data become available.

Table 2.16: Methods for measuring aquatic ecosystem health attributes in estuaries and assessing if outcomes have been met

Attribute	Outcome		Measurement method	Assessment method	Comments
	Numeric or narrative?	If narrative, suggested guidance			
Macroalgae	Narrative	Ecological Quality Rating (EQR) for macroalgae >0.5	Annual (where the EQR is <0.4) or five-yearly mapping of percentage cover using aerial photography, visual assessment and GIS-based mapping, plus measures of biomass and degree of macroalgal entrainment. This method is based on the work of Robertson and Stevens (2015a).	Determine EQR as per Robertson and Stevens (2015a) and compare the most recent EQR with the suggested guidance value.	The EQR assesses key parameters such as macroalgal biomass, entrainment and percent cover to provide an early warning of increasing or widespread algal growth. The guidance value relates to an EQR quality rating of 'moderate' or better. Macroalgal mapping is carried out over the entire estuary or harbour environment though it may be limited at times to the intertidal or subtidal areas.
Seagrass & saltmarsh	Narrative	Where present: • No significant decline in the area of dense seagrass cover (>50%) from the established baseline; • No significant decline in saltmarsh area from the established baseline; and • No significant decline in submerged macrophyte area from the established baseline.	At least 5-yearly mapping of percent cover of seagrass and saltmarsh using a combination of aerial photography, visual assessment and GIS-based mapping, to estimate the area and change in saltmarsh and seagrass habitat over time. This method is based on extensions to the National Estuaries Monitoring Protocol (Robertson et al. 2002; Stevens & Robertson 2013).	Comparison of the most recent percent cover result with the established baseline value. A decline in percent cover of more than 10% is considered significant.	Mapping should be carried out over the entire estuary or harbour environment; mapping of seagrass may extend to subtidal areas. The guidance is restricted to areas of dense seagrass cover (ie, where cover over an area is >50%) as low density seagrass meadows are expected to fluctuate for natural reasons over seasonal or annual cycles. Refer to Stevens & Robertson (2013) for more information on assessing seagrass density. Measures to assess the condition, or health, of seagrass are currently being developed.

Attribute	Outcome		Measurement method	Assessment method	Comments
	Numeric or narrative?	If narrative, suggested guidance			
Invertebrates	Narrative	Mud and organic enrichment rating (WEBI) <3.3	At least 5-yearly collection of intertidal sediment cores (3-10 replicates per site) at representative sites to identify and count the infauna and epifauna. This method is based on extensions to the National Estuaries Monitoring Protocol (Robertson et al. 2002; Robertson & Stevens 2012a) and the WEBI measurement is based on the work of Robertson and Stevens (2015b).	Determine WEBI rating as per Robertson and Stevens (2015b) and compare the most recent value with suggested guidance value.	A WEBI rating of <3.3 is indicative of a healthy benthic community with low levels of organic enrichment and low to moderate mud concentrations. Sampling should be undertaken at carefully selected representative sites during the same month of the year to avoid differences due to recruitment and seasonal variation. Epifauna (ie, animals living on the sediment surface) may also be monitored. Other physico-chemical variables (eg, sediment nutrient content) and invertebrate indices should be used to support this guidance.
Fish	Narrative	None currently available	To be developed. Likely to involve 3-yearly fish surveys using a variety of techniques to target different species, including set nets, beach seine nets, and longlines. Fishing effort will be quantified (eg, area fished or number of nets used) and species caught will be identified, counted and their lengths measured.	To be developed. Likely to include comparisons of the fish community against expected fish distributions and abundances based on expert opinion.	There are no national protocols for sampling or assessing indigenous fish community health in estuaries.

Attribute	Outcome		Measurement method	Assessment method	Comments
	Numeric or narrative?	**If narrative, suggested guidance**			
Sedimentation rate	Narrative	Mean annual sedimentation rate should be 1 mm/yr for Porirua Harbour (areal sedimentation rate of 1 mm/yr by 2035). Mean annual sedimentation rate for other estuaries should not exceed 5 x the RNSL (Retained Natural Sediment Load).	At least annual measurement of sedimentation rates over buried concrete plates at selected intertidal and subtidal locations in estuaries and harbours (Stevens & Robertson 2014b). Additional information from periodic bathymetric surveys and/or catchment sediment yield modelling may be used to support sedimentation rate data.	Comparison of the mean (rolling mean of most recent 5 years or less) sedimentation rate over all sediment plates within an estuary, and bathymetric survey results, where available, with the suggested guidance value.	The Porirua Harbour sedimentation rate is consistent with the Porirua Harbour and Catchment Strategy and Action Plan (PCC 2012). The RNSL is the magnitude of the average annual sediment load retained in the estuary under natural state (as estimated from a sediment retention model). The mean annual sedimentation rate is determined from >3 measurements over multiple sedimentation plates (~4 per site) (Stevens & Robertson 2014b). Sediment does not deposit evenly within the marine environment so the location of sediment plate sites needs to reflect the depositional areas within the harbour or estuary.
Mud content	Narrative	• No significant increase in mud content from the established baseline; and • No significant increase in soft mud (ie, >20% mud content) area from the established baseline.	At least 5-yearly: • measurements of mud fraction (<63 microns; 3-10 replicate cores per site) at selected intertidal sites through grain size analysis to calculate the relative proportions of mud and sand in the surface sediments; and • mapping of percent cover of soft mud habitat using a combination of aerial photography, visual assessment and GIS-based mapping, to estimate the area and change in soft mud habitat over time. These methods are based on extensions to the National Estuaries Monitoring Protocol (Robertson et al. 2002; Stevens & Robertson 2014a; 2014b).	Comparison of the mud content and substrate area measurements against the established baselines. An increase in percent mud content or the area of soft sediment of more than 10% is considered significant.	

3. Contact recreation

This section sets out guidance for contact recreation outcomes in Tables 3.1–3.3 of Objective O24 of the proposed Plan. Key principles around the contact recreation outcomes are introduced first, including alignment with the NOF, and brief comments on assessment methods and statistical considerations. Outcomes for each of the contact recreation attributes in Tables 3.1–3.3 are then discussed separately for fresh water (rivers and streams, lakes and wetlands) and coastal water (open coast, harbours and estuaries).

3.1 Introduction

There are two principal guidance documents for monitoring recreational waters in New Zealand:

- MfE/MoH (2003) Microbiological Water Quality Guidelines provide the basis of the microbiological indicators and assessment in both coastal and fresh water, and
- MfE/MoH (2009) interim cyanobacteria guidelines provide the basis of cyanobacteria assessment in fresh water.

The NPS-FM has drawn on both these documents to provide numeric attribute states for primary contact recreation in fresh water. In addition, the NOF provides microbiological numeric attribute states for secondary contact in fresh water based on analysis by McBride (2012). The secondary contact value is identified in the NPS-FM as a compulsory value for all fresh water while the primary contact recreation value is optional. The fresh water contact recreation outcomes in the proposed Plan align with the NOF minimum acceptable state and national bottom line attribute state for primary recreation and secondary contact, respectively (see GWRC 2015b).

3.1.1 Assessment and statistics

Statistically robust data sets will underpin assessment of attributes with numeric outcomes (ie, *E. coli* and enterococci) and narrative outcomes assessed using numeric measures (eg, interpretation of cyanobacteria in lakes). For the reasons outlined in Section 2.1.2:

- Median values should be determined from around 12–20 data points;
- 95th percentile values should be determined from around 30–50 data points; and
- All percentile-based statistics should be derived using the Hazen method.

As outlined in Section 2.1.2, generating sized data-sets of this size will almost certainly require data collection over multiple years. Three years is considered to be the optimum period in most cases and is preferable to annual assessments as attributes such as faecal indicator bacteria and cyanobacteria can be unduly influenced by a particularly wet or dry summer (or year). While only limited information on data-set size and statistical calculations are included in the NOF, guidance is currently under development and is expected to be similar to that proposed here.

3.2 Rivers and lakes

3.2.1 Attributes and outcomes

Attributes and outcomes for primary and secondary contact with water in the proposed Plan for fresh water are set out in Table 3.1. An explanation of the importance of each of these attributes is outlined in Table 3.2.

Table 3.1: Contact recreation and Māori customary use outcomes for fresh waters from Tables 3.1 and 3.2 of the proposed Plan

Primary contact recreation in significant contact recreation freshwater bodies					
Water body	***E. coli*/100mL**	**Cyanobacteria**		**Māori customary use**	**Toxicants and irritants**
	95th percentile	**Planktonic**	**Benthic**		
Rivers	≤ 540 at all flows below 3x median flow, September to April inclusive		Low risk of health effects from exposure	Fresh water is safe for primary contact and supports Māori customary use	Concentrations of toxicants or irritants do not pose a threat to water users
Lakes	≤ 540 September to April inclusive	≤ 1.8mm^3/L biovolume equivalent of potentially toxic cyanobacteria **OR** ≤ 10mm^3/L total biovolume of all cyanobacteria			

Secondary contact with water in freshwater bodies			
Water body	***E. coli*/100mL**	**Cyanobacteria**	
	median	**Planktonic**	**Benthic**
Rivers	≤ 1,000		Low risk of health effects from exposure
Lakes		≤ 1.8mm^3/L biovolume equivalent of potentially toxic cyanobacteria OR ≤ 10mm^3/L total biovolume of all cyanobacteria	

Table 3.2: Contact recreation attributes for fresh water

Attribute	Explanation
E. coli	*Escherichia coli (E. coli)* is the preferred faecal indicator organism for freshwaters (MfE/MoH 2003) and is used to indicate the presence of pathogenic micro-organisms such as viruses, bacteria and protozoa. These organisms can pose a health risk to humans when rivers and lakes are used for recreational activities such as swimming and kayaking.
Cyanobacteria	Cyanobacteria are photosynthetic prokaryotic organisms that are an integral part of many aquatic ecosystems. However, under favourable conditions cyanobacterial cells can multiply and form blooms which can be toxic. Toxins produced by cyanobacteria (cyanotoxins) are a threat to humans and other animals when consumed in drinking water or by contact during recreational activities (MfE/MoH 2009). Benthic cyanobacteria grow attached to the substrate of rivers and streams. Planktonic cyanobacteria grow in the water column of lakes and slow flowing rivers.
Toxicants and irritants	A large number of chemicals may be released into the aquatic environment and may be toxic to recreational water users, or cause irritation to their skin or mucous membranes. Chemicals include metals/metalloids, organic contaminants and pesticides listed in Tables 5.2.3 and 5.2.4 of the ANZECC (2000) guidelines.

3.2.2 Measurement and assessment methods

Table 3.3 sets out the methods and guidelines that will be used to measure the contact recreation attributes and assess whether or not the outcomes in Table 3.1 of the proposed Plan are being met.

The *E. coli* 95th percentile in rivers is heavily influenced by results collected during or shortly after heavy rainfall. During heavy rainfall large volumes of contaminated runoff from urban and rural land uses can flow into rivers and streams resulting in high *E. coli* counts. Inclusion of these rainfall related counts results in the 95th percentile being representative of wet weather/high flow conditions when contact recreation is less likely to occur (see Greenfield (2014) for more information). For this reason, results collected during three times median flow or higher are excluded from assessment of the *E. coli* outcome for primary contact recreation.

Table 3.3: Methods for measuring contact recreation attributes and assessing if outcomes have been met

Attribute	Outcome		Measurement method	Assessment method	Comment
	Numeric or narrative?	If narrative, suggested guidance			
E. coli (secondary contact)	Numeric	NA	Laboratory measure of *E. coli* count in cfu/100 mL of water samples taken monthly and analysed using standard APHA methods.	Sample statistic: median, based on a minimum of three years of data and updated annually.	The frequency of sampling aligns with current SoE monitoring for rivers and most lakes but will be reviewed. At least quarterly sampling is required to enable an assessment over 3 years.
E. coli (primary contact)	Numeric	NA	Laboratory measure of *E. coli* count in cfu/100 mL of water samples taken weekly for at least 20 weeks during the summer bathing season following the procedure in Note H (ii) of the MfE/MoH (2003) guidelines.	Sample statistic: 95^{th} percentile, based on a minimum of three years of data and updated annually.	Depending on recreational use at specific sites it may be appropriate to undertake measurements outside of the official summer season of November to March inclusive.
Benthic cyanobacteria	Narrative	≤20% cover of the river/ stream bed	Visual assessment of cyanobacteria cover of the river bed during summer for 20 weeks using the method outlined in Section 4.4.3 of MfE/MoH (2009) guidelines.	Appropriate sample statistic to be developed.	The MfE/MoH (2009) guidelines are interim and are still to be finalised. The 20% cover threshold equates to the 'alert' guideline.
Planktonic cyanobacteria	Numeric	NA	To be confirmed on a case-by-case basis for selected lakes but any monitoring is likely to involve at least 3-monthly determination of cyanobacteria cell concentration or biovolume using the method outlined in Section 4.3.2 of MfE/MoH (2009).	Sample statistic: 80^{th} percentile, based on a minimum of three years of data and updated annually.	There is currently limited monitoring of planktonic cyanobacteria in the Wellington Region.
Toxicants and irritants (primary contact)	Narrative	Tables 5.2.3 and 5.2.4 of the ANZECC (2000) guidelines	To be confirmed on a case-by-case basis but any water sample analysis will follow APHA standard methods.	To be confirmed.	The need for monitoring is to be determined and is unlikely to be required, if at all, at many sites. ANZECC (2000) guidelines are currently under review.

3.3 Coastal waters

3.3.1 Attributes and outcomes

The attributes and outcomes for contact recreation in coastal waters in Objective O24 of the proposed Plan are set out in Table 3.4. An explanation of the importance of each of these attributes is outlined in Table 3.5.

Table 3.4: Coastal contact recreation and Māori customary use outcomes from Table 3.3 of the proposed Plan

Coastal water	Pathogens: Indicator bacteria/100mL 95th percentile	Māori customary use	Shellfish quality
Estuaries[1]	≤ 540 *E. coli*	Coastal water is safe for primary contact and supports Māori customary use	Concentrations of contaminants, including pathogens, are sufficiently low for shellfish to be safe to collect and consume where appropriate
Open coast and harbours[2]	≤ 500 enterococci		

[1] Excludes Te Awarua-o-Porirua Harbour and includes Lake Onoke. Estuaries, including river mouth estuaries, should be treated as an estuary when they are dominated by saline water, in which case Table 3.3 applies, and as rivers when they are dominated by freshwater, in which case Table 3.1 or 3.2 applies.

[2] Includes Wellington Harbour (Port Nicholson) and Te Awarua-o-Porirua Harbour. Excludes the Lambton Harbour Commercial Port Zone delineated in Map 32.

Table 3.5: Contact recreation attributes for coastal waters

Attribute	Explanation
Indicator bacteria	Indicator bacteria are used to indicate the presence of pathogenic micro-organisms such as viruses, bacteria and protozoa. These organisms can pose a health risk to humans when coastal waters are used for recreational activities such as swimming and surfing. Enterococci is the preferred faecal indicator organism for coastal waters (MfE/MoH 2003). *E. coli* is the preferred faecal indicator organism for estuarine waters (MfE/MoH 2003).
Shellfish quality	Pathogens (disease-causing organisms) and stormwater contaminants (eg, copper and zinc) may be released into the aquatic environment and ingested by filter feeding shellfish, such as mussels, cockles and pipis. When these pathogens and contaminants accumulate in shellfish flesh they can become harmful to people that gather and consume these shellfish.

3.3.2 Measurement and assessment methods

Table 3.6 sets out the methods and guidelines that will be used to measure the contact recreation attributes for coastal waters and assess whether or not the outcomes in Table 3.3 of the proposed Plan are being met.

Table 3.6: Methods for measuring contact recreation attributes and assessing if outcomes have been met

Attribute	Outcome		Method(s) of measurement	Assessment	Comment
	Numeric or narrative?	If narrative, suggested guidance			
Indicator bacteria	Numeric	NA	Laboratory measure of indicator bacteria count in cfu/100 mL of water samples taken weekly for 20 weeks during the summer bathing season (November to March inclusive) following the procedure in Note H (ii) of the MfE/MoH (2003) guidelines.	Sample statistic = 95th percentile, based on a minimum of three years of data and updated annually.	Depending on recreational use at specific sites it may be appropriate to undertake measurements outside of the defined summer season.
Shellfish quality	Narrative	None recommended	To be developed. May involve periodic laboratory measurement of the concentration of microbiological contaminants and/or trace metals in the flesh of selected filter-feeding shellfish species (eg, mussels, cockles and tuatua) popular for collection in the area(s) of interest.	To be developed.	The MfE/MoH (2003) microbiological water quality guidelines include numeric guidance for recreational shellfish gathering waters but these guidelines have a number of limitations and cannot be relied upon to assess if shellfish are safe for human consumption (see Oliver et al. 2014). Food Standards Australia New Zealand provides guidance on safe concentrations of a range of microbiological (eg, *E. coli*) and natural contaminants (eg, arsenic) found in many shellfish but lacks guidance for common stormwater-related contaminants (eg, copper and zinc). See Australia New Zealand Food Standards code, Standard 1.4.1 (2013); Standard 1.6.1 (2014).

References

Australia New Zealand Food Standards code: Standard 1.4.1 Contaminants and natural toxicants (2013); Standard 1.6.1 Microbial Limits in Food. (2014). www.foodstandards.govt.nz/code

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