BEFORE THE PROPOSED NATURAL RESOURCES PLAN HEARINGS PANEL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER AND	of water quality provisions]
IN THE MATTER	of the submissions and further submissions set out in the S42A Officer Report

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STATEMENT OF PRIMARY EVIDENCE OF MICHAEL GREER ON BEHALF OF WELLINGTON REGIONAL COUNCIL

TECHNICAL – Water quality in regards to

1. **Objectives for contact recreation and Māori customary use (Objective O24)**
2. **Objectives for aquatic ecosystem health and mahinga kai (Objective O25)**

12 January 2018

TABLE OF CONTENTS

1. SUMMARY

1.1 My name is Michael John Crawshaw Greer.

1.2 I have been asked to provide technical evidence on the approach taken by the Wellington Regional Council (the Council) for objectives for fresh and coastal water quality in the Proposed Natural Resources Plan (the proposed Plan).

1.3 My key conclusions are:

(a) The planktonic cyanobacteria outcomes for contact recreation should be amended to < 1.8 mm^3/L biovolume equivalent of potentially toxic cyanobacteria or < 10 mm^3/L total biovolume of all cyanobacteria;

(b) Tables 3.1 and 3.2 should be updated to include attributes that relate to the aesthetic attributes of contact recreation, as they are major determinants of whether a river or lake is perceived as suitable for recreation;

(c) The river classes identified in Table 3.4 of Objective O25 are a fair representation of the natural variation in river and stream ecosystems in the Wellington Region, and are suitable for use as the basis for aquatic ecosystem health outcomes;

(d) The additional ecosystem health attributes requested by submitters (listed in para 6.58) for rivers and streams should not be included in Table 3.4. These attributes do not meet the criteria for inclusion in the proposed Plan as either; they are not considered key determinants of aquatic ecosystem health, or it is not possible to develop outcomes that are robust, defensible and feasible in terms of monitoring; and

(e) The narrative aquatic ecosystem health outcomes included in Tables 3.4 – 3.5 should not be replaced with numeric thresholds, as has been requested by submitters. The state of knowledge for these attributes simply does not allow for the development of numeric outcomes that are scientifically defensible.

2. INTRODUCTION

2.1 My name is Michael John Crashaw Greer. I work for Council as a Senior Environmental Scientist in the Environment Science Department.

2.2 I hold a PhD degree in Ecology and a Bachelor of Science in Zoology from the University of Otago. The title of my PhD is 'The effects of macrophyte control on freshwater fish communities and water quality in New Zealand streams'.

2.3 I have worked for local government, the Department of Conservation and NIWA. I have 6 years of work experience in freshwater ecology. As of the 30th of June 2016 I have been employed by the Greater Wellington Regional Council for six months. Prior to that I was employed by the Canterbury Regional Council as a Water Quality and Ecology Scientist (ii).

2.4 I have read the section 42A officers' reports prepared by Rachel Pawson on the water quality provision in the proposed Plan.

2.5 My evidence relates to the approach taken by Council on the following specific matters:

(a) The development of objectives for contact recreation and Māori customary use (Objective O24); and

(b) The development of objectives for aquatic ecosystem health and mahinga kai (Objective O25).

3. CODE OF CONDUCT

3.1 I confirm that I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note and that I agree to comply with the code. My evidence in this statement is within my area of expertise. I have not omitted to consider material facts known to me that might alter to detract from the opinions which I express.

4. SCOPE

4.1 I have been asked to provide evidence in response to submissions on the Proposed Natural Resources Plan (proposed Plan) received on the following matters:

(a) Objectives for contact recreation and Māori customary use (Objective O24),

(b) Objectives for aquatic ecosystem health and mahinga kai (Objective O25)

4.2 The scope of my evidence includes background on each topic, options considered and my opinion on the appropriateness of the relevant provisions.

4.3 Although the options that I consider take into account submissions received on the proposed Plan, my conclusions are limited to technical matters and I do not provided recommendations on policy.

5. OBJECTIVES FOR CONTACT RECREATION AND MĀORI CUSTOMARY USE (OBJECTIVE O24)

5.1 In this section I address three components of proposed Objective O24:

(a) Relationship between contact recreation and Māori customary use

(b) The identification and monitoring of significant contact recreation freshwater bodies

(c) Attributes for Tables 3.1 – 3.3

Contact recreation and Māori customary use

5.2 Objective O24 in the proposed Plan refers to both contact recreation and Māori customary use.

5.3 I understand that submissions have been made which reason that managing for contact recreation will also manage for Māori customary use. I also understand that the concept of Māori customary use has been addressed in previous reports. In this evidence I focus on the concept of contact recreation.

5.4 Contact recreation is defined in the *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas* as "recreational activities that bring people physically in contact with water, involving a risk of involuntary ingestion or inhalation of water" (MfE/MoH, 2003).

5.5 In freshwater, the risk of infection from waterborne pathogens through ingestion or inhalation of contaminated water is assumed to vary between recreational activities because of differences in the rate of accidental ingestion (McBride, 2012). Accordingly, Tables 3.1 and 3.2 of Objective O24 set out different attributes and outcomes for activities that involve 'primary' and 'secondary' contact with freshwater.

(a) Primary contact recreation encompasses those recreational activities where people's contact with freshwater is "likely to involve full immersion", or "a high incidence of ingestion or inhalation of water and water vapour such as swimming and kayaking" (from the National Policy Statement for Freshwater Management (NPS-FM) 2011). Attribute states relating to primary contact recreation are included in the NPS-FM 2014, but the minimum acceptable state only applies to those waterbodies identified as being valued for primary contact recreation.

(b) Secondary contact recreation was defined as part of the NPS-FM 2014, and encompasses those recreational activities where peoples contact with freshwater "involves only occasional immersion and includes wading or boating (except boating where there is high likelihood of immersion)".The NPS-FM 2014 identifies a national bottom line for secondary contact recreation. This bottom line applies to all freshwater bodies.

5.6 The objectives and attributes set out in Table 3.3 of Objective O24 are relevant for all forms of contact recreation (defined in para. 5.4) conducted in coastal waters. The concepts of primary and secondary contact with water do not apply in coastal environments, as the human health risks of immersive and non-immersive contact with water are considered similar due to factors such as wave action and aerosolisation of water particles. This assumption is based on the results of McBride et al. (1998), who found that paddlers' in the near-shore area who didn't immerse their heads but inhaled aerosolised sea water were in the highest risk category for respiratory effects.

5.7 The attributes and outcomes set out in Tables 3.1 to 3.3 of Objective O24 relate to the human health risks associated with contact recreation. These attributes are designed to ensure the risks to human health are managed at level that it is safe for activities likely to involve full immersion in all coastal waters and those rivers and lakes identified as significant for primary contact recreation[1]. For all other fresh water bodies, the attributes and objectives are set to ensure that human health risks are managed at a level that it is safe

[1] Fresh water bodies that are significant for primary contact recreation are identified in the proposed Plan as part of the definition of 'significant contact recreation freshwater bodies', which refers to Schedule H1 and Map 20.

for activities that involve occasional immersion and some ingestion of water (i.e. secondary contact).

5.8 Submitters have requested that Objective O24 be amended on the basis that the requirement for all rivers, lakes and natural wetlands to (at a minimum) meet the secondary contact recreation objectives sets either an inappropriately high or low standard. In a technical memorandum documenting the objective development process, Greenfield (2014c) stated that the input of science staff into the development of Objective O24 was limited to providing recommended attribute outcomes for both primary and secondary contact recreation. Where those outcomes were applied was a policy decision by Te Upoko Taiao, GWRC's Natural Resource Management Committee, and was made to align the objectives in the proposed Plan with the NPS-FM 2014. Consequently, it is out of the scope of my evidence to provide recommendations on where primary and secondary contact recreation outcomes should apply. However, information on how the specific outcomes for primary and secondary contact recreation in rivers were developed, and my opinions on their appropriateness are provided in para. 5.21 to para. 5.58.

The identification and monitoring of significant contact recreation freshwater bodies

5.9 The regionally significant primary contact recreation water bodies identified in Schedule H1 of the proposed Plan are the same as those selected in 2009 to populate Appendix 1 of the Regional Policy Statement (RPS) for the Wellington Region (Vujcich, 2014). These water bodies were identified from the results of a survey sent to 106 people belonging to organisations with interests in fishing, canoeing, trampling and hunting, as well as environmental groups like Forest and Bird (survey results are published in GWRC (2009)). Significant water bodies were selected based on the number of people found to use it for swimming, whether it was used for swimming by people throughout the region and beyond, and the reasons why respondents believed the river was suitable for swimming.

5.10 Submissions on the significant primary contact recreation water bodies raise concerns that they are identified in Schedule H1 of the proposed Plan at the river scale rather than the site or reach scale. A number of submitters have stated that not all parts of the rivers identified in Schedule H1 and Map 20 of the proposed Plan are used for primary contact recreation, and that it is inappropriate to classify reaches that are not used for contact recreation as significant. These submissions are correct, in that not every reach of every river identified in Schedule H1 will be used for primary contact recreation. However, in my opinion it is still appropriate to set outcomes relevant to primary contract recreation for the entire length of the rivers identified in Schedule H. Faecal pathogens that pose a health risk to recreational users, such as *Campylobacter*, persist in the environment for days to weeks (Buswell et al., 1998), during which time they are transported downstream from their source. Consequently setting less stringent objectives for reaches not used for swimming poses a potential risk to downstream reaches that are.

5.11 It is my opinion that the primary contact recreation objectives should apply to the entire length of the rivers identified in Schedule H1. Setting outcomes for primary contact recreation through an entire system is the best mechanism of ensuring that frequently utilised bathing sites are protected from faecal contamination in upstream reaches.

Attributes of Tables 3.1 and 3.2

5.12 Table 3.1 contains four attributes of primary contact in rivers and lakes. These are:

(a) *E.coli*

(b) Cyanobacteria

(c) Māori customary use

(d) Toxicants and irritants

5.13 Table 3.2 contains two attributes of secondary contact in rivers and lakes. These are:

(a) *E.coli*

(b) Cyanobacteria

E.coli

5.14 *Escherichia coli (E.coli)* is a bacterium that naturally occurs in the lower intestines of humans and animals; for that reason, its presence in freshwater is indicative of faecal contamination. Water contaminated by faecal material contains a range of pathogenic bacteria, viruses and other micro-organisms that present a risk to the health of people conducting recreational activities where water is ingested or inhaled (Harrington et al 1993). *E.coli* does not generally pose a significant risk to human health in itself. However, the level at which it is present can be used to quantify the risk of infection from faecal pathogens such as *Campylobacter, Salmonella, Giardia and Cryptosporidium* which are difficult or impractical to measure directly in water. Consequently, *E.coli* is the primary attribute used in New Zealand to assess the microbiological health risks associated with contact with recreational waters.

5.15 The numeric *E.coli* outcomes in the proposed Plan were selected to align with the minimum acceptable state for primary contact and the national bottom line for secondary contact in the National Objectives Framework (NOF) of the NPS-FM 2014. The *E.coli* attribute states in the NOF, upon which the outcomes in the proposed Plan are based, are scientifically underpinned by the MfE/MoH (2003) *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas* (henceforth referred to as the MfE/MoH (2003) guidelines) and the Quantitative Microbial Risk Assessment (QMRA) models upon which they are based.

5.16 The minimum acceptable *E.coli* attribute state for primary contact recreation in the NOF, and the corresponding outcome in the proposed Plan, were drawn directly from Microbiological Assessment Categories developed for the MfE/MoH (2003) guidelines. The Microbiological Assessment Categories are letter grades, ranging from ‘A’ to ‘D’, and are assigned to freshwater recreation sites based on the risk of *Campylobacter* infection. The NOF minimum acceptable state and the proposed Plan outcome of a 95th percentile *E.coli* ≤ 540 CFU/100 mL[2], corresponds with the threshold between the MfE/MoH (2003) 'C' and 'D' Microbiological Assessment Categories. Below this threshold "people are exposed to [no more than] a moderate risk of infection (less than 5% risk) when undertaking activities likely to involve full immersion" (NOF narrative attribute state based on MfE/MoH, 2003).

5.17 The *E.coli* national bottom line for secondary contact recreation in the NOF, and the corresponding outcome in the proposed Plan, are based on the work of McBride (2012). McBride (2012) reconfigured the QMRA model behind the MfE/MoH (2003) guidelines to develop *E.coli* attribute state thresholds for secondary contact recreation, based on the risk of Campylobacter infection. The NOF national bottom line and the proposed Plan outcome of a median *E.coli* ≤ 1000 CFU/100 mL correspond to the threshold recommended by McBride (2012) to ensure "people are exposed to [no more than] a moderate risk of infection (less than 5% risk) from contact with water during activities with occasional immersion and some ingestion of water"(Graham B. McBride, 2012; MfE, 2014).

5.18 The methodology for assessing *E.coli* against the primary and secondary contact recreation outcomes in the proposed Plan are outlined below:

(a) 95th percentile values for comparison with the primary contact recreation outcome for rivers and lakes are to be calculated from a minimum of 30 data points collected between September to April (inclusive) over three years using the Hazen method. For rivers, any results collected during three times median flow or higher are to be excluded from the assessment, as the *E. coli* 95th percentile is heavily influenced by results collected during or shortly after heavy rainfall. Consequently, the inclusion of these rainfall related counts would result in the 95th percentile being representative of wet weather/high flow conditions when contact recreation is less likely to occur (Greenfield, 2014d; Greenfield et al., 2015).

[2] The threshold between C and D MAC in the MfE/MoH (2003) guidelines is 550 cfu/100 mL. However, 540 cfu/100mL has been used in the NPS-FM and the proposed Plan to align with updated model outputs documented in McBride (2012)

(b) Median values for comparison with the secondary contact recreation outcome for rivers and lakes are to be determined from a minimum of 12 data points collected over three years.

5.19 The methodologies described in para. 5.18(a) and 5.18(b) were developed by Greenfield et al. (2015) to ensure that assessments of *E.coli* against the numeric outcomes in the proposed Plan are underpinned by statistically robust data sets (as prescribed by McBride (2005)). The methodology for assessing *E.coli* against the outcomes for primary and secondary contact recreation in the proposed Plan is in line with the draft NPS-FM monitoring guidance (MfE, 2015).

5.20 The main limitations of *E.coli* as an attribute for contact recreation are:

(a) The *E.coli* thresholds that underpin the NOF attribute states and the proposed Plan outcomes are precautionary. The 540 and 1000 CFU/100 mL thresholds are based on a 5% risk of Campylobacter infection, not illness, which is expected to occur in less than half of infection cases (McBride & Soller, 2017).

(b) Although the QMRA model used in McBride (2012) and the MfE/MoH (2003) guidelines was based on the best available information at the time of development, there is a need to review and update the scientific basis that underpins it. Specifically, indicator bacteria to pathogen ratios are in need of review, as the risk of microbial infection in fresh waters may be currently under, or more likely, over-stated (paraphrased from Milne et al. (2017)).

5.21 Despite the limitations presented in para. 5.20(a) and 5.20(b), the numeric *E.coli* outcomes in the proposed Plan are in line with the nationally accepted figures for primary and secondary contact with water, and were based on the best available science at the time that the proposed Plan was notified. Given the lack of better numeric thresholds, and the absence of any submissions requesting they be changed, it is my opinion that the numeric *E.coli* outcomes in Table 3.1 and 3.2 of Objective O24 should be retained.

5.22 Although there are no submissions requesting that the numeric *E.coli* outcomes in Table 3.1 and 3.2 be changed, Federated Farmers of New Zealand have requested amendments to the criteria used to identify rivers for inclusion in Schedule H2 as secondary priorities for improvement (S352/281). Currently, the relevant section of Schedule H2 identifies all rivers with an E. coli 95th percentile greater than 1000 CFU/100 mL. The submitter has requested that this be changed so that only rivers with median *E.coli* between 540 and 1000 CFU/100 mL are included, which reflects the thresholds of the 'C' attribute state for *E.coli* under the NOF. In my opinion, the criteria proposed by the submitter is a more accurate method of identifying "fresh water bodies with water quality approaching the NOF bottom line for the health of people and communities" than what is currently in the proposed Plan. Compared to a 95th percentile, a median concentration is less likely to be influenced by spikes in *E.coli* during high flow events when people are unlikely to undertake activities involving occasional immersion, and is more consistent with the NOF, upon which the *E.coli* outcomes for secondary contact recreation are based. Accordingly it is my opinion that the amendments requested by Federated Farmers of New Zealand are appropriate.

Cyanobacteria

5.23 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 in rivers and lakes (MfE/MoH, 2009).

5.24 Planktonic cyanobacteria grow in the water column of lakes and slow flowing rivers. Planktonic species produce a number of cyanotoxins (Stirling & Quilliam, 2001; Wood et al., 2006; Wood, Rasmussen, Holland, Campbell, & Crowe, 2007), exposure to which can cause skin rashes, nausea, tummy upset and tingling and numbness around the mouth or tips of fingers. The health risks associated with planktonic cyanotoxins are greatest during bloom events, and people using water bodies for recreational purposes are most likely to experience maximum exposure when a cyanobacterial bloom develops or forms surface scums near water entry points (MfE/MoH, 2009).

5.25 The numeric planktonic cyanobacteria outcome in the proposed Plan was selected to align with the national bottom line for contact recreation in NOF. The planktonic cyanobacteria attribute states in the NOF, upon which the outcome in the proposed Plan is based, are scientifically underpinned by the MfE/MoH *New Zealand guidelines for managing Cyanobacteria in recreational fresh waters – Interim guidelines* (henceforth referred to as the MfE/MoH (2009) guidelines) (Greenfield, 2014d)

5.26 The planktonic cyanobacteria national bottom line for contact recreation in the NOF, and the corresponding outcome in the proposed Plan, were taken directly from thresholds presented in the MfE/MoH (2009) guidelines. The MfE/MoH (2009) guidelines provides biovolume thresholds for all cyanobacteria and potentially toxic cyanobacteria species. Both these measures are in the included in the NOF national bottom line and the proposed Plan outcome for planktonic cyanobacteria.

(a) The NOF national bottom line and the proposed Plan outcome of an 80th percentile biovolume equivalent of potentially toxic cyanobacteria ≤ 1.8 mm^3/L, is intended to correspond with the threshold recommended in the MfE/MoH (2009) guidelines "to protect against health effects of repeated exposure to cyanobacterial toxins ingested during recreational activity". This threshold was derived from results of toxicological studies that quantified the effects of the cyanotoxin, microcystin on pigs (Falconer, Burch, Steffensen, Choice, & Coverdale, 1994) and mice (Fawell, Mitchell, Everett, & Hill, 1999), and "make[s] various assumptions about exposure, and also include[s] uncertainty factors" (MfE/MoH, 2009). Due to a typographical error, the outcome in the proposed Plan is currently expressed as '≤'[3] to the corresponding threshold as opposed to '<'[4] as documented in the MfE/MoH (2009) guidelines. This error also occurs in the NPS-FM cyanobacteria attribute.

(b) The NOF national bottom line and the proposed Plan outcome of an 80th percentile biovolume of all cyanobacteria ≤ 10 mm^3/L, is intended to correspond with the threshold recommended in the MfE/MoH (2009) guidelines to protect against "an increased probability of respiratory, irritation and allergy symptoms from exposure to very high cell densities of cyanobacterial material, irrespective of the presence of toxicity or known toxins" (MfE/MoH, 2009). This threshold was developed from the results of a systematic literature review that found there was an increase in the likelihood of symptom reporting in bathers above this approximate biovolume (MfE/MoH, 2009; Stewart, Schluter, & Shaw, 2006). Due to a typographical error, the outcome in the proposed Plan is currently expressed as '≤' to the corresponding threshold as opposed to '<' as documented in the MfE/MoH (2009) guidelines. This error also occurs in the NPS-FM cyanobacteria attribute.

5.27 The NOF does not differentiate between primary and secondary contact recreation for the planktonic cyanobacteria attribute, and the bottom line is designed to ensure there is a "low risk of health effects from exposure to cyanobacteria" "from any contact with fresh water". It is for this reason that the same planktonic cyanobacteria outcomes are used for Tables 3.1 and 3.2 of objective O24.

5.28 The methodology for assessing planktonic cyanobacteria against the proposed Plan outcomes was developed by Greenfield et al. (2015) to ensure that assessments are underpinned by statistically robust data sets (as prescribed by McBride (2005)). 80th percentile values for comparison with the contact recreation outcome are to be calculated from a minimum of three years of quarterly data using the Hazen method (Greenfield, 2014d; Greenfield et al., 2015). This

[3] Less than or equal to
[4] Less than

methodology in line with the minimum monitoring requirements prescribed in Appendix 2 of the NPS-FM 2014.

5.29 In their submission (S136/001) on the proposed Plan, Regional Public Health requested that the planktonic cyanobacteria outcomes in Tables 3.1 and 3.2 be amended to < the thresholds, as opposed to ≤, as the current outcomes are sufficiently high to be associated with potential health risk. This submission is correct; for the proposed Plan outcomes to give full effect to the guideline thresholds, the planktonic cyanobacteria outcomes should be amended to < 1.8 mm^3/L biovolume equivalent of potentially toxic cyanobacteria or < 10 mm^3/L total biovolume of all cyanobacteria. This change would mean the plan outcomes are slightly more stringent than the national bottom line under the NOF.

5.30 It is my opinion that the numeric planktonic cyanobacteria outcomes in Tables 3.1 and 3.2 of Objective O24 should be amended to read "< 1.8 mm^3/L biovolume equivalent of potentially toxic cyanobacteria OR < 10 mm^3/L total biovolume of all cyanobacteria".

5.31 Benthic cyanobacteria grow attached to the substrate of rivers and streams. In New Zealand rivers the dominant bloom-forming benthic cyanobacteria genus is *Phormidium* (Heath, Wood, & Ryan, 2010; Wood, Selwood, et al., 2007). *Phormidium* blooms are primarily associated with river or stream environments where they form leathery dark brown or black mats, but they can also establish in lakes and ponds (Quiblier et al., 2013). *Phormidium* can produce four lethal neurotoxins, known collectively as anatoxins, which cause convulsions, coma, rigors, cyanosis, limb twitching, hyper salivation and/or death. The presence of anatoxins in Phormidium mats is widespread. McAllister et al. (2016) found 67% *Phormidium*-dominated mats samples collected from across New Zealand contained anatoxins. However, the concentration of all four variants is highly spatially and temporally variable (Heath, Wood, & Ryan, 2011; Wood et al., 2012; Wood, Heath, Kuhajek, & Ryan, 2010)

5.32 The human health risks associated with benthic cyanobacteria are less well known than the risks associated with their planktonic counterparts, and the MfE/MoH (2009) guidelines are the only existing numeric thresholds against which the potential health risks associated with benthic cyanobacteria can be assessed. The MfE/MoH (2009) guidelines recommend coverage thresholds for potentially toxigenic cyanobacteria as part of three-tier surveillance, alert and action sequence for managing the public health risk associated with benthic cyanobacteria. However, these thresholds are based on preliminary observations, and still require significant refinement.

5.33 In the absence of defensible thresholds for managing the potential health risks associated with benthic cyanobacteria, narrative outcomes were developed for inclusion in Tables 3.1 and 3.2 of Objective 24 (Greenfield et al., 2015).

5.34 Although numeric outcomes are not provided in the proposed Plan, Greenfield et al. (2015) recommends a guideline value of < 20% be used when assessing cyanobacteria cover against the narrative outcomes [this is incorrectly stated as ≤ 20% in Greenfield et al. (2015) (Summer Greenfield pers. comm. 2017)]. This guideline is aligned with the ‘alert’ threshold in the MfE/MoH (2009) guidelines, and signals that a proliferation event is not necessarily likely and detaching mats are not likely to be washed on the shoreline where they could pose a health risk (MfE/MoH, 2009).

5.35 In their submission Fish and Game (S308) requested that the outcome for benthic cyanobacteria be amended to reflect the numeric guideline (< 20 % cover) presented in Greenfield et al. (2015). Although this guideline provides a useful tool for assessing benthic cyanobacteria against the narrative outcome, it is based on preliminary thresholds and is not appropriate for inclusion as a numeric outcome in the Plan.

5.36 Given the lack of defensible numeric thresholds, it is my opinion that the narrative benthic cyanobacteria outcomes in Tables 3.1 and 3.2 of Objective O24 should be retained.

Māori customary use

5.37 The use of the attribute Māori customary use is addressed in a separate report.

Toxicants and irritants

5.38 Toxicants and irritants are chemicals released into the aquatic environment that may be toxic, or cause irritation to the skin or mucous membranes of recreational water users who are exposed through direct contact with the waterbody, or by ingestion of the water. Rivers and lakes containing high concentrations of these chemicals are generally unsuitable for recreation (ANZECC, 2000), hence the need to manage their discharge into recreations waters.

5.39 Toxicants and irritants was chosen as an attribute for primary contact recreation in the proposed Plan based on the ANZECC (2000) guidelines and recommendations by Ausseil (2013). The use of toxicants and irritants as an attribute for contact recreation in New Zealand is primarily based on the ANZECC (2000) guidelines, which contains two tables that list chemicals of relevance to recreational waters and acceptable maximum concentrations. Ausseil (2013) recommended that the outcome for toxicants and irritants refer to the numeric limits set out for recreational waters in Tables 5.2.3 and 5.2.4 of the ANZECC (2000) guidelines. However, Ausseil (2013) acknowledged that the ANZECC guidelines were (and still are) under review, and that sufficient flexibility needed to be built into the proposed Plan to allow for the use of revised guidelines as they become available. Although not explicitly stated in the relevant technical reports, the upcoming release of the revised ANZECC guidelines is why a narrative outcome was chosen for the toxicants and irritants attribute, and why the numeric limits in the ANZECC (2000) guidelines are not referred to in the proposed Plan.

5.40 In their submission Fish and Game (S308) requested that the outcome for toxicants and irritants refer to the numeric limits set out for recreational waters the ANZECC (2000) guidelines. As discussed in para. 5.39 this would prevent use of revised guidelines when they become available. Other submissions do not refer to the scientific justification behind the narrative outcome for toxicants and irritants, but simply request the outcome be deleted, as it is provided for in other objectives and policies. This is not correct. The objectives and policies which refer to toxicants and irritants in relation to other values relate to different toxicants or concentrations of toxicants to those that can affect the health of river users.

5.41 It is my opinion that the narrative toxicants and irritants outcomes in the proposed Plan be retained in their current form, as explicitly referring to the ANZECC (2000) guidelines would prevent the use of revised guidelines when they become available.

Attributes that haven't been included

5.42 The recreational value and use of a river, lake or coastal area are dependent on a range of factors, and are often driven by factors other than human health risk. How a waterbody looks and smells also has a significant influence over whether people consider it suitable for recreation. The results of a 2015 survey conducted by Council (Greenfield & Martin, 2016), found that the majority of the respondents were put off entering the water by funny smells, dirty water, scum or bubbles, algae and seaweed growth and slime on rocks or the river bed (see Figure 1 in para. 5.43 for a summary of these results).

5.43

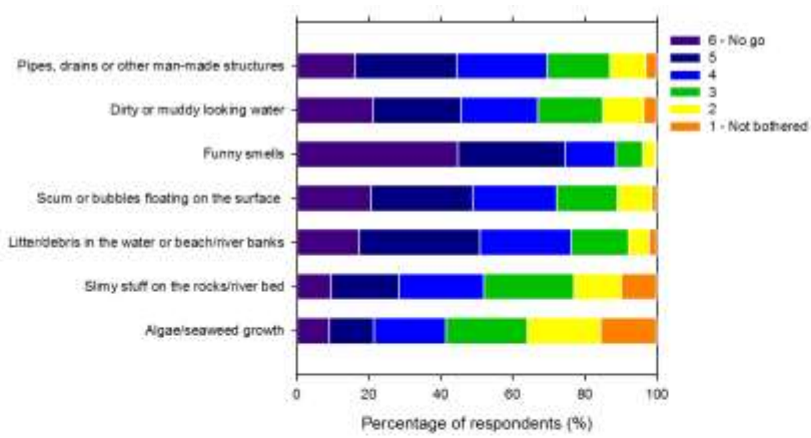

Figure 1: The degree to which each of seven factors put people off getting in the water based on the percentage of respondents that rated them on a scale of 1 to 6. Figure originally presented in Greenfield and Martin, (2016).

5.44 There are a number of attributes relevant to the aesthetic aspects of recreation in fresh waters that were originally included in the contact recreation objective of the draft Plan, and this is well documented in existing reports (see Greenfield (2014d) and Greenfield et al. (2013)). During development of the proposed Plan a policy decision was made to limit contact recreation attributes to those that impact upon on human health; aesthetic attributes were not included in the notified version of the proposed Plan.

5.45 In their submissions on the proposed Plan, Atiawa ki Whakarongotai (S398/011) and Fish and Game (S308) requested that Table 3.1 be expanded to include a range of additional parameters that would ensure that water quality standards provide for life supporting capacity, ecosystem health, recreation, Māori customary use and natural character. Many of the additional attributes requested (nutrients, dissolved oxygen and high temperature) do not directly impact upon recreational use and should not be included in Table 3.1 or 3.2 of Objective O24 for this purpose. However, the other attributes requested (water clarity, algae, macrophytes, heterotrophic growths and deposited sediment) have a significant impact upon the perceived recreational value and use of a river, and this is acknowledged in the reports written by Ausseil (2013) and Greenfield et al. (2013) to inform the development of Table 3.1. and 3.2

5.46 It is my opinion that Tables 3.1 to 3.2 should be updated to included attributes that relate to the aesthetic attributes of contact recreation, as they are major determinands of whether a river or lake is perceived as suitable for recreation. My opinion on the individual attributes to be included and the relevant outcomes for these attributes were drawn from Ausseil (2013) and Greenfield (2014d), and are presented in Table 1.

Table 1: Additional contact recreation attributes for rivers and lakes

Attribute	Outcome	Explanation
Macrophyte cover (rivers only)	30% emergent cover 60% total cover	Excessive plant growth have detrimental effects on the aesthetic values of water bodies and can be a hazard to recreational users (Matheson, Quinn, & Hickey, 2012)
Nuisance algae cover (rivers only)	30% cover (filamentous algae > 2cm long) 60% cover (mats > 3mm thick)	Excessive plant or algae growth have detrimental effects on the aesthetic values of water bodies and can be a hazard to recreational users (Biggs, 2000)
Water clarity	1.6 m	Water clarity is of considerable importance for the protection of contact recreation values as it directly affects the aesthetic quality of the water and the ability of recreational users to safely estimate depth and see subsurface hazards (ANZECC, 2000).

Attribute	Outcome	Explanation
Sediment cover (rivers only)	25 %	Deposited fine sediment can reduce the aesthetic appeal of a river or stream as well as affect the physical experience of contact recreation due to poorer water clarity on contact as well as a 'feel' of fine sediment under the toes (Clapcott et al., 2011)
Heterotrophic growths	No bacterial or fungal slime growths visible to the naked eye as plumose growths or mats	Heterotrophic growths can form on submerged substrate and need a source of existing organic carbon in order to grow. Such growths are unsightly and can have a detrimental effect on the aesthetic quality of rivers and streams (Ausseil, 2013)

Attributes of Table 3.3

5.47 Table 3.3 contains 3 attributes of contact in coastal waters. These are

(a) Pathogens

(b) Māori Customary use

(c) Shellfish Quality

Pathogens

5.48 Coastal waters contaminated by faecal material may contain a range of pathogens that present a risk to the health of people conducting recreational activities where water is ingested or inhaled. As in freshwaters *E. coli* is the preferred faecal indicator organism for estuarine waters (MfE/MoH 2003). However, for coastal marine waters, the preferred indicator organism is enterococci, another bacterium that occurs naturally in the gut of humans and animals. Enterococci, is used instead of *E.coli* in coastal waters as it is the indicator most closely correlated with health effects from faecal contamination.

5.49 The enterococci and *E.coli* outcomes for coastal waters in the proposed Plan were drawn from the Microbiological Assessment Categories presented in MfE/MoH (2003) guidelines. The Microbiological Assessment Categories range from 'A' to 'D', and are assigned to coastal marine recreation sites based on the risk of transmitting gastrointestinal and acute febrile respiratory illness, and estuarine sites based on the risk of *Campylobacter* infection. The enterococci outcome for contact recreation in the proposed Plan is a 95th percentile ≤ 500 CFU/100 mL. This corresponds with the threshold between the MfE/MoH (2003) 'C' and 'D' Microbiological Assessment Categories, above which the risk of gastrointestinal and acute febrile respiratory illness transmission is greater than 10% and 3.9% respectively (MfE/MoH, 2003). The proposed Plan outcome for estuarine waters is an *E.coli* 95th percentile ≤ 540 CFU/100 mL. This corresponds with the threshold between the MfE/MoH (2003) 'C' and 'D' Microbiological Assessment Categories, where there is a less than 5% risk of campylobacter infection.

5.50 The methodology for measuring pathogens and assessing whether contact recreation outcomes are being met is prescribed by the proposed Plan. The 95th percentile values for comparison with the contact recreation outcome are to be determined using the Hazen method from a minimum of 30 data points collected over three years. This assessment methodology was developed by Greenfield et al. (2015) to ensure that assessments against the numeric outcomes in the proposed Plan are underpinned by statistically robust data sets (as prescribed by McBride (2005)).

5.51 The input of science staff into the development of the coastal pathogen outcomes was limited to describing the risks of illness and infection associated with each of the Microbiological Assessment Categories presented in the MfE/MoH (2003) guidelines (Oliver, Milne, & Greenfield, 2014). The threshold between the 'C' and 'D' Microbiological Assessment Categories was selected as the outcome in Table 3.3 by Te Upoko Taiao based on what they deemed an acceptable level of infection risk to users (Oliver et al., 2014).

5.52 The pathogen outcomes in Table 3.3 were selected from nationally accepted figures for contact recreation in marine waters, and represent the best available option for managing the risk of infection and illness to recreational users at the level deemed acceptable by GWRC. Given the absence of technical evidence to support changing the numeric pathogen attributes in Table 3.3, and the absence of any submissions requesting such a change, it is my opinion that they should be retained in their current form.

Māori customary use

5.53 The use of the attribute Māori customary use is addressed in a separate report.

Shellfish quality

5.54 Pathogens (disease-causing organisms) and stormwater contaminants (e.g., 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.

5.55 The narrative outcome approach for shell fish quality in the proposed Plan was recommended by Oliver et al. (2014), as there is no nationally recognised/accepted measures (and associated thresholds) that represent this attribute. The MfE/MoH (2003) microbiological water quality guidelines do include numeric guidance for recreational shellfish gathering waters. However the 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)). Similarly, Food Standards Australia New Zealand provides guidance on safe concentrations of a range of microbiological and natural contaminants found in many shellfish but lacks guidance for common stormwater-related contaminants such as copper and zinc (Australia New Zealand Food Standards code, Standard 1.4.1 (2013); Standard 1.6.1 (2014)). Consequently Oliver et al. (2014) recommended that until suitable guidelines for shellfish quality become available, a narrative attribute outcome is most appropriate.

5.56 The methodology for measuring shellfish quality against the outcome in the proposed Plan is yet to be developed (Greenfield et al., 2015). However, it is expected to involve periodic laboratory measurement of the concentration of microbiological contaminants and/or trace metals in the flesh of selected filter-feeding shellfish species (Greenfield et al., 2015).

5.57 In their submission (S135/043) on the proposed Plan, Wellington Water Ltd, has requested that it be clarified in Table 3.3 that shellfish gathering is not appropriate within vicinity of stormwater or wastewater outfalls due to risk of pathogens from urban area contaminants. It is outside the scope of this evidence to respond to this submission, as it would require making recommendations on policy.

5.58 It is my opinion that the narrative outcome for Shellfish quality should be retained, as there are no nationally recognised/accepted water quality thresholds for this attribute.

6. Objectives for aquatic ecosystem health and mahinga kai (Objective O25)

6.1 In this section I address three components of proposed Objective O25:

(a) Relationship between aquatic ecosystem health and mahinga kai;

(b) Definition and mapping of river classes; and

(c) Attributes for Tables 3.4 – 3.5.

Aquatic ecosystem health and mahinga kai

6.2 Objective O25 in the proposed Plan refers to both aquatic ecosystem health and mahinga kai.

6.3 I understand that submissions have been made which reason that managing for aquatic ecosystem health will also manage for mahinga kai. I also understand that the concept of mahinga kai has been addressed in other reports. In this evidence I only focus on the concept of aquatic ecosystem health.

6.4 The concept of ecosystem health is defined in the proposed Plan as "the degree to which an aquatic ecosystem is able to sustain its ecological structure, processes, functions, and resilience within its range of natural variability".

6.5 Tables 3.4 - 3.8 of Objective O25 of the proposed Plan set out different attributes and outcomes for rivers and streams, lakes, groundwater, natural wetlands and coastal waters. The outcomes are set to help fulfil the objectives of the Regional Policy Statement (RPS) for the Wellington Region by achieving 'excellent' ecosystem health in ‘significant’, ‘regionally important’ and ‘outstanding’ water bodies, and ‘good’ aquatic ecosystem health everywhere else. Identifying the ‘level of protection’ at which outcomes should be set to give effect to the RPS for the Wellington region was an important part of the outcome development process.

(a) Objective 6 of the RPS states that ‘the quality of coastal waters should be maintained to a level that is suitable for the health and vitality of coastal and marine ecosystems’. Similarly, Objective 13 states that the region’s rivers, lakes and wetlands must support healthy, functioning ecosystems. Out of four levels of ecosystem health (‘excellent’, ‘good’, ‘fair’ and ‘poor’), ‘good’ ecosystem health was selected as the level that would give effect to the ‘healthy, functioning ecosystems specified in the RPS. This means that degradation is allowed from natural state (also referred to as reference condition) but not so much that the health and function of ecosystems is significantly impaired.

(b) Objective 16 of the RPS states that indigenous ecosystems and habitats with significant biodiversity values should be maintained and restored to a healthy, functioning state. To achieve this, outcomes for rivers identified as supporting significant indigenous ecosystems (based on macroinvertebrate community health) were set at the ‘excellent’ ecosystem health level. This means that these waterbodies must be maintained or enhanced to close to their natural state or reference condition.

6.6 The outcomes in the proposed Plan were set to manage the departure of attributes from a pre-human ‘reference’ condition (Greenfield et al., 2015). Setting outcomes relative to an appropriate reference condition is essential for the effective protection of aquatic ecosystem health. As alluded to in the definition provided in para. 6.4, community structure, composition and diversity vary naturally between aquatic ecosystems. Thus, ‘good’ (or ‘excellent’) ecosystem health encompasses a range of conditions, and cannot be defined by a single absolute state. This variability in reference condition is determined by aspects of catchment biogeography such as geology and climate. For instance, the higher water clarity and lower nutrient levels in high elevation river catchments with hard sedimentary geology means that biological communities in these systems contain a greater proportion of sensitive taxa than those in low elevation catchments dominated by sand and peat. This natural variability is accounted for in the proposed Plan by allowing 'good' or 'excellent' ecosystem health to be represented by different numeric outcomes depending on the reference condition of the water body in question. For example, in Table 3.4 of Objective O25 'good' macroinvertebrate community health in steep, hard sedimentary rivers (river class 1) is represented by a higher score for than that for small lowland streams (river class 6).

6.7 It is not possible to measure all attributes of aquatic ecosystem health, and only indicators that are suitable for describing when the objectives of the proposed Plan have been met are included in Tables 3.4 - 3.8 of Objective O25 (Greenfield et al., 2015). In general, the attributes are biological, as these are not only the most meaningful integrated indicators of aquatic ecosystem health, but are also robust, defensible and feasible in terms of monitoring (GWRC, 2015). Attributes for sediment quality and water quality are only included where they are considered a key determinant of aquatic ecosystem health (GWRC, 2015).

6.8 The state of knowledge for most of the attributes included in Tables 3.4 - 3.8 of Objective O25 does not allow for the development of numeric outcomes. Consequently, most of the outcomes are narrative. It is intended that the inclusion of narrative outcomes for some attributes will drive data collection and indicator development that will allow future identification of numeric outcomes. Until that time, the best available methods for determining whether narrative outcomes are being met are documented in Greenfield et al. (2015).

6.9 A number of submitters have pointed out that the narrative outcomes are difficult to interpret. To provide clarity, terms that are frequently referred to in these narrative outcomes are defined below (from Greenfield et al. (2015)):

(a) **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.

(b) **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 (e.g. plant biomass).

(c) **Composition**: The representation of different taxonomic groups (e.g., 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.

(d) **Diversity**: Diversity comprises two components; the number of taxa (richness) and the distribution of individuals amongst taxa (evenness) (Schallenberg et al., 2011).

6.10 The term “**balanced community**’ is also used in many of the narrative outcomes in Tables 3.4 to 3.5. What constitutes a balanced community varies depending on the ‘reference’ condition of the water body being assessed. 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 (Greenfield et al., 2015; Robertson & Stevens, 2014). Balanced communities will also typically be characterised by multiple age and size classes (Greenfield et al., 2015).

6.11 A number of submissions have requested that the narrative outcomes in Tables 3.4 - 3.8 of Objective O25 be deleted or replaced with numeric alternatives. As stated in para. 6.8, narrative outcomes have only been used where applicable and robust numeric guidelines do not exist. For that reason, the narrative outcomes included in Tables 3.4 – 3.8 of Objective O25 should not be replaced with numeric thresholds, since they would not scientifically defensible. It is outside the scope of this evidence to respond to submissions requesting that the narrative outcomes be deleted, as their inclusion in Tables 3.4 – 3.8 was a policy decision based on relevance, usefulness, achievability and reasonableness (GWRC, 2015).

6.12 Information on how the specific outcomes for aquatic ecosystem health were developed and my opinions on their appropriateness are provided in para. 6.22 through to para. 6.83.

Definition of river classes

6.13 Table 3.4 of Objective O25 contains aquatic ecosystem health attributes and outcomes for the six river classes listed below:

- 1: Steep, hard sedimentary
- 2: Mid-gradient, coastal and hard sedimentary
- 3: Mid-gradient, soft sedimentary
- 4: Lowland, large, draining ranges
- 5: Lowland, large, draining plains and eastern Wairarapa
- 6: Lowland, small

6.14 The six river classes are defined in the interpretation section of the proposed Plan, and are indicated in Maps 21a to 21e in the proposed Plan.

6.15 Rivers and streams were divided into river classes and assigned (some) different outcomes to account for natural variation in aquatic plant and animal communities across the region. River and streams differ in the nature of their catchment, geology and flows, which results in natural ecological variation between systems. If aquatic ecosystems are to be protected effectively, this natural ecological variation must be accounted for through river-specific ecosystem health outcomes. In the absence of ecological information for each river and stream, this can only be achieved by implementing a classification framework that groups similar waterways based natural ecosystem variability, and setting outcomes specific to each group (Barbour, Gerritsen, Snyder, & Stribling, 1999). To that end, rivers and streams have been divided in to classes in the proposed Plan based on key environmental factors known to drive ecological patterns (GWRC, 2015; Greenfield et al., 2013, 2015, Warr, 2009, 2010).

6.16 The river classes included in Table 3.4 of Objective O25 were developed by Warr (2009, 2010) to be broadly representative of the natural variation in river and stream ecosystems across the Wellington Region. The Freshwater Environments of New Zealand (FENZ) database is the basis of the river classes included in the proposed Plan, and was selected as it “has a greater ability to represent natural ecological variation in rivers and streams than the rule-based River Environment Classification” (Warr, 2009).

6.17 The FENZ database is a set of spatial data layers, developed by NIWA for the Department of Conservation, that describe environmental and biological patterns in New Zealand’s freshwater ecosystems. The FENZ classifies each river and stream reach in New Zealand based on a range of environmental factors (hydrology, substrate, riparian composition and catchment land cover), so that systems with similar ecological character can be grouped (Leathwick, Elith, Chadderton, Rowe, & Hastie, 2008). The classification was defined using a process that included four major steps:

- The assembly of relevant biological and environmental data;
- The use of analyses of relationships between biota and key environment variables to identify the best environmental predictors of biological patterns;
- The defining of environmental groups; and
- The testing of the ability of the resulting classification to summarise variation in the biological data.

6.18 The FENZ classification system is hierarchical and can be displayed at any level of detail from 1-400 groups (Leathwick et al., 2008). Based on the recommendations of Warr (2009), the FENZ 100-group level[5] was chosen as the most appropriate scale at which to classify Wellington rivers and streams, as it produces a manageable number of classes for the region. The FENZ classes were modified by Warr (2010) to better suit the Wellington region before being included in the proposed Plan. The number of classes was reduced through amalgamation, and class C6 was split into three to better represent differences within this river type. These amendments resulted in 11 classes in the Wellington Region, which Greenfield et

[5] River reaches are assigned to one of 100 groups

al.(2013) then grouped into the six river classes identified in the proposed Plan. Descriptions of the FENZ classes encompassed by the six river classes listed in Table 3.4 of Objective O25 are provided in Table 2.

Table 2: Description of the amended FENZ classes encompassed by the River classes identified in Table 3.4 of Objective O24 in the proposed Plan (modified from Warr (2010)).

PNRP river class	Description	GW FENZ class	Description
1	Steep, hard sedimentary	C7	Small to medium-sized streams occurring in inland locations with mild climates and low frequency of days with significant rainfall. Stream gradients are generally steep and substrates are generally coarse gravels. Predominant location: Lowland hills of the Tararua, Rimutaka and Aorangi ranges.
		C10	Small streams occurring in inland locations with cool climates and moderate frequency of days with significant rainfall. Gradients of these streams are generally very steep and substrates are generally cobbly. Predominant locations: Small, mid-elevation streams in the Tararua, Rimutaka and Aorangi ranges
		UR	A combination of 23 100-level classes that occur entirely within the upper Tararua or Rimutaka ranges.
2	Mid-gradient, coastal and hard sedimentary	C5	Small streams occurring in moderately coastal locations with mild, maritime climates and low frequency of days with significant rainfall. Stream gradients are generally moderate and substrates are predominantly coarse gravels. Predominant location: Wellington south coast, eastern Wairarapa coast and western Tararua foothills.
		C1	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. Predominant location: South Wairarapa coast, Rimutaka Range and Kapiti Island.
		C6b	A variant of 100-level class C6 and includes C6 rivers that have an upstream catchment dominated by class C5 streams. Location: Horokiri and Pauatahanui streams as well as some stream segments on the eastern Wairarapa coast.
3	Mid-gradient, soft sedimentary	C8	Small inland streams with mild climates and low frequency of days with significant rainfall. Stream gradients are moderate and substrates are generally coarse gravels. Predominant location: Eastern Wairarapa hill country and northern foothills of Tararua Range.
4	Lowland, large, draining ranges	C6a	This class is a variant of 100-level class C6 and includes C6 rivers that have an upstream catchment dominated by C7 rivers. These are larger rivers occurring in moderately inland locations with warm climates and low frequency of days with significant rainfall and a predominance of coarse gravelly substrates. Stream gradients are gentle. Predominant location: Lower reaches of larger rivers draining the Tararua Range.
5	Lowland, large, draining plains and eastern Wairarapa	C6c	A variant of 100-level class C6 and includes C6 rivers that have an upstream catchment dominated by class A and/or C8 rivers and streams. Predominant location: Larger rivers draining eastern Wairarapa hill country and lowland areas of the Kapiti Coast.

PNRP river class	Description	GW FENZ class	Description
6	Lowland, small	A	A combination of 100-level classes A4 and A2. These are small streams occurring in inland or coastal locations with very low frequency of days with significant rainfall. Gradients of these streams are very gentle to gentle and substrates are predominantly silty or sandy. Predominant location: Central Wairarapa Valley and Kapiti Coast.
		B	A combination of 100-level classes B1 and B3 of very limited extent in the Wellington region but has been retained due to the peat-dominated nature of the catchments which is likely to result in unique ecological characteristics. Location: Mangaroa Valley, Lake Wairarapa, Paraparaumu.

6.19 Limitations in the river classes identified in Table 3.4 of Objective O24 in the proposed Plan stem from uncertainties in the FENZ classifications that underpin them. As a model, the FENZ classification system is limited by potential modelling error, and bias in the biological data that informs it. The amendments made to the FENZ classification system by Warr (2010), such as the separation of the C6 class, were made to mitigate these limitations.

6.20 In their submission, Federated Farmers of New Zealand (S352/078) requested that the definition of river class in the proposed Plan be amended to clarify that classification included consideration of periphyton accrual period. Neither accrual period (in days) nor the annual frequency of flushing flows three times the median (FRE-3) are included as predictors in the FENZ river classification system. Therefore, the amendment requested by Federated Farmers of New Zealand is not technically correct, and it is my opinion that accrual period should not be referenced in the definition of river class. It is important to note that flow stability (measured as the ratio of annual low flow/annual mean flow) is one of the predictors used in the FENZ classification system. This metric, although not a direct measure of accrual period, is a good indicator of the potential for periphyton growth.

6.21 Despite the limitations presented in para.6.19, it is my opinion that the river classes identified in Table 3.4 of Objective O25 are a fair representation of the natural variation in river and stream ecosystems in the Wellington Region, and are suitable for use as the basis for aquatic ecosystem health outcomes. Given the lack of better a system (Warr, 2009), and the absence of any submissions requesting they be changed, it is my opinion that the river classes identified in Table 3.4 of Objective O25 should be retained.

Attributes of Table 3.4 Rivers and streams

6.22 Table 3.4 contains 5 attributes of rivers and streams. These are:

(a) Macrophytes

(b) Periphyton

(c) Invertebrates

(d) Fish

(e) Mahinga Kai species

Macrophytes

6.23 Macrophytes, which encompass macro-algae (Charophytes), mosses and liverworts (Bryophytes), ferns and angiosperms, are a common occurrence in waterbodies, and are found across a broad range of habitat types. These plants are a natural component of the biodiversity and functioning of stream and river systems – in particular those with stable, slow flows. However, excessive macrophyte growth, generally associated with introduced rather than indigenous species (Matheson et al., 2012), is detrimental to ecosystem function. At high densities, macrophytes can reduce habitat availability for fish and invertebrates. Large macrophyte stands also reduce stream hydraulic capacity, increase sediment deposition (Hearne & Armitage, 1993; Kaenel & Uehlinger, 1998) and alter daily oxygen patterns (Wilcock & Nagels, 2001; Wilcock et al., 1999).

6.24 The narrative macrophyte outcome in Table 3.4 of Objective O25 was developed by Greenfield (2014b, 2014d) and Greenfield et al. (2015). Due to a lack of empirical data, robust macrophyte cover and volume thresholds for the onset of detrimental effects on ecosystem health do not currently exist (Matheson et al., 2012). Currently, Matheson et al.'s (2012) review of the New Zealand instream plant and nutrient guidelines provides the only numeric cover and volume thresholds against which the potential effects of macrophytes can be assessed. Matheson et al. (2012) presents a macrophyte cross sectional area/volume guideline of less than 50% of the channel for the protection of instream ecological condition However, this threshold is provisional, and requires significant refinement (Matheson et al., 2012). Accordingly, Greenfield (2014b) recommended this guideline not be used in the Natural Resources Plan until there are sufficient macrophyte abundance data to assess its applicability to river and stream ecosystems in the Wellington Region. In the absence of defensible thresholds for managing macrophytes for aquatic ecosystem health, a narrative outcome was deemed most appropriate for inclusion in Table 3.4 (Greenfield, 2014b).

6.25 Although numeric outcomes are not provided in the proposed Plan, Greenfield et al. (2015) recommended the Matheson et al.'s (2012) cross sectional area/volume guideline value of < 50% be used to assess macrophytes against the narrative outcomes, until more robust thresholds become available.

6.26 In their submission, the Minister for Conservation (S75/028) requested that Matheson et al.'s (2012) provisional guidelines of < 50% macrophyte cover of the cross-sectional area/volume of the channel, and < 50% macrophyte cover of channel water surface area be included in Table 3.4 in lieu of the narrative outcome. As stated in para. 6.24, these thresholds are not sufficiently robust for inclusion as numeric outcomes in the proposed Plan. Furthermore, the channel water surface area guideline is set for protection of aesthetics and recreation, and is not relevant to ecosystem health.

6.27 In their submission (S352/078), Federated Farmers of New Zealand requested that the narrative outcome for macrophytes be deleted from Table 3.4. In my opinion macrophytes are a key indicator of riverine ecosystem health, and the removal of this outcome from the proposed Plan would leave a significant gap. Although the macrophyte outcome is narrative only, it is intended that its inclusion will drive data collection and development of robust numeric thresholds that can be used in future.

6.28 Given the lack of defensible numeric thresholds, and the importance of macrophytes in riverine ecosystems, it is my opinion that the narrative macrophyte outcome in Table 3.4 of Objective O25 should be retained.

Periphyton

6.29 Periphyton are primary producers and an important foundation of many river and stream food webs, particularly in rivers with hard, cobbly substrate. Periphyton also stabilise substrata and serve as habitat for many other organisms. However, an over-abundance of periphyton can reduce ecological habitat quality (Matheson et al., 2012). Large standing crops of periphyton can smother stream-bed substrate, thereby reducing the amount of suitable habitat available for fish and invertebrates. High densities of periphyton can also cause large daily fluctuations in dissolved oxygen concentrations and pH. Therefore, it is important to manage rivers and streams to reduce the risk of nuisance growths. Periphyton biomass covering the riverbed (measured in milligrams of chlorophyll *a* per metre squared of riverbed) is the most commonly used periphyton measure for assessing ecosystem health, and has been included as a compulsory attribute in the NPS-FM 2014.

6.30 The periphyton outcomes in the proposed Plan were selected to align with the boundaries of the A/B and B/C periphyton biomass attribute states in the NOF. The periphyton attribute states in the NOF, upon which the outcomes in the proposed Plan are based, were selected by Snelder et al. (2013), and are scientifically underpinned by the *New Zealand Periphyton Guideline* developed by Biggs (2000), and Matheson et al.'s (2012) review of the New Zealand instream plant and nutrient guidelines .

6.31 The periphyton biomass outcome of ≤ 50 mg chlorophyll *a* (chl-*a*)/m^2 for rivers identified as supporting significant indigenous ecosystems (based on the 'high macroinvertebrate community health'[6] criteria) is considered to represent 'excellent' ecosystem health in these systems (Greenfield et al., 2015). This threshold is also the boundary between the A/ B attribute states in the NOF, and corresponds with the guideline value recommended by Biggs (2000) for the protection of benthic biodiversity. Below this threshold there

[6] Identified in column 2 of Schedule F1 of the proposed Plan

are only “rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat” (NOF narrative attribute state).

6.32 Above 50 mg chl-*a*/m^2, invertebrate communities transition (albeit gradually (Snelder et al., 2013)) from being dominated by taxa that are sensitive to water quality and habitat disturbance, such as stoneflies, mayflies, and caddisflies, to being dominated by tolerant taxa, such as snails, worms, and midges (Biggs, 2000; Matheson et al., 2012). Consequently, setting a periphyton outcome greater than 50 mg chl-*a*/m^2 in rivers with ‘high macroinvertebrate community health’, would not protect the significant indigenous biodiversity values of these waterways, and would potentially conflict with the corresponding numeric invertebrate outcomes in Table 3.4.

6.33 The periphyton biomass outcome of ≤ 120 mg chl-*a*/m^2 for all rivers in classes 2-6 was chosen to achieve ‘good’ ecosystem health (Greenfield et al., 2015). This threshold is the boundary between the B/ C attribute states in the NOF, and corresponds with the filamentous periphyton biomass guideline recommended by Biggs (2000) for the protection of aesthetic/recreational values, and trout habitat/angling values. Below this threshold there are only “occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat” (NOF narrative attribute state). Below 120 mg chl-*a*/m^2 invertebrate communities are still expected to be composed of mostly pollution sensitive taxa, such as stone flies, mayflies, and caddisflies (Snelder et al., 2013).

6.34 The periphyton biomass outcome of ≤ 50 mg chl-*a*/m^2 for all rivers in class 1 reflects the unproductive nature of waterways in this class (Greenfield, 2014d). Rivers and streams in class 1 are located in the upper Tararua, Rimutaka and Aorangi ranges, and support naturally low levels of periphyton biomass as a result of short accrual periods and naturally low nutrient concentrations (Greenfield et al., 2013). For that reason, the periphyton biomass outcome of ≤ 120 mg chl-*a*/m^2 applied to other river classes is inappropriately high for rivers in class 1, and does not represent ‘good’ aquatic ecosystem health (Greenfield et al., 2013).

6.35 The methodology for assessing periphyton against the aquatic ecosystem health outcomes in the proposed Plan is described below:

(a) The NOF attribute state thresholds include an exceedance frequency to allow for the occasional periods of elevated periphyton biomass that can occur even in relatively non-enriched systems (Snelder et al., 2013). These exceedance frequencies have been incorporated into the periphyton outcomes of the proposed Plan. To be met, the outcomes must not be exceeded by more than 8% of samples from non-'productive' river classes and 17% of samples from 'productive' river classes.

(b) To ensure that assessments against the periphyton outcomes are underpinned by statistically robust data sets (as prescribed by McBride (2005)), exceedance rates are to be calculated from a minimum of three years of monthly data (Greenfield, 2014d; Greenfield et al., 2015). This methodology is in line with the minimum monitoring requirements prescribed in Appendix 2 of the NPS-FM 2014.

(c) In the NOF, the 'productive' class is defined as rivers and stream segments that fall into the River Environment Classification (REC) 'dry' climate categories <u>and</u> 'nutrient enriched' geology categories. In the Wellington Region, river and stream segments that fall into both 'dry' and 'nutrient enriched' categories are rare, and are mainly limited to areas of the eastern Wairarapa hill country. In the proposed Plan, the 'productive' class has been extended to include all rivers and streams in river classes 3, 5 and 6. These classes include rivers and streams in the soft sedimentary geology areas of eastern Wairarapa, as well as streams in lowland areas of the Wairarapa Valley and Kapiti Coast. They have been classified as 'productive' in the proposed Plan as they have longer periphyton accrual periods than other rivers in the region (Greenfield, 2014b). The extent of these classes roughly equates to that of the 'dry' <u>or</u> 'nutrient enriched geology' REC categories.

6.36 In their submission, Federated Farmers of New Zealand (S352/078) requested that the separate periphyton outcomes for rivers identified as supporting significant indigenous ecosystems based on the 'high macroinvertebrate community health'[7] criteria be deleted, and the outcomes for river classes 3, 5 and 6 be changed to ≤ 200 mg chl-*a*/m^2 in order to achieve 'fair' ecosystem health. As identified in para. 6.5, identifying the 'level of protection' at which outcomes should be set to give effect to the Regional Policy Statement (RPS) for the Wellington Region was an important part of the outcome development process. The outcomes in Table 3.4 of Objective O25 were set to achieve 'excellent' ecosystem health in rivers identified as supporting significant indigenous ecosystems and 'good' ecosystem health in all other rivers as these levels of protection were deemed to meet Objectives 13 and 16 of the RPS. Whether the levels of protection which form the basis of the outcomes in Table 3.4 of Objective O25 should be changed is a policy decision rather than a technical matter. However, if it is agreed that setting outcomes at a lower, 'fair', level of protection will still meet the objectives of the RPS, then the figures suggested by Federated Farmers of New Zealand would be appropriate for inclusion in Table 3.4, as they are in line with nationally accepted biomass thresholds (Biggs, 2000; Matheson et al., 2012; Snelder et al., 2013).

6.37 In his submission (S278/007) Derek Neal has requested that the numeric outcomes for periphyton biomass in Table 3.4 be changed into bands "to allow for natural variability in measurements". This is not necessary, as the outcomes are already based on an established 'band' system (see para. 6.30), and were selected to represent the 'bottom' of the band that best reflects the desired ecological state. Furthermore, natural variability in measurements is accounted for in the statistical methods used to assess the attributes against the outcomes (see para. 6.35).

6.38 In their submission (S316/033) DairyNZ and Fonterra have requested that GWRC clarify why the periphyton outcome for all rivers was set at a more stringent level than the relevant NOF

[7] Identified in column 2 of Schedule F1 of the proposed Plan

national bottom line. This clarification is provided in para. 6.30, para. 6.31, para. 6.32, para. 6.33 and para. 6.34 of this evidence. DairyNZ and Fonterra also state in their submission that 120 mg chl-*a*/m^2 is an unrealistic outcome for rivers that experience extremely long accrual periods during dry summer conditions, and cite sections of Snelder et al. (2013) to support this argument. However, it is recognised in the periphyton outcomes of the proposed Plan that rivers with long accrual periods have naturally high periphyton biomass, and this is accounted for in the assessment methodology prescribed in the footnotes to Table 3.4 of Objective O25. As discussed in para. 6.35, the frequency at which the periphyton outcomes can be exceeded in 'productive' river classes is higher than in 'non-productive' river classes, meaning that natural blooms over summer will not necessary mean the outcome is breached. This method of accounting for natural periphyton blooms in rivers with long accrual period was recommended by Snelder et al. (2013), is in line with the provisions of the NPS-FM 2014, and is, in my opinion, more appropriate than simply setting a less stringent outcome for those 'productive' river classes

6.39 The numeric periphyton outcomes in Table 3.4 were selected from nationally accepted guidelines for the protection of ecosystem health. In my opinion they represent the best available option for achieving 'excellent' ecosystem health in rivers with 'high macroinvertebrate community health', and 'good' aquatic ecosystem health everywhere else. Consequently, it is my opinion that they should be retained in their current form.

Invertebrates

6.40 The macroinvertebrate community is an important component of the stream ecosystem. 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.

6.41 Sensitivity to pollution and other physico-chemical stressors differs between macroinvertebrate taxa, and the composition of the invertebrate community in a stream can provide valuable information about how the state and trends in water quality and habitat are impacting ecosystem function. Consequently, benthic macroinvertebrates are one of the most widely used biological indicators of river and stream ecosystem health.

6.42 The Macroinvertebrate Community Index (MCI) is currently the only metric which can be used to set river-class specific numeric macroinvertebrate outcomes for the Wellington Region (Greenfield, 2014d), due to a paucity of reference data for other indices. The MCI is frequently used in New Zealand to capture the macroinvertebrate community response to stressors such as organic material and nutrients (Stark, 1985; Stark & Maxted, 2007). Invertebrate communities with high MCI scores are dominated by taxa that are sensitive to water quality and habitat disturbance, such as stoneflies, mayflies, and caddisflies; communities with low MCI scores are dominated by tolerant taxa, such as snails, worms, and midges. Generic MCI thresholds, developed by Stark and Maxted (2007), have been widely used in New Zealand to describe ecological condition. Based on these thresholds, MCI scores below 80 are indicative of poor ecological condition, scores between 80 and 100 are indicative of fair ecological condition, scores between 100 and 119 are indicative of good ecological condition, and scores above 119 are indicative of excellent ecological condition (Stark & Maxted, 2007).

6.43 The generic MCI thresholds outlined in para. 6.42 do not account for the natural variation in reference condition between river classes, and were deemed inappropriate for inclusion in Table 3.4 of Objective O25 (Greenfield, 2014d, 2014a). Instead, Clapcott and Goodwin (2014) developed a predictive model of macroinvertebrate metric scores for the Wellington Region, and used the results to define river class specific MCI thresholds for inclusion as outcomes in the proposed Plan. Briefly, the models predicted contemporary MCI condition of stream reaches belonging to each of the six river classes identified in Table 3.4 of Objective O25. Based on this, a set of thresholds were identified for each river class that describe ‘poor’, ‘fair’, ‘good’ and ‘excellent’ ecological condition. For river classes 2-6, the ‘excellent’ ecological condition threshold was selected based on the distribution between the 25th percentiles of measured and modelled MCI scores for rivers in 'reference' state (ie, sites in catchments with native vegetation > 85%, light pasture < 5%, heavy pasture = 0%, urban = 0%, surface water allocation = 0) and the 75th percentiles of measured and modelled MCI scores for all rivers. The 'poor'/'fair' threshold was selected based on the 5th percentiles of measured and modelled contemporary MCI scores for all rivers. The 'good' threshold was then defined as halfway between the 'excellent' and the 'poor'/'fair' threshold. Where the 5th percentile of measured and modelled MCI scores for a river class was below 80, (the recommended national bottom line (Collier et al., 2014)), 'the poor/fair' boundary was scaled up to 80 (Clapcott, 2017). For river class 1, the thresholds were developed by applying the same methodology, but only measured data from rivers in reference state was used to calculate the 'excellent' threshold (Summer Greenfield pers. comm., 2017).

6.44 For each river class, the 'excellent' threshold was selected as the outcome for rivers and streams identified as supporting significant indigenous ecosystems based on the 'high macroinvertebrate community health'[8] criteria, and the 'good' threshold was selected as the outcome for everywhere else. Further details on how the thresholds were developed can be found in Clapcott and Goodwin (2014).

6.45 Limitations in the MCI outcomes included in Table 3.4 of Objective O25 stem from issues with the models used by Clapcott and Goodwin (2014) to develop them. The method used to identify MCI thresholds involves estimation of an upper and lower limit for MCI scores for each river class in the region. While measured data to identify the lower limit of MCI scores is readily available, measured data to identify the upper limit (i.e. reference condition) is very limited for many river classes. This means that modelled reference condition is heavily relied on to identify MCI thresholds for many river classes in the region. It is acknowledged that the MCI outcomes could be improved by gathering more data to inform the

[8] Identified in column 2 of Schedule F1 of the proposed Plan

model, particularly macroinvertebrate metric data from reference sites belonging to river classes 3 and 6 (Clapcott, 2015a).

6.46 The methodology for assessing macroinvertebrates against the outcomes in the proposed Plan was developed by Greenfield (2015) based on recommendations by Clapcott (2015b), and consists of a calculating a rolling median of MCI scores collected annually over three years.

6.47 In their submission, Federated Farmers of New Zealand (S352/078) requested that the separate invertebrate outcomes for rivers identified as having 'high macroinvertebrate community health'[9] be deleted, and the outcomes for river class 3, 5 and 6 be amended to achieve 'fair' rather than 'good' ecosystem health. The outcomes in Table 3.4 of Objective O25 were set to achieve 'excellent' ecosystem health in rivers identified as supporting significant indigenous ecosystems and 'good' ecosystem health in all other rivers, as these levels of protection were deemed to meet Objectives 13 and 16 of the RPS. Whether the levels of protection which form the basis of the outcomes in Table 3.4 of Objective O25 should be changed is a policy decision rather than a technical matter. However, if it is agreed that setting outcomes at a lower, 'fair', level of protection will still meet the objectives of the RPS, then the MCI scores suggested by Federated Farmers of New Zealand would be appropriate for inclusion in Table 3.4, as they reflect the 'fair' ecological condition thresholds recommended by Clapcott and Goodwin (2014). Federated Farmers of New Zealand also requested that the outcomes for river classes 2 and 4 be amended to an MCI of 100 (the generic 'good' threshold recommended by Stark and Maxted (2007)). In my opinion the current MCI outcomes for river classes 2 and 4 are a more accurate measure of 'good' ecosystem health than the generic thresholds suggested by Federated Farmers of New Zealand, and should be retained.

6.48 In his submission (S278/007), Derek Neal has requested that the numeric outcomes for macroinvertebrate community heath in Table 3.4 be changed into bands "to allow for natural variability in

[9] Identified in column 2 of Schedule F1 of the proposed Plan

measurements". This is not necessary, as the outcomes are already based on a 'band' system (see para. 6.43), and were selected to represent the 'bottom' of the band that best reflects the desired ecological state. Furthermore, natural variability in measurements is accounted for in the statistical methods used to assess the attributes against the outcomes (see para.6.46).

6.49 The numeric macroinvertebrate outcomes in Table 3.4 were selected using models specific to the Wellington Region. In my opinion, they represent the best available option for achieving 'excellent' ecosystem health in rivers with 'high macroinvertebrate community health', and 'good' aquatic ecosystem health everywhere else. Consequently, it is my opinion that they should be retained in their current form.

Fish

6.50 Fish are a key component of river and stream ecosystems, and are a very useful indicator of ecosystem health because they respond to both local and catchment-scale impacts. 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 (McDowall, 1990).

6.51 The narrative fish outcome in Table 3.4 of Objective O25 was developed by Greenfield (2014d) and Greenfield et al. (2015). Assessment against the narrative fish outcome is likely to include comparisons against expected community composition, calculation of fish community indices such as the Index of Biotic Integrity (IBI) (Joy & Death, 2004), abundance of key species and determination of size-frequency classes for key species (Greenfield et al., 2015). However, there are currently no established numeric thresholds for these metrics which could be applied in Table 3.4 (Greenfield et al., 2015).

6.52 In their submission (S75/028), the Minister for Conservation requested that numeric outcomes for fish be included in Table 3.4 in lieu of the narrative outcomes. They suggest that a minimum fish IBI would be an appropriate outcome. However, as stated in para. 6.51, numeric thresholds that are sufficiently robust for inclusion as outcomes for ecosystem health, do not currently exist for fish community indices.

6.53 In their submission (S352/078), Federated Farmers of New Zealand requested that the narrative outcome for fish be deleted from Table 3.4. In my opinion fish are a key indicator of riverine ecosystem health, and removal of this outcome from the proposed Plan would leave a significant gap. Although the fish outcome is narrative only, it is intended that its inclusion will drive data collection and development of robust numeric thresholds that can be used in future.

6.54 Given the lack of defensible numeric thresholds, and the importance of fish in riverine ecosystems, it is my opinion that the narrative fish outcomes in Table 3.4 of Objective O25 should be retained.

Mahinga kai species

6.55 The use of the attribute “Mahinga kai species’ is addressed in a separate report.

Other attributes

6.56 There are a number of water quality, hydrological and habitat attributes relevant to riverine aquatic ecosystem health that were included in draft versions of the proposed Plan, but do not feature in Table 3.4 of Objective O25 (Greenfield, 2014d; Greenfield et al., 2013, 2014). These are listed below:

- Temperature
- pH
- Nutrients
- Dissolved oxygen
- Water clarity
- Toxicants
- Flows
- Sediment cover and substrate composition
- Habitat (including riparian vegetation and channel geomorphology)

6.57 While the attributes listed in para. 6.56 are important to riverine ecosystem function, they are considered to be drivers of ecosystem health rather than integrated indicators or ‘end points’ in themselves. Although these attributes can provide an early warning of changes in aquatic ecosystem health and are useful for assessing why outcomes are not being met, they are not required to describe when the objectives of the proposed Plan have been met. During development of the proposed Plan, a decision was made to limit the outcomes to meaningful integrated indicators of aquatic ecosystem health (GWRC, 2015). Consequently, the attributes listed in para. 6.56 were not included in the notified version of the proposed Plan.

6.58 In their submissions, Atiawa ki Whakarongotai (S398/011), Fish and Game (S308), The Royal Forest and Bird Protection Society and the Minister of Conservation (S75/027) requested that Table 3.4 be expanded to include numeric outcomes for the parameters listed below:

- Temperature
- pH
- Dissolved oxygen
- Water clarity
- Nutrients
- Toxicants
- Sediment cover
- A Habitat Quality/Natural Character Index (comprised of sediment cover substrate composition, riparian vegetation, woody debris, bank stability and channel geomorphology)

6.59 The majority of the attributes listed in para. 6.58 were originally recommended for inclusion in the proposed Plan by Greenfield (2014d) (including all but two of the components of the Habitat Quality/Natural Character Index requested by Fish and Game). However, as stated in the Section 32 report for aquatic ecosystems (GWRC, 2015), a review of Greenfield's (2014d) recommendations established that these attributes did not meet the policy criteria for inclusion in Table 3.4 of Objective O25. They were not considered key integrated indicators of aquatic ecosystem health and it was acknowledged that, for many of these attributes, outcomes could not be developed that were robust, defensible and feasible in terms of monitoring (GWRC, 2015; Greenfield, 2014d). I agree with this assessment, and it is my opinion that the additional attributes requested by submitters should not be included in Table 3.4 of Objective O25, including nutrients.

6.60 In their submissions, Fish and Game (S308) and The Royal Forest and Bird Protection Society (S75/027) suggest that numeric outcomes for dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) are required to ensure that macroinvertebrate outcomes are met. These recommendations are based on the assumption that there is a direct and orthogonal relationship between ecosystem health and nutrients. This is not the case. Firstly, nutrient enrichment is not always the most important driver of macroinvertebrate community structure in New Zealand rivers; in some systems the effects of factors such as deposited fine sediment are far more pervasive (Piggott, Lange, Townsend, & Matthaei, 2012). Secondly, even where it is a key driver of ecosystem health, the response of invertebrate communities to nutrient enrichment is difficult to predict from nitrogen and phosphorus concentrations alone. In natural systems, ecosystem health is driven by multiple interacting stressors, and the effects of nutrient enrichment is dependent on the state of a suite of other parameters (Piggott et al., 2012). As a result, the response of macroinvertebrate communities to nutrient concentrations will vary considerably across the region, even at a catchment scale, depending on factors such as the frequency of flood flows, deposited sediment and habitat availability. Therefore, it is not appropriate to stipulate generic numeric DIN and DRP outcomes at the river class scale, as they would not be robust or defensible. Instead river/reach specific nutrient outcomes should continue to be developed as part of the Whaitua processes. It should also be noted that a recent analysis of trends in GWRC’s water quality data found that, in the vast majority of monitored rivers, trends in DIN and DRP concentrations and macroinvertebrate community health over the past ten years could not be detected with certainty (Snelder, 2017). Consequently, while significant changes in habitat and water quality are required in many rivers to meet the ecosystem health outcomes, it is unlikely that increasing nutrient concentrations will further degrade ecosystem health before Whaitua specific nutrient outcomes/limits can be developed.

6.61 It is my opinion that the attributes included in Tables 3.4 should remain unchanged, as the additional attributes requested by submitters do not meet the criteria for inclusion in the proposed Plan (as set out in the Section 32 report for aquatic ecosystems (GWRC, 2015)).

Attributes of Table 3.5 Lakes

6.62 Table 3.5 contains 5 attributes of lakes. These are:

(a) Macrophytes;

(b) Phytoplankton;

(c) Fish;

(d) Mahinga Kai species; and

(e) Nutrients.

Macrophytes

6.63 Macrophytes (aquatic plants) provide food, refuge and habitat for a range of invertebrate and fish species; they 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 nutrient enrichment, sedimentation, changes in lake water levels, etc., can be detrimental to shallow lake ecosystems. In addition some exotic macrophyte species have the potential to outcompete and smother native macrophytes, reducing biodiversity and habitat values (Vant, 1987). Therefore, macrophyte communities are an important indicator of lake ecosystem health.

6.64 The narrative macrophyte outcome in Table 3.5 of Objective O25 was developed by Perrie and Milne (2014) and Greenfield et al. (2013, 2015). The LakeSPI (submerged plant index) provides a nationally recognised method for grading lake vegetation condition as either excellent (> 75% vegetated), high (50–75%), moderate (20–50%), poor (0–20%) or non-vegetated (0%). However, these grades do not account for natural variability in lake vegetation due to biogeographic factors (often referred to as reference condition). As such, they are not appropriate for use as generic numeric outcomes in the proposed Plan (Greenfield et al., 2015) As numeric macrophyte outcomes can only be developed for those lakes with existing LakeSPI data (Lake Kohangapiripiri, Lake Pounui and Lake Kohangatera), a narrative macrophyte outcome was recommended by Perrie and Milne (2014).

6.65 Although numeric macrophyte outcomes are not provided in the proposed Plan, Greenfield et al. (2013, 2015) and Perrie and Milne (2014) provide guidelines for assessing macrophyte communities in Lake Kohangapiripiri, Lake Pounui and Lake Kohangatera against the narrative outcome. The numeric LakeSPI guidelines for Lakes Kohangapiripiri and Pounui (≥ 63 and ≥ 56 respectively) are considered to reflect 'good' ecosystem health. In the case of Lake Kohangatera, the numeric outcome (≥88) represents 'excellent' ecosystem health, which reflects the fact that the lake is considered a nationally outstanding example of a lowland lagoon system (de Winton, 2013; de Winton, Champion, & Wells, 2011). These guidelines were developed from existing survey data (de Winton, 2013; de Winton et al., 2011), and numeric guidelines for assessing macrophyte communities have not been developed for other lakes in the region.

6.66 Submissions do not refer to the scientific justification behind the narrative outcome for macrophytes, but simply request the outcome be deleted. In my opinion, macrophytes are a key indicator of lake ecosystem health, and removal of this outcome from the proposed Plan would leave a significant gap. Although the macrophyte outcome is narrative only, it is intended that its inclusion will drive data collection and development of robust numeric thresholds that can be used in future.

6.67 Given the lack of defensible numeric thresholds that could be applied to all lakes, and the absence of submissions requesting it be changed (rather than deleted), it is my opinion that the narrative macrophyte outcome in Table 3.5 of Objective O25 should be retained.

Phytoplankton

6.68 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 (e.g., reduced water clarity) and food webs (i.e., some bloom-forming species are unpalatable). Blooms of some types of phytoplankton (cyanobacteria) are also potentially toxic (Vant, 1987).

6.69 The narrative phytoplankton outcome in Table 3.5 of Objective O25 was developed by Perrie and Milne (2014) and Greenfield et al. (2013, 2015). Phytoplankton biomass is a compulsory attribute in the NOF, and the boundaries between the NOF attribute states are established thresholds for the protection of ecosystem health. However, Perrie and Milne (2014) determined it was not appropriate to adopt the numeric attribute states provided in NOF as outcomes in Table 3.5 since:

(a) For many of the lakes in the region there is a deficiency of data and this precludes a robust assessment of the appropriateness of the NOF attribute state thresholds for these lakes; and

(b) The main lakes in the Wellington Region are typically shallow (e.g., Lake Wairarapa is mostly less than 2 m deep) and, as such, re-suspension of lakebed sediments (and associated nutrients) by wind/wave action are key drivers of lake water quality and ecosystem health. At this stage it is not clear how applicable the NOF attribute state thresholds are for shallow lakes and further discussion is required at a 'national level' around their appropriateness.

6.70 Although the numeric phytoplankton thresholds presented in the NOF have not been included in Table 3.5 of Objective O25, Perrie and Milne (2014) developed the narrative outcome to reflect a level of ecosystem health above the NOF national bottom lines.

6.71 While numeric phytoplankton outcomes are not included in the proposed Plan, Greenfield et al. (2013, 2015) and Perrie and Milne (2014) do provide guidelines for assessing phytoplankton in Lakes Kohangapiripiri, Pounui, Kohangatera, Waitawa, Onoke and Wairarapa against the narrative outcome. The guidelines recommended by Greenfield et al. (2013, 2015) and Perrie and Milne (2014) are that median phytoplankton biomass (based on three years of data) should be < 5 mg chl-*a*/m^3 in Lakes Kohangapiripiri, Kohangatera, Pounui and Waitawa, and < 12 mg chl-*a*/m^3 in Lakes Onoke and Wairarapa. Furthermore, the annual maximum phytoplankton biomass should not exceed 60 mg chl-*a*/m^3 in any lake. The median chlorophyll *a* concentrations of 5 mg/m^3 and 12 mg/m^3 equate to the boundaries of the B/C and C/D bands of the NOF, respectively. The maximum concentration is an interim value based on the boundaries of the C/D bands in the NOF. These guidelines are at a level that will ensure lake ecological communities are only "moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions" (NOF narrative attribute state)

6.72 In their submission, Federated Farmers of New Zealand (S352/078) requested that the phytoplankton outcome in Table 3.5 of Objective O25 be changed to a numeric threshold consistent with the NOF banded frameworks. As explained in para. 6.69, there is still significant uncertainty about the applicability of the NOF thresholds to lakes in the Wellington Region. Therefore, it is my opinion that the narrative phytoplankton outcome in Table 3.5 of Objective O25 should be retained.

Fish

6.73 Fish are a key component of lake ecosystems, and are a very useful indicator of ecosystem health because they respond to both local and catchment-scale impacts. 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 (McDowall, 1990)/

6.74 The narrative fish outcome in Table 3.4 of Objective O25 was developed by Perrie and Milne (2014) and Greenfield et al. (2013, 2015). Assessment against the narrative fish outcome is likely to include comparisons against expected community composition, abundance of key species and determination of size-frequency classes for key species (Greenfield et al., 2015). However, there are currently no established numeric thresholds for these metrics which could be applied in Table 3.5 (Greenfield et al., 2015).

6.75 Submissions do not refer to the scientific justification behind the narrative outcome for fish, but simply request the outcome be deleted. In my opinion fish are a key indicator of lake ecosystem health, and removal of this outcome from the proposed Plan would leave a significant gap. Although the fish outcome is narrative only, it is intended that its inclusion will drive data collection and development of robust numeric thresholds that can be used in future.

6.76 Given the lack of defensible numeric thresholds, and the absence of submissions requesting it be changed (rather than deleted), it is my opinion that the narrative fish outcome in Table 3.5 of Objective O25 should be retained.

Mahinga Kai species

6.77 The use of the attribute “Mahinga kai species’ is addressed in a separate report.

Nutrients

6.78 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.

6.79 The narrative nutrient outcome in Table 3.5 of Objective O25 was developed by Perrie and Milne (2014) and Greenfield et al. (2013, 2015). Total nitrogen and total phosphorus are both compulsory attributes in the NOF, and the boundaries between the NOF attribute states are established thresholds for the protection of ecosystem health. However, as with phytoplankton, Perrie and Milne (2014) determined it was not appropriate to adopt the numeric attribute states provided in NOF as outcomes in Table 3.5 since:

(a) For many of the lakes in the region there is a deficiency of data and this precludes a robust assessment of the appropriateness of the NOF attribute state thresholds for these lakes;

(b) The main lakes in the Wellington Region are typically shallow (e.g., Lake Wairarapa is mostly less than 2 m deep) and, as such, re-suspension of lakebed sediments (and associated nutrients) by wind/wave action are key drivers of lake water quality and ecosystem health. At this stage it is not clear how applicable the NOF attribute state thresholds are for shallow lakes and further discussion is required at a ‘national level’ around their appropriateness; and

(c) For total nitrogen the NOF provides different values for lakes that are either stratified or brackish and for lakes that are mixed (polymictic). Some lakes in the Wellington Region can fall into either category (e.g., Lake Wairarapa is a polymictic lake that is also at times brackish) and so it is unclear how the NOF attributes should be applied.

6.80 Although the NOF numeric total nitrogen and phosphorus attribute states have not been included in Table 3.5 of Objective O25, Perrie and Milne (2014) developed the narrative outcome to reflect a level of ecosystem health above the NOF national bottom lines.

6.81 While numeric outcomes for total nitrogen and phosphorus are not included in the proposed Plan, Greenfield et al. (2013, 2015) and Perrie and Milne (2014) provide guidelines for assessing nutrients in Lakes Kohangapiripiri, Pounui, Kohangatera, Waitawa, Onoke and Wairarapa against the narrative outcome. The guidelines recommended by Greenfield et al. (2015) for Lakes Kohangapiripiri, Kohangatera, Pounui and Waitawa are that the median concentration (based on three years of data) of total nitrogen should be < 0.337 mg/L and the median concentration of total phosphorus should be < 0.025 mg/L. In Lakes Onoke and Wairarapa the guidelines are median concentrations < 0.725 mg/L and < 0.043 mg/L for total nitrogen and phosphorus respectively. The nutrient concentration guidelines for Lakes Kohangapiripiri, Kohangatera, Pounui and Waitawa recommended by Greenfield et al. (2013, 2015) and Perrie and Milne (2014) are broadly consistent with the boundaries of the B/C bands in the NOF, while the guidelines for Lakes Onoke and Wairarapa fall within band C. These guidelines are set at a level that will ensure lake ecological communities are only “slightly” or “moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions" (NOF narrative attribute state).

6.82 In their submission, Federated Farmers of New Zealand (S352/078) requested that the nutrient outcome in Table 3.5 of Objective O25 be changed to numeric thresholds consistent with the NOF banded frameworks. As explained in para. 6.79, there is still significant uncertainty about the applicability of the NOF thresholds to lakes in the Wellington Region. Therefore, it is my opinion that the narrative nutrient outcomes in Table 3.5 of Objective O25 should be retained.

Other attributes

6.83 In their submission (S308), Fish and Game have requested that Table 3.5 of Objective O25 be amended to include a Trophic Lake Index (TLI) outcome. Although a widely used indicator of lake productivity, the TLI was not included in Table 3.5 as it was not considered to be an accurate measure of the ecological and/or water quality state of the vast majority of lakes in the Wellington Region (Alton Perrie pers. comm., 2017). Most lakes in the region are classified as 'shallow' (i.e. < 10 metres at their deepest point), and have close benthic-pelagic coupling, meaning that lakebed sediments are regularly resuspended by wind and wave action. The frequent resuspension of sediment in shallow lakes can have a significant impact on two of the four variables that make up the TLI, Secchi depth and total phosphorus. This can result in inflated/higher TLI scores that do not accurately reflect lake productivity. Accordingly, it is my opinion that TLI should not be included in Table 3.5 of Objective 025. However, it should be noted that while there is not an overall TLI outcome for lakes in the proposed Plan, outcomes for three of the four TLI variables (total nitrogen, total phosphorus and chlorophyll *a*) are included, which recognises that these variables are, or can be, important drivers/indicators of lake health.

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