PC1: JOINT WITNESS STATEMENT – Expert Conferencing - Table 3.11-1

Dated 17/06/2019

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INTRODUCTION

Expert conferencing of Waikato Regional Plan Change 1 Table 3.11-1 took place in person on Thursday 4th April (Day 1), Monday 15 April (Day 2), Wednesday 15 May 2019 (Day 3) and Wednesday 12 June 2019 (Day 4).

The conferencing was attended by:

Expert	Asked to attend by	Attendance days
Dr. Adam Canning (AC)	Fish and Game	1, 2, 3, 4
Dr. Adam Daniel (AD)	Fish and Game	1, 2, 3
Dr. Hannah Mueller (HM)	Beef and Lamb	1, 2, 3
Mr. Gerry Kessels (GK)	Beef and Lamb	2, 3(part), 4
Dr. Christopher Dada (CDa)	Beef and Lamb	1, 2, 3(part), 4
Dr. Tim Cox (TC)	Beef and Lamb	1, 2, 3, 4
Dr. Ngaire Phillips (NP)	Department of Conservation	1
Ms. Kathryn McArthur (KM)	Department of Conservation	1, 2, 3
Dr. Hugh Robertson (HR)	Department of Conservation	1, 3, 4
Dr. Craig Depree (CDe)	DairyNZ	1, 3, 4
Ms. Gillian Holmes (GHo)	Horticulture NZ	1, 2, 3, 4
Mr. Dean Miller (DM)	Mercury Energy	1, 2, 3, 4
Dr. Olivier Ausseil (OA)	Waikato and Waipa River Iwi	1, 2, 3, 4
Mr. Anthony Kirk (AK)	Waikato Region Territorial Authorities	1, 2, 3, 4
Dr. Martin Neale (MN)	Wairakei Pastoral Ltd	1, 2, 4
Mr. Nicholas Conland (NC)	Wairakei Pastoral Ltd	1, 2, 3, 4
Dr. Mike Scarsbrook (MS)	Waikato Regional Council	1, 2, 3, 4
Mr. Bill Vant (BV)	Waikato Regional Council	1, 2, 3, 4
Dr Bryce Cooper (BC)	Waikato Regional Council	2, 3, 4
Mr. Bevan Jenkins (BJ)	Waikato Regional Council	1, 2, 3
Mr. Garrett Hall (GHa)	Watercare	2, 3

CODE OF CONDUCT

We confirm that we:

- Have read the Environment Court Practice Note 2014 Code of Conduct and agreed to abide by it;

and in particular:

- Have read the Environment Court Practice Note 2014 Code of Conduct Appendix 3 – Protocols for Expert Witness Conferencing and agreed to abide by it.

We confirm that the issues addressed in this Joint Witness Statement are within our respective areas of expertise – as indicated by the initials signified against particular topic areas.

SCOPE OF STATEMENT

In our conferencing we discussed the issues relevant to PC 1 Table 3.11-1 that arise within our respective fields of expertise on water quality as it relates to human health and ecosystem health. Prior to attending the conferencing we each read the relevant parts of Waikato Regional Plan Change 1, the S32 report, the S42A report Block 1, submitter evidence and any relevant reports prepared by the other experts and circulated.

We were guided by the Hearing Panel's Minute 2 dated 13 March 2019 which directed that expert conferencing be undertaken to provide an opportunity for the experts to clarify the issues with Table 3.11-1 and address (and resolve if possible) the concerns regarding its robustness and the level of 'uncertainty' and 'completeness' of the provisions.

The Panel directed that the Expert Conferencing Brief be developed by Mr David Hill (Facilitator) in conjunction with the experts, but noting its expectation was that the brief would be developed so as to be able to:

- *Give effect to the NPS-FM and the Vision and Strategy;*
- *Use best scientific methods throughout the conferencing process;*
- *Proceed on the basis that plan and submission scope issues do not constrain the recommendations the experts make;*
- *Identify the competing positions and provide recommendations in the alternative; and*
- *At minimum, one set of numeric values be provided for:*
    - *Safe swimming, and*
    - *Safe food gathering along the entire length of both rivers (Waikato and Waipa), including their tributaries.*

The Hearing Panel re-advised, through the Facilitator, that we were not limited by scope and that any matter we thought relevant to Table 3.11-1 could be discussed and recommendations made to the Panel. We were advised by the Facilitator that we were not to be constrained by whichever party we had presented evidence for, but participated as experts on matters relating to Table 3.11-1 (although in practice the majority of time during conferencing was spent on the "core" Table attributes).

In addition to the attributes currently contained within Table 3.11-1, the experts determined that they should also consider and advise the Panel with regard to potential attributes for ecological health. While these were not as fully developed and debated as the "core" Table attributes, they are presented here for further consideration.

CONFERENCING PROCESS

<u>Preparation of Attribute statements</u>

Notified attributes in Table 3.11-1 which needed further work and proposed new potential attributes for Table 3.11-1 were identified on Days 1 and 2 of the conferencing. We agreed to the formation of task sub-groups to develop a discussion paper for each attribute, to report back on Day 3. Each sub-group identified who would lead that group.

We agreed that new attributes should be assessed, where relevant, using the Principles of Attribute Inclusion guide (the Principles) used by the Technical Leaders Group in development of PC1 (Attachment 1). Although Ms McArthur notes below her reservations with respect to the application of Principle 5 as set out in her evidence in chief for Block 1 at paragraph 83.

Draft discussion papers were (mostly) circulated prior to Day 3. Completed papers were finalised by email and on Day 4. We were asked to identify the attribute value, the issue(s) arising with respect to that attribute, the assessment of the attribute (if new) against the Principles, any options identified for amendments to or inclusion of the attribute in Table 3.11-1, and a recommendation to the Panel if appropriate. Each paper should also list its authors, and the information source(s) that we agree are relevant to the attribute topic.

The finalised discussion papers are attached to this Statement, as referred below in the section headed: **Attribute Statements**. We note that many of the documents would have benefited from additional expert discussion to further refine the content and views expressed.

Additional discussion papers were circulated by those who wished to do so to enhance discussion on any attribute. These are included within the relevant attachment for that attribute.

In addition to the attribute discussions, a number of matters were raised during discussions with a request that they be recorded as footnotes, qualifications, or for the record. Also raised was the question of the statistical test to be used to assess the significance of changes in attribute state, and some issues that are not attribute-specific and were not further discussed. These are summarised as follows. Some attribute papers also address other issues, such as sub-catchment delineation and additional monitoring sites.

Statistical test

Advice was sought from Dr Graham McBride (NIWA) regarding the most appropriate statistical method to be used to assess whether an attribute value in any 5-yearly monitoring period has maintained the current state value, or has changed (either degradation or improvement). The concern was that setting thresholds based on current state value, could lead to the default conclusion that if a future state value results in an increase in attribute concentration or decrease in clarity, either within a band or resulting in a downshift between bands (A to B or B to C), then the water quality objective has not been achieved / maintained. This is not necessarily the case; for example, a calculated 5-year median concentration might increase or decrease within an expected variability range without the state of the attribute actually changing. The question posed related to how the assessment of whether the current state has been maintained, or whether the Attribute has improved or degraded.

Dr McBride's advice is to apply the statistical methodology described in his recent paper (G.B.McBride (2019) - Has water quality improved or been maintained? A quantitative assessment procedure. Journal of Environmental Quality 48: 412-420) and which was used in the recent State of the Environment report 'Environment Aotearoa 2019': (available but not attached).

We agreed that WRC would prepare a report on how the initial attributes were measured and how the current state data were derived for PC1. Included in that report will be options on the statistical method(s) that might be used to assess changes in (and significance of) attribute states over time. At the time of finalising this Statement, this report had not been received and no further discussion or consensus has been reached regarding suitability of the trend assessment method for PC1.

Issues not yet addressed:

1. Sub-catchments that may need to be re-defined, though noting that Whangamarino sub-catchments are considered in Attachment 13;
2. Sub-catchment monitoring sites that may have been missed, additional to sites described in the attached papers;
3. How to address outstanding issues (classification, short- and long-term targets) for lakes in Table 3.11-1;
4. What narrative targets might be used for some attributes in the absence of numbers for ecosystem health, but noting that narrative targets may include a numeric value and that some have been described for some attributes in the attached papers;
5. Whether TSS load should be added as a key attribute for Whangamarino;

6. Uncertainty as to the period of time "current state" should be calculated/estimated over, for example 5 or 10 years, and which years;
7. How current state baseline threshold values are to be presented in PC1 Table 3.11-1, including whether separate Tables are advisable for, for example, ecosystem types.

Footnotes/qualifications/for the record

1. The *E.coli* attribute is not proposed for swimming in wetlands but experts acknowledge that historically some swimming in wetlands occurred; wetlands associated with lakes will be covered by lakes attributes.
2. Achieving *E.coli* targets will potentially be compromised in wetlands with large water fowl populations.
3. Experts were not prepared (inadequate information) to consider *E.coli* effects on the estuarine system (Waikato River mouth).
4. Effects of sediment (and nutrients) on the estuarine system (Waikato River mouth) have not been comprehensively considered in PC1.
5. *E.coli* is an imperfect indicator of microbial contamination.
6. Concern that lakes are so far off the clarity target of 1.6m that the relevance of including this target is questioned.
7. Re safe food gathering and shellfish – in the absence of any additional information and the lack of data for freshwater shellfish, the TLG recommendation should be applied. For food species that are thoroughly washed and cooked prior to eating, the TLG considered it would be appropriate to use the same *E. coli* attribute bands as for primary contact recreation.
8. A zone of reasonable mixing for point source discharges is presumed.
9. The various terms *objectives*, *limits* and *targets* are used inconsistently and their meanings require greater specificity; while this requires clarification, these were not discussed further;
10. Predictions made for *E.coli* assumed that the rate of change over time would be linear, but noted that it is not clear what the model concentrations did;
11. Any dissolved oxygen attribute would not apply to peat lakes.

ATTRIBUTE STATEMENTS

Attribute statements including the outcome of our discussions for each attribute and the options and/or recommendation to the Panel, have been prepared for a range of attributes. Attribute statements may also include authors' views that were not fully discussed due to limitations in time noted above.

Attribute statements are in **Attachments 2-16**. We have each provided a response to these, including whether we agree or disagree and reasons for our position, in **Attachment 17**. Some suggested narratives are included in the attribute papers.

A summary of whether or not we considered the attribute an important measure of value, which should be included as a narrative and/or numeric objective, is shown in **Table 1**.

A summary of our agreements and disagreements on the options proposed in the discussion papers is given in **Table 2**. For individual comments on those matters refer to **Attachment 17**.

The manner in which limits and targets were selected in each sub-catchment was agreed for TN and TP in the Nutrients report, and a general consensus reached on Day 4 that each of the (now) 76 sub-catchments should have a target and limit based on the short term PC1 objectives.

Table 1 – Summary assessment of importance of each attribute

Attribute	Important as measure of value		Narrative		Numeric in table	
	Yes	No	Yes	No	Yes	No
Nutrients	OA NC BC TC CDe GHo GK AK KM DM HM MN HR MS BV		HM	NC BC CDe GHo MS	OA NC BC TC CDe GHo GK AK KM DM HM MN MS HR BV	
E.coli	OA NC BC TC CDa CDe GHo KM DM HM MN MS BV GK		CDa	NC BC CDe GHo MS	OA NC BC TC CDa CDe GHo KM DM MN MS BV	
Deposited sediment	OA NC BC TC CDe GHo GK KM DM HM MN MS		OA NC BC TC CDe GHo GK KM DM HM MN MS BV		GK KM	OA BC NC CDe GHo GK DM HM MS BV

Attribute	Important as measure of value		Narrative		Numeric in table	
	Yes	No	Yes	No	Yes	No
Clarity	OA NC BC TC CDe GHo GK KM DM HM MN MS BV			NC BC CDe GHo HM MS	OA NC BC TC CDe GHo GK KM DM MN MS BV	
Dissolved oxygen	OA NC BC TC CDe Gho GK AK KM DM HM MN HR MS BV		OA NC BC TC CDe GHo GK DM MN HM MS BV		NC KM HM HR	OA BC TC CDe GHo DM MN MS BV
Macroinvertebrates	OA AC NC TC BC Cde GHo GK KM DM HM MN MS BV		AC BC CDe GK HM BV	OA NC TC GHo DM MN MS	OA AC NC GHo GK KM DM HM MN MS	TC BC CDe BV

Attribute	Important as measure of value		Narrative		Numeric in table	
	Yes	No	Yes	No	Yes	No
Macrophytes	OA NC BC TC CDe GHo GK KM DM HM MN HR MS BV		NC GK KM HR	OA BC TC CDe GHo DM MN MS	KM	OA NC BC TC CDe GHo DM HM MN MS BV
Periphyton	OA NC BC TC CDe GHo GK KM DM HM MN MS BV		OA NC BC CDe GHo DM MN MS		TC GK KM	OA NC BC CDe GHo DM MN MS BV
Fish	OA NC BC TC CDe GHo GK KM DM HM MN MS BV		OA NC GK HM MN	TC BC CDe GHo DM MS	GK KM	OA NC BC TC CDe GHo DM HM MN MS

Attribute	Important as measure of value		Narrative		Numeric in table	
	Yes	No	Yes	No	Yes	No
Riparian	NC GHo GK KM HM	OA BC TC CDe DM MN MS BV	NC GK KM HM	OA BC TC CDe GHo DM MN MS	GK KM HM	OA NC BC CDe GHo MN MS BV
Lakes	OA NC BC CDe TC GHo GK KM DM HR MS		NC	BC CDe GHo DM MS	OA NC TC BC CDe KM DM MS	
Whangamarino	OA NC BC TC CDe GHo GK DM HR MS BV		NC TC CDe GK DM MS	BC GHo	OA NC BC GHo GK HR	TC CDe DM MS BV
Other wetlands	OA NC BC TC CDe GHo GK DM HR MS		NC BC CDe GHo GK DM HR MS	OA TC		OA NC BC TC CDe GHo MS (**Note** - numeric values not actually proposed)

Attribute	Important as measure of value		Narrative		Numeric in table	
	Yes	No	Yes	No	Yes	No
Temperature	OA NC BC TC CDe GHo GK KM DM HM MN MS BV		CDe MN	OA BC TC GHo DM MS	KM	OA BC TC CDe GHo DM MN MS BV
Toxicants	NC BC TC CDe GHo KM DM HM MN MS BV		NC MN MS BV	OA BC TC CDe GHo DM	KM	OA NC BC TC CDe GHo GK DM MN MS BV

Table 2 Summary of agreement and disagreement for each attribute

Attribute	Agree	Agree in part	Disagree	N/A
Nutrients (Attachment 2)	OA NC TC GHa DM HM MN HR	BC CDe GHo GK AK KM MS BV		CDa
E.coli (Attachment 3)	OA NC BC TC CDe GHo (contact) GHa KM DM MN MS BV	CDa		GHo (shellfish) GK AK HM HR
Deposited sediment (Attachment 4)	NC TC GHa GK KM	GHo DM HM MN	OA BC CDe MS	CDa AK HR BV
Clarity (Attachment 5)	OA NC TC CDe KM MN BV	GHo HM	BC GHa MS	CDa GK AK DM HR
Dissolved oxygen (Attachment 6)	OA NC BC GHa KM HM NP MS HR BV	TC CDe GHo GK AK DM MN		CDa

Attribute	Agree	Agree in part	Disagree	N/A
Invertebrate communities (Attachment 7)	OA NC GHa GHo GK KM DM HM MN NP MS	BV	BC TC CDe	CDa AK HR
Macrophyte nuisance (Attachment 8)	OA NC BC TC CDe GHa GHo DM MN MS BV	HM	GK KM HR	CDa AK
Periphyton (Attachment 9)	NC TC GHa GK KM DM	OA BC CDe GHo HM MN MS BV		CDa AK HR
Fish Communities (Attachment 10)	GK KM	HM MN	OA NC BC TC CDe GHo DM MS	CDa GHa AK HR BV
Riparian (Attachment 11)	NC KM HM	GK	OA BC TC CDe GHa GHo DM MN MS BV	CDa HR

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</table>

SIGNED:

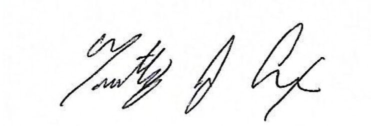
Dr. Olivier Ausseil

Dr. Adam Canning

Mr. Nicholas Conland

Dr Bryce Cooper

Dr. Tim Cox



Dr. Christopher Dada

Dr. Adam Daniel

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Mr. Garrett Hall

Ms. Gillian Holmes

Mr. Gerry Kessels

Mr. Anthony Kirk

Ms. Kathryn McArthur

Mr. Dean Miller

Dr. Hannah Mueller

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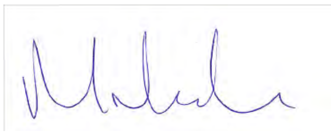
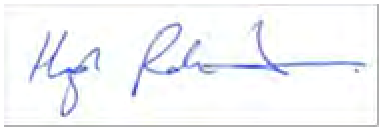
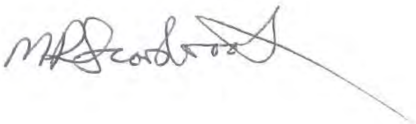


Dr. Ngaire Phillips

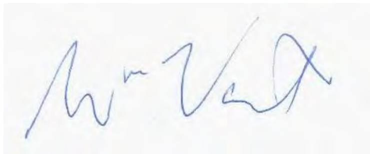
Dr. Hugh Robertson



Dr. Mike Scarsbrook



Mr. Bill Vant



Attachment 1 Principles for Attribute Inclusion

Attribute Assessment - Principles for Attribute Inclusion

In the process of developing the NOF, the Ministry for the Environment defined a set of principles that were subsequently used by officials and the NOF Reference Group to assess each potential attribute (Appendix 2). The five principles can be summarised as:

1. Does the attribute provide a measure of the value?
2. Are there agreed band thresholds, summary statistics and measurement protocols?
3. Do we know what to do to manage this attribute, do we understand the drivers and are there quantitative relationships that link the attribute state to resource use limits and/or management interventions?
4. Is there data of sufficient quality, quantity and representativeness to assess the current state of the attribute?
5. Can we assess the socio-economic implications of setting limits around this attribute?

The scope of the Healthy Rivers: Wai Ora Plan Change is restricted to improving the management of nitrogen (N), phosphorus (P), sediment and faecal bacteria. This scope is considerably narrower than that covered by the NOF. Therefore, with some minor changes the principles above were made more relevant to the Healthy Rivers: Wai Ora process:

1. Does the attribute provide a measure of the value?
2. Measurement and band thresholds
    - Are there established protocols for measurement of the attribute?
    - Do experts agree on the summary statistic and associated time period?
    - Do experts agree on thresholds for the numerical bands and associated band descriptors?
3. Management and limits
    - Do we know what to do to manage this attribute?
    - Are the four contaminants (N, P, sediment and faecal microbes) direct drivers of this attribute?
    - Do quantitative relationships link the attribute state to limits and/or management interventions to control N, P, sediment and faecal microbes?
4. Evaluation of current state
    - Is there data of sufficient quality, quantity and representativeness to assess the current state of the attribute within Waikato FMUs?
5. Implications
    - Can the social, cultural, economic and environmental implications of setting limits be assessed?
    - Are we able to model scenarios for these attributes within the Healthy Rivers: Wai Ora timeframe?

Attachment 2 Nutrient attributes for PC1

Waikato Healthy Rivers Plan Change 1
Water Quality Expert Caucusing
Nutrient Attributes for the Waikato River and tributaries

Olivier Ausseil; Bill Vant; Tim Cox; Craig Depree; Adam Canning; Mike Scarsbrook; Garrett Hall

1 Introductory notes:

This document uses the term “threshold” to generically define the “numbers” contained in Table 3.11-1. The Group did not specifically discuss what these thresholds should be called (targets, freshwater objectives, limits, etc.).

All thresholds in this document are the “long-term” thresholds, i.e. the desired long-term state (80-year targets in existing Table 3.11-1). Short-term thresholds can easily be back-calculated from existing state and long-term threshold if/as required.

The technical group considered it important that all changes to in attribute state were determined by an agreed statistical method which is included in the PC1 methods.

Table 3.11-1 in its current form defines chlorophyll *a* thresholds for all sites along the mainstem of the Waikato River. Chlorophyll *a* concentrations relate directly to the visual and ecological values of the river (as opposed to nutrient concentrations, which are controlling factors), and thus directly represent the desired state. These thresholds were defined as part of the collaborative plan development process, and the technical expert group does not have any reasons to recommend different thresholds. For this reason, all options described in this document use the chlorophyll *a* thresholds as currently set in Table 3.11-1, with the exception of small corrections to reflect updated calculations of “current state” statistics as presented in Dr Scarsbrook’s evidence (dated 1 March 2019).

One of the limitations identified in this work was that there is currently no monitoring site at the bottom of the Upper Waikato FMU at Karapiro. It is recommended that Waikato at Karapiro be added to the Waikato mainstem sites as the key “node” representing the bottom of the Upper Waikato FMU. “Current” TN and TP concentrations at Karapiro were estimated as 402 mg/m^3 for TN 27.1 mg/m^3 for TP. Details re provided in Appendix 1,

The notified sub-catchment 66 forms part of the Waikato River for at least 20km’s from Ohaki (sub-catchment 73). Along this reach the river is shallow (typically around 2-3 m deep), swift and follows a sinuous form of curves and turns. While below the Tutukau Bridge the river (in the remainder of sub-catchment 66) begins its impoundment behind the Ohakuri Dam and has significant tailrace effects from the dam, including reduced flow velocity, increased depth and increased weeds and the channel straightens out. The proposed mainstem site at Parekawau (sub-catchment 66A) is the last river stage before the first significant hydroelectric lake (Ohakuri) and is influenced by the Reporoa Catchment at the confluence of the Waiotapu River and has considerable geothermal influence. In summary the splitting of the sub-catchment 66 into 66a and 66b is based on the two different types of ecological systems present (riverine vs lacustrine) and the differing framework for managing a river versus a lake. Monitoring previously occurred at the Tutukau Bridge (66A site) from Oct 2004 to Feb 2011, the data proposed has been prepared from the RDST for the reference period 2010 to 2014.

Abbreviations and definitions:

- NPS FM means the National Policy Statement for Freshwater Management (2014, updated August 2017);
- NPS FM Attribute Tables means the tables in Appendix 2 of the NPSFM;
- Band means an Attribute State in the NPSFM Attribute tables;
- Current state means the statistics calculated based on WRC monitoring data for the period 2010-2014, as presented in Dr Scarsbrook's evidence (dated 1 March 2019);
- DIN means Dissolved Inorganic Nitrogen (the sum of ammoniacal, nitrate and nitrate nitrogen);
- DRP Means Dissolved Reactive Phosphorus;
- FMU means Freshwater Management Unit;
- TN means Total nitrogen;
- TP Means Total Phosphorus;

This document does not cover considerations of nutrient attributes for lakes (other than the artificial hydroelectric reservoir lakes along the mainstem of the Waikato River), wetlands or the coastal environment.

2 Issues considered

2.1 Waikato mainstem

PC1 Table 3.11-1 contains the following short- and long-term "thresholds" for the Waikato mainstem:

- Phytoplankton biomass, expressed as Annual median and annual maximum Chlorophyll *a* concentration (mg/m^3);
- Annual median TN and TP concentrations (mg/m^3);
- Annual median and 95^{th} percentile nitrate-N (mg/L);
- Annual median and maximum ammoniacal-N (mg/L).

The "thresholds" in Table 3.11-1 were defined based on the NOF Attribute State tables. Various issues were raised by experts regarding these thresholds, including:

- Inconsistencies in Bands applied to the three attributes at a given site (e.g. for Waikato at Waipapa, chlorophyll *a* and TP "thresholds" are in Band B, but TN is in Band A;
- The NPS FM Attribute tables contain two columns for the TN Attributes for Lakes, one for "Seasonally Stratified and Brackish" lakes and one for "Polymictic" lakes. "thresholds" were based on Numeric Attribute States for "Seasonally Stratified" lakes, whilst evidence points to most of the Waikato Hydro Lakes being "Polymictic";
- Only the Ohakuri hydroelectric reservoir lake may be seasonally stratified (which would require different treatment), although it should be noted this lake was classified as polymictic in Verburg (2012)[1];

[1] Verburg P. (2012). Classification and objective bands for monitored lakes. NIWA Client Report HAM2012-Sep 2012, prepared for Ministry of the Environment. 18 p.

- There is a lack of direct relationship between the outcome sought (limiting phytoplankton biomass to below certain thresholds) and the means by which the outcome will be met (TN and/or TP concentrations);
- In many locations, nitrate-N concentration thresholds are greater than TN thresholds;
- The way the "one band up" principle was applied to populate Table 3.11-1 has created large discrepancies in the level of improvement required of the different FMUs and sub-catchments.

2.2 Tributaries/sub-catchments

With regards to tributaries/sub-catchments, experts raised various issues with Table 3.11-1 including:

- Does not contain thresholds for phytoplankton or periphyton biomass or cover;
- Does not contain "Ecosystem Health" indicators such as MCI or Fish IBI;
- Contains nitrate-N and ammoniacal-N targets based on toxicity effect risk. The way the "one band up" principle was applied has again created large discrepancies in the level of improvement required of the different sub-catchments;
- Does not contain TN/TP or DIN/DRP thresholds (concentrations or loads).

Various issues were raised by experts regarding these targets, including:

- TN/TP load thresholds should be defined for the mainstem and load targets should be defined for sub-catchments (tributaries), based on "distributing" the mainstem TN/TP load requirements. Loads would provide a basis for managing the sub-catchment contributions (as a 5-yearly rolling mean) to achieve the desired state (chlorophyll *a* concentrations) in the mainstem;
- Nutrient concentration thresholds should be defined for sub-catchment/tributaries, based on correlations between nutrient concentrations and macroinvertebrate and fish community indicators;
- Nutrient concentration thresholds (DIN and DRP) thresholds should be defined for sub-catchment/tributaries, based on concentrations considered generally appropriate to meet periphyton biomass/cover "thresholds".

3 Nitrate and ammonia toxicity thresholds (Mainstem and tributaries)

Nitrate and ammonia toxicity concentrations should be applied on the basis of protecting an ecosystem state rather than as discrete concentrations. These should be based on a combination of a "no degradation" requirement and the thresholds presented in Table 1.

Table 1: Nitrate and Ammonia toxicity thresholds

Attribute	Unit	Compliance metric	Waikato and Waipā Rivers	All tributaries**
Nitrate	mg	Annual	<1.0	<2.4

(toxicity)	NO3-N/L	median	or current concentration, whichever is lowest	or current concentration, whichever is lowest
		Annual 95th percentile	<1.5 or current concentration, whichever is lowest	<3.5 or current concentration, whichever is lowest
Ammonia (toxicity)	mg NH4-N/L	Annual median*	<0.03 or current concentration, whichever is lowest	<0.24 or current concentration, whichever is lowest
		Annual maximum*	<0.05 or current concentration, whichever is lowest	<0.40 or current concentration, whichever is lowest

* Based on pH 8 and temperature of 20°C

** No degradation from baseline level

4 Waikato River Mainstem

Two main approaches can be used to define numerical nutrient concentration thresholds for the Waikato mainstem.

- Approach 1 utilises the NPS FM Attribute State "bands" for all three attributes (chlorophyll *a*, TN and TP). In this approach all three attributes are treated equally and are used as indicators of overall "trophic status";
- Approach 2 considers that phytoplankton biomass is the outcome being sought and TN/TP are the "controls" by which the outcome will be met. This approach uses quantitative relationships between phytoplankton biomass and nutrient concentrations to define the maximum nutrient concentrations acceptable to not exceed a given phytoplankton biomass.

Within each main approach, several options were considered, as described below. The nutrient thresholds determined under each approach, the corresponding reductions in TN/TP concentrations and estimated reductions in diffuse loads at each monitoring site are summarized in Table 2.

Approach 1: Use NPSFM Attribute State tables for all three Attributes.

- **Approach 1A**: Table 3.11-1 as it stands but with current state corrected to reflect Scarsbrook March 2019 evidence (changes from original Table 3.11-1 are highlighted in orange in Table 2);
- **Approach 1B**: Table 3.11-1 as corrected under Approach 1A and TN attribute corrected to use the appropriate NPS FM TN Attribute column as follows:
  1. Maintain the TN Attribute in the same "Band" as in current Table 3-11.1 (i.e. in Band A in the Upper Waikato FMU, and Band B for the middle and lower FMUs, Band B for chlorophyll *a* and TP for the whole mainstem);
  2. Use the "Seasonally Stratified" column for the Waikato at Ohakuri;
  3. Use the "Polymictic" column for TN for all other sites;

4. In all cases, TN and TP thresholds cannot be greater than the "current state" concentration, i.e. cannot allow an increase in TN or TP concentrations at any site (For example, at the Waikato at Narrows site, the TN Band B/C threshold is 500 ppb, but because the current concentration is 410 ppb, the long-term threshold under this option is defined as 410 ppb);

It is noted this option leads to a 26% reduction in TN required at Ohakuri, but none at Whakamaru and an 11% reduction at Waipapa, in spite of TN concentrations being lower at Ohakuri than at Whakamaru, and no evidence of chlorophyll *a* issues at that site. On that basis it seems more logical to set the nutrient threshold at Ohakuri to maintain current state – see approach 1C. This also seems justified on the basis of our uncertainty around the classification of Lake Ohakuri as a seasonally stratified, or polymictic lake (which have respective A band thresholds of 160 and 300 mg/m^3)

- **Approach 1C**: Table 3.11-1 as corrected under Approach 1B, but with nutrient thresholds at all sites upstream of Waipapa set to maintain current state.

Approach 2: Define TN/TP thresholds to meet the Chlorophyll *a* thresholds.

- **Approach 2A**: Use Table 3.11-1 Chlorophyll *a* threshold for the Waikato mainstem, then:
  1. Where the chlorophyll *a* threshold is defined as current state (Upper FMU), maintain TN and TP concentrations at current levels, and
  2. Where the chlorophyll *a* threshold is defined as requiring reduction (Middle and Lower Waikato FMUs), define TN and TP using the Yalden and Elliott (2018)[2] equations;
  3. In all cases, TN and TP thresholds cannot be greater than the "current state" concentration, i.e. cannot allow an increase in TN or TP concentrations at any site;
  4. For Karapiro: No equations are available due to the absence of monitoring data at that site. The Narrows equation was used to determine the TN and TP thresholds. As a check, the Y&E equation for Waipapa was run to "produce" a median chlorophyll a concentration of 5 mg/m^3. The outputs of this method (TN: 425 mg/m^3; TP: 33 mg/m^3) were greater than the "current" concentrations and were thus not used;
  5. The Yalden and Elliott equations for Mercer and Tuakau were parametrised without consideration of exogenous chlorophyll *a* (i.e. external inputs of chlorophyll a from eutrophic lowland lakes). The process below was applied to estimate TN/TP thresholds for these sites.
  6. For Mercer and Tuakau: the proposed median chlorophyll *a* threshold for Mercer/Tuakau is 5 $mg/^3$.
     a) Vant 2015 (WRC Technical Report 2015/13) estimated that the outflows from the shallow lakes contribute about one-quarter (or more) of the current load of chlorophyll *a* at Mercer during the summer. Using the same method and a corrected and updated dataset, it is estimated they contributed 23% of the annual load of chlorophyll *a* at Mercer. They therefore contribute about 2.4 mg/m^3 of the current annual median of 10.5 mg/m^3 observed in the river (23% of 10.5 is 2.4). So the

[2] Yalden, S. and Elliott S. (2018). A methodology for chlorophyll and visual clarity modelling of the Waikato and Waipa Rivers. *Waikato Regional Council Technical Report 2018/60. ISSN 2230-4355 (Print) ISSN 2230-4363 (Online).*

Chlorophyll *a* due to the rest of the Waikato/Waipā catchment is 8.1 mg/m^3 (= 10.5 minus 2.4).

b) The chlorophyll *a* concentration in these lakes (median values 80-90 mg/m^3) are currently well over the national bottom line (12 mg/m^3). The chlorophyll *a* concentration in these lakes need to be reduced by a factor 7 or so in order to meet the national bottom line.

c) Assuming the NPSFM bottom line is met at some point in the future in these lakes, i.e. assuming the median chlorophyll *a* in Lakes Waikare and Whangape was reduced to 12mg/m^3, and that there is no losses or increases in chlorophyll *a* loads between the lakes and the Waikato River, then the chlorophyll *a* at Mercer would reduce to 8.4 mg/m^3 from its current value of 10.5 mg/m^3. This would be composed of 8.1 mg/m^3 from "in river" processes from the catchment above Mercer as at present, plus 0.3 mg/m^3 from the shallow lakes.

d) The requirement from the rest of the catchment in order to achieve the 5 mg/m^3 threshold at that point would then be to reduce its contribution to the median chlorophyll *a* concentration at Mercer from 8.1 mg/m^3 currently to about 4.7 mg/m^3 – a reduction of about 42%.

e) Applying the Yalden and Elliott equations for Huntly to the Mercer and Tuakau sites indicates that annual median concentrations not exceeding 35 mg TP/m^3 and 439 mg TN/m^3 would be required in order to reduce the "in-river" contribution to the median chlorophyll *a* concentrations at or below 4.7 mg/m^3.

f) It is noted that the Huntly equations may underestimate the amount of chlorophyll *a* produced in the Waikato River mainstem in response to TN and TP concentrations. This is due to the fact that the Huntly site is located a short distance from the Waipā River confluence. In other words, some of the TN/TP present in the water column at that site may not have had sufficient residence time to "express" itself as planktonic algae biomass. The full response to the TN/TP inputs from the Waipā catchment may only be seen further downstream. The result is that the above TN/TP thresholds may be too "lenient" and may not lead to achievement of the chlorophyll *a* threshold at Mercer and Tuakau.

g) To provide a range of possible threshold values, the Yalden and Elliott equation for the Horotiu site was also used to estimate the TN and TP concentrations required to meet a median chlorophyll *a* concentrations at or below 4.7 mg/m^3, resulting in that annual median concentrations not exceeding 27 mg TP/m^3 and 309 mg TN/m^3.

h) Lastly, the TN/TP inputs from the shallow lakes need to be added back to the mainstem TN/TP thresholds calculated above. Assuming the NPSFM bottom line is met at some point in the future in these lakes, i.e. that the TN and TP concentrations in the lakes are reduced to 800 mg/m^3 and 50 mg/m^3 respectively, the correction that needs to me made to the TN and TP thresholds is estimated at 10 mg/m^3 for TN and 0.4 mg/m^3 for TP.

- **Approach 2B:** Use Table 3.11-1 chlorophyll *a* thresholds for the Waikato mainstem, then:
  1. Where the Chlorophyll a threshold is defined as current state (All sites down to Waipapa), maintain TN and TP concentrations at current levels, and

2. Where the chlorophyll *a* threshold is defined as requiring reduction (All sites from Narrows down), define TP thresholds using single-variable empirical equations.
3. This approach does not provide TN thresholds where improvement is required, because statistically significant positive correlations were not detected at any of the sites (as described in detail in Appendix 2 prepared by Dr Tim Cox).
4. As an interim position, TN thresholds were defined so that the proportional reduction of TN diffuse loads matched that of the TP diffuse loads;
5. Alternatively, another approach (e.g. Approach 1C or 2A) could be used to define TN thresholds for the lower river.

- **<u>Approach 2C</u>:** Same as approach 2B, but correcting the single-variable empirical equations at Tuakau for exogenous chlorophyll *a*, as follows:

1. all annual median chl-a values at Tuakau were corrected for exogenous chl-*a* by subtracting off 2.43 mg/m^3 (the estimated median concentration originating from the shallow lakes).
2. The linear regression calculations were re-calculated to come up with a new single variate regression model for the relationship between "river grown" chl-*a* and TP (just a different y-intercept).
3. This new regression equation was applied to calculate a TP threshold required to achieve 5 mg/m^3 at Tuakau, assuming 0.3 mg/m^3 exogenous input.
4. The same threshold result was applied to the Mercer site, given the lack of an acceptable empirical model for that site.

PC1 Short-term Mitigation Package Modelling Results for Mainstem

For reference, the Technical Group has undertaken modelling of the load reductions currently envisaged under PC1, to compare to the loads associated with achieving the threshold targets described above.

This exercise used the short-term "PC1 mitigation package" applied as an intervention over the whole catchment. The outcomes of this modelling (undertaken by Dr Cox and Mr Conland), for the mainstem, are presented in Table 3 and Table 4.

These modelling outputs are provided for the Panel's consideration, noting that one option may be to use these numbers as "short-term", i.e. 10-year, thresholds in Table 3.11-1 for mainstem sites.

Table 2: Mainstem Waikato River chlorophyll *a* and nutrient thresholds under various approaches. Numbers in red indicate reductions of the "diffuse load" exceeding 85%. (conc: concentration; N.D.: No Data; Diff Load: Anthropogenic Diffuse Load).

		Median Chlorophyll *a* (mg/m³)			Maximum Chlorophyll *a* (mg/m³)			Median TN (mg/m³)				Median TP (mg/m³)			
		Threshold	**Current**	**% change (conc.)**	**Threshold**	**Current**	**% change (conc.)**	**Threshold**	**Current**	**% change (conc.)**	**% change (diff. load)**	**Threshold**	**Current**	**% change (conc.)**	**% change (diff. load)**
Option "0" Table 3.11-1 as notified (for comparison purposes)	Ohaaki	1.5	1.5	0%	13	13	0%	134	134	0%	0%	10	10	0%	0%
	Ohakuri	3.2	3.2	0%	11	11	0%	160	211	-24%	-45%	17	17	0%	0%
	Whakamaru	5			25			160	271	-41%	-87%	20	20	0%	0%
	Waipapa	4.1	4.1	0%	25	25	0%	160	330	-52%	-111%	20	26	-23%	-30%
	Narrows	5	5.5	-9%	23	23	0%	350	410	-15%	-27%	20	28	-29%	-40%
	Horotiu	5	6.2	-19%	23	23	0%	350	441	-21%	-36%	20	36	-44%	-70%
	Huntly	5	6	-17%	19	19	0%	350	585	-40%	-62%	20	45	-56%	-95%
	Mercer	5	10.5	-52%	25	30	-17%	350	662	-47%	-74%	20	52	-62%	-100%
	Tuakau	5	12	-58%	25	38	-34%	350	595	-41%	-65%	20	53	-62%	-100%
1A (Table 3.11-1 as it stands, with Current State corrections as per Scarsbrook March evidence. Cells highlighted in orange show the changes)	Ohaaki	1.5	1.5	0%	13	13	0%	134	134	0%	0%	10	10	0%	0%
	Tahorakuri		N.D.			N.D.		160	290	-45%		20	22	-9%	
	Ohakuri	3.1	3.1	0%	11	11	0%	160	216	-26%	-45%	17	17	0%	0%
	Whakamaru	5	N.D.		25	N.D.		160	271	-41%	-87%	20	20	0%	0%
	Waipapa	4	4	0%	25	25	0%	160	336	-52%	-111%	20	25	-20%	-30%
	Karapiro	5	*5.3*	-6%	16	*16*	0%	160	402	-60%	-100%	20	27	-26%	-36%
	Narrows	5	5.5	-9%	23	23	0%	350	410	-15%	-27%	20	28	-29%	-40%
	Horotiu	5	6	-17%	23	23	0%	350	441	-21%	-36%	20	36	-44%	-70%
	Huntly	5	6	-17%	19	19	0%	350	585	-40%	-62%	20	45	-56%	-95%
	Mercer	5	10.5	-52%	25	30	-17%	350	662	-47%	-74%	20	52	-62%	-100%
	Tuakau	5	12	-58%	25	38	-34%	350	595	-41%	-65%	20	52	-62%	-100%
1B	Ohaaki	1.5	1.5	0%	13	13	0%	134	134	0%	0%	10	10	0%	0%

		Median Chlorophyll *a* (mg/m^3)			Maximum Chlorophyll *a* (mg/m^3)			Median TN (mg/m^3)				Median TP (mg/m^3)			
		Threshold	Current	% change (conc.)	Threshold	Current	% change (conc.)	Threshold	Current	% change (conc.)	% change (diff. load)	Threshold	Current	% change (conc.)	% change (diff. load)
(Same as 1A, but use Polymictic column for TN from Waipapa down)	Tahorakuri		3.8					160	290	-45%		20	22	-9%	
	Ohakuri	3.1	3.1	0%	11	11	0%	160	216	-26%	-45%	17	17	0%	0%
	Whakamaru	5	N.D.		25	N.D.		271	271	0%	0%	20	20	0%	0%
	Waipapa	4	4	0%	25	25	0%	300	336	-11%	-20%	20	25	-20%	-30%
	Karapiro	5	*5.3*	-6%	16	*16*	0%	300	402	-25%	-42%	20	27	-26%	-36%
	Narrows	5	5.5	-9%	23	23	0%	410	410	0%	0%	20	28	-29%	-40%
	Horotiu	5	6	-17%	23	23	0%	441	441	0%	0%	20	36	-44%	-70%
	Huntly	5	6	-17%	19	19	0%	500	585	-15%	-20%	20	45	-56%	**-95%**
	Mercer	5	10.5	-52%	25	30	-17%	500	662	-24%	-35%	20	52	-62%	**-100%**
	Tuakau	5	12	-58%	25	38	-34%	500	595	-16%	-22%	20	52	-62%	**-100%**
1C (Same as 1B, but Ohakuri at current state for TN and TP)	Ohaaki	1.5	1.5	0%	13	13	0%	134	134	0%	0%	10	10	0%	0%
	Tahorakuri		3.8					290	290	0%	0%	20	22	-9%	
	Ohakuri	3.1	3.1	0%	11	11	0%	216	216	0%	0%	17	17	0%	0%
	Whakamaru	5	N.D.		25	N.D.		271	271	0%	0%	20	20	0%	0%
	Waipapa	4	4	0%	25	25	0%	300	336	-11%	-20%	20	25	-20%	-30%
	Karapiro	5	*5.3*	-6%		*16*		300	402	-25%	-42%	20	27	-26%	-36%
	Narrows	5	5.5	-9%	23	23	0%	410	410	0%	0%	20	28	-29%	-40%
	Horotiu	5	6	-17%	23	23	0%	441	441	0%	0%	20	36	-44%	-70%
	Huntly	5	6	-17%	19	19	0%	500	585	-15%	-20%	20	45	-56%	**-95%**
	Mercer	5	10.5	-52%	25	30	-17%	500	662	-24%	-35%	20	52	-62%	**-100%**
	Tuakau	5	12	-58%	25	38	-34%	500	595	-16%	-22%	20	52	-62%	**-100%**
2A	Ohaaki	1.5	1.5	0%	13	13	0%	134	134	0%	0%	10	10	0%	0%

		Median Chlorophyll *a* (mg/m³)			Maximum Chlorophyll *a* (mg/m³)			Median TN (mg/m³)				Median TP (mg/m³)			
		Threshold	**Current**	**% change (conc.)**	**Threshold**	**Current**	**% change (conc.)**	**Threshold**	**Current**	**% change (conc.)**	**% change (diff. load)**	**Threshold**	**Current**	**% change (conc.)**	**% change (diff. load)**
(Table 3.11-1 for Chl-a, Yalden & Elliott equations for TN and TP, correction at Tuakau and Mercer for exogenous Chl-a)	Tahorakuri		3.8					290	290	0%	0%	22	22	0%	0%
	Ohakuri	3.1	3.1	0%	11	11	0%	216	216	0%	0%	17	17	0%	0%
	Whakamaru	5	N.D.		25	N.D.		271	271	0%	0%	20	20	0%	0%
	Waipapa	4.1	4.1	0%	25	25	0%	336	336	0%	0%	25	25	0%	0%
	Karapiro	5	*5.3*	-6%		*16*		359	402	-11%	-19%	25	27	-7%	-10%
	Narrows	5	5.5	-9%	23	23	0%	359	410	-12%	-20%	25	28	-11%	-15%
	Horotiu	5	6.2	-19%	23	23	0%	331	441	-25%	-40%	29	36	-19%	-30%
	Huntly	5	6	-17%	19	19	0%	474	585	-19%	-27%	38	45	-16%	-29%
	Mercer	5	10.5	-52%	25	30	-17%	439	662	-34%	-55%	35	52	-33%	-60%
	Tuakau	5	12	-58%	25	38	-34%	439	595	-26%	-45%	35	52	-33%	-60%
2B (Table 3.11-1 for Chl-a, Single variable linear regressions for TP)	Ohaaki	1.5	1.5	0%	13	13	0%	134	134	0%	0%	10	10	0%	0%
	Tahorakuri							290	290	0%	0%	22	22	0%	0%
	Ohakuri	3.1	3.1	0%	11	11	0%	216	216	0%	0%	17	17	0%	0%
	Whakamaru	5	N.D.		25	N.D.		271	271	0%	0%	20	20	0%	0%
	Waipapa	4.1	4.1	0%	25	25	0%	336	336	0%	0%	25	25	0%	0%
	Karapiro	5	*5.3*	-6%		*16*		378	402	-6%	-10%	25	27	-7%	-10%
	Narrows	5	5.5	-9%	23	23	0%	356	410	-13%	-19%	25	28	-11%	-19%
	Horotiu	5	6.2	-19%	23	23	0%	384	441	-13%	-19%	31	36	-14%	-19%
	Huntly	5	6	-17%	19	19	0%	361	585	-38%	-55%	31	45	-31%	-55%
	Mercer	5	10.5	-52%	25	30	-17%	375	662	-43%	-63%	32	52	-38%	-63%
	Tuakau	5	12	-58%	25	38	-34%	329	595	-45%	-65%	32	52	-38%	-65%
2C	Ohaaki	1.5	1.5	0%	13	13	0%	134	134	0%	0%	10	10	0%	0%

		Median Chlorophyll *a* (mg/m^3)			Maximum Chlorophyll *a* (mg/m^3)			Median TN (mg/m^3)				Median TP (mg/m^3)			
		Threshold	**Current**	**% change (conc.)**	**Threshold**	**Current**	**% change (conc.)**	**Threshold**	**Current**	**% change (conc.)**	**% change (diff. load)**	**Threshold**	**Current**	**% change (conc.)**	**% change (diff. load)**
(Table 3.11-1 for Chl-a, Single variable linear regressions for TP, correction for exogenous Chl-a at Tuakau and Mercer)	Tahorakuri							290	290	0%	0%	22	22	0%	0%
	Ohakuri	3.1	3.1	0%	11	11	0%	216	216	0%	0%	17	17	0%	0%
	Whakamaru	5	N.D.		25	N.D.		271	271	0%	0%	20	20	0%	0%
	Waipapa	4.1	4.1	0%	25	25	0%	336	336	0%	0%	25	25	0%	0%
	Karapiro	5	*5.3*	-6%		*16*		378	402	-6%	-10%	25	27	-7%	-10%
	Narrows	5	5.5	-9%	23	23	0%	356	410	-13%	-19%	25	28	-11%	-19%
	Horotiu	5	6.2	-19%	23	23	0%	384	441	-13%	-19%	31	36	-14%	-19%
	Huntly	5	6	-17%	19	19	0%	361	585	-38%	-55%	31	45	-31%	-55%
	Mercer	5	10.5	-52%	25	30	-17%	453	662	-32%	-45%	38	52	-27%	-45%
	Tuakau	5	12	-58%	25	38	-34%	400	595	-33%	-47%	38	52	-27%	-47%

Table 3: Predicted chlorophyll *a* and nutrient concentrations for the mainstem Waikato River under Approach 3 (application of PC1 mitigation package across whole catchment). (conc: concentration; N.D.: No Data; Diff Load: Anthropogenic Diffuse Load).

		Median Chlorophyll a (mg/m^3)			Median TN (mg/m^3)				Median TP (mg/m^3)			
		Predicted conc.	Current	% change (conc.)	Predicted conc.	Current	% change (conc.)	% change (diff. load)	Predicted conc.	Current	% change (conc.)	% change (diff. load)
3 Application of PC1 mitigation package across whole catchment	Ohaaki		1.5		130	134	-3%	-5%	8.5	10	-15%	-20%
	Tahorakuri				250	290	-14%	-40%	15	22	-32%	-46%
	Ohakuri	2.8	3.2	-11%	191	216	-12%	-18%	12	17	-29%	-40%
	Whakamaru		No Data		244	271	-10%	-17%	14	20	-30%	-40%
	Waipapa	3.6	4.1	-13%	302	336	-10%	-17%	21	25	-16%	-25%
	Karapiro	4.6	5.3	-13%	374	402	-7%	-11%	23	27	-15%	-23%
	Narrows	4.8	5.5	-13%	377	410	-8%	-11%	24	28	-14%	-23%
	Horotiu	4.9	6.2	-20%	407	441	-8%	-11%	31	36	-14%	-23%
	Huntly	6.0	6	-1%	545	585	-7%	-8%	40	45	-11%	-22%
	Mercer	9.7	10.5	-7%	615	662	-7%	-8%	46	52	-12%	-22%
	Tuakau	10.1	12	-16%	553	595	-7%	-8%	47	52	-10%	-20%

Table 4: Predicted Nutrient loads for the tributaries under approach 3 above Ohakuri Dam (application of mitigation packages across Ruahuwai catchment). All loads in Tonnes per year (T/yr) for the 2010-2014 period

SC#	Evidence Scenario	Current	No Action "Do nothing"	Background	Background proportion	Based on PC1 provisions	Objective 3 – Change in load required	Based on Vulnerable Land	Objective 1 – Change in load required
73- Waikato River @ Ohaaki	TN – Annual Average	**745**	**793**	587	79%	**750**	27%	**740**	33%
	TP – Annual Average	**75**	**74**	56	75%	**70**	23%	**70**	23%
66B – Waikato River @ Ohakuri	TN – Annual Average	**1460**	**1515**	583	40%	**1330**	21%	**1170**	39%
	TP – Annual Average	**170**	**172**	95	56%	**140**	43%	**135**	50%
66B- Waikato River @ Tahorakuri	TN – Annual Average	**1520**	**1592**	701	46%	**1410**	22%	**1260**	40%
	TP – Annual Average	**165**	**167**	106	64%	**145**	38%	**140**	46%

74- Pueto Stream	TN – Annual Average	**85**	**113**	47	55%	**100**	35%	**105**	22%
	TP – Annual Average	14	14	13	92%	14	49%	14	24%
72-Torepatutahi Stream	TN – Annual Average	**105**	**104**	8	8%	**80**	25%	**60**	46%
	TP – Annual Average	13	13	10	78%	11	55%	11	64%
65- Waiotapu Stream @ Homestead Rd	TN – Annual Average	**460**	**462**	97	21%	**385**	21%	**315**	41%
	TP – Annual Average	**50**	**51**	26	52%	**40**	46%	**37**	60%
69- Mangakara Stream	TN – Annual Average	**40**	**38**	4	10%	**30**	23%	**25**	37%
	TP – Annual Average	**5**	**3**	1	21%	**2**	19%	**2**	28%
62- Kawaunui Stream	TN – Annual Average	**35**	**33**	3	9%	**30**	9%	**25**	24%
	TP – Annual Average	**5**	**3**	0	6%	**2**	23%	**2**	21%
58- Waiotapu Stream @ Campbell Rd	TN – Annual Average	**110**	**108**	71	65%	**105**	6%	**95**	32%
	TP – Annual Average	**10**	**8**	5	51%	**7**	19%	**6**	33%
59- Otamakokore Stream	TN – Annual Average	**45**	**45**	4	8%	**40**	12%	**30**	35%
	TP – Annual Average	**10**	**10**	3	35%	**7**	42%	**7**	47%
56- Whirinaki Stream	TN – Annual Average	**6**	**6**	0.4	7%	**5**	20%	**4**	40%
	TP – Annual Average	**1**	**1**	0.2	19%	**1**	43%	**1**	58%

5 Sub-catchments and tributaries

All approaches developed for the mainstem require significant reductions in TN and TP concentrations and in-stream "diffuse loads" in the lower Waikato River. Achieving these reductions in the mainstem of the Waikato River will require reductions in all sub-catchments of the Waikato-Waipā River catchment.

Approach 3

The Technical Group has undertaken modelling to "distribute" the mainstem instream load reductions in the sub-catchments, in order to provide an indication of how these load reductions compare with those envisaged under PC1.

As noted above, this exercise used the short-term "PC1 mitigation package" applied as an intervention over the whole catchment. The outcomes of this modelling (undertaken by Dr Cox and Mr Conland), for the sub-catchment tributary locations are presented in Table 6.

These modelling outputs are provided for the Panel's consideration, noting that one option may be to use these numbers as "short-term", i.e. 10-year, thresholds in Table 3.11-1 for sub-catchments.

Approach 4

Approach recommended by Dr Canning in his evidence, i.e. use of DRP and nitrate-N "bands" that are correlative of various ecosystem health metrics, relating to macroinvertebrates (e.g. MCI and EPT), fish (IBI) and periphyton. If it is agreed that the goals set out by Scenario 1 (TLG scenario) and whatever other guidance we have is approximately a B-grade level of health, then any river below a B-band would need to improve to the bottom of the B band and any river above this would need to at least maintain (Table 5). Table 5 presents these thresholds and associated in-stream concentration reduction in each sub-catchment.

It is worth noting that some sites in the catchment have background concentration levels above the proposed 'B Band' and the desired concentration levels at a few sites in Dr Canning's evidence differ from the approach here (where all rivers are at least in the B band) as his evidence also incorporates the desired state sought by Fish and Game. The thresholds proposed here are only to achieve at least the bottom of the B-band.

The resulting thresholds are presented in Table 7.

Table 5: DRP and nitrate-nitrogen thresholds under Approach 4

Value	Ecosystem health	
Freshwater BodyType	Rivers	
Attributes	Nitrate-nitrogen and dissolved reactive phosphorus (mg/L)	
Attribute State	**Numeric Attribute State**	
	Dissolved reactive phosphorus (DRP) – Annual median	**Nitrate-nitrogen (NO_3-N) – Annual median**
Excellent (A)	≤ 0.006	≤ 0.10
Good (B)	> 0.006 and ≤ 0.019	> 0.10 and ≤0.46
Fair (C)	> 0.019 and ≤ 0.038	> 0.46 and ≤ 0.89
Regional Bottom Line	**0.038**	**0.89**
Poor (D)	> 0.038 and ≤ 0.057	> 0.89 and ≤ 1.32
Very poor (E)	>0.057	>1.32

Approach 5

Approach 5 seeks to set nutrient thresholds to manage the risk of excessive periphyton growth in tributaries. WRC currently does not monitor periphyton biomass (measured as mg chlorophyll *a*/m^2), and it is not possible to assess the current state of the streams and rivers in the "PC1" catchment in relation to the NPS FM compulsory attribute for periphyton biomass; however, the NPS FM Periphyton Attribute includes the following note:

"*To achieve a freshwater objective for periphyton within a freshwater management unit, regional councils must at least set appropriate instream concentrations and exceedance criteria for dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP). Where there are nutrient sensitive downstream receiving environments, criteria for nitrogen and phosphorus will also need to be set to achieve the outcomes sought for those environments.*

Regional councils must use the following process, in the following order, to determine instream nitrogen and phosphorus criteria in a freshwater management unit:

a) either –

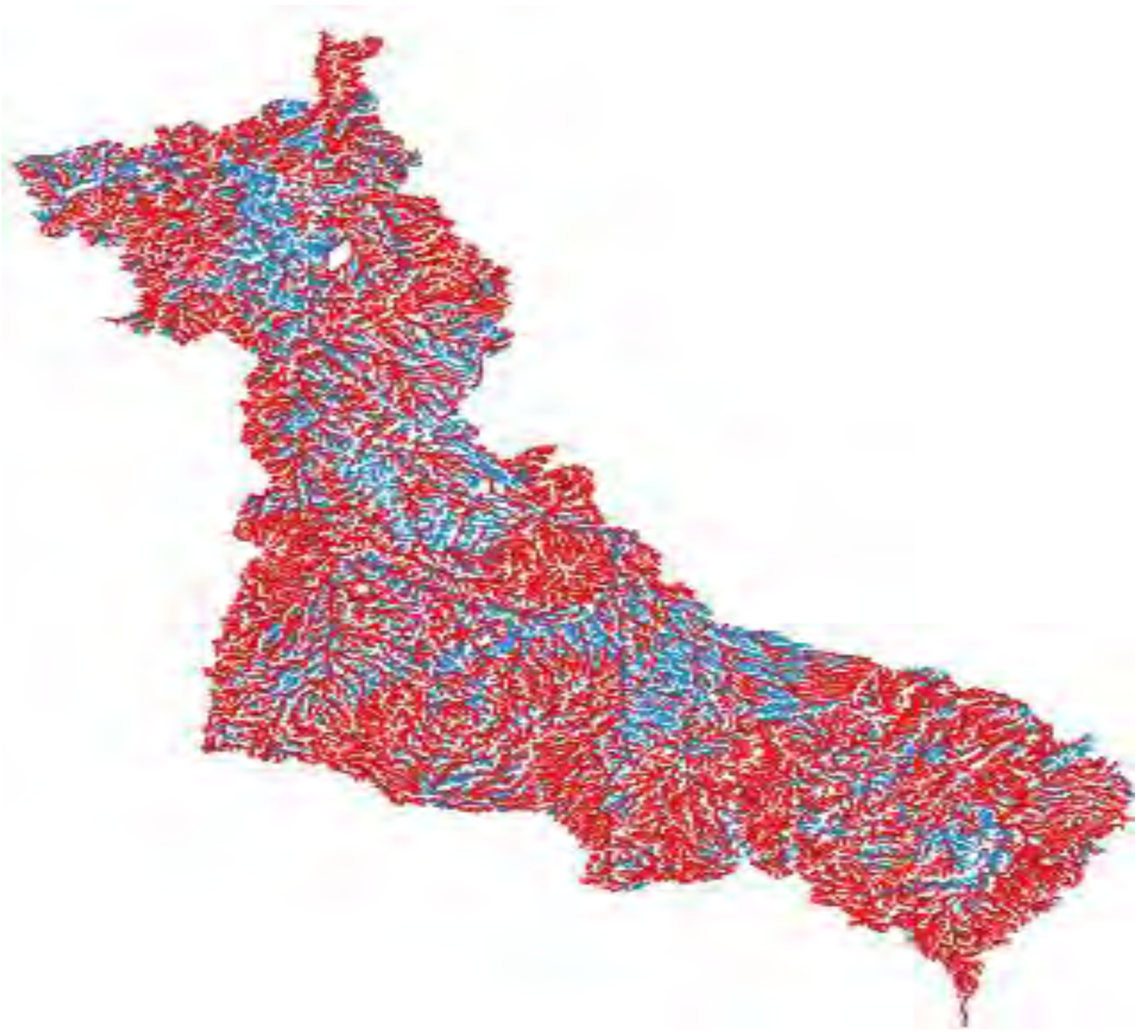
i) if the freshwater management unit supports, or could support, conspicuous periphyton, derive instream concentrations and exceedance criteria for DIN and DRP to achieve a periphyton objective for the freshwater management unit; or

ii) if the freshwater management unit does not support, and could not support, conspicuous periphyton, consider the nitrogen and phosphorus criteria (instream concentrations or instream loads) needed to achieve any other freshwater objectives:

b) if there are nutrient sensitive downstream environments, for example, a lake and/or estuary, derive relevant nitrogen and phosphorus criteria (instream concentrations or instream loads) needed to achieve the outcomes sought for those sensitive downstream environments;

c) compare all nitrogen and phosphorus criteria derived in steps (a) – (b) and adopt those necessary to achieve the freshwater objectives for the freshwater management unit and outcomes sought for the nutrient sensitive downstream environments."

The figure below shows the stream reaches within the PC1 catchment that are predicted to have less than 20% fine sediment cover naturally, i.e. that can be considered naturally "hard-bottomed" [source: Adam Canning].



Under this approach, dissolved nutrient thresholds are proposed to apply to all hard-bottomed, wadeable sites and their contributing catchments in order to manage the risk of nuisance periphyton growth and subsequent effects on ecosystem health and recreational/cultural use of water in wadeable tributaries of the PC1 sub-catchments.

Two sub-approaches have been identified:

Approach 5A:

recommended by Ms McArthur in her evidence, i.e. the following thresholds:

- 0.4 mg/L for DIN and
- 0.010 mg/L for DRP

Approach 5B:

Use the Matheson et al. (2016) nutrient criteria to achieve 85% compliance with the NPS FM periphyton Attribute States as follows:

Narrative	DIN threshold	DRP threshold
Achieve 85% compliance with NPSFM B band	0.63 mg/L	0.011 mg/L
Achieve 85% compliance with NPSFM C band (National Bottom Line)	1.1 mg/L	0.018 mg/L

In both sub-approaches, where the current state concentrations are lower than the above thresholds, the threshold must be set to maintain current state. The resulting thresholds for this approach are provided in Table 8. It is noted that the thresholds are applied generally to each sub-catchment as the assessment of where hard-bottomed wadeable sites are located is considered preliminary and would benefit from a review by WRC. Further, the DIN data was incomplete so median DIN concentrations were estimated as median nitrate, nitrite-nitrogen + and median ammoniacal-nitrogen.

6 Recommendations

This section presents the general consensus arrived at within the nutrient sub-group and with those exerts present at the 12 June 2019 caucusing session. Exceptions to this general consensus are recorded in individual expert's "run sheets".

There was general consensus that:

<u>Waikato mainstem (long-term thresholds)</u>

1) Nutrient thresholds for the mainstem of the Waikato River should be included in Table 3.11-1;

2) Planktonic algae biomass represents a direct, "visible" measure of the ecological and aesthetic values of the River. Planktonic algae biomass thresholds were determined in consultation with the community. These thresholds should be maintained as in the original (notified) version of Table 3-11.1, with the exception of the minor "current state" corrections referred to in this paper (Option 1A);

3) Option 1A (and Table 3.11-1 as notified) was based on an incorrect application of the NPS FM TN Attribute: the "stratified" column was incorrectly applied to all hydro lakes and

the lower river. This option was included as a comparison point but is not recommended for adoption in PC1.

4) For TP:

a) Options 1B and 1C result in TP concentrations requiring a complete elimination (100% reduction) of the anthropogenic TP load in the entire catchment, which does not seem realistic. These options are not recommended for determining TP thresholds for inclusion in Table 3.11-1;

b) **Option 2C is recommended** as it utilises revised empirical models linking the outcome sought (planktonic algae biomass) and the means by which it will be achieved (TP concentrations). This approach also provides a correction for exogenous chlorophyll *a* entering the lower Waikato (this was not considered as part of the development of PC1, but the technical group felt this was an important consideration).

c) Option 2C is preferred over 2A because the empirical models in 2C have a greater predictive power than the Yalden and Elliott equations.

5) For TN

a) Option 2A provides TN thresholds based on the Yalden and Elliott equations; however, the group has concerns about the predictive power of these equations, particularly as the predictions require extrapolation outside the range of measured data. Option 2A TN thresholds may be used, but as interim thresholds only;

b) Option 2C provides TN thresholds based on an equivalent degree of reduction of diffuse lads as required by the TP thresholds. Option 2C TN thresholds may be used, but as interim thresholds only;

c) Option 1C provides TN thresholds for the whole Waikato mainstem based on the same NPSFM “bands” as in the original Table 3.11-1 (as notified), but with corrections to ensure the correct application of the NPS FM TN Attribute. As such, it provides the same “state”/ level of protection as anticipated in the original Table 3.11-1.

d) On balance, the technical group preferred the logic underpinning Option 2A, but had little confidence in the robustness of the model available (Yalden and Elliott equations). **Option 1C is thus recommended for TN thresholds**, as best available approach.

6) Important notes:

a) the relatively high degree of uncertainty in the determination of TN/TP long-term thresholds should be acknowledged. These thresholds should be considered interim values for the duration PC1and should be reviewed before next plan change and amended if necessary to reflect contemporary knowledge. It may be useful to incorporate this requirement in PC1, possibly as a method;

b) TN/TP thresholds required for estuarine/coastal areas could not be considered in this paper due to a lack of data and information about the state and processes of these areas. It is recommended that appropriate monitoring and investigation programmes be carried out, to support the definition of TN/TP thresholds for the

Waikato estuarine/coastal areas before the next plan change. It may be useful to incorporate this requirement in PC1, possibly as a method.

Waikato mainstem (short-term thresholds)

7) TN/TP thresholds for the mainstem sites have been determined without direct consideration/accounting for any reductions that may need to happen further downstream. For instance, Approach 2C does not, at first glance, require any reduction in the Upper Waikato upstream of Waipapa. However, the reductions required at the bottom of the catchment (Mercer/Tuakau) will require reductions/mitigations over the whole of the catchment, including probably upstream of Waipapa. In other words, the reductions required in the lower catchment would need to be apportioned /distributed over the whole catchment. This apportioning cannot be done at this stage due to a lack of information and the absence of an allocation framework. PC1 should make clear that a "maintain current state" threshold at a given site does not necessarily means that no reductions will be required in the catchment above that point in the future. Approach 3 presents the advantage of clearly signalling this direction for the duration of PC1, without compromising/constraining the development of an allocation framework in the future.

8) **Approach 3 is recommended** for the definition of **short-term** **TN/TP** thresholds for the mainstem of the Waikato River. These short-term thresholds are presented in Table 3 of this paper.

Tributaries

9) Achieving, or progressing toward the recommended TN/TP thresholds for the mainstem of the Waikato River will require reductions across the whole catchment. Table 3.11-1 as notified Approach 3 presents the advantage of clearly signalling this direction of change across all sub-catchments. **Approach 3 is recommended** for the definition of **short-term** **TN/TP** thresholds for the tributaries of the Waikato River. These short-term thresholds are presented in Table 6 of this paper.

No consensus was reached on long-term nitrogen (TN, DIN or NNN) and phosphorus (DRP) thresholds for tributaries in relation to ecological health or periphyton objectives (Approaches 4 and 5). Individual experts' views on this topic are recorded in individual runsheets. It is noted that these aspects could not be discussed in any great detail during caucusing due to a lack of time.

Toxicity thresholds (nitrate and ammonia)

The approach detailed in Section 3 of this paper is recommended for the setting of nitrate and ammonia toxicity thresholds across the whole catchment.

Table 6: Sub-catchment TN and TP "thresholds" determined using "Approach 3".

	TN				Median TP (mg/m³)			
	Current Median Conc (mg/m³)	Current Diff. Load (T/y)	Mitigated Diff. Load (T/y)	% change (diff. load)	Current Median Conc (mg/m³)	Current Diffuse Load (T/y)	Mitigated Diff Load (T/y)	% change (diff. load)
Pueto Stm at Broadlands Rd Br	540	148.3	148.3	0%	93	10.1	7.5	-66%
Torepatutahi Stm at Vaile Rd Br	625	246.0	246.0	0%	96	15.0	13.2	-21%
Waiotapu Stm at Homestead Rd	1860	235.6	153.6	-52%	100	14.4	8.5	-73%
Mangakara Stm (Reporoa) at	1580	24.3	15.2	-57%	74	1.6	0.8	-87%
Kawaunui Stm at SH5 Br	2990	32.2	19.6	-53%	82	9.9	6.4	-52%
Waiotapu Stm at Campbell Rd Br	1955	47.6	35.1	-50%	72	3.3	1.8	-100%
Otamakokore Stm at Hossack Rd	990	75.6	59.4	-28%	144	4.5	3.4	-37%
Whirinaki Stm at Corbett Rd	810	12.8	10.9	-22%	62	0.8	0.6	-39%
Tahunaatara Stm at Ohakuri Rd	780	293.4	259.4	-16%	44	18.4	11.4	-60%
Mangaharakeke Stm (Atiamuri)	685	45.9	41.0	-20%	48	2.9	1.8	-86%
Waipapa Stm (Mokai) at	1355	154.5	141.7	-11%	95	12.1	6.7	-66%
Mangakino Stm (Whakamaru) at	760	221.8	161.9	-40%	47	16.0	10.9	-62%
Whakauru Stm at U/S SH1 Br	470	100.2	82.0	-23%	42	19.1	12.4	-52%
Mangamingi Stm (Tokoroa) at	3495	115.7	100.0	-16%	325	6.6	6.4	-4%
Pokaiwhenua Stm at Arapuni -	2010	571.1	571.1	0%	106	99.3	91.8	-13%
Little Waipa Stm at Arapuni -	1780	299.0	288.0	-4%	68	16.9	10.7	-46%
Karapiro Stm at Hickey Rd	860	93.8	90.5	-5%	86	16.8	16.1	-5%
Mangawhero Stm at Cambridge-	2930	99.0	93.4	-7%	163	7.2	6.5	-12%
Mangaonua Stm at Hoeka Rd	1905	130.1	125.2	-5%	52	6.4	6.1	-9%
Mangaone Stm (Waikato) at	3060	106.4	100.7	-7%	118	5.1	4.7	-16%
Mangakotukutuku Stm (Rukuhia)	1875	55.0	52.4	-6%	415	1.7	1.5	-15%
Waitawhiriwhiri Stm at	2110	35.7	34.3	-5%	91	1.5	1.4	-10%
Kirikiriroa Stm at Tauhara Dr	1490	18.5	17.9	-4%	63	0.8	0.7	-23%
Komakorau Stm at Henry Rd	2900	424.3	355.8	-19%	90	12.7	8.6	-53%
Mangawara Stm at Rutherford	1890	695.1	630.8	-12%	210	26.4	22.2	-28%

	TN				Median TP (mg/m³)			
	Current Median Conc (mg/m³)	Current Diff. Load (T/y)	Mitigated Diff. Load (T/y)	% change (diff. load)	Current Median Conc (mg/m³)	Current Diffuse Load (T/y)	Mitigated Diff Load (T/y)	% change (diff. load)
Awaroa Stm (Rotowaro) at	990	34.9	32.7	-12%	12	3.8	3.2	-33%
Matahuru Stm at Waiterimu Road	1310	113.3	106.8	-9%	98	9.3	7.4	-33%
Whangape Stm at Rangiriri-Glen	2116	337.9	317.4	-9%	122	31.8	30.7	-6%
Waerenga Stm at Taniwha Rd	1115	17.4	15.2	-23%	46	7.2	3.9	-67%
Whangamarino River at Jefferies	1085	117.4	109.2	-10%	88	6.5	5.3	-34%
Mangatangi River at SH2	493	173.1	167.8	-5%	72	12.4	11.7	-13%
Mangatawhiri River at Lyons Rd	181	20.7	20.4	-11%	23	3.5	3.2	-100%
Whangamarino River at Island	1831	134.1	130.1	-5%	152	9.0	8.6	-9%
Whakapipi Stm at SH22 Br	3875	101.9	98.4	-4%	51	3.8	3.6	-9%
Ohaeroa Stm at SH22 Br	1825	29.7	25.6	-18%	26	2.1	1.9	-9%
Opuatia Stm at Ponganui Rd	1070	71.4	68.1	-8%	31	7.2	5.9	-30%
Awaroa River at Otaua Rd Br	2095	51.0	47.4	-11%	46	3.6	3.5	-8%
Waipa River at Mangaokewa Rd	585	17.4	17.1	-5%	16	1.6	1.5	-15%
Waipa River at Otewa		223.9	214.7	-7%		16.1	15.2	-15%
Waipa River at SH3 Otorohanga	600	191.2	186.0	-5%	22	9.2	8.8	-11%
Waipa River at Pirongia-Ngutunui	860	976.8	937.1	-5%	48	30.1	27.7	-14%
Waipa River at SH23 Br		611.6	607.9	-1%		18.4	17.3	-13%
Ohote Stm at	1320	57.4	55.7	-4%	76	3.2	3.0	-8%
Kaniwhaniwha Stm at Wright Rd	590	116.2	112.2	-5%	29	7.8	7.3	-13%
Mangapiko Stm at Bowman Rd	2095	611.1	584.6	-5%	240	19.8	18.7	-10%
Mangaohoi Stm at South Branch	365	1.8	1.7	-9%	52	0.2	0.2	-18%
Mangauika Stm at Te Awamutu	275	4.4	4.2	-14%	8	0.4	0.4	-39%
Puniu River at Bartons Corner Rd	910	544.2	544.2	0%	48	16.7	15.0	-17%
Mangatutu Stm (Waikeria) at	510	151.7	147.0	-4%	20	7.1	6.9	-10%
Waitomo Stm at SH31	755	44.9	42.9	-7%	30	2.8	2.6	-14%
Mangapu River at Otorohanga	1240	236.4	228.2	-5%	60	19.8	19.0	-6%
Waitomo Stm at Tumutumu Rd	765	33.4	32.2	-6%	22	3.1	2.9	-15%

	TN				Median TP (mg/m³)			
	Current Median Conc (mg/m³)	**Current Diff. Load (T/y)**	**Mitigated Diff. Load (T/y)**	**% change (diff. load)**	**Current Median Conc (mg/m³)**	**Current Diffuse Load (T/y)**	**Mitigated Diff Load (T/y)**	**% change (diff. load)**
Mangaokewa Stm at Te Kuiti	775	165.4	160.3	-5%	36	13.5	13.0	-7%

Table 7: Sub-catchment NNN and DRP "thresholds" determined using "Approach 4".

	Median NNN (mg/m³)			Median DRP (mg/m³)		
	Threshold	Current	% change (concentration)	Threshold	Current	% change (concentration)
Pueto Stm at	0.46	0.495	-7%	0.019	0.074	-74%
Torepatutahi Stm at	0.46	0.535	-14%	0.019	0.082	-77%
Waiotapu Stm at	0.46	1.4	-67%	0.019	0.034	-44%
Mangakara Stm	0.46	1.36	-66%	0.019	0.048	-60%
Kawaunui Stm at SH5	0.46	2.7	-83%	0.019	0.054	-65%
Waiotapu Stm at	0.46	0.92	-50%	0.002	0.002	0%
Otamakokore Stm at	0.46	0.92	-50%	0.019	0.153	-88%
Whirinaki Stm at	0.46	0.8	-43%	0.019	0.061	-69%
Tahunaatara Stm at	0.46	0.65	-29%	0.019	0.031	-39%
Mangaharakeke Stm	0.46	0.61	-25%	0.019	0.031	-39%
Waipapa Stm (Mokai)	0.46	1.345	-66%	0.019	0.086	-78%
Mangakino Stm	0.46	0.72	-36%	0.019	0.039	-51%
Whakauru Stm at U/S	0.46	0.71	-35%	0.019	0.019	0%
Mangamingi Stm	0.46	2.65	-83%	0.019	0.29	-93%
Pokaiwhenua Stm at	0.46	2	-77%	0.019	0.087	-78%
Little Waipa Stm at	0.46	1.945	-76%	0.019	0.051	-63%
Karapiro Stm at Hickey	0.46	0.68	-32%	0.019	0.042	-55%
Mangawhero Stm at	0.46	1.96	-77%	0.019	0.04	-53%
Mangaonua Stm at	0.46	1.46	-68%	0.012	0.012	0%
Mangaone Stm	0.46	2.4	-81%	0.019	0.063	-70%
Mangakotukutuku Stm	0.46	0.85	-46%	0.019	0.213	-91%
Waitawhiriwhiri Stm at	0.46	0.86	-47%	0.019	0.031	-39%
Kirikiriroa Stm at	0.46	0.765	-40%	0.014	0.014	0%
Komakorau Stm at	0.46	1.4	-67%	0.01	0.01	0%
Mangawara Stm at	0.46	0.89	-48%	0.019	0.047	-60%
Awaroa Stm	0.46	0.525	-12%	0.002	0.002	0%
Matahuru Stm at	0.46	0.77	-40%	0.019	0.023	-17%

	Median NNN (mg/m³)			Median DRP (mg/m³)		
	Threshold	**Current**	**% change (concentration)**	**Threshold**	**Current**	**% change (concentration)**
Whangape Stm at	0.022	0.022	0%	0.002	0.002	0%
Waerenga Stm at	0.46	0.86	-47%	0.019	0.019	0%
Whangamarino River at	0.46	0.645	-29%	0.019	0.03	-37%
Mangatangi River at	0.225	0.225	0%	0.019	0.021	-10%
Mangatawhiri River at	0.052	0.052	0%	0.011	0.011	0%
Whangamarino River at	0.138	0.138	0%	0.006	0.006	0%
Whakapipi Stm at	0.46	3.9	-88%	0.019	0.022	-14%
Ohaeroa Stm at SH22	0.46	1.655	-72%	0.008	0.008	0%
Opuatia Stm at	0.46	0.785	-41%	0.006	0.006	0%
Awaroa River at Otaua	0.46	1.51	-70%	0.004	0.004	0%
Waipa River at	0.3	0.3	0%	0.005	0.005	0%
Waipa River at Otewa	0.285	0.285	0%			
Waipa River at SH3	0.44	0.44	0%	0.008	0.008	0%
Waipa River at	0.46	0.69	-33%	0.014	0.014	0%
Waipa River at SH23	0.46	0.78	-41%			
Ohote Stm at	0.46	0.495	-7%	0.019	0.02	-5%
Kaniwhaniwha Stm at	0.425	0.425	0%	0.007	0.007	0%
Mangapiko Stm at	0.46	1.71	-73%	0.019	0.115	-83%
Mangaohoi Stm at	0.197	0.197	0%	0.019	0.043	-56%
Mangauika Stm at Te	0.205	0.205	0%	0.002	0.002	0%
Puniu River at Bartons	0.46	0.68	-32%	0.019	0.022	-14%
Mangatutu Stm	0.35	0.35	0%	0.009	0.009	0%
Waitomo Stm at SH31	0.46	0.58	-21%	0.006	0.006	0%
Mangapu River at	0.46	0.81	-43%	0.019	0.023	-17%
Waitomo Stm at	0.46	0.615	-25%	0.01	0.01	0%
Mangaokewa Stm at	0.46	0.61	-25%	0.014	0.014	0%

Table 8: Sub-catchment NNN and DRP "thresholds" determined using "Approach 5A".

	Median DIN (mg/m^3)			Median DRP (mg/m^3)		
	Threshold	Current	% change (concentration)	Threshold	Current	% change (concentration)
Pueto Stm at		0.498			0.074	
Torepatutahi Stm at		0.537			0.082	
Waiotapu Stm at	0.4	1.521	-74%	0.01	0.034	-71%
Mangakara Stm		1.368			0.048	
Kawaunui Stm at SH5	0.4	2.706	-85%	0.01	0.054	-81%
Waiotapu Stm at		1.221			0.002	
Otamakokore Stm at	0.4	0.926	-57%	0.01	0.153	-93%
Whirinaki Stm at	0.4	0.802	-50%	0.01	0.061	-84%
Tahunaatara Stm at	0.4	0.653	-39%	0.01	0.031	-68%
Mangaharakeke Stm		0.613			0.031	
Waipapa Stm (Mokai)		1.348			0.086	
Mangakino Stm	0.4	0.723	-45%	0.01	0.039	-74%
Whakauru Stm at U/S	0.4	0.713	-44%	0.01	0.019	-47%
Mangamingi Stm		2.748			0.29	
Pokaiwhenua Stm at	0.4	2.002	-80%	0.01	0.087	-89%
Little Waipa Stm at	0.4	1.947	-79%	0.01	0.051	-80%
Karapiro Stm at		0.688			0.042	
Mangawhero Stm at	0.4	2.002	-80%	0.01	0.04	-75%
Mangaonua Stm at	0.4	1.497	-73%	0.01	0.012	-17%
Mangaone Stm		2.409			0.063	
Mangakotukutuku Stm		0.932			0.213	
Waitawhiriwhiri Stm at		1.118			0.031	
Kirikiriroa Stm at		0.869			0.014	
Komakorau Stm at		1.651			0.01	
Mangawara Stm at		1.001			0.047	
Awaroa Stm		0.549			0.002	
Matahuru Stm at		0.787			0.023	

	Median DIN (mg/m³)			Median DRP (mg/m³)		
	Threshold	Current	% change (concentration)	Threshold	Current	% change (concentration)
Whangape Stm at		0.03			0.002	
Waerenga Stm at		0.865			0.019	
Whangamarino River		0.656			0.03	
Mangatangi River at	0.231	0.231	0%	0.01	0.021	-52%
Mangatawhiri River at	0.055	0.055	0%	0.01	0.011	-9%
Whangamarino River		0.151			0.006	
Whakapipi Stm at	0.4	3.906	-90%	0.01	0.022	-55%
Ohaeroa Stm at SH22		1.658			0.008	
Opuatia Stm at	0.4	0.79	-49%	0.006	0.006	0%
Awaroa River at Otaua		1.532			0.004	
Waipa River at	0.4	0.303	32%	0.005	0.005	0%
Waipa River at Otewa	0.4	0.288	39%	0.01		
Waipa River at SH3		0.444			0.008	
Waipa River at	0.4	0.698	-43%	0.01	0.014	-29%
Waipa River at SH23		0.79				
Ohote Stm at		0.518			0.02	
Kaniwhaniwha Stm at		0.432			0.007	
Mangapiko Stm at		1.732			0.115	
Mangaohoi Stm at	0.2	0.2	0%	0.01	0.043	-77%
Mangauika Stm at Te	0.207	0.207	0%	0.002	0.002	0%
Puniu River at Bartons		0.687			0.022	
Mangatutu Stm	0.353	0.353	0%	0.009	0.009	0%
Waitomo Stm at SH31		0.588			0.006	
Mangapu River at		0.826			0.023	
Waitomo Stm at		0.619			0.01	
Mangaokewa Stm at	0.4	0.615	-35%	0.01	0.014	-29%

Appendix 1: Details of estimation of "current state" concentrations for the Waikato at Karapiro

1. WRC tech rep 2014/56 shows loads of N and P at river monitoring sites and point sources during 2003-12. Table 2 gives loads in the river and Table 4 gives loads from point sources, including Cambridge sewage and Hautapu dairy factory (i.e. inputs that enter the river between Karapiro dam and Narrows).
2. The loads passing Karapiro dam can be estimated as those at Narrows minus Cambridge sewage and Hautapu dairy (the various small unmonitored streams are assumed to enter the river upstream of the dam) (refer to p. 9 of the report);
3. The loads at Karapiro dam are therefore 3623.2 t N/yr (2% smaller than that at Narrows) and 270.8 t P/yr (3% smaller than at Narrows).
4. The median TN concentration at Karapiro in 2010-14 was calculated as {med TN at Narrows in 2010-14 times N load Karapiro divided by N load at Narrows} (i.e. 410 x 3623.2/3695). Med TN at Karapiro, 2010-14 is thus 402 mg/m^3. Corresponding calculations for med TP at Karapiro, 2010-14 gave 27.1 mg/m^3.
5. These values into Yalden & Elliott's equation for chla at Narrows, giving med Chla at Karapiro, 2010-14 of 5.3 mg/m^3 and max Chla of 16 mg/m^3.

	medChla	maxChla	medTN	medTP
Waipapa	4	25	336	25
Karapiro	***5.3***	***16***	***402***	***27***
Narrows	5.5	23	410	28

Appendix 2:

Setting Mainstem Chlorophyll-a Thresholds Using Single Variate TP Empirical Models ("Approach 2B")

1.) As part of the nutrient sub-group of the expert conferencing focusing on Table 3.11-1, I reviewed the Yalden and Elliott (2015) report to assess the validity of the chlorophyll-a (chl-a) empirical models presented in that paper. These models predict chl-a concentration as a function of total nitrogen (TN) and total phosphorus (TP) concentrations (and the ratio of the two). The models were used by the Technical Leaders Group (TLG) to forecast changes in chl-a as a function of modelled reductions in nutrient. It has been proposed by the expert conference that these models might be used to set TN and TP thresholds, as a function of chl-a thresholds, for Plan Change 1 (PC1). My focus in this exercise was on assessing the statistical defensibility of using these models in such a manner. I found that the paper itself presents no numerical justification for the models. Based on the paper alone, therefore, the validity of using the models for predictive purposes in the catchment is unclear.

2.) To further investigate this issue, I applied the Yalden and Elliott models to each of the mainstem monitoring sites using historical (1997 – 2018) measured data. I calculated median TP and TN values for each year in the calculation period. I used the models to calculate median chl-a concentrations for each year using these measured nutrient median values as inputs, for each site. I compared modelled median chl-a to measured median chl-a concentrations for the calculation period, for each site separately. Results of that exercise (**Figure 1**) indicate that the Yalden and Elliott models do a poor job of predicting the variability of median chl-a as a function of varying median nutrient concentrations. Using Microsoft Excel Regression function, I determined that none of the sites exhibit a statistically significant correlation between modelled and measured chl-a concentrations for the calculation period. In other words, the model is unable to reproduce the observed variability in chl-a for the past 22 years. I, therefore, have low confidence in the models' ability to predict future chl-a reductions as a function of TP and TN reductions.

3.) As alternatives to the Yalden and Elliott models, I investigated other forms of empirical relationships between chl-a and nutrients. I again used measured data from the period 1997 – 2018 for all mainstem monitoring sites and again used simple spreadsheet regression calculations for this analysis.

4.) A statistically significant positive correlation between median chl-a and median TN-a was **not** detected at any of the mainstem sites. In fact, at most sites, a negative cross-correlation between the two parameters was apparent. TN concentrations have increased dramatically in the mainstem for the calculation period, and chl-a concentrations have decreased slightly (not statistically significant) for the same period. I hypothesize that the lack of a positive correlation between the two parameters is likely due to TN availability in excess of phytoplankton growth requirements (i.e. growth is not limited by TN). This hypothesis is supported by the fact that median TN:TP ratios are greater than the Redfield ratio (7.2) throughout the mainstem. Note that these findings align closely with those presented by Verberg (2016) to the CSG.

5.) Annual median chl-a was found to be significantly correlated ($p < 0.1$) with median TP at the following middle and lower Waikato River sites: Narrows, Horotiu, Huntly, and Tuakau (**Figure 2**). I was unable to establish such relationships for Upper Waikato sites

(Waipapa and above) or for the Mercer Bridge site (discussed below). For those sites with a significant correlation, a shorter period of record (2005 – 2018) was sometimes required to establish, or strengthen, significance. Results show that median TP variability, following the simple linear model, explains 29%, 49%, 23%, and 49% of the observed variability in chl-a for the given calculation periods and the four sites, respectively.

6.) As discussed elsewhere, the Mercer data are complicated by the fact that significant exogenous chl-a mass from off-channel shallow lakes is delivered to the river just above this site. Vant (2015) estimated that the outflows from the shallow lakes contribute approximately 25% (or more) of the current load of chl-a at Mercer during the summer. It is therefore not surprising that correlations with nutrient concentrations are non-existent at this site. I recommend using the Tuakau model at this site to set threshold TP values.

7.) The lack of statistically significant chl-a models for the Upper Waikato sites (Ohaaki, Ohakuri, Waipapa, and Whakamaru) is a moot point since chl-a reductions are not required for any of the threshold options considered at these sites. We are recommending that threshold nutrient targets be set equal to current median concentrations. Predictive models are, therefore, not needed.

8.) For the middle and lower Waikato River sites, excluding Mercer, I applied the single-variate linear regression models shown in Figure 2 to calculate TP thresholds as a function of specified chl-a thresholds. In other words, I used the models to solve for the TP concentration that would result in the prescribed chl-a thresholds.

9.) Results of these calculations are summarised in **Table 1**. The recommended long-term TP thresholds, developed with this approach, are shown in the second column from the right ("Threshold Median TP").

10.) In summary, based on this work, I have little confidence in the Yalden & Elliott model's ability to predict river chl-a response to reductions in nutrients. I, therefore, am reluctant to support its use as a tool to set nutrient threshold values, in such an important forum. I have greater confidence in the use of simplified single variable (TP) linear regression models, such as presented here, for setting TP thresholds. There is, at least, some level of predictive significance inherent in these models. While not perfect, I believe this approach is more defensible than the Yalden and Elliott approach. The approach also has the added advantage of being simpler and more transparent than the Yalden and Elliott approach.

11.) As described above, I see no justification for using a similar method to set nitrogen thresholds. There simply lacks any evidence of a correlation between chl-a and TN within current targeted ranges. That said, there may be times, and/or locations, where phytoplankton growth is nitrogen limited. Further, we need to be protective of smaller tributaries in the catchment, and potential periphyton concerns, which could be different with respect to N/P limitation. Therefore, one of the other proposed approaches for N thresholds should be employed.

Table 1. Total Phosphorus Thresholds (Option 2c)

	Current Median Chl-a (ug/L)	Current Median TP (ug/L)	Modelled Current Median Chl-a (ug/L)	Threshold Median Chl-a (ug/L)	Threshold Median TP (ug/L)	Notes
Ohaaki	1.5	10	-	1.5	10	*threshold = current*
Ohakuri	3.2	17	-	3.2	17	*threshold = current*
Waipapa	4.1	26	-	4.1	26	*threshold = current*
Narrows	5.5	28	5.7	5	25	
Horotiu	6.2	36	6.4	5	31	
Huntly	6	45	6.5	5	31	
Mercer	10.5	52	11.8	5	32	*used Tuakau model*
Tuakau	12	53	12.1	5	32	

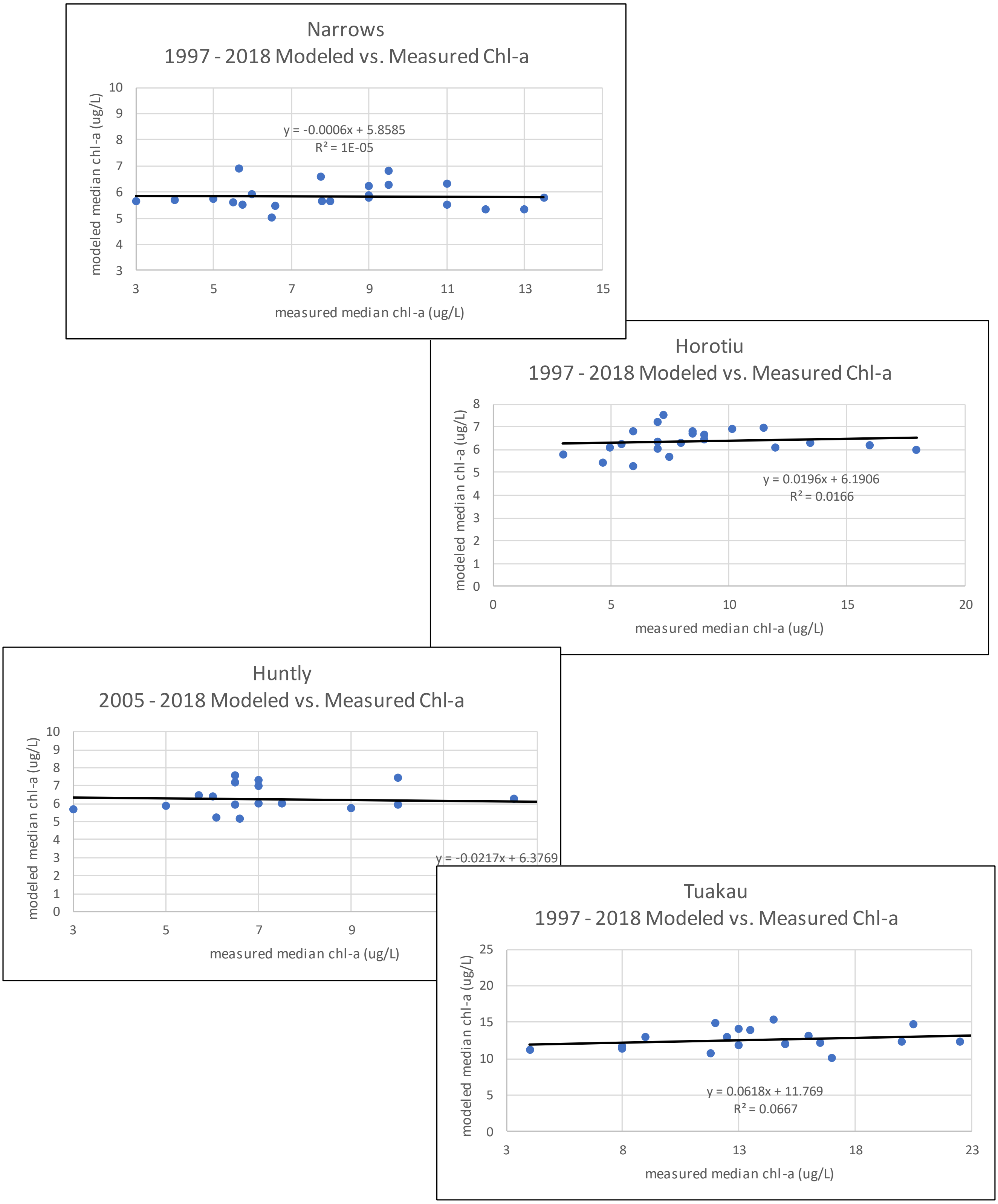


Figure 1. Yalden and Elliott Model Performance, 1997 – 2018

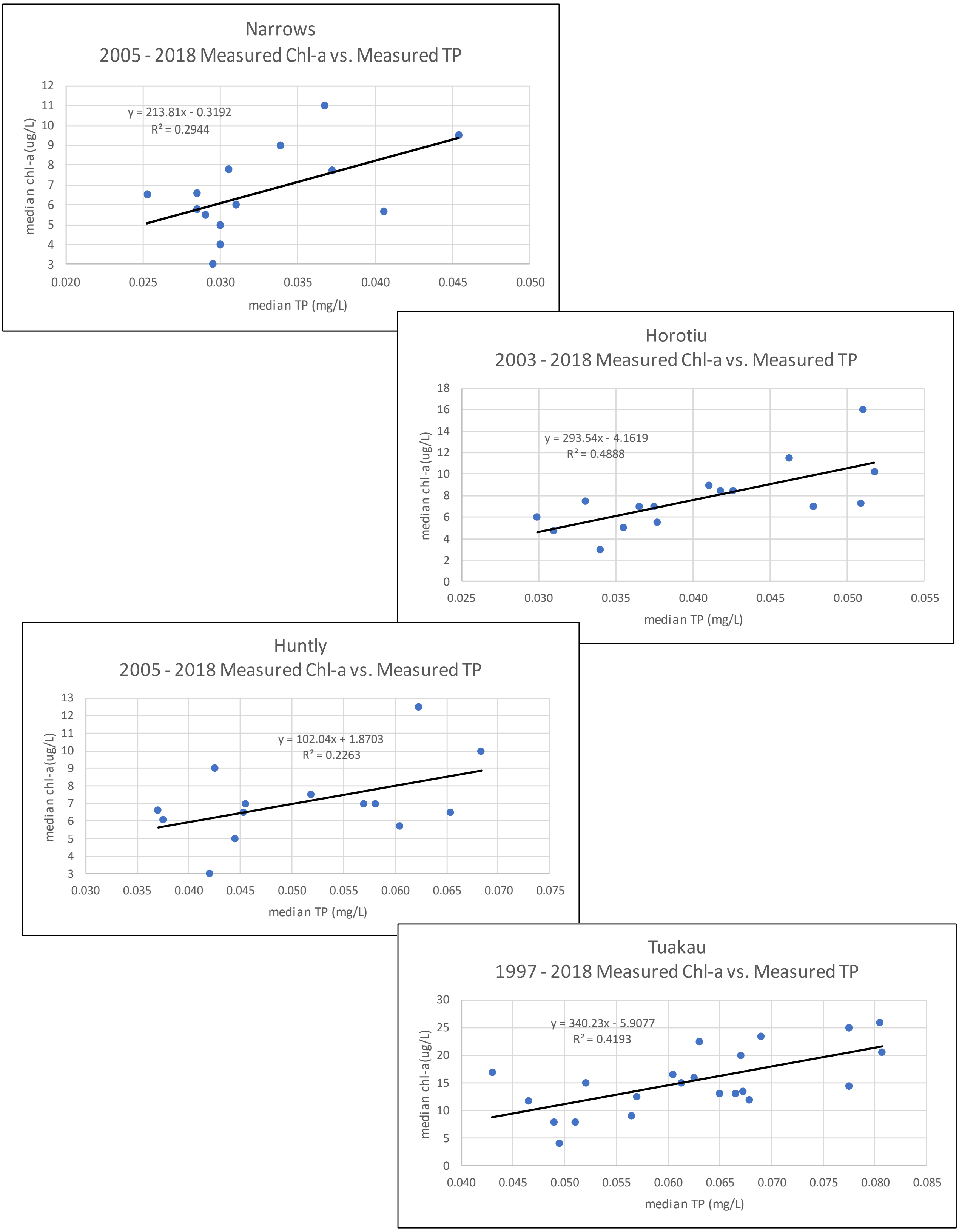


Figure 2. Single Variable (TP) Regression Models

Attachment 3 E.coli Attribute for PC1

- **Contact Recreation**

Key Issues:

1. Metrics to determine current and future state for the PC1 sites
2. Considerations for flow in the PC1 Attribute State Classifications
3. Uncertainties around the source of faecal pollution at PC1 sites and modelled future 'improvements'

Agreement reached on:

Applying the combined attribute numerics as stated in the NPS-FM policy document: The NPS-FM (2014) (Amended 2017) sets national thresholds and bottom lines for freshwater quality and designates a range of attributes that correspond to the national, compulsory values of ecosystem health and human health for recreation. For *E.coli* (human health for recreation), a combination of four metrics is used to determine attribute state viz:

a) exceedance of the 260 CFU/100mL threshold
b) exceedance of the 540 CFU/100mL threshold
c) median, and
d) 95th percentile

Having multiple measures within the attribute increases the risk of discrepancies in the implementation of the NPS-FM 2017 policy document. This results in instances where one numeric attribute statistic (e.g. median) classifies a stream into one attribute state while another statistic (e.g. 95th percentile) classifies the same water body as being of a poorer status. These discrepancies were observed in 12 out of the 52 PC1 sites for which there was observed *E.coli* data.

Agreement not reached on:

1. Considerations for flow (i.e. inclusion/exclusion of data associated with high flows) in the PC1 Attribute State Classifications
2. Uncertainties around the source of faecal pollution at PC1 sites and modelled future 'improvements'.

PC1 has established 'objectives' that will require significant reductions in *E. coli* concentrations in most sub-catchments of the Waikato-Waipa. It is important to note that we currently have very limited scientific information on the sources of contamination across the catchment. There was a Faecal Source Tracking (FST) study carried out by DairyNZ for the HRWO process (Moriarty 2015), but this only looked at five sub-catchment monitoring locations (5 out of the 62 monitored PC1 sites) during baseflow and post-rainfall conditions. Ruminant and avian markers were present at all sites. Moriarty (2015) indicated avian sources tended to dominate at baseflow, whereas ruminant sources became more dominant following rainfall, highlighting the influence of overland flow on faecal pollution loadings at the five PC1 sites. This information is relevant to how PC1 approaches reductions in *E. coli* concentrations. We know that faecal indicator bacteria (and associated pathogens) come from a variety of sources, but PC1 methods target livestock sources. It is likely that targeting these sources may not achieve desired/expected reductions, particularly at those sites where other sources (e.g. waterfowl, feral animals) and overland flow are the dominant contributors of faecal pollution.

Other critical considerations are the limitation with E.coli as an indicator organism. First, zoonotic pathogens from primary productive land are not reliably detected using the *E.coli* proxy. This is because there is often poor correlation between *E.coli* and zoonotic pathogens that they are meant to protect against. For instance, viral and protozoan pathogens are poorly correlated with standard bacterial indicators[3]. Hence, merely measuring *E.coli* as an indicator of risk on PC1 streams receiving input from primary productive lands may fail to protect the public from exposure to zoonotic pathogens. These concerns are well documented[4].

Second, not all E.coli are from faecal sources. Non-fecal environmental sources of E.coli confounds our ability to predict the fate of pathogens in animal waste management systems both on and off of farms.

A third limitation to the current risk assessment system, which relies on E.coli as indicator bacteria, is that E.coli can survive and proliferate outside of animal intestines, in tropical and temperate habitats. This calls into question their reliability as indicators in these habitats. The processes that control the survival and removal of microbes in water, such as competition, ultraviolet radiation, temperature, predation, and transport differ among pathogenic species. Thus, monitoring FIB alone is not sufficient to assess human health risk.

The MfE Freshwater Microbiological Study (McBride et al 2002)[5] upon which the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE 2003) and the NPS FM numbers were deducted also iterated these facts , as reproduced below:

- First, *E. coli* have been shown to be capable of growth outside the gut under certain environmental conditions
- Second, studies have often found poor correlations between *E. coli* and particular pathogens. Yet, one may expect that *E. coli* may still serve as an indicator of health risk, rather than as an indicator of particular pathogens (i.e., the dotted line on Figure 2).
- Correlations between indicators and pathogens were generally low. Correlations between indicators and pathogens were generally low and only moderate correlations between *E. coli* and Campylobacter was recorded in the study upon which the NPS FM guidelines were built.
- This study has demonstrated that *E. coli* concentrations alone are not sufficient to enable the health risk from recreational use of fresh waters to be assessed….
- The present New Zealand Recreational Freshwater Guidelines need to be reviewed.

(Source: Page 19 and 29, Freshwater Microbiology Research Programme, McBride et al 2002)

In conclusion, there are a number of issues with using of *E. coli* as an indicator of pathogen levels in freshwater. Despite these issues, we may still cautiously adopt E.coli as an indicator of health risk, "rather than as an indicator of particular pathogens…" (McBride et al 2002). The "moderate degree of correlation between *E. coli* concentration and Campylobacter has been used to formulate the acceptable limits used in the New Zealand, Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE 2003)." (Till et al 2008), and subsequently in the NPS-FM policy document.

3. Options/recommended option for consideration by the Panel:

To resolve issues related to discrepancies in the implementation of the NPS-FM 2017 combined statistics, the expert group considered the following options:

(i) Application of the four NPS-FM metrics to determine attribute state for the PC1 Table 3.11.1 sites while excluding storm flow conditions

(ii) Application of two NPS-FM metrics (median and 95th percentile) to determine attribute state for the PC1 Table 3.11.1 sites. In instances where discrepancies exist between the designated attribute state based on median versus the designated attribute state based on 95th percentile, the storm

[3] National Research Council (US) Committee on Indicators for Waterborne Pathogens. Indicators for Waterborne Pathogens. Washington (DC): National Academies Press (US); 2004. 4, Attributes and Application of Indicators.

[4] Sobsey, M.D.; Khatib, L.A.; Hill, V.R.; Alocilja, E.; Pillai, S. Pathogens in Animal Wastes and the Impacts of Waste Management Practices on Their Survival, Transport and Fate. In White Paper, Midwest Plan Service; Iowa State University: Ames, IA, USA, 2001

[5] McBride, G., Till, D., Ryan, T., Ball, A., Lewis, G., Palmer, S., & Weinstein, P. (2002). Freshwater Microbiology Research Programme. Pathogen Occurrence and Human Health Risk Assessment Analysis. *Jointly published by the NZ Ministry of Health and the NZ Ministry for the Environment, Wellington*, 94.

flow *E.coli* data should be exempted from the data and then reanalyzed without the storm flow conditions.

(iii) Application of <u>three</u> NPS-FM metrics (i.e. excluding 95th percentile) to determine attribute state for the PC1 sites only in instances where discrepancies exist when the four NPS-FM metrics are applied. For other sites, the four NPS-FM metrics should be applied.

(iv) Application of the four NPS-FM metrics, *as is*, to determine NPS FM attribute state for the PC1 Table 3.11.1 sites while noting in the attribute table footnote that:

'There may be instances where the one numeric attribute statistic (e.g. median) classifies a stream into an attribute state while another statistic (e.g. 95th percentile) classifies the same water body as being of a poorer status. The default position in these instances is to designate the stream as being of the poorer status (i.e. apply the most stringent measure to the status assessment). This does not necessarily translate into increased recreational health risk as the 95th percentile E.coli concentrations may be heavily influenced by storm flow events during non-swimming periods'. We would recommend that WRC continue to monitor and identify recreational quality at selected 'bathing beach' sites throughout the main recreational period. We support the use of the E. coli attribute across the Waikato-Waipa catchment and targets that will seek reductions in E. coli sources over time.

In agreement:

Consensus was reached by the expert group on option (iv), i.e., application of the four NPS-FM metrics, *as is* (but with an explanatory note), to determine NPS FM attribute state for the PC1 Table 3.11.1 sites

Not in agreement:

Consensus could not be reached on options (i) – (iii) and were therefore dismissed by the expert group.

Proposed Attribute Tables

Value	Human health for recreation				
Freshwater Body Type	Rivers				
Attribute	Escherichia coli (E. coli)				
Attribute Unit	*E. coli/*100 mL (number of *E. coli* per hundred millilitres)				
Attribute State1	Numeric Attribute State				Narrative Risk Descriptor
	% Exceedance over 540 cfu/100 mL	% exceedances over 260 cfu/100 mL	Median concentration (cfu/100 mL)	95th percentile of *E. coli*/100 mL	Description of risk of Campylobacter infection (based on *E. coli* indicator)
A (Blue)	<5%	<20%	≤130	≤540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 1%
B (Green)	5-10%	20-30%	≤130	≤1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 2%
C (Yellow)	10-20%	20-34%	≤130	≤1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 3%
D (Orange)	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is ≥50 in 1000 (>5% risk). The predicted average infection risk is >3%
E (Red)	>30%	>50%	>260	>1200	For more than 30% of the time the estimated risk is ≥50 in 1000 (>5% risk). The predicted average infection risk is >3%

*The predicted average infection risk is the overall average infection to swimmers based on a random exposure on a random day, ignoring any possibility of not swimming during high flows or when a surveillance advisory is in place (assuming that the *E. coli* concentration follows a lognormal distribution). Actual risk will generally be less if a person does not swim during high flows.

*Attribute state should be determined by using a minimum of 60 samples over a maximum of 5 years, collected on a regular basis regardless of weather and flow conditions. However, where a sample has been missed due to adverse weather or error, attribute state may be determined using samples over a longer timeframe.

*Attribute state must be determined by satisfying all numeric attribute states.

*There may be instances where the one numeric attribute statistic (e.g. median) classifies a stream into an attribute state while another statistic (e.g. 95th percentile) classifies the same water body as being of a poorer status. The default position in these instances is to designate the stream as being of the poorer status. This does not necessarily translate into increased recreational health risk as the E.coli concentrations can be heavily influenced by storm flow events particularly during non-swimming periods.

- **Shellfish gathering**

Recreational shellfish-gathering bacteriological guideline values for water are outlined in the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas, Ministry for the Environment and Ministry of Health (2003):

- The median faecal coliform content of samples taken over a shellfish-gathering season shall not exceed a Most Probable Number (MPN) of 14/100 mL, and not more than 10% of samples should exceed an MPN of 43/100 mL (using a five-tube decimal dilution test).
- These guidelines should be applied in conjunction with a sanitary survey. There may be situations where bacteriological levels suggest that waters are safe, but a sanitary survey may indicate that there is an unacceptable level of risk.

  Note:

  - The MPN method as described in Standard Methods for the Examination of Water and Wastewater; American Public Health Association (current edition), must be used to enumerate faecal coliforms unless an alternative method is validated to give equivalent results for the waters being tested.
  - Sampling to test compliance shall be over the whole shellfish-gathering season.
  - A sufficient number of samples should be gathered throughout the gathering season to provide reasonable statistical power in testing for compliance for both the median limit and the 90% samples limit.

Attachment 4 Sediment Attributes for PC1

To: PC1 Expert Conferencing Group

Cc: David Hill

From: Kate McArthur, Hannah Mueller, Adam Canning, Gerry Kessels

Date: 30 May 2019

Subject: Sediment attributes for Table 3.11-1, PC1 Wakato

Why sediment is an important consideration for Table 3.11-1

Currently the only sediment related attribute in Table 3.11-1 of PC1 is water clarity. The clarity attribute is primarily included in Table 3.11-1, we presume, is to provide for human uses of water for recreation/swimming/food gathering. The adverse effects of deposited sediment on recreation, cultural and aesthetic values are not currently included in Table 3.11-1 and there are no attributes related to sediment in Table 3.11-1 to provide for ecosystem health.

Experts **agree** that sediment in water (suspended and deposited) is an important consideration to provide for ecosystem health.

Excess levels of sediment in the water column (suspended sediment) and on the bed (deposited sediment) of a waterbody can have detrimental and wide-ranging effects on ecosystem health, habitats and species, as well as on recreation, cultural and aesthetic values. Key effects likely to result from excess sediment include:

- Physical alteration and infilling of waterbodies – resulting in noticeable deterioration and loss of available habitat for aquatic biota (as per Davies-Colley 1997 – see attachment 1);
- Changes in periphyton and aquatic vegetation communities (shift from periphyton primary production to nuisance macrophytes rooted in bed sediments);
- Changes in aquatic invertebrate communities (loss of sensitive EPT taxa) as indicators of ecosystem health, for their intrinsic biodiversity value and as food for other animals (e.g., fish) (Collier et al. 1998; Burdon et al. 2013);
- Physical impacts on the health of native fish and invertebrates through abrasion and clogging of sensitive gill structures and loss of refugia in the interstices of the bed (as per McEwan and Joy 2011; McEwan and Joy 2013a, b and c; Richardson et al. 2001 and Richardson and Jowett 2002);
- Disruption of native fish life-cycles and sedimentation of spawning habitats;
- Reduced food quality (macroinvertebrates), habitat and hunting opportunities for fish (both sight feeding in the water column and on the bed);
- Displacement of sediment sensitive native species (e.g., redfin bully, banded kokopu, lamprey as per Richardson et al 2001 and Richardson and Jowett 2002);
- Disruption of cultural, recreational and aesthetic values for water through fine sediment deposition (Clapcott et al. (2011) 25% deposited fine sediment guidelines for aesthetic values); and
- Reduced fish harvest and mahinga kai values.

Pingram et al. (2019) support the need for management of fine deposited sediment in the Waikato Region, identifying it as a key environmental stressor affecting aquatic life, stating "*These analyses identify that management actions targeted at improving instream habitat quality, particularly reducing* *fine sediment deposition, when applied across the entire stream network are likely to yield the most widespread improvement in biological condition indices. Our findings also highlight the importance of extending policy development beyond a singular focus on water quality if ecosystem health objectives are to be met.*" The risk analysis framework provide a quantifiable assessment across stressor gradient (e.g., degree of sediment deposition) using representative sites in the stream network.

WRC monitor indicators of ecosystem health and environmental stressors through the REMS programme (Collier et al. 2005 and updates since then). Fine deposited sediment has consistently been identified as a key stressor causing poor ecological condition in streams of the Waikato Region. The most recent results show: "*Unbiased estimates of wadeable stream extent based on the probability survey design indicate that for, perennial, non-tidal, <5th order streams on developed land from 2012 to 2014, … most (73% of stream length) had fine sediment cover above threshold values for benthic macroinvertebrates*."

Suspended sediment attribute for ecosystem health

The task group has considered providing an attribute for suspended sediments. However, we do not have sufficient evidential support on hand to form a robust basis for suspended sediments attribute for ecosystem health. Clarity may be a suitable surrogate and we suggest further discussion of this matter at the 3rd conferencing session.

Recommended deposited fine sediment attribute

We have used Clapcott et al. (2011) guidelines for fine sediment cover of naturally hard-bottomed, wadeable streams. A maximum 20% cover, or within 10% of reference condition threshold, is recommended for benthic biodiversity and a maximum 25% cover for amenity values.

Table 1. Suggested framework for deposited sediment attribute in Table 3.11-1 of PC1

Attribute state band	Deposited sediment % cover[6]
A	Within 10% of reference condition
B	≤20% cover
C	≤25% cover
D	>25% cover

Potential option: Use degree 10% of change from reference condition – use modelled data for the reference state for 'naturally hard-bottomed' catchments and add the 10% to get the threshold. Where this is greater than 20%, use the 20% as the maximum.

Alternative potential option (based on REMS monitoring): Percent bed cover by fine sediment (silt, particle size of<0.06 mm) was estimated by undertaking a modified Wolman assessment of streambed particles, whereby 100 particles are sampled across five evenly-spaced transects (20 per transect), using the intermediate axis dimension (width) to place the substrate into size divisions.

WRC staff have provided the following information with respect to the REMS monitoring data and fine sediment thresholds for ecological condition at the regional scale:

Table 2: Fine deposited sediment size classes, percentiles, and resulting Good (<75th percentile), Fair (in between), Poor (>99th percentile), bandings (based on modified Wolman pebble count). Based on data collected from c.25 reference sites across the Waikato region 2013-2015, sampled at least once. % of

[6] Using the protocols and methods in Clapcott et al. (2011) and applying to naturally hard bottomed streams as defined in the methods?

stream length in a given condition for Silt, and Sand, Silt, Clay (SSC) on developed land based on probabilistic network over same time period.

Percent cover of:	P1	P25	P50	P75	P99	mean	se	Good	Fair	Poor
Silt	0.0	0.0	0.0	2.0	18.0	2.3	0.5	<2.0	2-18	>18
Sand	0.0	1.0	4.0	16.0	50.0	9.8	1.5	<16.0	16-50	>50
Clay	0	0	0	0	8.5	0.55	0.19	<0	0-8.5	>8.5
Sand & Clay	0.0	1.0	4.0	16.0	50.0	10.4	1.5	<16	16-50	>50
Silt & Clay	0.0	0.0	0.0	3.0	22.0	2.9	0.6	<3	3-22	>22
Silt & Sand	0.0	1.0	7.0	20.0	52.5	12.2	1.6	<20	20-52.5	>52.5
Sand, Silt, Clay	0.0	1.0	8.0	20.5	52.5	12.7	1.6	<20	20.5-52.5	>52.5
% condition Silt								21.3	33.2	45.5
% condition SSC								25.3	19.9	54.8

These percent cover ranges for fine sediment (i.e., silt and sand) could be used as numeric attributes in PC1 associated with different levels of ecological condition (i.e., poor, fair or good). However, it may be inappropriate to set these attributes states for the sub-catchments in PC1 as the network of probabilistic sites was not established for this purpose.

WRC staff have indicated they are able to calculate extent (in stream length) of the differing thresholds for fine sediment in the Waikato and Waipā catchments (rather than regionally as reported in Pingram et al. (2019)). This information had not been provided at the time of writing. Understanding the extent of stream length in the PC1 catchments (as a whole) that are in good, fair or poor state with respect to fine sediment would be useful as a baseline for a trajectory of improvement.

A narrative 'objective' could be set in PC1 for an improvement over time in the extent of stream length exceeding the 'poor' threshold for fine sediment. This trajectory of improvement approach is recommended to capture aspects of ecosystem health in the tributaries of the Waikato and Waipā Rivers not currently accounted for in Table 3.11-1 and could also be applied with respect to macroinvertebrates and periphyton, using the WRC REMS monitoring framework.

Where should the attribute apply?

Wadeable streams that are naturally hard bottomed, perennial streams, <5th order, non-tidal.

Testing of the attribute against principles for attribute development (as per Scarsbrook 2018)

1. Does the attribute provide a measure of the value? **YES – for Ecosystem Health**
2. Measurement and band thresholds
   - Are there established protocols for measurement of the attribute? **YES**
   - Do experts agree on the summary statistic and associated time period? **To be discussed – suggest monthly monitoring and annual mean**
   - Do experts agree on thresholds for the numerical bands and associated band descriptors?

To be discussed

3. Management and limits

- Do we know what to do to manage this attribute? **YES**
- Are the four contaminants (N, P, sediment and faecal microbes) direct drivers of this attribute? **YES**
- Do quantitative relationships link the attribute state to limits and/or management interventions to control N, P, sediment and faecal microbes? **Yes**

4. Evaluation of current state

- Is there data of sufficient quality, quantity and representativeness to assess the current state of the attribute within Waikato FMUs? **YES – REMS programme is comprehensive**

References

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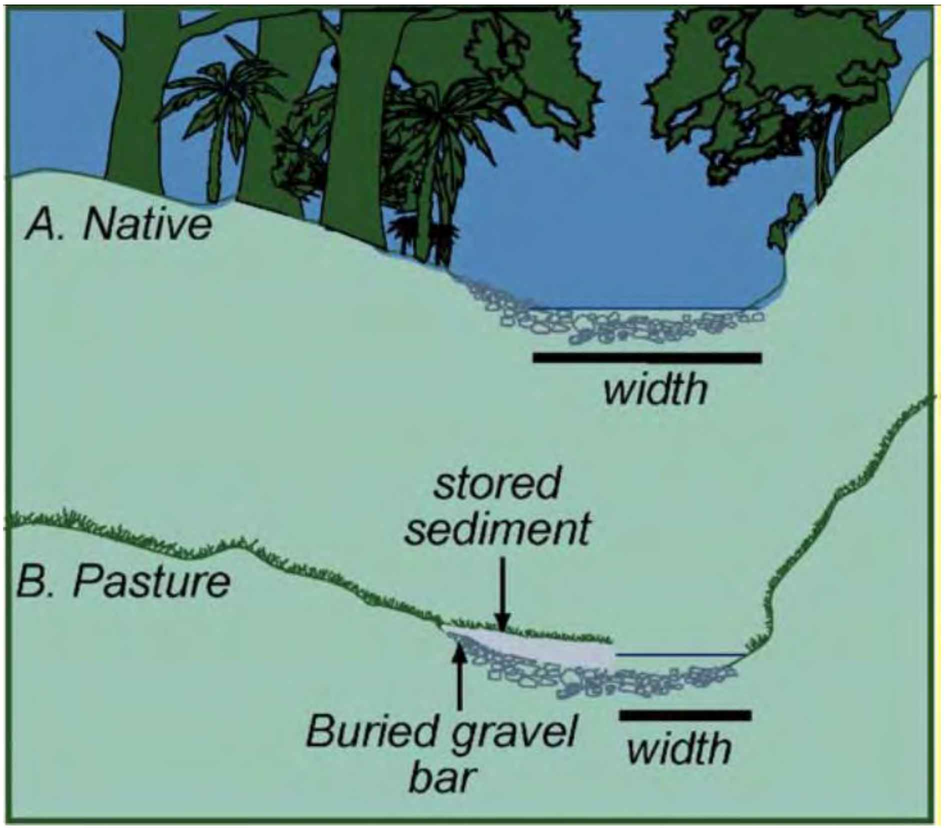
Richardson J, Rowe DK, Smith JP 2001. Effects of turbidity on the migration of juvenile banded kokopu (*Galaxias fasciatus*) in a natural stream. *New Zealand Journal of Marine and Freshwater Research 35:* 191-196.

<u>Attachment 1</u>

Figure 1. Change in stream channel width from native forest (A) to pasture (B), where pasture grasses trap sediment resulting in narrow and incised channels. (Reproduced from Parkyn (2004), following Davies-Colley (1997)).



Attachment 5 Water Clarity Attribute for PC1

MEMORANDUM

To: PC1 Expert Conferencing Group (Science)

Cc: David Hill

From: Martin Neale, Bill Vant, Craig Depree

Date: 3 June 2019

Subject: Water Clarity Attribute for PC1

Key Points

1. **Value** - water clarity is an important Attribute for swimming
2. **Methods**;
    a. There is an accepted measurement approach (i.e. black disc sighting distance).
    b. There are several published thresholds, which indicate water clarity is suitable for swimming above thresholds ranging from 1.0m to 1.6m[7].
    c. There is no agreement on the reporting statistic.
3. **Management** – the clarity of the Waikato catchment is determined by phytoplankton and other suspended particulate material. Therefore, water clarity can be improved through effective management of nutrient loads (through limiting algal growth) and sediment loads.
4. **Data** – water clarity is monitored routinely by WRC and there is sufficient data to describe current state. Indeed, this has been done for PC1, but the expert group sought to explore whether there was an alternative water clarity Attribute to better define the intent of the attribute - namely human health for primary contact recreation.

Discussion

5. Our main concern is that using median as the reporting statistic does not give effect to the value. Grading a site against a median means that the value is only meet 50% of the time, and for the other 50% of the time, the clarity could be markedly less than the median.
    a. For example, consider a site with a median visual clarity of 1.0 m. This indicates that 50% of the time the waterbody would have visual clarity lower than the bottom-line value of 1.0 m.
6. We developed two alternative options for a water clarity Attribute that are more aligned with the principles of the E. coli Attribute (i.e. applies to all flows and hence consistent with V&S);
    a. A modification of the existing Attribute, but the reporting statistic modified to 10th percentile. This requires visual clarity of a water way to meet or exceed the attribute state threshold 90% of

[7] It should be noted that the NZ perception studies about suitability for swimming included a range of relevant questions, not just clarity. The 'curves' relating to the 'clarity' responses reflect the interest of the authors in the optical properties of water, rather than clarity being the most important factor of for the suitability of the water body for swimming. For example, in Smith et al. (1995) the most frequent response was 'personal safety' (average about 65%) – although not defined, it could reflect the importance of E.coli for human health. Of the 45% of people that included 'water' as a factor, only half of these mentioned clarity (clearness as being important) - in other words, less than 25% specifically mentioned water clearness as a factor in determining suitability. Thus, we need to be aware of this, to not 'over play' the importance of a clarity attribute for human health

the time. This would mean that for a site to be graded in a particular band (i.e. attribute state) visual clarity in the water body would meet or exceed the upper band threshold 90% of time (thus, clarity would only be less than the threshold value <10% of the time). Like the current attribute, this modified attribute has different visual clarity thresholds and hence assumes that swimming is 'safer' with increasing clarity.

b. An alternative approach based on a single defined 'safe swimming' clarity, and then developing thresholds based on the percent of samples from a water body that meet or exceeds this threshold value. This approach is analogous to the E.coli attribute measures of the percent exceedance of 260 and 540 E.coli/100ml. This would clearly articulate the percentage of time a site meets or exceeds an operational defined minimum safe visual clarity value (i.e. minimum clearness/visibility the water should have so swimming can see obstacles).

7. Although E. coli and water clarity are both human health attributes, discussion at the third conferencing session indicated that the experts placed different levels of importance on the two attributes. It was agreed that a high degree of compliance with E. coli thresholds was required, presumably because when swimming, people cannot avoid exposure to water with high E. coli. In contrast, people can modify their behaviour when swimming in low clarity water (i.e. not dive or jump into the water to reduce the risk from some, but not all hazards). Therefore, if the expert panel considers that E. coli is the primary consideration for safe swimming, is a water clarity attribute for human health superfluous?

Decisions required by expert group

8. Is water clarity an important Attribute for swimming?
9. Should it be an Attribute in PC1 for this value?
10. If no to bullet 9, should it be an Attribute in PC1 for any other value? (e.g. ecosystem health)
11. If yes to bullet 9, what should the format of the Attribute be?
    a. TLG version (based on median)
    b. Option 1 presented here (similar to TLG, but based on a higher compliance statistic)
    c. Option 2 presented here (based on % compliance with a single threshold)

Purpose

As part of the PC1 expert conferencing on Table 3.11-1, a sub-group was set up to investigate the options for a Water Clarity Attribute.

The group consisted of Bill Vant, Olivier Ausseil, Craig Depree, Bevan Jenkins, Adam Canning and Martin Neale.

A sub-set of the group authored this Memo (Martin, Bill and Craig) and it may not reflect the opinions of the whole group.

Background

Water clarity has long been recognised as important consideration for recreational water use. Studies of the public's perception of water clarity and their associated use the water were carried out in New Zealand nearly 30 years ago (e.g. Smith et al., 1991; Smith & Davies-Colley, 1992).

The importance of water clarity resulted in it being included as measure in a proposed Water Quality Index for Recreation (Nagels et al, 2001) and the most recent published water clarity guideline for recreation is from the Canadian Ministry of Health (2012).

At the time of drafting PC1, and at the time of writing this Memo, water clarity has not been included in the NPSFM as an Attribute. Therefore, the TLG developed a clarity Attribute for the purposes of PC1 (Table 1) that was based on the work of Smith & Davies-Colley (1992), which was also used to develop a water clarity guideline published by the Ministry for the Environment (1994).

Table 1: TLG water clarity Attribute (adapted from Scarsbrook (2016))

Value	Human Health - swimmability	
Freshwater body type	Lakes, rivers and lake-fed rivers	
Attribute	Water Clarity	
Attribute Unit	Black Disc viewing distance (metres)	
Attribute State	Numeric Attribute State	Narrative Attribute State
	Annual median of samples*	
A	≥3.0	Eminently suitable for swimming
B	≥1.6 and <3.0	Suitable for swimming
C	≥1.0 and <1.6	Marginally suitable for swimming
Minimum acceptable state	1.0	
D	<1.0	Unsuitable for swimming

* after removal of sample results collected in the upper decile of flows

Smith & Davies-Colley (1992) stated that a water clarity of above 1.6m (measured using the black disc method) is required for water to be 'suitable' for swimming. The analysis also developed a relationship between water clarity and perceptions of suitability that provided a sliding scale of suitability based on perceptions (Figure 1).

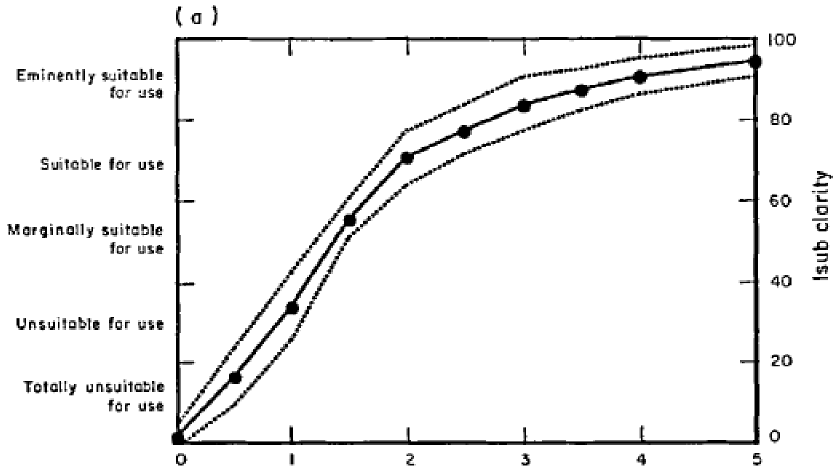


Figure 1 Water clarity (black disc) response curve for swimming (Smith & Davies-Colley, 1992)

It should be noted that this study was based on the perceptions of technical field staff, rather than the general public and used the 'Delphi' survey methodology which does tend to force the convergence of outliers. However, other studies of water clarity and suitability for recreation have supported the broad relationship shown in Figure 1, with some of the key observations summarised in Table 2.

In addition to the observations in Table 2, Smith et al (1995) reported that increases in water clarity above 2.0m had little effect on perceptions of swimming suitability. In contrast, the steepest part of the suitability curve is typically around 1m, so perceptions of suitability for swimming can be variable in this part of the curve. For example, Figure 2 shows the steepness in gradient in this area of the response curve showing marked changes in ‘suitability’ between clarity values of 0.8 and 1.4 m.

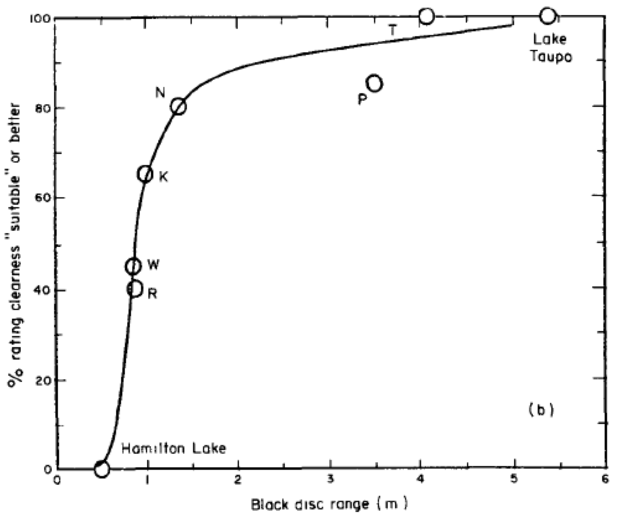


Figure 2 Water clarity (black disc) response curve for swimming “suitability” (Smith et al, 1991)

Table 2: Key observations from studies of water quality and perceptions of swimming suitability.

Water clarity (m)	Comment (source)
0.6m	60% of respondents consider suitable for swimming (Smith et al., 1991)
0.95m	Conversion of Canadian Guideline secchi disk value to horizontal black disk (Smith et al. 1991).
1.0m (secchi)	Minimum for primary contact recreation in Iowa Lakes (Burkart et al, 2008)
1.1m	‘Marginally suitable’ for swimming (Smith & Davies-Colley, 1992)
1.2m	75% of respondents consider suitable for swimming (Smith et al., 1991) ‘Just suitable’ for swimming (Smith et al, 1995)
1.2m (secchi)	Earliest water clarity guideline (NTAC, 1968) Current Canadian minimum guideline for recreation (Canadian Ministry of Health, 2012)
1.6	‘Suitable’ for swimming (Smith & Davies-Colley, 1992)

2.2m	90% of respondents consider suitable for swimming (Smith et al., 1991; 1995)

Reference condition

The concept of reference condition is used widely in ecological assessments of aquatic systems and provides useful context for ecologically focussed measures. For example, if a river is naturally turbid, one could argue that the biological communities in that stream would be adapted to such conditions.

In contrast, swimmers do not adapt to the underwater hazards (using the language from the guidelines "broken bottles, holes, snags") that water clarity guidelines are designed to manage the risk from. Therefore, we consider that the application of the reference condition approach to measures relating to water clarity is inappropriate.

If a site does not meet the MAS for water clarity in relation to swimming, then that should be recorded. However, the NPSFM provides for exceptions to the MAS when it is a result of 'naturally occurring processes' (Policy CA3). We consider that this is a more appropriate method to identify those sites that may not meet the MAS due to natural conditions, rather than to design an Attribute with lower thresholds, that would not give effect to the swimming value.

Proposed alternative Attributes

We have used the findings of the studies listed in Table 2 to guide the development of two alternative Water Clarity Attributes for consideration by the expert panel.

Alternative 1

Attribute states based on variable clarity threshold values – this is analogous to the existing PC1 attribute, with the main difference being a 90% compliance requirement.

Alternative 2

Attributes states based on single 'operationally defined' safe swimming minimum visual clarity - defined as 1.0 m - based on NZ studies and the conversion of the Canadian Guideline value of 1.2m (secchi depth distance).

Proposed attribute tables and additional information are provided for both alternatives in the following sections.

Alternative 1: Variable clarity attribute state (90% compliance)

Alternative 1 is conceptually similar to the TLG Attribute, with the main difference being the use of a different reporting statistic. We consider that the use of a median reporting statistics in the current TLG Attribute is not an appropriate way to report against water clarity guidelines or thresholds. This is because using a median would allow half of the samples to be below the relevant numeric value. When developing guidelines for Iowa Lakes, Burkart et al (2008) came to a similar conclusion, where they stated meeting 'the criterion only 50% of the time [as a median reporting statistic indicates] may satisfy few users'.

Therefore, we propose an Attribute that reflects that meeting (or exceeding) the relevant guideline or threshold is the key measure of what makes water suitable for swimming. However, we also agree with the Iowa approach on this issue, where they considered 100% compliance was unrealistic given the natural variability in water clarity, even in good quality waters.

The proposed Attribute presented here is based on the 10th %ile of samples, which indicates that the water quality meets the relevant guideline or threshold 90% of the time.

We consider that such an approach is more useful and informative to a potential user than using median value, as it gives greater confidence that the water clarity aligns with the value. Noting that the user can choose the threshold (or level of risk) they are prepared to accept – i.e. 2.2m (band A), 1.6 (B) or 1.0 (C).

For example, a Band B site under the TLG Attribute would have clarity suitable for swimming 50% of the time. In contrast, a Band B site under the proposed Attribute would have clarity suitable for swimming 90% of the time. We consider that somebody deciding whether to go swimming based on water clarity would have greater certainty that the value was being met using the proposed Attribute than the TLG Attribute.

There are additional minor changes from the TLG Attribute;

1. We have aligned the bands with the literature on perceptions of swimming suitability (see Table 2), thus;
    a. Band A threshold is 2.2m (this is a change from the TLG Attribute, which used 3.0m for the A band – the provenance of which is not apparent[8])
    b. Band B threshold is 1.6m
    c. Band C threshold is 1.0
2. We propose two bands below the MAS to be able to potentially show improvement in low clarity waters
3. The Attribute requires no censoring of the data prior to assessment as the Attribute provides for a small number of samples with low clarity to be recorded without affecting the band[9]

Table 3: Proposed Water Clarity Attribute 1

Value	Human Health - swimmability	
Freshwater body type	Lakes, rivers and lake-fed rivers	
Attribute	Water Clarity	
Attribute Unit	Black Disc viewing distance (metres)	
Attribute State	Numeric Attribute State	Narrative Attribute State
	10^{th} %ile of samples	
A	≥2.2	Very suitable for swimming
B	≥1.6 and <2.2	Suitable for swimming
C	≥1.0 and <1.6	Marginally suitable for swimming
Minimum acceptable state	1.0	

8 Smith et al. (1991) indicated that the critical 'zone' for managing clarity was between 0.7 and 1.2 m, and that at clarities beyond about 1.4 m "we have entered a clarity region of diminishing change in perceived suitability for bathing, where large increases in clarity bring about only small increases in "suitable" ratings." Based on this, attribute states based on water clarity >3.0m are arguably of limited relevance for defining 'safe swimming'

9 This is a change from the current WRC approach, but we consider that the hazard in the upper decile of flows relates to the strength of the river current, rather than to water clarity as such. It is also consistent with the grading process described for *E.coli* NOF attribute that similarly relates to human health values of freshwater.

D	≥0.5 and <1.0	Likely unsuitable for swimming
E	<0.5	Very likely unsuitable for swimming

Alternative 2: Single clarity attribute state (based on 1.0m)

The proposed attribute table using a single defined minimum visual clarity for 'safe swimming' is shown in Table 4. Attribute states are defined by percentage thresholds for meeting (or exceeding) 1.0m clarity of 90, 70, 50 and 30% as the thresholds for band A, B, C and D, respectively.

This option is consistent with the discussion of the expert group about having an attribute based on a single defined 'safe swimming' clarity, and then developing an attribute on the percent of time (based on percent of samples) a water body meets or exceeds this single safe swimming threshold value.

This approach is analogous to the E.coli attribute measures of the percent exceedance of 260 and 540 E.coli/100ml.

This would articulate the percentage of time a site meets or exceeds an operational defined minimum safe visual clarity value (i.e. minimum clearness/visibility the water should have so swimming can see obstacles).

Table 4: Proposed Water Clarity Attribute 2

Value	Human Health - swimmability	
Freshwater body type	Lakes, rivers and lake-fed rivers	
Attribute	Water Clarity	
Attribute Unit	Black Disc viewing distance (metres)	
Attribute State	Numeric Attribute State	Narrative Attribute State
	Proportion of samples that meet or exceed 1.0m visual clarity	
A	>90%	Exceeds the minimum safe swimming clarity 90% of the time (Very suitable for swimming)
B	70-90%	Exceeds the minimum safe swimming clarity 70-90% of the time (Suitable for swimming)
C	50-70%	Exceeds the minimum safe swimming clarity 50-70% of the time (Marginally suitable for swimming)

Minimum acceptable state	50%	
D	30-50%	Likely unsuitable for swimming
E	<30%	Very likely unsuitable for swimming

Comparison of alternatives

A comparison of the classification of the PC1 monitoring sites is provided in Figure 4 and we provide a pros and cons analysis in Table 5.

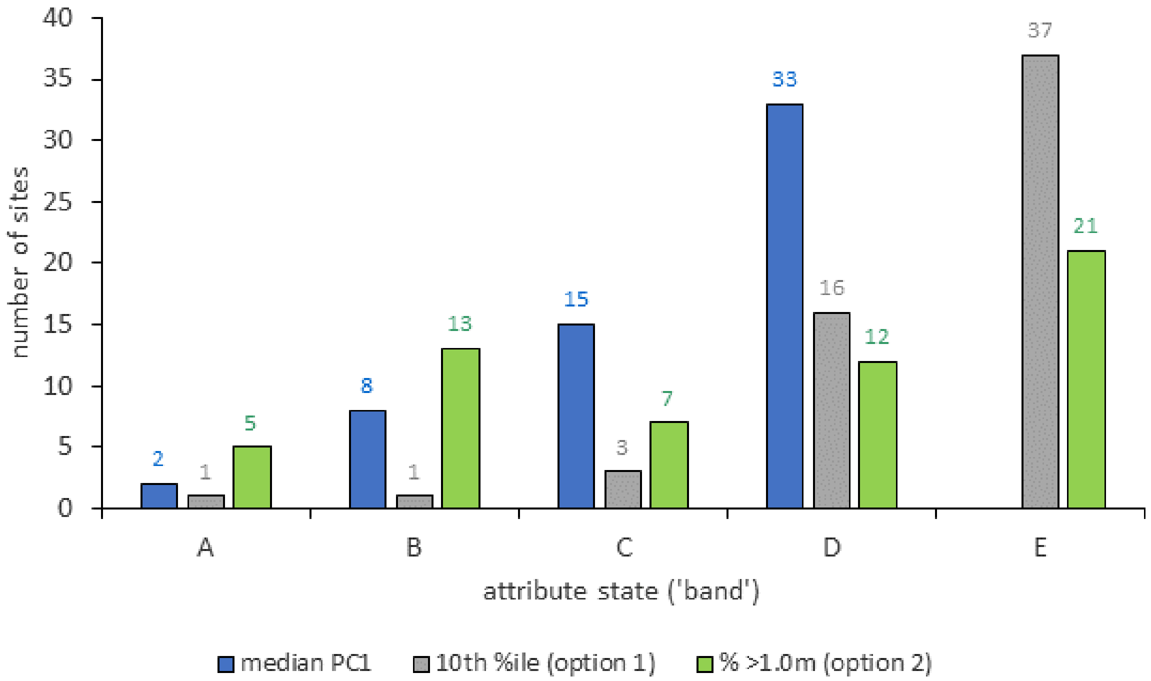


Figure 4: Comparison of distribution of bands based on PC1 attribute (blue bars) and alternative 1 attribute (based on 90th percentile – grey bars) and Alternative 2 attribute (based on % of sample above 1.0m).

Table 5: Pros and cons of Water Clarity Attribute options

Option	TLG Attribute	Alternative 1	Alternative 2
Pros	As notified in PC1, so no change required	Conceptually similar to TLG Attribute Bands aligned with published studies of perception	Based on a single clarity threshold associated with 'safe swimming' Easily understandable narrative states (i.e. % of time)
Cons	Median reporting statistic does not give effect to value Based on 'perception' of water, not necessarily 'swimming safety' Band A has little relevance for perception	High rates of non-compliance based on current state Based on 'perception' of water, not necessarily 'swimming safety' Considered too stringent by expert panel	No consensus on the 'safe' threshold Weak support from expert panel

References

Burkart et al 2008 Nutrient criteria for Iowa lakes – Recommended Criteria for Class A Recreational Uses. Report of the Nutrient Science Advisors. Available via Research Gate at this link - Iowa Lakes Report

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Smith D.G., Croker G.F. & McFarlane K. 1995. Human perception of water appearance, New Zealand Journal of Marine and Freshwater Research **29**: 29-43.

Smith D.G., Cragg A.M. & Croker G.F. 1991. Water clarity criteria for bathing waters based on user perception. Journal of Environmental Management **33**: 285-299.

Smith D.G. & Davies-Colley R. J. 1992. Perception of water clarity in terms of suitability for recreational use. Journal of Environmental Management **36**: 225-235.

Attachment 6 Dissolved Oxygen Attribute for PC1

To: PC1 Expert Conferencing Group

Cc: David Hill

From: Hannah Mueller, Kate McArthur, Ngaire Phillips, Nic Conland, Adam Canning, Mike Scarsbrook

Date: 24 May 2019

Subject: Potential Attribute for PC1 – Dissolved Oxygen

Role of DO for ecosystem health

DO is an important ecological indicator, as most of the organisms within a freshwater system consume DO; which also means that it must be continuously replenished (e.g. through flow, wind and plant growth, although plant growth also reduces available DO when photosynthesis ceases). Organisms can become stressed or die if insufficient oxygen is present and some fish may avoid water with low DO concentrations. Pressures on freshwater systems such as nutrient enrichment (via plant growth), microbial breakdown of organic matter and weed invasion can lead to depleted DO concentrations. Due to its importance to most organisms, and the intricate link to other water quality parameters, DO is a critical parameter to assess the ecological condition of freshwater systems[10,11] and to provide for ecosystem health.

Attribute assessment – Dissolved Oxygen (DO)

1. Attribute value

Does the attribute provide a measure of the value? Provides a measurement related to "Ecosystem Health": indicator of a desired state which supports ecosystem health in a waterbody. However, the response is expected to be site specific, depending on the contributing factors to DO listed above and there is a lack of continuous monitoring data.

There is uncertainty around the attribute's applicability to lowland sites which may be naturally lower in DO. Attribute would benefit from the establishment of baseline reference conditions, which are currently widely unknown.

Uncertainty regarding a clear bottom line for life supporting capacity under different reference conditions.

As a freshwater objective it requires limits to manage resources in the catchment to achieve this objective. For example, limits could be associated with nutrients (with respect to periphyton and plant growth), shade (as a function of riparian conditions), discharges of organic matter, and/or sediment (as it affects macrophytes and thereby DO).

Dissolved Oxygen is a universal indicator for ecosystem health and can be applied for all reaches of the Waikato and Waipa River Catchment.

The Peat Lakes which support unique ecosystems will require alternative bands for this attribute.

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[10] Butler, B & Burrows DW 2007. Dissolved oxygen guidelines for freshwater habitats in of Northern Australia. ACTFR Report No 07/32. Prepared for Department of Environment and Heritage, Canberra by the Australian Centre for Tropical Freshwater Research.

[11] DO fluctuates diurnally (over the 24 hours of the day) and continuous logging is required to understand the fluctuation in DO concentrations in a waterway and the daily minima, which is a critical value for aquatic life. DO saturation also changes with other parameters, particularly temperature.

2. Measurement and band thresholds

- *Are there established protocols for measurement of the attribute?* YES
- *Do experts agree on the summary statistic and associated time period*? There is potential to look at the range between the diel (24hr) variation as a measure of state. As opposed to the 7-day mean. Minimum thresholds (NOF) are largely agreed.
- *Do experts agree on thresholds for the numerical bands and associated band descriptors?* There is a knowledge gap on appropriate thresholds for the maximum range or diel variation although some guidance is provided by Young and Collier 2009[12], meaning the 7-day mean is the next preferred option, in conjunction with minimum DO thresholds.

3. Management and limits

- *Do we know what to do to manage this attribute?* YES – within an adaptive management framework, as the causal relationships are indirect and require multiple steps to drive change.
- *Are the four contaminants (N, P, sediment and faecal microbes) direct drivers of this attribute?* An indirect relationship only. Limitations on nutrient concentrations and sediment, functional relationships with primary production (phytoplankton, periphyton and macrophytes) can reduce DO fluctuations.

  There is insufficient data to assess representativeness. More robust data is required to assess direct effects on DO through shading, nutrient concentrations, and other parameters (such as reductions in organic matter from discharges).
- *Do quantitative relationships link the attribute state to limits and/or management interventions to control N, P, sediment and faecal microbes?* With limitations on nutrient concentrations and sediment to manage primary production depending on the ecosystem type (e.g. periphyton in hard bottomed rivers, macrophytes in soft-bottomed rivers and phytoplankton in lakes and the Waikato mainstem). Land use controls to provide riparian margins can also induce changes in attribute state in waterbodies with a channel cross-section under 5-10 metres via channel shading and reductions in periphyton/plant growth.

4. Evaluation of current state

- *Is there data of sufficient quality, quantity and representativeness to assess the current state of the attribute within Waikato FMUs?* Continuous DO monitoring is available for two mainstem Waikato sites only. A method can be required in PC1 to implement monitoring over a larger range of sites and ecosystem types. This method could include short term monitoring over critical time periods for DO on a rotational basis. i.e. Adopt a continuous monitoring programme which targets the water bodies in each FMU in summer-autumn, during periods of stable flow that are not greater than the 25th percentile, and for periods not exceeding two weeks. This would create a reporting period to target the highest risk for the ecosystem in any year.

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[12] Ecosystem metabolism metrics (GPP and ER) were calculated from continuous dissolved oxygen data recorded for a minimum of 24 hours at each site and using a published spreadsheet model based on the single station night-time regression method (Young & Collier 2009). Young RG, Collier KJ 2009. Contrasting responses to catchment modification among a range of functional and structural indicators of river ecosystem health. Freshwater Biology 54(10): 2155-2170.

Recommendations

Impact prioritisation

We recommend prioritising areas of flood control infrastructure that exacerbates DO issues through the (unconsented) discharge of low DO waters from drainage impoundments and small streams affected by nuisance submerged macrophyte growth. These discharges are known to lead to low oxygen conditions in the receiving waters, which can harm aquatic life including plants and biota. We recommend prioritising these areas for monitoring and management before attempting catchment-wide DO management.

Attribute: we recommend using the bottom-line values (7-day mean minimum and 1-day minimum) for all sites (except peat lakes) due to uncertainty around thresholds and baseline conditions.

<u>Suggested recommendation:</u>

We recommend DO to be implemented as a monitoring requirement, with the bottom-line set as a trigger value for management intervention.

Suggested attribute table – DO

Based on values proposed by Davies-Colley et al. 2013[13].

For lakes (except peat lakes), the suggested monitoring location is mid-lake. Some stratified lakes can naturally become hypoxic in the bottom layer. We recommend bottom layer oxygen levels should never be <1mg/L to avoid nutrient release from the sediment associated with anoxic conditions, especially when pH levels are elevated[14,15].

Value	**Ecosystem health**			
Freshwater body type	**Lakes (except peat lakes) and rivers**			
Attribute	**Dissolved oxygen**			
Unit	**mg/L**			
Attribute state	**Numeric attribute state**			**Narrative attribute state**
	7-day mean	**7-day minimum**	**1-day minimum**	
A	≥9.0	≥8.0	≥7.5	No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near-pristine) sites.
B	≥8.0	≥7.0	≥5.0	Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.
C	≥6.5	≥5.0	≥4.0	Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.
D	<6.5	<5.0	<4.0	Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.

[13] Davies-Colley, R, Franklin, P, Wilcock, B, Clearwater, S. & Hickey, C. 2013. National Objectives Framework – Temperature, Dissolved Oxygen & pH. Proposed thresholds for discussion. Report prepared for the Ministry for the Environment, NIWA Client report HAM2013-056, prepared by National Institute of Water & Atmospheric Research Ltd.

[14] Crawshaw JA, Schallenberg M, Savage C. 2018. Physical and biological drivers of sediment oxygenation and denitrification in a New Zealand intermittently closed and open lake lagoon, New Zealand Journal of Marine and Freshwater Research, DOI: 10.1080/00288330.2018.1476388

[15] Zhang H, Lyu T, Bi L, Tempero G, Hamilton DP, Pan G. 2018. Combating hypoxia/anoxia at sediment-water interfaces: A preliminary study of oxygen nanobubble modified clay materials. Science of The Total Environment, 637, 550-560.

Attachment 7 Macroinvertebrate Attribute for PC1

MEMORANDUM

To: PC1 Expert Conferencing Group (Science)

Cc: David Hill

From: Martin Neale, Hannah Mueller, Ngaire Phillips, Dean Miller, Adam Canning

Date: 10 June 2019

Subject: Macroinvertebrate Attribute for PC1

Document History

After discussion at Expert Conferencing session on 10 June 2019, the following five minor edits were made to this Memo. These edits were agreed upon by the group before the voting process.

- Long-term objectives changed to 0% (with minor consequential changes to short-term targets so that they represent 10% of the difference).
- Text covering the relationship between invertebrates and nutrients and sediment was edited to provide greater clarity on the nature and strength of the relationship.
- Note added to be explicit that this data is generated from WRC data using the REMS protocols (particularly as they relate to hard and soft bottom streams)
- Note added to recognise that streams with naturally poor status (e.g. geothermal streams) should be excluded from this attribute (consistent with Policy CA3 in the NPSFM).
- Explanation as to why the Lower and Mid-Waikato FMUs are combined for the Attribute.

Key Points

1. **Value** – macroinvertebrate communities are well established indicators of ecosystem health.
2. **Methods** – There are accepted methods for sample collection, analysis and reporting statistics, especially for wadeable streams.
3. **Management** – macroinvertebrate communities respond to a wide of environmental factors, including nutrients and sediment. Therefore, ecosystem health, as indicated by macroinvertebrate communities, can be improved by effective management of nutrient and sediment loads. For example, it was estimated that improving sediment, riparian and instream habitat management could reduce the extent of Poor QMCI scores by around a third each, each equivalent to c. 2600-2800 km of the stream network, with nutrient reductions could reduce the extent of poor QMCI by a further 960km.
4. **Data** – macroinvertebrate communities are routinely monitored by WRC as part of the Regional Ecology Monitoring of Streams (REMS) programme. However, this programme operates in wadeable streams, whereas most of the locations in Table 3.11-1 are not wadeable. Therefore, the locations where macroinvertebrate data are available do not align with the locations in Table 3.11-1 (which are based on WRC's water quality monitoring programme).

Discussion

5. We support the use of the macroinvertebrates being used for a PC1 Macroinvertebrate Attribute in wadeable streams and rivers.
6. We recommend that this Attribute is based on the wadeable stream monitoring network of 180 sites, which due the random nature of its design, allows an unbiased estimate of the ecological condition of "perennial, non-tidal, wadeable streams on developed land in the Waikato Region" (Pingram et al., 2014).
7. The most recent results from this programme estimate that 53% of the target stream length in the Waikato/Waipā catchment is in poor condition (indicated by a QMCI <4). We propose an Attribute that seeks to reduce the proportion of stream length that is in poor condition and have set objectives for discussion below.
8. However, this Attribute will not fit into the format of Table 3.11-1 and will require a separate table to express the current state and objectives. We illustrate this in Table 3, but note the objectives require discussion with the Expert Conferencing Group.
9. We consider this approach will be complimentary to the existing ecological indicator in Table 3.11-1, which is focussed on the main river (i.e. chl a). Together these two indicators would provide for an assessment of the ecological health of the majority of the catchment (main-river and tributaries) and provide an ecological measure of the effectiveness of mitigations that target water quality improvements.
10. Macroinvertebrate are also potentially useful indicators in deep rivers and lakes, but development work is required before a Macroinvertebrate Attribute can be used in these situations.

Purpose

As part of the PC1 expert conferencing on Table 3.11-1, a sub-group was set up to investigate the options for a Macroinvertebrate Attribute.

The group consisted of Hannah Mueller, Ngaire Phillips, Dean Miller, Adam Canning and Martin Neale.

The original Memo was jointly authored by the group, but this revised Memo reflects the views of Martin, Dean and Adam. We do not know whether Hannah and Ngaire support this approach (*subsequent agreement noted*).

Background

Macroinvertebrate communities have long been recognised as important indicators of ecosystem health, with their use in New Zealand facilitated by the development of the MCI family of indices for reporting and assessment (Stark, 1985).

Advice on the potential use of macroinvertebrates as Attribute in the NPSFM was sought by the Ministry for the Environment and Collier et al (2014) subsequently proposed a Macroinvertebrate Attribute based on the MCI index (Table 1). However, the proposed Attribute has not been included in the NPSFM at the time of writing, although the use of MCI as a monitoring tool was included in the 2017 NPSFM Amendments (see Policy CB3).

We understand that main reason that a Macroinvertebrate Attribute was not included is that direct links with management interventions were difficult to demonstrate. This is because macroinvertebrates (and the

MCI family of indices) respond to a range of environmental factors. This is consistent with why a Macroinvertebrate Attribute was not included in PC1 (Scarsbrook, 2016).

This issue has recently been considered by Pingram et al (2019) for wadeable streams in the Waikato catchment. Whilst they found macroinvertebrate responses are related to multiple environment factors (10 of the 12 considered), the strongest relationships were with total phosphorus (TP), sediment and habitat quality. The authors concluded that actions targeted at managing these factors are likely to result in an improvement in macroinvertebrate indices (in this case, QMCI).

Given this link to management actions, we consider it is appropriate to include a Macroinvertebrate Attribute in PC1 and we propose an Attribute based on the QMCI index utilising the current REMS programme.

Table 1 Macroinvertebrate Attribute proposed by Collier et al (2014)

Value	Ecosystem Health	
Freshwater Body Type	Rivers (wadeable only)	
Attribute	Macroinvertebrate Community Index (MCI)	
Attribute Unit	Dimensionless index units (up to theoretical 200)	
Attribute State	Numeric Attribute State	Narrative Attribute State
	Three year mean*	
A	>120	High quality environment where species composition is close to natural state most of the time
B	100-120	Good quality environment where human activities and/or natural disturbances cause some loss of sensitive species
C	80-100	Fair quality environment where moderately-highly tolerant species dominate
Minimum Acceptable State	80	
D	<80	Poor quality environment where highly tolerant species dominate most of the time

* minimum recommended rolling time interval for consecutive sampling years using standard collection methods based on Stark et al. (2001). Where these methods are not used and the habitats sampled are quite different, a calibration exercise should be undertaken.

Proposed attribute for PC1

We have used the findings of Pingram et al (2014; 2019), together with our collective knowledge of macroinvertebrate communities and assessment methods to develop the Macroinvertebrate Attribute below (Table 2).

Macroinvertebrates are commonly used to assess the ecological health of wadeable streams and rivers only. Sampling related issues complicate sample collection in non-wadeable rivers and macroinvertebrates are not commonly monitored in deep rivers in New Zealand.

The sites currently listed in Table 3.11-1 are based on the WRC's water quality monitoring network and many are non-wadeable. As a consequence, we have been informed that only ten of these sites have macroinvertebrate sampling data associated with them.

However, WRC also operate an ecology programme that samples wadeable streams across the region (i.e. the REMS programme). We propose to use the data from this network of sites to inform the development of a macroinvertebrate Attribute for PC1.

Unlike most monitoring networks in New Zealand, the REMS network is designed in a probabilistic manner, which means the sites were selected randomly. The importance of this network design is that it allows the data to be extrapolated to the remainder of the stream network to provide unbiased estimates of stream network that are in different condition (i.e. good, fair or poor). These statistics can be summed for the Waikato/Waipā catchment as required. The 180 sites in this region wide network are sampled over a three-year period.

We recommend that the power of this random network is utilised to develop a macroinvertebrate Attribute for PC1. However, this will mean that the Attribute will take a different format to the other Attributes and will require a supplementary table to Table 3.11-1. The Attribute can be used at a catchment scale or for each of the FMUs.

The current state is based on the results of the 2013-15 REMS cycle and progress towards the objectives will be based on the future results from the REMS programme.

The results of the programme are expressed as the percentage of the stream network that are in poor, fair or good condition based on the QMCI index. The current estimate of stream length in each category is provided in Table 2.

Table 2 Current state of the wadeable streams and rivers in the Waikato/Waipā catchment (data provided by Mike Pingram)

Spatial Unit	% of stream length in each Ecosystem Health category*		
	Poor	Fair	Good
Waikato/Waipā catchment	53	21	26
Waipā FMU	45	25	30
Upper Waikato FMU	49	7	43
Lower and Mid Waikato FMU	68	26	6

*Categories based on QMCI; Poor <4; fair 4 – 4.99; good >5 and using 2013-15 REMS cycle

The objectives will need to be discussed and agreed by the expert conferencing, but we propose a broad approach that is consistent with the way the water quality objectives have been developed;

- The long-term objective is set at a level that represents an acceptable level of restoration
- The short-term target is set at a level that seeks 10% of the difference between current state and the long-term objective

The proposed Attribute is based on the extent of the stream length that is poor (i.e. below minimum acceptable state) and is presented in Table 3.

Table 3 Proposed Macroinvertebrate Attribute for PC1[1,2].

Spatial Unit	% of stream length with QMCI <4		
	Current state	Short term objective	Long term objective
Waikato/Waipā catchment	53	47	0
Waipā FMU	45	40	0
Upper Waikato FMU	49	44	0
Lower and Mid Waikato FMU[3]	68	61	0

Table notes:

1. Data for calculating this Attribute is generated from WRC data using the REMS protocols and the probabilistic monitoring network.
2. Streams with naturally poor status (e.g. geothermal streams) should be excluded from this attribute (consistent with Policy CA3 in the NPSFM).
3. The Lower and Mid-Waikato FMUs are combined for this Attribute as there are too few sites within the FMUs to report individually.

References

Clapcott, J.E., Goodwin, E.O., Snelder, T.H., Collier, K.J., Neale, M.W. & Greenfield, S. 2016 Finding reference: a comparison of modelling approaches for predicting macroinvertebrate community index benchmarks, New Zealand Journal of Marine and Freshwater Research, DOI: 10.1080/00288330.2016.1265994

Collier KJ, Clapcott J, Neale M 2014. A macroinvertebrate attribute to assess ecosystem health for New Zealand waterways for the national objectives framework – Issues and options. Environmental Research Institute report 36, University of Waikato, Hamilton.

Pingram, M.A., Collier, K.J., Hamer, M.P. 2014. Ecological condition of Waikato wadeable streams based on the Regional Ecological Monitoring of Streams (REMS) Programme 2012 – 2014 report. Waikato Regional Council Technical Report 2014/46.

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Stark J.D. 1985. A macroinvertebrate community index of water quality for stony streams. Water and Soil Miscellaneous Publication; p. 53.

Stark J.D., Boothroyd I.K.G., Harding J.S., Maxted J.R., & Scarsbrook M.R. 2001. Protocols for sampling macroinvertebrates in wadeable streams. Sustainable Management Fund Project No. 5103. 57p. Available from: http://www.mfe.govt.nz/publications/fresh-water-environmental-reporting/protocols-sampling-macroinvertebrates-wadeable.

Attachment 8 Macrophyte nuisance Attribute for PC1

Macrophyte Attribute for Waikato Plan Change 1

Mike Scarsbrook

4 June 2019

Summary

- Does a Macrophyte attribute provide a measure of the Ecosystem Health value?
  - Yes
- Are there agreed band thresholds, summary statistics and measurement protocols?
  - Yes
  - Collier et al (2007) developed sampling methods relevant to Waikato streams
  - Collier et al. (2014) developed Waikato indices, but this approach would need further development to define bands
  - There are also provisional national guidelines that could be used (Matheson et al. 2012)
  - There are bands/thresholds relating to trout fishing value (Matheson et al. 2016)
- Do we know what to do to manage this attribute, do we understand the drivers and are there quantitative relationships that link the attribute state to resource use limits and/or targets
  - Yes, shading of lowland streams is frequently advocated to control macrophytes
  - But, "…there are not sufficient data available to allow recommendation of nutrient concentrations to limit macrophyte growth…" (Matheson et al. 2012)
- Is there data of sufficient quality, quantity and representativeness to assess the current state of the attribute?
  - Yes, Collier et al. (2014) note a macrophyte sampling network of 180 non-tidal perennial wadeable streams on developed land sampled on a 3-year rotating panel

Technical Caucusing Joint Witness Statement

Aquatic macrophyte biomass and/or cover is an important indicator of ecosystem health. The Waikato region has established monitoring networks and indicators for macrophytes in wadeable streams. However, there is currently limited ability to link macrophyte indicators to the four contaminants (particularly N & P) covered by PC1. Therefore, we do not recommend inclusion of macrophytes as a relevant attribute for stream ecosystem health value in PC1. We do recommend that WRC continue to monitor and report on macrophytes as key indicators of stream ecosystem health.

Technical Leaders Group (TLG) advice on macrophytes

An expert panel formed to assist attribute development agreed that macrophyte biomass was an important measure of Ecosystem Health relevant to the Waikato region (Scarsbrook 2016). Their recommendation to the Collaborative Stakeholder Group was to develop and apply a Submerged Macrophyte attribute to rivers in the Waikato-Waipa catchment.

In relation to lakes, it was noted in Scarsbrook (2016) that the condition and species composition of macrophytes in lakes is monitored in a number of shallow lakes in the region (Edwards et al. 2010). However, the drivers of macrophyte communities in shallow lakes are complex and a number of these drivers fall outside the scope of Healthy Rivers (e.g. water levels, pest fish). Furthermore, the relationship between Ecosystem Health and macrophyte biomass is not linear. Extensive beds of native macrophytes can indicate healthy conditions, whereas similarly extensive beds of introduced and nuisance species may indicate degraded conditions.

Overall, TLG recommended that Macrophytes not be included as an attribute. They recommended development of an indicator for surveillance monitoring (NB. WRC already monitor macrophyte cover as part of the REMS programme).

References

Collier, K. J., Kelly, J. & Champion, P. 2007. Regional guidelines for ecological assessments of freshwater environments: aquatic plant cover in wadeable streams. Environment Waikato Technical Report 2006/47.

Collier, K., Hamer, M, Champion, P. (2014). Regional guidelines for ecological assessments of freshwater environments: Aquatic plant cover in wadeable streams - version 2. TR 2014/03.

Edwards, T., De Winton, M., Clayton, J. (2010). Assessment of the Ecological condition of lakes in the Waikato Region using LakeSPI – 2010. Prepared by NIWA for Waikato Regional Council. Environment Waikato Technical Report 2010/24.

Matheson, F., Quinn, J., Hickey, C. (2012). Review of the New Zealand instream plant and nutrient guidelines and development of an extended decision making framework: Phases 1 and 2 final report. Prepared for the Ministry of Science & Innovation Envirolink Fund. HAM2012-081.

Matheson, F., Quinn, J., Unwin M. (2016). Instream plant and nutrient guidelines Review and development of an extended decision-making framework Phase 3. MBIE Envirolink Fund. HAM2016-064.

Scarsbrook, M. (2016). Water quality attributes for Healthy Rivers: Wai Ora Plan Change. Report HR/TLG/2016-2017/2.1A. Waikato Regional Council Technical Report 2018/66.

Attachment 9 Periphyton Attribute for PC1

Kate McArthur

Periphyton is the community of algae, microbes and cyanobacteria which grows on the bed of rivers and streams (and in some cases can grow on wood or macrophytes instream, known as epiphytic growth). It is the primary productive base of the aquatic food chain. However, nuisance periphyton growth can have effects on water quality (causing fluctuations in dissolved oxygen and pH), ecosystem health via effects on macroinvertebrates and water quality and adversely affect recreational, aesthetic and cultural values.

Aquatic primary production in PC1 is currently focussed on phytoplankton growth in the Waikato River mainstem and lakes. However, benthic periphyton is likely to be an issue in the tributaries, where there are hard-bottomed substrates for the attachment of nuisance growth. Although the majority of rivers in the PC1 sub-catchments are soft-bottomed, and therefore carry a low risk of adverse effects from periphyton, in hard-bottomed streams enriched by nitrogen and phosphorus there is a risk that periphyton may reach nuisance levels. There are some hard-bottomed sites in the PC1 sub-catchments (an initial identification of these is contained in the 'approach 5' table for the nutrient attributes) and included in the EIC of Kathryn McArthur at paragraph 90.

The experts discussed an approach for periphyton in the PC1 tributaries. Some experts noted that in the absence of information on periphyton, precautionary numeric thresholds for periphyton growth should be set where there is a risk of nuisance growth occurring. The experts identified key steps to determine areas where there is a risk of periphyton effects as follows:

i Determine the sites which have hard-bottomed substrates and their contributing sub-catchments,

ii Assess nutrient concentrations to determine whether there is a risk of periphyton growth occurring at these sites (e.g., dissolved inorganic nitrogen >0.4mg/L and dissolved reactive phosphorus >0.01mg/L – approach 5 in the nutrient attribute document),

iii Implement a monitoring programme to assess periphyton biomass and cover at these sites,

iv Assess exceedance of thresholds spatially and temporally.

Periphyton biomass (chlorophyll *a*) is an attribute in the NOF associated with the compulsory ecosystem health value in the NPS-FM. Currently there is no WRC data to compare the state of tributaries of the Waipā and Waikato against the NOF periphyton biomass attribute bands.

In the absence of this data, periphyton cover is suggested as an attribute for hard-bottomed wadeable streams in the PC1 catchments.

The REMS monitoring network is a probabilistic network of wadeable rivers and streams across the Waikato Region. Periphyton cover is visually assessed annually across the REMS network by WRC and streams exceeding the Regional Plan standard for periphyton cover have been identified in the REMS data. Pingram et al (2016)[16] found "*On streams flowing through developed land, macrophyte cover averaged 31% of the channel, while periphyton cover by long filaments and thick mats averaged 9% of substrate surfaces at the time of sampling, with 11% of wadeable stream length exceeding 25% cover by long filaments and thick mats*."

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[16] Pingram M, Hamer M, Collier K 2016. Ecological condition of Waikato wadeable streams based on the Regional Ecological Monitoring of Streams (REMS) Programme 2012 – 2014 report. Waikato Regional Council Technical Report 2014/46.

However, it is not clear the current extent of the issue in the Waikato and Waipā catchments (only at the regional level). Data relating the extent of periphyton (and fine sediment and MCI) issues in the Waikato and Waipā catchment has been requested from WRC but was not available at the time of writing.

If the extent data (stream length affected by nuisance periphyton cover) is provided there is the potential for including a narrative 'objective' in PC1 which specifies a degree of improvement from the current state over time in the wadeable stream length which exceeds the periphyton cover threshold, tested via the REMS programme. For example, a 10% improvement in the stream length affected by nuisance periphyton over ten years.

Recommendations:

1. Adopt a narrative 'objective' for periphyton cover which applies to all hard-substrate rivers and streams in the Waikato-Waipā catchments for at least a 10% reduction (improvement) in stream length exceeding 25% cover using the REMS monitoring network and protocols.

2. Adopt the NOF bottom line of 200mg/m^2 chlorophyll *a* as a numeric 'objective' for periphyton biomass for all hard-substrate rivers and streams in the Waikato-Waipā catchments.

3. Include a method in PC1 requiring identification of high-risk sites for periphyton in the Waikato-Waipā catchments, using the steps outlined above and require monitoring to assess whether the 'objectives' recommended in 1 and 2 are met over time at these sites.

Attribute Assessment - Principles for Attribute Inclusion

1. Does the attribute provide a measure of the value?

   Yes periphyton growth and biomass affects ecosystem health, also recreational and cultural uses of water.

2. Measurement and band thresholds

   - Are there established protocols for measurement of the attribute?

     Yes national protocols are available for both periphyton cover and periphyton biomass

   - Do experts agree on the summary statistic and associated time period?

     For periphyton biomass summary statistics and time periods are prescribed in the NOF Appendix 2 periphyton attribute. For periphyton cover methods in Matheson et al. (2012) are recommended.

   - Do experts agree on thresholds for the numerical bands and associated band descriptors?

     No, the experts have not had sufficient time to discuss numeric thresholds for periphyton and have instead focussed on a risk management approach to determine where there are issues associated with periphyton in the PC1 catchments. However, the experts acknowledge that there are existing standards for periphyton cover (25%) in the operative Waikato Regional Plan that could be useful as an interim approach. Some experts are of the view that in the absence of information a precautionary threshold should be applied.

3. Management and limits

- Do we know what to do to manage this attribute?

  Yes – manage dissolved nutrients in hard-bottomed rivers and streams where periphyton is able to grow on the substrate. Shade (from riparian planting/vegetation) is also a method for periphyton control in small rivers and streams (perhaps <5m in width). Flood frequency must also be considered due to its overriding influence on periphyton growth.

- Are the four contaminants (N, P, sediment and faecal microbes) direct drivers of this attribute?

  Yes, N and P are direct drivers of periphyton growth, flow regime (frequency of flood flows) is a critical factor controlling nuisance growth.

- Do quantitative relationships link the attribute state to limits and/or management interventions to control N, P, sediment and faecal microbes?

  Yes. However, these relationships can be site dependant depending on flow regime (flood frequency affects the degree of risk from nutrient enrichment) and shading of smaller rivers.

4. Evaluation of current state

- Is there data of sufficient quality, quantity and representativeness to assess the current state of the attribute within Waikato FMUs?

  No – currently there is only visual assessment of periphyton cover annually at REMS sites across the region. There is no monitoring of periphyton biomass. We recommend (as did the TLG) that a monitoring programme is implemented for sites in tributaries with a risk of benthic periphyton growth as described above.

5. Implications

- Can the social, cultural, economic and environmental implications of setting limits be assessed?

  Yes – reliant on assessing reductions in dissolved nutrients required in at risk sub-catchments and degree of shading provided by riparian planting/vegetation.

- Are we able to model scenarios for these attributes within the Healthy Rivers: Wai Ora timeframe?

  Potentially not. Initial assessment of the extent of risk in Waikato and Waipā rivers could be undertaken with current information. Reductions in dissolved nutrients are considered under approach 5 of the nutrients document. Methods are needed to ensure better monitoring information is available in future to manage the risk of nuisance periphyton in the hard-bottomed tributaries of the PC1 sub-catchments.

Attachment 10: Waikato Specific Fish IBI attribute for PC1

Waikato-specific Fish IBI

Fish sub-group: Gerry Kessels, Dean Miller, Hannah Mueller and Adam Canning

We propose the following attribute table, as derived from:

Joy (2007). A New Fish Index of Biotic Integrity using Quantile Regressions: the Fish QIBI for the Waikato Region. Environment Waikato Technical Report 2007/23. Environment Waikato: Hamilton, NZ.

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	**Fish Index of Biotic Integrity (F-IBI)**[1]	
Attribute Unit	Score between 0-60	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	Average	
A	≥47	Comparable to the best situations without human disturbance; all regionally expected species for the stream position are present. Site is above the 75th percentile of Waikato sites.
B	<47 and ≥36	Site is above the 50th percentile of Waikato sites but species richness and habitat or migratory access reduced. Shows some signs of stress.
C	<36 and ≥27	Site is above 25th percentile. Species richness is reduced. Habitat and or access is impaired.
Regional Bottom Line	**27**	
D	<27	Site is impacted or migratory access almost non-existent.

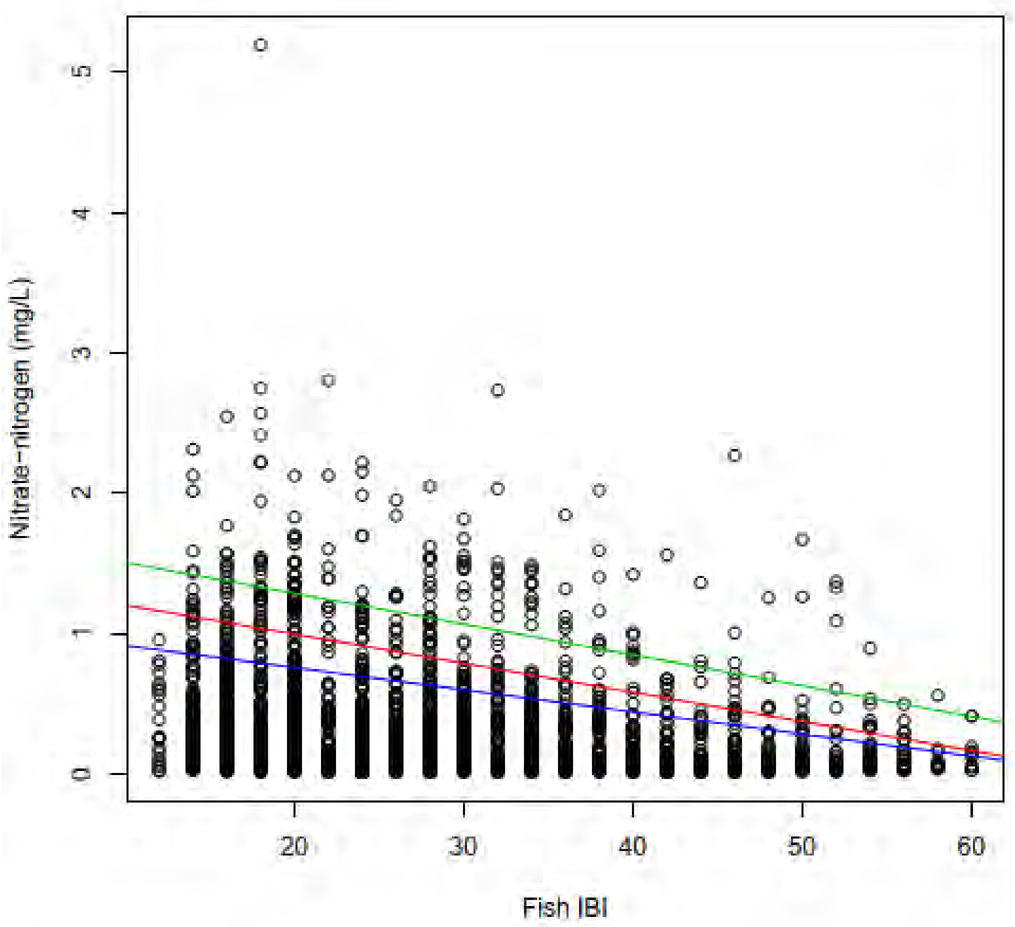
1. The Q-IBI as defined by Joy (2007). A New Fish Index of Biotic Integrity using Quantile Regressions: the Fish QIBI for the Waikato Region. Environment Waikato Technical Report 2007/23. Environment Waikato: Hamilton, NZ.
2. Applies only to wadeable rivers and fish are to be surveyed annually between December and March (inclusive) following the protocols in: Joy M, David B, and Lake M. 2013. *New Zealand Freshwater Fish Sampling Protocols (Part 1): Wadeable rivers and streams.* Palmerston North, New Zealand: Massey University.

1. The Fish IBI scores a site based the fish species present at a site relative to what is predicted to be there under ideal conditions. The IBI provides a value between 0 and 60, with 0 indicating no fish community at all (when there should be one) and 60 represents an extremely healthy fish community with all species expected being present. Unlike observed/expected community metrics, the IBI is based on functional groups of fish, eg "number of riffle dwelling species" appropriate for the altitude and distance in-land.

2. An attribute for fish, separate from macroinvertebrates and periphyton, is needed because fish respond to different stressors. For example, fish require greater interstitial spaces than invertebrates, have different sensitivity thresholds than macroinvertebrates (e.g., deposited sediment), and are more stable, long term integrators of impacts as higher trophic levels tend not to fluctuate as much as lower trophic levels (Jowett and Davey, 2007, Joy and Death, 2004, Canning, 2018, Leathwick *et al.*, 2005). Quantile regression also demonstrates that the probability of getting a high IBI score with high nutrients is very low. This is likely driven by indirect trophic effects, hypoxia and changes to dietary assimilation efficiency.

Assessment against criteria:

1. Does the attribute provide a measure of the value? **Yes**
2. Measurement and band thresholds:
   - Are there established protocols for measurement of the attribute? **Yes**
   - Do experts agree on the summary statistic and associated time period? **Yes**
   - Do experts agree on thresholds for the numerical bands and associated band descriptors? **Yes**
3. Management and limits:
   - Do we know what to do to manage this attribute? **Yes. It is a multi-stressor indicator but can be queried to determine the driver.**
   - Are the four contaminants (N, P, sediment & faecal microbes) direct drivers of this attribute? **Yes, direct (sediment) and indirect (nutrients). Indirect interactions should not minimised. No impact from faecal microbes**.
   - Do quantitative relationships link the attribute state to limits and/or management interventions to control N, P, sediment and faecal microbes? **Yes but not faecal microbes. See quantile regression example below with DIN vs IBI**



Evaluation of current state:

- Is there data of sufficient quality, quantity and representativeness to assess the current state of the attribute within Waikato FMUs? **Yes WRC has an extensive fish survey dataset**.

Attachment 11: Riparian Stream Cover Attribute for PC1

Proposed attribute – Riparian stream cover

Hannah Mueller

Attribute value

Does the attribute provide a measure of the value? **The attribute provides a measure of riparian stream cover related to the width of riparian margins, and percent cover in vegetation (length of stream bank cover).**

Measurement and band thresholds

Are there established protocols for measurement of the attribute?

Suitable protocols could be developed based on SEV Physical Habitat Quality Assessment protocols, DOC Stream Habitat Assessment[17]

Do experts agree on the summary statistic and associated time period?

Agreement could be found based on protocols applied, annual assessments are recommended

Do experts agree on thresholds for the numerical bands and associated band descriptors?

Thresholds have been established based on current knowledge around nutrient/contaminant attenuation of riparian zones.

Management and limits

Do we know what to do to manage this attribute?

Attribute can be managed through FEPs.

Are the four contaminants (N, P, sediment and faecal microbes) direct drivers of this attribute?

No – attribute will directly manage 3 out of 4 contaminants, with N being partially managed by this attribute

Do quantitative relationships link the attribute state to limits and/or management interventions to control N, P, sediment and faecal microbes?

Yes – elaborated in background discussion in this report; clear quantifiable linkages between riparian cover and contaminant loss from land use

Evaluation of current state

Is there data of sufficient quality, quantity and representativeness to assess the current state of the attribute within Waikato FMUs

Some high-level information on vegetation cover exists for the Waikato River (detailed below). Current WRC REMS protocols focus on instream vegetation, but SEV protocols record habitat, and REMS could be adapted to record data for this attribute.

[17] http://knowledgeauckland.org.nz/assets/publications/GD2011-001-Stream-ecological-valuation-SEV-users-guide-reprint-Nov-2015.pdf
https://www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-freshwater-ecology/im-toolbox-freshwater-ecology-stream-habitat-assessment-field-sheet.pdf

Proposed Attribute Tables

Value	Ecosystem health		
Freshwater body type	Rivers and streams		
Attribute	Riparian buffer		
Unit	Riparian vegetation width		
Attribute state	**Numeric attribute state**		**Narrative attribute state**
	m (average width)	**m (minimum)**	
A	**≤25**	**≤20**	Wide, resilient buffer vegetation close to natural state, high species diversity. Optimal shading, leaf litter and large wood inputs into the stream ecosystem.
B	**≤15**	**≤10**	Buffer vegetation present in most areas. Moderate to high species diversity. Some areas of optimal shading, leaf litter and large wood inputs into the stream ecosystem.
C	**≤5**	**≤3**	Riparian buffer vegetation present, but sparse. Moderate species diversity. Limited shading function, limited inputs of leaf litter and large wood into the stream system.
Bottom line	**5**	**3**	
D	**<3**	**<1**	Predominantly open channel, with occasional riparian vegetation. Low species diversity. The stream system is impacted by lack of shading, and minimal inputs of lead litter and large wood into the stream system.

Value	Ecosystem health	
Freshwater Body Type	Rivers and streams	
Attribute	Riparian cover	
Attribute Unit	Percent cover in riparian vegetation	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	Proportion of upstream reaches with riparian vegetation[1]	**Description**
A	≥80%	Most upstream reaches have riparian vegetation. Streams have high species diversity associated with riparian cover.
B	≥60% & <80%	A substantial proportion of upstream reaches have riparian vegetation. Streams have a moderate-high species diversity associated with riparian cover.
C	≥40% & <60%	Approximately half of upstream riparian vegetation. Streams have moderate species diversity associated with riparian cover.
Bottom Line	40%	
D	≥20% & <40%	Most of the upstream reaches have riparian that lacks riparian vegetation. There is a moderate-low diversity of species associated with riparian cover.
E	<20%	Almost all of the upstream reaches have riparian that lacks riparian vegetation. There is a low diversity of species associated with riparian cover.

1. Measured as the percentage of upstream river reach (including all tributaries described in the River Environments Classification) by length that has at least a 5m wide riparian buffer on each side of the stream that is covered in vegetation that is not grazed by cattle, trimmed or mown and is appropriate for the area. Buffers are not required to be fenced.

Background: Function of riparian buffers for ecological stream health

Vegetated riparian buffers can help to:

- Reduce nutrients (Parkyn, 2004, Parkyn et al., 2003)
- Reduce pathogen inputs
- Stabilise streambanks, limit erosion and reduce sediment inputs (Naiman and Décamps, 1997, Parkyn, 2004, Quinn and Stroud, 2002)
- Regulate water temperature (Quinn et al., 1997)
- Regulate water flows
- Provide habitat for adult aquatic insects (Collier and Smith, 1997)
- Provide and protect habitat for native fish
- Reduce excessive periphyton growth (Rutherford et al., 1997, Storey and Cowley, 1997)

- Provide food for invertebrates and fish (Collier et al., 2002, Jefferies, 2000, Thompson and Townsend, 2003)
- Influence food web stability (Huxel and McCann, 1998, Canning et al., 2018, Huxel et al., 2002, Jefferies, 2000, Takimoto et al., 2002, Thompson and Townsend, 2003)

It is for all these reasons that a compulsory objective on riparian cover is proposed. Death and Collier (2010) examine the relationship between upstream riparian cover and stream invertebrate biodiversity. They found that streams with 40-60% upstream native riparian vegetation is likely to retain 80% of the biodiversity that would be found in pristine forest streams, and that those with 80-90% native forest or scrub yields macroinvertebrate assemblages indicative of clean water. This has informed the basis of the proposed bottom-line and is consistent with the O/E MCI attribute, which also has a 20% deviance from reference state as the bottom-line.

Riparian management can be viewed as a last line of defence for attenuating contaminants before entering the stream. Fencing stock out of streams and retiring riparian margins from agricultural land use are also particularly important practices to improve stream water quality. Buffer zones can filter contaminants and sediments from overland flow by increasing the infiltration into soil, intercepting particulates, and removing soluble nutrients by plant uptake and denitrification (Parkyn 2004).

Quinn et al. (1997) found that ‘stream health’, as indicated by invertebrate communities, was similar in pine plantation streams to that in native streams (and very different from the pasture streams) in the Hakarimata Range – despite the sedimentation and turbidity in the pine plantation streams from bank erosion.

Parkyn et al. (2000) recommended a buffer width of 10-20 m as the minimum necessary for the development of sustainable indigenous vegetation with minimal weed control, and to achieve many aquatic functions.

Riparian planting effects on stream habitat for aquatic biota include:

- Provision of woody debris as trees fall into streams over the long term, providing habitat diversity and cover for aquatic invertebrates and fish;
- Increased shade and provision of terrestrial food sources (fallen leaves etc.) as riparian plants grow so that levels of instream productivity and trophic pathways resemble the natural state;
- Reduced erosion and inputs of fine sediment from (1) exclusion of livestock, leading to an improvement in streambed and bank habitat and (2) interception of hillslope sediment over the long term, and (3) tree roots that stabilise the stream banks and provide habitat;
- Reduced water temperatures if sufficient lengths of upstream shade exist, and lower air temperatures and humidities, and less wind exposure, in the riparian zone where the adult stages of some aquatic insects spend part of their lives and some native fish lay their eggs (banded kokopu, short-jawed kokopu).
- Vegetation in the riparian zone can influence water flow, both surface and subsurface (through root systems) and has direct effects on stream functioning.
- High light levels from deforestation around streams leads to increases in algae and in-stream primary production, and changes to invertebrate community composition.
- Forest vegetation in particular can shade streams and lower stream temperatures. Stream temperature has a direct impact on aquatic species as most metabolic processes are accelerated with increasing temperature and many fish and invertebrate species have thermal tolerances that can be exceeded in unshaded streams (Quinn et al. 1994, Martin et al. 1999).

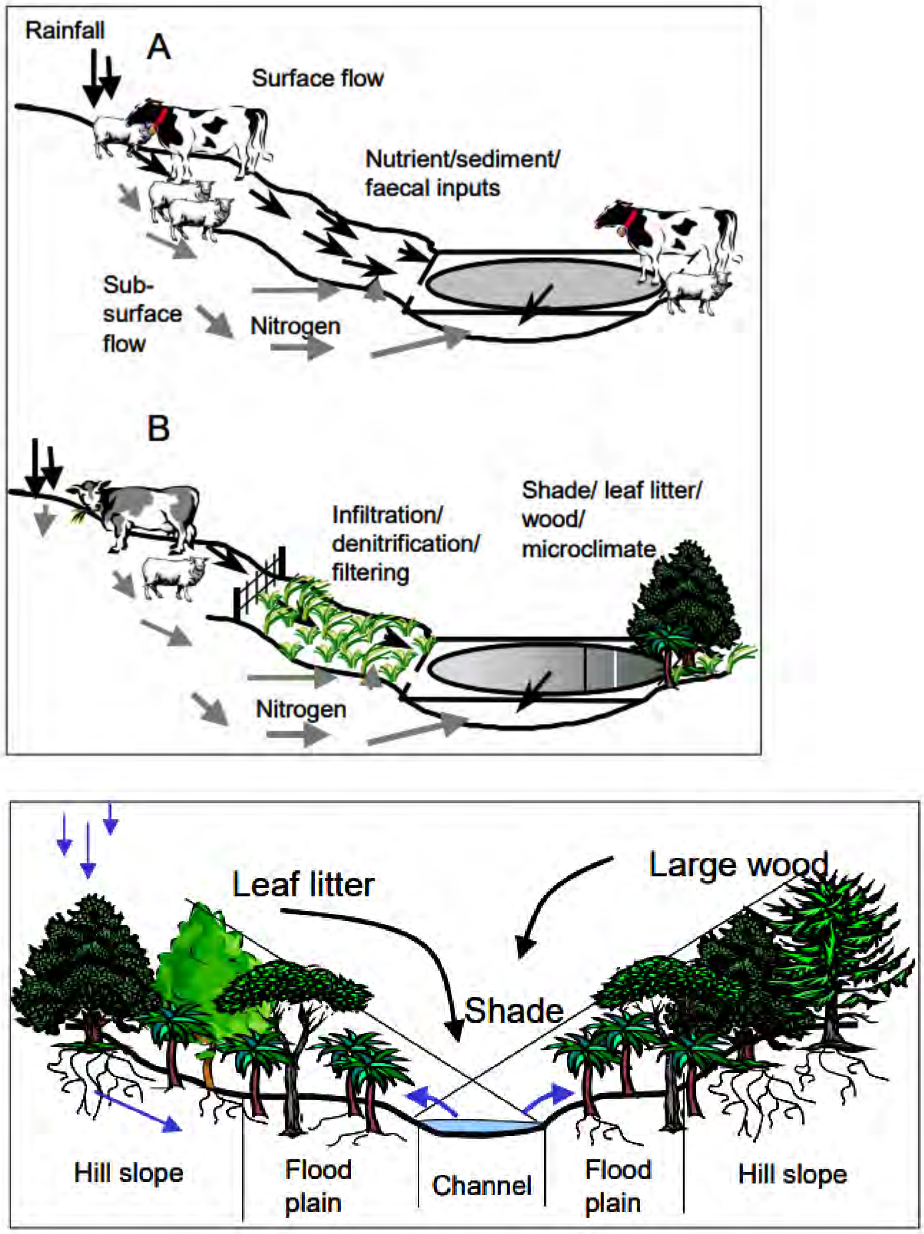
- Terrestrial insects may also be attracted to vegetated riparian zones and become a valuable food source for fish when they fall into the stream (Barling & Moore 1994).

Nutrient removal

- Grass buffer strips are effective at filtering sediment and sediment-associated pollutants (particulate P and N) from surface runoff
- Nitrate removal from subsurface flows is greater in forested buffers, partly through uptake by plants (Fennessy & Cronk 1997, Martin et al. 1999).
- The main mechanism by which nitrate is removed from groundwater is thought to be biological denitrification.
- Riparian carbon inputs to streams (i.e., leaf litter and wood) can also increase the potential for stream bed denitrification
- Nutrient removal efficiencies in buffers may also be affected by the age of the vegetation, with more nutrient uptake during the growth phase (Mander et al. 1997)

Locations of riparian buffers

Riparian buffers are most effective when targeted towards small headwater streams. Smith (1989) found that even retiring 10-13m of pasture can remove up to 67% of nitrate and 55% of dissolve phosphorus and reduced instream suspended sediment by up to 87% flowing into small headwater streams. However, the effectiveness of riparian buffers to remove nutrients is highly variable and depends on plant nutrient uptake rates (which can change as the riparian matures and recycling occurs), and the direction, depth of velocity of flows (Fennessy and Cronk, 1997, Parkyn, 2004). Therefore, riparian buffers cannot be used alone to control nutrients, rather the best way is reducing direct and indirect nutrient inputs. The proposed bottom-line is not intended as mechanism to reduce nutrient inputs, though there may be some benefit. Therefore, a relatively small buffer width of 5m is suggested as the minimum required to shade small headwater streams and provide habitat and food for insects and fish. The criteria do, however, apply to all streams regardless of how small (as long as it is defined in the River Environment Classification) – an important distinction from the criteria applied in the Clean Streams Accord.


Rainfall
A
Surface flow
Nutrient/sediment/
faecal inputs
Sub-
surface
flow
Nitrogen
B
Infiltration/
denitrification/
filtering
Shade/ leaf litter/
wood/
microclimate
Nitrogen
Leaf litter
Large wood
Shade
Hill slope
Flood
plain
Channel
Flood
plain
Hill slope

arkyn 2004

Current data on riparian vegetation

There is not currently a suitable database of riparian vegetation cover, widths and fencing, though some regional councils may hold this information for their region. Furthermore, for many regions the extent of the individual Freshwater Management Units has not been defined. Therefore, it is very difficult to assess current national state against the proposed riparian attributes.

In the absence of this data, a very approximate gauge can be assessed using the Freshwater Environments New Zealand (FENZ) geo-database. FENZ holds information on the proportion of native vegetation cover within 100m of a stream edge based on the Land Cover Database (LCDB) V1. If it is assumed that 5% cover corresponds with a 5m vegetation buffer, then the length of waterways with riparian cover can be assessed. It is important to note that the FENZ geo-database does not account for exotic vegetation cover, any recent planting efforts (such as the Clean Streams Accord), in many cases does not correspond to an immediate continuous buffer and does not include data on cattle exclusion. Table 1 shows the proportion of rivers within each region that have at least 5% native vegetation cover within 100m of the stream edge. This suggests that at the regional level, all regions are likely to meet the bottom-line. However, the proposed criteria applies at the FMU scale not the regional scale, and it is highly likely that FMUs without substantial conservation estate will fail the proposed bottom-line. For more insight, Table 2 shows the proportion of rivers (by length) within the catchment of Order 7 rivers that have at least 5% native vegetation cover within 100m of the stream edge. Figure 1 shows in red the river reaches that do not contain at least 5% native vegetation within 100m of the stream edge.

Table 1 The proportion of rivers (by length) within each region that have at least 5% native vegetation cover within 100m of the stream edge.

Region	% of river reaches	Region-wide grade
Northland	51	Fair
Auckland	50	Fair
Waikato	48	Fair
Bay of Plenty	72	Good
Gisborne	56	Fair
Hawkes Bay	56	Fair
Taranaki	54	Fair
Manawatu-Wanganui	55	Fair
Wellington	61	Good
Tasman	74	Good
Nelson	78	Good

West Coast	90	Excellent
Canterbury	69	Good
Otago	65	Good
Southland	73	Good

Table 2. The proportion of rivers (by length) within the catchment of Order 7 rivers that have at least 5% native vegetation cover within 100m of the stream edge.

Catchment	%	Catchment grade
Ashley River	79%	Good
Buller River	92%	Excellent
Kaituna River	66%	Good
Mokau River	44%	Fair
Ngaruroro River	63%	Good
Opihi River	51%	Fair
Oreti River	42%	Fair
Rakaia River	75%	Good
Rangitaiki River	47%	Fair
Rangitikei River	59%	Fair
Temuka River	50%	Fair
Tukituki River	25%	Poor
Waiau River	84%	Excellent
Waikato River	43%	Fair
Waimakariri River	70%	Good
Waioho Stream	64%	Good
Waipaoa River	46%	Fair
Wairoa River	45%	Fair
Whakatane River	57%	Fair
Manawatu River	66%	Good

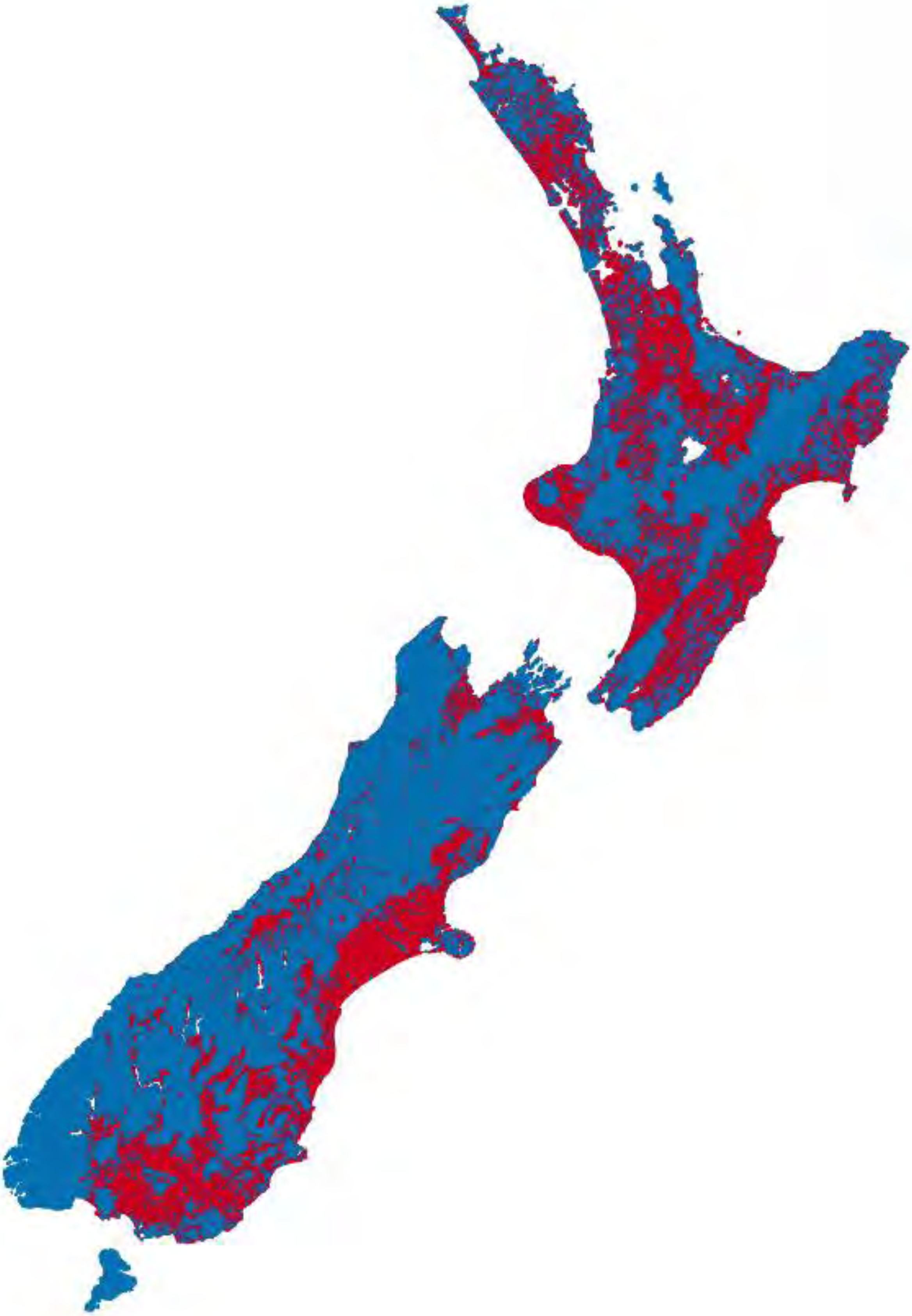


Fig. 1. Red shows the river reaches that do not contain at least 5% native vegetation within 100m of the stream edge.

Buffer width – analysis of existing studies (from Parkyn 2004)

Contaminant	Buffer width	Removal (%)	Slope (%)	Farm type	Buffer type	Reference
Sediment	30.5	90	2			Wong & McCuen (1982)
Sediment	61	95	2			Wong & McCuen (1982)
Sediment	24.4	92			Veg.	Young et al. (1980)
Sediment	22.9	33		dairy	Filter strip	Schellinger & Clausen (1992)
Sediment	61	80			Grassy swale	Horner & Mar (1982)
Sediment	30	75-80		Logging activity		Lynch et al. (1985)
Sediment	9.1	85	7 and 12		Grass VFS	Ghaffarzadeh et al. (1992)
NO3-N, NH4-N, PO4-P	4.6	90%			Grass VFS	Madison et al. (1992)
NO3-N, NH4-N, PO4-P	9.1	96-99.9			Grass VFS	Madison et al. (1992)
Sediment, N, P	9.1	84, 79, 73	11-16		Grass VFS	Dillaha et al. (1989)
Sediment, N, P	4.6	70, 61, 54	11-16		Grass VFS	Dillaha et al. (1989)
NO3-N	10	99.9%			forested	Xu et al. (1992)
N, P	19	89, 80			forested	Shisler et al. (1987)

Table 2: Some New Zealand studies of efficiency.

Contaminant	Buffer width	Removal (%)	Farm type	Buffer type	Reference
Nitrate	c. 3-4m	88-97	pasture	Riparian organic soils - wetland	Cooper 1990
Nitrate	c. 3-4m	0-62	pasture	Riparian mineral soils - wetland	Cooper 1990
Nitrate		−140-91	pasture	streambed	Cooper 1990
Nitrate		32-100%	Waste water treatment	wetland	Cooper 1994
Nitrate	10-13m	67	pasture	Retired pasture	Smith 1989
Dissolved P	10-13m	55	pasture	Retired pasture	Smith 1989
Particulate P, N	10-13m	80, 85	pasture	Retired pasture	Smith 1989
Total Suspended solids	10-13m	87	pasture	Retired pasture	Smith 1989

Flow type	Buffer type	Buffer width (m)	N retention (%)	N inflow (mg/l)
Subsurface	Forest	9	61-97	180
	Forest	10	70-90	13.5
	Forest	10	Up to 77	0.6-2.5
	Forest	19	93	7.4
	Forest	>20	90	7.4
	Forest	>20	99	6.8
	Forest	20	Up to 87	0.6-2.5
	Forest	25	68	~2-6
	Forest	26	~100	2-9
	Forest	30	~100	5
	Forest	>10-50	94	1.8
	Forest	50	95	8
	Forest	60	~100	10
	Herbaceous	22	84	2-12
Sub- and surface	Forest	16	90	10
Surface	Forest	19	60	4.5
	Forest	>20	79	4.5
	Herbaceous	5	54	-
	Herbaceous	8	20	20
	Herbaceous	9	73	-
	Herbaceous	16	50	20
	Herbaceous	27	84	-
	Herbaceous	30	11	20

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Attachment 12 - Lakes attribute

Table 1. Proposed short and long-term lake water quality targets (PC1 FMU delineation)

PC1 FMUs	Annual median Chl a (mg/m3)				Annual Median TN (mg/m3)				Annual Median TP (mg/m3)			
	Short-term target (20% improvement on current value)		Long term year target (80 years)		Short-term target (20% lower than current)		Long term year target (80 years)		Short-term target (20% lower than current)		Long term year target (80 years)	
Dune	2	A	2	A	386	B	300	A	10	A	10	A
Peat	20	D	12	C	1296	D	750	C	63	D	50	C
Riverine	29	D	12	C	1473	D	750	C	92	D	50	C
Volcanic	28	D	12	C	946	D	625	B-C	110	D	50	C

- Short-term target = 20% improvement on current state (medians for each FMU)
- Long term targets as per PC1 Table 3.11-1, except red text, which are targets proposed by Director-General that reflect what is considered achievable based on current state

Table 2. Proposed short and long term lake water quality targets (alternative FMU delineation)

FMU #	**Annual median Chla (mg/m3)**				**Annual Median TN (mg/m3)**				**Annual Median TP (mg/m3)**			
	Short-term target*		**Long term year target (80 years)**		**Short-term target ***		**Long term year target (80 years)**		**Short-term target ***		**Long term year target (80 years)**	
1	33	D	12	C	674	C	500	B	124	D	50	C
4	22	D	12	C	1489	D	750	C	94	D	50	C
5	30	D	12	C	1186	D	750	C	79	D	50	C
6	12	C	5 - 12	B-C	1197	D	500-750	B-C	50	C	50	C
7	24	D	12	C	1218	D	750	C	97	D	50	C
9	2	A	2	A	394	B	300	A	11	B	10	A
10	46	D	12	C	1488	D	800	C	95	D	50	C

- Short-term target = 20% improvement on current state (medians for each FMU)
- Long term targets as per PC1 Table 3.11-1, except red text, which are targets proposed by Director-General that reflect what is considered achievable based on current state

Relevant FMUs from Ozkundakci, D. (2015) An approach for reconciling the lake type classification for the Waikato region.

Attachment 13: Whangamarino attribute

Waikato Healthy Rivers Plan Change 1
Water quality expert caucusing: Whangamarino Wetland (TN and TP) and other wetlands

13 June 2019

Hugh Robertson

Summary

This report details the proposed amendments to Table 3-11.1 in relation to Whangamarino Wetland.

Whangamarino Wetland is a 7000 ha freshwater wetland and a waterbody that receives direct inputs of, and accumulates, water quality contaminants, particularly nutrients (TN, TP) and sediment.

It outlines:

- The setting of attributes and numeric targets for TN and TP for the Whangamarino River at Island Block Road
- Recommended changes to the delineation of sub-catchment boundaries
- Recommended inclusion of a monitoring site associated with the Pungarehu Stream/Canal, a contributing sub-catchment that was not included in Table 3-11.

In addition, this report presents the proposed narrative targets for TN, TP, sedimentation and hydrological alteration for other wetlands. This will be a separate narrative table in PC1.

Context

PC1 Table 3.11-1 (as notified) does not contain any targets for nutrients (TN, TP) that relate to managing (maintaining and enhancing) the ecosystem health of Whangamarino Wetland.

Whangamarino Wetland is a 7000 ha freshwater wetland. It is a receiving waterbody that receives direct inputs of, and accumulates, water quality contaminants, particularly nutrients (TN, TP) and sediment.

Ecosystem health in the wetland is adversely affected by elevated nutrient levels. Elevated TN and TP is directly associated with increased abundance of exotic wetland plants, and loss of native wetland plants. The link between nutrient inputs and changes in wetland plant composition is established in literature (refer below).

There was general consensus on Day 1 of the Expert Conferencing on 15 April 2019 that inclusion of water quality attributes (TN and TP) for Whangamarino Wetland was appropriate. It was recommended that the attributes and numeric targets apply at the *Whangamarino River at Island Block Road* monitoring site, given this site is associated with the Whangamarino Wetland as a receiving waterbody.

Attribute description and application: Whangamarino Wetland - Nutrients

Attributes: Total Nitrogen (TN) concentration, Total Phosphorus (TP) concentration.

Note: Nitrogen and Phosphorus cycles in wetlands are dynamic. Transformation and uptake of inorganic and organic forms change in response to physico-chemical conditions, e.g. pH, water levels. Total N and Total P are considered the most appropriate overall measure of nutrient enrichment.

Applied to: Whangamarino River at Island Block Road, which is WRC water quality monitoring site located within the wetland.

Value/s the attribute is providing for: Ecosystem health, principally to maintain and enhance native wetland plant dominance and diversity, by limiting nutrient and sediment contaminants that promote exotic plant species.

Basis: The application of TN and TP to Whangamarino Wetland is supported by three corresponding lines of information/evidence, that is:

- *Direct link between TN and TP and native plant dominance*
  Elevated nutrients are directly associated with loss of ecosystem health as exotic species are more dominant in enriched wetlands. Data from Whangamarino indicate a linear relationship for both TN and TP with exotic species abundance. i.e. both nutrients.

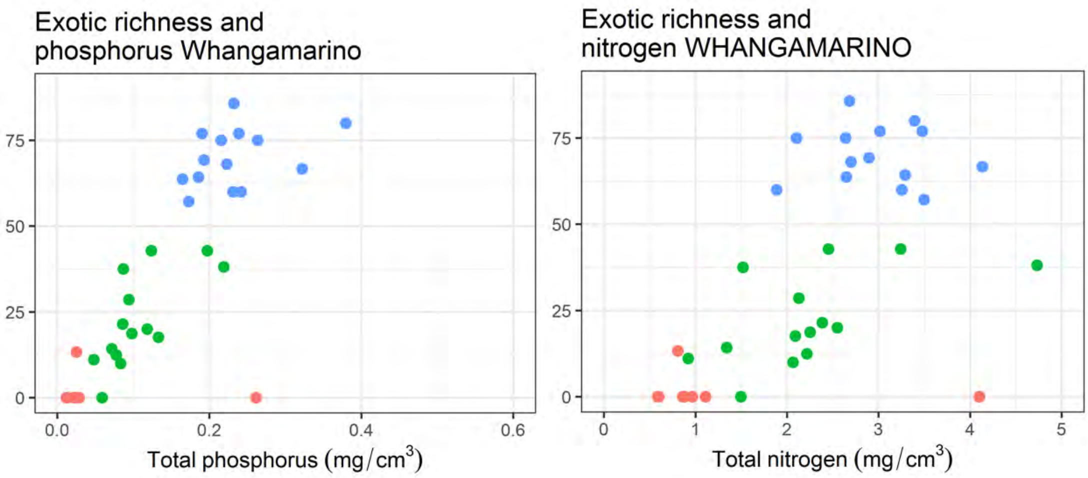

Figure 1: Relationship between soil total phosphorus (A) and soil total nitrogen (B) and the richness of exotic wetland plants in Whangamarino. [Source: EIC, H Robertson, Block 1 HRPC]

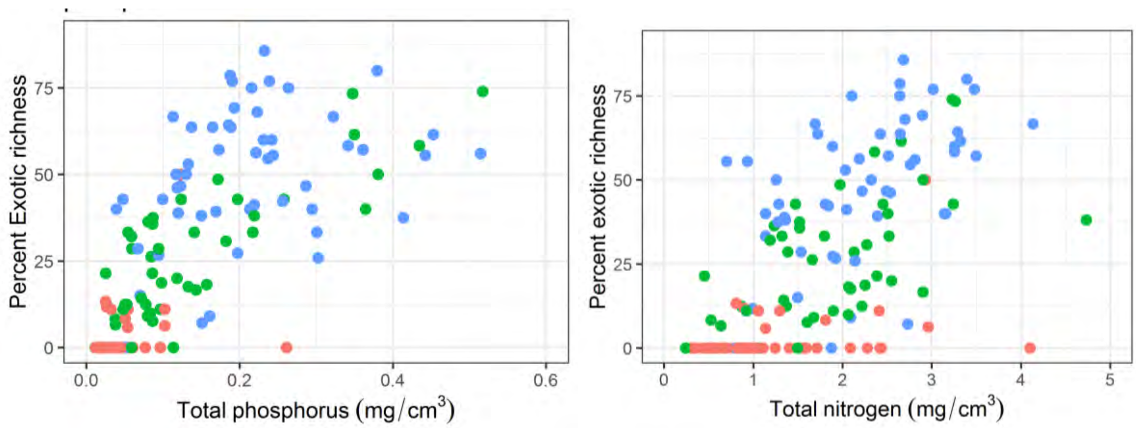

Figure 2: Relationship between soil total phosphorus (A) and soil total nitrogen (B) and the richness of exotic wetland plants in three New Zealand wetlands (Whangamarino, O Tu Wharekai, Awarua). [Source: EIC, H Robertson, Block 1 HRPC]

This relationship between changes in vegetation composition and productivity and nutrient enrichment is consistent with national (e.g. Clarkson et al. 2004, Sorrell et al. 2007, Blyth et al. 2013) and international literature (e.g. Bridgham et al 1998, Güsewell et al. 2003, Verhoeven et al. 2006, Venterink et al .2002) that reiterate that Nitrogen and Phosphorus are primary nutrients in driving wetland productivity and contribute to changes in plant species and biomass when elevated.

- *Current state of surface water quality in Whangamarino Wetland*
  WRC monitoring confirms the degraded state (over-allocation) at Whangamarino Wetland (Whangamarino River at Island Block Road) in terms of TN and TP, relative to the waterbodies that were natural water sources for the wetland, such as the Waikato River (Table 1).

  Information on nutrient loads to Whangamarino is also available (Annex 2). Investigations undertaken by PDP (2018) confirm that the wetland is attenuating a significant volume of contaminants (Annex 2b).

Table 1. Current state of water quality. Source: LAWA accessed 7 February 2019)**.** Refer to Annex 1 for other sub-catchments.

Monitoring site	**TP Median Conc. (mg/m3)**	**TN Median Conc. (mg/m3)**	**Comments**
Whangamarino River at Island Block Rd (Whangamarino Wetland)	131	1960	Highly elevated TP and TN relative to water bodies
Reference sub-catchments Mangatangi River SH2 Maramarua	62	530	Sub-catchment in better WQ state (closer to reference). Wetland function naturally driven by N and P concentrations in main stem
Waikato River at Rangiriri	52	620	Waikato River previously source of water to Whangamarino Wetland. Wetland function would have naturally been driven by N and P concentrations in main stem

The Whangamarino at Island Block Road water quality monitoring site is representative of the surface water across Whangamarino Wetland. This is because the Whangamarino River and the wetland are hydrologically connected. For example, the water level at this site is >3.2 m-asl for 70% of the time (Annex 3) and at this stage height over 1200 ha of the wetland is inundated (Annex 4).

Figure 3 below illustrates the hydrological connection between the river and wetland in Whangamarino. Therefore, setting TN and TP targets for the Whangamarino River at Island Block Road is considered appropriate as it represents the wetland receiving environment.

Figure 3.

- *Current state of wetland soil TN & TP*
  The current state of TN and TP in wetland soils in the swamp (TN, TP), fen (TN, TP) and bog (TN)wetland type is elevated relative to national wetland data (Clarkson et al. 2015), refer to Table 2.

  The 'swamp' wetland type is the primary receiving environment for surface water inputs of nutrients, although other wetland types (particularly fen) are also subject to contaminant loads.

Table 2.

Total phosphorus (TP) and total nitrogen (TN) concentration for the main wetland types in Whangamarino Wetland (DOC monitoring 2013), relative to wetland nutrient levels from national wetland monitoring (Clarkson et al. 2015).

Wetland type	Mean TP in wetland soils (mg/cm3) **[National]**	Mean TP in wetland soils (mg/cm3) **[Whangamarino]**	Mean TN in wetland soils (mg/cm3) **[National]**	Mean TN in wetland soils (mg/cm3) **[Whangamarino]**
Swamp	0.19	0.23	1.79	2.98
Fen	0.08	0.12	1.33	2.33
Bog	0.06	0.03	0.92	1.14

The direct linkage between surface water quality and wetland nutrient status is further illustrated in Figure 4. Habitats in Whangamarino Wetland with highest TN and TP levels are those areas of wetland most frequently inundated with surface water.

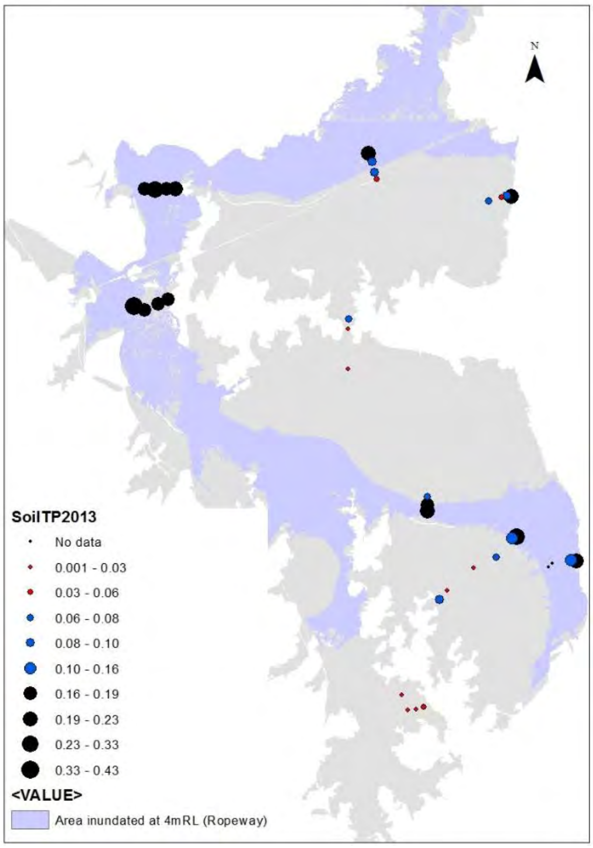

Figure 4: Variation in wetland Total Phosphorus (mg/cm3) in Whangamarino Wetland. Areas shaded darker depict lower-lying habitat (<4m amsl) that are associated with the swamp wetland type. [Source: EIC, H Robertson, Block 1 HRPC]

Published research by Blyth and others (2013) also provides evidence of the direct link between surface water quality and wetland nutrient status.

Figure 5 illustrates results from a monitoring transect in Whangamarino that transitions from the Whangamarino River into the wetland (Annex 5). Wetland habitats that are closer to the Whangamarino River have much higher mineral content (from catchment inputs) and high TN and TP concentrations.

Figure 5 also illustrates the historical extent of the low-nutrient status vegetation dominated by native *Baumea* and *Empodisma* species (Bt-Emp) that has retreated in its distribution. The cause of this retreat is linked to elevated nutrients and altered hydrology.

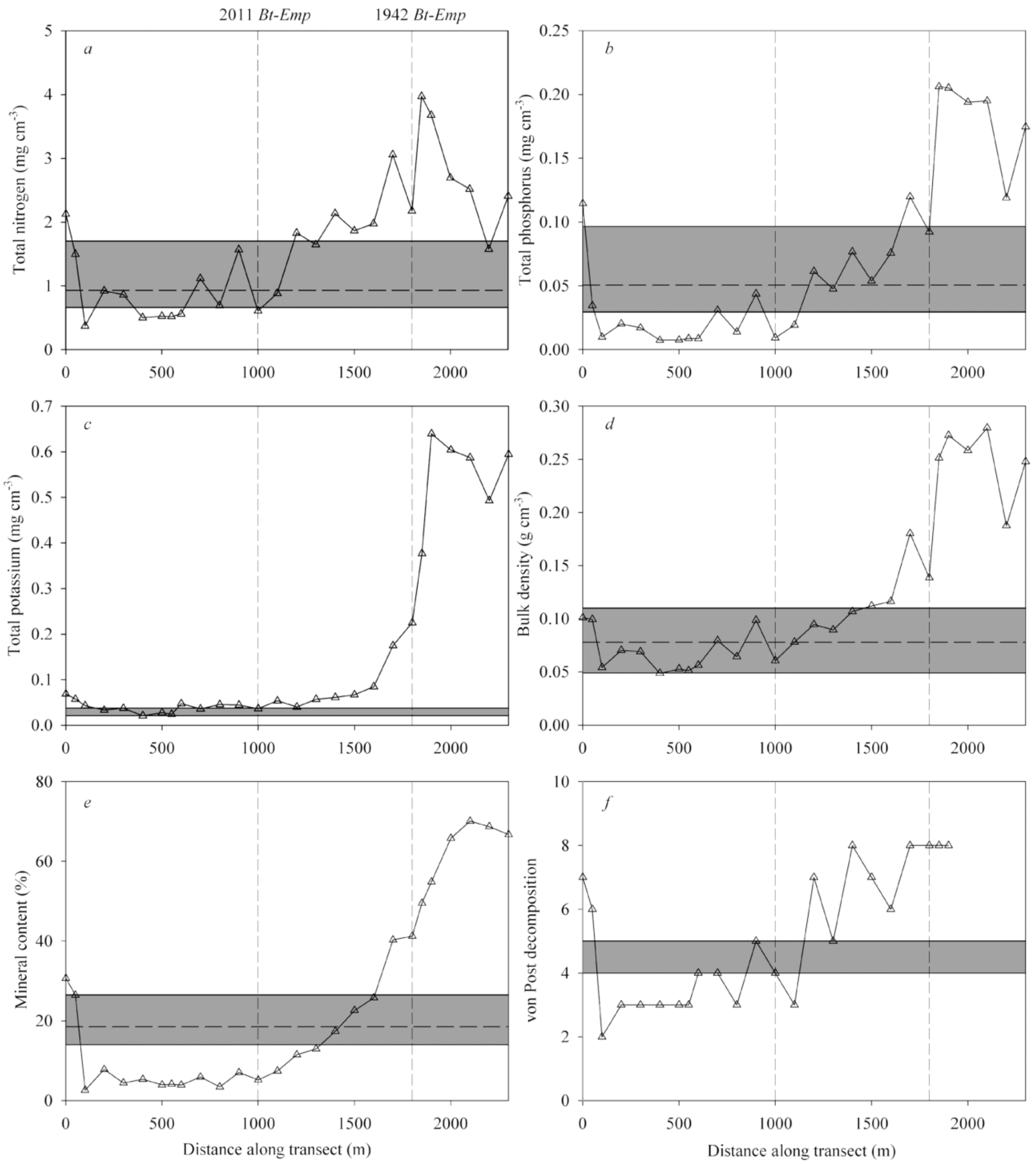

Figure 5

Wetland soil nutrient and physical characteristics along the ecohydrological transect in Whangamarino Wetland. Left hand y-axis corresponds with the Whangamarino River (a) total nitrogen, (b) phosphorus and (c) potassium, (d) bulk density, (e) mineral content and (f) von Post decomposition index. Shaded bands indicate medians (dashed horizontal lines), upper and lower quartiles (outer edge of bands) for each indicator from the Bt-Emp group included from the study conducted by Clarkson et al. (2004a). Vertical dashed lines indicate the boundary between the Bt-Emp and L. scoparium vegetation groups in 1942 (1800 m) and 2011 (1000 m). [Source: Blyth et al. 2013]

Targets: It is recommended to set 80-year targets and associated short-term targets (%improvement) for TN and TP concentration for Whangamarino Wetland at Island Block Road. The proposed targets are set out in Table 3.

Table 3.

Attribute	Site	Current state	80-year	Short-term
TP Median Conc. (mg/m3)	Whangamarino River at Island Block Rd (Whangamarino Wetland)	131	50	10% improvement over 10 years, 20% over 20 years
TN Median Conc. (mg/m3)	Whangamarino River at Island Block Rd (Whangamarino Wetland)	1960	800	10% improvement over 10 years, 20% over 20 years

The targets aim to achieve a progressive reduction in TN and TP concentrations at Whangamarino Wetland, towards a nutrient state that supports natural wetland functioning and native wetland plant communities (Ecosystem Health). The targets are aligned with the water quality targets proposed in PC1 for Riverine Lakes and the Waikato River (main stem).

TN and TP concentration is recommended as the measurement statistic (compared to nutrient load) because an improvement in long-term *water quality* is the ultimate outcome required which will also achieve a reduction nutrient load. Recognising that large discharges of load from regulated structures is an issue, this does not diminish from the need to improve water quality during low flows as well.

The 80-year numeric targets for TP (50 mg/m3) and TN (800 mg/m3) for Whangamarino River at Island Block Road have been determined based on:

- the current degraded state of surface water quality (Table 1)
- data confirming that habitats which receive surface water inputs have higher TN and TP levels in wetland soils (Table 2)
- the direct link between TN and TP and ecosystem health (exotic plant abundance) at Whangamarino, which is consistent with scientific literature
- the current state of water quality in water sources that represent natural inputs to the wetland (Waikato, Maramarua, Table 1). Current nutrient levels at these sites are TP 50-60 mg/m3 and TN 500-600 mg/m3alignment with water quality targets proposed in PC1 for Riverine Lakes and the Waikato River main stem (TP 50 mg/m3; and TN 800 mg/m3)
- acknowledgment that targets of TP 50 mg/m3 and TN 800 mg/m3 will achieve a reduction in nutrient inputs towards a state that will improve ecosystem health, and is in the range of water quality for natural inputs to the wetland (Waikato, Maramarua)
- recognition that the surface water quality monitoring site at Whangamarino River at Island Block Road represents the wider wetland receiving environment and is more effectively monitored than a broad spatial survey of wetland soils. Wetland soils are a long-term measure of wetland nutrient status and will not be adequately responsive to management interventions

Assessment against principles for attribute development

1. Does the attribute provide a measure of the value?	Provides for ecosystem health (wetland plants)
2. Measurement and band thresholds • Are there established protocols for measurement of the attribute? • Do experts agree on the summary statistic and associated time period? • Do experts agree on thresholds for the numerical bands and associated band descriptors?	Standard water quality monitoring Annual median Proposed 80-year target achieves progressive reduction towards desired end-state (TP:50, TN:800)
3. Management and limits • Do we know what to do to manage this attribute? • Are the four contaminants direct drivers of this, attribute? • Do quantitative relationships link the attribute state to limits and/or management interventions to control N, P, sediment and faecal microbes?	Yes. Management of nutrient inputs from sub-catchment Yes. Corresponds to *nutrients* Yes. Refer modelling applied in PC1 for nutrient management
4. Evaluation of current state • Is there data of sufficient quality, quantity and representativeness to assess the current state of the attribute within Waikato FMUs?	Yes. Long-term monitoring site

Amendment to sub-catchment boundaries

Application of Table 3.11-1 necessitates that sub-catchment boundaries are accurately aligned to the waterbodies and hydrological functioning of their respective catchment.

PC1 has incorrectly delineated the *Waikato at Mercer* sub-catchment. This sub-catchment inadvertently includes the Maramarua River sub-catchment, which flows into Whangamarino River near Island Block Road.

It is recommended to split the Waikato at Mercer sub-catchment (A) so that the Maramarua sub-catchment can be aligned to Whangamarino Wetland (as shown in B). See Figure 6.

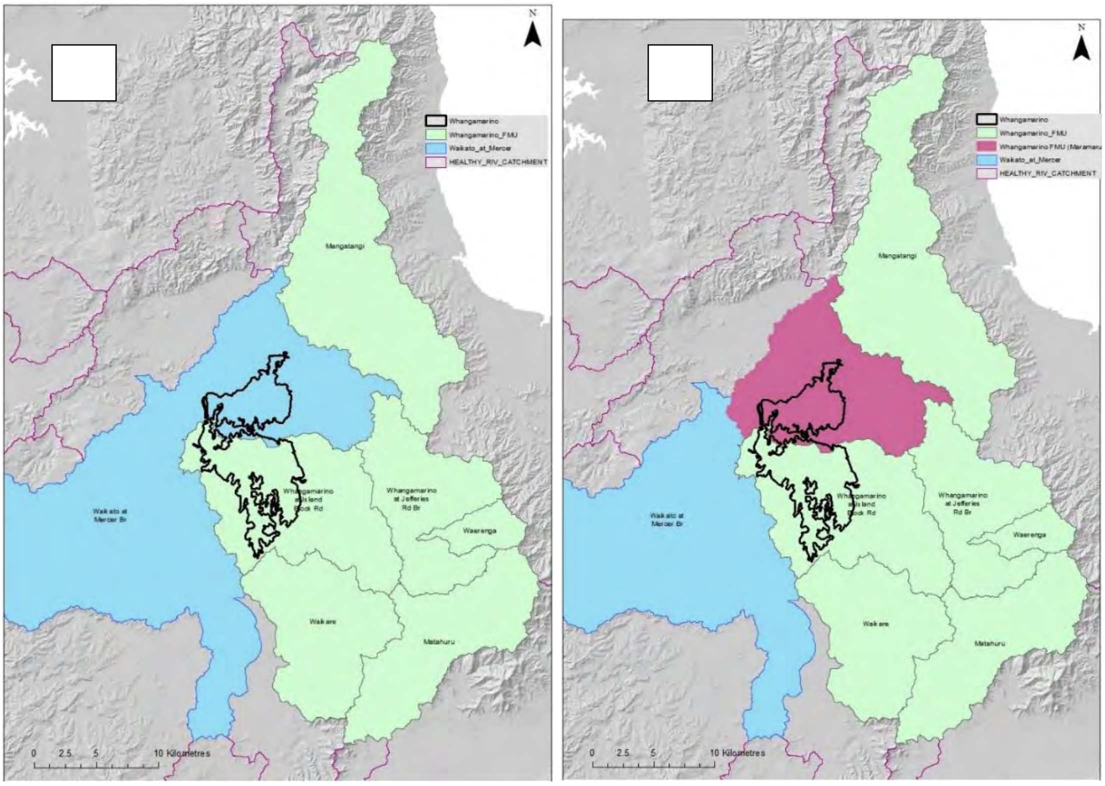

Figure 6. Amending the mapping of sub-catchments that contribute to Whangamarino Wetland.

Additional monitoring/sub-catchment site – Pungarehu

In Table 3.11-1 one key sub-catchment for Whangamarino Wetland has been omitted. This corresponds to the primary outflow from Lake Waikare (Pungarehu Canal/Stream). This water source contributes a very high contaminant load (e.g. ~67% of sediment loads based on 2017 data) to the receiving water body. The site has been routinely monitored by WRC since 2002 and recently been added to the regions SOE network.

It is recommended that Table 3.11-1 is amended to include a specific sub-catchment monitoring site for the Pungarehu Stream/Canal.

Definition of Narrative targets for other wetlands for PC1

In addition to the Whangamarino Wetland attributes for TN and TP concentration. It is recommended that narrative targets for all water quality attributes in PC1 are defined for:

- Total phosphorus
- Total nitrogen
- Sediment
- Hydrological regime (where altered hydrology contributes to or exacerbates water quality pressures)

The narrative targets described in Table 4 will be a separate table in PC1.

Table 4.

Wetland type	Attribute relating to water quality **(narrative target)**			
	TP	**TN**	**Sedimentation**	**Hydrological regime**
Bog Fen Swamp Marsh	Nutrient status (TP) is within healthy range for the specific wetland type	Nutrient status (TN) is within healthy range for the specific wetland type	Inputs of external sediment are within healthy range for the specific wetland type	Hydrological regime, if altered, does not exacerbate water quality impacts

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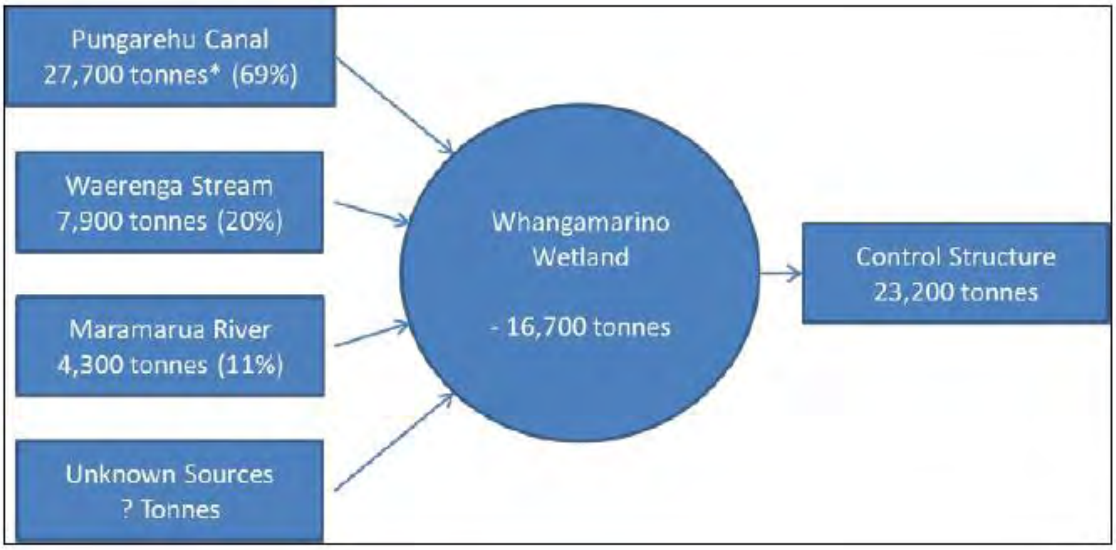
Annex 1. Summary of water quality monitoring data for primary surface water tributaries for Whangamarino Wetland. Source: LAWA accessed 7 February 2019, except Pungarehu Canal (WRC data, PDP 2018)

Monitoring site	**TP Median Conc. (mg/m3)**	**TN Median Conc. (mg/m3)**	**Clarity (m)**	**TSS Annual Load (T/yr)**
Matahuru Stm Waiterimu Road Below Confluence	91	1430	0.33	na
Waerenga Stm SH2 Maramarua	42	1100	0.86	na
Whangamarino River Jefferies Rd Br	85	1150	0.4	na
Mangatangi River SH2 Maramarua	62	530	0.51	na
Whangamarino River Island Block Rd	131	1960	0.21	na
Pungarehu Canal at Waerenga Rd or Farm Bridge	138	3000	~0.2	Mean TSS load 1980-2012 approx. 22,000 T/yr. TSS load in 2017 was 27,000 T/yr

Annex 2a: Whangamarino Wetland Sediment and Nutrient Loads from SOURCE catchment modelling. Jacobs (2015)

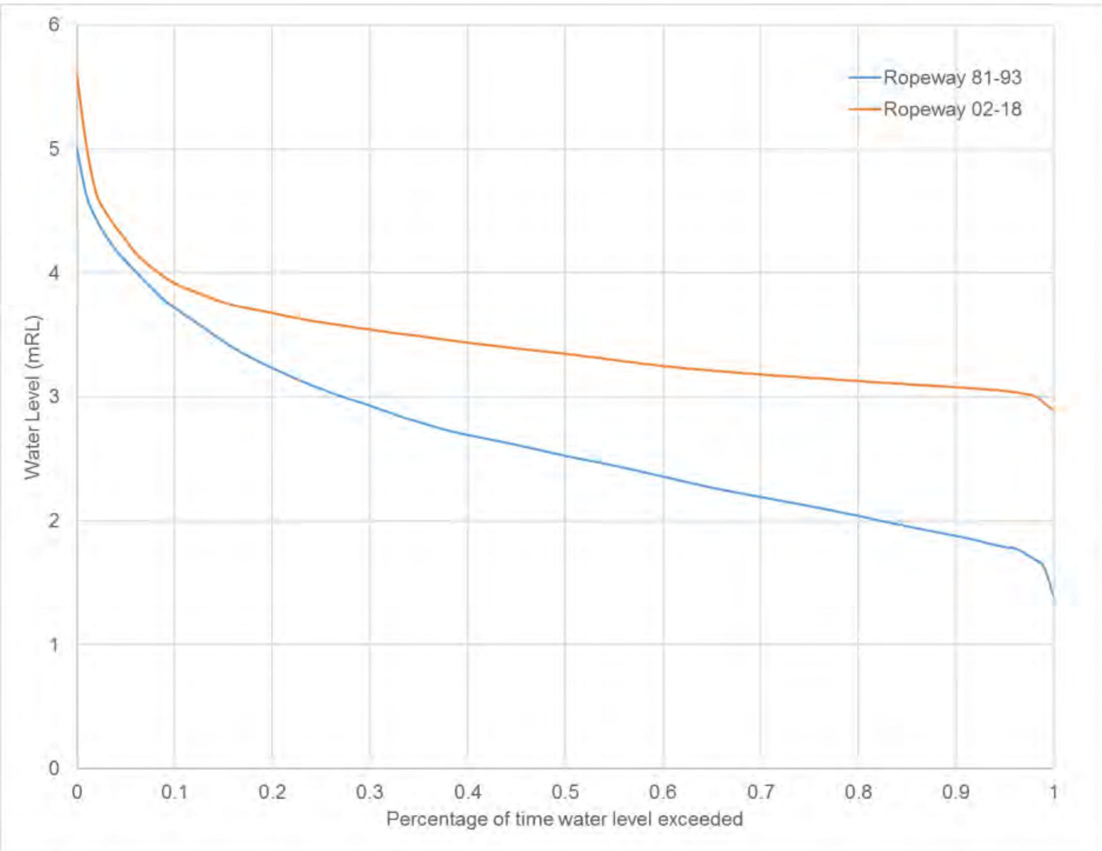
	Average TN Load (t/yr)	**% of total TN**	**Average TP Load (t/yr)**	**% of total TP**	**Average TSS Load (t/yr)**	**% of Total TSS**
Whangamarino River	142	18%	10	18%	22600	34%
Maramarua River	149	19%	14	25%	15400	23%
Lake Waikare	391	49%	22.5	40%	22850	35%
Northern	48	6%	3	5%	900	1%
Eastern	30	4%	3	5%	1800	3%
South Western	30	4%	2	4%	2000	3%
South	9	1%	1	2%	200	0%
Western	3	0%	0.5	1%	100	0%
TOTAL	802	100%	56	100%	65850	100%

Annex 2b: Particulate (sediment) budget for Whangamarino for the 2017 calendar year. Source: PDP 2018. For this particular year (2017) a 16700 tonne addition of sediment (and bound P) to the wetland was calculated



Annex 3:

Water level Exceedance Plot for Whangamarino at Ropeway (near to Island Block Rd water quality monitoring site). Source: Jacobs (2018)



Annex 4.

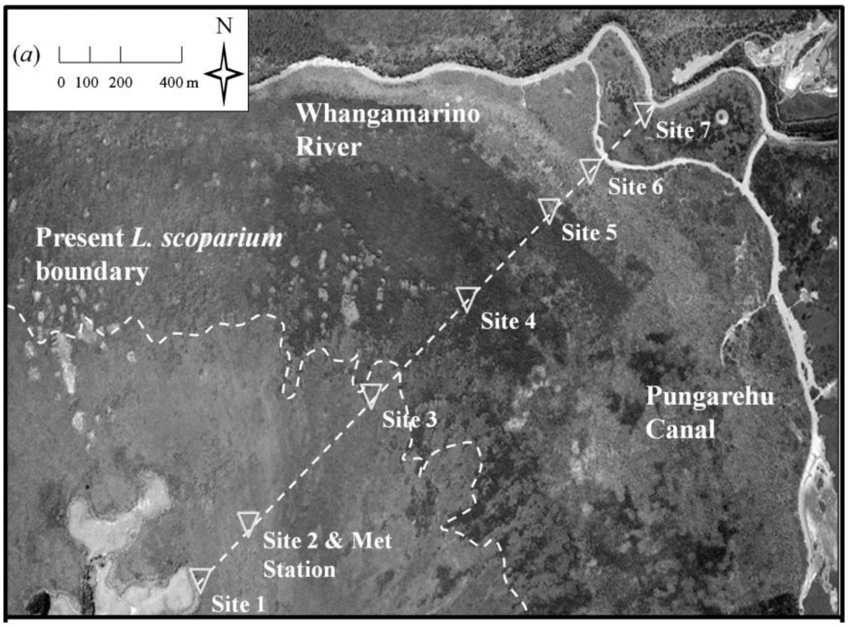
Area of Whangamarino Wetland inundated at different water level heights (depth). Source: Jacobs (2015)

Whangamarino Wetland Depth Area Volume Curve

Depth	Area (km^2)	Volume (hm^3)
3.0	9.69	0.00
3.1	10.49	0.00
3.2	12.61	0.05
3.3	16.38	0.33
3.4	19.72	0.87
3.5	22.03	1.61
3.6	23.64	2.59
3.7	24.35	3.55
3.8	25.06	4.59
3.9	26.18	5.88
4.0	27.52	7.15
4.1	30.34	9.08
4.2	33.46	10.84
4.3	35.53	12.89
4.4	37.16	15.11
4.5	38.41	17.48
4.6	39.43	19.95
4.7	40.43	22.53
4.8	41.43	25.21
4.9	42.46	27.99
5.0	43.71	30.88
5.1	45.65	33.89
5.2	46.94	37.10
5.3	47.92	40.46
5.4	50.21	44.51
5.5	52.35	48.29
5.6	59.93	53.14
5.7	62.59	63.29
5.8	63.20	68.16
5.9	63.60	74.55
6.0	66.91	91.15
6.1	67.12	96.13
6.2	72.41	119.54
6.3	73.97	129.76
6.4	74.11	134.78
6.5	74.27	139.83

Annex 4.

Location of wetland monitoring transect. Source: Blyth et al. 2013



Attachment 14: Temperature Attribute for PC1 – Adam Daniel

MEMORANDUM

To: PC1 Expert Conferencing Group (Science)

Cc: David Hill

From: Adam Daniel

Date: 5 June 2019

Subject: Water Temperature Attribute for PC1

Background

Water temperature has significant impacts on aquatic species in the Waikato and Waipa catchments and is listed as a key attribute of ecosystem health in the NPS FM. Both native fish and trout are negatively impacted by excessive water temperatures. Baker & Franklin (2019) found significant negative correlations between mean summer water temperature in the Waikato River and mean smelt (*R. retropinna*) length and weight (Figure 1 & 2). Similarly, Mora & Boubée (1993) found that the survival of smelt eggs were highest between 14 & 18°C and temperatures above 24°C caused a higher proportion of egg mortality.

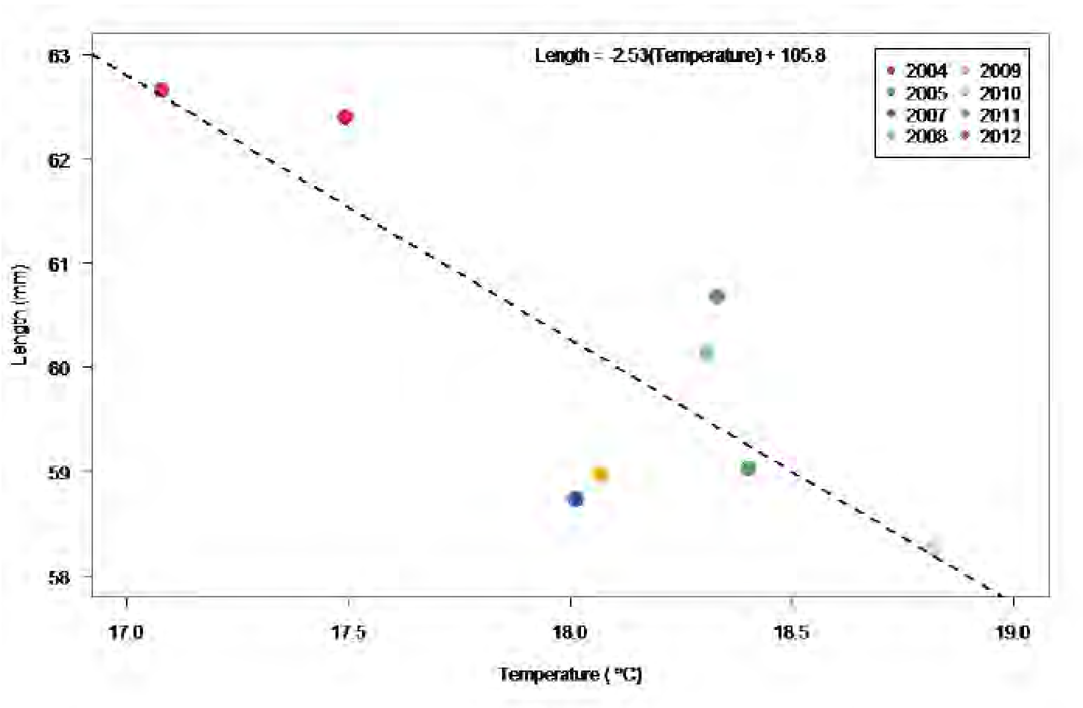


Figure 1. Scatter graph of mean smelt length and mean daily water temperature for the January to June survey period. The dashed line shows the linear regression relationship between the two variables (r_2 = 0.68; p = 0.011). (Source: Baker & Franklin 2012).

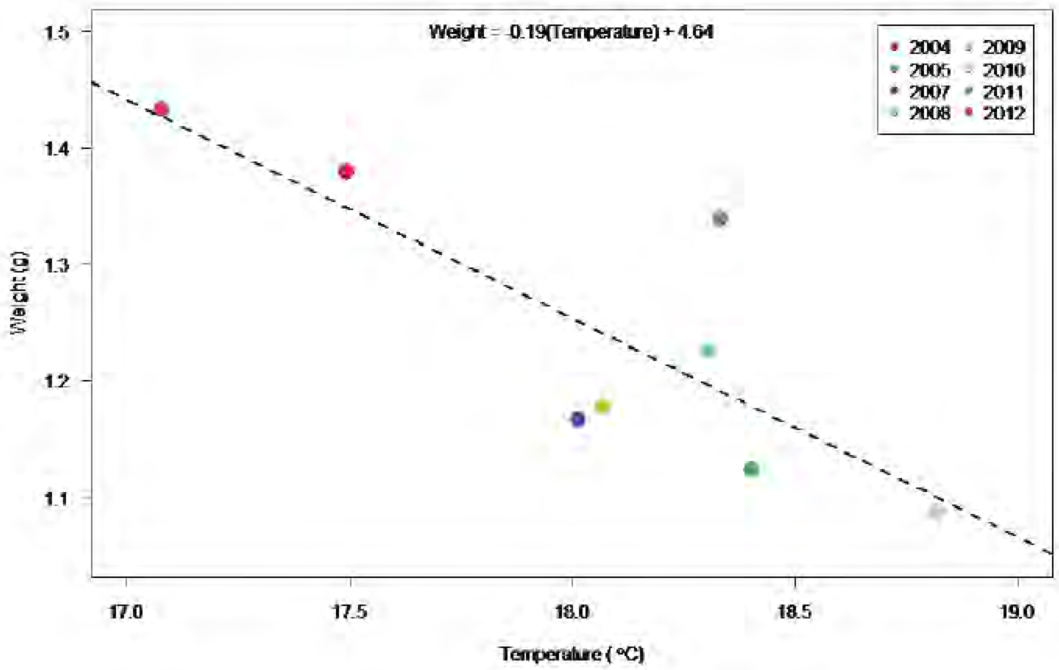


Figure 2. Scatter graph of mean smelt weight and mean daily water temperature for the January to June survey period. The dashed line shows the linear regression relationship between the two variables (r_2 = 0.66; p = 0.014). (Source: Baker & Franklin 2012).

Trout are also known to be very temperature sensitive and actively migrate to thermal refuges to survive when temperatures are above 19°C. Rainbow trout (*Oncorhynchus mykiss*) generally move upriver to find cooler temperatures and as stream temperatures increase fish are pushed further upriver to survive. Brown trout have a similar strategy to avoid high water temperatures but make substantial migrations to feed in lowland rivers when temperatures allow (Wilson and Boubee, 1996; Gabrielsson and Knight, 2014; Charteris, 2015). For example, Waipā River brown tout (*Salmo trutta*) occupy approximately 250 km of the river including the Lower Waikato (Karapiro to Tuakau) and most of the accessible mainstem Waipā River during winter months. However, when water temperatures increase in summer trout are only able to occupy the upper 43km (17% of winter habitat) of the Waipā above Otorohanga. Similarly, the upper reaches of most sub catchments in the region are critical thermal refuges for trout.

Reducing summer water temperatures in Waikato and Waipa tributaries could significantly improve ecosystem health in the Waikato and Waipa catchments. Even small reductions in water temperatures can allow trout to occupy kilometres of critical summer habitat and improve smelt condition.

Relevance to PC1

Riparian management and land use are the primary drivers of increased stream temperatures in Waikato and Waipa tributaries with water temperatures in pastoral streams 2.2 °C higher than forested streams (Quinn *et al.*, 1997). Increased sediment loads can also increase instream temperatures by absorbing and scattering sunlight at a faster rate than pure water (Wetzel, 2001) increasing maximum temperatures. For example Paaijmans et al. (2008) found that highly turbid stagnate pools had maximum temperatures 2.8 degrees higher than clear pools. Providing shade is probably the most important way to enhance stream life (Environment Waikato, 2007) and restoring streamside vegetation with appropriate buffers would reduce sediment loads and stream temperatures (Poole and Berman, 2001).

State of data/knowledge.

Waikato regional council currently has 11 sites on the Waikato River and 8 tributary sites (Table 1) with more than 100 readings (1990-2018). Typical mainstem temperatures are shown in Figure 3. Adding additional temperature loggers to monitor critical tributaries is cost effective as quality temperature loggers are now <$100.

Table 1. Current Waikato and Waipa tributaries temperature monitoring sites counts and maximum temperatures.

Site Name	Count	Max Temperature (°C)
Firewood Creek	19	13
Kaniwhaniwha Stm	131	18.8
Mangaohoi Stm	28	14.3
Mangaokewa Stm	39	13.9
Mangapiko Stm (Pirongia/Te Awamutu)	148	23.9
Mangapu River	132	21
Mangarama	29	15.5
Mangarapa Stm	30	15.9
Mangatutu Stm (Waikeria)	123	19.9
Mangauika Stm	3806	21
Moakurarua Stm	27	14.2
Ohote Stm	44	18.7
Puniu River	4810	25
Waipa River	284	19.6
Waitomo Stm	271	19.5

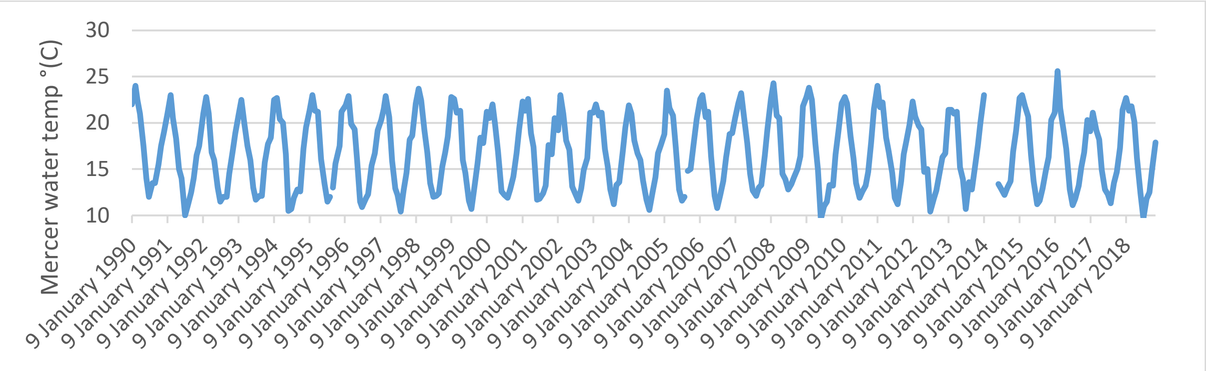


Figure 3. Example of existing Waikato River temperature monitoring data at Mercer from 1990-2018.

Proposed attribute

Including the existing limit for fishery class water of 20°C "to maintain or enhance existing water quality" (Appendix 1; Waikato Regional Plan 3.2.3 policy 7) would be sensible as an upper limit. Attribute bands could be defined by percentage days the maximum temperate exceeds 20°C. Bands for subcatchment streams would be defined as 95, 90, 85 and 80% as the thresholds for band A, B, C and D, respectively. Bands for mainstem and lowland rivers would be defined as 90, 80, 70 and 60% as the thresholds for band A, B, C and D, respectively.

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Appendix 1 Waikato Regional Plan 3.2.3

Policy 7: Fishery Class

The purpose of the fishery class is to maintain or enhance existing water quality and aquatic habitat in water bodies that currently support a diverse range of fish species and fish habitats with significant conservation values10, or which support significant recreational, traditional or commercial fisheries so that for these fisheries, trout or indigenous fish can complete their life cycles and/or maintain self-sustaining populations and managed trout and indigenous fisheries can be sustained.

This will include consideration of the need to:

a) Minimise fish entrapment at water intake structures.

b) Minimise adverse effects on fish spawning patterns in areas where spawning occurs

c) minimise adverse effects of sediment loads and other contaminants on fish or their habitat.

d) Maintain water temperatures and dissolved oxygen levels that are suitable for aquatic habitat and spawning.

e) Ensure that fish living in these waters are not rendered unsuitable for human consumption by the presence of contaminants.

f) Minimise structural or temperature barriers and changes in flow regimes that would otherwise prevent fish from completing their life cycle and/or maintaining self sustaining populations, including migration and spawning.

g) Minimise the adverse effects of physical disturbance to aquatic habitat.

3.2.4.5

b) Significant Trout Fisheries and Trout Habitat:

i) All water intake structures shall be screened with a mesh aperture size not exceeding three millimetres in diameter.

ii) The maximum intake velocity for any water intake structures shall not exceed 0.3 metres per second.

iii) The discharge of suspended solids shall comply with the standards in Section 3.2.4.5.

iv) As a result of added heat, the temperature of the water shall not be changed by more than 3 degrees Celsius, and shall not exceed 20 degrees Celsius at any time. Where spawning occurs the temperature shall not be caused to exceed 12 degrees Celsius between May and September.

v) Where water is to be taken or diverted from or into any water body, sufficient flow and/or water depth shall be maintained to allow for the unimpeded passage of fish at all times and for the maintenance of fish habitat and spawning.

vi) The discharge shall not cause dissolved oxygen to fall below 80 percent of saturation concentration. If the concentration of dissolved oxygen in the receiving environment is below 80 percent saturation concentration, any discharge into the water shall not lower it further.

vii) Fish shall not be rendered unsuitable for human consumption by the presence of contaminants.

viii) Ammoniacal-nitrogen shall not exceed 0.88 grams of nitrogen per cubic metre.

ix) No structure or activity that will prevent the natural passage of fish or has the potential to do so, shall be constructed or undertaken unless provision is made for the maintenance of fish passage both upstream and downstream.

Attachment 15: Temperature Attribute – Tim Cox

MEMORANDUM

To: PC1 Expert Conferencing Group (Science)

Cc: David Hill

From: Tim Cox

Date: 5 June 2019

Subject: Water Temperature Attribute for PC1

The focus of Plan Change 1 is on four categories of contaminants: nitrogen, phosphorus, sediment, and microbial pathogens. The scope of the plan is restricting to improving the management of these contaminants. Objective 1 of proposed PC1 is stated as "by 2096, discharges of nitrogen, phosphorus, sediment and microbial pathogens to land and water result in achievement of the restoration and protection of the 80-year water quality attribute targets in Table 3.11-1". The opening background summary of the proposed plan change states, "The Vision and Strategy is being given effect to in Chapter 3.11 by:
- reducing nitrogen, phosphorus, sediment and microbial pathogen losses from land; and
- ongoing management of diffuse and point source discharges of nitrogen, phosphorus, sediment and microbial pathogens…"

I'm of the opinion that the authors of the proposed plan change got this focus right, with respect to the primary drivers of water quality impairment in the river and with respect to the primary goals of swimmability and food-taking along the full length of the river. Further, as described in Report No. HR/TLG/2016-2017/2.1A, potential water quality attributes were assessed for inclusion in Table 3.11-1 using a well-defined set of criteria. One criterion is related to management of the attribute with respect to the four contaminants of concern, written as (direct screen capture of document excerpt):

3. Management and limits
   - Do we know what to do to manage this attribute?
   - Are the four contaminants (N, P, sediment and faecal microbes) direct drivers of this attribute?
   - Do quantitative relationships link the attribute state to limits and/or management interventions to control N, P, sediment and faecal microbes?

While I agree that water temperature impairment is a significant issue in the Waikato River and tributaries, particularly in the face of a changing climate, I would argue that temperature, as a potential attribute for this plan change, does not satisfy the criteria presented above. None of the four contaminants are direct drivers of the attribute in this basin, and mitigation of temperature impairment in the catchment could not be effectively achieved by managing the four contaminants of concern. Temperature should indeed be monitored and managed in the Waikato, but that work falls outside of the scope of this plan change. Temperature impairment in the catchment warrants its own focus, with its own policy and regulation. Further, I have concerns about potentially undermining the current focus of this plan change by introducing additional attributes into Table 3.11-1, less directly linked to the contaminants of concern. I am concerned that additional parameters may unnecessarily complicate the plan change and may lead to further delays and points of contention. This plan change should, in my opinion, focus on mitigating the primary source of water quality impairment in the catchment: diffuse source nutrient, sediment, and microbial pathogen loads. I, therefore, recommend that temperature not be added as an attribute to Table 3.11-1.

Attachment 16 - Other toxicants

Attribute for "Other toxicants" for Waikato Plan Change 1
Olivier Ausseil

Summary

- "Other toxicants" refers to toxicants not otherwise listed in Table 3.11-1 (i.e. ammoniacal and nitrate-nitrogen). Other toxicants includes metals, metalloids, and organic micro-contaminants such as pesticides, polycyclic aromatic hydrocarbons, etc.
- There is a very large number of "other toxicants" as defined above. It would not be practical to refer them all in PC1; further, the ecotoxicology field is constantly evolving, meaning that the list of toxicants of concerns and what might be defined as acceptable concentrations are also constantly evolving. If an "other toxicant" Attribute was considered suitable for inclusion in PC1, it is suggested the Attribute should be based on the ANZECC Guidelines risk assessment framework.
- If an "other toxicant" Attribute was considered suitable for inclusion in PC1, it could be worded as follows:

  "*Other toxicants: 95% species protection levels for toxicants (other than nitrate-nitrogen and ammoniacal-nitrogen) as stipulated in the most recent version of the ANZECC guidelines, unless natural levels already exceed this protection level.*

  Notes:

  1. *This applies unless natural contaminant concentrations already exceed this protection level.*
  2. *For clarity this Attribute requires that the risk evaluation process set out in the ANZECC Guidelines will be followed on the basis of the specified protection level (95%). It does not mean that default trigger values defined in the ANZECC Guidelines will be used as standards*."

- Note that the 95% protection level is seen as the "default" protection level, but higher protection level (99%) could be sought for pristine/ high conservation values areas.
- Other regional plans have adopted a similar approiac (e.g. Tukituki Plan Change 6, Horizons "One Plan")

Questions

- Does an "other toxicant" attribute provide a measure of the Ecosystem Health value?
  - **Yes, insofar as it seeks to avoid significant effects of toxicants on aquatic life**
- Are there agreed band thresholds, summary statistics and measurement protocols?
  - **Yes, the ANZECC guidelines provides a four-tier protection level system, as detailed below**
  - **Note that the ANZECC guidelines are structured around "trigger values" which trigger further** evaluation of risk if exceeded (as opposed to "standards")
- Do we know what to do to manage this attribute, do we understand the drivers and are there quantitative relationships that link the attribute state to resource use limits and/or targets
  - **Yes**
- Is there data of sufficient quality, quantity and representativeness to assess the current state of the attribute?

- Some data exist
   - **Some data exist**

- Are the four contaminants (N, P, sediment & faecal microbes) direct drivers of this attribute?
   - **No**

- Do quantitative relationships link the attribute state to limits and/or management interventions to control N, P, sediment and faecal microbes?
   - **No**

Background

The ANZECC (2000) guidelines provide a statistical derivation procedure for differing levels of ecosystem protection. The ANZECC descriptors recognise three broad ecosystem conditions:

1. "High conservation/ecological value systems (99% species protection9) — effectively unmodified or other highly-valued ecosystems, typically (but not always) occurring in national parks, conservation reserves or in remote and/or inaccessible locations. While there are no aquatic ecosystems in Australia and New Zealand that are entirely without human influence, the ecological integrity of high conservation/ecological value systems is regarded as intact.

2. Slightly to moderately disturbed systems (95% species protection) — ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained. Typically, freshwater systems would have slightly to moderately cleared catchments and/or reasonably intact riparian vegetation; marine systems would have largely intact habitats and associated biological communities. Slightly to moderately disturbed systems could include rural streams receiving runoff from land disturbed to varying degrees by grazing or pastoralism, or marine ecosystems lying immediately adjacent to metropolitan areas.

3. Highly disturbed systems (80-90% species protection). These are measurably degraded ecosystems of lower ecological value. Examples of highly disturbed systems would be some shipping ports and sections of harbours serving coastal cities, urban streams receiving road and stormwater runoff, or rural streams receiving runoff from intensive horticulture."

Proposed Attribute for Other toxicants

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	**Protection level from toxicants**	
Attribute Unit	% species protection level	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
A	99% protection level	Effectively unmodified ecosystem, ecological integrity is regarded as intact. No observed effect on any species tested
B	95% protection level	Biological communities remain in a healthy condition and ecosystem integrity is largely retained. Starts impacting occasionally on the 5% most sensitive species
C	90% protection level	Highly disturbed systems. These are measurably degraded ecosystems of lower ecological value. Starts impacting regularly on the 10% most sensitive species (reduced survival of most sensitive species)
Regional Bottom Line	**90%** protection level	
D	80% protection level or less	Highly disturbed systems. These are measurably degraded ecosystems of lower ecological value. Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species) Risk of acute toxic effects as exposure increases

Attachment 17 - Statements of agreement and disagreement (in alphabetical order)

Witness were asked to please indicate whether you agree with the paper (Y); disagree with parts or whole (N); not applicable to your area of expertise (N/A); and provide brief comments on any area of disagreement

Olivier Ausseil

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier

Nutrients	×			• Agree with paper and recommendations. **I support Approach 2C and 1C for the setting of long-term TP and TN thresholds respectively for the mainstem of the Waikato River;**
				• Important notes re. relatively high degree of uncertainty for TN/TP mainstem thresholds and inability to consider estuarine/marine areas. These thresholds should be seen as interim reviewed before the next plan change.
				• Approach 3 is useful in that it identifies that reductions in both TN and TP in the mainstem will not occur without reductions across the catchment and sets reductions in both TN and TP in every sub-catchment for the duration of PC1. These thresholds may be expressed as concentrations or loads. **I support Approach 3 for the setting of short-term thresholds for both the tributaries and mainstem.**
				• **I do not support Approach 4**, as I do not support its fundamental principles, as set out in my evidence;
				• I support the setting of nutrient thresholds to meet periphyton attributes in principle. However;
				    ○ There is a significant lack of information or data regarding the state of periphyton issues in the Waikato catchment and virtually no information on periphyton/nutrient relationships in the catchment
				    ○ Significant periphyton issues have not, to date, been identified in the Waikato catchment, and it seems difficult to justify setting thresholds without at least knowing first whether there is an issue to address;
				    ○ There is a significant risk that thresholds based on generalised relationships as recommended in Approach 5A) will not provide robust thresholds for the management of periphyton in the Waikato catchment
				    ○ PC1 sets a clear direction that nutrient concentrations will need to be

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
				maintained or reduced in all sub-catchments. There is therefore no real risk that periphyton issues will increase/get worse during PC1 implementation. It is unclear what additional thresholds would achieve that PC1 does not already achieve. • Based on the above, on balance, **I do not support Approach 5 for incorporation in PC1**. • However, if it was felt that nutrient thresholds must be set to control periphyton growth in tributaries, then approach 5B is the most sensible. These thresholds should however be treated as interim thresholds and be reviewed before next plan change to reflect contemporary information/knowledge. • In any situation, I support the implementation of a targeted monitoring programme seeking to identify o if, and where, periphyton issues occur in the catchment, and o nutrient/periphyton relationships where periphyton issues are identified. o It may be useful to include these monitoring requirements in PC1, possibly as a method. • Assessment against the NPSFM Attribute for periphyton will require monthly periphyton monitoring programme – this will require a significant change in WRC's monitoring programme • Similarly, understanding the periphyton to nutrient relationships in tributaries will require monitoring of nutrient concentrations at the same sites where periphyton data are collected. Again, this may require significant changes to the WRC monitoring programme.
E.coli	×			• **I support the recommendation** to use the NPSFM attribute in full in Table 3.11-1. • Uncertain about applicability of shellfish gathering guidelines to freshwaters. As a backstop, I recommend applying them to the estuarine/coastal areas only
Deposited sediment		×		• I agree that Deposited Sediment is a very important driver of ecological health, and there is management value in defining a deposited sediment Attribute; however, there are significant practical implementation issues with the Attribute as proposed in the paper, including:

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
				○ What constitutes a "hard bottom" stream both under natural and current conditions; ○ How the "natural" levels of hard/soft sediment are going to be determined needs to be specified; ○ The proposed attribute uses a mix of absolute numbers and % change compared to natural state. This leads to inconsistent outcomes (e.g. the attribute might be more stringent for streams with relatively high levels of soft sediment naturally (which would be relatively less sensitive to deposited sediment as a stressor) than for streams with very low levels of soft sediment naturally (which would be relatively more sensitive to this stressor); ○ Assessment method is unclear (modified Wolman count vs Clapcott et al protocols); • Additional work would be required to make a recommendation for inclusion of a numerical attribute in Table 3.11-1. **I do not recommend the numerical Attribute as proposed in the paper for inclusion in PC1**.; • A **narrative** such as suggested by Dr Canning and Mr Kessels has potential value; however significant **additional work** and caucusing would be required to gauge it practical applicability and robustness. In particular, it relies heavily on national models to estimate "natural" levels of deposited sediments and the accuracy and robustness of this model at the stream/reach scale in the PC1 area has not been tested.
Clarity	✕			• My key concern with all options is that some streams and rivers, particularly in the Waipā catchment may not be able to meet the bottom line, even under "natural" (meaning "reference state" , i.e. under full mature native vegetation cover) conditions, due to the soft sedimentary geological nature of their catchment (particularly in the Waipā catchment). It would be preferable to acknowledge that natural conditions may limit the achievability of the clarity thresholds; • I recommend that the Attribute includes the following exclusion (or wording to that effect) "unless natural water clarity already does not meet the bottom line" (noting similar exclusion clauses exist in other regional plans); • Generally comfortable with TLG Attribute and Table 3.11-1 as notified or "alternative

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
				2" (with the above addition). **On balance I recommend Alternative 2 for adoption in PC1** (with the above addition); • **I do not recommend Alternative 1.** My key concern with "Alternative 1" is that excluding only the 10% highest flows does not reflect well the natural functioning of most rivers (with the notable exception of lake or spring-fed rivers) in response to a runoff inducing rainfall event/flood. Assuming that 3*median flow is a reasonable indicator of "flood flows", one would expect that most rivers would naturally present low visual clarity under flood flow conditions. Flows above 3*median flow are expected to occur approximately 15-20% time on average; further, low visual clarity is expected to naturally occur for a period of time after a flood. The main exception to this would be lake-fed or spring-fed rivers/streams with limited surface catchment. This is illustrated by the fact that the only site that meets Band A in Alternative 1 is directly and nearly exclusively fed by Lake Taupo. As a result, many rivers and lakes are unlikely to meet the "bottom line" as defined in this attribute even under "natural" conditions;
TSS				• Not proposed as an Attribute
DO	×			• **I support the paper and recommendations** • I must note that I have no first-hand knowledge of the DO issues associated with the management of flood control infrastructure, or the status of these discharges, mentioned on page 2 (under "recommendations"), so I cannot confirm or otherwise the statements made in that paragraph.
Invertebrate Communities	×			• **Agree with paper and recommendations** • I note that NPS FM Policy CB3 makes use of MCI as indicator of macroinvertebrate community health, as opposed to QMCI as recommended for this attribute. This may raise issues of consistency between PC1 and NPS FM • QMCI score of 4 is roughly equivalent to MCI of 80, so not a significant issue from a technical standpoint, but planning/legal implications should be considered
Macrophyte nuisance	×			• **Agree with paper and recommendations** • Response to second question (page 1) should be "yes, with limitations"

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
Periphyton	**In part**	**In part**		• **I agree with the risk assessment steps described on page 1**, and suggest it is made clear these steps should be included in PC1, possibly as a method; • I also suggest that WRC monitor nutrient concentrations at the same sites as where periphyton is monitored, to provide an understanding of site-specific nutrient/periphyton relationships; • **I agree with the adoption of the NOF bottom line of 200mg/m^2 chlorophyll a** as a numeric 'objective' for periphyton biomass for all **hard-substrate wadable** rivers and streams in the Waikato-Waipā catchments; • **I do not recommend the adoption of the 25% periphyton cover threshold in PC1** as it is not based on existing, commonly accepted guidelines for periphyton cover (noting however that this threshold is already in the regional plan) • Assessment against the NPSFM Attribute for periphyton will require monthly periphyton monitoring programme – this will require a significant change in WRC's monitoring programme • Similarly, understanding the periphyton to nutrient relationships in tributaries will require monitoring of nutrient concentrations at the same sites where periphyton data are collected. Again, this may require significant changes to the WRC monitoring programme
Fish Communities		×		Generally comfortable with setting fish community health "objectives" in a regional plan; however the paper should acknowledge the limitations of fish IBI and the weak link with the contaminants PC1 seeks to manage. I also think that the paper as it stands is somewhat misleading because it does not acknowledge habitat (quality and accessibility) as the key driver of fish communities in New Zealand. Predation by introduced species is also a key driver. • Fish IBI is an indicator of fish species presence/absence and diversity but does not reflect fish community composition or structure. Thus, at a given altitude and distance from the coast, a degraded site where all species present occur in very low abundances can be scored the same as a pristine site where the same species are present, but in much higher numbers. This is particularly important considering the longevity and migratory nature of many species. For example, if a fish passage barrier

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
				is installed downstream of a healthy longfin eel population, large adults may persist in every decreasing abundances for as long as 80 years, during which time smaller eels will disappear and non-migratory prey species may increase in abundance. Such a change would reflect a significant shift in community structure, but would not be detected by the IBI until the last eels migrate downstream to breed, decades after the driver of the shift was installed. This limitation should be acknowledged in the paper; • The key issue with the paper is that it does not acknowledge that the single largest driver of fish communities in NZ is physical habitat quality (in-stream and riparian habitat) and accessibility (e.g. barriers to fish migration). • Sediment (suspended and deposited) can influence fish recruitment and habitat quality; however, direct quantitative relationships between fish community health and suspended or deposited sediment are not available; • As acknowledged in the paper, the effects of nutrients on fish communities are generally indirect. Indeed, aside from ammonia/nitrate toxicity, the most direct link between nutrients and fish community structure is through increased plant growth, which can affect macroinvertebrate prey communities and fish habitat. However, as the relationship between nutrients and periphyton/macrophyte growth is dependent on a range of factors, including flow, source of flow, bed substrate, shading and temperature, the effects that nutrients have on plant biomass will differ vastly between and even within streams, as will any consequential effects on fish. Predicting the effects of nutrients on fish is made even more difficult by the complex interactions of multiple stressors in streams. Even in streams where nutrients have the same effect on plant growth, the impact this will have on fish communities can differ depending what other stressors are present (i.e. a stream with low nutrients and low plant growth may still have a depauperate fish community due to a downstream barrier to migration, while a similar stream without a barrier may have a pristine fish community); • Whilst statistically significant, the correlations between nutrients and fish communities are not causative (i.e. one does not directly cause the other). Importantly, a simple statistical correlation does not mean that a change in one

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
				variable (e.g. a reduction in nutrients) will result in a predictable change in the other variable (in this case an improvement in fish communities). Rather, it is likely that the nutrients and fish variables co-vary, and that streams with higher nutrient concentrations are simply more likely to be subjected to more meaningful stressors, such as riparian vegetation removal, flood protection activities, fish passage barriers and sediment deposition. The nature and implication of theses statistical relationships should be acknowledged in the paper. • The riparian management provisions of PC1 should result in riparian and habitat improvements across the catchment, which should in turn result in improvement in fish community health. This is likely to be the single largest driver of improvement as a result of PC1 implementation; • I support in principle an Attribute reflective of fish community health in PC1; as long as the weakness of the links with the four contaminants PC1 seeks to manage are acknowledged (i.e. that quantifiable improvements in fish community health may or may not occur as a result of PC1 implementation). This may make a fish attribute unsuitable for inclusion in PC1
Riparian		×		• Riparian management is/should be a key component of farm management plans. It is a <u>tool</u> by which contaminants transported from land to waterbodies by surface runoff and, in some situations, shallow groundwater, can be intercepted/treated; however, it is not a measure of freshwater values, and it is doubtful whether an indicator of riparian "condition" it is a useful Attribute for the purpose of setting freshwater objectives • The proposed "riparian" attribute is completely untested. There are no established measurement protocols or band thresholds; • Riparian buffer width is only one measure of the measures of the "functional quality" (i.e. how well it intercepts contaminants and provides /improves in-stream habitat). It is uncertain whether width is the "right" measure for a "riparian" Attribute • The above points could be addressed, but significant additional work would need to be undertaken prior to making a recommendation for a riparian attribute to be included in Table 3.11-1;

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
				• **I do not recommend this Attribute for inclusion in PC1**

Lakes		✕		• No paper (only tables) has been circulated in relation to lakes Attributes and there has been very limited opportunities to discuss these aspects in caucusing.
				• I am not able to comment on the merits of the alternative FMU delineation proposed by DOC, as I have not been able to review the Ozkundakci, D. (2015) paper (which does not appear to be available publicly);
				• I support the adoption of "maintain or improve to national bottom line" thresholds for all Lakes in the PC1 area on principle
				• However, I am uncertain as to some of the thresholds proposed by DOC; for example:
				  o Table 1: Why are bottom line targets for riverine and peat lakes 750 (stratified) and not 800ppb (polymictic)?
				  o Table 1: what data is the 625 ppb target for TN in Volcanic lakes based on?
				  o Table 2: unsure of applicability of thresholds provided as a range (e.g. 500-750ppb for class 6 lakes)
				• On the basis of the above uncertainties, I cannot comment on the merits of the alternative approach (classification and thresholds) proposed by DOC

Whangamarino	✕			• I support inclusion of TN/TP attributes in Whangamarino wetland; however, linkages between TN/TP concentrations and plant growth in wetlands generally and Whangamarino Wetland in particular are not well established • I support additional investigations on the above. It is probable nutrient reductions will be required to improve/restore ecological health of Whangamarino wetland. On that basis **I support the use of national bottom line for lakes as an interim position** until robust thresholds can be determined, as they signal direction of change; • I am unable to comment on monitoring site location or sub-catchment boundaries as I don't have detailed knowledge of Whangamarino wetland hydrology and water quality, but support in principle detailed monitoring and management of Whangamarino wetland. • I support in principle the proposed narrative target for "other wetlands"; however its applicability in practice is doubtful (e.g. what constitutes "healthy range" of sediment inputs?)

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
Temperature (Daniel paper)		×		• Agree with most information presented Dr Daniel's paper, but disagree an attribute can be recommended in the absence of an understanding of "natural" temperature regimes. It is highly likely that lowland streams and rivers in the Waikato catchment would naturally exceed 20°C, but the proportion of time this may happen in any given year is unknown; • There is a significant risk that setting temperature "thresholds" without this information will result in unrealistic/unachievable thresholds. • My experience of maximum temperature thresholds in regional plans is that they are not particularly useful; however, a temperature change threshold (as already contained in the regional plan) is a useful way to manage effects of activities.
Temperature (Cox paper)	×			• Agree with Tim Cox's paper, including the absence of linkage with the four contaminants PC1 seeks to manage; • On balance **I do not support the inclusion of temperature as an Attribute for PC1**
Toxicants / Pesticides	×			• I note that there is **no direct link with the four contaminants** PC1 seeks to manage; on that basis the **inclusion of this attribute in PC1 is questionable**; • However, **if** it was considered a Toxicant attribute should be included, I support paper as circulated

Adam Canning

General Comments:

The process has been inappropriate and misleading. Sub-groups were asked to prepare discussion documents on each attribute, we are now being asked to support or disagree with attributes as proposed with little group discussion on some and no discussion at all on others.

As a result, my views are maintained as per my evidence in chief. Where I have co-authored a report - these are not necessarily my views.

A few comments on issues we have begun (not completely) discussed:

Nutrients: As it stands, I see no reason why nutrients in the mainstem should be changed from those proposed, except for the minor corrections identified in Mike Scarsbrook evidence (approach 1B). The further investigation done by the other approaches, based on correlations between phytoplankton and nutrients, strengthen my confidence that the proposed mainstem nutrient criteria are sufficiently stringent to achieve the phytoplankton objectives. Phytoplankton should not be the only reason nutrient criteria are set. Basing the nutrient criteria solely on relationships with phytoplankton (as proposed by the option 2 approaches), would lead to a substantial weakening of the proposed nutrient criteria and yield substantial differences in the level of ecosystem health proposed. For the mainstem, I still support the approach suggested in my evidence and reiterate that at a minimum we must set DIN and DRP to achieve periphyton objectives as per the NPS-FM 2017. We must also consider the effects on downstream environments. We have not yet considered the nutrient load requirements to achieve a healthy estuary.

Macroinvertebrates: I support the inclusion of both MCI and QMCI. I do, however, suggest that the regional bottom-lines be 90 and 4.5 respectively. It is disappointing that, despite my email enquiry as to why, the macroinvertebrate document I apparently assisted co-authoring no longer mentions my preference for this (earlier drafts did but was removed without explanation before submission).

E coli: At a minimum, we must apply the E coli table exactly as the NPS-FM 2017 prescribes. I do not support proposals to change the monitoring criteria, exclude flows or delete columns unless new risk assessments are done and these show criteria more stringent than that in NPS-FM 2017. If swimming is the value that the table supports, then criteria should be set at at-least the A-band as this is a synonymous level of risk to the minimum acceptable standard proposed by the 2003 microbiological guidelines for contact recreation.

Nic Conland

General Comments:

I co-authored the Nutrients and Dissolved Oxygen Memo's.

I raised in the caucusing that an approach/method to determining a change in attribute state is critical to the functioning of PC1.

I raised with others that additional sites are required for management of the Waikato and Waipa Catchments. These have been adopted as Tahorakuri, Karapiro and Island Block sites.

No agreement could be reached on the current state approach for baseline values (see climate Fig 1. as example).

I think a wider conversation is also needed on the delineation and naming of the sub-catchments (see attached memo).

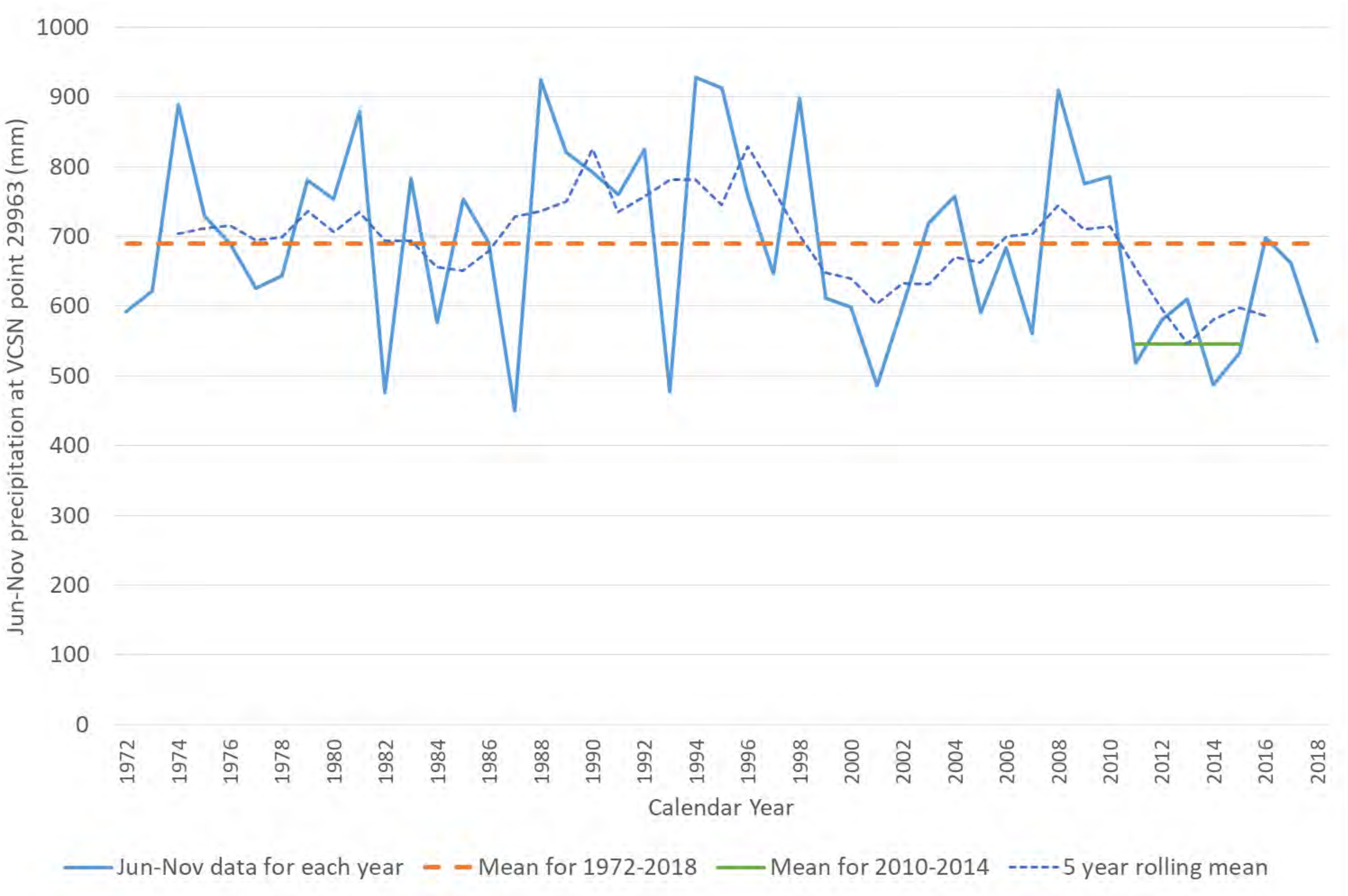


Figure 1 : VCSN data for Upper Catchment site (Block 2 evidence Dr Jordan)

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
Nutrients (based on final version)	**Y**			**Waikato mainstem** Support the inclusion of 66A and 66B catchment delineation Support the recommended changes for TN (Option 1C) and TP (Option 2C). Support the inclusion of 10-year targets (loads) based on mitigation proposals in PC1. **Tributaries** Support the introduction of the Vulnerable Land targets for TN and TP for the contributing sub-catchments to the Ohakuri Catchment. These levels are based on a process model with a daily timestep through groundwater and surface water. Support the inclusion of 10-year targets (loads) based on mitigation proposals in PC1 as short term objective these need to be for each of the (now including Tahorakuri, Karapiro and Island Block) 76 sub-catchments and be cumulative down the catchment. I note that the proposed load values in Table 6 need to be adjusted for significant figures. I also think that these values could be calculated as a mean of the three models (HRWO, Cox DST, and RDST) to the nearest significant figure and am happy to discuss and consider this on the 18th July 2019.

				Toxicity Support introduction of river and tributary bottom lines for nitrate and ammonia toxicity with a no degradation approach based on current state. The entire Table 3.11-1 hinges on a new method for determining change in an attribute state. This is key to managing the catchment.
E.coli	**Y**			I support the NOF proposals in the memo. Heath and toxicity is outside my expertise.
Deposited sediment	**Y**			I support a narrative objective with a method for determination of expected result.
Clarity	**Y**			Clarity is heavily biased by catchment geology and bed substrate. In the Upper Waikato bed movement is continuous and stream banks are highly active in terms of their geomorphology. I support Alternative 2, it's better for standardised reporting for PC1.
TSS			**?**	This seemed to become the deposited sediment attribute? What happened to TSS? I recommend inclusion of a monitoring method to collect data on TSS and Turbidity, for correlated turbidity and generating TSS rating curves. Recommend the introduction to PC1 of method for data collection and generation of rating curves. This is an important attribute for Whangamarino where there is little potential for flushing, and it acts as a sediment trap.

DO	**Y**			Agree with monitoring method being adopted by PC1 to provide minimum threshold. I support a global attribute as a FWO for a minimum ecosystem state as ‘bottom line’ 1 day and 7 day minimums. I recommend that a diel difference is a better measure of condition. Ie a 24hr difference in DO of less than 1 mg/L. I recommend that a monitoring method and perhaps a narrative objective is also required for DO similar to Deposited Sediment. Note: Am deeply concerned with state of lowland polder scheme influence on DO, however targeting compliance is outside the purpose of the plan.
Invertebrate Communities	**Y**			Support the amended attribute report to include MCI attribute(s) that reflects identification of appropriate long-term and short-term objectives. Need clear invertebrates method in PC1 (QMCI and relativity to MCI) based on standard WRC method. Otherwise will have inevitable false positives. Need clear identification of exceptions for geothermal areas and mechanism/method to determine compliance within a PC1 sub-catchment.
Macrophyte nuisance	**Y**			Agree – need to develop method for PC1 to account for two discrete cases: Lakes and Wadable waterbodies.

Periphyton	**Y**			Agree with including a narrative objective and a bottom-line attribute for wadable streams. Need to include a formal method (based on WRC current monitoring approach) for periphyton to ensure consistency and include assessment of shade as a potential controlling factor for nuisance periphyton in small-medium width streams.
Fish Communities	**N**			Agree in principle with an objective for fish communities. However how will a FWO be determined for each sub-catchment? Relative to historic populations and current predation based on existing trout and eel populations which values does this relate too? Also how is a decision made on this FWO for PC1?
Riparian	**Y**			This is a limit or target under the NPS FM as a constraint on resources which could achieve a FWO. I recommend a narrative limit requiring a minimum 5m riparian and a 15m average for the sub-catchment. This will encourage sub-catchment cooperation on mitigation and planning to achieve the other FWO's (noting this is not a FWO). A key question is – what other limits on resources will achieve the proposed FWO's relative to the guidance in the NPS FM? This is supported by the contemporary science and catchment practices.

				Needs to be understood in this context, rather than as an attribute or FWO. This is considered in Schedule C and forms part of constricting intensive land use on Vulnerable Land. I note that PC1 contains very few limits on resource use (NPS FM) as currently drafted, so addition is useful. Potentially can be drafted into Schedule 1.
Lakes	**Y**			Support general minimum attribute states for lakes as per the memo. From a catchment perspective recommend these can also relate to TN, TP and TSS loads as limits and targets. In terms of thresholds for lake productivity I'm not an expert.
Whangamarino	**Y**			Agree with catchment delineation changes Agree with monitoring site proposal (Island Block) Agree with attribute levels (baseline and FWO's) Agree with guideline states for catchment wide "lakes" I think a load for managing each catchment needs to be introduced.
Temperature	**N**			Recommend people read the WRP as already has temperature for water management class.
Toxicants / Pesticides	**N**			ANZECC Guidelines risk assessment framework is for use when actual BACI and site assessment hasn't been undertaken. Don't support inclusion in PC1 unless included as a method to mimic ANZECC.

Bryce Cooper

General comments:

1. Given the process to date and the constantly and up-to-the-last-minute changes and on-going email discussions between the group, I do have a sense of 'unresolved matters in my mind' and reserve the right to change my position and comments as a result.
2. Given what is being proposed by the expert group, if they were to be adopted it makes no sense to stick with the current format of Table 3.11.1.

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
Nutrients	**Agree IN PART (Option 1B)**			We received the final version of this paper at 21:25 pm on the 13th June with a review and response required by 10.00 am the next day. My comments are hereby caveated and short. 1. For the mainstem, I support option 1B.. This option corrects errors in Table 3.11.1. 2. For the mainstem, options that attempt to derive TN and TP targets based upon Chlorophyll responses are fraught, given all the other drivers on chlorophyll in this system (the paper itself and the papers and expert caucusing conducted for/by TLG all support this). 3. I do not support over-turning a community-derived set of long-term aspirations for river water quality when the alternative science-based approach is so unresolved. Rather, I support the recommendation of the TLG and others that a dynamic river model be developed before the next plan so that the community-driven long-term water quality objectives can be revisited *by the community* with an improved science basis. 4. I do not support Approach 3 being included in Table 3.11.1. While it is interesting work (and presumably aligns with the Doole et al Policy Mix report and its appendices conducted for PC1, although this would need to be checked) it should not be used for establishing short-term 10-year water quality 'targets'

				in Table 3.11.1. PC1 seeks to ensure a set of actions are put in place over the 10 year period that will, *at some point in time*, result in *at least a 10% step* towards the long-term target. Inserting the policy mix simulation results (either Doole et al or Cox & Conland) into Table 3.11.1 would set, generally speaking, much higher targets. This is not an appropriate role for technical experts. 5. I do not support approach 4. Due to the multiple drivers of MCI and IBI and the different importance of such drivers across the catchment, specifying nitrate and DRP concentrations will not necessarily achieve the desired ecosystem health outcomes. 6. I do not support approach 5, as presented. I do, however, support a periphyton attribute for hard-bottomed streams where a periphyton issue has been identified and then an approach to determine appropriate nutrient levels (as required by the NPSFM). Given there is a 'maintain' requirement for nutrients that applies to all tributary sub-catchments I do not see value in developing periphyton based nutrient limits for the tributary sub-catchments where there currently is no problem.
E.coli	**Agree**			I agree with the revision of E.coli in Table 3.11.1 so as to exactly follow the full approach prescribed in the 2017 revision of the NPS (i.e., without flow exclusion or adjustment) and satisfying all 4 metrics. Qualifier: I do *not* agree with the explanatory footnote. This is unnecessary and confuses the grading of waters with the need for surveillance and alerting.
Deposited sediment		**Disagree**		Disagree. While I do think a deposited sediment attribute would be appropriate for inclusion in Table 3.11.1 I am not yet confident that we have an attribute table that is robust.
Clarity		**Disagree**		1. I think I am disagreeing, but it is difficult to know as this paper

				does not put forward a single option to agree or disagree with. 2. I agree that clarity is an important attribute to have in Table 3.11.1, its more around the stats and the bands which, despite excellent work, the sub-group couldn't land on a preferred recommendation. In these circumstances I would be agreeing with the option to stick with what is already in the Table (i.e., median statistic), recognising that the choice of band aspired to in PC1 will also determine its stringency and be a key influence on the time distribution of clarities. 3. I do disagree with some of the narrative used. In my view, the importance of clarity as discussed through the PC1 process is *suitability* for swimming (rather than the more restrictive V&S 'safe for swimming') but also *suitability for other contact water-based activities* (e.g., fishing, waka ama, kayaking, baptism and cleansing practices). It is greater than '**safe** swimming', it is also about **perception** of the suitability of the water for swimming (which is what the Smith et al studies were about) and these other water-based activities. This connectedness (or lack thereof) to the water was a key view put forward in community engagement, particularly Maori.
TSS				
DO	**Agree**			Agree with paper that this should be recommended as a monitoring requirement with the bottom line set as a trigger value for management action.
Invertebrate Communities		**Disagree**		Would support a monitoring recommendation, with action when below bottom line or declining trend (as required by the NPS).
Macrophyte nuisance	**Agree**			Support the paper's recommendation of non-inclusion of macrophytes in Table 3.11.1. Qualifier - For lakes, I would support a LakeSPI monitoring recommendation in a similar manner to my views on fish IBI and macroinvertebrates.

Periphyton	**Agree (in part)**			Further development needed so can't agree with approach proposed. Agree that monitoring programme is in place, and where periphyton issues are identified that the NPSFM periphyton attribute table needs to be applied.
Fish Communities		**Disagree**		I am comfortable with the technical basis for the fish IBI bands presented although I stress I am not a subject matter expert. However, I do *not* agree that quantitative relationships that link the attribute state to the limits for the 4 contaminants exist – e.g., for any particular fish IBI outcome sought, nitrate concentrations could be widely different (as the plot provided shows). I am of the view that fish IBI is useful to monitor (and could be a monitoring recommendation) but inappropriate as an attribute for setting targets and limits in Table 3.11.1 for determining the effectiveness of PC1.
Riparian		**Disagree**		Managing riparian margins is one of a suite of tools for managing ecosystem health and input of the 4 contaminants to waterways, but it is *not* an attribute of freshwater. Therefore, I cannot support its inclusion in Table 3.11.1.
Lakes		**Disagree**		We have not had the opportunity to properly caucus these proposed attribute tables. I therefore am not currently comfortable with agreeing to their inclusion in Table 3.11.1 and would stick with what is currently in PC1 (no decline, and meet bottom line as required by PC1). As it stands: 1. I am not comfortable with the proposed short-term targets (why 20% rather than the 10%? – it's not a technical role to redefine this) and their achievability given internal loadings. 2. I don't understand how the short-term targets are to be interpreted – as a median value across all lakes in the FMU or a % improvement in each lake? 3. What about all the unmonitored lakes that therefore do not

				have current state from which improvement targets can be derived? For lakes, I would support a LakeSPI monitoring recommendation in a similar manner to my views on fish IBI and macroinvertebrates.
Whangamarino	**Agree**			Agree in full with the multiple lines of evidence rationale and recommendation for inclusion of the TN and TP attributes. On the amendment to the sub-catchment boundaries –I am comfortable to go with the change if all that know about this agree with it. Qualifier: On the additional site – agree that this would be useful but is this part of what we've been asked to caucus or something separate? There were a number of additional sites recommended by TLG, to which this could be added. Table 3.11.1 is about *existing sites* which have *existing data* from which to derive current state and thence targets. New sites can't fit in here.
Temperature	**Agree(Cox)**	**Disagree (Daniel)**		I agree with the analysis and reasoning presented in the Cox paper for *exclusion of T* from Table 3.11.1.
Toxicants / Pesticides		**Disagree**		This is an interesting paper, but toxicants (other than nitrate and ammonium) are not the subject of PC1 which is to manage the effects of the 4 contaminants – N, P, sediment, and microbes.

Tim Cox

Attribute paper	Agree	Agree in Part	Disagree	N/A	Comment / Qualifier
Nutrients	**Agree**				I am supportive of the paper's final recommendations, in entirety. I am also supportive of a total nutrient load allocation to the sub-catchments, based on science and other considerations, to be undertaken in the near future (e.g. along the lines of Approach 3).
E.coli	**Agree**				
Deposited sediment	**Agree**				
Clarity	**Agree**				
TSS					Nothing proposed
DO		**Agree in part**			I don't believe that this attribute can be managed by managing the 4 contaminants of concern only (other confounding drivers: flow, temperature, BOD/SOD), and no empirical evidence has been presented to suggest that it could be. Further, the primary production impact on DO should, in theory, be addressed with existing chl-a limits. **However, I have no objection to DO being included with a narrative standard only, ideally focusing on improvement in diel DO profiles.**
Invertebrate Communities			**Disagree**		Can't be managed by managing the 4 contaminants of concern.
Macrophyte nuisance	**Agree**				Agree that it should *not* be included as an attribute.
Periphyton	**Agree**				
Fish Communities			**Disagree**		Can't be managed by managing the 4 contaminants of concern.

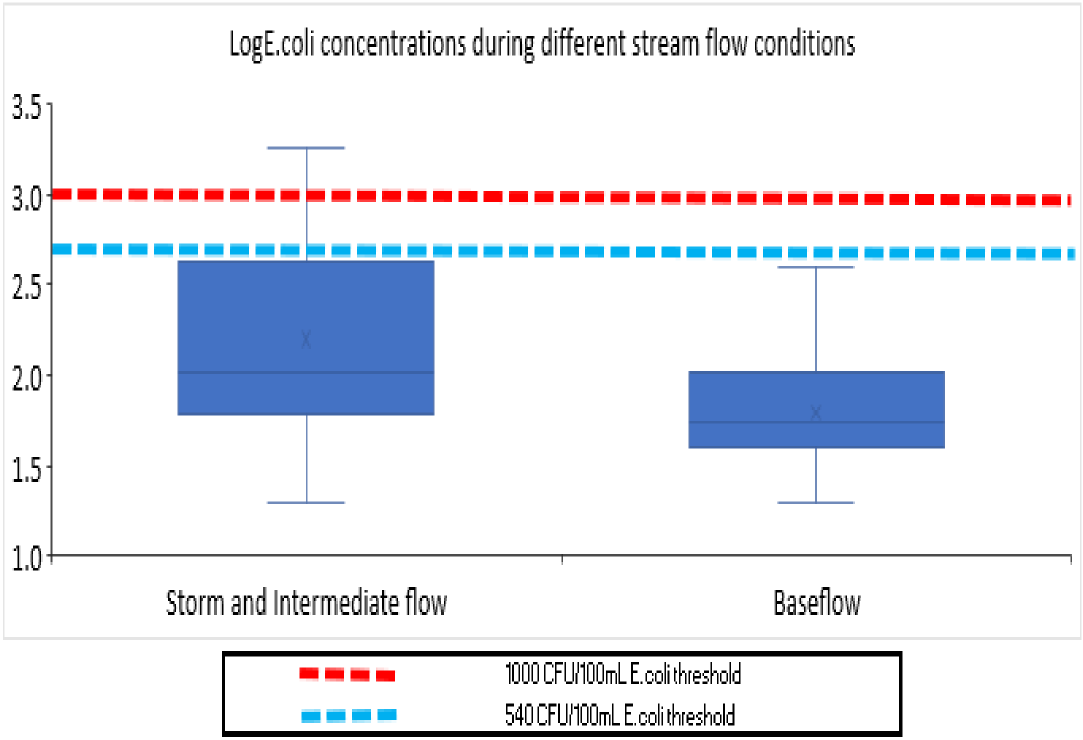
Riparian			**Disagree**		Riparian vegetation is not a water quality attribute. It is a management approach (restoration of riparian vegetation) that should be used to improve water quality.
Lakes	**Agree**				
Whangamarino			**Disagree**		Wetlands serve as critical filters of nutrient for receiving waters. Nutrient “recycling” in wetlands is significant and can complicate nutrient reduction strategies. Setting quantitative nutrient limits *within* a wetland complicates the policy and could be counter-productive to the goal of river water quality management. There was also no empirical evidence presented that demonstrates nutrient or sediment impairment in Whangamarino, with respect to ecosystem health. Further, existing nutrient limits throughout the river catchment should address the concern about over-enrichment of Whangamarino wetland.
Temperature	**Agree with Cox opinion.**		**Disagree with Daniel opinion.**		None of the four contaminants are direct drivers of temperature impairment in the catchment, and mitigation of temperature impairment in the catchment could not be effectively achieved by managing the four contaminants of concern.
Toxicants / Pesticides			**Disagree**		Can’t be managed by managing the 4 contaminants of concern.

Christopher A. Dada

Attribute	Agree	Agree in part	Disagree	NA
E.coli (Attachment 3)		CDa (kindly see run statement)		
Other attributes				N/A

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
Nutrients			**N/A**	
E.coli	**Y?**			• As the only practicing microbiologist in the panel, I have had reasonable difficulties communicating my technical viewpoints to the panel whose decision is tied to the number of votes. It is apparent that a pre-conceived conclusion has already been reached with respect to the E.coli attribute. None the less, these run statements as an opportunity to convey my technical position on the proposed E.coli attribute numbers. • For two reasons, I recommend caution with respect to the interpretation of the NPS-FM *E. coli* attribute state classes in relation to risk. Firstly, there is often zero or low correlations between concentrations of *E. coli* and zoonotic pathogens that they are meant to 'protect against'. This is in line with the conclusions of the Freshwater Microbiology Research Programme upon which the existing standards were built, "correlations between indicators and pathogens in the study were generally low" (see page 19 and 29, McBride et al 2002). Secondly, not all *E. coli* are from faecal sources and they can naturally survive and proliferate outside of animal intestines. Hence, when determining the attribute state of a waterbody, the quantity of *E. coli* is not necessarily correlated with increasing risk of infection. • Despite these issues, I agree that we may still cautiously adopt *E. coli* as an indicator of

				health risk, in line with the NPS-FM attribute state table (with some amendments). • The current approach to monitoring *E. coli* levels as a proxy for the presence of zoonotic pathogens does not distinguish between concentrations during different flow conditions. Non-exclusion of storm flow conditions in the determination of NPS-FM attribute state for the PC1 Table 3.11.1 sites overestimates risk associated with swimming during non-swimming periods. An analysis of PC1 sites data showed that low flow conditions (which coincide with swimming season) generally presented with lower *E.coli* concentrations and were generally below the single sample 540 CFU/100mL threshold, unlike concentrations during stormflow conditions (as an illustration, see Figure 1 below for a comparison between storm flow and base flow concentrations at Waikato River at Tuakau Br). Therefore, assessment of current or future attribute state without consideration of flow overestimates health risks associated with exposure to pathogens, particularly during non-swimming periods when the *E.coli* population are largely driven by periods of high flow.

				 River at Tuakau Br) • I recommend that for all the PC1 sites listed in Table 3.11.1, the five-year *E.coli* concentrations used to determine the NPS FM attribute state should be corrected for flow to eliminate exaggerated *E.coli* concentrations during storm flow conditions before determining the attribute state of a river. This is a standard procedure which helps to identify and quantify the effects of controlling factors other than river flow (e.g., land-use change) on water-quality trends (see page 23 in Larned et al's (2015) report on 'Analysis of

				Water Quality in New Zealand Lakes and Rivers’). • I partly agree with the recommendation of this panel to adopt all four NPS FM Attribute state metrics, (that is median, 95th percentile *E.coli* concentrations and percentages exceeding 260 and 540). However, I note that discrepancies currently exist in the designated attribute state based on the four NPS-FM metrics, as observed in 12 out of 62 PC1 sites for which there are monitoring data. Presented below is a list of the sites and the various conflicting current state predicted by the combined NPS-FM metrics. • As shown in the table, these disparities may occur as either narrow or wide disparities between the designated attribute state based on one NPS-FM metrics versus another NPS-FM metrics. I suggest that any of the different approaches below be used to resolve these disparities viz: • In instances of narrow disparities (when one NPS-FM metrics classifies a stream into an attribute state such as ‘blue’, while another statistic classifies the same water body as being of a slightly poorer status such as ‘green’), I suggest that the default position is to designate the stream as being of the poorer status. • In instances of wide disparities (when one NPS-FM metrics classifies a stream into an attribute state such as ‘blue’, while the 95th percentile classifies the same water body as being of a markedly poorer status such as ‘red’), I suggest that authorities designate the stream as being of an attribute state that is common to at least two of the NPS-FM metrics. • There is still high uncertainty with respect to the source of faecal pollution at the PC1 sites for which *E. coli* reduction targets are set, despite existing high-level microbial source tracking (MST) competencies. The MST approach has only been applied to 5 out of the 62 WRPC1 sites. Preliminary MST results show that wildfowl is the predominant source of faecal indicator bacteria in those 5 streams and that cattle markers only become prevalent following heavy rainfall impacted (i.e. surface run-off and overland) conditions. As the current sources of faecal pollution are not known for most of the PC1 streams and rivers, the modelled anticipated reductions in *E. coli* levels will most likely not be met in the medium or long terms. I suggest that MST studies be commissioned for each PC1 site that will support effective, site-specific approaches to reducing *E. coli* levels. • While further work is undertaken to improve our understanding of the sources of in-stream *E.coli* concentrations in the PC1 sites, I recommend that authorities: -- Put on hold requirements to fence hill country streams which seeks to improve *E.coli* attribute state of PC1 sites, considering that it is a counter-intuitive approach to stopping overland flow, the main source of faecal pollution loading in the Waikato Region. -- Increase requirements to identify and manage critical source areas and overland flow

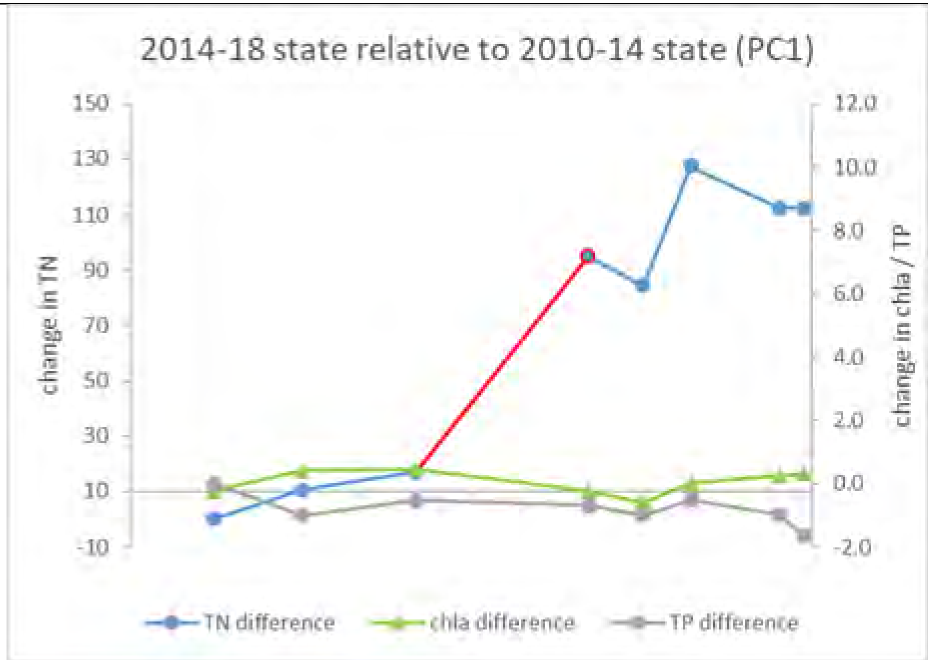
				pathways. This will then lead to catchment-specific management intervention rather than the current 'blanket' approach to effect fences for stock exclusion which does not address overland flow and will not cause improvement of the PC1 *E.coli* attribute states. -- Commission longitudinal site-specific MST studies targeted for each identified site in the WRPC1 Table 3.11.1. The study should also incorporate phylogenetic dimensions that are able to distinguish if these elevated bacteria levels in each WRPC1 site are due to naturalized *E.coli* from the stream bed and channel sediments. "Naturalized" E. coli populations falsely inflate measured *E.coli* levels, leading to exceedances of available thresholds, this incorrectly suggesting that pollution is present. • I support the most probable number (MPN)-based recreational shellfish-gathering bacteriological guideline values for water as outlined in the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas, Ministry for the Environment and Ministry of Health (2003). • I also support the stance that the shellfish guidelines should be applied in conjunction with a sanitary survey.

Site Station	Count	Exc260	Exc540	PercExc260	PercExc540	Median	95th Percentile
Awaroa River (Waiuku) at Otaua Rd Br opp Moseley Rd (41_9)	23	10	4	43%	17%	240	990
Awaroa Stm (Rotowaro) at Sansons Br @ Rotowaro-Huntly Rd (39_11)	39	24	7	62%	18%	290	1,580
Kaniwhaniwha Stm at Wright Rd (222_16)	23	10	6	43%	26%	250	1,940
Karapiro Stm at Hickey Rd Bridge - Cambridge (230_5)	38	20	10	53%	26%	295	2,665
Kawaunui Stm at SH5 Br (240_5)	39	13	7	33%	18%	200	1,770
Kirikiriroa Stm at Tauhara Dr (253_4)	38	33	20	87%	53%	570	3,080
Komakorau Stm at Henry Rd (258_4)	39	36	33	92%	85%	1,100	3,800
Little Waipa Stm at Arapuni - Putaruru Rd (335_1)	39	8	3	21%	8%	110	840
Mangaharakeke Stm (Atiamuri) at SH30 (Off Jct SH1) (359_1)	39	10	4	26%	10%	170	700
Mangakara Stm (Reporoa) at SH5 (380_2)	39	10	5	26%	13%	140	1,700
Mangakino Stm (Whakamaru) at Sandel Rd (388_1)	23	1	0	4%	0%	40	236
Mangakotukutuku Stm (Rukuhia) at Peacockes Rd (398_1)	38	36	18	95%	47%	515	8,775
Mangamingi Stm (Tokoroa) at Paraonui Rd Br (407_1)	39	31	20	79%	51%	580	2,060
Mangaohoi Stm at South Branch Maru Rd (411_9)	39	7	3	18%	8%	70	875
Mangaokewa Stm at Te Kuiti Borough W/S Intake (414_12)	23	19	10	83%	43%	490	5,340
Mangaone Stm (Waikato) at Annebrooke Rd Br (417_7)	38	35	27	92%	71%	800	2,130
Mangaonua Stm at Hoeka Rd (421_10)	38	37	33	97%	87%	1,500	6,930
Mangapiko Stm (Pirongia/Te Awamutu) at Bowman Rd (438_3)	22	13	6	59%	27%	325	4,960
Mangapu River at Otorohanga (443_3)	38	25	18	66%	47%	480	4,475
Mangatangi River at SH2 Maramarua (453_6)	23	19	7	83%	30%	380	4,180
Mangatawhiri River at Lyons Rd At Buckingham Br (459_6)	23	7	3	30%	13%	190	1,056
Mangatutu Stm (Waikeria) at Walker Rd Br (476_7)	38	9	4	24%	11%	160	715
Mangauika Stm at Te Awamutu Borough W/S Intake (477_10)	38	5	3	13%	8%	33	1,015
Mangawara Stm at Rutherford Rd Br (481_7)	23	21	16	91%	70%	1,000	5,200
Mangawhero Stm (Cambridge) at Cambridge-Ohaupo Rd (488_1)	37	33	19	89%	51%	590	2,780
Matahuru Stm at Waiterimu Road Below Confluence (516_5)	23	20	15	87%	65%	600	1,730
Ohaeroa Stm at SH22 Br (612_9)	23	12	7	52%	30%	300	2,470
Ohote Stm at Whatawhata/Horotiu Rd (624_5)	38	19	6	50%	16%	275	2,005
Opuatia Stm at Ponganui Rd (665_5)	38	26	13	68%	34%	390	3,115
Otamakokore Stm at Hossack Rd (683_4)	39	12	3	31%	8%	220	642
Pokaiwhenua Stm at Arapuni - Putaruru Rd (786_2)	39	9	5	23%	13%	150	1,410
Pueto Stm at Broadlands Rd Br (802_1)	39	0	0	0%	0%	21	74
Puniu River at Bartons Corner Rd Br (818_2)	22	6	5	27%	23%	140	2,990
Tahunaatara Stm at Ohakuri Rd (934_1)	39	5	4	13%	10%	110	720
Torepatutahi Stm at Vaile Rd Br (1057_6)	23	1	0	4%	0%	54	168
Waerenga Stm at Taniwha Rd (1098_1)	39	32	15	82%	38%	500	4,210
Waikato River at Horotiu Br (1131_69)	60	6	3	10%	5%	90	515
Waikato River at Huntly-Tainui Br (1131_77)	60	16	8	27%	13%	125	1,910
Waikato River at Mercer Br (1131_91)	60	12	7	20%	12%	80	1,505
Waikato River at Narrows Br (1131_101)	60	3	1	5%	2%	39	198
Waikato River at Ohaaki Br (1131_105)	60	0	0	0%	0%	14	71
Waikato River at Ohakuri Tailrace Br (1131_107)	60	0	0	0%	0%	2	15
Waikato River at Tuakau Br (1131_133)	60	11	7	18%	12%	80	1,600
Waikato River at Waipapa Tailrace (1131_143)	60	1	0	2%	0%	8	122
Waikato River at Whakamaru Tailrace (1131_147)	60	1	0	2%	0%	8	60
Waiotapu Stm at Campbell Rd Br (1186_2)	39	0	0	0%	0%	2	12
Waiotapu Stm at Homestead Rd Br (1186_4)	23	2	0	9%	0%	110	261
Waipa River at Mangaokewa Rd (1191_5)	23	8	5	35%	22%	210	1,360
Waipa River at Otewa(1191_7)	60	25	13	42%	22%	236	2,008
Waipa River at Pirongia-Ngutunui Rd Br (1191_10)	39	22	14	56%	36%	300	4,650
Waipa River at SH3 Otorohanga (1191_12)	39	14	7	36%	18%	180	3,190
Waipa River at SH23 Br Whatawhata(1191_11)	60	34	23	57%	38%	392	3,689
Waipapa Stm (Mokai) at Tirohanga Rd Br (1202_7)	39	4	2	10%	5%	100	630
Waitawhiriwhiri Stm at Edgecumbe Street (1236_2)	38	33	21	87%	55%	605	4,855
Waitomo Stm at SH31 Otorohanga (1253_5)	39	23	12	59%	31%	310	1,510
Waitomo Stm at Tumutumu Rd (1253_7)	39	15	8	38%	21%	180	2,160
Whakapipi Stm at SH22 Br (1282_8)	23	17	8	74%	35%	320	1,680
Whakauru Stm at U/S SH1 Br (1287_7)	38	33	16	87%	42%	480	2,145
Whangamarino River at Island Block Rd (1293_7)	23	9	4	39%	17%	180	645
Whangamarino River at Jefferies Rd Br (1293_9)	23	20	13	87%	57%	600	4,900
Whangape Stm at Rangiriri-Glen Murray Rd (1302_1)	23	10	2	43%	9%	220	549
Whirinaki Stm at Corbett Rd (1323_1)	23	0	0	0%	0%	16	49

Deposited sediment			**N/A**	
Clarity			**N/A**	
TSS			**N/A**	
DO			**N/A**	
Invertebrate Communities			**N/A**	
Macrophyte nuisance			**N/A**	
Periphyton			**N/A**	
Fish Communities			**N/A**	
Riparian			**N/A**	
Lakes			**N/A**	
Whangamarino			**N/A**	
Temperature			**N/A**	
Toxicants / Pesticides			**N/A**	

Craig Depree

Attribute paper	Agree	Agree in part	Disagree	N/A	Comment / Qualifier
Nutrients		**Agree in part**			**Section 3) Nitrate toxicity** I support the nitrate and ammonia toxicity attribute values proposed in Table 1 of the document. This will avoid the problematic issues arising from current 'band testing' which results in several examples of much larger improvements having to be made in catchments where the water quality (and hence impacts) are less. For example, if current C band for nitrate toxicity, need as little as 8% reduction in nitrate, but if B band, this reduction can be >50%. **Section 4) Waikato mainstem long-term thresholds (Approaches 1 & 2)** Numerous studies and analyses have indicated that TP is the main predictor of chla in the mainstem river. This have been further supported in the 4-year period since the 2010-14 PC1 'current state' with TN increasing in the river (largely between Waipapa and Narrows), but TP, Chla and visual clarity either remaining the same or improving (refer to figure below).



Accordingly, **I support Approach 2C for setting TP targets** that correspond to the community expectation of a target of 5 mg/m^3 of median chla along the length of the river.

Accepting that it is recognised both from a science perspective and community perceptions/expectation; it is essential to manage both P and N - indeed, some studies have indicated that at times (ie summer) that some parts of the river, maximum chla may be N-limited.

I do not support the N thresholds proposed in 2C, but rather support the TN thresholds proposed in 1B or 1C. The difference between these being whether Lake Ohakuri is regarded as ‘seasonally stratified’ or ‘polymictic’, which dictates an NPS-FM TN threshold target of 160 mg/m^3 or 300 mg/m^3, respectively. This has implications for management, as the former indicates the lake is ‘over allocated’ and the latter suggests it is not (as current state is c. 210 mg/m^3).

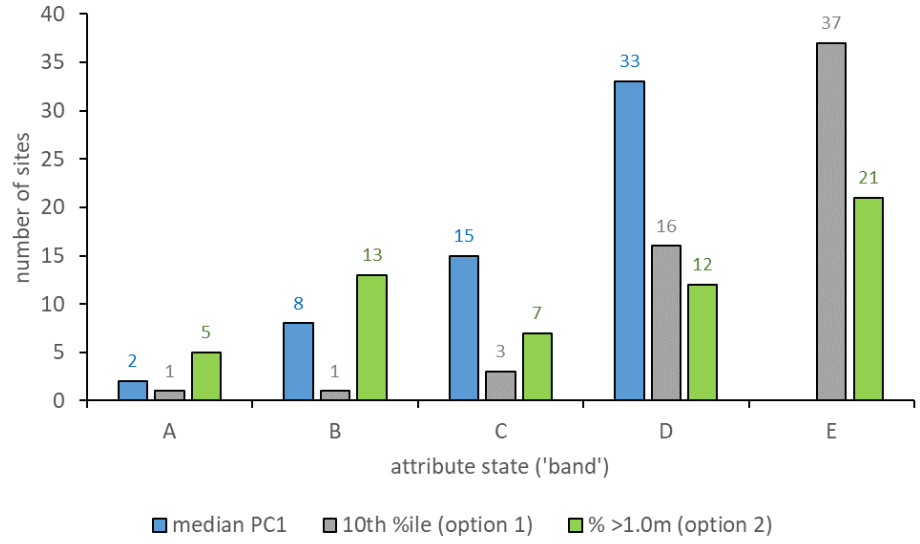
I am comfortable supporting TN targets from Approach 1C based on the following

					inclusions: 1) Table 3.11.1 has additional line (or replacement of Narrows) estimate water quality at Karapiro. Water quality at Narrows more closely represents water quality exiting the upper FMU, than water quality in the middle FMU. This is important given that increases in TN (using contemporary state - ie 2014-2018) are occurring between Waipapa and Narrows (oresumably Pokaiwhenua catchment is a major contributor), and these inputs are being 'registered' (or accounted) in the middle FMU site at the Narrows. Not having a Karapiro site means that the last site in the upper FMU assessed for 'compliance' against targets is Waipapa, which is 80km upstream. Without including Karapiro, Approach 1C and 2C indicated the upper FMU is not over-allocated with respect to nutrients. Including Karapiro site will explicitly define the upper FMU as being over-allocated with respect to both TN and TP. 2) That Lake Ohakuri is defined as not being seasonally stratified. It would also to reassuring to get additional information/monitoring on the eutrophic status of the Whirinaki Arm - as not indicating Ohakuri as over-allocated, lessens (in my opinion) the ability to address over-allocation in area contributing to this degraded (eutrophic) arm of Ohakuri. 3) Short term-targets for mainstem (based on 10% progress towards the 80-y target) will need to be recalculated based on new recommended targets (if adopted). For contaminants such as nitrogen that have increased markedly at selected sites since PC1 current state (2010-14), short-term targets should also factor in these increases, if the intention is to set these short-term targets at 10% progress towards long-term goals (note without changing TN thresholds, in the lower FMU, short-term targets now represent >50% progress towards 80y targets). Support the science rationale behind approach 2C. Logical to set TN and TP to achieve desired outcomes in Chlorophyll a, where there is robust evidence to do so. There is a strong body of evidence indicating P is more important than N in controlling Chlorophyll a along the mainstem of the Waikato river. Also support the rationale of more clearly defining the impacts associated with inputs from the riverine lakes (e.g.

					Waikare). **Waikato mainstem and tributary short-term thresholds (Approach 3)** These approaches are outline in Table 4 for mainstem sites and Table 6 for subcatchment tributaries. I have confidence in the work underpinning them, and that my understanding is that the load reduction from implementing the policy mix (in Doole et al. 2016) have resulted in complementary numbers. While these numbers are very useful, I am not convinced that they should be used to set short-term (10y) interim targets. The reason is that the CSG defined short-term targets as being 10% of the journey to 80 year targets. We know from the modelling of Doole et al (2016) that contaminants at almost all sites exceed the interim 10% progress targets. Thus the reality is that PC1 mitigation are likely to achieve greater than 10% progress towards 80y targets. For example, counting the 53 subcatchments in table 6 – reductions in TN and TP, from the mitigation scenarios are 623 and 89 t/y, respectively. Based on reductions required at Tuakau (1854 t TN/y and 257 t TP/y), **the progress towards the 80 year targets is 34% for TN and 35% for TP** – hence both are significant greater than 10% progress required in the 10 years of PC1. This needs to be taken into account if they are used as interim /short-term targets – as they represent progress towards the long-term targets (based on Tuakau) that is around 3x greater than that required in the duration of PC1. Because even if they are not met, it is likely that progress >10% has still be made, hence things would still be on-track for meeting 80-y targets. **Approach 4** **Do not support**. Overly simplistic and not based on Waikato data. Data based on macroinvertebrates / fish / and periphyton (mainly the former) – based on large

					national datasets. It is generally accepted (by scientists, including lead author of the study that derived the thresholds – i.e. Dr. Death) that nutrients effects on macroinvertebrates at subtoxic concentrations are most likely mediated by periphyton. Accordingly, what is the relevance of these numbers in streams that are hard-bottomed but do not 'express' nuisance periphyton growths, or the large proportion of streams in the Waikato that are soft-bottomed, and hence cannot support periphyton proliferations. Additionally, the method proposed ignores the process implemented by the CSG which looks at current state and sets targets to improve on that current state. This Approach just assigns a single target regardless of current state and catchment landuse. Highly problematic and idealistic. **Approach 5** Not supported, as very simplistic, and I do not even know the origins of the data. Worse than Approach 4, and suffers from the same issue around implementation – ie one size fits all, which seems inconsistent with the CSG approach of improving everywhere from current state etc. These proposed target are based on periphyton, which doesn't occur everywhere, and there are a huge number of factor that control its biomass (flood frequency, substrate, shade and nutrients) – hence very simplistic, and flawed approach. I support having at least a periphyton narrative attribute to make sure where periphyton proliferations occur, there is a mechanism for these to be monitored/identified and steps put in place to mitigate.
E.coli	**Agree**				**I support implementing the E.coli attribute as per the NPS-FM (amended 2017).** Needs recommendation for faecal coliform attribute relative to shellfish gathering. I do not support recreational shellfish gathering water quality guidelines for pathogens to be applied in PC1, as see are based on estuarine/marine water environments. I would recommend sampling of riverine shellfish and determination of E.coli in flesh, and then attempting to relate shellfish flesh bacteria levels to known water quality E.coli measure/metrics - this may allow derivation of meaningful water quality targets to protect shellfish harvesting.

					Do not support subset of measures or flow modification to grade sites
Deposited sediment			**Disagree**		Needs to be developed further. Support monitoring requirement with action when breaching bottom line - I was lead on initial sediment thresholds project for MfE , and several aspects of the attribute as proposed were unworkable as an attribute table (in my opinion). I would consider supporting a bottom-line type narrative attribute statement (i.e. similar to policy CB3 in NPS-FM for macroinvertebrates) – but I am concerned that this is based on assessments relative to natural reference state, and these are dependent on national models with large uncertainties. Potentially support a bottom-line based 'CB3' type statement, but there are significant issues around monitoring that need to be resolved. As with macroinvertebrates and periphyton, these are monitored annually, whereas temporal variation requires at least 2 years of monthly monitoring data (based on proposed national attributes for sediment, Phase 2 report for MfE).
Clarity	**Agree**				**I support alternative 2** - i.e.attribute based on % compliance with 1 m visual clarity. PC1 attribute for clarity is based on perception of water to recreate (which sites work based on water quality scientist perception). Cited work actually showed that clarity is a relatively minor aspect determining public's perception of swimming – more driven by environment, access, safety (currents etc). These studies showed that the critical area of clarity was between 0.7 and 1.2 m and that above this range there is a rapidly diminishing improvement of swimming perception and clarity. Hence thresholds such as 1.6 and 3 m simply do not relate to, or define conditions of safe swimming. **For example, what does 'eminently suitable for swimming' mean to the general public regarding safe to swim/recreate?** In contrast, Canadian has defined minimum clearness distances in water, and these translate in NZ black disc measurement of 1m. **Thus a more informative and less arbitrary basis for an attribute is the % a water body meets or exceeds this define safe swimming clarity value.** **A value of 1m is supported by Waikato perception studies at locations in the upper and middle FMU (Karapiro and Wellington Street Beach) showed 90-95% as public**

					surveyed perceived it as swimmable (and did swim) – these sites had clarity measurements of around 0.9m. Comparison of PC1, Alternative 1 and **recommended Alternative 2** shown below (2010-14 data - ie PC1 current state) 
TSS				**NA**	
DO		**Agree in part**			I do not support the attribute table in the document, I disagree with the having a mean DO measure (which is not present in the current NPS-FM DO attribute that applies downstream of point source discharge). **I do support the recommendation to use a bottom line DO narrative type objective (analogous to policy CB3 NPS-FM type statement).** I also recommend that if 1-day minima measures are used, this should be assessed from a DO record that is at least long enough to assess the 7-day minimum measure. This is do avoid compliance being assessed from a single 24 hour deployment of DO instrument (which is unsatisfactory).

Invertebrate Communities			**disagree**		Accept that macroinvertebrates is important, but conceptually have problems with aspect of proposed attribute. These include: • Use of QMCI as measure, without adequate explanation of why results vary so much compared to the more national recognised MCI measure. For example, the proportion of sites graded as 'poor' are 2 to 5 times greater when assessed using QMCI compared with MCI. The choice of metric and nature of attribute obviously has considerable implications for mitigations in PC1 – which I am uncomfortable with • I refer to MfE website for review of these 2 measures - https://www.mfe.govt.nz/publications/about-us/user-guide-macroinvertebrate-community-index/appendix-2-use-mci-qmci-and-sqmci • Complete mis-alignment of macroinvertebrate and water quality monitoring sites – hence don't have water quality data to respond to decreasing / impoverished macroinvertebrate communities at a site that could be very distant/remote from a subcatchment water quality monitoring site. • Uncertainties around hard-bottom vs soft-bottom scoring that makes up the regional data. It is my understanding that Waikato data apparently doesn't need to have correction for hard vs soft-bottom, despite this being a requirement in Auckland and Northland. If Waikato is dominated by soft-bottom streams, and soft-bottom streams naturally have less diverse/more impoverished (or 'pollution tolerant') communities, then how does this impact on regional/catchment results – is this contributing to the huge variation between QMCI and MCI assessments **I support a general narrative state around bottom-line and MCI, as per policy CB3 in NPS-FM.**
Macrophyte nuisance	**Agree**				**Agree, in that I do not support macrophyte as an attribute**. Needs further development at national and regional scale.

Periphyton		**Agree in part**			**I support recommendation (2)** stating we should adopt the NOF bottom line of 200 mg/m^2 chla in all hard-bottomed rivers and streams in the Waikato/Waipa catchment (i.e. CD3-type statement as per NPS-FM). Addition comments include: • Periphyton monitoring requires monthly monitoring, periphyton monitoring currently carried out at REM site annually – hence have same problem as macroinvertebrates in that were periphyton is monitored is not where water quality is monitored • Need to measure periphyton at water quality sites (although not many are apparently wadeable), or to increase monitoring to monthly at selected REM (regional ecological monitoring sites). Presumably this will require some aspects of prioritisation outline in recommendation (1).
Fish Communities			**Disagree**		**I do not support the Fish IBI attribute.** Fish QIBI relatively poor at discriminating stressor effects in Waikato. Fish index is heavily influenced by barriers to access and this limits its utility as a WQ indicator. I don't agree that we know what to do to manage for QIBI at a regional or FMU scale.
Riparian			**Disagree**		**Strongly disagree with this attribute** – it seems like it is a proxy for landuse cover, and hence doesn't make sense. Specific comment below: • I don't even really understand how the two attributes work in practice i.e. unclear to me whether both apply and how this works? • For example, if rural catchment and landowners achieved >80% riparian buffers (A band) , but if these were <5m average , then it would be 'D" band ? • Additionally, the first table has issues around dual measures (average vs minimum) , and inconsistent definitions of D band relative to the bottom line • **Length of riparian / or stock exclusion best dealt with via rules / FEPs (not attribute for Table 3.11.1)**
Lakes			**Disagree**		**I do not support alternative FMU delineation**. This is based on an incomplete and unreviewd piece of work by WRC. Should be referred to as (pers. Comm.), not Ozkundakci (2015). And also no technical information was submitted to the expert

					group for review. **I support retaining the lake attribute table currently in PC1.**
Whangamarino		**Agree in part**			**Support the monitoring of Pungarehu channel and the recommendations to change FMU** Conceptually I support the need to limit nutrients in wetlands, and this requires a reduction, but I have not seen any scientific information to support the application of lake-based NOF TN and TP values to protection of a wetland, where there a number of issues outlined below: • Part of the evidence provided in Table 2 shows slightly elevated TP and elevated TN in Whangamarino wetland soils relative to national wetland averages (swamp type). I don't have an appreciation for the relationship between nutrient concentrations in river water column, and wetland soil, and I am told that improvement in these aspects is looking at 500 year time scales. • Whangamarino is part of Waikato River flood scheme , although infrequent , what contribution to surface soil nutrients does episodic inundation of Waikato river (as part of flood scheme)? That is, can remediation be achieve if this wetland is subject to large amounts of nutrient enriched sediment as part of flood detention scheme? • What is the connectivity of Whangamarino river the adjacent wetlands – ie under baseflow conditions , does surface water move into wetland, or does this only occur during higher flows ? What is the relative importance of nutrient enrichment occurring under median/baseflow events vs high flow events resulting in more substantive inundation? Hence what is the relevance of thresholds based on median TN and TP concentrations? • Nutrients at island block road is hugely influenced by inputs via channel from a supertrophic lake (Waikere), hence setting a nutrient limit in Whangamarino river at island block road will require successful restoration of lake waikere?

					The important management goal should therefore focus on lake waikere restoration, not setting nutrient limit at island block road? The world lacks examples of lakes being returned from such flipped, extremely eutrophic states – in the case of Waikere, it is part of a flood detention scheme for Waikato river and has been lower by 1m , hence restoration would likely be difficult while it is still used as flood infrastructure (well is my understanding). • My general view is that like lakes, Whangamarino wetland, needs a detailed subcatchment management plan which will be developed as part of PC1 (ie. Policy 14 and 15)
Temperature			**Disagree (with attachment 14 – Dr. Canning)**		**Disagree with temperature being an attribute** in PC1 (i.e. as proposed in attachment 14 of the JWS). I agree with the assessment by Dr. Cox (attached 15), which recommends temperature is not included as an attribute.
Toxicants / Pesticides			**Disagree**		**Disagree with Toxicants/pesticides being an attribute in PC1.** Support narrative approach based on ANZECC Guidelines risk assessment framework, but don't support inclusion in PC1 (would change entire scope of PC1 from four contaminants to "all" contaminants).

Garrett Hall

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
Nutrients	**Y**			• For main stem, support approach 2C for TP, and approach 1C for TN • I do not support approach 4 and 5 for tributaries (too generic and does not recognise spatial variability), however support the approach outlined in approach 3
E.coli	**Y**			• Agree with recommended option (iv) • Approach to shellfish is an approach that is commonly used in marine waters, further comment needed in paper on its appropriateness to freshwater? (i.e. appropriateness of faecal coliform limits)
Deposited sediment	**Y**			• Support approach outlined in paper, particularly narrative objective seeking an improvement over time
Clarity		**N**		• Support current approach in PC1 (i.e. the use of a median statistic) • Alternative 1 too stringent and difficult to achieve, and alternative 2 not well supported by expert panel
TSS				• N/A
DO	**Y**			• Support approach outlined in paper • I am aware of lowland streams in the Waikato Region that would consistently not meet the bottom line and would therefore require management intervention
Invertebrate Communities	**Y**			• Agree with recommended approach
Macrophyte nuisance	**Y**			• Agree with recommended approach
Periphyton	**Y**			• Agree with steps outlined in paper

Fish Communities			**N/A**	• Not within my area of expertise
Riparian		**N**		• Do not support approach as outlined in paper, but recognise that further work should be undertaken to develop an attribute with greater resolution at the regional scale i.e. a greater ability be monitored both in terms of current and short/long-term targets
Lakes			**N/A**	• Not within my area of expertise
Whangamarino			**N/A**	• Not within my area of expertise
Temperature		**N**		• Support approach in paper of T. Cox • Recognise importance of temperature related effects as outlined in paper of A. Daniel, but do not support inclusion of temperature attribute at this time
Toxicants / Pesticides	**Y**			• Support approach outlined in paper

Gillian Holmes

Attribute paper	Agree	Disagree	Agree in Part	N/A	Comment / Qualifier
Nutrients			Y		Agree with the loads being calculated for both main stem and sub-catchments/tributaries as outlined in Section 2.2 of the paper, particularly as the sub-catchment loads will provide a basis for managing the subcatchment contributions to achieve the desired state of the mainstem. The current loads outlined in the Nutrients paper are "diffuse loads" which are instream (attenuated) loads. There needs to be further discussion on the use of attenuated loads given the level of uncertainty/disagreement around the parameters used to calculate attenuation in NIWA's modelling and parameters being proposed by other submitters. I agree with attenuated/diffuse loads being included in the table (or % change of diffuse loads) as objectives. However, I consider that unattenuated loads should be included within the table as limits given that they relate more to the NPS-FM definition of a limit (resource use). This point was outlined in my Block 1 evidence and will also be covered in the Block 3 evidence. I tentatively support Approach 2C for the main stem TP, while Approach 1C would cover TN, although a lot more work is required to pinpoint the exact numbers to be included within the table. I agree with Approach 3 for the subcatchments, taking into consideration my points above.
E.coli – contact recreation	Y				Agree with option 3 9iv) under contract recreation discussion as

E.coli – shellfish gathering				N/A	stated on page 3: "*Application of the four NPS-FM metrics, as is, to determine NPS FM attribute state for the PC1 Table 3.11.1 sites while noting in the attribute table footnote…*" Outside of area of expertise.
Deposited sediment			Y		Agree with the narrative objective approach given the lack of data at this time, although no specific narrative has been proposed so would like to see the before final decision made.
Clarity			Y		Agree that clarity is included in PC1 for ecosystem health as it is a surrogate for TSS at this stage. I also agree with clarity for safe swimming. More discussion is required on which Alternative approach to accept given the lack of final recommendation in the paper (disagreement between the experts completing this paper) A discussion was started in conferencing, however time was limited and it was not completed sufficiently for a final decision to be made.
TSS	Y				Agree with comment that insufficient evidential support to include as attribute – and clarity used as surrogate.
DO			Y		Agree with the prioritising areas with known DO issues for monitoring and management. Disagree with inclusion as attribute <u>at this stage</u> – given lack of data and indirect relationship to four key contaminants. Can be reviewed in next plan change once more monitoring has been undertaken. Agree with the proposed narrative objective, however no specific narrative has been proposed so would like to see the before final decision made.
Invertebrate Communities	Y				The approach outlined in the memo provided on 7 June differs from other attributes given it is not proposing actual numbers for

					Table 3-11-1, however following the discussion on 12 June with the other WQ experts and the updated paper provided, I agree with the approach outlined in this paper, i.e. proposing a separate table to Table 3-11-1 (Table 3) in the paper.
Macrophyte nuisance	Y				Agree to the recommendation not to include macrophytes as an attribute and WRC should continue to monitor and report on macrophytes.
Periphyton			Y		Given the lack of information currently available on periphyton, existing standards for periphyton cover in the Operative Waikato Plan, and the fact that management of nutrients (already covered in Table) can reduce periphyton, I believe periphyton should not be included in the Table as an attribute. However, I am happy to support the narrative objective approach, although no specific narrative has been proposed so would like to see the before final decision made.
Fish Communities		N			Disagree as there needs to be more information provided on the WRC data set available and how it relates to PC1 subcatchments, as well more justification on the assessment against criteria section. Also, a discussion is required on whether or not a narrative approach may be best following the example of other attributes that we have considered during the conferencing. This was not undertaken during the last day of conferencing due to time restrictions.
Riparian		N			Disagree with riparian being included as an attribute. Currently covered under proposed Rule 3.11.5.5 and associated Schedule 1 and to be included in FEP's for PC1. Site specific solutions to riparian management need to be considered rather than setting blanket limits. In this way, the correct riparian management can be set to mitigate the issue at

					the site.
Lakes				N/A	Outside of area of expertise
Whangamarino			Y		Agree with setting of attributes and objectives for TN and TP for Whangamarino wetland catchment, however I do not agree with setting these values as targets as specified in Table 3 – limits should be based on resource use not concentrations. Loads would be more appropriate as limits in for this situation. In addition, I would like to see what mainstem and sub-catchment values are determined before agreeing to the values outlined in the memo (need to make sure they are consistent). Agree with the change in sub catchment boundary and inclusion of the monitoring site associated with Pungarehu Stream/Canal.
Other wetlands			Y		Agree with narrative approach proposed
Temperature – Adam Daniel Temperature – Tim Cox	 Y	N			Agree that temperature should continue to be monitored but should not be included as an attribute in the Table, given the lack of understanding of background temperatures and the lack of linkage between temperature and the four main contaminants in PC1.
Toxicants / Pesticides		N			Agree that other toxicants are covered by ANZECC guidelines, but not the inclusion as an attribute given the lack of relationship with the four main contaminants of PC1.

Gerry Kessels

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
Nutrients	**Y (in part)**			Agree that nutrient management should be extended to tributaries to account for subcatchment variances and allow more refined, response and targeted management responses. For the mainstem I prefer Approach 2C. I have concerns about the limitations in the determination of the TN thresholds but note I do not have the expertise to provide further assistance in this matter. I emphasise the importance of defining and ensuring management of TN and TP in the mainstem to limit nutrient loads in the estuarine and costal ecosystems, as these marine systems are very sensitive to nutrient inputs. I support Approach 3, in part – see below, for tributaries as it acknowledges that a subcatchment approach is required to distribute load for TN/ TP thresholds across the catchment, which deals with limitations of a mainstem approach. However, to manage ecosystem health for invertebrates I am interested in exploring Approach 4 as an alternative to Approach 3 with direct links to biological indicators and hence ecosystem health. I would appreciate further discussion on this as the paper provides limited explanation and we have not had the opportunity to properly caucus this approach.
E.coli			**N/A**	
Deposited sediment	**Y**			I support both a numerical and narrative objective for a deposited sediment attribute. The numerical attributes are not fully developed in my view though I suspect that the revised NPS-FW will provide a numerical objective set. In the meantime, given widespread support for the importance of this attribute as being an important measure of ecosystem health,

				as a holding point, a narrative attribute is also presented in the paper which I support the inclusion of: “A narrative ‘objective’ could be set in PC1 for an improvement over time in the extent of stream length exceeding the ‘poor’ threshold for fine sediment. This trajectory of improvement approach is recommended to capture aspects of ecosystem health in the tributaries of the Waikato and Waipā Rivers not currently accounted for in Table 3.11-1 and could also be applied with respect to macroinvertebrates and periphyton, using the WRC REMS monitoring framework.”
Clarity			**N/A**	
TSS		**N**		Insufficient evidence to assign as an attribute at this point in time, but would be a useful attribute to include if sufficient information was available.
DO		**N**		Agree with adaptive management framework. Agree with continuous monitoring in each FMU, but two week annual monitoring window is problematic as it will easily miss severe climatic events.
Invertebrate Communities	**Y**			I support both a numerical and narrative objective for a macroinvertebrate attribute, as this is a key indicator of ecosystem health and has clear and quantifiable causality relationship with nutrients, DO, fine sediment metrics as well as morphology, and (less quantifiable at present) to periphyton/macrophytes and riparian cover. I, for the most part, support the attribute table based on QMCI on the basis of the demonstrated relationships between QMCI and nutrients and sediment in the Pingram et al. paper. But I do note that MCI is a more robust metric and that QMCI as a metric is particularly sensitive to seasonal variations, for example – low flow events would show declines in QMCI but less so in MCI, which is not dependent on number of individuals. The REMs programme needs to be expanded spatially and temporally to have more and better

				located representative sites in each of the subcatchment and to achieve better FMU coverage. If MCI is used I do not support any generic use of to 80 MCI as a bottom line. As Collier et al (2014) state: *"Bottom lines for sites with reference condition >120 could be higher* [than 80] *depending on the type of wadeable stream environmental classification supported at the regional level (see Appendix 2 for example). It also needs to be recognised that some sites may have naturally low MCI values and in extreme cases could fall below the lower threshold. This situation could potentially be accommodated through some sort of environmental classification."*
Macrophyte nuisance		**N**		Nuisance macrophytes should be included in PC1 as an attribute for rivers and streams with a bottom line of >50% cover from Matheson et al. (2012) The NPS – FW review will likely yield a more developed approach but this is suitable in the interim.
Periphyton	**Y**			I agree with the risk assessment process and best suited to method in PC1.
Fish Communities	**Y**			I support the paper recommendations on this topic. The IBI based on fish community attributes has now been applied widely in North America. The Waikato IBI presented is the best tool currently available to measure ecosystem health in relation to fish using an expansion for the REMS network. There are limitations with the IBI approach, but this should not prevent the application of this critical biological indicator of ecosystem health now. Refinement is required to address these limitations and deal with physical environmental factors, such as barrier effects can be applied using predictive multivariate techniques. These matters are highlighted in the narrative Attribute State of the suggested table. Nutrients and deposited fine sediment influences fish mostly through impacts on habitat and food supply in rivers and streams. This has been well documented overseas, but less so in New Zealand. But there is NZ

				related research to assist as outlined in the paper (e.g Clapcott 2011). Therefore, while interactions are complex, and accounting for underlying spatial variation in the environment when quantifying relationships between land use and the ecological integrity of streams is required, using IBI for fish is an appropriate tool to set ecosystem health objective in PC1.
Riparian	**Y (in part)**			I suggest this could be used as a narrative attribute supported by a guideline rather than assigning as a numerical attribute in the table. Improvements in water quality and ecosystem health can also be achieved using other land use/management means – refer to my primary evidence. For me to accept the inclusion of this attribute, the plan should allow for other mechanisms to achieve the narrative objectives through plan incentive methods and/or rules.
Lakes			**N/A**	
Whangamarino	**Y**			I agree with the proposed split at Mercer sub-catchment so that the Maramarua subcatchment can be aligned to the Whangamarino Wetland. I support the development of TN and TP thresholds. I agree with the narrative objective as shown in the paper.
Temperature			**N/A**	
Toxicants / Pesticides			**N/A**	

Anthony Kirk

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
Nutrients	**X (in Part)**			**Agree with approach for mainstream outlined as 2C** **Agree with approach for sub-catchments and tributaries outlined as 3.** **With regards to NO_3-N and NH_4^+-N, targets should represent eco-toxicity only. Targets would then reflect the lesser of current state (maintain) or ecotoxicity thresholds (improve) outlined in Table 1 of Attachment 2.**
E.coli			**x**	
Deposited sediment			**x**	
Clarity			**x**	
TSS			**x**	
DO	**x**			**Agree with approach outlined in sub-group paper**
Invertebrate Communities			**x**	
Macrophyte nuisance			**x**	
Periphyton			**x**	
Fish Communities			**x**	
Riparian				
Lakes			**x**	
Whangamarino			**x**	
Temperature			**x**	
Toxicants / Pesticides		**x**		**Vision and Strategy outcomes can be adequately achieved without the monitoring burden of extending testing to toxicants and**

				pesticides. The exception to this is considered to be NO_3-N and NH_4^+-N, as a notable component of nitrogen nutrients.

Kate McArthur

Attribute paper	Agree	Disagree	N/A	Comment / Qualifier
Nutrients	**Y (in part)**			Waikato River mainstem – support PC1 approach with corrections as outlined in evidence of Dr Scarsbrook (approach 1C in nutrients paper). Strongly disagree with any approach relying on management of a single or priority nutrient – both N and P must be considered. Also disagree that we should base lower river N and P attributes assuming lake contributions of chlorophyll a will be addressed separately. Lower river is an integrator of all upstream/contributing inputs and should be managed as such. Management of river Tn and TP loads are needed to ensure nutrients loads to the estuary/coastal environment are appropriate. Sub-catchments (tributaries) – support an approach to require tributary management of N and P to meet mainstem nutrient attributes as above **except** where more stringent dissolved nutrient thresholds are needed to manage ecosystem health for invertebrates (approach 4) and periphyton outcomes in hard-substrates (approach 5b agree with use of Matheson et al. 2016 in preference to DIN and DRP values in McArthur evidence) – In these cases the most stringent threshold for N or P should apply to support ecosystem health – consistent with NOF approach in Policy CA2 (e)(iii)
E.coli	**Y**			Agree with E. coli recommendations to follow full approach in NOF (all four attribute states) and without flow exclusion. Not within my expertise to comment on shellfish gathering
Deposited sediment	**Y**			Agree with including the recommended attribute states in Table 1 of the sediment document dated 7 June 2019 **AND** support inclusion of a narrative for an improvement trajectory in affected stream length (classified as 'poor' ecological condition) over time (WRC have provided data to enable this narrative to be developed – email from

				Michael Pingram dated 4 June 2019) Naturally hard substrate streams are defined as those with naturally <25% soft sediment substrate. Where naturally hard substrate streams are near this threshold (~75% hard substrate) they could naturally be close to or reach the recommended bottom line (>25% cover by fine deposited sediment). In this instance I recommend applying a qualifier that these sites need to be within 10% of reference condition to be considered within the bottom line."
Clarity	**Y**			Clarity is an important attribute for swimming. Clarity should be applied as an attribute in PC1. Format of the attribute should be consistent with TLG recommendation (median compliance statistic) and should apply to **all** rivers and streams
TSS	**Y**			Sediment group recommendation was not to have a TSS of similar numeric standards for suspended sediment. It is not within my expertise to comment on TSS load attributes for Whangamarino
DO	**Y**			Agree with use of NOF bottom line for all sites as the sole attribute, investigation and monitoring should be prioritised as indicated but DO attribute and bottom line should apply to all sites except peat lakes.
Macroinvertebrate Communities	**Y**			Agree with approach in paper dated 10 June 2019
Macrophyte nuisance		**N**		Disagree with recommendation in macrophyte paper. Recommended management of riparian margins in Block 2 evidence (McArthur) would provide for improvements in stream length affected by nuisance macrophytes. Pingram et al (2016)[18] found "*On streams flowing through developed land, macrophyte cover averaged 31% of the channel.* Nuisance macrophytes should be included in PC1 as an attribute for rivers and streams with a bottom

[18] Pingram M, Hamer M, Collier K 2016. Ecological condition of Waikato wadeable streams based on the Regional Ecological Monitoring of Streams (REMS) Programme 2012 – 2014 report. Waikato Regional Council Technical Report 2014/46.

				line of >50% cover from Matheson et al. (2012)
Periphyton	**Y**			Agree with all recommended steps
Fish Communities	**Y**			Agree with paper recommendations in full
Riparian	**Y**			Agree that riparian cover and buffer should be included as an attribute in PC1 related to Ecosystem Health. Recommended management of riparian margins in Block 2 evidence (McArthur) would provide for improvements in riparian cover
Lakes	**Y**			Agree with Director General's recommended numerics (in red text)
Whangamarino			**N/A**	
Temperature	**Y**			Agree that temperature should be included as an attribute in PC1 related to Ecosystem Health as proposed by A Daniel. Recommended management of riparian margins in Block 2 evidence (McArthur) would provide for improvements in temperature
Other toxicants	**Y**			Percent species protection from toxicants, metals and metalloids (excluding ammonia and nitrate toxicity which are already included in PC1) should be included as attributes, particularly in areas with high risk e.g., urban/industrial areas (as per McArthur evidence). Support approach in 'other toxicants' paper.

Dean Miller

Attribute paper	Agree	Agree in part	Disagree	N/A	Comment / Qualifier
Nutrients	Y				**Waikato River main stem** – I support the recommended approach for the development of TN and TP long-term thresholds. That is approach 1C for TN and approach 2C for TP. I had a concern through the development of the paper that no improvement in nutrient concentrations at all is required at some sites in the upper Waikato FMU under the recommended long-term threshold approach. Nutrient reductions are be needed over the entire catchment (as stated under the introduction in Section 5 of the paper) but then do not aggregate to an improvement relative to current state at all main stem sites for the long-term thresholds. I therefore support Approach 3 to developing short-term thresholds. The recommendation that long-term thresholds are interim also goes some way to addressing my concern, provided a review requirement is built into PC1, possibly as a method. I note that in my opinion, more main stem sites are also needed in the upper Waikato FMU (refer to my EIC). **Tributaries** – I support the development of TN and TP thresholds at tributary sites following approach 3. My view is that it is essential to understand tributary contributions to main stem nutrient conditions in order to make informed sub-catchment management decisions. I am comfortable that these thresholds are either included in Table 3.11.1 or used to support implementation of PC1 (i.e. used to inform management decisions and sub-catchment planning). My view is that there needs to be monitoring sites on more of the major tributaries as discussed in my EIC.
E.coli	Y				I agree with the recommendation in the paper (Option iv).
Deposited sediment		Y			I support the inclusion of a deposited sediment attribute for wadeable, naturally hard-bottomed streams. However, in my view this attribute needs

					more development before a numerical attribute table could be included in the Regional Plan. I support a narrative objective based on the catchment wide trajectory assessment using WRC REMS data as an alternative, provided there is adequate sub-catchment (tributary) coverage in the site schedule, and the data are suitable to guide sub-catchment specific mitigation planning (not just accounting). I also support the inclusion of a method in PC1 outlining monitoring requirements to develop a future numerical attribute. In my opinion the annual mean of monthly monitoring is the appropriate statistic and should be applied at existing REMS sites, although how existing REMS sites are distributed within the existing sub-catchments in PC1 is unclear. The data collection method should be consistent with the national protocol (SAM2). Deposited sediment monitoring sites should be aligned with the macroinvertebrate sites and scheduling (w.r.t. the probabilistic programme). I note that monthly monitoring would mean a significant change to WRC's REMS programme.
Clarity				**N/A**	
TSS				**N/A**	Not proposed as an attribute.
DO		**Y**			I generally support the paper and the recommendation that DO is a monitoring requirement, but not an attribute.
Invertebrate Communities	**Y**				I support the paper and the recommendations. There is some discomfort in the expert group on the use of MCI vs QMCI. I am comfortable with the attribute table based on QMCI on the basis of the demonstrated relationships between QMCI and nutrients and sediment in the Pingram et al. paper and that the monitoring and analysis methods are robust and repeatable. At this point there appears to be too few representative sites in each of the current PC1 sub-catchments or sufficient FMU coverage, which should be addressed. Macroinvertebrate monitoring sites should be aligned with the

					deposited sediment sites and scheduling (w.r.t. the probabilistic programme).
Macrophyte nuisance	**Y**				I agree with the paper and the recommendations. Needs further development.
Periphyton	**Y**				I agree with the risk assessment process suggested and think this sits best as a method. Monitoring should be monthly to best assess the scale of any periphyton issue and given the influence of other factors, like flow, on periphyton biomass. If the issue were investigated as a method in PC1 then I would be comfortable that "objectives" are parked until a subsequent plan change.
Fish Communities			**Y**		I generally support the concept of "objectives" based on fish communities but in my view there is currently no readily available or appropriate metric for use in PC1. My understanding is that IBI (based on species presence /absence and diversity) cannot show an improvement any other way than by the addition of a species? Fish passage (access) then become a critical factor potentially overriding any other factors. I'm also not convinced the direct links to the four contaminants are strong enough to warrant a fish attribute? I do not support the use of Fish QIBI as an attribute. I favour the use of macroinvertebrates as a biological attribute for PC1.
Riparian			**Y**		I disagree that a riparian attribute is needed in PC1. Riparian buffers are appropriate and proposed as a management tool for ecosystem health in PC1.
Lakes			**Y**		I agree that a more refined attribute is needed for lakes compared to the notified version of PC1. But more work is needed.
Whangamarino		**Y**			I support the development of TN and TP thresholds for the Whangamarino Wetland and the additional monitoring recommended. I support a narrative objective for PC1.
Other wetlands		**Y**			I support a narrative objective for other wetlands.
Temperature		**Y**			I agree with Dr Daniel's paper in that temperature is a key attribute of

					ecosystem health. However, there are not enough data for the Waikato catchment to characterise current state and inform well-considered thresholds. In my view, gathering more temperature data best sits in PC1 as a method.
Toxicants / Pesticides			**Y**		I don’t support this attribute for inclusion in PC1 due to the lack of links to the four contaminants and the associated management interventions.

Hannah Mueller

Attribute paper	Agree	Disagree	Agree in part	N/A	Comment / Qualifier
Nutrients	**Y**				I agree that nutrients (TN, TP, Chl a) need to be included as an attribute, but generally also note that a focus on chemicals alone does not ensure ecological health is safeguarded. I note the degree of uncertainty remaining, and the imperfections of the approaches suggested here. Waikato River main stem – I support approach 2A acknowledging uncertainties with respect to nitrogen relationships. I support the approach taken that seeks significant reductions in particular from the lower Waikato FMUs, though a focus will be needed here to ensure all subcatchments are monitored and managed (not just a focus on the main stem). Suggest more main stem sites in the upper Waikato FMU as there currently appears to be somewhat of a monitoring gap. Sub-catchments and tributaries – I support the inclusion of TN and TP thresholds at sub-catchment sites following approach 3. I agree with other comments that it is essential to understand tributary contributions to main stem nutrient conditions in order to make informed sub-catchment management decisions. No implications for marine/estuarine environments are considered.
E.coli				**N/A**	
Deposited sediment					Generally I agree with the narrative and the inclusion of a deposited sediment attribute for wadeable, naturally hard-bottomed streams and the proposed attribute state bands in Table 1. Need specification of 'natural conditions' and thresholds for soft-bottomed sites.

			Y		Attribute fits within the WRC REMS programme and sites and scheduling should be aligned.
Clarity			**Y**		Agree that clarity is an important attribute for swimmability and also ecosystem health (mainly as a proxy for TSS). I am not convinced that the attributes chosen for swimmability are valid based on how they were chosen. Clarity for ecosystem function is not universal and would depend on the system, i.e. naturally clarity would be expected to be lower for the shallow peat lakes, but the same clarity may present a severely compromised system for other sites.
TSS				**N/A**	Not proposed as an attribute
DO	**Y**				I generally support the paper and the recommendations. I would support the development of a monitoring/statistical approach that used diel variation to monitor variability beyond 'natural' conditions/fluctuation. Support prioritisation of sites as recommended in paper, however action should be required wherever oxygen conditions are found to put significant stress on ecosystems (not merely in cases of unconsented effluent discharges). Should include regular monitoring in lake sites.
Invertebrate Communities	**Y**				I support the narrative of paper and the recommendations. However, I would welcome the consideration of using 90 instead of 80 as minimum acceptable state to align with the 'life sustaining capacity' approach as a score <80 is generally associated with severe pollution. As for deposited sediment - Macroinvertebrate monitoring sites should be aligned with the deposited sediment sites and scheduling.
Macrophyte ~~nuisance~~			**Y**		I agree with some of the narrative of the paper. Macrophytes are not necessarily a nuisance and can be an integral part of a function system, including lakes (e.g. Waikare – destruction

					of macrophyte beds has been a major factor in decline of ecosystem resilience) More work is needed, but it would be possible to establish an attribute framework to assess ecosystem health. Agree with the recommendation to adopt as part of surveillance monitoring.
Periphyton			**Y**		Agree with the narrative and including a bottom line for relevant sites.
Fish Communities			**Y**		I support the inclusion of fish communities as general indicator for ecological health. I am not confident that this measure is understood well enough in the NZ context (in particular regarding fish passage barriers and natural distribution of species) to add value. More work is required to adapt this index to NZ conditions, but then would support its inclusion as an attribute. However, if Fish IBI is not included, MCI should most definitely be included as at least one biological attribute is needed to assess 'ecosystem health'.
Riparian	**Y**				Riparian buffer zones would be instrumental at restoring/maintaining ecological health. I understand that management is proposed as a tool in PC1 already, however I am not sure this has been sufficiently quantified or prescribed in a fashion that will lead to palpable improvements. Riparian buffers can significantly attenuate sediment, faecal contaminants and P (and N to a very limited extent). Having a riparian attribute may be useful to attain the desired chemical outcomes for the 4 main contaminants. I disagree that this is merely a management tool – riparian zones are integral components of freshwater systems, and while not a chemical attribute, they are indicators of freshwater health, just as MCI etc.

					I understand the limitations of this attribute, but I believe it should at least be considered as part of the attribute suite towards ecological health. This would be particularly useful for the tributaries. I note that no time was given discussing this attribute during caucussing. Further refinement of this attribute would be useful.
Lakes			**Y**		Agree with the narrative of the paper. A more refined attribute table is needed for lakes compared to the notified version of PC1. This attribute has not been discussed to any great extent during the caucussing. More work may be required to adequately address which attributes would be appropriate for lakes, and to agree on thresholds.
Whangamarino				**N/A**	
Temperature			**Y**		Temperature is a key attribute of ecosystem health. I do not see that temperature can be managed through addressing the four contaminants only. More monitoring data may be required to appropriately develop this as an attribute.
Toxicants / Pesticides				**N/A**	

Martin Neale

Attribute paper	Agree	Agree in part	Disagree	N/A	Comment / Qualifier
Nutrients	**X**				Agree that the management of nutrient should be focussed on achieving an outcome (e.g. algal biomass). Agree that nutrient management should be extended to tributaries. For management of loads, but also the ecological effects of these contaminants in the tributaries. Mainstem – Approach 2C for TP and Approach 1C for TN (because of the lack of correlation with TN for 2C). Tributaries – Approach 3 preferred.
E.coli	**X**				Agree with the application of the NPSFM Attribute for recreation (in my opinion, there are no compelling reasons provided for not doing so). The MfE/MoH guidelines include a guideline for shellfish gathering waters. It is not clear how this may relate to non-shellfish (e.g. water cress)
Deposited sediment		**X**			Agree that deposited sediment is important and should be included in PC1 as an Attribute. But the proposed Attribute requires further development. In particular, the method and reporting statistics need to be refined so that meaningful difference is distinguished from variability. This attribute is proposed to be a wadeable stream measure only, so can the REMS network/data be used to inform an

					Attribute at the FMU scale? For example, Pingram et al (2019) refer to the stream length with 'poor' sediment conditions as 55.7% at a regional scale.
Clarity	**X**				Agree with the paper about the shortcomings of the TLG Attribute – median is not an appropriate reporting statistic; some data is excluded from the calculation and the band A threshold does not reflect published science. The paper proposes two alternative attributes to address these issues. My order of preference is Alternative 1 > Alternative 2 > TLG attribute. The Attribute should explicitly recognise those locations where naturally turbid water affects the banding.
TSS	**X**				Agree with paper that is should not be an Attribute
DO		**X**			DO is obviously an important characteristic of freshwater but use as an Attribute is problematic for two reasons; 1. there is very little current state data and **2.** the proposed measurement approach in the paper (2 weeks in summer) is hit and miss. DO is temporally variable and the 2 week period may miss the critical low concentrations.
Invertebrate Communities	**X**				Agree with the paper that a numeric attribute based on the REMS wadeable steam monitoring network is implemented for the three FMU reporting areas (upper, lower-Mid and Waipa)
Macrophyte nuisance	**X**				Agree with the paper than this should not be an Attribute in PC1
Periphyton		**X**			Important characteristic of freshwater, but only applicable to wadeable hard bottom streams.

					No biomass data for current state, although some cover assessments at REMS sites. Could the REMS network/data be used to inform an Attribute at the FMU scale? For example, the paper refers to this network as indicating 11% of stream exceeding 25% cover. Requires further development. Possible narrative objective for PC1 in the meantime.
Fish Communities		**X**			Agree that fish communities should be the basis of an Attribute. As with some of the other wadeable stream attributes, can this Attribute be developed using the REMS network and be based on stream length. I understand the WRC fish monitoring programme is currently exploring this approach.
Riparian			**X**		Another important characteristic relating to freshwater systems but is not an Attribute (i.e. is not a measurable characteristic of freshwater). More useful as an indicator of management effectiveness rather than the state of freshwater.
Lakes				**X**	
Whangamarino				**X**	
Temperature		**X**			There are two papers on temperature that arrive at different conclusions. I agree temperature is an important attribute of freshwater, but do not agree that it should be a numeric Attribute in PC1. Possible narrative objective. The proposed Attribute requires further development, the monitoring data for current state is limited and the management of temperature is explicitly provided in existing

					plan,
Toxicants / Pesticides		X			Potentially suitable as a narrative Attribute because of the numerous potential toxicants and the absence of current state data for most. Would need to be applied on a 'risk' basis so that is doesn't create a need for extensive data collection of multiple toxicants where it is not needed (i.e. let's not manage an issue that doesn't exist)

Hugh Robertson

Attribute paper	Agree	Agree in part	Disagree	N/A	Comment / Qualifier
Nutrients	**Agree**				Support the refinement of nutrient (N, P) attributes in Table 3.11-1 and the recommendations relating to the Mainstem Support the intent of Approach 3 that provides for TN and TP thresholds for tributaries. Nutrient reduction is required across many sub-catchments in the region to improve the health of waterbodies, including wetlands, not only for the Waikato Mainstem. The absence of specific sub-catchment targets for TN and TP is a critical gap in Table 3-11.1 at present.
E.coli				**N/A**	
Deposited sediment				**N/A**	
Clarity				**N/A**	
TSS					
DO	**Agree**				Agree with the application of DO as outlined by the sub-group, including application to lakes.
Invertebrate Communities				**N/A**	
Macrophyte ~~nuisance~~			**Disagree**		In relation to lakes, the memo on macrophytes at present does not identify the link between light attenuation (due to water quality decline) and loss of native macrophytes. The memo is focused on nuisance macrophytes only. While there may be insufficient evidence in relation to TN/TP and macrophytes, light attenuation effects on native macrophytes has not been adequately covered.
Periphyton				**N/A**	
Fish Communities				**N/A**	

Riparian				**N/A**	
Lakes – Not assessed					It is not considered appropriate to assess lakes. No specific sub-group was formed during the expert conferencing However, this is a critical area for discussion given the current state of water quality for lakes within PC1.
Nutrients (Whangamarino)	**Agree**				Water quality attributes that provide for the ecosystem health of Whangamarino Wetland were previously absent from Table 3-11.1. Recommended attributes for TN and TP address this gap. Support the sub-catchment delineation and additional monitoring site.
Narrative targets (wetlands)	**Agree**				Support the specified Narrative targets being applied to all wetlands for TP, TN, sedimentation, and for hydrological alteration (where it exacerbates water quality contamination).
Temperature				**N/A**	
Toxicants / Pesticides				**N/A**	

Mike Scarsbrook

Attribute paper	Agree	Agree in part	Disagree	N/A	Comment / Qualifier
Nutrients		**Agree in part**			**Waikato mainstem long-term thresholds (Approaches 1 & 2)** Support the changes/corrections proposed as Approach 1C. Support the science rationale behind approach 2C. Logical to set TN and TP to achieve desired outcomes in Chlorophyll a, where there is robust evidence to do so. There is a strong body of evidence indicating P is more important than N in controlling Chlorophyll a along the mainstem of the Waikato river. Also support the rationale of more clearly defining the impacts associated with inputs from the riverine lakes (e.g. Waikare). ***Overall, I support the definition of TP levels in Table 3.11.1 using Approach 2C and the definitions of TN based on Approach 1C***. While the use of Approach 1C for TN is not supported by the empirical relationships that show little evidence for TN controls on Chlorophyll a, the approach in 1C retains the intent of PC1 and provides greater protection for receiving bodies that were not covered in caucusing (e.g. Coastal Marine Area). **Waikato mainstem and tributary short-term thresholds (Approach 3)** I have confidence that the catchment modelling undertaken by Dr Cox and Mr Conlan is appropriate. I also have confidence in the original modelling done for CSG by Prof Doole, Dr Elliott and others. I still support the original TLG recommendation to use TN and TP in tributaries as indicators of water quality that can help identify priority actions for methods such as Farm Environment Plans. My preference would be for the Doole and Elliott catchment modelling and the Cox and Conlan modelling approach to be aligned and averaged. For this reason, I do not support the recommendation to apply Approach 3, as it currently stands, to short-term thresholds for TN and TP in the mainstem, or “distribution” of loads across sub-catchments.

					My main concern with Approach 3 and the recommendation of an alternative set of short-term thresholds for the mainstem is this sits outside the role of technical experts. Setting of objective, limits, targets is a community decision. Should the Panel consider Approach 3 as an appropriate alternative to that already identified in Table 3.11.1 I would strongly recommend that the available catchment models be aligned and averaged. **Approach 4** Not supported. Overly simplistic and not based on Waikato data. Support inclusion of QMCI as measure of Ecosystem Health. Research by WRC has clearly identified the management actions needed to reduce extent of poor Ecosystem Health and nutrients are of secondary importance compared to sediments, riparian condition and in-stream habitat. **Approach 5** Not supported, as very simplistic. I support a narrative Periphyton objective based on a risk assessment, with management action to follow identification of nuisance periphyton growths.
E.coli	**Agree**				Needs recommendation for faecal coliform attribute relative to shellfish gathering. I would support inclusion of recommendation in line with TLG advice (i.e. "for food species that are thoroughly washed and cooked prior to eating TLG consider it would be appropriate to use the same E. coli attribute bands as for primary contact recreation"
Deposited sediment			**Disagree**		Needs to be developed further. Support monitoring requirement with action when breaching bottom line.
Clarity			**Disagree**		Recognise the excellent work done by the group on this topic (Fig. 4 is particularly useful), but I'm not sure why we're spending so much time on this. Happy with status quo – existing PC1 attribute. The proposed alternatives represent a similar (Option 2), or greater (Option 1) challenge to achieve. Given that it was recognised that even the PC1 attribute was

					likely to be unachievable in some parts of the catchment I don't think making the challenge even greater is warranted. Also, given the attribute refers to suitability for swimming (which I consider to be quite subjective) I don't see the point of investing more time in this.
TSS				**NA**	
DO	**Agree**				Support recommendation for use as a monitoring requirement based on risk, not attribute. Note that 'blackwater' events (leading to low DO conditions observed during/after flooding) are often associated with breakdown of allochthonous organic material, rather than the effects of nutrients/algae, so less directly relevant to PC1. WRC has a Technical report looking at DO and temperature issues in the Piako catchment that may be of interest: https://www.waikatoregion.govt.nz/assets/WRC/Services/publications/technical-reports/2018/TR201805.pdf
Invertebrate Communities	**Agree**				Support including QMCI attribute that reflects probabilistic design in Waikato and basing attribute on km of wadeable stream in Poor states. Identification of appropriate long-term and short-term objectives are not a job for scientists, but would support recommendations with appropriate caveats. Do not agree with Key Point 3. "Therefore, ecosystem health, as indicated by macroinvertebrate communities, can be improved by effective management of nutrient and sediment loads". This is overly simplistic and an inappropriate statement to be sending to the Hearings Panel. We should use the appropriate wording from Pingram et al. (2019) "It was estimated that improving sediment, riparian and instream habitat management groups to a Not Poor condition could reduce the extent of Poor QMCI scores by around a third each, each equivalent to c. 2600-2800 km of the stream network (< 1000 km for nutrient management; Table 2)."

Macrophyte nuisance	**Agree**				Needs further development at national and regional scale.
Periphyton		**Agree in part**			Further development needed and still support TLG recommendation for development of %cover monitoring regime. Agree with need for risk assessment and recommendation for monitoring programme where risk is high. The risk assessment should include an assessment of shade as a potential controlling factor for nuisance periphyton in small-medium width streams.
Fish Communities			**Disagree**		Pingram et al (2019) – Fish QIBI relatively poor at discriminating stressor effects in Waikato. Fish index is heavily influenced by barriers to access and this limits its utility as a WQ indicator. I don't agree that we know what to do to manage for QIBI at a regional or FMU scale – agree that at site scale we can diagnose and address constraints. Also disagree about the presence of quantitative relationships (correlation between nitrate and QIBI is just that, a correlation). I do not support the use of QIBI as an attribute in PC1.
Riparian			**Disagree**		Not a "measurable characteristic of freshwater", so not an attribute. Could logically (?) be extended to have a 'land use' attribute included too (A = 80-100% native forest cover) – not sensible. I don't consider it would be useful to develop this further as an attribute, but it is a management tool that desperately needs more science investigation.
Lakes			**Disagree**		Do not support alternative FMU delineation. This is based on an incomplete and unreviewd piece of work by WRC. Should be referred to as (pers. Comm.), not Ozkundakci (2015). Proposed changes to existing PC1 objectives for lakes (DOC Director-General submission) involve value judgements and I haven't reviewed the science to support/refute these.
Whangamarino		**Agree in part**			Support development of TN/TP attribute for application in Whangamarino wetland, but we're not there yet Support a narrative objective. Not sure the current monitoring site (Whangamarino River @ Island Block Rd) is representative of TN/TP conditions in

					the wetland. Support the inclusion of a new monitoring site at Pungarehu Canel.
Temperature			**Disagree**		Temperature exerts very strong controls on biological processes in freshwater. However, as Adam points out in his paper, it is already covered in the Waikato Regional Plan and as Tim mentions, it is outside the scope of PC1. Development of a temperature attribute would need to take into account significant variability between river types and other drivers (order, source of flow, altitude etc.).
Toxicants / Pesticides			**Disagree**		Support narrative approach based on ANZECC Guidelines risk assessment framework, but don't support inclusion in PC1 (would change entire scope of PC1 from four contaminants to "all" contaminants).

Bill Vant

Attribute paper	Agree	In part	N/A	Comment / Qualifier
Nutrients (version of 4.31 pm. 13 June 2019)		**Y** **TP: 2C** **TN: 1C**		**Main-stem** I agree with the PC1 objectives for chlorophyll *a* for the Waikato River main-stem sites. But I consider that use of the corresponding NPS objectives for TN and TP for "NZ lakes in general" is too simplistic, particularly for the lower river (which is both unimpounded and receives inputs of chlorophyll from the floodplain lakes). Therefore I do not support Approach 1. <u>I do support Approach 2</u> because this takes account of (1) the observed relationships between nutrients and chlorophyll in the river itself (rather than in "NZ lakes in general"), and (2) the likely input of chlorophyll to the river from the two largest floodplain lakes. The three sub-approaches (2A, 2B and 2C) give broadly-similar results for TP; I think Approach 2C makes the best use of the available information. In earlier versions of the table Approaches 2B and 2C had no threshold values for TN for sites between Narrows and Tuakau, based on advice from Dr Cox, which I agreed with. I don't understand why this later version has the relevant cells filled. So my position at this point is that the TN thresholds in Approach 1C are the best we have at the moment, and I support their use. I find the recently-added information for Tahorakuri puzzling, and don't see that it's helpful. Conclusion: Approach 2C for TP, Approach 1C for TN. **Tributaries** The results from Approach 3 are interesting. But I don't see that they should be prescribed (and wouldn't support this). I don't know enough about the effects on N and P on MCI and IBI in

				the Waikato/Waipa area to be able to support Approach 4. I support the development of a periphyton attribute in the PC1 area (see below). But I don't think we know enough about the current extent of periphyton there, nor how it is likely to respond to the currently-proposed reductions in the N and P loads. So I don't support Approach 5.
E.coli	**Y**			**Swimming** Note that NPS 2014 included a stringent category (95%ile <260 cfu/100 mL) that was used for two sites in PC1 (namely Waiotapu @ Campbell Rd and Waikato River @ Narrows). This "A-plus" band was omitted in the 2017 revision of the NPS where the most stringent value for this variable was 540 cfu/100 mL (for new Band A). Presumably the notified objectives for these two sites will be unchanged? The 2017 revision of the NPS included three "swimmable" bands (namely, A, B and C). The 95%ile limits for Bands B and C, namely 1000 and 1200 cfu/100 mL respectively, are less stringent than the 540 cfu/100 mL notified for many of the PC1 sites. Will the notified objectives for these sites be preserved? Or will new submissions be sought on whether the community wants the new Bands B and C to apply at certain locations? The 2017 revision also included three other metrics for *E. coli*, namely the %exceedances >540, the %exceedances >260 and the median (with values for Band A being <5%, <20% and <130 cfu/100 mL, respectively). Presumably these values will be added to Table 3.11-1 for all sites where the objective for 95%ile *E. coli* is <540 cfu/100 mL? However, I'm not sure what should happen for the two sites where the 95%ile objective is <260 cfu/100 mL? **Food gathering** If shellfish are consumed without cooking, then very stringent microbiological standards apply to the water they grow in (median

				faecal coliform <14 MPN/100 mL, 90%ile <43 MPN/100 mL). However, if shellfish were to be cooked before consuming, then less stringent standards could apply.
Deposited sediment			**N/A**	(I did find the discussion paper interesting.)
Clarity	**Y Alternative 1**			I agree that the proposed PC1 objectives permit too many exceedances: using median water clarity means that half of the time the requirements will not be met. I prefer Alternative #1.
TSS				No discussion paper, but I don't think there's a need for a separate attribute for TSS. I think the water clarity requirements for swimming in PC1 mean that suspended sediments concentrations in the rivers and streams will be lower than at present. I also think the existing PC1 water clarity requirements for Bands A and B will be more stringent than the suspended sediment requirement for trout fisheries in the Operative Regional Plan (namely SS < 25 g/m^3): see memo of May 2016 from B Vant to B Cooper, WRC document #6290335.
DO	**Y**			I agree that more information is needed, and that PC1 could require this. The proposed attribute table is based on that in the NPS – with the addition of what appear to be reasonable standards for average concentrations as well. Importantly, the proposed table omits the puzzling requirement in the NPS that the standards should only apply "below point sources". I support this omission.
Invertebrate Communities		**Y**		I support the intention to develop a macroinvertebrate attribute for wadeable streams in the PC1 area, based on the existing information on these. However, I consider this should not be rushed, and that the thresholds in Table 3 of the paper should be regarded as "preliminary only".

Macrophyte nuisance	**Y**			I support the paper.
Periphyton		**Y**		I support the intention to collect data so as to develop a periphyton attribute in the PC1 area. And I agree that the NPS bottom line for this (92%ile <200 mg/m^2) applies. But I consider that more work is needed to confirm the threshold (">25% cover") and actions ("reduce by 10%") proposed in this note.
Fish Communities			**N/A**	
Riparian	**N**			Although the discussion paper is helpful, I'm not confident that we know enough about the many and diverse ecological processes involved in riparian enhancement to prescribe whole of catchment interventions at present.
Lakes	**N**			Unfortunately this paper appears to be incomplete, consisting just of two tables and no supporting text. I can't support it.
Whangamarino (version of 7.51 pm, 13 June 2019)			**N/A**	I'm not sufficiently familiar with the work on nutrient enrichment and degraded plant communities in wetlands to be confident that there is necessarily a causal link here (rather than both variables being measures of disturbance, for example).
Temperature		**Y**		I agree with the general aim of generalizing the existing temperature standards in the Operative Waikato Regional Plan to all streams in the area. But I consider that more work is needed to confirm the thresholds proposed in Dr Daniel's note.
Toxicants / Pesticides	**Y**			This would formalize the existing informal practice at WRC which uses the ANZECC guidelines to assess and manage toxicants.