BEFORE INDEPENDENT HEARING COMMISIONERS

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER Proposed Waikato Regional Plan Change 1: Waikato and Waipa River Catchment

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STATEMENT OF PRIMARY EVIDENCE OF CRAIG DEPREE FOR DAIRYNZ LIMITED SUBMITTER 74050

15 FEBRUARY 2019

DairyNZ

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1. INTRODUCTION

1.1 My full name is Craig Verdun Depree

1.2 I am a Principal Scientist (Water Quality) at DairyNZ (since November 2018), and prior to this position I was a senior water quality scientist at NIWA for 18 years. My research experience includes urban contaminants from road runoff, sediment biogeochemical processes, eutrophication of water ways (streams and estuaries), in particular, diel variation in dissolved oxygen concentrations and nutrient dynamics. I have led several major consultancy projects relating to water quality and assessment of environmental effects (AEE) for industrial point source discharges and urban stormwater. I have considerably experience with the National Policy Statement for Freshwater Management (NPS-FM) – including development of attributes (e.g. dissolved oxygen, suspended and deposited sediment), technical guidance for implementation (e.g. co-author ‘Nutrient Note’ guidance document for periphyton attribute), and its application. I have previously been seconded (2015-16) to the Water Directorate (Ministry for the Environment, MfE) to provide expertise in various areas of water quality – including nutrient trends across water quality monitoring sites across NZ. I have been a member of MfE’s technical expert panels for sediment and dissolved oxygen, and I am currently a member of the Rotorua Lakes technical advisory group (TAG).

Background

1.3 I am familiar with Proposed Waikato Regional Plan Change 1: Waikato and Waipa River Catchment (hereafter referred to as PC1).

1.4 My direct involvement in this plan change process began when I was employed by DairyNZ Ltd in late 2018. At that time, I was asked to review the key elements of the water quality science underpinning PC1 and I attended the information forum and expert day on 21-22 November 2018.

1.5 I have been asked by DairyNZ to provide evidence that sets out water quality-related aspects of the technical underpinning of PC1 objectives, policies, methods and rules.

Code of Conduct

1.6 I have read the Environment Court's Code of Conduct for Expert Witnesses contained in the Environment Court's Practice Note 2014, and I agree to comply with it. In that regard, I confirm that this evidence is within my area of expertise except where I state that I am relying on the evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this evidence.

2. SCOPE OF EVIDENCE

2.1 I have been asked to provide evidence on water quality aspects of the technical work that underpins the proposed PC1.My evidence addresses the following matters:

(a) General comment of support regarding PC1

(b) Adequacy of water quality models used in for scenario modelling in PC1

(c) Requirement to manage all four contaminants, with a particular focus on the importance of nitrogen mitigation in PC1

(d) Whole of catchment vs sub catchment approach to water quality management

(e) Clarification regarding water quality site at boundary of Upper Waikato FMU

(f) Suggestions offered to potentially improve the consistency and rationale about how attributes and thresholds are currently applied in PC1 – topics include:

a. Relevance of lake trophic state attributes to Middle and Lower Waikato FMUs
b. Inconsistent use of lake trophic state thresholds in the Upper Waikato FMU
c. PC1 interpretation of 'improvement' as being a move to a band of higher water quality

d. Recommendation for PC1 to adopt the E.coli attribute as notified in the 2017 amended version of the NPS-FM.[1]

2.2 I will present evidence relating to fencing setbacks and the types of 'qualifying' waterways, but I understand these subjects are being covered in a subsequent hearing block.

3. SUMMARY STATEMENT

3.1 General statement of support for PC1

a. PC1 seeks to reduce the amount of contaminants entering the river from the Waikato and Waipa catchments and have been developed to achieve the Vision and Strategy for the Waikato River. In my opinion, PC1 responds to the water quality-specific objectives of the Vision and Strategy for the Waikato River. I have confidence in the results of the contaminant load (i.e. water quality) models and mitigation scenarios, the outputs of which indicate implementation of PC1 across the catchment will meet, and in many cases exceed, the 10-year water quality targets in Table 3.11-1.

3.2 Adequacy of water quality models used for scenario modelling in PC1

a. I am not a modeller, but I do understand the role the water quality models played in the scenario modelling outputs. In short, the models were required to relate catchment contaminant loads (from diffuse and point sources) to instream contaminant loads/concentrations at sub catchment nodes. Current state models were calibrated using measured data from 62 or 66 sub catchments.

b. Mitigation scenarios were applied at sub catchment scale and the 'mitigation' (i.e. reduced) loads were routed using the calibrated water quality load models and converted into instream contaminant loads/ concentrations for each sub catchment. These 'mitigation' instream contaminant concentrations were then used to assess extent of progress relative to water quality targets.

c. PC1 is also underpinned by a water quality model developed to estimate changes in chlorophyll (chla) concentrations and visual clarity in response to changes in nutrient concentrations and sediment loads, under various mitigation scenarios.

d. My understanding is that the requirements of the modelling were to enable the conversion of catchment loads (from current state and mitigation scenarios) into instream loads and concentrations at sub catchment nodes. I believe the modelling achieves this, and that the models are 'fit for purpose' for:

[1] NPS-FM (2017). National Policy Statement for Freshwater Management 2014 – updated August 2017 to incorporate amendments from the National Policy Statement for Freshwater Amendment Order 2017. Attribute tables are contained in Appendix 2.

i) converting sub catchment loads into instream loads/concentrations;

ii) Estimating contaminant concentrations at sub-catchment nodes that do not have water quality monitoring data;

iii) Estimating visual clarity in response to changes in chla concentrations (in response to changes in median TN and TP) and sediment loads.

3.3 **Managing all four contaminants in PC1**

a. PC1 includes a requirement to manage four contaminants, namely nitrogen, phosphorus, sediment and microbial pathogens. Because all four contaminants

b. affect the use of waters for swimming (i.e. visual clarity and human health from faecal pathogens), the inclusion of the four contaminants in PC1 is consistent with the Vision and Strategy for the river. In particular, objective k which states: *The restoration of water quality within the Waikato River so that it is safe for people to swim in and take food from over its entire length.*

c. Accordingly, I support PC1 requiring the mitigation of all four contaminants.

3.4 **Reasons for managing nitrogen**

a. Nitrogen needs to be managed for two reasons related to ecosystem health values 1) trophic states in lakes and rivers, and 2) nitrate toxicity in rivers (both NPS-FM ecosystem health attributes). It also needs to be managed in PC1 as water quality targets explicitly require either reductions or maintaining the current state concentrations of nitrate-N and TN. My understanding is that there is no ‘headroom’ for more nitrogen to be discharged to the Waikato River.

b. Trophic state for lakes is assessed by 3 separate NPS-FM attributes, phytoplankton (chla), TN and TP. These are lake attributes, but their application to the Waikato River has been justified because of the 8 hydro-dams in the Upper Waikato FMU that increase water residence times (10-fold) resulting in ‘lake-like’ management issues regarding nutrients and phytoplankton growth.

c. The impact of nutrients and residence time on phytoplankton concentrations and visual clarity is evident when comparing sites at Waikato@Ohaaki and Waikato@Ohakuri sites (c. 36 and 75 km from Lake Taupo). Median and maximum chla concentrations of 2 and 2 mg/m^3 at Ohaaki, increase to 4 and 20 mg/m^3, respectively, at Ohakuri. The growth of phytoplankton is a major reason for the decline in visual clarity from 4.5 m to 2.4 m between these sites.

d. Previous work[2] has estimated that phytoplankton accounts for up 70% of the light attenuation coefficient (i.e. inversely related to visual clarity) in the hydrolakes. Therefore, management responses to improve visual clarity in mainstem waters of the Upper Waikato FMU will, in my opinion, need to target phytoplankton, which requires management of phosphorus <u>and</u> nitrogen.

[2] Vant B. (2015).Visual clarity of the Waikato and Waipa Rivers. Waikato Regional Council Technical Report 2015/13R. 25 p. Doc#3416681.

e. Nitrate-N toxicity is not an issue in the Waikato River, because the highest concentration ((0.4 g/m^3) is still 2.5-times lower than the NPS-FM A/B threshold value of 1.0 g/m^3 (i.e. A-band). However, several sub catchment tributaries have nitrate-N concentration greater than the B/C threshold value of 2.4 g/m^3 (i.e. C-band)

f. PC1 requires nitrate-N (and TN in the mainstem) to be either decreased or held at current state. This will be very challenging given the 'load to come' and long-term trends indicating increasing nitrogen in many tributaries. For example, long-term TN trend data indicate that at sites where important trends were observed, 80% of these were deteriorating.[3] In the Waikato mainstem, 25-year trends showed nitrate-N concentrations have increased at a rate of around 3% per year (although this trend was less pronounced over the 2008-2017 period). This emphasises the cumulative effects that nitrogen losses in upstream sub catchments are having on nitrogen concentration in the more nutrient sensitive mainstem Waikato River (via phytoplankton response).

g. For the reasons above, I fully support nitrogen management in PC1.

3.5 **Water quality management at individual sub catchment vs catchment-scale**

a. I agree with the Officers assessment (S42a, para 142-143) that focussing on sub catchment management is not supported by the technical work, and in doing so runs the risk of not having an 'eye of the prize' (i.e. the whole river system).

b. Table 3.11-1 in PC1 has water quality targets for nitrate-N toxicity that apply to sub catchment tributaries and the mainstem. The table also contains targets for trophic state impacts of nutrients (i.e. TN/TP), which are derived from the NPS-FM lake trophic state attributes. Although not intended for rivers, they have been extended to the Waikato mainstem because of its lake-like issues regarding the potential for phytoplankton growth. It is important to note that adverse effects from plant responses to nutrients (i.e. eutrophication) occur at nitrogen concentrations much lower than those required to have adverse toxicity effects. This is important as it means mainstem river waters are the most sensitive receiving waters (within the river network).

c. Connectivity and the cumulative effect of contaminants on downstream receiving waters is important. Contaminants from sub catchments in the upper FMU are discharged into the mainstem, and these contaminants flow into and effect water quality in the middle Waikato FMU. Water from the middle FMU, and more importantly the Waipa FMU, impact water quality in the lower Waikato FMU (in addition to inputs from other sub catchment along the river length). Any management approach must, therefore, account for the flow of contaminants,

[3] Vant B. (2018). Trends in river water quality in the Waikato region, 1993-2017. Waikato Regional Council Technical Report 2018/30. 35 p.

and the potential for cumulative downstream effects. This is particularly relevant given the more sensitive trophic state attributes applied to the mainstem.

d. My understanding of the approach taken by PC1 is that it is based on modelling undertaken at the sub catchment-scale, but these sub catchment instream loads are routed downstream through the river network, via the mainstem sub catchments to the mouth of the river. As such, the modelling underpinning PC1 accounts for connectivity and the cumulative effects of upstream contaminant sub catchment discharges on downstream receiving environments.

e. Water quality targets in Table 3.11-1 are simply NPS-FM band thresholds. Importantly, these water quality targets do not account for neither the cumulative effects of contaminant loads on downstream receiving waters, nor that downstream receiving waters may have different susceptibility to contaminants. On their own, targets in Table 3.11-1 do not permit a sub catchment focussed approach. This would require water quality targets to be calculated by allocating a maximum instream contaminant load at certain points (i.e. FMU nodes) to upstream catchments, and then converting this sub catchment allocation into median instream contaminant concentrations. This is not the approach taken by the technical work underpinning PC1, and I do not support undertaking such an approach at this point in the process.

f. To conclude, I support the current PC1 approach that involves sub catchment modelling and importantly, account for the cumulative effect of contaminant loads throughout the entire catchment, including the mainstem of the Waikato River. Submissions seeking to remove the need to mitigate some contaminant discharges based on the current state of water quality relevant to Table 3.11-1 targets are, in my opinion, technically flawed.

3.6 **Water quality targets that apply at the boundary of the Upper Waikato FMU: clarification around the assignment of Narrows@Waikato as a proxy site**

a. The issue of the non-coincidence of the Upper Waikato FMU boundary (Karapiro tailrace) with the monitoring sites at the Narrows (23 km downstream) was discussed and justified.[4] My concern is that the Narrows site does not appear to be used as a proxy site for the Karapiro tailrace (i.e. representing water quality exiting the Upper Waikato FMU). I believe this has resulted in uncertainty about what water quality targets apply at the boundary of the Upper Waikato FMU (i.e. Karapiro tailrace).

[4] Doc#3408420. The non-coincidence of Freshwater Management Unit boundaries and monitoring sites - A report back from the Technical Leaders Group. 25 February 2015.

STATEMENT OF EVIDENCE

4. General statement of support for PC1

4.1 PC1 seeks to reduce the amount of contaminants entering the river from the Waikato and Waipa catchments and have been developed to achieve the Vision and Strategy for the Waikato River. As noted by the Council Officer (S42a), the Waikato Regional Council has a legal requirement to given effect to both the National Policy Statement for Freshwater Management 2014[1] (NPS-FM) and the Vision and Strategy – with the later taking precedence where there is any inconsistency.

4.2 To provide the necessary context, the Vision and Strategy for the Waikato River responds to four fundamental issues, namely:

1) the river and its catchments are degraded;
2) the cause of degradation is human activities (land use);
3) degradation is the result of cumulative effects; and
4) it will take commitment and time to restore and protect the river.

4.3 In order to realise The Vision and Strategy, comprises 13 objectives and although they are of equal importance, objectives *g*, h and *j* are particularly relevant, I believe, to water quality aspects of PC1. These objectives are:

g) The recognition and avoidance of adverse cumulative effects, and potential cumulative effects, of activities undertaken both on the Waikato River and within its catchments on the health and wellbeing of the Waikato River.

h) The recognition that the Waikato River is degraded and should not be required to absorb further degradation as a result of human activities.

j) The restoration of water quality within the Waikato River so that it is safe for people to swim in and take food from over its entire length.

4.4 These Vision and Strategy objectives, in my opinion, are quite explicit about the need to acknowledge and account for the following regarding the management of water quality in the catchment.

a. Manage the cumulative effects of multiple contaminants (i.e. 4 contaminants)
b. Manage the cumulative effect of contaminant loads in the whole river system - recognising that upstream land use can contribute to degradation in water quality in the lower catchment (particularly in the mainstem)
c. The river is already degraded, and efforts must start now to prevent the river from absorbing more contaminants and degradation
d. Water quality improvements are required everywhere in order to address the more degraded waters in the lower Waikato FMU that currently do not meet minimum standards for swimming. Water quality in the lower river reflects activities and contaminant discharges occurring in distant upstream catchments. Accordingly, to improve water quality will require improvements across the entire catchment.

4.5 In my opinion, PC1 responds to the water quality-specific objectives of the Vision and Strategy for the Waikato River. Section 9 of my evidence identifies several issues for clarification. I have confidence in the results of the contaminant load (i.e. water quality) models and mitigation scenarios that indicate implementation of PC1 across the catchment, in a staged manner, will meet or exceed the 10-year water quality targets. This target represent at least 10% movement towards the long-term, 80 year water quality outcomes for the Waikato River catchment.

5. Adequacy of water quality models used for PC1 scenario modelling

Summary of water quality modelling used for scenario testing

5.1 I am not a modeller, but I do understand the role that the water quality (i.e. contaminant load) modelling played in the scenario modelling (carried out within the economic model), and how the outputs have underpinned the technical justification of PC1. I have read, and I am familiar with the relevant reports.[5,6,7] In basic terms, the models were required to relate catchment contaminant loads to instream contaminant loads at the various sub catchment nodes (downstream boundaries). Except for sediment (which is not a water quality attribute in PC1),

[5] Semadeni-Davies A, Elliot S, Yalden S (2015). Modelling nutrient loads in the Waikato and Waipa River Catchments. Report No. HR/TLG/2016-2017/2.2A.94 p. DOC#345594.
[6] Semadeni-Davies A, Elliot S, Yalden S (2015). Modelling E. coli in the Waikato and Waipa River Catchments. Report No. HR/TLG/2015-2016/2.6.Doc#3428411.
[7] Elliot S, Yalden S (2015). A methodology for chlorophyll and visual clarity modelling of the Waikato and Waipa Rivers. Report No. HR/TLG/2015-2016/2.3.27 p. DM#3461382.

the instream contaminant loads were converted to instream contaminant concentrations (i.e. annual averages).

5.2 Various mitigation and land use scenarios could then be applied across a sub catchment,[8] and a 'modified' aggregate contaminant load determined. The water quality model was then be used to estimate the modified instream contaminant loads and concentrations at sub catchment nodes. The effect of each mitigation scenario could then be assessed by comparing the modified values against 'current state' concentrations and/or water quality targets (Table 3.11-1).

5.3 Briefly, the models received input loads for point and diffuse sources (for different land uses). Point sources were routed directly into the stream network, whereas diffuse source loads were subject to catchment attenuation prior to reaching the stream network. Once in the stream network, instream loads were routed down the network and subject to reservoir attenuation in sub catchments large lakes or hydro-electric impoundments.

5.4 Water quality modelling was also used to estimate instream contaminant concentrations for the sub catchment nodes that did not have monitoring data available. This was done by developing concentration regression equations using sub catchments with monitoring data (n=66 for nutrients' n=62 for *E.coli*).

5.5 For TN, TP and *E. coli* models, modelled instream loads were calibrated against estimated instream loads for 62 (*E.coli*) or 66 (TN and TP) water quality monitoring sites. Estimated loads were calculated from measured instream concentration data and either measured or estimated flow data. Models were therefore calibrated, but not validated.

5.6 For the nutrient load model, the overall regression (i.e. n=66 sub catchments) between modelled and estimated loads was very good with coefficient of determination (R^2) values of 0.98 and 0.93 for TN and TP, respectively. Concentration regression models to predict nitrogen concentrations at sites without water quality monitoring data had coefficients of determination (R^2)

[8] Doole et al. (2016). Simulation of the proposed policy mix for the Health Rivers Wai Ora process. Report No. HR/TLG/2016-2017/4.5.67 p. Doc#6551310.

values of between 0.58 to 0.71 (for median TN, nitrate and 95th percentile nitrate).

5.7 Two load models were developed for *E.coli* (detailed and coarse load models; DLM and CLM), both showing similarly good overall regressions between modelled and estimated loads. The coefficient of determination (R^2) for the DLM and CLM were 0.91 and 0.89, respectively. The concentration regression models were better at estimating median annual *E.coli* concentrations than 95th percentile concentrations, with R^2 values of 0.64 and 0.53, respectively. I note that the authors state that model performance was comparable to previous national-scale modelling studies.[9]

5.8 Sediment loads for sub catchments were calculated using the NZ Empirical Erosion Model (NZEEM).[10] There was good agreement between NZEEM calculated sediment loads and measured loads for 9 Waikato sub catchments with a coefficient of determination (R^2) of 0.80. Hughes concluded that NZEEM calculated sediment loads for sub catchments appeared reasonable, although he pointed out that a limitation was that NZEEM loads did not explicitly consider contributions from river bank erosion.

5.9 Differentiation of stream bank erosion and hillslope-type erosion is required so that mitigations targeting the different erosion types can be applied and reductions in sub catchment sediment loads calculated. Hughes indicated there was a dearth of stream-bank erosion literature, and so based largely on a single study in the Waipa catchment, a uniform stream bank erosion fraction of 0.6 was applied to all sub catchment tributaries. Hughes considered this value to be comparable to estimates from other catchments, and therefore a fair estimate to apply to the Waikato/Waipa sub catchments.

5.10 The final component of water quality modelling was to develop a method to estimate changes in chlorophyll concentrations and visual clarity in the Waikato and Waipa Rivers in response to changes in nutrient concentrations and sediment loads under various mitigation /landuse change scenarios. An

[9] Unwin M. et al. (2010). Predicting water quality in New Zealand rivers from catchment-scale physical, hydrological and land use descriptor using random forest models. NIWA Client Report CHC2010-037. 21p.
[10] Hughes A. (2015). Waikato River suspended sediment: loads, sources and sinks. Information to inform economic modelling for the Healthy Rivers Wai Ora Project. NIWA Client Report No. HAM2015-059. 26 p.

empirical relationship was developed between chlorophyll and TN and TP; and equations were produced that relate the magnitude of predicted changes in chlorophyll (i.e. phytoplankton) concentrations and sediment loads to potential changes in visual clarity.

5.11 PC1 is also underpinned by a water quality model developed to estimate changes in chlorophyll (chla) concentrations and visual clarity in response to changes in nutrient concentrations and sediment loads, under various mitigation scenarios. In my opinion, this is an important model as visual clarity is the water quality outcome that people can see and understand. Despite uncertainties, I agree with the authors conclusion that the novel empirical model is 'fit for purpose', given that it can adequately predict median chla concentrations from median TN/TP concentrations.

5.12 Despite a number of uncertainties, I agree with the authors conclusion that on balance, the empirical model is 'fit for purpose', based largely on the ability of the model to predict median chla concentrations from median concentrations of TN and TP. Although phytoplankton responses to nutrients (and other environmental factors) are more dynamic, the lake trophic state attributes (and PC1 targets) are based on median concentrations.

5.13 My understanding is that the requirement of the modelling was to enable catchment loads (from current state and mitigation scenarios) to be converted to instream loads and concentrations at each of the sub catchment nodes. I believe the modelling does this, and I have confidence that the water quality models used in PC1 have comparable performance to other water quality models applied at regional and/or national scales.

5.14 As such, I consider the models are fit for purpose, which includes:

a. converting sub catchment contaminant loads into instream loads/concentrations at each sub catchment nodes;
b. Estimation of contaminant concentrations at sub-catchment nodes without water quality, and importantly;
c. Estimating visual clarity in response to changes in chla concentrations (in response to changes in median TN and TP concentrations) and sediment loads.

5.15 Note that my evidence does not extend to the details of mitigation scenarios (e.g. contaminant removal efficiencies, assumptions regarding current state and mitigation uptake) which are used to estimate future sub catchment contaminant loads, which are fed into the water quality models. It is my understanding that these details were developed via a combination of literature review, expert opinions and sector/stakeholder input.

Alternative water quality models

5.16 It is my understanding that some submitters are planning to provide an alternative to the water quality modelling in PC1. Given that the model's purpose is to convert catchment loads into estimated instream concentrations, it is possible to come up with an alternative. For example, a relatively simple alternative would be to estimate the current sub catchment load (e.g. X) and the modified (mitigated) sub catchment load (e.g. Y), and then calculate the percent reduction between the mitigation scenario and current state (i.e. ((X-Y)/X)x100%). This percent reduction could then be applied to the instream load (and hence instream concentration).

5.17 I am not convinced that a different approach to water quality modelling would result in significantly different water quality outcomes. That is, if mitigations result in a significant reduction in sub catchment contaminant loads, then alternative load modelling approaches should route these loads and produce comparable reductions in instream loads/concentrations.

5.18 I support retaining the existing water quality models that underpin PC1. Specific concerns I have about new modelling approaches include:

a. Whether the overall outcome of a new model will result in tangible differences, given that the final policy mix was not run by forcing the model to achieve water quality guidelines. Instead, I understand the policy mix was decided, and the predicted instream concentrations were compared to the relevant water quality target. I am not convinced a new model would change the approach of PC1 to mitigating the four contaminants.

b. The current modelling has been developed as part of a multi-stakeholder collaborative process, with the modelling being done by independent science providers.

6. Managing all four contaminants in PC1

6.1 PC1 includes a requirement to manage four contaminants, namely nitrogen, phosphorus, sediment and microbial pathogens, given that these are the contaminants most commonly associated with water quality degradation. Briefly, microbial pathogens are a compulsory human health attribute for contact recreation, and suspended fine sediment is a major contaminant that adversely effects the visual clarity water, particularly in the Lower Waikato.

6.2 The importance of nitrogen and phosphorus (often measured as TN and TP) is less apparent, as on their own (and in the concentrations present in the mainstem), they do not degrade the appearance, or use, of water. The issue is that in certain water bodies, TN and TP can fuel the growth of phytoplankton (measured as chlorophyll a, or chla), which in-turn can adversely impact visual clarity.

6.3 Because all four contaminants affect the use of waters for swimming (i.e. visual clarity and human health from faecal pathogens), inclusion of all contaminants in PC1 is consistent with the Vision and Strategy for the river. In particular, objective k states:

a. The restoration of water quality within the Waikato River so that it is safe for people to swim in and take food from over its entire length.

6.4 Accordingly, I support PC1 requiring the mitigation of all four contaminants. In my evidence below, I consider the technical justification for the use of lake-fed attributes TN and TP for the Waikato River below the hydrolakes and have not changed my view regarding the importance of managing nitrogen in the catchment.

6.5 My understanding is that a number of submissions are opposed to (or at least question) the requirement to manage nitrogen in PC1.

Reasons for managing nitrogen

6.6 Nitrogen needs to be managed for two reasons related to ecosystem health values 1) trophic states in lakes and rivers, and 2) nitrate toxicity in rivers (both NPS-FM ecosystem health attributes). It is needs to be managed in PC1 as water quality targets explicitly require either reductions or holding current state of nitrate-N and TN concentrations.

6.7 There is a NPS-FM trophic state attribute for rivers, which is based on the amount of periphyton biomass on stream substrates. This attribute was considered by the TLG to be of limited relevance to tributary streams in the Waikato and Waipa catchments and was not included in PC1.[11] Trophic state for lakes is assessed by 3 separate NPS-FM attributes, phytoplankton (chla), TN and TP. These are lake attributes, but their application to the Waikato River has been justified because of the 8 hydro-dams in the Upper Waikato FMU that increase water residence times (10-fold) resulting in 'lake-like' management issues regarding nutrients and phytoplankton growth.

6.8 The impact of nutrients and residence time on phytoplankton concentrations and visual clarity is evident when comparing Waikato@Ohaaki and Waikato@Ohakuri sites (c. 36 and 75 km downstream from Lake Taupo). Median and maximum chla concentrations where 2 and 2 mg/m^3 at Ohaaki, compared with 4 and 20 mg/m3 at Ohakuri. The growth of phytoplankton is a major contributor of the median visual clarity reducing 2m, from 4.5 to 2.4 m (note that Table 3.11-1 has an incorrect value for Ohakuri of 3.4m). Vant[2] has shown that in the Upper Waikato FMU, phytoplankton concentrations (measured as chla) accounts for around 70% of the beam attenuation coefficient. Accordingly, management responses to improve visual clarity in mainstem waters of the Upper Waikato FMU most likely need to target phytoplankton, which requires management of TN and TP.

[11] Scarsbrook M (2016). Water quality attributes for Healthy Rivers Wai Ora Plan Change. Report No. HR/TLG/2016-2017/2.1A. 38 p. Doc#6154421.

6.9 Modelling[5,13] and chamber incubation studies (summarised and discussed in WRC Doc#3433551)[12] have shown that the phosphorus is more likely to determine the median concentration of chla in the hydrolakes (i.e. P-limited). However, work has also shown that nitrogen may limit maximum biomass during summer months. Although the nutrient assays[12] and modelling[13] indicate that phytoplankton biomass in the mainstem is limited more by phosphorus than nitrogen,[14] the single limiting nutrient concept is generally considered an overly simplistic model for the management of nutrient pollution (US EPA 2015, and reference therein).[15] The conclusion of the US-EPA authors was "given the dynamic nature of aquatic systems, the need to protect downstream waters, and the threat of harmful algal blooms, the weight of the scientific evidence supports the development of nutrient criteria for both N and P."

6.10 This case for applying lake-based attributes to manage trophic state in the Waikato River is compelling for the upper Waikato FMU, but, in my opinion, less so for mainstem reaches downstream of Karapiro (i.e. Middle and Lower Waikato FMUs). Given that the travel time from Karapiro to the ocean is around 4 days, and median chla concentration data do not support significant increases in median chla, I do believe that lake trophic state TN attributes (seasonally stratified lakes) is relevant to managing visual clarity in the lower river. A possible alternative would be to apply the polymictic TN trophic attribute downstream of Karapiro, although I believe that any issues with chla in the middle and lower river are likely to reflect inputs from the upper Waikato FMU and/or highly eutrophic riverine lakes (i.e. Waikere and Whangape).

6.11 Nitrate-N toxicity is not an issue in the Waikato River, where the highest concentration in the Lower Waikato FMU is 2.5-times lower than the NPS-FM A/B threshold value of 1.0 g/m^3 (i.e. A-band). However, smaller subcatchment tributaries contain relatively high nitrate-N concentrations. For example, the Mangamingi, Kawanui (both Upper FMU), Mangaone (Middle FMU) Whakapipi (Lower FMU) streams have median nitrate-N concentrations of 2.8, 2.6, 2.6 and

[12] Doc#3433551 (2015). Nutrients and phytoplankton (chlorophyll a) in the Waikato River. Report prepared by the TLG for the Healthy River Wai Ora Project. Report No. HR/TLG/2015-2016/3.6.
[13] Doc#3461382. Yalden S, Elliot S (2015). A methodology for chlorophyll and visual clarity modelling of the Waikato and Waipa Rivers. WRC Report No. HR/TLG/2015-2016/2.3.
[14] Under current conditions, the model predicted an average contribution to median chla concentrations of 69% and 16% for TP and TN, respectively (Doc#3461382)
[15] US EPA (2015). Preventing Eutrophication: Scientific Support for Dual Nutrient Criteria. Report No. EPA - 820-S-15-001. Office of Water. February 2015. 6 p.

3.5 g/m^3, respectively. Almost 10% of sites exceed the B/C band threshold (2.5 g/m^3), corresponding to growth effects on up to 20% of aquatic species.

6.12 PC1 requires nitrate-N (and TN in the mainstem) to be either decreased or held at current state. This will be very challenging given the 'load to come' and long-term trends indicating increasing nitrogen in many tributaries. For example, long-term TN trend data indicate that at sites where important trends were observed, 80% of these were deteriorating.[16] In the Waikato mainstem, 25-year trends showed nitrate-N concentrations have increased at a rate of around 3% per year (although this trend was less pronounced over the 2008-2017 period). This emphasises the cumulative effects that nitrogen losses in upstream sub catchments are having on nitrogen concentration in the more nutrient sensitive mainstem of the Waikato River (i.e. via phytoplankton response).

6.13 For the reasons above, I fully support nitrogen management in PC1.

7. Water quality management at individual sub catchment vs proposed FMU scale

7.1 The theme of many submissions was that the proposed plan should place a greater emphasis on management of water quality at sub catchment scale, as opposed to FMU-scale, or whole of catchment. It is my understanding that many submissions in favour of sub catchment management, are from parties in the upper Waikato FMU which have good current state water quality relative to water quality targets in Table 3.11-1. In which case, the reasoning is that mitigations are not required 'as we are already there'.

7.2 I agree with the Officers assessment (S42a, para 142-143) that a move to more of a focus on sub catchment management is not supported by the technical work, and in doing so runs the risk of not having an 'eye of the prize' – with the prize being the health and restoration of the whole river system. I attempt to provide a more technical basis about my why i) PC1 is not amenable to a subcatchment management via water quality targets in Table 3.11.1, or more specifically, why having current state water below targets in Table 3.11-1 is not a

[16] Vant B. (2018). Trends in river water quality in the Waikato region, 1993-2017. Waikato Regional Council Technical Report 2018/30. 35 p.

technically valid argument for not implementing property-scale mitigations of PC1.

7.3 Table 3.11-1 in PC1 has water quality targets for nitrate-N toxicity that apply to subcatchment tributaries and the mainstem. The table also contains targets for trophic state impacts of nutrients (i.e. TN/TP), which are derived from the NPS-FM lake trophic state attributes. Although not intended for rivers, they have been extended to the Waikato mainstem because of its lake like issues regarding the potential for phytoplankton growth. It is important to note that adverse effects from plant responses to nutrients (i.e. eutrophication) occur at nitrogen concentrations much lower than those required to have adverse toxicity effects. This is important as it means mainstem river waters are the most sensitive receiving waters (within the river network). I point out this would not always be the case in PC1 include the NPS-FM trophic state attribute for streams, based on periphyton. However, the TLG and Officers assessment (S42a) recommended against it inclusion.

7.4 Connectivity and the cumulative effect of contaminants on downstream receiving waters is important. Contaminants from sub catchments in the upper FMU are discharged into the mainstem, and these contaminants flow into and effect water quality in the middle Waikato FMU. Water from the middle FMU, and more importantly the Waipa FMU, impact water quality in the lower Waikato FMU (in addition to inputs from other sub catchment along the river length). Any management approach must, therefore, account for the flow of contaminants, and the potential for cumulative downstream effects. This is particularly relevant given the more sensitive trophic state attributes applied to the mainstem.

7.5 My understanding of the approach taken by PC1 is that it is based on modelling undertaken at the sub catchment-scale, but these sub catchment instream loads are routed downstream through the river network, via the mainstem sub catchments to the mouth of the river. As such, the modelling underpinning PC1 accounts for connectivity and the cumulative effects of upstream contaminant sub catchment discharges on downstream receiving environments.

7.6 Water quality targets in Table 3.11-1 are simply NPS-FM band thresholds. Importantly, these water quality targets do not account for neither the cumulative effects of contaminant loads on downstream receiving waters, nor that downstream receiving waters may have different susceptibility to contaminants. On their own, targets in Table 3.11-1 do not permit a sub catchment - focused approach A sub catchment management approach would require water quality targets calculated by allocating a maximum instream contaminant load at certain points (i.e. FMU nodes) to upstream catchments, and then converting this sub catchment allocation into median instream contaminant concentrations. This is not the approach taken by the technical work underpinning PC1, and I do not support undertaking such an approach.

7.7 To conclude, I support the current PC1 water quality modelling approach that involves sub catchment modelling but importantly, accounts for the cumulative effect of contaminant loads throughout the entire catchment, including the mainstem river. Submissions seeking to not mitigate based on the current state of water quality relevant to Table 3.11-1 targets are, in my opinion, technically flawed. A different approach, including different water quality targets would be required to shift PC1 to a sub catchment approach – which I do not recommend doing.

8. Water quality targets that apply at the boundary of the Upper Waikato FMU: clarification around the assignment of Narrows@Waikato as a proxy site

8.1 The issue of the non-coincidence of the Upper Waikato FMU boundary (Karapiro tailrace) with the monitoring sites at the Narrows (23 km downstream) was discussed and justified (refer to TLG Doc#3408420). My concern is that the Narrows site does not appear to be used as a proxy site for the Karapiro tailrace (i.e. representing water quality exiting the Upper Waikato FMU). Tables in Appendix D.4.1 and Table 3.11.1 indicate the Waikato@Narrows site is regarded as a Middle Waikato FMU site where the visual clarity target specifies band B[17] (threshold value 1.6 m). By contrast, mainstem sites in the Upper Waikato FMU have a visual clarity target of band A[17] (threshold value 3.0 m).

8.2 If the Narrows site is intended to be a proxy site for water exiting the Karapiro dam (and hence the boundary/node of the Upper Waikato FMU), then this be recognised in PC1 as representing a water quality site for the Upper Waikato FMU. If this is the case, then my understanding is that the Upper Waikato FMU

[17] Band threshold value or current state (5-year median), whichever is greater.

visual clarity target of 3.0 m (i.e. A-band) would be applied to this site, which currently has a 5-year median visual clarity of 1.8 m (WRC 2017).[18] In contrast, if the intent is to apply a B-band target of 1.6m, then this creates a potential issue of having two different thresholds for the mainstem river within the same FMU. This ‘transition’ would occur somewhere between the Waipapa dam tailrace and Karapiro tailrace, and therefore includes two hydroelectric lakes (Arapuni and Karapiro). Currently the last water quality monitoring site in the Upper Waikato FMU (in Table 3.11-1) is Waipapa tailrace which is approximately 50 km upstream of the FMU boundary.

8.3 This issue is illustrated using visual clarity and relevant targets in Figure 1 (left graph). Note that I have used the correct value of 2.4 m for Waikato@Ohakuri – the value in Table 3.11-1 of 3.4 m is incorrect. I believe PC1 needs to address the uncertainty around visual clarity targets that apply between Waipapa and Karapiro. For example:

a. What visual clarity targets apply to the mainstem at the Upper Waikato FMU boundary – currently uncertain about water quality targets
b. Is Waikato@Narrows is, as discussed in WRC Doc#3408420, a proxy for water quality at the Karapiro tailrace, and if so, this designation should be reflected in Table 3.11.1
c. Incorrect median 5-year visual clarity for Ohakuri@tailrace – should be closer to 2.4 (not 3.4 m as in Table 3.11.1), hence long-term water quality target should be 3.0 m (i.e. A-band).
d. There is incorrect assignment of water clarity at Ohakuri tailrace of 3.4 m. There appears to be a disconnect between targets set for phytoplankton (chla), which is presumably the main ‘driver’ of water clarity degradation in the upper FMU, and targets set for visual clarity. That is, chla targets (5 mg/m3) are effectively already met along the length of the FMU, however visual clarity (of which phytoplankton accounts for around 60-70% of the beam attenuation coefficient) current state is well below the 3.0 m target (i.e. 2.1 m and Waipapa and 1.8 m at Narrows). I have attempted to illustrate this in Figure 1.

[18] WRC 2017. Waikato River water quality monitoring programme: data report 2016. Waikato Regional Council Technical Report 2017/14. 50 p.

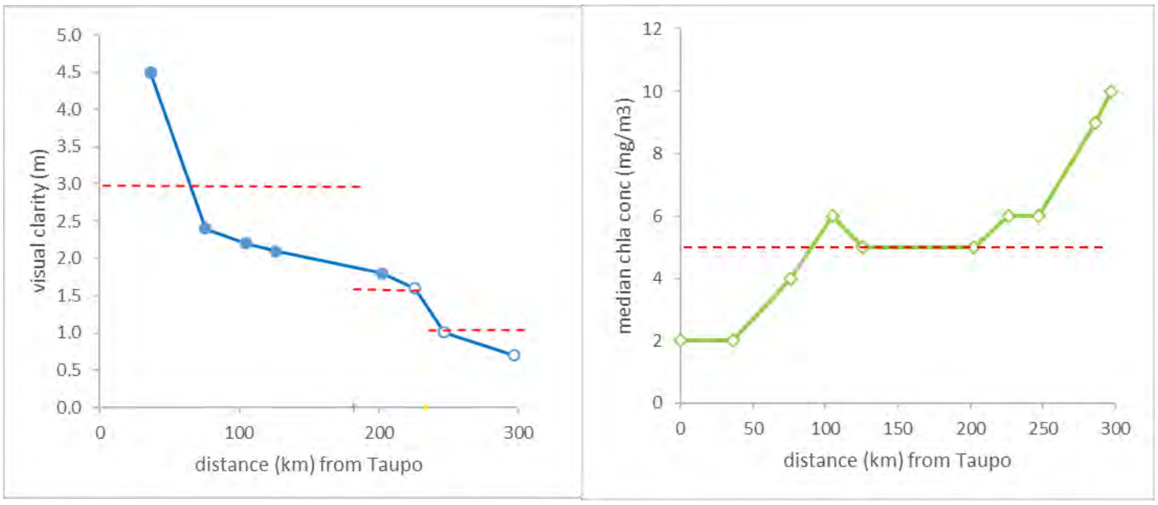

Figure 1: Longitudinal profiles of Waikato mainstem visual clarity measurements (left, blue) and median chlorophyll a concentrations (right, green). Red dashed lines show the 80 year water quality target values for the upper, middle and lower Waikato FMUs - note the same Chla value applies across the FMU (A/B band threshold), but where current state is <5 mg/m3, this is set as the water quality target.

9. Comments provided in the interests of improving the logic or rationale relating to Table 3.11-1 water quality targets of PC1

9.1 The evidence provided in this section is in recognition that DairyNZ submission did not request specific changes. Instead, the comments are intended to be helpful and contribute to improvements in PC1.

Application of NPS-FM lake trophic attributes to the mainstem Waikato

9.2 I consider that the application of NPS-FM trophic state attributes to the Waikato River is best justified in the upper Waikato FMU where the presence of 8 hydroelectric dams increase the residence time approximately 10-fold (from 4 to around 40 days under low flow conditions). The justification is that the longer residence times mean that the 180 km section (from Taupo to Karapiro) will be sensitive to phytoplankton blooms in response to nutrient enrichment, which degrade visual clarity properties of the river water.

9.3 In my interpretation of this, I would expect to see chla concentrations increasing downstream in the hydrolakes, reflecting the increasing total residence time for phytoplankton biomass between Lakes Ohakuri and Karapiro. Figure 2 shows median (2012-2016) and maximum (2016) chlorophyll concentrations for mainstem river sites. It is interesting that after Ohakuri/Whakamaru, there does not appear to be the expected trend of increasing phytoplankton concentrations with increasing total residence time of water in consecutive impoundments. It possible that the decrease between Whakamaru and Waipapa reflects the 'bottom mount' penstocks on Maraeti 1 powerstation.

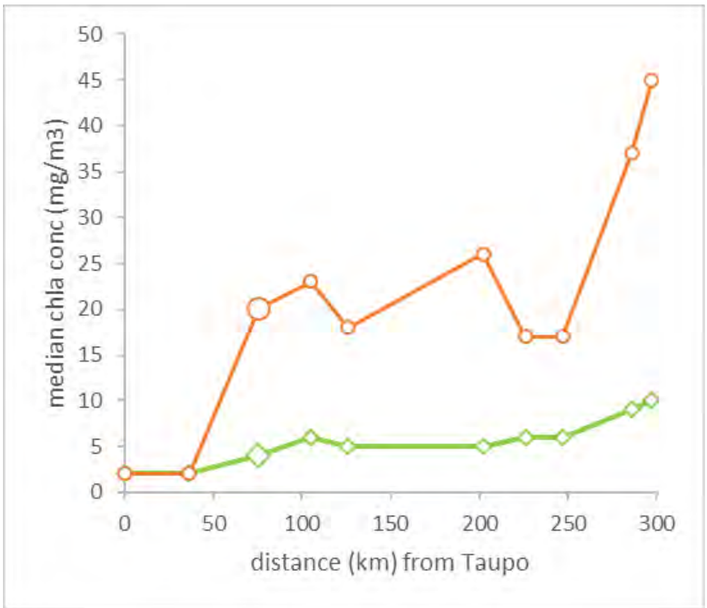

Figure 2: Longitudinal mainstem Waikato concentrations of median chla (2012-2016, green line) and maximum chla (2016, orange line). The large symbol 3rd from the right shows Waikato@Ohakuri tail race. The upper Waikato FMU extends to approximately 180km downstream of Taupo.

9.4 Another aspect that was not discussed in any detail, is that my understanding is that phytoplankton blooms are often 'concentrated' in low flush arms. In the case of Ohakuri, most issues seem to involve the Whirinaki Arm, where presumably a drowned valley and relatively low flows of water result in low flushing and long residence times in the arm (Figure 3). It would be interesting to understand more about the role of the Whirinaki Arm as a source of chla to the mainstem. I note that relatively minor inflows (relative to mainstem flow) from lake Whangape and Waikere account for, on average c. 30% of chla in the river at Mercer. If the Whirinaki Arm is a significant source of chla, a more specific approach may be needed in future, to address phytoplankton blooms. I note that the TN concentration in the Whirinaki Stream (at Corbett Rd contains 780 mg/m^3 of TN.

Figure 3: Google street view image of phytoplankton bloom in the Whirinaki Arm of Lake Ohakuri, - approximately 6-7 km upstream from the main lake

Anomalies assigning NPS-FM lake trophic state bands to the upper Waikato FMU

9.5 The approach taken for assigning bands for the three lake trophic states, chla, TP and TN, appears to be inconsistent with the NPS-FM. The NPS-FM specifies TN and TP bands that correspond to a phytoplankton (chla) band. I would expect consistency across the selection of trophic state bands. Hence if community select a phytoplankton B band as acceptable (≤5 mg/m^3 of chla), then to be graded a B band lake, the TP and TN must also be in the B band (i.e. ≤20 mg/m^3 and ≤350 mg/m^3, respectively). However, in the case of the Upper Waikato FMU, sites downstream of Taupo gates, chla and TP targets are set at a B band state, whereas TN concentrations are set at an A-band state. This imposes a maximum target TN concentration of ≤160 mg/m^3. Current state (2012-2016) indicates that only Ohaaki is meeting this value (c. 120 mg/m^3), whereas Ohakuri, Whakamaru, Waipapa and the apparent Karapiro 'proxy' site (i.e. Narrows), have TN concentrations of 200, 250, 330 and 410 mg/m^3, respectively.

9.6 Based on these inconsistencies with the rationale, I have the following suggestions for consideration:

a. PC1 only has TN targets based on maintaining A-band state. I would recommend having more stringent A-band trophic state targets for chla, and TP at Ohaaki.

b. For the upper Waikato mainstem sites (Ohakuri to Waipapa), TN is set at A band with chla or TP both band B. Most studies[5,12] indicate that median chla concentrations are correlated more strongly with median TP concentrations. In my opinion, it would be more consistent if the TN target value was based on the upper B band threshold (rather than the upper A band threshold value as it currently is) to align with the B band applied to chla and TP. This would mean a maximum target concentration of 350 mg/m^3 (as opposed to 160 mg/m^3). If adopted, target values in Table 3.11-1 would change for Ohakuri, Whakamaru and Waipapa from 160 mg/^{3} to their current state values (i.e. c. 200 mg/m^3, 250 mg/m^3 and 330 mg/m^3, respectively). If the Narrows site was a proxy for water quality at the Upper FMU boundary, then the water quality target for this site would be set at 350 mg/m^3 (current state value c. 410 mg/m^3).

Attributes

9.7 Microbial pathogens: *E. coli* - I note that the current attribute is not aligned with latest 2017 amendments of the NPS-FM. Suitability for swimming is now assessed (graded) using four summary statistics for *E. coli* indicator organisms, namely:

a. Percent of exceedences over 540 cfu/100 ml
b. Percent exceedences over 260 cfu/ml
c. Median concentration (cfu/100 ml)
d. 95th percentile concentration (cfu/100 ml)

9.8 I recommend that PC1 be consistent with the E. coli attribute for Human Health recreation notified in the August 2017 version of the NPS-FM (2014)[1] – Appendix2.

7. CONCLUSIONS

7.1 I support PC1, and have confidence in the water quality load models, and the outputs that underpin the technical basis of the plan change.

7.2 I am confident that the model outputs from the policy meet, and generally exceed the short term (10-year) water quality targets in PC1

7.3 I do not support the introduction of new water quality models in this stage of the process, as I believe the current approaches are sufficiently robust.

7.4 I support the catchment approach of PC1 for managing water quality – although contaminant load modelling was done for each subcatchment, the contaminant loads were routed downstream through the entire Waikato River network.

7.5 Based on the work to date, neither the technical work nor the water quality target in Table 3.11-1, in my opinion, permit a subcatchment approach that would take account of cumulative effects, and different susceptibility of downstream receiving environments (i.e. mainstem need to consider trophic responses from phytoplankton.

7.6 I support management of all four contaminants, including nitrogen.

7.7 I recommend PC1 provide more clarity around water quality and associate water quality targets that apply to the downstream boundary of the Upper Waikato FMU. The downstream Narrows site was supposedly a proxy for water quality exiting Karapiro (i.e. upper FMU), but the Narrows is regarded as a middle FMU site in Table 3.11-1.

7.8 I have made several suggestions for consideration to improve logic in Section 9 of my evidence.

Craig Verdun Depree **15 Feb 2019**