BEFORE THE HEARING PANEL

AT HAMILTON

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the Proposed Waikato Regional Plan Change 1 Waikato and Waipā River Catchments
AND	
IN THE MATTER	of Variation 1 to the Proposed Waikato Regional Plan Change 1 Waikato and Waipā River Catchments

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STATEMENT OF EVIDENCE OF NGAIRE ROBYN PHILLIPS FOR THE DIRECTOR-GENERAL OF CONSERVATION

TOPICS: B2, B3, B4, B5

15 February 2019

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Submission number: 71759

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Introduction

1. My full name is Ngaire Robyn Phillips. I am currently a Director and scientist at Streamlined Environmental Ltd, a company specialising in aquatic science consulting. My specialist roles within the company are as aquatic ecologist and ecotoxicologist.

2. I have worked in the field of environmental science, focusing on freshwater and marine ecosystems, for almost 30 years and have experience in government, academia and the private sector

3. I have lived and worked in the Waikato region for 16 years, where I have focused on resource management of fresh and estuarine waters.

4. I have been asked by the Director-General of Conservation (The Director-General) to provide evidence regarding the aspects of the Proposed Waikato Regional Plan Change 1 (Waikato and Waipā River Catchments) that relate to values, priorities and water quality targets for shallow lakes.

Qualifications and experience

5. I hold a Doctor of Philosophy in Environmental Science gained from Griffith University in Brisbane, Australia which I received in 1994. I also hold a Master of Science with First Class Honours (Zoology) and a Bachelor of Science (Zoology), both gained from the University of Auckland.

6. Prior to my current role, I was employed at NIWA in Hamilton as Group Manager and Scientist of Freshwater Biology and in its Australian subsidiary, NIWA Australia as Principal Scientist, Aquatic Ecology for a period of 10 years.

7. I have also held senior roles in Australian and New Zealand government agencies and environmental consultancies, providing specialist expertise in aquatic ecology and ecotoxicology.

8. I am an independent RMA Commissioner and have applied my environmental science knowledge to resource consent applications in the Waikato region.

9. I am appointed member of a Special Tribunal that is currently considering an application for a Water Conservation Order (WCO) for the Ngaruroro/Clive Rivers in the Hawkes Bay region. I am providing specialist expertise in water quality and freshwater ecology. The purpose of water conservation orders is to provide recognition of the outstanding amenity or intrinsic values of water bodies.

10. I am an appointed member of the HSNO (Hazardous Substances and New Organisms) Committee. In this role I participate/chair Decision Making Committees, whose function is to determine applications for potentially hazardous substances and organisms new to New Zealand.

11. I have worked on a wide range of environmental science issues as a researcher and consultant, including effects of land use on aquatic ecology (freshwater, estuarine and marine), water quality, environmental/human health links, customary fisheries, and response to contaminants by aquatic organisms (ecotoxicology).

12. I have undertaken research and consultancy projects on a diversity of lakes in New Zealand and Australia. For example, I developed a classification system for dune lakes in northern Queensland, many of which are characterised by acidic, tea-stained waters comparable with the Waikato peat lakes. Between 2005 and 2012 I was Programme Leader for 2 consecutive FRST-funded research programmes focused on investigating factors influencing taonga species in the Te Arawa lakes, which included lakes in the Bay of Plenty and Waikato regions. The results of this work supported the development of iwi management plans for these lakes. In addition, I have provided technical support to a range of clients on various aspects of lake management for naturally occurring and created lake systems (such as hydro lakes, pit lakes).

Code of Conduct

13. Although this is not an Environment Court hearing process, I have read the Environment Court “Code of conduct for expert witnesses”, and I agree to abide by it. I have prepared this Statement in accordance with that Code. I confirm that my evidence is within my area of expertise. I have not omitted to consider any material facts known to me that alter or detract from the opinions I express in this Statement. I have

acknowledged the material used or relied on in forming my opinions and in the preparation of this Statement.

Material Considered

14. In preparing this evidence I have considered the following information:

- The Director-General of Conservation’s Submission dated 8 March 2017
- The Director-General’s Submission on Variation 1 dated 22 May 2018
- The Director-General’s Further Submission dated 17 September 2018
- Waikato Plan Change 1, which includes the changes made as a result of Variation One: Waikato Regional Council (WRC) Policy Series 2018/05
- Waikato Regional Council Section 42A Report
- Other relevant references (see reference list)

Scope of Evidence

15. In this evidence I will comment on:

a. Shallow lakes within the Waikato and Waipā River catchments,

b. Values and significance of these lakes

c. Ecological condition of these lakes

d. Management strategy for restoring ecological condition

e. Concerns with the proposed approach for management of the Waikato-Waipā shallow lakes as set out in PC1; and

f. Recommended changes to PC1 to address appropriate management of shallow lakes.

Executive summary

16. The Waikato/Waipā shallow lakes provide for a diversity of values within the Waikato Region and the peat lakes are nationally important.

17. The Department of Conservation manages the lake and/or surrounding margins of just over 50% (30) of the 59 lakes subject to the proposed plan change.

18. Most of the lakes within the Waikato and Waipā River catchments have been significantly impacted by landuse, drainage, vegetation clearance, sediment and nutrient inputs and the impacts of invasive flora and fauna.

19. Many of the lakes have lost their macrophyte communities as a result of declining water quality and some have “flipped” to a new stable state dominated by phytoplankton.

20. It is generally accepted that actions to maintain lakes in a clear water, macrophyte-dominated state is preferable to the more challenging and expensive option of restoration, which would require a multi-pronged long term effort.

21. Climate change is predicted to exacerbate eutrophication, and therefore further increase the effort required to achieve desirable lake water quality outcomes in the future.

22. In its current form, Plan Change 1 does not provide a coherent or holistic management framework that is clearly focused on the Waikato-Waipā Lakes. As such, it provides little direction or certainty regarding their future management.

23. The Lake FMU classification system proposed in Plan Change 1 appears to be based solely on geomorphological lake formation processes and does not account for other variables that drive the differences between lakes.

24. Further refinement, and expansion of the number of lake FMU’s, using a more robust scientific approach, is required. A recently-developed method is supported which I discuss in my evidence.

25. The staging and timing of implementation is particularly important for lakes because of the long lag times associated with lake water quality improvements.

26. There appears to be a lack of consideration given to existing lake management initiatives, especially in relation to Policies 8 and 14, and the prioritisation of sub-catchments in Table 3.11-2.

27. The proposed changes to the prioritisation of some sub-catchments which include lakes has increased the number of high priority lakes. However, this approach doesn't prioritise the lake catchments in a consistent way or appear to influence the order of lake catchment plans under Policy 14.

28. There are also a number of anomalies in those lakes that have been given lower priority.

29. A more systematic and considered prioritisation system is proposed, based on existing work undertaken by the Department of Conservation (DOC) and others.

30. No short-term water quality targets have been set for lakes, while long term targets are currently set at the NOF National bottom Lines, or to maintain current conditions when lakes attributes were in "better than bottom line" condition.

31. These lake targets are not consistent with realising the potential to improve the water quality of some lakes, and do not equate to the "long term restoration and protection of water quality", which is the intent of Objective 1.

32. There is evidence to indicate that more aspirational water quality targets could be achieved for some lakes within the time frame of PC1. This would enable PC1 to meet the requirements of the NPS -FM or the Waikato River Visions and Strategy.

33. Ammonia toxicity is only one component of ecosystem health and should be considered as part of a suite of attributes used to describe ecosystem health.

34. A number of studies have been undertaken to determine high value or outstanding lakes within the Waikato/Waipā region, providing support for those lakes nominated in the Director-General's submission.

The values and significance of the lakes within the Waikato and Waipā River Catchments

35. There are 59 lakes within the Waikato and Waipā River catchments included in PC1, which can be classified into four types – thirty five peat lakes, fifteen riverine lakes, five volcanic lakes and four dune lakes. These lakes include i) those with a direct connection to the lower Waikato River (e.g. Lake Waikare), ii) lakes that contribute to the tributaries of the Waikato River (e.g Lake Ngaroto, which drains into the Waipā River) and iii) lakes associated with the historical Waikato River channel (and as such may now not have a direct connection with the river) (Hamilton et al., 2010)

36. These lakes form an inter-connected system of open water, wetland and swamp that supports valuable habitat for native flora and fauna (including threatened, taonga and game species). The lakes also have considerable cultural and spiritual significance to Māori, and many have historical occupation sites associated with them. The inherent natural values of these lakes occur in the presence of extensive human use of the lowland lakes for water supply; flood control; commercial and customary fisheries and recreation.

37. The lakes play an important ecological role within the larger Waikato-Waipā river-lake-wetland system, providing permanent habitat for some species, and temporary habitats for other species that use the lake seasonally in response to changing water levels elsewhere in the system (e.g. for nesting, moulting, summer feeding) (Cromarty & Scott 1996). The Waikato wetland system is consider to be the most extensive and important freshwater wildlife habitats in New Zealand (Ogle and Cheyne, 1981).

38. The lakes represent some of the last remaining wetland and floodplain areas that were once an extensive part of the Waikato region. As a result of land use development, few of the lakes retain the extensive marginal wetlands that existed in the past, and most have been subject to hydrological alteration as a result of drainage activities. A number of rare and threatened species occupy habitats within this system. Their

populations have become increasingly fragmented as a result of habitat modification and are particularly vulnerable to further change.

39. I note that lakes are not included as under Objective 3.11.1.1 Intrinsic Values - Ancestry and Historic Values. A number of the peat lakes in the Waipā District have pā sites associated with them (WRC, 2018a) and been the sites of significant settlements and events (e.g. Battle of Rangiriri around Lake Kopuera, battle of Hingakaka around Lake Ngaroto, respectively). As a consequence, some of the lakes are still considered tapu. Some of these sites are recognised by archaeologists as being some of the best preserved prehistoric open-air stone-age settlements in the world. Most of these lakes are of special significance to local iwi who whakapapa to these areas. These sites have been relatively well persevered due to the peat being semi-waterlogged which has aided in the preservation of wooden artefacts. The area of Ngaroto is steeped in ancient traditional history, being one of the more significant settlement regions following the migration of ancient Māori inland from the Käwhia shorelines circa 1400-1500 (Maniapoto et al., 2006).

40. I therefore consider that there is sufficient evidence to justify their inclusion under Objective 3.11.1.1 Intrinsic Values - Ancestry and Historic Values.

41. The lakes which are included in Plan Change 1 cover a total area of 6022 hectares. DOC manages the lake and/or surrounding margins of just over 50% (30) of the 59 lakes subject to the proposed plan change (Table 1). This amounts to a total area of 1713 hectares, which represents 28% of the total area of lakes covered by Plan Change 1. The lakes are primarily managed for the purposes of wildlife management, wildlife refuge, conservation and recreation and are administered under the Wildlife Act 1953 and Conservation Act 1987. Extensive additional conservation areas that have been transferred to Waikato-Tainui from DOC as part of their settlement have retained their conservation status e.g. Waikare Wildlife Refuge.

Table 1 Lakes within the Waikato/Waipā catchments managed by DOC (data supplied by DOC).

Name	Reserve	Area (ha)
Penekawa	Conservation Area - Lake Rotokawau	0.01
Ngapouri	Lake Ngapouri Marginal Strip	0.29
Whangape	Awaroa Swamp Wildlife Management Reserve	0.46
Ngahewa	Lake Ngahewa Recreation Reserve	0.48
Rotopataka	Lake Rotopotaka Wildlife Management Reserve	1.09
Serpentine E	Lake Serpentine Wildlife Management Reserve	1.42
C Komakorau	Wildlife Management Reserve - Horsham Downs- Lake Hotoananga Lake Pikopiko Lake Areare Lake C Lake B	1.58
E Tunawhakaheke	Hurrells Lake Wildlife Refuge Reserve	2.61
Waikare	Conservation Area - Lake Rotokawau	2.68
Ngarotoiti	Lake Ngarotoiti Wildlife Management Reserve	3.28
Serpentine W	Lake Serpentine Wildlife Management Reserve	4.28
Serpentine N	Lake Serpentine Wildlife Management Reserve	4.64
Pikopiko	Wildlife Management Reserve - Horsham Downs- Lake Hotoananga Lake Pikopiko Lake Areare Lake C Lake B	4.68
Orotu	Lake Orotu Wildlife Management Reserve	4.75
Koromatua	Lake Koromatua Wildlife Management Reserve	4.94
Puketi	Karioitahi Conservation Area	5.90
Rotomanuka (North & South lakes)	Lake Rotomanuka Wildlife Management Reserve	6.09
Okowhao	Lake Okowhao Wildlife Management Reserve	7.48
Hotoananga	Wildlife Management Reserve - Horsham Downs- Lake Hotoananga Lake Pikopiko Lake Areare Lake C Lake B	8.13
B Kaituna	Wildlife Management Reserve - Horsham Downs- Lake Hotoananga Lake Pikopiko Lake Areare Lake C Lake B	9.66
Ruatuna	Lake Ruatuna Wildlife Management Reserve	11.81

Rotomanuka (North & South lakes)	Lake Rotomanuka Wildlife Management Reserve	13.64
Rotokawau	Conservation Area - Lake Rotokawau	14.83
Ohinewai	Conservation Area - Lake Ohinewai	17.06
Areare	Wildlife Management Reserve - Horsham Downs- Lake Hotoananga Lake Pikopiko Lake Areare Lake C Lake B	30.20
Rotongaroiti	Lake Rotongaro Wildlife Management Reserve	44.25
Kimihia	Lake Kimihia Wildlife Management Reserve	48.77
Hakanoa	Lake Hakanoa Wildlife Refuge Reserve	55.88
Rotokawa	Lake Rotokawa Conservation Area	64.10
Rotongaro	Lake Rotongaro Wildlife Management Reserve	283.90
Whangape	Lake Whangape Wildlife Management Reserve	1054.12
TOTAL (ha)		**1712.99**

Peat lakes

42. Peat lakes are naturally acidic, with low nutrient and bottom dissolved oxygen concentrations[1]. These characteristics reflect their association with the historically extensive Komakorau, Rukuhia and Moanatuatua peat bogs that formed after the Waikato River changed course to its current orientation across the Hamilton basin some 17,000 years ago (McCraw 1967). The Waikato peat lakes comprise the largest collection of this lake type in New Zealand (Dean-Speirs et al. 2014; Abell 2018). They are also regarded as internationally unique and important (Dean-Speirs et al. 2014; Abell 2018). Examples includes lakes Rotokauri, Rotoroa and Ngaroto.

43. The thirty seven peat lakes that are found in the Waikato region a depth of all have a maximum depth of less than 10m deep, and generally small to moderate in size (1-33 ha), with relatively small catchments. Twenty of the peat lakes have estimated surface water catchment areas of 200 ha or less. The largest peat lakes include Lake Rotokauri (42 ha), Lake Rotoroa (55 ha) and Lake Ngaroto (108 ha) and each have catchment areas of 933, 258, and 1846 hectares, respectively. All are

[1] also known as dystrophic

predominantly located within pastoral catchments and few have extensive marginal wetlands remaining (Dean-Speirs et al. 2014).

Riverine Lakes

44. The riverine lakes were the subject of extensive surveys between 1980 and 2000 and, as such, are the best known (e.g. Town, 1980, 1982; Davenport, 1981; Boswell et al., 1985). These lakes are highly productive. They are mostly associated with the extensive floodplain-wetland system of the lower Waikato River and, as such, are ecologically dependent upon the hydrology of this system. In such lakes, wind-driven re-suspension can be an important process due to high fetch (Dean-Spiers et al. 2014).

45. All of the riverine lakes are extremely shallow, with a maximum depth of no more than 5m. However, they vary considerably in size from 1 – 3400 hectares, with eight lakes being greater than 50 ha in size and having catchment areas of 250 - 31,700 hectares. Amongst this lake type are some of the largest of the shallow lakes (e.g. Lake Waikare) (Dean-Spiers et al., 2014). Other examples include lakes Whangape and Waahi.

Volcanic Zone Lakes

46. In New Zealand, volcanic lakes are largely confined to the Taupō Volcanic Zone and the area around Auckland. The lakes have formed in craters resulting from volcanic eruptions and associated faulting within the lat 10,000 years (Viner, 1987). The five lakes that are located in the Volcanic Zone within the upper Waikato River area vary in size from 3 – 60 ha in size, with catchment areas of 500 - 1100 hectares. These lakes are, on average, larger and deeper than those in other lake categories. Examples are lakes Tutaeinanga and Ngahewa (Dean-Spiers, 2014).

Dune Lakes

47. There are four dune lakes located to the west of Waiuku near Karioitahi. These lakes are smaller and more consistent in size when compared with other lake type, ranging from 1 – 6.5 ha in size, with estimated

catchment areas between 40 and 114 hectares (TLG, 2015). Examples include lakes Otamatearoa and Puketi (Deans-Spiers, 2014).

Ecological Condition of the Lakes in the Waikato and Waipā River catchments

Water Quality

48. Many of the shallow lakes in the Waikato region have been highly impacted as a consequence of landuse practices such as drainage, vegetation clearance, sediment and nutrient inputs and the impacts of invasive flora and fauna (Abell, 2018, Hamilton et al. 2010). Indeed, some of the Waikato lakes are amongst the most nutrient polluted lakes within New Zealand (Abell 2018). Their trophic status was found to be comparable with highly degraded lakes in the USA and Europe that have been subject to intensive agricultural pressure for far longer than lakes in the Waikato region (Verberg et al. 2010, Abell et al. 2010).

49. The relationship between the water quality of Waikato shallow lakes and the proportion of high intensity pastoral land use within their catchments has been well documented (Abell 2011b; Hamilton et al. 2010). Abell (2018) reported that Total Nitrogen (TN) concentrations for the shallow Waikato lakes (1.503 mg/L) was greater than the mean TN concentration of approximately 85% of the lakes in EU countries, 66% of the USA lakes and 90% of the other New Zealand lakes in his sample. Abell (2018) uses Lake Mangahia as an example of a hypertrophic Waikato peat lake with a Trophic Lake Index (TLI) of 7.2 that exceeds the upper limit (of 7) that was envisioned when the TLI system was developed by Burns et al. (1999).

50. Most of the Waikato-Waipā lakes are shallow and have historically received extremely high external nutrient loads and remain nutrient enriched as a result of these ‘legacy’ loads. These nutrients have the potential to be recycled back into the water column under appropriate conditions, including via wind-induced sediment disturbance (in shallow lakes), anoxia-mediated release of phosphorus from redox-sensitive lake sediments (when lakes stratify), macrophyte die off, or through sediment disturbance such as can happen as a result of benthic feeding

by pest fish. Indeed, internal loads may exceed external loads on an annual basis in lakes that have highly nutrient-enriched sediments due to a legacy of external loads (Abell, 2018). As a consequence, nutrients can fuel the growth of phytoplankton, which can reach high concentrations and induce algal blooms in some shallow lakes. The presence of potentially toxic cyanobacteria in such situations presents a considerable risk to humans. Routine monitoring occurs in several shallow lakes, and health warnings are regularly in place for Lakes Kainui, Waikare, Ngaroto and Lake Whangape over the summer months.

51. Hamilton (2014)[2] presented a summary of the ecology and water quality issues for the lowland lakes in the Waikato region that showed the current status of the lakes, which emphasised the scale of the task involved in meeting the national bottom lines for chlorophyll a, TN, and TP within the National Objectives Framework (NOF). Some lakes are below the national bottom line for all 3 attributes (Otamatearoa, Harihari and Rotoroa), while a number of others are below this level for 1 or 2 attributes.

Ecological Health

52. While water quality is regularly monitored in a number of lakes the ecological health/integrity of the lakes is less well studied (Dean-Speirs, 2014). The Lake Submerged Plant Index (SPI) is one of few tools available to provide an integrated assessment of lake health/integrity.

53. Lakes in the Waikato Region would once have supported a diverse community of native plant species, whose distribution within the lake would have determined by water clarity. It is expected that most Waikato shallow lakes would naturally have supported plants across their lake beds (Burton and de Winton 2016; Abell 2018). In lakes, rooted macrophytes assist in maintaining clear water conditions by absorbing dissolved nutrients from the water column, stabilising bed sediments, providing refugia, and minimising wave action (Scheffer

[2] Presentation by Professor David Hamilton to the 6th workshop of the Collaborative Stakeholder group held on 15/16 September 2014.

2004; Abell 2018). Thus, there presence in shallow lakes is highly desirable.

54. Many of the shallow lakes have lost these plant communities as a result of declining water quality and subsequent declines in ecological condition. Increased nutrient loads have promoted the growth of phytoplankton which in turn increases turbidity, reduces light penetration and subsequently limits the distribution and biomass of rooted macrophytes. Once a critical turbidity threshold is reached, lakes may flip to an alternative stable state that is dominated by phytoplankton (Figure 1). Schallenberg et al. (2009) identified 37 lakes that had undergone these types of regime shifts, with 41% of these lakes being in the Waikato region.

55. Sheffer & van Nes (2007) emphasised that while the contrast between submerged macrophytes and a turbid phytoplankton state may be the most spectacular, many other less conspicuous shifts seem to occur in reality. As such, the change of biological communities along a gradient of eutrophication may really be seen as a continuum in which gradual species replacements are interrupted at critical points by moderate or more dramatic shifts to a contrasting community state.

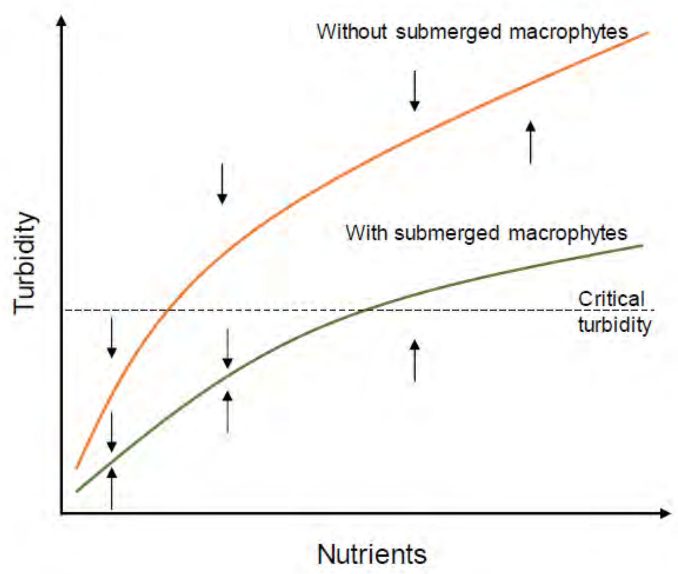


Figure 1 Alternative stable states in shallow lakes in temperate latitudes. Source: Abell 2018 (redrawn from Scheffer et al. 1993)

56. Three factors have been identified as having contributed to the loss of submerged plant communities, as well as the associated acceleration in decline of ecological condition of shallow lakes in the Waikato Region, namely: (1) declining water quality; (2) invasive fish species; and (3) invasive plant species (Burton & De Winton 2016; Schallenberg et al. 2009).

57. Between 2004 and 2016 NIWA undertook investigations to determine the Lake SPI scores for 62 shallow Waikato lakes that were mostly less than 10m deep (Burton & de Winton 2016). Of these, forty one occur within the Waikato-Waipā River catchment and of this subset, only 9 supported sufficient submerged aquatic plant communities to generate Lake SPI scores (Table 2). The remainder of the lakes surveyed (32) were defined as unvegetated, with most having ‘flipped’ to a phytoplankton-dominated state.

Table 2 Lake SPI results for nine Waikato-Waipā lakes (Burton & de Winton, 2016)

Lake Type	Lake Name	Most recent Survey	Lake SPI results	Native Condition index	Invasive condition index	Overall Condition
Peat	Serpentine North	26/04/2016	80	69	11	high
Peat	Serpentine East	26/04/2016	66	72	33	high
Peat	Rotoroa (Hamilton)	08/05/2009	20	17	37	poor
Peat	Mangakaware	20/05/2015	19	27	42	poor
Volcanic	Ngapouri	23/03/2016	45	40	41	moderate
Volcanic	Tutaeinanga	23/03/2016	15	11	84	poor
Dune	Puketi	30/03/2016	30	42	79	moderate
Dune	Otamatearoa	30/03/2016	18	24	93	poor
Dune	Parkinson	30/03/2016	17	10	86	poor

Can ecological condition be restored?

58. It is generally accepted that once lakes have 'flipped' to an alternative, phytoplankton-dominated, stable state, that restoration and management becomes a much more difficult and often expensive proposition. As a general rule, nutrient loads need to be reduced to a level lower than those which existed prior to the loss of the macrophytes (i.e. below the crucial turbidity threshold) in order for macrophytes to re-establish (Abell, 2018).

59. As a management strategy, it would appear to be far more cost effective to proactively maintain water quality to support clear water, macrophyte-dominated states, rather than to try and restore lakes that have transitioned to a turbid state (Abell 2018).

60. Lehman et al. (2017) employed a modelling approach to identify, evaluate and prioritise in-lake and catchment restoration options that could be applied to improve water quality and ecological health of peat and riverine lake types in the Waikato Region (Lehman et al. (2017)). The modelling was undertaken on 4 representative lakes (Rotomanuka, Ngaoroto, Waahi and Waikare), which were chosen on the basis of their social, cultural and ecological significance, as well as the availability of data and their relevance to other similar lake systems. Multiple lake management scenarios were simulated using a DYRESM-CAEDYM model calibrated to each lake application. The management approaches assessed included 1) external nutrient load reduction (e.g. erosion control), 2) hydrological modifications (e.g. increasing water levels) and 3) geochemical engineering (e.g. sediment capping). The authors concluded (amongst other things) that, for three of the modelled lakes, tipping points had been exceeded and consequently continued nutrient loading could result in unpredictable outcomes, such as Lake Waikare "turning red" with the alga Monoraphidium. Lehman et al. (2017) concluded that "The challenges for restoration are immense in dealing with some of the most eutrophic lakes in the world, and extraordinary measures and efforts will be required to not obviate responsibility in leaving a legacy for future generations to deal with."

61. Best management practices can achieve detectible reductions in external nutrient loads; however, it is generally accepted that these types of improvements alone will not be sufficient to improve the water quality of the Waikato-Waipā shallow lakes (e.g. Lehman et al. 2017; Abell, 2018). Other actions will be needed and may include changes to water level regimes, in-lake interventions, sediment removal or modification, macrophyte restoration, and biomanipulation (involving control of invasive fish) (e.g. Allen, 2016, 2018). The timing and effectiveness of these other interactions will depend, however, on adequate reduction of external nutrient loads to the lakes (Dean-Spiers et al., 2014).

62. Jenkins and Vant (2006) estimated that nitrogen loads to shallow lakes could be reduced by 7% and 36% if catchment management was improved from average to best practice, and best practice to the more rigorous potential practice, respectively. Phosphorus reductions of 18% and 39% were also estimated on the basis of a shift in catchment management practice from average to best practice, and from best practice to potential practice, respectively. More recent studies in the upper Waikato (e.g. Sustainable Milk project, Brocksopp et al. 2014) indicate that it may be possible to achieve a mean reduction of 8% for N and 21% for P when all farm plan actions are fully implemented.

63. Abell (2018) confirms that external nutrient load reductions will be key for the future management and restoration of the Waikato and Waipā lakes. Further, he notes that the magnitude of external nutrient load reductions required to restore clear-water conditions in shallow lakes is often under-estimated and that other actions to control internal nutrient loads will also be required to achieve even moderately ambitiously lake water quality targets within a 20 year timeframe. Hamilton et al. (2010) emphasise that options for internal load control are expensive and may have limited longevity without concomitant reductions in external load, often in the order of 50%.

64. Hamilton (2014) suggested that the following actions may be required to reverse the trend and improve the current state of lowland lakes in the Waikato:

    a. Substantially reduce external loads

b. Reinstate >20% native vegetation in catchments (as a possible threshold for regime shifts)

c. Reinstate >5% of catchment in to wetlands (to facilitate n, P and SS removal)

d. Manage the biological effects of invasive macrophytes and koi carp

e. Re-engineer some systems to manage nutrient inputs

f. Address nutrient legacies in lake sediments

65. The control of phosphorus is particular importance as a limiting nutrient in temperate lakes (Schindler 2012). Evidence also indicates that N loads should also be controlled concomitantly, as primary nitrogen limitation of phytoplankton biomass accumulation is relatively common in New Zealand (Abell et al. 2010). Lehman et al. (2017) recommend a precautionary approach, whereby phosphorus reduction is undertaken at the same time as nitrogen reduction, making sure that N:P ratios are not decreased. The need for this dual approach (i.e. N and P) is further supported by evidence that submerged macrophytes may collapse or fail to colonise under high nitrogen concentrations irrespective of P concentrations (Abell 2018).

66. Eutrophication is also predicted to be exacerbated by climate change (Abell, 2018) and increased effort will be required to achieve future desirable lake water quality outcomes. Increased temperatures are predicted to amplify phytopklankton biomass directly, and also cause a range of indirect effects, including proliferation of planktivorous fish, greater internal loading, increased nutrient mineralisation, reduced lake depth during droughts and higher nutrient loads in more frequent and intense storm events (Abell, 2018).

67. In their modelling of Lake Waahi, Lehman et al. (2017) observed that elevated water temperatures led to reduced dissolved oxygen levels throughout the water column to around 50% of saturation. Such reductions could result in significant impacts on fish communities (Franklin, 2014). Lehman et al. (2017) refer to these observations as a “call to action” for these degraded shallow lakes that appear to be highly vulnerable to impacts of a warming climate with fish kills likely to be a

direct impact from increased water temperature and loss of dissolved oxygen ….“

The proposed approach for management of lakes

68. In its current form, Plan Change 1 does not provide a coherent or holistic management framework that is clearly focused on the Waikato-Waipā Lakes. As such, it provides little direction or certainty regarding their future management.

69. In his submission the Director-General raises concerns about the following matters with respect to the future management of the Waikato-Waipā lakes:

    a. The design of the Lake FMUs

    b. FMUs, lake catchments and other sub-catchments and their relationship to one another

    c. Lake catchment management

    d. Lake Prioritisation

    e. Lake Water Quality Targets

    f. Identification of outstanding waterbodies

70. In the following sections I discuss what I consider to be the problems with the approach in PC1, (and some suggested alternatives), taking into account concerns also raised in the Director-General's submissions.

Method for determining Lake FMUs and lake prioritisation

71. In his submission the Director-General identified concerns about the basis for the designation of the 4 proposed Lake FMUs. The interpretation section of the NPS-FM 2014 (as amended 2017) defines Freshwater Management Units as "The water body, multiple water bodies or any part of a water body determined by the regional council as the appropriate spatial scale for setting freshwater objectives and limits and for freshwater accounting and management purposes. (Freshwater NPS definition)"

72. Regional councils have discretion over the spatial scale of FMUs but must define FMUs at an appropriate management scale to undertake freshwater accounting and set freshwater objectives and limits. An FMU may be made up of a group of water bodies that are similar, both physically and/or socially. Similar freshwater bodies can be grouped (eg, all first order streams originating from a mountain range) and be effectively managed as one FMU. Alternatively, an individual freshwater body or a part of a freshwater body (eg, a reach or sections of a river) could be set as an FMU.

73. In section 4.2 of the MFE Guide to freshwater accounting under the NPS-FM 2014, FMUs are described as being "the fundamental units of a freshwater quantity and quality accounting system". The guide acknowledges that the number and scale of FMUs in a region will have an impact on plan development and workability. It states that "FMUs will contain common freshwater objectives for the water body or bodies within it, so that representative monitoring sites can be readily established" (my emphasis). The guide also further explains that FMUs should be hydrologically coherent (of similar hydrology) and also similar from a social perspective, so that communities and iwi with common interests and values are contributing to common objectives. These descriptions of FMUs are consistent with the ecosystem-based classification approach which is invoked in the RMA by requiring that regulation be based on managing the effects of resource according to "the life supporting capacity" of the environment (e.g. Snelder & Hughey, 2005).

74. The Lake FMU classification system proposed in Plan Change 1 appears to be based solely on geomorphological lake formation processes and does not account for other variables that drive the differences between lakes. I consider this approach to be overly simplistic, as it groups lakes that are extremely diverse in terms of their physical characteristics. For example, the riverine lake FMU contains lakes that are the shallowest within the region but vary in surface area by several orders of magnitude (i.e. 1 -3440 ha). This variability will be reflected in differences in lake structure and function, which in turn influences ecological systems and, ultimately, management needs.

Grouping lakes on the basis of a limited range of attributes risks managing with a blunt tool.

75. Another reason that it is important for the lake FMUs adequately reflect the diversity of lakes within the Waikto/Waipā region is to ensure that monitoring programmes are appropriately designed. As a consequence of the high spatial and temporal variability in Waikato lake water quality data, lake water quality monitoring is required over long timeframes and at a high frequency to determine trends with statistical confidence (Ozkundakci & Allan 2018). To maximise cost and time efficiency, it is essential that lake monitoring programmes are designed in a scientifically robust way in order to categorise and select the most appropriate lakes (and sites within them) and be able to implement long term monitoring programmes which are appropriate and which are sensitive enough to detect changes and trends.

76. The variables listed in Table 3 are well known drivers of lake ecology and processes. These could form the basis of Lake FMUs that would underpin a robust and representative lake management and monitoring framework.

Table 3 Variables that could be used in developing Lake FMUs (Based on Ozkundakci, 2015).

Descriptive category	Variable	Description
Lake Morphology	Lake maximum depth	Shallow lakes have a lower buffering capacity (nutrient and contaminants) than deeper lakes
	Lake fetch	Distance over which the wind can affect the thermal structure of the water column. It also influences sediment resuspension in shallower lakes
	Lake hydraulic residence time	Length of time that water is held within the lake. This is a major determinant of the response time for environmental changes.
	Lake surface area	Key determinant of stratification, temperature and other parameters which influence biological processes.
Catchment Morphology	Catchment Area	Catchment area will determine contaminant yield and connectivity.
	Catchment Slope	Determines the rate of nutrient and contaminant flux associated with surface flows.

Catchment Geology	**Catchment Phosphorus levels**	**General indicator of background in-lake P concentrations.**
	% of Peat Soils	Will determine the dystrophic character of peat lakes.
	Catchment hardness	May influence the hydrology of the lakes, including groundwater-surface water interactions. Peat lakes generally have the lowest catchment hardness.
Climate	Average Air Temperature	Temperature is a master variable. There is a direct relationship between temperature change and ecological processes (based on metabolic theory).
	Wind speed	Major determinant of hydrodynamic processes, including thermal stratification (deeper lakes) and sediment resuspension (shallower lakes). Coastal lakes generally experience higher wind speeds.

77. The Director-General's submission sought that Freshwater Management Units be created for each of the 59 identified natural lakes and their catchments within the area of the plan change, in order that values, attributes and limits be identified at an appropriate scale to meet the future management and monitoring requirements of the lakes. This approach would be more consistent with the lake-specific management approach that is proposed by Plan Change 1 and would help facilitate the collection of monitoring data and information about individual lakes that will be required to develop successful restoration approaches (as described by Abell 2018).

78. In paragraph 491 of the s42A report, officers have recommended that this idea be rejected for practical reasons. While I agree that 59 FMUs is not necessarily practicable, the Director-General's concern again highlights the need for there to be a clear focus on having lake FMU's that ensure that the variability in the Waikato/Waipā lakes is allowed for in terms of targets and management strategies.

79. An alternative approach would be to identify a smaller number of FMUs using a multi-variable classification system using, for example, those variables identified in Table 3 Such a classification system would group lakes on the basis of the similarity of key functional lake characteristics that best relate to the objectives of the Plan Change, which would also

provide the basis for a more representative monitoring network. I would also recommend that the FMU apply to the lake and its catchment.

80. Another example is the Ministry for Environment's Lake Water Quality Monitoring Protocol, which clearly identifies the need for different approaches for shallow unstratified lakes and deeper stratified lakes (Burns et al. 2000). They refine these categories further into five categories that require modifications in approach. These groupings are as follows:

    a. Unstratified lakes - phytoplankton dominated
    b. Unstratified lakes – macrophyte dominated
    c. Intermittently stratified lakes
    d. Stratified smaller lakes
    e. Stratified larger lakes

81. This type of approach was also used to support the development of FMUs for 400 (mostly dune) lakes in the Northland region (Hughes 2016) following a 2-step process that:

    a. defined a management classification – to discriminate differences in lake water quality and functioning based on categories of depth and geomorphology of lakes
    b. defined a management zone – i.e. the land area that contributes to the water balance and contaminant loads of the lakes in each management class (i.e. the surface water catchments for some lakes, plus the recharge area (or capture zone) of lakes that are hydraulically connected to groundwater.

82. Using a comprehensive dataset collated for 73 Waikato lakes and covering 14 discrete characteristics from different data types including lake and catchment hydro-morphology, climate, and geology, Ozkundakci (2015) undertook a multivariate analysis in an attempt to develop a more robust classification of these lakes. This analysis produced 12 lake classes that reflect significant differences in their structure and function (Table 4) The classification obtained in this study takes a holistic approach by including a number of variables that have well documented relationships with in-lake bio-geochemical and

ecological dynamics. Ozkundakci (2015) concluded that “the results of this study highlight the complexity and diversity of lake types in the Waikato region based on the subset of 73 out of 200+ lakes in the region. The frequently used lake classification scheme based on lake formation should thus be used with caution for defining management units as it does not encompass all necessary characteristics that fundamentally drive ecosystem processes. As such, lake formation only provides one very particular data type and should thus be regarded as overly simplistic.”

Table 4 Summary table listing the lake class memberships of 73 lakes used in the present analysis. Historically used lake typology of each lake is denoted in parentheses. (Source: Ozkundakci 2015)

Lake class	Lake name (historically used lake type)
1	Blue (volcanic), Lower Tama (volcanic), Upper Tama (volcanic), Taharoa (dune), Rotokawa (geothermal), Orotu (volcanic), Ngapouri (volcanic), Ngahewa (volcanic), Rotongaio (volcanic), Rotowhero (geothermal)
2	Rotongaro (riverine), Rotokawau (peat), Rotongaroti (riverine)
3	Cameron (peat), Patake (peat)
4	Kainui (peat), Koromatua (peat), Mangahia (peat), Whakatangi (peat), Ohinewai (riverine), Kaituna (peat), C (peat), Maratoto (peat), Okowhao (riverine)
5	Rotokauri (peat), Kopuera (riverine), Rotoroa Hamilton (peat), Kimihia (riverine), Hakanoa (riverine), Ngaroto (peat)
6	Waiwhata (riverine), Rotopataka (peat), Serpentine North (peat), Okoroire (peat), Serpentine East (peat), Ngarotoiti (peat), Areare (peat), Mangakaware (peat), Serpentine West (peat), Rotomanuka (peat), Ruatuna (peat), Hotoananga (peat), Tunawhakaheke (peat), Pikopiko (peat), Waiwhakareke(peat)
7	**Tutaeinanga (volcanic), Rotokura (volcanic), Whangioterangi(geothermal)**
8	Numiti (dune), Rotongata (peat), Harihari (dune), Rotoroa Kawhia (dune)
9	Parangi (dune), Otamatearoa (dune), Puketi (dune), Rotokotuku (peat), Rototapu (dune)
10	Waahi (riverine), Waikare (riverine), Whangape (riverine)
11	Arapuni (hydro), Maraetai (hydro), Karapiro (hydro), Waipāpa (hydro), Aratiatia (hydro), Ohakuri (hydro), Atiamuri (hydro), Whakamaru (hydro)
12	Rotopounamu (vocanic), Hinemaiaia (hydro), Kuratau (hydro)

83. I consider that further refinement of the lake FMU’s, using a more robust scientific approach, is required. It is my opinion that the approach employed by Ozkundakci (2015) is a much more appropriate method for delineating FMUs and should be used as the basis for deriving FMUs in PC1.

Splitting of Lake Catchments is inconsistent with Lake Catchment Plans

84. In his submission, the Director-General raised concerns that splitting large lake catchments across multiple sub-catchments is not consistent with the Lake Catchment Plan approach of Policy 14, nor with the Waikato River Vision and Strategy (and in particular the objective which sets out to ensure “the integrated, holistic and coordinated approach to management of the natural, physical, cultural and historic resources of the Waikato River”). In particular, the catchments of Lakes Waikare and Waahi were split over sub-catchments 13/14 and 18/19, respectively (Table 3.11-2) in the proposed PC1. Lake Waahi’s subcatchments (18 and 19) were then prioritised differently (i.e. priority 1 and 2, respectively) without any rationale for the difference.

85. In the section 42A report, officers have responded to the Director-General’s concerns (about lake representation) by increasing the priority of seven catchments that contain lakes. This has resulted in catchments 18 and 19 now having equal priority (of 1). However, the combining of sub-catchments of Lakes Waikare and Waahi, respectively, into single units (i.e. all of Lake Waikare in one sub-catchment and all of Lake Waahi in another sub-catchment) to support whole catchment management for these lakes has not happened. The continued separation of parts of each of these sub-catchments appears to be inconsistent with an integrated, co-ordinated catchment approach for these lakes which would appear to be suggested by Policy 14. The risk would be that these lake catchments are not appropriately represented, prioritised or managed.

Staging and Timing for Implementation of Lake Catchment Plans

86. It would seem more efficient and transparent for land and lake owners/managers if the lake catchment and subcatchment planning processes were better linked and co-ordinated , especially as a number of the lakes are likely to require considerable reductions in contaminant inputs and other landuse management interventions (e.g. fencing, edge of field mitigations, wetland retirement etc.) in order to achieve even modest water quality improvements (Lehman et al. 2017, Abell 2018).

87. The staging and timing of implementation is particularly important for lakes because of the long lag times associated with lake water quality improvements. Lehman et al. (2017) indicates that it could take 10-30 years for catchment loads in lakes to reach a new equilibrium for many of the Waikato lakes, and could be much longer for some of the larger lakes. Abell (2018) reviewed overseas results and suggests that water quality improvements may occur within 15 years provided that external load reductions are sufficient and maintained. Within the literature, there is also evidence to suggest that additional interventions (e.g. biomanipulation) are likely to be most successful when internal loads are approaching equilibrium conditions (Sɸndergaard et al., 2007). Hence there is real urgency for lake catchment plans and contaminant load reductions to be undertaken to achieve water quality gains within the timeframes of Plan Change 1.

88. I consider that there is a need in PC1 need for the preparation of lake catchment management plans to be better co-ordinated with priorities and targets for water quality.

Existing catchment initiatives

89. In his submission, the Director-General raised concerns about the lack of consideration that appears to have been given to existing lake management initiatives, especially in relation to Policies 8 and 14, and the prioritisation of subcatchments in Table 3.11-2.

90. The section 32 and 42A reports refer to the size and difficulty of the task to restore the water quality of all of the riverine and many peat lakes to a more natural state and to achieve the NOF National Bottom Lines. This argument is then used to justify retaining the proposed attribute targets. While I accept this logic for the largest and most degraded lakes, I am concerned by the perception that the management of all Waikato-Waipā lakes is "too hard".

91. In comparison with other subcatchments within the plan change, many of the lakes have very small catchments. Assessment of 46 lakes within the Waikato-Waipā catchments show that 75% of the lake catchments involve less than 20 properties, with 40% (19) of the lake catchments involving less than 5 properties (see Appendix J of the Director-General's submission). Management programmes and catchment plans are also well advanced in some of these lake catchments (summarised in Appendix J, and by Abell 2018), which should further reduce the effort required in some catchments. For example, since the Director-General's submission, a substantial new collaborative project has also begun at Lake Whangape to improve water quality and enhance marginal habitats (https://www.waikatoregion.govt.nz/community/whats-happening/news/media-releases-recent/multi-agency-project-to-restore-lake-whangape-kicks-off/). This project involves significant funding from Ministry for the Environment, Waikato River Authority, WRC, DOC and Waikato-Tainui.

92. I consider that there would be substantial benefit in building on previous and existing work in lake catchments that are of a manageable scale (based on Appendix J of the Director-General's submission) in order to accelerate implementation for these lakes.

Lake Prioritisation

93. Some confusion is created by references to multiple priorities within policy 8 which sets out the framework for the prioritisation and staging of implementation for PC1 for 74 sub catchments in three tranches. Policy 8 refers to prioritisation of the implementation of policies 2, 3 and 9 in accordance with the sub catchment prioritisation in Table 3.11-2, as well as other priority areas including: subcatchments with the greatest gap between current water quality and the targets identified in Table 3.11-1, Lake FMUs; and the Whangamarino wetland. Dischargers in priority catchments with nitrogen leaching values in the 75th percentile are also identified as priorities for Farm environment plans.

94. It is not clear whether all lakes in the Lake FMUs are a priority under Policy 8 and how the 59 lakes will be prioritised against one another. Presumably, there will also be a need to reconcile lake and riverine subcatchment priorities, objectives and water quality targets where they overlap. While I understand the rationale to prioritise the most degraded riverine subcatchments for attention, I suggest that lakes should be prioritised on the basis of the highest ecological and water quality values (i.e. where the gap is smallest), and the catchments that are the focus of existing management efforts. This is because very few lakes retain high water quality and/or submerged plants, and because of the extreme difficulty, intense effort, and long timeframes associated with achieving water quality improvements for the most degraded lakes.

95. It appears that no attempt has been made in PC1 to prioritise individual lake catchments within the proposed Lake FMUs or in relation to other subcatchments. Policy 8 provides for Lake FMUs to be treated as priority areas, yet officers clarify in the s42A report (paragraph 644) that sub-catchments in Table 3.11-2 are prioritised regardless of whether they include Lake FMUs. As a result, the prioritisation of lakes is very unclear and requires clarification.

96. In his submission, the Director-General expressed concern that the proposed prioritisation of sub-catchments in Table 3.11-2 (associated with Policy 8) resulted in an under-representation of lakes and did not draw on available information about the known values and priorities of lakes, or the previous and existing effort (particularly for peat lakes) that could be built upon to target and accelerate implementation. Policy 14 also provides no information about the priority /order for development of lake catchment plans, which provides little certainty for land and lake owners and managers about how lake water quality improvement will occur.

97. In the section 42A report, officers acknowledge that there have been significant restoration efforts at many of the peat lakes, and that these lakes were poorly represented in the high priority subcatchments notified in PC1 (Table 3.11-2). In response to this, they propose to reprioritise seven (7) sub-catchments in Table 3.11-2 in line with section 8B of the RPS and the technical ranking system developed by Wildlands (2011) which is based on ecological significance, ecological condition, vulnerability and potential outcomes. This increases the priority of 27 lakes (i.e. almost half of the 59 lakes affected by PC1), such that 48 lakes now fall within priority 1 sub-catchments (according to Table 3.11-2).

98. Whilst I support these changes and acknowledge that this goes someway to addressing the Director-General's concerns for the priority peat lakes, this approach doesn't prioritise the lake catchments in a consistent way. Furthermore, there is no indication of the respective order that work will be progressed for the (now) 17 proposed priority 1 subcatchments that contain priority lakes.

99. Several anomalies also exist for the 11 lakes that remain in priority 2 and 3 catchments:

a. Whilst two of the Waiuku dune lakes (Lake Otamatearoa and Parkinsons) have been reprioritised as part of subcatchment 6 (Waikato at Port Waikato), the other 2 dune lakes that occur in subcatchment 5 (Lakes Puketi and Rotoiti) remain priority 3. This is problematic as, of the 4 dune lakes, Lake Puketi supports the best submerged plant communities (Burton and de Winton, 2016). In the context of the other Waikato lakes, these lakes fall within a very small proportion that retain any submerged vegetation and are therefore of regional significance. There is a very real risk that these plants could be lost if urgent action is not taken to improve the management of the lake and its catchment. As a result, I consider that all of the dune lakes should be given the highest priority in Table 3.11-2. On an international basis, dune lakes constitute a rare environment class with the only known occurrences in New Zealand, Australia, Madagascar, and the south-eastern coast of the USA (Porter 2009; Champion & de Winton 2012).

b. Whilst most of the Horsham Downs peat lakes are included in subcatchment 20 (Waikato at Huntly-Tainui Bridge) and allocated a priority 1, one of the lakes (Tunawhakaheke/Lake E) is in subcatchment 22 and has remained a priority 2. This is despite considerable work from Landcare Trust on farm plans for properties adjacent to this lake. Given the proximity of these lakes to one another, and the fact that some properties are likely to adjoin multiple lakes, I consider that it would be more efficient, logical and appropriate to plan for these lakes as lake complexes.

c. The catchments of the larger lakes Waikare and Waahi are still split over different subcatchments (Waikare – catchments 13 & 14; Waahi – catchments 18 & 19). The reprioritisation at least makes them all priority 1, but it remains unclear how the catchments will be managed for lake outcomes, or staged in a way that meets the lake objectives

A more robust and comprehensive prioritisation approach – recommended approach

100. In paragraph 645 of the section 42A report, officers express concern that lakes are particularly vulnerable, and difficult and expensive to restore, if they become degraded. I share this concern and consider that the plan change could identify and prioritise the lake FMUs, policies, plans and implementation methods in a far more systematic and considered way, using all of the information and expertise that Council has available to it, rather than by simply responding to submitters concerns.

101. In Appendix H of his submission, the Director-General identified 12 of the highest priority lakes, which were based on a range of different information sources, including:

    a. Lakes that have already been identified as being important within existing WRC Plans and Policies, including:

        - Lakes Maratoto, Rotopiko lakes (3), Otamatearoa, and Ngahewa (high condition and high vulnerability lakes listed in 8B of the Regional Policy Statement)
        - Lakes that are given a high priority for water quality in the Waipā Catchment Plan - for water quality (in order) - Lakes Mangakaware, Milicich, Posa and Pataka, Ruatuna, Ngaroto and Mangahia
        - Lake that are given priority for biodiversity in the Waipā Catchment Management Plan (in order) – Lakes Rotokotuku, Mangakaware, Mangahia, Ruatuna, Milicich, Ngaroto, Rotokauri, Henderson's Pond, Posa & Pataka, Koromatua, Waiwakareke, Rotopataka, Te Otamanui, Ngarotoiti
        - Lakes identified in Waikato Regional Council's Shallow Lakes Management Plan (Dean-Speirs et al. 2014)

    b. Lakes that are known to support or have recently supported submerged plant communities as identified by Burton and deWinton (2016). I understand that this currently involves:

        - High condition – Lakes Serpentine (North and East lakes)

- Moderate condition – Lake Ngapouri, Puketi,
- Poor condition – Rotoroa (Hamilton Lake), Mangakaware, Otamatearoa, Parkison, Tutaeinanga,
- Recently vegetated – Ngahewa, Serpentine South, Rotoiti, Kainui

c. Highly natural peat lakes that are unlikely to have ever supported submerged plants due their naturally dystrophic characteristics - Lakes Rotokotuku and Maratoto.

d. Lakes where previous management effort has been applied and can be further advanced (identified in Appendix J of the Director-General's submission)

e. Lakes that rank highly in the Wildlands (2011) ranking of Significant Natural Lake Areas. Using a scientifically-based ranking approach based on assessing multiple criteria, these authors were able to prioritise lakes for overall biodiversity management and highlight particular management issues (e.g. water quality). This approach also highlighted those lakes where data were deficient. Such a system could be used to prioritise lakes within PC1.

102. I have provided an example of how this information could be used to prioritise Waikato/Waipā lakes in Table 5. What this analysis highlights is that, of the 12 priority lakes identified in the Director-General's submission, 8 record the highest ranks using this method. Of the remaining lakes, factors such as local council priority (e.g. Lake Rotoroa) or recognition of existing restoration efforts have also been considered. This highlights the need to use multiple criteria and multiple lines of evidence when prioritising action.

103. It should be also noted that additional surveys of data deficient lakes have been undertaken since that report was completed, so it may be necessary to update this table with new information.

Table 5 Relative values for Waikato/Waipā lakes based on Wildlands (2010) criteria.

Lake	Overall Biodiversity Assessment	Water quality	Vulnerability	Ecological Significance	Ecosystem Condition	Potential Outcomes	Score relative to maximum	Relative Rank
Maratoto	1.00	1.00	0.75	0.80	0.94	0.91	0.90	1
Otamatearoa	0.88	1.00	0.75	0.46	0.90	1.00	0.83	2
Rotopiko	0.90	0.67	1.00	0.65	0.90	0.73	0.81	3
Mangakaware	0.76	0.33	0.75	0.35	0.87	0.88	0.66	4=
Ngahewa	0.76	0.33	0.75	0.37	1.00	0.73	0.66	4=
Rotomanuka	0.79	0.33	0.50	0.65	0.71	0.82	0.63	6
Rotoiti		0.67	0.75	0.20	0.71	0.70	0.61	7
Milicich	0.66	0.33	1.00	0.20	0.58	0.79	0.59	8=
Puketi		0.67	0.75	0.17	0.68	0.70	0.59	8=
Hotoananga	0.66	0.33	0.75	0.31	0.61	0.79	0.58	10
Ruatuna	0.68	0.33	0.50	0.41	0.71	0.82	0.57	11=
Okowhao	0.67	0.33	0.50	0.37	0.74	0.82	0.57	11=
Areare	0.64	0.33	0.75	0.31	0.68	0.70	0.57	11=
Parkinsons	0.58	0.67	0.50	0.15	0.77	0.70	0.56	14
Mangahia	0.71	0.00	0.75	0.41	0.55	0.82	0.54	15
Rotokawau	0.72	0.00	0.75	0.78	0.39	0.52	0.53	16
Pataka	0.54	0.33	1.00	0.09	0.58	0.52	0.51	17=
Posa	0.55	0.33	1.00	0.17	0.48	0.52	0.51	17=
Penewaka	0.64	0.00	0.50	0.50	0.52	0.67	0.47	19=
Henderson's Pond	0.55	0.33	0.50	0.24	0.55	0.64	0.47	19=
Rotokaeo	0.50	0.33	0.50	0.20	0.61	0.61	0.46	20
Cameron	0.51	0.33	0.50	0.28	0.68	0.42	0.45	21
Waahi	0.71	0.00	0.00	1.00	0.42	0.52	0.44	22=
Kaituna	0.57	0.33	0.00	0.59	0.71	0.42	0.44	22=
Rotokauri	0.57	0.00	0.50	0.39	0.65	0.52	0.44	22=
Rotoroa	0.43	0.33	0.75		0.55	0.12	0.44	22=
Rotongaro	0.61	0.00	0.50	0.65	0.45	0.39	0.43	26
Ngaroto	0.64	0.00	0.00	0.74	0.61	0.52	0.42	27=
Kainui	0.53	0.00	0.50	0.28	0.58	0.61	0.42	27=
Pikopiko	0.44	0.33	0.50	0.24	0.48	0.39	0.40	29
Whakatangi	0.44	0.33	0.50	0.19	0.39	0.48	0.39	30
Whangape	0.61	0.00	0.00	0.81	0.35	0.48	0.38	31
Waikare	0.59	0.00	0.00	0.83	0.32	0.42	0.36	32=
Koromatua	0.53	0.00	0.00	0.50	0.71	0.42	0.36	32=
Waiwhakareke	0.49	0.00	0.00	0.20	0.65	0.82	0.36	32=
Rotopataka	0.45	0.00	0.50	0.24	0.35	0.58	0.35	35
Kopuera	0.45	0.00	0.00	0.37	0.65	0.39	0.31	36

Rotongata	0.34	0.33	0.00	0.20	0.58	0.30	0.29	37=
Ohinewai	0.41	0.00	0.00	0.31	0.42	0.58	0.29	37=
Tutaeinanga	0.40	0.00	0.00	0.24	0.45	0.61	0.28	39=
Tunawhakapeka	0.32	0.33	0.00	0.20	0.42	0.39	0.28	39=
Hakanoa	0.41	0.00	0.00	0.39	0.45	0.39	0.27	41=
Komakorau	0.38	0.00	0.00	0.26	0.45	0.52	0.27	41=
Te Otamanui	0.33	0.00	0.00	0.15	0.39	0.48	0.22	43
Kimihia	0.33	0.00	0.00	0.33	0.23	0.39	0.21	44
Ngarotoiti	0.29	0.00	0.00	0.24	0.23	0.39	0.19	45=
Rotongaroiti	0.29	0.00	0.00	0.35	0.16	0.30	0.19	45=
Patetonga			0.00		0.35		0.18	47
Te Koutu	0.13	0.00	0.00	0.07	0.26	0.12	0.10	48
Rotokaraka	DD*							?
Rotokotuku	DD							?
Te Kapa	DD							?
Waiwhata	DD							?

DD = Data deficient

104. I consider that a lake prioritisation approach described in the preceding paragraphs and which is based on multiple lines of evidence and incorporates sound science and up-to-date information is more appropriate than the approach currently presented in PC1.

Lake Water Quality Targets

105. Table 3.11-1 of the proposed PC1 provides a list of short- and long-term numerical water quality targets for the Waikato and Waipā River catchments. For lakes, only long-term targets are presented, setting out the concentrations (all attributes except clarity) or visual distance (for clarity attribute) to be achieved in the long term (at 80 years) for lakes FMUs.

106. In his submission, the Director-General raised concerns about the lack of aspiration in Plan Change 1 for the restoration and protection (cf maintenance) of lake water quality, particularly that:

a. No short-term targets were set for lakes and that there is a heavy reliance on lake catchment planning processes. In contrast, the original PC1 (Implementation method 3.11.4.4) proposed that WRC would develop a set of 10 year water quality attribute targets for each Lake FMU. Proposed long term (80 year) targets for lake water quality attributes were either set (in Table 3.11-1) at the

NOF National bottom Lines, or to maintain current conditions when lakes attributes were in “better than bottom line” condition.

107. In his submission, the Director-General considered that these lake targets are not consistent with realising the potential to improve the water quality of some lakes, and do not equate to the “long term restoration and protection of water quality”, which is the intent of Objective 1.

108. On that basis, the Director-General sought that:

   a. Short term targets be established for lakes, and that a greater proportional (i.e. 20%) water quality improvement be sought for those lakes where work is already underway.

   b. Long term lake water quality attribute targets (in Table 3.11-1) be raised in order to be more aspirational for the restoration and protection (cf maintenance) of lake water quality for those lakes that are already better than D band for some attributes, or only just exceed the threshold for D band.

109. I discuss the issue of short and long term targets further in the next sections of my evidence.

Long Term Water Quality Attribute Targets

110. In his submission, the Director-General suggested an alternative approach to setting the long term (80 year) lake water quality attribute targets for the lakes. This approach sought to:

   a. Make better use of existing WRC water quality information for a number of the lakes;

   b. Identify those lakes that have water quality attributes that are (i) already better than the NOF bottom line or (ii) are at or only just worse than the NOF bottom line; and

   c. Set targets for these lakes that better reflect their existing state and restoration goals and seek an improvement in NOF band, in preference to maintaining them at their current level.

111. The approach involves applying the NOF thresholds to the 2010-2014 WRC lake water quality data presented to the CSG to derive current NOF bands for each lake (for 4 water quality attributes) and then predicting potential changes in NOF bands. This approach results in more aspirational long-term targets being established for a number of the high priority lakes that were identified in Appendix I of the Director-General's submission, when compared with what is currently proposed in PC1.

112. There is evidence to suggest that water quality improvements predicted by the Director-General in his submission are attainable for some of the lakes within the timeframes of Plan Change 1.

113. For example, for Lake Waiwhakareke, which is the subject of a substantial catchment retirement and restoration programme by Hamilton City Council, Duggan (2012) modelled lake nutrients and estimated that it would be possible to shift the lake from a hypertrophic to mesotrophic state as a result of a substantial catchment retirement and revegetation programme (which is already underway). His work indicated that this improvement could be expected to occur over a 10 - 20 year period once a new phosphorus equilibrium was established.

114. Modelling at Lake Ohinewai, showed that water clarity and the presence of submerged macrophytes were key to the restoration of a clear water state in this lake (Allan 2016). The study showed that integrated catchment management[3] would be required to restore lake water quality to mesotrophic conditions that may enable the re-establishment of macrophytes. The study further concluded that koi carp removal alone would not be sufficient to achieve lake water quality restoration in this lake.

[3] including riparian management and constructed wetland installation

115. In a recent project funded by WRC, WRA, Dairy NZ and the DOC-Fonterra (Living Water) partnership, Lehman et al. (2017) simulated future management scenarios for Lakes Waahi, Ngaroto and Rotomanuka which considered 3 types of intervention: (1) external nutrient load reduction; (2) hydrological modification; (3) geo-chemical engineering. This study highlighted that the outcomes were extremely lake-specific and were largely determined by the current state and physical characteristics of the lakes and their catchments. It also highlighted the value of regular water quality sampling and long -term data records, and knowledge of catchment hydrology.

116. Of the lakes modelled by Lehman et al. (2017), Lake Rotomanuka showed the most promise. Modelling results predicted that external nutrient load reductions (alone) would improve lake water quality sufficiently to transition the lake out of the NOF D Band. They predict that a 50% reduction in external TN and TP loads would shift Lake Rotomanuka out of the D band to the upper end of the C band for TN.

117. The prognosis for the larger lakes was less positive with none of the 14 scenarios for Lake Ngaroto[4], or the 9 scenarios for Lake Waahi being sufficient to transition these lakes out of the NOF D band. They concluded that intensive catchment management activity and higher risk in-lake actions (e.g. geochemical engineering) to remove nutrients directly from the lake water column would be necessary for Lake Ngaroto to meet the bottom line in the NOF within the next 30 - 40 years. For Lake Waahi, they concluded that external and internal nutrient load reductions, combined with increased lake water levels were likely to be necessary to meet the NOF bottom line within 2 - 3 decades.

118. Allan (2018) undertook further modelling for Lake Waahi and concluded that external load reductions of greater than 50% along with changes in ecological structure (reinstatement of aquatic macrophytes and control of pest fish) were necessary to restore tuna/eel biomass within Lake Waahi.

[4] 14 scenarios for Lake Ngaroto involving up to 50% reductions of internal and external nutrient loads, water level changes and an inflow diversion

119. Using the boundaries of the NOF bands as the target for the changes predicted, along with the 2010-2014 WRC lake water quality data presented to the CSG, I calculated the % change in water quality attribute concentrations that would be required to meet the long term water quality targets proposed by the Director-General (Table 6).

Table 6 % change in attribute concentrations in lake required to achieve long term water quality targets proposed by the Director-General. n/a = no change in NOF band predicted

Current Lake FMU	Lake	Annual median Chla (mg/m³)	Annual Median TN (mg/m³)	Annual Median TP (mg/m³)
Dune	Otamatearoa	0.00	36.31	0.00
Dune	Puketi	0.00	39.15	28.57
Peat	Rotomanuka	54.55	53.40	44.44
Peat	Rotoroa	37.50	38.20	50.00
Peat	Serpentine E	44.44	66.58	9.09
Peat	Maratoto	60.00	54.98	20.00
Peat	Serpentine N	61.54	58.02	33.33
Peat	Serpentine S	58.33	46.47	35.48
Peat	Rotokotuku	n/a	54.83	23.08
Peat	Kainui	57.14	49.24	33.33
Peat	Areare	52.00	54.21	n/a
Peat	Horseshoe	n/a	46.56	n/a
Peat	Milicich	n/a	n/a	n/a
Peat	Ngaroto	n/a	n/a	n/a
Peat	Mangakaware	n/a	52.24	n/a
Peat	Whakatangi	?	n/a	n/a
Peat	Tunawhakaheke	36.84	51.95	n/a
Peat	Mangahia	n/a	n/a	n/a
Riverine	Waahi	47.83	52.87	24.24
Riverine	Te Kapa	14.29	53.19	n/a
Riverine	Hakanoa	n/a	46.02	n/a
Riverine	Ohinewai	n/a	57.89	n/a
Riverine	Whangape	n/a	n/a	n/a
Riverine	Okowaho	42.86	n/a	n/a
Riverine	Waikare	n/a	n/a	n/a
Riverine	Penewaka	n/a	n/a	n/a
Volcanic	Tutaeinanga	60.00	47.44	n/a
Volcanic	Ngahewa	n/a	40.69	n/a
Minimum		0.00	36.31	0.00
Median		47.83	52.10	28.57
Maximum		61.54	66.58	50.00

120. Although my analysis is simplistic and reflects reductions in internal concentrations, it does indicate that the types of changes to meet the targets predicted in the Director-General's submission are within the realms of modelled results.

121. The studies show that for some lakes water quality improvements to better than the NOF bottom line are achievable within the time frame of the plan. I consider that this potential for improvement should be reflected in the long term water quality targets. In his submission the Director-General proposed long-term targets for individual lakes. These could readily be aggregated to provide targets for FMUs derived using the method described earlier by Ozkundakci (2015). I will present the results of this analysis at the hearing.

Short term/intermediate Targets

122. As I have stated previously, I consider that clear short-term /intermediate lake water quality attribute targets should be set in PC1 that reflect the fact that the response time to mitigations in lakes is much greater than in rivers.

123. This recommendation is supported by research. Lehman et al. (2017) considered the likely timeframe for bottom sediments of the lakes to equilibrate to new catchment (sediment and nutrient) loads. They suggest that there are 3 aspects to this happening, namely:

    a. Time for the catchment loads to reach a new equilibrium – estimated at 10-30 years for catchment loads to reach a new equilibrium in response to targeted actions within the catchment. They observe that partial (step-wise) reductions to catchment loads may increase the length of time for meeting restoration goals.

b. Internal (bottom sediment) loads to reach a new equilibrium – roughly estimated to be in the order of 20 years, but possibly longer for the larger lakes (Ngaroto and Waahi) that have a large legacy of enriched sediments. Lake Waikare is predicted to take even longer and possibly up to the 200 years that Rutherford et al. (1996) predicted for Lake Rotorua.

c. Ecological response timeframes – which are thought to be much more rapid.

124. What this means is that incremental changes are unlikely to yield significant short-term gains, because it takes a long time for lakes to respond. Large changes are required and the longer it takes to implement changes, the more prolonged will be the response. More frequent and faster changes will result in a faster response time. Of course, this is lake-specific, although all lakes need some level of management. Even lakes with reasonable water quality are susceptible, but they're also likely to be more resilient and so actions to improve water quality in such lakes are likely to yield a faster response. If lakes that currently support healthy macrophyte communities are not subject to some level of management action, it is likely such communities will be lost within 10 years (Dean-Speirs, pers. comm, Feb 2019).

125. Based on the lag in response time to management actions within lakes and lake catchment, I consider it would be appropriate to set short/intermediate water quality targets. The Director-General in his submission proposed a 20% improvement in water quality within the first 10 years of the plan. I support this as a short-term target. In my presentation at the PC1 hearing I will present an analysis of short-term targets that could be set on this basis.

Section 42 A response regarding Lake water quality attributes

126. In the 42A report, officers recommend that the long term lake water quality attribute targets (Table 3.11-1) be retained without modification, because of the complexity and difficulty of restoring degrading lakes to a more natural state, and the size of the task to achieve national bottom lines.

127. The s42A report does not address the Director-General's request specifically for short term lake targets or make any reference to those lakes that are in better condition and for which better water quality may be attainable over the 80 year timeframe. Again, there appears to be a perception that all of the Waikato-Waipā lakes are already degraded or degrading at rates that are impossible to reverse within the 80 year time horizon of PC1.

128. Using the approach outlined above, I have been able to show the variability in lake condition and the scope for improvement in those lakes that have not yet degraded to reach a new turbid-phytoplankton dominated stable state.

129. In response to other submissions, wording changes have been proposed to Table 3.11-1 that weaken the original references to 'short and long term numerical water quality targets' to 'short term water quality limits and targets, and long term numerical desired water quality states". This has changed the focus for lakes from 80 year water quality 'targets' to "desired water quality states".

130. This weakening of language, and the reluctance to set intermediate water quality limits and targets for lakes, in combination with the lack of a coherent policy and planning framework for lakes, is of real concern. As a result, there is little confidence that changes of sufficient magnitude will be made at a sufficient rate to achieve the objectives of the plan change or ultimately the Vision and Strategy for the Waikato River.

131. Therefore, I do not consider that the PC1 approach to lakes will meet the requirements of the NPS -FM or the Waikato River Visions and Strategy

Ammonia attributes

132. In response to a request by WRC, the s42a report now recommends inclusion of a long-term ammonia target for lakes (annual median of 0.24 mg NH_4-N/l and annual maximum of 0.40 mg NH_4-N/L), which is consistent with the changes sought by the Director-General's in his submission. As this target reflects only one element of overall

ecosystem health (namely chronic or long term toxicity), it should be considered as part of a suite of ecosystem health indicators.

Identification of outstanding lakes

133. In his submission the Director-General also seeks for PC1 to recognise and identify outstanding freshwater bodies, as required by the NPSFM. I understand that Waikato Regional Council is required to identify outstanding freshwater bodies and provide for their protection and where appropriate, enhancement, including setting limits and targets, as part of section 8.2. do of the Waikato Regional Policy Statement, but that this process has not yet been undertaken.

134. In his submission, the Director-General sought recognition of a number of sites as a starting point, including the Waikato peat lakes, and Lake Rotokotuku, based on the information provided in the submission.

135. The Waikato Peat Lakes are nationally significant and represent the largest collection of this wetland type in New Zealand. Peat lakes are regarded internationally as unique and important ecosystems, due to their unusual water quality characteristics. They provide critical habitat for a number of specialised and often rare and threatened plant and animal species and communities.

136. The formation of the Waipā Peat Lakes and Wetlands Accord was a milestone in working towards achieving focused multi-agency conservation and management. The Accord has been in place since 2002 and aims to align the activities of management agencies and iwi, in working towards the restoration and enhancement of peat lakes and wetlands in the Waipā District. Significant progress has been made in protecting and restoring these lakes. For example, since the accord was signed, 65% of the lakes have been fenced, with 19 of the 20 lakes fully fenced (WRC, 2018b). In addition, 70% of the lakes have a minimum water level, preventing them from getting smaller. Before the accord was signed, the majority of lakes were shrinking due to water levels being lowered.

137. In its 2004 report on characteristics for high value water bodies in the Waikato Region (Taylor et al., 2004), Waikato Regional Council identified a series of parameters that it used to determine high value lakes within the region and identified the following list of high value lakes (Table 7). I have highlighted (red text) the lakes that fall within the scope of Plan Change 1. The waterbodies listed are consistent with those outlined in the Director-General's submission.

138. The Directory of Wetlands in New Zealand (Cromarty & Scott, 1996) identified wetlands and wetland complexes of international importance (as defined using RAMSAR criteria). Included in this list (amongst others) are the Waikato Lowland Lakes and Mineralised Swamp Lands and the Waipā Peat Lakes, which encompass lakes nominated by the Director-General for inclusion as outstanding waterbodies.

139. Evidence for Lake Rotokotuku suggests that it is of comparable water quality to Lake Maratoto, which is considered to be the best quality lake in the region (Dean, 2011a, cited in Dean-Speirs & Neilson, 2014). It is considered to be one of the few strongly peat influenced lakes that retain their natural (dystrophic) condition (T. Dean-Speirs, pers. comm., 31 January 2019). It has previously been identified as being suitable for scientific reserve status.

140. Based on the above evidence I support the inclusion of the Waikato Peat Lakes and Lake Rotokotoku for consideration as outstanding waterbodies in the Waikato Region.

Table 7 Summary of WRC assessment of high value water bodies

Charateristics contributing to outstanding status		Lakes	Wetlands
Water quality	**Ecological Health** water quality attributes & thresholds	Lake Taupo	
	Contact Recreation Clarity, *E. coli*	Lake Taupo	
Dystrophic nature	Special water quality characteristics of neutral peat lakes that contain special (often rare and threatened) plants and animals that are adapted to living within them	Lake Maratoto	

Biotic characteristics -	fish community	Lake Rotopounamu Lake Taupo
	Aquatic macrophytes, riparian vegetation, wetland fauna, natural state	Lake Whangape Lake Serpentine Lake Kuratau Lake Rotopounamu
Natural State		Lake Taharoa Lake Rotopounamu
Conservation (assessed wetlands only)	A. Sites containing representative, rare or unique wetland types; B. Sites of international importance C. Waterbird criteria D. Fish criteria	Waikato Lowland Lakes Waipā Peat Lakes

Conclusion

141. In its current form, Plan Change 1 does not provide a coherent or holistic management framework that is clearly focused on the Waikato-Waipā Lakes. As such, it provides little direction or certainty regarding their future management.

142. Based on my assessment of the evidence I make the following recommendations:

   a. Inclusion of lakes under 3.11.1.1 Intrinsic Values - Ancestry and Historic Values

   b. Combine the sub-catchments of Lakes Waikare and Waahi into single units to support whole catchment management for these lakes.

   c. Further refinement of the lake FMU's, using a more robust scientific approach, is required.

   d. There is a need in PC1 for the preparation of lake catchment management plans to be better co-ordinated with priorities and targets for water quality.

e. There would be substantial benefit in building on previous and existing work in lake catchments that are of a manageable scale (based on Appendix J of the Director-General's submission) in order to accelerate implementation for these lakes.

f. Revise lake prioritisation using more rigorous methods.

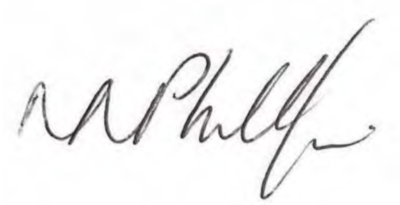
g. Set short-term water quality targets for lakes.

h. Set more aspirational long term targets for lakes.

i. Consider ammonia toxicity as part of a suite of attributes describing ecosystem health.

j. Include the Waikato Peat Lakes and Lake Rotokotoku for consideration as outstanding waterbodies in the Waikato Region.

Dr Ngaire Robyn Phillips



15 February 2019

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