IN THE MATTER OF	The Resource Management Act 1991
AND	
IN THE MATTER OF	Lake Rotorua Nutrient Management – **PROPOSED PLAN CHANGE 10** to the Bay of Plenty Regional Water and Land Plan

---

SUMMARY OF EVIDENCE IN CHIEF STATEMENT OF DAVID PHILIP HAMILTON ON BEHALF OF THE BAY OF PLENTY REGIONAL COUNCIL

3 March 2017

---

1. **INTRODUCTION**

1.1 My full name is DAVID PHILIP HAMILTON. I hold the Bay of Plenty Regional Council Chair in Lake Restoration and am a Professor in Biological Sciences at the University of Waikato. I will take it that my qualifications and experience as set out in my full evidence[1] have been read. Briefly, however, it should be noted that I have carried out research on Lake Rotorua since 2002. The research has been conducted in conjunction with studies by postgraduate students and staff whom I have supervised. The research has included nutrient-algae dynamics, lake mixing and transport processes, lake and catchment modelling, and sensor monitoring with satellites and lake buoys. These studies are directly relevant to the Proposed Plan Change 10. During the period I have studied Lake Rotorua, I have amassed one of the most comprehensive data sets and complete understandings of a single lake anywhere in the world. This is demonstrated in part through publications and reports that have been widely cited in the international literature, including New Zealand.

2. My evidence addresses the outcomes of work that I have done on nitrogen and phosphorus in respect of Lake Rotorua. The nutrients nitrogen and phosphorus have been identified as the primary ones of concern for Lake Rotorua because:

(a) They show statistically significant relationships to concentrations of chlorophyll a (viz., phytoplankton biomass; the concentration of suspended microscopic algae).

(b) Additions of dissolved forms of nitrogen and phosphorus have usually been found to stimulate phytoplankton growth in small-scale experiments. Concurrent nutrient additions (i.e., nitrogen plus phosphorus) usually stimulate phytoplankton growth to a greater extent than individual nutrient additions. This is known as co- or dual-limitation.

(c) Dissolved (viz., bioavailable) forms of nitrogen and phosphorus are commonly depleted to very low levels in Lake Rotorua during periods of increased growth of phytoplankton, consistent with these nutrients being available at concentrations that are limiting the growth of phytoplankton at these times.

2.1 A highly significant factor contributing to recent improvements in water quality is the action of dosing aluminium sulfate (alum) to Utuhina Stream (2006) and Puarenga Stream (2010). Concentrations of nitrogen and phosphorus in stream inflows to Lake Rotorua have

[1] Where I also confirm my adherence to the Code of Conduct for Exert Witnesses.

not similarly decreased in the period since alum dosing started. Alum dosing has been highly effective in reducing levels of phosphorus in the two stream inflows where the dosing takes place. Alum dosing has 'locked up' much of the phosphorus in the stream inflows. At high dosing rates (e.g., in 2012) the effects of alum dosing on phosphorus locking have extended beyond the stream inflows and into the lake.

2.2 Empirical data and model results indicate that at high dosing rates, there is increased sedimentation of organic matter which contains nitrogen and phosphorus. There are also likely to be reduced rates of release of nutrients from the lakebed sediments. With knowledge that nutrient loads from the catchment of Lake Rotorua have remained static or are increasing over the past decade, it has been possible to show that the improvements in water quality in Lake Rotorua since c. 2006 are almost entirely due to alum dosing. Modelling simulations support this analysis. As explained in my rebuttal it would be unwise to break up data into smaller time blocks (i.e., less than decadal) as this will reduce statistical confidence and could lead to false assessments of trends. This is particularly so for a period preceding alum dosing (2001 to 2005) when TLI values were high and also showed large variation.

2.3 Lake model simulations that artificially remove stream alum dosing for the period 2008-2012 indicate that without alum dosing, TLI values would be approximately 5.57, compared with the Regional Water and Land Plan (RWLP) TLI target of 4.2 and which was observed in some years within this period. Therefore, in the absence of the alum dosing, lake water quality would have been strongly degraded. Model simulations indicate that a nitrogen load of 435 t y-1 (the PC10 Managed Reduction Target), with a concurrent reduction in phosphorus load (see proposed Plan Change 10), could achieve the target TLI for Lake Rotorua of 4.2. This reduction conforms approximately to the nominal phosphorus external catchment load of 37 t y-1([2]).

2.4 Phytoplankton species composition may be altered with changes in nitrogen and phosphorus concentrations. It is important to decrease catchment phosphorus loads together with nitrogen loads, as set out in the proposed Plan Change 10. This will reduce the potential for cyanobacteria blooms as some species of cyanobacteria are able to fix nitrogen gas from the water column and therefore have much less dependence on concentrations of inorganic nitrogen (i.e., nitrate and ammonium) as their nutritional source of nitrogen. Alum dosing, which selectively targets phosphorus, increases the potential for limitation of phytoplankton growth by phosphorus, but model simulations have consistently indicated that

[2] This target includes stormflows and considers the current catchment phosphorus load to be 49 t y^{-1}.

there is co-limitation of phytoplankton growth by nitrogen and phosphorus over an annual cycle. This is supported by field studies in 2009 and 2010, both of which showed dominance of nitrogen limitation over phosphorus(3).

2.5 Alum dosing has risks. ‘Overdosing’ has been associated overseas with acute lethal effects on lake biota. The continuous low-dose strategy of alum dosing in Lake Rotorua may reduce risks of acute toxicity but there is little or no empirical data on such prolonged continuous dosing similar to what has been used for Lake Rotorua. If it was necessary to cease alum dosing (e.g., because of impact on biota, concerns about low pH or non-renewal of resource consent) then it is likely that over 2-3 years, trophic state would increase and TLI might approximate to the value of 5.57 which has been simulated in the absence of alum dosing.

2.6 Without alum dosing, the TLI target will not be attained without reaching the 435 t/yr PC10 Managed Reduction Target as well as achieving a managed phosphorus reduction for catchment sources. A focus on controlling only one nutrient (nitrogen or phosphorus) would be a risky strategy. Focus only on nitrogen could increase the potential for proliferation of cyanobacteria, as mentioned above. Focus only on phosphorus would also be risky because field observations and model simulations(4) indicate that there are locations and times when either nutrient or both can limit phytoplankton growth (i.e., dual limitation), and there are periods of strongly nitrogen-limited phytoplankton growth demonstrated in experimental bioassays, even during a period of intense alum dosing in 2012. The efficacy of controlling a single nutrient to limit phytoplankton growth is therefore not well supported by either direct measurements or model simulations.

2.7 In the absence of alum dosing, nitrogen reductions to meet the 435 t/yr PC10 Managed Reduction Target are required because of the large component of ‘natural’ phosphorus (approximately 52%) in the total load to Lake Rotorua. This unusually large component (relative to most other non-volcanic catchments in New Zealand) limits the extent to which the catchment phosphorus load of phosphorus can be reduced (i.e., only 48% of the incoming load can be managed). In my opinion alum dosing has provided unrealistic expectations of what level of water quality (i.e., TLI) may be attained by management of catchment phosphorus loads alone with no alum dosing. This is because the nature of the

---

[3] Smith VH, Wood SA, McBride CG, Atalah J, Hamilton DP, Abell J. 2016. Phosphorus and nitrogen loading restraints are essential for successful eutrophication control of Lake Rotorua, New Zealand. Inland Waters 6(2): 273-283.

[4] Abell, J. M., and Hamilton, D. P. 2014. Biogeochemical processes and phytoplankton nutrient limitation in the inflow transition zone of a large eutrophic lake during a summer rain event. Ecohydrology DOI: 10.1002/eco.1503.

alum treatment (i.e., introducing it via inflows and into the lake) has meant that it locks up all phosphorus irrespective of whether it was derived from natural or anthropogenic sources (i.e., acting on all 100% of the catchment phosphorus load). By contrast, a catchment phosphorus management strategy in the absence of alum dosing would act on 48% of the total catchment phosphorus load. Given that total phosphorus concentrations have approximately halved between 2004 and 2012, it could be surmised that achieving a similar outcome using catchment phosphorus management and no alum dosing, and with contemporary catchment nitrogen loads, would require the catchment phosphorus load to be approximately halved. This would represent removal of all of the anthropogenic sources of phosphorus. This is clearly preposterous. It serves to re-emphasise the importance of the 435 t y-1 PC10 Managed Reduction Target given that it cannot be guaranteed that alum dosing will continue in perpetuity.

2.8 A strategy of controlling both nitrogen and phosphorus loads to Lake Rotorua provides the safest and most sustainable mechanism to improve water quality and increase water clarity in Lake Rotorua, by increasing the duration and volume of water in which phytoplankton are strongly nutrient limited. The nitrogen reduction to 435 t y-1 (the PC10 Managed Reduction Target) and concurrent phosphorus reductions are required to meet the RWLP TLI target of 4.2.

Name: (Professor) DAVID PHILIP HAMILTON

Date: 3 March 2017