IN THE MATTER OF	the Resource Management Act 1991
AND	
IN THE MATTER OF	applications by Central Plains Water Trust to: Canterbury Regional Council for resource consents to take and use water from the Waimakariri and Rakaia Rivers and for all associated consents required for the construction and operation of the Central Plains Water Enhancement Scheme Selwyn District Council for resource consents to construct and operate the Central Plains Water Enhancement Scheme
AND	
IN THE MATTER OF	a notice of requirement by Central Plains Water Limited to: Selwyn District Council for the designation of land for works associated with the construction and operation of the Central Plains Water Enhancement Scheme

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RIGHT OF REPLY EVIDENCE OF PAUL CAMERON KENNEDY

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Introduction

1. My name is Paul Cameron Kennedy. My qualifications, and the basis on which I am giving this evidence, are as set out in my evidence in chief.

Scope of evidence

2. In this statement of evidence in reply I will respond to water quality related issues raised by submitters with particular reference to the following topics:

   (a) Water quality in the reservoir relating to proposed monitoring and triggers to mitigate the potential for poor water quality.

   (b) Nutrient limitation in Lake Ellesmere/Te Waihora.

3. The discussion in this evidence pertains to comments and/or issues raised by Professor David Hamilton, Dr Scott Larned and Dr Adrian Meredith.

Reservoir Water Quality

4. Dr Meredith discusses the management of lake levels and water quality in his supplementary evidence. In relation to maintaining reservoir water quality, the primary purpose of managing reservoir water quality is such that it meets the quality/purpose of being used for irrigation water within the Central Plains scheme and secondly that when discharged into natural waters it does not result in adverse effects within that receiving environment.

5. In paragraphs 73-76 of Dr Meredith's supplementary evidence he stated that the issue of stratification in the reservoir has been "dismissed by the applicant as likely to be a transitory issue for the first couple of years following lake filling." Dr Meredith stated that this suggestion is naïve given existing evidence in New Zealand and went on to discuss deoxygenation in the Opuha Dam and Auckland water supply dams as an example.

6. Dr Meredith commented that water quality issues in the Opuha Dam were only resolved through a formal consent review and consequently he recommended that the implementation of a suite of conditions similar to those resulting from the Opuha Dam review would avoid any chance of sustained periods of deoxygenation giving rise to a suite of effects on water quality and ecology.

7. Dr Meredith stated that building oxygenating devices into the reservoir at the time of construction is more cost effective than retro-fitting.

8. In response to Dr Meredith's comments I do not agree that the issue of stratification in the reservoir has been dismissed. Stratification and general water quality in the reservoir have been identified in the AEE (page 8.9), water quality report (pages 75 and 111) (Kingett

Mitchell 2006), S92 Response (pages 19-21), in my initial evidence (paragraphs 137-158) and in my supplementary evidence (page 10).

9. Through his supplementary evidence, Dr Meredith has shown that although retrospective changes to lake water management are not ideal, they can provide an appropriate response to issues when they arise. Dr Meredith proposes that all of the equipment that might be required should be purchased and installed prior to the reservoir filling. This may be seen as a logical approach to what has been seen to occur in the Opuha Dam. It is my opinion that monitoring and review followed by the installation of appropriate facilities/equipment that is matched to the specific issue/water quality condition identified at that time is a pragmatic approach.

10. There are a large number of dams and water supply reservoirs around New Zealand. Depending upon their size, depth and location (site specific features such as soils, temperature etc.), they have a water quality that reflects the local conditions. The Auckland water supply dams all have sparge lines on their bottom and these have been installed relatively recently subsequent to the dam construction. There are also cases such as the Opuha Dam identified by Dr Meredith and other water supply reservoirs where stratification has been dealt with through the introduction of mixing devices. The Auckland water supply dams do not have mixers installed.

11. To take this approach will require the installation of appropriate monitoring equipment to provide good water quality information from the reservoir. This data can be used to provide in the first instance, information on the changing water quality in the reservoir as it is filled and settles. It will also provide information on the extent of stratification which in turn will allow the take to be managed appropriately and will allow the identification of what specific equipment would be required if it was identified to offset any water quality issues.

12. It is proposed that water quality monitoring be undertaken in the reservoir. The initial monitoring proposed involved 2-monthly sampling of DO, temperature, turbidity, conductivity, total nitrogen, total phosphorous, total organic carbon, and chlorophyll-a. It is proposed that continuous measurement and recording of water quality will be carried out at the intake tower. This will allow information to be collected for key water quality constituents that determine stratification and or key processes in the reservoir. This should include temperature, dissolved oxygen, water clarity and chlorophyll-a.

13. It is proposed that the ongoing non continuous sampling will be modified to include three level sampling (top, middle, bottom) in at least two other locations on the reservoir for total suspended solids (TSS), turbidity, dissolved reactive phosphorous, total phosphorous, dissolved inorganic nitrogen (ammoniacal-N, nitrate-N) and dissolved manganese. I would envisage that this would all be set out and developed in a reservoir water quality monitoring

management plan which would be required as a condition of consent and would be approved by ECan.

14. In conclusion I recommend that the proposed monitoring program be modified as described above, but that no oxygenation or other equipment equipment is installed until the need for it and its functional requirements have been established by in reservoir monitoring.

Nitrogen and denitrification in Lake Ellesmere/Te Waihora

15. Professor David Hamilton presented evidence on the nutrient dynamics of Lake Ellesmere/Te Waihora. In his evidence he discusses denitrification rates for the lake.

16. In water bodies such as Lake Ellesmere/Te Waihora, concentrations of nitrogen play an important role in the productivity of the lake. The removal of nitrogen by denitrifiers can limit primary production (Seitzinger, 1988). As a consequence, the ability of denitrifying bacteria to reduce high concentrations of ambient nitrogen can become increasingly important as N loads to freshwater increase (Saunders & Kalff 2001).

17. Professor Hamilton described a number of important sources of nitrogen into Lake Ellesmere/Te Waihora. These contributions and the reservoirs of nitrogen within the lake (such as sediments, planktonic algae, plants etc.) are involved in a complex set of processes and interactions that are very dependent upon the state of that environment (e.g., temperature, dissolved oxygen in-sediment concentration and pH). Professor Hamilton identified sources of nitrogen to provide a mass balance of where nitrogen was entering and leaving the Lake Ellesmere/Te Waihora system. Based upon his calculations, a loss of nitrogen was identified of some 557.9 tonnes/annum. It was considered that this loss was attributable to both sedimentation and to denitrification and that as the sedimentation loss was not considered significant (due to resuspension) that the loss was primarily attributable to denitrification. Mass balance assessments are one way of potentially identifying denitrification losses (I will discuss this further below). It is important to realise that when mass balance assessments are undertaken the numeric values used are subject to errors which can often be large. These errors place ‘bounds’ on the figures often calculated.

18. From reading Professor Hamilton’s evidence, I understand that he considers the denitrification rates (0.0081 $g/m^2/day$) are already high (by world standards) and that he has concerns that increases in nitrate concentrations pose questions as to whether dentrification processes will be able to sufficiently reduce the nitrate concentration to limit phytoplankton growth in the lake. He also commented in paragraph 5.3 that “the estimated rate of denitrification in Lake Ellesmere/Te Waihora is extremely high for a lake in which there is no evidence of severe deoxygenation”. He concludes in paragraph 5.5 that

additional nitrogen loads associated with CPW could compromise the occurrence of nitrogen limitation in Lake Ellesmere/Te Waihora as areal rates of denitrification are unlikely to increase proportionately to maintain the current low levels of inorganic nitrogen to the lake. However, I note that there are international studies indicating that dentrification rates are likely to rise as nitrogen concentrations increased.

19. Biological denitritication is promoted by bacteria that are able to enzymatically mediate the reaction. The nitrogen gas that is then formed can be transferred from the water to the atmosphere if the nitrogen concentration exceeds the saturation concentrations. The reduction processes occur in anaerobic water, in the mud or at the mud-water interface but requires an organic carbon substrate.

20. There have been a variety of published studies that have identified and measured denitrification rates in lakes. Jensen & Dahi-Madsen (1976) (In Madsen 1996) found that from 12 to 28% of the nitrogen loading in Danish lakes is denitrified. Tiren (1977) also roughly estimated the total denitrification rate in Lake Erken to 1.2 gN/m^2/yr (0.0033 g/m^2/d). In general, rates were considered to reflect the nitrogen loading to the lake and measurements have ranged up to 55 g/m^2/yr (0.15 g/m^2/d) (Saunders & Kalff, 2001).

21. The nutrient mass balance approach may also be subject to errors based on incomplete or incorrect flux/storage estimates. Nonetheless there are examples where denitrification measurement methods such as incubation techniques and mass balance calculations were in general agreement. For example for Lake Okeechobee Messer & Bresonik (1983) predicted an average annual denitrification rate of 0.5-1.3 g/m^2/y (0.0014-0.0036 g/m^2/d), which represents 9-23% of the average annual nitrogen input to the large, unstratified lake they studied.

22. In summary, the possible denitrification rates calculated from mass loading data by Professor Hamilton are within the range presented in the literature (denitrification rates of zero are sometimes reported in some studies – refer below) but because of the errors associated with the various numeric values that the figure is derived from, it is not possible to identify whether the actual rates are lower, higher or at their potential maximum.

23. The denitrification rate and overall rate of nitrogen loss from the water column is a function of a range of factors. A number of studies have examined means of measuring denitrification rates, have compared methods of measuring dentrification and the factors affecting rates. There are also considerable spatial variations in denitrification rates in lake bed sediments. Denitrification rates are also typically higher in vegetated than in unvegetated sediments (Christensen & Sorensen 1986, Olsen & Anderson 1994). Aquatic plants can serve as a direct source of organic carbon, as traps for particulate matter from the open water and as microbiological reservoirs. Furthermore, plant roots release oxygen

into the sediment, thereby increasing the sediment redox potential and creating more favorable conditions for nitrate production through nitrification.

24. In addition, Messer & Bezonick (1983) indicated that wave action may result in periodic cycles of sediment aeration by suspension and deoxygenation following redeposition. The turbulent wave action that drives the sediment suspension process also delivers labile particulate organic substrates (planktonic detritus) to the sediments.

25. Overall, Lake Ellesmere/Te Waihora is in my opinion likely to have favourable conditions for high rates of denitrification. Professor Hamilton has modelled the lake to assess response to changed water quality. In that assessment it is evident that the lake is severely light limited with photosynthetic activity only occurring over a relatively small proportion of the lake depth and volume. The modelling undertaken indicated that phytoplankton in the lake were light limited for 51% of the year, phosphorus-limited for 12% of the year and nitrogen-limited for the remaining 37% of year. Light limitation occurred more frequently in winter, when nutrient levels were elevated, compared with summer.

26. The model indicates that although nitrate concentrations rise due to increased loads from tributaries, chlorophyll-a concentrations do not change significantly which may be a reflection of other factors such as phosphorous and light limiting phytoplankton growth.

27. Larned & Schallenberg (2006) in their evaluation of constraints on phytoplankton growth in the lake identified that no bioassays had been undertaken in the last 10 years (as at 2006) to help in understanding nutrient limitation in the lake. In 1995-1996, some bioassays were carried out in summer and autumn. The results of those bioassays indicated that N-limitation was more frequent than P-limitation but no information was provided about how severe that limitation was (Hawes & Ward 1996). The authors note that nutrient pools in the lake have changed since the mid-1990s when there were large peaks in concentration and the extent of nutrient-limitation and the identity of the limiting nutrient may have changed in the intervening decade.

28. Larned & Schallenberg (2006) also used limiting concentration data to assess limiting frequencies and identified that using that approach, between 1983 and 2005, phytoplankton in Lake Ellesmere was nutrient limited <10 % of the time with N-limitation on 8 out of 175 dates and P limitation on 8 out of 175 times. These indications of limitation are lower than those estimated in the Hamilton modelling.

29. Professor Hamilton has indicated his concerns in evidence on behalf of Ngai Tahu. Those concerns both technically, and in relation to Ngai Tahu's intentions for future lake management, are respected. However, the issues associated with Ngai Tahu's desire to

initiate restoration of the lake and improve mahinga kai resources are complex and involve a range of factors and issues not all related to the CPW scheme.

30. The technical studies associated with the CPW scheme have resulted in water quality predictions for waterways downstream of the scheme and consequently for Lake Ellesmere/Te Waihora. The modelling described by Professor Hamilton although useful has some limitations. It identifies the variable and different limitations of phytoplankton growth but does not demonstrate adverse growth in response to the assessed changes in nitrogen loads. Overall, the CPW Scheme is not likely to impede the opportunities for the rehabilitation of Lake Ellesmere by Ngai Tahu.

31. I am still of the opinion that the likely changes with respect to improved farm management practices that are intended to come from the scheme implementation will have significant benefits within the CPW scheme area, and elsewhere on the Canterbury Plains and New Zealand.

Phosphorus

32. Dr Larned discusses a number of matters relating to phosphorous. I will comment and reply in relation to those matters regarding limitations as set out in the PNRRP and to overall changes in phosphorous loads.

33. In relation to my comments about the PNRRP, Schedule WQL1 Water Quality Classes identified in the Class 2.2 (Hill) Rule (g) that:

> (g) The average annual concentration of:
> (i) soluble inorganic nitrogen shall not be increased by 0.02 milligrams per litre; or
> (ii) soluble reactive phosphorus shall not be increased by 0.002 milligram per litre.

34. Dr Larned noted in his evidence Para 4.4 that:

> "The NRRP recommendation that annual increases in DRP concentrations be capped at 0.002 g/m^3 is not necessarily unreasonable. Given a current average concentration in the Lake Ellesmere/Te Waihora tributaries of approximately 0.03 g/m^3 (from ECan monthly monitoring data), the NRRP recommendation allows for an increase in the first year of up to 7%, and a doubling in DRP concentrations in less than 20 years".

35. In my evidence I did not interpret the PNRRP Schedule rule in that way. The Rule states that the concentration shall not be increased by the specific amount in that year. It does not in my view allow that 'increase' each year that the discharge occurs on an ongoing basis – such that after concentrations would be allowed to double after 20 years. The NRRP numeric limit is in my view an annual limit not an accrued limit as suggested by Dr Larned.

36. Dr Larned raised the issue of phosphorus dynamics in Lake Ellesmere/Te Waihora in paragraph 4.28 of his evidence. He commented that very small increases in phosphorus input to phosphorus-poor streams and lakes can result in large changes in algal biomass. He went on to state that high DIN:DRP ratios should be seen as indicators of the risk of small increases in phosphorus input and that Dr Burrell and I had interpreted the high DIN:DRP ratios to indicate that nitrate may be of considerable concern but that phosphorus is not of concern.

37. Firstly, I agree with Dr Larned's statement that very small increases in phosphorus in phosphorus-poor waterbodies can result in large changes in algal biomass. I also agree that Lake Ellesmere/Te Waihora is probably phosphorous limited during part of the year (refer Professor Hamilton's evidence).

38. However I disagree with Dr Larned's comment that Dr Burrell and I consider that phosphorus in Lake Ellesmere/Te Waihora is not of concern. As stated in my evidence (paragraphs168-174 and 200), a range of mitigation measures (farm management plans, nutrient budgets, efficient irrigation practices) are proposed to minimise surface runoff and losses of phosphorous. These mitigation measures are achievable and consequently, as I have previously stated, I do not anticipate that phosphorus loadings in Lake Ellesmere/Te Waihora will increase as a result of CPW. I also noted in my evidence in chief that implementation of effective farm nutrient management practices will be very important to the overall CPW scheme and that prevention/minimisation of downstream effects is also very dependent on farm management practices to ensure that losses of both nitrogen and phosphorous are very limited. As with concerns about nitrates I consider that these practices if implemented rigorously will provide sufficient safeguards for the water quality in Lake Ellesmere.

Paul Kennedy
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