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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BRIEF OF EVIDENCE OF PAUL CAMERON KENNEDY

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INTRODUCTION

1. My name is Paul Cameron Kennedy. I hold the degrees of BSc and BSc. (Hons) in Botany and Zoology from Victoria University of Wellington and have been involved in environmental research and assessment since 1975. I am a Principal Environmental Consultant with Golder Associates (NZ) Ltd., a global engineering and environmental consulting company. Prior to December 2006 I had been employed by Kingett Mitchell Ltd since 1985 and was a Director of that Company. I am a member of the New Zealand Water & Wastes Association (Stormwater Special Interest Group), American Chemical Society, Society for Environmental Toxicology and Chemistry and the Water Environment Federation.

2. I am familiar with the issues associated with the developments proposed by Central Plains Water Limited. I have undertaken a wide range of environmental assessments that have a bearing on many of the issues that require consideration in the assessment of the application.

3. I was part of the review team assisting Environment Canterbury with the Project Aqua application.

4. I undertook the preparation of a series of 'pre-assessments of effects' reports (reports that were prepared prior to the preparation of the full Assessment of Effects) on the key sections of the Tongariro Power Scheme for Electricity Corporation of New Zealand Limited. These sections of the scheme were referred to as the Moawhango Pond (Wahianoa Aqueduct and Lake Moawhango), Poutu Pond (the Tongariro River upstream of the Poutu Dam), Rangipo Pond (the Tongariro River from the Rangipo barrage up to the Poutu Dam), Western Diversion and the Rotoaira-Taupo Pond (lower Tongariro River and Lake Rotoaira).

5. I have also been responsible for the preparation of environmental assessments for works in the Rangipo Power Station, Rangipo tailrace, dredging in the Otamangakakau Canal, and the Wairehu Canal for Electricity Corporation of New Zealand Limited. I have also been responsible for studies undertaken on the Wahianoa Aqueduct and for assessment of effects prepared for repair and maintenance work required on the intakes and aqueduct for Genesis Power Ltd.

6. I have been involved in a wide range of other environmental investigations and preparation of assessments of effects relating to activities in freshwater environments. Examples of this work of relevance to this hearing and evidence include:

   (a) An assessment of the effects of dredging of Lake Aratiatia on the Waikato River.

   (b) An assessment of the effects of changes in the spill times at the Aratiatia rapids on the Waikato River.

   (c) An assessment of effects for proposed works at the Waipapa Dam on the Waikato River.

   (d) An assessment of the effects of lowering the tailwater level below the Atiamuri Dam on the Waikato River.

   (e) An assessment of effects for the renewal of resource consents for Hays Creek and the Mangatangi Dams (public water supply in Auckland).

   (f) Preparation of parts of the assessment of effects (water quality) for the Waikato Water Supply intake and pipeline.

   (g) Assessment of effects for renewal of resource consents for the Waikanae (Waikanae River) and Otaki (Waitohu Stream) public water supplies.

7. I have been involved in environmental assessments for a number of large 'rural' developments often sited in sensitive environments. These have included the proposed Clifford Bay ferry terminal, the alternative transport corridor study associated with that development, the West Coast Coal terminal at Granity, and pipe lay sites for offshore oil field development in the Manawatu.

8. I have undertaken a wide range of other environmental assessments in relation to discharges including dairy and meatworks discharges to rivers and the discharge of treated and untreated sewage to freshwaters and coastal waters. I have published a number of scientific papers and publications (including Chapter 9 - Sewerage network and treatment plant monitoring and Chapter 10 - Discharge monitoring in the "New Zealand municipal and community wastewater monitoring guidelines") in the area of New Zealand ecology and environmental chemistry and have been involved in and prepared more than

400 reports on environmental assessments, impacts and resource investigations.

9. I have been involved with the Central Plains Water Scheme (CPW) since 2005, when Kingett Mitchell Ltd was first engaged by URS to provide ecological services. I am the project director for Golder Kingett Mitchell and I reviewed the water quality assessment report (Kingett Mitchell 2006).

10. I have read the code of conduct for expert witnesses in the Environment Court's Practice Note (31 March 2005). I have complied with it whilst preparing my written statement of evidence and I agree to comply with it as I give my oral evidence.

SCOPE OF EVIDENCE

11. In this statement of evidence I will focus primarily on the following effects of the proposed Central Plains Scheme on water quality:

    (a) The impacts of water use/landuse intensification on surface water quality in lowland streams and Lake Ellesmere will be addressed in detail, with particular emphasis on nutrient relationships in Lake Ellesmere and their potential to affect phytoplankton biomass and lake productivity. This is a key water quality issue associated with the project.

    (b) The effects of the water abstraction on water quality in the Waimakariri and Rakaia Rivers.

    (c) Water quality associated with the reservoir, canals and bywash discharges.

12. I will also comment on construction effects associated with the project.

13. Comments in relation to matters raised within the ECan staff report to the hearing committee will be addressed in an addendum to this evidence.

INFORMATION SOURCES

14. The data, models and information I have relied upon in preparing this evidence and forming my opinions are as follows:

    (a) Modelled river flows, reservoir levels and AEE reports provided by URS.

    (b) Groundwater modelling from Aqualinc, including simulated flows for lowland streams.

(c) Modelled groundwater quality data from Aqualinc, URS, and Glynn Francis (formerly from Crop and Food).

(d) Water quality data provided by ECan and Christchurch City Council, and collected by Kingett Mitchell Ltd (now Golder Associates (NZ) Ltd).

15. Much of my assessment also draws on the following reports prepared for CPW, which have been supplied by the applicant in support of its consent applications:

(a) Kingett Mitchell (2006a): Effects of construction, damming, diversion and water use on water quality.

(b) Kingett Mitchell (2006b): Effects of water abstraction on the Waimakariri River.

(c) Golder Kingett Mitchell (2007): Effects on the Rakaia River; fish screening issues; reservoir water quality and monitoring.

(d) URS (2005): Central Plains Water Enhancement Scheme – Assessment of environmental effects for resource consent applications to Canterbury Regional Council.

DESCRIPTION OF THE ENVIRONMENT

Introduction

16. My description of the Central Plains environment starts with a description of existing water quality. This material is presented to provide an overview of what the existing water quality is like and to provide an indication as to how sensitive water quality is to the activities associated with the CPW scheme.

17. The following description of the environment is based on a combination of data from existing data sources, particularly from Environment Canterbury and the Christchurch City Council. In addition, I have drawn on recent resource surveys by Golder Associates in the Central Plains area and in the south-west area of Christchurch. We also undertook targeted fieldwork for this project at approximately 50 sites in late winter 2005 and late summer 2006. Figure 1 attached to my evidence identifies place names and features described in my evidence.

18. Summary tables of water quality data for the waterbodies discussed in this evidence are available in the Appendix at the end of my evidence. Relevant water quality guidelines are also included. The water quality guidelines referred to include relevant standards from the following documents:

(a) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000 and Hickey 2002).

(b) Proposed Natural Resources Regional Plan (ECan 2004a).

(c) Waimakariri River Regional Plan (ECan 2004b).

(d) Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE 2003).

(e) Water Quality Guidelines No. 2 Colour and Clarity (MfE 1994).

(f) New Zealand Periphyton Guidelines (Biggs 2000).

(g) Rakaia River Water Conservation Order (1988).

Rakaia and Waimakariri Rivers

19. The Rakaia and Waimakariri Rivers are large, alpine and glacial-fed, braided rivers that are characterised by high flood frequency, mobile bed sediments, and naturally high concentrations of inorganic suspended sediment and low nutrient concentrations.

20. The water quality of the alpine-fed rivers is of very high quality in the headwaters, with high dissolved oxygen (DO), low nutrient concentrations and low faecal indicator bacteria numbers when compared to other river types in the region and compared to water quality guidelines.

21. Water quality degrades with distance downstream in the Waimakariri River, typically increasing in nitrate + nitrite-nitrogen (NOx-N) and faecal indicator bacteria, with little change in turbidity.

22. There are three major tributaries in the lower reaches of the Waimakariri River: Otukaikino Creek (formerly known as South Branch), the Styx River and the Kaiapoi River. Two minor tributaries, Jockey Baker Creek and

Saltwater/Kairaki Creek, also feed into the lower Waimakariri River near its mouth.

23. Compared with water quality in the lower Waimakariri River, water quality in Otukaikino Creek and the Styx River overall has higher clarity, higher nutrient concentrations and higher numbers of faecal indicator bacteria. Both ECan and National River Water Quality Network (NRWQN) data indicate that clarity declines in the Waimakariri River between the Gorge and State Highway 1 (Old Highway Bridge site). The difference in clarity between upstream and downstream sites increases with increasing clarity, following a log-log relationship (Figure 2 attached to my evidence).

24. There is no long term water quality monitoring data available for the Kaiapoi River.

25. The lower Waimakariri River receives inputs from a number of consented discharges, including treated meatworks and fellmongery wastewater, truck wash water and stormwater. These discharges enter the river either directly or indirectly via its tributaries.

26. Historically, treated sewage from the Kaiapoi and Rangiora wastewater treatment plants discharged into tributaries of the lower Waimakariri River. These discharges ceased in April 2006 following completion of the Waimakariri District Council ocean outfall. As a result, numbers of faecal indicator bacteria and phosphorus concentrations (DRP (Dissolved reactive phosphorous) and TP (Total Phosphorous)) in the lower Waimakariri River have declined (Pers. Comm. Adrian Meredith, ECan).

27. The Rakaia River has no major municipal or industrial wastewater discharges, or any significant tributaries downstream of the gorge that contribute poor quality water to the river. Thus, despite a long history of farming and cropping in the Rakaia River catchment downstream of the gorge, concentrations of nutrients and faecal indicator bacteria do not increase significantly from the gorge downstream to State Highway 1.

28. In summary, water quality of the Waimakariri and Rakaia Rivers is a reflection of the overall upstream catchment activities and inflows. The net result being that the water quality in the Waimakariri River is poorer than that in the Rakaia River in their lower reaches.

Waianiwaniwa River Valley

29. The Waianiwaniwa River is a foothills-fed river with intermittent flow. Landuse in the valley is predominantly pastoral farming, with some exotic pine plantation and scattered gorse and broom. Within this catchment is the Canterbury Coal Ltd coal mine which discharges treated mine water into Bush Gully stream, a tributary of the Waianiwaniwa River. The quality of the mine discharge is variable and prone to periods of low pH and elevated turbidity.

30. Dissolved oxygen concentrations are typically high in the Waianiwaniwa River main stem but can be relatively low (<50% saturation) in the more sluggish tributaries. Nutrient concentrations are slightly elevated but within the range expected for a Canterbury hill-fed stream. Nitrogen to phosphorus (N:P) ratios vary from site to site and indicate that nitrogen enrichment may occur at some sites but that other sites are nitrogen deficient. E. coli numbers were highest in the Oyster Gully tributary, which drains an agricultural catchment with little or no shading and riparian vegetation.

31. In summary, water quality of the Waianiwaniwa River and its tributaries is typical of a hill-fed river, although the presence of coal measures within its catchment may also influence water quality.

Central Plains

32. Foothills-fed streams in Canterbury, such as the Selwyn River and its tributaries, typically have perennial flow in their headwaters but their middle reaches lose substantial proportions of their flow to groundwater as they traverse the permeable gravels of the Canterbury Plains.

33. Water quality in the Selwyn River is routinely monitored by ECan and Golder Associates staff additionally sampled the Hawkins and Hororata Rivers, both tributaries of the Selwyn River. The upper reaches of the Selwyn River are described in this section whereas the lower reaches are described in the Lowland Streams section below.

34. Water quality in the Selwyn and Hororata Rivers is characterised by cool-moderate temperatures, high dissolved oxygen, good clarity and low numbers of faecal indicator bacteria.

35. The Hawkins River has slightly lower dissolved oxygen concentrations and higher numbers of faecal indicator bacteria. Water temperature and clarity in the Hawkins River are similar to the Selwyn and Hororata Rivers.

36. Nutrient concentrations in these rivers are more complex. The Hawkins River had much higher nitrate-n (NOx-N) concentrations (median 2.2 g/m^3) than other hill-fed rivers in the Canterbury Region (Meredith & Hayward 2002). NOx-N concentrations in the Hororata River (0.78 g/m^3) from samples collected were also outside the 25-75%ile values for hill-country rivers.

37. Dissolved reactive phosphorus (DRP) concentrations in all upland rivers are low. Samples we collected all had low DRP concentrations. The concentrations were at or below the guidance values for nitrogen limited streams identified by Biggs (2000). These values were <0.0028-0.026 g/m^3 for accrual periods of 40 and 20 days respectively. They were also below the ANZECC (2000) guidelines for upland rivers of 0.009 g/m^3.

38. The N:P ratio for the Selwyn River suggests that the river is phosphorus limited (DIN:DRP = 55) (DIN = dissolved inorganic nitrogen, nitrate, nitrite and ammoniacal nitrogen). The N:P ratio for the Hawkins River is much higher, at around 380, reflecting the very high concentrations of NOx-N in this river. I will discuss nutrient limitation in greater detail later in my evidence.

39. The Hawkins River has dairy farming in its catchment, there is regular stock access to the river, and there are two townships within its catchment. These are all likely reasons for it having higher nutrient concentrations than other Selwyn River tributaries. The Hororata River also shows a downstream decline in water quality (especially NOx-N), which is associated with an increase in agricultural landuse.

40. The Selwyn District Council's stock water race systems (Paparua, Malvern and Selwyn) are the only surface water bodies with contiguous surface flow, within each race system, from the foothills to the coast in the CPW area. Water quality at the intakes of the three water race systems is similar to the source water quality, as expected. However, comparison of water quality between the intake point and downstream discharge point in the water races is typified by increased suspended solids concentrations causing a decline in clarity, and higher numbers of faecal coliforms. Stock access to the water races is the most likely cause of the decline in water quality.

41. In summary, water quality in the Selwyn River and Hororata River is higher than that in the Hawkins River. The Selwyn River and Hororata River typically have good clarity, high DO and low numbers of faecal indicator bacteria compared with the Hawkins River which has elevated nutrient concentrations, lower DO and higher numbers of faecal indicator bacteria. Nutrient ratios indicate that all three rivers are phosphorus limited. Stock access to the Selwyn District Council's water race systems is the most likely cause of the downstream decline in water quality in the water races.

Lowland Streams

42. Waterbodies downgradient of the irrigation area (approximately between SH 1 and Lake Ellesmere) could potentially be affected by the CPW scheme (Figure 3). Waterbodies in the area between SH 1 and Lake Ellesmere include:

(a) Spring-fed tributaries of Lake Ellesmere (including the Selwyn River).

(b) Spring-fed streams south of Waimakariri River (including streams in Christchurch City).

(c) Spring-fed streams north of Rakaia River that flow directly to the sea.

(d) Wetlands east of SH1 (of which there are very few).

43. All lowland streams except the lower Selwyn River are perennial groundwater-fed streams, arising from springs at the edge of the unconfined and semi-confined alpine aquifers. The flow in lowland streams is generally stable, with few or minor floods and freshes. The slope of the lowland streams is also very low compared to hill and alpine rivers. These factors make the lowland streams sensitive to sediment and nutrient inputs.

44. Landuse surrounding the lowland streams is mainly agriculture, particularly dairy farming. The effects of conventional agriculture (in the absence of best practice mitigation) on freshwater includes elevated sediments, nutrients and bacteria in waterways. Lowland streams in the Canterbury region are generally eutrophic with excess nitrogen concentrations (Meredith & Hayward 2002). Most streams indicate faecal contamination and frequent high concentrations of ammoniacal-N (Meredith & Hayward 2002).

45. Nutrient concentrations in the lowland streams and nutrient loads contributed by lowland streams to Lake Ellesmere were assessed on an annual and

monthly basis, using flow and water quality data provided by ECan. A summary of this data is provided in the Appendix to this evidence. It was found that Boggy Creek recorded the highest annual median DIN concentrations (3 years of record) followed by the Selwyn River and Harts Creek (14 and 12 years of record, respectively). The lowest annual median DIN concentration was recorded in the Kaituna River (Figure 4).

46. Annual median DIN loads were highest in Harts Creek and LII River. Annual median DIN loads in the Selwyn River, although variable, have declined since the record began in 1993 (Figure 5). Annual median DRP loads were highest overall in the LII River, although the annual load median has declined since the record began in 1995 (Figure 6).

47. Seasonal trends for both DIN and DRP are evident. DIN concentrations tend to increase in the winter months (June – August) (Figure 7). This is most likely a result of aquifer recharge due to wet winter weather and greater plant uptake during summer when water temperatures are higher and growth rates are greater. DRP concentrations show the converse, however, with the highest concentrations recorded in the summer months (Figure 8). Interestingly, DRP concentrations show considerable variability outside the winter months, which may be related to phosphorus cycling from stream bed sediments since soft-bottomed streams e.g., Boggy Creek and Halswell River, showed greater DRP variability than those with predominantly cobbled substrate e.g., Selwyn River and Harts Creek.

48. Concentrations of nutrients in the lowland tributaries of Lake Ellesmere frequently exceed guidelines for nutrient concentrations which may cause nuisance periphyton growth such as those presented in Biggs (2000) and ANZECC (2000).

49. Several of the streams downstream from the CPW area have urban landuse within their catchments; these include the Avon, Heathcote and Styx Rivers. Pressures on urban streams can be slightly different to those in agricultural areas, as they receive stormwater runoff from residential, commercial and industrial areas and roading. Data provided by Aqualinc and others indicate that effects of the CPW scheme on the water quality of these urban rivers is expected to be minor compared with the tributaries of Lake Ellesmere, which form the major focus of this evidence.

50. A recent workshop on limiting nutrients reported that the average nitrogen to phosphorus ratio required for periphyton growth is 16:1 (molar ratio) or 7:1 (by weight) (NIWA 2007). Ratios lower than 7:1 suggest nitrogen limitation and higher suggest phosphorus limitation. Ratios of DIN to DRP exceed 40:1 in all lowland streams and drains sampled. This indicates that due to excessive nitrogen concentrations phosphorus, rather than nitrogen, is likely to be the limiting nutrient for plants in lowland streams in the CPW area. This is supported by recent field-based nutrient-limitation experiments conducted by NIWA at five locations along the length of the Selwyn River. The NIWA study found that addition of nitrogen alone did not stimulate periphyton growth at any of the sites, but addition of phosphorus stimulated periphyton productivity at four of the five sites, indicating that the Selwyn River is phosphorus limited, not nitrogen limited.

Lake Ellesmere/Te Waihora

51. Lake Ellesmere/Te Waihora is a large (189 km^2), shallow (average depth 1.4 m), wind-swept, brackish, coastal lagoon south of Banks Peninsula. The lake is triangular in shape being approximately 24 km in length along the Kaitorete Spit and 12 km in length along the northern and western edge of the lake (Hardy & Taylor 1989). The lake's shallow wind-swept nature means that it is generally well mixed and does not stratify. A National Water Conservation Order (NWCO) gazetted in 1990 seeks to protect the outstanding wildlife habitat that the lake provides.

52. Lake Ellesmere receives inflows from surface runoff, spring-fed tributaries, groundwater percolation, direct rainfall on the lake surface and seawater inflows (Te Rununga o Ngai Tahu & DoC 2004). Most tributaries transport elevated concentrations of nitrogen and phosphorus into Lake Ellesmere. Regular water quality monitoring in the lake has been in place at four sites since 1992.

53. The balance between freshwater and sea water inflows has implications on lake water quality. When the lake is closed to the sea, the main source of input is freshwater sources, from the tributary streams and rainfall, with associated loads of contaminants such as nutrients. When the lake is opened, lake salinity increases and there is the potential for dilution of nutrient concentrations and therefore an improvement in lake water quality.

54. The optical character of lake waters is very importance to lake ecology as it determines the amount of light present for plant growth and for vision of aquatic animals. High turbidity can reduce phytoplankton productivity even in nutrient-rich lakes due to rapid attenuation of light within the water column (Grobbelaar 1985). In Lake Ellesmere high suspended sediments result in an average euphotic depth1 of around 0.4 m (Larned & Schallenberg 2006), which is shallow compared to an average lake depth of 1.4 m. About 80% of the low clarity is attributed to inorganic suspended sediments that are resuspended by wave action, with the majority of the balance caused by phytoplankton (Hawes & Ward 1996). There are occasionally periods of higher water clarity and these may be associated with periods of higher phytoplankton productivity.

55. Lake Ellesmere regularly appears green, due to high phytoplankton biomass. Increased phytoplankton growth over summer can result in a dark green appearance (Taylor 1996).

56. Surface dissolved oxygen concentrations are typically at 100% saturation during daytime measurements.

57. Nitrogen concentrations in Lake Ellesmere are elevated, with median NOx-N concentrations of 0.08 - 0.14 g/m^3 and a median TN (Total Nitrogen) concentration of around 2.1 g/m^3.

58. Comparison of DIN and TN concentrations indicates that most nitrogen in the lake water is in the form of organic nitrogen (associated with algae and organic sediments). This is supported by the very high median chlorophyll a concentrations, which range from 0.077 to 0.085 g/m^3. Nitrogen and phosphorus concentrations vary over a wide range at each site in the lake, suggesting considerable variation in the input and uptake of nutrients.

59. Phosphorus concentrations are also elevated in the lake, with median TP concentrations of around 0.2 g/m^3 at each of the four lake monitoring sites. However, median DRP concentrations are low and around 0.004 g/m^3 at all four monitoring sites.

60. Most lakes in New Zealand have much lower TN concentrations than Lake Ellesmere, ranging from 0.06 to 0.95 g/m^3. Total phosphorus concentrations in Lake Ellesmere (median 0.22 - 0.24 g/m^3) are also substantially higher than

[1] The depth to which 1% of surface light can penetrate. Euphotic depth is often used to provide an indication of the

typical values in New Zealand lakes, which are less than 0.1 g/m^3. This is principally due to the elevated concentrations of suspended particulate material. Chlorophyll a concentrations are also very high compared to other New Zealand lakes (Burns & Rutherford 1998).

61. Tributary streams are the major nutrient source for Lake Ellesmere. A recent review by Larned & Schallenberg (2006) found that tributary streams contribute on average 1,260 tonnes of total nitrogen to the lake per year, of which approximately 80% is in the dissolved inorganic form (principally bio-available nitrate and nitrite). The Selwyn River, Halswell River, LII River and Harts Creek were identified as the greatest sources of total nitrogen into the lake. The same review also estimated that tributaries contribute an average of 17 tonnes of total phosphorus per year to Lake Ellesmere, with dissolved reactive phosphorus contributing around 80% of total phosphorus. The Selwyn River, Halswell River, LII River, and Irwell River were the greatest single contributors of phosphorus to the lake. These nutrient loads are higher than previously estimated (Hawes & Ward 1996) as the earlier estimate did not include the highest 5% of flows from tributaries. Calculations of nutrient loadings to the lake, which includes slightly more recent data (undertaken as a part of the work leading up to this evidence), show the same general trends discussed by Larned & Schallenberg (2006).

62. Although dissolved inorganic nitrogen concentrations in Lake Ellesmere are elevated, they are typically an order of magnitude higher in its tributary streams, where median concentrations can be up to 5.0 g/m^3. This is predominantly due to the rapid uptake of nitrogen by phytoplankton in the lake, converting DIN to organic nitrogen. Despite Lake Ellesmere having lower nitrogen concentrations relative to its tributaries, nutrients still remain in excess compared to biological demand. Thus, lake nutrient concentrations were considered to sufficiently high to be “unlimiting” (i.e., DRP concentration was >0.005 g/m^3 or the DIN concentration was >0.02 mg g/m^3) for > 90% of the 175 water samples collected by ECan from 1983-2005 (Larned & Schallenberg 2006).

63. Removal of bio-available nutrients from the water column in the lake can occur via biological uptake, precipitation or adsorption to sediments, and via losses to the sea (discharge from the lake). Biological uptake of dissolved nutrients is clearly quite considerable, as indicated by the lake’s high phytoplankton

depth threshold below which there is insufficient light for plant growth.

biomass. The pool of nutrients bound to bed sediments is also likely to be high, although I am unaware of any studies that have quantified the size of this pool.

64. Export of nutrients from the lake into the marine environment occurs when the lake is opened. The extent to which lake openings “flush” nutrients from the lake depends on how long the lake is open for, and my analysis of existing monitoring data indicates that any effect on lake nutrient concentrations is generally short lived. This is because the lake is usually opened for a relatively short period (ca 21 days on average). An analysis of the changes in salinity associated with different opening times indicated substantial seawater-lake water exchange is only detectable when the lake remains open for more than one month (Larned & Schallenberg 2006), and lake openings for more than a month are uncommon under the current operating regime.

65. A combination of nutrient limitation experiments and analysis of the lake’s light environment have shown that high turbidity and low light availability are the primary factors limiting phytoplankton productivity in Lake Ellesmere (Hawes & Ward 1996; Larned & Schallenberg 2006). The interplay between nutrients, water clarity and phytoplankton productivity will be discussed in greater detail in evidence by Dr Greg Burrell.

66. In summary, water quality in Lake Ellesmere is characterised by high surface dissolved oxygen concentrations during daylight, low clarity and high nutrient concentrations. Low water clarity is the primary factor limiting algal growth in the lake.

Compliance with water quality standards

67. Lake Ellesmere is classified under the proposed NRRP water quality schedule as Class Coastal. As such the lake is managed for natural character, amenity values, Ngai Tahu values and aquatic ecosystems. ECan have monitored water quality at four sites in the lake on a monthly basis since 1993. Average annual DIN concentrations have not exceeded the 0.34 g/m³ standard (identified in the PNNRP) at the Mid-lake, Taumutu and Timber Yard Point sites but have exceeded it three times at the Selwyn Mouth site 1993-2005 record (data source ECan). Average annual TP concentrations exceed the 0.02 g/m³ standard by approximately 10-fold at all sites (probably because of elevated total suspended solids (TSS) concentrations). Ammonia concentrations meet the PNRRP water quality standard of 0.5 g/m³ for a single sample. Dissolved

oxygen saturation is generally high at all sites and meet the PNRRP standard of 80%. The Lake Ellesmere National Water Conservation Order (1990) does not have specific water quality standards.

EFFECTS ASSESSMENT OVERVIEW

68. The following sections of my evidence concern the potential effects of the CPW scheme on a range of water quality issues. Some issues will be covered briefly in order to assess in detail those water quality issues which I consider to be paramount to this proposal.

69. The key water quality issues arising from the proposed CPW scheme are:

    (a) Construction effects on water quality.

    (b) The potential effects of the abstraction on water quality in the Rakaia and Waimakariri Rivers.

    (c) The potential for poor water quality in the reservoir.

    (d) The potential effects of landuse intensification and irrigation on water quality in lowland streams and Lake Ellesmere.

EFFECTS OF CONSTRUCTION ON WATER QUALITY

70. Potential effects of water quality from construction associated with the CPW scheme may occur in any of the following construction phases:

    (a) Construction of the three intake structures (two in the Waimakariri River, one in the Rakaia River);

    (b) Construction of the headrace;

    (c) Construction of the Waianiwaniwa Dam and tunnel;

    (d) Construction of the water race distribution network.

71. The primary water quality effect caused by construction is increased suspended sediment and sediment deposition. Waterways have the potential to be affected in different ways, depending on their sensitivity.

72. Spring-fed streams are highly sensitive to sediment inputs as they have high clarity and limited flushing ability due to their stable flow regimes. Although there are few spring-fed streams in the CPW area they may be affected by construction of the water race distribution network. Mitigation measures proposed include the installation of sediment traps downstream of the works to reduce sediment inputs. This will help minimise any adverse effects on spring-fed streams.

73. Hill-fed waterways such as the Selwyn, Hororata, Hawkins and Waianiwaniwa Rivers are less sensitive to sediment inputs than spring-fed waterways due to their hydrology i.e., higher frequency of disturbance events which move large volumes of suspended sediment as well as scouring the streambed and removing deposited sediments.

74. The Selwyn, Hororata and Hawkins Rivers may be affected by construction of the headrace, however measures such as retention ponds and sediment traps will be developed in a sediment management plan to mitigate against sediment inputs. Construction works will not affect these rivers' usual capacity to carry sediment in flood events.

Mitigation of construction effects

75. The mitigation of construction effects are detailed in the Environmental Construction Management Plan (presented in Mr Lewthwaite's evidence) which incorporates 12 separate management plans containing measures to avoid, remedy or mitigate the potential adverse effects of construction activities on ecosystems, people and communities, natural and physical resources, amenity values and the social, economic, aesthetic and cultural conditions that pertain to this particular area.

76. As discussed above, the primary construction effect on water quality is increased suspended sediment input to waterbodies and sediment deposition. The objective of the Stormwater and Wastewater Management Plan is to contain and treat all stormwater run off, waste water and wash water within the development area, to minimise the effects on waterbodies.

77. Management strategies identified to achieve the objective of the Stormwater and Wastewater Management Plan include, among others, construction of settlement ponds and a dilution system to treat high pH waters. The

implementation of sediment control measures such as perimeter drains and silt fences is also proposed, as well as revegetation of working areas on completion of works. The management plan also makes provision for monitoring of any discharges so that action can be taken in the event that any contamination occurs.

78. In my opinion, the mitigation measures proposed in the Stormwater and Wastewater Management Plan are sufficient to minimise the effects of construction on waterways in the CPW area.

EFFECTS OF THE WAIANIWANIWA DAM AND TUNNEL ON WATER QUALITY

79. Construction of larger structures such as the Waianiwaniwa dam have the potential to produce sediment laden water if good earthworks management practices are not followed. Sediment associated with stormwater runoff needs to be primarily managed during construction of the dam as upstream of the dam (post dam construction) any earthworks that might be carried out will be located within the reservoir footprint. As a consequence sediment generation within the reservoir footprint is not likely to be a concern. A wide range of sediment erosion control methods and devices will be utilised to minimise sediment losses during times when newly worked earth is exposed to rainfall. No other water quality issues of environmental significance are expected during construction.

80. Any stormwater generated within the dam footprint during the dam construction period will be 'treated' prior to discharge to the Waianiwaniwa River. Although the Waianiwaniwa River is a tributary of the Selwyn River it discharges to groundwater downstream of Coalgate before reaching the Selwyn River, so any discharge to the river would not affect clarity downstream in the Selwyn River.

81. During the construction of the tunnel, stormwater will not be a concern. There will be a need to discharge some 'groundwater' from the tunnel to an adjacent waterway. The quality of that water will reflect groundwater inflow quality but there will be some minor changes as a result of sediment entrainment and material picked up in working areas within the tunnel. This quality can be checked through monitoring and pre-discharge treatment where required.

Mitigation of Waianiwaniwa dam and tunnel effects

82. The primary effect of the Waianiwaniwa dam and tunnel on water quality is runoff of sediment laden water to nearby waterways. Mitigation proposed is the same as for the general construction effects previously described, and detailed in the Stormwater and Wastewater Management Plan.

83. As stated previously, I consider that the mitigation measures proposed in the Stormwater and Wastewater Management Plan will be sufficient to minimise the effects of the dam and tunnel on waterbodies in the CPW Scheme area. It is acknowledged that the discharge of groundwater from the tunnel to an adjacent waterway will cause some minor, but temporary, change in water quality.

EFFECTS OF THE INTAKE STRUCTURES ON WATER QUALITY

84. Construction of the intake structures may result in the release of sediment in either runoff from landward areas adjacent to the site (access etc.,) or as a consequence of disturbance of the bed of the river where the intake is sited. The upper Waimakariri River intake will cross the Kowai River, via a siphon, near its confluence with the Waimakariri River. The main stem of the Kowai River will be diverted around the active construction site and this will minimise sediment discharge downstream into the Waimakariri River.

85. The Rakaia and Waimakariri Rivers are the least sensitive waterways to any sediment inputs during construction as they are adapted to a high sediment transporting environment. High natural flood frequency in these rivers also causes high suspended solids concentrations as the riverbed is scoured and deposited sediments become resuspended.

86. The nature of the construction effect will be very similar to that of gravel abstraction from the river that currently occurs at many locations along the Waimakariri River. Effects will be temporary and minor in nature.

Mitigation of intake structure effects

87. The primary effect of the intake structures on water quality is the release of sediment to the rivers. Mitigation proposed is the same as for the general

construction effects previously described, and detailed in the Stormwater and Wastewater Management Plan.

88. In summary, the main potential effect of construction on water quality is sediment inputs that may occur into waterways. Waterways in the CPW area have differing sensitivities to sediment inputs and deposition. Based on the evidence of Mr Walter Lewthwaite and Dr Mark Mabin , and previous experience with other developments, I am confident that construction effects on water quality will be minor and only of a short term nature, provided construction best management practices are used.

EFFECTS OF WATER ABSTRACTION ON WATER QUALITY

Introduction

89. Abstraction of water can influence downstream water quality in two ways. The first is through changes in water depth which results in changes in thermal properties such as increases in temperature which can, in turn, influence biological activity such as decomposition rates etc. The second is through reduction in available dilution, consequently resulting in increases in concentrations of key constituents.

90. Rather than describe the assessed changes in both the Rakaia and Waimakariri Rivers, I have focussed my water quality assessment mainly on the Waimakariri River, as it is considered more sensitive to water abstraction than the Rakaia River. This is because the size of the proposed water take relative to mean or low river flow is proportionally far greater in the Waimakariri River and because there are significant discharges into the lower Waimakariri River that contribute to a downstream degradation in water quality.

91. Mr Tipler has stated in his evidence that there is a trade off between the maximum rate of take from the Waimakariri River and the requirement for stored water. A lower maximum rate of take requires a larger dam at a higher cost. He has suggested that a “base case” scenario (20 m^3/s from the Rakaia River and 25 m^3/s from the Waimakariri River) be used to assess the effects of the take. Thus Mr Tipler's base case scenario has a maximum rate of take of 25 m^3/s from the Waimakariri River and I have undertaken my assessment using this scenario. I am also aware that Mr Tipler emphasises that the application is

for a maximum rate of take of 40 m^3/s from the Waimakariri River. Having looked at various flow statistics from the two scenarios (i.e., maximum of 25 vs 40 m^3/s), I am satisfied that they are similar enough that conclusions reached by assessing the maximum rate for take at 25 m^3/s will also be valid for a maximum rate of take of 40 m^3/s. I understand from Mr Tipler that the reason for this is that the same volume of water is abstracted from the river for all scenarios considered.

Water temperature

92. Water temperature is a concern in rivers that have wide floodplains and little stream shading. Spot measurements indicate that water temperature in the lower Waimakariri River can get quite high in the middle of summer. Furthermore, although weak, there is a relationship between river flow and water temperature in the river, with lowest flows associated with highest water temperatures (Figure 9). Although there is no continuous or daily data, temperatures measured at the New Zealand River Water Quality Network (NZRWQN) site at the Old Highway Bridge (Site CH4) are always taken during the expected warmest part of the day (around 1 to 4 pm). Thus, existing temperature monitoring data probably reflects daily maximum temperatures. This would tend to suggest that water temperatures during low flows are unlikely to be an issue, as although maximum summer temperatures approach the potential range of adverse effects (i.e., 22-23 °C), they do not get appreciably higher (maximum temperature recorded is around 23 °C), even during very low flows (minimum river flow for temperature records was 28 m^3/s).

93. The Waimakariri River Regional Plan (ECan 2004b) has a temperature maximum of 25°C in the lower Waimakariri River below the Otukaikino Creek confluence (Class WAIM Water) pertaining to discretionary activities. Temperatures in the lower Waimakariri River have not exceeded 25°C in the data record to 2005 (data source ECan). Above the Otukaikino Creek confluence the river is classified as NS Water (natural state) and the plan states that “the natural quality of the water shall not be altered.”

94. A number of studies have assessed the relationship between river flow and water temperature in Canterbury braided rivers (Mosley 1983; Ryder 2003; Jowett 2006; Kingett Mitchell 2006b). Of these studies, perhaps the best comparison with the CPW take is an assessment of the effects of the Rangitata

Diversion Race (RDR) water take on flows of the Rangitata River (Ryder 2003). The Rangitata River has a mean flow of about 100 m^3/s and seven-day mean annual low flow (7DMALF) of about 42 m^3/s, which is very similar to the Waimakariri River (mean of 122 m^3/s and 7DMALF of 40.2 m^3/s). The RDR maximum rate of take is 30.7 m^3/s, subject to monthly varying minimum flows. Using temperature loggers placed upstream and downstream of the RDR intake, Ryder (2003) found that average and maximum water temperatures were higher downstream of the RDR intake, and variability was lower. However, the higher mean temperatures downstream did not exceed the 80th percentile of upstream temperatures, and therefore did not exceed ANZECC (2000) guidelines for protection of aquatic ecosystems. The relationship between low summer river flows and water temperature was not particularly strong; high flows were generally associated with low river temperatures, although some days with low flows also had low water temperatures (Ryder 2003). In the Rangitata River study it was concluded that biological communities are strongly structured by frequent flood disturbance events, and that flood disturbance would limit any potential temperature effects. It was also suggested that spring-fed pools or side channels may provide thermal refuges for temperature-sensitive salmonids, although Ryder was uncertain about the ability of fish to actively seek thermal refuges.

95. In the Rakaia and Ashley Rivers, Mosley (1983) found that water temperatures in small side channels were several degrees cooler than in major braids. These small side channels typically made up 30-40% of the total wetted area, and they are the preferred habitat of many native and introduced fish (Glova & Duncan 1985). A recent review of salmonid responses to low river flows found that fish are typically found in cooler side braids and spring-fed channels, and that a number of studies have found trout and salmon seeking refuge in these habitats when water temperatures in the main stem are elevated (Hay 2004).

96. Based on these studies, and that of Ryder (2003), it is concluded that while low river flows may result in slightly elevated water temperatures in the Rakaia River, the total temperature increase caused by the CPW water take would be very small as noted earlier, thermal refuges will remain (Dr Burrell will discuss habitat in waterways) and temperature-sensitive species will be able to use these refuges.

97. In the lower Waitaki River, Jowett (2006) predicted that reducing the flow from 350 to 75 m^3/s would cause a maximum increase of 0.8°C in daily mean water temperature and a predicted increase of 1.4°C in the daily.

98. A further factor to consider is the effect of daily or diurnal temperature variations on the biota. Cox & Rutherford (2000) found that the mid point between daily mean and maximum river temperature is probably the most valid value to compare against results from laboratory temperature lethal tests. There is no daily temperature data available from the Waimakariri River, but there is expected to be considerable daily variation. For example, in the Rangitata River daily maximum water temperatures are similar to those in the Waimakariri River (around 23 °C), with daily mean temperatures typically two or three degrees cooler (Ryder 2003). Therefore, the risk of adverse effects of the Waimakariri River take on water temperatures is considered to be low.

99. It is concluded that the CPW take will not adversely affect water temperature in the Waimakariri River. This assertion is supported by studies in Canterbury braided rivers, temperature measurements made in the Rakaia River itself, and knowledge of temperature refuge-seeking behaviour of sensitive salmonid fish.

Dissolved oxygen

100. As noted earlier, a variety of water quality characteristics influence dissolved oxygen concentrations including substances that consume oxygen and water temperature influences the degree of saturation. As discussed earlier in evidence, the takes will not affect dilution (and therefore concentration significantly) and temperature changes where they occur will be small. Dissolved oxygen is unlikely to be a low flow issue since DO saturation is currently typically high (>90%) at all monitoring sites and there is typically low benthic oxygen demand due to the naturally high flood frequency and low periphyton biomass in the river.

Water clarity

101. It has been suggested that the best salmon angling conditions in the Rakaia River occur at river flows when the black disk clarity is between about 0.5 and 1.0 m (Glova 1987). There is also the rule of thumb (elucidated at the Rangitata Water Conservation Order hearings) that optimal angling conditions occur when an angler can see the toe of their gumboot in knee-deep water. It

is difficult to quantify exactly what the equivalent black disk clarity is, but it is probably close to 0.4 or 0.5 m.

102. Using data from the NZRWQN, regression was used to determine the relationship between river flow and clarity in the Waimakariri River. Based on the river flow-clarity regression, black disk clarity of 0.5 to 1.0 m at the Old Highway Bridge site occurs at river flows between 75 and 50 m^3/s, and clarity of 0.4 m occurs at around 85 m^3/s (Figure 10). This could lead to the conclusion that reduced river flow will then lead to reduced river clarity and hence poorer salmon angling conditions. However, while river clarity is related to flow, it does not necessarily follow that water abstraction will appreciably reduce downstream clarity; as flood flows will still increase suspended sediment concentrations and reduce clarity fairly independently of how much water is removed for irrigation.

103. To test this assertion, the relationship between clarity measurements at different river flows from the Gorge and Old Highway Bridge sites on the Waimakariri River was examined. It was found that while clarity declines with distance downstream, there was no effect of river flow on the shape (or curve gradient) of this relationship (Figure 11). This indicates that the clarity relationship between upstream and downstream sites in the Waimakariri River is indeed independent of flow and that the CPW water take is unlikely to significantly affect water clarity between these two sites.

104. The major spring-fed tributary inflows in the lower river (downstream of the Old Highway Bridge site) have higher clarity than the mainstem. Because the relative flow contribution of these tributaries is greater during periods of lower Waimakariri River flows, there is a possibility that the tributary inflows could result in clarity increasing in the mainstem of the Waimakariri River. However, most of the tributaries discharge into the tidally-influenced section of the river, where water clarity will be affected more by incoming tides. Furthermore, the overall contribution of these tributaries to total river flow is small compared to flow in the Waimakariri River. It is therefore concluded that the effect of spring-fed tributaries on the clarity of the lower river is probably not significant and that the CPW take is unlikely to affect this.

Effects on diffuse pollution contributions

105. Diffuse pollution contributions refer to the contribution that the land use practices and activities within the catchment make to downstream water quality. These contributions come from a wide variety of sources such as grazing animals and fertiliser additions. The key contaminants involved or typically assessed include nitrogen, phosphorus and bacteria. To assess the possible changes the current work used a loads-based mass balance approach to test effects of the take on diffuse pollution in the Waimakariri River. NRWQN data was used from the Gorge site to calculate the contaminant load in the water abstracted in the CPW take. This load was then subtracted from the load calculated for the downstream site at the Old Highway Bridge to predict a downstream concentration.

106. The predicted changes in water quality in the Waimakariri River between sites upstream and downstream sites are shown in Figure 12 and Figure 13 as cumulative frequency plots, where water quality before and after the CPW take can be compared. Based on the river flow modelling data provided by URS, the CPW take is predicted to have negligible effect on nitrate nitrogen (NO_3-N) and dissolved reactive phosphorus (DRP) concentrations upstream of the Otukaikino Creek confluence. This suggests that the CPW water take will not exacerbate the effects of current diffuse sources of pollution on nutrients in the river.

107. I also note that periphyton biomass is affected by both nutrient supply and flood disturbance frequency; these data indicate that the take will not affect periphyton nutrient supply upstream of the Otukaikino Creek confluence. I will discuss effects of the take on water quality downstream of Otukaikino Creek further below. Effects of the take on flood disturbance and periphyton is covered in evidence by Dr Burrell.

Effects on point-source discharges

108. One question that needed to be answered was whether the take could influence the effects that any other discharges to the river had within the river. This possible effect is principally one of changes in dilution influencing the mixing and downstream effects of those other activities.

109. As an example, the PPCS discharge of treated woolscour, fellmongery and tannery effluent into the Waimakariri River at the Old Highway Bridge was considered. The model used to assess the effects of the PPCS discharge on water quality in the lower Waimakariri River is described in Kingett Mitchell (2006b). Given that the PPCS discharge rate is governed by river flows at the Old Highway Bridge flow recorder, the maximum consented discharge rate was assessed against the modelled river flows to determine whether the discharge rate was likely to be compromised by reduced river flows. This was re-assessed using the updated URS river flow data. When river flows are below 23 m^3/s, PPCS are not able to discharge at a maximum rate of 0.23 m^3/s (equating to the consent limit of 20,000 m^3/day). Under the Before CPW scenario (described in Section 2.2 above), this would occur on 14 days of the 34 year record or 0.11% of the time. The ability to discharge at the full rate was not compromised further by the After CPW flow scenario. Under the no abstraction scenario, PPCS could discharge at their maximum consented rate all of the time.

110. The assessment of effects on consent limited parameters in the PPCS discharge, described in Kingett Mitchell (2006b), was used to predict any changes in water quality in the lower Waimakariri River, as a result of the PPCS discharge and reduced flows from the CPW take. While this assessment predicted a negligible to minor change in various contaminant concentrations, it did not take into account background concentrations of contaminants already in the river. This was difficult due to disparity between the PPCS consent limited parameters and parameters measured in the National River Water Quality Network (NRWQN) data set.

111. The only parameter common to both datasets, that could be modelled to assess a maximum load in the PPCS discharge combined with the background in-river concentration at SH1, is ammoniacal-nitrogen (NH_4-N). The resultant data set predicts that in-river NH_4-N concentrations downstream of the PPCS discharge may increase slightly, as shown in Figure 14. The model predicts that in-river NH_4-N concentrations may increase by a median of 0.03 g/m^3 and a maximum of 0.13 g/m^3. Any resulting increases in NH_4-N in the lower Waimakariri River are considered to be minor and are well below USEPA (United States Environmental Protection Agency) (1999) toxicity criteria for ammonia. Compliance with in-river consent limits is not predicted to change as a result of the CPW take.

112. Based on the modelling of maximum consented discharge volumes, the CPW take has the potential to result in a minor increase in in-river concentrations of contaminants downstream of the PPCS discharge in the Waimakariri River. However, this is not considered likely to result in adverse environmental effects as the increases are small and in-river compliance limits will not be exceeded.

Effects on microbial pathogens

113. A modified modelling approach was used to assess effects of the take on pathogens numbers for all four of the ECan monitoring sites downstream of the gorge. This modified approach used faecal coliforms as the faecal indicator rather than E. coli, as the faecal coliform monitoring record is much longer. Although E. coli are currently the preferred faecal indicator for assessing health risk in recreational waters (MfE 2003), they are a subset of faecal coliforms, and therefore use of faecal coliforms is regarded as a conservative approach to assessing public health risk. The simple modelling approach used the proportional difference between flows recorded at the time of sampling and those predicted following the CPW take to predict the increase in faecal indicator bacteria at a given site. For example, if a faecal coliform count was 423 cfu/100 ml and the flow was 89 m^3/s on a given day, and if the flow was predicted to drop to 61 m^3/s on that day, then the predicted post-CPW coliform count would 89/61 x 423, which is 617 cfu/100 ml. This approach is regarded as being conservative as it takes no account of the effects of dilution from upstream.

114. Based on modelled river flow data from URS, the CPW take is predicted to result in a minor increase in the numbers of faecal indicator bacteria in the lower river (Figure 15). However, the increase in median faecal coliform counts is very low compared to the amount of existing variation in bacterial numbers, and is therefore unlikely to appreciably alter the existing health risk posed by contact recreation in the lower river.

115. For the Otukaikino, Stewarts Gully, and Ferry Road monitoring sites, the predicted increase in median faecal coliform counts is in the range of 6-9%, which is considered minor given the overall variability in bacterial numbers. Median coliform numbers for the Kairaki site are very high (3,300 cfu/100 mL), and the modelling approach used here predicted the CPW take would result in a 21% increase in coliform numbers (i.e., approximately 4,200 cfu/100 mL).

However, all of the faecal coliform records for the Kairaki site are over 20 years old and probably are a reflection of historic problems with wastewater discharges from the Kaiapoi wastewater treatment plant, which is immediately upstream. Sampling of E. coli at Kairaki in the last five years indicates considerably lower faecal contamination, with a median E. coli count of 115 cfu/100 mL (total of 37 samples). This suggests that the effect of the CPW take on microbial contamination at the Kairaki site will be minor and comparable to the other lower river sites that have lower faecal coliform counts.

116. Based on modelled river flow data from URS, the CPW take is predicted to result only in a minor increase in the numbers of faecal indicator bacteria in the lower Waimakariri River. The increase is very low compared to the existing variation in bacterial numbers and is therefore unlikely to appreciably alter the existing health risk associated with bacteria in river waters.

117. The Waimakariri River Regional Plan (ECan 2004b) has a water quality standard for faecal coliforms of “no more than 20% of samples within any 30 day period shall exceed 800 cfu/100mL” for class WAIM water i.e., the lower Waimakariri River below the Otukaikino Creek confluence.

118. ECan began sampling E. coli in place of faecal coliforms as the indicator bacteria from 2004. I have used this recent E. coli for assessing CPW effects as it provides a more recent dataset than the faecal coliform data which dates back to 1974. Although I appreciate that the Waimakariri River Plan standards relate only to faecal coliform concentrations, ECan ceased collecting faecal coliform data before the Plan came into effect. However, I do not consider this a significant weakness in my analysis, as E. coli are a subset of faecal coliforms and they are the preferred indicator of faecal pathogen abundance when assessing public health risk.

119. E. coli numbers at Otukaikino exceeded the 800 cfu/100mL standard in 7% of samples (15 out of 216 observations) which is well below the WAIM water standard of 20% exceedance. Monitoring is undertaken on a monthly basis at Stewarts Gully, Ferry Rd and Kairaki so the comparison to this standard has been based on one sample per month for these sites. 11% of samples at Stewarts Gully, Ferry Rd and Kairaki (4 out of 36 observations) exceeded 800 cfu/100mL, which meets the WAIM water standard.

120. The MfE (2003) recreational guidelines rely on E. coli monitoring data. The guidelines apply in the summer months (November to March) so I have only considered data from these months. The NRWQN monitoring site at the Old Highway Bridge is closest to a popular recreation area of the river so data from this site (2005-06) has been assessed against the MfE (2003) guidelines. One of six observations fell into the Alert/Amber Mode (i.e., greater than 260 cfu/100mL but less than 550 cfu/100mL) while the remainder of the data was well within the Acceptable/Green Mode of less than 260 cfu/100mL. Predictions on the effects of the CPW take on compliance with the recreational guidelines could not be made as the modelled flow series provided by URS did not extend beyond 2001. Based on our predicted minor increase in faecal coliform numbers described above, I do not anticipate that the CPW take will compromise the current level of compliance with the recreational guidelines at the Old Highway Bridge site.

121. In summary, the CPW water take is not expected to adversely affect water quality in the Waimakariri River. In particular:

(a) Water temperature may increase slightly during low flows, but any increase is likely to be minor and unlikely to adversely affect the biota.

(b) River clarity currently declines downstream of the gorge, and the water take is unlikely to appreciably increase or decrease clarity.

(c) The water take will not significantly increase the concentration of contaminants (e.g., nutrients and organic biochemical oxygen demand (BOD)) in the Waimakariri River that are derived from diffuse or point-sources.

(d) The take will not significantly increase the numbers of microbial pathogens in the lower Waimakariri River. Consequently it is considered that there will be no change in the ‘health risk profile’ of the river for people using the river for contact recreation.

Effects of water abstraction on water quality in the Rakaia River

122. As mentioned above, the Rakaia River has a very different sensitivity compared with the Waiamakariri River regarding effects on water quality due to the proposed CPW water abstraction. In the Rakaia River, there are no major municipal or industrial wastewater discharges, nor are there any significant

tributaries downstream of the gorge that contribute poor quality water to the river.

123. Although there has been a long history of farming and cropping in the Rakaia River catchment downstream of the gorge, concentrations of nutrients and faceal indicator bacteria do not increase significantly from the gorge downstream to State Highway 1 (Kingett Mitchell 2006a).

124. Beyond direct discharges to the river, the Rakaia Water Conservation Order (1988) makes provision for water quality in Clause 4: "Retention of natural waters in a natural state." The proposed CPW take is unlikely to significantly affect downstream concentrations of temperature, nutrients, organic loading or microbial pathogens. Water abstraction effects on dissolved oxygen are not considered significant in the Rakaia River, as it has a naturally high capacity for reaeration, cool temperatures, a low organic loading, and low biomass of periphyton and macrophytes. These assertions are backed up by the more detailed water quality assessment for the Waimakariri River. Therefore, I believe that the proposed CPW take will not conflict with the Rakaia Water Conservation Order (1988).

Sediment Sluicing

125. Naturally entrained sediment in the Waimakariri and Rakaia Rivers will accumulate in the intake ponds as it settles out prior to entry into the water races. The settled-out sediment would normally have been transported downstream in natural river flows and consequently the settlement process removes a proportion of sediment transported by the river. However, the quantity of sediment removed from downstream transport is relatively small, being smaller than the proportion of water taken out of the total flow, as the process does not remove water during larger floods when significant sediment transport occurs.

126. Sediment from the intake systems and settling ponds will periodically need to be sluiced or mechanically cleared back into the rivers systems to enable water to flow unimpeded into the scheme's canals. If sluicing occurs at times of low flow when water clarity is typically better, it has the potential to affect clarity downstream of the intake point. However, if sluicing occurs at times when flows are higher and natural suspended sediment and near bed load transport is higher then effects would be much lower.

127. In order to manage potential water clarity effects it is proposed that if sediment sluicing is to occur by discharge into either the Rakaia or Waimakariri River that the sluicing does not occur under low flow conditions, but only when the river is already discoloured. This scheme operational issue is covered further in evidence by Mr Lewthwaite.

128. It is worth noting that consent conditions for sediment sluicing for Waimakariri Irrigation Limited (who have consent to take up to 10.5 m^3/s of water from the Waimakariri River) have proven too difficult to meet so they have opted for mechanical clearing rather than exercising their consent. Their consent conditions include limits on duration of discharge, discharge rate, maximum change in river total suspended solids concentration and river sampling during discharge for compliance purposes.

129. The Barrhill Chertsey Irrigation Company (who have consent to take up to 17 m^3/s of water from the Rakaia River) has been issued with a discharge consent that includes conditions relating to the time of day that the discharge can occur, ramping rates for the discharge to prevent entrainment of fish and other conditions similar to the RDR (Rangitata Diversion Race) consent. However neither the water take nor discharge consents are as yet operative, so it is not known whether the conditions are practical or not.

130. The RDR, which has consent to take up to 30.7 m^3/s of water from the Rangitata River and 7.1 m^3/s from the Ashburton River) has less onerous sediment sluicing conditions, with limits on minimum river flows at the time of discharge and the discharge rate. The RDR sediment sluicing conditions appear to be practicable, and this consent has been operative for a number of years.

131. In order to avoid adverse effects of CPW on water clarity, sedimentation and associated effects on river aesthetic, recreational and ecological values, some condition relating sluicing to river flow is preferred.

132. The Rakaia River Water Conservation Order (1988) requires that any discharge, allowing for reasonable mixing, shall not change the natural colour and clarity of the water to a conspicuous extent. Similarly, the Waimakariri River Regional Plan (2004b) classifies water upstream of the Otukaikino Creek confluence as Class NS (natural state). The plan standard for water in this class is “the natural state of the water shall not be altered.” To meet these

water quality standards, sluicing would only be able to take place when the rivers are already discoloured, under high flow/flood conditions.

133. The area near to State Highway 1 and the Old Highway Bridge in the Waimakariri River is a popular place for contact recreation, including bathing. The MfE (1994) Water Quality Guidelines recommend a minimum black disk water clarity of 1.6 m is necessary for bathing. Our assessment of the relationship between river flow and clarity in the Waimakariri River at the Old Highway Bridge site indicates that for the 1989-2006 record, where flows ranged between 28 m^3/s and 901 m^3/s, 88% of the clarity observations (195 out of 222 observations) did not meet the bathing water clarity guideline of 1.6m (data source NRWQN). This indicates that bathing guidelines for clarity are usually not met, and therefore that water clarity in popular bathing locations such as the Old Highway Bridge site is relatively insensitive to potential changes caused by sluicing.

134. Given the comments regarding sensitivity of the receiving environment above, and the inclusion of appropriate conditions limiting the discharge to times when the river is already turbid, I do not anticipate any adverse effects on water clarity, suspended solids or sedimentation in the Waimakariri River or Rakaia River.

135. Based on the conditions recommended for other Canterbury rivers, in particular the Rangitata Diversion Race, I conclude that effects of sediment sluicing on water quality can be mitigated through appropriate conditions such as those noted above relating to river flow at times of flushing. Based on suspended sediment rating information supplied by Dr Mark Mabin of URS the Rakaia is significantly discoloured above 300 m^3/s, and the Waimakariri above 100 m^3/s. These would be suitable minimum river flows to set for sediment sluicing.

Mitigation of abstraction effects on the Waimakariri River and Rakaia River

136. Other than timing sediment sluicing for high flow periods, no other specific mitigation is proposed for any potential adverse effects on the Waimakariri and Rakaia rivers as a result of the water abstraction. I consider that this is appropriate as any potential adverse effects on these rivers are considered to be no more than minor.

THE WAIANIWANIWA RESERVOIR

137. When reservoirs are created, it is necessary to predict what the water quality will be like within the newly formed man-made lake. Water quality is typically affected by key factors such as the lake hydraulics (dimensions, depth, residence time etc.,) and past and current catchment landuses.

138. In newly constructed reservoirs, processes affecting water quality can include eutrophication and algal blooms, thermal stratification, hypolymnetic deoxygenation leading to periods of anoxia and production of toxic by-products. The extent to which these occur is largely dependent upon the morphometric (i.e., size and depth) and limnological characteristics of the reservoir such as mixing (wind and seasonal factors), light penetration, and biological productivity, all of which are affected to some extent by the source of water, chemistry of the soils being flooded and operation of the reservoir. These processes and associated effects must all be assessed to ensure minimised environmental impact.

139. Suspended sediment in the Waianiwaniwa Reservoir will be sourced primarily from the Waimakariri River intake, with a secondary source through the resuspension of sediments on the lake margins due to the influences of wind driven wave action and fluctuations in water levels. Based on an analysis of synthetic daily takes from the Waimakariri and Rakaia Rivers for 10 years of historical flow data (1990-2000), it is estimated that, on average, the suspended sediment load into the Waianiwaniwa Reservoir would be approximately 26,150 t/year (Tipler et al. 2002).

140. Water clarity will be affected by three key parameters; primary productivity, organic matter found in soils and particulate materials sourced from river intakes and resuspended at the lake margins. Humic substances will be leached from the flooded soil and vegetation of the lake margins and bed, and are likely to reduce over time as the leachable biomass is reduced. Primary productivity due to density stratification and elevated nutrient levels in the epilimnion (the warmer upper water layer in the lake) will result in a decrease in

water clarity during the summer period as the water column biomass (phytoplankton) increases.

141. Temperature in reservoirs are typically similar to those in natural lakes, however the Waianiwaniwa Reservoir is likely to have lower temperatures than a natural lake due to draw-off of surface water for irrigation, causing a constant heat loss from warmer surface waters. Furthermore, the effect is likely to be small as the average daily drawoff of water during the irrigation season is only about 0.5% of the volume of the reservoir.

142. The occurrence of hypolimnetic (the layer of water in a thermally stratified lake that lies below the thermocline) oxygen depletion in newly formed reservoirs has been well documented (Godshalk & Barko 1985; Henriques 1987). This effect is enhanced in newly formed reservoirs because of high biological oxygen demand from decomposing flooded terrestrial vegetation and organic soils (Gunnison et al. 1985).

143. Hypolimnetic oxygen depletion would be expected to occur in the Waianiwaniwa Reservoir during the first few years of operation, particularly during summer, when stratification becomes well established. The duration of thermal stratification would be the main determinant of the extent of oxygen depression.

144. Oxygen depletion is unfavourable for most aquatic organisms, and can have significant effects on water chemistry, particularly at the sediment-water interface, where the change in redox conditions (from oxidising to reducing) can result in the release of soil constituents such as manganese and ammonia. The extent of such effects would largely depend on the duration of summer stratification. However, given the relatively short residence time of water in the proposed reservoir, these conditions would be expected to improve with time. In the Opuha Reservoir in South Canterbury, such conditions persisted from January 1999 to April 1999, one year after the reservoir was filled (Meredith 1999). As stated above, oxygen depletion in the Waianiwaniwa Reservoir could be expected to occur during the first few years of operation.

145. Once stratification is established and the hypolimnion (lower, colder layer) becomes anoxic, sulfate reducing bacteria can metabolise organic materials and sulfate. A by-product of the metabolism is sulphur ions which can react with hydrogen to form hydrogen sulphide, which is highly toxic to many aquatic

organisms at low concentrations, and when released to the air results in an offensive “rotting egg” smell. Hydrogen sulphide oxidises rapidly to sulfate and typically would not be present in the upper epilimnion, except if sufficient quantities are built up in the hypolimnion to reach the surface during rapid turnover.

146. In the Opuha Dam in South Canterbury, stratification and the decomposition of drowned soils and vegetation led to the production of hydrogen sulphide in the hypolimnion (Meredith 1999). The dam was designed to release hypolimnetic water and subsequently discharged hydrogen sulphide to the receiving waters and air.

147. On the basis of the Opuha Dam experience it is likely that hydrogen sulphide will be generated in the hypolimnion, however the Waianiwaniwa Dam is designed as a top release, and as such is unlikely to discharge hydrogen sulphide. In the event of rapid turnover there is a possibility that hydrogen sulphide could be released, but it would rapidly oxidise provided that ample oxygenation occurs.

148. Eutrophication is expected to be an issue during the early life of the Waianiwaniwa Reservoir. Inundated soils and vegetation in lakes are likely to yield large quantities of nitrogen and phosphorus and promote phytoplankton growth (Viner & White 1987). However, eutrophication in the Waianiwaniwa Reservoir is likely to be limited due to two specific factors:

(a) Phytoplankton production in the Waianiwaniwa Reservoir is likely to be largely limited by low light penetration. Moderately high concentrations of suspended sediments in the reservoir would scatter down-welling irradiance and reduce light penetration (Davies-Colley 1989).

(b) In addition, the relatively short 2 year water residence time in the reservoir would tend to reduce eutrophication problems because of the mass export of nutrients from decomposition of vegetation and soils. Over time, nutrient levels in the Waianiwaniwa Reservoir should approach those of the source (i.e., the Waimakariri River), which would be relatively low and not support phytoplankton blooms.

149. In terms of potential deleterious effects, phosphorus and ammonia-nitrogen will dominate. Primary production in the epilimnion is likely to be phosphorus

limited. In anoxic and reduced pH conditions, the nutrients phosphorus and ammonia-nitrogen become more soluble and are released from the bottom sediments into the hypolimnion and can diffuse into the epilimnion. Once in the aerobic conditions of the epilimnion, some of the soluble phosphorus is likely to adsorb onto suspended sediment. Ammonia-nitrogen is potentially toxic to some aquatic species (if concentrations become high enough) and the increased concentrations in the epilimnion may be exacerbated by the elevated pH driving the ammonia-ammonium equilibrium toward the ammonia end.

150. In summary, the water quality of the Waianiwaniwa Reservoir is expected to be elevated in nutrients, particularly during the first 5-10 years of operation and during dry periods where the lake level is drawn down. The water quality is expected to be acceptable for the purpose of water storage for irrigation purposes. If it is decided that the reservoir should be used for other purposes, such as aquatic ecosystems or recreation, then a range of options are available to enhance the lake water quality to meet this purpose. These options include vegetation clearance and use of nutrient stripping crops prior to inundation.

151. Following the creation of Lake Opuha in the late 1990s, a number of concerns were raised regarding the new lake's water quality and effects of its discharge into the Opuha River (Meredith 1999).

152. Particular features that exacerbated water quality issues of the new lake include: it was a deep-release dam; there had been no stripping of vegetation prior to reservoir filling; water discharged from the lake received no significant treatment prior to being discharged into the Opuha River; there was no assessment of potential water quality or water management strategy devised prior to consenting.

153. Some of these issues will be avoided or mitigated in the new Waianiwaniwa reservoir. Recommended mitigation measures for the Waianiwaniwa reservoir include:

(a) Top release dam thus avoiding the potential to discharge hypoxic, poor quality water.

(b) Cessation of grazing and fertiliser and pesticide additions in the inundation area at least two years prior to reservoir filling (assuming CPWL has control of the reservoir land for the two years prior to lake filling).

(c) Removal of trees in the reservoir footprint thereby reducing the organic loading to the new reservoir.

(d) Implement intensive crop rotations on the future reservoir bed to help strip nutrients from the soil.

(e) Fence off reservoir margins, canals and water races to prevent stock access.

(f) Use wetland treatment to improve water quality to bywash discharges into surface water bodies.

154. Water quality monitoring has been proposed for the Waianiwaniwa reservoir. In addition to regular visual surveys for phytoplankton blooms, the following water quality parameters will be monitored: total phosphorus, total nitrogen, chlorophyll a, secchi depth (or turbidity), dissolved oxygen, temperature, faecal coliforms, and E. coli (if the reservoir is likely to be used for contact recreation).

155. Limnological processes within a newly created reservoir are difficult to predict with certainty. Collecting data, as described above, on the trophic status of the reservoir will, in time, allow a picture of lake functioning to build-up. Therefore, with time, the ability to predict and prevent episodes of poor water quality occurring will improve. If poor water quality becomes associated with stratification, then interventions could be implemented, such as hypolimnetic deoxygenation using aerators. Mixers to resolve stratification issues in the reservoir could also be employed if necessary.

156. Reservoir water quality monitoring conditions for the Opuha Dam consent include continuous monitoring of dissolved oxygen, temperature, turbidity, and conductivity, at 2 depths in the lake near the dam itself and in water discharged from the lake discharge. Trigger levels associated with these parameters may, as in the case of DO, activate mitigation measures, such as the operation of an aeration system. Three-monthly surface water quality samples are also collected from Lake Opuha and analysed for total nitrogen, total phosphorus and chlorophyll a.

157. It is likely that monitoring conditions such as those described above for Lake Opuha would be considered as a minimum for the proposed Waianiwaniwa reservoir.

158. In summary, it is my opinion that the proposed mitigation will mitigate or avoid any potentially adverse effects on water quality in the reservoir. Monitoring has been proposed to provide ongoing surveillance of water quality in the reservoir which will ensure that appropriate measures to mitigate or prevent declines in water quality can be implemented in a timely manner.

EFFECTS OF BYWASH DISCHARGES

159. Water within the water races that is not used for irrigation within the scheme area will be discharged to waterways as "operational" bywash. This includes water from the Waimakariri River intake, the Rakaia River intake and the Waianiwaniwa Reservoir, after it has travelled through the network of canals and water races. Eleven operational bywash discharge locations have been identified in the following waterways: Waimakariri River, Rakaia River, Selwyn River, Hororata River, Waianiwaniwa River and the Hawkins River.

160. The expected discharge volume across all water races is approximately 2 m3/s. As discussed in Mr Lewthwaite's evidence, the maximum operational bywash discharge into a single waterbody will be 1.5 m^3/s into the Rakaia River, followed by 0.8 m^3/s into the Selwyn River. All other operational discharges will be in the order of 0.2-0.4 m^3/s.

161. Discharge quality will vary over time, depending on the major water source at the time and to some extent farm management practices (however with good farm practices, this is not likely to be a concern). The potential effect on downstream water quality will also depend on the river flow at the time of discharge.

162. On very infrequent occasions (e.g., due to complete power and pump failure in the entire irrigation supply area) it may be necessary for the release of water within the headrace canal and water races. This bywash will mostly go into the Rakaia, Waimakariri and Selwyn Rivers. The "worst case" potential impact on receiving water quality is if very low river flows coincide with low reservoir draw down and hence potentially reduced discharge quality.

163. In summary, because the risk and frequency of 'emergency' bywash discharges is very low, and any impacts on water quality will be of short duration, this effect is considered to be minor.

Mitigation of effects of bywash discharges

164. It is however proposed to 'treat' operational bywash discharge water via either an existing or constructed wetland prior to entering any surface water-bodies at each of the proposed discharge locations. It is anticipated that some bywash discharge locations will involve small surface wetland systems and some pond and wetland systems depending on the volume of water that might pass through them.

165. Passage through wetland or wetland/pond is beneficially enhance water quality prior to entry into any receiving environment. This improvement arises through wetlands/ponds being able to remove suspended solids improving clarity as a result. Removal of suspended solids will also result in the reduction in concentration of other parameters (such as total phosphorous) which are associated with the particulate materials in the water. Constructed wetlands may also result in some removal of dissolved nutrients (DIN, DRP etc.) through plant uptake. This would improve water quality to a standard better than that expected in the water races. Given appropriate wetland design and maintenance, it is my opinion that even though effects of bywash discharge are unlikely, this mitigation measure will be an effective way of ensuring water quality effects caused by operational bywash discharges will be less than minor.

EFFECTS OF CPW ON LOWLAND STREAM WATER QUALITY

Introduction

166. Landuse intensification has the potential to affect surface water quality in lowland streams in a variety of ways. The key water quality matters that need to be considered include:

(a) Changes in hydrology resulting in changes to surface water quality.

(b) Increased sediment input and phosphorus concentrations in surface waters in the irrigation area from overland runoff.

(c) Increased nitrogen concentrations in lowland streams from increased nitrogen in groundwater beneath the irrigation area.

(d) Increased faecal contamination in surface waters in the irrigation area from overland runoff and potentially in lowland streams from any increases in groundwater beneath the irrigation area.

167. In this part of my evidence I will discuss water quality issues associated with landuse intensification in the CPW area. I discuss water quality issues associated with surface runoff and groundwater contamination separately, as the source, fate and mitigation of contaminants differs between these two issues.

Effects of surface runoff on water quality

168. Runoff from agricultural landuse may increase sediment in surface waters. The streams that flow through the CPW irrigation area currently have low suspended solids concentrations, particularly during baseflow conditions. Increased landuse intensification can result in increased soil exposure through treading and pugging damage from stock grazing; construction and use of farm tracks and races; and various other activities. This increases sediment runoff into streams, although the effect is lessened on lower gradient slopes and flat land, as a greater proportion of sediment is trapped by grass and other riparian vegetation before reaching waterways. Most of the land within the CPW irrigation area is flat, however there is potential for localised increases in sediment runoff, particularly as there is little significant riparian vegetation adjacent to waterways. Sediment runoff can be minimised by reducing the area of soil exposed (through establishment of permanent pasture) and restoring riparian margins. In particular, irrigation should be avoided on exposed soil, or after intensive grazing due to high stocking rates (Heatley 1998).

169. Phosphorus concentrations in waterways within the CPW irrigation area are typically low, but increase under flood flows, due to its presence in suspended sediment. Phosphorus concentrations may increase in receiving waters, due to surface runoff from intensive agriculture. Techniques used to reduce phosphorus inputs into waterways are generally based on reducing soil inputs, as already mentioned.

170. Agricultural activity can also increase faecal contamination of waterways, through runoff of stock waste and direct deposition of animal waste in waterways where stock have access to drains and banks or where farm tracks cross waterways. Appropriate management of waterways (e.g., fencing and

riparian management) can very effectively reduce faecal contamination. In addition, irrigation should be avoided after intensive grazing by high stock numbers (Heatley 1998). Irrigation of dairy shed effluent should be conducted according to best management practice to avoid contamination of waterways with faecal material.

Mitigation for surface runoff effects on water quality

171. With appropriate landuse management, the potential effects of landuse intensification on water quality through surface runoff can be reduced. However, the type and effectiveness of surface runoff mitigation depends on a variety of environmental and land management factors. Hill slope is an important determinant, with steeper slopes increasing the likelihood of overland flow and therefore greater contaminant transport into surface waterbodies. The CPW irrigation area is likely to be entirely on very low gradient topography, which will help minimise the likelihood of overland flow into waterways. A recent international review of various farming “best management practices” by McDowell et al. (2004) found that some of the most effective techniques for minimising loss of particulate P in overland flow were conservation tillage (75% removal of total P), grass riparian filter strips (50% removal), and nutrient management plans (45% removal). New Zealand research supports the value of riparian buffers, with 55 to 85% removal of dissolved and particulate P reported for retired pasture riparian buffers in hill country catchments (Smith 1989).

172. Given the low land gradient and relatively low rainfall within the CPW irrigation area, surface water contamination by surface runoff will be relatively easy to mitigate. However, concentrations of phosphorus and faecal indicators are already elevated in a number of upland streams within the CPW area, which suggests that stock access and bank erosion may therefore be more significant sources of surface water contamination than overland flow. Bank erosion and stock access can both be significantly reduced with waterway fencing and riparian management (e.g., planting trees or shrubs).

173. The Sustainability Protocol sets out the protocols, policies and procedures that CPW will follow in the development, operation and maintenance of the Central Plains Water enhancement scheme in order to ensure that both the scheme operators and the water users can achieve high environmental standards and

sustainable outcomes. The Sustainability Protocol provides detail on efficient water use (80% efficiency both on and off farm) and that water users will be required to construct and operate infrastructure in accordance with the New Zealand Irrigation Code of Practice and Irrigation Design Standards (Irrigation NZ 2007). This will ensure that surface runoff is minimised. Proposed consent conditions require that each water user has a Farm Management Plan which incorporates a nutrient budget as well as waterway and riparian management.

174. I conclude that provided appropriate sustainable land management practices are implemented, as proposed by the Central Plains Water Trust, then direct effects of the CPW scheme on surface water quality should be less than minor. In fact, if there is a net improvement in land management practices within the irrigation area, then there are opportunities for improvements to existing water quality.

<u>Compliance with water quality standards</u>

175. As stated earlier in my evidence, the proposed NRRP water quality chapter states that, for lowland streams, discharges must not result in an increase in the annual concentration of DRP in receiving waters of >0.002 g/m3. I consider this to be a lofty and probably unattainable goal to apply to the entire CPW scheme, regardless of any proposed mitigation measures. This is because such water quality standards are usually applied to point-source discharges, with little consideration given to cumulative effects. Phosphorus losses from the CPW scheme are equivalent to many individual discharges and effects of the scheme on receiving environment water quality represent the cumulative effects of landuse intensification over 60, 000 Ha of land.

176. For these reasons, I do not consider that the proposed NRRP standard of an annual <0.002 g/m3 increase in DRP concentrations in lowland streams should be applied to the CPW scheme. Rather, it is my opinion that management of diffuse sources of pollution, such as phosphorus, should be integrated at a catchment level. Unfortunately, I am not aware of any catchment management plans for lowland tributaries of Lake Ellesmere. However, in this regard CPW is essentially taking the lead by proposing detailed farm management plans to minimise nutrient losses from individual farms that are part of the CPW scheme.

177. As discussed earlier in my evidence, the New Zealand periphyton guidelines provide the best guidance on nutrient concentrations to prevent nuisance algal growths. As already indicated, all of the lowland tributaries of Lake Ellesmere currently have average (median and mean) DRP concentrations that exceed the New Zealand periphyton guideline limit of 0.004 g/m^3 for stable spring-fed streams (i.e., assuming a 40-day accrual period). Thus, lowland streams already exceed periphyton guideline limits for DRP and the CPW scheme is unlikely to change this factor. As indicated above, the focus should therefore be on mitigation in the form of sustainable farming practices, both on CPW land, and at a catchment scale. CPW has control over the former, but not the latter.

Effects of increased stream flows on water quality

178. Groundwater modelling results presented in evidence by Mr Weir indicate that the CPW scheme will result in significant increases in baseflow in waterways directly down-gradient of the CPW irrigation area, most notably the Selwyn and Irwell Rivers. Very low dissolved oxygen concentrations have been measured in several lowland streams at times when there is little baseflow or ponded water. The Irwell River in particular has had very low dissolved oxygen at times, at concentrations that could be expected to result in fish kills, if fish were present in the river at the time. Although some reaches of the Irwell River may in fact be naturally intermittent (although this is an area of some debate), the expected significant increase in baseflow would be beneficial to the Irwell River as it would reduce the frequency of low flow events and ponding, and therefore result in greater re-aeration and higher oxygen concentrations. Thus, increased flow is expected to improve water quality in some lowland streams.

Effect of increased nitrate loading on water quality

179. A number of submitters raised the issue of increased nitrate concentrations in lowland streams. Submitters included the Royal Forest and Bird Protection Society of New Zealand (Central Office), Malvern Hills Protection Society Inc and Environment Canterbury (Regional Engineer). The ECan submission raised the point that an increase in nutrient concentrations in the lowland streams may encourage vegetation growth and thus have subsequent effects on flood protection, braiding pattern and ecology. It would be fair to say that

effects of nitrates on lowland streams are one of the key environmental concerns the public has with the CPW scheme.

180. In his groundwater modelling evidence Mr Weir showed that the majority of water from the CPW irrigation area is predicted to flow towards Lake Ellesmere and its tributaries (pages 45 and 46 of his evidence). Similarly, Mr Weir showed that effects on lowland stream flows were greatest in rivers such as the Selwyn and Irwell Rivers immediately downgradient, but that flows would not be appreciably affected in streams further north (such as the Avon, Styx Rivers, and Waimakariri Rivers) and further south (e.g., the Rakaia River). Although no dedicated contaminant modelling has been undertaken, I consider it is a reasonable assumption that groundwater contaminants will flow along groundwater flow paths. Thus, the potential for effects of the scheme on nitrate concentrations in lowland streams will generally be restricted to streams south of the Avon River and north of the Rakaia River.

181. In his evidence on groundwater nitrate concentrations, Mr Tipler noted that the CPW scheme will result in an appreciable increase in the loading of nitrate to groundwater, in the order of an 80% increase. However, he also noted that CPW is not predicted to appreciably increase average groundwater nitrate concentrations, due to the increased volume of drainage water from the scheme.

182. Given that flows in lowland streams are groundwater-sourced it may seem reasonable to assume that based on groundwater modelling predictions, CPW will increase lowland stream nitrate loadings, but that concentrations will remain relatively unchanged. However, in my opinion this is an over-simplification, as the modelling ignores spatial variation in groundwater nitrate concentrations. Furthermore, monitoring of lowland streams shows that there is existing variation in concentrations and loads between streams (as shown earlier in my evidence), and spatial variation in nitrate concentrations will also likely occur with regards to effects of the CPW scheme.

183. Because there is a lack of spatial resolution to the groundwater nitrate modelling, I have taken the approach of looking at existing nitrate concentrations in different streams to assess the risk of lowland streams becoming eutrophic and causing adverse ecological effects. Earlier in my evidence, I showed that nitrate concentrations are already elevated and exceed

periphyton guidelines in all lowland streams downgradient of the CPW scheme that have regular monitoring data. The Kaituna River is the only tributary regularly monitored with nitrate concentrations typically below periphyton guideline limits. However the Kaituna River drains the Port Hills to the north-east of Lake Ellesmere and is in my opinion not affected by the CPW scheme. Thus, despite some variation in nitrate concentrations between tributaries, overall they all show low sensitivity to increased nitrate loading from CPW.

184. As discussed earlier in my evidence, if nutrient limitation were an issue in lowland tributaries of Lake Ellesmere, then phosphorus limitation is more likely than nitrogen limitation, due to the high N:P ratios and experimental evidence relating to the uptake of nutrients gathered from work in the Selwyn River.

185. It is my opinion that the CPW scheme presents a low risk to lowland streams from increased nitrate concentrations. This is because nutrient concentrations are already high (i.e., the streams are eutrophic), and nitrogen is unlikely to be a limiting nutrient. This is typically the case in lowland Canterbury streams, due to the dominance of agricultural landuse in their catchments. Thus, landuse intensification associated with the CPW scheme in a lowland environment presents a much lower environmental risk than in more pristine, upland streams with low nutrient concentrations, which would be comparatively sensitive to nutrient increases.

186. I will stress the point here that low sensitivity to nitrate increases does not necessarily mean that the streams are of low value, rather that the ecosystems and ecological values are not sensitive to increased nitrate concentrations. Indeed, I understand that a number of lowland streams in the CPW area support high ecological values, despite having high nutrient concentrations. Ecological values of streams in the CPW area are covered in evidence by Drs Allibone, Burrell and Glova.

187. I will also comment here that sustainable landuse practice should aim to minimise nutrient losses, regardless of the existing sensitivity of the receiving environment to nitrate increases. However, given the existing high nutrient concentrations in lowland streams, implementation of "best practice" nutrient management by CPW are unlikely to improve lowland water quality unless existing intensive landuse (in areas outside of the CPW area) also adopt best practice farming. CPW can not control nutrient management on farms outside

of the CPW irrigation area (e.g., east of State Highway 1), however by adopting best management practices, CPW can lead by example.

Mitigation for effects of increased nutrient loading to lowland streams

188. A recent report prepared by Li et al (2007) for CPW Ltd showed that application of "winter grazing off" management markedly reduced average nitrate leaching through irrigated Canterbury soils from 32 kg/ha/year to 18 kg/ha/year. For cropping systems, nutrient budgeting, including reduced fertiliser application during wetter winter months, is probably one of the most effective ways to minimise nitrate loss (Francis et al. 2003). Nitrate losses from cropping systems are typically appreciably higher than those from dairy operations (Power 2002), so careful fertiliser management of crops would be an effective way of significantly reducing the load of nitrate lost to groundwater and lowland streams downgradient of the CPW scheme.

189. The nitrification inhibitor dicyandiamide (DCD = 2-cyanoguanidine) has been shown to significantly reduce the amount of nitrate lost to drainage from cattle urine patches in dairy pasture. In a detailed Canterbury study, use of DCD reduced nitrate mass losses by around 75%, and reduced the annual average nitrate-N concentration under the urine patch from 25 to 7 g/m^3 (Di & Cameron 2004). Similar removal efficiencies of nitrate from dairy farm soils have been reported from Southland (Smith et al. 2005). Both the Canterbury and Southland studies also reported improvements in pasture productivity in the order of 10 to 30% when using DCD. Clearly, use of DCD on dairy farms within the CPW scheme has the potential to considerably reduce nitrate losses to groundwater and lowland streams. Although DCD use as a nitrification inhibitor is a comparatively new technology, Lincoln University, where much of the local research has been carried out, reported in 2005 that DCD was to be applied to approximately 12,000 hectares of pasture in Canterbury.

190. CPW has prepared a number of draft environmental management plans and consent conditions, to avoid and mitigate adverse effects of landuse intensification. The following lists the draft consent conditions relating to farm management plans that users of CPW will be required to adhere to. It is my opinion that implementation of the proposed mitigation measures would

significantly reduce the nitrate load from the CPW scheme and further reduce the risk of increased nitrate concentrations in lowland streams.

191. Draft consent conditions that would reduce the likelihood of nitrate increases in lowland streams include the following. I note here that these conditions are draft and are discussed in greater detail in the evidence of Ms Mulcock and Ms Robson.

(a) A nutrient budget shall be prepared and implemented for all properties receiving water from the Scheme.

(b) Limits will be placed on the annual loading of nitrogen per hectare of farm.

(c) Potential mitigation measures to ensure compliance with required limits include the use of nitrification inhibitors, winter cover crops, avoiding fertiliser use on saturate solids, and other appropriate technology or management practice, implemented to reduce the loss of nitrate nitrogen to soil drainage water.

<u>Compliance with water quality standards</u>

192. As stated earlier in my evidence, the proposed NRRP water quality chapter states that, for lowland streams, discharges must not result in an increase in the annual concentration of NOx-N of >0.02 g/m3. For the reasons already discussed above relating to DRP, I do not consider it is valid to apply this NRRP standard to effects of CPW on nitrate concentrations in lowland streams.

193. As discussed above, nitrate concentrations already exceed New Zealand periphyton guidelines in lowland tributaries of Lake Ellesmere and, in the absence of any mitigation, CPW is unlikely to significantly alter this fact. However, it is my opinion that the range of on-farm measures proposed to minimise nitrate losses to groundwater may help improve the likelihood of compliance with nitrate guidelines over time.

Summary

194. Water quality in lowland streams has the potential to be affected through the indirect path of landuse intensification, in the form of surface runoff and groundwater contamination. However, it is my opinion that CPW poses a low risk to water quality in lowland streams, due to the ability of CPW Ltd to implement mitigation measures on farms throughout the CPW scheme area,

and because the lowland streams are not considered sensitive to nutrient increases.

195. The key strategy to mitigating potential adverse water quality effects on lowland streams is sustainable landuse management practices. Minimising nitrate inputs to groundwater will aid in the reduction of nutrient concentrations in lowland streams where nuisance periphyton growth and potential toxicity to aquatic organisms are issues. Restoration of riparian margins including stock exclusion will mitigate sediment, phosphorus and faecal indicator bacteria inputs to streams. Increased baseflows are expected to improve water quality in some lowland streams, particularly the Irwell River.

EFFECTS ON LAKE ELLESMERE

Introduction

196. Concerns regarding effects of CPW on the water quality in Lake Ellesmere/Te Waihora were highlighted by a number of submitters including Dr Angus McIntosh and Dr Jon Harding (Canterbury University), DOC, Malvern Hills Protection Society, Royal Forest and Bird Protection Society, Te Runanga o Ngai Tahu and the Waihora Ellesmere Trust.

197. The hydrodynamics and water quality of Lake Ellesmere are expected to change to some extent following the development of the CPW scheme. Lowland streams are expected to bring increased nutrient loads into the lake, while increased tributary inflows and subsequent changes in the lake opening regime will also influence the water quality in the lake to some extent.

198. It is my opinion that CPW will affect water quality in Lake Ellesmere, but that any effects are likely to be minor and within the existing range of variable water quality already known and occurring in the lake. I discuss the supporting facts and expand on the details of this opinion in the following sections. In his evidence Dr Burrell goes into greater detail concerning potential effects on the lake ecosystem in general, while Drs Allibone and Glova discuss effects on native and introduced fish, respectively. Dr Bishop discusses effects on wetland vegetation and birds.

Effects of CPW on Lake Ellesmere water quality

199. I consider that the two key water quality issues associated with CPW and Lake Ellesmere are effects on lake nutrients and effects on lake salinity.

200. In his evidence, Mr Weir showed that CPW is expected to significantly increase freshwater inflows into Lake Ellesmere from tributary streams. As I have already mentioned, these tributary streams will carry an increased load of nitrate, but nitrate concentrations in the tributaries will not be appreciably different to the status quo. As I have also mentioned, control of phosphorus runoff from the CPW irrigation area will be achievable and therefore I do not anticipate effects on lake phosphorus loadings or concentrations.

201. It may seem intuitive that increased freshwater inflows caused by CPW will make the lake less saline. However, as Mr Mabin outlined in his evidence, increased freshwater inflows will mean that the lake will need to be opened more frequently to maintain lake operating levels. Therefore, increased lake openings will increase the opportunity for saline water to enter the lake (via increased lake openings), meaning that CPW could potentially increase lake salinity.

202. In my summary of water quality monitoring data presented above, I stated that there is a general relationship between lake opening status and lake salinity, but that this relationship is not strong and it is most apparent when the lake is open for a longer than average period (>30 days). I also note that salinity gradients are apparent within the lake, with the water generally being more saline closer to the lake outlet at Taumutu than near the tributary inflows (Ward 1994). Based on these observations, increased freshwater inflows into the lake, coupled with increased frequency of lake openings may be expected to have a minor effect on overall lake salinity, but this would most likely be within the range already seen within the lake. I consider a more likely detectable effect would be a reduction in salinity in the immediate vicinity of tributary inflows, associated with increased tributary flows, coupled with a slightly greater frequency of higher salinity occurring close to the lake's opening, due to increased lake openings. Thus, while overall lake salinity may remain relatively unchanged, I anticipate that CPW could result in a stronger salinity gradient between sites near tributary inflows and sites near the lake's outlet.

203. Because nitrate concentrations are not expected to increase appreciably in the tributary streams, it is tempting to assume that CPW will likewise not affect Lake Ellesmere nitrate concentrations. However, nutrient loadings, rather than concentrations, are generally of greatest interest when considering nutrient effects on lake environments. This is because high nutrient loads increase the pool of nutrients available for the biota, and any nutrients not taken up biologically may become stored in bed sediments and used later. Thus, effects of CPW on increased nitrate loadings to Lake Ellesmere are of interest.

204. As I have already discussed, nitrogen is currently in plentiful supply in Lake Ellesmere and nutrient limitation is unlikely. Rather, light limitation, caused by the lake's shallow and turbid nature, is the primary factor limiting phytoplankton production. It is therefore my opinion that increased loading of nitrogen to the lake will not increase the risk of phytoplankton blooms, regardless of the potential increase in nitrogen stored in bed sediments. Dr Burrell discusses effects on phytoplankton and invertebrate communities in greater detail in his evidence, but comes to similar conclusions as me.

205. Although I do not anticipate any adverse effects of CPW on nutrient concentrations within Lake Ellesmere, I also appreciate that reduced nutrient concentrations are a long term management goal for the lake (as articulated by organisations such as the Waihora Ellesmere Trust).

206. Reduced nutrient supply to the lake could be achieved via improved land management practices throughout the lake's catchment. However, reduced nutrient supply may not be sufficient on its own to improve lake water quality. This is because of the likely massive store of organic nutrients in the lake's sediments that will available to phytoplankton long after tributary nutrient loads decline. For this reason, I consider that the management goal of improved water quality may not be achievable solely by reducing catchment nutrient sources, rather it is my opinion that other interventions, such as increasing the flushing rate to the sea, would also be necessary. This is a lake management issue that clearly needs further investigation.

207. Similar issues are faced by lake managers elsewhere, and there are numerous examples where increased lake flushing to remove nutrients and/or sediment has been proposed. International examples include the Gippsland coastal lakes in Australia (Webster et al. 2001) and Lake Apopka in Florida, USA

(Schelske & Kenney 2001). The most locally relevant example to Lake Ellesmere is the recent proposal to construct a permanent opening to Lake Forsyth to improve lake water quality.

<u>Mitigation</u>

208. CPW have proposed a wide variety of on-farm measures to minimise nutrient losses to groundwater, lowland streams and ultimately Lake Ellesmere, as outlined above and in Ms Mulcock's evidence. In my opinion the proposed management practices and conditions are appropriate and will be effective in reducing the contribution CPW makes to the nutrient loading of Lake Ellesmere. However, I will reiterate my opinion that Lake Ellesmere's water quality will not improve unless water quality is managed in an integrated manner throughout its catchment, including areas outside of the CPW irrigation scheme.

<u>Compliance with water quality standards</u>

209. Lake Ellesmere is classified under the proposed NRRP water quality schedule as Class Coastal. As I have already mentioned, existing water quality standards for DIN, oxygen and ammonia are currently complied with, while limits on TP are exceeded.

210. As I have already discussed, dissolved oxygen concentrations in Lake Ellesmere are high due to the lake's shallow and wind-swept nature. CPW will not change the bathymetry or wind climate of the lake and therefore will not affect compliance with NRRP dissolved oxygen standards.

211. CPW will increase the nitrogen loading to the lake, primarily in the form of NOx-N. However, as discussed above, nitrate concentrations are not expected to increase in the lake, as the increased loading will be accompanied with increased freshwater inflows. Thus, CPW is not expected to reduce compliance with DIN standards. In addition, I also anticipate that the increased nitrogen loading will not increase ammonia concentrations or affect compliance with ammonia standards, because of the well-mixed and oxygenated state of the lake.

CONCLUDING REMARKS

212. My evidence has described the current water quality of the area proposed as part of the CPW irrigation scheme and the environments downstream. In

summary, water quality of the Waimakariri and Rakaia Rivers is a reflection of the overall upstream catchment activities and inflows. The net result being that the water quality in the Waimakariri River is poorer than that in the Rakaia River in their lower reaches. Water quality of the Waianiwaniwa River and its tributaries is typical of a hill-fed river, although the presence of coal measures and mining activity within its catchment may also influence water quality.

213. Water quality in the Selwyn River and Hororata River is higher than that in the Hawkins River. The Selwyn River and Hororata River typically have good clarity, high DO and low numbers of faecal indicator bacteria compared with the Hawkins River which has elevated nutrient concentrations, lower DO and higher numbers of faecal indicator bacteria. Nutrient ratios indicate that all three rivers are phosphorus limited. Stock access to the Selwyn District Council's water race systems is the most likely cause of the downstream decline in water quality in the water races.

214. All lowland streams except the lower Selwyn River are perennial groundwater-fed streams and generally have stable flow. Landuse surrounding the lowland streams is predominantly dairy farming. Landuse in these catchments influences water quality with key changes being in elevated sediments, nutrients and bacteria in waterways. ECan have identified that lowland streams in the Canterbury region are generally eutrophic with excess nitrogen concentrations. Concentrations of nutrients in the lowland tributaries of Lake Ellesmere frequently exceed guidelines for nutrient concentrations which may cause nuisance periphyton growth. A study undertaken in the lowland waterways found that addition of nitrogen alone to waters did not stimulate periphyton growth at any of the sites studied, but addition of phosphorus stimulated periphyton productivity at four of the five sites, indicating for example that the as noted above, the Selwyn River is phosphorus limited, not nitrogen limited.

215. Water quality in Lake Ellesmere is characterised by high surface dissolved oxygen concentrations during daylight, low clarity and high nutrient concentrations. Low water clarity is the primary factor limiting algal growth in the lake.

216. The project involves a range of construction activities including intake and tailrace construction and dam construction. The types of construction activity

are not new and have been undertaken elsewhere on other New Zealand rivers. Good construction and water management practices will ensure that activities will not result in adverse environmental effects. Ensuring that this occurs requires that specific management plans be prepared and this is intended as a part of the project.

217. The effects of the proposed irrigation scheme on water quality have been evaluated in relation to the take of water from the Rakaia and Waimakariri Rivers and the discharge of water to receiving environments. Take effects immediately downstream of intakes have been considered including changes in water temperature and changes in volumes of water available for dilution and the conclusion arising from the assessment was that there would be no significant effects of the takes.

218. Discharges arising from the operation of the irrigation scheme include the discharge of accumulated sediment removed from the intake water, bywash and the 'discharge' of water irrigated to land from the irrigation scheme.

219. Discharge of sluiced sediment is not an uncommon practice where intakes abstract water containing sediment (gravel, sand silt). As the sediment would typically have been transported downstream by the river the simplest management approach is to maintain the natural sediment balance by putting the sediment back into the river. This is carried out by undertaking the sluicing at times of high river flows. The specific way that this is done is covered in resource consent conditions which identify the minimum flows in the receiving water which trigger the sluicing. Undertaking sluicing at times of high flows ensures no adverse effects.

220. Bywash water is only discharged at times when water needs to be discharged from the tailrace in emergencies or there is excess water. Bywash water may differ in characteristics from the original water abstracted from the Rakaia or Waimakariri Rivers especially if the water has been derived from the reservoir. To mitigate any possible differences in water quality bywash water will pass through a 'wetland' prior to discharge to a receiving environment.

221. Irrigation water will pass to groundwater and will be discharged to receiving waters over a wide area depending on irrigation location and local hydrogeology. Extensive groundwater modelling has been undertaken to assess fate of irrigated water. Effects associated with irrigation centre

principally on changes in nitrogen concentrations in receiving waters. Lowland waters downstream of the CPW area contain significant concentrations of nitrogen with particularly high concentrations of DIN in places. Addition of further nitrogen where it did occur is not likely to have significant adverse effects. However, given the eutrophic condition of waterbodies in the Canterbury Plains downstream of the CPW area, significant effort in relation to improved farm management is intended to offset the increased irrigation and transport of nitrogen.

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APPENDIX OF FIGURES AND TABLES

To be inserted

Figure 1: Features of the Central Plains Water Enhancement Scheme

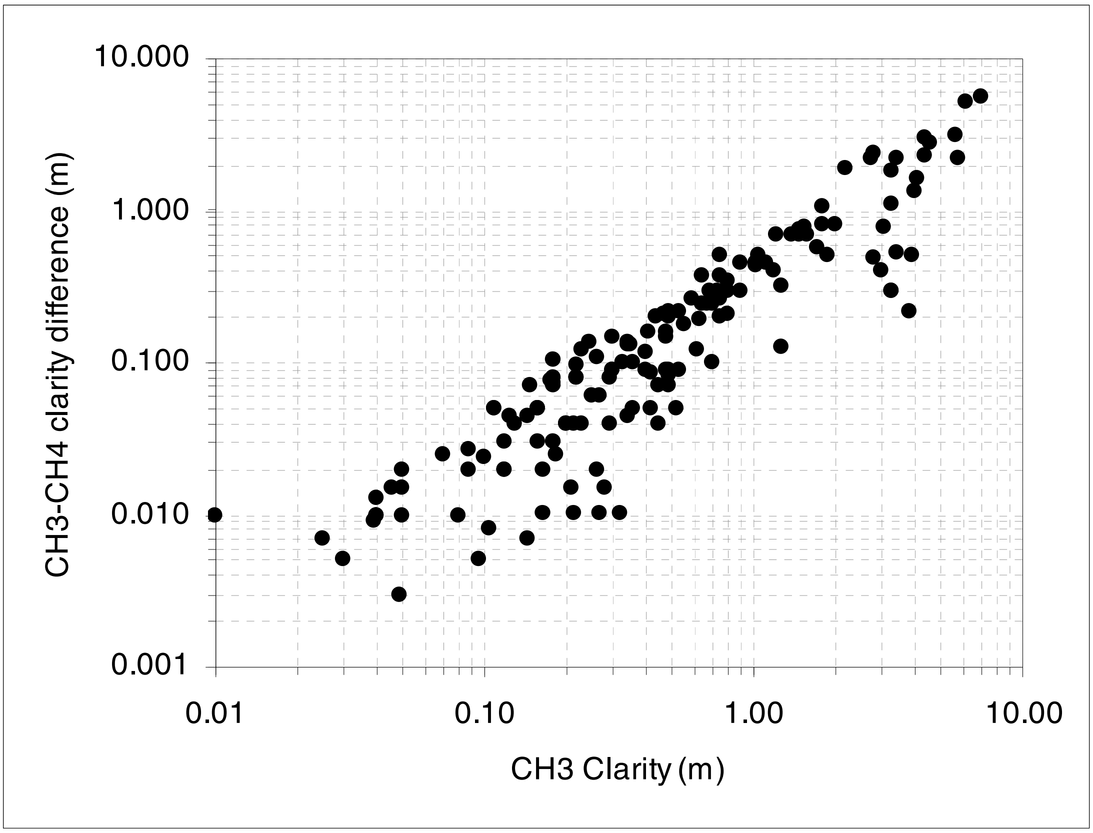

Figure 2: **Relationship between black disc clarity at site CH3 (gorge) and CH4 (Old Highway Bridge) in the Waimakariri River.**

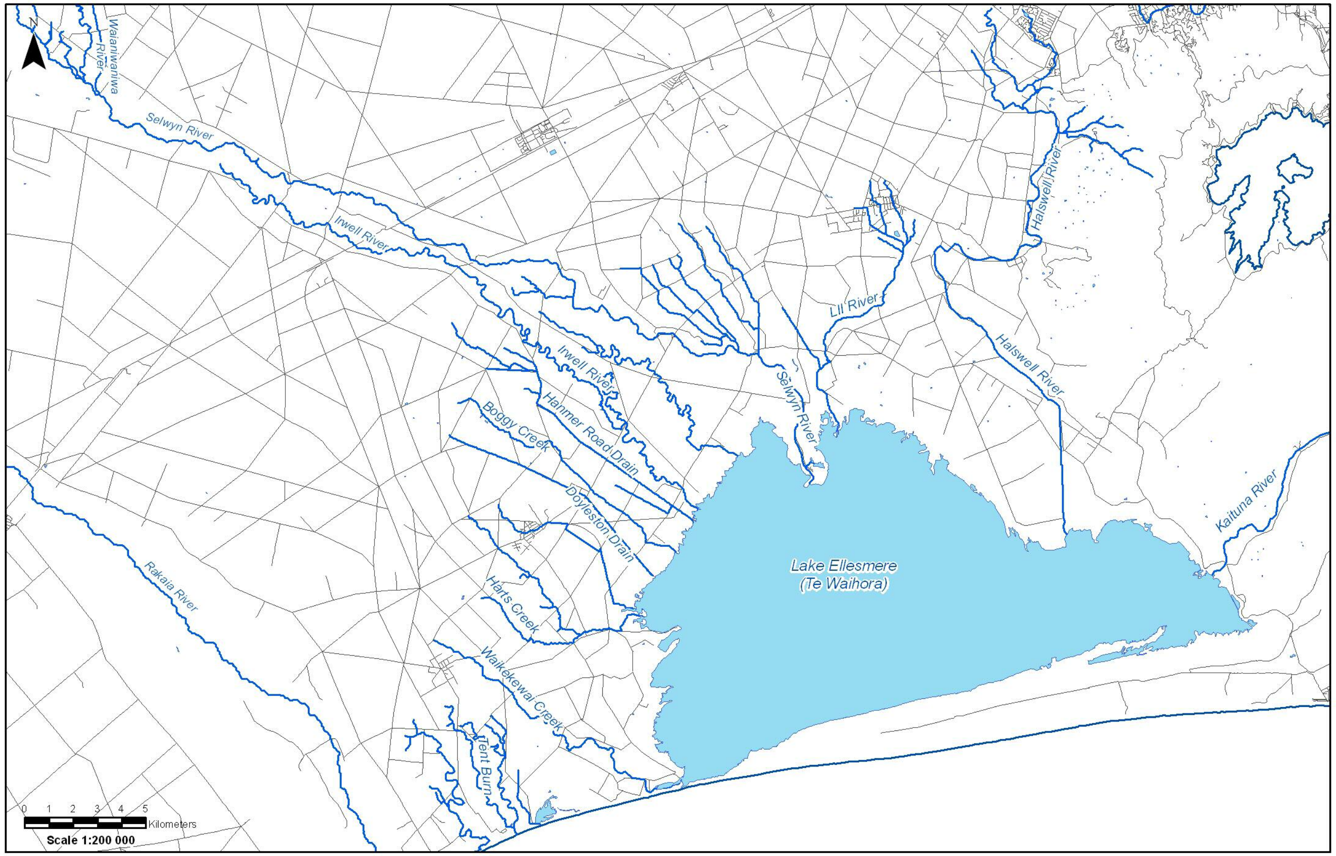

Figure 3: Lowland tributaries of Lake Ellesmere.

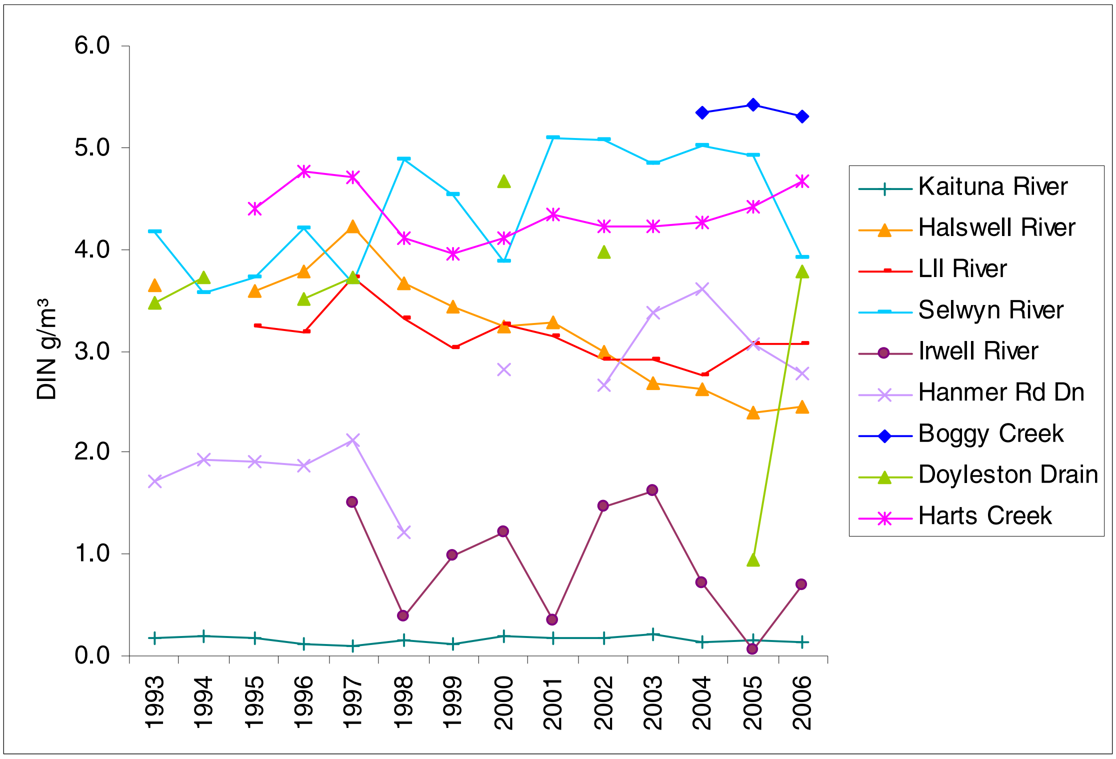

Figure 4: **Annual median DIN concentrations in lowland tributaries of Lake Ellesmere.**

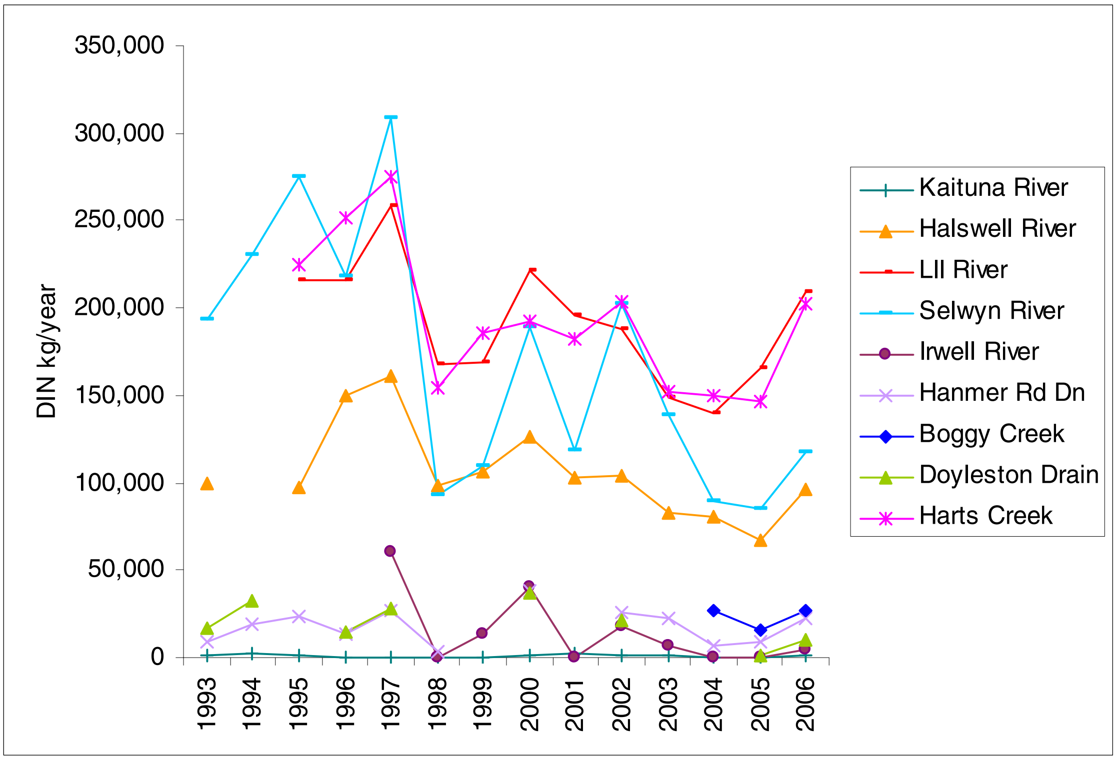

Figure 5: **Annual median DIN loads in lowland tributaries of Lake Ellesmere.**

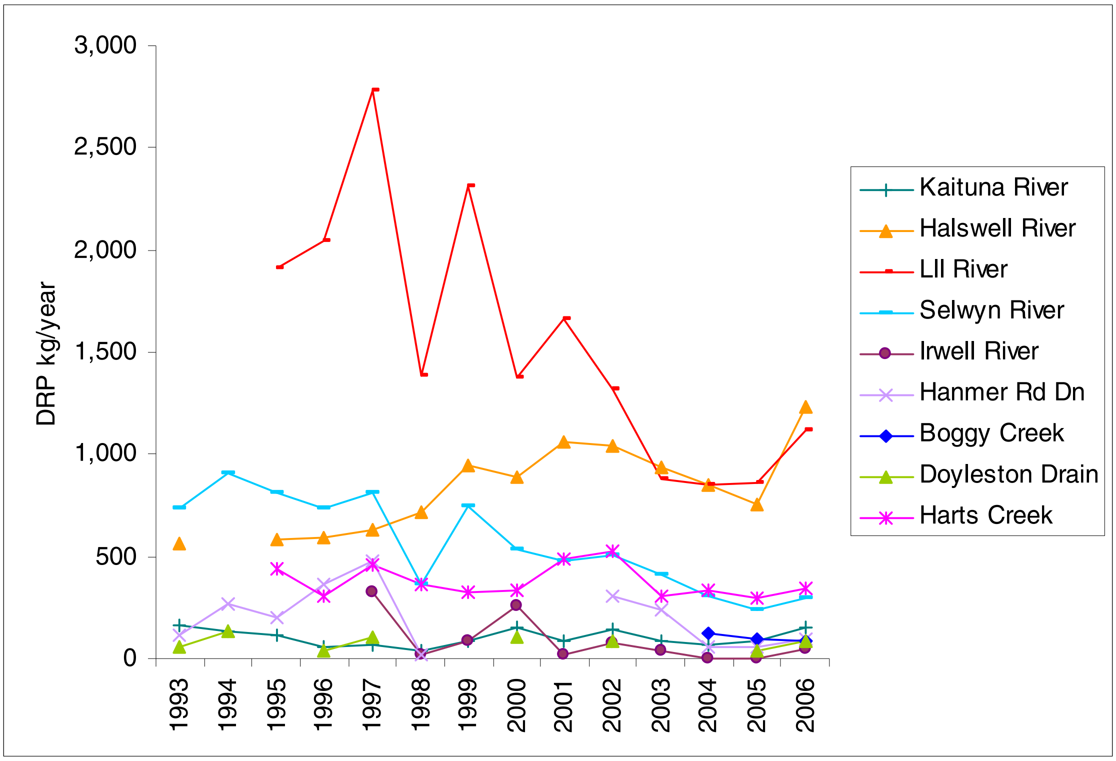

Figure 6: **Annual median DRP loads in lowland tributaries of Lake Ellesmere.**

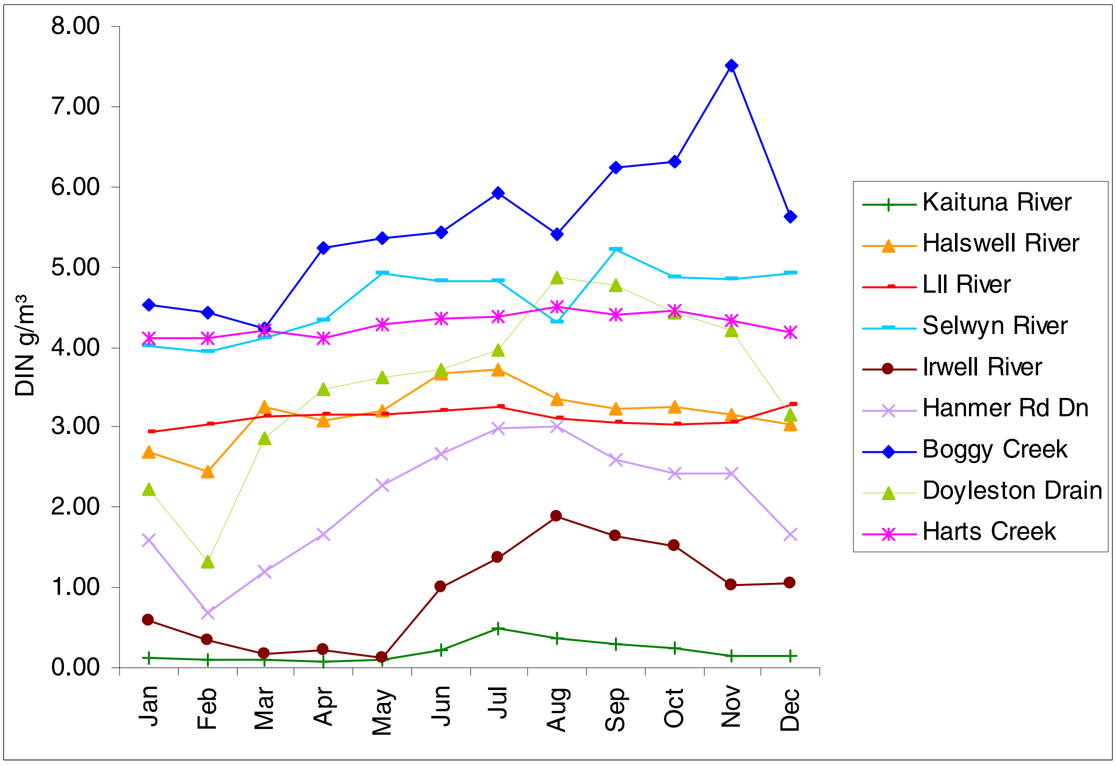

Figure 7: **Monthly median DIN concentrations in lowland tributaries of Lake Ellesmere.**

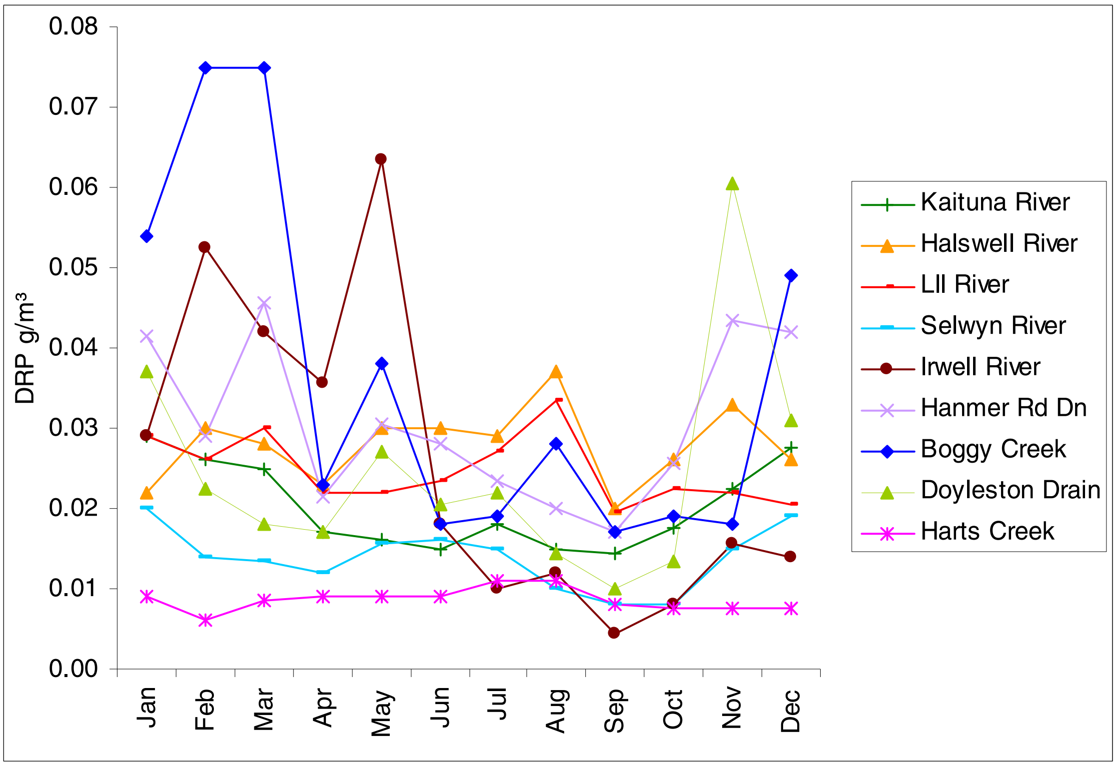

Figure 8: Monthly median DRP concentrations in lowland tributaries of Lake Ellesmere.

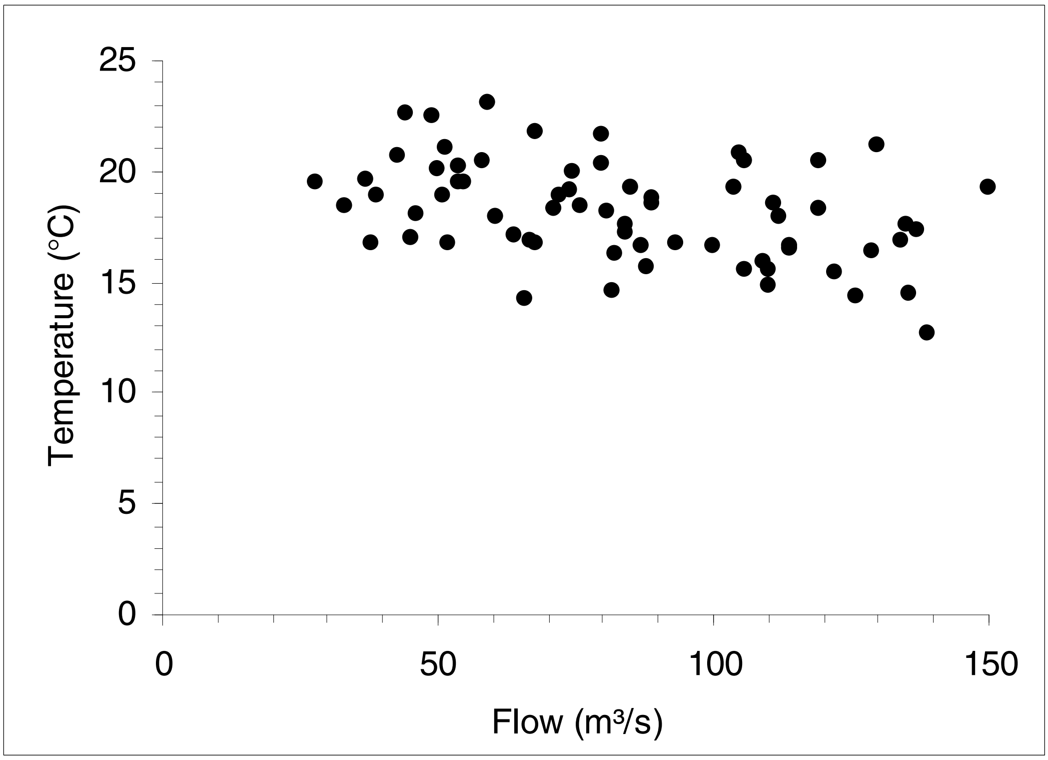

Figure 9: Summer (November – March) water temperatures at low flows in the Waimakariri River at Site CH4 (upstream of Old Highway Bridge).

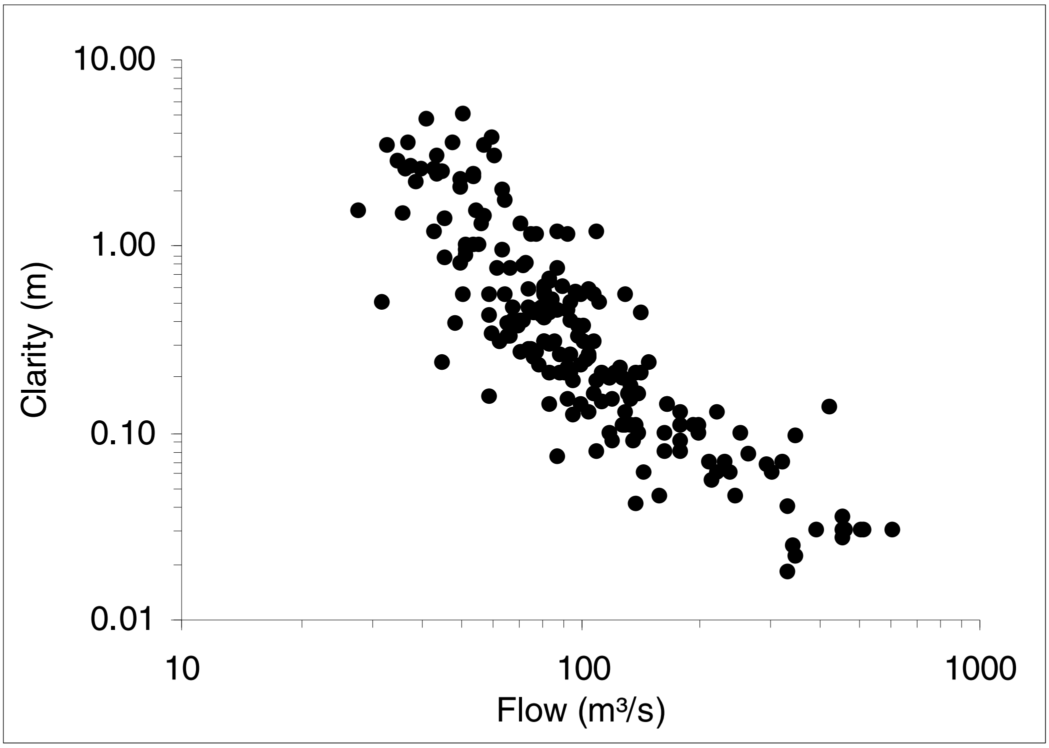

Figure 10: Relationship between river flow and clarity at Site CH4 (all flows).

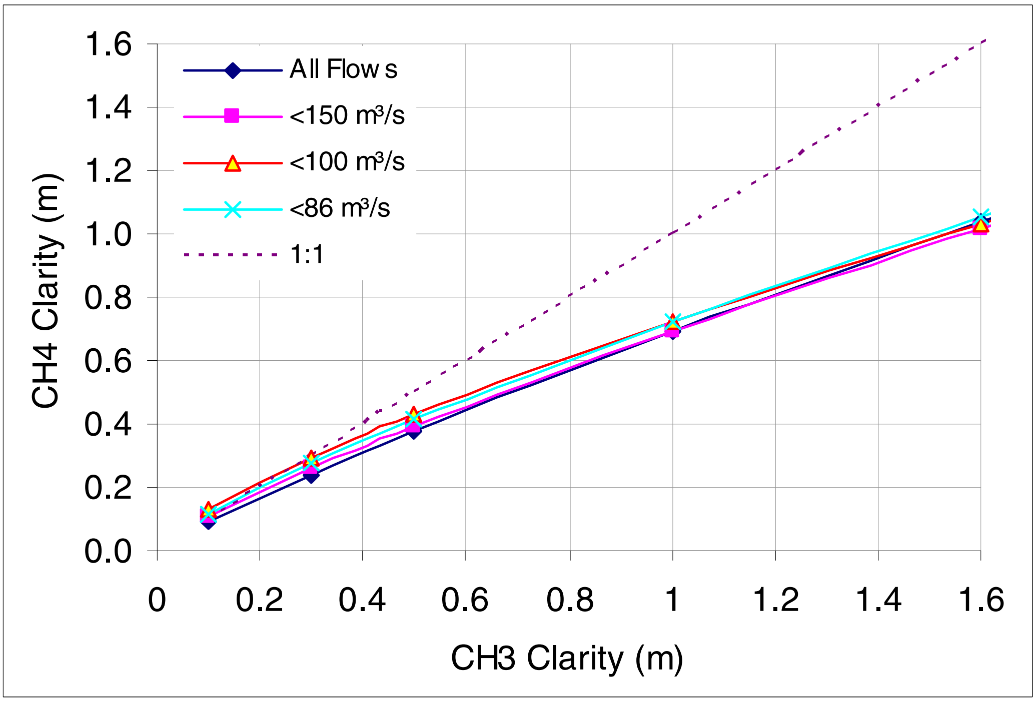

Figure 11: Predicted water clarity at downstream site CH4 based on upstream clarity at site CH3 at different flows (predictions based on log-log regression).

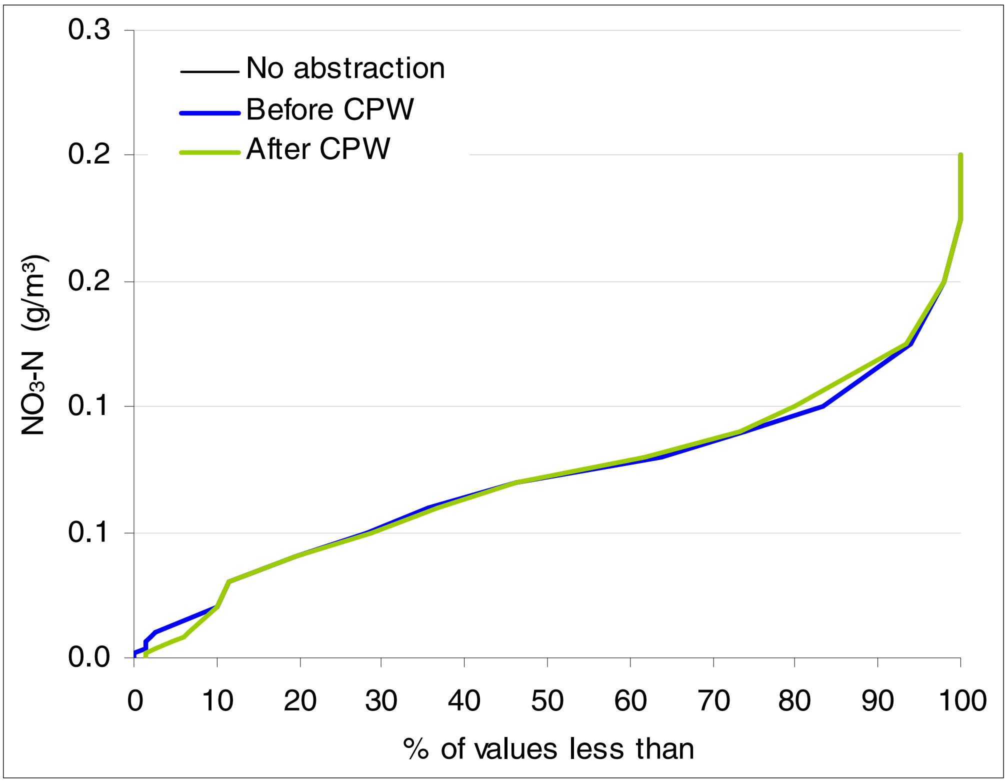

Figure 12: Cumulative frequency of NO3-N concentrations in the Waimakariri River at NRWQN Site CH4.

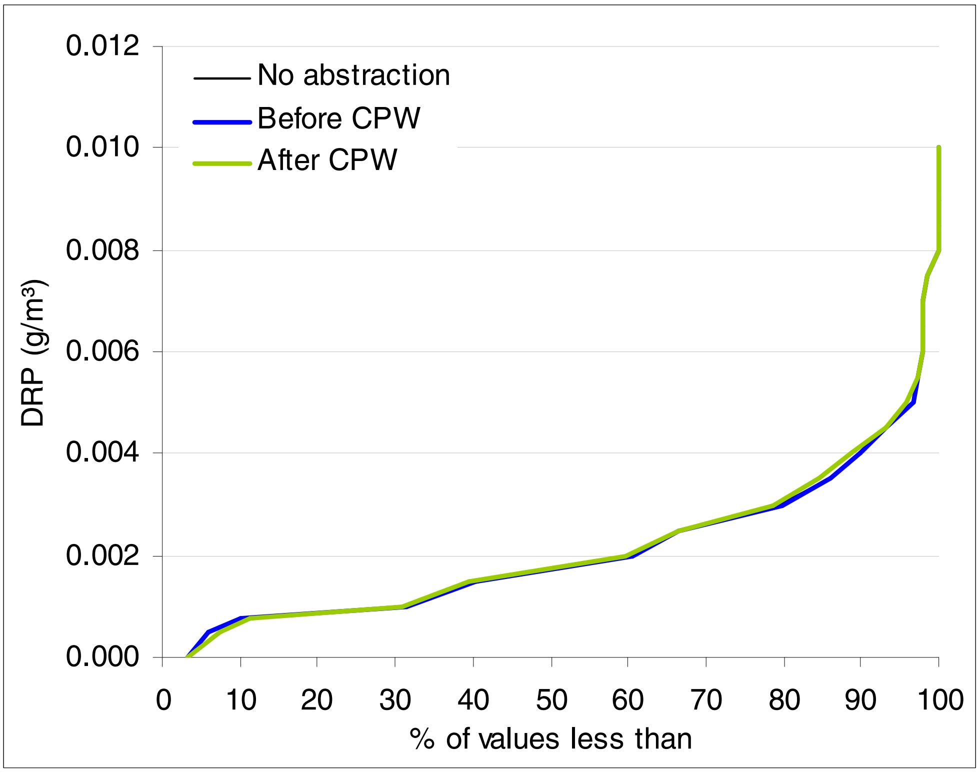

Figure 13: Cumulative frequency of DRP concentrations in the Waimakariri River at NRWQN Site CH4.

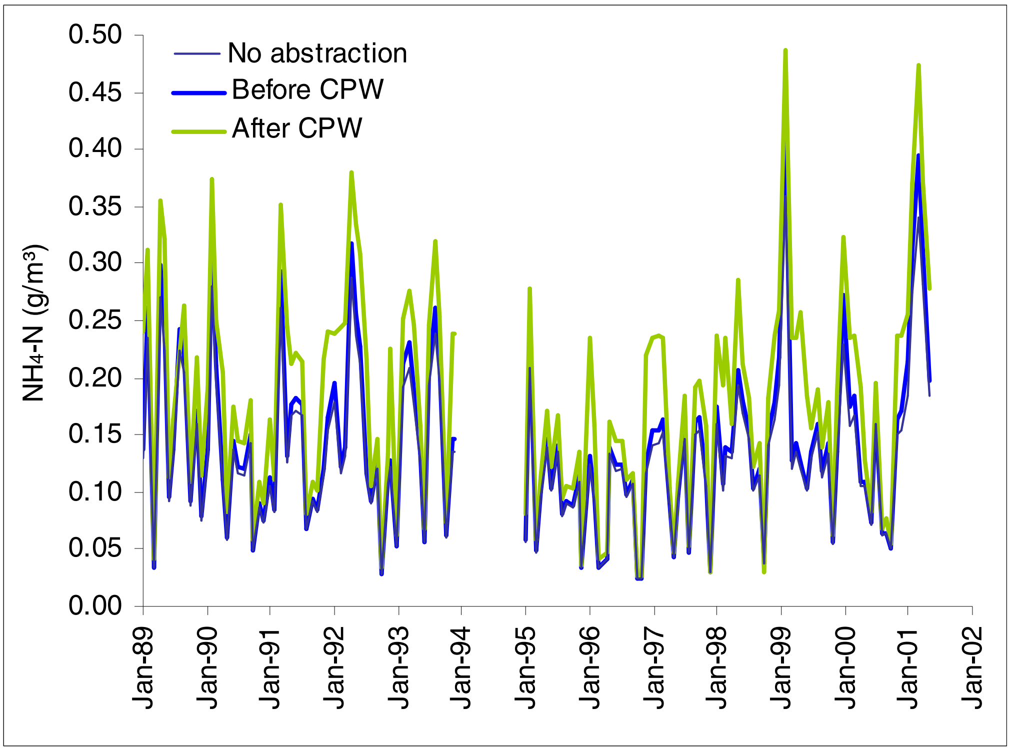

Figure 14: Predicted ammoniacal nitrogen (NH4-N) concentrations in the Waimakariri River downstream of the PPCS discharge, near State Highway One. Data are based on modelled flows from URS.

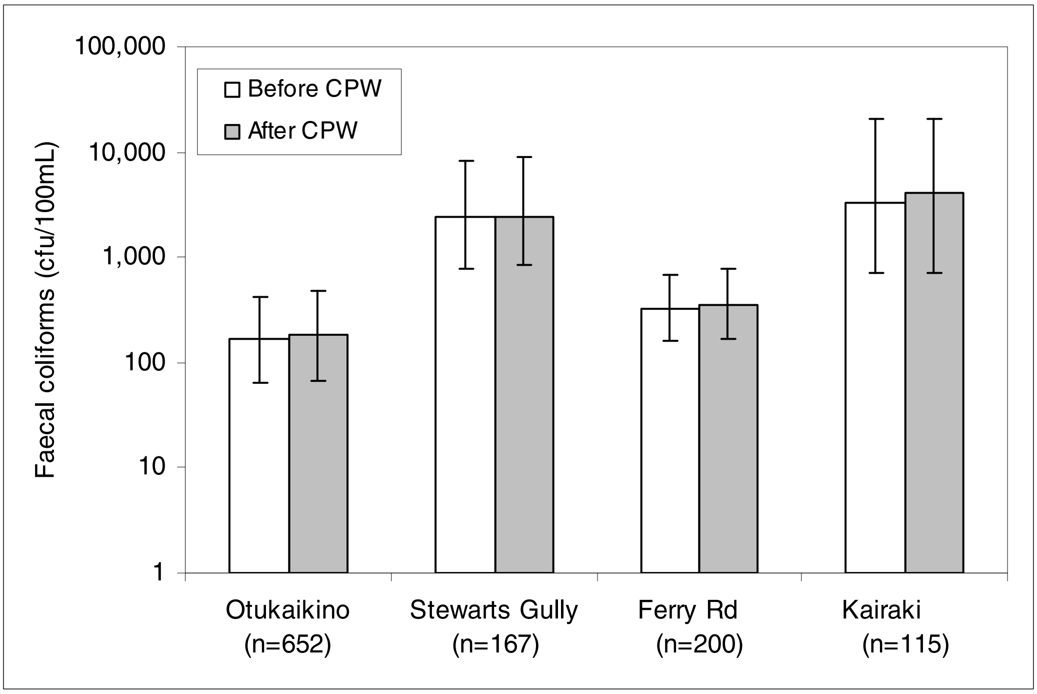

Figure 15: Predicted effects of the CPW water take on median (±25 and 75 percentile) faecal indicator bacteria numbers at four sites in the lower Waimakariri River.

WATER QUALITY DATA TABLES

Note that all data is presented in median (range) format. Data has been sourced from Environment Canterbury, Christchurch City Council and Niwa (National River Water Quality Network). Site locations are designated “E”, “C” or “N” according to data source.

Table 1: Summary of water quality data for Waimakariri and Rakaia Rivers.

River	Location	Grid Reference	Record	DO	Temp	pH	TSS	NOx-N [a]	TN	DRP	TP	Faecal Coliforms	*E. coli*[b]	*E. coli*
				%	°C	pH	g/m³	g/m³	g/m³	g/m³ P	g/m³ P	cfu/100 mL	cfu/100 mL	MPN/100 mL
Waimakariri														
	Bealey Bridge[E]	K34: 955-976	1984 – 2005	94 (83 - 150)	8.5 (4.9 - 13)	7.5 (6.6 - 7.9)	2.5 (2.5 - 24)	0.033 (0.0025 - 0.12)	0.04 (0.025 - 0.24)	0.003 (0.0015 - 0.008)	0.004 (0.002 - 0.18)	1 (0.5 - 23)	3 (1 - 7)	0.5 (0.5 - 2)
	Gorge[N]	L35: 330-604	1989 – 2006	100 (92 - 120)	9.4 (2.7 - 17)	7.7 (7.2 - 8.9)	nm	0.060 (0.016 - 0.16)	0.095 (0.025 - 0.52)	0.002 (0.0001 - 0.007)	0.013 (0.0006 - 1.1)	nm	51 (<10 - 517)	nm
	Old Highway Bridge[N]	M35: 813-546	1989 – 2006	101 (93 - 110)	14 (4.2 - 23)	7.8 (7.4 - 8.5)	nm	0.073 (0.003 - 0.28)	0.11 (0.02 - 0.62)	0.002 (0.0007 - 0.012)	0.018 (0.0007 - 1.8)	nm	130 (1 - 7200)	63 (0.5 - 69000)
	Stewarts Gully[E]	M35: 834-563	1974 – 2005	94 (16 - 110)	12 (4.5 - 22)	7.4 (5.9 - 8.7)	20 (2.5 - 2500)	0.11 (0.031 - 0.2)	0.24 (0.08 - 0.79)	0.014 (0.001 - 0.1)	0.034 (0.012 - 1.4)	2600 (20 - 2500000)	14000 (60 - 2500000)	130 (5 - 4800)
	Ferry Rd[E]	M35: 844-575	1992 – 2005	94 (70 - 130)	12 (1 - 20)	7.6 (6.4 - 8.5)	26 (1 - 1800)	0.17 (0.032 - 2.4)	0.345 (0.04 - 2.8)	0.01 (0.002 - 0.11)	0.033 (0.009 - 1.4)	330 (8 - 20000)	nm	150 (5 - 4800)
	Kairaki Yacht Club[E]	M35: 864-575	1973 - 2005	97 (74 - 110)	11 (4.5 - 22)	7.6 (6.9 - 8.2)	100 (15 - 190)	0.34 (0.064 - 0.85)	0.6 (0.12 - 1.4)	0.019 (0.007 - 0.2)	0.057 (0.019 - 0.64)	2900 (13 - 2200000)	7500	120 (1 - 3400)
Rakaia														
	Gorge Bridge[E]	K35: 014-425	2001 – 2005	100 (96 - 150)	10 (5.2 - 15)	7.8 (7.7 - 8.3)	nm	0.059 (0.0025 - 0.2)	0.065 (0.04 - 0.69)	0.003 (0.0005 - 0.01)	0.004 (0.004 - 0.57)	nm	nm	10 (0.5 - 120)
	SH1[E]	L36: 330-182	1980 – 2005	100 (56 - 153)	13 (4.5 - 21)	7.8 (7.1 - 8.7)	8 (2 - 495)	0.046 (0.003 - 0.29)	0.04 (0.04 - 0.67)	0.003 (0.0005 - 0.01)	0.009 (0.0025 - 2.1)	nm	36 (2 - 1600)	nm

Note: [a] Niwa NRWQN data (Gorge and Old Highway Bridge) is for NO_3-N only; [b] Gorge and Old Highway Bridge record from 2005-2006 only.

Table 2: Summary of water quality data for Upper Selwyn River and tributaries.

River	Location	Grid Reference	Record	DO	Temp	pH	TSS	NOx-N	TN	DRP	TP	Faecal Coliforms	*E. coli*	*E. coli*
				%	°C	pH	g/m³	g/m³	g/m³	g/m³ P	g/m³ P	cfu/100 mL	cfu/100 mL	MPN/100 mL
Selwyn	Whitecliffs[E]	L35: 204-490	1983 – 2005	100 (19 - 148)	12 (5.6 - 26)	7.6 (7.2 - 8.3)	11	0.24 (0.01 - 1.3)	0.78 (0.15 - 7.5)	0.007 (0.0005 - 0.11)	0.0495 (0.002 - 3.9)	52 (0.5 - 940)	31 (1 - 310)	20 (3 - 310)
Hawkins	Deans Rd Bridge[E]	L35: 318-543	2003 – 2005	94 (68 - 110)	9.8 (6.1 - 14)	7 (6.3 - 7.3)	1.3 (0.25 - 32)	2.2 (1.6 - 3)	2.3 (1.9 - 2.9)	0.0055 (0.003 - 0.016)	0.0065 (0.004 - 0.072)	nm	nm	140 (51 - 1000)

Table 3: Summary of water quality data for lowland streams, including tributaries of Lake Ellesmere

River	Location	Grid Reference	Record	DO	Temp	pH	TSS	NOx-N	TN	DRP	TP	Faecal Coliforms	*E. coli*	*E. coli*
				%	°C	pH	g/m³	g/m³	g/m³	g/m³ P	g/m³ P	cfu/100 mL	cfu/100 mL	MPN/100 mL
Styx	Marshlands Rd[C]	M35: 823-494	1992 – 2005	80 (65 - 94)	12 (9.4 - 15)	7.4 (6.7 - 7.9)	4 (1 - 25)	nm	nm	0.017 (0.0015 - 0.09)	nm	620 (50 - 8100)	530 (25 - 10000)	nm
Avon	Dallington Tce Bridge[C]	M35: 835-428	1992 – 2005	78 (55 - 91)	12 (6.3 - 19)	7.5 (7 - 7.9)	2.5 (0.5 - 25)	nm	nm	0.026 (0.004 - 0.071)	0.05	300 (10 - 3700)	210 (5 - 4200)	nm
Heathcote	Ford Rd footbridge[C]	M36: 830-390	1992 – 2005	71 (53 - 86)	12 (8.3 - 17)	7.4 (6.8 - 7.9)	3 (1 - 230)	nm	nm	0.043 (0.008 - 0.19)	nm	820 (100 - 220000)	630 (80 - 48000)	nm
Halswell	Duckpond Rd (Hodgins Bridge) [E]	M36: 754-193	1992 – 2005	82 (61 - 129)	12 (6 - 22)	7.5 (6.7 - 8.3)	2.5 (0.5 - 25)	nm	nm	0.037 (0.0035 - 0.23)	nm	nm	nm	nm
LII	Pannetts Rd[E]	M36: 657-235	1994 – 2005	86 (56 - 140)	12 (8.9 - 17)	7.8	2.5 (0.5 - 170)	3.1 (0.97 - 4.2)	3.4 (1.8 - 6)	0.03 (0.003 - 0.19)	0.046 (0.012 - 0.21)	120 (86 - 250)	nm	nm
Selwyn	Coes Ford[E]	M36: 627-234	1985 – 2005	98 (77 - 140)	13 (5.5 - 21)	7.6 (7.1 - 8.4)	2.5 (0.5 - 650)	3.7 (0.005 - 6.7)	5 (1.5 - 14)	0.02 (0.0005 - 0.57)	0.067 (0.004 - 1.4)	170 (10 - 3700)	180 (170 - 190)	170 (7 - 2000)
Irwell	Lake Rd[E]	M36: 598-179	1984 – 2005	94 (1.4 - 140)	12 (4.8 - 20)	7.2 (7 - 7.7)	3.5 (1 - 32)	1.1 (0.0025 - 4.5)	1.4 (0.17 - 4.8)	0.013 (0.001 - 0.45)	0.033 (0.004 - 0.89)	220 (100 - 3500)	nm	nm
Hanmer Rd Drain	Lake Rd[E]	M36: 594-172	1985 – 2005	100 (37 - 130)	11 (4 - 19)	7.3 (6.9 - 8.3)	3.8 (0.025 - 810)	2.2 (0.005 - 4.8)	2.8 (0.24 - 5.1)	0.027 (0.0015 - 0.62)	0.0505 (0.008 - 0.98)	220 (10 - 1500)	nm	nm
Boggy Creek	Lake Rd[E]	M36: 583-157	1985 – 2005	110 (68 - 160)	12 (5 - 20)	7.3 (6.8 - 8.7)	7.1 (2 - 310)	5.5 (4.2 - 7.5)	5.8 (4.6 - 7.7)	0.0205 (0.007 - 0.11)	0.055 (0.026 - 0.512)	480 (60 - 5300)	nm	4300 (1600 - 21000)
Doyleston Drain	Lake Rd[E]	M36: 580-148	1984 – 2005	100 24 - 180)	12 (4.5 - 23)	7.6 (7 - 9.5)	2.7 (0.025 - 460)	3.5 (0.034 - 11)	3.9 (0.28 - 7.6)	0.025 (0.001 - 0.67)	0.052 (0.013 - 1.2)	630 (330 - 5500)	nm	nm
Harts Creek	Lower Lake Rd[E]	M36: 568-121	1994 – 2005	89 (77 - 100)	12 (7.7 - 14)	7.7	5 (1.2 - 110)	4.2 (0.102 - 6.9)	4.4 (3.5 - 8.2)	0.008 (0.0005 - 0.22)	0.016 (0.004 - 0.38)	230 (210 - 630)	nm	nm

Table 4: Summary of water quality data for Lake Ellesmere/Te Waihora.

	Location	Grid Reference	Record	DO	Temp	pH	TSS	NOx-N	TN	DRP	TP	Faecal Coliforms	Chlorophyll *a*
				%	°C	pH	g/m³	g/m³	g/m³	g/m³ P	g/m³ P	cfu/100 mL	g/m³
Lake Ellesmere	Off Selwyn River mouth[E]	M36: 659-178	1983 –2005	100 (86 - 140)	12 (4.7 - 23)	8.2 (7.1 - 9.1)	170 (10 - 770)	0.063 (0.0025 - 4.3)	2.2 (0.18 - 9.6)	0.004 (0.0005 - 0.146)	0.22 (0.03 - 0.83)	25 (1 - 4000)	0.082 (0.0094 - 5.3)
	Mid-lake[E]	M36: 674-137	1983 –2005	100 (79 - 130)	13 (4.3 - 22)	8.3 (7.9 - 8.7)	210 (35 - 900)	0.021 (0.0025 - 2.6)	2.2 (0.2 - 7.5)	0.005 (0.0015 - 0.06)	0.24 (0.013 - 0.9)	5 (1 - 750)	0.0855 (0.006 - 58)
	South of Timber Yard Pt[E]	M36: 610-123	1985 –2005	110 (76 - 140)	13 (4.2 - 23)	8.3 (7.9 - 8.8)	180 (22 - 840)	0.026 (0.002 - 2)	2.1 (0.24 - 7.7)	0.004 (0.0005 - 0.049)	0.22 (0.018 - 0.84)	9 (1 - 980)	0.0849 (0.0123 - 49)
	Taumutu[E]	M37 600-064	1983 –2005	110 (90 - 140)	12 (4.5 - 23)	8.3 (7.6 - 8.8)	180 (26 - 590)	0.023 (0.0025 - 1.1)	2.1 (0.21 - 8.1)	0.004 (0.0005 - 0.069)	0.215 (0.016 - 0.84)	14 (1 - 600)	0.07695 (0.0028 - 10)

Table 5: Summary of sample sizes for Waimakariri and Rakaia Rivers

River	Location	Record	DO	Temp	pH	TSS	NOx-N	TN	DRP	TP	Faecal Coliforms	*E. col* (cfu/100 mL)	*E. coli* (MPN/100 mL)
Waimakariri	Bealey Bridge[E]	1984 - 2005	49	68	65	15	52	31	66	67	35	9	15
	Gorge[N]	1989 – 2006	215	216	215	0	216	200	210	209	0	23	0
	Old Highway Bridge[N]	1989 - 2006	222	223	222	0	223	207	223	219	0	27	0
	Stewarts Gully[E]	1974 - 2005	120	379	148	99	41	37	48	50	177	170	36
	Ferry Rd[E]	1992 - 2005	174	179	229	183	53	48	53	53	206	0	36
	Kairaki Yacht Club[E]	1973 - 2005	46	202	49	2	37	37	42	42	165	1	36
Rakaia	Gorge Bridge[E]	2001 - 2005	21	22	24	0	24	24	23	24	0	0	24
	SH1[E]	1980 - 2005	48	59	56	15	24	0	28	32	0	33	27

Table 6: Summary of sample sizes for Upper Selwyn River and tributaries.

River	Location	Record	DO	Temp	pH	TSS	NOx-N	TN	DRP	TP	Faecal Coliforms	*E. coli* (cfu/100 mL)	*E. coli* (MPN/100 mL
Selwyn	Whitecliffs[E]	1983 - 2005	50	96	55	1	401	442	401	456	96	8	24
Hawkins	Deans Rd Bridge[E]	2003 - 2005	14	14	16	12	16	16	16	16	0	0	15

Table 7: Summary of sample sizes for lowland streams, including tributaries of Lake Ellesmere.

River	Location	Record	DO	Temp	pH	TSS	NOx-N	TN	DRP	TP	Faecal Coliforms	*E. coli*	*E. coli*
Styx	Marshlands Rd[C]	1992 - 2005	31	38	61	60	0	0	61	0	157	155	0
Avon	Dallington Tce Bridge[C]	1992 - 2005	30	37	66	66	0	0	65	1	165	163	0
Heathcote	Ford Rd footbridge[C]	1992 - 2005	31	37	61	62	0	0	60	0	154	154	0
Halswell	Duckpond Rd [E] (Hodgins Bridge)	1992 - 2005	28	36	54	54	0	0	52	0	0	0	0
LII	Pannetts Rd[E]	1994 - 2005	121	133	1	150	150	128	150	150	5	0	0
Selwyn	Coes Ford[E]	1985 - 2005	200	231	62	170	611	506	661	716	80	2	24
Irwell	Lake Rd[E]	1984 - 2005	112	137	21	129	115	109	138	138	16	0	0
Hanmer Rd Drain	Lake Rd[E]	1985 - 2005	139	164	13	156	153	113	163	164	15	0	0
Boggy Creek	Lake Rd[E]	1985 - 2005	28	39	12	37	28	28	40	40	10	0	4
Doyleston Drain	Lake Rd[E]	1984 - 2005	128	153	17	149	138	100	153	153	13	0	0
Harts Creek	Lower Lake Rd[E]	1994 - 2005	122	132	1	131	131	109	131	131	5	0	0

Table 8: Summary of sample sizes for Lake Ellesmere/Te Waihora.

	Location	Record	DO	Temp	pH	TSS	NOx-N	TN	DRP	TP	Faecal Coliforms	Chlorophyll *a*
Lake Ellesmere	Off Selwyn River mouth[E]	1983 - 2005	143	166	16	163	166	154	161	167	113	144
	Mid-lake[E]	1983 - 2005	146	175	22	172	174	163	171	176	114	148
	South of Timber Yard Pt[E]	1985 - 2005	146	172	16	166	166	160	164	168	113	147
	Taumutu[E]	1983 - 2005	145	169	16	163	169	156	162	168	114	146