*in the matter of:* the Resource Management Act 1991

*and:* submissions and further submissions in relation to proposed Variation 1 to the proposed Canterbury Land and Water Regional Plan

*and:* **Various submitters as set out in Annexure 1**

# Joint rebuttal evidence of Nicholas Conland, Michelle Sands, Phillip Jordan and Richard Cresswell

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# JOINT REBUTTAL EVIDENCE OF NICHOLAS CONLAND, MICHELLE SANDS, PHILLIP JORDAN AND RICHARD CRESSWELL

## INTRODUCTION

***Nicholas Conland***

1 My name is Nic Conland, I am an Environmental Scientist. I have worked for Sinclair Knight Merz (now Jacobs) as an Environmental Consultant since 2010. My full qualifications and experience were outlined in our Evidence in Chief (EIC).

***Michelle Sands***

2 My name is Michelle Sands, I am an Environmental Scientist. I have worked for SKM (now Jacobs) since 2004 as an Environment Scientist. My full qualifications and experience were outlined in our EIC.

***Phillip Jordan***

3 My name is Phillip Jordan. I have worked for SKM (now Jacobs) as a Senior Hydrologist since January 2003. I am the Jacobs Practice Leader for Modelling Catchment Processes. My full qualifications and experience were outlined in our EIC.

***Richard Cresswell***

4 My name is Richard Cresswell. I have worked for SKM (now Jacobs) as a Senior Hydrogeologist since 2011 and lead the groundwater team in the Sydney office. Previously, I was a Principal Research Scientist with CSIRO Land and Water in Brisbane. My full qualifications and experience were outlined in our EIC..

## SCOPE OF EVIDENCE

5 In this evidence we address the EIC from the submitters selected in section 7:

5.1 We both raise point in support and disagreement in regards to specific points made by these witnesses

5.2 We briefly detail the findings from our calibrated Source model discussed in our EIC. This is primarily in response to submitters and to conclude our EIC.

6 As with our evidence in chief (*EIC*) we confirm we have read the Environment Court practice note and have complied with it in preparing this rebuttal evidence.

**SUBMITTER REBUTTAL**

7 In this evidence we have considered the evidence of the following submitters:

7.1 Fish and Game (Pearson);

7.2 Fish and Game (Cooke);

7.3 Fish and Game (Dewes);

7.4 Ngai Tahu (Wilcock);

7.5 Ngai Tahu (Begley);

7.6 Ngai Tahu (McK~~k~~erchar);

7.7 Central Plains Water (McIndoe).

**Fish and Game (Pearson)**

8 We have reviewed the EIC of Scott Pearson who proposes an alternative approach to managing the catchment based on “determining the ‘current state’ of the environment and the goal of returning this catchment back to ‘ecosystem health’~~.~~”. ~~-~~We agree with the assertion that a better understanding of the current state is required to make good decisions and our EIC makes note of several assessments made by our experts from the existing observed data to estimate the load to the lake and the function of denitrification in the baseflows around the large margins.

9 We agree with Pearson that there is a high level of uncertainty in the current modelling framework for the reasons discussed in our EIC. There is also a high reliance on OVERSEER® for determining the potential nitrogen loading rates to the shallow groundwater.

10 We also agree that a lack of time series and flow proportional monitoring makes it challenging for model calibration and predicative analysis. Any conclusions drawn from the current data are limited to the areas where the existing data sets are available.

11 In his EIC Pearson recommends a dual nutrient approach and while we agree with an adaptive management approach for determining the performance of regulatory measures it is equally challenging to apply an enforceable limit to catchment areas where the processes aren’t well understood and there is poor monitoring.

12 We agree with ECan that the phosphorus limits and loads are best managed as a lake load and the outcome managed through the recommended TLI range for the lake. However, this could change as

cause and effect relationships are established and monitoring data improves to support these conceptual and numerical models.

13 We find that while Pearson suggests that the most reliable measure of progress is against 'current state', we argue that decisions which require changes in peoples livelihoods and a cost benefit analysis require predictive modelling to answer questions about the outcomes for different regulatory options proposed. The suggestion that interim limits will provide certainty for regulators or landowners is flawed and will not solve issues with over-allocation.

14 We do agree that the Variation 1 plan would benefit from clear review methods, monitoring and an adaptive management approach.

**Fish and Game (Cooke)**

15 Dr Cooke raises some important issues regarding nutrient load impacts on surface waters in the Selwyn Te Waihora catchment and we agree, in principle, with two of the three critical conclusions of his evidence, namely (Dr Cooke's paragraph 9):

> "– there is justification in including phosphorous load limits in Selwyn-Waihora" considerations, thus applying a dual nutrient control approach for future assessments, and
>
> "– an improved methodology is required to monitor progress towards meeting the objectives of variation 1 and Policy A2 of the NPS-FM that the water quality of streams, rivers and Te Waihora should improve by 2037 (relative to current state)".

16 We do not, however, agree with Dr Cooke's third element of evidence, namely his approach to "load limit setting of nitrogen".

17 Specifically, the approaches adopted by both ECan and Dr Cooke will over-predict nitrogen loads to Te Waihora compared to currently observed loads from gauge data, or predicted by our revised modelling.

***Review and critique of current work on load limit setting***

18 Dr Cooke presents a relationship between flow and load and draws the incorrect conclusion that the power relationship illustrates that nitrate concentration increases with increasing flow.

19 Indeed, the relationship shown in Dr Cooke's Figure 1 demonstrates that the actual relationship involves a decrease in concentration with increasing flow, as the multiplier to convert flow to load is less than 1 (0.8972). The multiplier~~is~~ would need to be greater than 1 for concentration to increase under this relationship.

20 Further, examination of actual data from Coes Ford reveals there are likely three (not two as Dr Cooke surmises) flow regimes as illustrated in the figure below.

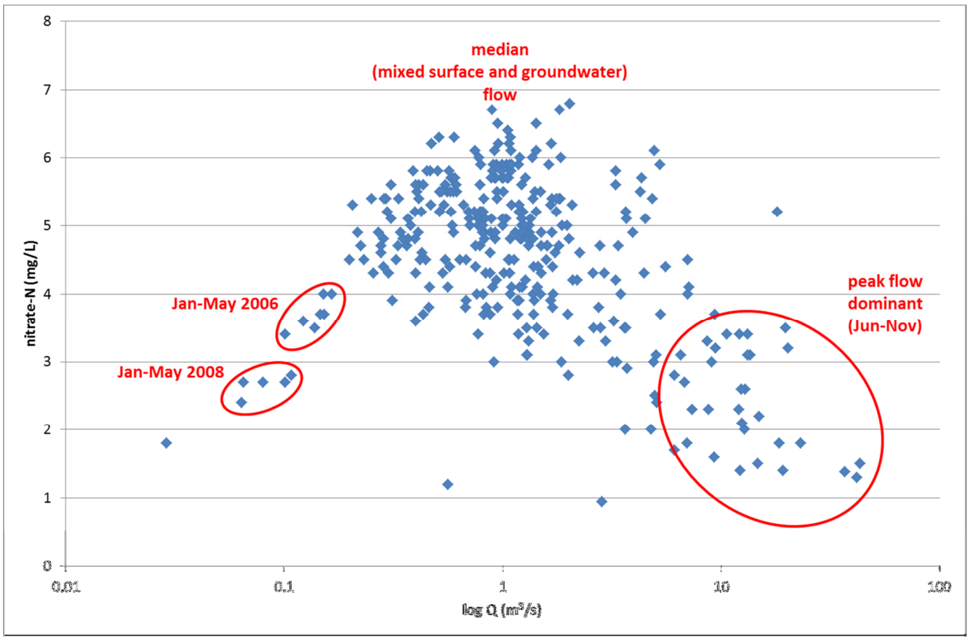


**Figure 1 – Nitrogen concentration vs flow relationship at Coes Ford gauge on the Selwyn River**

21 The data demonstrates why the curve generated by Dr Cooke deviates at low and high flows from the expected relationship. Thus, under median or normal flow conditions, there is a mix of nitrate derived from local surface water and groundwater sources. During high flow events (such as during winter and spring melt events) only surface water is seen, presumably dominated by surface water from high in the catchment and hence with low nitrate composition. During very low events (during dry summers), surface flow reduces almost to zero and flow is dominated by groundwater inputs that trend locally to ~3-4 mg/L nitrate N, as is seen in local bores in this area.

22 The relationship can also be seen when the time series of flow is plotted against nitrate concentration (~~figure below~~Figure 2). Peak flows correspond to distinctly reduced nitrate concentrations in the stream while very low flows have elevated nitrate concentrations.

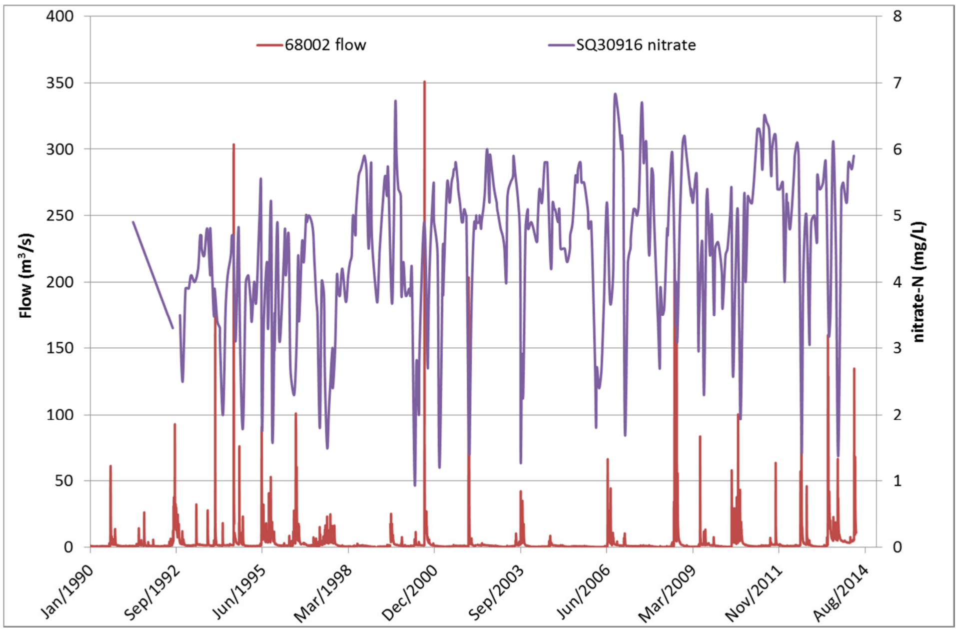


**Figure 2 – Time series of flow passing gauge 68002 at Coes Ford and samples from collector SQ30916 also at Coes Ford.**

23 Interestingly, there is a distinct increase in the average nitrate concentration after 1998. This can be explained by a shift in flow regime from a generally drying trend prior to 1992 to a wetting trend through to 1997 which kept nitrate concentrations lower than the long-term average and generated a greater number of peak flows higher than the long-term average. ~~The figure below~~Figure 3 illustrates this pattern by comparing the cumulative deviation from the long-term average daily flow to measured nitrate-N concentration at Coes Ford. Rising trends in the cumulative deviation curve represent wetter than average conditions (i.e. greater flow); falling trends represent drying conditions.

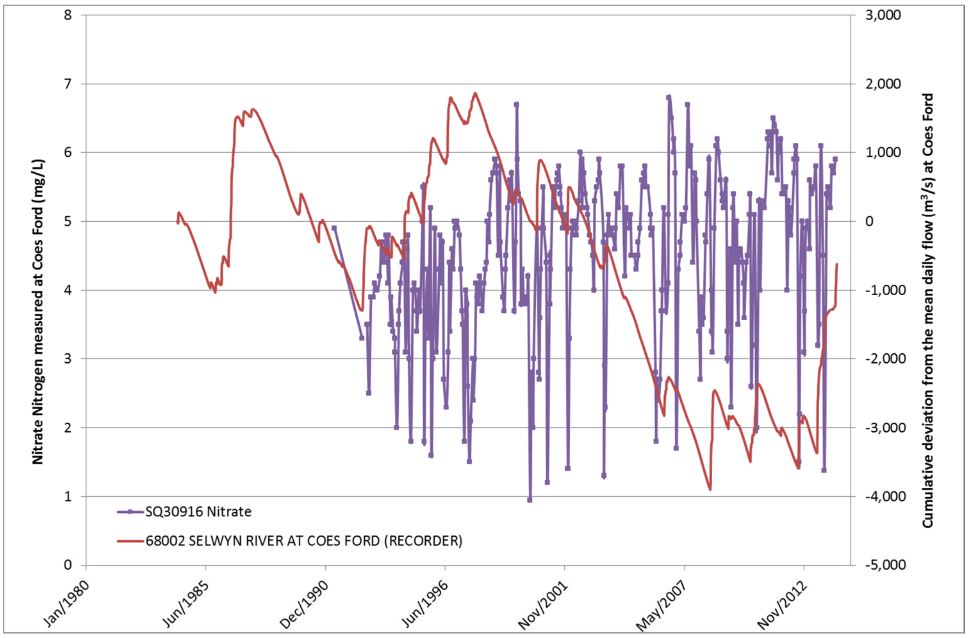


**Figure 3 – Cumulative deviation curve for flow at Coes Ford compared to nitrate concentration at the same location**

24 There is an apparent return to wetting conditions over the past year and this should be assessed against nitrate at Coes Ford to corroborate the previous observation of lower nitrate during wetter climate phases.

***Changes in water quality conditions for lowlands streams***

25 Regardless, ECan has assumed N concentrations in tributaries are independent of flow, while we can demonstrate that N concentrations are dependent on flow (specifically a decrease in concentration as flows increase). Hence, there will be lower concentrations in tributaries and the lake than those currently predicted by the ECan model and by Dr Cooke.

26 As Dr Cooke points out (paragraph 70): "The current ZCSP limit setting exercise is based on a top down (paddock to the lake) approach and because of lag and attenuation issues there has been no attempt to verify predictions with *[comparison to the]* current state of spring-fed tributary stream *[sic]* flowing into Te Waihora."

27 To produce reliable predictions of nutrient loads for scenarios that result in changes to groundwater recharge and surface runoff, the nutrient loads and concentrations transmitted via these different flow pathways should therefore be simulated in their own right.

28 The Source model simulates both surface and groundwater transmission pathways and attributes different concentrations to nutrients generated via both pathways.

***Is phosphorous an issue: the McDowell Paper on phosphorous transport in alluvial environments***

29 In general, we agree with Dr Cooke's summary and concerns regarding phosphorous transport in the Selwyn-Te Waihora catchment.

30 We would point out, however, that the presence of (low levels of) phosphorous is conducive to nitrate up-take by plants (including phytoplankton) and levels up to those currently observed do not pose a risk to the environment.

31 Further, phosphorous will tend to remain fixed in plant material, and will be buried as the plants die and sink to the lake floor during sedimentation. Hence, phosphorous (together with nitrate) will be removed from the water column under normal lake processes and will not be "recycled" as Dr Cooke states in paragraph 51.

32 Indeed, the addition of phosphorous to degraded (acidified) lakes in the northern hemisphere has been shown to aid in nitrate reduction, albeit at lower levels of phosphorous than is observed in Selwyn-Te Waihora, and this has been shown to aid in the restoration of endemic lake communities, which commonly does not happen using other remediation methods (such as liming) to fix nitrate and phosphorous.

33 The strongly correlated relationship between nitrate and phosphorous in ecosystem function and response emphasises the need to apply a combined nutrient control approach to future assessments.

34 Dr McDowell's research into phosphorous pathways between surface and groundwater systems is a focus of Dr Cooke's evidence and highlights a potential legacy for P enrichment for lowland spring-fed streams for decades to come.

35 As noted for nitrate, elevated levels (0.03 mg/L) of dissolved reactive phosphorous is observed in mid-catchments. Lower levels (<0.01 mg/L) are observed in bores near the lake.

36 Further investigations are therefore required prior to introducing P limits at farms as well.

**Fish and Game (Dewes)**

37 Dr Alison Dewes ~~(Dewes)~~ in her EIC makes statements about the assessment for nitrogen allocation for the catchment and in particular Central Plains Water (CPW).

38 The land use and nitrogen load assumptions we have made in our modelling differs slightly from those assumed by Environment Canterbury and discussed by Dr Dewes in T~~t~~able 1. (Tables 2-7 EIC)

39 Our assessment of the existing nitrogen allocation for CPW ~~at~~ in 2014 of 1884 tonnes is based on best available information landuse and Lilburne et al (2013) loads, and therefore the calculated average leaching rate is consistent to the loads calculated elsewhere within the catchment.

40 It is worth noting that Dr Dewes' assertion in paragraph 20 is incorrect. 1500 tonnes over 45000 ha would equal an average of 33kg/ha/yr, rather than the 44kg/ha/yr calculated by Dr Dewes. Furthermore, the CPW area is 60,000 ha and in the existing situation approximately half of the land is irrigated.

41 The existing load we calculated for the ~~remaining load~~ non-CPW catchment areas is ~~2730~~ 3204 tonnes~~; this is less than Environment Canterbury's assumed load of 2910 tonnes~~. Our load calculation was based on Lilburne et al (2013) leaching rates and landuse data supplied by Environment Canterbury, with minor modifications made for land use change, and includes 474 tonnes for hills. Our assumptions do not allow for intensification of existing land above the existing baseline for the respective landuses.

42 In paragraph 22, Dr Dewes discusses the additional load allocated to CPW. Our calculations indicate the additional load allocated to CPW is less than assumed by Environment Canterbury. The existing load for CPW is 1884 tonnes and the proposed load at 2017 is 1928 tonnes. The load following the clawback provisions is estimated at 1769 tonnes.

43 In reference to Dr Dewes' paragraph 24, we disagree that CPW land is allowed to leach more that existing users under the proposed V~~v~~ariation 1. Under Policy 11.4.14 where properties convert from dry land to irrigated, the nitrogen loss rates from the outset shall be managed in accordance with the proposed reductions in policy 11.4.14. Contrary to Dr Dewes' assertion, policy 11.4.17 requires a stricter level of land management to be adopted in CPW before it is required elsewhere in the catchment.

44 In paragraph 156 of her EIC, Dr Dewes states "For the Canterbury Plains aquifers, denitrification processes are unlikely to significantly reduce nitrate concentrations as drainage water moves down through the soil profile and gravels are overlying the aquifers". Dr Dewes provides no analysis to support this assertion. We disagree with this statement.

45 Our analysis of nitrate state indicates that denitrification is occurring, in the Canterbury Plains, particularly around the lake. Our understanding of the denitrification process is detailed in our EIC.

46 In paragraph 157, Dr Dewes goes on to assert the zone committee solutions package will result in the nitrate levels in groundwater and shallow wells rising by 20-25% as a result of the additional CPW load. Dr Dewes provides no analysis to support this assertion.

47 We have developed a calibrated model to assist in determining what impact the proposed plan would have on nitrate levels, and contrary to Dr Dewes' assertions we have concluded as outlined below.

**Groundwater quality and Likelihood of exceedance of Maximum acceptable values of nitrate in drinking water**

48 A number of submitters have touched on the issue of groundwater nitrate levels (as are relevant to drinking water).

49 Our EIC discussed a Monte-Carlo simulation approach, based upon observed Nitrate concentrations in groundwater bores, to estimate the likelihood of exceeding the Maximum Acceptable Value (MAV) for drinking water quality of 11.3 mg/L of Nitrate Nitrogen. The Monte-Carlo simulation approach also provided an estimate of the likelihood of exceeding 6.6 mg/L of Nitrate Nitrogen, approximately half the MAV.

50 The Monte-Carlo simulation approach was applied at bore L36/0871 which is located 5 km to the north-west of Te Waihora/Lake Ellesmere and is in an area with shallower groundwater levels, where the low observed Nitrate concentrations in the bores reveal that denitrification of the groundwater is occurring. On the basis of observed median nitrate concentrations in many observation bores, statistics estimated from Nitrate concentrations at bore L36/0871 would be representative of groundwater quality in a zone located up to about 10 km from the lake boundary.

51 The Source model was used to estimate the mean Nitrate Nitrogen concentration in groundwater across the climatic period in the model run from 1 July 1980 to 14 May 2014, for each modelled scenario. The Monte-Carlo simulation approach was then used to estimate the likelihood (on any given day) of exceeding 11.3 mg/L and 6.6 mg/L.

52 Table 14 in the Appendix shows that under all scenarios modelled the likelihood of exceeding the MAV in the shallow groundwater in the zone where denitrification is very low is approximately 0.1%. There is a very small simulated increase in the likelihood of exceeding the MAV under Scenario 2b (with CPW), although this change in probability is extremely low. Implementation of the proposed caps on Total Nitrogen (TN) leaching rates as set out in Variation 1 (modelled Scenario 3a) results in reductions in the likelihood of exceeding the MAV, although once again the reductions in probability are very small.

53 The likelihood of exceeding MAV for Nitrate Nitrogen concentrations in groundwater is higher under existing conditions further away from the Lake. At greater than about 10 km from the lake, the water table is beneath the land surface and most groundwater movement is either down on laterally towards the lake and hence there is limited capacity for denitrification to occur. The Source model was not able to provide reliable mean annual predictions on Nitrate Nitrogen concentrations in the groundwater more than about 10 km from Te Waihora / Lake Ellesmere. We have therefore not provided an estimate of the likelihood of exceeding the MAV for Nitrate Nitrogen for areas where groundwater flux is not upwards which corresponds to areas more than about 10 km away from the lake.

54 There are currently over 1,000 bores located within the shallow aquifer in the de-nitrification zone near the lake that we would argue would not undergo any significant nitrate increase.

**Ngai Tahu (Wilcock)**

55 We have reviewed the EIC of Dr Wilcock and strongly endorse the recommendations (near-lake wetlands and increased riparian vegetation) made in his evidence.

56 In particular we welcome the opportunity to improve the outcomes discussed in our EIC for increased denitrification and provide reductions in nitrogen loads to the lake.

57 We do note in Dr Wilcock's EIC at para's 21,22 and 34 he assumes the ECan groundwater lag times of 10 to 30 years will apply. Our own work to develop a conceptual model for the groundwater system indicated much quicker travel times. These indicate from the observed data that the mean groundwater travel times for nitrates are closer to 10 years or less.

58 This would imply that measures to manage nutrients through a matrix of good management (MGM) practices and through catchment interventions may have a more rapid effect on improving the lake TLI than Wilcock currently assumes.

59 We also note that Wilcock acknowledges that the predominant driver for lake TLI is the existing legacy nutrient cycling.

**Ngai Tahu (Begley)**

60 Ms Cath Begley's submission outlines a number of proposed changes to objectives policys and rules with an emphasis on reflecting Ngai Tahu cultural values and a long term vision for the receiving environments. We support the general concepts within the evidence, but we have not undertaken specific analysis to determine the effects of the Begley's proposed changes to rules and policy.

61 Ms Begley supports the principle of catchment load. In paragraph 70 of her EIC, she states “One should have a reasonable degree of confidence that, whatever the catchment load is, if it is adhered to then the water quality objectives will be reached”. ~~(para 70), w~~We agree with this statement~~, and~~. However, we consider the uncertainty in the methodology adopted by ~~of the assess the effects of Variation 1 by~~ Environment Canterbury to assess the effects of the load, does not provide sufficient confidence that variation 1 will have effects that are consistent with those outlined in the Section 32 report.

62 We agree with Ms Begley’s statement that setting the proposed clawback in policy 11.4.14~~-~~ prior to Environment Canterbury understanding~~–~~ the benefits of Good Management Practice (GMP)~~,~~” is not good planning”~~.~~ (paragraph 80). We recommend that a catchment load is set to account for ~~Good Management Practice~~GMP and is calculated in a manner that enables on-~~-~~farm calculations of leaching to be compared to the catchment load.

**Ngai Tahu (McKerchar)**

63 We support in general the EIC provide by Dr McKerchar.

64 Dr McKerchar (EIC) presents a regression model that demonstrates a temporal trend in seasonal (90 day) low flows in the Selwyn River at Coes Ford that is additional to the signal presented in estimated recharge to groundwater and recorded seasonal flow at Whitecliffs. Dr McKerchar identified an apparent trend of 32 L/s/year reduction in 90 day low flow across a 22 year period (1984-2006).

65 Dr McKerchar makes the assumption that the reduction in seasonal flows is caused by increases in irrigation within the catchment, hence causing an increase in evapotranspiration and reduction in long-term recharge to groundwater. However, the model used is purely statistical – there is no causative process reflected in the model. It is possible that some or all of the reduction in flow with time in the observed data is caused by a factor other than increase in irrigated water use in the catchment.

**CENTRAL PLAINS WATER MODELLING**

**Evidence of Mr Ian McIndoe**

66 We support in general the EIC provide by Mr McIndoe, in particular his comments on the previous review of the ECan modelling work.

67 As stated in our Evidence in Chief (EIC), we have established a Source integrated catchment model of the Selwyn-Waihora catchment area. The Source model simulates surface and groundwater transmission pathways for both flows and nutrients. The Source model also simulates irrigation and the extraction of

water from surface and groundwater to irrigated parts of the catchment.

68 As a single, integrated, model, Source has a considerable advantage over the modelling approach adopted by ECan, which relied upon integrating modelling from four separate models. ECan's modelling approach utilised separate models for modelling of the water balance within soils in the catchment, groundwater flow modelling, modelling of stream flows and hydrological modelling of water quality.

69 At the time we presented our EIC, we were still in the process of calibrating the Source model to observations in the catchment. The Source model calibration has now been completed and we present in this statement of evidence a summary of the outputs from the Source model.

70 We agree with the criticisms of the ECan approach in the evidence of Dr McIndoe that the adoption of separate models for each component of the water and nutrient balance in the catchment leads to potential inconsistencies in assumptions between models. We agree with Dr McIndoe's criticisms that the potential inconsistencies then result in incorrect predictions and conclusions made from the overall modelling suite.

71 In particular, we agree with Dr McIndoe's ~~(~~EIC (paragraphs 34-37) in that the ECan approach appears to have double counted the quick flow component of flow and that the approach used does not allow for the quick flow component to change as the modelled area under irrigation changes.

72 We also agree with the criticism of Dr McIndoe (EIC paragraph 58) that there is inconsistency with the land surface recharge rates estimated by Lilburne et al. (2013) for different soil types and landuses with the recharge rates to groundwater that were used in R14/11.

73 The Source model that we have developed does not suffer from these limitations, as the integrated model estimates the water required for irrigation water use, generates quick flow, generates drainage to groundwater and simulates transmission of groundwater flows in a single model that maintains the overall water balance.

74 The Source model simulates the water balance in the soil profile on a daily time step for the period between 1972 and 2014, using the Soil Moisture Water Balance Model (SMWBM). The Source model simulates the water stored in the soil profile on a daily basis using rainfall and potential evapotranspiration time series on a daily basis. For irrigated landuses, the Source model estimates the depth of

irrigation water likely to be required by the soil and adds this to the soil profile.

75 The Source model was run to estimate the mean annual rate of groundwater recharge in each subcatchment of the Source model, for irrigated and dryland landuses and for "lighter soils" (soil classifications XL, VL and L) and "heavier soils" (M, H, Pd and PdL). For each of the four combinations of irrigated / dryland and lighter / heavier soils, the outputs from the Source model were used to estimate the mean annual recharge rates for the modelling period for mean annual rainfall bands of 650, 750 and 850 mm.

76 The mean annual rates of recharge estimated by the Source model are presented in Table 4 in the Appendix. When compared with the mean annual rates of recharge estimated by Lilburne et al. (2013), the rates from the Source model on virtually all combinations are larger, typically between 30% and 150% larger than the estimates from Lilburne et al. (2013).

77 The Source model also estimated the mean annual load of TN from each landuse in each model subcatchment, which was the sum of the load generated via both surface and groundwater flow pathways. Some of the TN load generated and transmitted into the groundwater remains in the groundwater system, travelling beneath Te Waihora and out to sea. Some of the TN load that is generated as drainage and goes into the groundwater system is de-nitrified in the shallower layer of the groundwater system and the loads of Nitrate and TN transmitted into the lowland streams, for both reasons, are lower than the loads as they are generated in the catchment.

78 Table 1, Table 2 and Table 3 present the mean annual volumes of total surface runoff and drainage and mean annual TN loads generated for the Rakaia-Selwyn, Selwyn-Rakaia and Selwyn-Waimakariri zones respectively for the existing conditions scenario (Scenario 1). The loads and total runoff and drainage generated represent the mean values across each zone: the Source model internally simulates variability in the flow and TN load generated due to climatic variation between subcatchments within each zone.

79 The mean annual generation rates per unit area simulated in the Source model (as presented in the tables) may be slightly higher than the rates indicated in Lilburne et al. (2013) for two reasons. Firstly, the estimates from the Source model include both surface runoff and drainage to groundwater whereas Lilburne et al. (2013) only documents the drainage to groundwater and the TN load associated with drainage to groundwater). Secondly, the Source model simulates the rainfall signal occurring on each subcatchment in the model and there are some subcatchments with higher mean

annual rainfall (and hence higher total flow and TN load generation) than the three rainfall categories that were considered by Lilburne et al. (2013). Having stated those two qualifications, the mean annual TN loading rates across the three zones calculated by the Source model for the existing conditions scenario (Scenario 1) are comparable with those documented by Lilburne et al. (2013).

80 The mean annual TN loading rates per unit area estimated from the Source model demonstrate consistency with loading rates that would be expected (on average) with rates that would be expected from other models, such as ~~Overseer~~OVERSEER®. For the same landuse type in the Source model, irrigated land produces higher total flow generation and higher mean annual TN load per unit area than dryland. The highest loading rates per unit area are produced by dairy and dairy support landuse categories, with grazing, arable and horticulture in the mid-range and very low loading rates produced from native and plantation forests.

**SCENARIOS RUN USING THE SOURCE MODEL**

81 The Source model was run for five different scenarios discussed in our EIC in T~~t~~able 14.

82 The outputs of the model address a number of the matters raised in submitter evidence.

**Flows in Lowland Streams**

83 The Source model was used to estimate a daily time series of flows for each scenario. These daily time series of flows from the model run were used to estimate the mean daily flow (MDF) and mean annual 7-day low flow (7dMALF). Although the Source model was run for the period from 1 January 1972 to 14 May 2014, the analysis of flow statistics was restricted to the period between 1 July 1980 and 30 June 2013 to allow for adequate warm up period for the Source model to be accurately representing flows.

84 The MDF and 7dMALF for Scenario 1 are comparable, as a means of testing the model calibration, against gauged flow data for sites where it is available. MDF and 7dMALF flow statistics were computed from gauged flow data for the entire period of record, whilst the flow statistics were computed from the Scenario 1 outputs for the period between 1 July 1980 and 30 June 2013. Some of the differences in flow statistics between modelled and gauged may be attributable to differences in climatic conditions between the periods used for analysis of gauged data and model output – these differences are potentially more considerable where the gauged data record is shorter.

85 During the Source model calibration process, other criteria to establish calibration of the model were also used, including the correlation in the time series between gauged and modelled flows, the probability distribution (or flow duration curve) of gauged and modelled flows, the relative prevalence of generation of surface runoff from irrigated and dryland areas and mean annual drainage rates to groundwater (as discussed elsewhere in our evidence).

86 Table 5 presents a comparison between the mean daily flows estimated from the Source model for the existing conditions scenario (Scenario 1), gauged flows and the equivalent ECan Scenario 1. The comparisons vary between gauging sites, in some cases with the Source model over-estimating the mean daily flow and in some cases under-estimating. Given the potential inconsistency in the periods used for calculating the statistics from the gauged data and the model, these differences are acceptable.

87 Table 6 presents a comparison between the 7dMALF statistics estimated from the Source model for the existing conditions scenario (Scenario 1), gauged flows and the equivalent ECan Scenario 1. The comparisons vary between gauging sites but in general the Source model is producing lower estimates of 7dMALF for the existing conditions scenario than revealed by the gauged data or ECan’s equivalent model run. The Source model is apparently not sustaining baseflows in the lowland streams for the existing conditions scenario to an equivalent level as was observed in the gauged data. However, given the match in the mean daily flows, the Source model is representing flow conditions across moderate and high flow ranges that are comparable with gauged flows.

88 Table 7 compares the modelled mean daily flows between the Source model simulations for the Scenarios. The naturalised scenario results in an increase in mean daily flow compared with the existing scenario in the Halswell River, Harts Creek and the LII River but a minor decrease in mean daily flow for the Selwyn River and the Hanmer Road drain. The removal of irrigation extractions under the naturalised scenario also results in reduction in recharge to groundwater in some parts of the model and this redistribution of baseflow in the interconnected groundwater system represented in the Source model results in the variation in the impact of the naturalised scenario on mean daily flows. Table 8 shows that under the naturalised scenario 7dMALF is projected to increase substantially in the lowland streams from existing conditions, particularly for the lowland streams with smaller surface water catchments and hence a larger proportion of their flow contributed via groundwater.

89 As shown in Table 7, implementation of the proposed Schedule 10 limit on extractions provides no modelled improvement in mean daily flows under existing conditions. The Source model finds that implementation of the proposed Schedule 10 limit would actually reduce 7dMALF from existing conditions in most of the lowland streams (by between -1% and -5%), as artificial recharge from irrigation would be reduced in drier years and this more than offsets the reduction in extractions from groundwater.

90 Implementation of the CPW scheme (Scenario 2b) increases both MDF and 7dMALF from existing values in almost all of the lowland streams that were modelled.

**Water Quality in Lowland Streams**

91 The Source model was used to simulate Dissolved Inorganic Nitrogen (DIN) concentrations in the lowland streams on a daily timestep. The analysis of DIN concentrations was restricted in all simulations to the climatic period between 1 July 1980 and 30 June 2013. During the calibration process, the probability distribution of DIN concentrations from the Source model were compared to the probability distribution of DIN concentrations from in-stream water quality monitoring data.

92 Results from simulation of in-stream DIN concentrations are presented for the modelled scenarios – with median simulated concentrations presented in Table 9 and 95$^{th}$ percentile simulated concentrations presented in Table 10.

93 The naturalised landuse scenario results in substantial reductions in simulated DIN concentrations in the lowland streams. As would be expected, removal of all irrigated landuse and the associated conversion of landuse from those with higher TN leaching rates to lower TN leaching rates (assumed to be dryland arable farming) substantially reduced DIN concentrations.

94 Modelled in-stream DIN concentrations increase under Scenario 2a from the Scenario 1. Median DIN concentrations increase by between 2% and 18% while 95$^{th}$ percentile DIN concentrations increase by 1% and 15%. The increase in DIN concentrations were due to an assumed increase in TN load to 15 kg/ha/year for those landuses that were below this threshold in the Scenario 1 model.

95 Simulated changes for in-stream DIN concentrations for the CPW (Scenario 2b) were relatively similar to those simulated for Scenario 2a. Median in-stream DIN concentrations in the lowland streams increase between Scenario 1 and Scenario 2b by between 1% and 17%, with the exception of Harts Creek, where there was a projected reduction in median DIN concentration of 4%.

96 Implementation of the proposed caps on TN leaching rates as set out in Variation 1 (modelled Scenario 3a), results variable changes in DIN concentrations between the lowland streams from existing conditions (Scenario 1). Increases in median DIN concentration of 6-7% were simulated for Scenario 3a in the Selwyn and Halswell Rivers but reductions of between 3% and 16% in median DIN concentrations were simulated for the LII River, Harts Creek, Lee River, Boggy Creek, Hanmer Road Drain and Doyleston Drain.

97 Changes in DIN concentrations between scenarios vary between the lowland streams due to spatial variation in the generation and transmission of surface runoff and groundwater-fed baseflow, the differential impact of where the changes in TN loading rates are projected to occur in the catchments and the soil types upon which the TN loading rates are simulated to change.

**T~~O~~OTAL NITROGEN AND NITRATE NITROGEN LOADS DELIVERED TO LAKE ELLESMERE / TE WAIHORA**

98 The Source model was used to simulate the total flow of water, TN load and Nitrate load delivered to Lake Ellesmere / Te Waihora. The flows and loads were delivered in the Source model via the lowland streams draining to the lake, with those flows coming via a combination of surface and groundwater flow pathways.

99 Table 11 shows the simulated contributions to the DIN load to Lake Ellesmere / Te Waihora from each stream flowing into the lake for the existing conditions scenario (Scenario 1). The DIN mean annual DIN load is currently estimated to be slightly less than 1000 t/year.

100 Table 12 shows the simulated Source model estimates of TN generated by zone between scenarios. The naturalised scenario (Scenario 0) results in between -21% and -30% reduction in TN load, varying by zone. Implementation of restrictions on seasonal volumes results in minimal change in TN loads from existing conditions. Scenario 2b results in relatively small increases in TN loads from existing conditions.

101 The reduction in DIN load to Te Waihora / Lake Ellesmere under naturalised flow conditions is a relatively modest -6%. If irrigation were no longer undertaken in the catchment, while inputs of TN load would be substantially reduced there would also be a reduction in groundwater mounding (and hence shallow groundwater levels), which would reduce the relative impact of denitrification in the catchment, hence the more muted reduction in DIN load delivered to the lake.

102 The projected TN load generated increases in the Rakaia-Selwyn and Selwyn-Waimakariri zones are 8% and 10% respectively under

Scenario 2a, due to the assumed increase in TN load to 15 kg/ha/year for those landuse classes that were below this threshold in Scenario 1. This results in a simulated increase of 13% in mean annual DIN load to Te Waihora / Lake Ellesmere from Scenario 1.

103 The projected TN load generated increases in the Rakaia-Selwyn and Selwyn-Waimakariri zones are 13% and 14% respectively under Scenario 2b, due to the combined effects of implementation of the ultimate effect of CPW and the assumed increase in TN load to 15 kg/ha/year for those landuse classes that were below this threshold in Scenario 1. This results in a simulated increase of 16% in mean annual DIN load to Te Waihora / Lake Ellesmere from Scenario 1. The incremental impact on mean annual DIN load from implementation of CPW (between Scenarios 2a and 2b) is a relatively small 30 tonnes per year or 3% of the mean annual DIN load to Lake Ellesmere / Te Waihora.

104 The increase in DIN load delivered to the lake is muted by some proportion of the additional recharge induced by increased area irrigated travelling via deep groundwater flow pathways, and not reaching the lake, and also by denitrification occurring in shallow groundwater within approximately 10 km of the lake.

105 The Source modelling simulates a relatively modest 1% increase in TN load generated in the Little Rakaia zone for Scenario 2b over existing conditions but the accuracy of the change for the Little Rakaia zone is less reliable as less detail was available on existing and proposed future landuse for parts of this zone to the west of the Little Rakaia River.

106 Implementation of the proposed caps on TN leaching rates as set out in Variation 1 (modelled Scenario 3a) results in a modest overall increase of 3% in TN load generated in the Selwyn-Waimakariri zone but a 0.2% reduction in the Rakaia-Selwyn zone and 11% reduction in the Little Rakaia zone from existing conditions. The overall net effect of the reduction in loads is a 6% increase in mean annual DIN load to Lake Ellesmere / Te Waihora, or a reduction of approximately 10% in load to the lake when compared to Scenario 2b.

**CONCLUSIONS**

107 We present further arguments that the approaches adopted by both ECan and in particular Dr Cooke will over-predict nitrogen loads to Te Waihora compared to currently observed loads from gauge data, or predicted by our revised modelling.

108 We agree, however, that the strongly correlated relationship between nitrate and phosphorous in ecosystem function and response emphasises the need to apply a combined nutrient control approach to future assessments.

109 Our modelled scenarios as a generalisation of the catchment have answered some of the key questions raised by our review of the initial modelling by ECan (and which are relevant to the evidence of submitters):

**What is the projected N load to Te Waihora/Lake Ellesmere?**

110 The Source model predicts that the current load is around 973 (t/year) to the lake. This number is likely to increase in 2017 to 1103 (t/year) and peak in 2022 prior to a clawback mechanism at 1132 (t/year).

111 The proposed clawback mechanism will reduce the lake load back to close to the present value at 1033 (t/year).

112 The Source model simulations demonstrated that the further reductions in TN load per unit area (as a clawback mechanism) proposed in Variation 1 would result in changes for in-stream DIN concentrations that vary between streams.

113 With DIN concentrations simulated to increase in some streams and reduce in others, depending upon the assumed location of changes in TN loading rates in the catchment and the relative contributions of surface and groundwater flow in each of the lowland streams.

**What are the effects on regional groundwater quality?**

114 The Source model predicts that there is a very slight increase in risk of exceedance of the MAV (<0.02%) this risk is reduced to the current probability under the clawback scenario.

115 Under all scenarios modelled the likelihood of exceeding the MAV in the shallow groundwater in the zone where denitrification is very low – approximately 0.1%. There is a very small simulated increase in the likelihood of exceeding the MAV under Scenario 2b (with CPW), although this change in probability is extremely low.

116 The Source model was not able to provide reliable mean annual predictions on Nitrate Nitrogen concentrations in the groundwater more than about 10 km from Te Waihora / Lake Ellesmere. We have therefore not provided an estimate of the likelihood of exceeding the MAV for Nitrate Nitrogen for areas where groundwater flux is not upwards, which corresponds to areas more than about 10 km away from the lake.

**What are the effects on surface water quality (as dissolved inorganic nitrogen)?**

117 The Source model predicts that in 2017 when the 15kg/ha/year permitted activity rule is in place and the landuse lifts to the baseline values and a matrix of good management practices is developed the median and 95th percentile stream concentrations will increase by up to 18% from the current state.

118 The Source model predicts that in 2022 prior to a clawback mechanism and with a fully implanted CPW in place the median and 95th percentile stream concentrations will increase by a similar amount form the current state (up to 17%).

119 The introduction of the proposed clawback mechanism will cause an increase in the median concentration on Selwyn and Halswell Rivers of 7% and a decrease of up to 16% for the other tributaries to the lake.

**What is the effect on mean annual low flow (MALF)?**

120 The Source model predicts that proposed Schedule 10 approach to seasonal allocation will provide no improvement to the mean daily flows to the lake. I~~i~~t also suggests that the Schedule 10 will would actually reduce the MALF in most of the lowland streams by up to 5%.

121 The introduction of the CPW scheme into the catchment increases both the mean daily flows and the MALF in the majority of the lowland streams to the lake.

Dated: 8 September 2014

Nicholas Conland, Michelle Sands, Phillip Jordan and Richard Cresswell

**Annexure 1**

This brief of evidence is provided on behalf of a number of submitters including:

Central Plains Water Limited

Horticulture New Zealand Limited

Irrigation NZ Limited

DairyNZ

The Foundation for Arable Research

Dairy Holdings Limited

Beef & Lamb NZ

NZPork

Canterbury Grasslands Limited

Camden Farm Limited

**TABLES AND FIGURES**

**Table 1 Mean annual total volume of runoff and load of TN generated via groundwater drainage and surface runoff pathways for landuses represented in the Source model within the Rakaia-Selwyn zone under Scenario 1**

| Landuse Type | Area (ha) | Mean Annual Total Generated (mm/year) | Mean Annual TN Total Load (tonnes/year) | Mean Annual TN Total Load (kg/ha/year) |
|---|---|---|---|---|
| Arable Dryland | 554 | 469 | 8.8 | 15.9 |
| Arable Irrigated | 9679 | 469 | 166.9 | 17.2 |
| Beef Dryland | 2321 | 390 | 58.4 | 25.2 |
| Beef Irrigated | 2085 | 454 | 66.2 | 31.8 |
| Dairy 3 cows per ha | 9872 | 486 | 327.9 | 33.2 |
| Dairy 4 cows per ha | 19341 | 583 | 1073.9 | 55.5 |
| Dairy 5 cows per ha | 2093 | 495 | 111.6 | 53.3 |
| Dairy Support Dryland | 4291 | 424 | 193.3 | 45.1 |
| Dairy Support Irrigated | 4526 | 527 | 223.4 | 49.3 |
| Deer Dryland | 4095 | 620 | 54.3 | 13.3 |
| Deer Irrigated | 263 | 464 | 4.9 | 18.6 |
| Forestry | 6163 | 565 | 11.3 | 1.8 |
| Lifestyle | 3208 | 321 | 34.0 | 10.6 |
| Miscellaneous | 659 | 753 | 8.0 | 12.2 |
| Native Forest | 2415 | 568 | 3.6 | 1.5 |
| Orchard | 306 | 504 | 2.5 | 8.3 |
| Pigs | 555 | 355 | 18.2 | 32.8 |
| Sheep Dryland | 10762 | 517 | 127.5 | 11.8 |
| Sheep Irrigated | 3070 | 523 | 57.6 | 18.7 |
| Sheep and Beef 10% Dryland | 7438 | 660 | 197.6 | 26.6 |
| Sheep and Beef 10% Irrigated | 3364 | 648 | 109.8 | 32.7 |
| Sheep and Beef 20% Dryland | 4404 | 452 | 105.2 | 23.9 |
| Sheep and Beef 20% Irrigated | 2267 | 545 | 72.6 | 32.0 |
| Urban | 548 | 337 | 4.3 | 7.8 |
| Vegetables | 129 | 387 | 2.8 | 21.6 |
| Viticulture | 63 | 320 | 0.5 | 7.7 |
| Water | 1350 | 0 | 0.0 | 0.0 |
| **Totals for Zone** | **105819** | **521** | **3045.1** | **28.8** |

**Table 2 Mean annual total volume of runoff and load of TN generated via groundwater drainage and surface runoff pathways for landuses represented in the Source model within the Selwyn-Waimakariri zone under Scenario 1**

| Landuse Type | Area (ha) | Mean Annual Total Generated (mm/year) | Mean Annual TN Total Load (tonnes/year) | Mean Annual TN Total Load (kg/ha/year) |
|---|---|---|---|---|
| Arable Dryland | 603 | 292 | 5.8 | 9.7 |
| Arable Irrigated | 16295 | 580 | 353.8 | 21.7 |
| Beef Dryland | 4061 | 355 | 104.3 | 25.7 |
| Beef Irrigated | 2001 | 480 | 70.6 | 35.3 |
| Dairy 3 cows per ha | 9434 | 489 | 314.9 | 33.4 |
| Dairy 4 cows per ha | 6780 | 590 | 383.2 | 56.5 |
| Dairy 5 cows per ha | 1100 | 510 | 59.2 | 53.9 |
| Dairy Support Dryland | 5111 | 345 | 176.5 | 34.5 |
| Dairy Support Irrigated | 4564 | 512 | 218.7 | 47.9 |
| Deer Dryland | 3471 | 457 | 44.2 | 12.7 |
| Deer Irrigated | 943 | 448 | 17.6 | 18.7 |
| Forestry | 5991 | 451 | 11.3 | 1.9 |
| Lifestyle | 12116 | 316 | 129.6 | 10.7 |
| Miscellaneous | 237 | 669 | 2.8 | 11.9 |
| Native Forest | 1955 | 384 | 3.4 | 1.7 |
| Orchard | 356 | 510 | 3.1 | 8.7 |
| Pigs | 1040 | 298 | 26.4 | 25.4 |
| Sheep Dryland | 16570 | 366 | 165.8 | 10.0 |
| Sheep Irrigated | 4120 | 545 | 84.7 | 20.6 |
| Sheep and Beef 10% Dryland | 10822 | 437 | 234.0 | 21.6 |
| Sheep and Beef 10% Irrigated | 3522 | 573 | 106.8 | 30.3 |
| Sheep and Beef 20% Dryland | 9948 | 377 | 205.7 | 20.7 |
| Sheep and Beef 20% Irrigated | 3231 | 473 | 86.0 | 26.6 |
| Urban | 4467 | 316 | 32.9 | 7.4 |
| Vegetables | 595 | 483 | 20.9 | 35.2 |
| Viticulture | 226 | 328 | 1.7 | 7.6 |
| Water | 1899 | 0 | 0.0 | 0.0 |
| **Totals for Zone** | **131459** | **436** | **2864.0** | **21.8** |

**Table 3 Mean annual total volume of runoff and load of TN generated via groundwater drainage and surface runoff pathways for landuses represented in the Source model within the Little Rakaia zone under Scenario 1**

| Landuse Type | Area (ha) | Mean Annual Total Generated (mm/year) | Mean Annual TN Total Load (tonnes/year) | Mean Annual TN Total Load (kg/ha/year) |
|---|---|---|---|---|
| Arable Dryland | 2287 | 321 | 25.1 | 11.0 |
| Arable Irrigated | 4660 | 502 | 87.1 | 18.7 |
| Beef Dryland | 307 | 357 | 7.5 | 24.3 |
| Beef Irrigated | 181 | 503 | 7.0 | 38.9 |
| Dairy 3 cows per ha | 5279 | 408 | 143.3 | 27.1 |
| Dairy 4 cows per ha | 2248 | 612 | 124.0 | 55.2 |
| Dairy 5 cows per ha | 2003 | 515 | 116.5 | 58.2 |
| Dairy Support Dryland | 674 | 360 | 25.0 | 37.1 |
| Dairy Support Irrigated | 1886 | 576 | 106.4 | 56.4 |
| Deer Dryland | 248 | 548 | 4.2 | 16.8 |
| Deer Irrigated | 16 | 723 | 0.5 | 29.1 |
| Forestry | 842 | 315 | 1.3 | 1.6 |
| Lifestyle | 343 | 308 | 3.6 | 10.6 |
| Miscellaneous | 0 | | | |
| Native Forest | 2420 | 255 | 2.5 | 1.0 |
| Orchard | 28 | 467 | 0.2 | 7.9 |
| Pigs | 5 | 338 | 0.2 | 31.1 |
| Sheep Dryland | 1105 | 388 | 12.0 | 10.9 |
| Sheep Irrigated | 1014 | 549 | 21.5 | 21.2 |
| Sheep and Beef 10% Dryland | 364 | 612 | 9.7 | 26.7 |
| Sheep and Beef 10% Irrigated | 47 | 669 | 1.5 | 32.0 |
| Sheep and Beef 20% Dryland | 659 | 356 | 13.0 | 19.8 |
| Sheep and Beef 20% Irrigated | 1359 | 518 | 41.1 | 30.2 |
| Urban | 239 | 294 | 1.6 | 6.9 |
| Vegetables | 132 | 540 | 5.7 | 43.2 |
| Viticulture | 0 | | | |
| Water | 4032 | 0 | 0.0 | 0.0 |
| **Totals for Zone** | **32380** | **390** | **760.4** | **23.5** |

**Table 4 Comparison of estimated mean annual rates of recharge to groundwater from farm systems and soil types from the Source model and from Lilburne et al. (2013)**

| **Mean Annual Rainfall (mm/y)** | **650** | **750** | **850** | **650** | **750** | **850** | **650** | **750** | **850** |
|---|---|---|---|---|---|---|---|---|---|
| | **Source Model Estimated Recharge Rates (mm/y)** | | | **Lilburne Estimated Recharge Rates (mm/y)** | | | **Ratio of Source Model / Lilburne et al. (2013)** | | |
| Irrigated, XL, VL, L soils | 519 | 562 | 606 | 208 | 272 | 339 | 2.49 | 2.07 | 1.79 |
| Irrigated, M, H, Pd, PdL soils | 306 | 359 | 413 | 188 | 244 | 303 | 1.63 | 1.47 | 1.36 |
| Dryland, XL, VL, L soils | 320 | 366 | 412 | 140 | 232 | 323 | 2.29 | 1.58 | 1.28 |
| Dryland M, H, Pd, PdL soils | 179 | 231 | 283 | 125 | 208 | 290 | 1.43 | 1.11 | 0.98 |

**Table 5 Mean daily flows estimated from Source Model for Existing Conditions Scenario (Scenario 1, for model period 1980-2103), compared with estimate from gauged flows (for available record) and ECan Scenario 1**

| Stream Name | Site Name | Source Model Scenario 1 (L/s) | Gauged (L/s) | ECan Scenario 1 (L/s) | % Difference to Observed | % Difference to ECan Scenario 1 |
|---|---|---|---|---|---|---|
| Harts Creek | Timberyard Road | 1930 | 1379 | 1696 | 40% | 14% |
| Kaituna River | Kaituna Valley Road | 848 | 593 | Not Stated | 43% | |
| Selwyn River | Coes Ford | 3681 | 3204 | 2975 | 15% | 24% |
| Boggy Creek | Lower Lake Road | 92 | Not Gauged | 188 | | -51% |
| Halswell River | Ryans Bridge | 1290 | 784 | 1186 | 65% | 9% |
| Hanmer Road Drain | Lower Lake Road | 252 | Not Gauged | 216 | | 17% |
| LII River | Pannets Rd | 1317 | 2366 | 2307 | -44% | -43% |
| Doyleston Drain | Lake Road | 139 | 173 | 159 | -20% | -13% |

**Table 6 Mean annual 7 day low flows (7dMALF) estimated from Source Model for Existing Conditions Scenario (Scenario 1, for model period 1980-2103), compared with estimate from gauged flows (for available record) and ECan Scenario 1**

| Stream Name | Site Name | Source Model Scenario 1 (L/s) | Gauged (L/s) | ECan Scenario 1 (L/s) | % Difference to Observed | % Difference to ECan Scenario 1 |
|---|---|---|---|---|---|---|
| Harts Creek | Timberyard Road | 400 | 897 | 987 | -55% | -59% |
| Kaituna River | Kaituna Valley Road | 118 | 38 | Not stated | 215% | |
| Selwyn River | Coes Ford | 224 | 627 | 289 | -64% | -22% |
| Halswell River | Ryans Bridge | 198 | 418 | | -53% | |
| LII River | Pannets Rd | 114 | 1391 | 1544 | -92% | -93% |
| Doyleston Drain | Lake Road | 13 | 2 | 2 | 591% | 539% |

**Table 7 Mean daily flow compared between scenarios in lowland stream flow sites (for 1980-2013 climatic period)**

| Stream Name | Site Name | Mean daily flow (L/s) | | | | % Difference in Mean Daily Flow to Scenario 1 | | |
|---|---|---|---|---|---|---|---|---|
| | | Scenario 1 | Scenario 0 | Scenario 2a | Scenarios 2b and 3a | Scenario 0 | Scenario 2a | Scenarios 2b and 3a |
| Harts Creek | Timberyard Road | 1930 | 2019 | 1920 | 2041 | 5% | 0% | 6% |
| Selwyn River | Coes Ford | 3681 | 3569 | 3669 | 3720 | -3% | 0% | 1% |
| Boggy Creek | Lower Lake Road | 92 | 92 | 92 | 95 | 0% | 0% | 3% |
| Halswell River | Ryans Bridge | 1290 | 1414 | 1288 | 1323 | 10% | 0% | 3% |
| Halswell River | Hodgens Bridge | 1734 | 1901 | 1731 | 1777 | 10% | 0% | 3% |
| Halswell River | Neils Road | 1487 | 1628 | 1484 | 1524 | 10% | 0% | 3% |
| Hanmer Road Drain | Lower Lake Road | 252 | 232 | 251 | 268 | -8% | 0% | 6% |
| Irwell River | Lake Road | 96 | 96 | 95 | 104 | 0% | 0% | 9% |
| LII River | Pannets Road | 1317 | 1521 | 1313 | 1344 | 15% | 0% | 2% |
| Doyleston Drain | Lake Road | 139 | 139 | 138 | 143 | 1% | 0% | 3% |

**Table 8 Mean annual 7 day low flow (7dMALF) compared between scenarios in lowland stream flow sites (for 1980-2013 climatic period)**

| Stream Name | Site Name | 7dMALF (L/s) | | | | % Difference in 7dMALF to Scenario 1 | | |
|---|---|---|---|---|---|---|---|---|
| | | Scenario 1 | Scenario 0 | Scenario 2a | Scenarios 2b and 3a | Scenario 0 | Scenario 2a | Scenarios 2b and 3a |
| Harts Creek | Timberyard Road | 400 | 463 | 391 | 467 | 16% | -2% | 17% |
| Selwyn River | Coes Ford | 224 | 243 | 213 | 236 | 8% | -5% | 5% |
| Halswell River | Ryans Bridge | 198 | 346 | 195 | 207 | 75% | -1% | 4% |
| LII River | Pannets Road | 114 | 295 | 111 | 121 | 159% | -2% | 6% |
| Doyleston Drain | Lake Road | 13 | 37 | 13 | 13 | 187% | -2% | 4% |

**Table 9 Median Dissolved Inorganic Nitrogen (DIN) concentration simulated in Source model within lowland streams for different scenarios**

| Stream Name | Site Name | 50th Percentile DIN Concentration (mg/L) | | | | | % Difference in DIN Concentration Scenario 1 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Scen 1** | **Scen 0** | **Scen 2a** | **Scen 2b** | **Scen 3a** | **Scen 0** | **Scen 2a** | **Scen 2b** | **Scen 3a** |
| Harts Creek | Timberyard Road | 4.66 | 3.35 | 4.75 | 4.49 | 3.93 | -28% | 2% | -4% | -16% |
| | | ~~4.40~~ | ~~4.40~~ | ~~5.83~~ | ~~5.83~~ | ~~5.25~~ | ~~0%~~ | ~~32%~~ | ~~32%~~ | ~~19%~~ |
| Selwyn River | Coes Ford | 2.59 | 2.37 | 2.92 | 3.04 | 2.76 | -9% | 13% | 17% | 6% |
| Boggy Creek | Lower Lake Road | 4.19 | 3.10 | 4.36 | 4.33 | 3.93 | -26% | 4% | 3% | -6% |
| Halswell River | Ryans Bridge | 3.23 | 2.78 | 3.82 | 3.75 | 3.47 | -14% | 18% | 16% | 7% |
| Halswell River | Hodgens Bridge | 2.90 | 2.52 | 3.41 | 3.38 | 3.11 | -13% | 18% | 17% | 7% |
| Halswell River | Neils Road | 3.12 | 2.69 | 3.68 | 3.63 | 3.35 | -14% | 18% | 16% | 7% |
| Hanmer Road Drain | Lower Lake Road | 3.06 | 2.51 | 3.19 | 3.26 | 2.83 | -18% | 4% | 7% | -8% |
| Irwell River | Lake Road | 2.26 | 2.10 | 2.40 | 2.43 | 2.17 | -7% | 6% | 7% | -4% |
| Lee River | Te Moana | 3.60 | 3.12 | 3.68 | 3.69 | 3.32 | -13% | 2% | 2% | -8% |
| LII River | Pannets Road | 2.14 | 1.44 | 2.28 | 2.26 | 2.07 | -33% | 7% | 6% | -3% |
| Doyleston Drain | Lake Road | 3.92 | 2.41 | 4.05 | 3.95 | 3.60 | -38% | 3% | 1% | -8% |

**Table 10 Dissolved Inorganic Nitrogen (DIN) concentration not-exceeded on 95% of days simulated in Source model within lowland streams for different scenarios**

| Stream Name | Site Name | 95th Percentile DIN Concentration (mg/L) | | | | | % Difference in DIN Concentration Scenario 1 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Scen 1 | Scen 0 | Scen 2a | Scen 2b | Scen 3a | Scen 0 | Scen 2a | Scen 2b | Scen 3a |
| Harts Creek | Timberyard Road | 6.53 | 4.67 | 6.58 | 6.22 | 5.55 | -28% | 1% | -5% | -15% |
| | | ~~4.93~~ | ~~4.93~~ | ~~5.99~~ | ~~5.99~~ | ~~5.40~~ | ~~0%~~ | ~~22%~~ | ~~22%~~ | ~~9%~~ |
| Selwyn River | Coes Ford | 4.03 | 3.18 | 4.35 | 4.71 | 4.17 | -21% | 8% | 17% | 3% |
| Boggy Creek | Lower Lake Road | 4.93 | 4.24 | 5.17 | 5.07 | 4.55 | -14% | 5% | 3% | -8% |
| Halswell River | Ryans Bridge | 3.89 | 3.19 | 4.46 | 4.42 | 4.02 | -18% | 15% | 14% | 3% |
| Halswell River | Hodgens Bridge | 3.40 | 3.00 | 3.85 | 3.81 | 3.52 | -12% | 13% | 12% | 4% |
| Halswell River | Neils Road | 3.69 | 3.10 | 4.19 | 4.15 | 3.79 | -16% | 14% | 13% | 3% |
| Hanmer Road Drain | Lower Lake Road | 5.00 | 3.14 | 5.03 | 4.99 | 4.27 | -37% | 1% | 0% | -15% |
| Irwell River | Lake Road | 3.67 | 2.92 | 3.89 | 3.67 | 3.25 | -20% | 6% | 0% | -11% |
| Lee River | Te Moana | 5.46 | 3.60 | 5.55 | 5.38 | 4.69 | -34% | 2% | -1% | -14% |
| LII River | Pannets Road | 3.64 | 2.10 | 3.75 | 3.73 | 3.42 | -42% | 3% | 2% | -6% |
| Doyleston Drain | Lake Road | 4.95 | 3.99 | 5.10 | 5.01 | 4.46 | -19% | 3% | 1% | -10% |

**Table 11 Total contribution of flow and Dissolved Inorganic Nitrogen load to Te Waihora / Lake Ellesmere for existing conditions scenario (Scenario 1)**

| Stream Name | Mean Annual Flow to Lake (GL/year) | Mean Annual Flow to Lake (m³/s) | Mean Annual NNN Load (tonnes/year) | Mean Annual Ammonium Load (tonnes/year) | Mean Annual DIN Load (tonnes/year) |
|---|---|---|---|---|---|
| Selwyn River | 118.5 | 3.75 | 171 | 12 | 183 |
| Waikekewai Creek | 2.8 | 0.09 | 8 | 1 | 10 |
| Harts Creek | 60.9 | 1.93 | 227 | 36 | 263 |
| Doyleston Drain | 4.4 | 0.14 | 13 | 2 | 15 |
| Boggy Creek | 2.9 | 0.09 | 9 | 1 | 11 |
| Irwell River | 3.0 | 0.10 | 4 | 1 | 6 |
| LII River | 41.6 | 1.32 | 58 | 19 | 77 |
| Halswell River | 74.6 | 2.36 | 215 | 28 | 243 |
| Kaituna River | 26.8 | 0.85 | 93 | 9 | 102 |
| Prices Stream | 15.5 | 0.49 | 54 | 5 | 59 |
| Waikoko Stream | 1.5 | 0.05 | 4 | 0 | 5 |
| **Total of All Inflows to Lake** | **352.4** | **11.17** | **857** | **115** | **973** |

**Table 12 Comparison of mean annual Total Nitrogen (TN) loads generated in each zone for each scenario simulated by the Source model**

| | Mean Annual TN Load Generated (t/year) | | | | | % Change From Scenario 1 | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Zone** | **Scenario 1** | **Scenario 0** | **Scenario 2a** | **Scenario 2b** | **Scenario 3a** | **Scenario 0** | **Scenario 2a** | **Scenario 2b** | **Scenario 3a** |
| Rakaia-Selwyn | 3045 | 2282 | 3296 | 3449 | 3040 | -25% | 8% | 13% | -0.2% |
| Selwyn-Waimakariri | 2864 | 2269 | 3144 | 3274 | 2952 | -21% | 10% | 14% | 3% |
| Little Rakaia | 760 | 529 | 788 | 765 | 674 | -30% | 4% | 1% | -11% |

**Table 13 Comparison of mean annual Dissolved Inorganic Nitrogen (DIN) load delivered to Te Waihora /Lake Ellesmere simulated by the Source model**

| | Mean Annual DIN~~TN~~ Load Generated (t/year) | | | | | % Change From Scenario 1 | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Component of DIN** | **Scenario 1** | **Scenario 0** | **Scenario 2a** | **Scenario 2b** | **Scenario 3a** | **Scenario 0** | **Scenario 2a** | **Scenario 2b** | **Scenario 3a** |
| NNN | 857 | 789 | 971 | 993 | 908 | -8% | 13% | 16% | 6% |
| Ammonium | 115 | 120 | 132 | 139 | 125 | 4% | 15% | 21% | 8% |
| **Total DIN** | **973** | **910** | **1103** | **1132** | **1033** | **-6%** | **13%** | **16%** | **6%** |

**Table 14 Estimation from Source Model simulations of mean Nitrate Nitrogen concentration in the shallow groundwater layer and the probability of exceeding the Maximum Acceptable Value under the New Zealand Drinking Water Guidelines**

| Source Model Scenario | Mean Nitrate Concentration (mg/L) simulated in Source Model run in shallow groundwater layer | Probability of Nitrate Concentration exceeding 11.3 mg/L (MAV) | Probability of Nitrate Concentration exceeding 6.6 mg/L (half MAV) |
|---|---|---|---|
| 1 | 2.59 | 0.10% | 1.2% |
| 0 | 2.10 | 0.07% | 0.9% |
| 2a | 2.80 | 0.12% | 1.4% |
| 2b | 2.79 | 0.11% | 1.4% |
| 3a | 2.50 | 0.10% | 1.2% |