BEFORE THE INDEPENDENT COMMISSIONERS

IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of the Proposed Canterbury Land and Water Regional Plan

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EVIDENCE IN CHIEF OF JIM COOKE ON BEHALF OF NELSON/MARLBOROUGH, NORTH CANTERBURY AND CENTRAL SOUTH ISLAND FISH AND GAME COUNCILS
2 APRIL 2013

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QUALIFICATIONS AND EXPERIENCE

1. My full name is James Grainger Cooke.

2. I am currently (September 2007 – present) a Director of Diffuse Sources Ltd, a company specialising in the effects of agricultural and urban landuses on water resources. I am also on the Management Board of the International Water Association's (IWA) Specialist Group on Diffuse Pollution and Chair of the NZ Committee for IWA.

3. I hold the degrees of Bachelor of Science (University of Waikato 1973), Diploma in Agricultural Science and Master of Philosophy (Soil Science), Massey University 1974 and 1977) and Doctor of Philosophy (Oxford University 1986).

4. I have 35 years' experience in environmental science, the majority of it (29 years) with the National Institute of Water and Atmospheric Research (NIWA) or its predecessor organisations. At NIWA my career included research into nutrient runoff from agricultural catchments, nutrient cycling in natural wetlands receiving sewage effluent, and nutrient transformations in freshwater ecosystems. Other roles at NIWA included Business Development Manager, Manager Environmental Research and Services (NIWA Australia), and Leader of the National Centre for Water Resources.

5. I have also led or managed a large number of consultancy projects relating to the environmental effects of anthropogenic activities on aquatic ecosystems. Example projects include: Estimation of nutrient loads to Waituna Lagoon, Southland (2012), Independent Scoping Study for the restoration of the Waikato River and Catchment (2009), Development of a Decision Support System (for the application of Gemex™ to Rivers infected with Didymo (2008), and scientific methods to support a proposed National Environmental Standard on Ecological Flows and Water Levels (2007).

6. I am also accredited (through the 'Making Good Decisions' programme) to serve on hearing committees and I have been an Independent Commissioner (water quality expert) on panels making decisions on consent applications to take, use, divert, dam, and discharge water in the Upper Waitaki Catchment (Environment Canterbury, 2009-2012), and the discharge of treated sewage to water and groundwater (Waikato Regional Council, 2012).

7. I have also provided services to other Resource Management forums including: (i) advising Auckland Council on matters relating to reasonable mixing for the Auckland Air, Land and Water Plan (2007), (ii) chairing a group (applicant and submitters) seeking an interim solution for the discharge of treated sewage to Lake Waikare (2011-12), and, (iii) presenting evidence on behalf of Federated Farmers (Otago) on the proposed plan change 6A (Water Quality) for Otago (2012).

8. In preparing this evidence I have collaborated with my colleague Dr Tim Cox, a specialist water resource and water quality modeller. Dr Cox has a PhD in Engineering Science from the University of Auckland, an M.S. - Environmental and Water Resources Engineering from the University of Colorado, and a B.S. in Civil and Environmental Engineering from Duke University, North Carolina. Tim has extensive expertise (with US-based consulting company CDMSmith) in Water Supply Planning Analysis, Climate Change Adaptation in Water Resources, Watershed Hydrologic and Water Quality Modelling, Stream and Lake Water Quality Modelling. Dr Cox undertook the modelling cited in this evidence under my direction.

9. I have also reviewed the reports and statements of evidence of other experts giving evidence relevant to my area of expertise, including:
   a. Alison Dewes;
   b. Russell Death;
   c. Roger Young;
   d. Dan Marsh;

e. as well as the Section 42A evidence of Mathew McCallum Clark.

10. I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

SCOPE OF EVIDENCE

11. I have been asked by Scott Pearson of Canterbury Fish and Game Council to prepare evidence in relation to nutrient (particularly nitrogen) loads on Canterbury waterways and the implications of proposed Canterbury Land and Water Regional Plan (pCLWRP). My brief is quite specific and restricted to consideration of concentrations and loads and the effects of different allocation strategies on those concentrations and loads, with a brief discussion on the implications of this research. My evidence follows on from that of Associate Professor Death who provided evidence as part of Hearing Group 1 on the heath of aquatic ecosystems in the region, and the impacts of agricultural land use activities, on those ecosystems. Associate Professor Death, reviews the results of my modelling in his hearing group 2 evidence and comments on its ecological implications.

12. I have been requested by Fish & Game to focus on three catchments; namely the Selwyn-Waihora, Ashburton, and Rakaia. These are examples of catchments which are listed in the pCLWRP nutrient zones as ”water quality outcomes”: “not met”, “at risk” ,and “met”, respectively (Nutrient zones p 4-8 pCLWRP)).

13. My evidence includes:

a. A review and critique of water quality aspects of the pCLWRP and current work on load limit setting in particular;

b. Estimates of current nitrogen loads in example catchments;

c. Modelling the effects of current pCLWRP rules on nitrogen loads and concentrations;

d. Modelling the effects of alternative (Fish and Game proposed) rules on nitrogen loads and concentrations;

e. Comments on relevant Section 42A reports; and

f. Conclusions.

EXECUTIVE SUMMARY

14. This brief of evidence considers the effects of rules proposed under the pCLWRP on nitrogen loads and concentrations at measurement points in three catchments designated by ECan as being within zones where nutrient allocation is 'not met' (red - Selwyn-Waihora at Coes Ford), 'at risk' (orange - Ashburton at Mouth), and 'met' (green - Rakaia at Gorge).

15. I describe the calibration of a simple (does not consider pathways or lag time) model from ECan SOE data at these three sites, and the subsequent use of the model to predict nitrogen loads and concentrations as a function of nitrogen export coefficients under different farm uses, varying irrigation scenarios and with or without a 'nitrogen cap'.

16. The results of the modelling show that without a cap on nitrogen exports in the Selwyn-Waihora and Ashburton catchments (within red and orange zones), the current rules in the proposed CLWRP could lead to a significant increase in both annual N load and concentration at the measurement point during the period when up to 10% increases in N leaching rates are permitted. With the increase in irrigation proposed we predict a very large increase in N load and concentration (40-50%) over that measured (and predicted) in the river under current land use. Such increases would lead to changes in nutrient allocation status from orange to red in the case of Ashburton, and likely result in a measureable decrease in the life-supporting capacity of the ecosystem in the case of Selwyn-Waihora. This would be contrary to Policy A2 of the National Policy Statement on Freshwater Management (2011) (NPSFM).

17. However , with the imposition of a cap on the amount of nitrogen able to be leached from irrigated land, we predict there will be significant decrease in nitrogen load and concentration from that measured currently even with the irrigation increases proposed. This would provide a trajectory of decreasing nitrogen concentrations, which although not sufficient to meet instream targets proposed by Fish and Game's ecologist Dr Russell Death, would still constitute an improvement and would meet Policy A2.

REVIEW AND CRITIQUE OF CURRENT WORK ON LOAD LIMIT SETTING

18. As detailed in the evidence of Fish and Game's planner, Philip Percy, the NPSFM, sets objectives in respect of freshwater quality. To the extent that my expertise assists in drawing conclusions on predicting the effectiveness of plan provisions in achieving water quality objectives set nationally, part of my critique of the current work on load limit setting is in the context of the NPSFM provisions.

19. The NPSFM sets objectives relating to the life-supporting capacity of freshwater and directs that the overall water quality within a region should be maintained or improved and that in particular, water quality should be improved in waterbodies that have been degraded to the point of being over-allocated.

20. The NPSFM has three policies to give effect to its objectives, viz: (i) set freshwater objectives and water quality limits (policy A1), (ii) specify targets and methods to improve water quality within prescribed timeframes for those waterbodies that currently do not meet freshwater objectives (policy A2), and (iii) imposing conditions on discharge permits and/or making rules requiring adoption of best practicable options to prevent or minimise effects of contaminants on freshwater (policy A3).

21. My concern with the plan is twofold. Firstly while the plan identifies nutrients, and nitrogen in particular as being over-allocated in some zones, this is not reflected directly in terms of the establishment of any limits, targets or rules to address this over allocation. Secondly, there

is potential for further deterioration in water quality such that catchments currently meeting water quality outcomes become 'at risk', those currently at risk will 'not meet' the outcomes, and those currently 'not meeting' water quality outcomes will have such a large nutrient load 'in the system', that eventual actions to make them trend towards meeting water quality outcomes will take considerably longer to have an effect and/or will need to be more severe.

22. Whilst I understand Environment Canterbury's (ECan) position in only gazetting biologically-relevant 'outcomes' (such as filamentous algal cover) in Table 1a, this does make it extremely difficult to link the effects of land management (where nitrogen has been clearly identified as 'over-allocated' in some catchments), with actual dissolved inorganic nitrogen (DIN) concentrations in the river(s). This is discussed in the Hearing Group 1 evidence of Associate Professor Death.[1]

23. Fish and Game's proposed approach is to firstly identify the values of waterbodies that need protecting, then set limits to protect those values. For nitrogen, the approach is then to set catchment loads that will maintain river water quality within the limits, and then to calculate leaching allowances for individual properties that will result in acceptable catchment loads.

24. As proposed the plan does not link the management objectives and values for the freshwater bodies in table 1a to the regulatory framework with any limits or rules. Without the regulatory link to instream limits there is likely to be further degradation in the rivers before any more detailed zone or region wide rules are finalised.

25. Moreover, there is an apparent anomaly between Table 1a (rivers) and Table 1b (lakes) and Table 1c groundwaters. N concentrations are a component of the trophic level index (Table 1b), and nitrate-N concentrations are a direct indicator of human health outcomes in groundwaters (Table 1c). Elevated levels of nitrate-N have also been

[1] R Death, Evidence in Chief dated 4 February 2013, paragraph 16.

shown to be toxic to sensitive macroinvertebrates ((Hickey & Martin 2009; Hickey 2012) and therefore there are good arguments for including DIN (or nitrate-N) as an indicator of an adverse ecological outcome in rivers.

26. The most robust values for such ecologically relevant DIN concentrations will come from scientific studies at the Management Unit (river type) level. However, unless there are interim instream nutrient concentration targets based on analysis of relationships between current nutrient concentrations and indices of aquatic health (as Russell Death has done) then further river degradation in over-allocated catchments is likely before such studies can be completed.

27. In the remainder of my evidence I demonstrate the increase in average N concentration to three Canterbury Rivers as a consequence of (i) changes in landuse resulting in a 10% increase in N load as a permitted activity (as allowed under Rules 5.42-5.45 up to 2017), and, (ii) significant increases in the areas of land under irrigation as predicted under the CWMS. I also demonstrate how rules suggested by Fish and Game could create the 'headroom' whereby new areas of irrigation could be permitted in some catchments without leading to further deterioration of river quality.

Test catchments

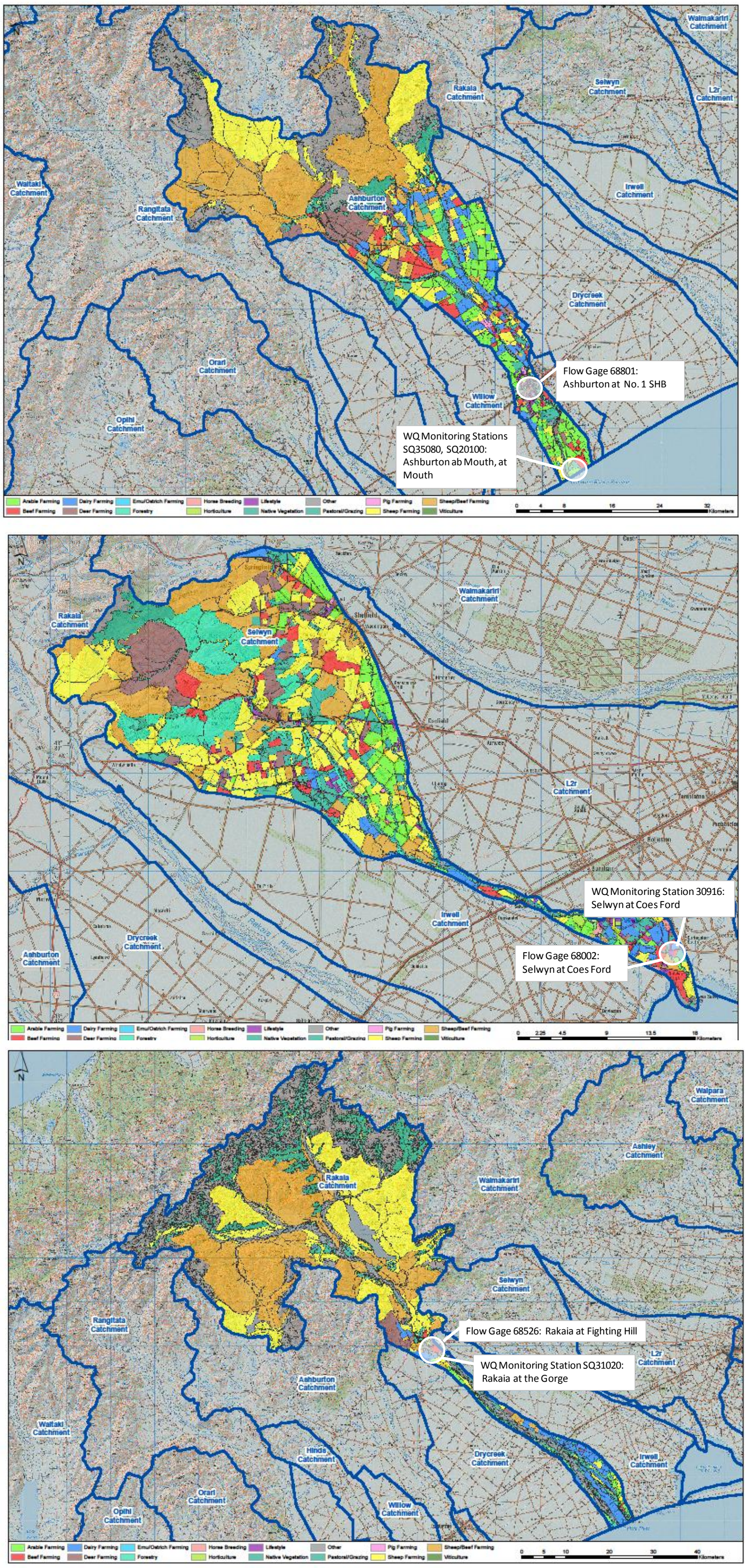
28. For the purposes of this evidence we chose three test catchments being the Selwyn-Waihora at Coes Ford, Ashburton at the mouth, and Rakaia at the Gorge. These catchments are within nutrient allocation zones designated in the pCLWRP as water quality outcomes not met (red), at risk (orange) and met (green), respectively.

29. It is important to be clear that here we are talking about catchments, whereas the pCLWRP is crafted in terms of much broader 'zones'. We have done this purposefully to model the relationships between N exports from different land uses and the N load or concentration at a particular river node. It would not be possible to do this on a zonal basis.

30. The nodal points in the catchments were based on ECan SOE monitoring points. This enabled us to estimate existing N loads and concentrations from available concentration and flow data.

31. Maps of test catchments showing the points from which catchment loads were estimated and current land use are shown in Figure 1.

Figure 1. Map of catchments showing point from which catchment loads were estimated and landuse



ESTIMATES OF CURRENT NITROGEN LOADS AND CONCENTRATIONS

32. In this section I outline the methods used to estimate current nitrogen loads in the Ashburton, Selwyn-Waihora, and Rakaia catchments and how we calibrated a simple model that provides an alternative method of estimating nitrogen load as a function of land use and catchment attenuation.

33. The load of nitrogen is defined as the total mass of nitrogen passing a nodal point in a specified time. Loads are a useful for relating to exports of nitrogen as a function of land use, which are expressed in units of mass per unit area per unit time (e.g. kg N/ha/y). However when considering rivers or streams, it is the concentration of N (particularly dissolved inorganic N, DIN) that is important in determining ecological response. The concentration is defined as mass per unit volume (e.g. mg/L).

34. ECan provided the hydrological and water quality data (SOE monitoring), used in making estimates of current nitrogen loads.

35. For each catchment, we obtained a regression relationship between log flow and log TN load (see Figure 2 for an example using the Ashburton catchment). This is one of the methods used by the United States Geological Survey (USGS) in their LOADEST program (USGS, 2004). This relationship was then used to calculate an annual mean N load over the period 1999-2011 using the complete hydrological record over that time. The resulting estimates of annual load (Table 1) are therefore derived using the range of hydrological variability recorded over a multi year periods.

Figure 2. Nitrogen Load vs. Flow Relationship, Ashburton River at Mouth

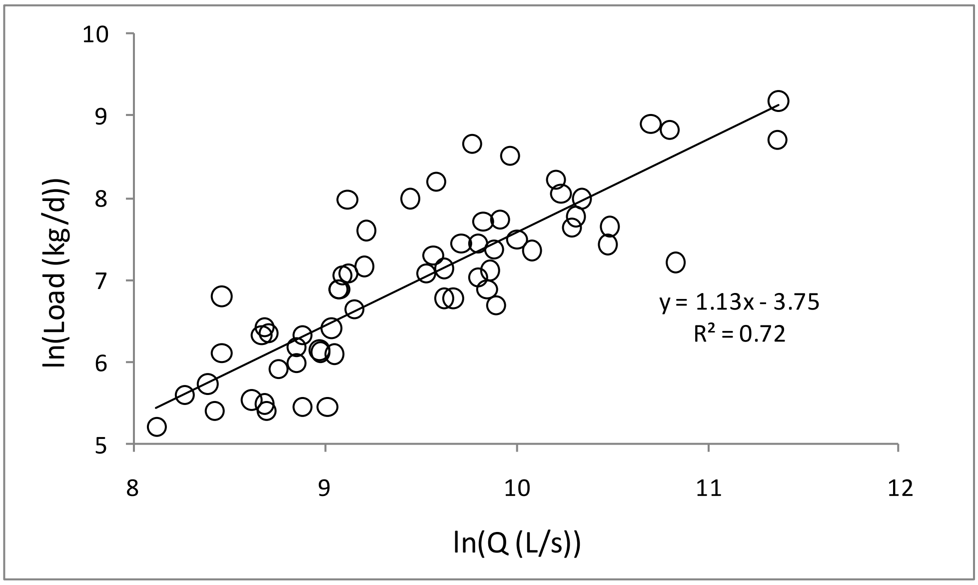


Table 1. Estimated River N Loads (kg y^{-1}) using Observed Data

Year	Ashburton at Mouth	Selwyn at Coes Ford	Rakaia at Gorge
1999	502,000	-	-
2000	1,096,000	-	-
2001	363,000	-	-
2002	706,000	-	-
2003	773,000	-	-
2004	558,000	-	-
2005	267,000	-	231,671
2006	818,000	368,181	317,394
2007	343,000	136,806	244,015
2008	793,000	569,124	297,857
2009	779,999	267,211	306,684
2010	1,027,000	588,708	357,950
2011	502,000	228,103	282,524
AVG	*656,000*	*360,000*	*301,000*

36. We then compared the average annual load in each catchment estimated using the observed river data (above) with an estimate derived from catchment export coefficients (typical quantum of N known to be lost from the rooting zone under a prescribed landuse). The following equation was used to estimate catchment loads:

$$Load = [\sum_{i=1}^{n} Area_i * C_i + \sum Point\ Sources] * K,$$

Eqn 1

where Load = annual nitrogen load delivered from catchment (kg-N y^{-1}), i = landuse category index, n = number of landuse categories in given catchment, Area = area of given landuse category (ha), C_i = export coefficient assigned to given landuse category (kg-N ha^{-1} y^{-1}), and K = lumped catchment attenuation coefficient (unitless).

The current non-agricultural landuses and their respective areas in the catchment were obtained from Environment Canterbury (Figure 1). We estimated agricultural landuse areas, sub-divided according to soil type (light, medium, heavy), based on a separate GIS analysis of each catchment. This analysis involved matching the relevant layers of S-Map (Landcare Research Ltd, the NZ Land Resource Inventory (NZLRI) and Agribase (Assure Quality Ltd). Landuse distributions were generated for two years: 2000 and 2013. The catchment export coefficients used are given in Table 2. Non-agricultural landuse export coefficients were derived from a literature review and agree well with those presented in Lilburne et al. (2010). Pastoral agriculture export coefficients were estimated by Dr Dewes and discussed in her evidence. Estimates of point source loads from each catchment were obtained from Loe (2012).

37. We also further divided sheep and beef land into “intensive” and “extensive” farms for the three catchments. This was based on landuse classification (LUC) designations for each farm parcel. Farm lands with LUC classifications of 1 – 4 were assumed “intensive”, while lands with LUC classifications of 5 – 8 were assumed “extensive”. Different export coefficients were assigned to each sub-category (Table 2).

Table 2. Assigned Average Export Coefficients (kg-N ha^{-1} y^{-1})

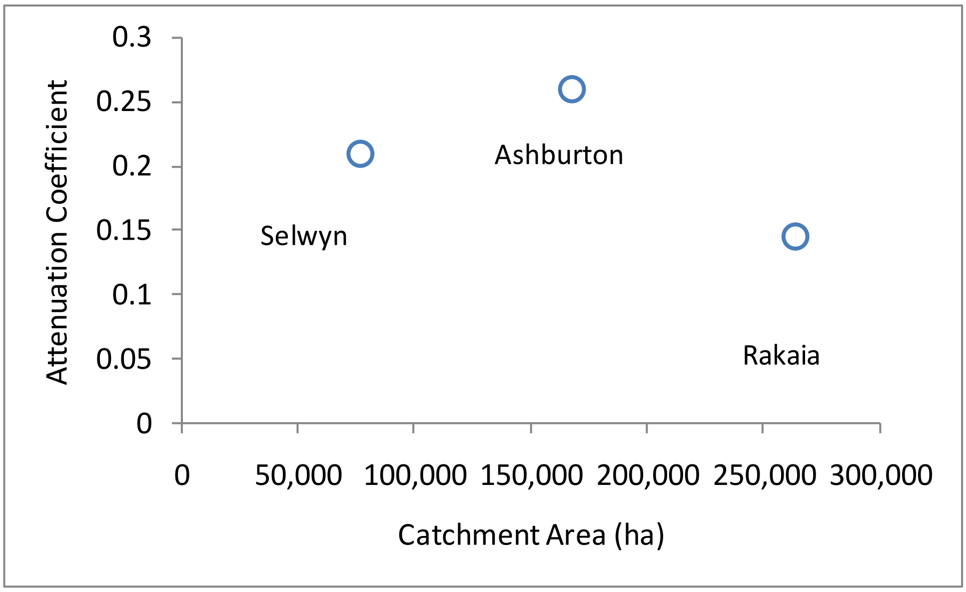
CATCHMENT	Arable Farming	Beef Farming	Dairy Farming	Deer Farming	Emu/Ostrich Farming	Forestry	Horse Breeding	Horticulture	Lifestyle	Native Vegetation	Other	Pastoral/Grazing	Pig Farming	Sheep Farming	Sheep/Beef Farming: Extensive	Sheep/Beef Farming: Intensive	Unclassified
Ashburton	21	18	67	11	10	1	10	80	17	1	1	10	12.5	9	18	20	2
Selwyn	13	15	73	9	10	1	10	80	16	1	1	10	10	7	13	30	2
Rakaia	17	21	33	13	10	1	10	80	18	1	1	10	15	11	16	16	2

38. By comparing loads estimated from Equation 1 to those observed in the river (Table 1), we are able to estimate average attenuation of nitrogen within the catchment. This was achieved through a "calibration" process whereby we iteratively varied attenuation coefficients (K) in Equation 1 until agreement was achieved with the observed river loads. For this exercise, we focused on the average annual observed loads for each catchment shown in Table 1. We compared these average loads to the average of those calculated using Equation 1 for the two time periods (2000 and 2013).

39. It is well-known in the literature that losses of N always occur between the root zone and an eventual measuring point in the river due to such processes as immobilisation, denitrification, and uptake by periphyton or aquatic macrophytes. The average attenuation is an estimate of the effects of all of these processes without attempting to quantify their relative importance.

40. Calculated attenuation coefficients for the three catchments using this technique are given in Figure 3.

Figure 3. Estimated N Attenuation Coefficients vs. Catchment Size



41. It may be noted that the calculated attenuations coefficients for the Ashburton and Selwyn-Waihora catchments were very similar (0.26 vs. 0.21) whilst that for the Rakaia was lower (0.15). As defined according to Equation 1, a lower attenuation coefficient equates to higher total attenuation losses. While a detailed analysis of the surface and subsurface hydrogeologic and biophysical characteristics of the three catchments has not been performed here, we can surmise that these differences may be, at least partially, attributable to catchment size (Figure 3). The Rakaia is the largest, and longest, of the three catchments and may have the longest associated travel times and, consequently, the greatest opportunity for attenuation.

42. Instream average annual total nitrogen concentrations (TN) at each of the three catchment locations were estimated by dividing modelled annual loads by mean annual river flow. Mean annual flow values were calculated using historical continuous daily gauging records from flow recorders at each site.

43. Average summer TN concentrations were estimated at each site by dividing annual loads by mean summer flow rates, also derived from gauge records. This simplified approach assumes that the N load is uniformly distributed throughout the year.

44. Despite the largest catchment area, the Rakaia generates the lowest annual river load of nitrogen (Table 3). In other words, while river flow rates are relatively high, nitrogen inputs are relatively low. This is attributable to low point source loading in the catchment and a lower mean export coefficient. The Rakaia, upgradient of Fighting Hill, includes no significant dairy farming and is dominated by dry stock farming and forested high country. The highest estimated N loads occur in the Ashburton catchment, an area dominated by a combination of dry stock and dairy farming with significant arable farming. Point source loads are also highest in the Ashburton catchment.

45. Dr. Russell Death presented, in evidence, dissolved inorganic nitrogen (DIN) concentration targets for maintaining acceptable water quality in Canterbury rivers and streams. These targets are provided according to the designated management unit category or river type. For the Ashburton at mouth (hill fed lower), the target is 0.47 mg-N/L. For the Selwyn at Coes Ford (spring fed plains), the target is 1.5 mg-N/L. For the Rakaia at Gorge (hill fed upper), the target is 0.21.

46. We can convert modelled TN concentrations to DIN concentrations estimates using ratios of DIN to TN obtained from measured data. Mean ratios were calculated from the available measured data sets: Ashburton = 0.93 and Selwyn = 0.94. Measured data for the Rakaia at the gorge were insufficient to calculate site specific DIN:TN ratios. Therefore, for subsequent calculations, we assume a value equal to the average of the other two sites (0.935).

47. Based on these ratios and the modelled TN values in Table 3, we see that instream nitrogen concentrations are well above the limits recommended by Dr. Death for both the Ashburton and Selwyn sites. For the Rakaia, modelled nitrogen concentrations are well below the recommended limit.

Table 3. Export Coefficient Modelling Results, Current Land Use

	Catchment Area (ha)	Diffuse Export (kg y^{-1})	Point Source Load (kg y^{-1})	Attenuation Coefficient (K)	Average Annual Load (kg y^{-1})	Average Annual N Conc. (mg L^{-1})	Average Summer N Conc. (mg L^{-1})
Ashburton at Mouth	168,000	2,273,000	632,000	0.26	755,000	1.2	1.8
Selwyn at Coes Ford	77,000	1,341,000	463,000	0.21	379,000	4.2	18
Rakaia at Gorge	264,000	2,114,000	11,000	0.15	319,000	0.05	0.05

48. The load estimates reflect current landuse and assume steady-state I.e. leachate from current landuse is reflected in current instream nitrogen load. This assumption ignores lag time (average time of travel for leachate from the root zone to reach the measuring point in the river). Whilst lag time is important in predicting actual concentrations or loads at a particular time, it does not invalidate the use of our modelling to predict the direction of change (i.e. increases or decreases in N load as a consequence of management actions.

EFFECTS OF RULES 5.42-5.45

49. Under Rules 5.42-5.45 and up to 1 July 2017 farmers can change their landuse providing nitrogen lost from their property is no more than 10% greater than is the case at present, or if they have been granted consent for a water permit that has not yet been exercised. Given that there is the potential (but no certainty) that long term region wide rule frameworks, and sub regional plan changes may be more restrictive, it is very possible that pastoral farmers will intensify land practices up to the permitted level of loss while they can.

50. I note the section 42A report recommends a different definition of “change” based on stock units. This definition cannot be modelled but in my view it does appear to allow even more intensification and nitrogen leaching than the 10% cap so permitted change could be even greater. The implications of this change in definition are discussed further in Dr Dewe’s evidence.

51. We modelled the 10% N cap scenario assuming that all pastoral farmers (dairy, sheep and beef, sheep, pastoral grazing) increased their N losses up to the permitted maximum (10%). We have assumed that the losses from all other land uses (arable, horticulture etc.) remain the same since there less likely to be production gains made from additional N use.

52. The results (Table 4) show there will likely be between 6-8% increase in N load in the three catchments if pastoral farmers increased their permitted N loss by up to 10%. There would also be a significant increase in mean annual N concentration in the over allocated Selwyn-Waihora catchments, which would be contrary to the NPSFM (Policy A2). Note the 20% increase in average N concentration in the Rakaia is due to an increase from 0.05 -0.06 mgN L^{-1}) and is of no significance.

Table 4. Export Coefficient Modelling Results, 10% increase in permitted N loss from pastoral landuse

	Projected Total Avg. Annual Load (kg y^{-1}) (% change)	Projected Average Annual N Conc. (mg L^{-1}) (% change)	Projected Average Summer N Conc. (mg L^{-1}) (% change)
Ashburton at Mouth	804,000(+6%)	1.3(+8%)	1.9(+6%)
Selwyn at Coes Ford	402,000(+6%)	4.4(+5%)	19(+6%)
Rakaia at Gorge	348,000(+8%)	0.06(+20%)	0.05(0%)

EFFECTS OF FUTURE IRRIGATION SCENARIOS

53. Two approaches were taken to estimate future loads arising from additional irrigation in the three catchments over and above the permitted increase. These were based on (i) the map provided by ECan showing the CWMS projections of potential new irrigation areas in each of the nutrient allocation zones, and (ii) projections of increases in irrigated land provided by researchers at Lincoln University (Aeru, 2012).

54. In the two land use conversion approaches, we assumed that the conversion of non-irrigated to irrigated land would be in the form of

conversion of sheep farms to dairy farms. We also assumed that for every hectare of new dairy farm, an additional ¾ hectare would be needed for “dairy support” land (0.75:1 ratio).

55. In the two land use approaches, we assumed that new dairy land would likely be on lighter soils to the extent available. For the Ashburton and Selwyn catchments, there are large areas of current sheep farms on light soils. For the Rakaia, the vast majority of current sheep farms are on heavy soils. Therefore we assigned export coefficients of 90 and 70 kg N ha^{-1} y^{-1} for all projected new dairy and dairy support land, respectively, in the Ashburton and Selwyn catchments. For the Rakaia, we assigned export coefficients of 20 and 25 kg N ha^{-1} y^{-1} for new dairy and dairy support, respectively. These export coefficients are typical of those obtained on light soils under dairying and dairy support using Overseer Version 6 (Alison Dewes pers. Comm).

56. In approach 1, we use ECan estimates of a potential 11% increase in irrigated land for the Ashburton zone and a potential 30% increase in irrigated land for the Selwyn-Waihora zone. We pro-rated these increases to the area of the zone within the Ashburton and Selwyn-Waihora catchments, respectively.

57. In approach 2, we assumed a conservative expansion of irrigated land per Table 2-4 of Aeru (2012) report (Scenario 3). The projected Canterbury-wide increase in irrigated land of 250,000 ha by year 2018 was translated into a conversion rate of 18% of all sheep farm land in the region into dairy. We applied this conversion rate to the sheep farm land in our 3 targeted catchments (Ashburton, Selwyn, Rakaia). An almost equal amount (0.75 ha for each ha of dairy) was assumed to be converted to dairy support land in each catchment.

58. Both approach 1 and 2 use conservative figures for irrigation expansion, and are broadly similar to each other. However for the projections based on the CWMS plan there are no existing dairy farms in the Rakaia upstream of the Gorge and we have assumed no further

irrigation, whereas using the Aeru projections a fixed percentage of sheep farms were assumed converted.

Table 5. Export Coefficient Modelling Results, Future Land Use Conversion

	New Dairy Land (ha)	Export Coeff. for New Dairy (kg ha^{-1} y^{-1})	New Dairy Support Land (ha)	Export Coeff. for New Dairy Support (kg ha^{-1} y^{-1})	Projected Total Avg. Annual Load (kg y^{-1}) (% change)	Projected Average Annual N Conc. (mg L^{-1}) (% change)	Projected Average Summer N Conc. (mg L^{-1}) (% change)
Approach #1: Environment Canterbury Projections							
Ashburton at Mouth	11,000	90	8000	70	1,100,000(+46%)	1.8(+50%)	2.6(+44%)
Selwyn at Coes Ford	8000	90	6000	70	557,000(+47%)	6.1(+45%)	27(+50%)
Rakaia at Gorge	0	20	0	25	319,000(0%)	0.05(0%)	0.05(0%)
Approach #2: Aeru Report projections (Scenario 3)							
Ashburton at Mouth	10,000	90	8,000	70	1,059,000(+40%)	1.7(+42%)	2.5(+39%)
Selwyn at Coes Ford	4000	90	3000	70	472,000(+25%)	5.2(+24%)	23(+28%)
Rakaia at Gorge	21,000	20	16,000	25	353,000(+10%)	0.06(+20%)	0.05(0%)

59. For the ‘red’ Selwyn-Waihora catchment, the additional irrigation would result in a significant increase in the nitrogen load (25 – 45%) and at least a 1 mg/L increase in average annual N concentration (Table 5). For the orange ‘at risk’ Ashburton catchment we predict an increase in average N load of approximately 45% for both methods and an increase in average annual N concentration of 0.5 - 0.6 mg/L. This may well be sufficient to move this catchment from orange to red. We cannot be definitive about this since the demarcations between ‘at risk’ and ‘not met’ are based on expert opinion. However I note that the commentary describing the reasons for the ‘orange category’ for the Ashburton catchment stated: “At threshold of likely effects. Large hill-fed river with moderate nutrient concentration increasing from groundwater gain in middle reaches” (Meredith et al. ,2012).

60. Because of the high attenuation in the Rakaia catchment, a significant increase in irrigable area (12,000 ha in the case of using the Aeru projections) is projected to result in only a minor increase in N load (at the gorge). In addition we predict that the average annual N concentration will not show a detectable increase (the current average concentration is 0.05 mg/L so it would require a 20% increase to move it to 0.06). In addition Meredith et al (2012) note the Rakaia has a ‘swift and flashy’ hydrology with no evidence of growths.

61. In all three catchments, the greatest effects would be expected to occur in summer when flows are lowest and temperatures highest. Tables 3 - 5 also include predicted average summer N concentrations (December-March) calculated using the complete hydrological record but only the summer flows. As expected the average summer N concentrations are predicted to be higher than the average annual N concentrations. Impacts of increased irrigation are shown to be exacerbated in the summer, with projected increases in summer N concentration of up to 0.8 mg/L for the Ashburton and up to 9 mg/L for the Selwyn.

THE EFFECTS OF ADDITIONAL RULES IN THE pCLWRP

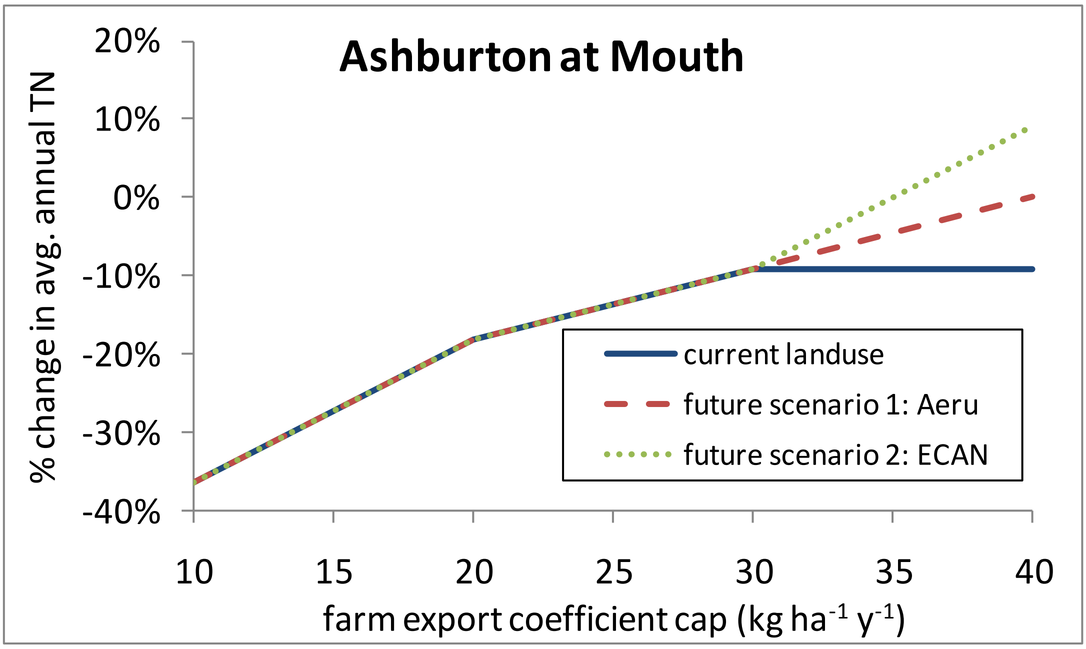
62. There is in my view a significant risk that development of Schedule 8 and regimes for sub catchments recommended in ZIPs and progressed through plan changes are uncertain and as such may be too little, too late to reverse the trends set in place by the rules 5.42-5.45 particularly in the over allocated (red) or at risk (orange catchments). As proposed by Fish and Game if farmers currently responsible for the greatest N losses were required to reduce their nitrogen footprint immediately, and others were not permitted to increase their exports, then there is more likelihood there would be sufficient 'headroom' for additional best practice irrigation.

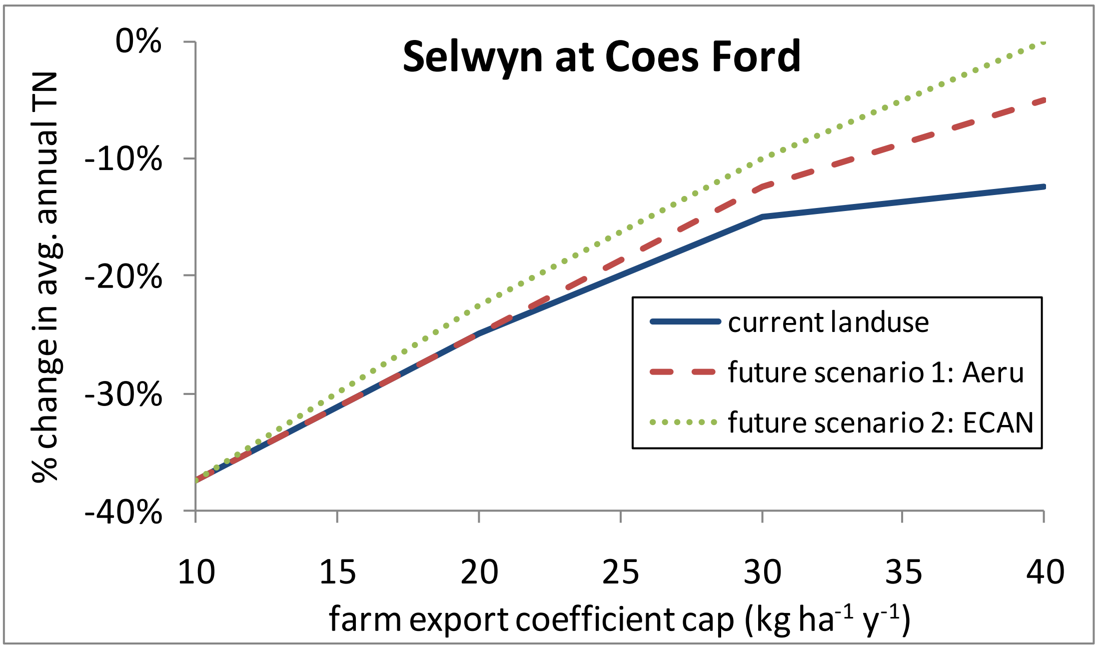
63. To illustrate this point, we modelled the effect of "capping" future N exports from all farm lands. We assumed caps in the range of 10 – 40 kg-N ha^{-1} y^{-1}. We applied these caps to all agricultural exports previously calculated with the current landuse distribution as well as our two landuse conversion scenarios. If the originally assigned export coefficients were lower than the assumed cap, then the original values were used. We focused our attention on only the Ashburton and Selwyn catchments for this exercise.

64. Results (Figure 4) are presented in terms of projected changes in average annual instream total nitrogen (TN) concentration, compared to current levels.

65. Results show that up to nearly 40% reductions in total nitrogen concentrations could be achieved in the two catchments with strict nitrogen export controls. Nitrogen caps of 20 kg ha^{-1} y^{-1} are projected to achieve nearly 20% reductions in TN concentrations for the Ashburton and approximately 25% reductions for the Selwyn, compared to current conditions.

Figure 4. Predicted effect of applying N caps on average annual N concentrations in the Ashburton and Selwyn-Waihora Rivers compared with the current state





66. Given that it is uncertain when sub regional plan changes will be place and what they will address, and that it is also uncertain what the complete framework for the region wide default rule framework will contain (including the Schedule 8 "look up" table for leaching rates), this reduction would give the zone committees some flexibility in deciding on strategies that meet the objectives of the CWMS, whereas

our predictions show that with the current rules in place they will have no (red zone) or little (orange zone) capacity to allow additional irrigation. Dr Dewe's evidence shows that the required reductions in N export can be made from the biggest N exporters for very little net cost and that over an investment cycle the measures proposed will result in a positive return for farmers. The immediate adoption of an N cap such as we have proposed will result in an improvement in water quality over time, which would be consistent with Policy A2 of the NPSFM.

Groundwater

67. Further evidence for the need for such a cap comes from the most recent survey of Canterbury groundwater quality (ECan, 2013).

68. The results for a 10 year trend analysis on the data collected each spring from 2002 to 2011, indicates that over the past 10 years, nitrate-nitrogen concentrations have been increasing in about 29% of wells sampled (305 wells – 220 wells have enough data to analyse trends). The Selwyn-Waihora and Ashburton zones together with Orari-Opihi-Pareora have the highest proportion of wells with increasing nitrate nitrogen trends. At least nine wells in the Ashburton Zone that showed an increasing trend had nitrate-nitrogen concentrations greater than 11.3 mg/L (the WHO drinking water standard) whilst a further 3 exceeded that limit but showed no trend (Figure 3, ECan, 2013). The Selwyn-Waihora Zone had no wells above the drinking water , but a high number in the 5.7-11.3 mg N/l range.

69. Interestingly E. Coli (indicator of pathogenic organisms) were not detected (<4 MPN/100 mL) in most wells but were present in 18% of the samples from wells less than 20m deep and 5% of samples were from wells between 20-50 m deep." (ECan), 2013). The Selwyn-Waihora and Ashburton zones each had four wells where E. Coli were detected. If increasing trends in nitrate-nitrogen is associated with livestock intensification, then in my view it is only a matter of time before E. Coli is detected in a higher number of wells.

SUMMARY AND CONCLUSIONS

70. A summary of the main predictions presented in Tables 3-5 and Figure 4 is given in Table 6.

71. For the ‘at risk’ Ashburton catchment we predict that in the absence of a cap on nitrogen exports, the current rules in the proposed CLWRP could lead to a significant increase in both annual N load and concentration during the period when up to 10% increases in N leaching rates are permitted. With the increase in irrigation proposed under either CWMS or Aeru scenarios we predict a very large increase in N load and concentration (40-50%) over that measured (and predicted) in the river under current land use. In my view, this would clearly result in the deterioration in key ecological indicators (macroinvertebrates and periphyton) as identified in the evidence of Associate Professor Russell Death. It would result in the Ashburton River catchment changing from ‘at risk’ to ‘not met’ (i.e. over allocated).

72. However , with the imposition of a cap on the amount of nitrogen able to be leached from irrigated land, we predict there will be significant decrease in nitrogen load and concentration even with the irrigation increase proposed by CWMS and Aeru. Whilst this would still not be sufficient to meet the target concentration proposed by Dr Death, it would still be a decrease from the current state and the trajectory of change would be downwards and it should be sufficient to maintain the catchments orange status, while trending towards ‘green’.

73. Similarly for the ‘not met’ Selwyn-Waihora catchment we predict that permitting a 10% increase in N leaching up to 2017 will result in a further increase in nitrogen load and concentration at Coes Ford and that the increase in irrigated area forecast by CWMS and Aeru will result in very large increases. Given this catchment is already under stress due to it being categorised as ‘not met’ (over allocated), my view is that increase in N load and concentration of the magnitude

forecast could be critical for the life-supporting capacity of the aquatic ecosystem.

74. However with the imposition of on the amount of nitrogen able to be leached from irrigated land, we predict there will be significant decrease in nitrogen load and concentration from the current state even with the irrigation increase proposed by CWMS and Aeru. Whilst this would still not be sufficient to meet the target concentration proposed by Dr Death, it would still be a decrease from the current state and the trajectory of change would be downwards. It is likely the catchment would still be considered over allocated but the trajectory of change (towards orange) may be sufficient to at least arrest any further deterioration in the life-supporting capacity of the ecosystem.

75. For the 'green' Rakaia catchment (at the gorge)our predictions are that a 10% increase in permitted N leaching would have no significant effect on N concentration or load in the river and nor would the 18% general increase in irrigable area forecast for Canterbury as a whole by Aeru. There would therefore be no need for a nitrogen cap. However we note the topography upstream of the gorge would limit expansion of irrigation in any case and that no increase as forecast under CWMS) is most likely. The catchment would therefore stay 'green' and meet the targets recommended by Dr Death.

Table 6. Summary of Nitrogen Export Modelling

Scenario	Avg. Annual TN Load (kg y^{-1}) (% change)	Avg. Annual N Conc. (mg L^{-1}) (% change)	Avg. Summer N Conc. (mg L^{-1}) (% change)
Ashburton at Mouth (proposed target 0.47 mg L^{-1} DIN)			
Current Land Use	755,000 (--)	1.2 (--)	1.8 (--)_
10% Increase	804,000 (+6%)	1.3 (+8%)	1.9 (+6%)
ECAN Land Use Change	1,100,000 (+46%)	1.8 (+50%)	2.6 (+44%)

Aeru Land Use Change	1,059,000 (+40%)	1.7 (+42%)	2.5 (+39%)
Current Land Use with 20 kg ha^{-1} y^{-1} cap	633,000 (-16%)	1.0 (-17%)	1.5 (-17%)
ECAN Land Use Change with 20 kg ha^{-1} y^{-1} cap	641,000 (-15%)	1.0 (-17%)	1.5 (_17%)
Aeru Land Use Change with 20 kg ha^{-1} y^{-1} cap	640,000 (-15%)	1.0 (-17%)	1.5 (-17%)
Selwyn at Coes Ford proposed target 1.5 mg L^{-1} DIN)			
Current Land Use	379,000 (--)	4.2 (--)	18 (--)
10% Increase	402,000 (+6%)	4.4 (+5%)	19 (+6%)
ECAN Land Use Change	557,000 (+47%)	6.1 (+45%)	27 (+50%)
Aeru Land Use Change	472,000 (+25%)	5.2 (+24%)	23 (+28%)
Current Land Use with 20 kg ha^{-1} y^{-1} cap	281,000 (-26%)	3.1 (-26%)	13 (-28%)
ECAN Land Use Change with 20 kg ha^{-1} y^{-1} cap	290,000 (-23%)	3.2 (-24%)	14 (-22%)
Aeru Land Use Change with 20 kg ha^{-1} y^{-1} cap	286,000 (-25%)	3.2 (-24%)	24 (-22%)
Rakaia at Gorge (proposed target 0.21 mg L^{-1} DIN)			
Current Land Use	319,000 (--)	0.05 (--)	0.05 (--)
10% Increase	348,000 (+8%)	0.06 (+20%)	0.05 (0%)
ECAN Land Use Change	319,000 (0%)	0.05 (0%)	0.05 (0%)
Aeru Land Use Change	353,000 (+10%)	0.06 (+20%)	0.05 (0%)

76. Whilst our modelling has not addressed groundwater concentrations, my view is that the imposition of a nitrogen cap would result in the

increasing trend of groundwater nitrate-nitrogen concentrations being arrested and eventually reversed in the Ashburton and Selwyn-Waihora catchments. Given there is undoubtedly a relationship between landuse intensity and the passage of pathogenic organisms to groundwater, the imposition of a nitrogen caps could arrest any further microbial contamination of aquifers in the Ashburton and Selwyn-Waihora zones.

77. Although our modelling is relatively simple, and does not take into account lag times between the leaching of nitrogen in the paddock, and its eventual appearance at a river measuring point, it is in my view sufficient to demonstrate a trajectory of change. This modelling has shown that the imposition of an immediate nitrogen cap is necessary to prevent any further increases in nitrogen within 'at risk' or 'not met' (over allocated) catchments.

DATED this 2nd day of April 2013

Dr James G Cooke

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