in the matter of: the Resource Management Act 1991

and

in the matter of: a number of applications to take and use water from the Upper Waitaki catchment

Brief of evidence of Matthew Ryan

Dated: 16 September 2009

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BRIEF OF EVIDENCE OF MATTHEW RYAN

INTRODUCTION

1 My full name is Matthew Ryan.

2 I am an Environmental Consultant and have worked in the agricultural/environmental science field for a period of 9 years in New Zealand, Germany and the Middle East. I am currently a director of Environmental Management Group Limited (EMG), an environmental consulting company specialising in the air, land and water resource areas.

3 I have the following qualifications: Bachelor of Agricultural Science (Honours) (Lincoln University); Graduate Certificate in Applied Computing (Lincoln University); Certificate of Proficiency in Hydrogeology (University of Canterbury); and Doctor of Philosophy in Soil Science (Lincoln University).

4 My PhD thesis titled "*Manipulating nitrogen dynamics in grazed dairy pasture soils to mitigate nitrous oxide emissions*" gave me a good understanding of soil nutrient dynamics, in particular soil nitrogen dynamics. Since the completion of my PhD (2002) I have been involved in a number of projects that have involved soil nutrient modelling of agro-ecosystems specifically to assess the environmental impacts of farming operations. Most recently, this has included being part of the team assessing the environmental impacts of farm intensification in South Canterbury associated with the proposed Hunter Downs Irrigation Scheme.

5 I confirm that I have read the Environment Court's Code of Conduct for expert witnesses and this evidence has been prepared in accordance with that code. I agree to comply with the code's terms. In that regard, I confirm that the statements made in this evidence are within my area of expertise (unless I state otherwise) and I also confirm that I have not omitted to consider material facts which might alter the opinions stated in this evidence.

6 In preparing this evidence I have reviewed:

6.1 Upper Waitaki-Mackenzie Irrigation Economic Impact Assessment (EIA); Prepared by Butcher Partners Ltd in association with McFarlane Rural Business (MRB);

6.2 Mackenzie Water Research Limited (MWRL), Farm Irrigation Analysis II. Partially Irrigated Farm Model. Prepared by Hugh Eaton of MRB;

6.3 Trolove, S. (2008). Yields of Dryland and Irrigated Crops Grown in the Upper Waitaki Catchment – Literature Review. Report prepared for GHD by Crop and Food Research;

6.4 Snow, V., King, W. (2008). Upper Waitaki Farm Systems and Nutrient Assessment. Stage 2: Pasture and Ryecorn Growth Modelling. Report prepared for GHD by AgResearch;

6.5 King, W. (2008). Upper Waitaki Farm Systems and Nutrient Assessment. Stage 2: Pasture Growth Literature Review. Report prepared for GHD by AgResearch;

6.6 Snow, V., Smeaton, D., Houlebrook, D. (2008). Upper Waitaki Farm Systems and Nutrient Assessment. Stage 3: Base Case Nutrient Assessments. Report prepared for GHD by AgResearch;

6.7 Snow, V., Smeaton, D., Houlebrook, D. (2009). Upper Waitaki Farm Systems and Nutrient Assessment. Stage 4: Irrigated Nutrient Assessments. Report prepared for GHD by AgResearch;

6.8 GHD: Cumulative water Quality Effects of Nutrients from Agricultural Intensification in the Upper Waitaki Catchment – Groundwater Report (2009);

6.9 GHD: Cumulative water Quality Effects of Nutrients from Agricultural Intensification in the Upper Waitaki Catchment – Summary Report (2009);

6.10 Relevant Policies and Rules of the Proposed Canterbury Natural Resources Regional Plan (2004) (PNRRP);

6.11 The evidence of **MR Ford/Mr** Harris and **Mr Rob Potts** on behalf of Meridian;

6.12 The evidence of **Dr Snow, Dr Monaghan,** and Joint evidence **of Dr Bright and Dr Robson** on behalf of MWRL; and

6.13 Relevant sections of the section 42A Officers' Reports.

7 I also note that I attended a caucusing meeting on the 22nd of July 2009 held at Environment Canterbury (ECan) with technical experts from MWRL, Meridian Energy Limited (Meridian) and ECan.

SCOPE OF EVIDENCE

8 In this evidence I have outlined:

8.1 Nitrogen cycling in soils under dryland farming;

8.2 the likely effects of further irrigation on soil nitrogen leaching in the Upper Waitaki Catchment;

8.3 the effectiveness of mitigation practices to reduce soil nitrogen losses;

8.4 the practicality of achieving significant reductions in soil nitrogen leaching in order to allow new development to occur; and

8.5 the significance of the inaccuracies highlighted above and relevance to the wider conclusions made in the MWRL Cumulative Water Quality Effects Assessment.

9 In my evidence I have concentrated solely on soil nitrogen losses and have not gone into any detail when commenting on the estimated soil phosphorus (P) leaching/runoff estimates in MWRL's study. My rationale for this is that the very low soil P losses presented (≤ 1 kg P/ha/yr) do not appear unreasonable. I would also state that any attempt to differentiate the small reported differences in P leaching between land use or farming systems is unrealistic, given that any P leaching /runoff differences between land use or farming systems involved are almost certainly within the margin of error of the OVERSEER model.

EXECUTIVE SUMMARY

10 After reviewing the MWRL Water Quality Assessment I believe that there are some fundamental flaws that I will outline in my evidence. However, my main conclusions from my review are as follows:

10.1 MWRL have significantly underestimated the extent of likely nitrogen leaching losses that will occur under new or renewed irrigated land.

10.2 The consequences of this are that the assimilative capacities of the various sub-catchment nodes and receiving environments having being significantly overestimated.

10.3 The required or expected level of farm mitigation has consequently been significantly under-estimated across all sub-catchments nodes and receiving environments; and

10.4 The expected levels of increased farm productivity able to be achieved with the addition of irrigation have also likely been significantly over-estimated.

NITROGEN CYCLING IN SOILS UNDER DRYLAND FARMING

11 The Upper Waitaki Catchment has historically been dominated by grazed grassland systems characterised by low inputs and stocking densities. This is primarily due to the region's extreme climatic conditions severely restricting dry matter production as a result of soil moisture deficits in the summer and shortened growing season as a result of cold winter temperatures. These climatic conditions have invariably affected soil development with minimal soil weathering (a function of rainfall and temperature) and low plant inputs. The end result is that much of the Upper Waitaki Catchment is characterised by soils with low levels of organic matter and fertility (particularly phosphorus and sulphur).

12 Dryland farming on these low quality soils and in the extreme environment presents a number of challenges that need to be overcome. Foremost is that the soils are low in organic matter and therefore have a low potential to supply plant available mineral nitrogen.

13 As elsewhere in New Zealand, the main option available to increase the mineral nitrogen status and productivity from extensive grassland soils has been to introduce and promote the growth of legumes (i.e. clover species) through the correction of nutrient deficiencies by the application of phosphate and sulphate fertilisers and pH adjustment. Through these actions introduced legumes are generally able to fix and supply from 100 to 200 kg of mineral nitrogen per hectare per year with moderate to high levels of superphosphate fertiliser inputs[1].

14 However, even with the introduction of legumes and the supply of mineral nitrogen they provide, dryland pastures are often still nitrogen deficient with any legume fixed nitrogen rapidly taken up by grasses within the pasture. Large yield responses (>60%) have been observed from the application of mineral nitrogen fertilisers[2]. However, given the large areas (thousands of hectares) normally associated with extensive dryland farming systems in the Upper Waitaki Catchment, topdressing with mineral nitrogen fertilisers is uneconomic and not a viable option. Hence, pasture production in these extensive dryland areas is severely capped to a low level (< 5

[1] Lambert (1987). Nitrogen fixation during improvement of North Island hill country pastures. New Zealand Journal of Experimental Agriculture 15: 267 – 270.

[2] Scott and Maunsell (1981). Pasture Irrigation in the MacKenzie Basin 1. Species comparison. New Zealand Journal of Experimental Agriculture 9: 279 -290.

t /ha/yr)[3] which ultimately severely restricts the stock carrying capacity (generally < 2 SUs/ha)[4] of the land.

15 It has been well established that animal urine patches are the main pathway for nitrogen leaching losses from New Zealand's grazed pastoral farming systems. However, given that the stocking rates on extensive dryland pastoral systems are very low, the actual amount of nitrogen leached from the soil from these farming systems is also very low (2 - 4 kg N/ha/yr)[4] and not much higher than levels from ungrazed tussock or scrub land (2 - 3 kg N ha/yr)[5].

EFFECTS OF FURTHER IRRIGATION ON SOIL LEACHING/RUNOFF OF NITRATE/NITROGEN IN THE UPPER WAITAKI CATCHMENT

16 Land use intensification as a result of irrigation inputs, higher fertiliser inputs and stocking rates results in increased drainage and runoff losses of nutrients from farming systems. MWRL have attempted to model these losses using the OVERSEER model[6] which is regarded as being a reasonable tool for modelling soil nutrient dynamics in New Zealand Agro-ecosystems.

17 However, the model is only as accurate as the input assumptions used, which need to be robust and representative of the systems being modelled. The OVERSEER model is principally driven by stocking rate and is sensitive to nitrogen fertiliser inputs, in particular nitrogen fertiliser inputs, which can have a large effect on the magnitude of soil nitrogen leaching estimates produced by the model.

18 My evidence provides comment on some of the assumptions used in the OVERSEER modelling and corresponding soil nitrogen leaching estimates from the existing and proposed farm systems within the Upper Waitaki Catchment. Comment is also provided on what the effect of altering key assumptions can make to the predicted leaching mass.

Nitrogen Leaching Load from Existing Farms

19 I have reviewed the Stage 3: Base Case Nutrient Assessments[7] used in MWRL's Water Quality Assessment and would like to comment on

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[3] Radcliffe and Cossens (1974). Seasonal Distribution of Pasture Production in New Zealand. New Zealand Journal of Experimental Agriculture 2: 349-358.

[4] Upper Waitaki Farm Systems and Nutrient Assessments. Stage 4: Base case nutrient assessments. AgResearch (2008).

[5] Cumulative Water Quality Effects of Nutrients from Agricultural Intensification in the Upper Waitaki Basin. Rivers and Lakes Report. GHD (2009).

[6]Developed by AgResearch, MAF and Fert Research

[7] Upper Waitaki Farm Systems and Nutrient Assessments. Stage 3: Base case nutrient assessments (2008).

some of the soil nitrogen leaching predictions made by OVERSEER for the various land uses from the 6 existing stations modelled, that are believed to characterise the existing farm systems within the Upper Waitaki catchment. The average nitrogen losses from different land uses (**Table 1**) across these 6 stations were then extrapolated to provide nitrogen leaching estimates for other existing farms within the Upper Waitaki catchment (see Paragraph 40.i in evidence of **Dr Snow**).

Table 1: Mean Soil Nitrogen Leaching Estimates by MWRL using OVERSEER from Different Land Uses on Existing Farms in the Waitaki Catchment Used in MWRL's Stage 3: Baseline Nutrient Assessment

Land Use	Area (ha)	Nitrogen Leached (kg/ha/yr)
Dryland Pasture	44,841	2.6
Irrigation	975	9[a] (31.4)[b]
Forage Crop	690	43.3
Grain	200	28
TOTAL	**46,706**	

[a] Developed soil setting
[b] Highly developed soil setting

20 However, I should also point out, that although not clearly apparent in any of the technical reports of the Water Quality Assessment, and as **Dr Snow** has stated in her evidence (see Paragraph 40.iii), the average nutrient loads for the different land uses (i.e. dryland, irrigation etc) from these existing farms were also extrapolated to calculate the nutrient loads from farms under the future case scenario with further irrigation development. And from my understanding from the Summary Report, for irrigated land the average nitrogen leaching estimate from the **developed** status was used (9 kg N/ha/yr).

21 **Table 1** shows the nitrogen leaching estimates from the various land uses under the existing farming systems modelled by MWRL in the Upper Waitaki catchment. The leaching estimates for land under dryland pasture, forage crops and grain do not appear to be unreasonable. However I do question the accuracy of the nitrogen leaching estimates (9 kg N/ha/yr) for irrigated land under the developed soil setting as this appears to be low.

22 It is likely that this is due to the use of inaccurate farm data in the OVERSEER modelling, in particular unreasonably low nitrogen fertiliser inputs relative to stated pasture dry matter yields

achieved, and the use of low stocking rates that do not correspond to the actual feed supply that is stated[7] as being able to be grown on the farms. For example, I question how Haldon Station can grow 14.4 t DM/ha on its irrigated blocks without any nitrogen fertiliser inputs (**Table 2**).

Table 2: Nitrogen Fertiliser Inputs and Pasture Dry Matter Production on Existing Irrigated Blocks on Existing Stations used in the Base Case Nutrient Assessment[7]

Station	Irrigated Area (ha)	Irrigation System	Nitrogen Fertiliser Loading (kg/ha/yr)	Pasture DM Yield (t/ha/yr)
Haldon	190	Pivot	0	14.4
Simons Hill	150	Pivot	150	13.4
Grays Hill	150	Pivot	120	13.8
Haldon	485	Border	0	14.4
Simons Pass	70	Border	100	4.0

23 In regard to using incorrect stock unit numbers, an example is the OVERSEER modelling for Simon's Hill station which was used in the base case nutrient assessment[7]. A review of the OVERSEER input file used in the modelling revealed that only 7,135 stock units were used in the simulation instead of the 9,600 that the station is stated in the report[7] as carrying, a difference of nearly 2,500 stock units.

24 As mentioned earlier, the OVERSEER model is driven by stocking rate and is particularly sensitive to nitrogen fertiliser inputs, both of which can have a large effect on the degree of soil nitrogen leaching losses predicted by the model. Hence, any underestimation of these two driving variables in the model will result in an underestimation of soil nitrogen leaching losses.

25 Rather than using the irrigated blocks from existing farms used in the baseline assessment, I believe that the projected nitrogen leaching loads (9 kg N/ha/yr) in the proposed developed irrigation scenario should have been based on the partially irrigated farm model[8] used in the MWRL's Economic Impact Assessment (EIA)[9]. As stated by **Mr Ford/Mr Harris** in his evidence, this farm model appears to be quite realistic of how irrigation is likely to be employed in the Upper Waitaki Catchment. I should also note that this farm model was developed by a reputable farm management consulting company that has a wealth of experience and good

[8] MacKenzie Water Research Limited. Farm Irrigation Analysis II. Partially Irrigated Farm Model. Prepared by MacFarlane Rural Business Limited (2009).

[9] Upper Waitaki-MacKenzie Irrigation Economic Impact Assessment. Prepared by Butcher Partners and MacFarlane Rural Business Limited (2009).

understanding of the existing farming systems in the Upper Waitaki Catchment and their irrigation potential. Therefore I am unsure why MWRL have chosen to adopt an alternative approach.

26 The EIA partially irrigated farm model was based on the assumption that an irrigated block with a moderate nitrogen fertiliser loading of 200 kg/ha/yr would produce around 10.2 tonnes dry matter consumed per year, enough to support around 16 - 18 stock units per hectare[10]. Assuming 75 to 85% pasture utilisation on irrigated blocks, this would equate to approximately 12 to 13.5 tonnes of dry matter per hectare per year. This is consistent with the levels of pasture production currently achieved with nitrogen fertiliser inputs on centre pivot irrigated blocks on two existing stations within the catchment (**Table 2**).

27 To further illustrate how appropriate the EIA partially irrigated farm model is with respect to the required level of nitrogen fertiliser inputs for a given level of pasture production, a direct comparison can be made with the Lincoln University Dairy Farm located near Lincoln in Canterbury. Coastal Canterbury has a more favourable climate for pasture growth than the Upper Waitaki Catchment, and the Lincoln University Dairy Farm produces around 16 tonnes dry matter per hectare with irrigation (centre-pivot) and moderate nitrogen fertiliser loadings of 200 kg N/ha/yr. The Lincoln dairy farm is considered to be in the top 5% of producing dairy farms in New Zealand. It achieves this very high level of production through very efficient irrigation and pasture management regimes. Hence, even in favourable climates - moderate amounts (100 to 200 kg N/ha/yr) of nitrogen fertiliser inputs are almost always required.

28 The application of moderate annual loadings of nitrogen fertiliser (which fully comply with the current Code of Practice for Nutrient Management[11]), is now common practice on many intensive pastoral systems in New Zealand in order to increase pasture growth[12] and achieve production targets, as most grass/clover pastures are chronically nitrogen deficient despite nitrogen fixation by clovers[13].

29 This is also in agreement with the actual farm nutrients plans already provided (e.g. Killermont, Glen Eyre Stations; August 2009) where annual nitrogen fertiliser loadings are expected to be at least 150 kg per hectare and effluent nitrogen loads of 110 kg N per hectare to give a total nitrogen loading of 260 kg N per hectare per year.

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[10] Assuming that 1 SU consumes 550 kg DM per year.

[11] Code of Practice for Nutrient Management. Fert Research (2007).

[12] McGrath et al. (1998). Using Nitrogen to Increase Dairy Farm Profitability. Proceedings of the New Zealand Society of Animal Production 58: 117 – 120.

[13] Pg C-17, Farm Technical Manual. Lincoln University (2003).

30 Given the farm assumptions used in the EIA, it is my opinion that the expected level of pasture production able to be achieved relative to the levels of nitrogen fertiliser and irrigation inputs is overly optimistic compared to actual levels that will be able to be achieved by the majority of farmers within the Upper Waitaki Catchment. I acknowledge that some farmers will be able to achieve higher levels of production on their irrigated blocks than others with lower nitrogen fertiliser inputs given more favourable soils and micro-climate in combination with efficient irrigation and pasture management etc. However these are the exceptions and not the norm. The farm assumptions used in the farm modelling in the Water Quality Assessment should be at a minimum geared towards the average farmer in combination of a robust sensitivity analysis of key driving variables (N fertiliser etc) on nitrogen leaching and factoring this in.

31 As outlined by **Mr Ford / Mr Harris** in his evidence, the farm assumptions outlined in the EIA partially irrigated farm model are a fair reflection of the average farm under the proposed developed irrigation scenario in the Upper Waitaki Catchment. In my opinion these assumptions should have been used in the Water Quality Assessment.

32 With regard to implications for the base line nutrient assessment, the effects of this underestimation on the baseline nutrient assessment are likely to be minor, mainly due to the fact that the nitrogen leaching underestimation is relatively small (2 kg N/ha/yr) and that the existing irrigated land in the catchment accounts for only a very small (<8%) area (8,432 ha) of the overall catchment (107,580 ha[14]).

33 However, this under-estimation does have significant implications in the overall Water Quality Assessment, because as indicated earlier (Paragraph 20), the average nitrogen leaching estimate for the **developed status** (9 kg N/ha/yr) was also principally used to calculate the proposed nutrient loads from irrigated land under the future development scenario.

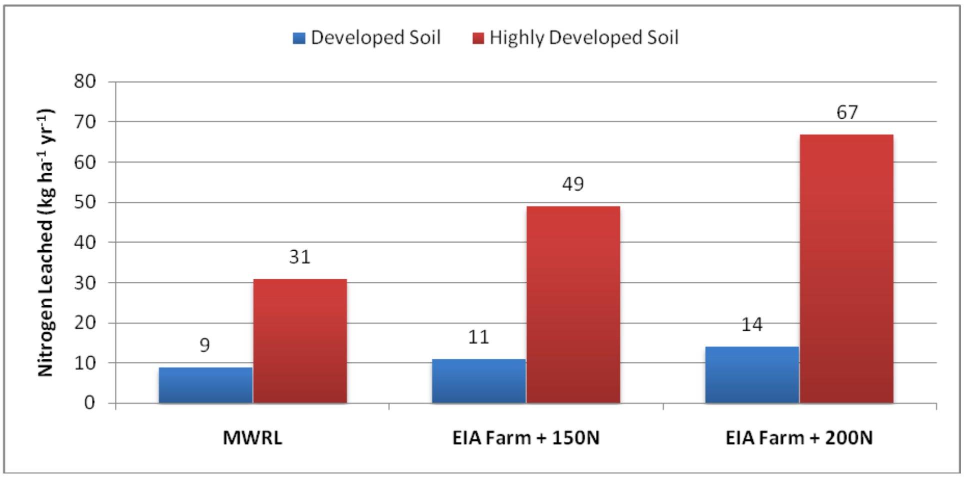
34 In essence, any under-estimation of this proposed nutrient load will also result in an underestimation of the degree of farm mitigation required to be under soil nutrient leaching/runoff caps so specific environmental thresholds are not breached.

Nitrogen Leaching Estimate Using the EIA Farm Model

[14] Water Quality Impacts from Irrigation Development. Upper Waitaki. Report prepared for Meridian Energy Limited by Glasson Potts Fowler Limited (2005).

35 **Figure 1** below shows the leaching estimates made by OVERSEER for an irrigated block under two nitrogen loading scenarios using the assumptions (grazed by sheep @ 16 - 18 SUs/ha) of the partially irrigated farm model in the EIA and compared with the leaching estimates for irrigated land used in MWRL's Water Quality Assessment. Leaching estimates for both a developed and highly developed soil setting have been provided. As can be seen from the graph, the nitrogen leaching projections under the EIA farm assumptions are significantly higher than MWRL's estimates for both developed and highly developed soil settings.

Figure 1: A Comparison of the Predicted Mass of Nitrogen Leached per Hectare by OVERSEER from Irrigated Land Grazed by Sheep using the EIA Partially Irrigated Farm Model Assumptions and the Nitrogen Leaching Projections made by MWRL under Developed and Highly Developed Soil Scenarios.



36 To put this in perspective over the wider catchment, I have scaled up the leaching estimates from above (Figure 1) and calculated the likely leaching loads from proposed new and renewed irrigation (29,357 ha)[15] in the overall catchment below in **Table 3** below.

[15] Evidence of Mr Robert Potts (Table 1).

Table 3: Calculated Nitrogen Leaching Loads from Proposed New and Renewed Irrigation (29,357 ha) in the Upper Waitaki Catchment Based on MWRL's Farm Assumptions and the EIA Farm Assumptions

Soil Development Status	Nitrogen Leached (t/yr)		
	MWRL	EIA Farm + 150N	EIA Farm + 200N
Developed	264 (9)	323 (11)	411 (14)
Highly Developed	921 (31.4)	1,438 (49)	1,967 (67)

Note:
Values in brackets indicate is the nitrogen leaching load (kg/ha/yr) on an aerial basis.

37 **Table 3** above shows that there is a significant difference in the projected nitrogen leaching loads over the overall catchment from new and renewed irrigation using MWRL's leaching projection (9 kg N/ha/yr) that appears to have been used in the Water Quality Assessment, and that projected using the EIA farm assumptions under both the *developed* and *highly developed* soil scenarios.

38 I believe that MWRL should have taken a conservative approach in their Water Quality Assessment and used the EIA farm (16 SUs/ha and 150 kg N fertiliser applied annually) assumptions. It also appears that no sensitivity analysis of key variables was undertaken in the OVERSEER modelling for the Water Quality Assessment that would have provided upper bound leaching estimates and a degree of comfort for projected leaching losses under the *developed* scenario. Given these short-comings in the modelling undertaken, I therefore believe that the Water Quality Assessment should have been based on the nitrogen leaching estimates modelled under the *highly developed* soil scenario.

39 Accordingly, on the understanding that MWRL have primarily based the Water Quality Assessment on the projected soil nitrogen leaching losses under the developed scenario (9 kg N/ha/yr), I believe that their assessment has underestimated the total annual load of soil nitrogen leaching losses from proposed new or renewed irrigated land by at least 1,174 tonnes per year, or around 40 kg of nitrogen per hectare (29,357 ha) of new or renewed irrigation per year.

40 It should be noted this estimation is based on the assumption that irrigated land would be utilised for sheep production only. In reality however, some of the irrigated land will also be used to grow forage crops and grazed by cattle, from which the extent of nitrogen leaching from the land would be greater. However I have not quantified this in my evidence.

41 The implications of this under-estimation of soil nitrogen leaching losses from the proposed new and renewed irrigation is that the

calculated assimilative capacity for water bodies within the overall catchment have likely been over-estimated on the basis that the assimilative capacity stated represents the difference between the proposed nutrient load and the environmental threshold. The effect of this over-estimation is that the stated level of required on-farm mitigation has been under-estimated.

42 This is highlighted in the **Tables 5 to 7** below, where I have taken and modified Tables 1, 2 and 5 from MWRL's Summary Report[5] and corrected the assimilative capacity for both *developed* and *highly developed* scenarios for each sub-catchment node to take into account the under-estimation of soil nitrogen leaching losses.

43 For example, the Ahuriri Arm receiving environment under the *developed* scenario, I have calculated would actually have positive assimilative capacity using the predicted nitrogen leaching estimate (11 kg N/ha/yr; **Figure 1**) generated in OVERSEER using the assumptions of the EIA+150N farm under the *developed* scenario. Where the corrected assimilative capacity for each sub-catchment or receiving environment can be defined by the following equation:

Where the **Corrected Assimilative Capacity** =

$$\frac{\text{MWRL Environmental Threshold} - (\text{Irrigation Area} \times \text{Leached N}_{\text{EIA Farm}})}{\text{Irrigation Area}}$$

For example, the corrected assimilative capacity for the Ahuriri River at Benmore sub-catchment node under the *developed* scenario (-7.0 kg N/ha/yr; **Table 5**) has been calculated accordingly:

$$= \frac{(27{,}000 \text{ kg N/ha/yr} - (6{,}696 \text{ ha} * \mathbf{11} \text{ kg N/ha/yr}))}{6{,}696 \text{ ha}}$$

$$= -7.0 \text{ kg N/ha/yr}$$

44 By dividing **MWRL's Environmental Threshold** for each sub-catchment/receiving environment by its respective **Irrigation Area**, the **Maximum Allowable N Leaching Load** to meet the Environmental Threshold can be back-calculated for each sub-catchment node or receiving environment. For example, the Maximum Allowable N Leaching load from irrigated land located in the Ahuriri River at Benmore sub-catchment node is only **4.0** kg N/ha/yr (= 27,000 kg N/ha/yr / 6,696 ha; **Table 6**).

45 By subtracting MWRL's value for **Total N Change to Achieve Environmental Threshold** from the **Maximum Allowable N Leaching Load**, the **MWRL Projected Future N Leaching Load**

for each sub-catchment or receiving environment can be calculated. For example, it can be seen in **Table 6** below that the MWRL Projected Future N Leaching Load for the Ahuriri River at Benmore sub-catchment node is **2.9** kg N/ha/yr (= 4.0 kg N/ha/yr – 1.1 kg N/ha/yr).

46 I would like to note that MWRL Projected Future Leaching Loads for the Ahuriri Arm (31.9 kg N/ha/yr; **Table 5**) and the Wairepo Creek (32.7 kg N/ha/yr; **Table 7**) appear to be calculated using a figure similar to the estimated leaching nitrogen leaching load (31.4 kg N/ha/yr; **Table 1**) from irrigated blocks on existing farms under the highly developed scenario. However, with the exception of the Omararma Stream sub-catchment node, the MWRL Projected Future N Leaching Loads from irrigated land going into the other sub-catchments range from only 1 to 4 kg N/ha/yr. To me these exceedingly low figures do not make sense and do not correlate with the nitrogen leaching loads MWRL have estimated (9 or 31.4 kg N/ha/yr; **Table 1**) to come from irrigated land.

47 I should point out that the corrected assimilative capacities in **Tables 5 to 7** below do not consider denitrification losses of nitrogen in drainage waters passing through riparian areas as the MWRL study has. The evidence of Mr Potts goes into this in more detail, but in brief, catchment scale denitrification losses of soil mineral nitrogen simply cannot be currently quantified and any model relying on this assumption is flawed and will underestimate the nitrogen leaching load into receiving surface waterbodies.

48 To summarise, in the MWRL Water Quality Assessment, with the exception of the Ahuriri Arm and Wairepo Creek receiving environments **(Tables 5 & 7**), all of the sub-catchment nodes or other receiving environments are stated as having positive assimilative capacity where no additional on-farm mitigation required under proposed irrigation. However after the correction of the assimilative capacities, the projected scenarios change dramatically. Under the **highly developed** scenario, all sub-catchments are likely to have negative or no assimilative capacity and significant on-farm mitigation will be required. Even under the less conservative **developed** scenario, the level of mitigation required after the correction is significantly more than what MWRL have predicted.

EIA Farm + 150 N Fert	Leached N (kg/ha/yr)
Developed	**11**
Highly Developed	**49**

Table 5: Permitted changes in nutrient loads to maintain the Ahuriri Arm of Lake Benmore in an Oligotrophic state

					Total N Change to Achieve Environmental Threshold (kg N/ha/yr)		
	Irrigation (ha)[a]	Environmental Threshold (kg N/yr)[a]	Max Allowable N Leaching Load to meet MWRL Environmental Threshold (kg N/ha/yr)[c]	MWRL Projected Future N Leaching Load (kg N/ha/yr)[d]	MWRL[a]	Corrected (Developed)[e]	Corrected (H. Developed)[f]
Ahuriri Arm	7,282	154,185	21.2	31.9	-10.7	10.2	-27.8

Table 6: Permitted changes in nitrogen loads at sub-catchment nodes for a 25% increase in periphyton biomass

					Total N Change to Achieve Environmental Threshold (kg N/ha/yr)		
Sub-catchment Node	Irrigation (ha)[a]	Environmental Threshold (kg N/yr)[a]	Max Allowable N Leaching Load to meet MWRL Environmental Threshold (kg N/ha/yr)[c]	MWRL Projected Future N Leaching Load (kg N/ha/yr)[d]	MWRL[a]	Corrected (Developed)[e]	Corrected (H. Developed)[f]
Stony River	-	9,175	-	-	-		-
Greys River	1,681	4,760	2.8	1.8	1.0	-8.2	-46.2
Tekapo	3,420	7,520	2.2	1.8	0.4	-8.8	-46.8
Mary Burn	1,152	4,850	4.2	2.7	1.5	-6.8	-44.8
Twizel River	1,230	3,440	2.8	1.8	1.0	-8.2	-46.2
Ahuriri River at Benmore	**6,696**	**27,000**	**4.0**	**2.9**	**1.1**	**-7.0**	**-45.0**
Omararma Stream	961	15,800	16.4	11.4	5.0	5.4	-32.6
Quail Burn	1,573	1,565	1.0	0.6	0.4	-10.0	-48.0
Pukaki at Benmore	10,156	23,150	2.3	1.8	0.5	-8.7	-46.7

Table 7: Required changes in nitrogen loads for no increase in tropic state in the Wairepo Arm and Kellands Road

					Total N Change to Achieve Environmental Threshold (kg N/ha/yr)		
Secondary Receiving Environment	**Irrigation (ha)[a]**	**Environmental Threshold (kg N/yr)[a]**	**Max Allowable N Leaching Load to meet MWRL Environmental Threshold (kg N/ha/yr)[c]**	**MWRL Projected Future N Leaching Load (kg N/ha/yr)[d]**	**MWRL[a]**	**Corrected (Developed)[e]**	**Corrected (H. Developed)[f]**
Wairepo Creek	3,642	59,484	16.3	32.7	-16.4	5.3	-32.7

[a]Sourced from Summary Report for the Water Quality Assessment

[b] **Max Allowable N Leaching Load** = MWRL Environmental Threshold/Irrigation Area

[c] **MWRL Estimated Future Leaching Load** = Maximum Allowable N Leaching Load – MWRL Total N Change to Achieve Environmental Threshold

[e]Based on an average N leaching loss from EIA +150 N Farm of **11** kg N /ha/yr

[f]Based on an average N leaching loss from EIA + 150N Farm of **49** kg N /ha/yr

THE EFFECTIVENESS OF MITIGATION PRACTICES TO REDUCE NITRATE LEACHING

49 MWRL have highlighted[16] up to 40 mitigation practices that could be employed by farmers to reduce N and P leaching/runoff from farming systems. I would contend that many of these measures highlighted are either not yet recognised as viable mitigation practices, impractical or are actually Best Management Practices (BMPs) that are either already in use or should already be employed by farmers in all locations. I should, also point out that many of the mitigation options identified that are in fact BMPs are already assumed in OVERSEER. Hence, any nutrient budget undertaken for a farm using OVERSEER will be based on the assumption that these BMPs are already in use on the farm.

50 I also contend that these mitigation measures are also only really applicable to land that is already intensively farmed or is land that will be irrigated. On extensive farm land with low stocking rates (< 2 SUs/ha) and where the nitrogen leaching load is already very low (< 3 kg N/ha/yr), any of the outlined mitigation would have very little or no effect.

51 In **Appendix A** I have summarised the mitigation practices highlighted by MWRL. From this table it is clearly evident that the mitigation measures available to reduce N and P leaching/runoff losses and N leaching in particular are actually quite limited. Apart from reducing stocking rates, nitrogen fertiliser inputs and scaling back the overall intensity of land use and production from the land, the only real mitigation tools available for farmers to reduce the nitrate leaching load from their land is to either:

51.1 Use nitrification inhibitors; and/or

51.2 Restricted grazing.

52 However, even using both these mitigation measures, I would question the actual effectiveness or degree of mitigation that could be achieved without having to scale back the intensity (i.e. stocking rate and fertiliser inputs) of land use on irrigated blocks. To illustrate this point **Table 8** of my evidence shows the result of an OVERSEER simulation of an irrigated block in the developed soil phase that is grazed by sheep at 16 SUs/ha and receiving a moderate fertiliser loading of 150 kg N/ha/yr. Using the two mitigation options (i.e. restricted grazing and/or the use nitrification inhibitors) available in the OVERSEER model, this exercise shows that the mitigation options could only achieve a maximum 27% reduction in soil nitrogen leaching losses. For some reason the

[16] Cumulative Water Quality Effects of Nutrients from Agricultural Intensification in the Upper Waitaki Catchment. Mitigations Toolkit. GHD (2009).

OVERSEER model cannot model these mitigation options under the highly developed soil setting, therefore I have assumed that this degree of mitigation would also apply for highly developed soils and have calculated accordingly in table 8 of my evidence.

Table 8: OVERSEER Simulation of Irrigated Land on the EIA Farm (+150 N Fert) Showing the Effectiveness of Two Mitigation Options Available in OVERSEER.

Measure	**Nitrogen Leached (kg ha^{-1} yr^{-1})**	
	Developed[a]	**H.Developed**[b]
No Mitigation	11	49
No Winter Grazing only	10 (-9%)	45 (-9%)
Nitrification inhibitors only	8 (-27%)	36 (-27%)
No Winter Grazing + Nitrification Inhibitors	8 (-27%)	36 (-27%)

[a]Derived from OVERSEER
[b]Calculated

53 The example showed in Table 8 shows, that using the mitigation options currently quantifiable in OVERSEER, the maximum level of nitrogen leaching mitigation likely able to be achieved from a typical farm will only be 3 to 13 kg N/ha/yr for soils in a developed or highly developed state respectively. This clearly demonstrates that using the two available mitigation options that can be quantified in the OVERSEER model, the level of mitigation will fall well short of that required to comply with MWRL's Environmental Thresholds set for the sub-catchment nodes and receiving environments (**Tables 5 to 7**).

THE PRACTICALITY OF ACHIEVING SIGNIFICANT REDUCTIONS IN NITROGEN LEACHING LOSSES IN ORDER FOR DEVELOPMENT TO PROCEED

54 As I have discussed, the level of nitrogen leaching reductions required to meet the required environmental thresholds for the receiving environments (**Tables 5 to 7**) will be unachievable with the mitigation options available in OVERSEER. Failing mitigation, the only other viable mitigation option is to lower the level of production (i.e. reducing stocking rate and N fertiliser inputs) on irrigated land to achieve the required reduction targets for nitrogen leaching (**Tables 5 to 7**).

55 **Table 9** of my evidence shows the modelled expected nitrogen leaching from an irrigated sheep farm under various stocking rates and nitrogen fertiliser inputs, without and with the two mitigation measures (i.e. nitrification inhibitors and restricted grazing) that can be quantified in OVERSEER. These estimates were modelled in OVERSEER under both *developed* and *highly developed* soils.

Table 9: OVERSEER Projected Nitrogen Leaching Loads and Expected Nitrogen Leaching Reduction Achieved from Developed and Highly Developed Soils on Irrigated Sheep Blocks under Varying Stocking Rates and Nitrogen Fertiliser Inputs with and without Mitigation Measures

Developed Soil

						No Mitigation		With Mitigation	
Stocking Rate (SUs/ha)	**DM Intake[a] (kg/ha)**	**Required DM Supply[b] (kg/ha)**	**Pasture N Uptake[c] (kg N/ha/yr)**	**Clover N (kg N/ha/yr)**	**Required N Fert[d] (kg N/ha/yr)**	**N Leached (kg/ha/yr)**	**N Leaching Reduction (kg/ha/yr)**	**N Leached (kg/ha/yr)**	**N Leaching Reduction (kg/ha/yr)**
16	8,800	11,733	352	200	152	11	-	9	-2
15	8,250	11,000	330	200	130	9	-2	7	-4
14	7,700	10,267	308	200	108	8	-3	6	-5
13	7,150	9,533	286	200	86	7	-4	6	-5
12	6,600	8,800	264	200	64	6	-5	5	-6
11	6,050	8,067	242	200	42	5	-6	4	**-7**
10	5,500	7,333	220	200	20	5	-6	4	-7
9	4,950	6,600	198	200	-	4	-7	4	-7
8	4,400	5,867	176	200	-	4	-7	3	-8
7	3,850	5,133	154	200	-	4	-7	3	-8
6	3,300	4,400	132	200	-	4	-7	3	-8
5	2,750	3,667	110	200	-	3	-8	3	-8
4	2,200	2,933	88	200	-	3	-8	3	-8
3	1,650	2,200	66	200	-	3	-8	3	-8

Highly Developed Soil						No Mitigation		With Mitigation	
Stocking Rate (SUs/ha)	DM Intake[a] (kg/ha)	Required DM Supply[b] (kg/ha)	Pasture N Uptake[c] (kg N/ha/yr)	Clover N (kg N/ha/yr)	Required N Fert[d] (kg N/ha/yr)	N Leached (kg/ha/yr)	N Leaching Reduction (kg/ha/yr)	N Leached[e] (kg/ha/yr)	N Leaching Reduction (kg/ha/yr)
16	8,800	11,733	352	200	152	49	-	36	-13
15	8,250	11,000	330	200	130	42	-7	31	-18
14	7,700	10,267	308	200	108	35	-14	26	-23
13	7,150	9,533	286	200	86	28	-21	20	-29
12	6,600	8,800	264	200	64	22	-27	16	-33
11	6,050	8,067	242	200	42	15	-34	11	-38
10	5,500	7,333	220	200	20	10	-39	7	-42
9	4,950	6,600	198	200	-	7	-42	5	-44
8	4,400	5,867	176	200	-	6	-43	4	**-45**
7	3,850	5,133	154	200	-	6	-43	4	-45
6	3,300	4,400	132	200	-	6	-43	4	-45
5	2,750	3,667	110	200	-	6	-43	4	-45
4	2,200	2,933	88	200	-	6	-43	4	-45
3	1,650	2,200	66	200	-	6	-43	4	-45

[a]Based on 1 standard SU requiring 550 kg DM/yr

[b]Based on 75% pasture utilisation

[c]Based on mean DM N content of 3%

[d]N Fert = Pasture N uptake - Clover N

[e]Assumes 27% reduction in N leaching load with mitigation (restricted grazing and nitrification inhibitors)

56 For example a sheep farm located in the Ahuriri River at Benmore sub-catchment node, would require an annual nitrogen leaching reduction of 7 or 45 kg N per hectare of new or renewed irrigation under *developed* or *highly developed* soils respectively (**Table 6**). Assuming a farmer was planning to irrigate 100 ha of their property, then the total nitrogen leaching reduction required from the farm would be 700 or 4,500 kg N/ha/yr for developed and highly developed soils respectively (**Table Error! Reference source not found.10**).

Table10: Example Soil Nitrogen Balance for a Farm Situated in the Ahuriri River at Benmore Sub-catchment Node

Ahuriri River at Benmore Sub-catchment Node	**Unit**	**Developed Soil**	**H. Developed Soil**
Required N Leaching Reduction per Hectare of Irrigation	kg N/ha/yr	7	45
Irrigation Area	ha	100	100
Total Farm N Leaching Reduction Required	kg N/yr	700	4,500
N Leaching Reduction Achieved from Reduced Stocking Rate and N Fert Inputs	kg N/ha/yr	7	45
Total Farm N Leaching Reduction Achieved	**kg N/yr**	**700**	**4,500**
Farm N Leaching Load over Environmental Threshold	kg N/yr	-	-
Farm Compliance with Environmental Threshold		**YES**	**YES**

57 In order to achieve a total farm nitrogen leaching reduction of 700 or 4,500 kg N/ha/yr (7 or 45 kg N/ha/yr), we can see in **Table 9** (rows highlighted red) that a farmer would have to employ on-farm mitigation measures, apply very low (i.e < 45 kg N/ha/yr) or zero nitrogen fertiliser to the irrigated block, and would only be able to add an additional 11 or 8 stock units per hectare of irrigation to their farming operation respectively with *developed* or *highly developed* soils. This is significantly less than the 16 - 18 SUs/ha that irrigated land in the Upper Waitaki can potentially support.

58 As shown in **Table 11** below, the overall net impact on the farm with respect to stock units being able to be farmed with and without irrigation, is that the farm would have a net gain of only 950 or 650 stock units under developed or highly developed soils respectively if deciding to irrigate.

Table 11: Stock Unit Comparison of an Example Sheep Farm Located in the Ahuriri River at Benmore Sub-catchment Node with and without Irrigation under Developed and Highly Developed Soils

	Unit	No Irrigation (Developed Soil)	With Irrigation (Developed Soil)	With Irrigation (H. Developed Soil)
Grazed Dryland Irrigated Land	ha ha	3,000 -	2,900 100	2,900 100
Total Farm Area	**ha**	**3,000**	**3,000**	**3,000**
Dryland SR Irrigated SR	SUs/ha SUs/ha	1.5 -	1.5 11	1.5 8
Total Farm Stock Units	**SUs**	**4,500**	**5,450**	**5,150**
Stock Unit Differential	**SUs**	-	**950**	**650**

RESPONSE TO MWRL EXPERT EVIDENCE

59 In this section I would like to take the opportunity to respond to the evidence of the following MWRL experts:

59.1 Dr Valerie Snow;

59.2 Dr Ross Monaghan; and

59.3 Dr John Bright and Dr Melissa Robson (joint evidence).

Comment on Evidence of Dr Valerie Snow

60 In her evidence, Dr Snow has stated (Paragraph 34) that nutrient leaching/runoff estimates from irrigated land were made under the highly developed soil setting in OVERSEER to provide a conservative or worst case scenario of nutrient leaching/runoff from irrigated blocks. She also stated the following in Paragraph 39 (iii) of her evidence:

"usage of the "Highly Developed" values is recommended as it represents a conservative upper bound on the nutrient losses"

61 It is my opinion that the *highly developed* nutrient leaching loss estimates can only be viewed as perhaps extreme potential upper limits and cannot be relied upon with any degree of confidence. My rational for this is that OVERSEER has been well calibrated and validated for farming systems on *developed* soils. It has not been well calibrated or validated for farming systems on *highly developed* soils, simply due to the fact most New Zealand agricultural soils are

still in a *developed* phase. And as the developers of OVERSEER quote:

"Developed (developed soil) is the default value that transpired from research trials used to calibrate the model. Highly Developed has only been measured in a single research trial where effluent was applied for a long period of time at high rates. Given this uncertainty, it is recommended that the Developed setting is selected unless there are good reasons to select an alternative." (OVERSEER Help module, 2009).

However, as no sensitivity analysis of key OVERSEER input variables for the developed scenario has been undertaken and accounted for in the Water Quality Assessment to provide upper bound estimates (under the developed soil scenario), I would therefore suggest that using the highly developed leaching estimates in this situation is appropriate.

Comment on Evidence of Dr Ross Monaghan

62 In his evidence, Dr Monaghan states that the OVERSEER model is an appropriate tool for estimating nutrient losses from farming systems in the Waitaki catchment. Although he does also state that nitrogen leaching losses from shallow soils in the Waitaki Catchment are likely to have been underestimated by 10 to 20% (Paragraph 17).

I would agree with Dr Monaghan that OVERSEER is an appropriate tool to use in the Upper Waitaki Catchment Water Quality study, however I would question his suggestion that the nitrogen leaching estimates have been underestimated (10-20%) due to large areas of the Upper Waitaki being covered by shallow soils and OVERSEER not modelling these areas well. The OVERSEER model is primarily developed from field nitrogen leaching trials, with many of these recent studies undertaken on free-draining soils in Canterbury. Therefore, I therefore see no reason why the OVERSEER model would underestimate nitrogen leaching losses from shallow soils in the Upper Waitaki catchment. Rather, as stated earlier in my evidence, I believe that the underestimation of nitrogen leaching losses from irrigated farm land is the result of use of incorrect farm assumptions.

Comment on Joint Evidence of Dr John Bright and Dr Melissa Robson

63 In Paragraphs 10.26 to 10.32 of their evidence, two dairy farm examples are given for two proposed dairy farms (Killermont and

Glen Eyrie) located in the Ahuriri Arm and Wairepo Creek sub-catchments as examples to demonstrate the feasibility of the required degree of nutrient discharge reduction. I would agree with their assessment, that these two farm systems where grazing is restricted and cows are essentially housed most of the year should have a significantly reduced leaching load compared to a typical New Zealand dairy farm system. In these systems, nitrogen leaching losses are typically in the order of 20 - 30 kg N/ha/yr with moderate (100 – 200 kg N/ha/yr) nitrogen loadings. I agree that these type of dairy farm systems proposed would likely have nitrogen leaching loads less than the permitted maximum nitrogen leaching loads (21 and 16 kg N/ha/yr) for the sub-catchments mentioned, assuming that the Environmental thresholds calculated for the sub-catchments are realistic.

64 However, the two dairy farm examples presented are unusual and certainly not typical of how irrigation would likely be employed, where partially irrigated sheep and beef farms would likely predominate. And as I have demonstrated in my evidence, most farms wanting to irrigate would need to have a significant degree of on-farm mitigation as well as actually reducing the level of production from a level they might have otherwise considered to levels that would comply with tight environmental thresholds in most catchments.

COMMENT ON SECTION 42A OFFICERS REPORT

65 I have read the relevant sections of the officer's report and I agree with the conclusions (Paragraphs 61 - 64) of Dr Brent Clothier, specifically I agree with his conclusion (Paragraph 62) that the nitrogen leaching estimates in the Water Quality Assessment are low.

CONCLUSIONS

66 From my review of the Water Quality Assessment I believe that MWRL have significantly underestimated the extent of likely nitrogen leaching losses that will occur under new or renewed irrigated land.

67 The consequences of this are that the assimilative capacities of the various sub-catchment nodes and receiving environments having being significantly overestimated.

68 The required or expected level of farm mitigation has consequently been significantly under-estimated across all sub-catchments nodes and receiving environments.

69 The expected levels of increased farm productivity able to be achieved with the addition of irrigation have also likely been significantly over-estimated.

70 I would therefore recommend that the Commissioners seek the following:

70.1 That MWRL undertake further farm system modelling using realistic farm assumptions that are more consistent with those used in the EIA. Specifically, this should include:

(a) Use of realistic future farm assumptions with respect to nitrogen fertiliser loadings (i.e. 100 to 200 kg N/ha/yr) and stocking rate (16 - 18 SUs/ha) on irrigated land used for intensive pastoral animal production;

70.2 Undertake a robust sensitivity analysis of the effect of varying nitrogen fertiliser inputs (i.e. 100 to 300 kg N/ha/yr) on nitrogen leaching under the **developed** soil scenario to create realistic upper bound nitrogen leaching estimates; or

Calculate the proposed nitrogen leaching load for all sub-catchments based on OVERSEER nitrogen leaching estimates under the **highly developed** soil setting; and

70.3 Do not assume that denitrification losses of nitrogen in water passing through riparian zones will reduce the leaching load entering surface water bodies.

Dated: 16 September 2009

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Matthew Ryan