IN THE MATTER of the Resource Management Act 1991

AND IN THE MATTER of resource consent applications to take and use water for irrigation in the MacKenzie Basin

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STATEMENT OF Valerie Olga Snow

Rebuttal of Evidence

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1. My name is Valerie Olga Snow. My qualifications and experience are set out in my evidence in chief dated 9 August 2009. I confirm that I have read and am familiar with the "Code of Conduct for Expert Witnesses" in the Environment Court Practice Note (31 July 2006). I agree to comply with the Code.

2. The purpose of this statement is to respond to the Section 42A report of Dr Brent Clothier and the evidence submitted by Mr Robert Potts and Dr Matthew Ryan, to summarise points of agreement reached during a caucus of experts discussing the nutrient modelling, and to address a remaining point of primary disagreement following the nutrient caucus.

Nutrient Caucus 12 October 2009

3. Nutrient caucusing between technical experts acting for Mackenzie Water Research Limited (Dr Melissa Robson, Dr Ross Monaghan and myself), Meridian Energy Limited (Dr Matthew Ryan, and Dr Robert Potts) and Environment Canterbury (Dr Brent Clothier) was undertaken by video conference on 12 October 2009.

4. The purpose of the caucus was to address points of clarification arising from written evidence provided to the Hearings Panel, identify points of agreement and discuss remaining points of disagreement. Meeting notes were taken and circulated accordingly. The notes are attached as Annexure A of this evidence.

Points of Agreement Reached During the Nutrient Caucus

5. During the caucus several points were agreed. The points of agreement relevant to my evidence are summarised as follows.

6. It was clarified that AgResearch's future/generic farm systems modelling was not used to derive nutrient loadings in the water quality study, but was only used as a 'passive' cross-check. Following this it was agreed that many of Dr Clothier's issues outlined in his Section 42A report were no longer of concern.

7. It was agreed that:
    a. Monitoring of nutrient losses from some farms would be useful but this need not be carried out on all farms because representative testing on targeted farms could be interpreted and extrapolated for use throughout the catchment.
    b. It was further agreed that there should be a higher burden of monitoring requirement for farms that were running more intensive systems with modelled nutrient losses closer to their Nutrient Discharge Allowance

8. It was agreed that:
    a. If a proposed farm system could meet its Nutrient Discharge Allowance using the Highly Developed setting in OVERSEER® then monitoring of their soils for development status should not be required.
    b. Those farms that would not meet their Nutrient Discharge Allowance at the Highly Developed setting in OVERSEER® but that would meet their Nutrient Discharge Allowance at the Developed setting should be:
        i. required to undertake some degree of monitoring of soil development status, and,
        ii. use interpreted data from the representative lysimeters, and,
        iii. should consider using mechanistic modelling to support the monitoring data, and that,
        iv. the greater the N immobilisation estimated by OVERSEER® at the Developed setting, the greater the monitoring requirement should be.

9. It was agreed that OVERSEER® was an appropriate tool for monitoring compliance to Nutrient Discharge Allowances.

10. It was agreed that monitoring of compliance to a Nutrient Discharge Allowance should be done annually, but it should be calculated as an average of the previous 3 to 5 years. The duration of the averaging should be decided depending on the transport time lags in the sub-catchment.

11. Full notes on these points of agreement are attached as Annexure A.

Points of Disagreement Remaining Following the Nutrient Caucus

12. Following the Nutrient Caucus one primary and one follow-on point of disagreement relevant to my evidence remained.

13. The primary point of disagreement was that Dr Clothier and Dr Ryan asserted that, at about 14 tonnes of dry matter per hectare per year, the EcoMod estimates of irrigated pasture growth were unrealistically high. They asserted that a more reasonable estimate of pasture growth was about 12 tonnes of dry matter per hectare per year.

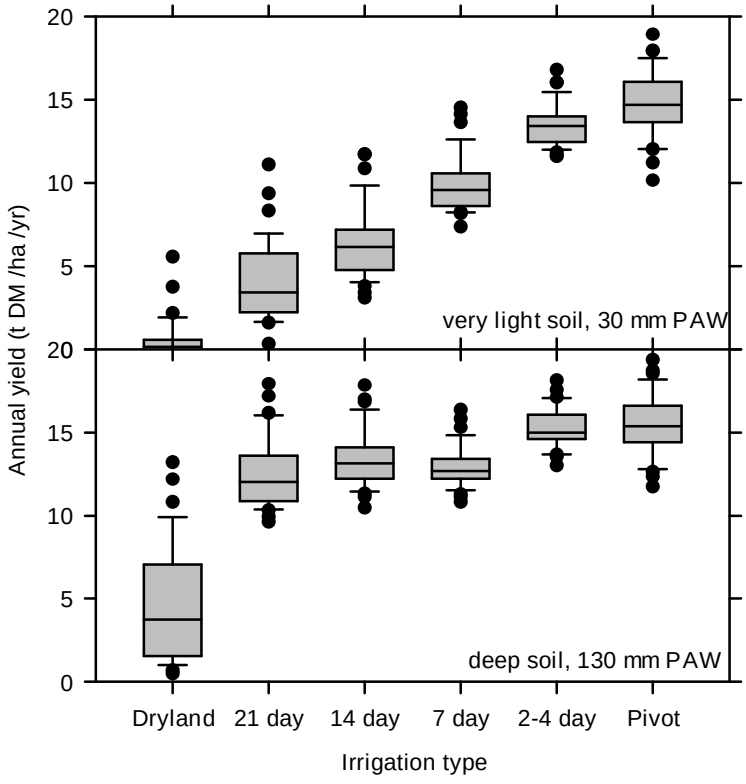
14. The follow-on point of disagreement focussed on the estimated nitrogen leaching from the irrigated sheep and beef farms.
    a. Drs Clothier and Ryan asserted that, because the EcoMod estimates of pasture growth were too high, farmers would add nitrogen fertiliser to grow an additional 2 tonnes of dry matter /ha /yr and that the additional nitrogen fertiliser would increase leaching from the irrigated sheep and beef farms from 9 kg N /ha /yr to 11 kg N /ha /yr.
    b. Dr Ryan argued that the additional mitigation required by sheep and beef farmers to meet their Nutrient Discharge Allowances after the additional nitrogen fertiliser was applied would render those farms economically infeasible.
    c. Dr Monaghan argued that the difference between 9 and 11 kg N /ha /yr of leaching was substantially less than the ability of current technologies to measure and that it was not possible to definitively argue that one value was more likely to be correct than the other.

15. Full notes on these points of disagreement are attached as Annexure A. The following section of my rebuttable evidence focuses on the estimates of pasture growth as the primary source of disagreement. Dr Melissa Robson will present rebuttal evidence addressing the likely, minimal, impact of the difference between 9 and 11 kg N /ha /yr leaching should Dr Ryan's concerns, which hinge on the pasture production estimates, eventuate.

Estimates of Irrigated Pasture Growth Rates

16. Both Dr Clothier and Dr Ryan are of the opinion that the irrigated pasture growth estimated by EcoMod produced production values that are unrealistically high. Dr Clothier compares the EcoMod pasture production against measurements from trials conducted during the 1980s in the Mackenzie Basin. Those measurements produced irrigated yields up to 15 t DM /ha /yr but was generally between 5 and 10 t DM /ha /yr depending on species, soil type, irrigation management and fertiliser additions. The EcoMod yields, at about 14 t DM /ha /yr, were considerably higher than much of the 1980s trial data.

17. There is a sound reason for the differences between the EcoMod estimates and the 1980s trial data. The irrigation trials in the 1980s were done with a return interval or 14 or 21 days while the irrigation design for the consent applicants is for pivot irrigation with return intervals of 2 or 4 days. To illustrate the effect of irrigation return interval on pasture production EcoMod was set up with a range of return intervals and the resulting pasture yields were examined and are shown in Figure 1.



18.

Figure 1. Annual growth rate in the "500 mm" rainfall climate and the "30 mm" and "130 mm" soils for a range of irrigation assumptions. In the labelling "14 day", for example, refers to the return interval between 100 mm irrigations. The "Pivot" irrigations were as designed by Aqualinc. The box-whiskers show the spread of likely growth rates across the simulation years.

19. Figure 1 shows pasture production on either a light soil or a deep soil for several irrigation return intervals. That range includes the 14-day return interval commonly used in the reported irrigation trials as well as the return intervals used in modern irrigation systems. The only difference between simulations was the selected soil type or the irrigation scheduling. As would be expected, there is a much stronger impact of return interval on pasture production from the shallow soil than the deep soil.

20. It is clear from Figure 1 that, when using a 14-day return interval as was used in much of the trial work in the 1980s, the pasture growth estimated by EcoMod is consistent with the measured values that Dr Clothier cites. While this work cannot be used to categorically state that EcoMod's estimates are correct under the short return intervals it does lend considerable support to the estimates.

21. Dr Clothier reproduced a figure from Scott and Maunsell[1] to support his assertion that the EcoMod estimates of pasture growth were too high. In this case he used a growth curve from irrigated Apanui cocksfoot grown as a monoculture with no pasture legumes present. The figure clearly shows a growth depression in late summer which is presumably from heat stress in the grass. He notes that EcoMod's estimates did not mimic the growth depression.

22. Dr Clothier's choice of a grass monoculture to support his argument is interesting and worthy of further investigation. The cocksfoot monoculture is presented below along with ryegrass and legume monocultures and the one mixed-species treatment used in the Scott and Maunsell work.

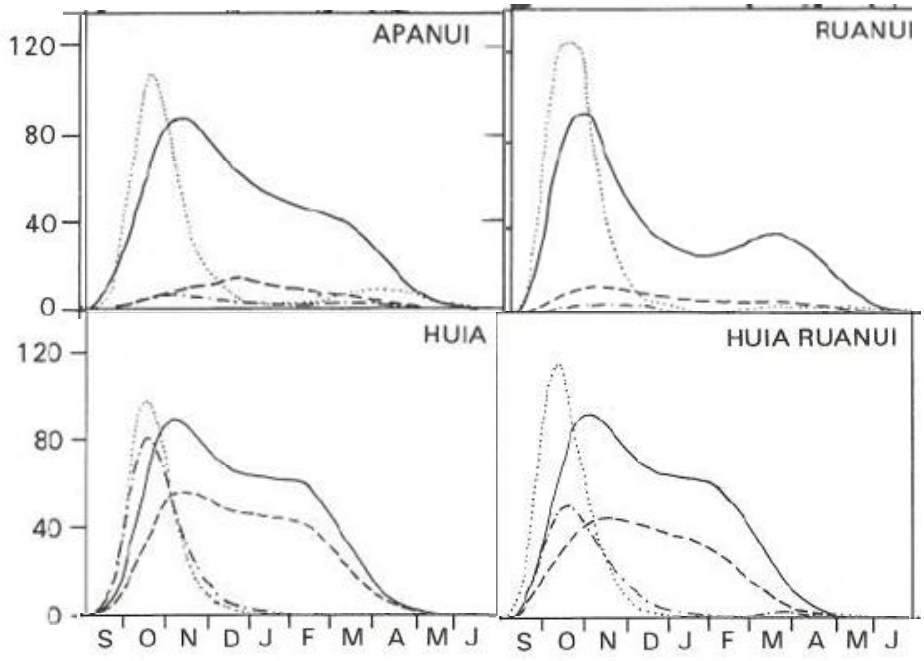


Figure 2. Selected growth patterns as reported by Scott and Maunsell[1].

23. In Figure 2, the vertical axis is growth rate in kg DM /ha /day. The lines represent alternative irrigation and fertiliser strategies with the solid line showing the highest level of irrigation and fertiliser. "Apanui" is a

[1] Scott D, Maunsell LA (1981) Pasture irrigation in the Mackenzie Basin. 1. Species comparison. New Zealand Journal of Experimental Agriculture 9, 279-290.

monoculture cocksfoot, “Ruanui” is a monoculture ryegrass, “Huia” is a monoculture white clover, and “Huia Ruanui” is a ryegrass-white clover mix. The full range of species from Scott and Maunsell[1] is given in Annexure B.

24. It is clear from these figures that the legumes and the legume-mixtures have a growth advantage over the grass monocultures in summer. This occurs because the critical daily maximum temperature that causes heat stress and depressed growth is lower in the C3 grasses than in legumes. Literature values[2] have been used in EcoMod to set the onset on heat stress in ryegrass at 26 C and in white clover at 30 C. This reflects the growth advantage that legumes have over ryegrass provided they have sufficient water and are adequately fertilised with phosphorus and potassium.

25. EcoMod reflects this advantage of legumes over grasses in summer because it explicitly models each of the species. It is possible that Dr Clothier's perceptions of likely pasture growth in late summer have been tuned by his experience with the estimates of SPASMO. I have some knowledge of SPASMO through previous conversations with its author, Dr Steve Green. Those conversations were held between 2001 and 2004. At that time SPASMO did not explicitly model a grass-legume mix but instead modelled the pasture as if it were a ryegrass monoculture but then added a fixed legume contribution to ensure a reasonable calculation of nitrogen fixation. This is a pragmatic solution to a difficult modelling issue and in many places in New Zealand would have little effect on the modelled pasture growth. However in the Mackenzie Basin under irrigated conditions, and in light of the data from Scott and Maunsell[1], is likely to underestimate summer pasture growth.

26. In Paragraph 22 of his evidence Dr Ryan questions why irrigated blocks on Haldon Station were modelled in their current state as achieving 14.4 t DM /ha /yr with no nitrogen fertiliser while irrigated blocks on Simons Hill and Grays Hill Stations required 150 kg N /ha /yr to achieve less than 14 t DM /ha /yr. Examination of the information about the current state of the stations[3] will show that Haldon Station has a high Olsen P level, greater than 30, whereas the other stations have considerably lower soil P fertility, with Olsen P values between 15 and 23. Where pasture production is to be supported by fixed nitrogen it is necessary to have a good level of P

[2] White TA, Johnson IR, Snow VO (2008) Comparison of outputs of a biophysical simulation model for pasture growth and composition with measured data under dryland and irrigated conditions in New Zealand. *Grass and Forage Science* **63**, 339–349.

[3] Snow VO, Smeaton DC, Houlbrooke DJ (2008) Upper Waitaki Farm Systems and Nutrient Assessment. Stage 3: Base case nutrient assessments. Report prepared for GHD. August 2008. AgResearch, Palmerston North.

fertility. The estimated production level on the irrigated blocks at Haldon Station is quite reasonable in this context.

27. In summary, after reviewing that comments of Dr Clothier and Dr Ryan, I am confident that the growth rates estimated by EcoMod are reasonable and are appropriate to represent the likely growth rates under good irrigation practice in the Mackenzie Basin.

Response to and Comments on the Section 42A Report of Dr Brent Clothier

28. I agree with Dr Clothier's the statement in Paragraph 21 that finds that using the "Highly Developed" option provides an upper limit on the nutrient losses from the properties.

29. Paragraph 22 of Dr Clothier's report refers to a lack of comparison between the AgResearch estimates of nutrient losses and earlier work by Dr Steve Green in 2005[4]. Such a comparison was presented in Paragraphs 43-44 of my primary evidence. In summary, Dr Green assumed different irrigation inputs, fertiliser inputs, and farm management systems that all will cause higher estimated leaching than the inputs and management in the AgResearch assessments. I argue, given the greater emphasis in collecting farm management information relevant to the Mackenzie Basin in the AgResearch modelling than in the earlier modelling by Dr Green, that the AgResearch results have the greater credibility.

30. Paragraph 23 makes reference to new modelling with SPASMO that might produce even higher leaching estimates than the earlier work of Dr Green[4]. This is of some concern because the 2005 nutrient loss estimates were already too high to be consistent with measured water quality in the Basin or with measured nutrient losses from other environments.

31. I agree with, and am heartened to see, the statement in Paragraph 24 that Dr Clothier endorses OVERSEER® for work in the Mackenzie Basin and finds that it should be useful in assessing and auditing mitigations. Dr Clothier does not agree with the values of the nutrient estimates produced but argues that it is the modelling of the inputs rather than the OVERSEER® methodology that is at fault. While I do not agree with Dr Clothier's statements about the inputs, the corollary of Dr Clothier's statement is that when 'real', rather than 'modelled', input and production data are available from irrigated farming systems then Dr Clothier would

[4] Green SR (2005) Potential for nitrate leaching under irrigation development in the Upper Waitaki catchment. April 2005. Research report commissioned by HortResearch and Glasson Potts Fowler. HortResearch Client Report No. 13650/2005. In "Glasson Potts Fowler Limited (2005) Meridian Energy Limited. Water quality impacts from irrigation development, Upper Waitaki. December 2005."

agree that reliable nutrient calculations will be produced. These nutrient calculations would then be suitable for use within an audited nutrient discharge management system.

32. In Paragraph 29 Dr Clothier has extrapolated a statement well beyond the context in which it was made. He is correct in that the report describing the pasture growth modelling[5] stated that there was no significant effect of soil type or rainfall zone on modelled irrigated pasture growth. However this was clearly in the context of using the pivot irrigation systems designed by Aqualinc[6] that were tailored to the soil type and rainfall zone concerned. It is clearly not appropriate to take the statement out of that context and apply it to very different irrigation systems. Modelling of irrigation systems similar to those in the trials that Dr Clothier cites was reported in Appendix 5 of my primary evidence and compares well against the data.

33. Paragraphs 30 to 38 of Dr Clothier's outlines his concerns with the prediction of pasture growth by EcoMod. I have addressed these concerns earlier in this evidence.

34. Dr Clothier's report indicates that he is concerned that any overestimates of likely pasture yield will lead to an under-prediction of nutrient losses. He states in Paragraph 31 "... an over-prediction of pasture yield, such that silage can be made rather than using imported feed, would when used as an input into OVERSEER® likely result in an under-prediction of nitrate leaching". This statement is only partially correct. If the modelled pasture yield is not achieved on farm then the effect of this on nutrient losses will depend on the management actions of the farmer.
    a. If the stocking rate and target production is maintained and feed gap is filled with N fertiliser then leaching will increase to some extent.
    b. If the feed gap is filled with imported silage there will be no effect on leaching or perhaps a small decrease if a feeding pad with effluent collection is used.
    c. If the feed gap is filled with imported concentrate then leaching will likely decrease.
    d. If stocking rate or target production declines to meet the pasture production then, all other things being equal, leaching will decline as well.

    Dr Robson's rebuttal evidence will address the likely impact should the management action be to increase nitrogen fertiliser usage.

[5] Snow VO, King W (2008) Upper Waitaki Farm Systems and Nutrient Assessment Stage 2: Pasture and ryecorn growth modelling. Report prepared for GHD. May 2008. AgResearch, Palmerston North.

[6] Aqualinc Research Limited (2008) Irrigation and Drainage Modelling of the Upper Waitaki Basin. Prepared for GHD Limited. Report No C08054/1. August 2008. Aqualinc Research Limited.

35. Dr Clothier's interpretation of the work of Scott and Maunsell[1] shown in Figure 4 in Dr Clothier's evidence is in conflict with the original text of the publication. Dr Clothier interprets the vertical axis as an annual yield in t DM /ha where as the original text on page 287 gives the yield response as "... increase in yield relative to unamended soil ..." so the figure is more correctly interpreted as a 15-fold response rather than a 15 t DM /ha /yr yield as stated by Dr Clothier in Paragraph 36. It should also be noted that this response was for grass-only treatments rather than the normal grass-legume mix that will likely be used in irrigated pastures in the Mackenzie Basin. The nitrogen responses would be considerably muted in grass-legume pastures.

36. Paragraph 40 and Table 1 of Dr Clothier's report present modelled leaching from a dairy farm for a range of different soil types reproduced from SPASMO modelling by Dr Steve Green[4]. It is interesting to note that the SPASMO modelling in 2005 predicted greater leaching from sheep systems than from the dairy systems which is contrary to most expectations and only seen in our modelling when comparing the most intensive sheep and beef systems to the lowest intensity dairy systems under the "Highly Developed" scenario. It is also interesting to note that the deepest soil, the Pukaki soil, is estimated to have more leaching that all but the two shallowest soils. As soil organic matter will generally accumulate after dryland systems are irrigated, this might suggest some quirks in SPASMO's calculations of C and N dynamics in soil.

37. Dr Clothier's statements in Paragraph 41 of his report about the percentage differences in leaching estimated by AgResearch and Green (2005) are incorrect. The differences are not "42% to 85% less" as reported by Dr Clothier but are actually either "42% to 85% of" or "15% to 58% less".

38. While I have concerns over the validity of the input assumptions and the SPASMO modelling I do agree that the nutrient estimates in the AgResearch modelling are likely to be low for the lighter soils and probably under-states the soil-to-soil variation. This point has already been discussed in my primary evidence in Paragraphs 51 and 52 and in the evidence of Dr Ross Monaghan in Paragraphs 16 and 17 of his evidence. The spread of the leaching estimates in Dr Clothier's Table 1 might give a better indication of the spread across soil types. Properties are unlikely to have only one soil type so considering the average of the two lighter soils compared to the two heavier soils gives a range of about 16 kg N /ha /yr. As a worst-case scenario perhaps the leaching from the dairy farms on the lightest soils might be 8 kg N /ha /yr higher than that modelled and presented in Figure 7 and Table A3 of my primary evidence. This is about equal to the difference between the "Developed" and "Highly Developed" scenarios for the more intensive farm systems.

39. In Paragraph 43 of his report Dr Clothier states that neither OVERSEER® nor SPASMO take account of urine patches. I assume that it is true that SPASMO does not take account of urine patches as this is clearly stated by Dr Green on page 55 of his 2005 report[4]. This is however not true of OVERSEER®. OVERSEER® does model the effect of urine patches and does so because it is not possible to adequately model N leaching from grazed pastures without explicit treatment of urine patches.

40. In Paragraph 44 of his report Dr Clothier has concerns that the median modelled nutrient losses are low and they could result in "significant downstream implications". However Dr Clothier has failed to note that the farmers will be constrained by the agreed nutrient discharge allowances. Dr Clothier has agreed that OVERSEER®, given sensible inputs, will produce sensible estimates of leaching. If pasture production is not as high as wished, or modelled, and farmers are tempted to remedy this by applying more nitrogen fertiliser then OVERSEER® will model increased nutrient losses. Farmers however will not be able to continue to add nitrogen fertiliser if their Nutrient Discharge Allowance is exceeded and this renders many of Dr Clothier's concerns about the EcoMod-Farmax-OVERSEER® modelled leaching moot. The farm discharges will be assessed using actual production and actual farm inputs and these can be put directly into OVERSEER®. Dr Clothier has already stated that he believes that, given appropriate inputs, OVERSEER® can give good estimates of nutrient losses.

41. Paragraphs 45 to 55 are concerned with the within- and between-year variation in drainage and leaching. Dr Clothier is concerned that the modelling has ignored this effect and that this will affect water quality. I argue that the temporal smoothing resulting from transport through the vadose zone, varying distance from receiving water, and paddock-to-paddock variation within farm will so smooth out the pulses in leaching that this is not an issue of any real concern. The exception to this is the need for best practise management, at all times and places, but particularly near surface water bodies where the temporal smoothing is limited.

Response to and Comments on the Evidence of Mr Robert Potts

42. In Paragraph 62.3 Mr Potts recommends that if tools other than OVERSEER® are used to estimate nutrient losses that they should be calibrated against OVERSEER®. I endorse this statement. Some of the intended farm management systems proposed by the applicants currently cannot be modelled by OVERSEER® and other tools can provide useful information. However the other tools should first be compared against OVERSEER® to ensure that they can adequately capture the known effects of farm management on nutrient losses. The input files for OVERSEER®, or any alternative model, should be available for third-

parties to examine for auditing or quality control purposes. If an alternative model is used then the software to run that model should be obtainable by third-parties.

Response to and Comments on the Evidence of Dr Matthew Ryan

43. Dr Ryan's Paragraph 10 summarises his evidence that the farm system modelling has underestimated the nitrogen losses from the farming systems. I disagree with these statements and suggest that Dr Ryan has not understood the effect of the Nutrient Discharge Allowances on the future farming systems.

44. In Paragraph 13 of Dr Ryan's evidence he cites experimental work conducted in North Island hill country where fixation of nitrogen ranged from 100 to 200 kg N /ha /yr. Later in his evidence, on pages 18 and 19, he uses the upper level to calculate some nitrogen balances. The environmental conditions between the North Island hill country and the Mackenzie Basin are such that it is not appropriate to extrapolate those values without significant modification. Both the EcoMod and OVERSEER® modelling indicated that expected nitrogen fixation was substantially less than Dr Ryan's assumption. For irrigated pastures with no nitrogen fertiliser EcoMod estimated annual fixation to range between 70 and 90 kg N /ha /yr. OVERSEER®'s estimates were a little lower, generally in the range of 50 to 70 kg N /ha /yr for pastures with no nitrogen fertiliser added.

45. I agree with Dr Ryan's statements in Paragraphs 16 and 17 of his evidence that OVERSEER® is a reasonable tool to assess nutrient losses and that it requires robust inputs. However I only partially agree with Dr Ryan's statements about the sensitivity of the model to N fertiliser inputs. Dr Ryan's evidence might be read as implying that OVERSEER®'s leaching estimates are more sensitive to fertiliser inputs than stocking rate – this I do not agree with. The addition of fertiliser to an OVERSEER® model will increase leaching but there are several parts to this increase that only become evident when the model is used correctly. There is a direct loss of fertiliser that is modelled to accompany any addition but, provided the model is used correctly and consistently with the underlying assumptions on which is was based, these direct losses are small compared to the other changes that should follow. According to best practice, nitrogen fertiliser should not be applied unless the conditions are such that it can result in a reasonable pasture growth response that will be utilised by grazing or making supplements. Either of these usages of the additional pasture grown will result in an increased stocking rate and should also result in additional nitrogen removed from the farm in animal product, increased nitrogen losses through volatilisation, reduced inputs from nitrogen fixation and may change the amount of immobilisation of soil organic nitrogen. Some users, in error, judge the sensitivity of

OVERSEER® to nitrogen fertiliser inputs simply by changing the input of fertiliser and examining the resulting output of nitrogen in leaching. This is not a proper usage of OVERSEER® because either, OVERSEER® has not been provided with reasonable inputs[7], or the fertiliser was inappropriately used in the system[8]. In either case the user will get an unrealistic impression of the sensitivity of OVERSEER® to nitrogen fertiliser addition.

46. In Paragraph 20 it would seem that Dr Ryan has not understood which scenarios were used in the water quality assessment. He will read in the GHD summary report[9] that environmentally-conservative assumptions were made by taking the developed case for assessment of the current nutrient losses, Scenario 1, and the highly developed case for the irrigated nutrient losses, Scenario 4. Much of Dr Ryan's evidence is flavoured, at least to some extent, on his assumption that the developed irrigated case, Scenario 2, was used for the future case.

47. In Paragraph 22 Dr Ryan again states that pasture growth is too high and stocking rates are too low - which does seem a little contradictory - given the amount of nitrogen fertiliser added to the properties in their current state. These points have been addressed earlier in this evidence.

48. In Paragraph 23 of his evidence Dr Ryan reviewed the OVERSEER® model constructed for the current condition of Simons Hill Station and found the total stock units to be 7135 SU whereas the report[10] stated 9600 SU. Following this feedback we examined all the Farmax and OVERSEER® files used in the assessment of the current state of the stations. First, it is clear that the OVERSEER® file was opened in the wrong version of OVERSEER®. The recipients of all the files were cautioned that the file was formatted for OVERSEER® version 5.2.6 and that if the file was opened in a later version of OVERSEER® that it would not return the same outputs values as reported. The actual number of stocking units input into OVERSEER® was 7432 SU which we acknowledge as an error. This arose from an incorrect reference in an Excel calculation and only occurred in the Simons Hill simulations. The

[7] In this example the unreasonable input is that there has been no change in the farm production system as a result of the fertiliser addition

[8] The fertilizer was applied under conditions when it could not result in increased utilised pasture growth

[9] GHD (2009) Cumulative Water Quality Effects of Nutrients from Agricultural Intensification in the Upper Waitaki Basin. Summary Report. Prepared for Mackenzie Water Research Ltd. August 2009. GHD.

[10] Snow VO, Smeaton DC, Houlbrooke DJ (2008) Upper Waitaki Farm Systems and Nutrient Assessment. Stage 3: Base case nutrient assessments. Report prepared for GHD. August 2008. AgResearch, Palmerston North.

correct stock units have now been inserted into OVERSEER® 5.2.6 but resulted in no change to the modelled nitrogen leaching. Other simulation outputs did change: nitrogen fixation, exports in animal production and atmospheric outputs all increased by 1 kg N /ha /yr and immobilisation decreased by 1 kg N /ha /yr. While the error in transfer of the data from Farmax Pro to OVERSEER® was regrettable, it was confined to the one property and had no effect on the modelled leaching.

49. In Paragraph 27 of his evidence, Dr Ryan compares the pasture growth rates estimated for the farm systems modelling against those achieved by the Lincoln University Dairy Farm. He states that the Lincoln University Dairy Farm produces 16 t DM /ha /yr. However the SIDDIC web site[11] clearly shows that the 16 t DM /ha /yr is the pasture consumed not the pasture grown. Using an indicative utilisation rate of 80% this suggests that the pasture grown might be 20 t DM /ha /yr. If the nitrogen response rate averages out at between 10 and 20 kg DM /kg N fertiliser then the amount of pasture grown without nitrogen addition might be 16-18 t DM /ha /yr. It is also worth noting that the Lincoln University Dairy Farm is managed for maximum metabolisable energy yield and the low post-grazing residuals needed to attain this could well result in reduced dry matter yield. It is also interesting to note that we have previously modelled irrigated pasture growth in the Lincoln environment. The EcoMod estimate for pasture grown at Lincoln[12] ranged between 14.0 and 15.9 kg DM /ha /yr depending on soil type, suggesting that EcoMod might under-estimate rather than over-estimate irrigated pasture growth.

50. Dr Ryan is correct in Paragraph 28 of his evidence that it is common practise to apply nitrogen fertiliser to intensive pastoral farms. However the farms being considered here will be constrained by their allocated Nutrient Discharge Allowance. Dr Ryan, in Paragraph 29, also makes comment that two stations are planning to apply up to 260 kg N /ha /yr from a combination of fertiliser and effluent. He does not add, for context in this, that those farms are planning to run confined dairying systems with cut-and-carry pasture management and so will not be receiving direct returns of dung and urine.

51. Dr Ryan, in Paragraph 35, seems to be suggesting that 49 to 67 kg N leaching /ha /yr are credible losses for a sheep farm system. I suggest that it is much more likely that in his modelling the farm N fertiliser inputs are somewhat unrealistic compared to the animal production entered.

[11] SIDDC (2009) Lincoln University Dairy Farm. www.siddc.org.nz/ludf.html, SIDDC (2009) SIDDC LUDF Focus Day. 2nd July 2009. Profit Comparison: LUDF Unveiled. www.siddc.org.nz/docs/FDayHandoutJul09.pdf (both accessed 18 September 2009).

[12] Snow VO, Bryant JR, Monaghan RM, Campbell J, Scott K (2008) Steady-state nitrate leaching: Predictions for selected Canterbury Plains soil types, climates and farm systems. September 2008. Client report prepared for Environment Canterbury. AgResearch, Palmerston North.

Because the values cited in Paragraphs 36 to 45 are based on Dr Ryan's OVERSEER® estimates above they should be discounted.

52. In Paragraph 38 Dr Ryan states that the Water Quality Assessment should be based using the highly developed nutrient loss estimates. This was indeed the case.

53. In Paragraph 50 Dr Ryan suggests that mitigation measures might not be applicable on dryland farms. However where dryland farms are using winter forage crops theses blocks can lose substantial amounts of nitrogen and phosphorus and add-on mitigations such as nitrification inhibitors and system mitigations such as alternative winter management can be used to reduce nutrient losses.

54. Dr Ryan's Table 9 contains several fundamental flaws. The pasture nitrogen uptake has not included the nitrogen needed for root growth, for the difference between net and gross pasture growth[13], or for the nitrogen internally recycled in the plant. The value of 200 kg N fixation /ha /yr is not likely in the Mackenzie Basin at 12 t DM /ha /yr pasture production and is simply incredible at less than 2 t DM /ha /yr. Dr Ryan has also ignored the processes of cycling in the soil organic matter and also of likely changes in the amount of soil organic matter. The calculated mitigation requirements should be disregarded given the flaws in the contributing values.

Conclusions

55. My rebuttal evidence has outlined my responses to the report of Dr Clothier and the evidence presented by Dr Ryan. I do not agree with many of the statements that Dr Clothier and Dr Ryan have made and have given reasons, and where possible, explanations of factors they may not have correctly considered.

56. Many of the disputed facts and figures were either settled or became moot following a caucus held on 12 October 2009. The primary point of disagreement remained the EcoMod estimates of pasture growth and the potential follow-on impact of those estimates. In this evidence I have presented more information supporting EcoMod's estimates of pasture growth.

57. After reviewing the comments of Drs Clothier and Ryan, I remain confident that the nutrient estimates used in the Water Quality Study are robust.

Val Snow, 5 November 2009

[13] Dr Ryan has allowed for a pasture utilisation of 75% but this is minor compared with the difference between gross growth and net growth, which includes respiration and inevitable senescence losses. Net pasture growth is roughly 50% of gross growth and requires nitrogen to fuel the metabolic processes.

Annexure A: Notes from the Nutrient Caucus - 12 October 2009

Attended by - Brent Clothier, Matt Ryan, Ross Monaghan, Rob Potts, Val Snow, Melissa Robson

Preamble
It was agreed that this discussion was without prejudice and that notes taken would be circulated and signed off before they were released.

Points of clarification

1) Melissa Robson to seek from GHD and provide the modelled dairy losses used for the proposed scenarios.
2) Melissa Robson to provide the area of dairy in each sub-catchment
3) Melissa Robson to seek from GHD the recalculated thresholds for river sub-catchment nodes (periphyton thresholds) from GHD

Points of agreement

- There was agreement that as AgResearch report 4 was not used to derive nutrient loadings in the WQS and was used only as a passive cross check, concerns about the report do not need to be further addressed. This is especially relevant for Brent Clothier's S42a report which focused on this report 4 (referred to there as AgResearch 2009d).

- There was agreement that measuring, as well as modelling nutrient losses from farms (such as through the use of lysimeters and soil monitoring), would be useful. However that this need not be on all farms and that representative testing on some farms across soil types and farm system could be interpreted for use throughout the catchment.

- Ross Monaghan stated and repeated that in his opinion that there was no justification for using the Highly Developed setting of OVERSEER and that scientifically is should not be used as a default. Matt Ryan and Val Snow agreed to this last point. However Brent Clothier asserts that in terms of prudence that the highly developed setting of OVERSEER should be used in the FEMPs, especially given that there can be a large increase in predicted N leaching losses between the classification choices of 'Developed' and 'Highly Developed' for irrigated blocks in some farm systems. This was intimated in Val Snows evidence.

- There was agreement that in the FEMPs there should be a higher burden of monitoring requirement for farms that were running more intensive systems with modeled nutrient losses closer to their NDA. It was agreed that, if the proposed farm system can meet its NDA using the Highly Developed setting, then they should not be required to monitor their soils for development status. Those farms that do not meet their NDA at Highly Developed but do at Developed should be required to undertake some

degree of soil monitoring of development status and use interpreted data from the representative lysimeters[1]. The greater the N immobilisation estimated by OVERSEER at the Developed setting the greater the burden of monitoring requirement should be.

- There was agreement about the magnitude of losses used for the dairy farming indicated verbally by Melissa Robson (Melissa Robson to seek from GHD and circulate dairy losses used to fully sign this point off).

- There was agreement in the use of OVERSEER as a tool for monitoring compliance.

- There was agreement that compliance with a threshold should be done annually, but as an average of the previous 3 – 5 years, depending on the sensitivity of the catchment.

- Brent Clothier expressed concern, also voiced by Rob Potts about the temporal variations of farm losses. It was agreed that those temporal variations would be much less of an issue if there was 'smoothing' in the groundwater caused by lag times. It was agreed that this issue would be deferred until the outcome of the hydrogeology caucus later this week.

- There was concern raised by Rob Potts about the scale of denitrification. Ross Monaghan stated that losses of this scale (although not necessarily just through denitrification) he thought were reasonable and probably low. Rob Potts disagreed especially for the catchments draining to the Northern Arm. It was agreed to leave the questions of denitrification and where it occurs to be answered at the hydrogeology caucus later this week.

- There was not agreement on the N loss used for irrigated beef and sheep, derived from the 7 modelled farms and used in current and proposed scenarios (9 kg N/ha loss was modelled). Matt Ryan raised concern about this figure and indicated that he though that it was too low as it was based in part on modelling done on one station where high pasture growth rates (>14 t/ha) were inversely predicted by Farmax with no N fertiliser. Brent Clothier supported this concern. Matt Ryan proposed using the figure of 11 kg N/ha loss instead. Val Snow did not support this concern and felt that this growth was possible. Ross Monaghan stated that the difference between 9 and 11 kg N on the irrigated areas was not significant. Val Snow is to produce a defense of this figure next week.

[1] This could be aided via other mechanistic modeling to extend and extrapolate the measured data to link it to OVERSEER (BC)

- In addition to having confidence in the figure itself, Val Snow stated that the establishment of farm NDAs and compliance testing against these should give the commissioners confidence that even if there were underestimates in the modeling, the risk is incurred by the farmers and not the environment. Matt Ryan accepted this but stated that it was important that the commissioners had as accurate an idea of what the possible impacts would be before granting consent.

Other discussions

- There were questions about a trigger response level in the river nodes posed by Rob Potts. Melissa Robson briefly explained that a 75 % of the node load would trigger some response, however stated that these conditions would be fully laid out in John Kyle's evidence this week.

- Concern was expressed that submitters had not yet seen the FEMPs

- There was a discussion about the sensitivity of OVERSEER to rainfall. Matt Ryan thought that it was relatively insensitive to rainfall and Brent Clothier found from his work at Horizons that it was sensitive to rainfall. It is proposed in the WQS that a consistent source of rainfall data should be used for assessing compliance when using OVERSEER. NIWA weather data was suggested, however no further discussion took place on this topic.

- Brent Clothier expressed concern about the use of average values (which are exceeded 50% of the time) for loads at nodes and that a higher standard than this might be required. He stated the use of HD in the FEMPs would confer this higher standard. This fed back into the discussion of the use of Developed and Highly Developed in FEMPs and the consequent impact on further monitoring.

- In a review of the caucus notes, Matt Ryan notes that if a developed scenario is used in the WQS to predict nutrient losses, he recommends that a sensitivity analysis be conducted based on N losses from increased N fertiliser usage on irrigated sheep and beef and dairy farms.

Annexure B: Figure 2 from Scott and Maunsell 1981

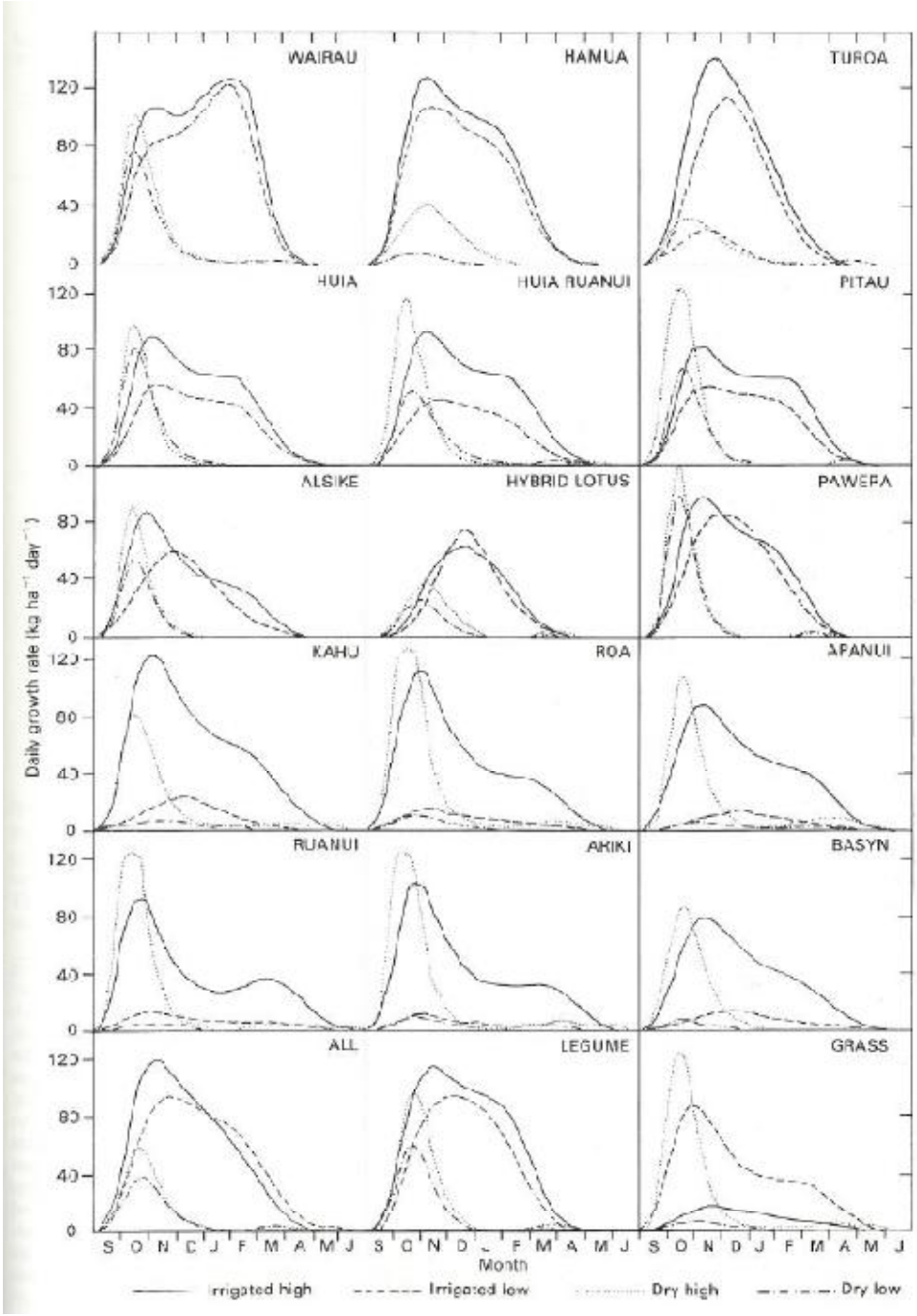


Fig. 2 Seasonal variation in growth rate of legumes and grasses. Key: Irrigated high, irrigation and high fertiliser levels; Irrigated low, irrigation and low fertiliser levels; Dry high, dryland and high fertiliser levels; Dry low, dryland and low fertiliser levels .