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 Robert John Potts on farm management

Dated: 16 September 2009

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BRIEF OF EVIDENCE OF ROBERT JOHN POTTS

INTRODUCTION

1 My full name is **Robert John Potts**.

2 I am the National Environmental Science Leader of the multidisciplinary consulting firm CPG New Zealand Limited (CPG) (which was formerly Duffill Watts Limited and before that Glasson Potts Fowler Limited) and have worked in the area of water resources and environmental engineering for over 30 years.

3 I have the following qualifications: New Zealand Certificate in Engineering (Civil); Bachelor of Engineering (Honours) Agricultural (University of Canterbury); Graduate Diploma in Hydrology (Groundwater) (University of New South Wales), MIPENZ and am a Chartered Professional Engineer (CPEng). I am a member of Water New Zealand, New Zealand Irrigation Association, and New Zealand Land Treatment Collective.

4 I have been involved in numerous irrigation scheme development projects and water resource investigations in New Zealand and overseas in my current employment and previous employment with Ministry of Agriculture and Fisheries (MAF), Lincoln University (NZAEI – now Lincoln Ventures), Lincoln International, Pattle Delamore Partners Limited and Glasson Potts Fowler. My roles have included: project management; assessing plant water requirements; assessing groundwater resources; assessing soils; designing on and off-farm irrigation infrastructure; measuring and modelling nutrient losses; and assessing the effects of irrigation development.

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 my evidence I have reviewed:

6.1 the report *Cumulative Water Quality Effects of Nutrients from Agricultural Intensification in The Upper Waitaki Catchment –*

Summary Report by GHD and all the other accompanying and supporting reports[1].

6.2 The evidence of **Dr Ryan**, **Mr Ford** / **Mr Harris** and **Mr Callander**.

6.3 The evidence on behalf of MWRL by **Dr Snow**, **Dr Bright** and **Dr Robson**, **Mr McIndoe**, **Mr Kyle**, **Dr Ryder**, and **Dr Monaghan**.

6.4 A number of other technical reports and these are cited throughout my brief of evidence.

7 I also note that I have prepared a separate brief of evidence covering water allocation in the upper Waitaki catchment.

SCOPE OF EVIDENCE

8 In this evidence I:

8.1 Comment on the farm modelling and nutrient assessment provided in the MWRL Cumulative Water Quality Effects Assessment;

8.2 Provide commentary on the assumptions around the inputs and outputs of the modelling work and to highlight the significance of these assumptions on the outcome of the work;

8.3 Draw attention to the best management practices to ensure the efficient and reasonable use of water and the implications of various farming systems for nutrient management; and,

8.4 Discuss the practicality of the applicants achieving significant reductions in nitrogen and phosphorus through the proposed mitigation measures.

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[1] Irrigation & Drainage Modelling of Upper Waitaki Basin - Aqualinc Groundwater Report – GHD;
Cumulative Water Quality Effects of Nutrients from the Upper Waitaki – Groundwater Report
Rivers and Lakes Report - GHD
Mitigation Toolkit – GHD
Crop & Food - Yields of Dryland Literature Review – Crop & Food Research
Stage 2 - Pasture & Rye Corn Growth- AgResearch
Stage 2 - Pasture Growth and Literature Review - AgResearch
Stage 3 - Base Case Nutrient Assessment - AgResearch
Stage 4 - Irrigated Nutrient Assessment - AgResearch

FARM MODELLING AND NUTRIENT ASSESSMENT AND ASSUMPTIONS

Irrigated Areas

9 In my recent work on the consents in the Upper Waitaki (described in more detail in my Water Allocation brief of evidence[2]), I estimated the total existing consented irrigated area to be approximately 8,432 ha as at 28 August 2009 and the total area for replacements was approximately 4,357 ha.

10 The Aqualinc drainage modelling report[1] states that "*Current irrigated areas have been estimated from satellite imagery taken in January 2007, from consented irrigation takes, and from local knowledge (Appendix 4). A total of 7,600 ha was identified, 4,800 ha of surface irrigation and 2,800 ha of spray irrigation (primarily centre pivots)"*. These areas and the associated soil types were the basis of the drainage rate estimates used in subsequent work and reports.

11 The total existing irrigated area in Table 14 of the MWRL Final Summary Report[3] is 8,850 ha including 1,906 ha for replacements. The table has been modelled around the definitions of Scenarios 2 and 4 and makes a distinction between existing, proposed irrigation (current consent applications), allocated areas that already hold consents but are not yet irrigating (excluded in the existing areas) and tranching irrigation giving a total of 26,255 ha additional irrigation and a total of 35,105 ha irrigation. The key point to note is that the 8,850 ha is exclusive of the 1,527 ha "allocated areas" area. If this was included (and in my opinion it should be) the total existing area would be 10,377 ha including replacements.

12 Section 4.2.3 of the same report[3] states that "*Current irrigated areas have been estimated from satellite imagery taken in January 2007, consented irrigation takes, local knowledge (Aqualinc, 2008) and from information derived from farmer questionnaires. A total of 8,990 ha was identified; 4,378 ha of surface irrigation and 4,612 ha of spray irrigation*". It is not clear if the 8,990 ha includes replacements.

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[2] Potts, R. J. (2009) *"Brief of evidence of Robert John Potts in the matter of the a number of applications to take and use water from the Upper Waitaki catchment". Unpublished.*

[3] Cumulative Water Quality Effects of Nutrients from the Upper Waitaki – Summary Report, FINAL. August 2009.

13 In Table 1 below, I have summarised the areas presented in the reports, the areas that I presented at the WAB[2] and those I assessed for the Upper Waitaki Catchment[2].

14 **Table 1 – Summary of the Annual Volume Allocations for the Upper Waitaki Catchment for Ag & Hort. as at 28/08/2009**

	GHD (2008) in MWRL Reports	Potts - WAB Areas in 2005 (ha)	Potts - Areas As at 28/08/09 (ha)
EXISTING	7,600[1] – 8,160[2] - 8,990[3]	9,680[4]	8,432
REPLACEMENTS	1,906[5]		4,357
NEW APPLIED FOR	16,853[5]	25,000	15,684
STILL AVAILABLE UNDER MIC	8,147		9,316
TOTAL	35,105[5]	34,680	37,789

1- 7,600 ha in the Aqualinc report and used as the basis for the drainage modelling (see Paragraph 10 above);
2- As confirmed by GHD;
3- From Section 4.2.3 of the Final Summary Report[1] (see Paragraph 12);
4- Included all takes "currently irrigating (a total of 5,420 ha taken from satellite imagery) and currently consented (e.g. Benmore Irrigation Company, approximately 4,000 ha)";
5- From Table 14 in the Final Summary Report[1] (see Paragraph 11).

15 Table 1 shows that the existing irrigated areas presented in the MWRL reports and associated studies vary from 7,600 ha to 8,990 ha. Without full access to the different models used, I am unable to comment on the effect this has on the study outputs. A sensitivity analyses around the different variables, including the areas has been requested and this would have helped to understand the implications of over or underestimating the existing areas in calibration of the nutrients in the groundwater model.

Irrigation and Drainage Modelling – Upper Waitaki Basin by Aqualinc[1]

16 I have reviewed the Aqualinc Report[1] which sets out the background and basis for the drainage rates.

17 Table 2 of the report suggests irrigation application depths of 10, 20, 20 and 20 mm for profile available waters (PAWs) of 30, 60, 90 and 120 mm respectively. The proposed application depths are equivalent to allowable depletions of 33%, 33%, 22% and 15% of the respective PAWs.

18 My staff have been in contact with **Dr Brown** (the author of the Aqualinc Report) by phone and subsequent e-mail correspondence. **Dr Brown** confirmed that the intention of adopting the lower application depths was to maintain a buffer below the field capacity to minimise drainage and runoff losses after irrigation and/or rainfall.

19 While it is good theory to apply depths less than 50% of PAW, the reality is that existing irrigation systems were designed to apply as much of the PAW as possible and will continue to operate in that way. Therefore, for existing systems the model will underestimate drainage rates, as in reality higher application depths will continue to be applied. For existing irrigators to achieve these application depths, they would have to increase their amount of irrigation equipment to allow more frequent applications and lower application depths, whilst still covering the same land area.

20 The theory could possibly work for new planned systems. However, unless there are specific consent conditions requiring the systems to be designed to only apply these low application depths, then a more conservative modelling approach is needed, as in practice new systems will be designed and operated to apply depths equivalent to 50% of PAW.

21 Designing the irrigation for short return periods as a result of using lower application depths increases the capital costs of the irrigation systems, for example, on the deeper soils, three times as many travelling irrigators would be required to irrigate the same farm area. However, this can be overcome to a certain extent by using centre pivots. Therefore, unless irrigators are mandated to adopt low application depths through consent conditions, it is unlikely that farmers will volunteer to adopt these.

22 The Aqualinc Report does not show that any sensitivity analyses were undertaken to quantify the effects of different assumptions to the modelling results.

23 I cannot quantify the implications of the above assumptions used for the irrigation modelling parameters on the drainage because of the lack of a sensitivity analyses, and the lack of specific information on the IrriCalc Model. Although requested, the detailed input parameters for IrriCalc have not been made available. However, while not being able to review the model inputs, the mean annual drainage losses provided in Tables 3 and 4 of the Aqualinc Report look reasonable and are comparable with modelling I have done in the area (e.g. in GPF 2005, the drainage was calculated to be from 30 – 106 mm/year for low rainfall dryland depending on soil type (cf Aqualinc of 41 – 153) and 100 – 196 mm/year for irrigated (cf Aqualinc of 115 – 225)).

24 The drainage model results are summarised in Tables 3 – 5, which have been appended as Attachment 2 below. Table 4 in the Stage 2

Report – Pasture & Rycorn Growth Modelling (also appended in Attachment 2) gives the spray irrigation rates for the different soil types across the different rainfall regions. The values for drainage are slightly greater than those calculated in the Aqualinc Report. However, the differences are less than 1% and within the margin of error, therefore I do not consider they will affect the overall results of the nitrogen concentration values derived from the OVERSEER farm system modelling.

25 Overall, although I do not agree with all the inputs, and have not been provided with the model variables, I consider the drainage rates appear to be reasonable.

26 The annual irrigation demand figures are also comparable with modelling I have undertaken in the area, with spray irrigation requiring a mean application depth of 400 – 600 mm/year and border-dyke of 800 – 1,200 mm/year. As I have discussed in my Water Allocation[2] brief of evidence, I calculated 614 mm for spray (rounded down to 600 mm to match the MIC/Meridian Agreement) and 1,300 mm for border-dyke to be appropriate (1 in 5 year demand).

Groundwater Denitrification in Riparian Margins

27 Groundwater issues for Meridian are covered in the evidence of **Mr Callander**.

28 I have read the GHD Draft and Final Groundwater Reports and have one issue I would like to comment on.

29 Appendices G and H of the Final Summary Report (dated August 2009) reproduces some nitrate attenuation factors from the CLUES (Catchment Land Use for Environmental Sustainability) project[4] and states that these factors were used with soil information to estimate denitrification from nitrate enriched water passing through riparian margins and recharging surface waters.

30 I note from the CLUES report that "attenuation factors for Gley Soils and imperfectly drained soils are based on anecdotal evidence and theory".

[4] Woods, W., Bidwell, V., Clothier, B., Elliott, S., Shankar, U., Hewitt, A., Gibb, R., Parfitt, R. and Wheeler, D. (2006). The CLUES project: Predicting the Effects of Land Use on Water Quality – Stage II.

31 Assumptions of high attenuation factors for poorly drained soil, fails to take into account the fact that poorly drained soils will have high runoff coefficients. The soils in the areas subject to these current consent applications are very free draining, as reported by Aqualinc in assuming all rainfall is effective (i.e. no runoff).

32 The information provided in the GHD Groundwater Report lacks specifics on:

32.1 How the groundwater model has been calibrated with respect to nitrogen as the denitrification losses are outside the model i.e. have attenuation factors been applied or has denitrification been used to calibrate the model; and

32.2 What proportion of the groundwater is assumed to pass through this denitrification zone.

33 Over the years I have undertaken a lot of work in the Upper Waitaki Catchment. Gley soils may be present in small pockets where there are areas of shallow groundwater but I have doubts if these are as widespread as shown in Figure 7 of the Final Summary Report. For example, when I overlaid Figure 7 on to Figure 13 (the proposed irrigated areas) in the same report, I noticed that:

33.1 a large proportion of the poorly drained soils are above or upstream of the proposed irrigated areas; and,

33.2 Figure 7 does not actually account for the highland topography in some places as the shaded areas also include hill areas.

34 The denitrification loss rates quoted seem very high, ranging from 99% in peat areas to 50% in the Quail, Hen and Stony Rivers, and down to 20% in the remaining subcatchments. Denitrification not only needs anoxic or anaerobic conditions (saturated soils) but also warm temperatures, the right pH and significant freely available carbon (a high carbon:nitrogen ratio (C:N)). I have concerns that these required conditions do not all exist.

35 As a result of the interactions among these factors, the degree of denitrification is highly variable. Other studies show the following:

35.1 Barton (1999)[5] concluded that as carbon was important for denitrification, soil texture tended to have an effect on the degree of denitrification to the extent that it affected diffusion of carbon through the microsites. For example, heavier clay soils had lower denitrification rates compared to loamy soils because of the limited movement of carbon to the areas where denitrification was taking place.

35.2 Rutherford *et al*, 1999[6] found that the denitrifying capability of riparian margins can be affected by 'short circuiting' of groundwater to above-ground seepages in the riparian zone due to increased hydraulic load from the irrigation.

35.3 Cooper (1994) in Tomer *et al*[7] (2000) suggested that denitrification rates in wetlands and riparian margins could be lower as the rates are dependent on adequate contact time between nitrate-bearing waters and organic soils of a wetland.

36 The range of values under the different land practices is large. In addition to the other factors affecting denitrification, I would expect the low temperatures and the limited available carbon of the study area to produce results on the lower end of the scale, e.g. Twizel has an average of 114 frost free days per year vs Rotorua (where a lot of the research has been done) has an average of 315 frost free days.

37 Appendix 3 of my evidence shows a table that has been extracted from Lowe *et al*[8] (2007). It summarises denitrification rates as a percentage of the nitrogen passing through wetlands following irrigation of effluent areas from several studies as follows:

37.1 Tozer *et al* (2005) concluded that only 3% was denitrified in riparian wetlands, whereas near to 100% was expected;

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[5] Barton, L., C.D.A. McLay, L.A. Schipper, and C.T. Smith. 1999a. Annual denitrification rates in agricultural and forest soils: A review. Aust. J. Soil Res. 37:1073–1093.

[6] Rutherford, Kit, et al. Towards a model for nitrate removal in wetlands, Proceedings of the Land Treatment Collective Conference, New Plymouth, 14-15 October 1999

[7] Tomer MD, Charleson TH, Smith CT, Barton L, Thorn AJ, Gielen GJ. THE NEW ZEALAND GUIDELINES FOR UTILISATION OF SEWAGE EFFLUENT ON LAND. Proceedings of the Poster Session with supplemental papers2000. Evaluation of treatment performance and processes after six years of wastewater application at Whakarewarewa Forest, New Zealand. Auckland, 2000.

[8] Lowe A, Gielen G, Bainbridge A, Jones K. 2007. The Rotorua Land Treatment Systems After 16 Years. The Land Treatment Collective. Proceedings for 2007 Annual Conference. Auckland, 2000. Eds. Wang H. and Quieturn M.

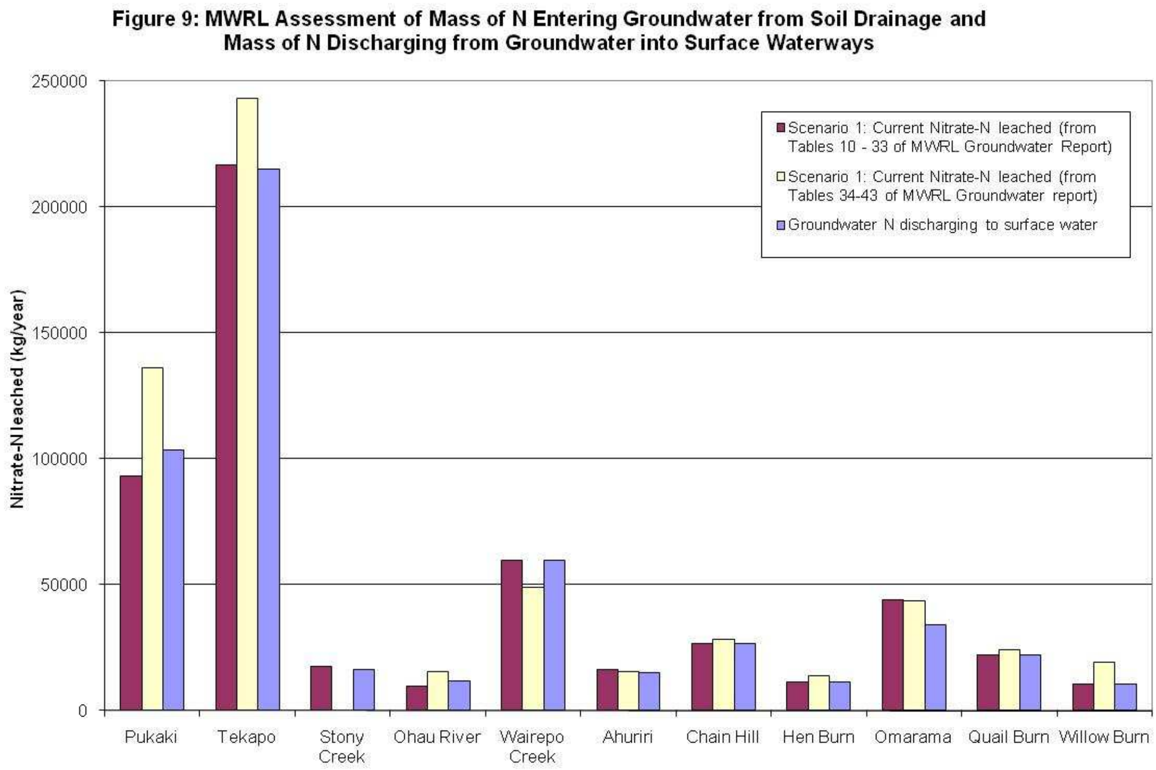
37.2 Peacock et al (1998) found the rate of denitrification in wetlands to be minimal;

37.3 Burton et al (2000) found that only less than 1% of the nitrogen was denitrified.

38 As no specific information has been provided with respect to the C:N ratio in the riparian areas in the MWRL reports, assumptions of available carbon and denitrification are entirely theoretical and appear to be too high compared to those reported in literature in warmer areas. Values in the order of 1 – 3% appear more realistic. The reports do not provide details of how much nitrogen is assumed to be removed by denitrification in each sub-catchment as the percentage of groundwater passing through the riparian zone has also not been provided.

39 However, **Mr Callander** has created a graph (Figure 9 in his evidence) based on the data provided in the MWRL reports. The graph shows the mass transfer of N from soil drainage into groundwater (Scenario 1: Current Nitrate Leached) and from groundwater to surface water for the different sub-catchments. Therefore the difference between the two numbers is presumably due to the nitrogen removal that has been inferred to occur due to denitrification of groundwater as it passes through riparian zones. The two sets of leached numbers in the graph have been derived from the Final Groundwater Report and the Final Summary Report and the groundwater discharged numbers from Appendix CC of the Final Summary Report. The two sets of leached numbers should be the same.

40 The graph shows that most of the N carries on through to the surface waterways, apart from perhaps the Pukaki, Tekapo and Omarama groundwater zones but this depends on which set of leaching data are used. If it is used, then these equate to a 10, 25, and 22% reduction in total groundwater N. If Tables 10 – 32 in the Summary Final Groundwater Report are used, then apart from the Omarama zone, where around 22% nitrogen reduction occurs, most of the nitrogen reaches the river, as would be expected. However, if this set of input data is used, then the Pukaki Catchment has an increase in nitrogen in groundwater.



41 In summary, the attenuation rates provided in Table 4 of the Summary Report appear to bear no resemblance to that calculated and shown in the graphs. I do not believe the high rates of denitrification assumed by the MWRL assessment in Table 4 would occur.

42 There also appears to be inconsistencies in the two sets of leaching data, making an overall assessment difficult. However, it would appear (depending on which data are used) that denitrification is minimal in most subcatchments.

BEST MANAGEMENT PRACTICES AND MITIGATION TOOLKIT

43 I have been asked to provide a discussion on best management practices intended to ensure the efficient and reasonable use of water; and the implications of various farming systems for nutrient management.

Irrigation System Design, Operation and Auditing

44 Adoption of best management practices (BMPs) will ensure efficient and reasonable use of water and at the same time help mitigate potential adverse effects as a result of the change in the farming systems. The following are the basic practices that should be required:

44.1 Proper design and construction of the irrigation off-farm and on-farm structures through certified designers using the Irrigation New Zealand (INZ) Irrigation Code of Practice and Irrigation Design Standards (2007);

44.2 Use of proven irrigation scheduling methods and soil moisture monitoring;

44.3 Audits of irrigation system design and management and action on the audit recommendations;

44.4 Minimisation of losses between the off-takes and the farms;

44.5 Centralised management and training programs, such as development and/or demonstration of BMPs;

44.6 Communication and education of the BMPs; and,

44.7 Training programs to educate irrigators about the benefits of sustainable irrigation practices.

44.8 The farm management plans should have a provision for the evaluation of these irrigation systems. Evaluations could be done once in every five years based on the methodologies set out by Irrigation New Zealand in the Irrigation Evaluation Code of Practice (2006). This Code of Practice sets out methods for evaluating several different types of irrigation systems.

44.9 The irrigation system designs associated with the proposed takes be undertaken by qualified and experience personnel to ensure adherence with the best practices outlined in Irrigation Code of Practice and Irrigation Design Standards (2007).

45 These BMPs should, in my opinion, be adopted for all new water takes in the upper Waitaki catchment. This will ensure best practice

consistency across the basin and help maximise the beneficial use of water for irrigation.

44. If the above practices are not adopted, then the theoretical application depths and leaching rates that have been modelled will not be achieved in practice. In other words, it is important that the modelling base assumptions should be included in any consent conditions should the commissioners decide to grant the consents.

45. In this respect the MWRL reports include a mitigation toolkit. I have read the proposed mitigation measures and I can confirm that some of the BMPs I have discussed are included.

46. However, it is my opinion that although the mitigation measures look good in theory, the MWRL assessments are very vague as to what has already been included in the input assumptions to the water quality work and where and how the various mitigation measures will be applied.

SUMMARY OF IMPLICATIONS ON EFFECTS

47. I have highlighted inconsistencies in the MWRL Reports. For example, the areas quoted across the technical and summary reports are different as I outlined in Table 1. While the variations may in some cases appear minor, they do have an effect on model calibration and thus outputs from the different models. Unfortunately, none of the modelling work included sensitivity analyses which would have been useful in ascertaining the impact of using values other than those used for modelling.

48. I agree with the point that Mr Ford makes his evidence when he writes "*Although the promise of the opportunity to become involved in an iterative process with the modellers of the water quality report was offered at the beginning of their study, this opportunity never eventuated*". It is my opinion that had this opportunity been provided, MWRL and Meridian's advisors would have been able to narrow down most of the inconsistencies in the modelling work.

49. Of particular relevance I also note Table 1 in Mr Ford's evidence which compares the farm systems adopted in the economic impact assessment by MWRL modelling and those produced by McFarlane Rural Business (MRB). The dry matter production in the MWRL assessment was about 40% higher than the MRB assessment and with about half the nitrogen fertiliser input.

50. A combination of these assumptions would result in lower nitrogen and cropping inputs thus resulting in lower N drainage concentrations than would likely happen in practice.

51. On this aspect Dr Ryan finally concludes that the Water Quality Assessment has underestimated the extent of leaching losses from proposed new and renewed irrigated land (29,357 hectares) in the overall catchment by at least 1,174 tonnes per year. It should be noted this estimation is based on the assumption that irrigated land would be just utilised for sheep production only.

52. Mr Callander concludes that the groundwater assessment is useful to understand the overall catchment hydrology but not sufficiently robust to provide reliable verification of future changes in nutrient migration, with the main uncertainties:

 52.1 Emergence to surface water is poorly defined due to a lack of data and there are inconsistencies between reports regarding deep groundwater and highland contribution, thus there is a lack of data to calibrate the models.

 52.2 The groundwater model is an annual average and thus seasonal trends cannot be seen.

 52.3 There is no consideration of phosphorous in the migration of groundwater.

53. When looking at groundwater quality, Mr Callander has calculated that it may take up to 10 – 20 years to see full migration of drainage water through the aquifer system and this is on top of the period for soils to fully develop.

54. He concludes that the groundwater model should only be viewed as providing a general indication of flow patterns and the quantification of these flows has a degree of uncertainty.

55. Summing up all the above, the drainage rates look reasonable however the technical experts assisting Meridian consider the nitrogen leaching rates to be underestimated and the groundwater modelling lacks detail, culminating in the overall conclusion that we do not consider it has been robustly demonstrated that the predicted effects are accurate. If further detailed information or clarification of assumptions can be provided, this conclusion could be changed.

56. To avoid the concerns set out in the evidence it would be necessary for:

 56.1 Provision of a sensitivity analyses for all the modelling work showing the effect of changes to the various modelling inputs on the modelling results. This will enable Meridian, other submitters and indeed the Commissioners to understand the resulting impacts if the modelling assumptions are not achieved;

56.2 All future nutrient leaching modelling work to take a conservative approach with respect to denitrification by assuming that denitrification rates are zero in the riparian zones;

56.3 There be consistency across the modelling work with respect to irrigated areas, drainage values, N leaching into groundwater. This will enable a more robust review of the perceived effects;

56.4 Modelling is more detailed spatially and seasonally;

56.5 That if any consents are granted, sufficient guarantees be placed to ensure that the applicants will operate within the limits of the modelling assumptions. This will be achieved by way of consent conditions to cover:

(a) The design of the irrigation systems;

(b) Nutrient management;

(c) Land use;

(d) Adherence to the specific toolkit measures assessed for each sub-catchment.

COMMENTS ON EVIDENCE PRESENTED ON BEHALF OF MWRL

57. In her evidence, **Dr Snow** points out the effects of potential errors in the farm systems modelling and points out in Paragraph 45(i)(b) that "*over - or insufficient sensitivity of the current case farm nutrient losses to soil, climate or farming intensity factors would lessen the quality of the validation and might affect the value of the calibrated factor for denitrification in the shallow ground water*..". As I have highlighted in Paragraphs 29 - 42 above, assumptions made on denitrification rates have been overstated and I therefore expect the actual N losses through denitrification to be lower. Paragraph 45(iv)(a) in **Dr Snow's** evidence aptly summarises this point by stating that "*under-estimates of future case farm nutrient losses has the potential to lead to future farming systems that exceed their NDA*[9] *and result in intolerable decreases in water quality*"

58. I agree with **Dr Snow's** point in Paragraph 49 that should consents be granted, the irrigators should be required to ensure that best practices are followed and that consent conditions should require adequate monitoring to ensure that those practices are adhered to.

[9] Nutrient Discharge Allowances

59. I have read **Dr Bright** and **Dr Robson's** joint statement of evidence and I note that they have proposed a comprehensive monitoring programme in Table 12. **Dr Robson's** evidence also proposes similar measures in Table 3 and 4 of her evidence. I agree that if consents are granted and the proposed monitoring regime is implemented, that this will go a long way towards addressing my concerns regarding inadequacies in water quality modelling. However, it pushes the risk out and may make it difficult for consents for irrigation infrastructure to be reversed or unwound.

60. I, however, disagree with the conclusion that has been drawn in **Dr Bright** and **Dr Robson's** evidence in Paragraph 12.3 that *"the WQS has found that an additional 25,000 hectares……..can be irrigated without significant adverse effect on the aquatic environment, providing the proposed farming activities do not exceed the NDA's specified by the study"*. As I have highlighted in my evidence, the extent of the effects arising from the irrigation of a further 25,000 ha is predicated on the assumptions used in the modelling. Some of these assumptions (for example denitrification rates) have not been adequately quantified.

61. The evidence of **Mr Kyle** discusses the proposed adaptive management in detail in Paragraph 6.3. I agree that adaptive management will enable on-going changes to the farming systems ensuring on going adherence to best practices. But I believe that the original baseline nutrient losses and associated water quality need to be estimated with some degree of accuracy and as I have highlighted in my evidence and has been in the evidence of others (e.g. **Dr Ryan**, **Mr Callander**) some of the assumptions have not been robust enough to give me confidence that the baseline assessments are correct. This may also make it difficult to get future adaptive responses, as it will not be apparent how the future scenario differs from the baseline assessment that was predicted.

62. The following are my comments on some of the proposed conditions in **Mr Kyle's** evidence and Appendix 3:

62.1 Condition 16(a) lists a number of "good agricultural practices". These include the following:

62.2 The consent holder shall prepare a nutrient budget annually for [farm property]. A nutrient budgeting tool will be used to determine fertiliser requirements and inputs from non-fertiliser sources of nutrients. Records shall be maintained throughout the year (including farm management practices and associated data) that will be used as input to the approved method of nutrient budgeting.

62.3 In their respective evidence, **Drs Snow** and **Monaghan** have explained at length the advantages and disadvantages of different nutrient modelling tools including OVERSEER. OVERSEER was chosen as a tool of choice in this case and all the nutrient losses in the Water Quality Study are therefore benchmarked to the model's properties. I therefore recommend that any future nutrient budgets be based on OCERSEER. Use of any other tools should only be done after they have been calibrated against the OVERSEER outputs. Therefore, the above condition should be re-worded to reflect this.

62.4 Condition 16(e) states that the Farm Environmental Management Plan (FEMP) for a property shall include an annual auditing process and presents Table 1 showing the proposed monitoring regime. An extract from Table 1 is shown below:

Table 1: On-Farm Monitoring

On-farm	**Monitoring type**	**Parameter to be measured**	**Sites to be monitored**	**Frequency of monitoring**	**Reporting**
Soil		Carbon, Nitrogen. Organic Matter.	Irrigated and non irrigated paired sites on each soil type on farm	Every 3 years	Report as part of annual farm audit report to ECan and MIC

62.5 Table 1 states that the soils should be monitored every three years and the reporting should be done annually as part of the farm audit report to ECan and MIC. I presume that the author intended to propose that the soils be monitored annually as well. In any case, as part of nutrient budgets, soils tests will be done on an annual basis. I therefore suggest that the frequency of soil monitoring be changed to annually. I also recommend that for completeness, total P and dissolved reactive P (DRP) be included in the list of soil parameters to be measured.

62.6 In summarising my comments on the proposed conditions by **Mr Kyle**, I would say the conditions contain the basic ingredients for a robust monitoring regime. However, the FEMPs requirements are generic and it is the detail within these plans that will make a difference to managing the effects. In Paragraphs 44 and 56 I highlighted some of the things that I think should be contained within the consent conditions or the FEMPs.

COMMENTS ON THE OFFICERS SECTION 42A REPORT

63. I have read the s42A Reports and my relevant comments are set out below.

Section 42A Report 1 Appendix 6

64. Water Permit condition WP05 states that:

> *"WPO5. The consent holder shall take all practicable steps to:*
>
> *(a) Ensure that the volume of water used for irrigation does not exceed that required for the soil to reach field capacity; and*
>
> *(b) Avoid leakage from pipes and structures; and*
>
> *(c) Avoid the use of water onto non-productive land such as impermeable surfaces and river or stream riparian strips.*
>
> *Purpose: Ensures water is used efficiently and is not left to go to waste and soils are not 'over-watered'."*

65. The modelling work that was carried out by Aqualinc for the four PAW soils assumed specific application depths and irrigation trigger levels. To ensure that the drainage volumes that were derived from this modelling work and later used in subsequent farm systems modelling are not exceeded I recommend that the trigger values should be included in this condition for each property.

Section 42A Report 4A – Mr Heller

66. Throughout my evidence I have highlighted my concerns regarding the denitrification rates and how the N leaching rates could have been underestimated. In Paragraphs 18 -20, **Mr Heller** raises the same issues that I discussed, For example he notes in Paragraph 20 that:

> *"The application and effects of denitrification into the N mass balance is not clear in the GHD reports and has not been provided within any appendices. There appears to be a denitrification factor applied to soils as discussed above, which is addressed in evidence of Dr Clothier. The soils in which significant denitrification may take place are considered by the applicants to contain high soil moisture, low oxygen, and high soil temperature with the presence of organic matter. However, Dr Clothier (in evidence) states that the*

> *soils in the upper Waitaki are inconsistent with those properties. Thus, in terms of N mass balance, it is unclear how the application of soils N-leaching vulnerability is applied to the overall N-flux utilised for cumulative effects assessment."*

67. **Mr Heller** concludes in Paragraph 120 of his report that "*I am not convinced that the applicants' consultants' Cumulative Effects Assessment has demonstrated that the additional irrigation development in the Upper Waitaki catchment can be undertaken without causing significant adverse water quality effects ….*". I have also come to the same conclusion as **Mr Heller**. It would have been somewhat helpful had the modelling work included sensitivity analyses to provide an understanding of the potential effects resulting from adopting different input parameters.

Section 42A Report 4B (Land Management) – Dr Clothier

68. I agree with **Dr Clothier's** statement in Paragraph 13 of his report that it is not clear how the soil types modelled represent the soil types across the proposed irrigated areas. I would also add that, the models do not demonstrate how the rainfall values applied represent or compare to the rainfall distribution across the Upper Waitaki Catchment

69. In Paragraphs 29 - 40 above, I discussed my concerns on denitrification and the attenuation factors used. **Dr Clothier** has also discussed these factors in Paragraphs 58 – 60 of his report and concludes in Paragraph 60 and 62 that:

> *"The hydro-geological modelling in GHD (2009a) accounts for attenuation by riparian soils which are presumed to favour the anaerobic conditions that would lead to denitrification. There would be I consider a significant degree of uncertainty in the estimates of attenuation because of the generic nature of the attenuation factors used and the lack of local consideration of the specific pathways of water entry into rivers and streams via the riparian zone.*
>
> *I would imagine given the generic nature of the attenuation factors in Appendix H, and the lack of consideration of the specific recharge mechanisms locally to arrive at the catchment multipliers, that the predicted attenuations would have a large degree of uncertainty associated with them."*

70. My comments in Paragraph 33 above are also highlighted in **Dr Clothier's** s42A report when, in Paragraph 59, he states that:

> *"The spatial pattern of these poorly drained soils (Figure 7 in GHD, 2009a) indicate that most of these riparian zones are upstream of the proposed irrigation developments. Is this spatial mismatch of the presumed ability of the riparian zone to denitrify, with the expected pattern nitrogen loading into surface waters taken into account? GHD (2009a) do not provide, it seems to me, any quantitative mass balance values for how much nitrogen is lost via this attenuation pathway. Such information would have been, from an audit perspective, useful. It should have been possible to add the mass balance values of the attenuated losses to the nodal flow diagrams of Appendix CC."*

Section 42A Report 4D (Water Quality) – Mr Hanson

71. I have read the s42A report by **Mr Hanson**. **Mr Hanson**, like other reviewers, expresses his concerns on the assumptions made with respect to denitrification factors. He also notes (in Paragraph 43) that:

> *"**details of the calculations of nitrate attenuation at river margins** — Section 4.3.1 of the Summary Report discusses denitrification, and it says that an "attenuation multiplier" was used to simulate the effects of denitrification where groundwater discharges to surface water. The report includes a map (Figure 7) showing areas of expected denitrification, primarily along stream margins. However, the details of these calculations are not explicit. In addition, I have concerns about extrapolating information on surface soils to subsurface saturated groundwater processes. In my opinion, there will be very little denitrification along most of the stream reaches shown in Figure 7. The groundwater discharging through these stream margins will be well oxygenated, and flow rates are likely to be high, so there will be little opportunity for denitrification to occur. However, without explicit details of the denitrification calculations, I cannot assess how much difference the attenuation factors make to the assessment's conclusions."*

72. Having reviewed the various technical s42A reports discussed above and **Dr Freeman's** concluding summaries on the report, I can

confirm that I share the concerns that they have raised with respect to the modelled levels of N leaching.

CONCLUSIONS

73. In my evidence I have discussed drainage modelling undertaken by Aqualinc. Although the model architecture and the input data were not made available as part of this review and there are some points I do not agree with, the resultant figures look reasonable.

74. I also note that modelled leachate figures require both good irrigation and good farm practices to be adopted. To ensure these occur, they would need to be articulated and form part of the consent conditions.

75. The study added high reductions in nitrogen via denitrification of groundwater within riparian margins. The rates do not appear consistent with the graph **Mr Callander** has prepared (Figure 9), with either very little dentrification, or high removal. From my experience with designing wastewater and land treatment systems trying to encourage denitrification, I know that it is extremely difficult to achieve at optimal levels, even in controlled conditions. After carrying an extensive literature review, I believe that the assumed rates were highly optimistic. A maximum of 1 - 3% denitrification losses would appear more reasonable and it would be a conservative approach to ignore denitrification completely.

76. The MWRL reports have proposed a toolkit from which mitigation measures will be drawn. Only general measures have been proposed. Some of these have been proven to work and some of these are already incorporated into the OVERSEER modelling and there is a risk that these will be double counted. I have gone a step further and proposed some Best Management Practices that could be adopted under irrigated agriculture.

77. Finally, I recommend that specific nutrient loss/management consent conditions to be attached to any consents issued such that they limit/control any potential deviations from the model assumptions so that the resulting nutrient loses and effects are not off the curve of the modelled scenarios.

Dated: 16 September 2009

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Robert John Potts