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| IN THE MATTER | **of the Resource Management Act 1991 and the Environment Canterbury (Temporary Commissioners and Improved Water Management) Act 2010** |
| AND | |
| IN THE MATTER | **of the hearing of submissions on the Proposed Canterbury Land and Water Regional Plan** |
| BY | **by agKnowledge Ltd on behalf of Canterbury Pastoral Limited** |
| | **Submitter** |
| **TO** | **Commissioners of the Canterbury Regional Council** |
| | **Local authority** |

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**STATEMENT OF EVIDENCE OF DOUGLAS CHARLES EDMEADES ON BEHALF OF CANTERBURY PASTORAL LTD**

Dated 2 April 2013

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**INTRODUCTION**

1) My name is Douglas Charles Edmeades. I am the Managing Director of agKnowledge Ltd, a privately owned science consulting business.

2) I hold the following qualifications: MSc (Hons) Chemistry, Auckland University; PhD (Soil Science), Canterbury University; and Diploma in Management (Auckland University).

3) I have received the following awards: ANZAC Fellow (1985); Federated Farmers Personality of the Year (2012).

4) My employment record is as follows: 1976 – 1988 Soil Scientist MAF, Ruakura; 1988-1991 Group Leader, Soils and Fertiliser Group, MAF, Ruakura; 1991-1997 National Science Leader, Soils and Fertiliser, AgResearch. It was during the latter period that I instigated and managed the science project to develop what is now called OVERSEER. I have written over 100 scientific papers.

5) In 1997 I left AgResearch and formed my own company agKnowledge Ltd. agKnowledge provides science-based information to farmers and farm consultants, including the development of nutrient management plans for individual farms, which includes regular use of Overseer.

6) Of particular relevance to these proceedings, I was a member of the Foundation for Arable Research (FAR) Committee which recently reviewed the new Cropping Model now incorporated in Overseer 6. Also, I have been retained by Canterbury Pastoral Ltd (2009 to the present) to provide them with advice on soil fertility, soil tests, fertiliser and nutrient management for their 4 properties at Rakaia in Canterbury.

**CODE OF CONDUCT**

7) I have read the Environment Court Code of Conduct for expert witnesses and agree to comply with it. I confirm that I have not omitted to consider materials or facts known to me that might alter or detract from the opinions I have expressed.

**SCOPE OF EVIDENCE**

8) My evidence will cover the following issues:

    a) The use and application of Overseer,

    b) Questions about the application of water quality science to a given farm situation (Canterbury Pastoral Limited, CPL).

    c) The implications of applying the proposed Canterbury Land & Water Regional Plan (pCL&WRP) to CPL.

## OVERSEER

**Agreement with Dr A.H. C. Roberts**

9) I agree with the following statements made by Dr A.H.C. Roberts (on behalf of the New Zealand Fertiliser Industry) in his Brief of Evidence:

    a) Para 14: "OVERSEER® is a world class Decision Support System…"

    b) Para 26: Quoting from the recent review of Overseer by the Foundation for Arable Research: Overseer "is the best tool currently available for estimating N leaching losses from the root zone across the diversity and complexity of farming systems in New Zealand".

    c) Para 26d: "Furthermore, as model predictions are inherently uncertain for a variety of reasons e.g. random error, inaccurate specification of parameters, and biases in process representation, models such as OVERSEER are generally more robust in predicting relative changes than absolute values. Regulatory authorities, and all model users, need to recognise this aspect of model application."

    d) Para 30: "This [estimate of nitrate being leached] is primarily the estimate of how much N moves below the root zone in drainage water, particularly on flat land. It is not, nor should be interpreted as, the amount of N which necessarily enters receiving water (confined, unconfined aquifers or surface water)."

    e) Para 36: "A strength of OVERSEER is that it is able to demonstrate the impact of changing management, inputs or mitigations on N loss from a farm or block. However, the user of OVERSEER must be conversant with its operating principles to ensure that the consequences of any changes made are consistent with all the other input parameters used to set up the original nutrient budget. Scenario testing provides the farmer with valuable information to assess what management changes he/she could make and to reduce N loss if that is required. Further analysis of the costs associated with changes to management and indeed the practical feasibility of changes also need to be completed outside of the OVERSEER analysis".

f) Para 40: "With respect to N loss estimates, it is neither practical nor cost effective for individual farmers to measure N loss, either as total load (i.e., kg N/ha) or concentration (e.g. mg N/L) from their properties nor in the short term is it useful given the biological variability associated with N loss processes in the real world (see paragraphs 41-44, 48-49 below). This is one of the reasons for having models such as OVERSEER."

g) Para 60: "The discussion of the errors [in the Overseer estimates of nitrate leaching], both in real life measurements and in modelled estimates, needs to be kept in mind when tying Plan standards or resource consent conditions to single number N loss limits, however those limits are derived."

I wish to elaborate on and/or clarify the following points:

**Errors in Overseer Estimates.**

10) In the context of this evidence I use the word "error" in the statistical sense being the difference (positive or negative) between the computed (estimated, predicted or calculated ) value based on the model (Overseer) of N loss (leaching) and P loss (runoff), and the measured value of these losses in the field. Biometricians express errors in many different ways, but, simply for convenience, they are often expressed as a percentage, for example the predicted N leaching loss = 30 kg N/ha/yr +/- 30%.

11) There are two sources of error in the Overseer outputs for P and N. These arise from mistakes or uncertainties in the input data required to 'drive' Overseer, which I will refer to as Type A errors, and uncertainties in the output data (Type B errors).

Figure 1, attached, attempts to demonstrate these points, noting that the width of the band of uncertainty can and will vary from situation to situation.

12) Type A errors fall into several categories:

a) Errors arising from using incorrect or inaccurate input data. Examples affecting N leaching include: pasture clover content, pasture development, soil type, subsoil physical characteristics. Examples affecting P runoff are soil P status and soil slope. Ledgard and Waller (Precision of estimates of nitrate leaching in OVERSEER, Report to FertResearch, AgResearch Ruakura 16p. 2001) usefully categorise these into 'Farmer-provided' inputs such as farm area, stocking rate, production and 'Consultant-provided' inputs such as the those listed above.

b) Errors arising because the necessary information is not known at the level of detail required (i.e. at the farm and paddock scale). Examples include, soil type, soil slope and subsoil texture.

c) Errors arising because the mathematical models in Overseer are simplifications of complex biological systems and because these models have not been tested in all possible situations. AgResearch (Overseer: Answers to commonly asked questions. Report prepared for the Ministry for Primary Industries, February 2013) warns that Overseer nutrient losses derived in such situations "need to be considered extremely cautiously".

13) Type B errors arise because the outputs such as N leaching and P runoff are variable in time (monthly, yearly) primarily because they are determined by rainfall patterns and intensity. Overseer estimates the long-term **average** N and P loss based on the **average** rainfall and therefore does not express this type of temporal variability. Dr Roberts in his evidence (para 54) provides an example of this. In addition N and P losses are variable in space, depending on spatial changes in soil texture and nutrient deposition, adding another layer of uncertainty.

14) DairyNZ has developed "A protocol for the use of the Overseer model to measure, model and audit nitrogen information from New Zealand Dairy Farms" (New Zealand

Dairy Industry Audited Nutrient Management Scheme, DairyNZ, 2013). This may minimize Type A(a) errors but will have no impact on the other types of errors listed above.

15) In the original versions of Overseer (Pastoral Model e.g. Overseer Version 5), the estimated Type B error for nitrate leaching was given as +/- 30%. There was no estimate of the Type A error for nitrate leaching. Also there was no estimate for the errors (Type A or B) assigned to the predicted P runoff and this was reflected in the qualitative expressions of P runoff risk, being high, medium or low.

16) The estimated (from Overseer 6) and actual (from field measurements) nitrate leaching losses have been tested in 7 trial sites throughout NZ . There is a good correlation between the estimated and measured nitrate leaching (see Figure 5, Dr A.H.C Roberts' Brief of Evidence ) and there appears to be no systematic bias in the predicted N loss estimates from the model in Overseer (the best fit line is close to 1:1). For this set of data the input errors (Type A) can be assumed to be relatively small, reflecting well defined experimental sites and assuming competent Overseer users. The Type B errors (the horizontal bars in the graph) reflect the errors in measuring annual nitrate losses under field conditions. Ledgard and Waller (2001) estimated this error to be +/- 20% at the block level (a block being a component of a whole farm) and +/- 25-30% at a whole farm level.

17) Overseer 6 was released in August 2012. It is reasonable to assume that the Pastoral Model in Overseer 6 is at least as accurate as that in Overseer 5 with regard to nitrate leaching. The owners (AgResearch 2013) "appear" to accept the figure of +/- 30% for the error in the predicted N leaching (the speech marks are required because their wording is ambiguous - they describe it as a "conceptual starting point for discussion").

18) However, a new cropping model was incorporated in Overseer 6. This model was a modified version (to accommodate its inclusion into the Overseer 6 framework) of a more complex model developed by several scientists in the CRIs Plant and Food and AgResearch (Cichota et al. 2010, NZ Journal of Crop and Horticultural Science Vol 38, No 3 September 2010, 189-207). This model was field validated, but

only on one site. The modified version of the cropping model now in Overseer 6 has not been field validated or validated against other models.

19) There is currently very little information on the size of the Type A errors in Overseer (5 or 6). What is required is a formal sensitivity analysis of Overseer 6. By this I mean that the effect of altering each input variable one at a time in an incremental manner, on N leaching (and P runoff) is required. This would be very instructive to Overseer users because it would indicate those input variables for which accurate information is required when predicting N leaching and P runoff (to assist with minimising Type A errors).

20) Some sensitivity analysis has been done using the older version of Overseer and this identified some of the more sensitive input parameters (meaning input parameters which if altered have a relatively large effect on estimated N or P losses) and further work is proposed (AgResearch 2013).

21) Some indication of the size of Type A errors can be deduced from recent work by Pellow et al. (2013) (In: Accurate and Efficient Use of Nutrients on Farms, Fertiliser and Lime Research Centre, Occasional Report 26). Using Overseer 6 on a well defined research farm, they explored the effect of changing some input variables on the predicted N leaching. They reported that relative to using the default options in Overseer, applying some farm specific input data reduced the predicted N leaching from about 37 to about 21 kg N/ha/yr (about -40%). Relative to using default options other farm specific data increased the predicted N leaching from about 38 to about 63 kg N/ha/yr (about +60%). Changing some input variables had little effect (see another example at Para 53).

22) To summarise; the available information suggests that Type A errors could be in the range -40% to +60% and that Type B errors are in the range +/- 30%. These estimated errors could theoretically be reduced by conducting many more experiments (measuring actual N losses versus predicted N losses) covering all the known situations in which the model may be used and greatly increasing the number measurements of actual N loss. The cost of doing so would be prohibitive.

23) The Type B errors are of little practical consequence for Overseer users ***providing*** Overseer is being used to do 'what-if analyses, where the emphasis is on determining how N leaching losses ***change*** with changes in management inputs and not to generate absolute values of the predicted rate of N leaching (see para 29). In other words providing Overseer is used qualitatively not quantitatively.

24) However Type B errors become important if the intention is to estimate absolute changes in N leaching from farmland into water bodies. Overseer 6 estimates the nitrate moving out of the rooting zone of the topsoil. The proportion of this nitrate moving into the ground water depends on what hydrologists refer to as the attenuation. I understand that for convenience this is taken to be about 50% but that it can vary considerably depending on the catchment. The estimated nitrate N leaving the root zone and getting into water bodies could be calculated if the attenuation figure was known in a given catchment but it would need to be qualified by the size of the Type B error.

25) Dr Richard McDowell (pers comm) has advised that the confidence interval (a measure of the error) for the slope of the relationship between observed and predicted P runoff using Overseer 6 is +/- 21%, based on data from 32 sites, This is a measure of the Type B errors from the P runoff model. There is no estimate of the Type A errors for P runoff.

**Application of Overseer to the pCL&WP**

26) Despite Overseer 6 representing a "world class Expert System" and despite the fact that it represents the best available expression of current scientific knowledge, it has the following limitations:

   a) The estimated Type B errors in the predicted rate of N leaching are about +/- 30%, similar to that for the predicted P runoff.

   b) In the absence of information from formal sensitivity analyses the best guess at the size of the Type A errors is minus 40% to plus 60%.

c) Within these limits of error, Overseer predicts the amount of nitrate N leaching from below the plant rooting zone (of pasture and crops).

d) The amount of nitrate N leaving the root zone does not necessarily represent the amount reaching water bodies.

e) The current Cropping Model in Overseer 6 has not been field validated.

27) These limitations do not mean that Overseer should not be used as one of the tools for managing nitrate leaching and P runoff. It does mean however that Overseer 6 must be used and applied with caution and with a full knowledge of what the predicted outputs for N and P losses mean. In my opinion, this limits the use of Overseer 6 to a specific role in terms of managing nutrient losses from farms, as will be discussed later.

28) This situation (with regard to the errors in Overseer) is not unusual in biological sciences. Indeed it is analogous to soil testing. The typical variability in common soil tests, in the hands of a trained and knowledgeable operator, is between 20-30% (i.e. Type B errors). It is greater with an unskilled operator (Type A errors). This does not mean the soil testing is not a useful tool. It is, but because of the inherent errors associated with measuring soil fertility, soil test results are best used to follow trends over time.

29) By analogy Overseer 6 is useful tool best used by suitably trained and experienced personnel (to minimise Type A errors) to undertake 'what-if analyses' at a specific farm level. Overseer can be used to examine the effects (the trends whether positive or negative from a given base line) of different farm management options on the estimated losses of P and N. Because of the size of the errors in predicting N and P losses the focus in such analyses in not on the absolute number (of the estimated N and P losses) but on the trend (either positive of negative) away from a given baseline.

30) From this type of analysis, a consultant can inform the farmer about which farm management options could be implemented to reduce N and P losses consistent with the requirements of the water quality values, standards and criteria set by the community involved in the particular catchment. This can be taken further by determining the costs

and benefits of the various possible farm management options (see example at para 58).

31) The 'Look-up' tables proposed by the pCL&WP could be instructive for the consultant and farmer at this point to determine how a given farm is performing (with respect to N and P losses) benchmarked against industry norms (Good Management Practices).

32) The most cost effective and beneficial farm management option(s) selected by the farmer could then be written into a farm-specific Nutrient Management Plan or Farm Environment Plan (FEP), which could be open to scrutiny and auditing by the Regional Council. It is recommended that this farm specific document (the FEP) would then become the basis for a 'contract' (to be updated and audited as required) between the farmer and the Regional Council. In effect the FEP is the regulatory tool (not the Overseer output) and hence the focus for the Regional Council.

33) The proposed 'Look-up tables' (LUT) could also provide useful benchmarks against which a Regional Council could assess the current and intended performance of a given farm.

34) The errors in the predicted outputs of P and N losses from Overseer outputs have been discussed above. Because the information in the previous LUTs were derived largely, but not solely, from Overseer 5 and because (I understand) they are to be updated using Overseer 6, the errors in the LUT values are likely to be similar to those from Overseer 6. It is possible that in some instances they are likely to be greater because they have been derived by extrapolating Overseer outputs for N and P into situations in which Overseer has not been tested. In other words some of the values in the LUTs will be 'guesstimates' (see also para 12c).

35) I now wish to consider the application of either the LUTs, or the N or P outputs from Overseer 6, in a regulatory setting. Assume that a rule is introduced, say for a given Canterbury subzone and farm type (dairying, cropping, dry-stock), which requires that the rate of N leaching (or P runoff) is not to be greater than a certain limit. For the sake of discussion I will choose an arbitrary figure for N leaching of say "not greater than 30 kg N/ha/yr as determined by Overseer 6". For the purpose of this discussion it does not matter whether the intention of this limit

is as a trigger point to action an NMP or to declare a particular farm a permitted activity or non-complying activity.

36) Assume further that Consultant A runs Overseer 6 for a given farm and determines that the predicted N loss is 36 kg N/ha/yr. Not happy with this result the farmer employs Consultant B and he calculates a predicted N leaching of 24 kg N/ha/yr. Both predictions are within the limits of error for Overseer 6. If it is assumed that Type A are about 30% (which is modest see para 21) then the true value lies between 21 and 39 kg N/ha/yr. The differences in the predicted N losses from the two Consultants arise because they have used different input data for some key variables, such as the pasture clover content or dominant soil type or the dominant subsurface drainage characteristics (to use but a few examples), for which there may be no absolutely correct figure (see para 53).

37) For these reasons, it would be unwise in my opinion for Overseer 6 to used in a regulatory role. It could result in endless litigation as Consultants argue their cases over the "correct" input variables to be used in a given situation. The DairyNZ protocol for the use of Overseer does not solve this problem because of the Type A (and in particular Type A b) and c) errors – refer to para 12). In contrast I foresee fewer problems if Overseer 6 is used for what it is designed to do; for examining 'what-if options' for managing N and P losses from farming operations.

**QUESTIONS ABOUT WATER QUALITY**

38) I am not an expert in water quality. However in my role as a science consultant to farmers there are a number questions related to water quality which I need to answer in order to provide them with informed professional advice.

39) As I understand these matters there are 4 major contaminants that contribute to poor water quality: sediments, pathogens (e.g. faecal coliforms), P and N content.

40) The current pCL&WRP focuses on N leaching at the exclusion of the other 3 components. It appears to be assumed that either a) N is the primary factor limiting water quality in Canterbury, or, b) if N leaching is controlled this will

concurrently mitigate the movement of sediments, pathogens and P into water bodies.

41) I am not aware of any evidence to support the conclusion that N is the primary factor limiting water quality in Canterbury and it appears to me to be illogical to assume that managing N leaching will simultaneously limit the movement of sediment, pathogens and P into water ways. This is because the mechanisms by which these pollutants move into water bodies are different; nitrate losses into ground water are largely due to N leaching down through the soil profile, whereas the movement of sediments, coliforms and P occur via surface movement of water.

42) Further, controlling nitrate leaching is more difficult and hence, it is assumed, more expensive than controlling the surface movement of water and with it sediments, pathogens and P. With the incorrect information as to the cause of the poor water quality a Consultant could give potentially costly and incorrect advice to a farmer wishing to improve water quality.

43) It seems obvious to state that it is essential that the factor(s) limiting water quality in a given catchment must first be defined **before** any on farm decisions are made with respect to which mitigation options to adopt.

**CANTERBURY PASTORAL LIMITED – AN EXAMPLE OF THE PRACTICAL IMPLICATIONS OF THE pCL&WRP.**

44) Canterbury Pastoral Ltd (CPL) operate 4 farms on the northern bank of the Rakia River in the Selwyn-Waihora catchment. This includes 3 large dairy platforms (900 ha) and a support block (450 ha). These farms generate significant income (turnover $11m) and employment (25 staff) for the region.

45) Because of the technical nature of the pL&WRP, CPL have asked agKnowlege Ltd to assist them to understand what the pCL&WRP plan could mean to their large dairy farming operation.

46) Preliminary information (Mr Carl Hanson, email 30/08/12) from Environment Canterbury indicates that all of the ground water (i.e. carrying leached N) from these 4 farms drains away from

the Rakaia River, some to Lake Ellesmere and some to the 'streams to the south'.

47) Professor Hamilton (Brief of Evidence to Environment Canterbury and Selwyn District Council) states that the limitations to water quality (phytoplankton) in Lake Ellesmere are: light (i.e. lack of light due to suspended sediments) (51%), N (37%) and P (12%). McCabe (Brief of Evidence pCL&WRP) goes further and states (para 5.6) that 'restrictions on nitrogen leakage from farming in the catchment (into Lake Ellesmere) will be pointless" if the macrophyte beds are not restored first. This evidence implies to me that advising CPL to limit N and P losses from their farms would not contribute at present to the improvement in water quality in Lake Ellesmere.

48) As noted it is possible that some of the nitrate leached from these farms goes to the 'streams to the south'. As this time I have no knowledge of the factor(s) limiting water quality in these streams.

49) Based on the above (para 47 and 48) I do not currently have the information required to provide CPL with technical advice on which management practice(s) they need to adopt on their farms to enhance the quality of the water in the receiving water bodies in their catchment

50) agKnowledge Ltd has been offering CPL technical advice on soil fertility, fertiliser use and nutrient management for 4 years. The table below shows the predicted N leaching and P runoff (averaged over the whole enterprise – the four farms), for the 4 years; 2009 to 2012, using the various versions of Overseer available at the time.

| Year | Overseer version | Nutrient loss (kg/ha, average of 4 farms) | |
|---|---|---|---|
| | | N leaching | P runoff |
| 2009 | 4 | 43 | 0.3 |
| 2010 | 5 | 40 | 0.3 |
| 2011 | 5 | 46 | 0.3 |

| | | | |
|---|---|---|---|
| 2012 | 6 | 86 | 0.8 |

51) There has been no substantial change in the operation and management of these 4 properties over the period 2009 to 2012. Thus these annual changes in the predicted nitrate leaching are due to changes in the version of Overseer or changes (refinements) in the input data used.

52) The difference in the predicted N leaching and P runoff from Overseer 6, relative to the earlier versions, is large (about 100% increase). This is most likely due to the changes made in Overseer 6 to better reflect the drainage characteristics of stony and sandy soils. Given the size of this change and given the frequency of such soils in Canterbury it is essential, in my view, that the proposed LUTs and trigger points in the pCL&WRP (viz. 'change in land use defined as > 10% increase in N leaching and a threshold N loss of > 20 kg N/ha/yr for requiring a Farm Environmental Plan) need to be reviewed.

53) There are 5 soil types represented on these 4 farms: Lismore, Waimakariri, Eyre, Rakaia and Rangitata. Overseer 6 does not include the last 2. The soil maps available for this region area are at a scale of 1: 50,000. To get down to the paddock scale or block scale (a block being a group of paddocks of similar soil type, topography, soil fertility and land use) would require a scale of about 1 to 10,000 (Mr P Singleton, pers comm.). In other words the soil pedological information required to operate Overseer 6 is not currently available and would have to be derived by a suitable qualified person in any given case.

54) This may be of little consequence in this case (CPL) because using either of these five soil types makes little difference to the predicted N loss. However it is of significant importance in other cases. For example in planning work for a resource consent on the Waitaki, which agKnowledge in undertaking, there are 4 soil types. The predicted N leaching losses range from 29 to 136 kg N/ha/yr depending on the choice of soil type. These differences in soil type occur over small distances (i.e within farm) and would not be apparent to those except for trained pedologists.

55) Not withstanding the above, Overseer 6 requires other soil physical input data: is the topsoil stony? (yes/no), soil texture (light, medium heavy), is there a non-standard soil layer? (yes/no), is the non-standard layer sandy, stony, or stony matrix? and what is the depth of the non standard layer (7 depth increments down to 1.3 m). Returning

to the CPL case if a Waimakariri silt loam is assumed then this combination of input variables can give predicted N leaching losses from 79 to 135 kg N/ha/yr (a range of 56 kg N/ha/yr or 70%).

56) To summarise, the Type A errors referred to in this Brief of Evidence which can arise when applying Overseer 6 , by either not knowing the correct input variables or using the incorrect input variables are large in absolute or relative terms: 16 kg N/ha/yr (40%) (see para 21), 25 kg N/ha/yr (60%)(see para 21), 107 kg N/ha/yr (270%) (para 54) and 56 kg N/ha/yr (70%) (para 55) and these examples are by no means exhaustive.

57) The pCL&WRP suggests applying two thresholds with respect to N leaching which will trigger specified decisions: change in land use is defined as an increase of > 10% in N leaching and a threshold of > 20 kg N/ha/yr triggers the requirement for implementation of a Farm Environmental Plan. These trigger points fall well within the limits of the Type A errors. Because of this if they were implemented they would give rise to confusion and possibly unnecessary litigation (see also para 37).

58) I recommend therefore that the owners of Overseer 6 are asked to compete a full and thorough sensitivity analyses of Overseer to quantify the effects of all the input variables on the predicted N and P losses.

59) Once this is completed it is suggested that the threshold values in the pCL&WRP are re-examined and adjusted giving cognizance to the practical limitations in the application of Overseer 6. The same would apply also to the proposed LUTs.

60) The CPL operation includes a support block of (450 ha), which is used to grow crops for the dairy platforms. Despite the changes to Overseer 6, to include a more comprehensive Cropping Model, Overseer 6 cannot accurately represent the complexities of the cropping regimes and rotations that are currently used on the CPL support block. For this reason there is no way to estimate the likely N leaching rate from this block, or indeed any of the other outputs from Overseer 6.

61) The issue of the treatment of 'support blocks' when determining N losses from dairy farms also needs to be considered. The DairyNZ protocol for Overseer users (referred to earlier) specifically excludes support blocks (page 12 section 3.1.2). This appears to be

inconsistent with the fact that dairy Support Blocks can contribute disproportionally to N leaching given that they are often intensively managed during the winter time when N leaching mainly occurs.

62) The pL&WRP is focussed on N leaching and it is implicit that the overall intention of the plan is to reduce nitrate leaching by adopting mitigating farm management practices. The Table below sets out for **one** of the CPL farms, the potential mitigation options that could be implemented and their impact on nitrate leaching and P runoff.

63) All of these mitigation options will incur costs, some of which are very significant. The option which has the largest beneficial effect in terms of reducing nitrate leaching, will reduce the predicted N loading from 121 to 36 kg N/ha/yr.

64) Under this best scenario and assuming a price of $6/kg milk solids, income per/ha would decrease by about $2000/ha, and net operating surplus would decrease by about $1000/ha, a reduction in profit of about 30-40%. This cost estimate does not include the likelihood that land value will decline.

65) Until the pCL&WRP is further developed and in particular the look-up table values are finalised it is not possible to determine whether the CPL farms would be classified as a permitted activity or otherwise after 1 July 2017.

| **Mitigation option** | **N (kg/ha/yr)** | **P (kg/ha/yr)** |
|---|---|---|
| None (current management and production) | 121 | 1.0 |
| Current plus DCD (March & May) | 111 | 1.0 |
| 10% less cows but same production | 117 | 0.9 |
| 10% less cows and 10% less production | 110 | 0.9 |
| Reduce irrigation to 100 mm/month | 72 | 0.8 |
| 10% less cows & production and 100 mm/month irrigation | 65 | 0.8 |

| | | |
|---|---|---|
| 10% less cows & production, 100mm/month irrigation and reduce fertiliser N to 25 kg/N/application | 57 | 0.8 |
| 1300 kg MS/ha, 25 kg N/ha/application, 100 mm / month irrigation | 50 | 0.7 |
| Current situation plus feed pad | 107 | 1.0 |
| Current situation, feed pad and 100 mm/irrigation/month | 63 | 0.8 |
| Current situation, feed pad, 100 mm irrigation/month and DCD | 54 | 0.8 |
| Current situation, feed pad plus herd home | 96 | 1.0 |
| Current situation, Feed pad, Herd home, 100 mm irrigation and DCD | 57 | 0.8 |
| 1300 kg MS/ha, Feed pad, Herd home, 100 mm/irrigation/month, 25 kg N/ha/application and DCD | 36 | 0.7 |

**CONCLUSIONS**

66) Overseer 6 is a world–class expert system and incorporates the best and the latest science.

67) Overseer 6 can be used to predict the losses of N (by leaching) and P (by runoff) leaving a given farm. It does not predict the proportion of that N and P reaching a given water body.

68) Overseer was designed as an expert-system, to be used by suitably trained personnel to undertake with-if analyses at the individual farm level.

69) There are two types of errors arsing from the application of Overseer 6. Type A errors are associated with errors in and uncertainty about the input variables (these errors can be large - about 40 to 270% based on a few examples). Type B errors

arise from the variability of N leaching and P runoff over time and space (these errors are about 30%).

70) There is little that can be done to reduce Type B errors in the short-term. Type B errors can be reduced but will not be eliminated by the development of a 'User Protocol' for Overseer.

71) Given the errors associated with the practical use of Overseer 6 it would be unwise to use Overseer 6 in a regulatory setting whereby farmers would be required to farm below specified predicted Overseer 6 thresholds. This conclusion is consistent with the Ministry for the Environment's assessment (Freshwater reform 2013 and beyond 2013, p49)

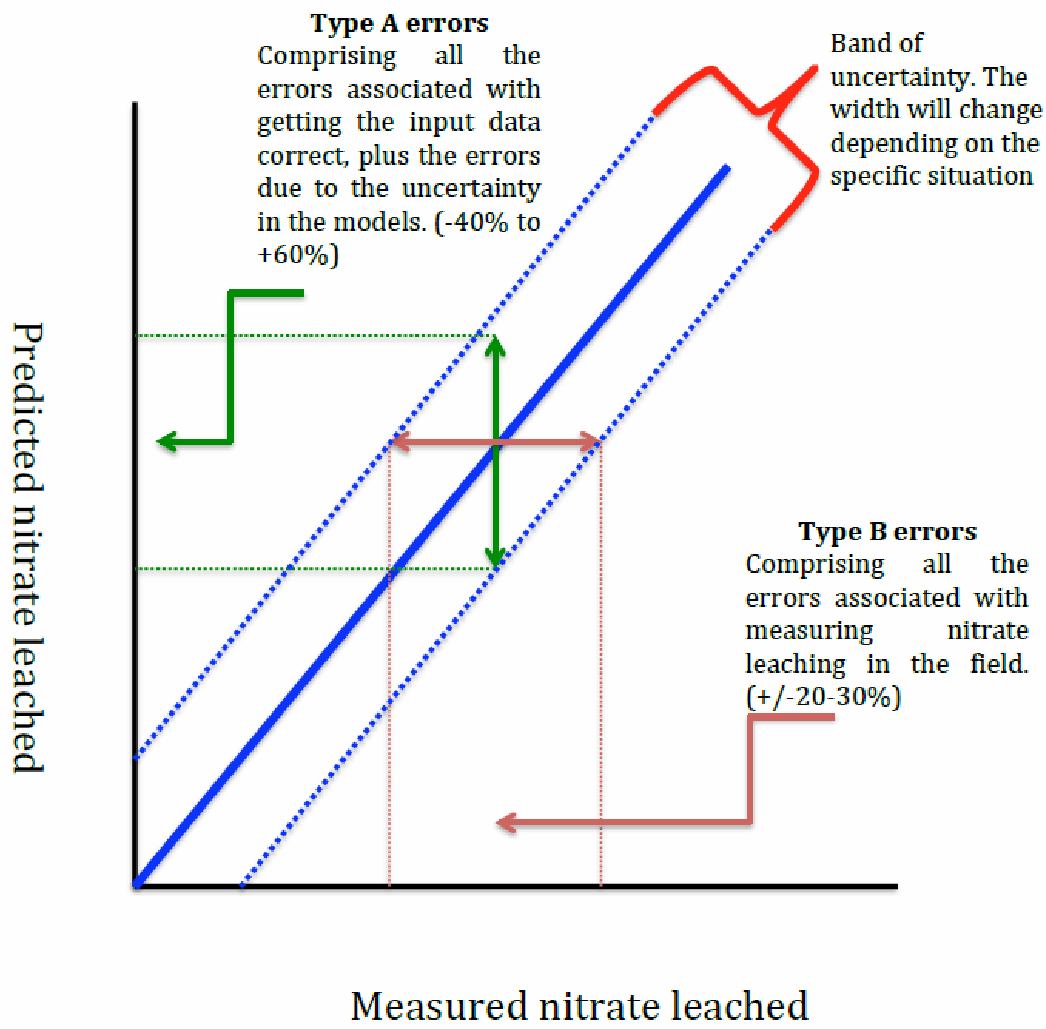
72) Overseer 6 is best used to undertake what-if scenarios for specific farms from which the farmers can then select those management practices which best suit his/her operation to reduce N and/or P loadings consistent with the water quality standards set by the community for a given catchment.

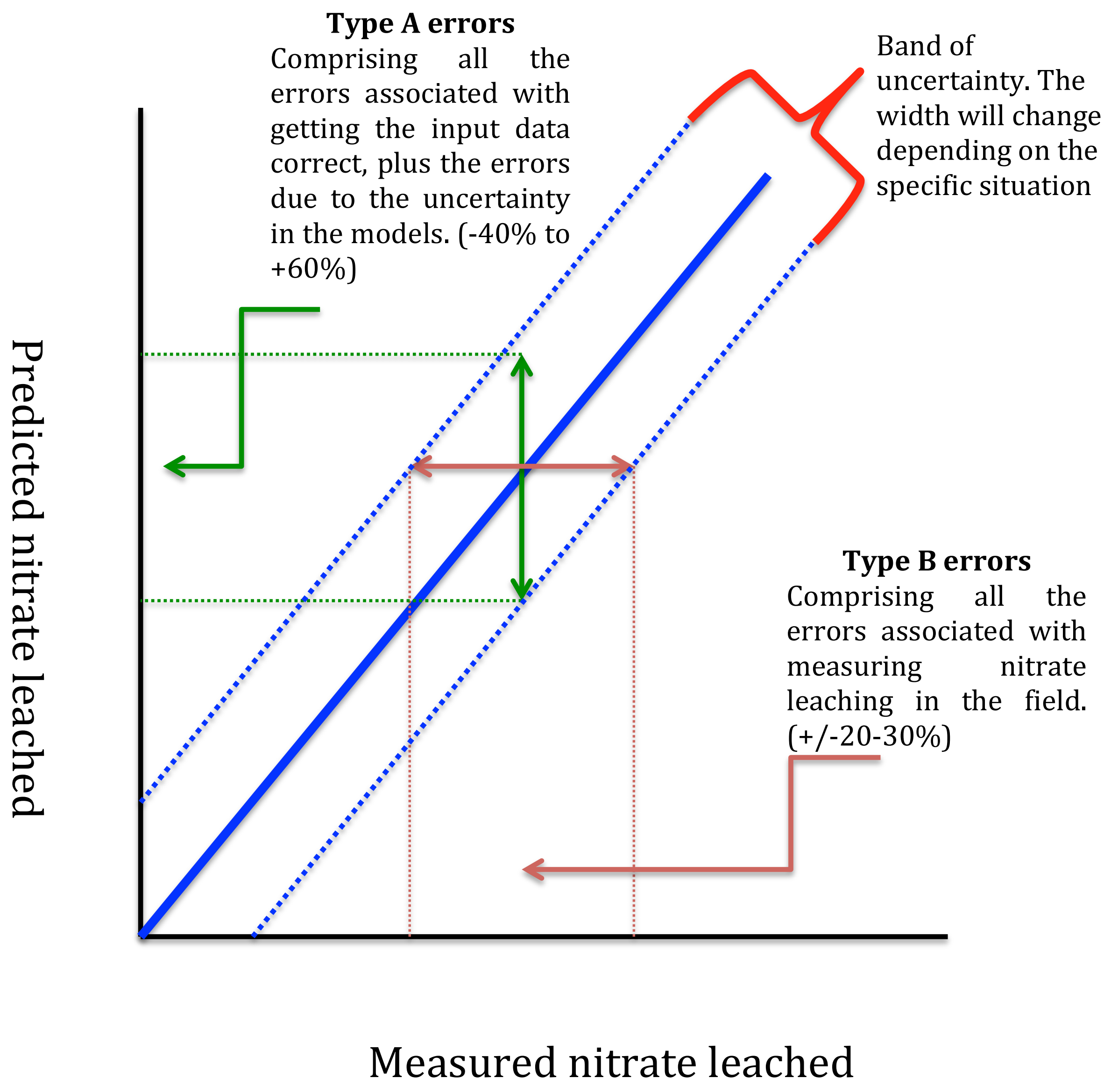
73) It is recommended that the best farm management options are then embedded into the Farm Environmental Plan and that this document and not the Overseer 6 output is used as the regulatory focus.

74) It is essential that the factor(s) limiting water quality in a given catchment are clearly defined so that farmers are properly informed about which farm management practices they need to implement on their farms to improve water quality in the catchment to which they contribute.

75) It is recommended that the owners of Overseer 6 undertake a comprehensive sensitivity analysis of Overseer and that once this is done the thresholds in the pCL&WRP of > 10% increase in N leaching (to define land use change) and > 20 kg N/ha/yr (to require a Farm Environmental Plan) be revised. The same applies to the proposed LUTs.

**Figure 1**


Type A errors
Comprising all the errors associated with getting the input data correct, plus the errors due to the uncertainty in the models. (-40% to +60%)
Band of uncertainty. The width will change depending on the specific situation
Type B errors
Comprising all the errors associated with measuring nitrate leaching in the field. (+/-20-30%)
Predicted nitrate leached
Measured nitrate leached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