BEFORE THE HEARINGS PANEL

IN THE MATTER	**of hearings on submissions concerning the Proposed One Plan notified by the Manawatu-Wanganui Regional Council**

SECTION 42A REPORT OF DR STEWART FRANCIS LEDGARD ON BEHALF OF HORIZONS REGIONAL COUNCIL CONCERNING WATER QUALITY

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1. INTRODUCTION

My qualifications/experience

1. My name is Stewart Francis Ledgard. I hold a Bachelor of Agricultural Science (Hons. 1) (1979) majoring in Soil Science, and a Ph.D. in Biological Sciences (1984) from the Australian National University. I have been employed as a soil scientist with AgResearch (New Zealand Pastoral Agricultural Research Institute Ltd) at Ruakura Research Centre since 1979. I have more than 20 years experience as a scientist with a particular speciality in nitrogen (N) cycling in agricultural systems.

2. I currently lead a multi-disciplinary research programme entitled “Nitrogen and Lake Taupo”. This programme is funded by the main government research funding body, Foundation for Research Science and Technology ($2 million/year) and focuses on the development and evaluation of technologies and management practices to reduce N leaching from farms around Lake Taupo.

3. I have been and am currently also involved in Sustainable Farming Fund research programmes, working with farmer groups around Lakes Taupo and Rotorua targeting farm systems and management practices to reduce N leaching from farms.

4. I was actively involved in and led the development of the N model in the OVERSEER® nutrient budget model (hereafter called OVERSEER). I have presented reviews on N cycling and losses from agricultural systems at national and international conferences, and have published more than 120 refereed scientific papers on N in agricultural systems.

5. I have read the Environment Court’s practice note, Expert Witnesses – Code of Conduct, and agree to comply with it.

Scope of evidence

6. Specifically, in my evidence, I will cover:

i. Background

OVERSEER development, ownership and availability for use.

ii. OVERSEER – how it works, what it measures, who uses it and its application to farm monitoring

How OVERSEER works.

The forms of nitrogen and phosphorus included within OVERSEER and where to find the summary of losses.

The uses of OVERSEER for nutrient management in agricultural systems.

Other Regional Council uses of OVERSEER.

iii. OVERSEER accuracy, assumptions and limitations

Accuracy of nutrient loss predictions.

Best practice assumptions and the relative differences to predicted losses if best practice is not employed.

Included and excluded activities, and the relative differences to predicted losses if excluded activities are incorporated.

What inputs to the model are the leaching results most sensitive to?

iv. Ongoing development of OVERSEER and implications for the Proposed One Plan

Current development work

The process for updating OVERSEER

Implications of new versions on nutrient loss predictions

Comparison of OVERSEER with SPASMO

v. Conclusion

2. EXECUTIVE SUMMARY OF EVIDENCE

OVERSEER development, ownership and availability for use

7. Nutrient budgets are a useful tool to estimate nutrient requirements for production on farms and to determine the potential for nutrient losses to waterways. During the past decade there has been increasing recognition that losses of the nutrients nitrogen (N) and phosphorus (P) from farms can be exacerbated by the excessive use of fertilisers or other inputs, such as in brought-in feed or dairy effluent. The OVERSEER nutrient budget model was first developed in the mid-1990s as a decision support model for farmers and their advisors, such as farm consultants and fertiliser industry staff. OVERSEER covers all common pastoral farming systems and most arable and horticultural crops. Recent OVERSEER development has focused on predicting N and P losses from farm systems, and mitigation practices to reduce such losses. OVERSEER is jointly owned by MAF, AgResearch and FertResearch and regularly updated to incorporate the latest research results and meet user needs. OVERSEER is freely available for downloading from the AgResearch website.

8. OVERSEER – how it works, what it measures and who uses it

8. OVERSEER processes farm-specific information (e.g. fertilser application rates, stocking rates, slope and soil type) via a series of equations to calculate the movement of nutrients through the farm system, including nutrient losses. OVERSEER predicts long-term average N and P losses, even though actual losses may vary from year to year, particularly due to climatic variability. Where some input variables are not known, OVERSEER's internal databases generally provide credible national or regional default values.

9. The N leaching sub-model within OVERSEER predicts the movement of N below the root zone which can subsequently enter groundwater and then surface water. The major source of N leaching on pastoral farms is via animal urine, with relatively minor contributions from animal dung, effluent, background soil N and direct leaching of fertiliser N. The main driver of urine N losses is the amount of N eaten (estimated from animal pasture intake, supplementary feed and farm productivity information). The P loss sub-model in OVERSEER has equations driven by slope, soil properties, soil Olsen P status, rainfall, fertiliser, Farm Dairy Effluent (FDE) and irrigation management practices. For the overall nutrient budget, all nutrient inputs, outputs (animal product and losses) and changes to soil nutrient reserves are shown in OVERSEER as the annual change in kilograms of nutrient per hectare per year, such as "kg N/ha/yr" and "kg P/ha/yr".

10. In order to reflect the complexity of typical farm systems, OVERSEER allows the user to divide the farm into "blocks" based on different characteristics (e.g. different soil type, slope, effluent block, different stocking policy, etc). Nutrient flows and losses are then provided for each block and for a whole farm.

11. OVERSEER is widely used throughout New Zealand, including by fertiliser company representatives, farmers, farm consultants and Regional Councils. More than 90% of dairy farmers have had nutrient budgets prepared using OVERSEER, in order to meet the Dairying and Clean Streams Accord requirement for nutrient budgets. Environment Waikato uses OVERSEER to calculate Nitrogen Discharge Allowances for Lake Taupo farmers. Similarly, Environment Bay of Plenty is using OVERSEER to benchmark Rotorua farmers under its 'Rule 11'. Other Regional Councils use OVERSEER to assess effects in specific resource consent application processes.

OVERSEER accuracy, assumptions and limitations

12. The accuracy of nutrient losses predicted by OVERSEER depends on the accuracy of the input information, and how well this information can be processed within OVERSEER to predict actual losses. Variability in selecting inputs can give differences in N leaching losses in the order of $\pm$ 20%. This variability can be minimised if users have a good understanding of the model and, ideally, have undergone training in its use, such as through Massey University Nutrient Management courses. Under the proposed FARM Strategy, the relative effect of inaccurate input information diminishes because many site factor inputs (e.g. area, soil, slope, rainfall) will be the same under any FARM strategy scenario for the same farm.

13. The OVERSEER model has been validated in a range of farm research studies throughout New Zealand, covering different farm types and management practices, and physical environments. Several aspects of the OVERSEER model have greater uncertainty due to relatively limited validation research, including: winter forage crops; sites with high rainfall; and pastoral systems dominated by trading animals. For each of these situations, current or scheduled research will allow future versions of OVERSEER to make improved predictions of N leaching.

14. OVERSEER includes all the important on-farm activities that influence N and P losses, in terms of inputs, transfers and management practices. These comprise:

- Stocking rate and productivity
- Fertiliser and supplementary feed
- Effluent management and irrigation
- Winter grazing management and feed pads or animal shelters
- Mitigation tools such as application of Dicyandiamide (DCD), wetlands, riparian management.

15. An OVERSEER input sensitivity analysis for N leaching was carried out in 2006 for Environment Waikato, using contrasting farm types. The most sensitive farmer-derived input variables were: amount and timing of N fertiliser; stocking rate, type and animal productivity; and winter management practices. These factors highlight the importance of good farm records. The most sensitive user-derived variables were: rainfall; pasture development status; and clover content. For each variable, users should take a consistent approach in order to minimise inaccuracy.

Ongoing development of OVERSEER and implications for the Proposed One Plan

16. The OVERSEER model has been evolving for more than a decade and will continue to do so as new research enables more sophisticated and flexible analysis. New and scheduled development work includes:

- July 2008: additional feed pad and effluent options, DCDs, wetlands and riparian strips.
- May 2009: expanded fruit, arable and vegetable models.
- Late 2009: crop and pastoral model integration.
- Longer term: dairy goats, cut and carry systems and improved fodder sub-model.

17. All OVERSEER updates are subject to pre-release testing as part of the ongoing development of the model. While all updates typically represent improvements in model accuracy, flexibility and usability, there are potential implications of using different OVERSEER versions in terms of the Proposed One Plan. The magnitude of N and P losses may change with different versions but some reassurance is provided via pre-release testing showing excellent correlation between successive versions in recent years.

Conclusion

18. OVERSEER is based on sound scientific principles and validated against New Zealand field measurements. There is institutional and research commitment to invest and continually improve OVERSEER in a manner that gives transparency and confidence to users. While OVERSEER upgrades may result in small differences in predicted nutrient losses between different versions, this is more than outweighed by the improved flexibility to model different farm systems and nutrient mitigation techniques. Although successive versions of OVERSEER provide increased sophistication, the required inputs remain common, easily obtained farm parameters or inputs with acceptable default values. The simplifications inherent in OVERSEER, such as the assumptions on using effluent best practice, have been shown to have only a minor effect or can be explicitly modelled. OVERSEER is a long-term average model, and so it is appropriate for long-term planning and policy development.

i. Background

OVERSEER development, ownership and availability for use

a. Production on farms is dependent on having adequate soil fertility, which can be bolstered by the use of fertilisers. The application of nutrients in fertilisers represents one of the largest costs to farmers. However, during the past decade there has been increasing national recognition that leaching of the nutrients nitrogen (N) and phosphorus (P) from farms can be exacerbated by the excessive use of fertilisers or other inputs such as in brought-in feed or dairy effluent, and that this can adversely affect water quality in groundwater, rivers, and lakes. Nutrient budgets are a useful tool to estimate nutrient requirements for production on farms (thereby avoiding the likelihood of excess inputs, including fertiliser), and to determine the potential for nutrient losses to waterways.

b. In 1998, the OVERSEER nutrient budget model (OVERSEER) was first developed as a decision support model covering N, P, potassium (K) and sulphur (S), primarily for farmers and their support specialists (e.g. farm consultants and fertiliser industry staff). It is New Zealand's most widely used nutrient model and covers all pastoral farming systems, and some arable and horticultural crops. It was initially developed in consultation with end-users, with a focus on nutrient efficiency and estimating maintenance fertiliser-nutrient requirements (excluding N). In recent years, the focus on model development has shifted to predicting N and P losses from farm systems, and the inclusion of mitigation practices to reduce N and P losses. Further modules within OVERSEER have been developed recently to estimate Greenhouse Gas emissions and farm energy usage.

c. Development of the OVERSEER model is determined by the three owners, MAF, AgResearch and FertResearch. MAF's focus in the development of OVERSEER has been on its potential role for environmental management on farms, whereas FertResearch has emphasised nutrient efficiency. AgResearch is the major research provider to the development of OVERSEER and its emphasis has been on developing a user-friendly tool which enables users to estimate on-farm nutrient losses and to examine the effects of alternative management practices on reducing nutrient losses. Strong support by the owners (e.g. $5 million committed over the next five years for development of OVERSEER) means that there is an ongoing process of development to include new management options and to incorporate new science over time.

d. The OVERSEER model is freely available for downloading from the AgResearch website. Users are encouraged to register so that they can receive information on updates. While the model is free to download and use, it is subject to copyright (all rights reserved to AgResearch Ltd) and the term "OVERSEER®" is a registered trademark of AgResearch. Anyone who downloads and uses OVERSEER is subject to a license agreement which includes an obligation not to alter the software in any way, thus protecting the integrity of the model.

e. The owners of OVERSEER have a long-term vision for the model that will ensure that OVERSEER will continue to be freely available and that new and improved versions will be regularly released**.** The funding commitment for ongoing development is associated with an intention of regular updates at approximately 18-24 month intervals. These updates will focus on improving the model by updating various science components as new research becomes available, as well as incorporating new features, such as improving the breadth of the model components (as recently included for forage crops within the pastoral model) and for including new mitigation practices.

ii. OVERSEER – how it works, what it measures, who uses it and farm monitoring applications

How OVERSEER works

a. In general terms, OVERSEER is a computer model into which a user enters farm-specific input information. This information feeds into a series of equations that calculate a range of nutrient outputs, including nutrient losses. Simplistically, the model can be likened to a financial budget with a number of inputs and outputs where the sum of the inputs equals the sum of the outputs. Results for inputs and outputs are presented on an annual basis, e.g. kg N/ha/year.

b. The equations in the model were developed by researchers based on summaries of all relevant New Zealand research trial data, and overseas data when New Zealand data was limited. These equations represent relationships between the main contributing factors and nutrient outputs. There are a series of sub-models within the OVERSEER model, which calculate specific nutrient processes.

c. I would like to outline the basis for the development of the N leaching sub-model used in OVERSEER. By the term “leaching” I mean the movement of N in drainage water down through the soil below the root zone, which can eventually enter groundwater or surface waters such as streams and lakes. Research has identified a number of sources of N leached from pasture systems. The major contributor to N leaching is animal urine and other minor contributors are animal dung, effluent from dairy farms, background soil N, and direct leaching of fertiliser N. These are all estimated in the model in order to calculate the total amount of N leached. The model was constructed as shown in Figure 1.

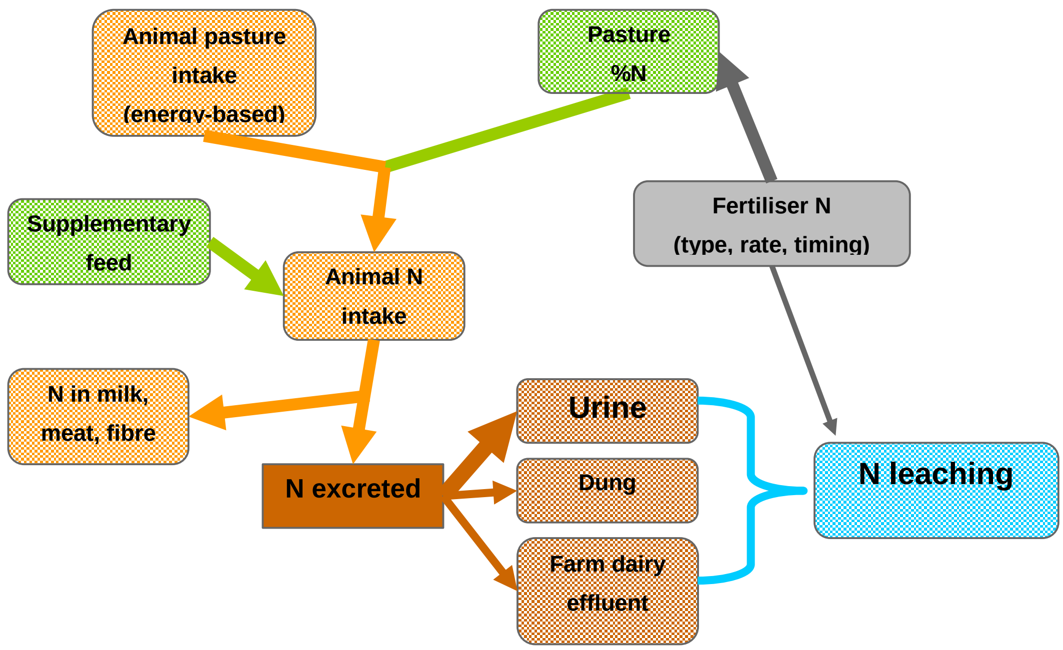

Figure 1. Representation of components within OVERSEER used in calculating N leaching

d. The main factor driving the amount of N excreted by animals is the amount of N eaten. The pasture N eaten is estimated from animal pasture intake (expressed as dry matter), which itself is calculated using energy-based equations. The latter were developed by Clark (2001) and are used for New Zealand's national inventory for greenhouse gas reporting. The pasture dry matter intake is multiplied by the nitrogen concentration (%N) in pasture to calculate the amount of pasture N consumed. From the total N intake, N in animal product, such as meat and wool, is subtracted and the N excretion is calculated. This is further partitioned into urine and dung, based largely on the N concentration in the feed.

e. OVERSEER contains internal databases with summarised information on soil properties and nutrient concentrations (including N) for a wide range of animal products, supplementary feeds and fertilisers.

f. For each box and arrow in Figure 1, information on the main determining factors was summarised from New Zealand and overseas published literature. and equations were derived to predict them using parameters which could be readily obtained or could be calculated within the model. The pasture intake sub-model uses input information on animal type, numbers and productivity. The pasture N concentration is determined by some site factors and the N fertiliser rate. Nitrogen leaching from the various sources is determined by some site, pasture, animal, and management factors. Many of the equations have been published in reports or scientific papers. Thus, OVERSEER has been developed using summaries of all available New Zealand research data on the various parts of the N cycle (Wheeler *et al*., 2003).

g. Similarly, the P run-off/leaching loss sub-model in OVERSEER has equations relating to the main loss determinants. These are land slope, inherent soil properties (physical and chemical), soil Olsen P status, rainfall, and management practices for fertiliser, farm dairy effluent and irrigation. This sub-model was published by McDowell *et al*. (2005).

h. The Proposed One Plan requirement to use OVERSEER to assess nutrient losses arises out of Rule 13-1 and its cross-reference to the FARMS Workbook via condition (b). The Workbook (Module 1, Step 2) specifies what OVERSEER input information is required. Completing the required input information will enable OVERSEER to generate a nutrient budget, including a property average for N leaching losses in kg N per hectare. This enables a comparison with the allowable N leaching loss calculated in Step 3 of Module 1, based on the various LUC-based N loss limits (Proposed One Plan's Table 13-2, repeated as "Table 1" in Module 1, Step 3, FARMS Workbook).

The forms of nitrogen and phosphorus included within OVERSEER and where to find the summary of losses

i. Nitrogen and phosphorus are present in different forms in agricultural systems, including mineral and organic forms. The OVERSEER user can choose relevant nutrient inputs, such as fertiliser and feed supplements, based on their common commercial name (e.g. Ballance "Superten") or specific N and P rates and contents can be used as inputs if these are known. In all cases, OVERSEER will use its internal databases (e.g. for N and P content of fertilisers) and algorithms to determine the appropriate N and P form, amount and location (or "pool").

j. In order to provide the user with a coherent overall nutrient budget, all nutrient inputs, outputs (animal product and losses) and changes to soil nutrient reserves are shown as the annual change in kilograms of nutrient per hectare per year. For example, N leaching losses are predominantly in the dissolved mineral nitrate form NO_3^-, which OVERSEER will show as a loss of the element N in units of kg N/ha/year. The summary of all the nutrient losses for the whole property, together with the nutrient inputs and transfers, is given in the "Nutrient Budget" within OVERSEER (an example is shown as Figure 2).

(kg /ha/yr)	N	P	K	S	Ca	Mg	Na	H+*
Inputs								
Fertiliser, lime and DCD	212	32	60	38	80	23	0	0.0
Farm effluent added	4	3	2	2	3	2	0	-0.5
Atmospheric / clover N	32	0	3	5	4	9	36	0.0
Irrigation	0	0	0	0	0	0	0	0.0
Slow release	0	3	15	0	3	5	6	0.0
Supplements imported	0	0	0	0	0	0	0	0.0
Outputs								
Product (milk, meat, fibre)	63	11	15	3	13	1	4	0.0
Net transfer	20	1	20	4	2	1	-1	-0.3
Supplements removed	0	0	0	0	0	0	0	0.0
Atmospheric	62	0	0	0	0	0	0	0.0
Leaching/runoff	35	0	10	80	17	21	70	-2.3
Net immobilisation/absorption	69	22	0	-43	0	0	0	-0.1
Change in inorganic soil pool	0	4	35	0	59	15	-31	2.2

* acidity (affects lime requirements)

Figure 2. An example OVERSEER nutrient budget screenshot with the N leaching/run-off value circled.

k. Typical farm systems are complex, and OVERSEER allows the user to reflect some of that complexity by dividing the farm into "blocks" based on different characteristics (e.g. different soil type, slope, effluent block, different stocking policy, etc). Where multiple blocks have been entered, OVERSEER will give a separate "Block N report" and "Block P report". The tabs for these reports are easily located next to the main nutrient budget tab. Within the block reports, more detail is provided (including, for nitrogen, the N concentration in drainage water in parts per million (ppm)). For example, see Figure 3 with a Block N report for a farm with multiple blocks. The Block P report provides a relative index-based (low, medium or high) breakdown of the main loss sources: soil, fertiliser and dung, and an estimate of the amount of P loss (kg P/ha/year) by run-off and leaching. For example, see Figure 4 with a Block P report for a farm with multiple blocks.

Current farm

	N in drainage* (ppm)	N leached (kg N/ha/yr)	N surplus (kg N/ha/yr)	Added N** (kg N/ha/yr)	Wetland reduction (%)
Overall farm	na	10	49		
Block name					
easy sloping blocks	na	11	59	20	0
steep blocks	na	7	34	0	0
hay paddocks	1.8	13	80	40	0
trees	na	3	3	0	0

* N concentration in drainage water at the bottom of the root zone. Maximum recommended level for drinking water is 11.3 ppm (Note that this is not an environmental water quality standard)

** Fertiliser and external effluent inputs.

na : N in drainage not calculated for easy and steep blocks or non-pastoral blocks.

Click for information on N mitigation

Figure 3. An example OVERSEER nutrient budget screenshot for a Block N report for a sheep and beef farm with multiple blocks.

Current farm

	P loss indices				P lost (kg P/ha/yr)	% P removed by filter strip
	Soil	Fertiliser	Effluent	Overall		
Overall farm (pasture)					0.6	
Block name						
easy sloping blocks	Low	Low	n/a	Low	0.6	n/a
steep blocks	Low	Low	n/a	Low	0.6	n/a
hay paddocks	Low	Low	n/a	Low	0.4	n/a
trees	n/a	n/a	n/a	n/a	0.1	n/a

Click for information on P mitigation

Figure 4. An example OVERSEER nutrient budget screenshot for a Block P report for a sheep and beef farm with multiple blocks.

l. The OVERSEER model presents outputs of N in units of kg N/ha/year in whole units. Potentially, these could have been presented to one decimal place. However, in view of the uncertainty around the exact magnitude of some of the input information entered by users, and the biological variability associated with equations within the model, it was considered inappropriate to imply the model worked at such a level of precision.

m. In addition to the per hectare average N leaching loss, OVERSEER also provides average losses on a per block basis in units of “kg N/ha/year” and a total loss per property in units of “kg N/year”. These are found on the “Block N report” and “Default values” tabs respectively.

The uses of OVERSEER for nutrient management in agricultural systems

n. There are more than 1,000 registered users of OVERSEER around New Zealand. Registered users receive regular information on updates and ongoing model development, but there are also many other users who have downloaded the model but are not registered. Specific examples of the use of OVERSEER include:

- All fertiliser company technical representatives from the three main companies have the model and use it regularly. They have also had training sessions on its use, including courses from Massey University.
- More than 90% of all dairy farmers in New Zealand have had nutrient budgets prepared using OVERSEER, in order to meet the requirement for nutrient budgets identified in the Dairying and Clean Streams Accord (May 2003).
- Distributed to all Agriculture New Zealand [1] farm consultants throughout New Zealand.
- Supplied to many private consultants and farmers on request.
- Used in the consent process for three dairy farms for Hawke’s Bay Regional Council, to estimate N leaching losses.
- Used in the consent process on behalf of Waikato Regional Council for wastewater application to Anchor Products Hautapu dairy farms, to check nutrient balances and N leaching.
- Used with and for all farmers in five focus dairy catchments in New Zealand, as part of a national project jointly funded by government and the dairy industry, with an emphasis on examining N and P losses and the potential to reduce these.
- Used on behalf of 26 dairy farmers in the Lake Rotorua catchment in a Dairy Insight[2] study to assess N leaching for years 2001 to 2006 and to examine management options to reduce N leaching. This was linked with an assessment of implications for farm production and

[1] A PGG Wrightson-owned farm advisory business
[2] Dairy Insight has since merged with Dexcel to form Dairy NZ, the dairy farmer-owned organisation responsible for dairy industry research, development, extension and education projects and activities.

profitability. This study was carried out to examine possible implications of regulations for the Rotorua lakes being proposed by Environment Bay of Plenty.

- Used in a Sustainable Farming Fund[3] study in the Lake Taupo catchment, with case farms representing different farming types to estimate N leaching losses and to examine management options to reduce N leaching.

o. Section n highlights that the use of OVERSEER on farms is widespread throughout New Zealand and that it has a wide range of users including farmers, agricultural companies and Regional Councils.

p. Farm consultants or fertiliser industry representatives typically supply farmers with a printed report from OVERSEER. These reports would then be used to modify fertiliser use recommendations and to make recommendations on possible improved farm management practices. Examples of the latter include ensuring adequacy in the dairy shed effluent application area to meet regional council requirements, appropriate timing and rate of N fertiliser use, and N mitigation options where estimated N leaching is high (Ants Roberts, *pers. comm.*). Some consultants and fertiliser companies are now developing these into nutrient management plans for farmers.

Other Regional Council uses of OVERSEER

q. OVERSEER is being used by Environment Waikato as the model to calculate Nitrogen Discharge Allowances (NDAs) for individual farms in the Lake Taupo catchment, as part of the consent process. It is also used, as part of this process, for checking adequacy of a new Nitrogen Management Plan for a farm in meeting its NDA. The November 2008 Environment Court interim decision on the Environment Waikato Taupo Variation endorsed the use of OVERSEER within this regulatory context (Environment Court, 2008).

r. Similarly, Environment Bay of Plenty is using OVERSEER for calculating nutrient benchmarks for N and P losses from farms around five lake catchments in the Rotorua District. This benchmarking process is driven by “Rule 11” of the Bay of Plenty Regional Water and Land Plan. Environment Bay of Plenty is also using OVERSEER to consider property specific

[3] A MAF fund that supports projects designed to improve the financial and environmental performance of New Zealand’s productive land-based sectors.

mitigation options (Andy Bruere, Rotorua Lakes Programme Manager, *pers. comm.*).

s. OVERSEER has also been used as a requirement by a number of Regional Councils in relation to specific farm consents relating to farming systems and/or farm dairy effluent management. These include Environment Bay of Plenty, Environment Waikato, Hawke's Bay Regional Council, Horizons Regional Council, Environment Canterbury and Otago Regional Council.

iii. OVERSEER Accuracy, Assumptions and Limitations

a. The application of OVERSEER in a regulatory context requires a consideration of its accuracy, assumptions and limitations, as well as the effects of not including some aspects of farm activities that may contribute to nutrient losses.

Accuracy of nutrient loss predictions

b. There has been some confusion over the "accuracy" of estimates from OVERSEER. Accuracy is associated with: 1) Input information, and 2) Comparison with measured values. A report by Ledgard and Waller (2001) indicated that there is variability in estimates of the amount of N leaching from OVERSEER associated with uncertainty around values for inputs, and that in total this is of the order of ± 20%. This highlights the importance of OVERSEER users having a good understanding of the model and preferably having undergone training in its use, such as through the Massey University Nutrient Management courses.

c. In practice under the proposed FARM Strategy, the effects of the potential inaccuracy associated with input information becomes minor within a farm where the user is examining the effects of changes in on-farm practices. This is because many of the parameters (e.g. site factors such as area, soil, slope, and rainfall) will be the same under any FARMS scenario for the same farm. The most important aspect of accuracy (point 2) is how well it predicts measured data from New Zealand research.

d. The OVERSEER model has been validated in a range of farm research studies around New Zealand. Figure 3 shows a highly significant agreement between measured and calculated N leaching using OVERSEER for a range of New Zealand dairy grazing system studies.

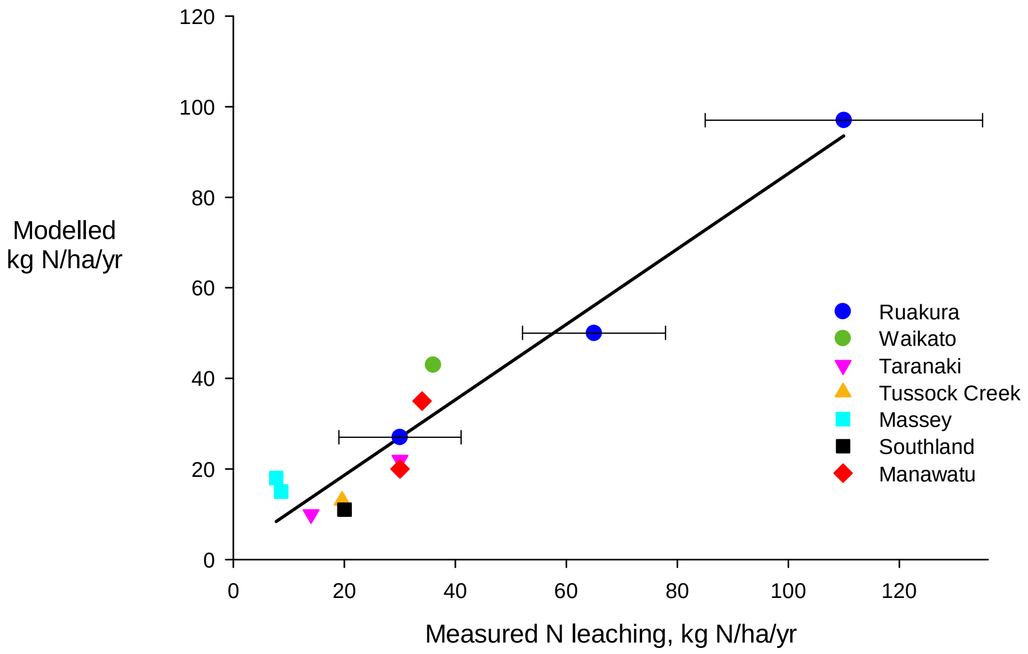

Figure 3. Relationship between the amount of N leaching measured in seven dairy grazing system studies and that estimated for the sites using OVERSEER. Data for Ruakura, Waikato, Taranaki, Tussock Creek, Massey, Southland and Manawatu studies were from Ledgard *et al.* (1999 & unpublished), Sprosen *et al*. (2002), Chadwick *et al.* (2002), Monaghan *et al.* (2005), Monaghan (unpublished) and Houlbrooke *et al*. (2003). Ruakura measured data was an average of five years and is shown with ± Standard Error. Correlation was highly significant (R^2=0.93).

e. Figure 3 is based on data from a range of dairy grazing system studies and covers different sites and treatments (e.g. different N fertiliser inputs). Each data point in Figure 3 represents the average for 2-5 years of measurement of N leaching. The actual N leaching rates in Figure 2 were measured using ceramic cup samplers at about 90-100 cm depth in free-draining soils, or using hydrologically-isolated paddocks with mole drains to intercept and collect drainage water in poorly-drained soils.

f. Measurement of N leaching from a grazing study on a dairy farm on pumice soil near Rotorua in 2005 and 2006 (Ledgard *et al*., 2007) averaged 63 kg N/ha/yr (84 and 42 kg N/ha/yr in years 1 and 2) compared to the OVERSEER-modelled value of 56 kg N/ha/yr. Again, this is a reasonable fit and the OVERSEER estimate is within the measured range.

g. As shown in the following table, results for the Sustainable Farming Fund Taupo beef cattle study, which was carried out in the Lake Taupo catchment, also showed close agreement between measured and modelled values.

Table 1. Effect of winter management practices on N leaching estimated using the OVERSEER model compared to field data (average of two years) from a beef cow grazing system study in the Lake Taupo catchment (Betteridge *et al.*, 2005).

	N leaching (kg N/ha/yr)	
Winter management	Modelled	Measured
All-grazing	15	16
Winter-off (April-Aug)	8	7

h. The lower leaching rates in the Taupo beef cattle study reflected the lower intensity of the farming system than for dairy farming. There are fewer New Zealand research studies on sheep and beef farm systems where N leaching was measured compared to that for dairy farm systems. Within Horizons' Region, the only published research was the recent study of Parfitt *et al.* (2009). Results from this study (Table 2) showed good agreement between measured N leaching and estimates calculated using OVERSEER

Table 2. N leaching estimated using the OVERSEER model compared to field data from a sheep grazing system study in the Manawatu (Parfitt *et al*., 2009). The low fertility farmlet carried eight stock units/ha while the high fertility farmlet had 16 stock units/ha.

	N leaching (kg N/ha/yr)	
	Modelled	Measured
Low fertility	7	6
Low fertility +300 kg N/ha	21	18
High fertility	26	24
High fertility +300 kg N/ha	116	114

i. Several aspects of the OVERSEER model have greater uncertainty associated with the calculated N leaching, as a result of limited validation research. These aspects include winter forage crops and sites with high rainfall (greater than about 1600 mm/year). The use of winter forage crops (e.g. brassicas for grazing by animals in winter) is relatively common, although they typically occupy only a small area on farms (e.g. less than 5%). Research has now commenced to address this data limitation with field grazing studies near Mangakino (South Waikato) and in Southland evaluating N leaching from brassica crops.

j. There has been no research in New Zealand involving measurement of N leaching under high rainfall conditions and therefore there is no potential for validation of OVERSEER under such conditions. The site of highest rainfall with N leaching research was near Rotorua on the Wharenui dairy farm under an annual rainfall of 1500 mm. Reasonable agreement between measured and modelled estimates occurred for this farm (discussed before in section f).

k. Nevertheless, in my experience, the principles used in calculating losses for sites with high rainfall are similar to those used by other researchers in New Zealand and overseas in their studies using more complex models for research purposes. Thus, with increasing annual rainfall, OVERSEER predicts increased N leaching in a curvilinear relationship, recognising that there is a maximum substrate for leaching dependent on systems inputs. This would occur with all mechanistic N models.

l. I acknowledge that OVERSEER is less effective in modelling those pastoral systems with a dominance of trading animals and only partly accounts for the strong seasonality in N leaching that potentially can occur in trading systems. This has been recognised by the model owners, and the next upgrade of the model will incorporate a monthly-based model to better account for the strong seasonality of farms dominated by trading systems. This upgrade is likely to be completed in late 2009.

Best practice assumptions and the relative differences to predicted losses if best practice is not employed

m. Various algorithms and relationships defined within OVERSEER were based on research data using good practices for various inputs. Thus, it is stated that the model refers to where farmers are applying best practices to a range of inputs including fertiliser (meeting the Code of Practice for Nutrient Management from the fertiliser industry, e.g. avoiding application to saturated soils, or in cold winter conditions; not exceeding 50 kg N/ha/application, 200 kg N/ha/year, or 100 kg P/ha/application; not using soluble P forms in high loss-risk periods; avoiding direct application to waterways), farm dairy effluent (not exceeding best practices as described in the DairyNZ Managing Farm Dairy Effluent Manual or defined by Regional Councils in relation to mm/application and annual rate of N application, i.e. ≤ 150-200 kg N/ha/year), irrigation (water is applied in relation to soil water deficits and excess applications to above soil field capacity are avoided). Similarly, it is assumed that there is no direct excreta connectivity to waterways, such as via direct animal access to streams/rivers or via stock crossings, tracks or lanes.

n. In principle, if those best practices are not met, the nutrient loss to waterways is likely to be higher than calculated by OVERSEER.

o. One example could be N fertiliser. Best practice recommends restricting individual applications to less than 50 kg N/ha, and to avoid application during winter when temperatures fall below 6°C. If an annual use of N fertiliser of, say 150 kg N/ha with split applications on a dairy farm (ash soil, 1200 mm rainfall), resulted in N leaching of 35 kg N/ha/year, this might increase to at least 45 kg N/ha/year if all of it was applied in one application in winter. However, this aspect can be modelled in OVERSEER and the effect accounted for, although it would not account for the greater inefficiency due to one large application.

p. Consider a farm applying farm dairy effluent (FDE) using a travelling irrigator and best practice on a block of land with mole-drained soil. Monaghan and Smith (2004) showed that direct FDE drainage would occur if large excesses were applied when soils were wet and there was nil or limited FDE storage. The increased N loss could be 3-5 kg N/ha/yr if a fast irrigator groundspeed was used; or up to 5-10 kg N/ha/yr if the travelling irrigator was left on its slowest travel setting. Note that these figures are computed on a whole-farm basis (effluent area assumed to be 13% of farm) and are considered to be a worst case scenario, given that almost every dairy farm has at least some FDE storage now (Ross Monaghan, *pers. comm.*, 2009).

Included and excluded activities and the relative differences to predicted losses if excluded activities are incorporated

q. The main activities that influence N and P loss included in OVERSEER, in terms of sources and practices, can be considered for three areas, namely inputs, transfers and management practices.

r. The key inputs are animal stocking rate and productivity; brought-in feed and different areas of feeding; fertiliser (including timing relative to high loss-risk periods); effluents including farm dairy effluent; irrigation with associated nutrient inputs.

s. Nutrient transfers accounted for in the model include transfers to farm lanes and animal camping areas (with associated increases in loss); transfer of nutrients in farm dairy effluent from dairy shed, feed pad or animal shelter to pond, or application to land; direct animal access to streams; and deer pacing and wallowing.

t. Management practices accounted for in OVERSEER include taking animals off-farm (off-farm effects would be accounted for in separate analyses); animal stand-off or feed pads and shelter systems and their associated effluent production and use; timing of fertiliser application (as noted under inputs); removal of supplementary feed off farm; mitigation practices, including use of DCD, wetlands and riparian management.

u. Activities not included in OVERSEER are some minority farming systems (e.g. milking goats), some management practices (e.g. all-year cut-and-carry system), and point source emissions (e.g. offal holes, silage pit leachate).

v. A Sustainable Farming Fund project with the NZ Dairy Goat Co-operative is currently collecting data with the aim of adding dairy goats into OVERSEER within about two years. Similarly, full cut-and-carry systems are on the list of new practices to incorporate into OVERSEER within 2-3 years.

w. Point source emissions are not currently being considered for incorporation into OVERSEER. Such emissions may be locally significant if they void directly to a waterway. For example, the Managing Farm Dairy Effluent manual (Dairy NZ and the Environment Committee, 2007) identifies that silage stack leachate *"…contains high levels of nutrients, and has levels of ammonia likely to be toxic to fish*". The manual goes on to emphasise the importance of wilting grass before ensiling, and the diversion and treatment of any leachate. However, from a nutrient loss perspective at a farm scale, such potential point source losses would be insignificant relative to other non-point sources of loss.

What inputs to the model are the leaching results most sensitive to?

x. A simple single-factor sensitivity analysis for N leaching, using OVERSEER, was carried out in 2006 for Environment Waikato. While this is a confidential report, I can summarise the methodology and key findings. Three farms were assessed: a dairy farm, an intensive sheep and beef farm, and an extensive sheep and beef farm. The analysis considered inputs usually provided by the farmer (e.g. stock type and stocking rate, fertiliser type and rate) and those determined by the OVERSEER operator (e.g. rainfall, pasture development status, and soil drainage class).

y. It is possible to group the list of variables which are input to OVERSEER according to the effect they have on changes in nitrogen leaching losses into high, medium and low effect categories. The analysis was largely based on altering single variables only. In practice, changes in some variables (e.g. milksolids production/ha) are associated with changes in other variables (e.g. inputs such as N fertiliser or purchased feed), which influences the sensitivity.

z. The high impact farmer-derived input variables were: 1) amount of Nitrogen fertiliser applied; winter application of N fertiliser; 2) stocking rate and animal productivity; 2) winter management practices (e.g. grazing dairy animals off over winter); and 4) stock type (sheep, beef and deer farms). For all of these, it is important that the farmer is able to supply good data and records.

aa. The high impact user-derived variables were: 1) annual rainfall; 2) pasture development status; and 3) clover content. For each of these variables, it is important that the user takes a consistent approach, such as a using an annual average rainfall map based on long-term monitoring sites. OVERSEER has been well validated with pasture development status in the "developed" mode and therefore it is appropriate to use this as a default input. Similarly, for clover status it is recommended that the default Medium level is used in almost all cases, since all research used in model development refers to this category. As noted on the model, this Medium status accounts for variation over time and with inputs such as N fertiliser, and it should only be changed in extreme situations, such as where clover root weevil has markedly reduced clover content in the long-term.

iv. Ongoing development of OVERSEER and implications for the Proposed One Plan

a. The OVERSEER model has been evolving for more than a decade and will continue to do so as new research enables more sophisticated and flexible analysis of farm systems. The related issues of OVERSEER's scientific integrity and impacts on the Proposed One Plan regulatory framework are considered below, along with a comparison with SPASMO, the nutrient model. Finally, a technical conclusion is given on the suitability of

OVERSEER for assessing nutrient losses within the Proposed One Plan regulatory framework.

Current development work

b. OVERSEER is undergoing continuous improvement, with two recent updates and one further update planned for late 2009. Key new and proposed features include:

   i. July 2008 update (version 5.3.6): Additional mitigation options for feed pads to cover a wider range of systems including aninmal shelters and associated effluent management options, wetlands, riparian strips and nitrification inhibitors**;** a new drainage model.

   ii. March 2009 (version 5.4.3): Major expansion of fruit, arable and vegetable crop models; new ability to print a report of all user inputs to the model.

   iii. Late 2009: Integration of the fruit crop and arable/vegetable crop model in the detailed pastoral model, hence allowing arable cropping farms and land use change to be modelled.

   iv. Longer term: Inclusion of options for dairy goats; full cut-and-carry systems; improved fodder crop sub-models; and enhanced ability to handle more detail about the N-cycle mechanisms including monthly management options.

c. There is a range of ongoing research supported by the Foundation for Research, Science and Technology (FRST) that is anticipated to result in OVERSEER improvements, like incorporating more N-cycle detail as described in paragraph b above. Similarly, farm sector groups (like the NZ Dairy Goat Co-operative) are using the Sustainable Farming Fund (SFF) to generate data that enables additional stock types to be incorporated. This flexibility to expand OVERSEER is important to ensure it remains relevant to users and that it employs the latest research findings. The updating process and the implications of different versions are considered next.

The process for updating OVERSEER

d. The owners of OVERSEER (MAF, AgResearch and FertResearch) have a governance structure and a strategic plan for ongoing development of the model. This involves use of a Technical Advisory Group. Each update will be developed by a contract research group with expertise specific to the update and involving a transparent review process. Algorithms and sub-models developed by the contract research group would be programmed into a beta version of the model, which will be tested by an OVERSEER User Group that includes representatives from the main users of the model.

e. The OVERSEER development team uses a robust pre-release testing programme for all new versions. This includes testing of the user interface and software code to uncover any potential bugs prior to release. Part of the testing involves running files (provided by users) through both the incumbent and new versions, and checking for differences in model outputs. Prior to the release of version 5.4.3, more than 150 files were tested using versions 5.3.7 and 5.4.3; changes for both N and P losses were minimal.

Implications of new versions on nutrient loss predictions

f. Neither the Proposed One Plan nor the FARMS Workbook specifies which version of OVERSEER to use. It is anticipated that users will generally use the most up-to-date version available at the time that the assessment is carried out. Given that the Proposed One Plan envisages at least a 20-year timeframe, over which several LUC classes have a diminishing allowable N loss, it is inevitable the future assessments (either by landowners or Horizons staff) will use updated versions of OVERSEER that incorporate improved science and flexibility of mitigation options. The issue therefore arises of how new versions affect N loss predictions.

g. One potential scenario is that a FARM Strategy is prepared showing how a farm will reduce its N loss based on some mitigation practice (e.g. nitrification inhibitor) available in the current OVERSEER version 5.4.3. After several years, the nutrient loss reductions attributed to that mitigation practice may go up, down or remain the same, depending on what new research becomes available and is incorporated into the model.

h. OVERSEER version 5.4.3 was released in May 2009 and was accompanied by release notes on the AgResearch website (see www.agresearch.co.nz/overseerweb/files/release-notes.pdf). These notes include comparisons of N and P losses between the current version 5.4.3 and the previous version 5.3.7, based on running over 150 farm OVERSEER files. The results, reproduced in Figure 4 below show excellent agreement between model versions for both N and P losses.

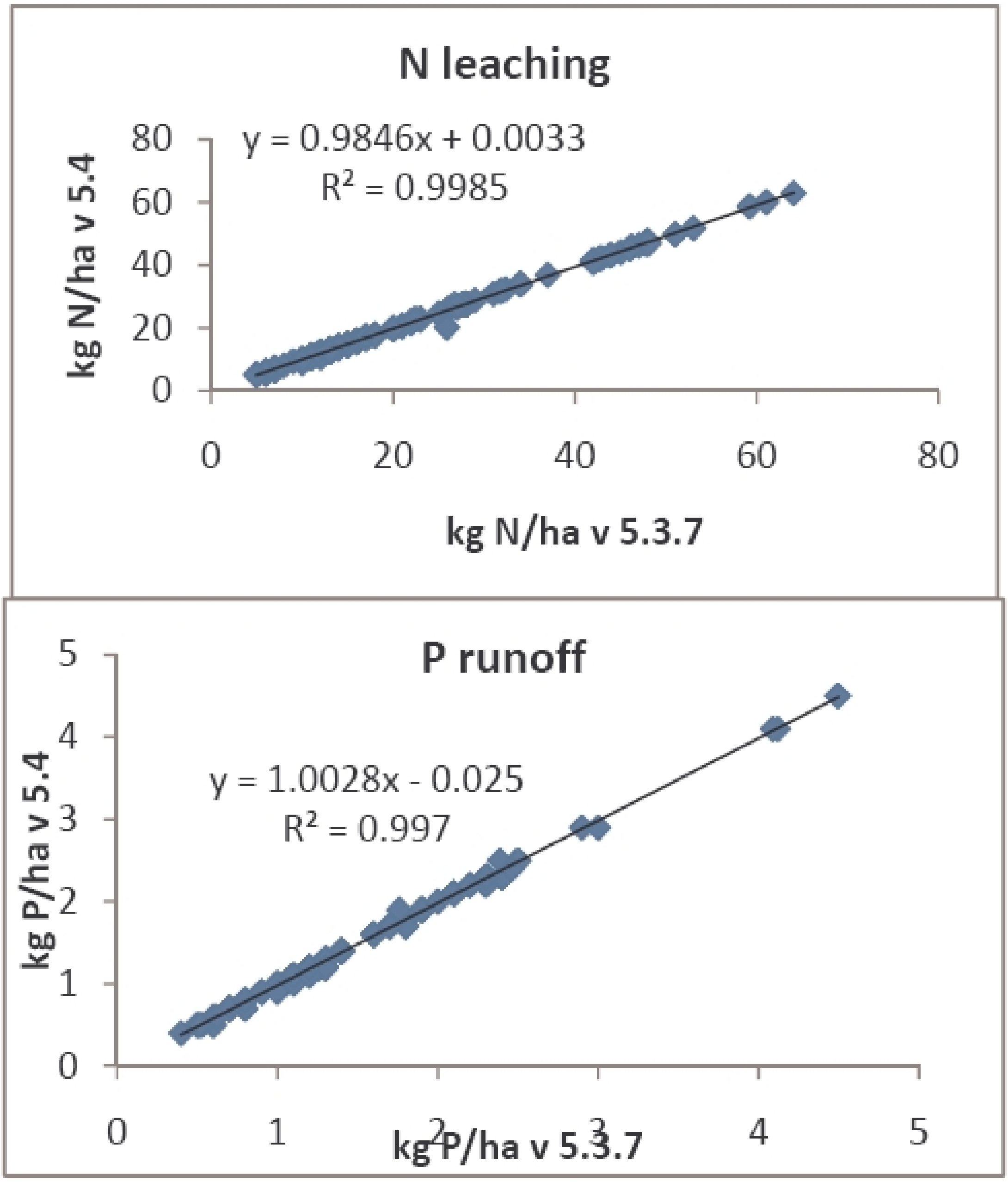

Figure 4. Correlation in N and P losses between OVERSEER versions 5.3.7 and 5.4

i. While the correlation shown in Figure 4 is reassuring, the model development principle of continuous improvement will inevitably lead to some situations where incorporation of new science will result in a change in calculated nutrient losses relative to that from use of an earlier version of the model.

j. Any change to OVERSEER in future to a new version involving updating sub-models would only be done where the OVERSEER science and technical groups are confident that new science indicates the change is appropriate (and estimates would be more accurate). Thus, the preferred approach would generally be to consider compliance of the actual or proposed farm system using the new OVERSEER version.

k. It will be important to consider the situation where future OVERSEER versions lead to a different estimate of N leaching that affect a farm's compliance with the Proposed One Plan prescribed N loss limits. This would be particularly important if, on the basis of an early OVERSEER version, the farmer had committed to an initially complying but capital intensive system, such as an animal shelter. If that system subsequently proved to be non-complying under a later version, then some adjustment to the allowable N loss or its time threshold may be warranted. This potential scenario may be relatively uncommon as it requires a combination of circumstances (significantly different OVERSEER predictions on capital intensive mitigation that negatively impacts on compliance).

Comparison of OVERSEER with SPASMO

l. SPASMO (Soil Plant Atmosphere System Model) has been developed by HortResearch (now merged into Plant & Food Research) over the past decade. SPASMO is a detailed mechanistic, daily time-step model which provides risks assessment of irrigation needs, nutrient requirements, and the fate of contaminants. SPASMO considers seasonality and long-term impacts, for the model is often run on 20-to-50 year sequences of actual weather data (see Rosen *et al*., 2004).

m. A comparison of predictions of N leaching by SPASMO and OVERSEER was carried out by Dr Brent Clothier as part of his evidence for the Environment Court appeal on the Lake Taupo Variation. This comparison was between SPASMO simulations by Green *et al*. (2002) for a typical farm in the Taupo Catchment with a range of stocking rate and fertiliser rates. These were compared with the predictions found using OVERSEER by Ross Gray (an accredited OVERSEER user) for the same inputs, soil and weather conditions (Ross Gray, AgResearch, *pers. comm.*, 31 October 2007). Comparison was also made with the leaching measurements of Ledgard *et al*. (1996) for farmlets under somewhat comparable fertiliser-use conditions in the Waikato region near Hamilton. The results are summarised in Table 3. There is good agreement between all three sets of results across a range of stocking and fertiliser rates.

Table 3. Comparison between SPASMO and OVERSEER predictions of N leaching for a typical dairy farm in the Taupo Catchment using the same inputs, soil and weather conditions, and leaching measurements of Ledgard *et al.* (1996) for farmlets under somewhat comparable fertiliser-use conditions in the Waikato region near Hamilton (from Clothier, 2008).

Stocking rate (cows/ha)	Fertiliser N use (kg N/ha/yr)	N leaching (kg N/ha/year)		
		SPASMO	OVERSEER	Ledgard et al.
2.0	0	28	27	
2.4	0	28	32	43
2.7	100	38	38	
3.0	200	54	59	57
3.3	300	78	77	
3.6	400	108	116	110

v. Conclusion

n. OVERSEER is based on sound scientific principles and validated against New Zealand field measurements. There is institutional and research commitment to invest and continually improve OVERSEER in a manner that gives transparency and confidence to users. While OVERSEER upgrades may result in small differences in predicted nutrient losses between different versions, this is more than outweighed by the improved flexibility to model different farm systems and nutrient mitigation techniques. Although successive versions of OVERSEER provide increased sophistication, the required inputs remain common, easily obtained farm parameters or inputs with acceptable default values. The simplifications inherent in OVERSEER, such as the assumptions on using effluent best practice, have been shown to have only a minor effect or can be explicitly modeled. OVERSEER is a long-term average model, and so it is appropriate for long-term planning and policy development.

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