

**IN THE ENVIRONMENT COURT
WELLINGTON REGISTRY**

**I TE KŌTI TAIAO O AOTEAROA
TE WHANGANUI-A-TARA ROHE**

UNDER	the Resource Management Act 1991
IN THE MATTER	of appeals under sch 1, cl 14(1) against the decision of Manawatū-Whanganui Regional Council on Plan Change 2 to the One Plan
BETWEEN	TE RUNANGA O RAUKAWA ENV-2021-WLG-20 NGĀTI TURANGA ENV-2021-WLG-21 ANDREW DAY ENV-2021-WLG-22 WELLINGTON FISH AND GAME COUNCIL ENV-2021-WLG-23 Appellants
AND	MANAWATŪ-WHANGANUI REGIONAL COUNCIL Respondent

**STATEMENT OF EVIDENCE OF DAVID JOHN HORNE ON BEHALF OF THE
MANAWATŪ-WHANGANUI REGIONAL COUNCIL**

ON-FARM MANAGEMENT PRACTICES

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STATEMENT OF EVIDENCE OF DAVID JOHN HORNE**A. INTRODUCTION**

- [1] My name is David John Horne. I am a Professor at Massey University, based in Palmerston North. I hold a PhD in Soil Science from Massey University.
- [2] I have 35 years of experience in the research and teaching of soil science. I also regularly review intensive farming land use (**IFLU**) proposals, including proposals for the design, operation and management of land irrigation for Manawatū-Whanganui Regional Council (**Horizons**), and other entities, with particular regard to the impact on soils.
- [3] I have been involved with farmers and nutrient management in the Horizons Region for many years. I have worked with Massey colleagues and students, local farmers, farm advisors, scientists and Horizons staff on farm nutrient loss issues over that time, including with respect to the use of the Overseer nutrient budget model. My experience has extended to presenting evidence on behalf of Horizons before Hearing Panels and in the Environment Court, with particular regard to the use of Overseer in the context of Chapters 5 and 14 of the One Plan.
- [4] I have been engaged by Horizons to provide advice and data with regard to on farm practices and related nitrogen (**N**) loss reductions, for the purpose of supporting Proposed Plan Change 2 to the One Plan (**PC2**) since 2018.
- [5] I have co-authored a number of reports (Hanly *et al.*, 2018a; Hanly *et al.*, 2018b; Hanly & Horne, 2018) for Horizons regarding the intensive farming land use provisions in the One Plan, and recalculating the N leaching maximums for Land Use Capability (**LUC**) classes using Overseer.
- [6] I prepared s42A reports for the Council-level hearing of PC2 and was involved in the hearing before the Independent Hearing Panel in 2020.
- [7] I have since been involved in a range of expert conferences relating to development of a nitrogen risk assessment tool for pastoral farming, within PC2. As I discuss below, this work was in response to the Government's

response to the Overseer peer review report in August 2021 (the **Overseer Reports**).¹

[8] I also attended mediation on 12 December 2022 and 15 March 2023.

B. BACKGROUND

[9] The One Plan sets out a planning framework for the management of land and water resources in the Manawatū-Whanganui Region. The One Plan requires intensive farming land uses to be managed within a cumulative nitrogen leaching maximum (**CNLM**) set in Table 14.2. Where the CNLM is not met, farmers were intended to be able to apply for a resource consent to operate above the CNLM limit. However, my understanding is that the policy framework of the One made this challenging for many farming operations.

[10] In my experience, this has raised very real issues for farmers who in many cases are unable to meet Table 14.2 for reasons out of their control (including soil and climate in some cases). Regular changes in Overseer also meant that the CNLMs within Table 14.2 became out of date and redundant.

[11] PC2 sought to address these issues by recalibrating Table 14-2 and also providing a pathway for farmers to apply for resource consent where they may not meet the updated CNLM.

[12] At the Council-level hearing, I was involved with Dr Hanly in recalibrating Table 14.2 and provided evidence in respect of farm systems. In doing so, I have provided advice and data to Council officers regarding the potential N loss reductions associated with farm management practices that may enable compliance with the recalibrated Table 14.2, and eventually, an alternative pathway for pastoral farms, requiring specified N leaching reductions.

[13] Since then, I have participated in expert conferencing with farm systems experts to reformulate the specified reduction pathway, which relied on the implementation of farm practices to reach an Overseer-modelled N leaching

¹ Ministry for the Environment and Ministry for Primary Industries *Government response to the findings of the Overseer peer review report* (August 2021).

reduction, into a new risk assessment tool, which relies on the implementation of those practices to reduce the risk of N leaching.

C. CODE OF CONDUCT

- [14] I confirm that I have read and agree to comply with the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2023. This evidence has been prepared in accordance with that Code. I confirm that I have not omitted to consider material facts that might alter or detract from the opinions that I express. The evidence I am giving is within my area of expertise, except where I state I am relying on the opinion or evidence of other witnesses. I understand it is my duty to assist the Court impartially on relevant matters within my areas of expertise.

D. EXECUTIVE SUMMARY

- [15] Pastoral farmers in the target catchments in the Horizons region need to be able to operate profitable businesses in a manner that poses a low risk to water quality. In my view, there should be a pathway to securing a resource consent that reflects these twin objectives.
- [16] At the time of PC2, Overseer was the only tool available to help regional councils develop their Plans, including setting limits, and for farmers to demonstrate compliance with these targets. Since that time there has been a growing interest in the development of alternative tools to help achieve desired water quality outcomes, in particular frameworks that assess risk. By helping farmers identify and mitigate risks to N loss from their farms, such assessments often provide a more straightforward (but not more lenient) pathway to consent. They focus on comprehensive and systematic changes to the farm system (through the adoption of wide-ranging GMP/BMPs) rather than relying on Overseer.
- [17] Overseer was always a means to an end in the original PC2, which recognised that water quality was only going to improve as a consequence of behaviour change by farmers, which is to say, the adoption of GMP/BMPs. Hence the emphasis on identifying the suite of Good Management Practices (**GMPs**) Best Management Practices (**BMPs**) at that time.

- [18] In my view this original approach gets the question exactly right – what is the best way to get farmers to adopt GMP/BMPs? Overseer can be used very effectively to help farmers identify the appropriate GMP/BMPs. However, as noted above, there is now a recognition that there are other equally effective, and perhaps, more straightforward ways to achieve this.
- [19] In a series of conferences, a team of farm system experts have developed a risk framework for use in the target catchments in the Horizons region. I consider this framework can provide an effective alternative pathway in PC2.
- [20] The risk assessment tool uses the Nitrogen Risk Scorecard (**NRS**) as the basis for a risk scorecard, modified to reflect local requirements. The importance of biophysical characteristics when considering the risk of N loss from farming activities was also recognised. The NRS has therefore been placed within a larger matrix which reflects the very significant influence of climate and soil type. As a result of a greater risk from biophysical factors, some farmers will need to achieve a lower risk score from their on-farm practices in the scorecard; whereas farmers with a lower risk from biophysical factors will have more flexibility to score slightly higher in the scorecard (i.e. make less on-farm practice changes to reduce risk of nitrogen leaching).
- [21] The NRS considers the risk posed by farm management and awards points according to the magnitude of this risk. The score from each of the factors is then combined to give an overall score for the farm. An overall risk rating is then given within five bands (very high risk, high risk, medium risk, low risk and very low risk). The experts agreed that farmers could be expected to manage their farm management risk profile to within a 'low' risk band. This was considered to be robust/stringent, yet still achievable for many farmers.
- [22] It is my view that the risk assessment framework developed by the farm systems experts will lead to the same or very similar change in farmer behaviour and will encourage the adoption of the same, or very similar, GMP/BMPs. This has been confirmed through analysis I have carried out between the 20% specified nitrogen reduction pathway and the risk assessment tool. In comparing the likely outcomes using the risk assessment

framework with those from Overseer, it is obvious that they both lead to very similar changes to farm management practices, and N loss reductions.

- [23] The analysis supports the view of experts in developing the risk assessment tool that a similar outcome should occur for N loss reductions, given that both the Decisions Version of PC2 (**DV-PC2**), and the risk assessment tool are working the same levers to seek the same outcome – the adoption of GMP/BMPs on farms.
- [24] It is my opinion that as an alternative method the use of the risk assessment tool will provide a workable consenting pathway and will inspire farmers to do what they do best - manage their farms. The systematic use of the risk framework will help them identify their risk profile and where required manage it down. In recognition of the effectiveness of this effort, which in many cases will be costly, they will have the ability to access a consenting pathway, which they require to farm with confidence.

E. SCOPE OF EVIDENCE

- [25] My evidence focuses on the following matters:
- (a) On-farm practices which influence nitrogen loss in farming systems, including good management practices, best management practices and system changes/innovations;
 - (b) The efficacy of these management practices/mitigation measures for the purpose of achieving reductions in N loss in existing IFLUs;
 - (c) The development of the alternative 'specified reduction' consenting pathway through the PC2 pre-hearing and hearing process;
 - (d) The Government response to the Overseer peer review report and its implications for PC2;
 - (e) The development of the pastoral risk assessment tool through expert conferencing and an explanation of how it operates; and
 - (f) The N leaching outcomes expected from the implementation of the pastoral risk assessment tool.

- [26] In addition to my own observations, I rely on the evidence of Ms Maree Patterson, Dr Ton Snelder, and Dr Tim Cox.
- [27] I have also worked with Dr Anne-Maree Jolly on aspects of the nitrogen risk assessment tool, with Dr Jolly advising Horizons on nitrogen leaching under commercial vegetable growing (**CVG**) in the Region. In doing so, I have provided information on the costs associated with on-farm management practices in the Region to Dr Jolly, and her colleague Mr Kerry Mayes.
- [28] Finally, I rely on, and confirm the contents of, the joint witness statements produced following expert conferences relating to the proposed nitrogen risk assessment tool (the **JWS**). These are listed below for completeness:
- (a) JWS of farm system and planning experts dated 28 June 2022;
 - (b) JWS of farm system experts dated 25 August 2022;
 - (c) JWS of farm system and planning experts dated 7 October 2022;
 - (d) JWS of pastoral farm system experts dated 3 February 2023;
 - (e) JWS of pastoral farm system and planning experts dated 13 March 2023; and
 - (f) JWS of pastoral farm system experts dated 15 March 2023;
- [29] I discuss the JWS in further detail below.

F. THE SIGNIFICANCE OF ON-FARM MANAGEMENT PRACTICES

- [30] Farmers cannot influence soil type or climate. Therefore, they have to limit the quantity of surplus N that accumulates in the soil profile. They do this by managing the quantity of N that they add to the farm (mostly via fertilizer and supplements), and by using the N that is cycling in their farm system as efficiently as possible.
- [31] The overriding objective here is fairly obvious - adopt the management practices that convert as much of the N as possible into saleable product (milk) and, relatedly, minimise losses of N from the system, particularly those

to the environment. Farmers achieve this end by adopting GMP/BMPs. It is noteworthy that the NRS, identifies the risk associated with N inputs and the efficiency with which N is converted to product.

- [32] This explains the significance of farm management, and GMP/BMPs. They are, so to speak, the only means available to reduce N leaching. While this is all obvious, it bears rehearsing given the emphasis that is placed on Gmp/BMPs. All farm systems experts agreed that GMP/BMPs will deliver the reductions in N leaching sought in PC2, and consequently, a tool that can identify these practices in a straightforward way would assist in providing an alternative pathway in PC2. This led to the development of the risk assessment tool.

G. TABLE 14.2 AND CONSENTING PATHWAYS

- [33] To explain the provisions that are now before the Court in this appeal – in particular, the new risk assessment tool – it is necessary to outline some of the underlying work which resulted in DV-PC2.

Adoption of on-farm management practices

- [34] As originally intended, the One Plan, in particular Policy 5-8, anticipates that ‘most’ farms would meet Table 14.2 with the adoption of GMP as the term was understood at the time. In other words, at the inception of Table 14.2, it was anticipated that the majority of farmers would need to adopt GMPs in order to comply with the CNLMs in a stepped down manner over the period of 20 years given in Table 14.2.
- [35] There is no nationally consistent definition of GMP. Furthermore, GMP and BMP are not applied in a uniform way. It is widely recognised that there is no such thing as a ‘one size fits all’ approach when it comes to identifying the practices required to reduce nutrient loss from a wide range of unique farms.
- [36] There is also presently no definition of GMP or BMP in the One Plan. At the time the One Plan was introduced, there was an understanding of the farm practices which farmers and growers may have elected to adopt to manage

N loss. In particular, Dr Ross Monaghan outlined in his evidence for the original One Plan hearings² a wide ranging suite of practices that farmers might need to adopt to help them comply with their CNLM.³ See **Attachment A**. Therefore, in my view, GMP as referred to, and relied on in the One Plan, reflected a broad manner of practices, some of which were fairly onerous to implement and capable of delivering very substantial reductions in N loss.

- [37] At that time, it was envisaged that farmers with leaching losses close to the CNLMs would be required to make relatively small changes to their farm system, while farmers who were well in excess of the CNLM would be required to make more substantial changes so as to achieve a greater reduction in N leaching from their farm. It was also understood that there would be a group of farmers who for one reason or another (e.g. high rainfall and/or coarse textured soils) would not be able to comply with Table 14.2 in a financially sustainable manner. Many of these farms were of relatively low intensity and so had only limited options to reduce leaching losses.
- [38] The approach proffered by Dr Monaghan provided some flexibility for farmers and growers by allowing farmers to make their own decisions about the practices they would adopt on their farms. This approach followed the ethos that it is not Horizons' role to choose mitigations, but the owner's, and that Horizons' role is to ensure that the individual practices achieve the required reductions in N leaching.
- [39] Similarly at the Council-level hearing for PC2, it was agreed that there is a spectrum of farm management practices that would result in N leaching reductions, to varying degrees, on particular farms, depending on their circumstances. Regardless of how these were defined, it was my view that there was a 'toolbox' of options available to farmers to adopt to achieve N loss reductions. The need for flexibility was recognised by the Hearing Panel in its decision, and the policy framework provided for the adoption of GMP/BMP and any other measures that may result in N loss reductions.

² Section 42A Report of Dr Ross Martin Monaghan.

³ Dr Monaghan called these practices 'Good Management Practices', stating that he did not care for the term 'Best Management Practices'.

Meeting CNLM

- [40] With some major changes to Overseer, which resulted in the model increasing the value of its estimates of N leaching from farms, it became apparent that most farmers were unable to meet Table 14.2 with GMP. What had already been a difficult task, to meet the CNLM, was becoming increasingly difficult. In some cases, it was all but impossible, for farmers to meet the CNLM with on-farm practices. This led to the work I undertook with Dr Hanly, regarding recalibration of Table 14.2 to provide for the (then) most recent version of Overseer.⁴ I understand that recalibration of Table 14.2 is accepted by the appellant parties, other than Mr Day. Dr Hanly discusses the recalibration process in his evidence.
- [41] As was the case with the originally notified Table 14.2, PC2 recognised that even under the recalibrated Table 14.2, not all (but most) farmers would be able to comply and access the controlled activity pathway with GMP.⁵
- [42] I undertook an analysis of IFLU in the region, the results of which suggested that if the farmers who exceeded their CNLM by 0 to 10–12 kg N ha⁻¹ yr⁻¹ introduced the appropriate GMPs/BMPs, they were able to close this gap, and thereby meet their Table 14.2 commitments. Approximately 65 to 70% of farmers fell into this group of farmers who would be able to comply with the recalibrated Table 14.2. This would be ‘most’ IFLU in the region.
- [43] The analysis involved interrogating outputs from the Overseer (Version 6.3.1) files of 259 dairy farmers in the four target catchments i.e. Upper Manawātū (116 farms), Mangatainoka (61 farms), Horowhenua (18 farms) and Rangitikei (64 farms). The inputs to these files reflect the farm system as they were in 2012 and so will be called the ‘base’ files.⁶ I also established an Overseer file for a case study irrigated sheep and beef farm in the Rangitikei and an Overseer file for a case study arable farm in the Rangitikei. I did so in

⁴ The reports I co-authored with Dr Hanly are set out at paragraph [5] above.

⁵ What constituted a GMP or BMP occupied a lot of discussion at the first instance hearing. Since then, given the shift to a risk management approach which requires assigning risk score to specified management practices, this discussion has been overtaken.

⁶ The 2012 baseline was important as it is quite likely that most farms are leaching less N by 2020 due to the more widespread acceptance of the role of agriculture in the deterioration of water quality and the adoption of the GMPs/BMPs/Innovations.

reliance on my experience of Overseer and farming in the Region. Using these files I then explored the range of reductions in N leaching rates in order to meet the recalibrated Table 14.2. As I discuss later on, this same analysis was carried out in establishing the 20% specified reduction alternative consenting pathway in the DV-PC2.

[44] This analysis confirmed that there was a clear and direct link between the practices that many farmers would have needed to adopt in 2009 (identified in Dr Monaghan's expansive list) to comply with the original Table 14.2 and those practices that many farmers will need to employ to meet the CNLM under the recalibrated Table 14.2 (under PC2). Indeed, it was my view, they amounted to more or less the same practices.

[45] In the notified PC2, if a farmer was not able to achieve their CNLM with GMPs, they would have been required to seek a discretionary consent.

[46] I also understand that PC2 provided a functional transitional pathway for those looking to exit an existing IFLU activity. I do not understand the transitional pathway to have been challenged through the appeals on PC2.

H. ALTERNATIVES TO TABLE 14.2

[47] Following the notification of PC2, submitters⁷ who were dissatisfied with the only available pathway for a controlled activity consent being compliance with the CNLMs in Table 14.2 requested alternative controlled consent pathways be included in PC2. The reasons provided in support of the alternative pathway varied, including, arguments that expected N leaching reductions should be achievable for most farmers, and proportional water quality improvements could be made even without reliance on Table 14.2.

[48] The intention of the original Table 14.2 was to drive behaviour change and help farmers meet their CNLM through the use of GMP/BMPs (Dr Monaghan's original list). As I have noted, it was recognised that, even after adoption of these GMPs/BMPs, not all farmers would meet their CNLM. This remained the case following my analysis for the Council-level hearing,

⁷ Notably DairyNZ, Federated Farmers and Hort NZ.

although the number of the remaining unconsented farms that could not comply with the recalibrated table was higher, particularly in the Upper Manawatu. This is one of the reasons why an alternative pathway, still focused on GMP/BMP and N loss reductions, was considered, alongside the outcomes from Dr Snelder's original water quality modelling undertaken to inform PC2 and responses to submissions.

- [49] My expectation (informed by the modelling analysis I have described above) was that with implementation of appropriate GMPs and BMPs, tailored for the particular circumstances of an individual farm, N loss reductions in the range of 10–20% would result for pastoral farms. It was my view, that this would have resulted in a significant reduction in the quantities of N leached from the root zone of dairy farms in the target catchments, while at the same time allowing farmers to run profitable businesses.
- [50] A 10–20% reduction markedly moved farmers toward the N reductions that would be required to achieve the CNLMs. To illustrate, my analysis demonstrated that if dairy farmers in the Upper Manawātū sub-catchment reduced N leaching by 10% then (approximately) 24% would meet their Table 14.2 CNLM. If these farmers reduced N leaching by 20%, then approximately 44% would comply with their CNLM.
- [51] In my view, a 10% reduction and simply maintaining the status quo may not have been enough. For that reason I supported the higher limit of the range I provided (20%). The DV-PC2 adopts this threshold for the alternative pastoral specified nitrogen reduction pathway.
- [52] With this change, there was a potential pathway open to all farmers to at least try to obtain resource consent, and under any scenario there would be a reduction in the amount of N leaching for pastoral IFLU in the targeted catchments. In my opinion, this was an improvement on the situation Horizons was facing at the time (and still is), where implementation of the One Plan has practically stalled due to the policy framework only providing for activities which exceed Table 14.2 to seek consent in very narrow circumstances. In those cases, the One Plan is not able to work to drive reductions in N leaching loss from farms.

- [53] As I discussed above, the implementation of GMPs/BMPs was always the central focus of the One Plan, as encapsulated in Dr Monaghan's original evidence. I remain of the opinion that the alternative consent pathway within DV-PC2 drove the implementation of those practice changes.
- [54] By way of example, the recalibrated Table 14.2 allowed for the leaching of 360 t N yr⁻¹ from the (currently) unconsented dairy farms in the Upper Manawatu catchment. On the basis of their base Overseer files, N leaching from these farms was 182 t N yr⁻¹ greater than this allocation. This could be thought of as the excess or overshoot of the recalibrated Table 14.2 allowance. In comparison, if after the adoption of GMPs/BMPs, N leaching from these dairy farms was reduced by 20% or, if required reduce to the 75th percentile value, then the excess or overshoot quantity is 74 t N yr⁻¹ (from 182 t N yr⁻¹ down to 74 t N yr⁻¹).
- [55] It remains my opinion that these were significant reductions in the amount of nitrogen leaching from the dairy farms in this target catchment and quantify the changes that the controlled pathway would have driven.
- [56] The viability of this alternative pathway was supported by the water quality modelling undertaken by Drs Cox and Snelder. I provided the N leaching data which fed into that modelling. This modelling showed that there were modest water quality improvements, with little (marginal) difference in the modelling outcomes (as between Table 14.2 and the alternative pathways). I understand Dr Snelder provides an overview of this modelling in evidence.⁸

I. OVERSEER INDEPENDENT PEER REVIEW FINDINGS

- [57] The development, implementation and regulation of regional plans to manage water quality requires quantitative values for nutrient losses from farm systems. Given that field-scale measurements of nutrient fluxes in drainage and runoff are not practicable for multiple farms, these regional plans are reliant on simulation models. Field scale measurements would also

⁸ Statement of Evidence of Antonius Snelder dated 6 October 2023.

likely cost farmers tens of thousands of dollars, be extremely difficult to interpret, and in all likelihood provide no more certainty than models.

- [58] The One Plan presently relies on farm scale nitrogen losses being assessed in a quantitative manner. As discussed in the evidence of Dr Hanly, the CNLM in Table 14.2 are Overseer-derived. Equally, the specified nitrogen reduction pathways I have described above, also rely on a quantitative value for nutrient loss (for pastoral a 20% N loss reduction).
- [59] In the past, Overseer would have been used to predict nitrogen losses from farms. Specifically, Overseer can describe a farm management system in a manner which produces a N leaching value which is directly comparable to the One Plan policies and rules in Chapter 14. The One Plan also requires preparation of a Nutrient Management Plan (**NMP**), which until PC2, was defined only by reference to Overseer's inputs and outputs. I note that PC2 broadened this requirement to include any recognised nutrient management model, which includes, but is not limited to, Overseer.
- [60] The most important use of quantitative assessments of N loss from individual IFLU (Overseer modelling) is forward looking i.e. to determine compliance with the CNLM in Table 14.2 or the percentage change required under the specified nitrogen reduction pathways. Historically, if considered appropriate, I am aware that it had been used to determine whether the farming activity has managed nitrogen loss such that it has met the relevant CNLM and/or satisfied the NMP.
- [61] As I noted in evidence for the Council-level hearing, the question then is not whether 'to model or not' but 'which model will suit this purpose best', or more directly, 'is Overseer fit for purpose'?
- [62] I remain of the view that Overseer has a place in helping farmers to identify the most appropriate and effective GMP/BMPs to help reduce the N leaching rate from their farm. Overseer has been developed for New Zealand conditions and is built on the results and knowledge produced in many years of research conducted locally. I am of the view that if we stop over-interpreting the actual values generated by Overseer, and concentrate more

on the general impact it suggests that GMP/BMPs will have on leaching rates then it can be a useful tool in the search for improved water quality.

[63] However, I accept that the Overseer Reports and Ministry advice means that Horizons must look to other options to assist it in regulating N loss on farms. In my view, the nitrogen risk assessment tool that has been developed as part of the PC2 appeal proceedings is an effective tool in this regard.

[64] As I discuss below, importantly, the focus remains (as it always was under the One Plan) on GMPs and BMPs. I have previously stated in my s42A reporting that any debate over Overseer may be overtaken by a regulatory framework focused on farm management practices. Specifically,⁹

A regulatory framework focused on good and best management practices (GMP and BMP) might overtake the debates and concerns about the uncertainties associated with OVERSEER® (and other models). By this I mean that the question of fundamental suitability may be somewhat moot where an available option was for a farmer to commit to the implementation of a range of GMPs and BMPs with a percentage reduction in nitrogen loss. The key step in that case is adopting the necessary level of management (e.g. a prescribed set of BMPs): while this step is informed by modelling, in some ways it precedes modelling...

J. DEVELOPMENT OF THE PASTORAL NITROGEN RISK ASSESSMENT TOOL

[65] Following the release of the Overseer Reports, I participated in a number of expert conferences with farm system and planning experts involved in the appeals on PC2. The conferences explored the possibility of a new method to determine and assess appropriate nitrogen reductions on farm. The method would rely on the use of on-farm practices to reduce the risk of N leaching, similar to the GMPs and BMPs that would have been required to achieve the N leaching reductions for the specified reduction pathways.

[66] An initial expert conference was held in June 2022, following which it was agreed that the possibility of an alternative should continue to be explored.

⁹ Section 42A Technical Report, 4 September 2020, at paragraph [42].

This initiated a series of expert conferences which resulted in development of the nitrogen risk assessment tool, as recorded in the JWS.¹⁰

- [67] Some of my evidence from here on will provide insights into the process that resulted in the nitrogen risk assessment tool for CVG. However, I will focus on the pastoral nitrogen risk assessment tool and the statement of evidence of Dr Jolly will address the CVG nitrogen risk assessment tool in detail.

Expert Conferencing and Mediation

- [68] As I note above, the expert conferences producing a series of JWS. The pastoral farm system experts involved in the conferences included:

- (a) Dr Paul le Miere on behalf of Federated Farmers;¹¹
- (b) Gavin Marshall on behalf of Federated Farmers;¹²
- (c) Ian McNab for Horizons;¹³ and
- (d) Dr Elizabeth Parlato for Wellington Fish and Game and Ngāti Turanga;¹⁴

- [69] Dr Jolly observed the pastoral expert conferences with a view to ensuring (as far as possible) consistency in the underling approach to the nitrogen risk assessment tool being developed for CVG.

- [70] An overview of the stages of development of the pastoral nitrogen risk assessment tool is attached as **Attachment B**.

- [71] The starting point for developing a risk-based tool was identifying factors of IFLU activities which influence (increase or decrease) the risk of nitrogen

¹⁰ The JWS are described at paragraph [28] above.

¹¹ Attended all expert conferences listed in paragraph [28] above.

¹² Only attended expert conferencing on 28 June 2022, 25 August 2022 and 7 October 2022.

¹³ Only attended expert conferencing on 28 June 2022 and 25 August 2022.

¹⁴ Only attended expert conferencing on 3 February 2023, 13 March 2023 and 15 March 2023.

leaching. It was agreed by farm system experts¹⁵ that there are two important influences on the risk of nitrogen loss to waterways:

- (a) Underlying biophysical factors, and
- (b) On-farm management practices.

[72] The JWS records agreement on the identified lists of on-farm management practices that create or mitigate risk of nitrogen leaching.¹⁶ In identifying these factors it was agreed that they needed to meet a suite of criteria.¹⁷ Any factor or practice relied on any risk assessment tool would need to be:

- (a) Certain (Unambiguous);
- (b) Able to be consistently applied (with limited discretion);
- (c) Verifiable/able to be interrogated (transparent);
- (d) Measurable;
- (e) Able to show change in relation to a baseline;
- (f) Evidence-based (using best available information); and
- (g) Accessible.

[73] The risk-based nitrogen assessment tool utilised by Fonterra was agreed to be the basis for discussions by the experts.¹⁸ As the NRS had been used in a pastoral context since 2018, it was considered to provide a useful starting point for the format and content of a risk tool. One key advantage was that the NRS already contained all the management factors that would commonly contribute to N loss risk for a dairy farm.

[74] The NRS assesses the risk associated with six management factors; stock management, nitrogen fertiliser, imported feed, cropping and cultivation, irrigation, and effluent management. The score for the management factor

¹⁵ Joint Witness Statement dated 28 June 2022.

¹⁶ Joint Witness Statement dated 28 June 2022, Annexure A, pages 10-13.

¹⁷ Joint Witness Statement dated 28 June 2022, pages 7-8.

¹⁸ Joint Witness Statement dated 25 August 2022, Annexure A, page 5.

is the aggregate score of a number of subfactors. Interestingly, although they are very different tools, at the input level, there is a degree of similarity between the architecture of the NRS and Overseer.

- [75] For example, the 'nitrogen fertiliser' factor assesses the risk associated with nitrogen use on the dairy farm. Increased risk is identified in the subfactors for; larger annual rates of fertiliser, applying it the winter period, high rates when applying the fertiliser, and inefficient use of this fertiliser N.
- [76] It was acknowledged that the NRS only focusses on farm practices and does not consider underlying biophysical factors of the land or climate.¹⁹ This was a factor which required further consideration and discussion between the experts.
- [77] The scoring mechanism in the NRS works on a points basis which is then translated into risk bands ranging from "Very Low" to "Very High".²⁰ It was agreed by the farm system experts that a similar format would be created for PC2 with points leading to risk bands. Therefore, the farm system experts were tasked with agreeing how each of the risk factors (biophysical factors, on-farm practices and mitigations) should be measured and quantified.
- [78] During the expert conference on 25 August 2022, the farm system experts separated into pastoral experts and CVG experts to agree on factors to include within any framework and how these should be measured and quantified. The factors agreed by pastoral experts were largely based on the NRS factors and are set out in Table 2 of the JWS dated 25 August 2022.²¹ These factors were grouped into six categories, namely:

- (a) stock management,
- (b) cropping and cultivation,
- (c) irrigation,

¹⁹ Joint Witness Statement dated 25 August 2022, Annexure A, page 5.

²⁰ Joint Witness Statement dated 25 August 2022, Annexure A, page 5.

²¹ Joint Witness Statement dated 25 August 2022, Annexure A, page 12.

- (d) effluent management,
- (e) nitrogen fertiliser, and
- (f) imported feed.

[79] The pastoral experts also largely agreed with the methodology for measuring and quantifying the factors which were adopted from the NRS. For some factors, scoring was adjusted or developed based on the knowledge of the experts present or evidence provided by research or modelling.

[80] A list of mitigations was also agreed between all the farm system experts and is provided in Table 3 of the JWS dated 25 August 2022. I note that many of the on-farm practices identified in Table 2 of the JWS dated 25 August 2022 can be both aggravating and mitigating factors. For example, increasing stocking rate will generally increase nitrogen leaching risk while decreasing stocking rate will decrease nitrogen leaching risk. The mitigations provided in Table 3 are additional measures that farmers could incorporate which will directly decrease their nitrogen leaching risk. I further note that the experts included some edge-of-field technologies which were further investigated and narrowed down in expert conferencing on 7 October 2022.²²

[81] It was also agreed that the two most significant biophysical factors influencing nitrogen leaching on intensive land use farms were:²³

- (a) soil type/soil vulnerability to nitrogen leaching, and
- (b) rainfall for its influence on drainage quantity.

[82] While all experts agreed that underlying biophysical factors are important for nitrogen leaching, consensus could not be reached around how they should be addressed within the consenting process. It was agreed that two options would be explored further:²⁴

²² The experts agreed that wetlands, bioreactors and plantain would be included as mitigations in the pastoral scorecard but there was insufficient evidence to include dung beetles. Joint Witness Statement dated 7 October 2022, Annexure A, page 6.

²³ Joint Witness Statement dated 25 August 2022, Annexure A, Table 4, page 16.

²⁴ Joint Witness Statement dated 25 August 2022, Annexure A, page 8.

- (a) Incorporation of underlying factors in the scorecard as a 'multiplier' to the aggregate score from on-farm practices, and
- (b) Exclusion of underlying factors from the scorecard but incorporating them elsewhere in the consenting pathway.

[83] Over the following few months, I considered the question of whether the two biophysical factors agreed by experts (i.e., soil type and rainfall) should be incorporated into the scorecard (the 'multiplier' approach) or whether they should sit outside of the scorecard elsewhere in the consenting process.

[84] This led to my alternative proposal which is set out in my paper attached to the JWS of pastoral farm system experts dated 3 February 2023.²⁵ The alternative approach became the agreed preferred approach by experts and is now the format of the risk assessment tool for both pastoral and CVG. Under this approach the NRS scorecard is used to assess the risks associated with on-farm management practices. This score can then be compared with the target scores listed in the matrix for a range of soil types and rainfall bands. The scorecard essentially sits within this broader framework (with soil type and rainfall) to determine the N leaching risk associated with the land.

[85] In short, a large biophysical risk must be matched by a small management risk, whereas a small biophysical risk allows for greater management risk. This is accepted on the basis that:²⁶

the risk that surplus nitrogen on farms in low rainfall/fine textured soil landscapes will leach beyond the root zone is relatively small, requiring less on-farm management interventions. Conversely, where the soil type and [rainfall] are likely to result in much of the surplus [nitrogen] leaching from the root zone, more stringent management interventions are required to reduce the net risk.

²⁵ "A matrix to help interpret the Fonterra Risk Scorecard and achieve the improvement in farm management sought by Plan Change 2", Joint Witness Statement dated 3 February 2023, Attachment A, page 13.

²⁶ "A matrix to help interpret the Fonterra Risk Scorecard and achieve the improvement in farm management sought by Plan Change 2", Joint Witness Statement dated 3 February 2023, Attachment A, page 14.

- [86] I note that Overseer yields the same general relationship.
- [87] It was proposed that to qualify for the controlled activity pathway, a farm should achieve, at most, no more than an overall low risk to nitrogen leaching. As a result of a greater risk from biophysical factors, some farmers will need to achieve a lower risk score from their on-farm practices in the scorecard; whereas farmers with a lower risk from biophysical factors will have more flexibility to score slightly higher in the scorecard (i.e. make less on-farm practice changes to reduce risk of nitrogen leaching).
- [88] Initially, I populated the matrix with risk bands which needed to be achieved for the different types of land.²⁷ This required farms with coarse soil and high rainfall to score within the “Very Low” and “Low” risk bands while farms with fine soil and low rainfall were able to score within the “Low” and “Medium” risk bands. It was later agreed that these risk bands should be translated into numerical scores that farmers are required to score below to meet the necessary risk threshold within the plan framework. I carried out this work for the purpose of producing an updated version of the risk tool.²⁸
- [89] This alternative matrix approach was agreed by pastoral farm system experts as the preferred format of incorporating biophysical factors in the nitrogen risk assessment tool with soil type (measured by profile available water (**PAW**)) and rainfall (measured in bands of average annual rainfall).²⁹ The experts agreed with the use of the reference map for determining soil type by profile available water in the Fundamental Soil Layer from the Manaaki Whenua portal and that the ranges provided in that map should correspond to the columns in the matrix.³⁰ Further, the experts agreed that the reference map for rainfall would be the NIWA long-term rainfall map.³¹ The planners agreed that both of these maps should sit in the plan.³²

²⁷ “A matrix to help interpret the Fonterra Risk Scorecard and achieve the improvement in farm management sought by Plan Change 2”, Joint Witness Statement dated 3 February 2023, Attachment A, Figure 3, page 16.

²⁸ Joint Witness Statement dated 3 February 2023 and Joint Witness Statement dated 13 March 2023.

²⁹ Joint Witness Statement dated 3 February 2023, Annexure A, page 6.

³⁰ Joint Witness Statement dated 13 March 2023, Annexure A, pages 8-9.

³¹ Joint Witness Statement dated 13 March 2023, Annexure A, page 9.

³² Joint Witness Statement dated 13 March 2023, Annexure A, pages 8-9.

- [90] After some further road-testing and calibration of the values in the nitrogen risk assessment tool (discussed further below), this became the pastoral risk tool as agreed by pastoral farm system experts.³³

K. DATA ANALYSIS/CALIBRATION OF THE PASTORAL MATRIX

- [91] It is difficult to undertake a comparison exercise of the nitrogen risk assessment tool and Overseer estimates. Overseer estimates the quantity of nitrogen that will leach from a farm and expresses this as a flux (measurement of kg N/ha/yr), whereas the pastoral nitrogen risk tool does not attempt to model nitrogen loss and instead provides an assessment of the risk of N leaching from an IFLU. In my opinion, a more important comparison between the two tools is the extent to which they each drive similar on-farm practice changes.
- [92] As part of my calibration/analysis of the risk assessment tool, I completed a comparison of Overseer and the risk tool using 10 typical farm systems in the upper Manawatu sub-catchment. I modelled these farms using both Overseer and the pastoral nitrogen risk assessment tool. The result of this exercise suggested that if a typical farm used the risk assessment tool to identify the on-farm management practices it needed to adopt, then it would leach approximately 35 – 45 kg N/ha/yr. This compared very favourably with the CNLMs in Table 14.2 and illustrated the need for significant on-farm practice change, resulting in nitrogen leaching reductions, in a manner consistent with the specified reduction pathway in the DV-PC2.
- [93] The next stage of calibrating the pastoral nitrogen risk assessment tool was undertaken by Dr Paul le Miere who used Fonterra data cross-referenced with Dairy NZ data to locate consented and unconsented farms in the Manawatū-Whanganui Region. He found 194 unconsented farms and completed an assessment of the pastoral risk assessment tool using this data.
- [94] Following his assessment, Dr le Miere proposed a number of adjustments to the values in the matrix. As demonstrated to me, the adjustments were made to ensure that the requirements of the risk assessment tool, while stringent

³³ Joint Witness Statement dated 15 March 2023, Annexure A, page 4.

in managing risk of N loss, were still achievable. Having reviewed his assessment and workings, I was comfortable with Dr le Miere's analysis and adopted his adjusted values into the risk assessment tool.³⁴

[95] Over recent months, I have undertaken further work to road-test the nitrogen risk assessment tool against aggregated farm data from the NRS.³⁵ This is described below in section L of my evidence.

[96] In my view, the nitrogen risk assessment tool will drive on-farm practice change which will result in reductions in N leaching from ILFU in targeted catchments in the Horizons region.

[97] As with Table 14.2 and the 20% specified reduction pathway, there will be some farmers that will not be able to meet the Low risk category and will require resource consent as a discretionary activity. This is consistent with the approach under the One Plan, including the DV-PC2. I accept that not the case that every IFLU will be a controlled activity. This is appropriate. The higher the level of risk of N leaching, the greater the scrutiny and expectation around reductions in N, or use of the transitional pathway under PC2.

L. OUTCOMES OF RISK ASSESSMENT TOOL

[98] Models like Overseer, which estimate nitrogen leaching in absolute numbers (i.e. expressed as kg N/ha/yr) are different to risk matrices which rank the relative risk of practices. As I have noted, however, both provide useful perspectives on reducing nitrogen leaching and both can help achieve the desired outcome of change in farmer behaviour by encouraging the adoption of GMP/BMPs.

[99] At expert conferencing, I was of the opinion that, to qualify for the controlled activity pathway, a farm should achieve no more than an overall 'Low' risk of N leaching.³⁶ In my view, a 'Low' risk score was an appropriate target as it

³⁴ Joint Witness Statement dated 13 March 2023, Annexure A, page 6.

³⁵ Data provided to Horizons from Fonterra.

³⁶ Joint Witness Statement dated 3 February 2023, Attachment A, page 14.

would require significant on-farm practice change, but would not be unachievable.

- [100] As the risk assessment tool is based on a widely used and accepted tool (the NRS) which sought to identify both risk and the means to decrease this risk, I did not consider any direct correlation with Overseer during the development of the risk assessment tool for PC2. Furthermore, Overseer was receiving widespread criticism at the time following the Overseer Reports.
- [101] The likely effectiveness of a risk matrix, or any tool for that matter, should be evaluated and tested. While Overseer may have some limitations, it is, in my view, a good tool for identifying the GMP/BMPs appropriate to any particular farm. While I acknowledge that Overseer's simulation of actual values for leaching rate have a degree of uncertainty (as do the predictions of all models), it can still usefully inform / 'ground truth' the adoption of farm practice change on farms, with a view to informing water quality outcomes (catchment modelling).
- [102] This is important, as it is my view that it will be the adoption of GMP/BMPs on farm that will lead to a reduction in nitrogen leaching rates and, in turn, an improvement in water quality in the targeted catchments. Therefore, I consider an appropriate evaluation/test is whether the risk matrix and Overseer identify and guide farmers towards the adoption of effective GMP/BMPs. In my opinion, the risk assessment tool does this.
- [103] Further, it is important to understand whether the risk assessment tool will lead to a similar improvement in water quality in the targeted catchments as the DV-PC2 would have. Therefore, I have compared:
- (a) the likely reduction in the average leaching rate from the farms in the targeted catchments that would result following the consent pathways provided for farmers under the DV-PC2;³⁷ and

³⁷ These include the 20% and 35% specified nitrogen reduction pathways.

- (b) the average reduction from the same farms using the risk assessment tool.

[104] In this exercise, I started with the baseline leaching rates. These are the rates that Horizons were seeking to manage downwards through the One Plan and PC2. I then constrained farmers to take the most straightforward pathway to achieving a consent i.e. meet their modified Table 14.2 allocation, or a decrease in leaching rate by the greater of a 20% reduction or reduction to the 75th percentile value. I then subtracted their 'consented rate' from their baseline value. This was the same modelling exercise I undertook for the when establishing the specified nitrogen reduction pathway in the DV-PC2.

[105] As noted above, the risk assessment tool does not yield a leaching rate which can be subtracted from the baseline risk value to calculate the likely reduction in leaching rate associated with the adoption of the risk tool. Therefore, to identify the likely leaching rate from farms meeting their risk score, I prepared three generic or case study farms in each of the major cells in the risk assessment tool. For example, in the Upper Manawatū, I identified areas where the soil has a 'medium' PAW value and the rainfall is 1500 mm. For this farm, I then ascribed the risk scores to the individual management factors that would give this property a total risk score of a little less than 130 (the target in the risk assessment tool for that catchment).

[106] To inform the selection of values for these farms (e.g. the quantity of nitrogen applied), and to provide robustness to my approach, I undertook the following:

- (a) Firstly, I had a workshop with two dairy systems experts, Mr Mark Laurence (Regional Leader, DairyNZ) and Mr Ian McNab (Rural Advisor, Horizons), who are very familiar with dairy farming in the Horizons region. We identified the defining characteristics of the range of dairy farms in the targeted catchments.
- (b) Secondly, I had access to NRS data from Fonterra. Due to privacy concerns, I was only supplied with aggregated scores. As I was constructing generic farms, this was not a major limitation as it provided a check on my input values to the risk matrix and Overseer

i.e, the values I selected are representative of farms in the region, based on my working knowledge, Overseer files, and experience.

- [107] Having developed farms which were representative of the cells in the risk assessment tool (rainfall and PAW combinations) but with the important proviso that they met the required risk score (from the risk assessment tool), I then created an Overseer file for each of the farms.
- [108] This allowed me to identify a representative nitrogen leaching flux (kg N/ha/yr) for each cell of the risk assessment tool. I then compared (i.e. subtracted) this leaching rate from the baseline values for the proportion of farms in the cell i.e. reduced the baseline leaching rate to match the target value. This gave me an average reduction in leaching rate for each of the targeted catchments.
- [109] The results of this exercise are presented in the following Table 1. The first column shows the reduction in the average leaching rate from farms in the targeted catchments if farmers had acted on the DV-PC2. The second column shows, by way of comparison, the average reduction in nitrogen leaching rates from farms if they had changed on-farm practice management in a manner that allowed them to meet their risk score as set in the risk assessment tool.

Table 1: Comparing percentage reductions from DV-PC2 and Risk Matrix

Average % decrease in N leaching flux from farms		
	DV-PC2	Risk matrix
Upper Manawatu	16	13
Other Upper Manawatu	9	7
Rangitikei	1	1
West Coast Lakes and Horowhenua	5	4

- [110] In my view, given the assumptions made in this exercise, there is no material difference between the values for the two approaches in any of the water management sub-zones in Table 1.
- [111] The analysis I have described above is illustrative of the similarity of the two approaches specified reduction pathways in DV-PC2 and the risk assessment tool) and the likelihood that they will lead to the same outcome when acting

on the same population of farms. It does not enable me to be definitive about the actual reduction in N leaching from farms in the targeted catchments, and in any event, it was not the purpose of the analysis.

[112] In relation to outcomes for water quality, I had previously supplied Dr Ton Snelder with N leaching rates from dairy farms to input into the catchment scale model for quantifying the effects of the original PC2 on water quality. This modelling indicated a 'modest' improvement in water quality.³⁸

[113] From my more recent analysis, I provided the percentage reductions in N leaching to Dr Snelder. The results of Dr Snelder's assessment are explained in his statement of evidence; however, I understand that it confirms that the same water quality outcome (modest improvement) is expected to occur under the risk assessment tool, as the pathways under the DV-PC2.

[114] I note that Dr Snelder's conclusions are in line with my own expectations of the impact of the risk assessment tool on water quality when developing the risk assessment tool. The GMPs or BMPs that I anticipated farmers needing to adopt for 20% reductions in nitrogen leaching rates are very similar to the on-farm practices that will be required under the risk assessment tool, and for that reason, I had a level of confidence that this would lead to the same or better outcomes from reduced nitrogen loss rates from farms.

M. OTHER RISK ASSESSMENT TOOLS

[115] I am aware the Ministry for the Environment is developing a nitrogen contaminant discharge risk index tool (RIT) for on-farm nutrient management. I understand the first phase, Phase One, is due to be released in late 2023.

[116] According to the publicly available information,³⁹ Phase One of the RIT will provide a risk score for nitrogen loss from farms and plantation forestry

³⁸ Joint Witness Statement dated 15 March 2023, Annexure A, page 4.

³⁹ <https://environment.govt.nz/acts-and-regulations/freshwater-implementation-guidance/freshwater-farm-plans/risk-index-tool-for-on-farm-nutrient-management/>.

based on environment characteristics, management practices and mitigations, and a farm score at farm and block scale.

[117] An operator port will be provided for users to complete nitrogen loss risk assessments, and it is suggested via the public website that the Ministry will be seeking feedback from Councils, land managers and other users to inform the roadmap and future phase iterations of the tool.

[118] I have revised the Ministry's information pack available on its website and note the following points, when considering the risk tools prepared for PC2:

(a) The risk assessment framework proposed by the farm systems experts as an alternative pathway and the RIT are very similar. They assess many of the same 'inputs' (biophysical factors, nitrogen inputs, practice-based factors) to produce a risk score. This congruence in approach is not surprising as the science informing the development of models, and by extension risk frameworks, is now well established and widely agreed upon.

(b) While the process of developing the risk framework and the RIT is similar and the way that they operate may have much in common, I would note that the risk assessment framework is bespoke as it was developed in 'place', which is to say in the specific context of Horizons targeted catchments.

(c) Furthermore, it would be fair to say that the risk assessment tool has, to some degree, been 'field tested' in the targeted catchments.

[119] In my view, the risk assessment framework systematically and comprehensively evaluates the risks posed across all aspects of farm management, and identifies the GMP/BMPs required to reduce a risk profile. Equally, it is my view that behaviour change that results in farms that pose a low risk to water quality needs to be encouraged. There are, if you like, two constraints here: a well-defined list of BMP/GMPs and the requirement that farmers adopt the practices required to ensure a low risk profile. The risk assessment framework will bring these two together. I dare say that RIT will be able to produce this outcome, but it will not fundamentally change it.

- [120] Finally, it is evident from the information available that the Ministry does not hold the RIT out as the only tool that may be appropriate for determining risk of N leaching from farming activities. To the contrary, the notes state:

No one approach is the solution to managing diffuse nutrients. A systems approach, at place, is required.

- [121] It is my opinion, that just such a systems approach, with an emphasis on behaviour change through the adoption of GMP/BMPs is what has occurred in the case of PC2. The nitrogen risk assessment tool has been developed and prepared specifically for the priority catchments i.e 'place' was a key consideration in the development of the risk framework and the evaluation of its likely effectiveness. In my view the risk framework address the objectives of PC2, with particular regard to the systems characteristics of land use, management practices, and biophysical factors in the targeted catchments in the Horizons Region, and is appropriate for PC2.

- [122] The RIT is also some time away, based on the Ministry's currently published timeframe. While Phase One is projected to be published by the end of the year, the Ministry acknowledges that this Phase will still require further development. From what I reviewed to date, there is nothing to suggest that the risk assessment tool for PC2 could not be refined to address any further information emerging from the RIT development. For now, I am comfortable that the approaches are similar enough in nature and effect, that the risk assessment tool for PC2 could be utilised without creating future issues.

N. NUTRIENT MANAGEMENT PLANS / FARM ENVIRONMENTAL PLANS

- [123] The One Plan requires preparation of a NMP which is currently defined only by reference to Overseer inputs and outputs. PC2 broadens this definition to include any recognised nutriment management model and cover all sources of nutrients, sediment and pathogens. In my view, the nitrogen risk assessment tool can fit easily within this broader definition of an NMP. This is appropriate, in my view.

- [124] I also acknowledge that PC2 provides opportunity for freshwater farm plans (FFPs) prepared for the purpose of Part 9A of the Resource Management Act

to be utilised in the future. Again, this is appropriate, in my view, and also, appropriate when considering implementation of the risk assessment tool.

6 October 2023

David John Horne

O. REFERENCES

- Parliamentary Commissioner for the Environment, *Overseer and regulatory oversight: Models, uncertainty and cleaning up our waterways* (December 2018).
- Prepared for the Ministry for Primary Industries and Ministry for the Environment by the Science Advisory Panel, *Overseer whole-model peer review: Assessment of the model approach* (July 2021).
- Ministry for the Environment and Ministry for Primary Industries, *Government response to the findings of the Overseer peer review report* (August 2021).
- Further Supplementary Statement of Dr Ton Snelder dated 22 October 2020.

P. ATTACHMENTS

Attachment A

Section 42A Report of Dr Ross Martin Monaghan on behalf of Horizons Regional Council (August 2009).

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 ROSS MARTIN MONAGHAN
ON BEHALF OF HORIZONS REGIONAL COUNCIL**

1. INTRODUCTION

My qualifications/experience

1. My name is Dr Ross Martin Monaghan. I am a research scientist working within the Climate, Land & Environment (CLE) Group at AgResearch, based at Invermay, Mosgiel. I have a Bachelor's degree in Agricultural Science (First Class Hons, Lincoln University) and a PhD in Soil Science (University of Reading).
2. I have 14 years work experience with AgResearch plus the research experience gained during my PhD and post-doctoral studies (3 years for each). My research projects focus on: 1) defining the impacts of intensive pastoral agriculture on soil and water quality; and 2) identifying cost-effective options to reduce these impacts where mitigation is deemed necessary. My technical speciality is in nitrogen and, to a lesser extent, P cycling in grazed pastoral systems. Much of my current research focuses on quantifying N and P losses to water and assisting end-user groups with policy development and/or management guidelines that can reduce these losses. I currently co-lead a national Dairy Catchments Study, an industry-led initiative that aims to benchmark soil and water quality in five contrasting catchments located in the major dairy regions. I have authored more than 40 peer-reviewed publications and numerous technical reports and conference papers.
3. I acknowledge the contribution to this report from my colleague Ms Denise Bewsell, a social scientist who works for the AgSystems group based at AgResearch, Lincoln. Ms Bewsell has seven years research experience and is involved in a number of projects focused on understanding the adoption of good environmental management practices among farmers.
4. I have read the Environment Court's practice note, Expert Witnesses – Code of Conduct, and agree to comply with it.

My role in the Proposed One Plan

5. I have not been directly involved with the development of the Proposed One Plan, other than having read and commented on the draft document, *Implementation of FARM strategies for contaminant management: further questions*, prepared by MacKay *et al.* (2008). I have also read and commented on the evidence of Drs D. Houlbrooke and R. Parfitt.

Scope of evidence

6. Some of the mitigation options, hereafter referred to as Good Environmental Practices (GEPs), currently available for minimising losses of nitrogen (N), phosphorus (P) and faecal micro-organisms (FMOs) from farms to water bodies are documented. A generalised overview of their effectiveness and cost is also provided, although I stress here that the relevance, effectiveness and cost of any particular mitigation is typically very farm-specific due to variations in soil type, topography, climate, land use, and farm management system. Commentary is also provided on the rates of adoption of some GEPs. The contribution of my colleague Ms Denise Bewsell to this latter aspect is here acknowledged. The term GEP is used here instead of BMP (Best Management Practice) to avoid the implication that any particular management is “best” –often there are a number of management practices that can deliver similar environmental outcomes, although in many cases some may be more suitable than others due to cost, soil type, topography etc. The development of new technologies can also mean that “best” practice today will be inferior some time in the future.

2. EXECUTIVE SUMMARY OF EVIDENCE

7. Some of the key sources of contaminant losses from pastoral farms to water bodies in New Zealand are briefly reviewed. The effectiveness and cost of a range of practices and technologies that can minimise these losses are documented. Research has identified a suite of mitigation systems and technological measures that are able to deliver reductions in nutrient and faecal bacteria losses from pastoral farms. However, issues of cost, complexity, compatibility with the current farm system, and a perceived uncertainty of actual environmental benefits are identified as potential barriers to adoption of some of these technologies. The effectiveness of individual GEPs depends on factors such as soil type, topography, climate, land use and farm management system. Thus, there is usually no “one size fits all” approach to mitigating N and P losses from farms, as these factors need to be considered on a farm-specific basis.
8. As noted for the effectiveness of individual GEPs, the cost associated with each can also vary considerably depending on factors such as farm management system, soil type, topography, climate, and land use. However, case study analyses of “typical” farms in New Zealand do provide some indicative estimates of the costs of GEPs. Some measures, such as improved fertilization practices and the use of nitrification inhibitors, are estimated to incur small or negative costs (ie. deliver a net benefit). Other measures that involve the purchase of significant farm infrastructure or expensive feed, such as stand-off or wintering pads, could incur considerable cost, sometimes the

equivalent of up to \$200 per cow when expressed on an annualised basis. Other less capital intensive measures such as stream fencing, improved effluent management systems and the installation of constructed wetlands tended to incur more modest annualised costs of typically less than \$50 per cow per year.

9. For dairy farms, the improved management of farm dairy effluent (FDE) has been shown to be an important step for reducing losses of P and FMOs, particularly for farms on naturally poorly draining soils or sloping land. Targets set within the Clean Streams Accord (the Accord) aim to ensure that milk suppliers to New Zealand's largest milk company, Fonterra, have a consistent level of environmental performance for some of the land use practices that are known to influence contaminant losses from farms, such as FDE management. Annual monitoring shows that there has been good progress towards the scheme's targets for some of the easier measures, such as having nutrient management systems in place or fencing off streams. However, compliance rates remain lower than desired for the more difficult target of meeting local regulatory authority requirements for effluent management. It is important to note that the Accord only addresses some of the obvious land use practices that are known to impact on water quality; as such it can only be viewed as an important first step on the path to improving farm environmental performance, and may not go far enough to meeting targets for catchment water quality, particularly those that focus on mobile forms of nutrients such as N.

10. Research by social scientists suggests that a combination of voluntary and regulatory approaches is likely to be required for optimum uptake of GEPs. The Accord is perhaps one of the most relevant examples of a mixed regulatory and non-regulatory approach to managing contaminant losses from farms. Given the mixed success observed in compliance with the Accord targets, and that it only represents a first step in controlling contaminant losses from farms, this indicates the difficult challenges that lie ahead for controlling contaminant losses from farms to water bodies.

3. EVIDENCE

What are the primary non-regulatory alternatives currently available for mitigating P and N losses to surface water?

Key sources of N and P

11. The magnitude of nutrient inputs to a farm system is generally the main factor determining the nutrient surplus and, therefore, the potential for nutrient loss. A number of studies in New Zealand show how nitrate leaching losses progressively increase as N inputs to the grazed system, usually via fertiliser, increase. Two major inefficiencies in the cycling of N in grazed pastures and the conversion into product-N are: 1) the high protein content of pastures compared to the dietary requirement of grazing animals; and 2) the high concentration of excreted N in urine patches (delivering equivalent loads of up to c. 1000 kg N ha⁻¹). A large amount of research in New Zealand and overseas over the past three decades has clearly shown that the amount of N excreted by animals, and in particular urine N, is the most important determinant of N losses including leaching, run-off and gaseous losses from pastoral farms. Consequently, the amount of N excreted by animals is the primary driving factor of N losses rather than inefficiencies related to N fertiliser usage. The amount of N excreted is closely tied to the amount of N consumed by the animals which, in turn, is broadly related to the animal stocking rate. The main effect of fertiliser N use on N cycling efficiency in grazed pastures is an indirect one, whereby N fertiliser inputs allow for an increase in pasture production, animal stocking rate and thus urine N excretion. The relationship between N losses and stocking rate is closer for sheep and beef farms because of the relatively small variation between farms in external N inputs, whereas on dairy farms there is a wide variation in external N inputs and in per-cow production and intake of feed-N (eg. approximately three-fold). Thus, stocking rate (animals ha⁻¹) is only a crude proxy for the magnitude of N loss to the environment for a dairy farm. However, if all other things remain equal, nitrate leaching losses can be expected to increase as stocking rates increase.
12. Sources of P losses from dairy farms tend to vary more than for N. Phosphorus losses depend heavily on spatial factors and the type of management practices employed on farm, such as how effluent or manures are handled, and the degree of protection of streams banks and stream beds from erosion and animal treading. Phosphorus losses from intensively grazed pastures arise from dissolution and loss of particulate material from the soil, washing-off of P from recently grazed pasture plants, dung deposits and fertiliser additions. All P losses, except those from fertiliser additions, are influenced by the action of grazing, whether it is the ripping of pasture plants or the influence of

treading on soil erosion and surface run-off potential. Clover-based pasture dairy systems typically have relatively large P fertiliser requirements to maintain adequate soil P fertility for optimum clover growth. Of the P recycled via the grazing cow, most is excreted in dung and in a soluble form. Dung therefore represents a concentrated form of readily available P that can have a large impact on surface water quality if voided directly into water. Therefore, stock access to streams, effluent pond treatment systems, and effluent/manure applications to land are key land management practices that can potentially contribute substantially to farm P losses. Overland flow processes can also make a large contribution to the total P lost from dairy farms, unlike N. Although overland flow volumes are usually small relative to the volumes of water discharged in sub-surface drainage, the entrainment of soil and dung P in this flow makes it a concentrated source of P and other potential stream contaminants, such as ammonium-N and faecal micro-organisms. Despite much research on P loss from agricultural soils, the contributions from overland flow sources are still difficult to define because of problems associated with spatial and temporal variability, making sampling and measurement of flows under field conditions very difficult. Current understanding suggests that near stream areas are important sources of overland flow, as are areas of land underlain by artificial drainage systems, which act as direct conduits between soil and stream.

Mitigating N and P losses

13. A number of GEPs that mitigate the impacts of farming systems on water quality have been identified and documented in the scientific literature. These measures target the following broad areas where reduced nutrient losses or water quality improvements have been demonstrated through the use of these GEPs:
 - i. Balancing nutrient inputs and outputs at field and farm levels, eg. nutrient budgeting. The OVERSEER[®] nutrient budgeting program (hereafter referred to as OVERSEER) is a tool that has been developed to assist with such planning decisions. It accounts for nutrient flows into and away from farm blocks in fertiliser, feed, animal transfer, animal product and via loss pathways such as leaching and volatilisation. The planning objective is to ensure that nutrient inputs and outputs are balanced to avoid situations of deficit or surplus.
 - ii. Improved farm dairy effluent (FDE) management practices. These include pond storage provision, low-depth applications, low-rate application tools and improved scheduling of applications based on farm-specific monitoring information (refer also to the evidence by Dr David Houlbrooke).

- iii. Stock exclusion from streams and riparian margins, and riparian planting for shade and habitat values.
- iv. Improved fertilisation practices. Although direct losses of nutrients from fertilisers applied to pastures are usually small, relative to amounts lost from other sources such as soil and dung, these losses can be significant on some landscapes if applications are not carefully managed. Practices that consider the form, quantities and timing of fertiliser applications can help to avoid these “incidental” losses of fertiliser nutrients eg. using low solubility P fertiliser forms, split applications to match short-term plant demands, and scheduling applications for months when the risk of runoff events occurring are relatively low.
- v. Improved utilisation of dietary N and P. Within a New Zealand context, this is most relevant to mitigating N losses, where inclusion of a low N feed in the diet, such as maize or cereal silage, has been shown to reduce excretal N output and consequent N losses.
- vi. Manipulating the timing of excretal deposition. Studies show that there is a greater risk of nutrient losses from excreta deposited shortly before surplus autumn-winter rains arrive. Therefore, a number of strategic grazing regimes have been trialled to see if losses can be decreased by reducing the amounts of excreta nutrients deposited during these critical periods. By using stand-off and/or winter pads to remove animals from pastures at these times, significant reductions in nutrient losses to water have been demonstrated.
- vii. Intercepting P, sediment and FMOs in farm run-off. A wide range of systems for attenuating or “capturing” contaminants in drainage or stream flow have been trialled within a New Zealand context. These include constructed wetlands, grass buffer strips, the placement of nutrient-absorbing materials in flow pathways, harvesting of nutrients contained within water crops such as watercress, and the use of impoundment structures.
- viii. Introducing nitrogen process inhibitors to the soil or animal. This area is the subject of much on-going research in New Zealand. The most promising of these technologies is the use of dicyandiamide (DCD), which inhibits the transformation of ammonium (NH_4^+) to nitrate (NO_3^-) in soil. In contrast to nitrate, ammonium is usually retained in the soil because of cation exchange reactions; it is thus less subject to losses in drainage. Although much is still unknown about this technology, grazing systems studies in Southland indicates that strategic applications of DCD targeting animal urine patches that are deposited close to periods when drainage occurs, can reduce N leaching losses from grazed pastures by up to 55%. Due to the warmer temperatures in the Manawatu province, its effectiveness is likely to be less than observed in Southland, although

it is probably still one of the more cost-effective N mitigation technologies currently available to farmers in Horizons' Region.

How effective are these non-regulatory alternatives for mitigating P and N losses?

14. The effectiveness of individual GEPs depends on factors such as soil type, topography, climate, land use, and farm management system. Thus, there is usually no “one size fits all” approach to mitigating N and P losses from farms, as these factors need to be considered on a farm-specific basis.
15. However, research has shown that certain land use practices can potentially result in large transfers of P, N or faecal micro-organisms (FMOs) from soil to water, particularly if practised on landscapes that present some level of inherent risk. Poor management of FDE applications to land is an obvious example of this: studies conducted in Manawatu and Otago have shown large transfers of these contaminants in mole-pipe drainage following FDE applications that exceeded either the soil's water holding capacity or its infiltration rate.
16. Adherence to some GEPs that addressed issues of FDE storage, application depth and/or application rate were estimated to reduce farm-scale P and FMO losses from dairy farms in the Bog Burn catchment, in Southland, by approximately 30% and 78%, respectively. This and other research has supported the development of Regional Council policy and guidelines that provide options for farmers to avoid direct losses of FDE from soil to water. Although problems remain concerning the effective implementation of these guidelines, the knowledge exists at a technical level, to manage FDE in a way that ensures direct run-off losses are avoided.
17. Case study analyses based on four intensively farmed catchments in New Zealand provide some estimates of the likely effectiveness of some key GEPs relevant to dairy farms in these contrasting catchments (Monaghan *et al.*, 2008). The catchments were: Toenepi (Waikato); Waikura (Taranaki); Waikakahi (Canterbury); and Bog Burn (Southland). For these particular case study examples, some of the key farm management practices for reducing diffuse losses of nutrients to water were:
 - i. Applying the nitrification inhibitor dicyandiamide (DCD) to pastures. This was projected to reduce losses of N in drainage by 9-30% for the model farms evaluated.
 - ii. Wintering pads also appeared to be an effective management system for dairy farms in the catchments, reducing drainage N losses by 10-30%. Combined with

- restricted grazing protocols during autumn (assumed four-hour grazing times), the use of these pads during autumn and winter was estimated to reduce drainage N losses by up to 55%.
- iii. Low N feed supplements and low fertiliser N input management systems were other management strategies that were projected to reduce N losses in drainage from dairy farms by 13-40% and 29-36%, respectively. However, relative to the options described immediately above, these management strategies were often the least cost-effective (ie. net cost per kg of N leaching reduction, \$ per kg N) approach for mitigating farm N losses in drainage.
 - iv. Reducing fertiliser P inputs, and thus soil Olsen P values, to their economically optimum levels was the most cost-effective strategy for reducing losses of P to water for these model farms. Based on modelling using the OVERSEER nutrient budgeting model, this was projected to reduce P losses by 7-37%, depending on the catchment.
 - v. Improved management of FDE was estimated to deliver reductions in farm P losses of 10-55%. The greatest reductions were estimated for farms with poor-draining soil types and where little or no FDE storage was available.
 - vi. Irrigation wash from border dyke-irrigated land in the Waikakahi catchment in South Canterbury was calculated to contribute approximately 70% of annual P losses to water from dairy farms. Improved irrigation practices, such as bunding, re-levelling or greater precision with watering times were estimated to reduce approximately farm P losses by approximately 50%.
18. Estimates of the effectiveness and relevance of many of the GEPs currently available for mitigating contaminant losses from farms to waterways in Horizons' Region can be assessed using the OVERSEER model. As the model is upgraded on a regular basis, this tool captures our current understanding of how effective mitigation practices are at a farm scale. In the case of P, OVERSEER produces an estimate of P loss risk that is the combined loss risk factors for soil, fertiliser and effluent sources (Figure 1). The calculated risk is a reflection of total P loss risk from in-field sources and does not account for erosion as a source, other than the sediment-bound P carried in overland flow and subsurface drainage. Bank erosion and direct deposition of dung-P to streams are also not included in the combined P loss risk factor. It is important to recognise that, strictly speaking, the block P loss estimate reported in the OVERSEER nutrient budget is a risk assessment index rather than a predicted load, although the index does correlate reasonably well with measured loads for the limited number of sites for which good data is available (refer Figure 2). A more accurate assessment of farm-specific losses requires a more detailed consideration of hydrology to better define contributing

areas and also consider those other sources mentioned above (eg. erosion, stream sources etc). However, without input from specialist expertise, it is difficult for land managers to characterise the hydrology of farms and contributions from erosion. The risk framework partly overcomes this difficulty by incorporating weighting factors for soil, slope, and management attributes, all of which have been shown to have an important influence on P losses from grazed pastures. Of the soil attributes, Olsen P level and soil type have the greatest influence on predicted soil P losses. In broad terms, higher Olsen P levels will increase the soil P loss risk estimate. Low soil P retention values and high soil structural vulnerability will further increase this loss risk. In effect, this means that some soil orders, such as Pallics, are inherently “leakier” for P because they tend to be more prone to compaction (ie. have a high structural vulnerability) and often have relatively low P retention values. In contrast, most of the Allophanic soils have a low soil P loss risk because of their high P retention values and low structural vulnerability. These features are embedded within the OVERSEER model (Figure 1), as are a range of mitigation options that modify the P loss risk estimate (see text box). Most of these options are also discussed within the context of Horizons’ Region in the hearing evidence of Dr Roger Parfitt. Together with assessments of the economic costs of these mitigations, they are also captured in the BMP Toolbox that has been recently developed (Monaghan, 2009). It is intended that this Toolbox functionality will be offered for incorporation into future releases of the OVERSEER model, as well as being available for expert farm systems modellers and users.

OVERSEER P mitigation options:

- i. Soil Olsen P kept to the minimum required for economically optimal production.
- ii. Soluble P fertilisers applied when transport risk is low (typically late spring until early autumn).
- iii. Low solubility P fertilisers used where/when transport risk is high.
- iv. Effluent storage during wet conditions
- v. Low-rate and/or low-depth effluent application methods used on soils with low infiltration rates or artificial drainage.
- vi. Border dyke wash volumes kept to a minimum.
- vii. Full effluent containment around feed pads and stand-off pads.

19. There is a relatively high level of uncertainty attached to the estimates of mitigation effectiveness for some of the mitigations available within the OVERSEER model. The use of nitrification inhibitors is such an example; although much plot scale research has been published concerning the effectiveness of DCD at reducing nitrate leaching losses,

much less research has been done at a grazing systems level, and under the range of temperature and rainfall conditions found in Horizons' Region. The ability of some attenuation technologies, such as constructed or facilitated wetlands, to intercept and treat drainage flows from farms is another example where a relatively high level of uncertainty is attached to estimates of mitigation effectiveness.

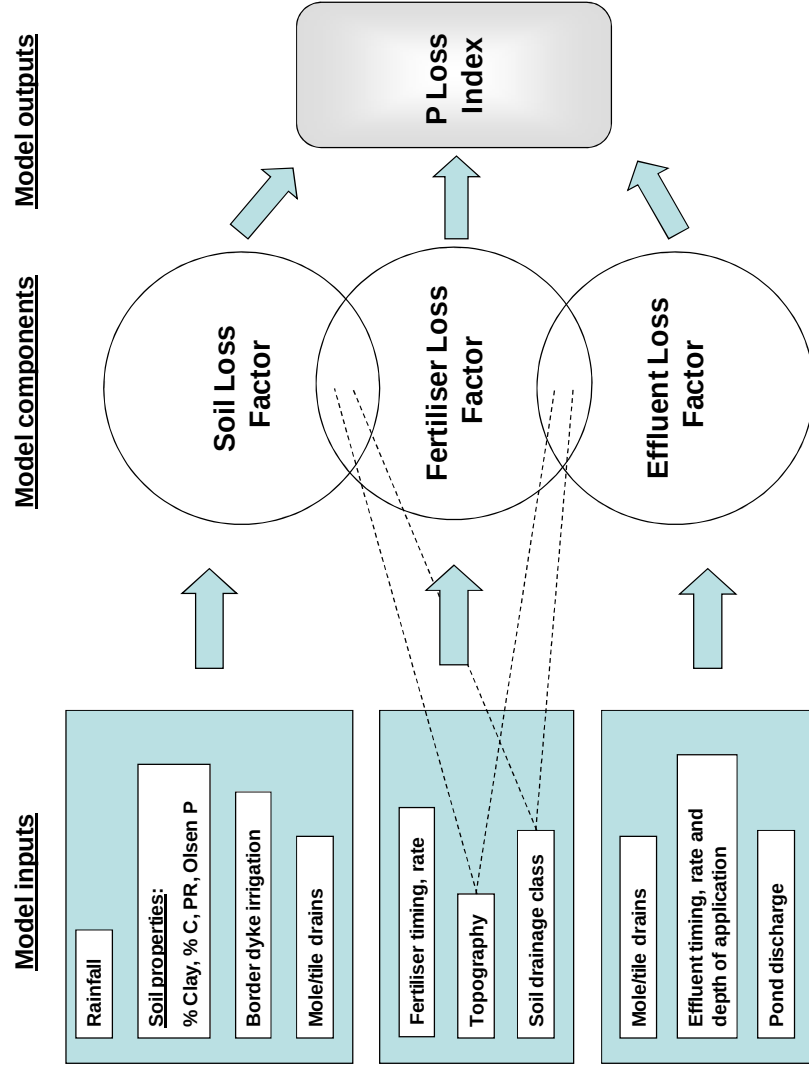


Figure 1. Conceptual diagram of OVERSEER P loss model (from McDowell *et al.*, 2005).

How much do these mitigation measures cost?

20. As noted for the effectiveness of individual GEPs, the cost associated with each GEP can also vary considerably, depending on factors such as farm management system, soil type, topography, climate, and land use.
21. Two cost components are of importance to those outlaying the expenditure: 1) the capital cost required for each mitigation practice; and 2) an assessment of the annualised cost associated with the use of the mitigation. The latter incorporates annual cost components for the opportunity cost of capital (8%), depreciation, maintenance, additional labour and feed, and revenue foregone as a result of land lost to production.

This annualised cost is also informative when comparing against the profitability of any particular enterprise.

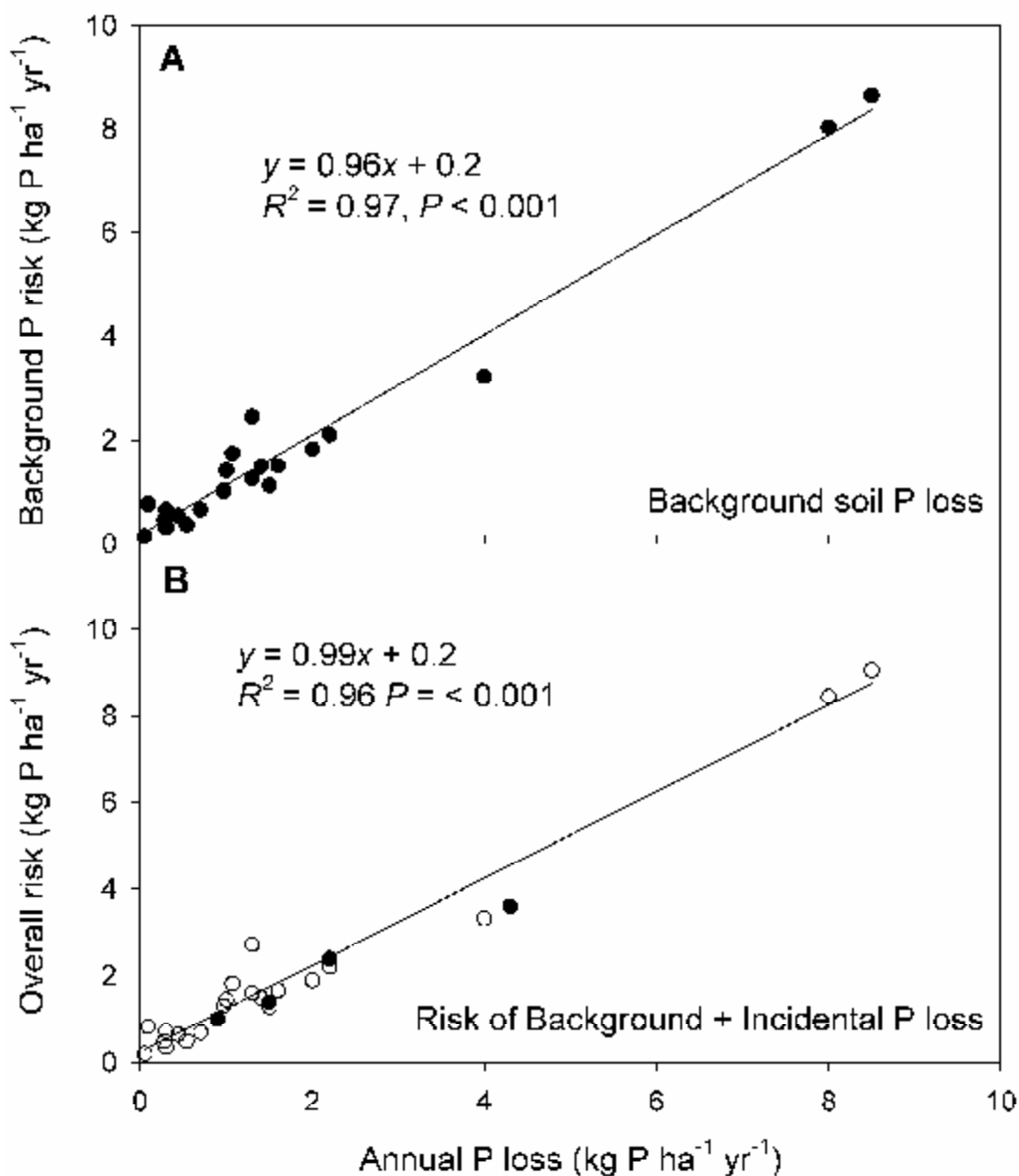


Figure 2. Relationship between (A) measured and estimated background losses of soil P, and (B) estimated overall risk of P loss, and measured annual P loss for field studies with (filled circles) and without (open circles) much incidental P loss (McDowell *et al.*, 2005).

22. Indicative costings for some GEPs have been detailed in recent literature (Monaghan *et al.*, 2008; Monaghan, 2009). Some of the key GEPs relevant to Horizons' Region are shown in Table 1 for illustrative purposes. Again, it is stressed that these figures are

provided to illustrate some of the likely potential costs incurred when a GEP is adopted; because of the diverse array of potential management responses to the adoption of some of the GEPs, cost-benefit analysis needs to be undertaken at the level of the individual farm to gain a more accurate assessment of the full economic costs associated with each GEP.

23. To elaborate on this important point, the case of adopting a winter shelter provides an example of how management responses can influence an economic analysis. One simple scenario is that such a shelter is purchased and used only for the winter period as an alternative to wintering cows in paddocks. A second scenario is that the winter shelter is also used as a feeding platform, to allow for greater use of purchased supplement during the lactation season, thus increasing both on-farm costs (via feed and labour costs) as well as milk revenue. A third scenario could be that the shelter is additionally used for extending lactation into late autumn and early winter, further increasing both costs and revenue.
24. Cost-benefit analyses of some of the GEPs relevant to dairy farms in the four catchments described above provide additional estimates of the costs incurred when mitigation practices are implemented (Monaghan *et al.*, 2009). For the farms in the Waiokura catchment (Taranaki), the study catchment closest to Horizons' Region, some of the cost implications at an assumed payout of \$4.50 per kg of milk solids were:
 - i. Use of the nitrification inhibitor dicyandiamide (DCD) was projected to be the most cost-effective GEP for mitigating N losses, delivering an estimated net benefit of approximately \$150 ha⁻¹year⁻¹.
 - ii. Adopting a nil N fertilisation policy or a restricted autumn grazing system were both estimated to incur a net annual cost of \$50-70 per hectare.
 - iii. The substitution of N fertiliser for low N feed and the use of wintering pads were the most costly N mitigation strategies evaluated, incurring estimated net annual costs of \$150 and \$390 per hectare respectively.
 - iv. Reducing fertiliser P inputs, and thus soil Olsen P values, to their economically optimum levels on farms was the most cost-effective strategy for reducing losses of P to water, delivering an estimated net benefit of approximately \$70 ha⁻¹year⁻¹ over a 10-year period.
 - v. The adoption of a deferred effluent irrigation management strategy to reduce farm P losses was estimated to incur a net annualised cost of approximately \$25 ha⁻¹.
25. Stream fencing costs were not considered in the above case study analyses. With an assumed stream density in the Waiokura catchment, in Taranaki, of approximately 32

metres ha⁻¹ and using the annualised cost figures contained in Table 1, the estimated annualised cost of fully fencing both sides of the streams on dairy farms in the catchment would be between \$16 and \$44 ha⁻¹ if it was assumed that no stream fencing currently existed. However, field surveys indicate that many of the stream lengths within the Waikura catchment have already been fenced to exclude stock.

How effective are non-regulatory methods generally at reducing contaminant losses from farms?

26. This complex question is the focus of ongoing research being conducted within the programme funded by FRST (Foundation for Research, Science and Technology), Enhancing water quality in managed landscapes (FRST contract C10X0320). However, based on this ongoing research and other published work, we can draw some conclusions regarding some key issues relating to the adoption of Good Environmental Practices (GEPs) on farms:
 - i. Farmers will make changes if there is a benefit to them.
 - ii. What is of benefit to farmers depends a great deal on the context in which they farm, and their goals.
 - iii. Environmental considerations generally do not drive adoption of GEPs; logistics, economics and the development of “symbolic” or “cultural” capital are instead important.
 - iv. Generally, a combination of voluntary and regulatory approaches is required for optimum uptake of GEPs.
27. Research studies inform us that GEPs are adopted by farmers when there is a demonstrated benefit to doing so. Benefits can include both financial and non-financial considerations. Objectives of publicising good land stewardship, improved relationships with neighbours, and demonstrated compliance with environmental regulations have been identified as some of the important non-financial factors influencing farmer adoption of GEPs or Environmental Farm Plans (EFPs).

Table 1. Indicative capital and annualised costs for some GEPs relevant to farms in Horizons' Region. Cost assumptions derived from Monaghan (2009).

Mitigation measure	Capital cost	Annualised cost estimate, \$ ha ⁻¹ year ⁻¹ (unless otherwise indicated)
Nitrification inhibitors (DCD)	Nil	Dependent on land use, soil type, climate; can typically range from a net benefit of \$150 to a net cost of approx. \$120.
Winter shelter (dairy)	Typically \$500-2000 per cow	Can range between nil and \$500
Avoiding fertiliser applications during high-risk drainage months	Nil	Minor
Stand-off pads (dairy)	Typically \$100-200 per cow	\$50 - \$100
Substituting N fertiliser with a low N feed (dairy)	May require construction of a feeding pad and/or purchase of a feedout wagon	Can range between nil and \$500; very dependent on payout and price of low N feed
Nil N fertiliser	Nil	Varies according to product prices, cost of N fertiliser, etc.; mostly incurs a significant net cost though.
Constructed wetlands	\$800 per ha of "treated" farmland, assuming 1% of farm area taken out of production	\$100-120
Effluent storage ponds	\$35-100+ per cow depending on pond lining requirements	\$20+
Low-rate effluent application	\$14-20 per cow (not including cost of storage ponds or drying beds)	\$10-16, depending on type of applicator used (K-line pods usually the cheapest option)
Stream fencing	Dairy: \$2-6 per m Sheep: \$10-16 per m Deer: \$12-20 per m	Dairy: \$0.25-0.70 per m Sheep: \$1.10-1.80 per m Deer: \$1.30-2.00 per m
Reduced shed water use and effluent volume generated, eg. "Dungbuster"	\$5 per cow	Typically less than \$5

28. However, overseas studies also indicate that the voluntary uptake of some GEPs or EFPs can be limited. Cited impediments to the wider adoption of improved practices include lack of time and money (particularly for smaller farm units), the excessive documentation associated with some EFPs, risks of disclosure of potentially incriminating information, and uncertainty about the environmental and economic impacts of adoption.
29. Experiences in Europe suggest that many agri-environmental measures may not be effective in inducing permanent change in farmers' attitudes and behaviours. By being too prescriptive and designating specific areas for agri-environmental work, it is suggested that schemes often fail to allow farmers to develop or demonstrate skilled role performance, thus inhibiting the development of what they term "embodied cultural capital". The implications of this are that if voluntary schemes are to be effective in changing long-term behaviour, they need to: 1) allow for innovation in how conservation practices can meet specific conservation goals; 2) include a component that allows farmers to learn through experience the connection between management skills and environmental outcomes; and 3) limit the use of designations of specific "conservation" areas. The latter can encourage the dislocation or separation of environmental and production goals, which is not helpful for learning and improving long-term behaviours. These findings implicitly suggest that behaviour change is a continual and long-term process.
30. It should also be recognised that it is very difficult to verify the rates of adoption and effectiveness of individual GEPs. Within a New Zealand context this is likely to apply to both regulatory and non-regulatory GEPs, where many are practically very difficult or extremely costly to monitor.
31. The balancing of nutrient inputs and outputs at field and farm levels is an example where New Zealand farming can justifiably claim a relatively high level of success in terms of adopting efficient nutrient management procedures. In contrast to many intensive livestock systems abroad that generate large amounts of animal excreta, which are often returned to relatively small areas of land, the nutrient value of farm effluents and imported feedstuffs is now widely recognised in New Zealand agriculture. With the help of nutrient budgeting tools such as the OVERSEER model, the nutrient contents of these materials are usually recognised and factored into farm fertilisation programmes, to ensure that annual nutrient loadings to individual paddocks are not excessive and losses are thus minimised. A number of voluntary and regulatory responses by stakeholders have likely contributed to this success. Of the former, some

of the key factors that have helped to increase adoption of “Good Practice” are: (1) recognition of the economic value of farm effluents; 2) the availability of the OVERSEER nutrient budgeting tool to assist with planning decisions; and 3) the extension support offered by the main fertiliser companies when preparing farm fertilisation programmes. The insistence by most Regional Councils that effluent N loading rates do not exceed certain thresholds, and the inclusion of nutrient budgets as a component of the Clean Streams Accord, are two examples where regulatory approaches have further supported the adoption of systems to manage farm nutrient inputs and outputs.

32. The Clean Streams Accord is the most obvious example of a farmer-focused scheme that has been established to improve the environmental performance of farmers, in this case those that supply to Fonterra, New Zealand’s largest milk company. The Accord sets out five targets for farms, dealing with: stream fencing and crossings, wetland protection, and effluent and nutrient management systems. While it is unclear whether this scheme can be defined as a regulatory or non-regulatory approach (it can be argued it is a mix of both), reporting to date highlights a number of interesting points that are relevant to this discussion concerning the effectiveness of non-regulatory methods (MAF, 2009):
 - i. With the exception of effluent compliance, there has been a progressive increase in the proportion of farms compliant with the scheme’s targets, eg. cattle are now excluded from water bodies on 78% of farms; 99% of farms now have a system in place to manage nutrient inputs and outputs; and only 2% of Accord-type crossings remain unbridged or unculverted. This indicates that good on-farm progress has been achieved with the scheme, probably due in part to: 1) the leadership shown by the industry; and 2) the “do-ability” of some of the easier measures, such as having nutrient management systems in place or fencing off streams.
 - ii. Levels of effluent compliance remain low relative to the goal of 100% compliance, at 70% overall, a figure deemed unacceptable by the scheme’s signatories (Fonterra, MAF, MfE and Local Government NZ). Some of the factors that are likely to contribute to this low compliance rate are: 1) the apparent complexity of the issue (eg. some soils are at much greater risk than others; 2) matching the appropriate technology to soil types; 3) the costliness of some of the mitigation measures required (eg. storage ponds or improved effluent applicators); and 4) the lack of readily-apparent visual cues that improved management is required.
33. It should be noted that the Clean Streams Accord only addresses some of the obvious land use practices that are known to impact on water quality. It does not specifically

address some of the other key sources of nutrients lost from farms to water bodies, such as N from animal urine patches, or P, sediment and FIOs contained in artificial subsurface drainage flows or surface run-off. Therefore, the Accord can be viewed as an important first step on the path to improving farm environmental performance, but it may not go far enough to meet local targets for catchment water quality. Accordingly, the relevant industry partners recognise the need for using nutrient management tools as part of a wider next step towards implementing comprehensive nutrient management plans. An important step in developing such plans will be the process of identifying nutrient loss targets that are relevant to local catchment water quality concerns and objectives. Until recent policy developments concerning lake catchments in the central North Island, it had generally been the case that there were very few, if any, limits on nutrient losses from diffuse (ie. farming) sources.

34. Other than the obvious sources captured within the Accord framework (ie. effluent and direct deposition by grazing animals), it is currently difficult to accurately define where and how much P is lost from farmed landscapes. This knowledge gap is likely to hinder the development of regulatory tools focusing on managing diffuse sources of P, as have been developed for N.
35. The implications from the above points are that: 1) voluntary adoption of GEPs will occur where there is a congruence of farmers' economic, environmental and social or cultural goals; and 2) where such a congruence does not occur, adoption rates will be slow without some mix of regulation and enforcement, industry direction and education/communication.

Some suggested approaches for minimising pollutant leakages from farms

- i. Because environmental considerations are generally not a major driver of farmer decision-making, GEPs will also need to be 'sold' based on other attributes, eg. improved farm logistics and/or profitability; perceived superior performance; ancillary benefits such as aesthetics, increased farm values; etc.
- ii. It appears likely that a combination of voluntary and regulatory approaches will be required to ensure that currently recommended GEPs are implemented on farms. This recognises that, while many land managers are proactive regarding the adoption of agri-environmental measures, others are not and will require some incentive to change behaviour.
- iii. The targets set within the Clean Streams Accord would appear to be the most obvious GEPs to prioritise and implement. These targets are clearly defensible, address many of the key on-farm sources of water pollutants, and incur relatively little cost. Further work is probably required around defining some of the specific goals and policy statements that address effluent management systems.
- iv. It will be important that a greater extension effort is coupled with the promotion and implementation of GEPs. This will require the development of much greater capability than currently exists in New Zealand.

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Attachment B

An overview of the stages of development of the pastoral nitrogen risk assessment tool

