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); Waiokura (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.

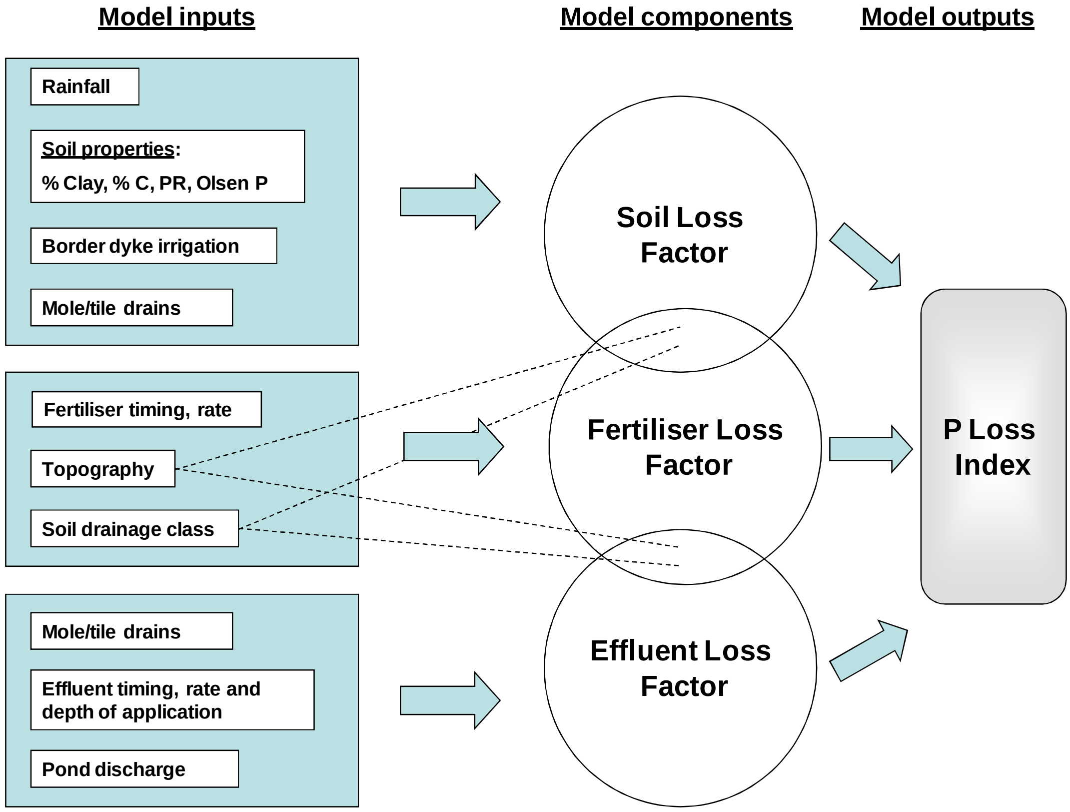

Figure 1. Conceptual diagram of OVERSEER P loss model (from McDowell *et al.*, 2005).

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.

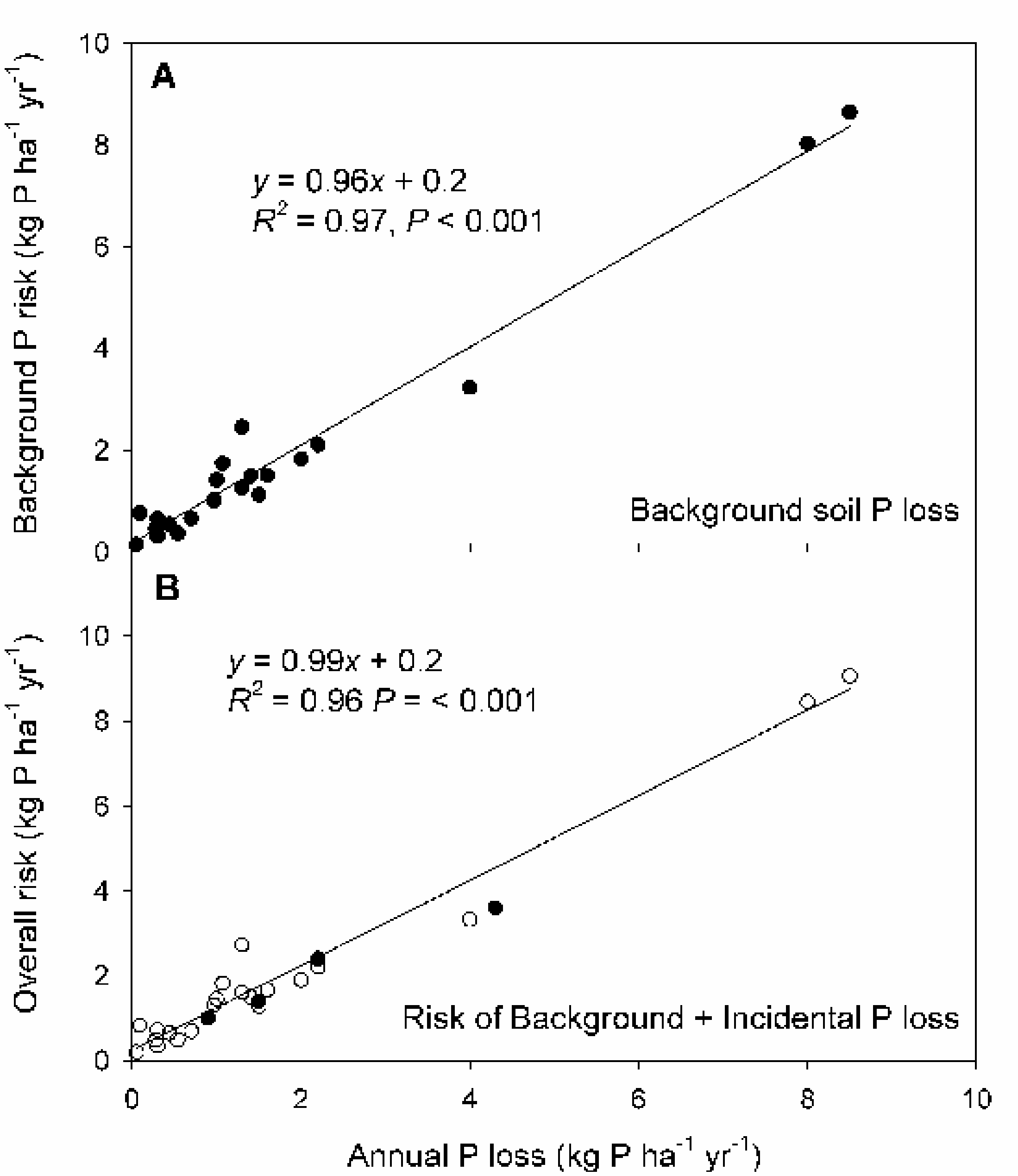

Figure 2. Relationship between (A) measured and estimated background losses of soil P, and (B) estimated overall risk of P loss, and measured annual P loss for field studies with (filled circles) and without (open circles) much incidental P loss (McDowell *et al*., 2005).

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 $ha^{-1}year^{-1}$.

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 $ha^{-1}year^{-1}$ 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 Waiokura 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 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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