BEFORE THE INDEPENDENT COMMISSIONERS

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the Proposed Variation 1 to the Proposed Canterbury Land and Water Regional Plan

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EVIDENCE IN CHIEF OF DR ALISON DEWES ON BEHALF OF NORTH CANTERBURY FISH AND GAME COUNCIL AND THE ROYAL FOREST AND BIRD PROTECTION SOCIETY

September 2014

North Canterbury Fish and Game Council

Environmental Advisor – Scott Pearson

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1. My name is Alison Dewes.

2. I am presently Lead Consultant for Headlands, a consultancy company based in Te Awamutu, focussed on developing farm systems for optimal profit while minimising farming's environmental footprint. Headlands is undertaking several projects in the Upper Waikato specifically focussed on understanding which farm systems have the highest profit and lowest environmental footprint. I undertake farm analysis and strategy design plans using UDDER, Farmax Dairy Pro, Red Sky and Overseer. Headlands main role is the application of whole farm planning services for agriculture in sensitive catchments.

3. I am a registered veterinarian and hold a practising certificate. I hold a BVSc from Massey University (1987). I am presently undertaking a Masters in Biological Science (Ecology) at Waikato University.

4. My higher education in the past decade has included the following courses: A) Intermediate Nutrient Management (Massey 2009) B) Advanced Nutrient Management Course (Massey 2009).C)Farm Dairy Effluent System Design and Management (Massey 2012). E)Business Lending Fundamentals: Developing Client Relationships and Negotiate Client Solutions: Tier 111 registration for Agribusiness, Commonwealth Bank of Australia 2007; F)In Calf Training, Certified 2006;G) Certified Adult Trainer, Melbourne 2004;H)Dairy Leadership Course Melbourne 2004;I)Advanced Dairy Nutrition, Australia 1999;J)Dairy Nutrition Course, Lean, Massey 1990;K)Soils and Pastures Course, Massey 1993; L)Milking Machine Testers Course, Flockhouse, 1992.

5. I practised as a dairy and equine veterinarian in Waikato from 1987 to 1997 and was also a Director of Hamilton Analytical Laboratories (Consultants in Animal Nutrition and Applied Science) over that time.

6. My parents family established a dairy farm at Ellesmere, then at Deep Spring in Leeston. I am a fourth generation farmer and spent 20 years dairy farming in New Zealand and Australia with my husband. We sharemilked in the Waikato then bought and developed three pasture-based dairy and support farms in Victoria Australia over the 2001 to 2008 period. One was irrigated.

7. In the period from 1997 to 2001, I held a position in Milk Procurement, for Nestle, in Warrnambool, Western Victoria, Australia. During this time, I was involved in the development of the "on farm quality assurance programme" for Nestle Australia.

8. In 2001, I took over as Business Development Manager for Intelact in Australia. The business services were based on full farm analysis for intensive pastoral farms, businesses faced with reconfiguration of systems as they faced major constraints on their surface and ground water allocations. This challenge was amplified by two major droughts occurring between 2002 – 2007.

9. In 2006, I became Agribusiness Lender for the Commonwealth Bank of Australia and was heavily involved in the appraisal and risk assessment of new farm businesses for the bank.

10. In 2009, I returned to New Zealand, I was contracted to Agfirst at this time, and undertook the Upper Waikato Nutrient Efficiency Study. As part of that study, I analysed more than 380 overseer files for eco efficiencies for MAF farm monitoring during 2009 and 2010.

11. I have been an expert witness for the Horizons One Plan, the proposed Canterbury Land and Water Plan (2013), the recent Tukituki River Catchment Plan Change 6(2013), and the South Waikato District Plan Change.

12. I hold a part time consultancy role as Sustainable Land Use Advisor to Raukawa Charitable Trust in the Upper Waikato.

13. I am a professional member of the NZVA, NZIPIM & NZFWSS.

14. In preparing this evidence I have reviewed: Variation 1 to CLWP, Section 42a and the zip addendum along with all technical papers referenced and in the footnotes

Expert Witnesses Code of Conduct

15. I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

SCOPE OF EVIDENCE

16. I have been asked by Fish and Game to prepare evidence in relation to the proposed Canterbury Land and Water Plan. This includes:

    a) Context/ Background

    b) Changing Landscape in Canterbury

    c) Externalities of Concern in Vulnerable Landscapes

    d) What are GMP – Overseer already assumes a lot of GMP.

    e) Overseer Assumes a lot of GMP already in place

    f) Changing farm systems – last decade

    g) Mitigations for Dairy Farming To Reduce N Leaching – Irrigation

    h) Farm System Reconfigurations to Reduce N Leaching

    i) P Mitigations

    j) Approaches to managing land use in the region.

k) References.

l) Appendices

EXECUTIVE SUMMARY

17. The Selwyn te Waihora catchment is currently over allocated. This over allocation creates risk for both business and the environment. This risk arises from a failure to adequately account for the current degradation of freshwater resources and appropriately allocate ecosystem (assimilation) services provided by the catchment with a robust regime underpinned by robust ecological monitoring and adaptive management.

18. The Zone Committees Solution Package, adopted in Variation 1, seeks to allow expansion and intensification while at the same time attempting to achieve catchment wide improvements. This requires careful evaluation as no irrigation schemes have actually managed to make improvements at the same time as intensifying (i.e.: adequate mitigations/reductions to counteract the net increases in discharges).

19. In order to assess this approach it is necessary to consider the proposed expansion and intensification and evaluate what can be achieved through improved management practises. These issues need to be considered in the light of the regulatory framework, including the Freshwater NPS, which contains an objective (A2(c)) to improve water quality in over allocated water bodies and a policy (A1(b)) to avoid over allocation.

20. After proposed expansion and intensification and improvements in management practise are taken into account, Variation 1 provides for a 20 %[1] increase in the catchment load as set out in Table 1 between current load and 2017.

Table 1: Loads used to advise the Variation. Source - Melissa Robson email 12 Aug 2014.

	2011 (current)	2017	2022 and beyond, to be met by 2037
Total CPW (includes dairy support)	1500	1,944	1,741
Total non CPW	2910	3,366	2,970
Catchment agricultural total	4530	5,429	4,830

21. This increase in load does not appear to be consistent with the objective to improve water quality in over allocated water bodies. Water quality will deteriorate. An increase in the load also appears inconsistent with the requirement to establish methods to avoid

[1] I have had to to assume that if 1500 T is the present load on 45000 ha(new dairy plus dairy support proposed CPW) then this equates to 43 kg N leached per ha per year – this seems very high for unirrigated land. In the absence of knowing this answer (Melissa Robson from ECan would not communicate with me in the final week of preparing this evidence, I have had to assume this is current/in place. This means the net increase to 2017 has to be assumed to be from a total catchment load of 4530 to 5429 which is only a 20% increase rather than a 35% increase. .

over allocation. The increase in load will result in additional over allocation that will exacerbate, not avoid, the over allocation issue.

22. The additional load is allocated to CPW, which has been allocated a load of 1,944 in 2017. In addition to the issues that arise regarding the NPS, there are significant equity and risk issues for established farmers who make up the current load (modelled to be 3,366 in 2017, from Overseer). Variation 1 proposes that established farmers in the lower Selwyn catchment are required to lower their total N loss to the tune of approximately 20% initially as GMP is implemented, and a further 30% between 2022 and 2037. However, a new entrant under CPW can potentially leach up to 80 kg N per ha per year. This raises both economic and equity issues.

23. Is it an efficient use of the resource to require expensive mitigation on soils that have superior assimilative capacity to attenuate discharges from dairying, while allowing significant expansion on soils that do not?

24. Why should an established farming operation be forced to undertake significant and expensive steps to reduce nitrogen losses, when new entrants are allowed to leach significantly more nitrogen. The over allocation of new assimilative capacity (that doesn't actually exist) will penalise the best farmers not once – but twice. This occurs as the best farmers have already been allocated a low N loss right through a grand parenting regime in the CLWP which rewards the polluter, and penalises the innovator. Further to this, they are now expected to drop further, from a BMP position, to facilitate the allocation of an already "over allocated ecosystem service".

25. A possible outcome from this situation is "stranded capital" on new and existing farms in the future. An almost inevitable result of the provision of an additional 1944 tonnage of nitrogen in an already over allocated catchment is an "overshoot" of ecological capacity. This may result in more painful claw-backs in the future.

26. In terms of possible improvements in management practises, there are a range of mitigations and changes to farming practices that can have a significant effect on achieving water use efficiency, and reducing contaminant losses to water including N and P losses. There are numerous examples of farmers and studies reducing N loss by 20-60% in both actual and observed cases. However, significant reductions can put some businesses at risk if they are forced to change in a short time. Hence, careful allocation of ecosystem services aligned with legitimate ecological monitoring regimes; along with applying a precautionary principle at the outset of this plan given current uncertainties and risks, is just part of "good business planning".

27. Other issues that arise from Variation 1 include the use of Overseer and consideration of P.

28. Variation 1 relies on Overseer to determine catchment load. The use of Overseer raises issues regarding good management practice and its use on coarse and stony soils:

29. Good management practice: Overseer already assumes many good management practices are in place, so just implementing these assumptions will have no effect on total N loads. Examples include: no connectivity of effluent to ground or surface water, effluent applied only via precision irrigation methods, all streams and waterways protected from stock and soils and crops managed to avoid critical source area loss.

30. Validation required on course and stony soils: I consider Overseer is generally fit for purpose to indicate nitrogen loss risk from a land use activity (dairy, dairy support, sheep and beef intensive, sheep and beef extensive, deer) providing that the actual farm data is used and soil types and irrigation methodology is able to be validated. However, I concur with Carrick et al (2014) that validation of the model for dairying on coarse and stony soils is urgent to allow continued legitimate use of the tool.

31. The Zone Committee Solutions Package assumes no additional P is added to the catchment, and all pathogens are able to be adequately attenuated at the source or destination point. I consider that these assumptions are unrealistic.

32. In response to these issues, Fish & Game's suggested approach is to "hold the line of the current non CPW load" (that is, maintenance of existing load) in the medium term, with a long term goal of restoring the ecological health of the catchment.

33. This is to be achieved through the allocation of a nitrogen baseline (grand parented 2011-2013 N losses) and a cap on new land uses, there is an assumption other contaminants (P, pathogens and sediment) where output controls cannot be established are being 100% effective in preventing any further ecological decline. This is with GMP along with the BMP assumed in Overseer being implemented.

34. It is on this basis that I support the approach proposed by Fish and Game, which establishes a long term plan for nutrient loss reduction and allocation combined with adaptive management and legitimate ecological monitoring. I also recommend that P limits and outcomes be imposed and steps are taken to validate on course and stony soils immediately.

35. This approach will give current businesses a degree of certainty as they implement their GMP and reconfigure their systems accordingly in response to ecological monitoring. These checks and balances are necessary to ensure that any new intensification occurs within sustainable limits, while the present freshwater issues are being addressed as a priority.

A. CONTEXT

36. The Canterbury region has 70% of New Zealand's irrigated land and is one of the most dependent regions on irrigation due to its low rainfall, high temperatures, coarse textured soils, strong winds and high levels of evapotranspiration. There has been a rapid rise of

dairying in the region reflected by a 51.4% increase since 2005-6. The extent of irrigation and growth of particularly dairying in the last decade has largely been on stony soils which pose the highest risk to receiving environments. It is likely that most of the future irrigation development will occur on similar stony soil types.

37. The Selwyn Waihora catchment is characterised by a wide range of drainage behaviours and varying water holding capacities mostly characterised by a vulnerability to nitrogen leaching.

38. Canterbury farming systems are more intensive on average. For example, 63% of dairy farm systems in Canterbury were reported as importing 20-50% of their feed (via direct supplements or off farm grazing) (Agfirst Waikato, 2009). More intensive systems also rely heavily on a high proportion of support land in order to meet their feed requirements for young stock, wintering cows, and supplementation. This situation results in the intensification of traditionally extensive land uses in order to support this farm system configuration. Intensive systems are more vulnerable to volatility – e.g. climatic or commodity price changes, and have increased risk of contaminant losses thereby requiring more advanced mitigations.

39. The externalities of concern from pasture based agriculture are: effluent/pathogen run off from the land which contributes to the contamination of water bodies; erosion and soil loss from the land leading to increased sediment loads to water bodies; loss of wetland habitats and riparian vegetation; erosion of stream banks, leading to stream bank instability; phosphate and nitrogen loss both across land and into receiving groundwater. These externalities which contribute to ground and surface water enrichment are amplified by the abstraction of water from ground and surface water bodies for irrigation purposes, dairy shed wash down, and stock drinking water. Management policies are compelled to "protect" waterbodies under the provision of the NPS, and no further degradation of receiving waters should be allowed to occur.

40. There are a range of mitigations and changes to farming practices that can have a significant effect on achieving water use efficiency, and reducing contaminant losses to water including nitrogen and phosphorus losses. My conclusions in this regard are based on research throughout New Zealand, Australia and Canterbury. Mitigations and associated methods include:

a) Metering water use and moving to efficient irrigation and precision application technology using spray irrigation systems.

b) Ensuring all best management practices "assumed by Overseer" are actually implemented in their entirety.

c) Focussing on "optimal nutrient management" across the whole property.

d) Adoption of best management practices in regards to effluent management including adoption of best practice soil moisture deficit irrigation over an extensive area to optimise nutrient use efficiency and ensuring that effluent ponds are sealed to prevent leaching.

e) Ensuring an "optimum stocking rate" is adopted for the farm system, management and the landscape.

f) Ensuring diets are well balanced including making use of mixed pasture swards to better utilize nutrients and meet animal health needs.

g) Advanced Infrastructure improvements (e.g. feed pads, housing systems) to assist with standing off, improved feed utilisation, pasture protection, and effluent capture during inclement weather.

41. The move to "active management" for irrigation scheduling is a key mitigation delivering 30 – 50% reductions in nitrogen leaching. This has the potential to address some of the current water quality and quantity challenges. The top 20% of farmers are presently doing this, it should therefore be mandatory good management practice.

42. More advanced mitigations, when integrated in to a whole farm system incur capital costs to implement, however, they can also have significant benefits. Including increased productivity, improved efficiencies and corresponding profitability benefits if a farm system is optimised.

43. Aside from some basic "minimum practices", mitigation options are generally not a 'one size fits all'. Rather they should be tailored to each individual farm business, to ensure recommended mitigations are suitable for the business operator.

44. Three "typical Canterbury farms" were assessed in 2013 using Overseer 6.0 for current performance and lowered nitrogen loss scenario plans on behalf of Fish and Game. This work was undertaken to ascertain what types of farm system reconfigurations may be necessary to meet nutrient limits as proposed by the zone committees in red zones such as Selwyn Waihora. The three farms were chosen to reflect "high risk" farms in red zones on the basis of farming intensity and soil types. As such, these are worst case scenarios. (Appendix 4a & 4b). Farm system reconfigurations using both "tier one" and subsequently more advanced mitigations resulted in the following:

a) Farm one reduced nitrogen losses from 81 kg N/Ha/yr[2] to less than 20 kg N/Ha/yr, profitability was improved and risk was reduced. Capital was required to move from flood to spray irrigation.

b) Farm two reduced their nitrogen losses by over 70%. Return on total capital improved, and business risk was reduced.

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[2] Overseer version 6.0 April 2013

c) Farm three reduced their nitrogen loss by over 70% from the base examples, using a mix of “good practises” and farm system reconfigurations. Return on total capital was improved when the farm was optimised to take advantage of the mitigations.

45. This modelling work(above) is also supported by modelling work conducted by Ridler et al for both MAF Policy (31/07/2007) and DairyNZ (Howard July 2013) and earlier work in the Hurunui area (12 October 2012) using the GSL resource allocation model and that particular work was supported by (David McCall – on behalf of Fonterra) [3]

B: A CHANGING AGRICUTURAL LANDSCAPE IN SELWYN WAIHORA

Description of change in agricultural land use in Canterbury over the last decade and predicted future changes

46. Over the last two decades, there have been significant changes in land use within the Canterbury Region. Of primary focus is the intensification of land traditionally used for sheep or mixed cropping farming to intensive irrigated dairy farming. The historic areas under pastoral farming were around 150,000 Ha in 1985, increasing to 350,000 Ha in 1999, with a further increase to approximately 586,000 Ha in 2011 (Lillborne *pers com* Dec 2011). Of the irrigated area in Canterbury, a decade ago, the spread of land use was assumed to be across these industries: 34% is dairy pasture, 36% other pasture, 27% arable, and less than 3% horticulture and viticulture[4].

47. The Dairy Statistics Report 2011 - 2012 (Dairy NZ) states that around 219,275 Ha is currently assumed to be in dairying. This up from 137,340 Ha[5], a 60% increase in area under dairying in a 5 year period. The rapid rise of dairying is reflected by a 51.4% increase in the number of dairy farms since 2005 – 2006, from 632 dairy farms to around 974 dairy farms. Along with the increase in dairy farms the total cow number has also increased. Between 1989-99 and 2010-11, dairy cow numbers increased from 235,534 to 662,425 animals, with 91.9% of this increase occurring since 2005 (Ford.R., 2012).

48. In Selwyn (S42 report 2014) there is 272,000 ha, 77% of this is flat, 11% classed as hill. Agriculture covers 88% of the land area. Irrigated land accounts for 105,000 ha and a further 30,000 ha of new irrigation is proposed to result from new water from the CPW

[3] The GSL model was chosen over Farmax (which was used for the calculations presented in Brown et al 2011, and of which the author of this evidence was a developer). This was because GSL is more efficient at finding optimal resource use allocations due to it being an optimising, rather than a simulation model. With simulation models (such as Farmax) the definition of optimal resource use requires the user to iterate their way to an optimum solution. This iteration is time consuming, not always full-proof and optima may be missed. Predictions from Farmax and GSL are very close, given similar resource inputs. This is shown in Table 1 where predicted outputs for the current configuration for three of the farms which had previously been loaded into Farmax by another user, were compared with predictions by GSL. It means that the only significant difference between the models is in the model structure (optimising – GSL, versus simulation - Farmax). Footnote Page 6 (Evidence of Mc Call on behalf of Fonterra in Hurunui + Waiau River Regional Plan.

[4] Saunders, 2012, (from MAF estimates based on a Lincoln Environmental report 2000

[5] which was reported as effective dairy hectares by LIC (LIC, 2007)

scheme, facilitated by an allocation of 1944 T of N (proposed load 2017 for CPW dairy and dairy support).

49. Much of the new development in Selwyn has occurred in the past decade. Dairying increased six - fold, from 2002 to 2012, cow numbers increased from 199,014 to 1,200,000. (pt 1.10 S42a). With the advent of the increased area available due to CPW scheme, the catchment may carry in excess of 2 million milking cows and the associated replacements, on support land (15,000 ha)

50. The Canterbury region has 70% of New Zealand's irrigated land. Canterbury is one of the most dependant regions on irrigation due to its inherently low rainfall, high temperatures, coarse textured soils, strong winds, and high levels of evapotranspiration (Environment Canterbury Regional Council, 2012). As such Canterbury dairying farming systems differ from most other regions in New Zealand, as it is almost entirely dependent on significant freshwater inputs for irrigation of pasture and crops.

51. The extent of irrigation and growth of particularly dairying in the last decade has largely been on stony soils which pose the highest risk to receiving environments. Satellite images collected from 2008 to early 2011 estimate that at least 196,000 Ha or 40% of all irrigation in Canterbury was occurring on coarse textured, permeable, stony soils, with low water storage capacity.

52. In Selwyn in particular, the region is characterised by a high percentage of light, to very light and extra light soil types. In the command area for CPW, the percentages of different soil types that lie in a 100,000 ha boundary are tabulated in Table 2.

Table 2: Soil Types in the Command Zone for CPW

Description	**Soil Series**	**ecansoil**	**Total Ha**	**Area Ha (High Vulnerability)**
Deep	Barhill, Templeton, Wakanui (100cm deep)	**D**	89.94	
Heavy	Hatfield, Templeton, Wakanui (100 cm deep)	**H**	1233.16	
Light	Chertsey, Lismore shallow and stony silt loam	**L**	59525	59525
Medium	Hatfield, Templeton, Wakanui (mod deep)	**M**	25126.86	
Poorly Drained	Temuka deep clay loam (150 cm)	**Pd**	1468.21	
Very Light	Waimakiriri, Eyre stony silt loam, Lismore and Balmoral very stony silt loam	**VL**	9585	9585
Extremely Light	Waimakiriri very stony sand	**XL**	2337	2337
Total			**99,365.42**	**71,447**
Source: Linda Lillburne August 2014				72% L, VL or XL

53. However, with the more recent development in the past 5-7 years, the balance has changed significantly, and now 71% of all dairying is occurring on stony soils. (Carrick, S.,pers comm., 2013).

54. Landcare Research suggests that intensive land use on stony soils is creating conditions with a high risk for leaching of soluble nutrients and has the greatest risk of contaminant losses including microbes (Sam Carrick, Landcare Research, pers comm.). Lillburne et al (2013) also caution against relying too heavily on the Overseer calculated loads to determine ecological outcomes: "There are many difficult issues in estimating nitrate N leaching rates for the main land uses on different soils and rainfall zones including the rarity of good long term measured data which means that models cannot be reliably calibrated for Canterbury conditions."

55. The challenge is the "next step up" in research with regards to leachate monitoring under on-farm conditions over a number of years. The only site at present is at Lincoln University Dairy farm – where the data from the Eyre soil lysimeters is directly relevant to the stony soil leaching. (Personal Comm – Sam Carrick Aug 2014)

56. A recent published by Dairy NZ in 2012 indicated that in the Selwyn catchment, dairying was occurring on 42,134 Ha of the catchment. Dairying on heavy soils accounted for 15,430 Ha (36% of total) while the dairying on the coarse (light soils) was on 26,704 Ha (63% of total) (Howard, 2012).

57. The solutions package relies on the management and reduction of diffuse N loss from the catchment, as well as the removal of 50% of the catchment load of phosphorus while nitrogen loads are allowed to increase to a point of toxicity in the lowland springfed streams.

58. The Zone Committee Solutions package, by default, assumes and expects that "no further loads of phosphorus will arrive in the post in groundwater." However much of the development of the Selwyn catchment has occurred in the past decade, therefore it may be that "lag loads of phosphorus resulting from this development" are still to arrive at their destination.

59. This proposed solution relies on the fact that there will be no further addition of P to the catchment and periphyton will be limited by limits placed on diffuse N sources.

C. EXTERNALITIES OF CONCERN WHEN INTENSIFYING VULNERABLE LANDSCAPES.

60. The externalities of concern from pasture based agriculture are noted in point 39 of this Evidence. The impacts of these externalities are discussed further in the evidence of Mr. Brett Stansfield and Dr. Jim Cooke.

61. All of these externalities contribute toward declining aquatic ecosystem health (water quality and habitat) and issues of public health significance such as coliforms, campylobacter, cyanobacteria, and salmonella among other potential pathogens. Increased pathogenic loads to surface and ground waters from agricultural land uses can contribute to higher rates of zoonotic and enteric disease[6] and loss of public amenity.

62. "Prior to the 1980s, it was thought that phosphorus, unlike nitrate, was so strongly held by soil particles that loss of phosphorus though drainage to natural waters was minimal. But now it is recognised that bypass flow can cause significant amounts of phosphorus to drain through soils into field drains and then surface waters (Powlson 1998). Recent research indicates discharge of phosphorus to groundwater may also be more important than previously thought (Holman et al. 2008, Abraham and Hanson 2009). Some New Zealand soils have very low P retention values, and significant phosphorus loss can occur through soil macropores, predominately co-transported with mobile colloids (Thomas et al. 1997, McDowell et al. 2008)[7]

63. Selwyn catchment has issues with bacterial and nutrient enrichment of wells along with a high incidence of zoonotic disease. Data provided by CDHB indicates that Selwyn has the highest incidence of Campylobacter in the country.(see appendix 3) This is a cost borne by the public: The major risk to suppliers are in the shallower sources – such as those used by lifestylers in the region rather than reticulated supplies. There are estimated to be around 1500 shallow (<30m from surface) drinking wells vulnerable to elevated N and pathogen levels in Selwyn. Current average concentration is expected to increase (up to an average of 8.5 mg/l[8]) as intensification and expansion occurs in the catchment under the proposed solutions package.

64. Sam Carrick et al (2014) noted that there is still a lack of validated research of the true losses from stony soils in Canterbury and there is an urgent need to address this in order to truly ascertain diffuse losses.

> *"Environmental models consistently predict stony soils as having a high vulnerability to leaching under intensive land use, but there is little experimental research to validate model predictions."*

65. And the "high risk" of contaminant losses from both urine deposition and the application of FDE are significant on these soil types.

> *"Our results confirm the high-leaching-vulnerability assessment of young stony sand soils for a range of possible contaminants. In the periodic-irrigation*

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[6] Zoonoses denotes disease is an infectious disease that is transmitted between species from animals other than humans to humans or from humans to other animals. Pathogens of concern are some of the more widely known *Campylobacter*, *Salmonella*, *Giardia*, *Cryptosporidium* and viruses that cause diarrhoea and cold and flu-like symptoms.

[7] ECAN report: Page 13: Mapping of vulnerability of nitrate and phosphorus leaching, microbial bypass flow, and soil runoff potential for two areas of Canterbury"

[8] Table 6-2 of Report to support water quality and water quantity limit setting process in Selwyn Waihora catchment: predicting consequences of future scenarios. Groundwater quality. Hanson 2014.

experiment the cow urine deposition was the key driver of leaching, with increased leaching of N, P, C, and Cd starting within 15–60 mm of drainage."

66. This scoping study confirms model predictions that young stony sand soils have high potential leaching vulnerability, and Carrick (2014) strongly recommends that further research is urgently needed to validate these results and ascertain the extent of leaching risk under field conditions.

67. Current validation sites for Overseer do not adequately provide for the types of soils in the CPW command zone. – (pers comm Mark Shepherd[9] Aug 2014):

> *"The [new] P21 sites are, I'm afraid, the 'usual suspects'; they are Massey, Scott farm (DNZ, Hamilton), Lincoln and S.Otago. There are no 'farmlet' scale experiments on loose gravelly soils as far as I am aware. "Farmlet' scale trials are the type that have been used to evaluate Overseer to date (see Watkins paper from FLRC last year for a list of available data). We are now able to evaluate the model against lysimeter data, which is a new feature. This equates to an individual urine patch scale and of course then relies on the model correctly scaling to a paddock/block/farm, but it now starts to offer opportunities to more cost effectively collect data on different soil-types and environments – at least to establish that the underpinning principles within Overseer are correct once we move from our well researched soils."*

68. Richard McDowell (2014) (Appendix 5) has also released a stocktake of the risk of phosphorus loss under dairy systems. His conclusion suggests that a precautionary principal be adopted when the intensification of vulnerable, shallow, stony soils are proposed due to the heightened risk of phosphorus loss to groundwater, and receiving surface waters where anoxic[10] waters well up at lowland points adding to the anthropogenic phosphorus load.

> *Methods to mitigate P losses under irrigated dairying include: varying the rate of irrigation according to available water holding capacity to minimise drainage (Hedley et al., 2011); applying the minimum fertiliser-P to maintain optimal pasture growth (McDowell et al., 2003); applying less P but maintaining pasture production with N-fertiliser (Dodd et al., 2012); <u>and not irrigating vulnerable soils or using vulnerable soils for practices that lose significant P such as effluent application or cropping for grazing in winter</u> (McDowell and Nash, 2012). <u>However, perhaps the most obvious would be the consideration of the vulnerability of soils and aquifers prior to landuse change or development.</u>*

[9] Mark Shepherd – Senior Scientist – Climate Land Environment, Agresearch.
[10] Redox state: without good supplies of oxygen.

69. Nitrogen toxicity theory (single nutrient management) which underpins the zone committee solution package relies on the notion that diffuse P loads can be stopped, reduced or mitigated to zero.

70. The solutions package (to enhance further intensification) relies on the current load of P being reduced by 50%, and the “in lake load of P” being reduced by 50% while additional N is allowed to enrich the watershed.

71. In the most recent decision by the EPA (2014a) on the Tukituki Plan plan change proposal, the summary of the decision notes:

> *[7] One of the most contentious features of PC6 as notified was its approach to managing phosphorus and nitrogen. The proposed plan adopted what was described as a ‘single nutrient’ approach focussing on the management of phosphorus. Nitrate-nitrogen controls were only intended to avoid toxicity effects on aquatic ecology.*
>
> *[8] Having considered all the information before it, <u>the Board rejected this approach in favour of a ‘dual nutrient’ control which manages both phosphorus and nitrogen.</u> Rather than basing nitrogen limits on toxicity, the Board has taken <u>instream ecological health as the basis of the levels it has set.</u>*

72. The clean-up of the present load of phosphorus from the catchment is relying on the following actions being undertaken and providing legitimate results – (from 4-3 Proposed variation to the pCLWrP):

a) Consented alpine water introduced to the catchment for additional irrigation development and is also used to replace groundwater takes, enable stream augmentation and/or managed aquifer recharge;

b) Water allocation limits, to deliver ecological and cultural flows;

c) New takes in over-allocated water management zones are prohibited and the volume of water allocated is reduced;

d) Reducing legacy phosphorus in Te Waihora/Lake Ellesmere by 50 percent and improved management of lake-level and opening;

e) Restricting the agricultural nitrogen load losses from the catchment;

f) A 50 percent reduction in the catchment phosphorus load;

g) Requiring all farming activities to operate at <u>good management practice then make further improvements over time in managing nitrogen.</u>

D. WHAT IS GMP? – OVERSEER ASSUMES SOME BMP ARE ALREADY HAPPENING.

73. We do not presently know exactly what GMP is – however, a fair assumption would be based on Variation 1 Plan Schedule 24 for dairy that include:

a) Use of Overseer for monitoring losses;

b) Abiding by the Spreadmark COP for fertiliser application; and

c) for all intensive winter grazing adjacent to any river, lake, artificial watercourse (excluding irrigation canals or stock water races) or a wetland, a 5m vegetative strip (measured from the edge of the bed of the river, lake, artificial watercourse, or wetland) from which stock are excluded, is maintained around the water body

74. These practices on their own would result in no net decline in the proposed N load – simply because they actually just represent "business as usual" with respect to N lost between baseline levels (2009-2013) and 2022. Overseer already assumes these practices are in place.

75. The agricultural loads of N (3366T 2017) already assume a standard of GMP is in place on all farms across the region. Therefore GMP that reproduce these recommendations will not provide any beneficial net reduction in modelled load.

Overseer

76. Overseer is a model developed by AgResearch initially for the purposes of fertiliser recommendations. It is now extensively used by the pastoral industry as a nutrient budgeting tool, and for the estimation of nutrient losses from farming systems. It is also currently used to benchmark pastoral industries for nutrient loss and efficiency. Overseer assumes that the farm system is in "quasi–equilibrium", that inputs are commensurate with productivity, and users supply actual and reasonable inputs, that the correct data is inputted, and that the farm data used is "sensible".

77. Overseer also assumes that best management practices are already in place, (Ref Appendix 6) such as stock excluded from waterbodies, there are no direct discharges of contaminates to waterbodies, or discharges from the base of effluent ponds, and that all codes of practice are implemented in order to avoid adverse effects. Also assumed is that the Fertiliser Code of Practice is followed; deferred effluent irrigation is used; and that effluent is spread according to best management practices. Overseer estimates nutrient losses based on long term annual average losses, rather than those of a particular year.

78. Overseer assumes that points of connectivity (added fertiliser, effluent, soil runoff etc.) are well mitigated on any farm when nitrogen and phosphate loss outputs are calculated. It assumes:

a) That surface runoff of effluent from land to water is minimal;

b) That connectivity of effluent with groundwater is not occurring through irrigation of effluent to saturated soils, leakage from ponds, or holding facilities, and that all stock are excluded from wetlands and waterways;

c) That stock crossings or tracks near waterways do not provide any sort of connectivity from surface deposition or runoff to water bodies;

d) In terms of winter cropping Overseer assumes there are no critical risk areas (hot spots) where runoff from wintering practices occurs, (i.e., – pugging is “rare") and that a buffer zone operates to break points of connectivity.

79. The nutrient losses, nitrogen leaching, phosphorus runoff and gaseous emissions are calculated to edge of stream, below rooting depth. More recent versions of Overseer have been modified to more accurately represent the soil type, better reflect the drainage though soils and the effects of irrigation management.

80. Farm output results from Overseer 6.1 are dependent on input accuracy and the protocol that is expected of the operator for desired outcome. Expert users of Overseer are faced with the challenge that Overseer files may be produced or populated using a range of input protocols. This is illustrated by Pellow (2013).

> *“Overseer can result in a range of different outputs depending on what the intended use of the model is. Protocols are in place to ensure consistent methodology for reporting for different benchmarking requirements.”*

81. It is essential that the data for Overseer is collected and entered with a high degree of rigour to ensure the most accurate farm system is represented. Hence suitably qualified accredited nutrient advisors are an essential part of the reporting process. Without this, reliable, transparent and credible reporting of information will not be achieved. This factor is fundamental to any form of legitimate self-management or self- reporting for N baseline purposes and FEPs.

82. There is a larger availability, and ever increasing capability than previously amongst the supporting agricultural professionals. There are 404 professionals who have completed the Advanced SNM and 1,437 have undertaken the Intermediate course. There are currently 73 Canterbury-based people who have completed the Advanced SNM and, of the 93 enrolled in this course in 2014, 24 are Canterbury-based.(pers comm. Lance Currie, FLRC, Massey, Aug 2014).

83. While I acknowledge that Overseer version 6.1 still has some limitations, I do believe that Overseer is the best tool we have available to indicate nitrogen loss risk from a land use activity (dairy, dairy support, sheep and beef intensive, sheep and beef extensive, deer) providing that the actual farm data is used and soil types and irrigation methodology is validated urgently.

84. Overseer remains the most appropriate tool available to the pastoral industry to manage land use within environmental constraints, as it provides the comparative risks to the receiving environment of a management activity at a farm scale. Without Overseer, farmers would be facing a cumbersome regime of unwieldy “input controls” in order to minimise their effects on the environment.

85. Overseer enables pastoral agriculture the opportunity to manage its effects to an “output based standard”. Thus enabling the establishment of output controls in regards to nitrogen leaching. This fosters farm system reconfiguration and innovation at lowest cost.

86. It is the most appropriate tool to be used by both regulators and the pastoral industry as a whole, as it provides comparative risks of a management activity to the receiving environment.

Good management practise

87. With no clear definition available of Industry Derived Good Management Practice, it is impossible to have any certainty around whether the proposed solutions package approach will provide a suitable and legitimate solution for the management of nitrogen loads in this catchment. If it is described by what is illustrated in the table in Appendix 7, then it is simply nothing more than “business as usual”

88. A common sense assumption would be that “Good Management Practice” would be defined as “methods and techniques found to be the most effective and practical means in achieving an objective (such as preventing or minimising pollution) while making the optimum use of the resources”

89. Many good farmers are already operating with advanced (Level 1) Appendix 7 mitigations already,” with a nutrient loss rate of >20 +% below that of an average farm.

90. In order to address this unfairness: early adopters that have implemented advanced mitigation (Level 3, Advanced & System Change: Appendix 7)) practices and system changes should be recognised when determining additional nutrient discharge reductions (below the grand parented level)

91. These innovative (leading) farmers are operating at levels significantly above good management (best management) – leaching around 40-50% below the average, and have invested heavily in advanced mitigation structures on their farms in order to reduce their environmental impact. These leading farmers unfortunately are penalised through a grand parenting system of N allocation.

92. These BMP farmers are leaders (top 5%) and include farms such as Cloverdale Farm, and Willie Leferink operation (with advanced mitigations and system reconfigurations in place). These farmers provide the industry with examples of “Best Management Practice” examples for 2014; demonstrating extremely low footprint farm systems are

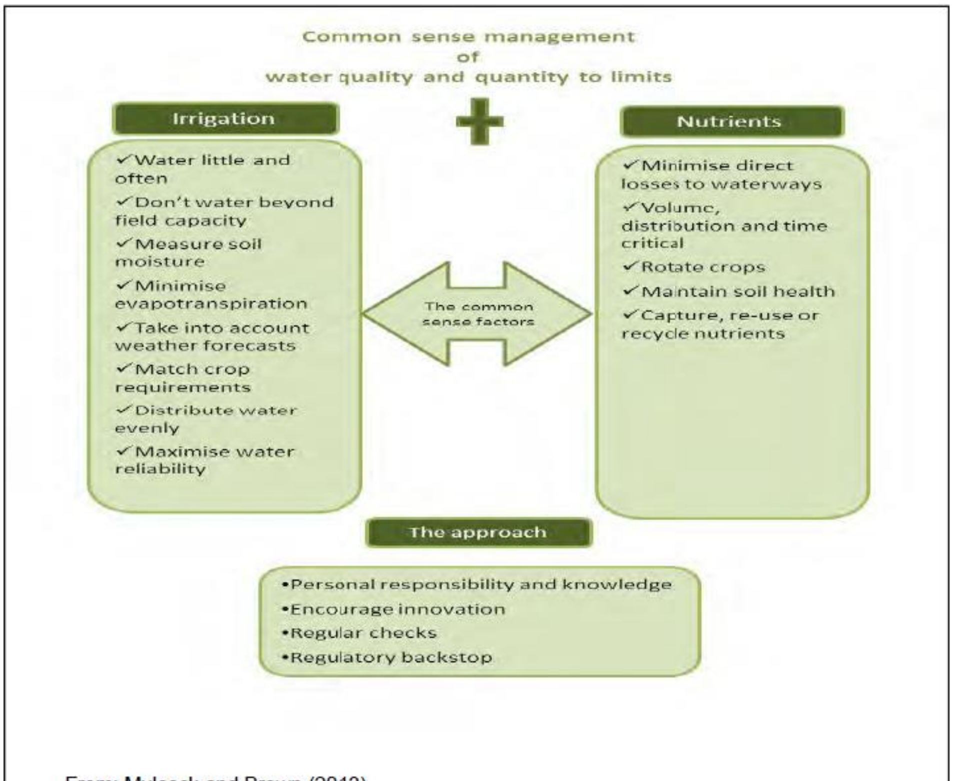
achievable. (The Panetts Dairies example of two free stall barns are in operation with a cut and carry enterprise, and the N leaching is 34 kg N(Ovp version 6.11) per ha per year.)[11] However, it is important to note that advanced mitigations and reconfigured farm systems such as Leferinks, favour a higher milk price.

93. A further example of farmers trying to achieve top 5% in environmental performance was cited by Peter Kemp on 25/08/2014 is the Garrett family at Ellesmere, who farm 1200 cows on 440 Ha and who have seen a production increase of 40% while their nitrogen leaching has declined from 18 to 6 kg N per ha per year. (Indicating the farm was achieving a 60% decline in N leached)[12]

94. One must assume that "common sense management factors" noted by Claire Mulcock, on behalf of Irrigation NZ (EPA 2013) of irrigation management will inevitably be part of any GMP.

95. According to Mulcock, this includes factors such as watering little and often, not beyond field capacity and matching applied water to crop requirements.

Figure1[13]



From: Mulcock and Brown (2013)

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[11] Fielday at Pannetts Dairies LTD (28 March 2014) NZIPIM Canterbury/Westland Branch – Introduction to Free Stall Dairy Housing in Canterbury.
[12] http://www.stuff.co.nz/business/farming/opinion/10418694/How-are-farmers-keeping-rivers-clean (25/08/2014)
[13] Exhibit 2: from Evidence in Chief of Claire Mulcock Sept 2013, for the Board of Enquiry Hearings on the Tukituki Catchment Proposal

F. CHANGE IN FARM SYSTEMS

96. The key feature of New Zealand farming systems has historically been the ability to maintain a 'low cost' production base, through low cost pasture based milk production and profit. However, the expanding use of nitrogen and phosphorus in the 1980s and 1990s resulted in production responses, facilitating increases in stocking rates on a range of land classes.

97. This phenomenon reflected assumptions that increasing stocking rate was correlated in a linear manner to increased pasture harvest and subsequently profit. These assumptions have remained largely unchallenged to the current day.

98. Linear intensification models of a dairy farm making a transition to high levels of milk solids (MS) per hectare (Ha), has historically assumed that these benefits would occur, by utilising more nitrogen, stock and high protein supplements per Ha (grass silage).

99. In the past decade, the operational profile of farming has altered. Responses to increased stocking rate and fertiliser use on intensive systems have resulted in a net loss in productivity (-0.6%) while the risk profile has increased e.g. volatility in seasons, milk and feed prices. NZ is no longer a "low cost down under" producer of milk (Moynihan 2013).

100. To manage this risk, more intensive farming systems have moved to importation of feeds to decrease the threat of lowered production that can result from the combination of difficult seasons, high stocking rates and impaired feed management.

101. In 2002, New Zealand began importing Palm Kernel Expeller (PKE) to supplement locally sourced supplementary feeds in order to maintain milk output and body condition; New Zealand now imports over 1.9 million tonnes of PKE annually. Increasingly, cereals and a range of by-products, including alternative supplements, from offshore markets are imported to maintain production levels.

102. However the long term economic resilience of advanced mitigation systems has been strongly challenged by a number of critics (Riden 2007 MAF Policy project 31/07/2014; Ridler 2009 UK Vet Production vs Profit ; Anderson 2010 NZSAP, Ridler 2010 NZARES; Ridler 2014 NZARES, and Journeaux 2013 in a report on behalf of Dairy NZ

103. This trend has failed to result in higher productivity (see figure 2) nor increased profitability[14] as discussed below.

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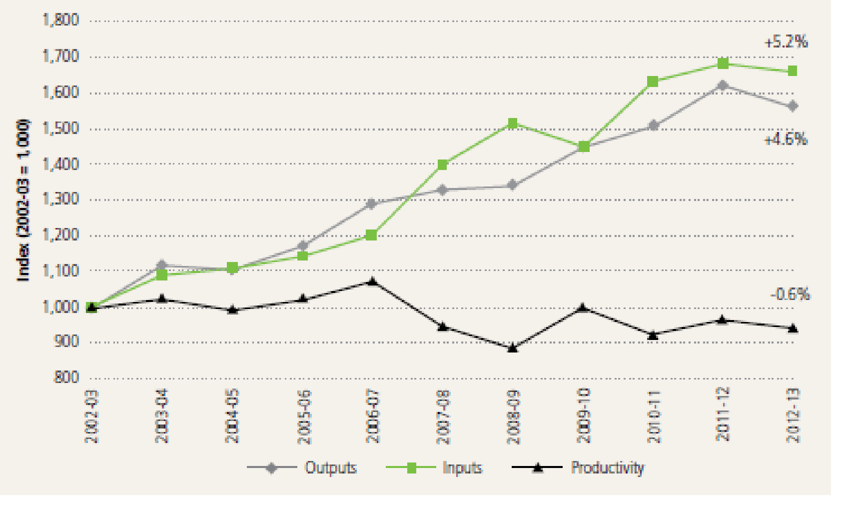
[14] "Increased profit that is ideally measured as an increase in total return on assets"

Figure 2[15]

Figure 3.5: Dairy Farm Output, Input and Productivity Movements



104. Referring to the above figure: *"In the dairy sector in particular, production processes appear to have become much more input-intensive (greater use of supplementary feed and irrigation) so that higher gross output (gross dairy output rose 35-40 per cent in the decade from the 2002/03 season) does not translate to similar growth in real value-added in that sector"* **–** Daan Steenkamp**,** Reserve Bank of New Zealand. [16]

105. Self-contained, pastoral based dairy farms are no longer the predominant farming system in operation. There is now a wide range of farming systems in operation, for example, the Dairy NZ systems 1-5[17]. System 1 – "Self Contained" No feed imported, all stock on the dairy platform. System 2: 4-14% feed imported, System 3: 10-20% feeds imported to extend lactation, System 4: 20-30% of overall feeds imported. System 5: 25-50% of feeds imported, all year.

106. Canterbury (and Selwyn) farm systems are more intensive than what is seen at a national level. 63% of farm systems in Canterbury were reported as importing 20-50% of their feed (via direct supplements or off farm grazing) (Agfirst Waikato, 2009). This results in a farm system that is more intensive and specifically configured to capitalise on these opportunities. They rely on a high proportion of support land (0.5-1.0 ha per milking ha) for young stock, wintering cows, and supplementation. This results in intensification of the extensive land as well.

107. During 2002-2013 the largest increase nationally, has been in the system 3 and system 5 farms (>40% feed imported). The availability of more imported supplements combined

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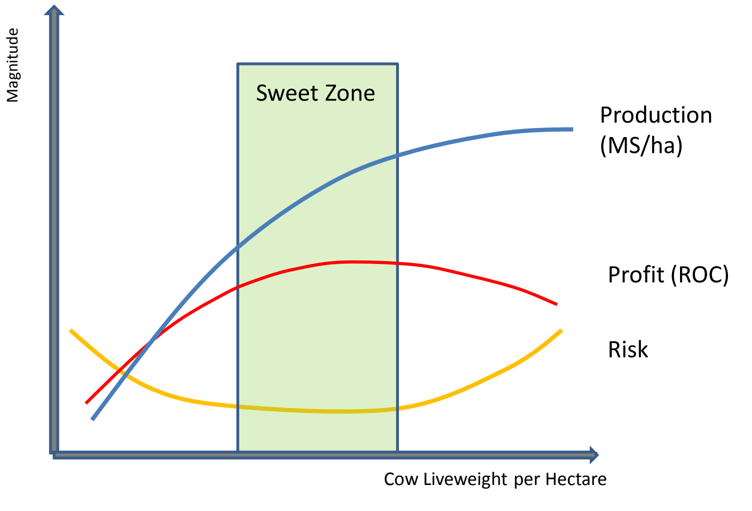
[15] Dairy NZ Economic Survey 2012-13 (50 Years of Economic Analysis)
[16] Structural adjustment in New Zealand since the commodity boom AN 2014/2 Daan Steenkamp April 2014 Reserve Bank of New Zealand Analytical Note series ISSN 2230-5505
[17] Dairy NZ systems 1-5 is a classification system of farm types based on the different amounts of feed that are imported to the milking platform from external sources.

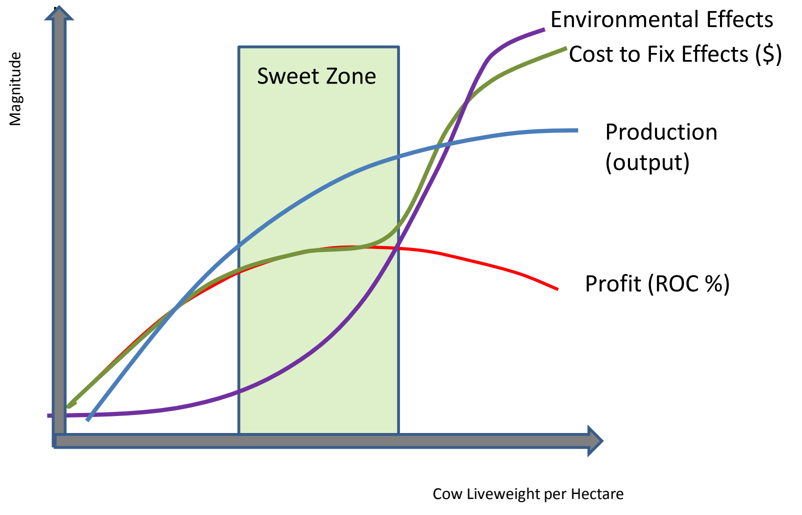
with the need for a more consistent cash flow to meet and service their financial obligations (debt).

108. More intensive farming systems lead to higher environmental risk as well as financial and physical system risk.

109. Figure 3 illustrates a conceptual diagram of the magnitude of production, risk, profit, in a farming system relative to cow live weight per unit area - illustrating a hypothetical “sweet zone” of cow live weight per unit area that best balances production, profit and risk that takes into account the inherent strengths and weaknesses of the farm, landscape, animals and people (Dewes, 2014).



110. Figure 4 - Conceptual diagram (below) of profit vs environmental effects vs cost to fix effects (Dewes, 2014). This diagram shows that once a farm is operating in a more “intensive status” there is a higher risk of environmental damage, contributing to an ever increasing cost to “mitigate the effects”



111. Any form of volatility (i.e.; climatic, commodity prices) results in a heightened vulnerability and increased risk of failure for the business. The most common risks that make a dairy business more vulnerable may be as a result of large fluctuations in milk price (+/- 20%), resource constraints, elevated feed prices, and unstable and tight labour markets.

112. The typical milking platform in Canterbury (and Selwyn) is shown in Appendix 1 (Physical Data Summary 2010 and 2011). The key features that are different from other parts of NZ are the higher pasture harvested per Ha than other regions, 14-16 T DM per Ha vs 11-13 T DM per Ha in Waikato. This leads to a configuration of system that is typically more highly stocked (3.4-3.9 cows per Ha) with higher average use of nitrogen fertiliser than Waikato for example, to drive a pasture based system under irrigation. On average irrigated Canterbury dairy farms use between 250-360 kg N per Ha per year, in comparison, Waikato farms would typically use 100-150 kg N per Ha per year. These examples illustrate the higher level of intensity of irrigated dairy systems vs dryland dairy systems.

113. A recent study conducted using a mix of dairy base data and a phone survey on 80 farms in Canterbury for the purposes of modelling nutrient loss reductions, was conducted by Dairy NZ (2012). This study noted that 38% of farm businesses in the survey are making a loss after interest and drawings at a $6.00 kg MS payout (Howard, 2012) (Table 10 Page 58).

114. At the projected payout in the 2014-15 season ($6.00 per kg MS), many farms will not be "solvent" nor economically resilient. This is already occurring in schemes where the irrigation water is at a lesser cost than the CPW proposed scheme costs.

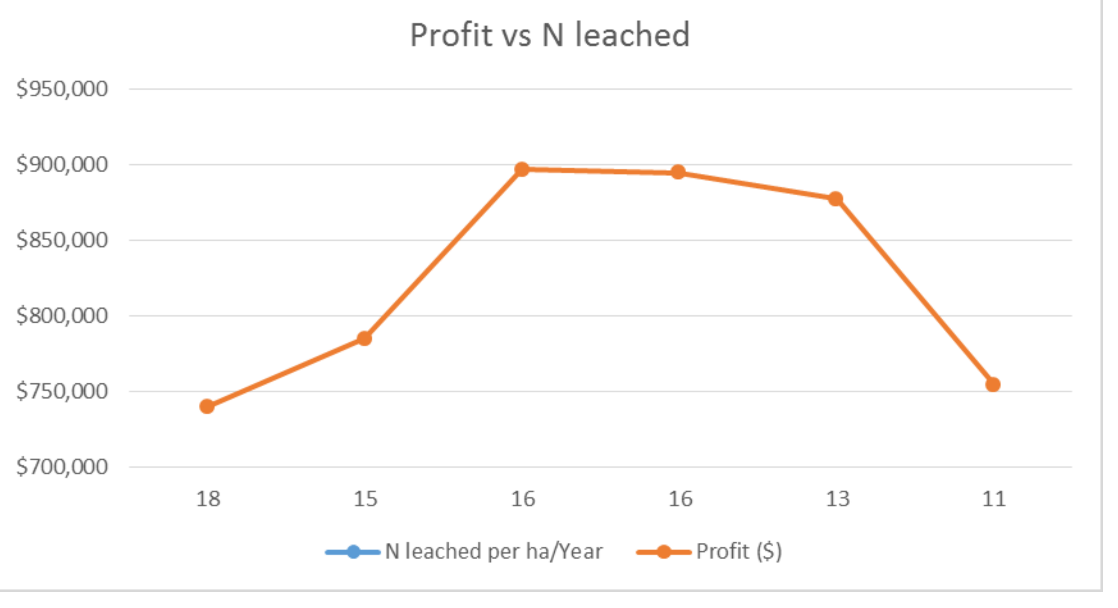
115. The annual costs likely to be incurred in the CPW scheme are to the tune of $800-850 per ha per year. Although this provides water at the farm boundary under pressure (requiring no significant electricity or pumping costs), this will still be around twice the current/typical cost of groundwater for an irrigating agricultural business in Selwyn at

present. The current average cost of pumping from groundwater sources is $400 per ha per year.

116. This study conducted by Dairy NZ (Howard 2012) serves to illustrate the high vulnerability of dairy business in this region, illustrating what has been an over-permissive lending regime by banks in the recent decade. These permissive lending regimes have failed to take into account volatility in commodity pricing, resource constraints, climatic variation and policy change. It has been cited by several parties as a rationale for the use of more lenient policy approaches.

117. As shown in Figure 5 and Appendix 2 (profit vs N leached – Ridler et al), a farm system can improve profit from its baseline level, whilst reducing N leaching. But once a specific farm production system point is reached, farm profit decreases at an increasing rate with each additional unit of N leach reduction. The Fish and Game modelling that was undertaken for the submission on the pCLWP showed the same result.

Fig 5: Profit vs N leached (Ridler et al 2014) See Appendix 2 for supporting Data



118. "A challenge for dairy farmers is to retain profitability while reducing N leach by a prescribed percentage, calculated to ensure an average reduction in nitrates in water catchment areas." (Ridler et al 2014)

119. This fixed percentage decrease in N leaching per farm is an example of averages being used without understanding the implications or alternate possibilities. As shown in Figure 5 (above), a farm system can improve profit while reducing N leach. But once a specific farm production system point is reached, farm profit decreases at an increasing rate with each additional unit of N leach reduction.

120. There are some very inefficient farms with high inputs, high leaching and poor profits. The industry should be targeting these farms to reduce N leaching (as they will then also improve profits) rather than impose restrictions on efficient farms and reduce profits

rapidly due to the steeply rising marginal costs per additional reduction in N leach. The linear programming approach used by Ridler allows the marginal effect of reducing N leach to be calculated for each farm. (Ridler et al 2014).

121. The solutions package proposal to allow a further increase of N load in the Upper Selwyn Catchment through the additional load of N from CPW, means that all established farmers lower in the catchment may be forced to reduce their N losses significantly in order to allow new development to occur.

122. This raises a question **of the equity of pollution rights between farmers**. One could argue that it is unfair for established farmers in the lower Selwyn catchment to be required to implement reductions of 30% initially (over and above GMP) – to allow further high N loss development to occur in the Upper Catchment (additional allocation to CPW for 30,000+ ha of new irrigation, dairy and dairy support).

123. For Example – a dairy farm in Leeston, leaching presently 58 kg N per ha per year, with all GMP in place already (SMD spray irrigation, dietary optimisation, stocked at 3.9 cows/ha doing 95% milk solids (as a % of bodyweight). This farm is faced with a further reduction of 30% of N loss to 40 kg N loss per ha per year from 2022, to allow for an extra load of N as new farms are developed in the upper catchment, likely on coarse stony soils, along with the potential to leach 80 kg N loss per ha per year, contributing more leaching to an already over-allocated catchment load.

124. As noted extensively through this evidence– there is a relatively straight forward transition for the first 20-40% decline, through improvement and optimisation of the farm system - however to drop the subsequent 20% (from 30% to 50% or from 40-60% N loss reduction) there are significant changes, investment and advanced mitigations required.

125. If there is a "flawed" solutions package to start with, that will not solve the nutrient over-allocation legitimately**, and then the established farmers in the lower catchment have the greatest to lose and suffer the most inequity in the future.** They will be compelled to reduce N losses further in the future, as additional claw backs are required once true (actual) nutrient loads from CPW are validated through improved ecological monitoring and adaptive management is in operation.

126. Neither the environment, community, established farmers nor subsequent generations should be encumbered with clean-up costs resulting from continued "marginal growth" which is based on the combination of permissive resource allocation and lending regimes.

G. MITIGATIONS FOR DAIRY FARMING DISCHARGES AND REDUCTIONS IN NITROGEN LEACHING: IRRIGATION

127. Andrew Curtis (EPA 2013) describes Good Management Practice of irrigation as that meeting the following criteria: (1) The irrigation system can apply water efficiently (2) The use of water is justified. This is achieved through: (1A) Any new development, upgrade or redevelopment is consistent with the INZ Irrigation, Design and Installation Codes of Practice and Standards. 1B) The new development, upgrade or redevelopment is commissioned to demonstrate that it has achieved the Design Performance Indicators. 1C) The irrigation system is self-evaluated annually to demonstrate that it continues to perform efficiently. And furthermore that : Annual justification of irrigation applications to demonstrate responsible use. Mulcock (EPA 2013) also establishes that "Common Sense Management Tools" should be part of any GMP for irrigation. (as noted point 95)

128. All water abstractions should be metered, and water should be used efficiently. In March 2013, actual water use data was unavailable for the Canterbury region. 65% of all abstractions from surface water over 20L/s were still unmetered and 35% of all groundwater takes were still unmetered. A deadline to meter all takes over 20L/s was extended by 9 months to June 2013. Therefore, if industry wide compliance has now been achieved, in July 2014, all water abstractions should have been metered for one year.

129. Efficient water management plays an important role in irrigated agricultural systems (Kim and Evans, 2009). The gains from improved water use efficiency result in a significant reduction in nitrogen leaching (↓30-50%)[18] through reduced or minimised drainage from the root zone of the crop or pasture, and decreased water use.

130. Scheduling irrigation applications to more accurately match plant requirement and evapotranspiration losses should be part of any good management (common sense) approach to minimise water use reducing runoff and drainage and consequently lowering nutrient loss.

131. Good Management Practice is something that is continually evolving and largely is the practices represented by the top 25% in any demographic profile. Good practice is about moving the average farm performers to the right hand side of the statistical bell shaped curve – to where the good management practice farmers are (top 20%) and the early adopters/innovators lie (top 5%).

132. The methods of irrigation used to 2012 are described by Saunders. Of the 385,271 Ha of irrigated land in Canterbury, 17% is recorded as being flood systems, with over 81% in spray systems. Many "early adopter" farmers in New Zealand now recognise the need

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[18] Selwyn Te Waihora Nutrient Performance and Financial Analysis : Prepared for: Irrigation NZ and ECan
Prepared by: The AgriBusiness Group: September 2012.

for more precise application of water, and are implementing technologies to monitor soil moisture deficits.

133. There is no clear understanding of how many farmers are using a combination of tensiometers, variable rate nozzles for application and Fieldmap software technology on their farms in Canterbury. However a survey of Headlands and Intelact Ltd clients who use spray systems, suggested that 20% would use tensiometers to guide their irrigation applications, and probably less than 2% of all irrigators would be able to claim the most efficient water use (absolute best management).

134. The move to active management for irrigation scheduling is a common sense - GMP delivering 30-50% reductions in N leaching. This included upgrading from flood or border dyke irrigation to active management irrigation as part of the farm system modelling undertaken by Intelact & Headlands on behalf of Fish and Game (Appendix 4a &4b). The cost of upgrading these systems based on current pricing has been assumed to be close to a total of $8,800 per Ha to upgrade from flood to precision delivery via pivot, and includes the costs of upgrading of farm races, fencing, pastures, water abstraction and pumping infrastructure. Economic efficiency is also improved.

135. By upgrading to efficient irrigation (GMP) irrigators have the potential not only to reduce their environmental effects, but also reduce their overall water use, pumping costs by up to 30%, as well as significantly reducing the amount of nutrients lost from the root zone.

H. FARM SYSTEM RECONFIGURATION TO IMPROVE RESOURCE USE EFFICIENCY AND LOWER NUTRIENT LOSSES

136. In my experience farms can reduce leaching by 10 to 40% or in some cases more, with some farm system modifications, and time to adapt. Smeaton and Ledgard have provided evidence that reductions of between 10 – 15% can be achieved without any significant impact on farm profitability.

137. Smeaton (evidence 42a Horizons 2009) also notes that, in his experience in Rotorua (dryland dairy farming), farmers were able to reduce nitrogen leaching by 5-25% which had a minor negative to slightly positive effect on profit. He also noted that case studies demonstrated that it would be possible to reduce nitrogen leaching to the catchment by 12% without having a negative effect on profit.

138. Smeaton (evidence 42a Horizons 2009 point 17), describes these practices that reduce leaching with minimal effects on profit : “ The results of the Rotorua catchment case studies showed that the following can reduce N leaching by 5 to 25% and have a minor negative to slightly positive effect on profit: a) Conversion to land based application of effluent; b) No N fertiliser applied in the winter; c) Quitting the use of crops; d) Use of self-feed wintering pads but not herd homes; e) Use of DCD; f) Reduction in use of N

fertiliser, if present use is excessive; g) Switching to more efficient cows (not well modelled as yet); and Reducing stocking rate and producing more per cow, if currently highly stocked.

139. There are a range of mitigations available to assist dairy and irrigated intensive farms reduce the adverse effects of the nutrient and pathogen discharges from their farms. Some involve initial capital costs to implement, but most have benefits including productivity, improved efficiencies and corresponding profitability benefits. It is not a one size fits all approach – each farm/business must be assessed on its own strengths and weaknesses.

140. A study conducted in 2009 (Agfirst Waikato, 2009) investigated the impact of change on profitability as a result of gradual nutrient loss requirements being placed on dairy businesses in the Upper Waikato. The net impact on return on total capital (ROC) of having to meet 40% lower levels of nutrient loss was in the range of 4-8% provided the businesses could optimise their performance. However the impact of a $1.00 reduction in milk solids pay out resulted in a 100% reduction in return on capital for the businesses in the study.

141. A similar study conducted by Dairy NZ in the Horizons region [19](2013) confirmed similar findings. That if farms are to decrease leaching from their allocated LUC N discharge allowance by a further 20%[20] there will no significant impact on profitability providing the farmers have time to adapt. (The starting point assumed Overseer BMP were in place).

142. A study conducted by Stuart Ford, on behalf of Irrigation NZ, in the Selwyn Waihora catchment (2012) investigated options for N loss. The priority options chosen to reduce N loss were the following, in order of preference:

a) DCD use in Autumn (not applicable but ↓N loss by 14%).

b) Reduce Autumn N use (↓19%).

c) Improve Cow Efficiency (to 95% of Bwt as MS) (↓7%).

d) 15% fewer cows with no corresponding increase in production (↓57%) (Note: there is conflicting modelling on the financial effect of reducing stocking rates & this study failed to model a benefit from lower SR).

e) Active Water Management (This is achieved by setting the irrigation settings to this option in OVERSEER.- This then calculates the amount of water applied if the irrigation system is responsive to what the plant needs. In this model/study annual water applied was reduced from 575 mm to 380 mm a saving of 195 mm).(↓38%).

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[19]. Bell, B., Brook, B., Fairgray, D., McDonald, G., & Smith, N. (2013). Section 32 Analysis of Horizons One Plan Cost Benefit and Economic Impact Analysis: A report prepared for DairyNZ

[20] The drop expected depends on LUC. Lower class land(6-8) have a lower drop than better class land. With some farms having a mix of LUC on their farms, ave N loss reduction will vary between farms. So the net change is a case by case basis but say for a LUC mix of 1 &2, the average drop will be around 20% over 20 years.

f) On – Off Autumn Grazing (↓15%).

g) Wintering shelter and housed at home (↑2%).

h) Top BMP of pastoral only farms. (adopting a best practice system of no supplementation of the farm, and farm operating at performance levels (grass and milksolids production) in the top 5% of farms using the latest technology in irrigation application but using relatively high rates of N application) (↓38%)

143. An on farm trial considering lower stocking rates with higher per cow production is occuring at Scott Farm in Hamilton results are confirming a leaching reduction of 40-50% when compared with a conventional farm system. A summary of the results are shown below (Clark, 2012).

144. The Scott Farm trial aims to lower the nutrient footprint from the (dryland pastoral) system while retaining similar profitability. To do this the farm system has dropped stocking rate and associated costs with running more cows at lower productivity, and lifted the feed consumed per cow per annum to close to 5 T DM of home grown feed eaten per cow. These higher genetic merit cows have largely converted this to milk solids resulting in a lower cost system with similar milk solid outputs, and a significant reduction in nitrogen leached (approximately 50% lower) when compared with the Waikato average.

Table 3: Lower Footprint Farm Systems Study: Presented by Dave Clark, Principal Scientist, to Intelact Consultancy Conference Nov 2012 & updated by Chris Glassey in March 2013.

SCOTT FARM : WAIKATO	CURRENT	EFFICIENT
Pasture Harvested	15.6	14.4
Stocking Rate	3.2	2.6
MS per Ha	1202	1207
Operating Profit/Ha	$3109	$3004
Nitrogen Leached/Ha	50	22 (50% DROP)

145. Furthermore the Lincoln University Dairy Farm has also developed an “efficient farm model” denoted as “Low Stocked Efficient” in the figure below. This farm system trial is aiming to assess whether leaching can be reduced significantly through a range of mitigations within the farm system. This is a positive move by the dairy industry, and will assist by providing local information to farmers on what combinations or approaches

within an irrigated farm system can be adopted in order to reduce the risk of N loss to the receiving environment by over 20% without significantly affecting the profitability.

Table 4: "Low Footprint Farming Systems" Presented by Dave Clark, Principal Scientist, to Intelact Consultancy Conference Nov 2012.

LINCOLN	LUDF	High Stocked Efficient	Low Stocked Efficient
Pasture Harvested	17.3	18.8	15.7
Pasture % of total diet	92	85	99
MS per Ha	1860	2210	1810
Operating Profit/Ha	$4850	$4590	$4810
Nitrogen Leached/Ha	23	43	18 (↓22% from base)

146. This work has also been confirmed as being possible "in the field" by a recent SFF (Tomorrows Farms Today) study in the Upper Waikato. In this study, 25 farms were assessed for their economic and environmental performance from 2011-2014. 25% of the farms were shown to retain good levels of profitability (ROC) at a range of milk prices ($5.50 – $7.50/kg MS) while demonstrating N losses 30% below the average. These "more profitable, lower footprint" farms were typified as having a) "low cost efficient" systems, b) not overstocking, feeding cows well on home grown feed (>4.0TDM home grown feed eaten) and having high levels of production efficiency, (>90% milksolids as bodyweight)

147. The report generated by Dairy NZ in 2012 looking at mitigations possible in the Selwyn – Waihora catchment (Howard, 2012) suggested that there might only be around a 5% reduction in profit for a 32% reduction in N leached (Table 17 of Dairy NZ Report). This study is likely to reflect the upper bounds of effects on profitability as a result of the mitigation costs estimated in this report because:

   a) Assumptions relating to N leaching have not been clearly articulated in the report and may have led to over estimation of the effects of single costs.

   b) Precision irrigation was not considered as mitigation, yet this could have yielded the most profitable mitigation approach.

c) Benefits of some mitigations may not have been fully accounted for and have not been clearly stated.

d) Focus on a net change in operating profit rather than full return on capital (ROC) may also lead to underestimation of the benefits of some mitigations.

148. The winner of the Dairy Business of the Year Environmental sector in 2012 was Cloverdale Farm, run by Andrew & Nicky Watt. This is a 2840 cow farm in Ashburton producing 1649 kg MS/Ha on coarse (light) soils demonstrating “Good Management Practices”. This farm demonstrates high profit, low risk and low impact dairy farm. Cloverdale has light stony Lismore soils with a water holding capacity of between 21 to 35% (majority at the lower end). The farm has a Nitrogen leaching value of 18 – 19kg N/Ha/yr.

149. The low environmental footprint achieved by Cloverdale is a result of:

a) Minimal NPK inputs (less than 100kg N applied per ha per year).

b) Monitoring water inputs (AquaFlex water meters). Most area under centre pivot (20% under rotorainer).

c) Low nitrates in pastures (pasture test monthly average 3.5%).

d) Moderate stocking rate (3.75 cows/Ha).

e) Spread effluent over large areas. 85% or more of the cows’ diet is pasture.

f) Flat land, no wetlands or waterways of concern.

g) The farm has a very good pasture harvest and moderate animal performance despite low nitrogen use. The Red Sky Farm performance data shows Cloverdale still to be trending with the top 10% in Canterbury (see Red Sky data attached Appendix 1a & 1b).

150. Benchmarking of the potential reductions in nitrogen and phosphorus losses to water from some model farm types in the Hurunui catchment was done by Campbell, Monaghan, Thompson and Glass in 2011. (Table 5) This study revealed that significant reductions in nitrogen leaching could be made, while maintaining on farm profitability. The most significant (20-30% reductions) and cost effective benefits are made by ensuring that water is used efficiently by moving from flood to deficit spray irrigation

Table 5: Percentage reductions in N leaching and increases in profit for the different scenarios tested, compared to the base model. The figure below is replicated from Page 17 of Appendix 1: (Campbell J, 2012) to the Study "Nutrient Management in Hurunui: A case Study in Identifying Options and Opportunities."

Scenario	Reduction in N leaching from base (%)	Increase in profit from base		Cost effectiveness $/kg N
		$/Ha	%	
Limit N fertiliser to 60 kg N/Ha/yr	43	-$254	-18	$12
Herd shelter wintering	31	-$156	-11	$10
Herd shelter + restricted grazing	46	-$156	-11	$6
Herd shelter + restricted grazing + DCD 5.5% increase in pasture production	49	$34	2	-$1
DCD	20-30			
Changing from border dyke to spray irrigation				

Increasing cost effectiveness ↓

151. In my opinion, the inclusion of low protein[21] feeds to maximise per cow performance and minimise nitrogen concentrations in urine could be given greater consideration in developing or reviewing farm systems. Low protein feeds (e.g: cereals), can aid in enhancing rumen efficiency, improve feed conversion efficiency, lowering of urea production as a by-product of protein from the gut, which subsequently "lowers the nitrogen load" that the cow has to excrete. This was covered in detail in the section 42a evidence of Dewes and Waldron 2012 (Horizons One Plan). NZ pasture based cows consume a diet of around 26% crude protein all year round. However, their requirements are actually a lot lower, at around 16% if one was to use an annual average. This surplus of protein in the diet, comes at a cost to the cow, and the environment, as it is excreted as urea in the urine, which then leaches as nitrate N to groundwater.

152. Farm System Modelling undertaken on behalf of Fish & Game (2013 – Appendix 4a &4b) pCLWP evidence: In summary – the farms that were modelled on behalf of Fish and

[21] Low protein feeds such as maize, grain or cereals, wheat, barley etc, that have protein levels lower than 10%, and that balance out the crude protein in pasture which is usually around 22-28%.

Game represented intensive, irrigated dairy farms on coarse soil types. These are worst case scenarios in regards to the financial implications of reducing their environmental impacts given that these farms are on the most sensitive soils with the highest rates of contaminant losses. The most suitable options for all businesses was the implementation of efficient irrigation techniques, either by upgrading from flood to spray, or by changing to precision application techniques on spray irrigation, in order to reduce the risk of nutrient loss as modelled by Overseer. Provided their corresponding stocking rates are set at optimal levels as per paragraphs 158-165 below.

153. In the Fish and Game farm system modelling (Appendix 4) another effective way to reduce nutrient loss from the farming system was to move to a 24/7 housed barn situation on a “cut and carry block”, this reduced nitrogen losses by 91% to less than 20 kg N//ha/yr. However, while this can be profitable for a highly technical operator, it does require significant investment in capital, and may not suit operators that are in a risky equity position with high fixed costs: these systems are better suited to high commodity prices (>$7.50 kg MS).

154. For the two businesses that were operating at stocking rates over 3.5 cows/Ha and more than 20% of feed imported, (Hinds and Ashburton Farms) a review of the stocking rate was also a viable, low risk, and profitable option, as it did not place stress on the equity position of these farms, yet, it yielded a more efficient, profitable and lower risk system when combined with precision irrigation technologies leading to overall lower nutrient losses, a reduction of >70%. Refer to the Appendix 4 & Additional Tables for Farm System Modelling Summary.

155. In my own experience, when investigating cases of impaired dairy herd performance on irrigated dairy pastures in the Millicent region of South Australia in the period 1997 to 2004[22], it was not uncommon to find crude protein levels in the pasture of 35-42%. This was effectively as a result of high Nitrates in the groundwater which was being used for irrigation. It is now recognised there was a flume of high Nitrate groundwater in this particular region. (Bolger.P, 1999).

156. This is a risk for Canterbury. As noted in the report by Ford in 2012: “*Attenuation of Nutrients*": - Once nutrients enter a river, lake or wetland, they may be taken up by plants, temporarily retained, and released back into the water column as growth ceases (“nutrient spiralling”). As little is known about the extent of this process, the net assimilation of nutrients is assumed to be zero. Nutrients may also be permanently removed by denitrification, burial or be flushed from the catchment. The scale and extent to which these processes reduce nutrient concentrations is not known. For the Canterbury Plains aquifers, denitrification processes are unlikely to significantly reduce

[22] Refer to (Case Study 1 – page 54: Pasture, Mixed Agriculture and Forestry – South East, South Australia in Contamination of Australian Groundwater with Nitrate (Bolger.P, 1999).

nitrate concentrations as drainage water moves down through the soil profile and gravels are overlying the aquifers.

157. The “zone committee solutions package” will result in the nitrate levels in groundwater and shallow wells rising by 20-25% as a result of the additional CPW load.

158. Better productivity, from fewer better fed cows at a more optimal stocking rate is a sound option for some farms when reconfiguring a farm system. This philosophy is being demonstrated by the most recent “efficient dairy trials at Scott Farm and LUDF and the recent TFT study. (points 144-148 above). The average New Zealand cow would need to lift production by around 25% and consume more home grown feed in order to achieve this result, as noted in study. This can occur in a relatively short time frame (18 month period of altered management). This “reconfiguration option and the associated profitability” was demonstrated in the Farm System Modelling studies done by Ridler et al and also was demonstrated in the Fish and Game farm system modelling study.

159. There is no doubt that the cost of compliance to a farmer is likely to involve some up-front costs, as mitigations and good practices are put in place. This is normal with any business, as the business owner continues to invest in technology and infrastructure, in order to remain viable, saleable and profitable. It is not sound business practice to let a business, or its infrastructure run down over time.

160. It is essential that we relate stocking rates to pasture harvested and subsequent profitability rather than production. As noted in figure 3 increased milk production per hectare does not necessarily align with more profit per hectare. However farm optimisation does align with improved profit. (“sweet zone concept”).

161. It is essential that pastoral based systems align their stocking rate to pasture harvested (carrying capacity), and ensure careful use of supplements with appropriate infrastructure. This can lead to higher pasture harvested overall due to maintenance of longer rotations and more appropriate grazing systems to suit the plants and animals. Where stocking rate is not well aligned to long term average pasture harvested (as noted by Smeaton 2009) (overstocked) then there can be measurable lifts in productivity and efficiency from adopting lower stocking rates.

162. Many of the assumptions underpinning technical reports that have advised the zone committee are on the premise that increasing stocking rate leads to increased profit and dropping stocking rate reduces both output and profit – Both Feitje[23] and Ford[24] made these assumptions in their N mitigation modelling, which was used by Harris 2014[25] to

[23] Modelling of N mitigation costs 2013 by Feitje – ECAN

[24] Selwyn Te Waihora Nutrient Performance and Financial Analysis - Prepared for: Irrigation NZ and ECan
Prepared by: The AgriBusiness Group -September 2012

[25] Predicting the consequences of future economic scenarios – Economic Impact Assessment – Simon Harris. 2014

underpin the macro-economic assumptions for the region. The above analysis needs to be interpreted with caution in my opinion.

163. Lower stocking rates do not always eventuate in lower production and lower profits as noted by Smeaton 2009, the Dairy NZ Scott Farm Trial, The Lincoln Low Stocked Efficient trial, and the findings Ridlers work, the Fish and Game modelling (2013) and also demonstrated in the TFT study.

164. In my experience, this is the case only when properties are under stocked. That is not the case on most farms now. Many farms are overstocked, by 10-20%, a level that does not allow cows to be fully fed in order to reach optimal performance. A 500kg cow can consume over 4.5 - 5 T DM of home grown forage per cow per year and produce >90% of her bodyweight as milk-solids. This has been demonstrated by the more profitable, resilient farm systems.

165. Most NZ cows, consume considerably less home grown forage than 4.5-5.2 T DM on average (3.2-3.6 T home grown feed/cow/year and <70% of bodyweight as MS) due to poor matching of stocking rate to home grown feed. As a result, ½-2 T DM/cow/year of externally sourced feed is required to satisfy cow health, welfare and productivity requirements in order to sustain heavily stocked systems that cannot adequately feed cows. In the case of Canterbury, the farm systems are configured so that alternative feed sources are provided in part from a heavy reliance on "dairy support land" which is additional to the milking platforms.

166. Harris notes in his report, (page 14) he used the packages from the solutions options that were reflective of reductions in revenue, but increases in expenditure (i.e. mitigations that cost - rather than optimise farms) in order to demonstrate the regional economic effects. He also notes that his modelling should be used with caution however, as it does not recognise that the "most effective on farm mitigation may be through practices that reduce the intensity of operation and expenditure" rather than the approach he proposed. Harris acknowledges that Dairy NZ is aware there are better solutions for farmers, solutions offering improved business and environmental performance. He has however elected not to use this in his macro-economic modelling because these solutions result in lower revenue and reduced regional outcomes. Substantiation of this claim was unavailable for us to review.

167. There is no 'one size fits all' approach to mitigating nitrogen and phosphorus losses from farms, as these factors need to be considered on a farm-specific and farm systems basis.

168. The single cost and single mitigation approach used by Harris[26] is "out of step" when reviewed against recent evidence and modelling studies that show farm system

reconfiguration to more efficient, lower footprint systems can occur without significant impacts on farm profitability and when farm systems are optimised.

169. On this basis, I do not believe that robust conclusions cannot be made from assessing the costs of one off farm system mitigations as has been presented by many experts. For this reason the technical report on macro-economic effects is flawed, in my view.

170. As increasing knowledge emerges from a range of top farmers in all regions across NZ, it is evident that farm systems reconfiguration is a normal process of adaptation. This is being taken on board by the early adopters who are leading the way. Consequently, costing of single mitigations is continually being adapted downwards as scientists endeavour to keep up with innovative farmers[27] developing new and innovative systems to "meet and beat the rules" in NZ.

I: PHOSPHATE MITIGATIONS

171. Phosphorus losses from the farm largely occur through overland flow pathways. The most common being: effluent run off into surface water; stock in waterbodies; attached to sediment released from the land through poor farm practices; run off from farm drains, tracks, or stock crossing points; from soil run off from intensively grazed pastures; dung deposits; and fertiliser additions. The amount of phosphorus lost from the farm depends heavily on spatial factors and the type of on farm management practices.

172. Winter cropping, and winter grazing management practices for stock can have significant impacts on the risk level of phosphate loss from a farm system. Feed pads and "standing herds off" during inclement weather, herd homes, and wintering structures are all part of mitigating the risk of phosphate loss to the receiving environment.

173. The following table produced by Richard McDowell, AgResearch indicates some options and costs of mitigation of phosphate lost.

ssessment – Simon Harris. 2014

Table 6: Cost Effectiveness of Various Phosphate Mitigations.

Strategy		Effectiveness (%)	Cost ($/kg P conserved)
Effluent pond storage / low rate application	Source management	7-10	20-25
Optimum soil test P		15-45	0-6
Low water soluble P		5-48	1-9
Restricted grazing		30-50	10-100
Tile drain	In-field amendment	15-50	41-54
Aluminium sulphate to pasture / cropland		10-40	125-160
Buffer strips	Edge of field	0-10	>200
Stream fencing		14-50	19-27
Sorbents in and near streams		30-80	59-91
Irrigation water use and recycling		10-80	-80 - >400
Natural and constructed wetlands		-3-20	229-271

174. Phosphorus mitigations are generally low cost and should be encouraged and utilised on farm whenever possible. These mitigations usually involve ensuring that <u>minimum good management practice is applied</u>. Including ensuring that: stock are excluded from waterbodies; no direct runoff of soil or contaminants occur from pasture, farm tracks, bridges or culverts; and that effluent is managed appropriately.

175. Any plan that relies on managing phosphorus alone is risky. Nitrogen and phosphorus both contribute to primary productivity and eutrophication in rivers and lakes; the Selwyn – Waihora catchment is no different. Nitrogen and phosphorus concentrations are influenced by season, flow characteristics, differences in factors such as land management practices between sites, and plant uptake of available nutrients (from substrate or water). This variability means that relying on the control of phosphorus alone, as proposed by the Zone Committee Solutions package, while allowing nitrogen to reach toxic levels, is fraught with risk. This strategy relies on the assumption that phosphorus concentrations can be constantly maintained at very low concentrations with zero tolerance for occasional elevated concentrations.

176. There is a **lack of "tools" available to measure diffuse phosphorus loss from farms.** At present, we have Overseer at our disposal. This is not reliable for quantifying P loss. Predictions can be 30% out, and have varied by 30% between versions. Overseer does not quantify P loss during storm events when the greatest losses occur. Overseer is best used as a tool to manage N outputs from farms, and quantify the relative gains from mitigations.

J. APPROACHES TO MANAGING FARMING IN VARIATION 1 TO THE CLWP - FISH AND GAME PROPOSED APPROACH

177. I have reviewed the approaches proposed by Environment Canterbury in the Variation 1 of the pCLWRP in regards to managing land use activities, the section 32 Report, the technical reports, and the zip addendum. If the objective is to reduce nitrogen leaching and contaminant losses from agriculture, then I have a number of significant concerns in regards to this framework. I do not believe it will promote fair management of the resources nor will it provide for protection of the current ecosystem.

178. Although the regional council acknowledges that the region has significant freshwater issues due to over allocation, management approaches in the Variation1 fail to address these issues in a legitimate manner. This approach is not consistent with the NPS. In regards to water quality the Variation fails to establish a management framework ensuring that nutrient loses from land uses are reduced such that ongoing water quality degradation is halted and water quality is eventually improved over time. This is discussed in the expert evidence of Mr. Brett Stansfield, and Dr Jim Cooke.

179. In my opinion an appropriate management approach would be to establish standards in regards to nutrient leaching (output controls) and ensure that minimum practice standards are met on farm, by mandating these through regulation. Minimum practice standards should include; ensuring stock are excluded from waterbodies, best management practice is met in regards to fertilizer use, effluent management, and efficient irrigation is used. These standards should ensure that the assumptions made by Overseer in regards to farm management are 100% met. Establishment of minimum practice standards guarantee that where contaminant output control[28] cannot be established: farm management practices are managed to reduce discharges. The Fish and Game approach would expect good practice is in place on all farms by 2022.

180. With GMP expected to be in place on all farms by 2022 this should result in a catchment wide load reduction. This should be aligned with adequate spatial and temporal ecological monitoring to assess the legitimacy of the proposed approach. If tributary streams to Lake Ellesmere show an improvement (net reduction) in N and P load, then this may reduce the need for further compulsory reductions, however if this is not the case, then more advanced mitigations (Tier 2) type mitigations would be required in order to achieve a further 20% reduction in the overall catchment load from all land uses.

181. To ensure that the assumptions made by Overseer are met and that the data has been entered into the model correctly, the regional council needs to ensure that it possesses the ability to legitimately audit the farm. This should be done via a peer review of the input data to validate the output from the model. Accurate farm data that has been ground-truthed and reconciled with actual farm management is necessary to ensure that

[28] Diffuse Phosphorus, Sediment and Pathogen losses

the output from the model is robust and that databases of "actual" farms and nutrient losses collated are accurate.

182. This "on farm performance analysis" and auditing needs to be done by a suitably qualified professional. There are significantly more professionals available to do this than there were five years ago.

Farm Environment Plans (Schedule 7)

183. The Farm Environment Plans (FEP) that are proposed in Schedule 7 of the pCLWRP encourages farmers to undertake a process of recording their current practices with respect to a range of management, irrigation and environmental practices. However there is no nutrient leaching reduction goal articulated as yet. If there is no clear goal and no compulsion to achieve it, then I question how a valid plan can be made. The Fish and Game approach is to have clarity of what is expected by clear time frames, and in addition to this, legitimate ecological monitoring will test the validity of the proposed approach

184. In my view, farmers are well aware of the environmental issues that occur from farming activities. They are well connected with their environment, they observe the changes occurring to their resources (scarcity, over-allocation, nutrient enrichment of receiving water bodies). As stated by Judge Thompson in his recent Environment Court decision on Horizons One Plan in response to Fonterra assertion that there are land managers out there who are unaware of the need to manage nitrogen loss from pastures, and who are unaware of available techniques to do so, "We can only assume that if those land managers do exist, they have been farming in an information vacuum for the last 20 years, and certainly for the nine years since the Accord [dairy clean streams accord] was signed"[29].

185. The issue is not a lack of knowledge or understanding by farmers but a lack of leadership for farmers. Farmers want to do the right thing. They want to invest their time and money into meaningful mitigations that will not only improve their asset, but also enhance the overall health of the catchment. However, without a legitimate catchment solution that responds, and is being monitored and reviewed in order to ultimately protect ecological health; farmers will be uncertain as to how much they need to do, resulting in business uncertainty and inequity issues due to inefficient resource allocation.

186. Some farmers will also not willingly change farming practices or adopt mitigation which is seen to be overly expensive or risky. Without a framework which is equitable across land uses in regards to the establishment of goal orientated standards, early adopters will do more than their fair share, and "free riders" will do less than their fair share. This results

[29] Day et al v Manawatu Wanganui Regional Council Decision No [2012] NCEnvC 182, paragraph 5-133

in inequitable outcomes for all concerned, and further degradation of an over allocated catchment.

187. The Farm Environment Plans (FEP's) fail to satisfy any submitters concern that the current recommendations to retard water quality decline are satisfactory as there is no clarity on the GMPs at this stage.

188. I am unclear why a farmer would make a voluntary change, given there is no degree of certainty over the amount of change and whether reductions in contaminant losses will lead to improved ecosystem health. With a lack of certainty in catchment outcomes, some farmers will avoid engaging in this process in a meaningful way. Unclear guidance in regards to the adoption of mitigation measures, failure to establish contaminant output standards, and unclear outcomes are unlikely to achieve a change in farm management practices or address the regionally significant freshwater issues. As stated by Judge Thompson in his recent decision on Horizons One Plan "(Voluntary approaches)… need the reinforcement of a regulatory regime to set measureable standards and to enforce compliance with them by those who will not do so simply because… it is the right thing to do" [30](para 5-9,). I concur with his statement.

Alison Dewes

29 August 2014

[30] Day et al, paragraph 5-9

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APPENDICES

1. Red Sky Data – Canterbury Average and Top 10%
2. Ridler(2014) Table to support Figure 4
3. Canterbury District Health Board – Disease Incidence Selwyn.
4. Fish and Game Farm System Modelling (2013) Three Farms
5. Mc Dowell (2014)Provisionally Approved Paper: A National Assessment of the Potential Linkage Between Soil and Surface and Groundwater Concentrations of Phophorus.
6. Overseer – What BMP are already assumed.
7. Summary of the Modelled Land Management Options (MRB 2013) for Modelling Economic Impacts of Nutrient Allocation Policies in Canterbury: Hinds Catchment. (Landcare Research 2013)

Summary Farm Performance - Dairy
Canterbury Dairy 2011 Benchmarks
Canterbury Dairy 2011 Owner

	2010/11 Canterbury Average	2010/11 Canterbury Top 10%	2011/12 Canterbury Average	2011/12 Canterbury Top 10%
PHYSICAL PARAMETERS				
Peak Milking Cow Numbers	**748**	**685**	**748**	**685**
Total Effective Dairy Hectares	230.3	190.6	230.3	190.6
Effective Milking Hectares	**228.7**	**188.4**	**228.7**	**188.4**
Cows per Milking Hectare	**3.27**	**3.64**	**3.27**	**3.64**
Milksolids per Cow	**397**	**439**	**417**	**461**
Milksolids per Milking Hectare	**1,299**	**1,595**	**1,364**	**1,674**
Milksolids Price ($/kgMS)	**$ 7.58**	**$ 7.60**	**$ 6.00**	**$ 6.00**
Pasture Dry Matter Harvested (tDM/Ha)	**13.1**	**15.5**	**13.6**	**16.0**
KEY PERFORMANCE INDICATORS				
Operating Profit per Hectare	**$ 4,423**	**$ 6,682**	**$ 2,722**	**$ 4,545**
Operating Profit per Cow	$ 1,353	$ 1,838	$ 832	$ 1,250
Total Assets per Ha at Start of Year (4-Yr Av Values)	$ 47,005	$ 49,212	$ 47,005	$ 49,212
EQUITY % at 4-Yr Av Values	**58.3 %**	**58.1 %**	**58.3 %**	**58.1 %**
RETURN ON CAPITAL (ROC) at 4-Yr Av Values	**9.1 %**	**12.9 %**	**5.8 %**	**8.9 %**
Return on Assets (ROA) at 4-Yr Av Values	**9.3 %**	**13.1 %**	**5.9 %**	**9.0 %**
ROA including Capital Gain at 4-Yr Av Values	11.2 %	16.3 %	7.8 %	12.2 %
RETURN ON EQUITY (ROE) at 4-Yr Av Values	**10.1 %**	**17.4 %**	**4.2 %**	**10.0 %**
ROE including Capital Gain at 4-Yr Av Values	13.6 %	23.2 %	7.6 %	15.8 %
OPERATING PROFIT MARGIN	**41.0 %**	**50.4 %**	**29.8 %**	**40.6 %**
Cost of Production per kg Milksolids	**$ 4.42**	**$ 3.66**	**$ 4.24**	**$ 3.52**
Financing Costs per kg Milksolids	$ 1.45	$ 1.22	$ 1.38	$ 1.16
Cost of Prod'n + Financing Cost per kgMS	$ 5.60	$ 4.71	$ 5.36	$ 4.53
Total Operating Expenses as % Gross Revenue	49.2 %	42.0 %	58.6 %	50.3 %
Financing Costs as % Gross Revenue	17.4 %	14.6 %	20.6 %	17.3 %
Core per Cow Cost	**$ 715**	**$ 665**	**$ 715**	**$ 665**
Core per Hectare Cost	$ 1,084	$ 1,136	$ 1,084	$ 1,136
Core per Hectare Cost per tDM Pasture Harvest	**$ 83**	**$ 73**	**$ 80**	**$ 71**
Management + Staff Costs per Cow	$ 405	$ 344	$ 405	$ 344
Cows per Full Time Staff Equivalent	**150**	**188**	**150**	**188**
Total Feed/Supplement Costs per Cow	$ 696	$ 660	$ 698	$ 667
Pasture as % of Total Consumed	**83.5 %**	**83.5 %**	**84.0 %**	**83.7 %**
Average Cost of All Consumed Feed (/tDM)	**$ 299**	**$ 267**	**$ 292**	**$ 262**
Pasture Cost (Per tDM)	**$ 277**	**$ 244**	**$ 270**	**$ 239**
Forage Cost (/tDM Consumed incl.wastage)	**$ 401**	**$ 371**	**$ 401**	**$ 370**
Concentrate Cost (/tDM Consumed incl.wastage)	**$ 416**	**$ 397**	**$ 415**	**$ 396**

Financial Farm Performance - Dairy
Canterbury Dairy 2011 Benchmarks
Canterbury Dairy 2011 Owner

	2010/11 Canterbury Average	2010/11 Canterbury Top 10%	2011/12 Canterbury Average	2011/12 Canterbury Top 10%
BALANCE SHEET ASSESSMENT				
Total Assets at End of Year at Market Values	$ 11,663,559	$ 9,912,987	$ 11,663,559	$ 9,912,987
Total Assets at End of Year at 4-Yr Av Values	$ 11,558,816	$ 9,829,608	$ 11,558,816	$ 9,829,608
Total Liabilities at End of Year	$ 4,818,474	$ 4,114,279	$ 4,818,474	$ 4,114,279
EQUITY at Market Values	$ 6,845,085	$ 5,798,708	$ 6,845,085	$ 5,798,708
Change in Equity at Market Values	$ 214,338	$ 304,467	$ 214,338	$ 304,467
EQUITY % at Market Values	58.7 %	58.5 %	58.7 %	58.5 %
EQUITY at 4-Yr Av Values	**$ 6,740,342**	**$ 5,715,329**	**$ 6,740,342**	**$ 5,715,329**
Change in Equity at 4-Yr Av Values	**$ 219,969**	**$ 310,397**	**$ 219,969**	**$ 310,397**
EQUITY % at 4-Yr Av Values	**58.3 %**	**58.1 %**	**58.3 %**	**58.1 %**
Change in Equity at 4-Yr Av Values	3.4 %	5.7 %	3.4 %	5.7 %
PROFIT & LOSS FOR YEAR				
Gross Revenue	$ 2,470,048	$ 2,500,456	$ 2,089,604	$ 2,109,878
Gross Operating Expenses	$ 1,458,293	$ 1,241,600	$ 1,467,069	$ 1,253,512
OPERATING PROFIT/(LOSS)	**$ 1,011,755**	**$ 1,258,856**	**$ 622,535**	**$ 856,365**
Operating Profit/(Loss) per Hectare	**$ 4,423**	**$ 6,682**	**$ 2,722**	**$ 4,545**
RETURN ON CAPITAL (ROC) at 4-Yr Av Values	**9.1 %**	**12.9 %**	**5.8 %**	**8.9 %**
Return on Assets (ROA) at Market Values	9.2 %	13.0 %	5.8 %	8.9 %
Return on Assets (ROA) at 4-Yr Av Values	**9.3 %**	**13.1 %**	**5.9 %**	**9.0 %**
Capital Efficiency Ratio at 4-Yr Av Values	21.5 %	25.6 %	18.2 %	21.6 %
Profit/(Loss) incl. Capital Gain at Market Values	$ 1,232,463	$ 1,566,396	$ 843,243	$ 1,163,905
Profit/(Loss) incl. Capital Gain at 4-Yr Av Values	$ 1,238,094	$ 1,572,326	$ 848,874	$ 1,169,835
ROA incl. Capital Gain at 4-Yr Av Values	11.2 %	16.3 %	7.8 %	12.2 %
PROFIT (LOSS) incl. Financing Costs	**$ 600,943**	**$ 906,410**	**$ 211,723**	**$ 503,920**
Return on Equity (ROE) at 4-Yr Av Values	**10.1 %**	**17.4 %**	**4.2 %**	**10.0 %**
ROE incl. Capital Gain at 4-Yr Av Values	13.6 %	23.2 %	7.6 %	15.8 %
WORKING CAPITAL POSITION				
Operating Surplus	$ 1,274,765	$ 1,466,760	$ 885,545	$ 1,064,270
Change in Working Capital	**$ 443,095**	**$ 600,715**	**$ 53,875**	**$ 198,224**
RISK RATIOS				
Operating Profit Margin	**41.0 %**	**50.3 %**	**29.8 %**	**40.6 %**
Total Operating Exp. as % Gross Revenue	49.2 %	42.0 %	58.6 %	50.3 %
Financing Costs as % Gross Revenue	17.4 %	14.6 %	20.6 %	17.3 %
Cost of Production per kg Milksolids	$ 4.42	$ 3.66	$ 4.24	$ 3.52

APPENDIX 2: Table of Data – To support Figure 4 (Ridler et al 2014)

	Base Farm	Run 2	Run 3	Run 4	Run 5	Run 6
LP run kg MS/cow	750 cows 350	Opt cows 350	Opt cows 384	Opt cows 384	Opt cows 384	Opt cows 384
[1]Nx kg	Base 93,990	79,950	85,233	90% Base Nx level	80% Base Nx level	70% Base Nx level
Herd size (cows)	750	618	631	620	557	494
Milksolids kg	262,935	216,774	242,502	238,782	213,968	189,563
Profit ($	740,235	784,841	896,770	894,777	877,364	754,524
% change in profit		↑6%	↑21%	↑21%	↑19%	↑2%
kg DM bought- in feeds	648,500	23,000	136,000	107,500	0	0
Supp. made kg DM	0	16,000	9,000	0	7,000	25,000
Total kg DM used	3,143,800	2,558,650	2,751,000	2,708,940	2,403,640	2,122,440
R 1 yr grazed off	All. 197 Nov-Jul	All. 162 Nov-Jul	All. 133 Nov-Jul	All. 130 Nov-Jul	All. 117 Nov-Jul	All. 104 Nov-Jul
R 2 yr grazed off	All. 188 Jul – Jul	All. 155 Jul – Jul	All. 126 Jul – Jul	All.124 Jul – Jul	All. 111 Jul – Jul	All. 99 Jul – Jul
Cows grazed off	All. 8 weeks	All. 8 weeks	All. 8 weeks	All. 8 weeks	All. 8 weeks	All. 8 weeks
N leached /ha/year	18	15	16	16	13	11
% ↓ N loss		↓16%	↓11%	↓11%	↓27%	↓38%

APPENDIX 3: CDHB 2012. Incidence of Gastro- intenstinal disease in Selwyn- Waihora region

Average Annual Rates[1] (per 100,000 population) of Campylobacteriosis by Age in Selwyn District, Canterbury Region and New Zealand, 2006 to 2012

Age / Area	**0-4**	**5-9**	**10-14**	**15-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70+**
Selwyn District	656	201	164	343	581	231	249	239	297	359
Canterbury Region	614	237	179	259	386	302	266	270	305	252
New Zealand	382	151	126	216	301	191	188	217	264	231

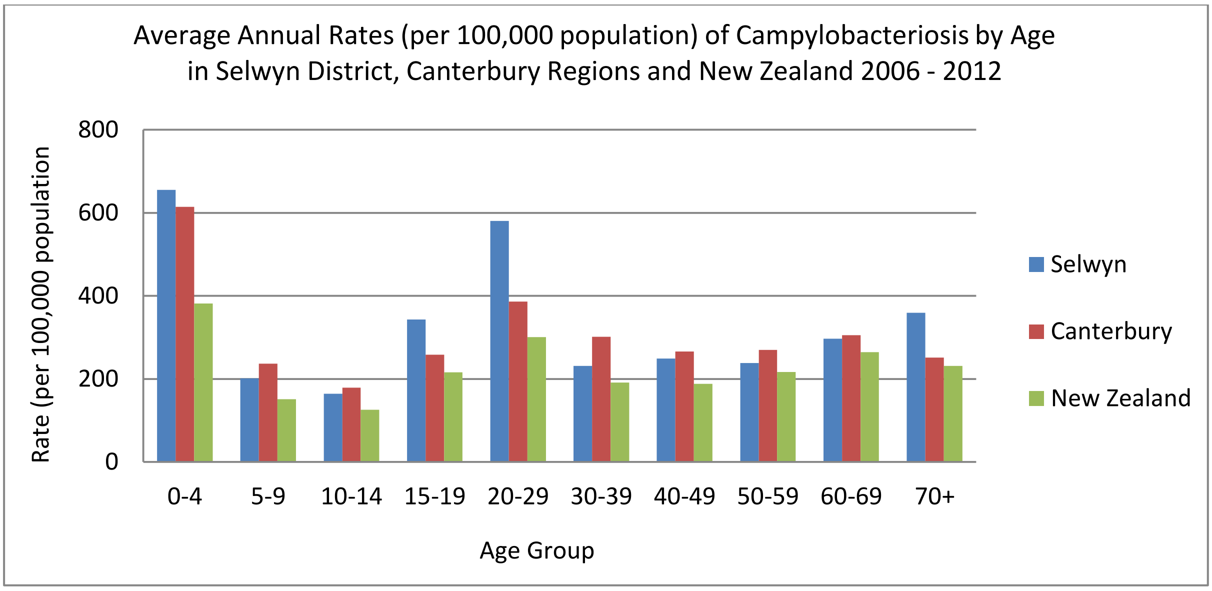
1 Rates based on 2006 Census data

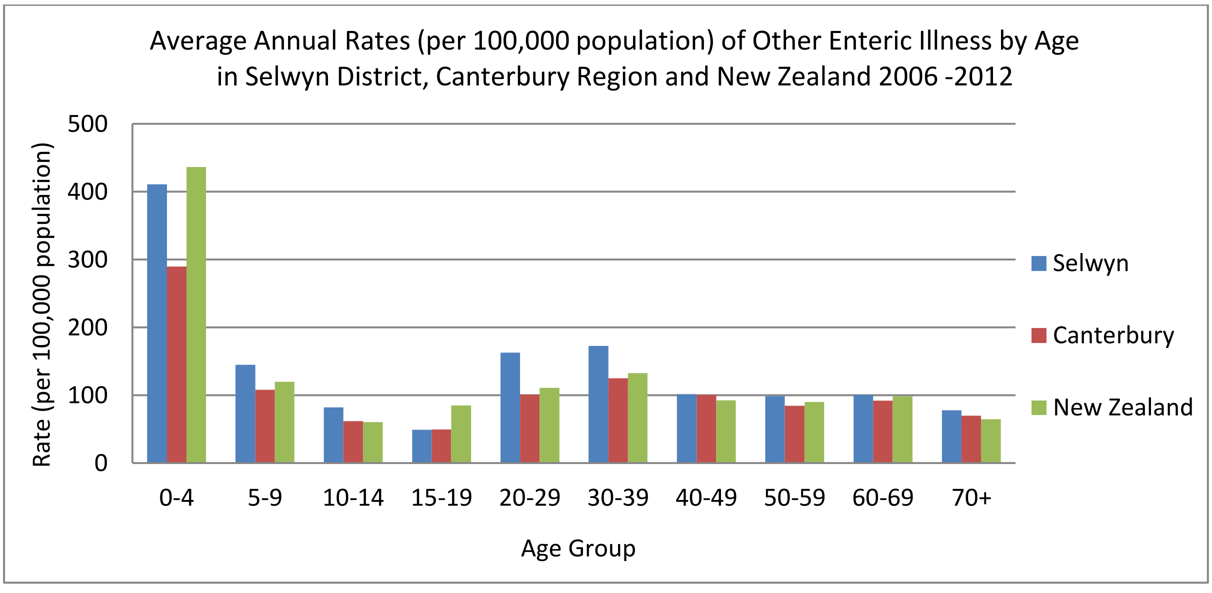
Average Annual Rates[1] (per 100,000 population) of Other Enteric Illness[2] by Age in Selwyn District, Canterbury Region and New Zealand, 2006 to 2012

Age / Area	**0-4**	**5-9**	**10-14**	**15-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70+**
Selwyn District	411	145	82	49	163	173	102	99	101	78
Canterbury Region	290	108	62	49	101	125	100	85	92	70
New Zealand	437	120	60	85	111	133	93	90	99	65

1 Rates based on 2006 Census data

2 Other Enteric Illness includes Cryptosporidiosis, Gastroenteritis – unknown cause, Giardiasis, Paratyphoid Fever, Salmonellosis, Shigellosis and Yersiniosis





(Source – Williamson, CDHB 2014)

APPENDIX 4 FISH AND GAME FARM SYSTEM MODELLING (notes from cLWP Evidence 2013)

FISH AND GAME FARM SYSTEM MODELLING (to be read with supporting Tables)

1. Three farms were assessed for current performance (2013), and low nitrogen loss scenario plans on behalf of Fish and Game. This was undertaken to ascertain what types of farm system reconfigurations may be necessary to meet nutrient limits that may be set in Red and Orange Zone catchments to reduce the overall catchment load, or to create "nutrient headroom" such as Selwyn where there are plans for irrigation expansion yet no further decline in water quality is to be achieved.
    a. Farm system modelling was undertaken using the following method: Compilation of a base model of Overseer 6 for the 2011-12 year using actual farm data and reconciling it with accounts (feed and fertiliser purchases etc.).The farms 2011-12 economic and physical data was entered into Red Sky Farm Performance Analysis.Farm system models (UDDER) were in operation for all three farms, and had undergone several years of validation and verification by an experienced consultant. The lower leaching scenarios were developed in line with what the farmers were thinking about doing in nearly all cases. These were modelled in UDDER and Red Sky and then nutrient loss from Overseer 6 was based on the farm system changes.
2. These case study farms were chosen for the following reasons:
    a. They reflected the likely intensity of farming system we are to transition to under a "business as usual scenario" (system 4-5). There is continuing intensification of the industry, with more cows, and more bought in feeds. Unless there is consistent industry messaging to avert this, it is likely to be a trend that continues.
    b. These farms were selected to reflect "typical higher risk farms" on the basis of their soil types, and intensity. They essentially represent worse case scenarios. The farms are a mix of light (coarse textured) soils – Pahau silt loam, Balmoral silt loam and light Lismore silt loam in orange and red catchments typical of Canterbury.
    c. These farms and soil types typify the coarse (light) soil types in the catchments modelled by Fish and Game for total nutrient loads.

3. One farm was a Flood Irrigated Culverden Farm on Pahau silt loam (typical of Amuri Plain). This flood irrigation reflects the 18% of farms across Canterbury that still use this system, and the potential capital investment and profit and efficiency (improved pasture harvest and water use) changes that may occur, as a result of moving to precision, spray irrigation. This farm had N loss of 81 kg N/Ha/yr in the base year. Scenarios run for this farm included precision irrigation and improved productivity via better effluent use, reduced nitrogen use by 20%, reduced labour though efficiencies gained, improved milk solids production and pasture harvested of 2 T per year (worth $600/Ha/yr in equivalent feed value). Nitrogen losses were reduced to < 20 kg N/Ha/year through improved irrigation technology and farm system efficiencies. The profitability improved while the farm system risk was reduced.

4. The second farm Hinds Farm was stocked at 4.05 cows/Ha, on stony (coarse textured) Lismore soils typical of Ashburton and Selwyn, harvesting 15 T DM per annum. Stocking rate was at 4 cows/Ha, using 364 kg N/Ha/yr wintered on an adjoining lease block, on fodder beet, kale and oats. This farm had a Nitrogen loss of 146 kg N/Ha/yr. Two directions of scenario planning were undertaken on this farm. The first scenario was to maintain the current level of intensity using a 24-hour cut and carry barn scenario, and using precision irrigation technology on the pastures, which yielded a 91% drop in Nitrogen loss from the farm, down to 18 kgN/ha/yr, (using actual data in Overseer) with a slightly improved ROC from base. However this scenario did require the business operator to undertake capital expenditure of $1.4 million. This increased the risk to their equity position.
5. In order to ensure this "Hinds" business was not exposed to further risk through low equity, a lower risk scenario was undertaken to "destock and use precision irrigation". This yielded a 77% drop in N loss, down to 26 kg N/Ha/yr (using actual farm data in Overseer), without significant change to debt risk, and lifted profitability, while lowering the business risk profile.

6. The Third Farm: Ashburton Dairy was harvesting 16.6 T DM with nitrogen use over 300 kg N/Ha/yr, and cows consuming only 3.62 T DM per cow as home grown feed, and stocked at 4.52 cows/Ha. Hence options to review this system included an "extensification" scenario combined with an upgrade to precision irrigation technology. The winter cropping with cows on crops 24 hours per day, consuming kale, fodder beet and straw, and wintering cows on also reflects a higher loss risk. This farm "status quo model" had an N loss of 141 kg N/Ha/yr (actual farm data in Overseer). The "extensification" scenario involved lowering stock numbers by 25% to increase home grown feed eaten per cow. Irrigation was upgraded across the whole farm, and effluent was better used resulting in nitrogen use being reduced by 60%. Scenarios to reduce nitrogen loss on this farm demonstrated a reduction of 80% Nitrogen loss from the base, down to 42kg N/**h**a**/**yr (actual farm data in Overseer)**,** while the return on total capital improved and risk was reduced. The equity position in the business was also strengthened.

7. For further detail on these farm system scenario plans, economic and environmental performance, please refer to Tables Attached of Modelling.

8. The table 5 below is a modification of a "Good Management Practice Table" from the report by R Ford (Managing the effects of land use on water quality 2012). The modifications include a range of mitigations used in the Farm System Modelling Study conducted on behalf of Fish and Game.

Table 5: Modified TIER 1 - TIER 2 Mitigation Table: Farm System Modelling Study

Category	GMP Principles/Practices As suggested by ECAN in 2012	F & G amendment + BMP's adopted in the Farm System Modelling	Scenario Tested	Examples of Measures to Implement: GMP Principles(adapted from Ledgard 2010 table in report by Ford.R., 2012
TIER 1 (F&G)	Full review of farm system (performance analysis) and stocking rate to ensure stocking rate is optimum for the farm system.	Matching stocking rate to pasture harvest through historical assessment of the farm system can be a profitable option.	√	
	Efficient use of irrigation water.	Assumed implementation of tensiometers on all soil types, variable rate nozzles on spray irrigators, SMD irrigation using Fieldmap software, transition all flood irrigation to precision spray. >90% application efficiency.	√	Use of soil moisture meters. Uniform application of water. Accurate irrigation scheduling (time & application depth). Capturing bywash.
	Optimum fertiliser management.	Used fertigation[1] wherever possible, lower and more strategic N use, captured + recycled effluent, N matched to pasture harvested.	√	Nil N use in winter, Split N applications, fitting N inputs to farm requirements.
TIER 2	Choice of animal type to increase spread of urine & reduce N leaching.		x	Increase sheep &/or deer component, male cattle replace female cattle
	Avoid direct discharge from livestock to water.	Overseer assumes that this is in practice.	√	Fencing waterways. Stock crossings.
	Reduction in N losses from winter cropping.		√	Nil cropping, direct drilling, short grazing time on the crop each day.
	Practices to increase recovery of urine N.		x	Nitrogen inhibitors, winter growing grasses, addition of a carbon source, tannin containing plants, deeper rooting grasses.
	Practices to reduce animal output of urine N.	Transitioned to low protein cereal feeds/high utilisation wherever possible.	√	Low protein feed sources ie: maize, high tannin grasses.
	Winter Management + Management Practices to reduce deposition of urine N.	Herd Homes for 24/7, stand off or sheltered feed pads, cut and carry blocks with full barn management + fertigation.	√	Winter grazing off, standoff pad, feed pad, herd homes.

9. The above table shows the choices of mitigations and farm system reconfigurations modelled by Intelact Consultants on light soils in sensitive catchments, on behalf of Fish and Game.

10. The profit, risk and, physical outcomes of moving from flood irrigation to active management (precision irrigation) and a range of whole farm system reconfigurations to both intensify using 24/7 barn housing systems, and also extensify[2] the farm system using *destocking as an option are detailed in the attached Tables.*

11. The gains from improved water use efficiency are a result of reduced or minimised drainage from the root zone of the crop or pasture. This requires the data to be entered into Overseer correctly

[1] Fertigation is the application of fertilizers, effluent, soil amendments, or other water-soluble products through an irrigation system.
[2] Extensification of farming is the opposite of intensification. It is the process of decreasing the use of capital and inputs (e.g. fertilisers, pesticides, machinery) relative to land area.

in order to reflect what is happening on farm. The irrigation module is set up to have monthly data inputs. Overseer has a set of internal rules that add to water balance in the soils. If the irrigation is greater than the soils requirement, then this adds to extra drainage. This has important consequences as increased drainage can lead to increased leaching (Overseer Technical Notes June 2012). For the purposes of the modelling that was undertaken for Fish and Game, the farms did not have tensiometers in place in order to accurately measure the available moisture content of their soils and were applying water without being guided by soil moisture deficit technology. Hence the option of irrigation method plus monthly amount (mm) applied was used to formulate the base farm models quoted in the examples.

12. **In summary** – the farms that were modelled on behalf of Fish and Game represented intensive, irrigated dairy farms on coarse soil types. These are worse case scenarios in regards to the financial implications of reducing their environmental impacts given that these farms are on the most sensitive soils with the highest rates of contaminant losses. The most suitable options for all businesses was the implementation of efficient irrigation techniques, either by upgrading from flood to spray, or by changing to precision application techniques on spray irrigation, in order to reduce the risk of nutrient loss as modelled by Overseer.
13. Another extremely effective way to reduce nutrient loss from the farming system was to move to a 24/7 housed barn situation on a "cut and carry block", which reduced nitrogen losses by 91% down to less than 20 kg N//ha/yr. However, while this was profitable, it does require significant investment in capital, and may not suit operators that are in a risky equity position and is better suited to high commodity prices..
14. For the two businesses that were operating at stocking rates over 3.5 cows/Ha and more than 20% of feed imported, (Hinds and Ashburton Farms) a review of the stocking rate was also a viable, low risk, and profitable option, as it did not place stress on the equity position of these farms, yet, it yielded a more efficient, profitable and lower risk system when combined with precision irrigation technologies leading to overall lower nutrient losses being reduced by >70%.

Refer to the TABLES OF FARM SYSTEM MODELLING FISH AND GAME 2013.

FARM 1 – FLOOD IRRIGATION LIGHT SOILS

	N LOSS Kg N/Ha/Yr (MED soil texture protocol)	% Change In N Loss	ISSUES TO CONSIDER: Changes PH – Pasture Harvest	ASHBURTON Profit(P) – ROC Risk(R)- OP Profit Margin[1] Equity(Eq) % Cap Ex.	
BASE FARM	81 (N-leaching across the whole farm is 81kgN/ha using actual farm data,-dairy platform blocks ranging from 36kgN/ha leached to 102kgN/ha leached.)		Current system is 3.8 cows/ha. 15.2 T/DM/Ha/Yr Pasture Harvested/25% feed imported 488 T PKE /332 T Barley Grain/19 T Barley Straw/102 T Fodder Beet/92 T Pasture silage from support/230 T Pasture silage platform Cows -support area in winter 12% support land in addition to MP + a range of pivot, flood and K-Line irrigation. Average N use across the whole farm is 241kgN/ha. N-leaching across the whole farm is 81kgN/ha using actual farm data;-dairy platform blocks ranging from 36kgN/ha leached to 102kgN/ha leached.	P: 4.0% R: 26.2% Eq: 75%	
SCENARIO 1 Convert from flood irrigation to precision spray(see NOTE) 17.1T PH 3.9 cows/ha	19	↓80%	Upgrade from flood to pivot: $1.2M: $225K to upgrade to precision across irrigation area. $300K to re-fence, re-grass + re-lane dairy farm. Other Changes to farm system: 411 T PKE/347 T Barley Grain/20 T Barley Straw/106 T Fodder Beet/96 T Pasture silage from support/260 T Pasture silage cut from platform Cows on support area in winter	P-5.5% R-35.7% Eq –64% Cap Ex-$1,725,000 to upgrade to precision irrigation.	**Stronger Profit** **Lower Risk** **Sound Equity**

NOTE: *Farm 1(and many other farmers) don't want to go backwards or even stay static. Staying with border dyke (BD) would only work to manage nutrient losses if he took his production level right back and that goes against the grain for many farmers. So farm 1 feels he's more or less forced to go centre pivot. Higher economic return isn't the whole story for a lot of farmers; they want to feel they make "progress" (even if that means higher risk/same ROA); having up to date, spray irrigation makes the farm more versatile for whatever future challenges may come up, whereas with a low intensity system on BD he probably feels he's boxing himself into a corner*." (Dr. Helwi Tacoma DVM– Intelact Consultant, Veterinarian, & Farm Owner March 2013)

[1] Operating Profit Margin denotes risk level. A higher figure denotes lower risk.

CULVERDEN(C)				
PHYSICAL	BASE FARM MODEL	BMP MODEL – Precision Irrigation, LOWEST RISK	Average Canterbury Farm	Top 10% Canterbury
Stocking Rate	3.81	3.98	3.3	3.6
Bodyweight per Ha	1906	1989	1622	1800
Milksolids/Ha	1826	1994	1364	1674
MS/Cow	479	501	417	461
MS/kg Liveweight %	96	100	83	92
Pasture Harvested T/DM/Ha/Yr	15.2	17.1	13.6	16
Tonnes Home Grown Forage eaten/Cow	3.82	4.11	3.98	4.2
Pasture % of Total Diet	74	78	84	84
Feed Conversion Efficiency (Kg DM/KG MS)	10.6	10.44	11.2	10.8
Labour Efficiency	120	156	150	188
FINANCIAL 2011-12 $6.08 MS Payout				
Profit ROC%	4.0	5.5	5.8	8.9
Operating Profit/Ha$	3486	5051	2722	4545
Operating Profit Margin	26	36	30	41
Equity %	75	64	58	58
Cost of Production per kg MS	4.47	3.81	4.24	3.52
ENVIRONMENTAL				
Kg N loss/Ha/Yr	81	17 (↓80%)	Coarse Soils (70+)	Coarse Soils(70+)

FARM 2 - HINDS DAIRY FARM SYSTEM LIGHT SOILS

HINDS DAIRY Coarse, Free Draining Lismore Soils. – SYSTEM 4-5 FARM: 30% Feed Imported.							
	N LOSS (MED soil texture protocol) KgN/Ha/Yr	% Change in N Loss	N LOSS (LIGHT soils - actual) KgN/Ha/Yr	% Change From Base	Issues to Consider: Changes	Profit(P) – ROC Risk(R)Op Profit Margin[2] Equity(Eq) % Cap Ex.	Change to Business
BASE FARM 4 cows/Ha, 1920kg MS/Ha, 15T PH	101		146	↑46%		P- 5.9% R- 30% Eq – 44%	
Move to active management irrigation across the whole platform	43	↓57%	56	↓62%	Pivot Upgraded to Precision Technology. May be slightly more labour in monitoring. Lower water use, lower pumping costs by up to 30%	Cap Ex- $50,000	
Reduce N use to 200kgN/ha and reduce cow numbers by 142	33	↓10%			Same wintering area may need to be refined with less cows		
EXTENSIVE SYSTEM Drop SR to 3.35 cows/ha 170 Ha with. 14.5 T PH. 480 MS/cow. 11.5kgDM/Kg MS. N Use regular, 110 kg N/ha rate, Pro Gibb.	26 kg N lost		48 kg N lost	↓77%	Eff ha 170ha: Cow 575 (-32.4%) $50,000 for precision irr. Interest @ 6% - $3000- Depreciation $5000 Capitalised out.↓ 1 staff member ↓ wages-↓N to 110kgN/ha – removed some cost. Stock reduction value off debt.Prodn:280000 kg MS, 115 T Grass silage made at home, 220 T Grass silage purchased, 75 T Maize Silage bought, 315 T Barley fed in shed.	Profit: 7.6% Risk: 45% Eq: 37% Sale of cows, no cap ex required.	**Improved Profit** **Lower Risk** **Lower Equity**
INTENSIVE SYSTEM 24/7 Barn. Full CUT + CARRY pasture system. 620 kg cows @620 kg MS/cow	9	↓91%	18	↓88%	18 TDM harvested under full cut carry system.3000TDM grass silage made on block.89TN + 10TP imported back as effluent from cows fully housed.25TN + 4.5TP also required for 18TPasture harvested.850TDM grain imported.1200TDM Maize Silage 65TDM Straw imported.	Profit : 6.8% Risk -29% (higher risk) Eq -28% (reduced equity) Cap Ex - $1,390,000	**Improved Profit** **Higher Risk** **Lower Equity**

[2] Operating Profit Margin denotes risk level. A higher figure denotes lower risk.

HINDS FARM					
PHYSICAL	BASE FARM MODEL	BMP MODEL – 24/7 BARN + CUT CARRY BLOCK	LOW RISK MODEL	Average Canterbury Farm	Top 10% Canterbury
Stocking Rate	4.05	4.51	3.4	3.3	3.6
Bodyweight per Ha	2064	2593	1725	1622	1800
Milksolids/Ha	1920	2800	1047	1364	1674
MS/Cow	474	621	487	417	461
MS/kg Liveweight %	91	100	94	83	92
Pasture Harvested T/DM/Ha	15	18	14.6	13.6	16
Tonnes Home Grown Forage eaten/Cow	3.6	4	4.2	3.98	4.2
Pasture % of Total Diet	71	61	82	84	84
FCE (Kg DM/KG MS)	10.5	10.2	10.4	11.2	10.8
Labour Efficiency	218	222	213	150	188
FINANCIAL 2011-12 $6.08 kg MS payout					
Profit ROC%	6.1	6.8	7.4	5.8	8.9
Operating Profit/ha $	4058	5784	5198	2722	4545
Operating Profit Margin	30	28.6	45.9	30	41
Equity % %	44	30	37	58	58
Cost of Production per kg MS	4.33	4.97	3.20	4.24	3.52
ENVIRONMENTAL					
Kg N lost/Ha/Yr	146	18	48	Coarse Soils (70+)	Coarse Soils(70+)

ASHBURTON –B Well Drained, Lismore Stony Soils: SYSTEM 4 FARM 25% feed imported.							
	N LOSS (MED soil texture protocol)	% Change	N LOSS (LIGHT soils - actual)	Change From Base	ISSUES TO CONSIDER: Changes	Profit(P) ROC Risk(R)Op Profit Margin[3] Equity(Eq) % Cap Ex.	Change from Base
BASE FARM 4.52 Cows/Ha	81		141			P: 6.0% R: 30.5% Eq: 31.2%	
SCENARIO 1 Active management irrigation across the whole platform – Keep 165 Ha additional to Milking Platform for wintering on crops.	19	↓77%	39	↓72%	4 x 450 m pivots upgraded to precision.($250K) May be slightly more labour in monitoring Lift Irrigation efficiency, sell rotorainers – pivot. Total cost $400K amortised 15 yr.)lower pumping costs. Reduce N use from 334 T to 160T. Reduce Cows ↓17.5%. Effluent spread via pivots and subsequent use of soluble N reduced. Effluent N source replaces some bought N. Production down to 795000 - Feeds reduced, costs reduced, Total pasture consumed per cow from 3.0 TDM to 4.06 T DM per cow.	P: 6.5% R: 35.5% Eq: 35% Cap Ex- $400,000	**Improve Profit** **Lower Risk** **Stronger Equity**
SCENARIO 2 EXTENSIVE SYSTEM: No winter crop under management winter off, total farm area under control reduced.	24	↓70%	42	↓70%	Milking platform 491 Ha, 100% cows wintered off and no leasing of 165 Ha for crops. Feed: 460 T Grain, 400 T Maize, 30 T straw, No FB or Kale, in system. 280 T Silage cut and fed back out, PH similar. Home grown feed consumed/cow up 30%. Drop SR to 3.35 cows/ha.(↓25%) 14.5 T PH. 432 MS/cow.11.04kgDM/Kg MS Fertigation assumed. N Use regular, 110 kg N/ha rate, Pro Gibb.	Profit: 6.3% Risk : 39.4% Eq: 35% Sale of cows, no cap ex required.(assumed $400K spent on pivots as above)	**Improve Profit** **Lower Risk** **Stronger Equity**

[3] Operating Profit Margin denotes risk level. A higher figure denotes lower risk.

Ashburton: Well Drained Lismore Soils. System 4 Farm					
PHYSICAL	BASE FARM MODEL	S1 ↓cows 18%, + precision irr.	S2 LOW RISK ↓ cows 25% + precision irrigation	Average Canterbury Farm	Top 10% Canterbury
Stocking Rate	4.52	3.73	3.35	3.3	3.6
Bodyweight per Ha	2215	1826	1644	1622	1800
Milksolids/Ha	1957	1576	1448	1364	1674
MS/Cow	433	423	432	417	461
MS/kg Liveweight %	88	86	89	83	92
Pasture Harvested T/DM/Ha	16.6	15.3	14.8	13.6	16
Tonnes Home Grown Forage eaten/Cow	3.62	4.06	4.34	3.98	4.2
Pasture(home grown feed) % of Total Diet	75	86	90	84	84
FCE (Kg DM/kg MS)	11.03	11.10	11.04	11.2	10.8
Labour Efficiency	166	161	159	150	188
FINANCIAL 2011-12 ($6.08 payout)					
Profit ROC%	6.0	6.5	6.3	5.8	8.9
Operating Profit/Ha $	3975	4020	3800	2722	4545
Operating Profit Margin %	30.5	35.5	39.4	30	41
Equity %	31	30	35	58	58
Cost of Production per kg MS	4.35	3.79	3.76	4.24	3.52
ENVIRONMENTAL					
Kg N loss/Ha/Yr	141	39 (↓72%)	42(↓70%)	Coarse Soils (70+)	Coarse Soils(70+)

A NATIONAL ASSESSMENT OF THE POTENTIAL LINKAGE BETWEEN SOIL, AND SURFACE AND GROUNDWATER CONCENTRATIONS OF PHOSPHORUS

R.W. McDowell, N. Cox, C.J. Daughney, D. Wheeler and M. Moreau[1]

ABSTRACT: A meta-analysis of three national databases determined the potential linkage between soil and surface and groundwater enrichment with phosphorus (P). Soil P was enriched especially under dairying commensurate with an increase in cow numbers and the tonnage of P-fertilisers sold. Median P concentrations were enriched in surface waters receiving runoff from industrial and dairy landuses, and in groundwater beneath dairying especially in those aquifers with gravel or sand lithology, irrespective of groundwater redox status. After geographically pairing surface and groundwater sites to maximise the chance of connectivity, a subset of sites dominated by aquifers with gravel and sand lithology showed increasing P concentrations with as little as 10 years data. These data raise the possibility that groundwater could contribute much P to surface water if: there is good connectivity between surface and groundwater, intensive landuse occurs on soils prone to leaching, and leached-P is not attenuated through aquifers. While strategies are available to mitigate P loss from intensive farming systems in the short-term, factors such as enriched soils and slow groundwater may mean that despite their use, there will be a long-term input (*viz*. legacy), that may

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sustain surface water P enrichment. To avoid poor surface water quality, management and planning may need to consider the connectivity and characteristics of P in soil-groundwater-surface water systems.

(KEY TERMS: base flow; filterable reactive phosphorus; lag-time; legacy; management; storm flow)

INTRODUCTION

Phosphorus (P) can impair surface water quality by stimulating eutrophication (Carpenter, 2008). The dominant source of P entering surface waters has been identified in many countries as agricultural (Sharpley, 2000). Additional work has also shown that the magnitude of P losses generally reflects the intensity of agricultural systems, where for example, soils may have been enriched well beyond concentrations sufficient for plant requirements and become leaky as their ability to retain additional P declines (McDowell and Sharpley, 2001a). Due to large P inputs (fertiliser or feed) or management practices that unduly enrich certain parts of a farm (e.g. through repeated application of P-rich dairy shed effluent), dairy farming or horticulture are often cited as landuses that lose much P (Cooper and Thomsen, 1988; McDowell and Wilcock, 2008; Sharpley, 2000).

Although the source of P loss have been the focus of considerable research, over the last 20 years work has increasingly focused on the routes by which P enters surface waters. The majority of this work has centred on surface runoff generated during storm events that carries a considerable proportion of particulate-associated P into surface waters (e.g. McDowell and Sharpley, 2001b; Romkens et al., 1973; Smith 1989). This research has led to the development of strategies that focus on managing P in the topsoil (e.g. conservation tillage; Djodjic et al., 2002). These strategies have been effective at decreasing particulate-associated P, but in some cases losses of dissolved (often termed soluble or filterable) reactive P continues to increase (Richards et al., 2009). Work has also focused on sub-surface losses where much P can be lost from soils with poor P storage capacity (e.g. Peats, Sands or Podzols; De Bolle et al., 2013) or where artificial drainage networks rapidly transfer P-rich drainage from topsoil to surface waters (McGrath et al., 2013). However, because most soils have a moderate to high capacity to sorb and retain P in the unsaturated zone, losses via 'deep' drainage to groundwater have been considered small (e.g., McClaren and Cameron (1996) and hence dismissed.

A number of studies have reported P-rich groundwater samples and attributed their P concentrations to reflect natural inputs via specific geology (e.g. ignimbrite) or aquifer conditions (e.g. reducing conditions) (Morgenstern and Daughney, 2012). However, in an assessment of groundwater samples in the UK and Ireland, Holman et al. (2008) found that dissolved P concentrations were greatest in wells under intensive agriculture. At a local scale, Domagalski and Johnson (2011) were able to link agricultural activity to P concentrations in subsurface transport and through into surface waters.

The enrichment of groundwater is a well-known phenomenon associated with nitrate lost from agricultural practices (Di et al., 2005). If, as with nitrate, groundwater becomes enriched with P due to agricultural activity, then base flow contributions to stream flow loads could continue or even increase depending on groundwater residence times long after efforts to mitigate P losses from the soil have been put in place. This lag-time between landuse and effect has been attributed as a "legacy" of past landuse by Kleinman et al. (2011). However, the potential for agriculturally-derived P to enter surface waters via groundwater will likely depend on the intensity of losses from the soil, the aquifer characteristics and distance, and time of travel, between the P source and surface waters.

This paper outlines a meta-analysis of New Zealand national datasets aimed at determining P concentrations of soil, surface and ground waters by landuse and testing the hypothesis that intensive agriculture results in high concentrations of P in the soil and in the receiving waters. For surface and groundwater, filterable reactive P (FRP) is compared as other fractions such as organic P (which may also contribute to a decline in water quality; Whitton et al., 1991) are not routinely measured in groundwater. Surface and groundwater sites are then matched geographically to maximise the chance of connectivity and trends in FRP concentrations examined. A coincidence of trends within the same local recharge basin suggests a link exists between sites. At such sites, the enrichment of groundwater with P could therefore result in a legacy of P enriched surface waters that may be difficult to mitigate.

DATASETS AND METHODS

Data in this analysis draws upon three national scale datasets:

1) Soils

A 14 year dataset of 246,000 soil samples submitted to a commercial laboratory for analysis soil Olsen P concentrations from 1988 to 2001 (see Wheeler et al., 2004 for details) was augmented by an additional two years data (*c*. 10,000 samples) from the same laboratory. Briefly, all samples were classified, where possible, into land use (drystock [sheep and beef] and dairy) and soil type (New Zealand soil orders [Hewitt, 1998]: sedimentary, volcanic, pumice, peats and others). As the dataset contained commercially sensitive data, sites could not be more geographically identified.

2) Surface waters

A database collated by McDowell et al. (2009) and later Ballantine et al. (2010) contains measurements of filterable reactive phosphorus (FRP) concentrations at more than 1,000 sites of known geographic co-ordinates on New Zealand streams and rivers sampled by regional authorities and as part of a National River Water Quality Network (NRWQN; Davies-Colley et al., 2011). The database contains records of samples collected as early as the late 1970s, but to reduce issues related to changes in methodology associated with water quality analyses or natural climatic variation (Ballantine and Davies-Colley, 2010), and to more closely align to available groundwater data, we only used data from 1998-2007. To consolidate these data into a uniform structure and minimise the potential for error, we filtered the data so that: 1) sites were only included in the database if there were 15 or more measurements to increase the likelihood that median values were representative of potential population median at each site although we could not account for periods when more of less data were collected; 2) of the 4.3% of sites with a FRP concentration less than the detection limit (which ranged from 0.002 [*c*. 60% of sites] to 0.004 mg L^{-1}), concentrations were set at half the detection limit; and 3) sites in estuarine waters were omitted to avoid complications involved in trying to take account of tidal/seawater effects. It is also important to note that flow data was only available for a minority of sites. Hence, medians are estimated from the entire flow record. This may not represent the best comparison against groundwater FRP concentrations, which would be achieved with samples measured at baseflow.

3) Groundwater

The same filtering rules for surface water were applied to data for FRP in groundwater of known geographic co-ordinates that had been sampled by regional authorities and as part of a National Groundwater Monitoring Programme (NGMP). This dataset, complied by Daughney and Randall (2009), contained data for the concentration of FRP from 1995 to 2008, but was restricted to 1998-2007 for analysis. Sites were classified by the immediate overlying land use, aquifer lithology and redox status using the categorisation system of Daughney and Reeves (2005).

Much like surface water sampling, the frequency of surface and groundwater sampling varied across the sites from fortnightly to bimonthly, while soil sites were rarely sampled more than once. In addition, constraints and different objectives associated with the design of regional sampling programmes meant that geographical and environmental coverage is uneven and variable; Daughney et al., 2012) (Figure 1).

Data analysis

For soils, mean concentrations of soil Olsen P concentration were sorted by soil order and by landuse over the period of record. Visual inspection of the data noted that Olsen P tended to increase with time, but a natural break was noted around 1997, commensurate with an increase in fertiliser sales and expansion of dairying in the South Island (*c*. 583,478 Mg in 1996 and 1,232,196 Mg in 2002; Statistics New Zealand, 2013. Hence, means were compared for two periods 1988-1996 and 1997-2003.

For surface and groundwater, median concentrations and trends were extracted from publications for each of the surface and ground water sites. The trends were based on the relative Seasonal Kendall Sen Slope Estimator (RSKSE) for flow-adjusted (surface) and unadjusted data, and determined as the mean annual increase in FRP concentration divided by the median concentration for the period of record (Ballantine and Davies-Colley, 2010). This ratio allows for the direct comparison of trends between sites. Landuse data were available for both surface and groundwater sites, but classified according to LCDB2 data for the dominant (greatest percentage cover) landuse: parks/reserves, horticultural, forestry, urban, industrial and grassland which was further classified into drystock and dairy landuses according to Daughney and Randall (2009).

A non-parametric Mann-Witney test was performed to determine differences in mean soil Olsen P concentrations by landuse (sheep vs. dairy) and for concentrations collected under dairying between 1988-1996 and 1997-2003. A one-way analysis of variance using ranks was conducted to determine differences in the average median concentrations between landuses in both surface and groundwater sites, and between aquifer lithology for the most FRP-enriched landuse. Where there were sufficient data (five or more sites), an additional test was conducted to determine if their concentrations were significantly enriched with FRP compared to reference sites (park/reserves). Redox status is known to be an important control on FRP concentrations in groundwater (Carlyle and Hill, 2001) and so comparisons to landuse were also made on the subsets of oxidised groundwaters and reduced groundwaters (as classified by Daughney and Reeves, 2005) for those lithology classes that contained at least three data points for the majority of landuses.

Using geographic coordinates, sites were paired if surface and groundwater sites were within 2 km of each other. It is acknowledged that selection of a distance threshold is poorly constrained because the capture zones of most New Zealand groundwater monitoring sites have not been delineated. However, a recent study reported length dimensions from 0.2 to 20 km for the capture zones of selected wells within one region (Gusyev et al., 2011) and so until more information is collected the threshold of 2 km is adopted as a mid-point, on a log scale, of typical capture zone dimensions. This maximises the possibility that surface and groundwater sites are considered to be hydrologically linked, but does not preclude the fact that some may not be. Pearson correlation coefficients were then generated for FRP concentrations over time in paired sites by landuse.

RESULTS

For soil samples with landuse data approximately 54% of the samples came from dairy properties and 46% from drystock properties. Among soil orders, most samples were classified as sedimentary (47%), followed by volcanic (34%), pumice (8%), peat (6%) and other (5%). It was not possible to determine the frequency of repeat sampling for samples up to 1992, thereafter data for 70% of farms had submitted samples for only one year, 20% for two years and 10% for three or more years. Although samples are usually submitted on a field or block basis within a farm there was no guarantee that the indicated soil order extended across the entire block and hence it is possible that a sample could be incorrectly categorized.

Mean concentrations of Olsen P from 1988 to 2003 were greater in all soil orders used for dairying than for drystock (Figure 2). For dairy soil samples, the mean percentage of samples that had an Olsen P concentration greater than the agronomic optimum for the relevant soil order was 44% overall. However, significantly more sites were in excess of the agronomic optimum submitted in the period 1997-2003 than from 1988-1996 (Figure 2). This is commensurate with an increase in the national number of dairy cattle which averaged 3.6M over 1988-1996 (3.2M from 1971-1996) and 4.9M from 1997-2003 (MPI, 2013), and an increase in the tonnage of P-fertiliser applied to dairy farms from 49,000 in 1996 to 350,000 in 2002 and 440,000 in 2006 (Statistics New Zealand, 2013). Although the enrichment of Olsen P occurred nationwide, and we were unable to assign specific locations to soils, Wheeler et al. (2004) in their examination of the 1988-2001 dataset also found evidence that the rate of enrichment was greater in regions with an established history of dairying.

After filtering rules were applied there were 723 surface and 540 groundwater sites available for analysis of median concentrations and trends. A one-way analysis of variance indicated that there was a significant difference between landuse classes in the average median FRP concentration in both surface and groundwater, with sites in both datasets classified as under dairying identified as most enriched with FRP. Surface water sites classified as industrial were also enriched, but represented far fewer sites than those under dairying (Figure 3). Further examination of landuse by redox status indicated that for data-rich aquifers (gravel and sand lithologies) the average median FRP concentration of reduced groundwater was greater than oxidised groundwater (Figure 4). Moreover, concentrations were greater in sites under dairy landuse irrespective of their redox state.

Groundwater sites under dairying (n = 70) were also examined by their aquifer lithology. Of those lithology classes with five or more sites, FRP concentrations were greatest in those in gravel (n = 32) compared to ignimbrite (n = 6), pumice (n = 6) and sand (n = 14). Sites under dairying with sand and gravel lithology had FRP concentrations significantly greater than sites of the same lithology under parks/reserve *viz*. pseudo-reference sites (n = 11, 1, 2 and 4 for sites with gravel, ignimbrite, pumice and sand lithology, respectively; Figure 5). For sites with ignimbrite and pumice lithology too few data were available for a comparison (Figure 5). A comparison of lithology in drystock landuse indicated that of 214 drystock sites, 174 were under gravel, but had an average FRP concentration (0.033 mg L^{-1}) not significantly different to the average for all drystock sites (0.046 mg L^{-1}). This suggests that on average landuse may influence FRP concentration to a greater extent than lithology, but does not discount the possibility that other factors that have not been taken into account could be important, such as: the extent to which land use data is representative of catchment land use and changes in FRP concentration have occurred over time that reflect other factors such as landuse lithology interactions.

Median values for the relative changes in FRP concentrations over time (i.e. trends) indicated little change across most landuses (values are at or near zero in Table 1), but there was a wide range in both the magnitude and direction of relative trends that may show patterns not evident by a comparison of medians or means. After pairing surface water sites with the nearest groundwater site not less than 2 km away, 70 sites were isolated. These are the sites within the databases that were most likely to be connected. Among landuses, Pearson correlation coefficients (Table 2) indicated a strong correlation between increasing median FRP concentrations from 1997-2007 for paired surface and groundwater sites under dairying and drystock landuses. Median concentrations for these dairy and drystock sites were found to be not significantly different from the wider dairy or drystock surface or groundwater datasets and hence represent sites that are increasing, but are not yet enriched enough to increase the overall dataset means (by landuse). Of those surface and groundwater sites exhibiting an increase in FRP concentrations over time (n = 29), 80% contained an aquifer lithology that would facilitate the rapid transport of P (either gravel or sand). A similar proportion (72%) represented sites where groundwater was classed as oxidised. Focusing on only oxidised sites did not decrease the significance of the correlations (P<0.01).

DISCUSSION

Current concentrations and links between soil, surface and groundwater

The main concern surrounding P loss is the unwanted growth of algae (periphyton and/or phytoplankton) in surface waters and subsequent effects on the uses and values of those waters (Carpenter, 2008). There are a variety of sources of P on land that are transported under surface and sub-surface flow paths. Sources include, but are not limited to, point sources such as septic tanks

(Withers et al., 2011), wastewater treatment plants (Haggard et al., 2003) and nonpoint sources largely associated with agricultural landuse (Sharpley et al., 1994). Of the agricultural sources present in New Zealand, dairying and drystock landuses dominate (McDowell and Wilcock, 2008). Sources from dairy and drystock include fertiliser applied P, soil, dung, and for dairy – land-applied dairy shed effluent. The relative proportion coming from soil varies, but experiments have estimated soil P losses to freshwater accounts for 30-80% of annual P losses in a New Zealand dairy farm (McDowell et al., 2007).

It is well established that the potential for P loss from soil increases with soil test P concentration, determined as Olsen P in New Zealand, especially when in excess of the agronomic optimum (McDowell and Sharpley, 2001b). The data reported here indicate that enrichment beyond the agronomic optimum was prevalent and had increased in the more recent data under dairying (Figure 2). However, McDowell and Condron (2004) also showed that soils with lower anion storage capacity (ASC: also called P retention; Saunders et al., 1965) lose much more P than soils with greater ASC, but the same Olsen P concentration. Soils that tend to have low ASC include those derived from river beds, sands and that have been well leached of iron oxides (Hewitt, 1998). A low ASC is also likely to exist in gravel and sand based aquifers that have few fines.

Although a particular landuse may represent a potential source of P loss, conditions must exist to transport P into surface or groundwater. Furthermore, P losses can be attenuated depending on the flow path taken. For instance, rainfall events may generate surface runoff dominated by particulate-associated P that enriches surface waters, but is filtered out in subsurface matrix flow. However, large subsurface losses of P to surface waters may be facilitated by preferential flow paths especially if intercepted by artificial drainage. For instance, Houlbrooke et al. (2008) demonstrated P losses of 1-2 kg ha^{-1} from a single large dose of dairy shed effluent that flowed into drains via preferential flow pathways, compared to losses < 0.2 kg ha^{-1} when the same depth was applied slowly and moved via matrix flow.

Dairying has been cited as a cause of enrichment of surface waters in New Zealand (e.g. Ballantine et al., 2010; McDowell and Wilcock, 2008), because of high P inputs and the need for moderate rainfall (or irrigation) to support pasture growth, but also though poor management such as applying effluent to wet soils or maintaining an Olsen P concentration beyond the agronomic optimum (Houlbrooke et al., 2008). For groundwater, Holman et al. (2008) found that landuse had a significant effect on FRP concentrations thereby debunking the hitherto well accepted hypothesis that "anthropogenic sources of P are unlikely to have significant impacts on P concentrations in groundwater because of immobilization in soil and the unsaturated zone". Our data indicates that under certain conditions, significant quantities of P can enter groundwater and that this potential varies with landuse (Figure 3). Furthermore, there is some evidence to suggest that enrichment is exacerbated for sites under dairying, irrespective of redox state (Figure 4) and with gravel or sand aquifer lithology (Figure 5). Within New Zealand, there is much site-specific data to show that dairying on gravel or sandy soils leads to large losses from the unsaturated zone. For example, Toor et al. (2004) measured losses of 0.3-2.3 kg P ha^{-1} over two years deeper than 0.7 m below the ground surface. There is much overseas data to show that P is mobile in aquifers comprised of sand and alluvial gravels due to high transmissivity, potential for bypass flow and low P sorption capacity (Corbet et al., 2002; Stollenwerk 1996).

Due to the absence of data for fractions other than FRP we were not able to determine their concentrations or trends. However, we acknowledge that many filterable unreactive (*viz*. organic) P species and desorption of P from particulate-associated P may influence periphyton growth in surface waters (McDowell et al., 2004).

Temporal changes

Moving beyond the state of FRP concentrations there is also some evidence for a linkage between groundwater and surface water that is detectable with 10 years or less of data under certain site characteristics. The fact that there were a greater proportion of gravel and sand aquifers represented in the pairing than in, for example, enriched dairy groundwater sites (Figure 5) suggests that these aquifers may be vulnerable to P inputs. When examined on a national scale, few studies have detected significant changes in groundwater FRP concentrations. This has been attributed to several factors including insufficient data to class landuse or aquifer lithology or geochemistry, too few data or poor temporal sampling within or between years and a change in analytical methods or data management (Holman et al., 2010). Although we have been able to classify aquifers, there is a possibility that some changes may have occurred in landuse and analytical methods (or detection limits). Furthermore, the sampling regime may not be temporally or spatially optimal. For example, only a few sites were geographically close enough to be paired or had sufficient data to detect a trend. It is also likely that more trends may be detectable if consistent data were available for more than 10 years. Certainly, a greater number and diversity of trends among analytes and edaphic factors (e.g. climatic variation) has been detectable in a national surface water network of sites where 20 vs. 5 years of data have been available (e.g. Ballantine et al., 2010; Ballantine and Davies-Colley, 2010).

Using the National Groundwater Monitoring programme of New Zealand (a subset of that used here), Morgenstern and Daughney (2012) were able to show that FRP concentrations tended to increase with groundwater age. This is also well established in other parts of the world (MPCA, 1999). The relationship between FRP and groundwater age exists because older groundwater is more likely to be reduced (anoxic) (Daughney et al. 2010) and such conditions favour dissolution of iron oxide minerals, which in turn leads to the release of associated P (Carlyle and Hill, 2001). We have shown that with a wider dataset, FRP concentration in groundwater also varies with landuse (especially dairying), irrespective of redox status. Increasing FRP concentrations in surface water have also been linked to intensive landuse (e.g. Ballantine et al., 2010). However, given that in many sites the majority of stream flow is groundwater-derived and that base flow occurs most often during summer-autumn months when the potential for periphyton growth is greatest (Biggs and Smith, 2002), groundwater P may strongly influence periphyton growth. This may be exacerbated in streams with a high base flow index and groundwater concentrations are enriched. For example, the mean FRP concentration for the sites under dairy was 0.33 mg L^{-1} in groundwater and approximately

0.05 mg L^{-1} in surface water sites. Such concentrations are in excess of those considered likely to cause nuisance periphyton growth in New Zealand streams and rivers (<0.026 mg L^{-1}; MfE, 2000).

Management

Differences in the rate at which FRP is delivered to surface waters via different flow paths means that in addition to land practices and the loss of P via runoff we should also consider groundwater P inputs in surface water P management. The time elapsed between the adoption of land management strategies to mitigate non-point source pollution and the improvement of surface water quality has been termed the "lag time" (Meals et al., 2010). For P, the source and transport mechanisms causing the water quality issue has been termed "legacy phosphorus" (Jarvie et al., 2013). With the occasional exception, groundwater inputs have largely been ignored as a source of legacy P due to the dominance of stream flow loads by runoff-derived P and the speed, relative to most groundwater, that runoff-derived P contributes to stream loads (Holman et al., 2010). However, our data suggests that in some cases groundwater inputs may be significant. Hence monitoring of hydrologically-linked surface and groundwater sites needs to be continued and our understanding of surface and groundwater interactions improved to inform strategies to address potential future legacy effects. Such monitoring needs to encompass standardised analytical techniques and sampling strategies to capture trends, sampling in areas where landuse intensification is likely, and some estimate of background contributions to avoid alarm being raised due to natural inputs from geological sources like hydroxyapatite within ignimbrite (Timperley, 1983).

Focusing on those factors that promote P loss via groundwater over time, it is also important to understand their spatial distribution and optimise how management could be altered to avoid groundwater being a legacy source of P to surface water. The greatest risk comes from those soils being used for intensive agriculture (e.g. dairying) and vulnerable to P leaching, and once in groundwater our evidence would suggest that receiving aquifers of gravel and sand lithology have limited capacity to attenuate P movement through into surface waters. Webb et al. (2010) concluded that those soils most vulnerable to soil P leaching in Canterbury, New Zealand, were recent soils, stony or very stony soils with low ASC, sand dunes and shallow soils overlying rock except where there is a topsoil layer of moderate to high ASC. Such vulnerable soils are widely found throughout other provinces of New Zealand and may coincide with sand or alluvial gravel aquifers in the Hawke's Bay, Wellington, West Coast, and Southland (and parts of Otago) regions (Rosen, 2001). More importantly, many parts of these regions are undergoing landuse change with the development of irrigation (EPA, 2013).

Many stony or coarse-textured soils will have limited available water holding capacity. Hence, to be used for dairying, irrigation is required to maintain soil moisture. However, because irrigation maintains greater soil moisture than dryland agriculture, irrigation will generally result in more drainage. Irrigation management is therefore a key factor in minimising P losses in vulnerable soils and aquifers entering surface waters. Although we have no evidence to show on a national scale that irrigation will exacerbate P losses in surface waters there are several catchment-specific examples. For instance, irrigation, coupled with low soil ASC and a high hydraulic conductivity were cited by McDowell and Kitto (2013) as causes of subsurface P losses from a sandy soil under dairying that emerged as surface water loads of 4 kg P ha^{-1} yr^{-1} in a catchment in Central Otago, New Zealand. Domagalski and Johnson (2011) also found evidence that almond and corn production on a sandy (92%) soil in California enriched groundwater which in turn increased FRP concentrations in surface water. Under dairying, methods to minimise subsurface P losses are fewer than those available to prevent surface runoff P losses, and those pertinent to irrigated land are fewer still (McDowell and Nash, 2012). Methods to mitigate P losses under irrigated dairying include: varying the rate of irrigation according to available water holding capacity to minimise drainage (Hedley et al., 2011); applying the minimum fertiliser-P to maintain optimal pasture growth (McDowell et al., 2003); applying less P but maintaining pasture production with N-fertiliser (Dodd et al., 2012); and not irrigating vulnerable soils or using vulnerable soils for practices that lose significant P such as effluent application or cropping for grazing in winter (McDowell and Nash, 2012). However, perhaps the most obvious would be the consideration of the vulnerability of soils and aquifers prior to landuse change or development.

CONCLUSIONS

A meta-analysis of three databases and published data has shown evidence for the enrichment of soil P, and increasing enrichment beyond an agronomic optimum, under dairying. On average, median FRP concentrations were enriched at surface water sites with dairy and industrial landuses. Groundwater sites located in areas with a predominance of dairying were also identified as enriched especially when the aquifer lithology was either gravel or sand and regardless of the redox state of the groundwater. After geographically pairing surface and groundwater sites to maximise the chance of connectivity, a subset of sites dominated by aquifers with gravel and sand lithology indicated an increasing trend in FRP concentrations with as little as 10 years data. These data raise the possibility that groundwater could contribute significant quantities of FRP to surface water if connectivity between surface and groundwater is good, intensive landuse such as dairying is coupled with soils prone to leaching, and P is not attenuated while in aquifers (e.g. comprised of gravels and sands). There are many strategies available to mitigate P loss from intensive farming systems in the short-term. However, P-rich soil can take decades to reach to a level where environmentally insignificant concentrations of P are leaching. Furthermore, depending on the degree of FRP-enrichment and potential dilution via recharge, groundwater P concentrations may be similarly slow to decrease. This means that despite using mitigation strategies on land, there may still be a long-term input, or legacy, leading to significant lag-times in surface water quality improvement. Therefore, to avoid poor surface water quality, it is recommended that management and planning consider the connectivity and characteristics of P in soil-groundwater-surface water systems.

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TABLE 1. Summary statistics for the percentage annual change (seasonal Kendall slope estimate divided by median concentration; 1997-2008) in filterable reactive P concentrations for surface water (SW) and groundwater (GW) sites under all landuses except forestry which had too few sites.

	------ Mean------		**---- Median ----**		**---- Minimum----**		**---- Maximum ----**		**Interquartile range**	
	SW	**GW**	**SW**	**GW**	**SW**	**GW**	**SW**	**GW**	**SW**	**GW**
Drystock	-1.4	0.0	0.0	0.0	-23.6	-2.1	30.1	1.9	2.9	0.1
Dairy	-0.5	-0.6	0.0	-0.1	-16.8	-6.2	11.1	0.0	0.3	0.1
Horticultural	1.1	-0.1	0.0	0.0	-11.6	-3.9	30.1	1.2	4.0	0.2
Urban	-3.2	-0.1	-0.5	0.1	-23.6	-2.0	22.8	0.8	8.2	0.2
Industrial	-1.0	-0.6	0.0	0.0	-10.8	-2.9	12.6	0.1	15.2	0.0
Park/Reserve	1.3	-0.1	0.0	0.0	-10.3	-0.6	31.3	0.2	3.6	0.2
Unknown	4.3	0.5	1.4	0.1	-14.2	-0.4	30.1	11.0	7.1	0.2

TABLE 2. Pearson correlation coefficients (and significance) for trends in filterable reactive P concentration in groundwater sites that were within 2 km of a surface water sites of the same landuse (1997-2008).

Landuse	**Pearson correlation coefficient**	**Number of pairs**	**Significance (*P* value)**
Drystock	0.825	14	<0.001
Dairy	0.740	15	0.002
Horticultural	0.320	18	0.196
Urban	0.161	11	0.636
Industrial	0.782	5	0.118
Park/Reserve	-0.649	7	0.115
Unknown	-0.070	74	0.556
Overall	0.175	144	0.036

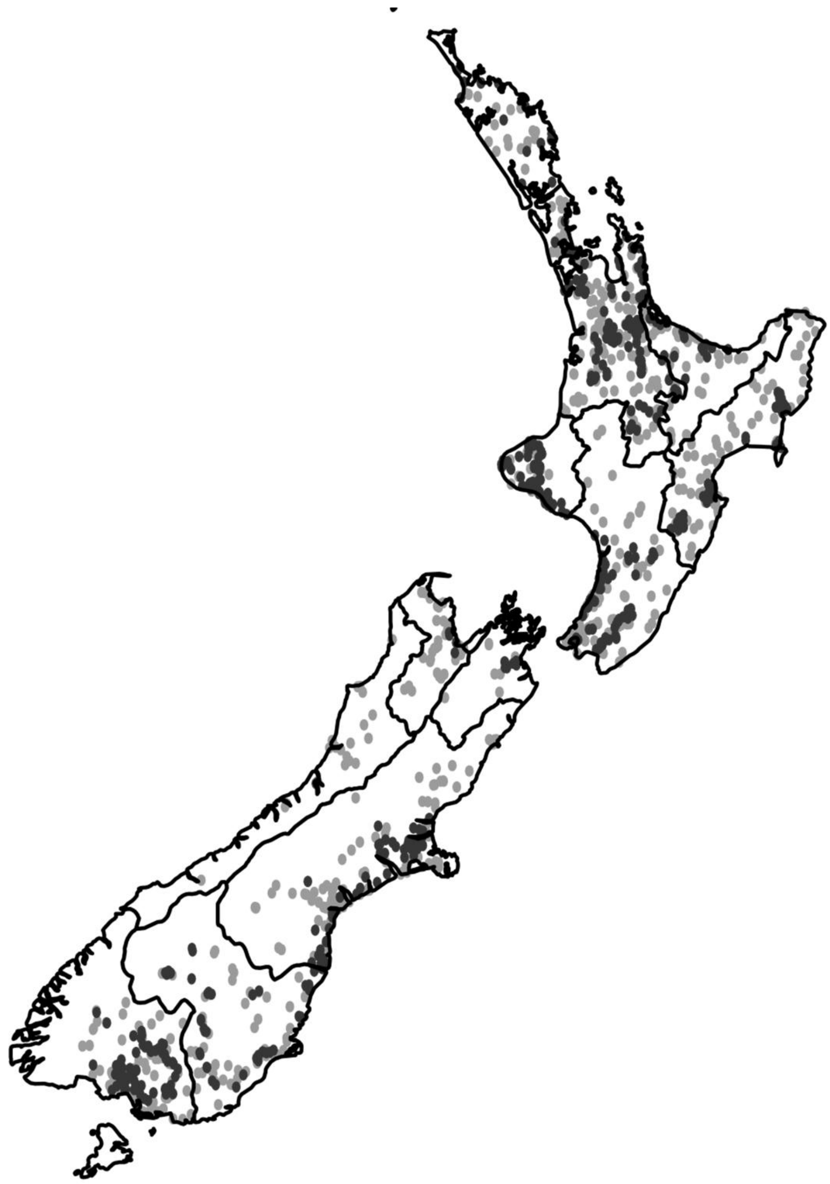

FIGURE 1. Location of surface water (light grey) and groundwater (dark grey) sampling sites used in the analysis.

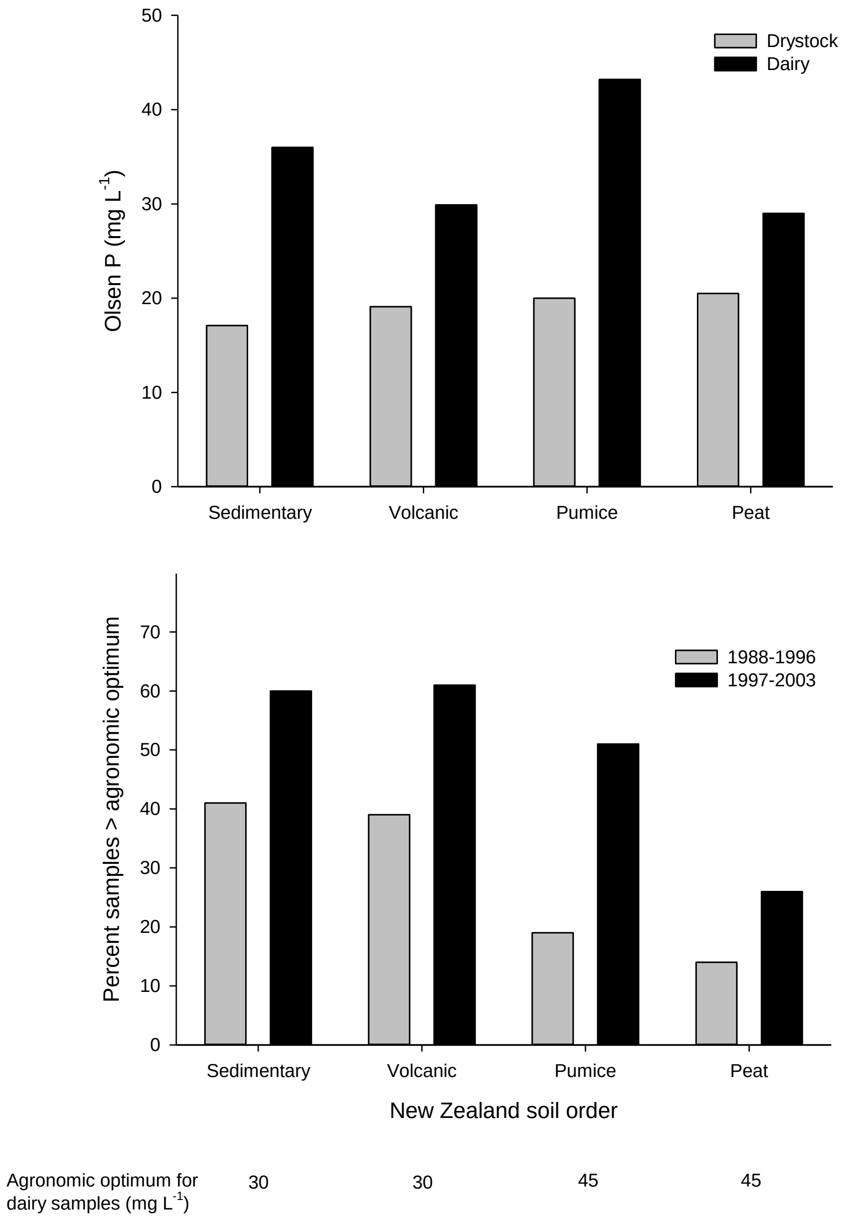

FIGURE 2. Mean concentration of soil test P (Olsen P) across all samples (N > 250,000) under drystock and dairy landuse (top) and the relative percentage of samples under dairy landuse in excess of the agronomic optimum, 1988-1996 and 1997 to 2007 (bottom).

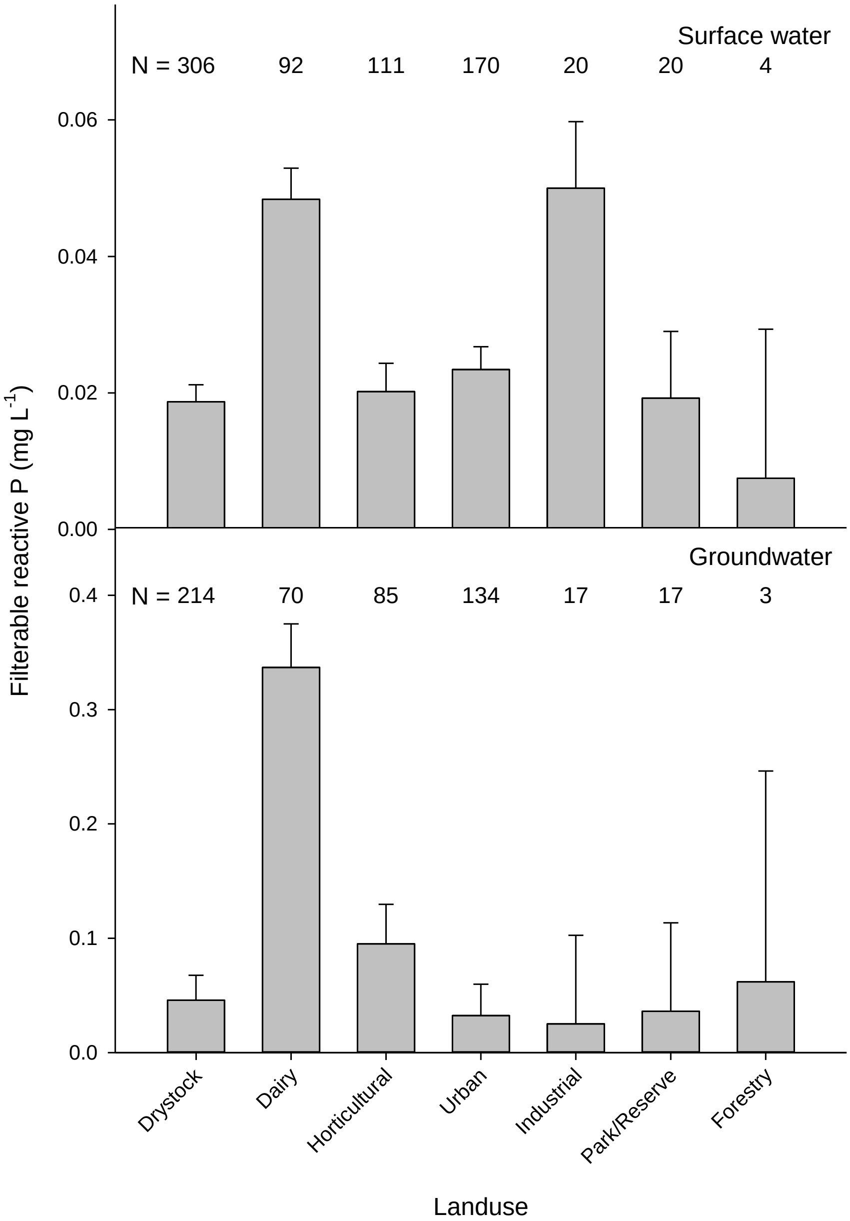

FIGURE 3. Average median filterable reactive P (FRP) concentration (with standard error of the mean shown as error bars) for all sites classified by landuse in surface and groundwater datasets. N = the number of sites in each landuse. A one-way analysis of variance using ranks indicated a significant difference between landuse FRP concentrations in both datasets (*P*<0.001).

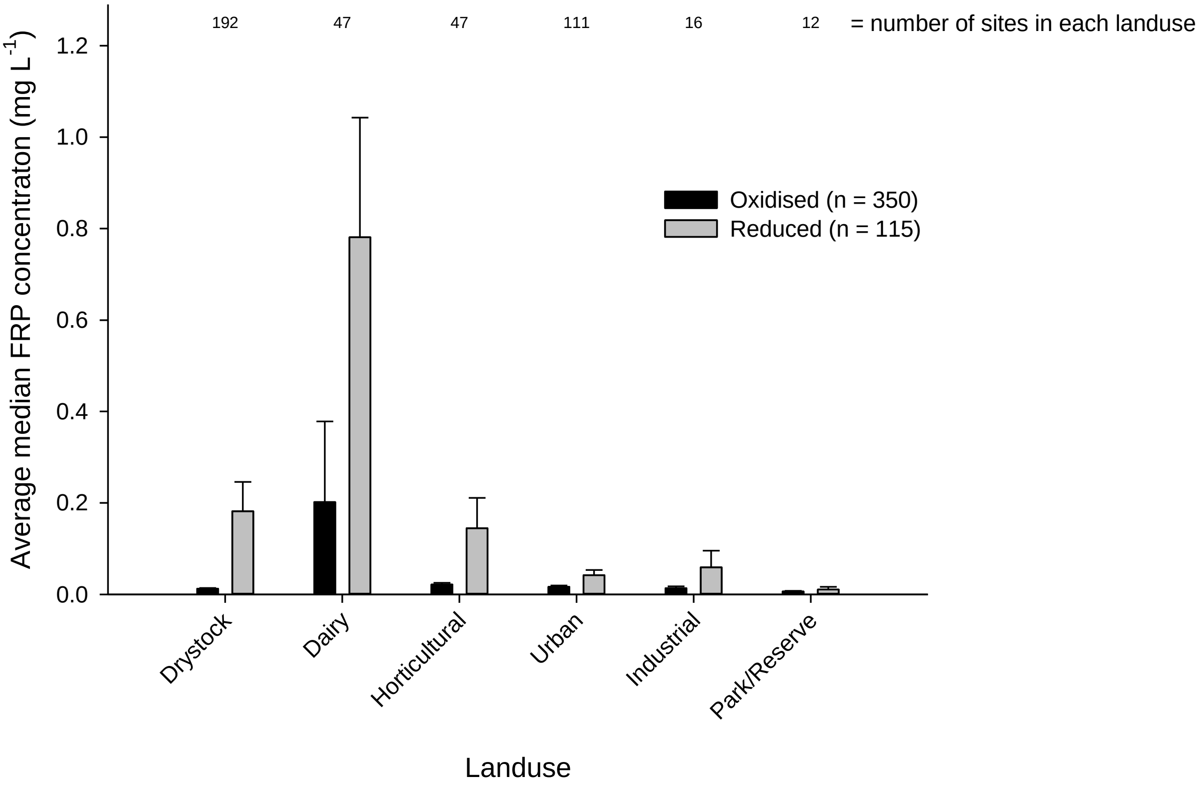

FIGURE 4. Average median filterable reactive P concentration (with standard error of the mean shown as error bars) in groundwater of sand and gravel lithology and further classified by landuse and redox status. A one-way analysis of variance using ranks indicated a significant difference between landuse (*viz*. dairy) FRP concentrations in both datasets (P<0.001).

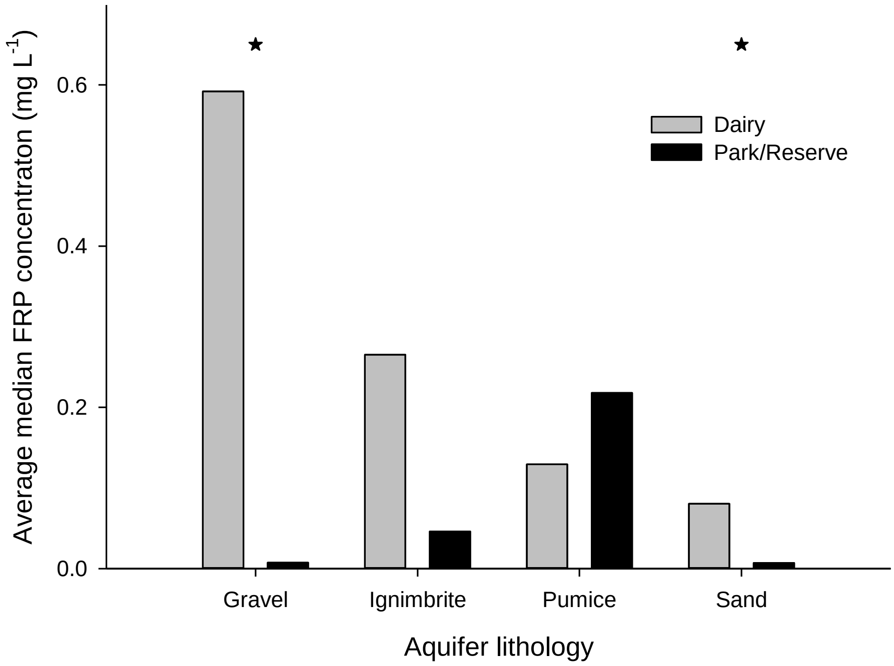

FIGURE 5. Average median filterable reactive P concentration in groundwater of different aquifer lithology for dairy and park/reserve (*viz*. reference conditions) landuses. The asterisk indicates a significant difference (P<0.05) in concentrations between landuses (Wilcoxon test).

APPENDIX 6	**Nitrogen Loss Prevention: Best Management Practice**		
BMP	**Rationale**	**Reflected in Overseer?**	**Assumed to be already in place on farm by Overseer**
N Fertiliser Application Requirements Meet Fert. Research COP[i]	Nitrogen fertiliser applied in compliance with the Fertiliser Research Guide Code of Practice. In doing so the risk of N loss from fertiliser is reduced.	✓	✓
Effluent BMP in place	Best Management Practices for Effluent Management in place		✓
Direct connectivity to waterbodies does not occur	Overseer assumes that surface runoff of effluent, and sediment runoff does not occur from hot spots, crops, or poor soil management.	×	✓
Restricted Autumn/Winter Grazing	Most N leached on livestock enterprises comes from the urine patches Limiting the amount of time stock spends on an area reduces N loss	✓	
Winter feed pad/herd home	The more time animals spend on sealed surfaces in autumn/winter the greater the N loss reduction. Effluent can be captured and applied more evenly and at more appropriates times.	✓	
Stock exclusion from waterways	Preventing stream and water body access to stock will reduce the amount of direct nutrient contamination occurring.	✓	✓
Wetland and riparian attenuation zones	Trapping and retaining nutrients and sediment in wetlands and vegetation buffers reduces direct contamination of waterways. Wetlands also can facilitate de-nitrification of N in water.	✓	✓

BMP	Rationale	Reflected in Overseer?	Assumed to be already in place on farm by Overseer
Deficit irrigation of effluent	Irrigating dairy effluent to soil moisture deficit reduces drainage and runoff of effluent nutrients. N remains in the root zone for longer where a larger proportion of available N is able to be utilised by the plant.	✗	✓
Ensure effluent block adequate to accommodate effluent volumes and N concentration	The effluent block must be of sufficient size to be able to spread the amount of effluent generated at a rate which does not allow for the over application of N. The effluent block size must also be matched to the N concentration of the effluent generated.	✓	
Have sufficient effluent storage volume	The ability to irrigate effluent to soil moisture deficit is determined by the level of storage available. If effluent storage is not large enough to allow for deferred irrigation when soil moisture levels are high, then the user must irrigate when soils are too wet which greatly increases N loss. (deferred irrigation occurs 100% of the time)		✓
Deficit and variable rate irrigation	Deficit and variable rate irrigation reduces the risk of sediment run-off and nutrient loss through drainage by keeping nutrients in the root zone and not over applying water causing excess leaching.	✓	✓
Balance dietary nitrogen and carbohydrates to optimize rumen function	Balancing and synchronizing the carbohydrate and protein supply to an animal's rumen will allow maximum conversion of N in the diet into animal protein, and minimize the amount of N excreted.	✗	
Use of cover crops during fallow period	Cover crops reduce the amount of N leached during an otherwise fallow period for soil.	✓	

APPENDIX 7: Management Practice Bundle Description and Management Options	
Current (Base) Practices	Typical farming practises in the catchment in the absence of water quality management policy.
Good Management Practices*	* • Reduction in fertiliser in crops following large winter depositions of nitrogen. • Dairy to install 30+ days' effluent storage and greater reduction in N use on effluent applied land.
Advanced Mitigation Level 1 Practices (Management changes)	• Installation of soil moisture monitoring gear and VRI on existing centre pivots. • No urea applications in May. • Adjust cropping fertiliser rates and types to best suit plant requirements and timings. • Use of yield maps to define an assumed 10% of the paddock which only yields half of the paddock average. • Use variable rate fertiliser technology. • Limit each urea application to <140kg/ha. • Variable Rate Fertiliser. • Gibberellic Acid to substitute some Spring and Autumn Nitrogen on Pastures. • DCD (Dicyandiamide) Use combined with nitrogen based fertiliser reductions to match. • Mixed Pasture Sward. • Short Rotation Ryegrass and White Clover Pasture. • Modify existing centre pivot irrigators to Variable Rate Irrigation technology on 90% of area. • Optimise stocking rates.
Advanced Mitigation Level 2 Practices (Capital investment)	Modify 90% of irrigated area to include centre pivots/laterals fitted with Variable Rate Irrigation technology. • Employ Normalised Difference in Vegetative Index (NDVI) sensing technology and consequent Variable Rate application of liquid urea. • Dairy farms to install covered feed pads and required effluent systems.
Advanced Mitigation Level 3 Practices (System change)	Reduce nitrogen fertiliser applications by 15% and model appropriate reductions in production. • Reduce stocking rates by 10% (without increasing production to compensate). • All cows wintered in barns and dairy farms grow sufficient winter feed (fodder. beet to lift). • No winter feed crop yields over 14t/ha. *

*Good management practises generally reflect what the top 50% of farmers are doing as of June 2012. These practices typically reflect farmer compliance with supplier regulations and local government law.

SOURCE Modelling Economic Impacts of Nutrient Allocation Policies in Canterbury: Hinds Catchment: Landcare Research on behalf of MfE 2013.