APPENDICES

Appendix 1: Beef + Lamb New Zealand Allocation Principles

Appendix 2: Economic Evaluation of the Government's proposed "Action for Healthy Waterways" Policy Package by BakerAg

Appendix 3: Technical report of Mr Andrew Burtt

Appendix 4: Evidence in Chief of Dr Chris Dada on behalf of Beef + Lamb New Zealand on Waikato Regional Council PC1

Appendix 5: Technical report of Dr Ben Hancock

Appendix 6: Technical report of Dr Jane Chrystal

Appendix 7: Evidence in Chief of Mr Simon Stokes on behalf of Beef + Lamb New Zealand on Waikato Regional Council PC1

Appendix 8: Beef + Lamb New Zealand LEP II Guidelines and Workbook

Appendix 9: Beef + Lamb New Zealand LEP Factsheet

Appendix 10: Pan Sector Intensive Grazing Report

Appendix 11: Selection of articles illustrating the depth and breadth of concern about grandparenting

APPENDIX 1: BEEF + LAMB NEW ZEALAND ALLOCATION PRINCIPLES

These principles have been developed to guide decisions on nutrient allocation within catchments. *They seek to ensure that nutrient allocation is fair, equitable, recognises the complexity of farming systems, is informed by the best science, and provides for continued flexibility of land use. B+LNZ supports catchment specific solutions to nutrient management and that different allocation regimes will be established that reflect differences between communities and their catchments, and to meet water quality objectives in those catchments. These principles should be considered carefully when forming any nutrient allocation policies or methods to achieve them. Each principle is important but they should be considered as a whole to inform allocation discussions.*

Principle 12

Regulation, monitoring, auditing and reporting of nutrients within an allocation regime needs to relate to the degree of environmental impact and pressure

If there is limited environmental pressure and if an activity has a low impact then regulation – and the financial cost of complying with that regulation – should be commensurate with the degree to which the activities are causing an adverse effect on water quality

Principle 13

As a minimum expectation, in all catchments, all land users should be at or moving towards (industry defined) Good Management Practice (GMP), recognising that GMP is constantly evolving and continuous improvement is inherent in GMP

In many catchments, lifting everyone to GMP is likely to go a long way towards achieving community objectives for managing to water quality limits. In catchments where nutrients are not over allocated, requiring good management practice is a sound alternative method to allocating nutrients to a farm (property based) level.

Principle 14

Nutrient allocation must be informed by sound science and stable and reliable catchment and farm system modelling and measurement

Modelling nutrient loss is important to inform nutrient allocation, but all models have limitations. Overseer is a key tool for understanding and managing nutrients on farms and to inform nutrient allocation decisions. In the short term there are significant limitations that need to be catered for in determining any regulatory or nutrient allocation regime (e.g. assumptions in Overseer regarding GMP, modelling of cropping regimes, ability of Overseer to estimate nutrient loss from the adoption of certain mitigations and the validation of Overseer estimates). Other measures may need to be included in the approach to managing nutrient loss to ensure innovative change is incentivised and that the focus remains on promoting good practice. Over time modelling designed to estimate nutrient loss will improve. Modelled estimates will change, so allocation regimes should account for modelling uncertainty and provide for appropriate transition periods.

Estimates of nutrient loss are a necessary input to decisions on nutrient management but broader catchment-scale modelling is critical if these decisions are to be robust. There is an urgent need to increase the emphasis placed on catchment-scale modelling.

Level 4, Wellington Chambers,
154 Featherston Street,
PO Box 121, Wellington 6011, NZ
0800 BEEFLAMB (0800 233 352)
www.beeflambnz.com

beef+lamb new zealand

BY FARMERS.
FOR FARMERS

Principles for the Allocation of Nutrients

beef+lamb new zealand

BY FARMERS.
FOR FARMERS

Beef + Lamb New Zealand

Principles for the Allocation of Nutrients

"Land owners need to have the ability to respond to changes in climate, input costs, markets and technological innovation in order to maintain a profitable and sustainable farming enterprise"

"Maximum economic efficiency of land use could be assisted by a mechanism for transferring nutrient discharge allowances within the same catchment"

Principle 1

Like land should be treated the same
Allocation should be based on the intrinsic qualities of the land. Two pieces of land with the same qualities should receive the same allocation. This principle recognises that allocation regimes should not be overly influenced by existing land use.

Principle 2

Those undertaking activities that have caused water quality problems should be required to improve their management to meet water quality limits
All New Zealanders have a responsibility to manage their activities to maintain or improve water quality. This principle reflects the need for those who have caused water quality problems or who are contributing a greater amount to them to take a greater responsibility for meeting the costs of reducing nutrient loss to water. It also reinforces that those who have managed responsibly should not be required to have their land use constrained as a result of others' activity.

Principle 3

Flexibility of land use must be maintained
Land owners need to have the ability to respond to changes in climate, input costs, markets and technological innovation in order to maintain a profitable and sustainable farming enterprise. Allocating nutrients in such a way that unnecessarily limits land use change constrains the ability of land users to respond to those changes and optimally utilise the land resource.

Principle 4

The allocation system should be technically feasible, simple to operate and understandable
A high level of technical feasibility is fundamental to a successful allocation approach. The simpler the system, the more likely it is to be able to operate effectively. The approach must also be understandable by land users and the wider community. It must be able to be administered fairly and at minimum transaction costs to users and the regulator.

Principle 5

The natural capital of soils should be the primary consideration when establishing an allocation mechanism for nutrient loss
A natural capital approach allows for an economically efficient allocation of nutrients. Those soils with the greatest ability to retain nutrients and optimise nutrient use give land users the greatest flexibility to optimise production, respond to markets and technology while managing potential effects on water quality. Allocation systems should reflect the ability of these soil types to optimise production and land use flexibility.

Principle 6

Allocation approaches should provide for adaptive management and new farm systems information
Allocation decisions are primarily made on the information we know now and modelled future scenarios. Our understanding and the availability of both catchment and farm systems will change over the life of an allocation system as will possible management techniques. Allocation systems should provide sufficient flexibility to provide for adaptive management and be reviewed regularly to incorporate new information. Adequate transition times should be provided to incorporate new information where allocation changes as a result.

Principle 7

Appropriate timeframes must be set to allow for transition from current state to one where allocation of nutrients applies
Timeframes should take account of the degree to which any waterway is over-allocated (if that is the case), the period over which this state has come about and the costs for businesses and the current ability to manage to that allocation.

It should be recognised that current water quality issues are sometimes the result of many years of land use within catchments and may have developed over generations. Consideration needs to be taken of the legitimate expectations of people and natural justice. Accordingly time should be provided for them to adjust. There needs to be a balanced approach and recognition of the uncertainty associated with water science versus the likely economic impact on businesses and the region. The primary objective should be to set an appropriate direction of travel that will see a steady improvement in water quality.

Principle 8

Long term investment certainty is a critical feature of a viable nutrient management system
Changes to nutrient allocation regimes must be signalled as far out as possible. Refinements to those systems must be managed to minimise their impacts on business viability, land value and the flexibility of land use. The aim must be to reflect the underlying elements of sustainable management in achieving improved water quality outcomes including reducing those adverse impacts on social and economic outcomes.

Principle 9

Improvement in water quality must remain the primary objective of adopting any nutrient allocation regime
When exploring the adoption of methods to achieve water quality improvements and manage to limits, the focus of community debates, modelling and discussion of allocation of nutrients can distract from the primary goal – maintaining and improving water quality. This principle emphasises that allocating nutrients to a property level doesn't in itself result in improved water quality; it is the actions of land users that ultimately result in improved nutrient management.

Principle 10

In under-allocated catchments, where property based nutrient allocation has not been adopted in setting water quality limits, the system for allocating nutrients must be determined well before the limit is reached, be clear and easy to understand, and designed to avoid over-allocation
The mechanism for allocating nutrients, even if it does not have immediate effect, should be clear from the time when water quality limits are set. Allocation mechanisms should reflect the level of risk that the catchment will become over allocated. This may include the adoption of a pre-agreed catchment-specific environmental threshold (e.g. 75%-90% of a limit) to determine when an allocation regime should be adopted.

Principle 11

In designing the allocation system the benefits of a nutrient transfer system within the catchment or water management unit must be considered
Maximum economic efficiency of land use could be assisted by a mechanism for transferring nutrient discharge allowances within the same catchment.

APPENDIX 2: ECONOMIC EVALUATION OF THE GOVERNMENT'S PROPOSED "ACTION FOR HEALTHY WATERWAYS" POLICY PACKAGE BY BAKER AG

Economic Evaluation of the Government's Proposed "Action for Healthy Waterways" Policy Package

31st October 2019

Richmond Beetham, Chris Garland - BakerAg

Client Report

Economic Evaluation of the Government's Proposed "Action for Healthy Waterways" Policy Package

Client: Beef + Lamb New Zealand (B+LNZ)

Authors: Richmond Beetham, Chris Garland - BakerAg

Due Date: 28th October 2019

Enquiries or requests to:

BakerAg
SH2, Waingawa
Masterton 5810
New Zealand
+64 6 370 6880

DISCLAIMER

BakerAg (NZ) Limited ("BakerAg", "us" or "we") has compiled this report, as contracted by B+LNZ.

This report is for B+LNZ and is not for wider distribution except as specifically agreed between BakerAg and B+LNZ.

BakerAg's findings are based on the information provided to us. We have not audited or otherwise verified the information, including actual and budgeted financial information, provided to us.

We have no responsibility to update this report for events and circumstances that may occur after the date of this report.

To the extent permissible by law, neither BakerAg nor any person involved in this publication accepts any liability for any loss or damage whatsoever that may directly or indirectly result from any advice, opinion, representation, statement or omission, whether negligent or otherwise, contained in this publication.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The true financial impact of the regulations proposed under the Action for Healthy Waterways discussion paper are considerably higher than those suggested by MfE. For a summary of these costs see Table 1 below.

On our calculations, and across a range of property types, the estimated capital costs of compliance per farm varies from $185,000 (mixed cropping farm) to $680,000 (hill country sheep & beef farm).

The annual costs of compliance range from $35,000 to $80,000. These annual costs comprise 5.4% to 30% of these properties' respective Earnings before Interest, Tax, Rent and Manager's Salary (EBITRm). We would consider that any annual cost greater than 10% of annual EBITRm is unsustainable.

Annual opportunity costs or "loss of future income" ranged from $85,000 to $184,000.

It is significant that three of the four case study farms already have very high levels of environmental compliance. They have won awards, been held up as industry models and recognised by their own district and regional councils. Yet all these businesses incur severe land use restrictions and significant costs in order to comply with the Action for Healthy Waterways regulations. These findings suggest that the Action for Healthy Waterways proposed regulations are out of step with the well-developed best practice standards of experienced and recognised land owners and of regional councils.

The most expensive impacts arise on hill country properties, largely through the cost of fencing for stock exclusion and providing alternate stock water supplies.

This is the area where MfE has grossly underestimated the economic impact. The cost of fencing to exclude stock from waterways and wetlands on hill country is substantially higher than on lowlands because (i) broken and steep contour accentuates the expense of fencing, (ii) four-wire electric construction is a minimum for practical purposes and (iii) the cost of reticulating alternative water supplies is substantially higher on hill country.

Direct access of stock to waterbodies is not the primary concern in the hill country. Rather, the potential impact to waterbodies is from the overland flow of pathogens and other contaminants to waterbodies. Therefore, a more appropriate approach to manage risk is through the identification and management of critical source areas. A fence does not stop an overland flow pathway. A 5m setback is also unlikely to stop overland flow through rainfall events.

A disturbing outcome of this analysis is that many of the proposed Action for Healthy Waterways regulations would have landowners divert time and capital into works that would have a dubious impact on the environmental health of receiving waterways. Many informed farmers are already addressing the "big ticket items" that are affecting water quality, such as critical source areas and sediment flows. There is a grave risk that this legislation would cause a misdirection of resources into capital expenditure and policy shifts that have much less effect on freshwater quality, than do the mitigating actions that they are already employing.

The grandparenting (compliance rules based around historical performance) of farming enterprises and feed cropping programmes has a substantial impact on both lowland and non-lowland properties. This approach assumes negative effects unless proven otherwise (i.e. it is not effects-based). Under grandparenting rules, farms with the higher nutrient losses stand to sustain a higher level of productivity, have more flexibility, and will be valued more highly. Farms with a low level of loss and potentially better environmental footprint are effectively capped with a ceiling on stock numbers, production, land value and future income-earning potential. There is no recognition for the differential in nutrient losses between drystock and mixed cropping farms and other more intensive sectors. Grandparenting favours businesses that already have a high environmental impact. This runs counter to a "polluter pays" principle, because those farms with the lowest environmental footprint are bearing a much larger burden. This blunt, one-size-fits-all mechanism reinforces existing inefficiencies and rewards high-intensity farms.

There are a number of vagaries in the wording of the proposal that render it unworkable in its current form. For example, definitions of wetlands and definitions of carrying capacity. We have had no option but to take the most literal interpretation of these regulations to demonstrate the literal economic impact.

The proposed legislation would have the most comprehensive impact on property management and property rights that this industry has ever seen. It is unhelpful that the proposal makes little effort to differentiate between urgent and non-urgent action. A sensible approach would be to identify the “big ticket items”, i.e. the actions for each property that will deliver the greatest improvements to environmental impact. What is noticeably lacking in this legislation is a sense of “bespoke practice”, whereby priorities for individual farms are identified and prioritised, with incentive and encouragement to pursue those priorities. Instead, this is a “one size fits all” approach which is confronting and represents an insurmountable capital cost for many landowners, while not necessarily delivering the desired environmental outcomes.

Table 1: Summary* of the impacts of the "Action for Healthy Waterways" policy package on four case study farms											
Farm	**Effective Area (ha)**	**Description**	**Up-front capital costs ($/farm)**	**Length of fencing (km)**	**Costs ($/farm/yr)**	**Costs ($/ha/yr)**	**Increase in farm working expenditure per effective ha (%)**	**Nitrogen (N) leaching (kg N/ha/yr)**	**Phosphorus (P) loss (kg P/ha/yr)**	**Opportunity costs or "Loss of future income" ($/farm/yr)**	**Lost income from 5m stock exclusion set backs ($/farm/yr)**
A	**622**	Hill country sheep & beef breeding and finishing	$643,508	35	$79,514	$128	21%	11 (2019)	0.7 (2019)	NC	$18,389
B	**819**	Hill country sheep & beef breeding and finishing	$566,712	27	$72,468	$88	14%	18 (2018)	0.7 (2018)	$95,000	$12,318
C	**655**	Mixed cropping, bull and lamb finishing	$185,350	16	$35,337	$54	8%	17 (2018)	0.3 (2018)	$117,520	$17,415
D	**900**	Hill country sheep & beef breeding and finishing	$680,485	24	$80,304	$89	29%	7 (2016)	1.9 (2016)	$184,195	$6,408

* A full explanation and calculations are in the body of the report and in appendix 3 to 6.

NC : Not calculated

1. ACKNOWLEDGEMENTS

The authors would like to acknowledge and thank the case study farmers who gave up their time freely over a very busy period in the farming calendar. What was evident on the farm visits was the passion the farmers had for the land. The information supplied and input from the farmers was a key part of the analysis and we thank them for this.

2. INTRODUCTION

2.1 Action for healthy waterways

The Government has a vision to see a substantial improvement in freshwater quality in five years and to restore freshwater to a healthier state "within a generation". The Government has conducted a public consultation process on their proposed "Action for Healthy Waterways" policy package. This report looks at the management and economic impacts of the proposed policy package on four case study farms.

2.2 What is proposed?

There are three strategies proposed under the policy package to change the way land and freshwater are managed.

- The first is through amendments to the National Policy Statement for Freshwater Management (NPSFM). The NPSFM sits under the Resource Management Act (RMA) and directs local authorities to implement certain objectives and policies within their regional plans and regional policy statements over time. The first NPSFM was put in place in 2011 and this required regional authorities to implement water quality and quantity limits. In 2014, it was replaced and amended, and now includes national bottom lines for water quality and a national objectives framework.

- The second mechanism is the development of new National Environmental Standards (NES). NES are regulations issued under section 43 of the RMA and can apply regionally or nationally (although all current apply nationally). They can prescribe technical and non-technical standards, methods or other requirements for land use. Each regional, city or district council must enforce the same standard. In some circumstances where specified in the NES, councils can impose stricter or more lenient standards.

- Third are regulations under section 360 of the RMA that allow the government to regulate at a national level certain activities and aspects of environmental management.

2.3 New environmental bottom lines

The current NPSFM includes bottom lines for nine indicators, known as attributes, which mostly relate to measures of physical and chemical water quality[1]. The Science and Technical Advisory Group (STAG) has considered the available science and provided advice on updated, new attributes and bottom lines[1]. There are proposed new in-stream nitrogen attributes for ecosystem health. The new in-stream

[1] Ministry for the Environment. 2019. Action for healthy waterways – A discussion document on national direction for our essential freshwater. Wellington: Ministry for the Environment.

nitrogen or dissolved inorganic nitrogen (DIN) has changed from 6.9 to 1mg/L. There are also new instream sediment attributes and phosphate attributes being proposed in the NPSFM. STAG has proposed a bottom line for phosphorus in rivers at an annual median of 0.018 milligrams per litre of dissolved reactive phosphorus (DRP). As an example, see Appendix 1 for a table showing monitored streams in the Wellington region and whether they comply with the new bottom lines for nitrogen and phosphorus based on current levels.

Regional councils will be required to set rules to maintain or, where degraded, improve levels to achieve the new bottom lines. For sediment the proposals take into account natural erosion processes and recognise that natural levels of sediment in rivers vary across New Zealand. The implications for farmers however are that regional councils will identify catchments that have an erosion risk and they are likely to increase rules around land use activities. Farmers will need to have a Farm Environmental Plan which will specify activities that would need to be undertaken to reduce sediment loss.

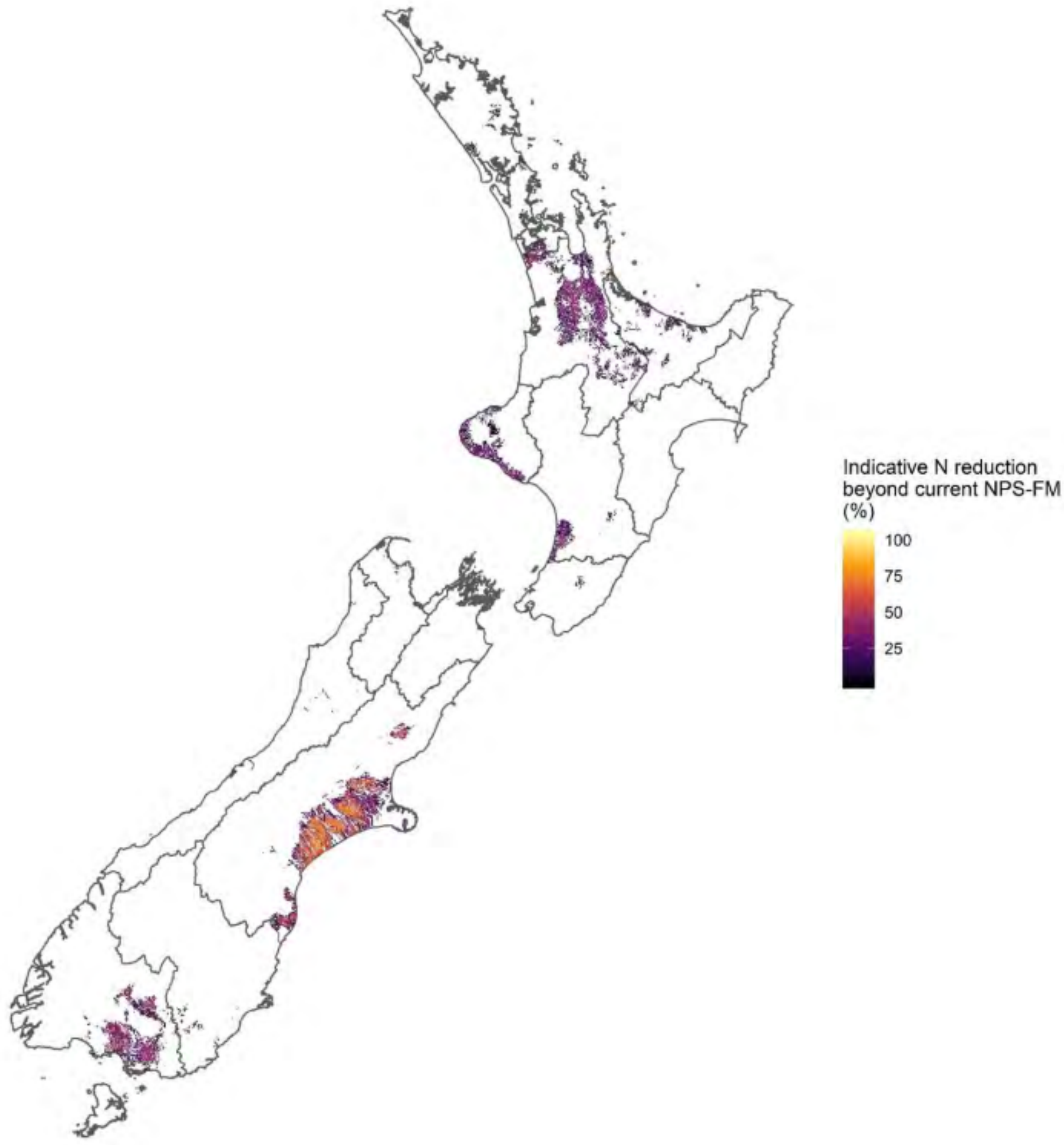
There will be substantial implications for land use where the bottom line is breached. Figure 1 below indicates major reductions in Nitrogen (N) needed in primarily Dairy intensive regions. From our calculations N leaching figures from Dairy systems are around 250% to 290% higher pe ha than sheep & beef dry stock farms. The average N use from Dairy Base owner operated dairy farms in the Waikato for the 2014-15, 2015-16, 2016-17 and 2017-18 seasons was 127, 132, 138 and 143 kgN/ha/yr. Contrast this with average N use on farms in the B+LNZ Sheep and Beef Farm Survey in Waikato-BOP which was around 9.2 kgN/ha/yr for 1990-91 to 2015-16. Recent B+LNZ analysis on 38 sheep and beef farms in Waikato showed that an average of 20 kgN/ha/yr was applied as fertiliser.

Reaching the proposed new bottom lines across the country would mean tighter restrictions on some lowland agriculturally dominated areas, beyond the existing limits, especially in parts of Waikato, Canterbury and Southland[1]. National scale modelling below (Figure 1) gives an indication of how much further nitrogen loads would have to be reduced under the proposed new bottom lines. The areas that are red/orange/yellow show where further reductions of more than 50 per cent may be required. It appears that the current allocation approach through the Action for Healthy Waterways policy package is a form of grandparenting. Grandparenting dry stock farms in these regions with a one-size-fits-all mechanism, risks supporting existing inefficiencies and rewarding high-intensity farms at the expense of low-intensity farms.

2.4 Giving effect to the NPSFM

The NPSFM directs regional councils to make or change regional plans to the extent needed to ensure the national bottom lines for water quality and national objectives are met. It is important to remember that these proposals require implementation at the regional level by councils. Depending on the water quality issues in different regions, the regional councils can set more stringent guidelines so they can meet the new national bottom lines. This has been evident in places such as Waikato where nitrogen was 'grandparented' under the proposed Plan Change 1.

Figure 1. Indication of impact of proposed new nutrient bottom lines[1]



3. PROPOSED POLICIES

3.1 Interpretation of the policies

B+LNZ and the author have interpreted to the best of their abilities the proposed policies. Where the Ministry for the Environment (MfE) could not give any further clarification, assumptions had to be made about the interpretation of the policy and what it meant on the case study farms. Some of the policies were unclear or silent on the exact mechanisms of implementing the policy and what methodology needed to be used.

3.2 Interpretation: excluding stock from waterways

The following is from MfE's policy proposals:

"We propose new standards for when stock must be excluded from wetlands, lakes and rivers more than one metre wide".[1]

"We also propose that farmers are required to have a freshwater module in their farm plan setting out how and when they will exclude stock from rivers and streams less than a metre wide and drains[1].

- "Through tailored Freshwater Modules in the Farm Plan (FM-FP) develop bespoke approaches for excluding stock [includes sheep?] from waterbodies, including smaller than 1m wide, and wetlands"[1],
- "For streams less than one metre wide and drains, farmers would be required to set out a plan for fencing and setbacks in the freshwater module of their farm plan. The timetable, type of fencing and setbacks would be tailored to the individual circumstances of the farm"[1].

"Dairy and beef cattle, and pigs, are not permitted to cross water bodies except by a dedicated culverted or bridged cross point (unless that crossing is no more than twice per month)"[2].

We interpret from these definitions that the ultimate intention is for all stock (including sheep), to be excluded from all waterways (including those <1 m).

3.3 Stock exclusion - no further loss of wetlands

As part of the proposals stock need to be excluded from all wetlands and MfE is proposing to require a setback of five metres, on average, across a farm.

"The RMA defines a 'wetland' as including permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to

[2] Draft Stock Exclusion Section 360 Regulations. Retrieved from: https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/draft-stock-exclusion-regulations.pdf

wet conditions. This does not include wet pasture or paddocks where water temporarily ponds after rain, or that contain patches of exotic sedge or rush species, or constructed wetlands."[1]

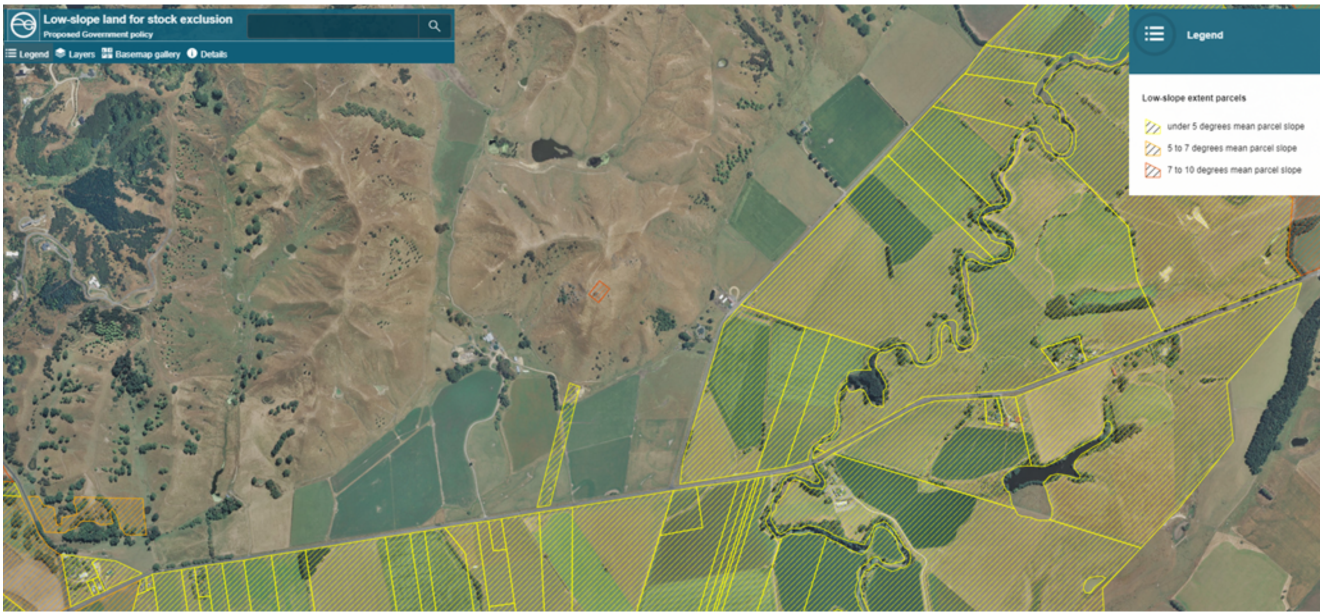
3.4 Interpretation: Low-slope land for stock exclusion

All cattle, deer, and pigs are to be excluded from permanently or intermittently flowing waterbodies that are greater than 1m wide in areas mapped as low slope by 1 July 2021.

New Zealand farm land has been mapped into two broad categories by MfE. These are low-slope (LS) land and non-low-slope (NLS) land. Slope is determined across a land parcel (title?), e.g. it is an average slope across a land title.

The map on the MfE website shows the extent of area considered to be LS, which is defined as land parcels with an average slope of less than 5 degrees (yellow), 5 to 7 degrees (orange) or 7 to 10 degrees (red) (see Figure 2). These areas are under consideration for mandatory stock exclusion from all wetlands and lakes, and all rivers over 1 metre wide. It must be noted that land is mapped at 1:50,000 nationally to identify low slope. Slope is determined across a land parcel, which while making it simpler to apply, fails to identify variable slope within a farm.

Figure 2: MfE Mapping Low-slope land for stock exclusion



The MfE is consulting on setback distances. "For large rivers and streams (more than one metre across), lakes and wetlands, MfE are proposing to require a setback of five metres, on average across a farm"[1]. Setback requirements are 5m on average across a property with a minimum width of 1m. Where an existing fence does not comply with setback requirements, it shall be allowed to remain in its current position until 2025, unless the existing setback has a minimum 2 metre average width and is not less than 1 metre at any point, in which case the setback requirements do not apply until 2035.

Table 2: Stock exclusion on "Low-slope" land (MfE - Draft Stock Exclusion Section 360 Regulations)

Waterbody	Stock	Setback	Timeframe
Wetland	Dairy and dairy support cattle, pigs, beef cattle and deer	5 metres on average across a property (with a minimum width of 1m)	1 July 2021 for wetlands identified in regional or district plans. 1 July 2023 for all other wetlands
Wetland	Any new pastoral system for all cattle, pigs or deer establishing after gazettal	5 metres on average across a property (with a minimum width of 1m)	Immediately
Rivers (> 1 m wide), and lakes	Dairy and dairy support cattle and pigs	5 metres on average across a property (with a minimum width of 1m)	1 July 2021
Rivers (> 1 m wide), and lakes	Beef cattle and deer	5 metres on average across a property (with a minimum width of 1m)	1 July 2023
Rivers (> 1 m wide), and lakes	Any new pastoral system for all cattle, pigs or deer establishing after gazettal	5 metres on average across a property (with a minimum width of 1m)	Immediately
Rivers (> 1 m wide), and lakes	Land where any cattle or deer are feeding on fodder crops, or break feeding, or where pasture is being irrigated, or has been irrigated in the previous 12 months.	5 metres on average across a property (with a minimum width of 1m)	1 July 2021 Unless it is a new pastoral system established after gazettal, in which case, immediately

3.5 Interpreting land outside the low-slope category

Non-low-slope land is land that is not classified as low land on the MfE mapping tool and where the average slope at the land parcel scale is greater than 5 [or 7, 10] degrees. (TBC)

"In areas that are not mapped as low-slope, stock exclusion is still important, particularly where the land can sustain reasonably intensive uses. The stock exclusion requirements (that is to exclude cattle, pigs and deer) will therefore also apply to areas where:

- at the farm scale, the land has an average carrying capacity equal to or greater than 14 stock units per hectare
- at the paddock scale, the land has a carrying capacity equal to or greater than 18 stock units per hectare (regardless of the average carrying capacity of the farm)
- at the paddock scale, the land is or has previously been irrigated

- at the paddock scale, the land is used for fodder crops when cattle, pigs or deer are on that land[1]".

MfE has said it will be necessary to develop a methodology (or identify an existing methodology) to calculate carrying capacity.

Table 3: Stock exclusion from waterways on "Non-low-slope" land (MfE - Draft Stock Exclusion Section 360 Regulations)

Waterbody	Stock or land use	Setback	Timeframe
Wetland	Dairy and dairy support cattle, pigs, beef cattle and deer	5 metres on average across a property (with a minimum width of 1m)	1 July 2021 for wetlands identified in regional or district plans. 1 July 2023 for all other wetlands
Wetland	Any new pastoral system for all cattle, pigs or deer establishing after gazettal	5 metres on average across a property (with a minimum width of 1m)	Immediately
Rivers (> 1 m wide), and lakes	Dairy cattle, but not dairy support, and pigs (unless housed)	5 metres on average across a property (with a minimum width of 1m)	1 July 2021 Unless it is a new pastoral system established after gazettal, in which case, immediately
Rivers (> 1 m wide), and lakes	Beef cattle, dairy support cattle, and deer on land with a base carrying capacity • of 14SU/ha or more at the farm scale, or • 18 SU/ha or more at a paddock scale if the base carrying capacity is less than 14SU/ha at the farm scale	5 metres on average across a property (with a minimum width of 1m)	1 July 2023 Unless it is a new pastoral system established after gazettal, in which case, immediately
Rivers (> 1 m wide), and lakes	Land where any cattle or deer are feeding on fodder crops, or break feeding, or where pasture is being irrigated, or has been irrigated in the previous 12 months.	5 metres on average across a property (with a minimum width of 1m)	1 July 2021 Unless it is a new pastoral system established after gazettal, in which case, immediately

It appears that hill country or non-low slope land has been captured a number of ways in terms of stock exclusion in the policy. The freshwater module in the farm plan needs to set out how and when farmers will exclude stock from rivers and streams less than a metre wide and drains. If stock at any time are stocked at a rate of or exceeding 14SU/ha per farm or 18SU/ha per paddock, then they need to meet the 360 regulations (note this includes exclusion from both permanent and intermittently flowing waterbodies greater than 1m wide). The way this is written, it captures all rotational grazing and mob stocking through individual paddocks. E.g. One mob of 50 R2 Steers @ 5 SU/hd equals 250 SU. If these were rotating through a 7ha hill country paddock with a stream, the stocking rate per ha would be 36 SU/ha so would trigger the stock exclusion rule and the fence set back requirements of 5m.

If the carrying capacity of the farm (carrying capacity is defined currently as the methodology used on Crown Pastoral Land) is greater than 14su per farm or 18su per paddock then irrespective of whether or not the actual stocking rate exceeds this, the stream needs to be fenced.

3.6 Certified farm plan with a freshwater module

MfE is proposing that all farmers be required to have a certified farm plan (FP) with a freshwater (FW) module by 2021 for schedule 1 catchments[3], and by 2025 for all other areas. The consultation document includes a range of options, but the Government's preferred approach is for a mandatory requirement in the draft Proposed National Environmental Standards for Freshwater (NES).

The freshwater module description in the draft NES is very prescriptive and includes needing to have a nutrient budget and demonstrating how a landowner will "reduce" all emissions of nitrogen, phosphorus, sediment and microbial pathogens. "The action points in a FW-FP must address the risk identified under subclause (3) and set out the actions that the person implementing the FW-FP is undertaking, or will undertake, to avoid, remedy, or mitigate the loss of contaminants, along with timeframes for those actions"[4]. This implies grandparenting a farm's current level of emissions, regardless of impact or whether there is any land use change.

The freshwater module requires stock exclusion, which implies excluding sheep from waterbodies (irrespective of size and permanent or intermittently flowing). It's important to note that a waterbody is the RMA definition of a waterbody, which includes intermittent and potentially ephemeral waterbodies and includes drains and ditches.

The freshwater module must identify environmental risks and set out time-bound auditable actions to address those risks and reduce losses. The farm plan must be certified by a farm environmental planner approved by the Minister for the Environment and Minister for Agriculture. The farm plan must also be audited by an approved auditor within 24 months.

[3] These catchments are presented on page 25 of the draft NES.

[4] Proposed National Environmental Standards for Freshwater, September 2019. Retrieved from: https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/proposed-nes-for-freshwater.pdf

3.7 Restricting further intensification of rural land use

By 2025 MfE anticipate that regional councils' implementation of the NPSFM will manage further intensification. In the meantime, the policy package looks to put a temporary restriction on further intensification. The proposal applies restrictions to the following activities:

- Increases in the area of land in irrigated pastoral, arable or horticultural production greater than 10 hectares
- Changes in land use above 10 hectares from:
  - arable, deer, sheep or beef to dairy-support
  - arable, deer, dairy-support, sheep, or beef to dairy
  - woody vegetation or forestry to any pastoral use
- Increases in forage cropping beyond the area in intensive winter grazing in the past five years; or if the applicant didn't previously carry out intensive winter grazing, then beyond a minimum threshold. MfE is seeking feedback on this minimum threshold – whether it should be 30 ha or 5 per cent of the property, or 50 ha or 10 per cent of the property, or somewhere between.

3.8 Increasing irrigation by more than 10 ha

An increase in irrigation is a discretionary activity if the increase since the commencement date is more than 10 ha. "Any resource consent granted for the discretionary activity must include at least the following conditions" [4]:

a) the applicant has a certified FW-FP

b) the FW-FP includes actions to avoid, remedy, or mitigate the adverse effects of the activity's contaminant discharges into freshwater, or onto land in circumstances that may result in the contamination entering water

c) the nitrogen, phosphorus, sediment, or microbial pathogen discharges of the farm that will result from the increased land used for irrigated production will not exceed the average discharges of those contaminants from the farm during the farm year 2017/2018.

3.9 Winter grazing on forage crops

The slope threshold being consulted on, permits winter grazing on forage crops if the slope is below a certain level. Thresholds of 10 degrees or 15 degrees are suggested in option one (see page 77 of the discussion document[1]) or 20 degrees in option 2 (see page 78 of the discussion document[1]). Therefore, a farmer will need a consent for winter crops above 10 or 15 degrees slope.

It is unclear how slope will be determined and if it is on a paddock by paddock basis or if it is determined across a land parcel via the MfE mapping tool. The mapping tool would make it simpler to apply but it fails to identify variation in slope across a farm. Using the mapping tool would mean that even if a farm contains a portion of land that is under 10 degrees in slope, and upon which the grazing of feed crops could be conducted with minimum emission risk, the farmer will still require a consent because the parcel of land has average slope exceeding 10 degrees. It is also unclear if farmers will need a consent each year for each paddock or if they will get a consent for certain areas over a certain timeframe.

3.9.1 Low-Lands (permitted)

The area of cropping needs to be considered alongside the slope of the land that farmers plan to grow and graze winter forage crops on. The proposal is that intensive grazing on winter forage crops is permitted activity as long as the size of the forage crop is less than:

a) 30 hectares or 5 % of the farm, or

b) Less than 50 hectares or 10% of the farm.

It is permitted if the farmer:

a) Provides a 5m (20m) vegetated setback from waterbodies

b) Follows strategic grazing principles

c) Protects critical source areas (no grazing)

d) The grazed paddock is re-sown within 1 month, or as soon as practicable, after the end of the grazing

e) And has no pugging above 20cm (10cm) for greater than 50% of the paddock.

3.9.2 Hill country & activities that do not meet standards (consent required)

The crop area is 'grandparented' to no greater than 2013/14 to 2018/19 years

"For the purpose of granting a resource consent for the restricted discretionary activity, discretion is reserved over the following:"[4]:

1. The area of annual forage crop
2. Methods of grazing management (such as requiring that grazing on sloping land occurs progressively downhill from the top to bottom of the slope)
3. Methods for protecting critical source areas
4. Provision for vegetated strips to protect waterbodies from stock grazing

5. Provisions for re-sowing the grazed paddock
6. Methods for preventing pugging
7. Applicant must have a certified FW-FP

4. OVERVIEW OF THE SHEEP & BEEF SECTOR

4.1 Overview

The sheep and beef industry is diverse, adaptable and to date has been resilient, continually making eco-efficient gains in how it produces red meat. Sheep and beef farmers have managed to increase meat production, while decreasing the total number of animals farmed, made significant progress in reducing their environmental footprint, while losing some of their most productive land to other land uses. In the drystock sector there is significant variation in topography, soil type, climate, stocking rates and livestock policies. No two sub-catchments are the same and often no two farms are the same. In terms of water quality in these catchments one farm might have a problem with P loss or sediment, while in more intensively farmed areas and in areas where soil may be coarse textured and free draining the main issue could be N. Given this large variation, a prescriptive "one size fits all" regulatory approach to managing contaminant losses is not a cost-effective or fair approach. Mitigation measures need to be implemented at a farm scale (matched to the farm system), be effects-based and be the most cost effective available.

4.2 Externalities of concern in the Sheep & Beef sector

In terms of water quality, the main contaminants of concern are sediment, nitrogen (N), phosphorus (P) and faecal bacteria. For sheep and beef farms the loss of P, sediment and faecal bacteria are the main concern. Sheep and beef farms are generally minor contributors to N loss. Nitrate leaching is the main pathway of nitrogen loss from soils. One of the major sources of nitrate leaching is from urine patches. Typically, the higher the stocking rate the more urine patches per unit area and the more N leaching. Intensive farming on vulnerable soils (coarse textured free draining) results in an increased amount of N making its way to our waterways[5]. High rainfall and irrigation on these free draining soils further increases the risk of N leaching. Nitrogen losses from sheep and beef farm systems are typically much lower than other pastoral land uses. Nitrogen leaching from dairy farms is higher than from sheep and beef farms.

This means that for sheep and beef farms, the main issues are in relation to contaminants which flow over the land (P, sediment, faecal bacteria), rather than those that flow through the soil profile such as N. The most efficient and effective approach to managing the impacts of sheep and beef farming on the environment is through tailored farm environment planning and the identification and management of critical source areas (CSA).

[5] Ms. Dewes, Evidence in Chief. Before the Board of Inquiry Tukituki Catchment Proposal. In the matter of the Resource Management Act. 1991. October 2013.Paragraph 21, page 6.

5. METHODOLOGY

5.1 Farm selection

With the tight time frame available to make submissions the authors chose farms located primarily on the East Coast of the North Island and one in Waikato. Farms were selected that had adequate existing data such as OVERSEER modelling, financial benchmarking, Farmax, and farm maps to make the data gathering exercise quicker and data analysis easier. Three out of the four farms have already made significant investments in environmental protection and are using technology to mitigate their environment imoacts as well as having Farm Plans. Ideally a farm would have been chosen in the South Island however time did not allow. The farms chosen gave a good representation of the B+LNZ farm classes in the North Island, including Farm Class 3, 4 and 5. The farms in table 4 were identified on the MfE web mapping tool to determine if they were classed as “low-slope” farms or if areas were classed as “low-slope” for stock exclusion.

Table 4. Case study farms

Farm	Effective Ha	Farm type	Location	B+LNZ Farm Class#	Classed as "low-slope" land for stock exclusion*
A	622	Hill country sheep & beef breeding and semi finishing	Eastern Wairarapa	3	N
B	819	Hill country sheep & beef breeding and finishing	Tararua	4	N (Only small parcels that are in separate titles)
C	655	Mixed cropping, bull and lamb finishing	Hawke’s Bay	5	Y
D	900	Hill country sheep & beef breeding and finishing	Central Waikato	4	N (Only small parcels that are in separate titles)

 # BakerAg estimate of B+LNZ farm class
**Ministry for the Environment web map showing areas considered to be low-slope land for stock exclusion*

5.2 Farm visit and property inspection

Farms A, B and C were visited in October 2019. Farm D was visited in 2016 for another piece of work involving stock exclusion from water bodies and the data gathered was updated and used for this report. A full farm tour was undertaken on all farms, identifying and mapping all water bodies from which stock had to be excluded under the proposed policy package. The maps were not included in this report because all farmers wanted to be anonymous. There is a 5m setback requirement on average across the whole property, so an assessment was made if waterways that had existing fencing had a 5m set back.

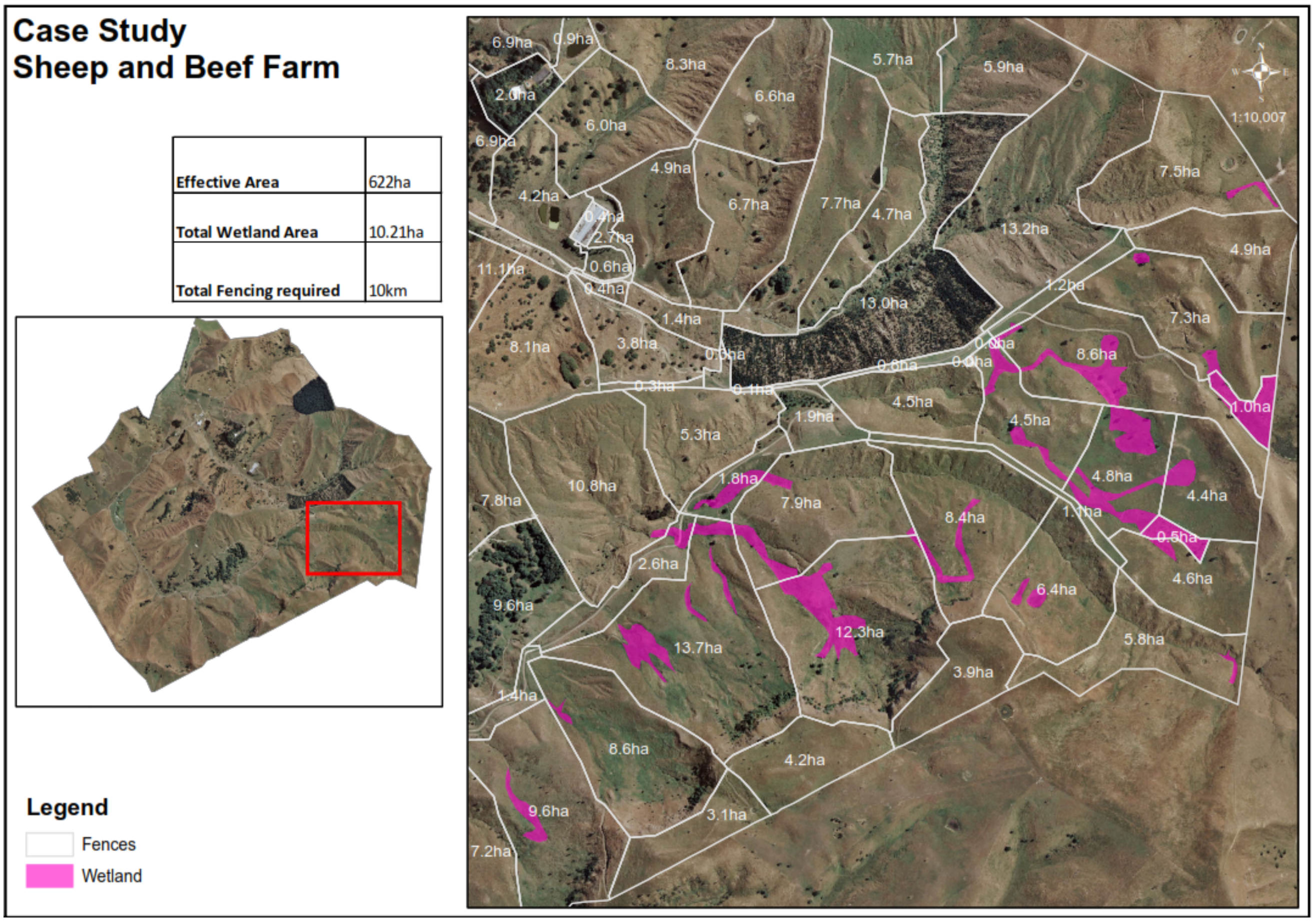
Figure 3: Waterways fenced with riparian planting on farm C. The fence setback on these do not meet the proposed 5m requirements.

5.3 Identifying wetlands for stock exclusion

Wetlands were identified on farms A, B and C. The consultant was not an expert in the area of wetland classification and found it difficult to apply the RMA wetland definition in the field so engaged a Senior Environmental Monitoring Officer from Greater Wellington Regional Council (GWRC). The officer identified all the wetlands that needed stock exclusion on Farm A (see figure 5). The consultant then made their best judgement on the other farms in terms of what comprised a wetland. Farm D has many wetlands but unfortunately due to time constraints these were not identified, and stock exclusion was not costed as part of this report on this farm.

Figure 4: Examples of a fenced wetland and an unfenced wetland on case study Farm A

Figure 5: Farm map showing wetlands that will need stock exclusion on case study Farm A



5.4 Estimate of fencing costs

QGIS mapping software was used to measure waterways, wetlands and fence lines needed to exclude stock. Where an existing fence was in place on one side this was kept, and the opposite side of the waterway was measured. A four-wire electric fence was chosen (explained below) to fence on both sides. No allowance was made in the costs for removing existing fences that don't comply with the setback rules. Fencing labour and material on flat land was priced a $10/linear metre, for hill country $16.50. These figures were based on pricing from BakerAg records and the Ministry for Primary Industries (MPI) Stock Exclusion Costs Report[6]. It's important to note that fencing materials and labour costs have risen significantly since the 2016 MPI report and this was considered when determining the per-metre rates. Several other sources and methods were used to estimate fencing costs on a per-metre rate:

- Recent on-farm fencing project costs were gathered from farms.
- The consultant made an independent assessment based on his own practical experience with fencing and the costs associated.

[6] Ministry for Primary Industries Stock Exclusion Costs Report. MPI Technical Paper No: 2017/11, January 2016

- Evidence was gathered on each property as to the current fencing and what was required to fit their stock policies.

5.4.1 Why haven't one-wire or two-wire fences been used?

All of the farmers mentioned if they were going to exclude stock from waterways it would not be with one or two wires, the minimum would be a four-wire electric and a number of the case studies preferred permanent eight-wire post and batten fences for a number of reasons:

- The stock policy and type of animal farmed, and contour played an important role in determining the type of fence.
- Single or double wire fencing is unsuited for stock exclusion when sheep are part of the policy due to the damage caused by sheep continually pushing through fences to feed and during mustering. This is especially relevant in a drought year or when power is down. All four of the farms run sheep as part of their stock policy.
- Three of the farms had cows which were set stocked for calving and there are issues with newborn calves slipping under one or two wires and getting shocked and not coming back to the cow for milk which is an animal welfare issue.
- If power is down due to a short and the one wire is low and sheep run under, they can catch the wire and get entangled in it which is an animal welfare issue.
- A single wire (no matter how much power) would not provide enough of a barrier to freshly weaned mobs of beef weaners that some of the properties farm.
- Riparian planting cannot be undertaken with one wire as sheep can access newly planted plants
- There are also issues with getting power to isolated parts of the farm.
- The dairy industry often uses one or two wires to fence waterways. Dairy farms are typically flat to rolling so the contour means fewer dips in the fence line. Dairy farms don't run sheep. Cows are large (no chance to fit under high points in the wire), hand-reared and quiet (handled in the shed each day). They are shifted twice daily for milking and often never push under fences to get extra feed. Grazing residuals are higher, so cattle don't go looking for feed. Power in the fence lines is typically easier to manage on a smaller property with less chance for shorts and often because of the shorter distance the voltage is significantly higher than large extensive properties with electric fences.
- It therefore cannot be assumed that a one-wire or two-wire fence is suitable in many situations and the consultant has used his professional judgment in choosing a four-wire electric with post spacings at 5 m. Waterways that have been fenced off on the

farms were typically with permanent eight-wire post and batten fences or seven-wires with two electrified wires.

5.4.2 Are temporary fences the solution?

In cases where stock is intensively grazed, such as strip grazing saved grass or on forage crops, then fencing waterways is practical in most hill country situations with a temporary fence.

Temporary fences have been put forward as a solution to exclude stock from waterways in hill country in extensive all-grass situations. This is simply not practical unless significantly more staff are employed on these farms. The reason it is not practical is stock are often on rotation through paddocks so before stock are moved into a paddock a temporary fence would have to be erected each time and then taken down including moving a portable fence unit. Often winter stock rotations are on one-day or two-day shifts going through multiple paddocks with waterways in hill country therefore the time commitment is simply not feasible without a dedicated person to do this. In the spring animals are often set stocked (stay in the paddocks permanently) for lambing and calving. This would mean temporary fences across the whole farm in multiple paddocks with multiple portable fence units. This is all assuming a one wire temporary fence so if sheep are excluded it would need a four-wire temporary fence which would be extremely difficult and time consuming to erect in hill country on both sides of the streams.

5.4.3 Streams were not straight and the contour varied

Many of the waterways were not straight and the terrain varied. The cost of fencing on this type of terrain and hill country greatly increases for several reasons:

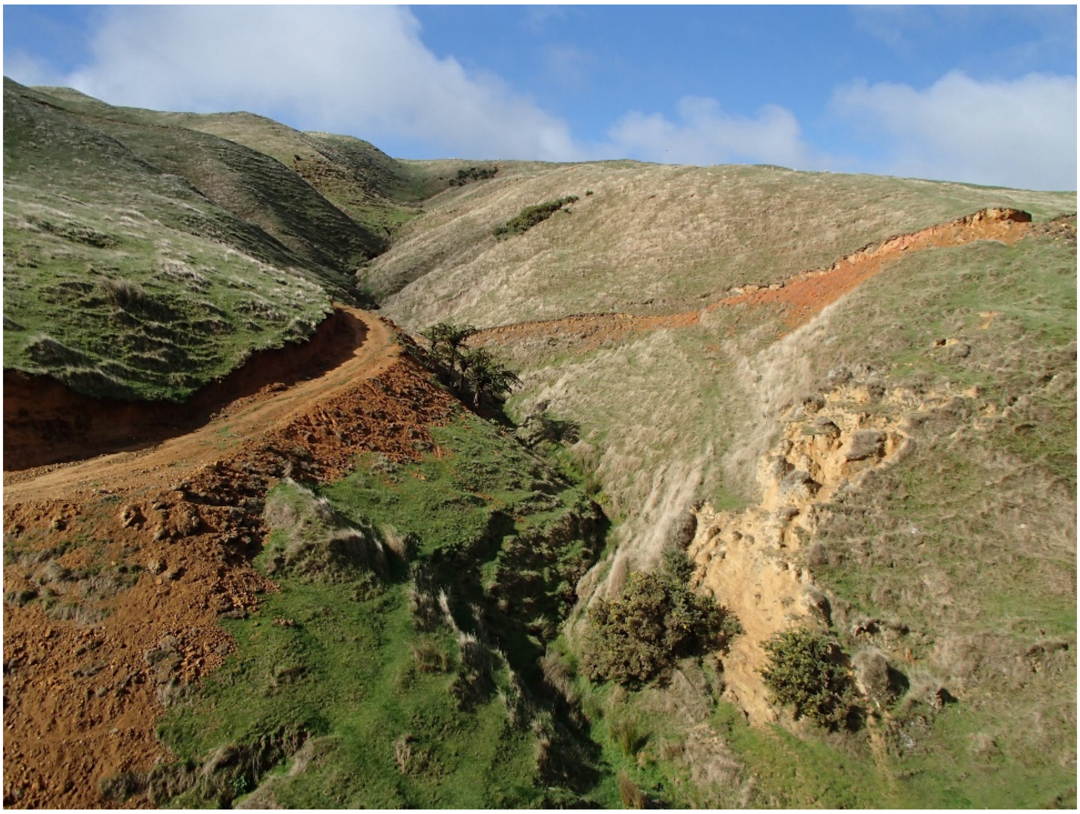
- Cost to get the material into the site. Often this must be walked in.
- Less opportunity to use a labour-saving post rammer, so that more manual labour is required.
- More 'benching' preparation by machinery needed to allow fence lines (see figures 8 & 9).
- A lot more angles needed and additional stays.
- Posts are much closer together.
- More foots needed in dips.
- More floodgates needed in dips.

Figures 6 & 7: Water ways that will be expensive to fence in hill country

5.5 Unintended consequences of fencing hill country streams?

To create a suitable stock proof fence line with minimal dips, many hill country fence lines will be bulldozed. The hills will be "benched" to create the fence lines as well. Some of the hill country farms visited already have extensive erosion control measures in place with poplar and willow pole planting to stop sediment entering waterways. This benching of fence lines will create a huge amount of sediment for many years after the fencing project and these scars often don't fully recover adding more sediment to waterways. Benching the bottom of a hill is problematic as well as the 'toe' of the hill is removed, and the hill can erode into waterways. Slumping of the benched areas is also common adding further sediment. Another unintended consequence is that by fencing waterways you provide more subdivision and smaller paddocks which intensifies the stocking rate per ha. In rain events stock will track up and down fences opening the soil and creating risk areas for sediment, pathogen and nutrient run-off. If stock are concentrated in these smaller paddocks, then pugging can be a risk during a rain event compared to larger paddocks where the stock can spread out and seek shelter. Below are a number of pictures of fence lines that have been bulldozed in hill country and the large quantities of sediment created. One of the pictures shows stock tracking along fence lines (figure 9) and cattle in a small paddock after a rain event (figure 10).

Figures 8 & 9: Bulldozed tracks for fence lines in hill country that are above streams



Figures 9 & 10: Stock tracking along a fence line and shallow pugging with surface mud caused after a rain event.

5.6 Erosion and sediment control

The action points in a FW-FP must set out the actions that the person implementing the FW-FP is undertaking, or will undertake, to avoid, remedy, or mitigate the loss of contaminants, along with timeframes for those actions. Some of the main critical source areas from which sediment, nitrogen, phosphorus and microbial pathogens could be lost have already been identified by the farmers. There wasn't time at the visit to identify all actively eroding areas, erosion prone areas, and areas of bare soil for erosion and sediment control and re-vegetation. The number of poplars needed for planting was estimated based on the size of the property and erosion status, however this would need more investigation to get an exact figure. Popular pole costings were calculated after talking with GWRC.

Figure 11: Extensive pole planting of a critical source area on one of the case study farms

5.7 Estimate of water reticulation costs

After excluding stock from waterways on farms A, B, and D, alternative water supplies (or water reticulation) would be required. Google Earth and QGIS mapping software were used to design the water reticulation system and estimate associated costs. Key reticulation costs such as additional pumps, power, header tanks, source dams and main lines were calculated for the properties. Costings were adapted from the report titled "Implications of the proposed Waikato Plan Change 1". [7]

5.8 OVERSEER modelling to determine nutrient losses

OVERSEER modelling for farms B and C was carried out by the Senior Environment Data Analyst from B+LNZ using best management input standards. The analyst is a certified nutrient management adviser with 14 years' experience using OVERSEER, and version 6.3.2. was used. OVERSEER results for farm A were obtained from Ballance Agri-nutrients and reviewed by a BakerAg consultant. OVERSEER results for farm D were obtained from the report "Implications of the proposed Waikato Plan Change 1".[7] Any OVERSEER data in the report should not be used for consenting or compliance purposes.

5.9 Estimated costs of livestock crossing structures

Environment Waikato's "Best Practice Guidelines for Waterway Crossings" was used to determine appropriate livestock crossing structures for each situation. For smaller culvert crossings not needing consent, prices were obtained from local rural supply firms and based on the consultant's practical experience of placing culverts on farm. It must be noted that farm B had a significant river running through the property that at peak stock movement times they would move stock through more than two times a month. Three large engineered bridges would be the only possible solution to exclude stock out of these streams otherwise stock would have to be mustered long distances on the main road.

5.10 Calculations of the potential loss of future income

For the three farms B, C and D on which the proposed policy package will have the biggest impact in terms of potential loss of future income, current financial performance was analysed using annual accounts, BakerAg Financial Analysis Benchmarking (FAB), and cash books such as Xero & Figured and Cash Manager. This was then used to develop the status quo level of financial performance. The key financial KPI used was Earnings before Interest, Tax, Rent and Manager's Salary (EBITRm).

For the properties that were compared and contrasted with B+LNZ sheep & beef farm survey data a judgment was also made on the potential of each property run under an average efficient operator and at top 20% performance. The status quo was then compared to similar properties in the farm class for those financial years to determine the opportunity costs.

[7] Implications of the proposed Waikato Plan Change 1 Report. BakerAg, R Beetham. C Garland. June 2018.

A change of policy on the property was then modelled in OVERSEER to see the impact this would have on the property's nutrient losses. Reduction in nutrient losses was also modelled and the resulting impact on stocking rate. The cost of the reduced stocking rate was then calculated.

6. CASE STUDY – FARM A

6.1 Introduction to Farm A

Farm System:	Hill country sheep & beef - breeding and semi finishing
Location:	Eastern Wairarapa
Altitude:	191m to 430m
Area:	646ha Total – 622ha effective.
Contour:	55ha flat to rolling, remainder hills. 20ha forestry and 3ha of QEII National Trust protected swampland.
Rainfall:	860mm average rainfall pa.
Soil tests taken in June 2017:	Averages: pH 5.9, Olsen P 16, Sulphate Sulphur 8
Subdivision:	95 main paddocks (6.7ha average size).
Water:	Bulk of farm fed by gravity from springs via troughs. Dams and spring fed creeks through others without troughs.
Stocking Rate:	9 SU/ha (4 year av)
Sheep System:	2800 mixed age (MA) and two tooth (2th) Ewes, 800 in-lamb hoggets. Lambing 145% 4-year average. A proportion of lambs are sent to the works at weaning and the rest are sold store or to the works through autumn season dependent.
Cattle System:	100 mixed age (MA) Angus cows. 20 in-calf R2 heifers. Weaner steers generally sold at the weaner fair, with weaner heifers taken through for replacements and finishing.
Cropping:	Circa 10-15ha of rape and some turnips. Main reason/purpose of these crops is to start growing out the ewe lambs. Fed out in summer-autumn. 6ha of red clover, 2.5ha annual clover and 20ha of plantain.

Current Environmental Management:

- Winners of several Farm Environment Awards
- Regular soil testing along GPS transects
- Variable rate fertiliser technology
- Farm modelling using Ballance MitAgator including nutrient budgets

- Retired 12.5ha of highly erodible country in 2012 and planted pines, acacias, lusitania, redwood and eucalyptus through the Greater Wellington Regional Council's afforestation scheme.
- A sediment dam has been developed to help reduce the amount of sediment entering the waterways.
- Minimal use of winter forage crops
- Stock crossing structures across creeks for stock
- Retired two small blocks of limestone spring wetland areas into QEII National Trust covenants, which are the source of farm stock water, with a third smaller one in the process of being fenced.
- More than 2000 poplar and willow poles have been planted for erosion control, shade and fodder in drought.

6.2 Impacts of the "Action for Healthy Waterways" policy package on farm A.

6.2.1 Environmental Overview

Farm A is not only award-winning for its excellence in sustainable farm practices but also has a strong emphasis on innovation in order to create a sustainable, environmentally friendly and aesthetically pleasing farming system. As part of their forward-thinking, Farm A was modelled using Ballance's latest tool MitAgator - a spatial critical source area model for predicting nitrogen, phosphorus, sediment and bacteria loss and management within agricultural land. MitAgator highlights target areas that can then be prioritised based on their impact, cost and effectiveness in reducing environmental concerns. Having identified key areas which would benefit in reducing their environmental footprint, Farm A has been able to plan its approach to reducing losses by using their cashflow strategically to get the greatest environmental benefit.

Farm A has spent a considerable amount of money on environmental protection in the last 5 years. This has been enabled by lifting farm performance to create an operating profit, which has allowed them to spend more on protecting the environment for future generations. Profit is driven by a highly efficient farm system: increased reproductive efficiency, faster lamb growth rates and higher carcass weights. The feed cropping underpins Farm A's ability to efficiently grow and finish lambs/cattle quickly, which in turn reduces the amount of stock on the farm during winter months when the risk of nutrient and sediment losses is higher. The efficient system contributes to the operating profit, which gives Farm A the ability to direct funds into fencing and planting critical source areas. This is in contrast to some farmers who may be in the development phase and don't have funds available for environment projects.

More than 2000 poplars and willows have been planted on Farm A to reduce soil erosion, which can allow sediment and phosphorus into waterways. Furthermore, 12.5ha was retired to afforestation and other areas to QEII covenants. The covenant is an agreement between the QEII National Trust and the landowner to protect land forever. The landowner continues to own and manage the protected land, and the covenant and protection stays on the land, even when the property is sold to a new owner. A sediment trap was built in a main catchment to mitigate sediment and nutrient run-off. Several wetlands have been retired for their protection and to reduce stock losses in dry years. Farm A continually monitors work already done to protect the environment while allocating additional funds for future work required to manage nutrient and sediment losses. In terms of environmental management, we estimate Farm A would be in the top 5% of sheep and beef farms.

6.2.2 Nitrogen (N) loss and Phosphorus (P) Loss

Farm A has OVERSEER-modelled N losses in 2019 of 11kg/N/ha/yr and P losses of 0.7kgP/ha/yr. These are low levels of N and P loss and lines up with typical losses for sheep & beef farms in the studies in tables 12 & 13.

6.2.3 Up-front capital costs

The up-front capital cost of $643,508 (Table 5) is mainly for fencing up to 5515m of streams greater than 1m wide, 19,537m of streams less than 1m wide but accessible to stock, plus water reticulation, wetland fencing and planting, and the consenting/compliance cost. For a business that has already spent an immense amount of time and money on creating a sustainable farming system of their own volition, and which is already well recognised for their environmental efforts, these costs are hard to accept and are something of an insult. Given the size of the business, the capital costs required to meet environmental compliance are untenable and the effectiveness of the prescribed works is highly dubious.

Table 5: Costs associated with complying with the Essential Freshwater Policy Package.

Farm A	
Up-front capital costs	$643,508
Ongoing annual costs	$79,514
Ongoing annual costs per effective ha	$128
% Increase in farm working costs per effective ha	21%

6.2.4 Increased economic costs

Ongoing annual compliance costs were calculated at $79,514 p.a. for Farm A. This represents a 21% increase in farm working expenses. These annual costs represent 25% of Farm A’s annual EBITRm which is unsustainable.

6.2.5 Loss of flexibility

Using MfE's low slope land stock exclusion mapping tool, Farm A would not be permitted to grow a winter crop without a resource consent under the proposed policy, as the farm falls into the non- low slope land category because the majority of the land is 10 degrees or greater. As the targeted crops are generally fed out in summer/autumn, some clarification would be necessary to see whether this was captured by the winter cropping regulation. Farm A would be unable to increase the area of crop grown under the land use change restrictions and grandparenting of nutrients. This could impede the business's ability to grow out their capital stock and performance/profitability could be impacted in the future.

The main permanent waterway that runs through the farm is just over 4km long. The fencing required to meet the MfE proposal not only requires fencing of both sides of the waterway but also disrupts the farm system, as paddock areas would need to be changed to reflect the change in paddock size, and water availability. This can have a flow-on effect as mob sizes are allocated to paddocks based on paddock size, shelter, and water. New fencing would take away much of the natural value of the paddock and would give less flexibility to the business and where they can put their stock.

6.2.6 Loss of Income ("Frozen Income")

Small farm management policy changes to Farm A to optimise the system and bring resilience in a changing climate will be stymied under the proposal which requires a reduction in all emissions regardless of current levels or environment effect. This is highly inequitable on a property such as Farm A which already has a low environmental footprint. This approach assumes negative effects unless proven otherwise (i.e. it is not effects-based), and it essentially locks-in land use options, limiting business growth and capital growth.

The annual lost income to Farm A from stock exclusion set-backs, as laid out in the MfE framework, can be found in table 6. Because of the numerous streams, drains, wetlands, and ditches stretching throughout Farm A and the requirements of a 5m set back, 37ha of current productive pasture would be lost and used as a buffer to capture nutrient losses. This represents a 5.9% loss of productive land.

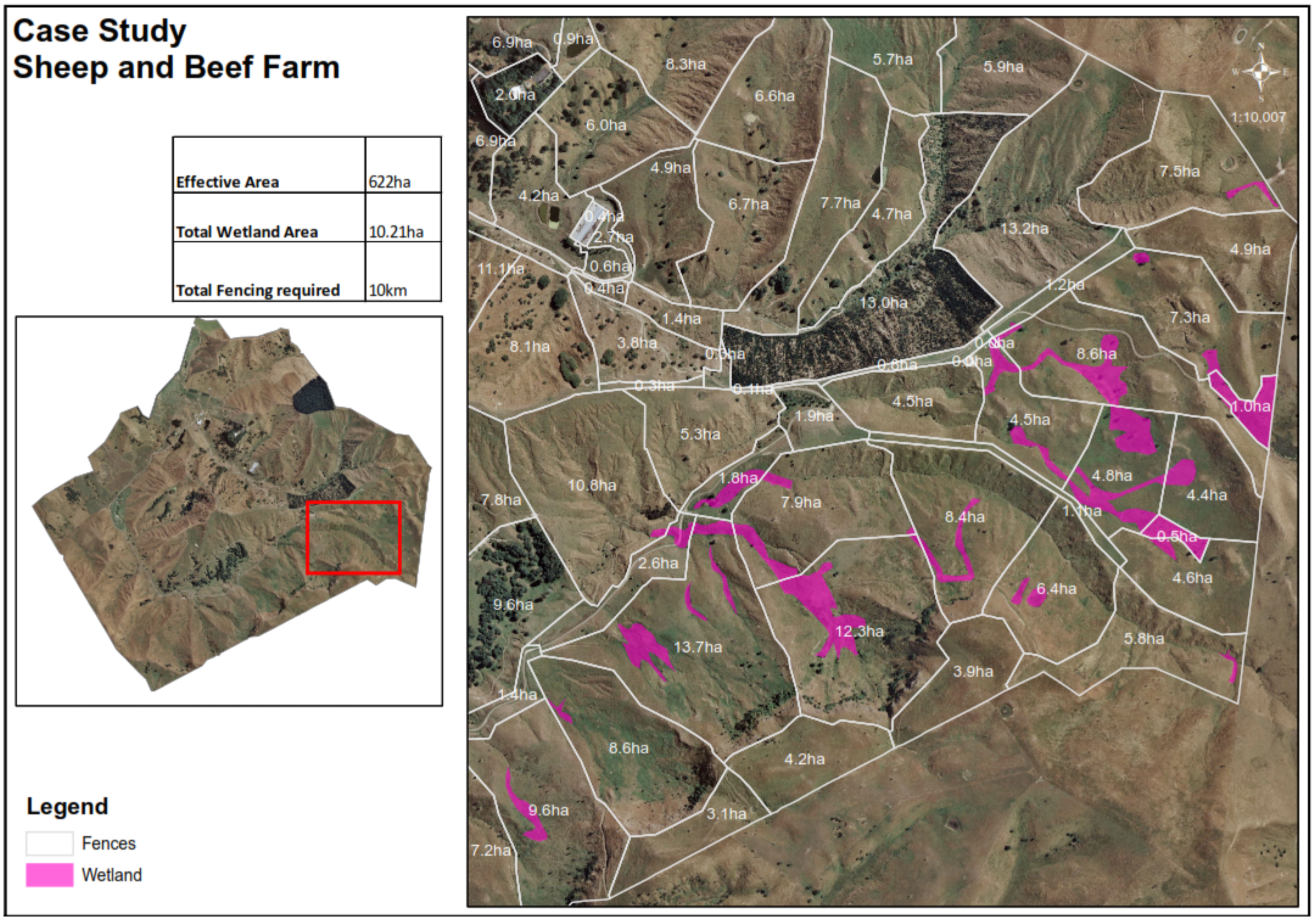
Table 6: Annual lost Income from stock exclusion set-backs

Annual lost Income from stock exclusion set-backs			
Land lost from production due to new set-back requirements	**Area ha loss**	**EBITRm/ha**	
5m set-back distance on waterways	22	$497	$10,934
Assumed half of the lost wetland area were grazable all year round	5	$497	$2,485
5m set-back distance around wetlands	10	$497	$4,970
	37		**$18,389**

6.2.7 Stock exclusion from Wetlands

Farm A has already retired three wetlands on the property and planted these areas. These wetlands were large and easier to retire due to the nature of the terrain and location. Due to the nature of the property with limestone soils there are more wetlands that would need stock excluded according to the wetland definition used. To the untrained eye, the additional wetlands identified in figure 12 by the wetland specialist look to be no more than wet 'seeps' on the hill side and natural springs which are common across many hill country properties in the Wairarapa. The author questions the biodiversity benefits or environmental outcomes that would be achieved from excluding stock from these areas based on his own personal experience of fencing areas like this where no natural regeneration has been evident. The practicalities and cost of fencing these minor wetlands across Farm A would mean a lot of land retired and funds diverted away from other biodiversity projects and environmental management such as erosion control. Once again, this one-sized fits all blanket approach is not effects-based and has dubious environmental value.

Figure 12: Wetlands on case study Farm A



7. CASE STUDY – FARM B

7.1 Introduction to Farm B

Farm System:	Hill country sheep & beef breeding/finishing. Summer dry winter wet.
Location:	Tararua
Altitude:	130m to 460m
Area:	970ha Total – 819ha effective.
Non effective:	22 ha in forestry, 41 ha in bush, 54 ha of regenerating scrub, 28 ha of unvegetated gorge slopes.
Contour:	Circa 18% of the property is flat to undulating, 36% is rolling to strongly rolling, 36% is moderately steep to steep hill country with the remaining 10% being steep to very steep hill country and gorges. Soils include banded mudstone and argillite and crushed argillite with some alluvial flats and colluvium on some of the lower slopes.
Rainfall:	1,000 to 1,250 mm annually
Soil Fertility:	Averages October 2017: pH 5.6, Olsen P 15, Sulphate Sulphur 7
Subdivision:	In 2015 there were 106 paddocks greater than 1 ha.
Water:	Stock water consists of reticulated water and troughs, or dams.
Stocking Rate:	6610 SU July 2019 = 8 SU/ha. Moved to more of a trade component and better per head performance with lower stocking so stocking rate not that relevant. 8144 SU (9.9SU/ha) in 2015.
Sheep System:	3700 MA & 2th Ewes, 700 Inlamb hoggets. Lambing 135% to 145%. Lambs killed prime to 17kg CCW season dependent.
Cattle System:	Changeable depending on margins. Now running circa 100 MA cows. Trading component of steers, heifers, and bulls sold store or prime depending on season and margins.
Cropping:	Extensive cropping program. Growing kale for tupping ewes on in March and also wintering in-lamb ewes. Growing rape, chicory and leafy turnip as lamb finishing feed. Growing greenfeed crops to winter cattle.

Current Environmental Management:

- Winners of a number of Farm Environment Awards

- Developed and implemented a Whole Farm Plan (WFP) as part of Horizons Regional Council's Sustainable Land Use Initiative (SLUI), that aims to identify farm-specific opportunities for sustainable resource management and sustained business development.
- Aim to plant at least 250 poplar or willow poles annually
- Retired many areas on the farm including riparian planting. Still riparian areas to be fenced off in line with the Whole Farm Plan (WFP).
- Lowered stock numbers to enhance stock performance
- Soils are tested annually for the main fertiliser application over the whole farm. The farm is divided into five main nutrient management blocks according to soil type, topography and production.
- Active Overseer nutrient budget file in place
- Nitrogen is used as a strategic tool on selected areas of the farm when required.
- Before any nitrogen is applied to crops, soil Available Nitrogen is tested to see how much (if any) nitrogen is needed before any applications occur. All efforts are made to mitigate the negative effects of nitrogen use.

7.2 Impacts of the "Action for Healthy Waterways" policy package on farm B.

7.2.1 Environmental Overview

Farm B is an award-winning farm for its environmental work to date. As part of Horizon's Sustainable Land Use Initiative (SLUI), Farm B has carried out Land Use Capability mapping and identified vulnerable and sensitive areas of the farm which need protecting. They also identified areas that had not reached their productive potential and it is these areas that drive the business and allow investment in environmental protection and enhancement on the other areas.

Farm B has spent an estimated $120,000 on environmental protection over the last four years but they have only been able to do this by lifting productivity. This has included growing 60ha of forage crops such as kale, which, along with genetics and ewe body condition scoring, Farm B credit for significantly lifting reproductive performance in their Romney ewes. The lift in reproductive performance has allowed the farm to drop ewe numbers and reduce the stocking rate.

These farm system changes are what the industry call "eco-efficiency gains" which result in increasing farm performance while reducing the environmental footprint of the business across soil health, greenhouse gas emissions, and freshwater health.

The SLUI plan is a work in progress each year, in consultation with Horizon's staff. Farm B allocates funds to environmental protection work on areas they consider a priority. Up-coming work includes fencing off a wet area to create a nutrient and sediment trap and more pole-planting.

7.2.2 Up-front capital costs

The up-front capital costs of $566,712 (Table 7) mainly for fencing and water reticulation is insurmountable for any landowners with a business of this scale. For a business that has already made significant environmental investments, won awards, made huge eco-efficiency gains, and has a small environmental footprint these costs are unjustifiable in relation to the environmental outcomes.

Table 7: Costs associated with complying with the Essential Freshwater Policy Package.

Farm B	
Up-front capital costs	$566,712
Ongoing annual costs	$72,468
Ongoing annual costs per effective ha	$88
% Increase in farm working costs per effective ha	14%

7.2.3 Increased economic costs

Ongoing annual compliance costs were calculated at $72,468 p.a. for farm B. This represents a 14% increase in farm working expenses. This level of increase in expenses is unsustainable especially as the policy does not allow flexibility to marginally intensify parts of the land to cover rising costs.

7.2.4 Loss of flexibility

Under MfE's proposed policy, the growing of feed crops on slopes of 10 degrees or greater – which is most of Farm B would be prohibited without a resource consent. Also, Farm B would be unable to increase the area of crop grown under the land use change restrictions and freshwater module of the farm plan. For Farm B this would impact on production and slow down investment in environmental work as it wouldn't be generating the income to enable it to invest in fencing, land retirement, erosion control or wetland development.

The FW-FP implies grandparenting a farm's current level of emissions, regardless of impact or whether there is any land use change. OVERSEER modelling (Tables 8 & 9) showed lifting Farm B's stocking rate from the 2018 OVERSEER level of 9.14/ha to the same as the B+LNZ farm class 4 Top 20% average of 9.43/ha lifted N leaching from 17,197kg total to 17,305kg total, although the stock unit lift is minor there is still a small increase in the nutrient output and under the proposed policy this would not be permissible.

Table 8: Modelled stock unit changes in OVERSEER

Base, Revised Stock Units (RSU) (OVERSEER)			Alternative scenarios modelled in OVERSEER						
		2017/18	Reducing stock numbers to the average for Farm Class 4* in 2017/18	Increasing stock numbers to the top^ 20% for Farm Class 4* in 2017/18	Increasing beef numbers to the top 20% for Farm Class 4* in 2017/18	Decreasing stock numbers to achieve a 10% decrease in N loss (aim 15477 kg N)	Decreasing stock numbers to achieve a 5% decrease in N loss (aim 16337 kg N)	Increasing winter kale by 20%
Farm Name	**Description**	**Stocking rate (RSU/ha)**	**Stocking rate (RSU/ha)**	**Stocking rate (RSU/ha)**	**Stocking rate (RSU/ha)**	**Stocking rate (RSU/ha)**	**Stocking rate (RSU/ha)**	**Stocking rate (RSU/ha)**
Farm B	Revised stock units per effective hectare (cattle/sheep)	9.14 (1.29/7.85)	8.89 (1.25/7.64)	9.43 (1.29/8.14)	9.43 (1.58/7.85)	5.79 (1.05/4.75)	7.09 (1.17/5.93)	9.17 (1.30/7.88)

*B+LNZ Farm Survey East Coast NI, Farm Class 4

^The top 20% of the B+LNZ sample ranked by EBITRm/ha

Table 9: Modelled Nitrogen (N) leaching kg/ha/yr changes on case study farm B

			Alternative scenarios modelled in OVERSEER					
		2017/18	Reducing stock numbers to the average for Farm Class 4* in 2017/18	Increasing stock numbers to the top^ 20% for Farm Class 4* in 2017/18	Increasing beef numbers to the top 20% for Farm Class 4* in 2017/18	Decreasing stock numbers to achieve a 10% decrease in N loss (aim 15477 kg N)	Decreasing stock numbers to achieve a 5% decrease in N loss (aim 16337 kg N)	Increasing winter kale by 20%
Farm Name	**Description**	**N leaching kg/ha (kg total)**	**N leaching kg/ha (kg total)**	**N leaching kg/ha (kg total)**	**N leaching kg/ha (kg total)**	**N leaching kg/ha (kg total)**	**N leaching kg/ha (kg total)**	**N leaching kg/ha (kg total)**
Farm B	925 ha sheep and beef Class 4 farm	18 (17197)	18 (17099)	18 (17305)	18 (17358)	16 (15546)	17 (16332)	18 (17239)

*B+LNZ Farm Survey East Coast NI, Farm Class 4

^The top 20% of the B+LNZ sample ranked by EBITRm/ha

Note: N loss reported using Overseer v 6.3.2. The data above should not be used for consenting or compliance purposes. Overseer files were completed by a certified nutrient management advisor using best management input standards.

7.2.5 Loss of Income ("Frozen Income")

The freshwater module description in the draft NES is very prescriptive and includes needing to have a nutrient budget and demonstrating how a landowner will "reduce" all emissions of nitrogen, phosphorus, sediment and microbial pathogens. Modelling was undertaken on Farm B to reduce N leaching from the 2018 baseline by 5% and 10%. To do this stock numbers had to be reduced in OVERSEER (see Tables 8 & 9).

For a 5% reduction in N losses, stock units/ha had to reduce by 2.05 SU/ha. This would represent an annual lost income of $116/ha EBITRm based on B+LNZ class 4 average figures in 2018. Over Farm B's 819 effective ha this represents $95,000 EBITRm in lost income. At a 10% reduction in N losses, stock units had to reduce 3.35 SU/ha. Over the 819 ha this represented $155,153 EBITRm in lost income.

Table 10 shows the annual lost income from stock exclusion set-backs through loss of productive land on Farm B where a total of 26ha will be lost. Combining a 5% reduction in N losses and the lost production land to set-back requirements generates an annual loss of income of $107,318 EBITRm.

Table 10: Annual lost Income from stock exclusion set-backs

Land lost from production due to new set-back requirements.	**ha Loss**	**EBITRm/ha**	
5m set-back distance on waterways	22	$481	$10,582
Assumed half of the lost wetland area grazable all year round	1.7	$481	$813
5m set-back distance around wetlands	1.9	$481	$924
	26		**$12,318**

8. CASE STUDY – FARM C

8.1 Introduction to Farm C

Farm System:	Mixed cropping, bull and lamb finishing	
Location:	Central Hawke's Bay	
Altitude:	70m to 100m	
Area:	665 Total - 655ha effective	
Rainfall:	750 mm average pa.	
Soil Fertility:	pH	5.8 – 6.5 variable
	Olsen P	20 – 50 Peat high
	Potash	4 – 20 variable, peat generally low
	Sulphate Sulphur	5 – 20 variable
Irrigation:	275ha under precision irrigation system. Water is provided from water storage dams and bores. Planning on another storage dam this summer and have consent to take total irrigated area to 450ha.	
Drainage	Sub-surface tile drains. 400ha approx.	
Cash Crops:	Cropping 450-500ha pa. Barley (malting/feed), wheat, maize, oats, squash, sweet corn, processed peas and beans. Small seed crops (ryegrass, chicory, carrots, bunching onions, radish, choi-sum), hemp.	
Forage Crops:	15 – 40ha under irrigation after a cash crop. Planted mid-January grazing 60 days later at about 3500kgDM/ha.	
Water:	Water for stock is provided via water troughs through a reticulated water system.	
Stocking Rate:	This changes year to year depending on cropping rotations and trade stock numbers.	
Sheep System:	Trading circa 5000 male lambs. Target slaughter weights of 22kg CW July to October.	
Cattle System:	Trading circa 300 Bulls. R1yr and R2yr bulls 50:50 Autumn/Winter. Target slaughter above 300kgCW whether it be June or October.	

Current Environmental Management:

- Active Foundation for Arable Research (FAR) Farm Environmental Plan in place
- Detailed land use capability mapping

- 95% of open drains on property are fenced off. Approx 15km of fencing.
- Main creek has a 5-10m buffer fenced off along it.
- Uses precision agriculture technology (differential application) to ensure optimal use of nutrients and water, preserve soil structure and minimise the impact on the environment.
- Minimal tillage to preserve soil carbon, nitrogen and soil structure.
- Tractors and harvester are under real-time kinematic (RTK) positioning and GPS guidance (which is accurate to 2cm).
- Yield monitoring producing yield maps.
- 150ha mapped for soil conductivity (water holding capacity).
- Using variable rate precision irrigation
- Moisture probes used for irrigation scheduling. Monitoring soil moisture levels so that informed decisions for turning on irrigation can be made.
- Soil grid sampling 1 ha blocks.
- Variable rate drilling and spreading fertiliser from prescription maps. This helps match the timing and the amount of fertiliser inputs, to meet the crops requirements and minimise the risk of contaminate losses to the environment.
- Variable rate application of lime using prescription maps
- Controlled traffic farming (CTF), every tractor, harvester and machinery use the same wheel tram lines, which limits compaction.
- Active Overseer nutrient budget in place.
- Nitrogen is used as a strategic tool on selected areas of the farm when required.
- Before any nitrogen is applied to crops, soil Available Nitrogen is tested to see how much (if any) nitrogen is needed.
- Detailed nitrogen budgets are used based on crop requirements, predicted yields, and soil and weather conditions.

8.2 Impacts of the "Action for Healthy Waterways" policy package on farm C.

8.2.1 Overview

Farm C is situated in Hawke's Bay and falls under the Hawke's Bay Regional Council's Plan Change 6 (PC6) Tukituki Catchment which became operative on the 1 October 2015 following a Board of Inquiry and High Court statutory processes.

The Tukituki Catchment plan[8] establishes Freshwater Objectives which are implemented through numerical water quality limits and targets set out in Tables 5.9.1A and 5.9.1B[8]. These include zone-specific environmental bottom lines for Dissolved Inorganic Nitrogen (DIN) of 0.8mg/L. It is important to note that the proposed environmental bottom line for DIN in the Essential Freshwater Package changes to the NPSFWM is 1mg/L.

The Tukituki plan then establishes management frameworks for primary productive land uses through various rules which require among other conditions farms to have a Farm Environment Management Plan (FEMP) and to be operating in accordance with nitrogen leaching allocation/ authorisations based on the natural capital of their land, as provided by Land Use Capability framework in Table 5.9.1D[8]

Farm C has calculated its nitrogen leaching allowance (Table 11) which under PC6 provides flexibility up to 22.6kgN/ha/yr for the whole farm, given the farm's individual makeup of Land Use Capability classes. The approach provided in PC6 enables Farm C to optimise their land use and farming systems within the natural capital of their land and within environmental limits.

Table 11: Farm C, calculated nitrogen leaching allowance under PC6 based on LUC allocation rules. Note this was when the farm was 621 effective hectares.

LUC	Limit (Kg N/ha/yr)	Blk 1	Blk 2	Blk 3	Blk 4	Blk 5	Blk 6	Blk 7	Blk 8	Blk 9	Blk 10	Blk 11	Blk 12	Blk 13	Blk 14	Blk 15	Blk 16	Blk 17	Blk 18	Total area (ha	Total leaching
1	30.1					24.02	3.72	1												28.74	865.074
2	27.1																			0	0
3	24.8	12.58	39.39	30.05	17.6	5.94	12.88	1.66	17.39	23.09	30.63	0.37	33.46			2.75	1.46			229.25	5685.4
4	20.7				39.71		0.01	5.01	2.34	20.37	27.04		25.65	55.25	83.17	59.75	2.84	24.39	4.76	350.29	7251.003
5	20														0.45			0.17		0.62	12.4
6	17				11.57													0.64		12.21	207.57
7	11.6																			0	0
8	3																			0	0
Total		12.58	39.39	30.05	68.88	29.96	16.61	7.67	19.73	43.46	57.67	0.37	59.11	55.25	83.62	62.5	4.3	25.2	4.76	621.11	14021.447
																			Total Leaching / Total area =	22.57	kg/N/ha/yr

[8] October 2015. Hawke's Bay Regional Resource Management Plan, Plan Change 6 – Tukituki River Catchment

8.2.2 Environmental overview

Farm C's extensive use of technology and 'soils first' approach has led to an extremely efficient and highly productive mixed cropping and livestock system which is operating within current environmental limits. The farm has a detailed FAR Land Environmental Plan and has already fenced 95% of waterways on the property with approximately 15km of fencing. The business uses extensive technology to help protect the environment (see more details under farm summary) including precision agriculture technology (differential application) to ensure optimal use of nutrients and water, preserve soil structure and minimise the impact on the environment. Minimal tillage is used to preserve soil carbon, nitrogen and soil structure. Moisture probes are used for irrigation scheduling along with variable rate irrigation. For this class of country, the farm system has a very low environmental footprint and based on our assessment would be in the top 5% of farmers in terms of farm performance.

8.2.3 Nitrogen (N) loss

Nitrate leaching is the main pathway of nitrogen loss in soils. One of the major sources of nitrate leaching is from urine patches from animals. Typically, the higher the stocking rate the more urine patches per unit area and the more N leaching. Intensive farming on vulnerable soils (coarse-textured, free draining) results in an increased amount of N making its way to our waterways[9]. High rainfall and irrigation on these free draining soils further amplifies the risk of N leaching.

Farm C has calculated its nitrogen leaching allowance (Table 11), which under PC6 provides flexibility up to 22.6 kgN/ha/yr for the whole farm, given the farm's individual makeup of Land Use Capability classes. The approach provided in PC6 enables Farm C to optimise their land use and farming systems within the natural capital of their land and within environmental limits. Based on information provided by Farm C, the whole farm average N loss from the root zone in 2018 was 17 kgN/ha/yr, well within the allowance under PC6 see table 11. Comparing this with other data sets available to BakerAg on similar country, this would be considered average to low N loss especially on irrigated country and the property is still well within its environmental limits. A BakerAg data set of similar finishing farms (but with less cropping) was reviewed, and the average N loss was 19.9 kgN/ha/yr with a range of 13 to 31 kg.

To compare and contrast with other industries, more intensive systems such as dairying have N loss in the 30-50 kgN/ha/yr range depending on location, soil type and farm system (see Tables 12 & 13). There are dairy farms that sit higher than this range as evidenced in Appendix 2 where two advertised dairy farms had N losses of 72 and 85 kgN/ha/yr.

[9] Ms. Dewes, Evidence in Chief. Before the Board of Inquiry Tukituki Catchment Proposal. In the matter of the Resource Management Act. 1991. October 2013.Paragraph 21, page 6.

Nitrogen losses from sheep and beef and mixed cropping farm systems are typically much lower than other pastoral land uses. When we compare the modelled N losses from this business in 2018 of 17kg/N/ha/yr with the Dairy farm studies in Tables 12 & 13 and Appendix 2, Farm C has a very small environmental footprint in terms of N losses.

Table 12: Industry nutrient losses

Industry	N leaching (kg/ha)	P loss risk (kg/ha)	Gross margin, 2012 ($/ha)
Dairy	29-49	0.8-2.1	$3,000-$4,500
Sheep and beef	8-18	0.1-0.5	$50-$800
Forestry	2	0.1	$250

Source: AgResearch - (Kaye-Blake et al 2013**)**

Note: The gross margin figures are for 2012 data on prices, costs and productivity

Table 13: Nutrient losses across different land use

Study	Land use	Region	Average N leaching (kgN/ha/yr)	Range (kgN /ha/yr)	Average P loss risk (kgP/ha/yr)	Range (kgP/ha/yr)
1	Dairy	Southland	30	22-49	0.8	0.8-1.3
1	Wintering/Support	Southland	55	39-114	1.2	0.7-2.0
1	Sheep/Beef/Deer Intensive	Southland	12	8-23	0.6	Not available
1	Sheep/Beef/Deer Extensive	Southland	6	4-8	0.3	Not available
2	Dairy 1997/98	Waikato	32	26-39	0.8	0.7-0.9
2	Dairy 2007/08	Waikato	38	33-47	0.8	0.7-0.9
2	Sheep & Beef	Waikato	13	10-16	1.6	0.5-2.1

[1] 2014. George Ledgard, An Inventory of Nitrogen and Phosphorus Losses from Rural Landuses in the Southland Region

[2] 2009. Environment Waikato. Nutrient Budgets for Waikato Dairy and Sheep, Beef and Deer Farms

8.2.4 Phosphorus (P) loss

Average phosphorus (P) loss from Farm C in 2018 was 0.3 kg P/ha/yr. Comparing this with other data sets available on similar country this would be considered low P loss. A BakerAg data set of similar finishing farms was reviewed, and the average P loss was 0.9 kgP/ha/yr with a range of 0.3 to 1.9 kg. When Farm C is compared to dairy farms in Tables 12 & 13, a loss of 0.3 kg P/ha/yr is low.

8.2.5 Proposed 120 ha new irrigation

Currently farm C has 275 ha under centre pivot irrigation from water storage dams and bores. Storage dams capture 'flood flow water' from surrounding hill country. Storage dams provide approximately 120,000 cubic metres of water or circa 150mm/ha/yr. The regional council has issued another consent to take and use water at high flow from a stream to fill 'off stream' water storage reservoirs for subsequent irrigation areas planned. This consent would take the total irrigated area to 450ha. The consent expires on 31 May 2034.

Farm C is currently preparing the farm to develop another 120ha of irrigation under a centre pivot. The Essential Freshwater Proposals prevents land use optimisation within the natural capital of the land through a number of key mechanisms:

1. Restrictions on land use change where emissions from the farm would increase from historic levels
2. FM-FP requires all emissions, irrespective of starting point or environmental impact on aquatic ecosystem health, to reduce over time.

Restrictions on irrigation development are proposed to apply from June 2020. A resource consent would be needed to irrigate more than 10 ha of unirrigated land, and this would only be granted if there is evidence that emissions (nitrogen, phosphorus, sediment, pathogens) from the new land use would not exceed the average discharges of contaminants from the old land use (farm) during the farm year 2017/18.

8.2.6 OVERSEER modelling new irrigation project

Farm C was modelled through OVERSEER for the 2017/18 year to determine the farm's nutrient losses. Table 14 shows N leaching in 2018 was 17 kgN/ha/yr. Irrigating a further 120 ha increased the N leaching by 5kgN/ha/yr to 22 kgN/ha/yr. Significantly, this is still within the allocation under the PC6. Phosphorus (P) loss also increased from 0.3 kgP/ha/yr to 0.4 kgP/ha/yr. Based on the scenario modelled, Farm C would not be able to implement the proposed 120 ha irrigation project because it would not get consent as the nutrient losses have increased from the baseline year of 2017/18.

For comparison a dairy farm system was modelled on the property. Based on the assumptions in the model, the dairy farm had higher N loses of 32kgN/ha/yr. P losses were also significantly higher at 1.1kgP/ha/yr vs 0.4 kgP/ha/yr. These losses are in line with other dairy data sets seen in Tables 12 & 13.

Mixed cropping farmers have long been suspicious of models such as OVERSEER and question whether the results truly represent losses from their farms and these concerns were raised by Farm C. To date, there has been little measurement of N losses from the root zone of cropping rotations and the industry is short of robust scientific data to calibrate the cropping components of the OVERSEER model. The "Rootzone Reality Project" is funded by the Ministry for Primary Industries' Sustainable Farming Fund and led by FAR. It aims to scientifically prove what is happening under cropping systems such as Farm C and ensure accurate reporting of nutrient losses from them.

Farm C's concerns over the OVERSEER model were backed up by the Senior Environment Data Analyst from B+LNZ who found the OVERSEER model did not accommodate for different aspects of the complex cropping system.

Table 14: Nitrogen (N) leaching kgN/ha/yr on case study farm C and alternative scenarios modelled in OVERSEER

Baseline 2018			Alternative scenarios modelled in OVERSEER			
		2018	Irrigating a further 120 ha from 2018. Increasing cropping area and yields and lambs finished. Decreasing bulls finished	Increased winter Kale by 20ha for the Bulls, buying bulls a month earlier	Increased Summer Rape by 20ha and buying and finishing lambs a month earlier	Dairy farm, 2.9 cows/ha, 505 ha irrigation, cows wintered on kale, young stock grazed off.
Farm Name	**Description**	**N leaching (kg/ha)**	**N leaching (kg/ha)**	**N leaching (kg/ha)**	**N leaching (kg/ha)**	**N leaching (kg/ha)**
Farm C	655ha Mixed cropping and livestock finishing.	17	**22**	**18**	**17**	**32**

Key: Red represents an increase in the farm's N leaching from 2018 based on modelled scenarios . A resource consent would be needed to irrigate an additional 10 ha of unirrigated land, and this would only be granted if there is evidence it would not increase nitrogen, phosphorus, sediment or microbial pathogen discharges above the property's baseline.

Note: N loss reported using Overseer v 6.3.2. The data above should not be used for consenting or compliance purposes. Overseer files were completed by a certified nutrient management adviser using best management input standards.

Table 15 : Average Phosphorus (P) loss kgP/ha/yr on case study farm C and alternative scenarios modelled in OVERSEER.

Baseline 2018			Alternative scenarios modelled in OVERSEER			
		2018	Irrigating a further 120 ha. Increasing cropping area and yields and lambs finished. Decreasing bulls finished	Increased winter Kale by 20ha for the Bulls buying bulls a month earlier	Increased Summer Rape by 20ha and buying and finishing lambs a month earlier	Dairy farm, 2.9 cows/ha, 505 ha irrigation, cows wintered on kale, young stock grazed off.
Farm Name	**Description**	**P loss (kg/ha)**	**P loss (kg/ha)**	**P loss (kg/ha)**	**P loss (kg/ha)**	**P loss (kg/ha)**
Farm C	655ha Mixed cropping and livestock finishing.	0.3	**0.4**	**0.3**	**0.3**	**1.1**

Key: Red represents an increase in the farm's P loss from 2018 based on modelled scenarios. A resource consent would be needed to irrigate an additional 10 ha of unirrigated land, and this would only be granted if there is evidence it would not increase nitrogen, phosphorus, sediment or microbial pathogen discharges above the property's baseline.

Note: P loss reported using Overseer v 6.3.2. The data above should not be used for consenting or compliance purposes. Overseer files were completed by a certified nutrient management adviser using best management input standards.

8.2.7 Loss of income ("Frozen income")

The Essential Freshwater proposals effectively grandparent extensive or environmentally responsible farms like Farm C to current or historic farming systems, removing their ability to innovate, adapt, or optimise their land uses and farming systems to meet a range of pressures including changing markets, changes in climate, personal aspirations, and individual life circumstances.

The risk of multiple crop failures in the Hawkes Bay climate is a real concern with climate change. Irrigation brings resilience in a changing climate with reliable yields. The income earning potential of the proposed 120 ha of dryland on Farm C has effectively been 'frozen'. Table 16 shows the gross margin of a dryland area versus the same land irrigated. The gross margin per ha difference is $979, over 120 ha this is an annual opportunity cost of not having irrigation of $117,520. This analysis is conservative and doesn't take into account options that open up to grow high value specialist crops that can return up to $10,000/ha. Contracts to grow these crops can only be secured with irrigation and if the farmer can achieve consistent quality crop yields. Another element not factored into this gross margin is the improved livestock finishing system with better margins as a result of a more controlled system.

Table 16: Dryland gross margin vs irrigated

	$/ha
Annual cropping gross margin - irrigated	$1,871
Annual cropping gross margin - dry land	$892
Difference	$979
Annual opportunity cost on 120 ha	**$117,520**

Source: Farm C Gross Margin information. Rotation of Wheat, Peas and Moata grass seed. Crop gross margins do not include livestock trading revenue.
Irrigated gross margins include irrigation running costs and interest on the capital investment

8.2.8 Summary of compliance costs

Table 17: Costs associated with complying with the Essential Freshwater Policy Package

Farm C	
Up-front capital costs	$185,350
Ongoing annual costs	$35,337
Ongoing annual costs per effective ha	$54
% Increase in farm working costs per effective ha	8%

8.2.9 Up-front capital costs

Full detail on the capital costs can be seen in Appendix 5. The main cost is fencing to meet the stock exclusion rules and particularly the 5m set-back requirements. Farm C has already fenced 95% of the waterways (approx. 15km) on the property, however on average the set backs are not 5m. Photos in figure 3 (above) show existing waterways fenced but the set-back is not 5m. Spending $157,000 on more fencing on this property in the author's opinion would be of dubious value and not likely provide any additional environmental benefits. It must be noted that no costs were included to remove the existing fences when changing set-backs. On flat cropping land where the risk of overland flow is minimal the proposed 5m buffer seems excessive and there needs to be clear science showing better environmental outcomes from having this level of set-back distance. There is considerable loss of annual income by taking out this productive land (see Table 18).

Table 18: Annual lost Income from stock exclusion set-backs

Land lost from production due to new set back requirements.	**ha Loss**	**EBITRm/ha**	
5m set-back distance waterways	11	$1,625	**$17,415**

8.2.10 Increased economic costs

Ongoing annual compliance costs were calculated at $35,337 p.a. for Farm C. This represents an 8% increase in farm working expenses for a farm that already has a low environmental footprint. Farm C will not have the opportunity to marginally intensify to cover these additional costs.

8.2.11 Proposed irrigation development – 'Stranded assets'

The total cost of the 120ha irrigation project is estimated at $750,000. Farm C has already undertaken significant investment (see Table 19) in developing the 120ha irrigation area including construction of storage dams. The total costs to date have been $287,200. Under the proposal the irrigation development will become obsolete with $287,200 of 'stranded assets'.

Table 19. Irrigation development expenditure for 120ha

Expenditure to date	**$ GST excl**
Valves, pumps, pipes, welding	$262,200
Consulting fees	$10,000
Engineering fees	$15,000
	$287,200
Budgeted expenditure to complete project	
Dam engineering & detailed design for consent	$90,000
Dam construction (est. $100 to $150K)	$125,000
Main line pipe	$28,000
Electricity	$5,000
Pivot Irrigator for 120ha	$215,000
	$463,000
Total estimated investment cost	**$750,200**

9. CASE STUDY – FARM 'D'

9.1 Introduction to Farm 'D'

Farm System:	Hill country sheep & beef - breeding and finishing
Location:	Central Waikato
Altitude:	20m to 250m
Area:	1000ha total – 900ha effective
Contour:	150ha flat to rolling, 350ha rolling hills, 500 ha medium to steep hills.
Av Rainfall:	860mm pa.
Fertility 2016	Hill averages: pH 5.6, Olsen P 7, Sulphate Sulphur 6 Decommissioned dairy farm averages: pH 5.9, Olsen P 37, Sulphate Sulphur 5.
Water:	There is approximately 400ha of reticulated country fed from two separate bores. A number of stock water dams are also on the property. Most hill country stock water is from springs or dams.
Stocking Rate:	4.2 SU/ha at 1 July 2017 and 4.8 SU/ha 30 June 2018
Sheep System:	Small Coopworth breeding flock with 280 MA & 2th Ewes. All lambs killed prime.
Cattle System:	For ease of management farming a high cattle ratio of 90% cattle 10% sheep. Approximately 150 - 200 breeding cows. The cows calve in September with the calves weaned in April at around 200kgLW. Surplus heifers and own-bred steers are fattened, plus additional beef steers and Friesian bulls are bought in at 350-400kgLW and finished to heavy weights of around 700kgLW (350-360kg CW).
Cropping:	Minimal cropping with typically 8 ha white clover and plantain followed by permanent pasture.

Current Environmental Management:

- Some ponds are fenced to exclude stock
- Some drains are fenced
- The decommissioned dairy farm was fenced under the dairying and clean streams accord

- Willow stakes have been planted in drains and gullies

9.2 Impacts of the "Action for Healthy Waterways" policy package on farm D

9.2.1 Environmental overview

Due to a number of different circumstances, Farm D has not optimised the farm system. The hill country currently has low soil fertility and therefore a low stocking rate. Farm D has OVERSEER modelled N losses in 2016 of 7kgN/ha/yr and P losses of 1.9kgP/ha/yr. The stocking rate and farm policy is very similar in 2019.

In terms of Farm D's environmental footprint, it would be described as minimal compared with other more intensive land uses in the Waikato. The low stocking rate has driven a lower than average operating profit therefore the ability of the farm to sustain a high level of environmental expenditure has been limited. To date there has been expenditure on stock exclusion from waterways on the decommissioned dairy farm.

9.2.2 Up-front capital costs

The up-front capital costs of $680,485 (Table 20) mainly for fencing and water reticulation is insurmountable for a farm business of this scale. It's important to note that the waterways and measured lengths were mapped as part of another report[7] looking at the impacts of the proposed Waikato Plan Change 1. In this report the waterways on Farm D were only mapped up to 25˚ degrees in slope. Under this new proposed policy more streams would be captured in the hill country and the capital fencing costs would increase. Due to time constraints the Wetlands on Farm D were not identified and stock exclusion from these was not costed as part of these calculations.

Table 20: Costs associated with complying with the Essential Freshwater Policy Package.

Farm D	
Up-front capital costs	$680,485
Ongoing annual costs	$80,304
Ongoing annual costs per effective ha	$89
% Increase in farm working costs per effective ha	29%

9.2.3 Increased economic costs

Ongoing annual compliance costs were calculated at $80,304 p.a. for Farm D. This represents a 29% increase in farm working expenses. This level of increase in expenses is unsustainable, especially as the policy does not allow flexibility to marginally intensify parts of the land to cover rising costs.

9.2.4 Loss of flexibility

Grazing animals on winter forage crops in the hill country on Farm D will require a resource consent, irrespective of how it is managed or its proximity to a waterbody. The total area under forage crop must not exceed the highest annual amount of area in annual forage crop in any farm year between 2013/14 and 2018/19. This will impact Farm D as there has been very little use of these crops to date. Farm D will not have the chance to make eco-efficiency gains such as Farm B by using crops strategically on the property. The ability of Farm D to optimise the farm system and create resilience in a changing climate will be taken away.

9.2.5 Loss of income ("Frozen income")

The Essential Freshwater proposals effectively grandparent extensive farms like Farm D to current or historic farming systems, removing their ability to innovate, adapt, or optimise their land uses and farming systems to meet a range of pressures including changing markets, changes in climate, personal aspirations, and individual life circumstances.

Using OVERSEER the FW-FP implies grandparenting a farm's current level of emissions, regardless of impact or whether there is any land use change. Focussing on N, in the OVERSEER software, stocking rate is one of the key drivers of N leaching, so by grandparenting a farm's level of N leaching, in a rough sense, stocking rate is being capped. For farms that have been developed and are running at near optimum levels this may be seen as an appropriate course of action but it places unfair restrictions on farms that are not currently well developed.

An example of this is farm D. Soil fertility is well below optimum levels. Due to this, and the current maturity of the business, it is not being farmed to optimal levels. This is highlighted in Table 21 below that shows farm D was only carrying 4.6 SU/ha in 2015 compared to the B+LNZ class average of 9.3 SU/ha and the B+LNZ top 20% of 10.2 SU/ha. In June 2018 the farm was carrying 4.8 SU/ha.

This low stocking rate is driving a low N loss figure of 7kgN/ha/yr. Compare this to similar land classes that are optimised where the N loss would be in the 15-20kg/ha/yr range. The impact of the Essential Freshwater proposals is that farm D, which to this point has had very little N impact, would lose the opportunity to invest in improving soil fertility and improving the profitability of the business in the future.

Table 21: Farm D's stocking rate (SU/Ha) compared to the B+LNZ Class 4 Average.

	Farm D	B+LNZ 2015 Class 4	B+LNZ 2015 Class 4
	2015	**2015 Mean**	**2015 Top 20%**
Effective Ha	900	334	341
Total SU	4150	3116	3488
SU/Ha	4.6	9.3	10.2

If property D were to lift performance to the average for the B+LNZ Class 4 and run a similar policy the increased annual income potential would be $184,195, or $205/ha. OVERSEER modelling was undertaken to see what impact this would have on Farm D's level of nutrient losses particularly N loss. Table 22 shows N loss lifted to 8 kgN/ha/yr therefore under the proposed policy the farm would not be able to do this and capture the additional income.

Table 22: N loss results on Farm D and scenario modelling in OVERSEER

	Baseline			Alternative scenarios modelled in OVERSEER	
	2014-15	2015-16	Baseline	Stocking Rate & Cattle Ratio to B+LNZ Class 4 Mean	Stocking Rate & Cattle Ratio to B+LNZ Class 4 Top 20%
Farm Name	N leaching (kg/ha/yr)	N leaching (kg/ha/yr)	N leaching (kg/ha/yr)	N leaching (kg/ha/yr)	N leaching (kg/ha/yr)
Farm D	7	7	7	8	10

Key: Red represents an increase in the farms N loss from the baseline, based on modelled scenarios.
Note: N loss reported using Overseer v 6.2.3. The data as stated above should not be used for consenting or compliance purposes.

The annual lost income to Farm D from stock exclusion set-backs, can be found in Table 23. Because of the numerous streams, drains, wetlands, and ditches stretching throughout Farm D and the requirements of a 5m set back, 24ha of current productive pasture would be lost and used as a buffer to capture nutrient losses.

Table 23: Annual lost Income from stock exclusion set-backs

Annual lost Income from stock exclusion set-backs			
Land lost from production due to new set-back requirements	ha Loss	EBITRm/ha	
5m set-back distance on waterways	24	$267	**$6,408**

9.2.6 Impact on land value

Purchasers would assess the large up-front capital costs ($680,485) to comply with the proposals and factor this into what they are prepared to pay for the property.

The current very low nutrient losses particularly N of 7kgN/ha/yr 'grandparents' the future potential of the property and will have a big impact on the property's future value. Effectively the stocking rate is capped at a low level leaving few options for prospective purchasers.

Analysis was undertaken in the BakerAg "Implications of the proposed Waikato Regional Plan Change 1" report[7] to see what impact grandparenting of N would have on Farm D's land value.

Results found this could potentially drop the value of this property by $4,400/ha or $3,960,000, or a 44% drop in land value. A land value devaluation of this magnitude would have serious ramifications on the balance sheet position of farm D. This would impact the bankability of this business and ongoing viability.

10. IMPLICATIONS FOR THE SHEEP & BEEF SECTOR

The broad stock exclusion rules particularly on hill country will severely impact the on-going viability of the sector.

Requiring a reduction in all emissions regardless of current levels or environment effect is inequitable and will put further pressure on the viability of some land uses. This is inefficient and is likely to be ineffective at addressing specific freshwater issues relative to the farm and its contribution to those issues. For example, for an extensive farming operation in a catchment where sediment is an issue, it would be more effective and efficient to focus action on erosion control and mitigation rather than diluting efforts across all four potential contaminants e.g. phosphorus, nitrogen, and pathogens.

Under grandparenting rules, farms with higher nutrient losses stand to sustain a higher level of productivity, have more flexibility, and will be valued more highly. Farms with a low level of loss and potentially better environmental footprint are effectively capped with a ceiling on stock numbers, production, land value and future income-earning potential. There is no recognition for the differential in nutrient losses between drystock and mixed cropping farms and other more intensive sectors. Grandparenting favours businesses that already have a high environmental impact. This runs counter to a "polluter pays" principle, because those farms with the lowest environmental footprint are bearing a much larger burden. This blunt, one-size-fits-all mechanism reinforces existing inefficiencies and rewards high-intensity farms.

In the OVERSEER software, stocking rate is one of the key drivers of nitrogen leaching, so capping a farm's level of nitrogen leaching indirectly limits its stocking rate. This may be an appropriate course of action for sheep and beef farms that have been optimised, but it places unfair restrictions on farms that are not currently optimised or, are underdeveloped in relation to the natural capital of their land.

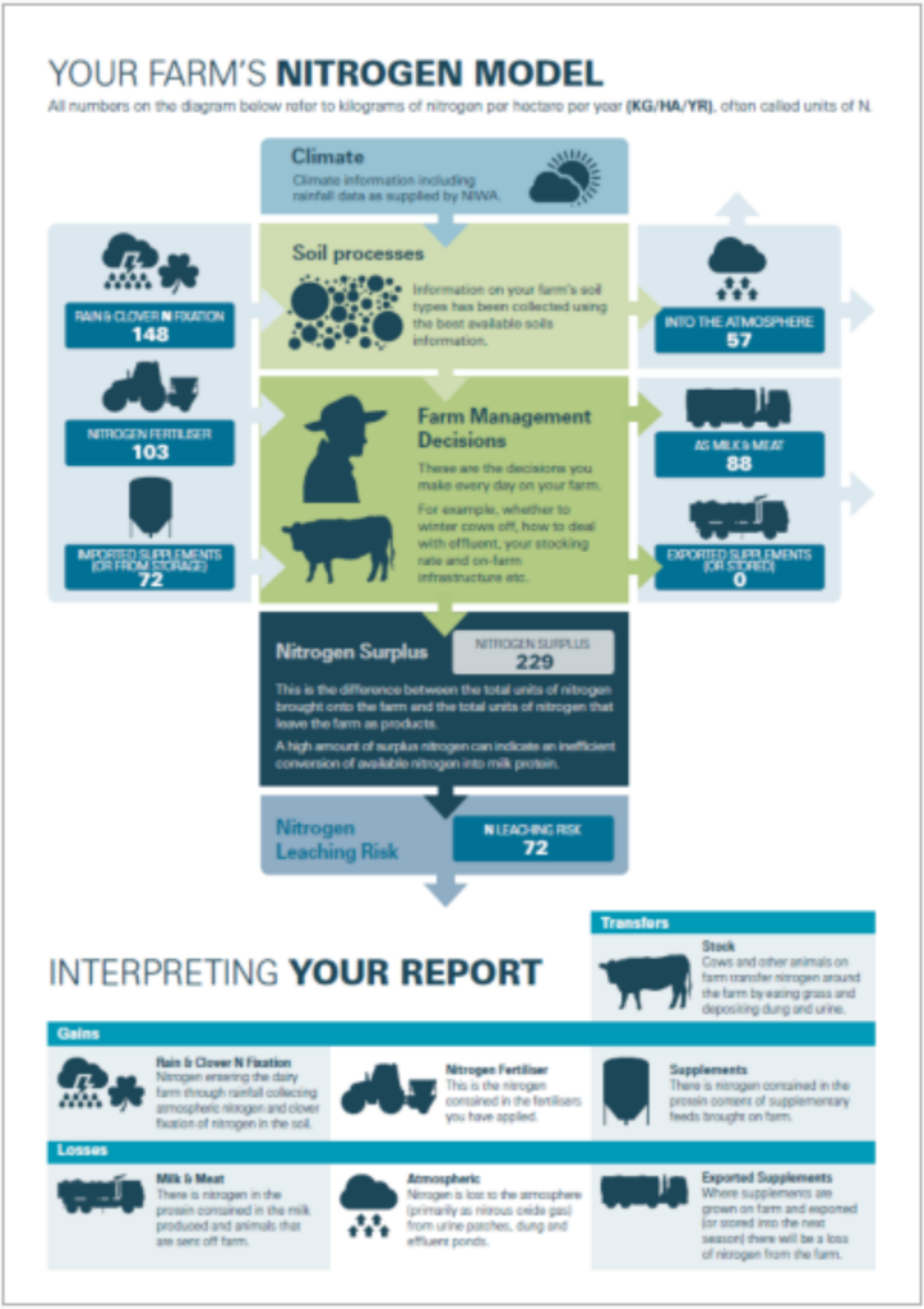
11. APPENDICES

11.1 Appendix 1.

Site Name	TON 5 year median	Ammoniaca l N 5 year median	DIN	Comply NPS? 1.0		DRP 5 year median	Comply NPS? 0.018
Ruamāhanga River catchment							
Huangarua River at Ponatahi Bridge	0.23	0.005	0.235	YES		0.0058	YES
Kopuaranga River at Stuarts	0.96	0.005	0.965	YES		0.014	YES
Mangatarere River at State Highway 2	1.06	0.034	1.094	NO		0.029	NO
Parkvale Stream at Weir	1.6	0.01	1.61	NO		0.022	NO
Parkvale tributary at Lowes Reserve	4.45	0.005	4.455	NO		0.01125	YES
Ruamāhanga at State Highway 2		0.003				0.00245	YES
Ruamāhanga River at Gladstone Bridge	0.395	0.005	0.4	YES		0.0089	YES
Ruamāhanga River at McLays	0.021	0.005	0.026	YES		0.00205	YES
Ruamāhanga River at Pukio	0.37	0.007	0.377	YES		0.0133	YES
Ruamahānga River at Te Ore Ore	0.35	0.005	0.355	YES		0.0053	YES
Ruamāhanga River at Waihenga Bridge	0.485	0.006625	0.491625	YES		0.011625	YES
Taueru River at Gladstone	0.73	0.006	0.736	YES		0.01785	YES
Waingawa River at South Road	0.0625	0.005	0.0675	YES		0.0031	YES
Waiohine River at Bicknells	0.365	0.006	0.371	YES		0.0109	YES
Waipoua River at Colombo Road Bridge	0.75	0.005	0.755	YES		0.00375	YES
Whangaehu River at 250 m from Confluence	0.59	0.005	0.595	YES		0.033	NO
Whareama River catchment							
Whareama River at Gauge	0.01	0.005	0.015	YES		0.0036	YES

Source Irrigation NZ 2019: Data has been obtained from Land Air Water Aotearoa website (LAWA), as at 10 October 2019.

11.2 Appendix 2.



OVERSEER® **NUTRIENT BUDGETS**

OVERSEER® is the preferred farm systems modelling tool used by fertiliser companies, farm consultants, regional councils and the dairy industry to demonstrate improved nutrient management practice on New Zealand dairy farms. It is well suited to providing an assessment of relative change (year-on-year and farm-to-farm). Your data has been processed through OVERSEER® by our experienced QCONZ and Fonterra team in accordance with the OVERSEER® Best Practice Data Input Standard and the entire process has been externally audited.

If this form was incomplete, our processing teams may have made some assumptions while processing the data through OVERSEER® 6.2.3.

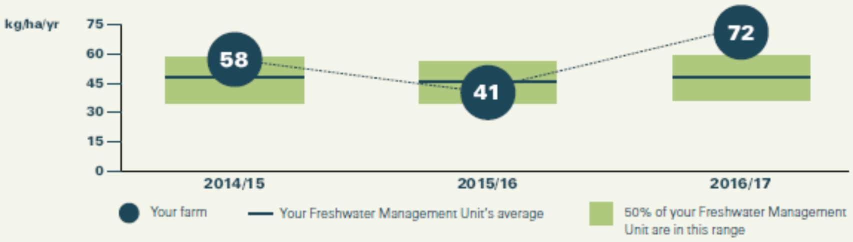
YOUR FARM'S **NITROGEN LEACHING RISK**

72 KG/HA/YR

Nitrogen Leaching Risk

This indicates the risk of the loss of nitrogen from the farming system into either the groundwater system or into waterways.

A small number indicates a lower risk of nitrogen loss.



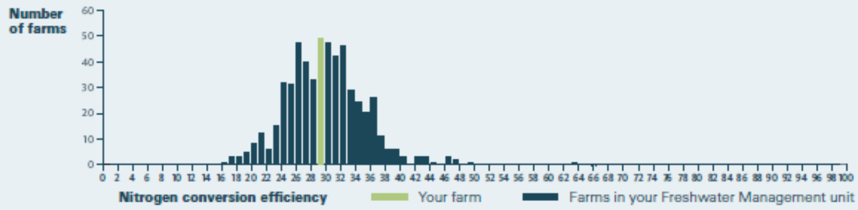
YOUR FARM'S **NITROGEN CONVERSION EFFICIENCY**

29 %

Nitrogen Conversion Efficiency

This is the percentage of nitrogen that is brought into the farming system (fertiliser, supplementary feed and clover fixation) that is converted to products (milk and meat).

The higher the percentage the more efficient the farm is at using its nitrogen resources.



YOUR SOILS INFORMATION HAS BEEN UPDATED

The soils information used for the generation of this Nitrogen Report is sourced from Landcare Research S-map datasets. The soils dataset for your area has been updated during the 2016/2017 season, this means that the soils information used to generate this report will be different to the soils information used during previous seasons. As a result, you may see differences in modelled output numbers from previous seasons – such as Nitrogen Leaching Risk.

Source: 2017. Property Information Memorandum, Farmlands Real-Estate. Te Awamutu Dairy Farm

Taupo 581 Otake Road, Marotiri

Versatile 229 hectares

581 Otake Road is known as Jacaroma and is situated in the renowned farming district of Marotiri. Comprising approximately of 203ha easy to rolling, 20ha hilly, making the effective area 223ha from the total of 229ha. There is approximately 10ha in the Taupo catchment. The Nitrogen Reference Report completed using overseer 6.2.3 gives a number of 85. Enabling the new owner to be in the best position going forward under the proposed Healthy Rivers plan one change. The current owners also have a policy for bio security and only source cattle within the current farming operation. Jacaroma is well supported with a three bedroom house, woolshed, and two sets of cattle yards. Located just 14km from Kinloch Village, with Taupo only 32km away.

Source: Property Information Memorandum, Bayleys.

11.3 Appendix 3 .Farm A – Detailed Calculations

Ongoing annual costs to comply with the Action for Healthy Waterways policy package

Yearly OVERSEER file			
OVERSEER file to test any farm policy changes, and track reduction in emissions overtime as per the FW-FP	**Hrs.**	**$/Hr.**	
Farm visit and OVERSEER file	8	160	$1,280
Travel 100Km @ 80c km			$80
OVERSEER FM Charge			$200
			$1,560
Compliance with the FW-FP audited by an approved auditor			
An audit must be conducted every 2-years, unless the approved auditor is satisfied the environmental performance of the farm is at a level that means the audit can take place every 3-years.			
Assumed farm needs audit every 2-years ($1280 for audit/2 years = $640/pa)			**$640**
Water reticulation ongoing annual costs			
*Additional R&M with new system $20/Trough			$340
Annual depreciation 40 Yr lifespan			$850
Interest @ 5%			$1,700
			$2,890
* Fixing water leaks, replacing trough fittings, maintenance of pumps, maintenance of trough surrounds with metal etc.			
Winter grazing on forage crop			
Resource consent for winter crops above 10 or 15 degrees slope. Slope is determined across a land parcel. Consent estimated at $5,000, analysis of impacts in line with FW-FP. Assumed consent in place for 5-years ($1,000/yr)			
			$1,000
Fencing ongoing annual costs			
*Additional R&M required on new fences			$9,647
Annual depreciation 40 Yr. lifespan			$14,459
Interest @ 5%			$28,918
		Total Costs	**$53,024**
*1.5% of capital cost, inflated at 1% per year for 20-years. More fences to look after, more flood damage, erosion damage, bank slumping, stock pushing wires. Keeping electrics going, finding faults, spraying lines to keep power up.			
Freshwater module , schedule of actions to mitigate contaminant losses			
Erosion control, poles planted to control erosion and critical source areas (CSAs)		**Poles/Yr.**	
Poles cost $25 per pole with 50% subsidy reimbursed		200	**$2,500**
Riparian planting assumed 1km per year planted (Owners choice)	**Meters**	**$/M***	
Costs 2 rows planted both sides (if 5m Buffer)	1000	$14.8	**$14,800**
Weed and pest control in riparian areas. Assumed 16-hours plus chemical			**$2,300**
Additional administration			
Monitoring, record keeping, reporting and gathering information to demonstrate compliance with the farm environment plan including the freshwater module			
	Hrs	**$/Hr**	
	20	$40	**$800**
***Total annual costs**			**$79,514**
Effective Ha	**622**	**$/Ha**	**$127.84**
% increase in farm working costs/Ha/Yr			**21%**

* Assumes 1km of riparian planting with a 5m buffer (owners choice)

Upfront capital costs to comply with the Action for Healthy Waterways policy package

Certified farm plan (FP) with a freshwater (FW) module (FW-FP)			
	Hrs	**$/Hr**	
Farm A does not have a current farm plan. Develop a certified farm plan including a freshwater module (FW-FP)	0	$0	$5,000
FW-FP to be signed off by a credited farm environment planner and the council notified	5	$160	$800
Audited within 24-months of completion (audited by an approved auditor). Report to council	9	$160	$1,440
			$7,240

Note: The estimated cost of preparing a certified farm plan depended on if the farmer had a base plan, the farm size, farm system and local rules. The cost also depended on soil information available and if the farm had farm maps. AgFirst NZ, EnviroPlan Canterbury, AgriMagic and BakerAg were all canvassed regarding the cost of farm plans and the costs ranged from $2,000 to $8,000. With the requirements under the proposed NES and addition of the freshwater module the minimum cost was estimated at $5,000 per plan if the farmer had no plan already in place.

Soil tests to determine current soil fertility			
	Tests	**$/Test**	
Five tests to develop nutrient budget	5	$75	**$375**

Develop base OVERSEER nutrient budgets for FW-FP			
As part of the FW-FP farmers need to have a base nutrient budget and demonstrate how they are “reducing” nitrogen, phosphorus, sediment and microbial pathogens.	**Hrs**	**$/Hr**	
Develop base file for farm A	8	$160	$1,280
Travel 100Km @ 80c km			$80
OVERSEER FM charge			$200
Note: Ballance environmental team Est range for one year $800-$2,880 for sheep & beef , for 2 files they have indicated $3,000. More for cropping farms			**$1,560**

Excluding stock from waterways	
[1] Fencing waterways and wetlands.	**$578,358**
[2] Additional water reticulation needed after fencing waterways off.	**$34,000**
[3] Livestock crossing structures including engineering & consents ($935/culvert)	**$4,675**
Note: Farm A already has provision for stock crossing in most places. No provision for fish passages was priced.	

Freshwater module, schedule of actions to mitigate contaminant losses			
Erosion control, poles planted to control erosion and critical source areas (CSAs)		**Poles/Yr.**	
Poles cost $25 per pole with 50% subsidy reimbursed		200	**$2,500**
Riparian planting assumed 1km of streams at outset planted (Owners choice). No subsides included.	**Meters**	**$/M***	
Costs 2 rows planted both sides (if 5m Buffer)	1000	$14.8	**$14,800**
Total Costs^			**$643,508**

[1] Assuming a four wire electric fence on both sides if no existing fence was in place. No allowance for removing existing fences that don't comply with the set back rules. Fencing labour and material on flat land of $10/linear metre, for hill country $16.50. These figures are based on pricing from BakerAg records and the *Ministry for Primary Industries Stock Exclusion Costs Report. MPI Technical Paper No: 2017/11, January 2016.* Note fencing materials and labour costs have risen significatly since the 2016 MPI report.

[2] Additional troughs on current reticulated system. Reticulated system formula of $2,000/trough used from *Implications of the proposed Waikato Plan Change 1 Report. BakerAg, R Beetham. C Garland. June 2018.*

[3] Installing Nexus Culvert 400mm x 6m, includes retaining posts, rails, labour and digger.

*Ministry for Primary Industries Stock Exclusion Costs Report. MPI Technical Paper No: 2017/11, January 2016
^Assumes 1km of riparian planting at a 5m buffer

Fencing - Stock exclusion

Description	Fence Type	Meters	$/m	Total	Comments
Excluding stock from permanent and intermittent waterways more than one metre wide	4 Wire electric, posts at 5m spacings	5515	$16.50	$90,998	One wire fence not suitable. Fences to keep sheep and young cattle out
Farm plan freshwater module. Excluding stock from streams, drains, and ditches less than a metre wide	4 Wire electric, posts at 5m spacings	19537	$16.50	$322,361	One wire fence not suitable. Fences to keep sheep and young cattle out
Excluding stock from wetlands	4 Wire electric, posts at 5m spacings	10000	$16.50	$165,000	One wire fence not suitable. Fences to keep sheep and young cattle out
Total Fencing Costs				**$578,358**	

11.4 Appendix 4 .Farm B – Detailed Calculations

Ongoing annual costs to comply with the Action for Healthy Waterways policy package

Yearly OVERSEER file			
OVERSEER file to test any farm policy changes, and track reduction in emissions overtime as per the FW-FP	**Hrs.**	**$/Hr.**	
Farm visit and OVERSEER file	8	160	$1,280
Travel 100Km @ 80c km			$80
OVERSEER FM Charge			$200
			$1,560
Compliance with the FW-FP audited by an approved auditor			
An audit must be conducted every 2-years, unless the approved auditor is satisfied the environmental performance of the farm is at a level that means the audit can take place every 3-years.			
Assumed farm needs audit every 2-years ($1280 for audit/2 years = $640/pa)			**$640**
Water reticulation ongoing annual costs			
*Additional R&M with new system $20/Trough			$540
Annual depreciation 40 Yr lifespan			$2,063
Interest @ 5%			$4,125
			$6,728
* Fixing water leaks, replacing trough fittings, maintenance of pumps, maintenance of trough surrounds with metal etc.			
Winter grazing on forage crop			
Resource consent for winter crops above 10 or 15 degrees slope. Slope is determined across a land parcel. Consent estimated at $5,000, analysis of impacts in line with FW-FP. Assumed consent in place for 5-years ($1,000/yr)			
			$1,000
Fencing ongoing annual costs			
*Additional R&M required on new fences			$7,524
Annual depreciation 40 Yr. lifespan			$11,277
Interest @ 5%			$22,554
		Total Costs	**$41,355**
*1.5% of capital cost, inflated at 1% per year for 20-years. More fences to look after, more flood damage, erosion damage, bank slumping, stock pushing wires. Keeping electrics going, finding faults, spraying lines to keep power up.			
Freshwater module , schedule of actions to mitigate contaminant losses			
Erosion control, poles planted to control erosion and critical source areas (CSAs)		**Poles/Yr.**	
Poles cost $25 per pole with 50% subsidy reimbursed		250	**$3,125**
Riparian planting assumed 1km per year planted (Owners choice)	**Meters**	**$/M***	
Costs 2 rows planted both sides (if 5m Buffer)	1000	$14.8	**$14,800**
Weed and pest control in riparian areas. Assumed 16-hours plus chemical			**$2,300**
Additional administration			
Monitoring, record keeping, reporting and gathering information to demonstrate compliance with the farm environment plan including the freshwater module			
	Hrs	**$/Hr**	
	24	$40	**$960**
***Total annual costs**			**$72,468**
Effective Ha	**819**	**$/Ha**	**$88.48**
% increase in farm working costs/Ha/Yr			**14%**

* Assumes 1km of riparian planting with a 5m buffer (owners choice)

Upfront capital costs to comply with the Action for Healthy Waterways policy package

Certified farm plan (FP) with a freshwater (FW) module (FW-FP)			
	Hrs	**$/Hr**	
Farm B has a current Sustainable Land Use Initiative plan(SLUI). Likely need updating in line with a certified farm plan and to include a freshwater module.	10	$160	$1,600
FW-FP to be signed off by a credited farm environment planner and the council notified	5	$160	$800
Audited within 24-months of completion (audited by an approved auditor).	9	$160	$1,440
Report to council			**$3,840**
Note: The estimated cost of preparing a certified farm plan depended on if the farmer had a base plan, the farm size, farm system and local rules. The cost also depended on soil information available and if the farm had farm maps. AgFirst NZ, EnviroPlan Canterbury, AgriMagic and BakerAg were all canvassed regarding the cost of farm plans and the costs ranged from $2,000 to $8,000. With the requirements under the proposed NES and addition of the freshwater module the minimum cost was estimated at $5,000 per plan if the farmer had no plan already in place.			
Soil tests to determine current soil fertility			
	Tests	**$/Test**	
Six tests to develop nutrient budget	6	75	**$450**
Develop base OVERSEER nutrient budgets for FW-FP			
As part of the FW-FP farmers need to have a base nutrient budget and demonstrate how they are “reducing” nitrogen, phosphorus, sediment and microbial pathogens.	**Hrs**	**$/Hr**	
Develop base file for farm B	8	160	$1,280
Travel 100Km @ 80c km			$80
OVERSEER FM charge			$200
Note: Ballance environmental team Est range for one year $800-$2,880 for sheep & beef , for 2 files they have indicated $3,000. More for cropping farms			**$1,560**
Excluding stock from waterways			
[1] Fencing waterways and wetlands.			**$451,087**
Water reticulation needed after fencing waterways off.			**$82,500**
[2]Livestock crossing structures including engineering & consents ($935/culvert)			**$9,350**
Note: No provision for fish pasages was priced. Three engineered bridges would be needed over large streams and rivers on farm B. These would be a significant cost, estimated at $100,000 plus per bridge. They are not included in the livestock crossing costings.			
Freshwater module, schedule of actions to mitigate contaminant losses			
Erosion control, poles planted to control erosion and critical source areas (CSAs)		**Poles/Yr.**	
Poles cost $25 per pole with 50% subsidy reimbursed		250	**$3,125**
Riparian planting assumed 1km of streams at outset planted (Owners choice). No subsides included.	**Meters**	**$/M***	
Costs 2 rows planted both sides (if 5m Buffer)	1000	$14.8	**$14,800**
Total Costs^			**$566,712**

[1]Assuming a four wire electric fence on both sides if no existing fence was in place. No allowance for removing existing fences that dont comply with the set back rules. Fencing labour and material on flat land of $10/linear metre, for hill country $16.50. These figures are based on pricing from BakerAg records and the *Ministry for Primary Industries Stock Exclusion Costs Report. MPI Technical Paper No: 2017/11, January 2016.* Note fencing materials and labour costs have risen significatly since the 2016 MPI report.

[2]Installing Nexus Culvert 400mm x 6m, includes retaining posts, rails, labour and digger.

*Ministry for Primary Industries Stock Exclusion Costs Report. MPI Technical Paper No: 2017/11, January 2016
^Assumes 1km of riparian planting at a 5m buffer

Fencing - Stock exclusion

Description	Fence Type	Meters	$/m	Total	Comments
Excluding stock from permanent and intermittent waterways more than one metre wide	4 Wire electric, posts at 5m spacings	7792	$16.50	$128,568	One wire fence not suitable. Fences to keep sheep and young cattle out
Farm plan freshwater module. Excluding stock from streams, drains, and ditches less than a metre wide	4 Wire electric, posts at 5m spacings	17625.8	$16.50	$290,826	One wire fence not suitable. Fences to keep sheep and young cattle out
Excluding stock from wetlands	4 Wire electric, posts at 5m spacings	1920.8	$16.50	$31,693	One wire fence not suitable. Fences to keep sheep and young cattle out
Total Fencing Costs				**$451,087**	

Reticulation costings	
Main System Details	
Hill block	
2 X Tank @ 454m asl	
Spring with diesel pump @ 215m asl	
780m main line pump to tank	
Details & Costs	
System design	$2,500
2 X 30,000 L tank (Range $3500 - 3900)	$7,000
Excavation of site, level, base	$2,500
Deliver tank to site -helicopter ($1600/Hr)	$3,200
Spring works, well liner, tap	$3,400
Pump diesel ($3500-5000)	$5,000
Startomatic for pump	$900
Tank level meter	$500
Pump shed with concrete Base	$3,500
	$28,500
Costs for Main System & Troughs	
Total troughs	27
System formula $2000/Trough	**$54,000**
Total Costs	**$82,500**
Final Costs	**$82,500**
Ongoing annaul costs post instalalation	
Additional R&M with new system $20/Trough	$540
Annual depreciation 40 Yr lifespan	$2,062.50
Interest 5%	$4,125
Total Costs	**$6,728**

11.5 Appendix 5. Farm C – Detailed Calculations

Ongoing annual costs to comply with the Action for healthy waterways policy package

Yearly OVERSEER file			
OVERSEER file to test any farm policy changes, and track reduction in emissions overtime as per the FW-FP	**Hrs.**	**$/Hr.**	
Farm visit and OVERSEER file (More time because of detailed cropping)	12	160	$1,920
Travel 100Km @ 80c km			$80
OVERSEER FM Charge			$200
			$2,200
Compliance with the FW-FP audited by an approved auditor			
An audit must be conducted every 2-years, unless the approved auditor is satisfied the environmental performance of the farm is at a level that means the audit can take place every 3-years.			
Assumed farm needs audit every 2-Years ($1,280 for audit/2-years = $640/pa)			**$640**
Water Reticulation - Ongoing annual costs			
			NA
Fencing ongoing annual costs			
*Additional R&M required on new fences			$2,627
Annual depreciation 40 Yr. lifespan			$3,937
Interest @ 5%			$7,874
		Total Costs	**$14,437**
*1.5% of capital cost, inflated at 1% per year for 20-years. More fences to look after, more flood damage, erosion damage, bank slumping, stock pushing wires. Keeping electrics going, finding faults, spraying lines to keep power up.			
Freshwater module , schedule of actions to mitigate contaminant losses			
Riparian planting assumed 1km per year planted (Owners choice)	**Meters**	**$/M***	
Costs 2 rows planted both sides (if 5m Buffer)	1000	$14.8	**$14,800**
Weed and pest control in riparian areas. Assumed 16-hours plus chemical			**$2,300**
Additional administration			
Monitoring, record keeping, reporting and gathering information to demonstrate compliance with the farm environment plan including the freshwater module	**Hrs**	**$/Hr**	
	24	$40	**$960**
***Total annual costs**			**$35,337**
Effective Ha	**655**	**$/Ha**	**$53.95**
% increase in farm working costs/Ha/Yr			**8%**

* Assumes 1km of riparian planting with a 5m buffer (owners choice)

Upfront capital costs to comply with the Action for Healthy Waterways policy package

Certified farm plan (FP) with a freshwater (FW) module (FW-FP)			
	Hrs	**$/Hr**	
Farm C has a current Foundation for Arable Research (FAR) farm plan. Likely need updating in line with certified farm plan and to include a freshwater module.	10	$160	$1,600
FW-FP to be signed off by a credited farm environment planner and council notified	5	$160	$800
Audited within 24-months of completion (audited by an approved auditor).	9	$160	$1,440
Report to council			**$3,840**
Note: The estimated cost of preparing a certified farm plan depended on if the farmer had a base plan, the farm size, farm system and local rules. The cost also depended on soil information available and if the farm had farm maps. AgFirst NZ, EnviroPlan Canterbury, AgriMagic and BakerAg were all canvassed regarding the cost of farm plans and the costs ranged from $2,000 to $8,000. With the requirements under the proposed NES and addition of the freshwater module the minimum cost was estimated at $5,000 per plan if the farmer had no plan already in place.			
Soil tests to determine current soil fertility			
	Tests	**$/Test**	
Farm C has detailed tests already	0	75	**$0**
Develop base OVERSEER nutrient budgets			
Must show emissions (nitrogen, phosphorus, sediment, pathogens) from the new land use does not exceed the average discharges of contaminants from the old land use (farm) during the farm year 2017/18	**Hrs**	**$/Hr**	
Complex file with multiple crop rotations and many blocks (7-days to develop base)	56	160	$8,960
Travel 100Km @ 80c km			$80
OVERSEER FM charge			$200
Note: Ballance environmental team Est range for one year $800-$2,880 for sheep & beef, for 2 files they have indicated $3,000. More for cropping farms			**$9,240**
Excluding stock from waterways			
#Fencing waterways. Moving existing fences to comply with set back requirements			**$157,470**
Water reticulation needed after fencing waterways off			NA
Livestock crossing structures including engineering & consents			NA
Freshwater module , schedule of actions to mitigate contaminant losses			
		Poles/Yr.	
Erosion control, poles planted to control erosion and critical source areas (CSAs)			**$0**
Riparian planting assumed 1km of streams at outset planted (Owners choice). No subsides included.	**Meters**	**$/M***	
Costs 2 rows planted both sides (if 5m Buffer)	1000	$14.8	**$14,800**
Total Costs^			**$185,350**

#Assuming a four wire electric fence on both sides if no existing fence was in place. No allowance for removing existing fences that dont comply with the set back rules. Fencing labour and material on flat land of $10/linear metre, for hill country $16.50. These figures are based on pricing from BakerAg records and the *Ministry for Primary Industries Stock Exclusion Costs Report. MPI Technical Paper No: 2017/11, January 2016.* Note fencing materials and labour costs have risen significatly since the 2016 MPI report.

*Ministry for Primary Industries Stock Exclusion Costs Report. MPI Technical Paper No: 2017/11, January 2016
^Assumes 1km of riparian planting at a 5m buffer

Fencing - Stock exclusion

Description	Fence Type	Meters	$/m	Total	Commnets
Excluding stock from rivers and streams more than one metre wide	4 Wire electric, posts at 5m spacings	13101	$10.00	$131,010	Fences to keep weaner bulls out and sheep out of riparian areas.
Farm plan freshwater module. Excluding stock from streams, drains, ditches less than a metre wide	4 Wire electric, posts at 5m spacings	2646	$10.00	$26,460	Fences to keep weaner bulls out and sheep out of riparian areas.
Total Fencing Costs				**$157,470**	

11.6 Appendix 6. Farm D – Detailed Calculations

Ongoing annual costs to comply with the Action for Healthy Waterways policy package

Yearly OVERSEER file			
OVERSEER file to test any farm policy changes, and track reduction in emissions overtime as per the FW-FP	**Hrs.**	**$/Hr.**	
Farm visit and OVERSEER file	8	160	$1,280
Travel 100Km @ 80c km			$80
OVERSEER FM Charge			$200
			$1,560
Compliance with the FW-FP audited by an approved auditor			
An audit must be conducted every 2-years, unless the approved auditor is satisfied the environmental performance of the farm is at a level that means the audit can take place every 3-years.			
Assumed farm needs audit every 2-years ($1280 for audit/2 years = $640/pa)			**$640**
Water reticulation ongoing annual costs			
*Additional R&M with new system $20/Trough			$2,000
Annual depreciation 40 Yr lifespan			$6,244
Interest @ 5%			$12,488
			$20,732
* Fixing water leaks, replacing trough fittings, maintenance of pumps, maintenance of trough surrounds with metal etc.			
Winter grazing on forage crop			
Resource consent for winter crops above 10 or 15 degrees slope. Slope is determined across a land parcel. Consent estimated at $5,000, analysis of impacts in line with FW-FP. Assumed consent in place for 5-years ($1,000/yr)			
			$1,000
Fencing ongoing annual costs			
*Additional R&M required on new fences			$6,658
Annual depreciation 40 Yr. lifespan			$9,980
Interest @ 5%			$19,959
		Total Costs	**$36,597**
*1.5% of capital cost, inflated at 1% per year for 20-years. More fences to look after, more flood damage, erosion damage, bank slumping, stock pushing wires. Keeping electrics going, finding faults, spraying lines to keep power up.			
Freshwater module , schedule of actions to mitigate contaminant losses			
Erosion control, poles planted to control erosion and critical source areas (CSAs)		**Poles/Yr.**	
Poles cost $25 per pole with 50% subsidy reimbursed		150	**$1,875**
Riparian planting assumed 1km per year planted (Owners choice)	**Meters**	**$/M***	
Costs 2 rows planted both sides (if 5m Buffer)	1000	$14.8	**$14,800**
Weed and pest control in riparian areas. Assumed 16-hours plus chemical			**$2,300**
Additional administration			
Monitoring, record keeping, reporting and gathering information to demonstrate compliance with the farm environment plan including the freshwater module			
	Hrs	**$/Hr**	
	20	$40	**$800**
***Total annual costs**			**$80,304**
Effective Ha	**900**	**$/Ha**	**$89**
% increase in farm working costs/Ha/Yr			**29%**

* Assumes 1km of riparian planting with a 5m buffer (owners choice)

Upfront capital costs to comply with the Action for Healthy Waterways policy package

Certified farm plan (FP) with a freshwater (FW) module (FW-FP)

	Hrs	$/Hr	
Farm D does not have a current farm plan. Develop a certified farm plan including a freshwater module (FW-FP)	0	$0	$5,000
FW-FP to be signed off by a credited farm environment planner and the council notified	5	$160	$800
Audited within 24-months of completion (audited by an approved auditor). Report to council	9	$160	$1,440
			$7,240

Note: The estimated cost of preparing a certified farm plan depended on if the farmer had a base plan, the farm size, farm system and local rules. The cost also depended on soil information available and if the farm had farm maps. AgFirst NZ, EnviroPlan Canterbury, AgriMagic and BakerAg were all canvassed regarding the cost of farm plans and the costs ranged from $2,000 to $8,000. With the requirements under the proposed NES and addition of the freshwater module the minimum cost was estimated at $5,000 per plan if the farmer had no plan already in place.

Soil tests to determine current soil fertility

	Tests	$/Test	
Ten tests to develop nutrient budget	10	$75	**$750**

Develop base OVERSEER nutrient budgets for FW-FP

	Hrs	$/Hr	
As part of the FW-FP farmers need to have a base nutrient budget and demonstrate how they are "reducing" nitrogen, phosphorus, sediment and microbial pathogens.			
Develop base file for farm D	12	$160	$1,920
Travel 100Km @ 80c km			$80
OVERSEER FM charge			$200
Note: Ballance environmental team Est range for one year $800-$2,880 for sheep & beef , for 2 files they have indicated $3,000. More for cropping farms			**$2,200**

Excluding stock from waterways

[1] Fencing waterways (Wetlands not mapped or measured)	**$399,185**
Water reticulation needed after fencing waterways off.	**$249,760**
[2] Livestock crossing structures including engineering & consents ($935/culvert)	**$4,675**

Note: No provision for fish passages was priced.

Freshwater module, schedule of actions to mitigate contaminant losses

Erosion control, poles planted to control erosion and critical source areas (CSAs)		**Poles/Yr.**	
Poles cost $25 per pole with 50% subsidy reimbursed		150	**$1,875**
Riparian planting assumed 1km of streams at outset planted (Owners choice). No subsides included.	**Meters**	**$/M***	
Costs 2 rows planted both sides (if 5m Buffer)	1000	$14.8	**$14,800**
Total Costs^			**$680,485**

[1] Assuming a four wire electric fence on both sides if no existing fence was in place. No allowance for removing existing fences that don't comply with the set back rules. Fencing labour and material on flat land of $10/linear metre, for hill country $16.50. These figures are based on pricing from BakerAg records and the *Ministry for Primary Industries Stock Exclusion Costs Report. MPI Technical Paper No: 2017/11, January 2016.* Note fencing materials and labour costs have risen significatly since the 2016 MPI report.

[2] Installing Nexus Culvert 400mm x 6m, includes retaining posts, rails, labour and digger.

*Ministry for Primary Industries Stock Exclusion Costs Report. MPI Technical Paper No: 2017/11, January 2016
^Assumes 1km of riparian planting at a 5m buffer

Reticulation costings

Main System Details	
Block 1	
Tanks @ 245m asl (Sheep & Cattle Yards)	
Spring 235m asl - 190m main line spring to tank	
Details & Costs	
System Design	$2,500
3 X 30,000 L tank (Range $3500 - 3900)	$10,500
Excavation of tank sites, level, base x 3	$1,800
*Helicopter Tanks to Site -($1200 Ferry, $320 Tank)	$2,160
Tapping Spring Source + Materials	$2,500
Pump diesel ($3500-5000)	$4,000
Startomatic for pump	$800
Tank Level Meter	$500
Pump Shed - Concrete Base	$2,500
	$27,260
Costs for Main System & Troughs	
Ha	500
Ha/Trough	5
Total Troughs	100
System Formula $2000/Trough	**$200,000**
Total Costs	**$227,260**

* Helicopter $1600/Hour

Additional troughs on reticulated country	
$1,250 including 100m pipe x 18	**$22,500**
Final Costs	**$249,760**

Ongoing annaul costs post instalalation	
Additional R&M with new system $20/Trough	$2,000
Annual Depreciation 40 Yr Lifespan	$6,244
Interest 5%	$12,488
Total Costs	**$20,732**

Fencing - Stock exclusion

Description	Fence Type	Meters	$/m	Total	Comments
Excluding stock from streams >1m. Farm plan freshwater module. Excluding stock from streams, drains, and ditches less than a metre wide	4 Wire electric, posts at 5m spacings	24193	$16.50	$399,185	One wire fence not suitable. Fences to keep sheep and young cattle out
Excluding stock from wetlands	4 Wire electric, posts at 5m spacings	0	$16.50	$0	One wire fence not suitable. Fences to keep sheep and young cattle out
Total Fencing Costs				**$399,185**	

Fencing - Stock exclusion

Description	Fence Type	Meters	$/m	Total	Comments
Excluding stock from streams >1m. Farm plan freshwater module. Excluding stock from streams, drains, and ditches less than a metre wide	4 Wire electric, posts at 5m spacings	24193	$16.50	$399,185	One wire fence not suitable. Fences to keep sheep and young cattle out
Excluding stock from wetlands	4 Wire electric, posts at 5m spacings	0	$16.50	$0	One wire fence not suitable. Fences to keep sheep and young cattle out
Total Fencing Costs				**$399,185**	

APPENDIX 3: TECHNICAL REPORT OF MR ANDREW BURTT

APPENDIX 3

TECHNICAL REPORT OF MR ANDREW NEIL BURTT

30 October 2019

IN THE MATTER	of the Beef + Lamb New Zealand submission on the Essential Freshwater Policy document
BY	**BEEF + LAMB NEW ZEALAND LIMITED** **Submitter**

TABLE OF CONTENTS

BACKGROUND

QUALIFICATIONS AND EXPERIENCE

1. My name is Andrew Neil Burtt.

2. I am employed by Beef + Lamb New Zealand Ltd (B+LNZ) as Chief Economist.

3. I hold a B.Agr.Econ. from Massey University.

4. I have been employed by what is effectively B+LNZ since the mid-1980s. I started as a Research Economist with the then New Zealand Meat & Wool Boards' Economic Service. In mid-1990, I moved to the New Zealand Meat Producers Board and have spent the majority of the period since then in trade policy analysis and advocacy in both New Zealand and overseas – in Brussels and Washington DC. I spent three years in Brussels and nearly 10 – in two tranches – in Washington DC representing New Zealand sheep and beef farmers. In 2012, I returned to New Zealand to B+LNZ.

SCOPE

5. This document provides background to the sheep and beef cattle sector in New Zealand. It includes:

   (a) Background to B+LNZ's Economic Service and its Sheep and Beef Farm Survey;

   (b) Background to sheep and beef farming enterprises in New Zealand; and

   (c) Sheep and Beef Farm Survey data for New Zealand, namely data to demonstrate that sheep and beef farming is:

      (i) a significant industry;
      (ii) complex and heterogeneous; and
      (iii) becoming more efficient over time.

6. A description of the B+LNZ Sheep and Beef Farm Survey is attached as APPENDIX 1: DESCRIPTION OF B+LNZ SHEEP AND BEEF FARM SURVEY.

SUMMARY

7. Sheep and beef farming is conducted in diverse and complex ways in diverse and complex environments.

8. Overall, an average of under 80 percent of a farm is used for grazing. The other 20+ percent provides non-farming services – such as native vegetation cover – a substantial portion of New Zealand's native vegetation is on sheep and beef farms. The majority of New Zealand's covenants that protect land in perpetuity under the QEII National Trust are on sheep and beef farms.

9. Sheep and beef farms have also generated significant eco-efficiency gains. Greenhouse gas emissions for the sheepmeat sector are down 40 percent on 1990 levels; for the beef cattle sector they are down 10 percent on 1990 levels.

10. The average stocking rate for sheep and beef farms trended down between 1990-91 and 2017-18. The weighted average stocking rate was 6.4 SU per effective hectare, which is equivalent to about three-quarters of one Friesian cow per ha, in 2017-18.

11. The reduction in average stocking rate reflects conversions of better land closer to the rivers' main stems to dairying while Hard Hill and Hill Country farms continued to farm with regard to the natural capital of their properties and with long-term sustainability – economically, environmentally and socially – in mind.

12. Dairy Grazing Revenue averages 4-5 percent of total gross farm revenue.

13. The **application** of elemental Nitrogen, Phosphorus, Potassium and Sulphur is low.

14. Nutrient **losses** are low, with other parts of this submission, particularly those written by Dr Jane Chrystal, and Richmond Beetham of BakerAg, addressing this point in detail via analysis of actual sheep and beef farms. The average nitrogen leaching rate as modelled by OVERSEER for the sheep and beef sector is 17kgN/ha/yr and a bottom range of 9kgN/ha/yr which is just above the modelled nitrogen leaching for forestry.

BACKGROUND TO B+LNZ'S ECONOMIC SERVICE AND ITS SHEEP AND BEEF FARM SURVEY

15. The data discussed here comes from analysis by B+LNZ's Economics and Insights team and draws on B+LNZ's Sheep and Beef Farm Survey.

16. B+LNZ's Economics and Insights team provides credible, authoritative and independent information and analysis about the sheep and beef value chain, and farming in particular, in New Zealand that supports informed decision-making.

17. A core part of this is the Sheep and Beef Farm Survey, which was initiated after a 1949 Royal Commission that was instructed by the government of the day to "Inquire into and Report Upon the Sheep-Farming Industry", concluded "there is no consistency of facts on which we can rely".

18. The Survey has been running continuously since 1950, which means 2020 is its 70th year and makes it one of, if not, the longest running primary sector survey of its type on earth.

19. Even though the Survey originated in the 1950s, it has not remained static but has evolved and changed to meet needs of the industry and issues of the time.

20. The Survey framework and the operational structure of B+LNZ supports making credible forecasts of production and farm outcomes.

DATA LIMITATIONS AND CONSTRAINTS

21. The Sheep and Beef Farm Survey is a sample survey in which the sample is randomly selected from Statistics New Zealand's business frame, which is used in the country's census of agricultural producers, to reflect New Zealand's sheep and beef cattle livestock base. Statistical methods can be used to provide reliable population estimates, albeit with some measure of variability/uncertainty. Generally, statistics as a discipline reduces such uncertainty, but absolute knowledge cannot be assured until the population of farms across a region and timeframes envisaged by policy measures is surveyed. That is not practicable for such policy development.

BACKGROUND TO SHEEP AND BEEF FARMING

22. The New Zealand sheep and beef farming sector is complex and diverse. Commercial sheep and beef farms have multiple enterprises for a variety of reasons, including:

    (a) The physical characteristics of the property, e.g. topography, slope, soil types, locations of waterways, altitude, climate, pasture growth rates;

    (b) The objectives of the owner(s); and

    (c) Because sheep and beef cattle complement each other on individual properties in a number of production and financial ways, e.g. to mitigate financial risks, to manage pasture, to manage parasites.

23. Sheep and beef farms vary considerably in size and on other measures for such reasons.

24. Figure 1 and Figure 2 show the distribution of size according to the Sheep and Beef Farm Survey. It emphasises the diversity of operations, which is often overlooked when the generic term "farm" is used. "Farm" oversimplifies things because it understates the heterogeneity – and overstates the homogeneity – of them. Frequently, "farm" describes the physical characteristics thereby ignoring the complex and diverse financial/economic, environmental and social aspects of farming. Further, the charts summarise the diversity that occurs within and between regions.

Figure 1: Distribution of Total Effective Area per farm by Number – New Zealand – 2017-18

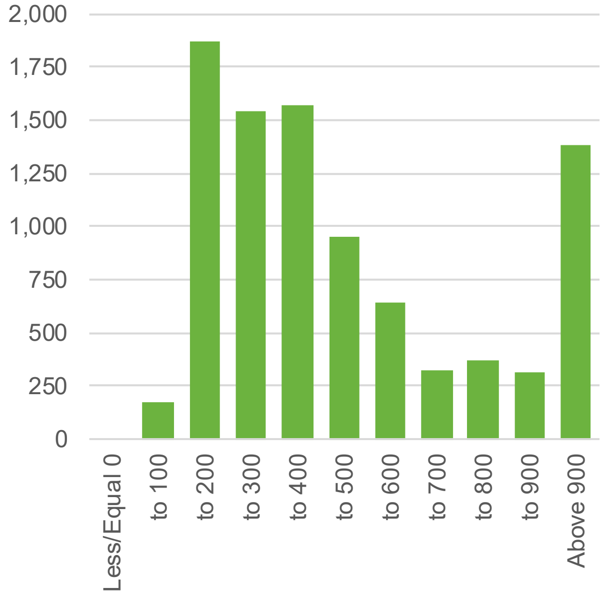
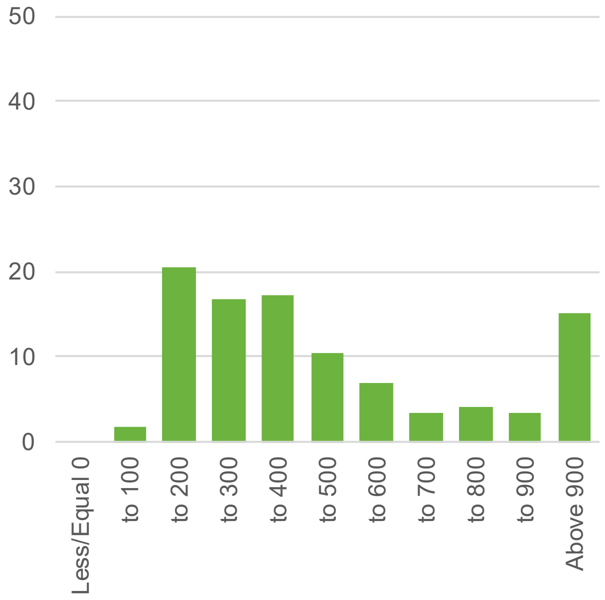


Figure 2: Distribution of Total Effective Area per farm by Percentage – New Zealand – 2017-18

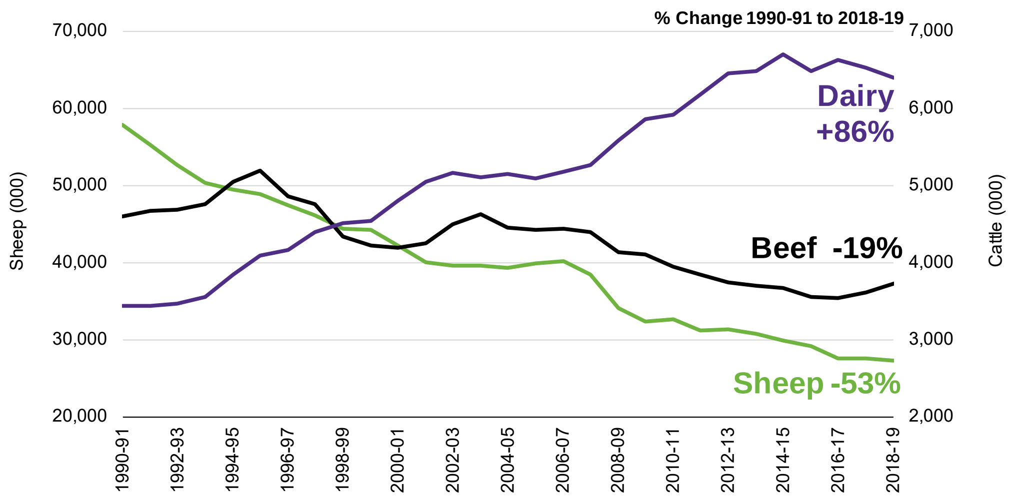


25. New Zealand relies heavily on agriculture, defined in broad terms to include farming and further processing. The share of GDP from agriculture, which is defined more narrowly for statistical purposes because livestock processing and associated activity is included in manufacturing, was 4.2 percent in the year ended March 2017 according to Statistics New Zealand Regional GDP data (MBIE, 2019). This varies considerably between regions, which reflects what we know intuitively about the New Zealand economy.

LIVESTOCK NUMBERS AND LIVESTOCK UNITS

26. Figure 3 provides an overview of the trends in livestock numbers in New Zealand based on the Agricultural Production Census (APC), which is funded by the Ministry for Primary Industries (MPI) and conducted by Statistics New Zealand (SNZ). They start at 1990-91 which we consider the season by which the vast majority of support had been removed after the mid-1980s deregulation by the Labour government that won the 1984 general election.

Figure 3: New Zealand Livestock Numbers



Source: Beef + Lamb New Zealand Economic Service | Statistics New Zealand

27. We are often asked the following questions about stock units:

(a) What is a “stock unit”?; and

(b) Why use “stock units”?

28. A stock unit, for which the abbreviation is SU, reflects feed consumption or utilisation of animals.

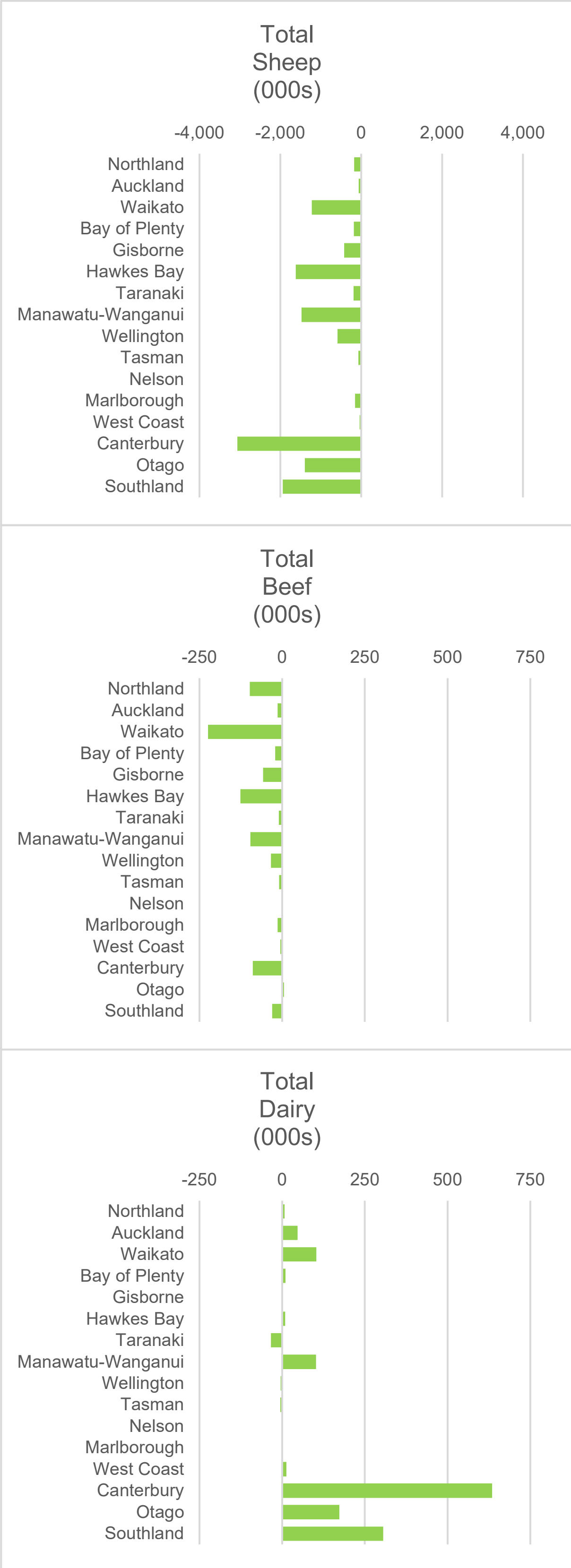
29. SU provides a means of comparing like-with-like. It provides a “common currency” that allows the counts of different species to be reported consistently, or, more colloquially, to compare apples with apples. It measures different livestock species, ages and classes relative to a breeding ewe. It is based on research into dry matter (feed) consumption. For example, a Friesian dairy cow is calculated to be 8.5 SU, i.e. a Friesian dairy cow consumes/demands 8.5 times the feed of a breeding ewe.

30. The factors that B+LNZ uses to convert stock numbers to SU are available in the "Definitions" tab of B+LNZ's Benchmarking Tool page on the B+LNZ website. They are those that resulted from detailed research by Lincoln University.

31. Figure 4 and Figure 5 show the absolute and percentage changes in Livestock Numbers between 1990-91 and 2017-18 for each of the regions in New Zealand for each species – sheep, beef cattle and dairy cattle.

32. In the North Island, Waikato experienced the largest increase in the absolute *number* of dairy cattle, but South Island regions experienced larger increases – in absolute numbers and percentage changes.

Figure 4: Change in Livestock Numbers between 1990-91 and 2017-18



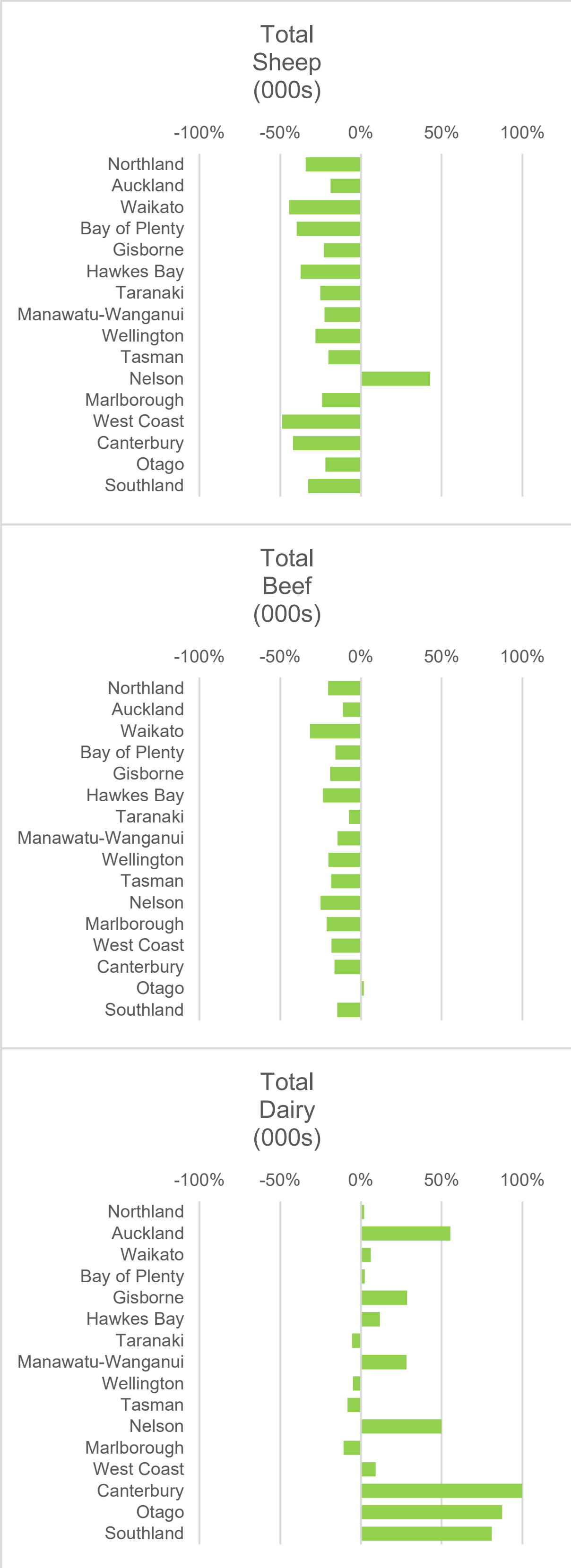
33. Figure 5 shows:

(a) There was a large *percentage* decrease in the number of sheep in all regions except Nelson, which is a unitary authority with few livestock;

(b) The largest *percentage* decrease in beef cattle occurred in Waikato;

(c) Auckland experienced the largest *percentage* increase in dairy cattle in the North Island (albeit from a low base), and there were large *percentage* increases in the South Island.

Figure 5: Change in Livestock Numbers between 1990-91 and 2017-18 (%)



34. Figure 6 and Figure 7 show the absolute and percentage changes in Livestock *Units* between 1990-91 and 2017-18 for each of the regions in New Zealand for each species – sheep, beef cattle and dairy cattle.

35. Figure 6 shows:

(a) The absolute *number* of sheep and beef cattle stock units decreased in Waikato;

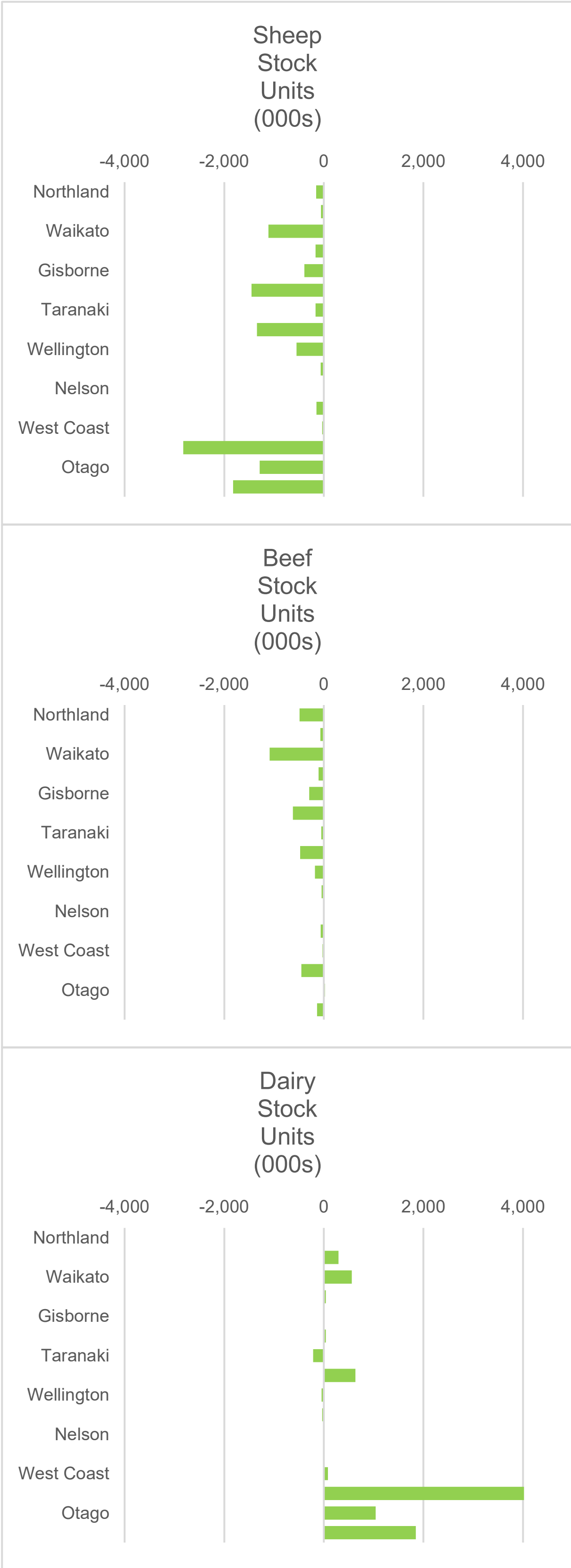
(b) The absolute *number* of dairy cattle stock units increased in Waikato;

(c) There were larger absolute decreases in the number of sheep stock units in South Island regions than in Waikato;

(d) Waikato experienced the largest absolute decrease in beef cattle stock units; and

(e) Manawatu-Wanganui experienced the largest absolute increase in dairy cattle stock units in the North Island, followed closely by Waikato, while South Island regions experienced considerably larger increases.

Figure 6: Change in Livestock Units between 1990-91 and 2017-18 (000 SU)



36. Figure 7 shows:

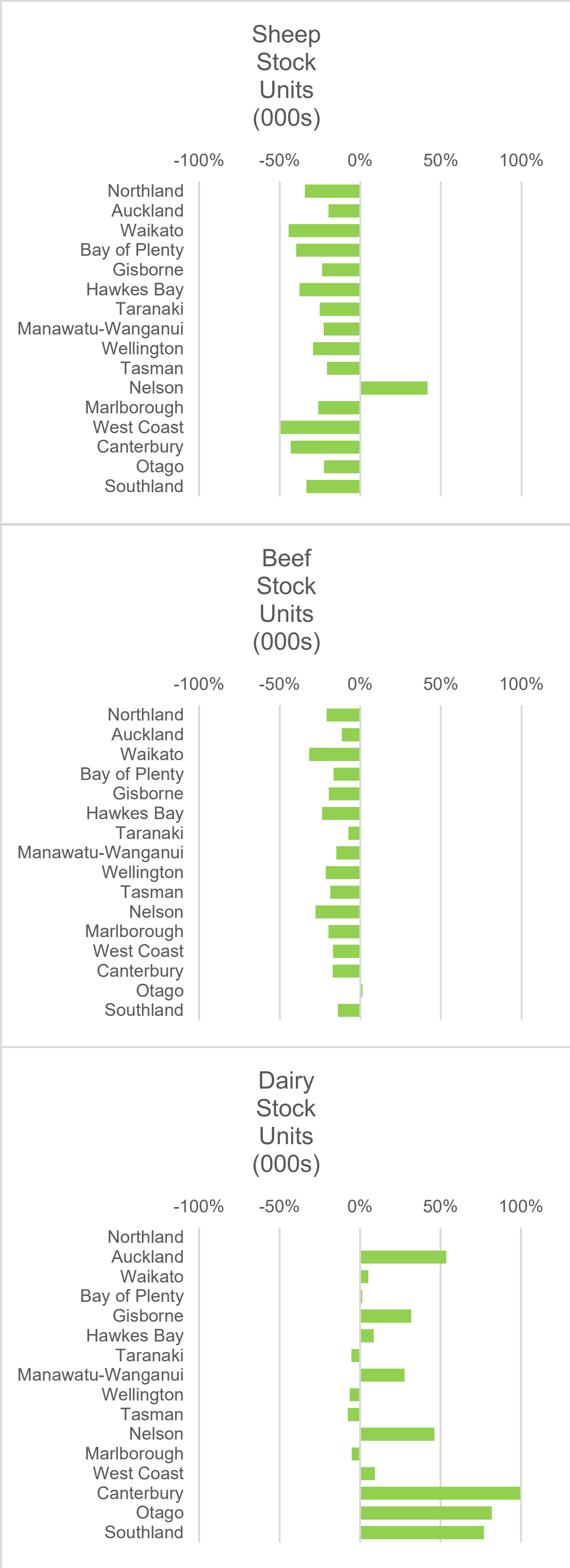
(a) There was a large *percentage* decrease in the number of stock units in all regions except Nelson, which is a unitary authority with few livestock;

(b) The largest *percentage* decrease in beef cattle stock units occurred in Waikato;

(c) Auckland experienced the largest *percentage* increase in dairy cattle stock units in the North Island (albeit from a low base); and

(d) There were large *percentage* increases in dairy stock units in the South Island.

Figure 7: Change in Livestock Units between 1990-91 and 2017-18 (%)



KEY PHYSICAL AND FINANCIAL FEATURES OF COMMERCIAL SHEEP AND BEEF FARMS

37. B+LNZ's Sheep and Beef Survey analyses and reports on farm **businesses**, which means combining financial accounts. Usually there is more than one set of accounts associated with a "farm". Further, the financial structures of farm businesses vary greatly, for various reasons.

38. In summary:

    (a) Farms vary considerably;

    (b) Farm businesses vary considerably;

    (c) Overall, an average of under 80 percent of a farm is used for grazing. The other 20+ percent provides non-farming services.

    (d) Most farms have multiple sources of revenue, reflecting the management by the farmer of the natural capital and the objectives of the owner(s);

    (e) On average, revenue from sheep and wool combined accounts for about 55 percent of total gross farm revenue – more on some farms, and less on others;

    (f) Dairy Grazing Revenue averages 4-5 percent of total gross farm revenue;

    (g) The weighted average stocking rate was 6.4 SU per effective hectare, which is equivalent to about three-quarters of one Friesian cow per ha; and

    (h) These farms have the equivalent of about 1.75 FTEs of labour on average. That is equivalent to 16,000 FTEs working on commercial sheep and beef farms.

SECTOR REVENUE – ON-FARM

39. The charts in Figures 14-17 provide an overview of the estimated value of production at the farm gate. This values all on-farm production at prices received for production as it leaves the farm.

40. Sheep and beef has been increasing gradually, and roughly doubled, to just under $200m in nominal terms (i.e. not adjusted for inflation). Note that this trend is the opposite of the trend in sheep and beef cattle numbers, which was described earlier, i.e. fewer livestock and less total area.

41. Dairy grazing revenue increased steadily – in response to the farm-gate milk price – and declined sharply when the farm-gate milk price turned down.

42. Dairy production has increased more rapidly, but the trend also reflects volatility in farm-gate milk prices, which is most clearly seen in recent years.

SHEEP AND BEEF FARMING IS COMPLEX AND HETEROGENEOUS

43. Sheep and beef farming is carried out on all land types, climate zones, and topographies, and there are considerable differences in farm size. Thus, sheep and beef farming is as diverse as these characteristics, combined with the diversity that is farmers as humans who adapt to those factors while endeavouring to meet their objectives. The fundamental principle is to optimise the farming systems to take account of the natural capital of the land and the farming business's objectives. This includes intra-seasonal patterns of pasture growth, which means sheep and beef farmers have to manage carefully their resources. As a result, sheep and beef farmers have to be resilient and responsive to climate, weather and market signals.

44. This includes the connections throughout the value chain. Certain sheep and beef farms, particularly hill country, specialise in breeding stock that are sold as so-called *store* stock to other farms that finish them for processing as *prime* stock. Thus there is an integrated market system of livestock flow – from breeding to finishing to processing to sales to markets – both domestic and export.

45. Since the reforms in the 1980s and the expansion of dairy onto what was prime sheep finishing land, a bigger proportion of the lambs born on hill country is finished on hill country.

46. In 1990-91, we estimate around 30 percent of the lambs processed in New Zealand were finished on hill country, and 70 percent were finished on finishing land. By 2016-17, the split was 50:50 – 50 percent of lamb processing was of lambs finished in hill country.

TYPES OF COMMERCIAL SHEEP AND BEEF FARMS

47. B+LNZ characterises farms (farm businesses) into eight farm classes, which, for the avoidance of doubt, combine physical and financial characteristics that means *"Farm Class"* is broader than just the physical characteristics, e.g. Land Use Capability (LUC) class. Indeed, many of the properties that one would call a "farm" have multiple LUC units. The constraints provided by physical characteristics of a farmer's property are taken into account when conducting business to meet the family's objectives so that the farming

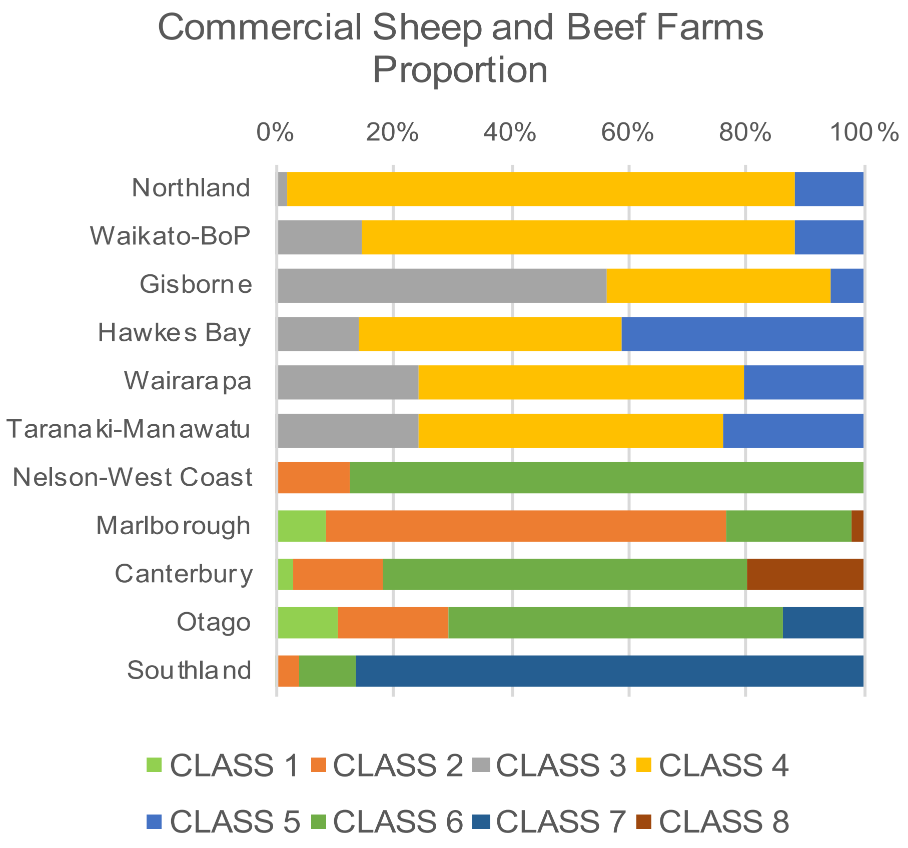
system is sustainable across all capitals i.e. natural capital (natural resources), and financial capital; socially and culturally.

48. The characteristics of each of the Farm Classes are described in Appendix 1: Description of B+LNZ Sheep and Beef Farm Survey.

NUMBER OF COMMERCIAL SHEEP AND BEEF FARMS

49. The number of commercial sheep and beef farms has declined as farms have amalgamated, dairy conversions have occurred, as the public conservation estate and urban New Zealand have expanded among other reasons (see Figure 8).

Figure 8: Estimated Proportions of Commercial Sheep and Beef Farms by Region



PHYSICAL CHARACTERISTICS OF COMMERCIAL SHEEP AND BEEF FARMS

50. We estimate, from New Zealand's official statistics that are collated by Statistics New Zealand, there were approximately 9,200 commercial sheep and beef farms in New Zealand in 2017-18.

51. The results of B+LNZ's Sheep and Beef Farm Survey and forecasting estimate the effective area averages about 680 ha though it varies considerably (see Figure 9).

Figure 9: Average Effective Area of Commercial Sheep and Beef Farms (ha)

52. About 1,400 or 15 percent of these farms exceed 900 hectares (see Figure 10 and Figure 11). These farms carry thousands of Stock Units (SU) but have a low stocking rate, which reflects the farmer assessment of his environment.

Figure 10: Distribution of Effective Area (ha) by Number – 2017-18

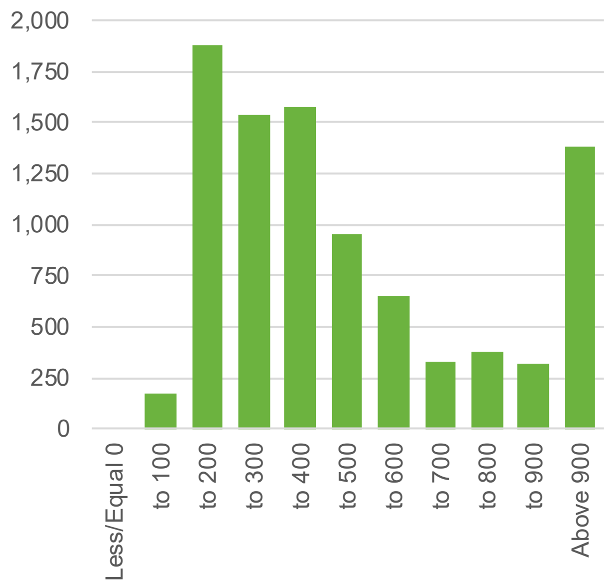
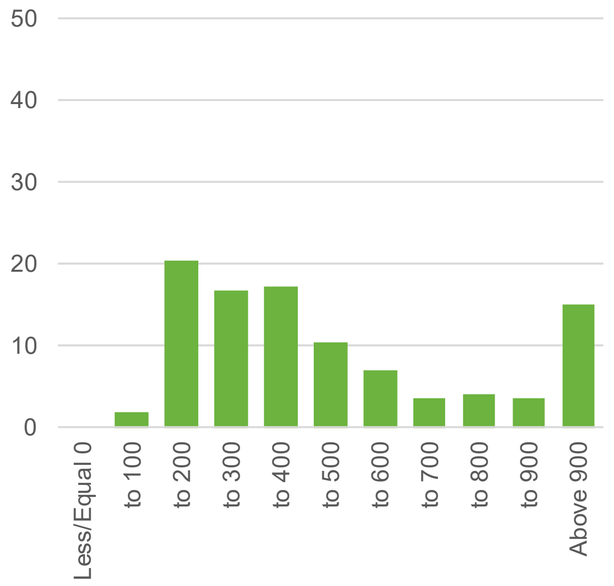


Figure 11: Distribution of Effective Area (ha) by Percentage – 2017-18



53. The average stocking rate has trended down over the last 30 years (see Figure 12) – faster in the North Island than in the South Island (see Figure 13).

Figure 12: Average Stocking Rate (SU/ha) in New Zealand

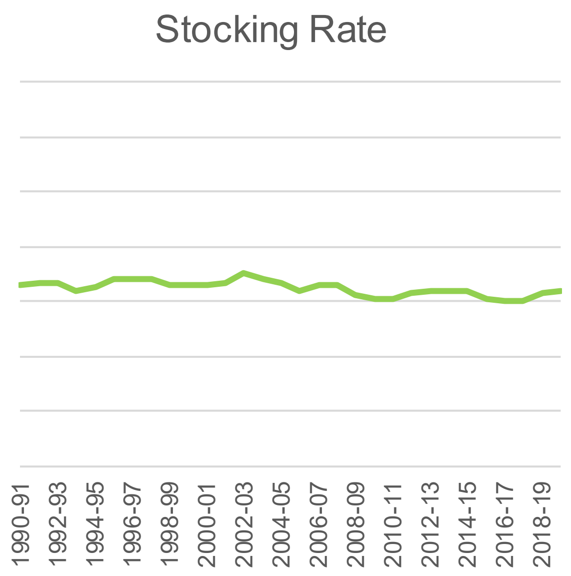
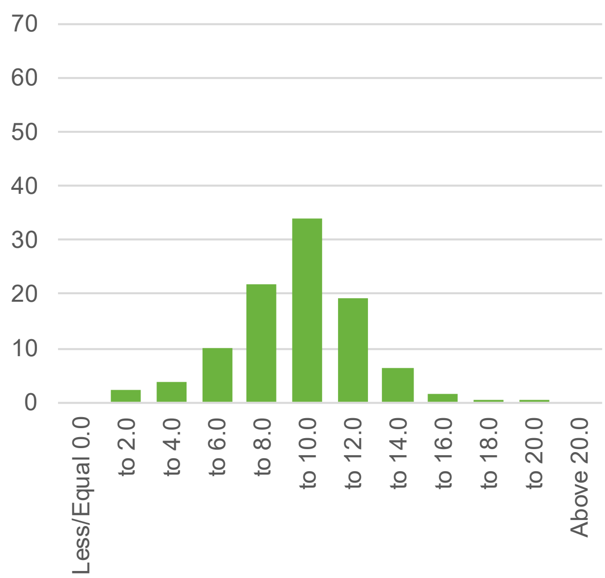


Figure 13: Average Stocking Rate (SU/ha) in North Island and South Island

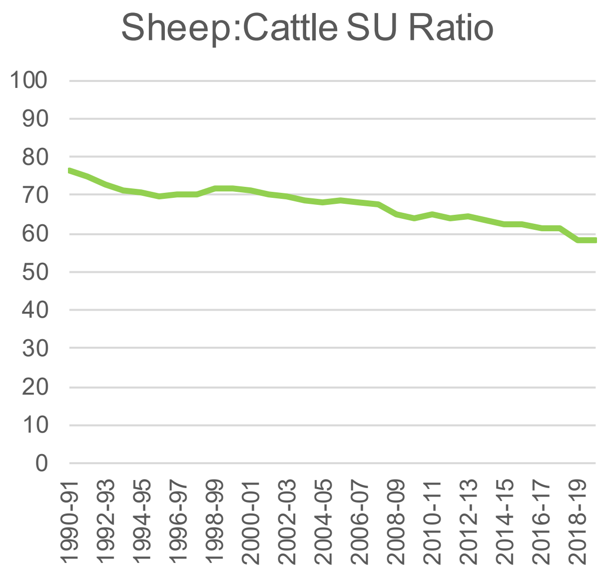
54. The distribution of stocking rate is shown in Figure 14. Ninety-seven percent of commercial sheep and beef farms had a stocking rate that was less than or equal to 14 SU/ha in 2017-18. Therefore, about three percent of commercial sheep and beef farms (or 250) have a SR exceeding 14 SU/ha.

Figure 14: Distribution of Stocking Rate in New Zealand - 2017-18



55. The average ratio of sheep-to-cattle SU has also trended down (see Figure 15).

Figure 15: Average Sheep-to-Beef Cattle Ratio in New Zealand



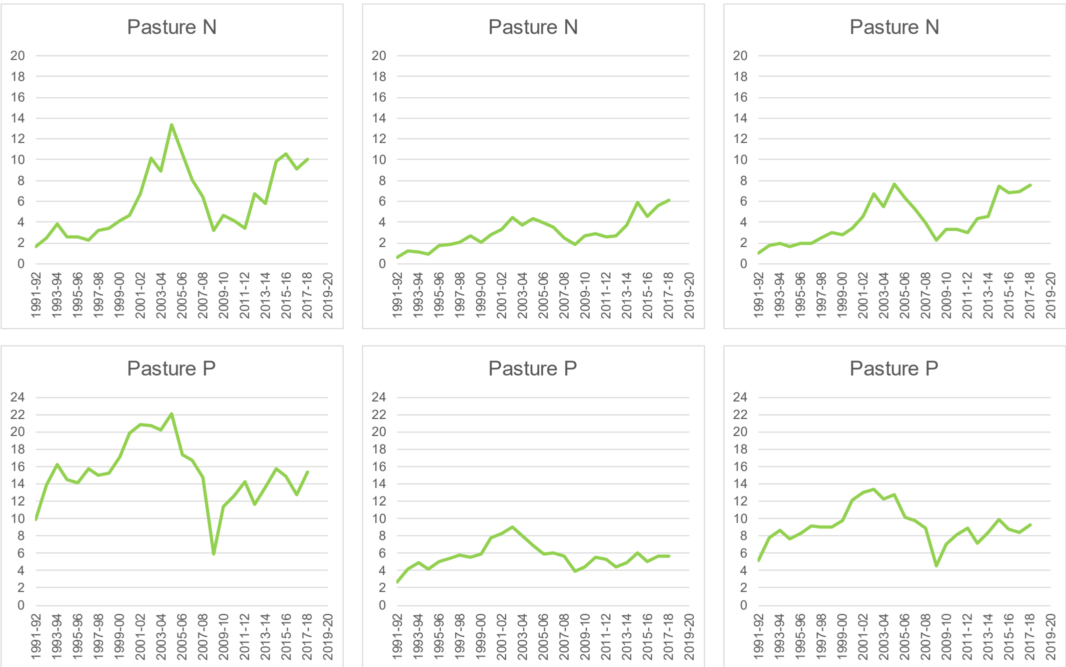
FERTILISER USE

56. Figure 16 show time-series information about fertiliser **applications** on sheep and beef farms.

57. In summary, the **application** of elemental N and P, which are shown in Figure 16, is low. The same can be said of applications of K and S.

58. Nutrient **losses** from case study farms, are covered in other sections.

Figure 16: Fertiliser Applications by Nutrient (kg/ha) for North Island, South Island and New Zealand



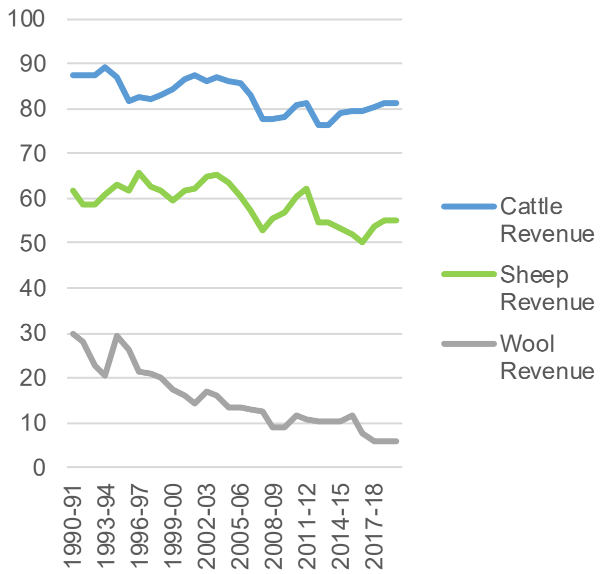
GROSS FARM REVENUE – WEIGHTED AVERAGE ALL CLASSES

REVENUE FROM SHEEP AND BEEF CATTLE

59. Figure 17 shows the trends in sources of average Gross Farm Revenue per farm for commercial sheep and beef farms New Zealand from 1990-91 to 2017-18. It provides a useful overview for broad understanding of the sector though one needs to consider the complexity and diversity of farms around the average.

60. Over time, the importance of wool has declined and thus so has the combination of wool, sheep and cattle revenue as farmers have diversified. In 1990-91, nearly 90 percent of Gross Farm Revenue came from sheep (wool and meat) and cattle. In 2017-18, 80 percent of Gross Farm Revenue was from these three sources combined.

Figure 17: Cumulative Share of Gross Farm Revenue (percent)



REVENUE FROM DAIRY GRAZING

61. “Winter/dairy/intensive grazing” means different things to different people because of the diversity and complexity of sheep and beef farming and the business relationships between sheep and beef farmers and those wanting to graze out their livestock.

62. Dairy grazing revenue is defined in the Sheep and Beef Farm Survey as revenue earned from grazing dairy livestock – of any age.

63. Dairy grazing revenue grew steadily through the 2000s in the North Island and then plateaued, while in the South Island dairy grazing revenue has increased steadily though fluctuated since 2010-11 (see Figure 18).

64. However, to put this in perspective:

(a) Note that dairy grazing revenue averages 4-5 percent of Gross Farm Revenue on commercial sheep and beef farms;

(b) Around 85 percent of commercial sheep and beef farms did not earn any revenue from dairy grazing in 2017-18 (see Figure 20), with the proportions in the North and South Islands similar to each other;

(c) In the North Island, nearly 60 percent of commercial sheep and beef farms did not have any winter feed area in 2017-18 (see Figure 19);

(d) In the South Island, winter feed is more important. The area planted in winter feed crops was the equivalent of up to 10 percent of Effective Area on just over half of commercial sheep and beef farms (see Figure 19).

Figure 18: Dairy Grazing Revenue as a percentage of Gross Farm Revenue for North Island, South Island and New Zealand

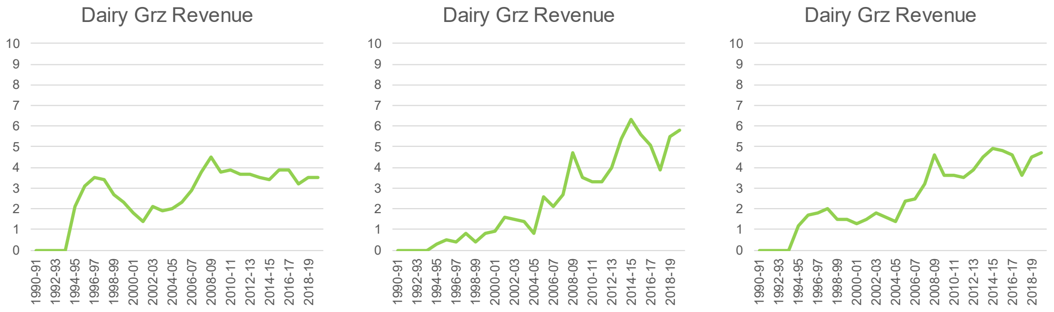


Figure 19: Distribution of Winter Feed Area as a percentage of Effective Area for North Island, South Island and New Zealand

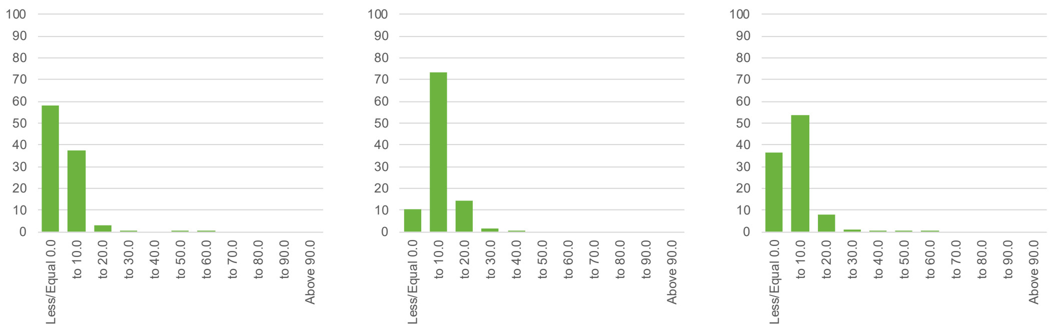
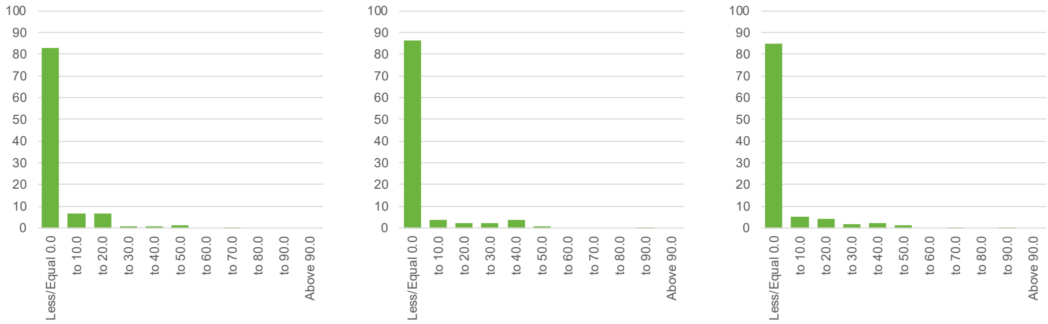


Figure 20: Distribution of Dairy Grazing as a percentage of Gross Farm Revenue for North Island, South Island and New Zealand



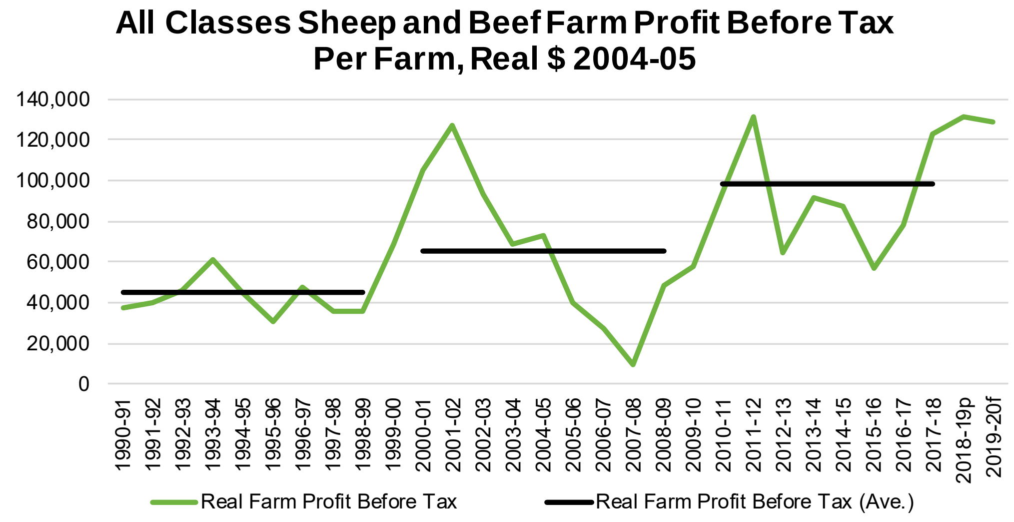
PROFITABILITY

65. Profitability in sheep and beef farming has fluctuated over time. It weakened during the 1980s and 1990s following deregulation and improved in the early 2000s as depreciation of the New Zealand dollar boosted revenue. Subsequent fluctuations have resulted from fluctuations of product prices, and seasonal conditions, which impacted on productivity. It is important to note the diverse range of products that come from sheep and beef farms. This reflects farmers' approach to risk management as they respond to the limitations imposed by the factors of production – land, labour and capital – and to the physical and financial environment.

66. Figure 21 shows the average inflation-adjusted profitability (using real[1] farm profit before tax) for commercial sheep and beef farms between 1990-91 and 2017-18. The peaks and troughs reflect the mix of livestock and the fortunes of each.

[1] That is, adjusted for inflation

Figure 21: Inflation-adjusted Farm Profit Before Tax per Farm



Source: Beef + Lamb New Zealand Economic Service, Sheep and Beef Farm Survey

67. The same trend applies when size is accounted for, i.e. moving from per-farm to per-hectare measures.

LAMB EXPORTS

68. New Zealand exports lamb to nearly 100 countries but there are some key countries, however, China, US, UK, Germany, Netherlands and Germany accounted for two-thirds of the volume exported in 2018-19. The UK is a longstanding market for New Zealand lamb having first become a market following the industrial revolution, when the steam engine was developed, which resulted in freezing technology.

69. The UK was overtaken by China in 2016-17 and the US in 2018-19, however, the countries demand different products, which is reflected in the different average value figures shown in Figure 22. China moved up from sixth-largest market by total value in 2008-09 to largest in 2016-17. It has traditionally been a market for cuts of lower average value but more recently higher value cuts, such as those from shoulders and legs, are beginning to feature, which reflects new growth opportunities.

Figure 22: Top Lamb Export Markets by Value – September Year

	2008-09	2015-16	2016-17	2017-18	2018-19	2018-19 $ 000	2018-19 $ per tonne	$ per t % change 2017-18 to 2018-19
1	UK	UK	China	China	China			
2	France	China	UK	UK	USA			
3	Germany	USA	USA	USA	UK			
4	USA	Germany	Germany	Germany	Germany			
5	Belgium	Netherlands	Netherlands	Netherlands	Netherlands			
6	China	France	France	France	Canada			
7	Canada	Canada	Canada	Canada	France			
8	Saudi Arabia	Belgium	Saudi Arabia	Belgium	Japan			
9	Netherlands	Switzerland	Belgium	Japan	Belgium			
10	Japan	Japan	Japan	Jordan	Saudi Arabia			
11	Switzerland	Jordan	Jordan	Saudi Arabia	Jordan			
12	Italy	Saudi Arabia	Switzerland	Switzerland	Malaysia			
13	Jordan	Italy	Malaysia	Malaysia	Switzerland			
14	Hong Kong	Sweden	Sweden	Taiwan	Hong Kong			
15	Greece	Hong Kong	Taiwan	Sweden	Taiwan			
						3,206,691	10,508	3.1%

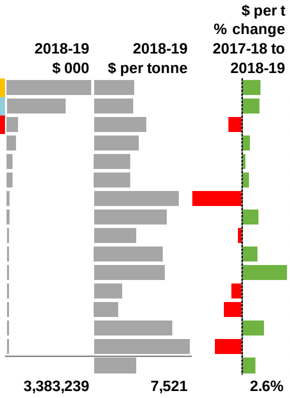
Source: Beef + Lamb New Zealand Economic Service

BEEF AND VEAL EXPORTS

70. China and the US are the key markets for beef exports. New Zealand has a long history of supplying lean beef to the US, primarily for blending with, and adding value to, fat that is trimmed from steers and heifers that are finished in feedlots – in the US mostly, and Canada – to produce ground beef. The majority of beef consumption in the US is in ground beef form. Frozen New Zealand beef provides a valuable ingredient because, among other things, it is consistent, and production is reliable, it has superior food safety credentials, there are well-established supply chain processes, including processing in New Zealand, shipping services, business practices, commercial and legal remedies if needed, and distribution through the US system. Market significance is reflected through export volumes, which are predominantly ingredient beef and sold at a low price per tonne. Exports to China, which became New Zealand's largest market by value in 2018-19, have grown rapidly increasing from less than 500 tonnes in 2007-08, to over 170,000 tonnes in 2018-19. This reflects a large increase in demand as supply chains develop, and as demand for lower value cuts increased.

Figure 23: Top Beef and Veal Export Markets by Value – September Year

	2008-09	2015-16	2016-17	2017-18	2018-19
1	USA	USA	USA	USA	China
2	Japan	China	China	China	USA
3	Canada	Taiwan	Taiwan	Taiwan	Japan
4	Taiwan	Japan	Japan	Japan	Taiwan
5	South Korea	Canada	South Korea	South Korea	South Korea
6	Indonesia	South Korea	Canada	Canada	Canada
7	Hong Kong	Indonesia	Netherlands	Netherlands	Netherlands
8	French Polynesia	Netherlands	Indonesia	Malaysia	United Arab Emirates
9	UK	French Polynesia	United Arab Emirates	United Arab Emirates	Switzerland
10	Singapore	United Arab Emirates	Hong Kong	Hong Kong	French Polynesia
11	Italy	Hong Kong	French Polynesia	French Polynesia	Hong Kong
12	Philippines	Malaysia	Singapore	Indonesia	Malaysia
13	United Arab Emirates	Singapore	Malaysia	Philippines	Indonesia
14	Netherlands	Germany	Germany	Singapore	Singapore
15	Spain	Saudi Arabia	Saudi Arabia	Germany	Germany



Source: Beef + Lamb New Zealand Economic Service

71. Meat processors and exporters produce and export a wide range of items from the livestock they process. This includes hides and skins, tallow and offal – edible and inedible – meat and bone meal. These make significant contributions to New Zealand's merchandise exports.

CONCLUSION

72. Agriculture is a major economic activity in New Zealand and is becoming relatively more important over time. The sheep and beef sector is significant and a major employer. These factors combined mean that the sheep and beef sector is inextricably linked to the viability and economic success of the country and communities within it.

73. The New Zealand sheep and beef sector's total value of production is $12.7 billion with exports worth $9.8 billion and domestic sales worth an additional $2.9 billion in 2018. The sector employs around 80,000 people, of which 59,000 are directly employed, while an additional 21,000 are indirectly employed.

74. The sector exports over 90 percent of its production, it is New Zealand's second largest goods exporter and New Zealand's largest manufacturing industry. The health and wellbeing of the red meat sector within New Zealand is important to the economy and regional New Zealand, accounting for 4.2 percent of gross domestic product in 2017.

75. The sheep and beef industry is an adaptable and resilient sector, and is continually making efficiency gains in red meat production. Through continued innovation and adoption of technology of all sorts, including but not limited to digital technologies, sheep and beef farmers have increased meat

production, while decreasing total animal numbers, and while losing to other land uses the land that is most productive for production of high-quality protein. To remain resilient in future, sheep and beef farmers need flexibility to adjust their systems to respond to changing conditions.

76. Farming is not always profitable, yet farmers have undertaken considerable amounts of environmental activity. Any new on-ground actions must be spread over a number of years to manage the volatility that occurs from fluctuating physical and financial performance.

APPENDIX 1: DESCRIPTION OF B+LNZ SHEEP AND BEEF FARM SURVEY

BACKGROUND

77. The B+LNZ Sheep and Beef Farm Survey (the Survey) is conducted using a random sample of over 500 farm businesses ("farms") each year. Data for the whole farm business are collected and analysed, and recorded in a computer database, characterising each farm on over 2000 metrics, including:

    (a) Reconciliations of livestock, wool production and sales, feed, and cash crops;

    (b) Production, such as meat weights, wool grades, calving and lambing percentages;

    (c) Inputs, such as fertiliser (Nitrogen, Phosphorus, Potassium, and Sulphur), animal health, labour, repairs and maintenance, interest, and rates; and

    (d) Full financial analysis of revenue and expenditure, the balance sheet and flow of funds to identify the cash flows in and out of the business.

78. The Survey is about actual data, not intentions.

79. To qualify for the Survey, a farm has to winter at least 750 sheep (or equivalent sheep plus beef cattle Stock Units (SU)), must be privately operated (i.e. not run by the State), and must not be run in conjunction with another property. In addition, three other conditions must be satisfied:

    (a) At least 70 percent of the farm revenue must be derived from sheep, or sheep plus beef cattle (except in the case of mixed finishing farms of Canterbury);

    (b) At least 80 percent of the Stock Units (SU) on the property must be sheep and/or beef cattle SU; and

    (c) The farm must be run as an ordinary commercial sheep and beef farm (i.e. not as a stud or dealer-type farm).

80. The sampling unit and analysis in the Sheep and Beef Farm Survey is of the farm and farm business.

HOW ARE THE DATA COLLECTED?

81. A team of Economic Service Managers (presently eight) is employed to collect and analyse data for the Survey. Their role is to:

    (a) visit each farm annually for a production and financial interview;

    (b) conduct two other surveys – of livestock numbers and lambing – using the same Survey sample/framework;

    (c) obtain, standardise and balance financial accounts;

    (d) create accurate and realistic livestock reconciliations;

    (e) calculate a property valuation using data available from Quotable Value Ltd;

    (f) canvas and solicit new farms, which have been randomly selected by Statistics New Zealand and whose principals have authorised SNZ to provide B+LNZ with the PII (personally identifiable information) required to contact the farmer;

    (g) manage the relationship with each farmer's accountant as agreed with the farmer;

    (h) forecast returns to an animal species and age level;

    (i) biannually forecast Income and Production by Farm Class and production region;

    (j) clarify/improve existing data definitions and promote new metrics (e.g. environmental); and

    (k) address industry stakeholders at key times during the season.

HOW IS THE SAMPLE MANAGED TO ENSURE IT IS STATISTICALLY REPRESENTATIVE?

82. To ensure the survey sample is statistically representative, the following methods are used:

    (a) Survey farms are randomly selected;

    (b) The population is stratified by farm size, location; and type (Farm Class);

(c) Variable sampling fractions; and

(d) At least 25 farms are included in each stratum to avoid outliers skewing the results.

RANDOM SELECTION

83. The sample is drawn by Statistics New Zealand from Agricultural Production Census records using the above criteria. During the first farm visit, B+LNZ's Economic Service Manager will make a final determination on whether the farm qualifies for the Survey.

STRATIFICATION

84. The population is divided into groups (strata) that are more or less homogeneous. Each stratum is sampled at random which ensures that groups within the population are adequately represented.

85. Three main kinds of stratification are used:

Geographical Stratification

86. The aim is to spread the total sample of farms over the vast majority of sheep and beef farming districts in New Zealand, by a process of random selection proportionate to the sheep and beef farm populations.

Size Stratification

87. Initially, all farms with fewer than 750 stock units and Crown properties are excluded. This reduces the population to those defined as "commercial sheep and beef farms". Farms are then randomly selected in proportion to the distribution of sizes within the geographical stratification.

Farm Class Stratification

88. The Survey results are classified into eight Farm Classes, see Table 1. It must be stressed that this classification is about the nature of the farm business, which includes, but is not limited to, topography, and the way in which the farm is managed, not solely Land Use Capability (LUC) class, with which it is sometimes confused.

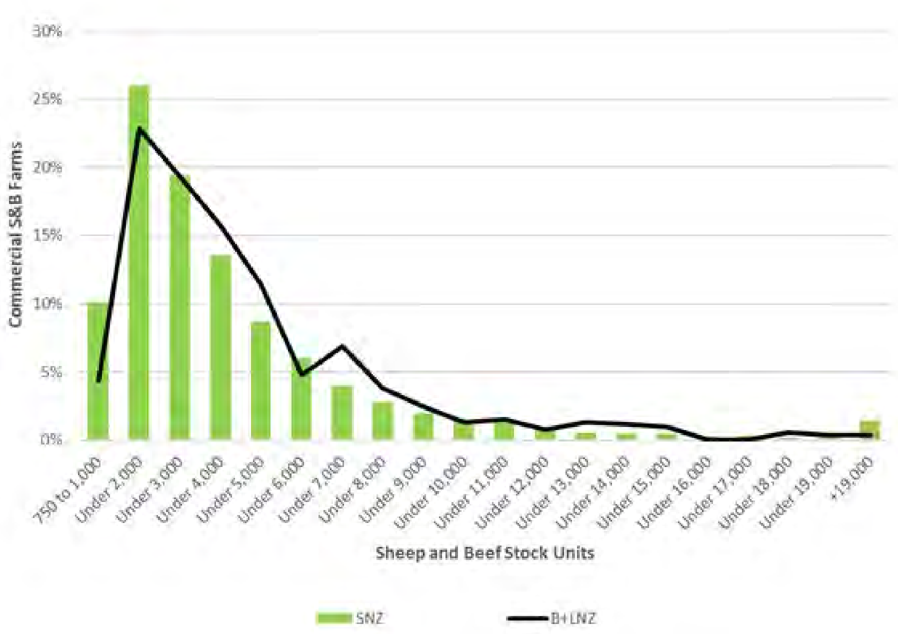
Table 1: Farm Class Descriptions

Farm Class 1 - South Island high country	Extensive run country at high altitude carrying fine wool sheep, with wool as the main source of revenue. Located mainly in Marlborough, Canterbury and Otago.
Farm Class 2 - South Island hill country	Mainly mid-micron wool sheep mostly carrying between two and seven stock units per hectare. Three quarters of the stock units wintered are sheep and one quarter beef cattle.
Farm Class 3 - North Island hard hill country	Steep hill country or low fertility soils with most farms carrying six to 10 stock units per hectare. While some stock are finished a significant proportion are sold in store condition.
Farm Class 4 - North Island hill country	Easier hill country or higher fertility soils than Class 3. Mostly carrying between seven and 13 stock units per hectare. A high proportion of sale stock sold is in forward store or prime condition.
Farm Class 5 - North Island intensive finishing	Easy contour farmland with the potential for high production. Mostly carrying between eight and 15 stock units per hectare. A high proportion of stock is sent to slaughter and replacements are often bought in.
Farm Class 6 - South Island finishing-breeding	A more extensive type of finishing farm, also encompassing some irrigation units and frequently with some cash cropping. Carrying capacity ranges from six to 11 stock units per hectare on dryland farms and over 12 stock units per hectare on irrigated units. Mainly in Canterbury and Otago. This is the dominant farm class in the South Island.
Farm Class 7 - South Island intensive finishing	High producing grassland farms carrying about 10 to 14 stock units per hectare, with some cash crop. Located mainly in Southland, South and West Otago.
Farm Class 8 - South Island mixed cropping and finishing	Located mainly on the Canterbury Plains. A high proportion of their revenue is derived from grain and small seed production as well as stock finishing.

HOW DO SAMPLE DATA RELATE TO POPULATION DATA?

89. Farms included in the Survey represent about 4.5 percent of commercial Sheep and Beef Farms in New Zealand by number.[2] The sample is drawn to represent the productive base of the industry, as measured by Stock Units (SU).[3]

Figure 24: Commercial Sheep and Beef Farm Population vs. Sheep and Beef Farm Survey Sample



"WEIGHTED AVERAGE ALL CLASSES" FIGURES ARE USED TO PRESENT REGIONAL AND NATIONAL PICTURES

90. Weighted averages are calculated by weighting the average of each metric of the eight Farm Classes by their proportion of farms to total farms in the population. The weighting process allows each Farm Class to be represented in proportion to its relative importance in the sheep and beef farm industry.

---

[2] A commercial sheep and beef farm is defined by a number of criteria, the most significant of which are that the farm winters at least 750 sheep and beef Stock Units and earns at least 70 percent of its revenue from sheep, beef cattle, long-term dairy grazing and crops.**Invalid source specified.**

[3] One Stock Unit (SU) is the equivalent of one breeding ewe that weighs 55 kg and bears one lamb. The amount of feed consumed by this ewe over a year is approximately 550 kg dry matter (including the feed consumed by her lamb up to weaning, at about 3.5 months). (Trafford and Trafford, 2011).

91. For example, consider the South Island high country farms (Farm Class 1) that make up around 1.5 percent by number of the total sheep and beef farm population covered by the Survey. This percentage is the weight that Farm Class 1 data have in the "Weighted Average All Classes" data. In contrast, North Island Hill Country (Farm Class 4) farms make up around 30 percent of the sheep and beef farm population, so their weight in the New Zealand "Weighted Average All Classes" data is more significant. The simple average of the individual Farm Class averages cannot be used because this would assume that each Farm Class is of equal importance within the industry, which it is not. The weights used to calculate the "Weighted Average All Classes" data are reviewed regularly using the population frame discussed earlier.

92. The "Weighted Average All Classes" figures are used to describe trends for the whole industry at the regional and national level. These averages provide a guide to the physical and financial characteristics of the sheep and beef farm sector and are useful to evaluate trends, policy changes and shifts in economic conditions.

93. The "Weighted Average All Classes" data provide a concise statement of the sheep and beef industry at a point in time. The "Weighted Average All Classes" data should be used with discretion and only after a full understanding of its derivation is gained, particularly because farms are distributed around the average of each metric.

APPENDIX 4: EVIDENCE IN CHIEF OF DR CHRIS DADA ON BEHALF OF BEEF + LAMB NEW ZEALAND ON WAIKATO REGIONAL COUNCIL PC1

BEFORE THE INDEPENDENT COMMISSIONERS

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the Proposed Waikato Regional Plan Change 1- Waikato and Waipā River Catchments and Variation 1 to proposed Plan Change 1
AND	
IN THE MATTER	of submissions under clause 6 First Schedule
BY	**BEEF + LAMB NEW ZEALAND LIMITED** **Submitter**

BRIEF OF EVIDENCE OF DR CHRISTOPHER AYOKUNLE DADA

15 February 2019

FLETCHER VAUTIER MOORE
LAWYERS
PO BOX 3029
RICHMOND 7050

Telephone: (03) 543 8301
Facsimile: (03) 543 8302
Email: cthomsen@fvm.co.nz
Solicitor: CP Thomsen

TABLE OF CONTENTS

BACKGROUND

QUALIFICATIONS AND EXPERIENCE

1. My full name is Christopher Ayokunle Dada.

2. I am an environmental health microbiologist, specializing in the fate, transport, detection, and control of pathogens in environmental media.

3. I hold a BSc honours degree (First Class) in Microbiology from the University of Ado-Ekiti. I also completed an MSc in Water Science, Policy and Management at Oxford University's Centre for the Environment which adequately equipped me to provide high-level advisorial support to decision makers, managers and policy makers in water policy and management. My PhD research focused on the molecular characterization of faecal indicator bacteria and antibiotic resistant pathogens in aquatic environments.

4. I have published extensively on public health aspects of faecal pollution in water (co-authored 38 peer-reviewed scientific publications, 10 as lead author and 26 in international journals). I am still actively engaged in research, especially around the environmental fate and effects of microbial contaminants in New Zealand.

5. I have also been involved in environmental effects assessment projects in New Zealand. This involved using a variety of catchment, hydrodynamic and empirical models to assess/predict the effect of past/future management decisions on water quality.

SCOPE OF EVIDENCE

6. I have been requested by Beef + Lamb New Zealand to provide expert evidence on the fate and transport of faecal indicator bacteria (FIB) and pathogens from pastures to receiving waters relevant to the proposed Waikato Regional Council proposed Plan Change 1 and variation 1 (henceforth PC1) for the Waikato and Waipa River Catchments. This analysis is undertaken as numerical *E.coli* freshwater outcomes and targets are provided for in WRPC1 through table 3.11-1, along with associated management responses in relation to land use and stock access to waterbodies. My evidence is structured under the following headings:

(a) An overview on the sources, fate and transmission pathways of microbial contamination from primary productive land into receiving water,

(b) Zoonotic diseases of concern from primary productive land uses conveyed through freshwater,

(c) Issues with monitoring waterborne pathogens in New Zealand,

(d) A summary of regionally relevant studies and comments on E coli reduction approaches/targets (including Table 3.11-1) and concerns specifically related to the assumptions used in the adopted *E.coli* models. This section also includes an analysis of *E.coli* data for streams in the PC1 catchment to identify the occurrences of peaks in FIB concentrations, during actual baseflow and stormflow conditions, and,

(e) An assessment on the proposed rules that require cattle, deer and pigs to be excluded from all permanently flowing waterbodies up to a land slope of 25 degrees. This section also includes an assessment on the effectiveness of fencing small waterbodies to reduce catchment microbial loads, which is supported by an analysis of relationships between *E.coli* and stream order using monitoring data and review of other regionally relevant studies.

EXPERT WITNESS CODE OF CONDUCT

7. I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2014. This evidence has been prepared in accordance with it and I agree to comply with it. I confirm that the opinions I have expressed represent my true and complete professional opinions. The matters addressed by my evidence are within my field of professional expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

REPORTS USED IN PREPARING THIS EVIDENCE

8. In preparing this evidence I have reviewed the reports and statements of evidence of other experts including:

(a) Officers section 32 report;

(b) Officers section 42A report;

(c) Expert evidence of Mr Andrew Burtt;

(d) Expert evidence of Dr Jane Chrystal;

(e) Expert evidence of Mr Richard Parkes;

(f) Expert evidence of Dr Cox.

EXECUTIVE SUMMARY

9. The modelling that underpins the PC1 decision making failed to include key factors that influence variabilities in *E.coli* levels in primary productive land and receiving streams. Furthermore, formula and coefficients applied in the model were not explicitly stated, thus preventing independent verification of inputs and outputs of the model. This is important because modellers 'optimise' these coefficients/functions to best make the data fit and the failure to disclose this information means that the model on which the PC1 decision making was based cannot be independently verified to be trustworthy. Also, the *E.coli* models that informed the decision making process in the PC1 were not tested with new measured data not originally included during the model development, a standard process in model validation. These uncertainties coupled with other reasons previously stated seem to render the model unfit to inform or underpin PC1.

10. The approach taken in PC1 to monitoring *E.coli* levels as a proxy for the presence of zoonotic pathogens does not distinguish between concentrations during different flow conditions. The PC1 uses the 95th percentile sample results from the previous 5 years as an indicator of an overall achievement of the E. coli target in Table 3.11-1. This evidence notes that 95th percentile *E. coli* concentrations are rare events that are associated with storm flows and will only reflect in 5% of the observed data used to make this judgement. In simple terms, only 5% of the monitoring data will be higher than the 95th percentile concentration, regardless of the number of "previous years" of data considered. A conservative threshold set at 540 colony forming units (CFU)/100mL 95th percentile concentration, regardless of the season may mean that health risks associated with exposure to pathogens are over-estimated, particularly during non-swimming periods when the FIB population are largely driven by periods of

high flow. Considerations for flow conditions may warrant the establishment of a stringent maximum limit for faecal coliform bacteria per 100mL sample during the "swimming season" (typically during base and low flows) and a less stringent limit for all other times (storm flows). Based on these conclusions , I recommend that:

(a) The *E.coli* targets need to be revised and the policy wording should be amended to read 'the *E.coli* concentration of the water must not exceed (table 3.11-1 revised numerical parameter given in CFU/100mL) when the river is at or below medium flow (the 50th percentile flow).

(b) If it is impossible to designate revised Table 3.11-1 *E.coli* targets in line with recommendation (a) above, then the *E.coli* targets should be amended to comply with the National Policy Statement for Freshwater Management (NPS-FM) *E.coli* Attribute State thresholds. Using this approach, an indicator of improvement in bacteriological water quality could be tied to at least two of the four numeric attribute statistics in the NPS-FM guidance document. For instance, this could be a combination of median and 95th percentile *E.coli* concentrations to infer improvement in NPS-FM Attribute States rather than a reliance on the single 95th percentile as it is currently in the PC1 Table 3.11-1. A table of suggested targets is also presented in this evidence. This approach will help authorities work with more realistic short-term targets hinged on improvements in the NPS-FM attribute state of the PC1 sites.

11. A key issue for the PC1 with respect to *E.coli* is the source of faecal pollution at the PC1 sites for which *E.coli* reduction targets are set. Currently, it is not known for certain what the sources of faecal pollution are for these streams and rivers, yet declarations have been made to drastically reduce *E.coli* levels to certain levels (up to 2000% anticipated reduction for some streams). Only when we cross over the first milestone of reliably identifying sources responsible for elevated bacteria levels at each site, can we begin to identify an appropriate solution that will drive down observed elevations in *E.coli* levels, rather than a mere declaration of anticipated reduction targets without the means of achieving it. In hilly or steep lands in New Zealand and in flat, poorly drained land in the greater Waikato region, high

runoff potential under high rainfall is largely associated with overland transport into receiving streams. A review of published studies indicate that direct deposition is a minor percentage of total annual catchment *E.coli* loads to waterways in the Waikato Region, and that surface runoff is the major source of faecal pollution from agriculture in the Waikato Region. It is logical that if the streambank fencing is erected for reducing animal access and delivery of *E. coli* to water ways, there could still be elevated *E.coli* levels in PC1 streams that run through agricultural catchments. Rather than a 'blanket fencing approach' currently proposed in the WRPC1, a more effective response to reduce the risk of pathogens from agricultural land uses entering waterbodies is the identification and management of critical source areas.

12. Apart from critical source areas, site-specific management options informed by microbial source tracking (MST) studies at each PC1 site can help determine the contributory source of faecal pollution, and hence support mitigation efforts for the PC1 streams. Without these MST studies, I am of the opinion, from a technical (microbiological) perspective, that the targets related to *E.coli* reductions at the freshwater sites listed in PC1 are ambitious, unrealistic, and unecessary, and they present a cart 'before the horse' approach. We need to begin to ask the hard questions. Are elevated bacteria due to direct deposition of farm animals? If yes, which animals are largely responsible for these faecal droppings? While for some sites, it may be unreasonable to commit financial resources to erecting wired fences when the cause of elevated *E.coli* levels is mainly as a result of wildlife faecal deposits during low flows and overland flow during wet events, for some other sites, erecting barriers to prevent direct access to animals during low flows may actually be needed. At this stage, without the MST studies, it is difficut to apply a generic management option to tackle *E.coli* loads at the PC1 sites.

13. Currently, the MST approach has only been applied to 5 out of the 62 WRPC1 sites. Even then, preliminary MST results show that wildfowl is the predominant source of faecal indicator bacteria in the WRPC1 streams and that cattle markers only become prevalent following heavy rainfall impacted (i.e. surface run-off and overland) conditions. Based on these arguments, I therefore recommend that authorities:

(a) Delete requirements to fence hill country streams, considering that it is a counter-intuitive approach to stopping overland flow.

(b) Increase requirements to identify and manage critical source areas and overland flow pathways. This will then lead to catchment-specific management intervention rather than a blanket approach to effect fences for stock exclusion which only stops direct deposition.

(c) Commission longitudinal site-specific MST studies targeted for each identified site in the WRPC1 Table 3.11.1. The study should also incorporate phylogenetic dimensions that are able to distinguish if these elevated bacteria levels in each WRPC1 site are due to naturalized *E.coli* from the stream bed and channel sediments. "Naturalized" *E. coli* populations falsely inflate measured *E.coli* levels, leading to exceedances of available thresholds and suggesting pollution that is present.

14. While further work is undertaken to improve our understanding of the sources of in-stream *E.coli* concentrations in the PC1 sites, authorities can adopt tentative yet cautious approach that includes consideration for flow conditions since surface runoff is the major source of faecal pollution from agriculture in the Waikato Region (as in recommendations (a) and (b) above).

SOURCES, FATE AND TRANSMISSION PATHWAYS OF MICROBIAL CONTAMINATION FROM LAND USED FOR PRIMARY PRODUCTION PURPOSE

15. In the context of this evidence, and in line with international literature, land used for primary production purposes refer to land used for one or more of the following activities:

(a) Cultivating crops for the purposes of selling the produce, including in a processed or converted state.

(b) Cultivating or propagating plants, seedlings, vegetables, mushrooms or orchids for sale.

(c) Maintaining animals or poultry for the purposes of selling them, their offspring or bodily produce (e.g. beef and sheep farming and dairying)

16. I agree with previously published literature[1] that one of the most important issues related to primary productive land use is the impact and interdependence of this form of land use on water resources. Agricultural production requires a stable supply of fresh, clean water for stock watering, irrigation of crops and pasture, as well as for other aspects of the farming operation. Farm 'runoff' includes contaminants from farm operations, and intensive operations usually also produce a stream of spent water and solid waste that can potentially affect the quality of receiving waters.

17. The impact of primary productive land use on water quality can be observed at differing temporal and spatial scales. For instance, these could range from the presence of individual stock at a stock crossing or an unprotected stretch of a waterway, to impact of improper manure management at the farm scale, to whole catchment effects of land management practices (for example massive catchment-wide changes in production systems).

18. Sources of faecal contamination from primary productive land include humans, livestock and wild animals, with pathogens being excreted in the faeces and occasionally urine. Although human faecal wastes present the highest risk of waterborne disease, given that the probability of human pathogens (disease-causing microorganisms) being present is highest, waste from this source is almost always adequately disposed of through some form of on-site or reticulated treatment system. Notwithstanding this treatment of human wastes, direct discharge of post-treatment effluent into

---

[1] Davies-Colley, R. (2003). Effects of rural land use on water quality. Ministry for the Environment.

FAO(1993) Water Resource Issues and Agriculture. In The State of Food and Agriculture , FAO Agriculture Series No. 26, ISSN 0081-4539

MfE (2004) Water Programme of Action: The Effects of Rural Land Use on Water Quality . Ministry for the Environment Technical Working Paper, July 2004. ME number: 563

PCE (2013) Water quality in New Zealand: Land use and nutrient pollution. Parliamentary Commissioner for the Environment report, November 2013.

receiving waters, or poorly-maintained septic tank systems can also be major sources of faecal loadings into receiving waters.

19. Per capita, faecal production by agricultural animals such as cattle and pigs exceeds that of humans. Hence, other than human waste, pastoral agriculture is the other major source of FIB in aquatic systems. Also, land use plays an important role in the inoculation, persistence, and dissemination of FIB. Faecal bacteria from primary productive lands can enter the stream network via direct deposition of faecal matter into the stream or via indirect pathways such as discharges of dairy effluent into streams, drainage via artificial drains, surface wash-off in areas of steep terrain, as well as from overland flow from excess irrigation water and water-logged conditions.

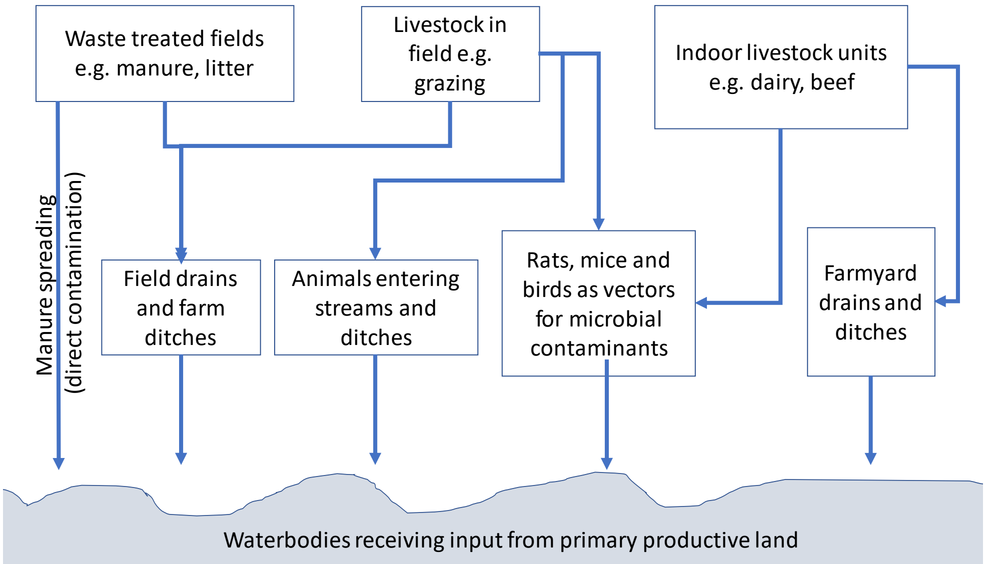


Figure 1: Sources and pathways of microbial water contamination from primary productive lands.

20. Of particular interest to this evidence are microorganisms associated with livestock (i.e. animal waste and animal manure) that are deposited on land, and on or near water bodies. The animal faecal wastes and other wastes (such as respiratory secretions and urine) of livestock and feral animals often contain high concentrations of pathogens. This include a variety of viruses such as hepatitis E virus, bacteria such as Salmonella species, and parasites such as Cryptosporidium parvum. A number of these pathogens

are endemic in commercial livestock and difficult to eradicate, and pose potential risks to human when transmitted to the wider environment

21. I agree with previous studies (e.g Doole, 2016[2], Romera and Doole, 2015[3]) that the amount of faeces deposited by livestock over the last 20 years has very likely increased given that stocking rates have increased. For example, the average national stocking rate for dairy cows increased by 18% from 2.44 cows ha-1 to 2.87 cows ha-1 over 1994–2014. It should be noted however that while this stocking rate versus faecal loading may logically appear positively correlated, the relationship between these is often cofounded by many other variables and uncertainties, as will be discussed later in this evidence.

22. Concentrations of some pathogens occur at levels of millions to billions per gram of wet weight faeces or millions per ml of urine. For instance, cattle manure contains up to 109 colony forming units (CFU) of indigenous bacteria g-1. Among this population of heterogenous bacteria, faecal indicator bacteria (Escherichia coli and enterococci) constitute up to 10^5 to 10^7 CFU g^{-1} of cattle manure. Proportions of other specific pathogens have been documented. For instance, faecal material from a cattle herd that has been colonized by Salmonella could contains up to 102 to 107 CFU g^{-1} of this pathogen[4]. In other studies[5], up to 2.6 × 107 oocysts g^{-1} of protozoans such as Cryptosporidium and Giardia have been documented in cattle excreta.

---

[2] Doole (2016) Evaluation of scenarios for water-quality improvement in the Waikato and Waipa River catchments. Business-as-usual assessment 20 October 2016.

[3] Romera, A. J., & Doole, G. J. (2015). Optimising the interrelationships between intake per cow and intake per hectare. Animal Production Science, 55, 384-396.

[4] Himathongkham, S., Bahari, S., Riemann, H., and Cliver, D. (1999). Survival of Escherichia coli O157: H7 and Salmonella typhimurium in cow manure and cow manure slurry. FEMS Microbiol. Lett. 178, 251–257

[5] Medema, GJ; Shaw, S; Waite, M; Snozzi, M; Morreau, A; Grabow, W. Catchment characteristics and source water quality. In Assessing Microbial Safety of Drinking Water Improving Approaches and Method; WHO & OECD, IWA Publishing: London, UK, 2003; pp. 111–158.

Bradford, S. A., and J. Schijven. 2002. Release of Cryptosporidium and Giardia from dairy calf manure: impact of solution salinity. Environ. Sci. Technol. 36:3916-3923.

23. An understanding of the diverse fate and transport behaviour of faecal borne microorganism is critical for public health risk assessment and management. Following the discharge of faecal waste from animal sources, a number of factors and processes determine the fate (survival, growth, transmissibility, etc) of the pathogens in the excreta in its new environment. These pathways are broadly divided into two: (a) In-land processes and (b) In-stream processes.

(a) In-land processes:

i. Processes that influence the faecal transmission pathway within the terrestrial environment of primary productive land and determine faecal content loadings that reach receiving waters. A general conceptual representation of pathways of transmission of faecally-associated microorganisms generated in primary productive land use is presented in Figure 2.

ii. On agricultural productive land, risks potentially associated with the livestock faecal waste will depend on a number of factors, such as: (1) Composition (manure bulk density, aggregation, porosity, and water contents), (2) age and treatment of the manure, (3) characteristics of the faecal microbes[6], as well as (4) the degree of specific microbial association within the manure/soil matrix.

iii. Risks potential associated with the livestock faecal waste also depends on climatic factors such as intensity and frequency of precipitation and ultraviolet radiation. For instance, rainfall energy and duration affect the release of microbes from manure and soil, higher intensities of rainfall increase levels of microbial release from manure on a farm. The increased water content in manure between rainfall events one and two may also promote bacterial survival and

---

[6] e.g. differing specific physical and chemical properties (size, hydrophobicity, secrete extracellular polymeric materials, and possession of surface structures) of the faecal microorganisms that affect their propensity to dislodge from their microhabitats or surrounding soil layer, preferential attachment of different strains to soil particles of different size fractions (i.e., sand, silt, and clay)

growth and thus increased levels in run off. Conversely, faecal bacteria released from animal waste into surface runoff can also decrease during consecutive rainfall events, particularly when manure-borne bacteria is bound to soil particles below the manure deposition zone, or in gaps between manure so they are less susceptible to runoff removal in a subsequent rainfall event.

iv. Another important factor is land use, cover, and soil type. Differences in soil type and vegetative covers affects the transport of E. coli during rainfall events. Vegetation may also reduce microbial release by providing a canopy to reduce raindrop impact, thus protecting manure microhabitats from dispersion through overland flow during rainfall events. The export of matter from soils to an adjacent aquatic ecosystem is also partly controlled by the slope angle and the concentration of organic matter in the soils. For instance, in sloping lands, the export of organic matter and bacteria can be particularly high, presenting important implications for downstream aquatic ecosystems. Also, in intensive farming areas where manure production is high, there is a greater possibility of faecal contamination, particularly if these production zones are near to streams and rivers or if the animals have direct access to the stream. Land-use associated factors such as the stocking density of grazing animals, presence/absence of infected animals that carry zoonotic pathogens, the stage and severity of infection, the species and numbers of pathogens carried by the animals and shedding rates, the extent of direct access to the stream and/or its tributaries and the potential for live bacteria in cowpats and soil to be transported from 'contributing areas' into the stream.

(b) In-stream processes

i. In-stream processes are those processes that drive variabilities in levels of faecal bacteria in water bodies receiving input from primary productive lands. These relate to bacterial survival and transport in the water column, settling into sediments, survival in streambed sediments, release and resuspension into the water column, advection, and dispersion. Factors specifically related to the survival and persistence of faecal microbes include temperature and extent of sunlight inactivation. The presence of other bacteria viruses and predators, metabolic capacity, and associations with particles and other non-host organisms, all influence the decay (or loss) rates of microbes within water bodies.

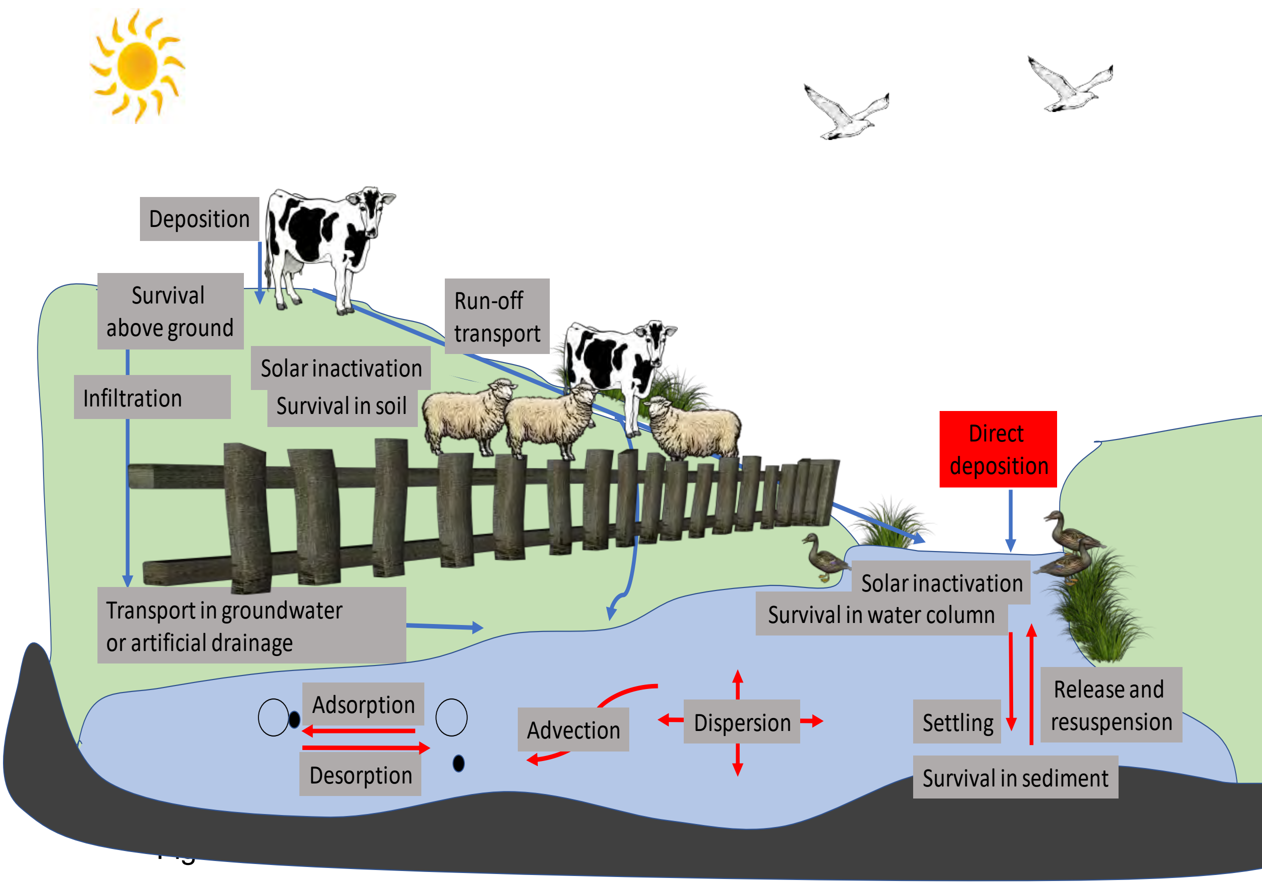
ii. Most enteric pathogens have no means of transport (such as motility) in the aquatic environment other than being transported with the water flow. Hence, a critical factor which drives the occurrence and persistence of bacteria in the aquatic environment is frequency and intensity of storm events and inter-storm flow periods. The relative amount of groundwater[7] also exerts an influence on the magnitude of dilution effect of bacteria loads during floods, contrary to the situation in overland flows which strongly contributes to soil erosion and hence, bacteria erosion processes. Generally, inflows dominated by overland flow will contain elevated loads of suspended particles and bacteria. Once delivered to the river, sediment and bacteria can then accumulate on riverbeds before being re-suspended after an increase in river discharge. Highly erosive rain results in the resuspension of particles as a function of flow, thus leading to resuspension of several orders of magnitude of bacteria into the water column.

iii. Our knowledge of factors affecting fate and transport of pathogens in receiving waters stems largely from studies using FIB as the target organism(s). It is clear from these studies that stream sediments play an important role as reservoirs of microbes. My view is that better understanding of variabilities in FIB levels observable in water monitoring

[7] Tend to have low microbial loads

programs hinges on our ability to understand the population dynamics of these sediment reservoirs under both base- and storm-flow conditions.

iv. I also agree with Stott et al (2011)[8] who suggest that a greater understanding of stream channel dynamics with respect to faecal microbes and considerations for microorganism specific factors is required before the ramifications of mitigations applied at a farm-scale can be determined at a catchment scale, in a similar manner to that done for nutrients.

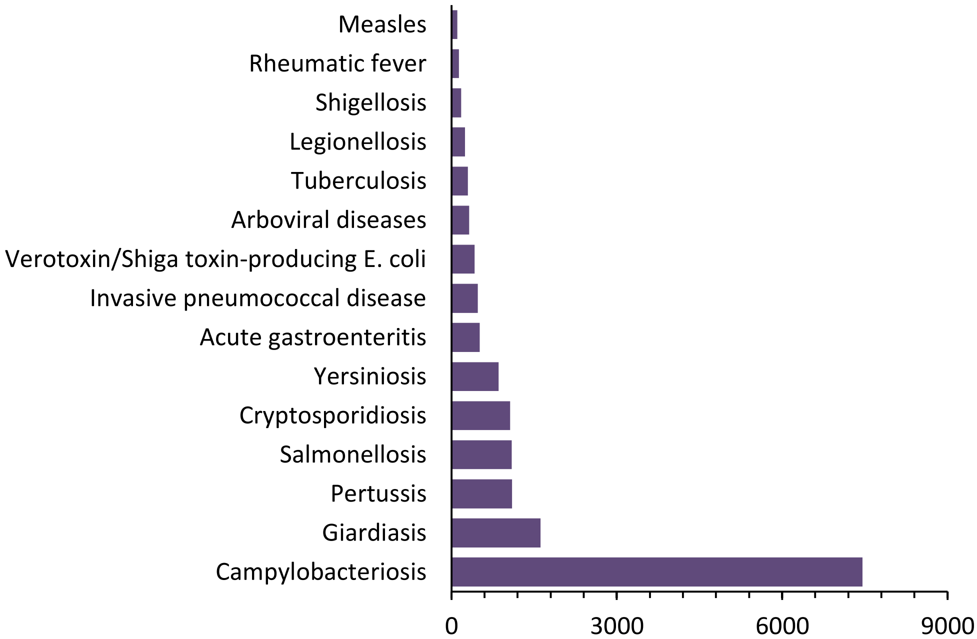


concentrations in pastoral catchments.

[8] Stott, R., Davies-Colley, R., Nagels, J., Donnison, A., Ross, C., Muirhead, R., 2011. Differential behavior of Escherichia coli and Campylobacter spp. In a stream draining dairy pasture. J. Water Health 09 (1), 59e69. http://dx.doi.org/10.2166/wh.2010.061.

ZOONOTIC DISEASES ASSOCIABLE WITH PRIMARY PRODUCTIVE LAND USE

24. Zoonotic pathogens—organisms that originate from animals and cause disease in humans—account for nearly two-thirds of emerging infectious diseases in humans (Voro et al 2007)[9]. In New Zealand and other developed countries, enteric zoonotic diseases are major contributors to water and food-borne disease, including gastroenteritis. Historically, New Zealand has a high incidence of enteric zoonotic diseases as reported for developed countries and the number of cases has increased annually. Enteric zoonotic diseases constitute about 80% of the total notified illnesses in New Zealand[10]. In New Zealand, the most significant micro-organisms causing zoonotic diseases are the bacteria Campylobacter spp., some strains of Escherichia coli, Salmonella spp., and the protozoa Giardia and Cryptosporidium[11]. For instance, in 2016, Campylobacteriosis, Giardiasis, and Cryptosporidiosis accounted for over 60% of notified diseases in New Zealand.



---

[9] Vorou, R. M., Papavassiliou, V. G., & Tsiodras, S. (2007). Emerging zoonoses and vector-borne infections affecting humans in Europe. *Epidemiology & Infection*, *135*(8), 1231-1247.
[10] https://thewaternetwork.com/_/climate-change-and-the-environment/blog-Jl6/zoonoses-in-new-zealand-lNbgfO1psWDbvKpOvPwOWw
[11] https://www.health.govt.nz/system/files/documents/pages/zoonosespmlt_0.pdf

Figure 3: Number of notifications by disease, New Zealand (2016)[12]

25. Campylobacteriosis[13], caused by Campylobacter species, is the most common human bacteria-related diarrhoeal illness in New Zealand, as well as in developed and developing countries of the world. Although seldom disease-causing in animals, Campylobacter infects most warm-blooded wild and domestic animals. Humans become infected through ingestion of contaminated unpasteurized milk, drinking water, or undercooked meat (US Centers for Disease Control and Prevention 2009). Infection rates in New Zealand have steadily increased since 1980, peaking in 2006 at over 15,000 notifications (Baker et al. 2012[14]). While the incidence rate for Campylobacteriosis in New Zealand has reduced since 2016, the current incidence is still 1.5 to 3 times higher than reported incidence rates in Australia, England and Wales, and several other developed countries[15]. Although previous surveillance efforts identified poultry as the primary source of human disease, it also found that other animal sources such as sheep and cows account for disease transmission, probably due to environmental and occupational exposures.

26. Cryptosporidiosis is an important cause of gastroenteritis worldwide, and New Zealand has one of the highest reported rates in the world with between 26·1 and 32·3 new cases per 100,000 population per year[16]. Cryptosporidiosis is caused by infection with protozoan parasites of the genus Cryptosporidium. *S*ymptoms of gastroenteritis typically last from several days to several weeks. Routes of transmission are largely from poorly treated drinking water, swimming in swimming pools, contact with

---

[12] https://surv.esr.cri.nz/surveillance/annual_diseasetables.php

[13] http://scientists.org.nz/files/journal/2011-68/NZSR_68_2.pdf

[14] Baker, M. G., Kvalsvig, A., Zhang, J., Lake, R., Sears, A., & Wilson, N. (2012). Declining Guillain-Barré Syndrome after Campylobacteriosis Control, New Zealand, 1988–2010. Emerging Infectious Diseases, *18*(2), 226-233.

[15] Lane, R., Briggs, S. (2014) Campylobacteriosis in New Zealand: room for further improvement. The New Zealand Medical Journal. 127(1391), 6-9

[16] Learmonth JJ et al (2004). Genetic characterization and transmission cycles of Cryptosporidium species isolated from humans in New Zealand. Applied and Environmental Microbiology. 70:3973–3978.

farm animals and person-to-person transmission. In New Zealand, Lake et al (2008)[17] argued that human cryptosporidiosis demonstrates spring and autumn peaks of incidence. The authors argued that in the spring livestock are most infectious due to the birth of large numbers of new, and hence highly infectious, livestock while the autumn cryptosporidiosis peak is related to increased recreational water use, swimming, outdoor activities and increased person-to-person spread.

27. Giardiasis is an important cause of gastroenteritis worldwide. It is one of the most commonly notified waterborne disease in New Zealand, which has high incidence rates compared with other developed countries[18]. Giardiasis is caused by Giardia, a protozoan parasite that can cause water-borne diarrhoeal infections to both man and animals. Transmission occurs from ingestion of faecally-contaminated food or drinking-water, swallowing recreational water (for example, swimming and wading pools, streams and lakes), exposure to faecally contaminated environmental surfaces, and person to person by the faecal-oral route. Like C. parvum, Giardia cysts are very resistant to conventional water disinfection treatments. Prevention of their spread is, therefore, essential to prevent contamination of fresh waters.

ISSUES WITH MONITORING ZOONOTIC DISEASE IN NEW ZEALAND

28. Surface waters are prone to contamination by zoonotic pathogens (from various point and nonpoint sources) as a result of faecal wastes from intensive agriculture-related practices on primary productive lands. Detection of these infectious pathogens requires the use of recovery and isolation methods employing multiple steps of cultivation for bacteria, cell cultures or experimental animals. Going beyond presence/absence enumeration analysis, detecting pathogens by their infectivity or cultivability is more important for decision making about pathogen risks to human and animal health, because only live or infectious pathogens pose health risks. Unfortunately, even some advanced technologies (e.g. nucleic acid

---

[17] Lake IR, Pearce J, Savill M (2008) The seasonality of human cryptosporidiosis in New Zealand. Epidemiology and Infection 136 (10): 1383–1387

[18] Hoque E, Hope V, Scragg R, Baker M, Shrestha R. A descriptive epidemiology of giardiasis in New Zealand and gaps in surveillance data. N Z Med J. 2004;117:U1149.

amplification by PCR, immunoassays, etc.) will still capture dead or inactivated pathogens during analysis of agricultural waste samples. As dead cells no longer pose health risks, detection of these dead or inactivated pathogens are "false-positives" which tend to confound our ability to accurately determine risks of infectivity.

29. In New Zealand, current risk assessment is based on a monitoring system that assesses the levels of Escherichia coli. *E.coli* is typically used an indicator of the presence of potential enteric pathogens given that it is commonly present at high concentrations in the intestinal tracts and faeces of animals, including humans. Despite the widespread use as of *E.coli* as an indicator organism, it is quite debatable as to whether the levels of FIB adequately predict the presence of all types of pathogens, including viruses and parasites. Zoonotic pathogens from primary productive land are not reliably detected using the *E.coli* proxy. This is because there is often no correlation between *E.coli* and zoonotic pathogens that they are meant to 'protect against'. Hence, merely measuring *E.coli* as an indicator of risk on streams receiving input from primary productive lands may fail to protect the public from exposure to zoonotic pathogens. These concerns are well documented[19]

30. Another consideration is that not all FIB are from faecal sources (Ferguson 2006; Ksol et al 2007; Yan et al 2011)[20]. Non-fecal environmental sources of FIB (e.g. decaying plants, algae and biofilms, indigenous *E.coli* in sands and soils) tends to confound our ability to predict the fate of pathogens in animal waste management systems both on and off farms. Besides, the relationship of the FIB from non-fecal sources to the occurrence and

---

[19] Sobsey, M.D.; Khatib, L.A.; Hill, V.R.; Alocilja, E.; Pillai, S. Pathogens in Animal Wastes and the Impacts of Waste Management Practices on Their Survival, Transport and Fate. In White Paper, Midwest Plan Service; Iowa State University: Ames, IA, USA, 2001

[20] Ferguson, D. (2006). Growth of E. coli and Enterococcus in Storm Drain Biofilm. Presentation at 2006 U.S. EPA National Beaches Conference.

Ksoll, W.B., Ishii, S., Sadowsky, M.J., Hicks, R.E. 2007. Presence and Sources of Fecal Coliform Bacteria in Epilithic Periphyton Communities of Lake Superior. Applied and Environmental Microbiology 73: 3771-3778.

Yan, T., Goto, D.K., Feng, F. 2011. Concentration dynamics of fecal indicators in Hawaii's coastal and inland sand, soil, and water during rainfall events. PATH6R09. Water Environment Research Foundation, Alexandria, VA.

distribution of enteric pathogens[21] in these examples has not been demonstrated (EPA 2014[22]).

31. Also, current risk assessment is based on a monitoring system that does not distinguish between animal versus human faecal contamination, or even between animal strains such as ruminate or avian. It is intuitive to believe that non-human faeces probably carry fewer pathogens that might be hazardous to humans. For example, viruses that are specific to humans do not normally occur in animals; therefore, the risk from animal faeces may not be equivalent to that associated with human faeces. The dilemma, however, is that the presence of such faecal indicators may or may not be an indication of actual risk from pathogens at that time and are of little use in determining if their faecal source is human or animal. A detailed knowledge of the sources of faecal material in the catchment impacting on a waterway, be they human or animal in origin, and data related to the spatial and temporal loadings of expected pathogens from such sources will, in profound ways, assist the assessment of a public health risk.

32. Another limitation to the current risk assessment system, which relies on FIB as indicator bacteria, is that FIB can naturally survive and proliferate outside of animal intestines, in tropical and temperate habitats. This calls into question their reliability as indicators in these habitats. That is, the quantity of *E.coli* is not necessarily correlated with increasing risk of infection. Also, viral and protozoan pathogens are not well correlated with standard bacterial indicators such as FIB[23]. The processes that control the survival and removal of microbes in water, such as competition, ultraviolet radiation, temperature, predation, and transport differ among pathogenic species. Thus, monitoring FIB alone is not sufficient to assess human health risk.

---

[21] and the potential for those microbes to predict human health effects

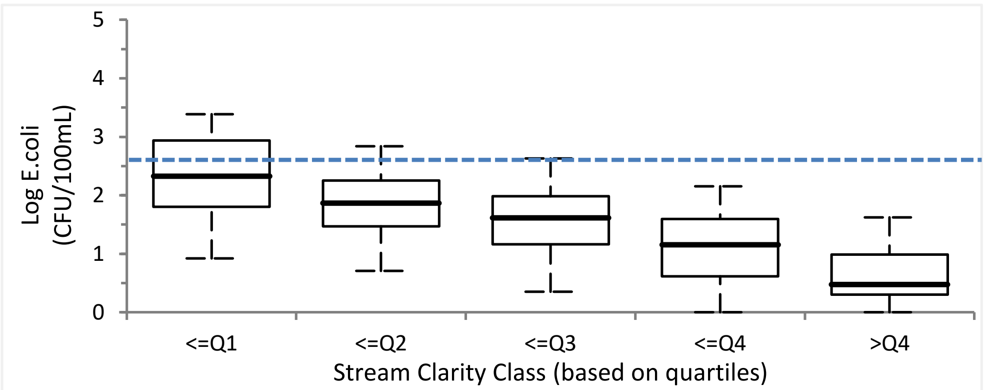
[22] EPA (2014) Overview of Technical Support Materials: A Guide to the Site-Specific Alternative Recreational Criteria TSM Documents. EPA-820-R-14-010 U.S. Environmental Protection Agency Office of Water Office of Science and Technology Health and Ecological Criteria Division

[23] National Research Council (US) Committee on Indicators for Waterborne Pathogens. Indicators for Waterborne Pathogens. Washington (DC): National Academies Press (US); 2004. 4, Attributes and Application of Indicators.

33. In New Zealand, levels of FIB in water is used to determine whether the water intended for drinking or recreational purposes are free of zoonotic pathogens. For contact recreation, less than 540 CFUs/100 mL of E. coli are recommended by the NPS-FM 2014 and warnings (advisories) are usually issued to the public when contaminant levels exceed these concentrations[24].

34. *E.coli* concentrations in New Zealand Rivers are strongly correlated with water clarity (e.g. Dada and Hamilton 2017; Davies-Colley et al 2018; Dada 2019)[25]. The same observation holds for rivers and tributaries in the Waikato region (Figure 4a,b). Correlations between water clarity (reflective of turbidity) and *E.coli* concentrations is understandable as the primary pathway for pathogens to enter surface water from agricultural land uses is via overland flow pathways (Paragraph 59). The strong coupling of water clarity and *E.coli* concentrations suggest that efforts geared towards monitoring and improving water clarity may also quite reasonably allow for concomitant reductions in *E.coli* levels in New Zealand waterways.

(a) New Zealand



[24] National Policy Statement on Freshwater Management

[25] Davies-Colley, R., Valois, A., & Milne, J. (2018). Faecal pollution and visual clarity in New Zealand rivers: Correlation of key variables affecting swimming suitability. Journal of Water and Health, wh2018214.

Dada, A. C., & Hamilton, D. P. (2016). Predictive models for determination of E. coli concentrations at inland recreational beaches. Water, Air, & Soil Pollution, 227(9), 347.

Dada (2019) Seeing is Predicting: Water Clarity-based Nowcast Models for E.coli Prediction in Surface. Accepted for publication, Water Global Journal of Health Science

(b) Waikato

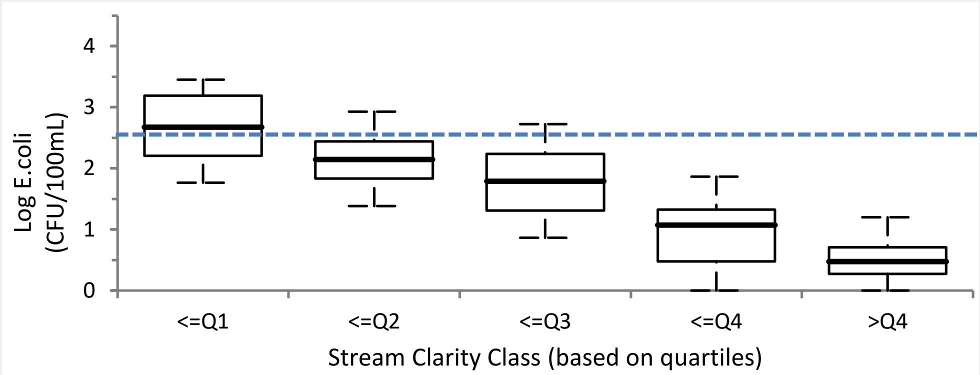


Figure 4: Box plots of Region *E.coli* concentrations versus water clarity grouped by quartiles, 2005-2013 for (a) New Zealand and (b) Waikato Region (Dotted blue line is the log-transformed bathing water standard of 540 CFU/100mL (i.e. 2.54 LogCFU/100mL, Q1-Q4 represent first, second, third and fourth quartile of the water clarity values, based on black disc measurements)

35. I note that the approach taken in PC1to monitoring *E.coli* levels as a proxy for the presence of zoonotic pathogens does not seem to distinguish between concentrations during different flow conditions (e.g. see Figure 8). A conservative threshold set at 540CFU/100mL 95th percentile concentration regardless of the season may actually mean that health risks associated with exposure to pathogens are over-estimated, particularly during non-swimming periods when the FIB population are largely driven by periods of high flow. Considerations for flow conditions may warrant the establishment of a stringent maximum limit for faecal coliform bacteria per 100mL sample during the “swimming season” (typically during base and low flows) and a less stringent limit for all other times (storm flows).

36. The WRPC1 uses the 95th percentile sample results from the previous 5 years as an indicator of an overall achievement of the E. coli target in Table 3.11-1. This is based on the assumption that ‘the 95th percentile of sample results from the previous 5 years accommodates infrequent or rare high flow events’. It is important to note that the 95th percentile *E. coli* concentrations are rare events that are associated with storm flows and will only reflect in 5% of the observed data used to make this judgement. In simple terms, only 5% of the monitoring data will be higher than the 95th percentile

concentration, regardless of the number of "previous years" of data considered.

37. The WRPC1 also argues that the proposed 95th percentile target and monitoring regime already provides for the exclusion of extreme events, and hence no need is required for an amendment of the Table 3.11-1 such that the targets for E. coli do not apply during high flow events. Details are however not available about the 'proposed monitoring regime' and the exclusion criteria that will be used to adjudge when sampling should be conducted to implement targets in the Tables 3.11-1. Are the monitoring officers to use their discretion to determine when sampling is to be done while monitoring compliance with the targets specified in the WRPC1 Table 3.11-1? These issues require clarification, as footnote 1 of the NPS-FM *E.coli* Attribute State Table differs from this position of 'subjective determination of monitoring regime that excludes high flow events'. The NPS-FM 2017 states categorically that '…samples should be collected on a regular basis regardless of weather and flow conditions'. Hence, the proposed attribute monitoring programme (to determine achievement of the targets) is NOT consistent with the guidance contained in the NPS-FM as it presents ambiguities associated with when monitoring officers are to sample and not to sample.

38. Based on the arguments in paragraphs 33-36, I recommend that:

(a) the proposed WRPC1 monitoring needs to be consistent with the NPS-FM guidance document with samples collected on a regular basis regardless of weather and flow conditions;

(b) The *E.coli* targets however need to be revised and the policy wording should be amended to read 'the *E.coli* concentration of the water must not exceed [table 3.11-1 revised numerical parameter given in CFU/100mL] when the river is at or below medium flow (the 50th percentile flow)'.

(c) If it is impossible to designate revised Table 3.11-1 *E.coli* targets in line with recommendation (ii) above, then the *E.coli* targets should be amended to comply with the NPS-FM *E.coli* Attribute State thresholds. Using this approach, an indicator of improvement in bacteriological water quality could be tied to at least two of the four numeric attribute statistics in the NPS-FM guidance document. For instance this could be a combination of median and 95th percentile *E.coli* concentrations rather than a reliance on the single 95th percentile as it is currently in the PC1 Table 3.11-1. A table of suggested targets based on this criterion are presented in Appendix 1 of this document. In this way, authorities can work towards progressive improvement of the NPS-FM Attribute State of the particular site being considered.For instance, the Attribute State of Mangauika Stm Te Awamutu Borough W/S Intake, is currently C (Yellow) which is equivalent to median *E.coli* concentrations <130 CFU/100mL and 95th percentile concentration <1200. A short term target should be set at improving the Maramaruaa NPS FM attributre state to B (Green) which is equivalent to median *E.coli* concentrations < 130 CFU/100mL and 95th percentile concentration <1000 CFU/100mL. This approach does not only comply with the NPS-FM requirements, it also makes monitoring and reporting of progress seamless.

REVIEW OF REGIONALLY RELEVANT STUDIES AND COMMENTS ON *E.COLI* REDUCTION APPROACH/TARGETS

39. I have read a number of reports that have been published to support WRPC1. These reports, and a synopsis of their objectives are presented in Paragraph 39 to 40 of this evidence.

40. Doole et al. (2015[26]) described outputs from a predictive-modeling approach that aimed to identify the economic implications of altering land and point-source management to achieve the water-quality limits proposed for each of four scenarios:

(a) Substantial improvement in water quality for swimming, taking food, and healthy biodiversity,

[26] Doole et al (2015) Economic evaluation of scenarios for water quality improvement in the Waikato and Waipa River catchments. Assessment of first set of scenarios 24 August 2015. Report No. HR/TLG/2015-2016/4.1, Draft for discussion purposes, 10 November 2015

(b) No further degradation and improving sites to at least minimum acceptable standard for all attributes

(c) Some general improvement in water quality for swimming, taking food, and healthy biodiversity, and,

(d) No further degradation in spite of lags.

41. The modelling approach used also predicted the economic implications of these scenarios at the farm, catchment, regional, and national scales.

42. Other relevant reports arising from the WRPC1 are highlighted below:

(a) Doole et al. (2015[27]) further described using the predictive-modeling approach the implications of altering land and point-source management to achieve the water-quality limits proposed for steps towards Scenario 1, across a number of alternatives.

(b) Doole et al. (2016[28]) employed the HRWO economic model to simulate the policy mix associated with WRPC1 under several different situations, to assess its impact on economic and water-quality outcomes within the Waikato River and Waipa River catchments.

(c) Doole et al. (2016[29]) estimated the state of water quality in the Waikato and Waipa River catchments in 1863 using predictive modelling and highlighted the effect that future policy actions—derived from the HRWO process—are likely to have on surface water quality. The science model behind the predictions was the *E. coli* model previously reported by Semadeni-Davies et al. (2015)[30].

---

[27] Doole et al (2015) Evaluation of scenarios for water-quality improvement in the Waikato and Waipa River catchments. Assessment of second set of scenarios 24 September 2015. Report No. HR/TLG/2015-2016/4.2, Draft for discussion purposes, 10 November 2015

[28] Doole et al (2016) Simulation of the proposed policy mix for the Healthy Rivers. Report No. HR/TLG/2016-2017/4.5, Draft for discussion purposes, 13 July 2016

[29] Doole et al (2016) Prediction of water quality within the Waikato and Waipa River catchments in 1863. Report No. HR/TLG/2016-2017/4.3, Draft for Discussion Purposes, 2 August 2016

[30] Semadeni-Davies et al. (2015) Modelling E. coli in the Waikato and Waipa River Catchments: Development of a catchment-scale microbial model Prepared for the Technical Leaders Group of the Healthy. Rivers/Wai Ora Project. Report No. HR/TLG/2015-2016/2.6

(d) Doole 2015[31] outlined the cost and levels of mitigation achieved for each of the four contaminants for a range of management practices across a broad array of land uses. A feature of this report is an extensive sensitivity analysis that is performed to test how profit changes within the catchment-level model utilized within the HRWO process

(e) In Doole (2016)[32], an economic model — considering the farm-, catchment-, regional-, and national-level economic implications of water-quality limits — was utilised to investigate and predict the changes that may be associated with partial movements from the current state towards the most aspirational of the initial water-quality scenarios previously developed (Scenario 1). (Scenario 1, key output of the HRWO process, involves an improvement in water quality everywhere in the Waikato and Waipa catchments, even if it is already meeting minimum acceptable state).

(f) Doole et al (2016[33]) outlined the reasons why certain key decisions have been made during the design and development of this HRWO economic model

(g) Doole (2016)[34] outlined the potential implications of what would happen in the absence of the proposed policy mix—the prediction of outcomes associated with moving forward according to a "business-as-usual" scenario.

---

31 Doole (2015) Description of mitigation options defined within the economic model for Healthy Rivers Wai Ora Project. Description of options and sensitivity analysis 28 September 2015. Report No. HR/TLG/2015-2016/4.6, Draft for discussion purposes, 10 November 2015

32 Doole (2016) Model structure for the economic model utilised within the Healthy Rivers Wai Ora process. Report No. HR/TLG/2015-2016/4.8, Draft for Discussion Purposes, 23rd February 2016

33 Doole et al (2016) General principles underlying the development of the Healthy Rivers Wai Ora (HRWO) economic model. Report No. HR/TLG/2015-2016/4.7, Draft for Discussion Purposes, 23rd February 2016

34 Doole (2016) Evaluation of scenarios for water-quality improvement in the Waikato and Waipa River catchments -Business-as-usual assessment. Report No. HR/TLG/2016-2017/4.4, Draft for discussion purposes, 21 October 2016

(h) Semandeni-Davies and Elliot (2016)[35] reported on the calibration of a national catchment-scale model that predicts the effect of stock exclusion (i.e., fencing to restrict stock access to waterways and their riparian margins) on water quality.

43. I note that the Doole et al. (2015) report cited a successful integration of diverse hydrological/water quality models that relate contaminant losses within and across subcatchments to pollutant concentrations at the various monitoring sites represented within the catchment. These models concern *E. coli* (Semadeni-Davies et al., 2015)[36], sediment, nitrogen and phosphorus. Given that hydrological/water quality models are a core driver of the HWRO model, I have decided to focus on a review of the *E.coli* model (Semadeni-Davies et al., 2015) that informed the HRWO model and plan change decision-making. The Semadeni-Davies et al (2015) study reported the calibration of three steady-state catchment models to estimate *E. coli* loads and concentrations in the Waikato and Waipa River catchments from Lake Taupo to Port Waikato. In this evidence, my comments, thus, specifically relate to concerns on the assumptions used in the adopted *E.coli* models, in relation to the estimated fate-transport matrices and processes that drive variabilities in the flow and attenuation of *E.coli*. These are presented in subsequent sections.

44. First, in the Semadeni-Davies et al (2015) study, the authors note that *E.coli* concentrations and loadings were generated for sites that do not have flow data. I note that out of the 63 sites that formed the basis for the study, only 20 of these sites had flow data (see Figure 2-1 in Semadeni-Davies et al 2015). This represents less than 30% of the entire dataset. Using a model with 'generated dataset' comprising of more than 70% of the observed dataset is technically flawed, potentially vulnerable to bias and could be distorted in the directions of certain vested policy interests.

45. While rainfall and flow were considered as variables in the Semadeni-Davies et al (2015) *E.coli* model, my experience analyzing *E.coli* data in

---

[35] Semadeni-Davies, A. Elliott, s (2016) Modelling the effect of stock exclusion on E. coli in rivers and streams: National Application. MPI Technical Paper No: 2017/10. Prepared for Ministry for Primary Industries by NIWA, 229 pages.

[36] As previously cited.

New Zealand reveals that antecedent rainfall and antecedent flow (which could be incorporated as a lagged component) explains a higher proportion of variability in *E.coli* dataset than actual rainfall or flow does (Dada and Hamilton, 2017).

46. The load models reported in the Semadeni-Davies et al (2015) study are simply steady-state models that predict mean annual loads. The implication of this is that the more important seasonal changes in *E. coli* generation and transport are not captured by the models[37]. This reduces the importance of the model as there is a huge variability of *E.coli* loads, travel time and in-land/in-stream dynamics that is missed out during varying seasons and flow conditions.

47. The Semadeni-Davies et al (2015) study states that '…under the NPSFWM (2014) National Objectives Framework (NOF), it is assumed that if *E. coli* are present in fresh water bodies, then other more pathogenic faecal micro-organisms are also likely to be present.' This is a technically inappropriate statement. It is not the fact that *E.coli* may be present that is material. Rather the correct approach is to note that *E.coli* may be indicative of a heightened probability of potentially infective pathogens if the *E.coli* is present at levels above certain thresholds that have been previously demonstrated to be so.

48. I note that the Semadeni-Davies et al (2015) study used a rating curve method to estimate measured mean annual *E. coli* loads at sites where there were sufficient concurrent flow data at or near the site. Following an intense search into published literature, the lack of refereed publications that use this approach for bacteria indicates that it is rarely used for *E.coli*. Besides, the number of the formula and coefficients stated in this report were not explicitly stated, which prevents independent verification of inputs and outputs of the model. For instance, a, b and s in the 'bacteria rating curve' equation are not stated. In another instance, the authors mention that '…in the ratio method, the median concentration is multiplied by a factor to convert to flow-weighted concentration' (page 22) but fail to mention what

[37]Based on an analysis of available data, I note specifically that storm flow conditions is responsible for at least 80% of total *E.coli* loads in the Waikato region. Steady state models used in the Semadeni-Davies et al (2015) *E.coli* model will not capture these storm flow loads.

the factor is and how it was generated. This is important because modellers 'optimise' these coefficients/functions to best make the data fit and the failure to disclose this information means that the model on which the WRPC1 decision making was based cannot be independently proved to be trustworthy.

49. I also note that the Semadeni-Davies et al (2015) modelling study only incorporated 4 out of at least 21 factors that influence variabilities in *E.coli* levels in primary productive land. Variables incorporated into the model were surface decay, drainage type, rainfall class and land use class incorporating a conservative per hectare animal population[38]. Important but missing variables in the calibrated model are detailed in paragraph 22(a) of this evidence. Concentration of organic matter in different soil types which affect microbial survival, presence/absence of infected grazing animals that carry zoonotic pathogens, the stage and severity of infection, the species and numbers of pathogens carried by the animals and shedding rates, the extent of direct access to the stream, manure composition, degree of specific microbial association within the manure/soil matrix.

50. In addition the *E.coli* model in the Semadeni-Davies et al (2015) study incorporated only 3 out of at least ten factors/variables that influence variabilities in *E.coli* levels in streams. Important but missing variables in the calibrated model are detailed in stated in paragraph 22(b) of this evidence. This include factors related to bacterial survival and transport in the water column, settling into sediments, survival in streambed sediments, release and resuspension into the water column, advection, and dispersion.

51. I note that the in-stream attenuation factor was calibrated to zero in the Semadeni-Davies et al (2015) model. Despite the importance of microbial die-offs and growth potentials in streams, Semadeni-Davies et al (2015) argued that 'adding microbial die-off into the model significantly reduced the performance of the model and hence it was avoided in the model'. Whilst it could be argued this makes the model conservative, I would argue that by ignoring a process known to be important by all environmental microbiologists, it fails to properly demonstrate accurate and realistic *E.coli*

---

[38] (see Table 2-4 in Semadeni-Davies et al 2015)

loadings. In my view, it is not surprising that there were 'anomalies'[39] in the results of the model.

52. It is important also that the *E.coli* models reported in the Semadeni-Davies et al. (2015) study were not validated. This means that the models are not fit to inform or underpin Plan Change 1, that is the models are not fit for purpose. Model validation assesses if a model possesses a satisfactory range of accuracy consistent with the intended application of the model. Validation checks the accuracy of the model's representation of the catchment as the modeller compares the model input-output transformations to corresponding input-output transformations for the catchment. In layman terms, this means the Semadeni-Davies et al. (2015) *E.coli* models that informed the decision making process in the PC1 were not tested with new measured data not originally included during the model development. This is worrying. When the authors decide to test one of the developed models in another published report (Doole et al. 2016[40]), they chose a year for which there was no observational data (1863), thus allowing heavy reliance on 'generated data'. The authors applied the 'developed model' to predict water quality outcomes 'thought to have existed in 1863' with the current state and with the established long-term goal for water quality established within the HRWO process—known broadly as "Scenario 1". I am of the opinion that to robustly assess the *E.coli* loads prediction the application of the empirical models to estimate water-quality outcomes in past natural conditions across the Waikato and Waipa River catchments should have been done for other years for which there are observed data, for the sake of comparison. This would greatly reduce potential uncertainties and errors associated with the *E.coli* loads prediction and the HWRO decision making. These uncertainties coupled with other reasons previously stated seem to render the model unfit to inform or underpin PC1.

53. While the targets for microbial reduction as stated in Scenario 1 are a step in the right direction, it is important to note that the estimates that formed

---

[39] As the authors quoted in Semadeni-Davies et al (2015)

[40] Graeme Doole1, Neale Hudson2, and Sandy Elliott (2016) Prediction of water quality within the Waikato and Waipa River catchments in 1863. Report No. HR/TLG/2016-2017/4.3

the targets are associated with very significant uncertainties Doole (2016[41]) stated categorically that 'changes in microbial loadings to water that will occur over the next decade—as indicated by *E. coli* yields—are problematic to assess'. Unlike the case for nutrients where a lot of research work has been undertaken to help our understanding of in-land and in-stream processes, there is a general lack of knowledge regarding key elements of their generation, survival, preponderance, and transport from farming systems in receiving waters[42]. These uncertainties coupled with other reasons stated in Section 23 make it impractical to realistically estimate loads or in-stream *E.coli* concentrations.

54. I have reviewed the Semandeni-Davies and Elliot (2016) report on 'Modelling the effect of stock exclusion on E. coli in rivers and streams: National Application'. The report used a national model to analyse changes in *E. coli* concentrations in freshwater around the country as a result of fencing. Eight fencing scenarios were modelled and the predicted *E.coli* concentrations during these scenarios were used to classify rivers into bands (attribute states). These scenarios are:

(a) Scenario 1 – current level of fencing;

(b) Scenario 2 (status quo) – current level of fencing, with further fencing in regions which either have fencing policy in place or are planning new fencing policies to be in place by 2017;

(c) Scenarios 3a to 3e (Land and Water Forum progressive) – status quo with fencing along Water Accord streams on land with an average slope of less than 16° (a) dairy platform; (b) dairy runoff on land owned or leased by dairy farmers; (c) dairy grazing on land owned by a third party; (d) sheep and beef; and (e) deer;

41 Doole 2016 Evaluation of scenarios for water-quality improvement in the Waikato and Waipa River catchments: Business-as-usual assessment 20 October 2016. Report No. HR/TLG/2016-2017/4.4

42 Muirhead, R. (2015), 'A farm-scale index for reducing faecal contamination of surface waters', Journal of Environmental Quality 44: 248–255.

(d) Scenario 4 (Steep Hill Country) – fencing along all streams, including non-Accord streams, accessible to all stock on land with an average slope of less than 28°.

55. I note a number of critical issues with the Semandeni-Davies and Elliot (2016) report and highlight these below:

(a) Band classification: the classification used to delineate rivers into bands (attribute states) is predicated on outdated numeric attributes (NPS-FM 2014). For example, assuming reported annual median *E.coli* concentrations are consistent[43], rivers adjudged to be in the best attribute state (Band A) in the Semandeni-Davies and Elliot (2016) report have been re-classified by MfE as A, B, C and D in the revised NPS-FM document (2017). Hence, a river adjudged to be of excellent quality (Band A) in the Semandeni-Davies and Elliot (2016) report may actually be poor, based on the updated policy document. It is thus not surprising that, during the 'do nothing' scenarios, Semandeni-Davies and Elliot (2016) reported that 'around 80% of non-Accord streams and 90% of Accord streams nationally have median E. coli concentrations in NOF Band A'. This outdated classification scheme used in the Semandeni-Davies and Elliot (2016) report thus makes it unreliable for the current policy decision making related to stock exclusion.

(b) Meanwhile a careful analysis of the results of the Semandeni-Davies and Elliot (2016) study in Table 1 shows that that only very marginal increases (1.0 – 8.7%) in the proportion of stream length in Band A/B/C/D was associable with 'upgrades' in fencing approach. For example:

i. Only 1.06% increase in the stream length categorised as Band A was predicted when policy decision makers apply fencing conditions in Scenario 2 instead of Scenario 1;

---

[43] i.e. over the space of 5 years, as stipulated in the updated NPS-FM (2017)

ii. Only 1.19% increase in the stream length categorised as Band A was predicted when policy decision makers apply fencing conditions in Scenario 3a instead of Scenario 1;

iii. Only 1.20% increase in the stream length categorised as Band A was predicted when policy decision makers apply fencing conditions in Scenario 3b instead of Scenario 1;

iv. Only 1.33% increase in the stream length categorised as Band A was predicted when policy decision makers apply fencing conditions in Scenario 3c instead of Scenario 1;

v. Only 2.61% increase in the stream length categorised as Band A was predicted when policy decision makers apply fencing conditions in Scenario 3d instead of Scenario 1;

vi. Only 2.64% increase in the stream length categorised as Band A was predicted when policy decision makers apply fencing conditions in Scenario 3e instead of Scenario 1;

vii. Even during conditions of Scenario 4 (Steep Hill Country), less than 10% increase in the stream length categorised as Band A was predicted.

56. Analysis of results reported in the Semandeni-Davies and Elliot (2016) study indicates that additional fencing investment does not produce significant additional improvement in *E.coli* conditions or Band classifications nationwide. The potential for live bacteria soil to be transported from 'contributing areas' into the stream, as depicted in Figure 2, also aligns with this conclusion. That is, fencing may be beneficial in some intensively farmed areas where livestock can disturb stream beds and transport soil into waterways if not excluded. However, in other areas, fences can only stop direct deposition from animals but not overland flow of pathogens into the stream. For example, in hilly or steep lands in New Zealand and in flat, poorly drained land in the greater Waikato region, high runoff potential under

high rainfall (Collins et al 2007[44]) is largely associated with overland transport into receiving streams (McDowell and Wilcock 2008[45]).

Table 1: Length and proportions of nation-wide streams with estimated median E. coli concentrations in the NOF bands for each scenario. Included in this table also are increases and decreases in the % of stream length in each band.

		NOF Bands			
		A	**B**	**C**	**D**
Parameters	**Fencing Scenarios**	***E.coli* median : ≤260**	***E.coli* median : > 260 and ≤ 540**	***E.coli* median : > 540 and ≤ 1000**	***E.coli* median : >1000**
Total Stream Length (km) in Band	S1	353295	45810	968	16
	S2	357551	41613	911	14
	S3a	358050	41143	884	13
	S3b	358083	41113	879	13
	S3c	358603	40594	879	13
	S3d	363727	35514	835	13
	S3e	363855	35389	832	13
	S4	388209	11460	417	3
% of Stream Length in Band	S1	88.30	11.45	0.24	0
	S2	89.37	10.40	0.23	0
	S3a	89.49	10.28	0.22	0
	S3b	89.50	10.28	0.22	0
	S3c	89.63	10.15	0.22	0
	S3d	90.91	8.88	0.21	0
	S3e	90.94	8.85	0.21	0
	S4	97.03	2.86	0.10	0
Change in % Stream Length in Band after fencing upgrade	S1	N/A	N/A	N/A	N/A
	S2	1.06	-1.05	-0.01	0
	S3a	1.19	-1.17	-0.02	0
	S3b	1.20	-1.17	-0.02	0
	S3c	1.33	-1.30	-0.02	0
	S3d	2.61	-2.57	-0.03	0
	S3e	2.64	-2.60	-0.03	0
	S4	8.73	-8.59	-0.14	0

[44] Collins, R., Mcleod, M., Hedley, M., Donnison, A., Close, M., Hanly, J., ... & Matthews, L. (2007). Best management practices to mitigate faecal contamination by livestock of New Zealand waters. New Zealand Journal of Agricultural Research, 50(2), 267-278.

[45] McDowell, R.W and Wilcock, R.J. (2008) Water quality and the effects of different pastoral animals. New Zealand Veterinary Journal 56(6): 289-296

57. I recommend therefore, rather than a 'blanket fencing approach' currently proposed in the WRPC1, a more effective response to reduce the risk of pathogens from agricultural land uses entering waterbodies is the identification and management of critical source areas.

RESTRICTION OF ANIMAL ACCESS: IMPLICATIONS FOR TARGET REDUCTIONS IN *E.COLI* LEVELS IN RECEIVING STREAMS

58. I have reviewed the Ritchie and Donnison (2010[46]) report on 'Faecal Contamination of Rural Waikato Waterways: Sources, Survival, Transport and Mitigation Opportunities'. The report generally supports the focus in the draft Regional Policy Statement on possible mitigation efforts i.e. stock effects in and near water bodies, including access to the beds and banks of waterways and intensive grazing near water, particularly when soils are saturated or poorly-drained. Ritchie and Donnison (2010) also reached some important conclusions: (a) that transportation pathways by which microbes reach water are important; (b) that direct deposition is a minor percentage of total annual catchment *E.coli* loads to stream, and (c) that direct deposition into a typical stream would not produce a measurable change in the concentration of Campylobacter when considered on an annual contribution basis.

59. It is logical to raise questions related to stocking class and effects on *E.coli* loadings in streams flowing through agricultural catchments, as these are important considerations for risk assessments. Inputs like volume and composition of manure, proximity to stream/watering radius and watering requirements tend to vary between stocking class e.g. sheep versus cattle, etc. For instance, in pastoral lands, a study has shown that sheep normally graze within a radius of about 2.5km of a watering point while cattle within a radius of about 5km, cattle need between 40-100 litres per day of water while sheep require 2-6L per day (Table 2). Cattle have longer legs and sturdier bodies and can wade through streams that sheep would panic to enter. Contaminants from their legs and hoof disturbance of streambed

[46] Ritchie, H. and Donnison, A. (2010) Faecal Contamination of Rural Waikato Waterways: Sources, Survival, Transport and Mitigation Opportunities. A review for Environment Waikato. Document #: 1789463

sediments and banks are more vigorous with cattle than is the case with sheep. Although Moriarty (2013)[47] reported a slightly higher proportion of *E.coli* concentration in sheep faeces than cattle faeces[48], the higher requirement for water and longer water radius distance in cattle invariably has implications on the probability of direct deposition of *E.coli*-laden faecal material in or close to water bodies. Another NZ study[49], reported that 246 cows deposited 37kg of faeces on just two crossing events. The study concluded that cows are much more (up to 50 times) likely to defecate in stream water than on adjacent raceways. In general, however, associated data based on robust microbiological science to affirm the relative importance and or contribution of different livestock are largely unavailable. On this basis, I disagree with previous studies [50], that have, merely on the basis of *E.coli* counts in culture media, argued that given the same stocking rate, losses of *E. coli* in overland flow are similar among stock classes.

---

[47] Moriarty (2013) Sheep as a Potential Source of Faecal Pollution in Southland Waterways. Report Prepared for Environment Southland

[48] It is important to note that the observation reported in Moriarty (2013)[48] of a slightly higher proportion of *E.coli* concentration in sheep faeces than cattle faeces, does not necessarily mean that cattle faeces present relatively lower risks than sheep faeces. Additional FIB-pathogen correlational analysis for the different animal sources will be required to confirm this.

[49] Davies-Colley, R., Nagels, J., Smith, R., Young, R., Phillips, C. (2002) Water quality impact of cows crossing the Sherry River, Tasman District. Cows and Creeks, LandCare Knowledge Base.

[50] McDowell, R.W and Wilcock, R.J. (2008) Water quality and the effects of different pastoral animals. New Zealand Veterinary Journal 56(6): 289-296

McDowell, R.W. (2006). Contaminant losses in overland flow from cattle, deer and sheep dung. *Water, Air, and Soil Pollution* 174, 211–22

Wilcock, R.J. Assessing the Relative Importance of Faecal Pollution Sources in Rural Catchments. Technical Report TR 2006/41, Environment Waikato, Hamilton, NZ, 2006

Table 2: Average water requirements of stock

Stock type	Consumption Per head per day (L)
Sheep (weaners)	2-4
Sheep (adult dry sheep)	2-6
Sheep (ewes with lambs)	4-10
Cattle (lactating cows)	40-100
Cattle (young stock)	25-50
Cattle (dry stock, 400kg)	35-80
Horses	40-50

60. Meanwhile, studies[51] which have analysed *E.coli* loadings in waterways in the Waikato region affirm that surface runoff is the major source of faecal pollution from agriculture, despite inputs from dairy herds crossing streams and from drains (Figure 2). For instance, based on datasets for Toenepi, Davies-Colley et al. (2008[52]) estimated that direct deposition accounted for only about 0.23% of the total annual *E. coli* 'production' from the catchment streams and that 95% of the annual yield was exported during the thirty storm flood events that occurred over a twelve-month period. In a particular instance, stream *E. coli* concentrations were significantly reduced following the installation of bridge crossings for dairy herds over the Sherry River near Motueka, but this reduction was not sufficient to meet contact recreation standards (Ritchie and Donnison 2010)[53]. In a previous study by McDowell

[51] McDowell, R.W and Wilcock, R.J. (2008) Water quality and the effects of different pastoral animals. New Zealand Veterinary Journal 56(6): 289-296

McDowell, R.W. (2006). Contaminant losses in overland flow from cattle, deer and sheep dung. Water, Air, and Soil Pollution 174, 211–22

Wilcock, R.J. Assessing the Relative Importance of Faecal Pollution Sources in Rural Catchments. Technical Report TR 2006/41, Environment Waikato, Hamilton, NZ, 2006

[52] Davies-Colley R, Lydiard E, Nagels J 2008. Stormflow-dominated loads of faecal pollution from an intensively dairy-farmed catchment. Water, Science and Technology 57:1519-1523.

[53] Ritchie, H. and Donnison, A. (2010) Faecal Contamination of Rural Waikato Waterways: Sources, Survival, Transport and Mitigation Opportunities. A review for Environment Waikato. Document #: 1789463

(2008)[54], water quality was monitored on a tributary of the Dow Stream with the goal of assessing if fencing-off an area of the stream channel with a known contaminant source (a wallow) and riparian planting improved water quality as measured by the two-weekly concentrations and annual loads. Results revealed that mean concentrations of *E. coli* showed no significant difference with fencing-off and planting.

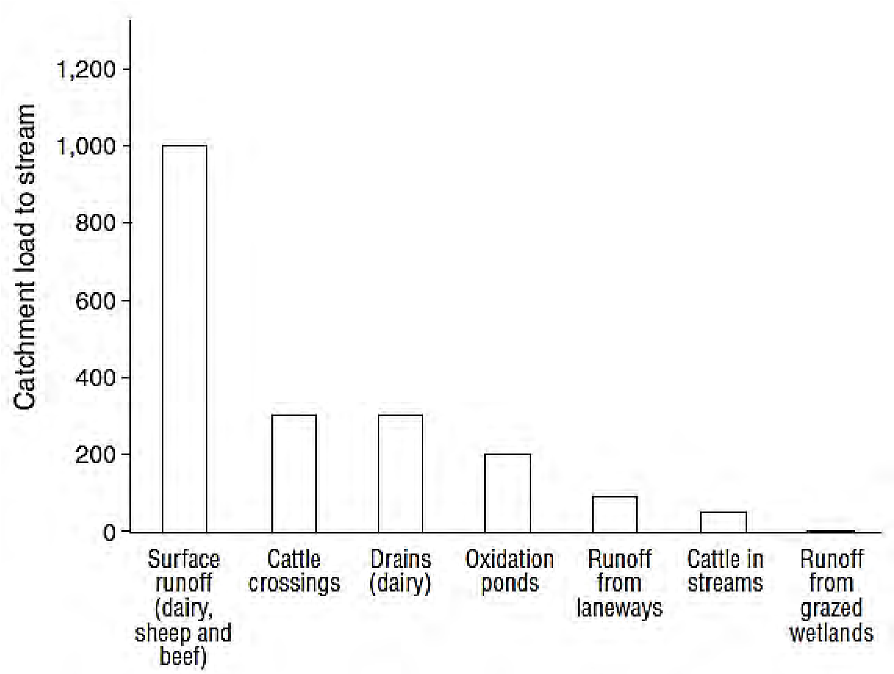


Figure 5: Waterway loadings of Escherichia coli (CFU x 108/ha./pasture/year for major sources of faecal matter in the Waikato Region, New Zealand. Source: McDowell and Wilcock 2008)

61. These published information suggest that if the streambank fencing is erected for reducing the delivery of *E. coli* to water ways, there could still be elevated *E.coli* levels in these streams (listed in Table 3.11.1 in the WRPC1) that run through agricultural catchments. At this juncture, it is important to mention that the Doole (2015)[55] report (which describes the mitigation

54 McDowell (2008) Water quality of a stream recently fenced-off from deer. New Zealand Journal of Agricultural Research 51(3):291-298

55 Doole (2015) Description of mitigation options defined within the economic model for Healthy Rivers Wai Ora Project. Description of options and sensitivity analysis. Report No. HR/TLG/2015-2016/4.6

options defined within the economic model for Healthy Rivers Wai Ora Project), applied certain estimates 58% and 65% for median and 95th percentile dairy and drystock loads when estimating the efficacy of streambank fencing for reducing the delivery of *E. coli* to water ways. These values were, according to the report, based on personal communication and published studies (see Table 3). It should be noted that a review of the published studies cited as a basis for these estimates indicate that a more conservative estimate of 36% should have been applied, going by the average of these variously published figures which range from 20-65%. Applying a near maximum stream bank efficacy estimate as was done in the Doole 2015 report tends to allow for a gross overestimate of the stream bank fencing efficacy for reducing the delivery of *E. coli* to water ways. This suggests that the estimated stream bank fencing efficacy which formed the basis for the decision making may actually be unrealistic or over-optimistic.

Table 3: Reported efficacy levels for streambank fencing for reducing *E. coli* loadings, extracted with modifications* from Doole 2015 report

Reduction in *E.coli* delivery (%)		Land use	Reference**
	27.5*	Cattle	McKergow et al. (2007)
	40	Cattle	Monaghan and Quinn (2010)
	60	Dairy and drystock	Monaghan and Quinn (2010)
	25	Dairy and drystock	Muirhead et al. (2011)
	20	Dairy and drystock	Longhurst (2012)
	24	Drystock	Longhurst (2012)
	47.5*	Dairy and drystock	Quinn
	20	Dairy and drystock	Semadeni-Davies and Elliot (2012)
	24	Dairy and drystock	Semadeni-Davies and Elliot (2012)
	20	Dairy and drystock	Semadeni-Davies and Elliot (2013)
	50	Dairy and drystock	Semadeni-Davies and Elliot (2013)
	20	Dairy and drystock	Elliot et al. (2013)
	50	Dairy and drystock	Elliot et al. (2013)
	55	Drystock	McDowell et al. (2013)
	20	Dairy	Ross Monaghan (pers. Comm., 2015)
	30	Median reductions in dairy and drystock 95th percentile	Ross Monaghan (pers. Comm., 2015)
	58		Richard Muirhead (pers. Comm., 2015)
	65	Reductions in dairy and drystock	Richard Muirhead (pers. Comm., 2015)
Average	36.44		
	*	an average of min and max estimates reported in the study	

62. A recent paper by McDowell et al. (2017) based on GIS modelling, concluded that fencing small waterbodies in head water hill catchments will be required to significantly reduce catchment contaminant loads. It is important that decision makers are confident that endorsing the proposed fencing rules for all stock classes, will result in the *E. coli* reductions in streams predicted by the PC1 modelling. The McDowell et al (2017), which is based on analysis of stream orders appears to reinforce the WRPC1 approach, albeit at a national level and based on modelling. I therefore re-examined historical water quality monitoring data[56], by comparing *E.coli* concentrations in rivers and streams with varying stream order classification with a view to evaluating if the proposed fencing requirements will be effective in mitigating pathogens. A total of 8108 nation-wide *E.coli* datasets which had associated discharge and water clarity data were used. Based on this statistical analysis, I found that trends in *E.coli* concentrations and loads in New Zealand rivers are not related to stream order (Figure 6 and Figure 7). In contrast to the results of McDowell report, this indicates that stream order is not relevant to the faecal indicator bacteria levels observable during monitoring programs. On the basis of this statistical analysis on actual monitoring data (as against modelled input in the McDowell et al. 2017 study), I posit that if potential regulation in New Zealand is requiring livestock to be fenced off from certain rivers based on their stream order classification, there might be no notable effect on *E.coli* loadings in the receiving waters. This position is also strengthened by those of other studies (see paragraph 59) which affirm that surface runoff is the major source of faecal pollution from agriculture in the Waikato Region, as opposed to direct defaecation in streams. Fencing, without additional measures such as riparian buffer strips, is therefore unlikely to have a meaningful effect on

[56] A total of 145,040 water quality dataset that have been routinely collected by regional authorities from as early as the late 1980s for New Zealand rivers and tributaries (https://data.mfe.govt.nz/) was used in the analysis. This dataset contained measured values for several notable parameters such as ammoniacal nitrogen, total nitrogen, nitrate-nitrogen, dissolved reactive phosphorus, total phosphorus and *E.coli*. All *E.coli* datasets were extracted (n=8170). Among these, a total of 8103 *E. coli* datasets which had corresponding discharge data were thus used for the analysis. *E.coli* data used thus spanned from 2005 to 2013.

stream *E coli* concentrations, particularly with hill country sheep and beef properties.

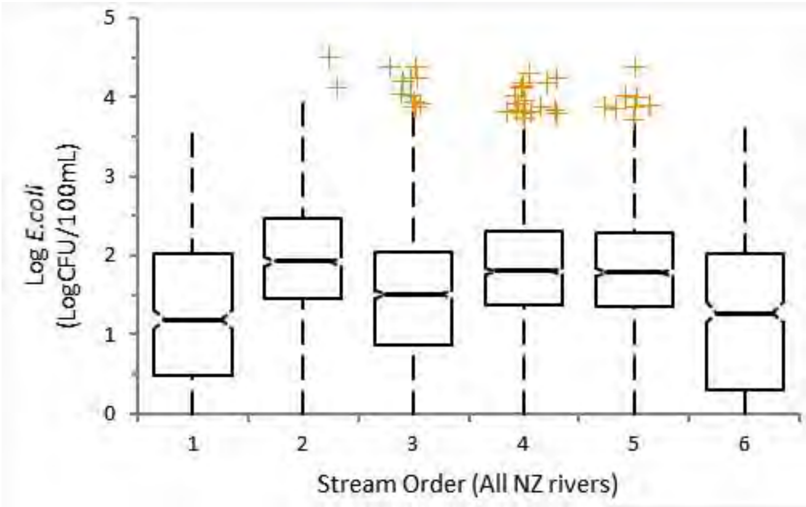


Figure 6: *E.coli* concentrations in New Zealand rivers in relation to stream order designation

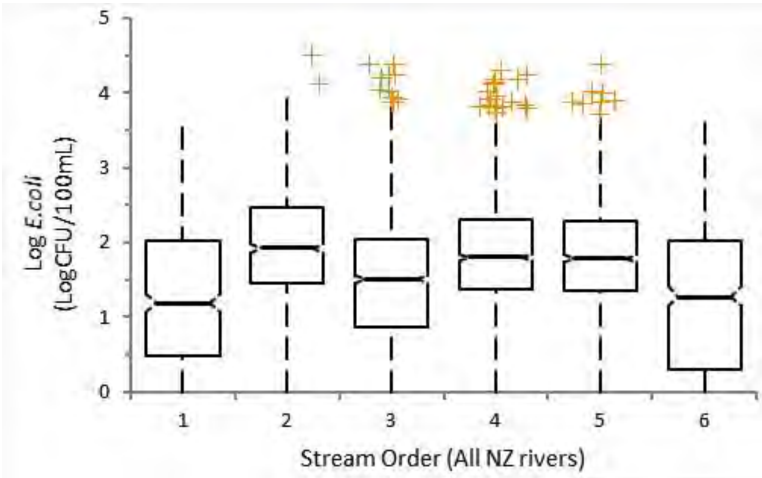


Figure 7: *E.coli* loads in New Zealand rivers in relation to stream order designation

63. I, however, agree with the arguments of Ritchie and Donnison (2010)[57], Moriarty (2015)[58] and Monaghan et al. (2010[59]) that the short-term and immediate effects of direct deposition in smaller lowland streams cannot be discounted. This is particularly so because, from the health risk point of view, direct faecal deposition could still be important given that it occurs at base flows when there is less dilution, and when downstream use is more likely. Also, in-stream faecal deposition delivers viable pathogens directly to water, with no land-based die-off effects thus leading to an erratic elevation in *E.coli* levels.

64. Although exceedances are also associable with low flow river discharge conditions, elevated *E.coli* levels are more pronounced during storm flow discharge conditions for rivers and tributaries in the Waikato region (Figure 8). In Figure 8, it is however, difficult to decipher from an analysis of discharge conditions versus FIB concentrations, what factor (direct stream deposition, over land flow, etc.) is responsible for elevated *E.coli* concentrations in the receiving water (i.e. sites identified in - Table 3.11.1). While it may be convenient to statistically analyse 'box plots' of *E.coli* concentrations under varying land use and river discharge scenarios, and posit that 'higher' *E.coli* concentrations observed in New Zealand streams are due to a particular factor/source, the *E.coli* concentrations may actually be confounded by *E.coli* from other hitherto unidentified sources (such as non-faecal environmental sources highlighted paragraph 29).

---

[57] As previously cited

[58] As previously cited

[59] Monaghan R, Semadeni-Davies A, Muirhead R, Elliott S, Shankar U 2010. Land use and land management risks to water quality in Southland. Report prepared for Environment Southland. Invermay, AgResearch

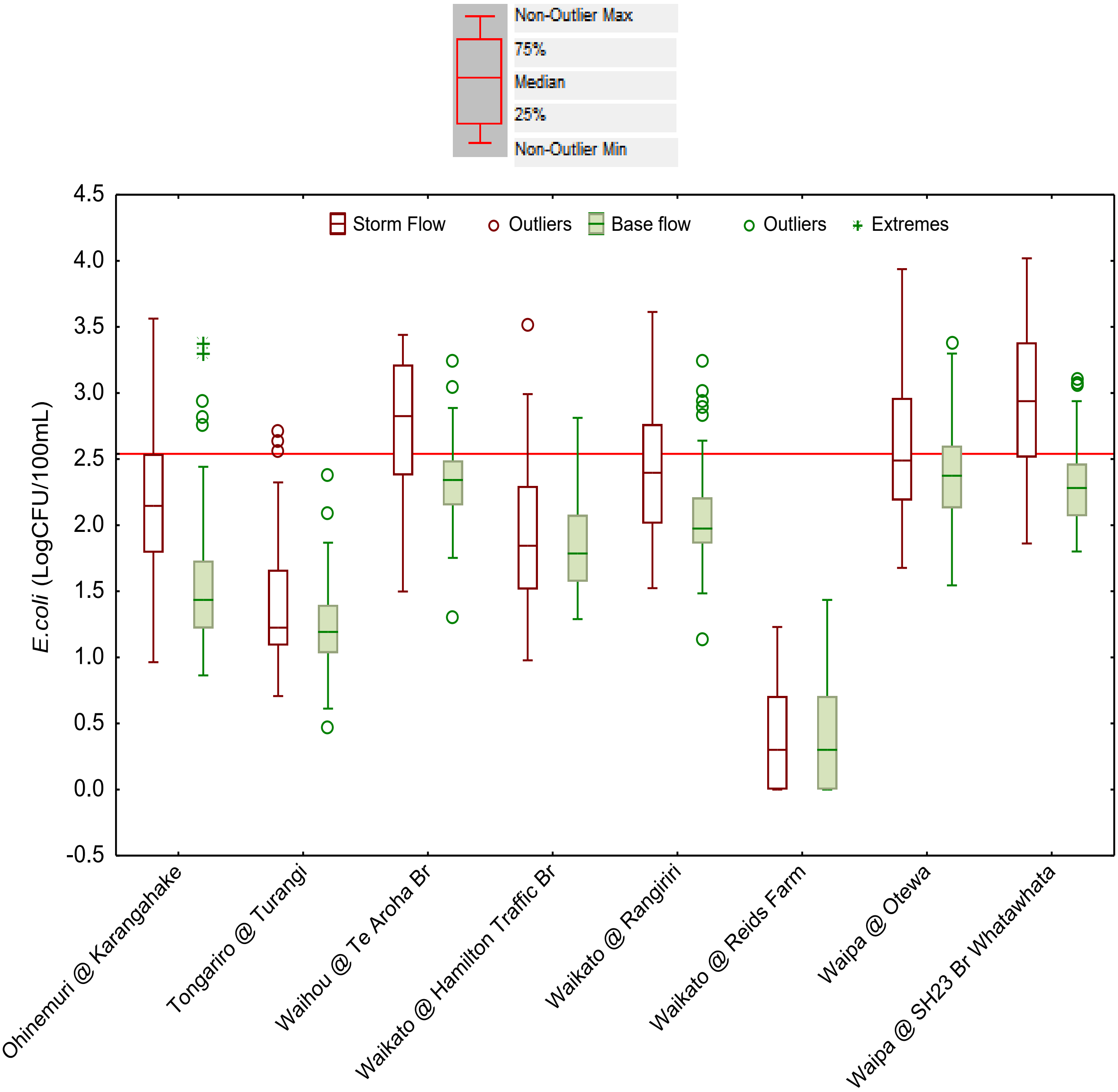


Figure 8: Box plots of *E.coli* concentrations during baseflow and storm flow conditions, Waikato Region waterways, 2007-2013. Red horizontal line is the 540 CFU/100mL *E.coli* threshold

65. Summarily, published studies indicate that direct deposition is a minor percentage of total annual catchment *E.coli* loads to waterways in the Waikato Region, and that surface runoff is the major source of faecal pollution from agriculture in the Waikato Region, if the streambank fencing

is erected for reducing animal access and delivery of *E. coli* to water ways, there could still be elevated *E.coli* levels in streams (listed in Table 3.11.1 in the WRPC1) that run through agricultural catchments. I therefore recommend that authorities:

(a) Delete requirements to fence hill country streams, considering that it is a counter-intuitive approach to stopping overland flow,

(b) Increase requirements to identify and manage critical source areas and overland flow pathways. This will then lead to catchment-specific management intervention rather than a blanket approach to effect fences for stock exclusion which only stops direct deposition.

SHORT & LONG-TERM *E.COLI* TARGETS STATED IN PC1 TABLE 3.11-1

66. Table 3.11-1 in the PC1 sets out the *E.coli* concentrations to be achieved by actions taken in the short-term and long term (at 80 years) for rivers and tributaries. I note that these projected reductions are generally less than[60] 10% reductions for the short term but could be as high as 2000% reduction for the 80-year reduction target. For instance, Mangakotukutuku Stream which currently has a base 95th percentile of >12,000CFU/100mL has a long-term target of 540 CFU/100mL.

67. From a technical (microbiological) perspective, I am of the opinion that these targets related to *E.coli* reductions at the freshwater sites listed in WRPC1 are ambitious, unrealistic, and unecessary, and they present a cart 'before the horse' approach. Management options applied for the mitigation of *E.coli* in the PC1 need to be site-specific and this would be dependent on the successful execution of a reliable microbial source tracking (MST) study at each site to determine the contributory source of faecal pollution.

68. Currently, it is not known for certain what the sources of faecal pollution are for these streams and rivers, yet ambitious declarations are made to drastically reduce *E.coli* levels to certain levels (up to 2000% anticipated reduction for some streams). Only when we cross over the first milestone of reliably answering the teething question related to sources responsible for elevated bacteria levels at each site, can we begin to identify an appropriate

---

[60] or equal to

solution that will drive down observed elevations in *E.coli* levels, rather than a mere declaration of anticipated reduction targets without the means of achieving it.

69. We need to begin to ask the hard questions. Are elevated bacteria due to direct deposition of farm animals? If yes, which animals are largely responsible for these faecal droppings? While for some sites, it may be unreasonable to commit financial resources to erecting wired fences when the cause of elevated *E.coli* levels is mainly as a result of wildlife faecal deposits during low flows and overland flow during wet events, for some other sites, erecting barriers to prevent direct access to animals during low flows may actually be needed. To answer these questions, there is the need to commission a carefully designed MST study targeted at these sites. Such study has to be longitudinal, capturing samples collected from different seasons and flow conditions for each identified site in the WRPC1 Table 3.11.1.

70. Also, from a technical perspective, I suggest the need to commission a study that distinguishes if these elevated bacteria levels identifiable for sites listed in PC1 Table 3.11.11 are due to naturalized *E.coli* from the stream bed and channel sediments, which become resuspended following sheer disturbances that allow releases of additional microbial contamination to the water column during low flow conditions. These "naturalized" *E. coli* populations may survive and proliferate[61] in terrestrial (soil) and aquatic environments independent of pollution events (as have been documented in literature[62]). The genetic structure of these naturalized *E.coli* tends to be different from those isolated from animals and often suggesting that they were not recently deposited by animals. "Naturalized" *E. coli* populations could also falsely inflate measurement levels, leading to exceedances of

---

[61] i.e. grow

[62] Ishii, Satoshi et al. “Presence and Growth of Naturalized Escherichia Coli in Temperate Soils from Lake Superior Watersheds.” Applied and Environmental Microbiology 72.1 (2006): 612–621. PMC. Web. 3 Jan. 2018

Perchec Merien, A. M. (2014). Naturalization of Escherichia coli in New Zealand freshwater streams (Doctoral dissertation, ResearchSpace@ Auckland).

Ishii, S., and M.J. Sadowsky. 2008. Escherichia coli in the environment: implications for water quality and human health. Microbes Environ. 23:101–108.

available thresholds and suggesting pollution that is present (Devane, 2015)[63]. On the one hand, management options may be targeted towards restricting access to agents (animals or humans) that disrupt streambed sediments[64] during low flow conditions. On the other hand, while access restriction may be possible for animals, humans can also stir up and remobilize bed sediment with its faecal reservoir during contact recreation or food harvesting at base flows. Invariably, elevated concentrations of *E.coli* may continue to be recorded during restricted animal access and low flow conditions at these freshwater sites. A crucial piece of the puzzle thus lies with our ability to decipher by way of phylogenetic studies, if these elevated *E.coli* are due to naturalized *E.coli* and also to assess risks of exposure to pathogens during conditions of elevated levels of naturalized *E.coli.*

71. To shed more light on the arguments above on identifying sources of faecal contamination in waterways before a management solution or target is set, I reviewed the MST results of a recent study (Moriarty 2015)[65] that was completed on five sites with typically elevated concentrations of *E. coli* in the routine Environment Waikato testing (Karapiro, Komakorau, Mangaone, Mangaonua and Mangawhero Streams). These sites are also five out of the 62 sites identified in the proposed plan change (Table 3.11.1). Sampling occurred both during dry weather for 'base-flow' sources and following heavy rainfall. In Mangawhero, during base flow conditions, mean concentrations of *E.coli* was 9933 CU/100mL (higher than the 540CFU/100mL primary contact benchmark). However, further MST investigation under these base flow conditions revealed that wildfowl pollution was the dominant faecal source detected while pollution from ovine and bovine sources was not or rarely detected at Mangawhero Stream (Table 7, Moriarty 2015). Only after heavy downpour (>10mm of rain) was ovine, bovine and wildlife pollution detected, indicating additional pressure from the catchment during rainfall impacted conditions. A similar

---

63 Devane M (2015) The sources of "natural" microorganisms in streams. Client Report CSC15004, Prepared for Environment Southland and West Coast Regional Council

64 Stock access can also serve to re-charge bed sediment stores of microbes, thereby increasing peak concentrations during rainfall events.

65 Moriarty, E (2015) Sources of Faecal pollution in Selected Waikato Rivers - July 2015. Report commissioned by Dairy NZ. Report No. HR/TLG/2015-2016/7.3

observation was made for samples collected from Mangaone River during baseflow and rainfall impacted conditions, although sheep faecal pollution was not detected under these conditions. Similarly, wildfowl markers were found present in one of three Komakorau Stream samples with extremely elevated *E.coli* concentrations during baseflow conditions. During rainfall-impacted conditions, wildfowl pollution was detected in all samples collected, as well as faecal pollution from humans and ruminants in some of the samples, indicating additional pressure from the catchment during rainfall impacted conditions.

72. Based on the Moriarty (2015) MST results, the high prevalence of wildfowl markers during conditions of low flow (the most critical times for public exposure to health risk) coupled with the comparatively low prevalence of cattle markers during conditions of low flow (Table 5) suggest that pressure due to cattle droppings in these streams during low flow conditions may, in reality, be insignificant compared to wildlife droppings on streams marked in the WRPC1 as having elevated *E.coli* concentrations. Sunohara et al. (2012)[66] found that the cattle exclusion fencing promoted greater numbers and types of plant species and notably greater degrees of wildlife. In another study[67], protecting habitat through cattle exclusion fencing increased inputs of wildlife (C. goose) faecal material significantly, yet where cattle have open access to a stream (where they eat plants, trample soil and plants, etc.), the wildlife faecal markers were significantly reduced in relation to protected upstream sites.

73. The Moriarty (2015) study also reported total coliform and *E.coli* concentrations for the water samples collcted durign the MST study. While the total coliform analysis is not specific to bacteria of faecal origin[68] and

---

66 Sunohara MD, Topp E, Wilkes G, Gottschall N, Neumann N, Ruecker N, Jones TH, Edge TA, Marti R, Lapen DR. 2012. Impact of riparian zone protection from cattle on nutrient, bacteria, F-coliphage, and loading of an intermittent stream. J. Environ. Qual. 41:1301–1314

67 Wilkes, G., Brassard, J., Edge, T. A., Gannon, V., Jokinen, C. C., Jones, T. H., … Lapen, D. R. (2013). Coherence among Different Microbial Source Tracking Markers in a Small Agricultural Stream with or without Livestock Exclusion Practices. Applied and Environmental Microbiology, 79(20), 6207–6219.

68 In extreme cases, a high count for the total coliform group may be associated with a low, or even zero, count for faecal coliforms, this would not necessarily indicate the presence of faecal contamination (WHO 1996).

may be related to decaying organic matter surrounding the streams or in the stream bed, the test for *E. coli* is a more specific indicator of faecal contamination due to human sewage or animal droppings which could contain other bacteria, viruses, or disease-causing organisms. Generally lower *E.coli* to total coliform ratios were recorded during baseflow compared to rainfall impacted flow (Table 5) at the five Waikato Streams reported in the Moriarty (2015) study. Without further sampling and analysis to prove otherwise, this results tends to suggest that non-faecal contamination was higher compared to faecal contamination during low flow conditions.

Table 4: ESR *E. coli* and faecal source tracking results for Karapiro, Komakorau, Mangaone, Mangaonua and Mangawhero Streams (adapted from Moriarty, 2015)

Discharge condition	Faecal Pollution Source	No. of samples positive for marker	Total No. of observations	Prevalence (%)
Low flow	Wildfowl	11	14	78.6
Low flow	Cattle	6	14	42.9
Rainfall-impacted	Wildfowl	15	15	100
Rainfall-impacted	cattle	11	15	73.3

Table 5: *E.coli*: Total Coliform Ratio of Samples collected during the Moriarty (2015) MST study (adapted from Moriarty, 2015)

Flow conditions	**Sample No-Date**	***E.coli*: Total Coliform Ratio**				
		Karapiro	**Komakorau**	**Mangaone**	**Mangaonua**	**Mangawhero**
Base flow	Sample 1 -4 May	0.03	0.11	0.12	0.20	0.29
	Sample 2 -20 May	0.06	0.10	0.04	0.06	0.01
	Sample 3 - 11 June	0.07	0.09	0.04	0.11	0.06
	Mean	**0.05**	**0.10**	**0.07**	**0.12**	**0.12**
Rainfall impacted flow	Sample 1 - 13 April	0.02	1.00	1.00	0.07	1.00
	Sample 2 - 20 April	0.09	0.30	0.08	0.13	0.12
	Sample 3 - 28 April	0.30	0.29	0.10	0.30	0.13
	Mean	**0.14**	**0.53**	**0.39**	**0.17**	**0.42**

74. Care, however, should be taken in interpreting results from the Moriarty (2015) for decision making with regards to sources of elevated *E.coli* levels in Waikato waterways. The adopted sampling regime was limited in scope and frequency e.g. no sampling was conducted during summer (the most critical times for public exposure to health risk). The study also did not adequately capture considerations for flow in the study design. Instead, it defined baseflow as the period which there is no antecedent 24-hour rainfall greater than 10mm. Depending on the peculiarities of the catchment being considered (e.g., size, predominant land use, etc), what constitutes baseflow to each would differ. For instance, in some catchments, antecedent rainfall of up to 72 hours can impact on the flow of the downstream water bodies, despite the absence of rain in the previous 24 hours before sampling for faecal bacteria. Without any stream flow measurements reported in the MST study, it is difficult to know what flow conditions were referred to in the report as ‘during base flow’. Further MST studies are needed that adopt comparative approaches in a way that can reliably inform our understanding on the drivers of *E.coli* variability during

different flow and animal stream access conditions within the Waikato Region[69]. Only upon the successful execution of these source tracking studies shall we be able to inform appropriate management interventions that set realistic and achievable *E.coli* reduction targets for these streams.

75. Based on the above-mentioned, I recommend that:

(a) Site-specific management options, which is supported by flow-specific microbial source tracking (MST) studies at each site to determine the contributory source of faecal pollution, be applied for the mitigation of *E.coli* in the streams listed in the WRPC1. At the phylogenetic level, these studies will help to distinguish if these elevated bacteria levels identifiable for PC1 sites are due to faecal sources or non-faecal environmental *E.coli* from natural stream processes. Currently only 5 out of the 62 PC1 sites have adopted this approach. Even then, preliminary MST results show that wildfowl is the predominant source of faecal indicator bacteria in the streams and that cattle markers only become prevalent following heavy rainfall impacted (i.e. surface run-off and overland flow) conditions. Results from MST studies for the PC1 sites will then inform appropriate site-specific solutions that will drive down observed peaks in *E.coli* levels;

(b) While further work is undertaken to improve our understanding of the sources of in-stream *E.coli* concentrations in the PC1 sites, authorities can adopt tentative approaches already stated in paragraph 38c in order to meet the requirements of the NPS-FM.

CONCLUSIONS

76. I have within the ambit of available published literature (globally and regionally), as well as region-specic data analysis, presented evidence that supports the following arguments:

(a) The *E.coli* modelling science underpinning the economic modelling used to justify draft PC1 rules associated with very significant uncertainties and hence unreliable. It also does not effectively capture important variables related to sources, fate and transmission

[69] Technologies to achieve this are available, tests could be easily executed at ESR

pathways of microbial contamination from primary productive land into receiving water

(b) Targets related to *E.coli* reductions at the freshwater sites listed in PC1 are not based on scientific evidence and somewhat ambitious as they present a cart 'before the horse' approach. Management options applied for the mitigation of *E.coli* in the PC1 need to be site-specific and this would be dependent on the successful execution of reliable microbial source tracking studies at each site to determine the contributory source of faecal pollution.

(c) *E.coli* does not reliably predict the presence of all types of zoonotic pathogens associated with primary productive land. Also, not all FIB are from faecal sources, hence non-fecal environmental sources of FIB confound *E.coli*-pathogen correlations in streams. These uncertainties suggest the need to be cautious when determining *E.coli* targets as stated in Table 3-11.1 and associated interventions on land use.

(d) Until such time as reliable microbial source tracking is undertaken I propose that long term targets should be deleted from Table 3.11-1 given the myraids of uncertainties associated with the PC1.I also propose that the *E.coli* freshwater objectives be included in Table 3.11-1 in a way that meets the requirements of the NPS-FM. For instance, short term targets could be amended to include a combination of median and 95^{th} percentile *E.coli* concentrations rather than a reliance on the single 95^{th} percentile as it is currently in the PC1 Table 3.11-1. In this way, authorities can work towards a more realistic short-term target that is hinged on improvements in the NPS-FM attribute state of the P1 sites.

(e) Considering that surface runoff is the major source of faecal pollution from agriculture in the Waikato Region, as opposed to direct defaecation in streams, the proposed fencing rules are unlikely to be cost-effective in reducing the delivery of E. coli to Waikato water ways.

Christopher Dada
15 February 2019

APPENDIX 1: SUGGESTED ALTERNATIVE *E.COLI* TARGETS FOR PC1 SITES

			Current PC1 approach				Suggested PC1 Approach		
			Short term	80 year target	Base level		short term		
Catchment number	Catchment description	Site	95th percentile (E. coli/100mL)	95th percentile (E. coli/100mL)	95th percentile (E. coli/100mL)	Current NPS FM Attribute State	median	95th percentile (E. coli/100mL)	Short term target NPS-FM attribute state
73	Upper	Waikato River Ohaaki Br	70	70	70	Green	≤130	<540	Blue
66	Upper	Waikato River Ohakuri Tailrace Br	15	15	15	Green	≤130	<540	Blue
67	Upper	Waikato River Whakamaru Tailrace	60	60	60	Green	≤130	<540	Blue
64	Upper	Waikato River Waipapa Tailrace	162	162	162	Green	≤130	<540	Blue
74	Upper	Pueto Stm Broadlands Rd Br	92	92	92	Green	≤130	<540	Blue
72	Upper	Torepatutahi Stm Vaile Rd Br	216	216	216	Green	≤130	<540	Blue
65	Upper	Waiotapu Stm Homestead Rd Br	281	281	281	Green	≤130	<540	Blue
69	Upper	Mangakara Stm (Reporoa) SH5	1584	540	1700	Red	≤130	<1200	Yellow
62	Upper	Kawaunui Stm SH5 Br	2335	540	2534	Red	≤130	<1200	Yellow
58	Upper	Waiotapu Stm Campbell Rd Br	18	18	18	Green	≤130	<540	Blue
59	Upper	Otamakokore Stm Hossack Rd	680	540	696	Green	≤130	<540	Blue
56	Upper	Whirinaki Stm Corbett Rd	98	98	98	Green	≤130	<540	Blue
54	Upper	Tahunaatara Stm Ohakuri Rd	783	540	810	Green	≤130	<540	Blue
57	Upper	Mangaharakeke Stm SH30 (Off Jct SH1)	684	540	700	Green	≤130	<540	Blue
70	Upper	Waipapa Stm (Mokai) Tirohanga Rd Br	1147	540	1214	Red	≤130	<1200	Yellow
71	Upper	Mangakino Stm Sandel Rd	251	251	251	Green	≤130	<540	Blue
49	Upper	Whakauru Stm SH1 Br	2106	540	2280	Red	≤130	<1200	Yellow
48	Upper	Mangamingi Stm Paraonui Rd Br	2151	540	2330	Red	≤130	<1200	Yellow
45	Upper	Pokaiwhenua Stm Arapuni - Putaruru Rd	1363	540	1454	Red	≤130	<1200	Yellow
44	Upper	Little Waipa Stm Arapuni - Putaruru Rd	1377	540	1470	Red	≤130	<1200	Yellow
33	Middle	Waikato River Narrows Boat Ramp	340	260	340	Green	≤130	<540	Blue
25	Middle	Waikato River Horotiu Br	774	540	800	Green	≤130	<540	Blue
32	Middle	Karapiro Stm (Hickey Rd Bridge)	4518	540	4960	Red	≤130	<1200	Yellow
35	Middle	Mangawhero Stm (Cambridge- Ohaupo Rd)	2920	540	3184	Red	≤130	<1200	Yellow
29	Middle	Mangaonua Stm Hoeka Rd	6372	540	7020	Red	≤130	<1200	Yellow
31	Middle	Mangaone Stm Annebrooke Rd	2052	540	2220	Red	≤130	<1200	Yellow
30	Middle	Mangakotukut uku Stm Peacockes Rd	11394	540	12600	Red	≤130	<1200	Yellow
28	Middle	Waitawhiriwhiri Stm Edgecumbe Street	5922	540	6520	Red	≤130	<1200	Yellow
23	Middle	Kirikiriroa Stm Tauhara Dr	2124	540	2300	Red	≤130	<1200	Yellow
20	Lower	Waikato River, Huntly-Tainui Br	1944	540	2100	Red	≤130	<1200	Yellow
9	Lower	Waikato River, Mercer Br	1494	540	1600	Red	≤130	<1200	Yellow
4	Lower	Waikato River, Tuakau Br	1584	540	1700	Red	≤130	<1200	Yellow
22	Lower	Komakorau Stm, Henry Rd	3474	540	3800	Red	≤130	<1200	Yellow
17	Lower	Mangawara Stm Rutherford Rd Br	4955	540	5446	Red	≤130	<1200	Yellow
19	Lower	Awaroa Stm (Rotowaro) Sansons Br @ Ro	1800	540	1940	Red	≤130	<1200	Yellow
14	Lower	Matahuru Stm Waiterimu Road Below, Con	6147	540	6770	Red	≤130	<1200	Yellow
16	Lower	Whangape Stm Rangiriri-Glen Murray Rd	584	540	589	Green	≤130	<540	Blue
12	Lower	Waerenga Stm SH2 Maramarua, Taniwha Rd	5098	540	5604	Red	≤130	<1200	Yellow
8	Lower	Whangamari no River Jefferies Rd Br	4712	540	5176	Red	≤130	<1200	Yellow
2	Lower	Mangatangi River SH2 Maramarua	5567	540	6126	Red	≤130	<1200	Yellow
1	Lower	Mangatawhir i River Lyons Rd	5108	540	5616	Red	≤130	<1200	Yellow
68	Lower	Waipa River Mangaokewa Rd	2417	540	2626	Red	≤130	<1200	Yellow
60	Lower	Waipa River Otewa	2036	540	2202	Red	≤130	<1200	Yellow
51	Lower	Waipa River SH3 Otorohanga	3289	540	3594	Red	≤130	<1200	Yellow
43	Lower	Waipa River, Pirongia-Ngutunui Rd Br	4441	540	4874	Red	≤130	<1200	Yellow
34	Lower	Waipa River Whatawhata Bridge	3657	540	4003	Red	≤130	<1200	Yellow
26	Lower	Ohote Stm Whatawhata/Horotiu Rd	2142	540	2320	Red	≤130	<1200	Yellow
36	Lower	Kaniwhaniwha Stm Wright Rd	1917	540	2070	Red	≤130	<1200	Yellow
38	Lower	Mangapiko Bowman Rd Stm	7074	540	7800	Red	≤130	<1200	Yellow
39	Lower	Mangaohoi Stm South Branch Maru Rd	943	540	988	Green	≤130	<540	Blue
37	Lower	Mangauika Stm Te Awamutu Borough W/S	1008	540	1060	Yellow	≤130	<1000	Green
40	Lower	Puniu River Bartons Corner Rd Br	2790	540	3040	Red	≤130	<1200	Yellow
47	Lower	Mangatutu Stm Walker Rd Br	738	540	760	Green	≤130	<540	Blue
46	Lower	Waitomo Stm SH31 Otorohanga	1453	540	1554	Red	≤130	<1200	Yellow
53	Lower	Mangapu River Otorohanga	4284	540	4700	Red	≤130	<1200	Yellow
52	Lower	Waitomo Stm Tumutumu Rd	2241	540	2430	Red	≤130	<1200	Yellow
63	Lower	Mangaokewa Stm Lawrence Street Br	6224	540	6856	Red	≤130	<1200	Yellow
10	Lower	Whangamari no River Island Block Rd	655	540	668	Green	≤130	<540	Blue
3	Lower	Whakapipi Stm	1773	540	1910	Red	≤130	<1200	Yellow
7	Lower	SH22 Br Ohaeroa Stm	4667	540	5126	Red	≤130	<1200	Yellow
11	Lower	SH22 Br Opuatia Stm	2898	540	3160	Red	≤130	<1200	Yellow
5	Lower	Ponganui Rd Awaroa River	1017	540	1070	Yellow	≤130	<1000	Green

APPENDIX 5: TECHNICAL REPORT OF DR BEN HANCOCK

APPENDIX 5

TECHNICAL REPORT OF DR BENJAMIN MALCOLM HANCOCK
23 October 2019

IN THE MATTER	of the Beef + Lamb New Zealand submission on the Essential Freshwater Policy document
BY	**BEEF + LAMB NEW ZEALAND LIMITED** **Submitter**

BACKGROUND

1. My name is Dr Benjamin Malcolm Hancock.

2. I have a PhD in Ecology from Lincoln University (2015), a Master of Science majoring in Biodiversity and Ecology (Victoria University of Wellington, 2008), and a Bachelor of Science in Conservation and Ecology.

3. I am currently employed by Beef + Lamb New Zealand Ltd as a Senior Insights Analyst. I began in this role in October 2019.

4. In my previous employment I have worked for Beef + Lamb New Zealand Ltd as Senior Agricultural Analyst (2016-2019) in the Economic Service, and Policy Analyst for the Ministry for Primary industries (2015-2016) in the Biosecurity and Animal Welfare Directorate.

5. I am a Member of the New Zealand Institute of Primary Industry Managers.

6. I have read the Code of Conduct for Expert Witnesses in the Environment Court's 2014 Practice Note and agree to comply with it. I confirm that the opinions I have expressed represent my true and complete professional opinions. The matters addressed by my evidence are within my field of professional expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

SCOPE OF REPORT

7. I have been asked by Beef + Lamb New Zealand Ltd (B+LNZ) to provide summaries on:

   a. Applicability of the proposed methodology for measuring carry capacity in the Draft Stock Exclusion 360 regulations;

   b. Alternative existing and accepted methods of assessing stocking rate capability of productive land.

8. In the Essential Freshwater policy proposal, the proposed methodology for the 'Draft Stock Exclusion 360 regulations' to quantify a farm's carrying capacity uses "*The Rules for Assessment of Carrying Capacity of Crown of Crown Pastoral Land (Rents for Pastoral Leases)*" published on Land Information New Zealand's (LINZ) website. Quantifying the carrying capacity of a farm business is central in defining which non-lowland properties are required to exclude livestock from all waterbodies.

9. The LINZ South Island high-country methodology was created for quantifying potential carrying capacity of pastoral lease land – largely high-country, exclusively in the South Island – without any land development. The methodology is set out in figure 2 and includes incorporation of a narrow suite of Land Use Capability (LUC) units specific to the South Island high-country, the productive capacity of a unit under indigenous cover, along with mean elevation, mean aspect, mean soil temperature, and mean water vapor deficit.

10. The LINZ South Island high – country methodology is not fit for the purpose proposed in the Essential Freshwater policy proposal. This is discussed further below.

11. The research to support and inform the co-efficients was carried out by Landcare Research/Manaaki Whenua specific to South Island high-country. In LINZ South Island high-country methodology co-efficients that are fit for purpose for the North Island and LUC Classes 1, 2 and 3 do not exist (see Figure 2). LUC Classes 1-4 are suitable for multiple land uses (Figure 1), any methodology in the policy to assess carrying capacity must be applicable to all LUC Classes across both the North and South Islands and applicable to all productive land.

Figure 1: Increasing limitations to use and decreasing versatility of use from LUC Class 1 to LUC Class 8. †Includes vegetable cropping[1].

Increasing limitations to use ↓

LUC Class	Arable cropping suitability†	Pastoral grazing suitability	Production forestry suitability	General suitability
1	High	High	High	Multiple use land
2	↓	↓	↓	
3				
4	Low			
5	Unsuitable			Pastoral or forestry land
6				
7		Low	Low	
8		Unsuitable	Unsuitable	Conservation land

Decreasing versatility of use ↓

12. Some LUC Class 2 and 3 land occurs in the South Island high-country but there are only 261 ha of Class 2 (0.02% of total in NZ) and 19,298 ha of LUC Class 3 (0.8% of total on NZ) – Class 6 and 7 areas in the South Island high-country are only 10% and 19% of NZ totals, which means that they are not statistically representative of the suit of these land Classes across New Zealand. Any representation of lower elevation and high carrying capacity land was extremely limited and it would be inappropriate to apply the empirically derived high-country coefficients to the South Island lowlands let alone the whole North Island.

13. The LUC Classes 4 through 8 are better represented, however, only those LUC units occurring in the South Island high-country were considered in the LINZ analysis. There is limited representation of other units in these Classes, such as units representing soft rock hill country or volcanic and tephra mantled landscapes that cover large proportions of the North Island[1].

14. Beef + Lamb New Zealand (B+LNZ) supports land planning and management that is relevant to the natural capital specific to the land that the farm business is based off. While the LINZ South Island high-country methodology is not fit for the purpose set out in the Essential Freshwater policy proposal, its underlying LUC base is appropriate. The LUC system uses units that are built on aspects the contribute to the natural capital of the farm's environment across New

[1] Lynn IH et al 2009, Land Use Capability Survey Handbook – A New Zealand handbook for the classification of land, 3rd Ed, Hamilton - AgResearch, Lincoln – Landcare Research, Lower Hutt – GNS Science

Zealand (see paragraph 22), and their associated potential production within these environments.

15. There is a long history to the development and use of the LUC system within New Zealand which has established it as the foundational approach to land resource mapping and sustainable management within New Zealand, as it provides national, regional, and farm scale multi-factor information and analysis that allows an interpretation of the landscape to be used for a range of purposes.

16. The LUC system underpins soil conservation and management, work of Regional Land Management Advisors, advanced farm environment planning and as such is a cornerstone to B+LNZ Land Environment Plans, and Horizons Sustainable Land Use Initiative (SLUI), which is supported and part funded by the Ministry of Primary Industries. LUC is utilised in National Policy such as the NES-PF, Regional Policy, and research such as underpinning national and regional modelling. LUC is discussed in detail in the Expert Evidence of Mr Stokes given during the regional hearings on Waikato Regional Councils Plan Change 1[2].

17. The basis of the Land Use Capability classification is defined as a systematic arrangement of different kinds of land according to those properties that determine its capacity for long term sustained production. Capability is used in the sense of suitability for productive use or uses after considering the physical limitations of the land[1].

18. The robustness and place of LUC within sustainable natural resource management is supported by scientific research and peer-reviewed papers nationally and internationally[2]. Regional councils, primarily, find a common language and scientifically robust process of analysis, to manage and protect land and water in farm planning. The breadth of environmental issues and risks associated with sections of landscape – whether in agricultural, horticultural or conservation use – has expanded to meet wider needs of the community and landowners. This does not affect the validity of using the LUC system or undermine its role in providing a clear platform for analysis in managing the needs of stakeholders and risks into the future.

19. The complexities of the natural environment must be considered and incorporated into the frameworks used to assess them. Natural ecosystems and economic system cannot be measured in single factor steps even when focussing on a single issue, such as water quality.

20. The LUC Classes are built on five primary physical factors that are central to the natural capital of a farming system[1]. These relate to how the land behaves under various uses, either individually or in combination, and are critical to long-term sustainability and water quality management. Add in climate, knowledge about current and past land use, and other supplementary information, then the capability of the land can be assessed for permanent sustained production. The five factors that LUC is based on are:

    a. Rock type

[2] Stokes. S. (3 May 2019) Brief of Evidence of Mr Simon John Stokes on Behalf of Beef + Lamb New Zealand on Waikato Regional Plan Change 1- Waikato and Waipā River Catchments and Variation 1 to Plan Change 1

b. Soil

c. Slope angle

d. Erosion type and severity

e. Vegetation cover[1]

21. In the last decade new tools for understanding and mitigating effects on natural resources have been developed, such as; lidar, geo-magnetic surveying, catchment modelling (e-source, land models), MyLand, Mitigator, LUCI, GIS, S-map, riparian planner, and the many varied farm environmental plan options. These tools are beneficial to participants in achieving an overarching outcome of managing natural resources sustainably. Much of their utility and application is built and relies on the LUC system.

22. GIS maps created and published by Landcare Research/Manaaki Whenua are available that cover New Zealand, with the most regions at 1:50,000 scale but at least 1:63,000 in the NZLRI. Generally, the NZLRI at 1:50,000 nominal scale is marginal for larger properties like the high-country runs and of limited use for smaller properties. B+LNZ supports farm-scale LUC mapping as part of land and environment planning (LEP).

23. Each LUC unit includes three attributes of carrying capacity – plus a ranking index for *Pinus radiata* plantations. When the New Zealand Land Resource Inventory (NZLRI) mapping project was carried out to create LUCs, regional productivity indices were created and attributed to each LUC Class to the unit level. The NZLRI is a national database of physical land resource information. The LUC unit is its most detailed level of the classification.

24. Ministry of Agriculture and Fisheries Advisory Officers assessed each LUC unit in development of the NZLRI. Each LUC unit was attributed with three carrying capacities (see Figure 2):

a. Present Average – The number of stock units per hectare (SU/ha) which the 'average farmer' was typically carrying on a particular LUC unit.

b. Top Farmer – SU/ha that the farmer with the highest level of stocking rate, with at least average stock performance, was carrying on a particular LUC unit.

c. Attainable Physical Potential - SU/ha capable of being carried on a particular LUC unit, assessed within the limits of present technology and given favourable socio-economic conditions[1].

25. The carrying capacities attributed to each LUC unit incorporate aspects that relate to grazing systems that operate within the natural grass curve, the farm's production capability and environmental constraints. To achieve this intent, the LUC system adhered to:

a. The land was assumed to be managed exclusively for livestock grazing.

b. On-farm feed cropping only was considered.

c. It was assumed that the stock were carried all year (i.e. winter carrying capacity in most instances) except for high country where stock were carried for part of the year only. In this case, seasonal figures were converted to an annual stocking rate.

d. It was assumed that each LUC unit was managed as a discrete entity[1].

Figure 2: Land Use Capability Extended Legend for the Waikato Region[3]

UNIT	GRAZING: PRESENT AVERAGE	GRAZING: TOP FARMER	GRAZING: ATTAINABLE PHYSICAL POTENTIAL	FERTILIZER REQUIREMENTS: INITIAL	FERTILIZER REQUIREMENTS: PRESENT AVERAGE	FERTILIZER REQUIREMENTS: ATTAINABLE PHYSICAL POTENTIAL
Iwl	16	20	22	750 kg/ha superphosphate	400kg/ha 15% potassic super	615 kg/ha 15% potassic super
					1.0 t/ha lime every 4 years	1.5 t/ha lime every 4 years
					600kg/ha 30% potassic super	700kg/ha 30% potassic super
					1.0 t/ha lime every 4 years	2.5 t/ha lime every 4 years
Isl	18	27	30	1000 kg/ha superphosphate	375 kg/ha 15% potassic super	400 kg/ha 15% potassic super
					500 kg/ha 30% potassic super	650kg/ha 30% potassic super

26. The data attributed to a LUC unit is still applicable regardless of scale, but appropriate definition is needed for on-farm planning. At 1:50,000 is not suitable for farm-scale but would give a reasonable indication of land qualities, but the boundaries are often too crude and resolution of units too coarse. At farm scale (1:10,000), LUC units would be sub-divided into component management blocks that are mapped as a single entity at the coarser scale. It is at this scale that farm based planning is appropriately based off and can be applied.

27. B+LNZ supports using a natural capital approach in characterising environmental conditions or aspects such as soils, geology, slope, aspect, and climate among other characteristics. The natural capital approach can be used to assess the potential impact or risk of a farm system to the environment, and in informing how these risks should be managed.

28. The proposed carrying capacity methodology for the 'Draft Stock Exclusion 360 regulations' are not fit for the intended purpose. The research and formulation of the proposed methodology is specific to South Island high-country and not representative or translatable to the rest of New Zealand.

29. If a proxy of suitability for fencing or intensity of livestock is to be implemented, rather than actual stocking rates, then the LUC system should be adopted. The LUC system is a robust and widely accepted method of assessing the natural capacity of land, which was an element of the proposed methodology. LUC systematically records characteristics of the landscape along with identifying environmental vulnerabilities. There are already attributes of carrying capacity

[3] Jessen. M.R., & Booth. A.K (1980) Stock Carrying capacities and Fertiliser Data for the Waikato Region. Waikato Region Land Use Capability Extended Legend NZLRI.

existing within the LUC system that are aligned with these characteristics for animal production systems.

Figure 3: Methodology for calculating LINZ South Island high-country methodology

Model 2

Determine the value for BASE produced by the following formula applied to 25mx25m cells

$$BASE = Fmask \times \exp(-5.971040435 + (slope * 0.017525954) + LUC\ Class\ value + (vpd\_january * 0.046918408) + (vpdyr * -0.098763683) + (nzmas * 0.043276909))$$

Where:

LUC Class value is the coefficient in the table below that corresponds to the LUC Class ascribed to the area in the relevant authoritative dataset.

Where the LUC Class is...	then the coefficient is...
4...	-0.457559805
5...	-0.027060915
6...	-0.810075484
7...	-1.49966985
8...	-4.017955247

Nzmas is a value in watts per metre square (W/m^2) for mean annual solar radiation taken from the relevant authoritative dataset.

VPD_January is a value in kilopascals (kPa) for mean vapour pressure deficit in January taken from the relevant authoritative dataset.

Vpdyr is a value in kPa for mean annual vapour pressure deficit taken from the relevant authoritative dataset.

Fmask is a variable which is 0 if the area of the cell is shown as any of the following in the authoritative dataset: indigenous forest, river beds, water bodies, glaciers, or permanent snow, and otherwise is 1.

And use the result to obtain the BASE output produced by the formula according to the following table:

Purpose	**Examples of this purpose in these rules**	**How to output BASE for the purpose**
For making maps showing BASE in SU attributed by this model to the areas of instances of LUC unit	Rule 1.1.2(a)(iv)	Use the values for base produced by the formula to calculate mean BASE/ha for the instance of the LUC unit and then multiply it by the area of the instance of the LUC unit in ha, round the result to the nearest 1 stock unit
For producing mean BASE in SU/ha for all instances of an LUC unit	Rule 1.1.2(a)(iv)	Use the values for base produced by the formula to calculate mean BASE/ha for all instances of the LUC unit and round the result to the nearest 0.01 SU/ha
When producing total BASE stock units for a modelled area substantially corresponding to a pastoral lease	Rule 1.1.2(a)(iv)(i)(E)	Use the values for base produced by the formula calculate mean BASE/ha for the modelled area and multiply it by the area of the modelled area in ha, round the result to the nearest 1 SU/ha

Authoritative datasets

VALUE or other component of Model1	Relevant authoritative dataset	Where the dataset can be obtained
Slope	A 25m gridded layer derived from Landcare Research 25m digital elevation model using a standard slope function to calculate slopes from a neighbourhood of nine (3x3) adjacent cells	The 25m gridded layer is available at: http://lris.scinfo.org.nz/#/layer/318-slope/
Mean January Vapour pressure deficit	A 25m gridded layer derived by re-sampling (with bilinear interpolation) from the 100m gridded layer for 30 year normals to 1980 from Land Environments of New Zealand (LENZ)	The 25m gridded layer is available at: http://lris.scinfo.org.nz/#/layer/321-mean-january-vapour-pressure-deficit-vpdjan/
Mean Annual Vapour pressure deficit	A 25m gridded layer derived by re-sampling (with bilinear interpolation) from the 100m gridded layer for 30 year normals to 1980 from Land Environments of New Zealand (LENZ)	The 25m gridded layer is available at: http://lris.scinfo.org.nz/#/layer/320-mean-annual-vapour-pressure-deficit-vpdyr/
Mean Annual Solar Radiation	A 25m gridded layer derived by re-sampling (with bilinear interpolation) from the 100m gridded layer for 30 year normals to 1980 from Land Environments of New Zealand (LENZ)	The 25m gridded layer is available at: http://lris.scinfo.org.nz/#/layer/317-mean-annual-solar-radiation-nzmas/
LUC Class	A 25m gridded dataset converted from the polygon format of the New Zealand Land Resource Inventory	The 25m gridded layer is available at: http://lris.scinfo.org.nz/#/layer/316-luc-coefficient-model-2/ The original vector land use capability data is at: http://lris.scinfo.org.nz/#/layer/76-nzlri-land-use-capability/

VALUE or other component of Model1	Relevant authoritative dataset	Where the dataset can be obtained
Slope	A 25m gridded layer derived from Landcare Research 25m digital elevation model using a standard slope function to calculate slopes from a neighbourhood of nine (3x3) adjacent cells	The 25m gridded layer is available at: http://lris.scinfo.org.nz/#/layer/318-slope/
Mean January Vapour pressure deficit	A 25m gridded layer derived by re-sampling (with bilinear interpolation) from the 100m gridded layer for 30 year normals to 1980 from Land Environments of New Zealand (LENZ)	The 25m gridded layer is available at: http://lris.scinfo.org.nz/#/layer/321-mean-january-vapour-pressure-deficit-vpdjan/
Mean Annual Vapour pressure deficit	A 25m gridded layer derived by re-sampling (with bilinear interpolation) from the 100m gridded layer for 30 year normals to 1980 from Land Environments of New Zealand (LENZ)	The 25m gridded layer is available at: http://lris.scinfo.org.nz/#/layer/320-mean-annual-vapour-pressure-deficit-vpdyr/
Mean Annual Solar Radiation	A 25m gridded layer derived by re-sampling (with bilinear interpolation) from the 100m gridded layer for 30 year normals to 1980 from Land Environments of New Zealand (LENZ)	The 25m gridded layer is available at: http://lris.scinfo.org.nz/#/layer/317-mean-annual-solar-radiation-nzmas/
LUC Class	A 25m gridded dataset converted from the polygon format of the New Zealand Land Resource Inventory	The 25m gridded layer is available at: http://lris.scinfo.org.nz/#/layer/316-luc-coefficient-model-2/ The original vector land use capability data is at: http://lris.scinfo.org.nz/#/layer/76-nzlri-land-use-capability/

<table>
<tr><th>VALUE or other component of Model1</th><th>Relevant authoritative dataset</th><th>Where the dataset can be obtained</th></tr>
<tr><td>Fmask</td><td>A 25m gridded dataset derived from Land Cover Database (LCDB2) where the following land cover classes are set to 0, and all others to 1
<table>
<tr><th>Class</th><th>Name</th></tr>
<tr><td>65</td><td>indigenous forest</td></tr>
<tr><td>54</td><td>broadleaved indigenous hardwoods</td></tr>
<tr><td>20</td><td>lake or pond</td></tr>
<tr><td>21</td><td>river</td></tr>
<tr><td>14</td><td>permanent snow and ice</td></tr>
<tr><td>16</td><td>gravel and rock</td></tr>
</table></td><td>A 25m gridded layer showing all the cells forced to 0 is available at:
http://lris.scinfo.org.nz/#/layer/314-zero-base-mask-fmask/</td></tr>
</table>

APPENDIX 6: TECHNICAL REPORT OF DR JANE CHRYSTAL

APPENDIX 6

TECHNICAL REPORT OF DR JANE MARIE CHRYSTAL

23 October 2019

IN THE MATTER	of the Beef + Lamb New Zealand submission on the Essential Freshwater Policy document
BY	**BEEF + LAMB NEW ZEALAND LIMITED** **Submitter**

TABLE OF CONTENTS

BACKGROUND

1. My name is Dr Jane Marie Chrystal.

2. I have a PhD in Soil Science from Massey University (2017), a postgraduate diploma in Agricultural Science (Massey University, 2011), and a Bachelor of Applied Science majoring in Agriculture (Massey University, 2000). I have a certificate in Advanced Sustainable Nutrient Management (Massey University, 2007).

3. I am currently employed by Beef + Lamb New Zealand Ltd as Senior Environment Data Analyst. I began in this role in April 2018.

4. In my previous employment I worked for AgResearch Ltd as a Scientist (2017/2018) and Research Associate (2006-2017) in the Farm Systems and Environment group.

5. While employed with AgResearch I was a member of the AgResearch Overseer Expert Users Group and was involved in testing new versions of the Overseer nutrient budgeting model prior to release. I have extensive experience in farm systems modelling, including application of Overseer and FARMAX, which are decision support tools for pastoral farmers.

6. I have been lead or co-author in four peer-reviewed journal articles, 11 conference papers and at least 10 other forms of dissemination.

7. I am a CNMA (Certified Nutrient Management Advisor; August 2018).

EXECUTIVE SUMMARY

8. There is an inextricable link between agricultural land uses and freshwater quality. In particular, agricultural losses of nitrogen and phosphorus from farming systems and practices to surface and groundwater, can ultimately impact on the health of freshwater ecosystems.

9. The scale and magnitude of the impacts from agriculture on freshwater are dependent on a range of factors, including the type of agricultural land use, scale and intensity of land use, farming systems and practices, along with

environmental conditions such as climate, and catchment and farm geology and topography.

10. Some farming activities pose a higher risk of contaminant losses to water than others. These include:

    (a) irrigation;

    (b) effluent, storage, land application, management;

    (c) cropping;

    (d) high stocking rates and densities; and

    (e) fertiliser use, including type, timing, and load.

11. Mitigation approaches which are tailored to the farm and the catchment including the utilisation of new farmer support tools such as LUCI and MITIGATOR are likely to result in improved outcomes and result in reductions in contaminants to water. Taking a tailored farm and catchment approach to the management of farming systems and practices is likely to deliver greater environmental outcomes while providing for the ongoing viability of dryland agricultural land uses, than prescriptive input type standards and rules.

12. Understandably effects arising from intensification of land use, raise concerns in relation to the health of freshwater ecosystems. However, it is important that decision makers on Essential Freshwater are confident that the range and magnitude of policy intervention proposed is justified in relation to the relative cause or contribution from the agricultural sectors to state and trends in water quality and impacts on aquatic ecosystem health.

13. Overseer is a useful tool when used with an understanding of the purpose it was designed for and the strengths and weaknesses of the tool.

14. Overseer was originally designed as a fertiliser support tool and to help farmers understand the implications of applying nutrients to land at different times of the year, in different forms, and at different rates. Overseer was never designed to be an integral part of catchment modelling in relation to

determining the allocable load within a catchment or water quality outcomes. The Parliamentary Commissioner for the Environment report (PCE report) lists four key application issues with the use of Overseer in regulation (Upton, 2018):

1. “data input uncertainty;

2. version change;

3. the inability of Overseer to represent farm systems in particular regions; and

4. uncertainty in a compliance setting.”

15. The boundary of the Overseer model is the farm gate and the plant root zone (for N loss) or the block boundary (for P loss). Not volumes of N in the water leaching from the farm.

16. Critical Source Area’s (CSA’s) are areas of the farm contributing the greatest volume of P loss, and within Overseer are not easily accounted for, thus P loss estimates can have a high degree of uncertainty.

17. The level of uncertainty in the model outputs come from a number of sources including:

(a) user error,

(b) bugs in the model,

(c) sub-models with less data to validate the model against,

(d) temporal and spatial variation in validation data, and

(e) Overseer version changes.

18. OVERSEER is not recommended to be used in a policy setting to hold farming systems to historic land uses or emissions profiles.

19. Significant limitations which need to be carefully considered in relation to the application and use of OVERSEER, especially in relation to underpinning catchment modelling, mitigation modelling, and in regulation.

20. The use of OVERSEER in policy needs careful consideration to enable the appropriate use of the model to reduce risk and assist with informing on farm management approaches. Given the evidence set out above, there are significant risks associated with utilisation of the model to grandparent farming practices at a particular point in time. Alternative approaches including consideration of thresholds should be considered in relation to establishing outcome or output based risk management frameworks

21. In establishing policy or regulatory frameworks for agricultural land uses is that it is extremely important to realise that there is no 'one-size-fits-all' approach to farm mitigation strategies, as currently proposed in the Essential Freshwater provisions. It is important that there is an effective management framework that is tailored to the specific farm and catchment. The framework must identify and manage those activities (outlined above) and areas on the farm that pose a higher environmental risk.

WHY NUTRIENT MANAGEMENT IS IMPORTANT

22. Nutrient management on farms is important because it can affect the quality of water in rivers, lakes, and streams, as well as groundwater reservoirs in relation to nitrogen. Farming practices can lead to an impact on the aquatic environment via nutrient losses to water. To understand this, an understanding of how water and nutrients move through soils is required.

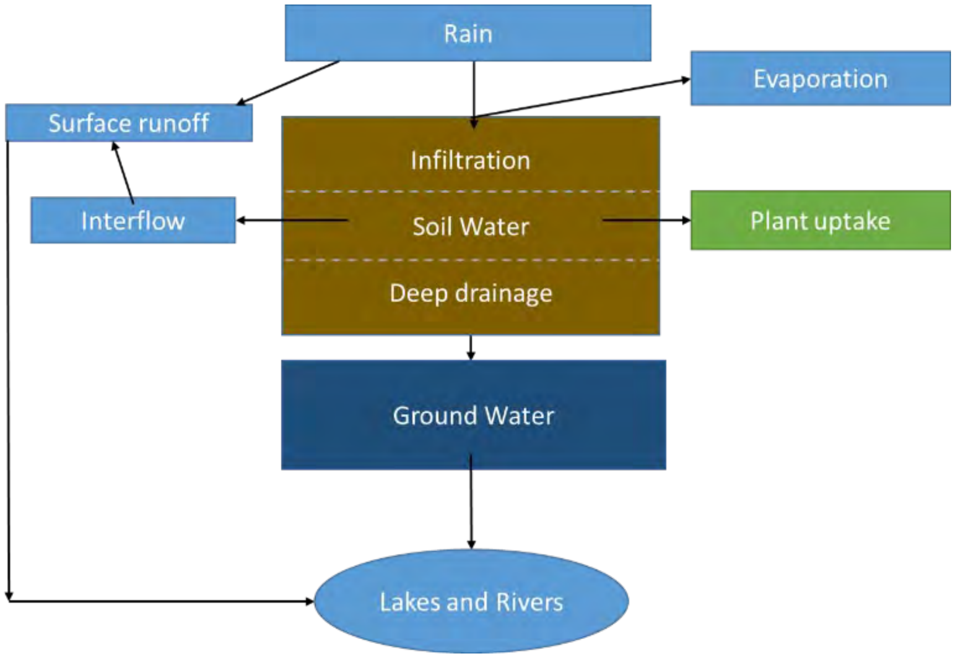
Water movement through soils

23. Water applied to the soil surface either enters the soil matrix where it is stored in micropores approximately < 30 micrometres (μm) in diameter. Larger macropores (> 30 μm in diameter) remain aerated providing drainage.

24. A soil water balance (SWB) can be calculated (taking in to account: irrigation, drainage, discharge from drains, surface runoff, flow within a soil

and evapotranspiration). This SWB generates an estimate of the surplus water available for loss as drainage or surface runoff which is important because it is these pathways that transport nutrients from the soil profile into ground and surface water (Figure 1). The calculation of a SWB uses readily available data of daily rainfall, daily potential evapotranspiration and available water holding capacity (AWHC)(Woodward et al., 2001).

Figure 1: Components of the hydrological cycle that relate to soil water.



Drainage in permeable soils – matrix flow

25. Drainage in permeable soils is more uniform than in poorly drained soils. The uniform drainage of water through a saturated soil profile is termed matrix flow. The rate of this flow of water through micropores within and around the soil aggregates (as opposed to rapidly around the aggregates) is influenced by the soil structure. Fine and uniformly structured soils have a faster flow of water than soils with blocky, platy or prismatic aggregates (Bowler, 1980). This has implications for the transportation of nutrients from land. If you had the same farming system, the same water inputs and climate, you could have a different drainage (and thus nutrient loss) profile due to the soil structure.

Preferential flow

26. Preferential (or bypass flow) flow occurs when water moves through the soil profile in a non-uniform way. This can be natural cracks in the soil, worm holes, or through the fissure network created by a mole plough (Monaghan and Smith, 2004). This preferential flow rapidly transports water and any surface applied nutrients or contaminants, through the soil matrix allowing little time for filtration, plant uptake or nutrient transformation (Monaghan & Smith 2004).

27. This process is not to be confused with free-draining soils.

28. When considering the relationship between drainage and the magnitude of nitrogen leaching from a soil, it is important to account for the water-holding capacity (measured as plant available water) and drainage porosity of that soil. A soil can be well-drained, which means that there is no impediment to drainage (such as a clay pan or high-water table) but that doesn't necessarily mean that the soil is prone to excessive drainage and thus leaching.

29. It helps to think of a soil profile as a sponge. A sponge has the ability to hold water up until a certain point, after which the addition of more water will result in drainage out the bottom of the sponge. The bigger the sponge, the more water it can hold. So, a soil that has a large water-holding capacity (the "size of the sponge") can hold a large volume of water before the commencement of drainage. Soils with a large water holding capacity have a relatively large capacity to store rainfall in the late spring to autumn period and so drainage is less unlikely in this period. Furthermore, as it takes more rainfall to fully re-wet soils with large water holding capacities, the drainage season will typically start later in late autumn- winter. Numerous free draining soils have deep soil profiles coupled with large water holding capacities and so result in higher storage and evapotranspiration and subsequently smaller annual drainage volumes.

30. A given quantity of surplus rainfall will 'flush' the pore system with a large drainable porosity (measured as a soils pore volume of water) fewer times in the winter/spring seasons and so leach less nitrogen than is the case for

a soil with a small pore volume. Again, many free draining soils have a relatively large drainable porosity.

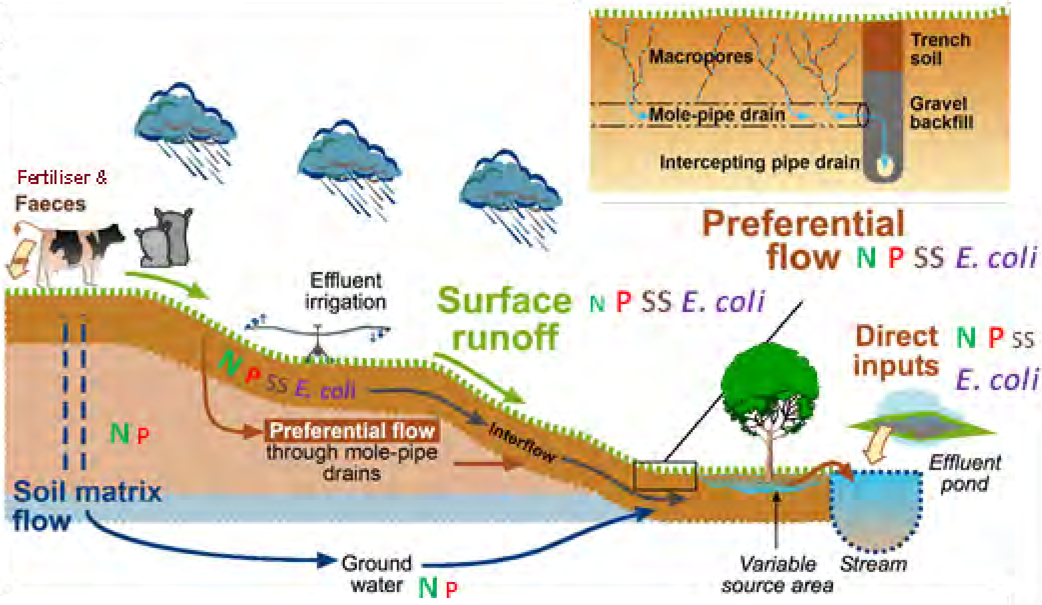
31. Thus, a well-drained soil is not necessarily what is colloquially called a “leaky” soil.

32. Excessively well drained soils that have a small water holding capacity and small pore volume (e.g. stony soils with large macropores) and a poorly developed shallow topsoil depth have less ability to hold on to the water before it is lost as drainage and excess rainfall will result in a through flushing of the pore system. These soils are ‘leaky’.

Nutrient movement - pathways of N, P, sediment and pathogen (e.g *E. coli*) loss to receiving waters

33. Most elevated losses of N and P to water begins with an enriched source area being mobilised (CSA). This can result from nutrient input (e.g. fertiliser) or mobilisation of nutrients already in the system. The enriched sources of N and P and loss pathways in a pastoral farming system are depicted in Figure 2. These include: cultivation of pastures for pasture renewal, fertiliser spreading, effluent application, dung and urine deposition. Losses to water are in surface runoff and drainage.

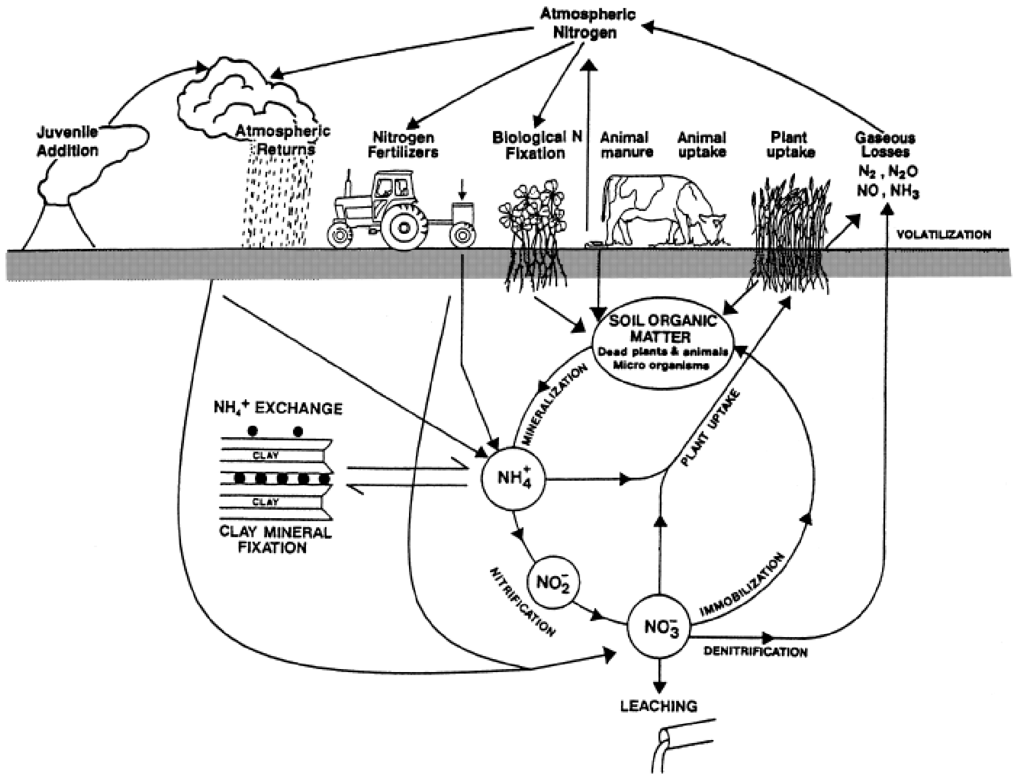
Figure 2: Conceptual diagram of the transport pathways involved in the transfer of contaminants (N, P, SS, and *E. coli*) from land to water. The presence and relative size of each of the contaminants indicates the importance of the pathway to contaminant-specific loss (McDowell et al., 2016).



Nitrogen loss to receiving waters

34. The majority of the N leaching losses from grazed agricultural systems are in the form of nitrate-N (NO_3^-)(McDowell et al., 2011; Monaghan et al., 2016; Monaghan et al., 2007). Nitrates are generated in the soil by microbial nitrification of ammonium ions. The dominant forms of N in different sources entering the soil are: urea in urine (Selbie et al., 2015), ammonium-N in effluent (NH_4^+) (Monaghan and Smith, 2004), and fertiliser N is mostly applied to pastures as urea or NH_4 based fertiliser. The nitrogen cycle is shown in Figure 3.

Figure 3: The Nitrogen Cycle in agricultural systems (Di & Cameron, 2002, Figure 1)



35. The majority of N loss is via leaching rather than surface runoff. This is because (i) nitrate (NO3-) is generated in soil and (ii) is not adsorbed by positively charged soil surfaces. Leaching of nitrate occurs when there is nitrate present in the soil in excess of plants requirements at a time when there is drainage occurring.

36. McDowell and Wilcock (2008) found, in assessing 32 studies conducted since 1975, that significantly more N was lost from dairy catchments than other catchments.

37. The ranking of median N loads from 32 studies was (McDowell and Wilcock, 2008):

Dairy > deer = mixed > sheep > non-agricultural

38. In summary the main drivers of N leaching loss are:

(a) **Urine patches.** Effected by the: stocking density (higher = greater losses), stock class (mature cattle > young cattle > deer/sheep > lambs), concentration of N in urine (high protein feed increases urinary N).

(b) **N fertiliser.** Via: applying excessive fertiliser that exceeds plant requirements, applications during high risk months of the year (around winter), applications directly followed by a heavy rainfall event. Direct inputs of N fertiliser to water is a cause of increased N in waterways but not via leaching.

(c) **Effluent.** Losses via: preferential flow pathways, high application depths (>20 mm), ineffective effluent systems, application at high risk times of the year. Direct discharges to waterways are a cause of increased N in waterways but not via leaching.

Measurement of N leaching losses

39. Losses of nitrate in drainage differ temporally and spatially and thus system, or paddock, scale losses can be difficult to accurately measure. There are a number of methods for measuring N leaching losses.

(a) Measurements using lysimeters can record losses under urine patch and under inter-patch areas (non-urine) and then these losses can be extrapolated to paddock scale (Cameron and Di, 2004; Di and Cameron, 2002; Di and Cameron, 2003; Di and Cameron, 2004; Di et al., 2009; Malcolm et al., 2015; Malcolm et al., 2016; Menneer et al., 2008);

(b) Another method, suited for soils with impeded subsoil drainage (clay pan), utilises artificially drained plots where the drainage is captured by mole and pipe drainage systems and volumes measured at "end of pipe". These are used in an attempt to capture the drainage from an area that represents the whole paddock (Christensen et al., 2010; Monaghan et al., 2002; Monaghan et al., 2005; Monaghan and Smith, 2004; Monaghan et al., 2009; Monaghan et al., 2016).

(c) The third method to measure nitrate leaching losses is to install porous ceramic cups in the soil at a depth below the root zone (e.g. 60 cm for pasture) in a paddock. The cups are placed under tension and draw free water samples from the soil to be representative of dissolved N concentrations in drainage. A soil water balance model is required to estimate the drainage depths associated with the free water samples (Smith et al., 2012; Sprosen et al., 2009).

40. It is because of the difficulty and cost of measuring actual leaching values, particularly at a whole farm scale, that modelling tools such as Overseer are used to estimate the potential losses from a particular farm. The overseer model does incorporate the data from field experiments using the techniques above and that data is extrapolated to cover a range of climates and soil types

Phosphorus loss to receiving waters

41. The predominant loss pathway for P to waterway is via surface flow (also known as overland flow). This is because P is attached to soil particles and is lost during erosion events.

(a) Examples of this are stream bank erosion caused by stock accessing streams; fence pacing, wallowing by deer, bare soil, heavy animals on steep slopes.

(b) In addition, the soil Olsen P level is an important consideration. When Olsen P exceeds optimum soil test levels there is an increased risk of P loss during overland flow events.

42. Some P is lost via subsurface flows (Figure 2). Phosphorus losses in drainage are small and tend to be dominated by rainfall events of low intensity but high frequency which tend to force dissolved inorganic P (DIP) into subsurface flow. The forms of P lost vary depending on land use and soil characteristics. In surface runoff from grazed pastures and non-cultivated soils there is little sediment thus the small amount of P lost is in the form of readily available DIP (or as analysed, dissolved reactive P; DRP) (McDowell, 2012). Cultivated soils induce erosion and the loss of

particulate-bound Total P (TP). This form of P is not as readily available but can become available over the longer term.

43. Losses of P are very site specific and occur from a small percentage of the landscape from areas commonly referred to as CSAs.

44. As P loss is strongly related to losses from CSAs then identifying these areas and applying good management and mitigation practices to manage CSAs can result in considerable reductions in the losses of P, sediment and faecal microbes (represented as losses of *E. coli)*.

45. In summary the main drivers of P loss are:

(a) Losses of sediment and soil. This occurs in CSA's and a small area of the farm can be contributing the majority of the P loss.

(b) Olsen P levels. Levels above the optimum for pasture or crop result in increased P losses.

(c) Fertiliser form, timing of applications and loading. Applications of fertiliser and/or effluent and rainfall events causing overland flow can result in losses of P. Readily available forms of P fertiliser have a high risk of losses than slower release forms such as reactive phosphate rock (RPR). Levels exceeding plant requirements increase the risk of losses.

(d) Effluent applications causing ponding (when the soil infiltration rate is slower than the effluent application rate) increases the risk of effluent P losses.

46. As mentioned above there are other important contaminants that are lost from agricultural landscapes. These are sediment and *E. coli.* The main loss pathways for these are in overland flow. Therefore, management practices addressing CSAs and the avoidance, or interception of, overland flow result in the reduction of multiple contaminants (P, sediment and *E. coli*).

47. Management practices that involve the interception of nutrients and contaminants lost in overland flow include:

(a) Buffer strips. A strip of grass left to decrease P sediment and *E. coli* in runoff by a combination of filtration and improved infiltration.

(b) Sediment traps are used for the retention of course sized sediment. The water flows into the 'trap', which should be longer, wider and deeper than the existing channel bed, the sediment drops to the bottom of the 'trap' and the filtered water flows out. These need to be emptied of sediment on a regular basis.

(c) Natural and constructed wetlands:

(i) Natural wetlands can be a sink or source of P. Particularly if the input is sediment-rich (e.g from cropland or largely from surface runoff). As a wetland becomes choked with sediment its ability to retain P decreases. The form of P retained by wetlands is particulate P rather than dissolved P.

(ii) Constructed wetlands can be designed to remove P from waterways by decreasing flow rates and increasing contact with vegetation thus encouraging sedimentation.

High risk farm management practices that increase nutrient and contaminant losses to water

48. Higher risk farm management practices that have the potential to result in increased losses of nutrients and contaminants are:

(a) **Cropping.** This is a high-risk farm management practice as it has the potential to incorporate some or all of points b to e below. To reduce the impact of grazing any or all of the points b to e can be addressed to minimise risk.

(b) **Cultivation.** This can leave soil exposed and vulnerable to erosion. Erosion results in losses of, primarily, P and sediment. Cultivation also results in mineralisation of the N in the soil which is then available for either plant uptake – or in some cases leaching to groundwater.

(c) **Intensive grazing on wet soils.** The impact of intensive grazing can occur in two ways. Firstly, having a large number of animals per area results in soil damage which can increase the risk of overland flow and thus losses of P, sediment and *E. coli.* It also can reduce subsequent pasture growth. Secondly, it results in an area where there has been a condensed area of urination events. Animal urine is high in N and large concentrations of N deposited on wet soils (where the soils are at or nearing field capacity) results in increased N leaching losses. Stocking density for dairy cows during the milking season can be around 70-90 cows/ha for a 24-hour period. Based on a dairy cow being 7.5 stock units this equates to a stocking density of 525-675 su/ha. During winter grazing this figure can be a stocking density of 300-600 cows/ha (2,250-4,500 su/ha) in the north of New Zealand (Drewry et al., 2008). The impacts on both soil structure and N leaching are increased when the area is grazed by larger animals. This is due to the size of the animal and also the volume and concentration of urinary N. For example, the figures most often quoted for urinary N load are 500 kg N/ha for a ewe and 1000 kg N/ha for a dairy cow (Haynes and Williams, 1993).

(d) **Intensive grazing on soils with a low soil water holding capacity (e/g stony soils and excessively free-draining soils).** In these situations, the main risk is N leaching loss. This comes from large numbers of animals per area held for periods of time resulting in large numbers of urination events per hectare. As these stony and excessively free-draining soils have a low capacity to hold water the N in the urine patches is more prone to leaching during rainfall events. The higher the stocking density the higher the risk and also the larger the size and higher the N concentration in the urine patches the higher the risk of N leaching. Thus, mature female cattle have a higher risk than sheep/deer or younger cattle.

(e) **Fertiliser applications.** Fertiliser applications need to be calculated using current soil test results to ensure that nutrient applications do not exceed soil and plant requirements for optimal soil nutrient pools and for plant growth. The two pathways of nutrient loss from fertiliser applications are:

(i) direct applications into waterways; and

(ii) when nutrients exceed requirements and are available in the soil to be lost via leaching when drainage events occur.

49. Despite saying that different farm practices have different nutrient outputs. There are other factors that impact on the degree of nutrient loss. These include soil type, climate and topography. So identical farming systems and practices could occur on different soil types and under different climates and result in different nutrient loss values.

50. The impact of this on Essential Freshwater is that it is extremely important to realise that there is no 'one-size-fits-all' approach to farm mitigation strategies. It is important that there is an effective management framework that is tailored to the specific farm and catchment. The framework must identify and manage those activities (outlined above) and areas on the farm that pose a higher environmental risk.

51. The sections above outline the main flow pathways and risk factors that should be considered when developing policy frameworks to support sustainable and resilient farming systems and land use practices. For nitrogen the main levers are in relation to stock type and stocking rate relative to the farms soil, geology and climate, feed types, grazing management, fertiliser application, effluent management, irrigation, and crop grazing management including stocking density. Recent work modelling losses from a Canterbury dairy farm business found reductions in N leaching of 19% with no impact on profitability (Beukes et al., 2018). This was done using a combination of mitigation strategies including:

(a) Applying less N fertiliser;

(b) Reducing crop area;

(c) Using a catch crop (a crop sown soon after the end of winter to 'mop up' any nitrogen in the soil);

(d) Wintering cows on a different block; and

(e) Using diverse pastures .

52. Reducing N leaching on already low input farms, may not result in any meaningful reduction on instream N concentrations or benefit to aquatic ecosystem health, and can have the unintended consequence of rendering the farm financially unsustainable. A study looking at the intensification of NZ sheep and beef farming systems modelled the impacts of intensification using small applications of N fertiliser or feeding maize silage (White et al., 2010). Both methods of intensification increased the kg beef produced but only the farm where N fertiliser was used, rather than maize silage, was financially viable. That was a property with 75% hill country applying <50 kg N/ha/yr applied in autumn and late winter. These small amounts of fertiliser N only increased N leaching slightly from 11 to 14 kg N/ha/yr, but resulted in an increase in farm profit of $9/ha from a net loss of $34/ha to a loss of $25/ha (none of the farms include the base farms resulted in a per hectare profit; using Overseer v5.2.6).

Non-management losses of N

53. There are a number of factors which govern the potential risk of nitrogen losses to ground waters which relate to matters outside of management interventions. Those are:

(a) **Soil available water capacity** (AWC i.e. how much water a soil can hold before it leaches out the bottom of the soil profile). Stony, shallow soils with a low water holding capacity have a higher risk of N leaching; and

(b) **Rainfall** which impacts on drainage and the rate at which nitrogen in the soil moves down through the soil profile and is then available to be lost in drainage.

Management losses of N

54. While the issues of AWC and rainfall are site specific there are other factors that relate to specific management practices and farming system and are, to differing degrees, within the control of the farm manager. These are.

(a) **Nitrogen in Urine**.

(b) **Stock type.** Larger animals excrete more N. Cattle excrete more than sheep and deer.

(c) **Feed type influences the concentration of N in the urine.** Feeds with higher crude protein (CP) have higher concentrations of N.

(d) **Grazing management influences losses of N in different ways.** Grazing on wet soils increases the risk of urinary N being lost in drainage because the soil 'bucket' is full and drainage is occurring. Also stocking density impacts N loss as a higher stocking rate means more urinary N is deposited per area of ground. Stocking management also influences the amount of time that animals remain on one area.

55. Fertiliser can result in N losses to water via direct application to waterbodies or by leaching losses. Timing of applications are important so that N is applied at times when the plant is actively growing and can take up the N for plant growth.

56. Effluent can result in losses to water via a number of pathways:

(a) Ammonium-N losses to water occur when there is a direct loss pathway of effluent into a waterbody. This can be via preferential flow pathways, overland flow, or direct deposition into water.

(b) Nitrate losses occur when effluent application loads exceed plant requirements, often when nitrogen fertiliser applications to effluent blocks haven't been decreased to account for the additional nitrogen in the applied effluent.

(c) Inefficient effluent systems that apply effluent at a high rate and high depth mean that the application exceeds the ability of the soil to soak up the effluent resulting in ponding which is then susceptible to losses via overland flow.

57. Imported supplements are another source of N brought onto the farm or transferred to another part of the farm. Supplementary feeds vary in their N content with supplementary feeds with a high crude protein (CP) content

increasing the amount of N consumed by the animal which then results in increased nitrogen in the urine of the animal.

Non-management losses of P

58. There are a number of factors which govern the potential risk of phosphorus losses to water which relate to matters outside of management interventions. Those are:

(a) **Topography.** This has a significant impact on P losses with steeper slopes having an increased risk of P loss.

(b) **Rainfall.** This impacts P loss particularly during overland flow events.

(c) **Soil properties.** Specifically, the properties of soil texture and soil structure influence the infiltration rate of the soil which influences the potential for overland flow.

Management losses of P

59. There are other factors that influence the loss of P that are within the control of the land owner and are related to farm management and the farm system. These are:

(a) Fertiliser – P form (slow-release vs fast release), concentration, rate, timing of fertiliser applications.

(b) Effluent - P concentration, rate, timing of effluent applications. Also form of application; rate and speed of effluent irrigator;

(c) Stock management – erosion, access to streams, wallowing and fence pacing by deer;

(d) Irrigation – specifically border dyke irrigation:

(i) Mole and tile drainage provide a pathway for topsoil to enter streams and waterways.

(ii) Olsen P level. Olsen P above the optimum range for the pasture or crop results in increased risk of P loss.

(iii) Management of critical source areas (CSAs):

i. Most P loss is from CSAs because these areas are where high concentrations of P are found. Such as deer wallows, stock camp-sites (Selbie et al., 2013).

ii. Fencing of streams has been shown to decrease in stream P loads by 32% (James et al., 2007).

60. Intensive dairy farming is often highlighted as a significant contributor to P loss to waterways. For example, in a survey of 37 catchment-scale studies in New Zealand undertaken in 2008 (McDowell and Wilcock, 2008). It was found P losses from dairy-dominated catchments ranged from 1 to 10 kg P/ha/yr, depending on geographical features (e.g. soils, topography, climate) and management factors (e.g. irrigated or dryland, effluent management). The range of P losses from sheep and beef farmed land was much narrower at 0.1 to 2.2 kg P/ha/yr, while deer ranged from 0.6 to 3.0 kg P P/ha/yr and native vegetation ranged from 0.1 to 0.6 kg P/ha/yr.

61. The sections above outline the main flow pathways and risk factors that should be considered when developing policy frameworks to support sustainable and resilient farming systems and land use practices. For phosphorus the non-management drivers are soil, slope and climate. With management related drivers being fertiliser use, and land use activities which destabilise soil or result in critical source areas. The main levers are therefore in relation to the identification and management of critical source areas, use of fertiliser, stabilisation of soil and reducing erosion risk. McDowell and Houlbrooke (2008) found that 30% of P losses from an irrigated crop were attributable to the irrigation alone. Research looking at CSA management during grazing of a winter crop by dairy cows found that P losses could be reduced by ~ 80 % (Monaghan et al., 2017).

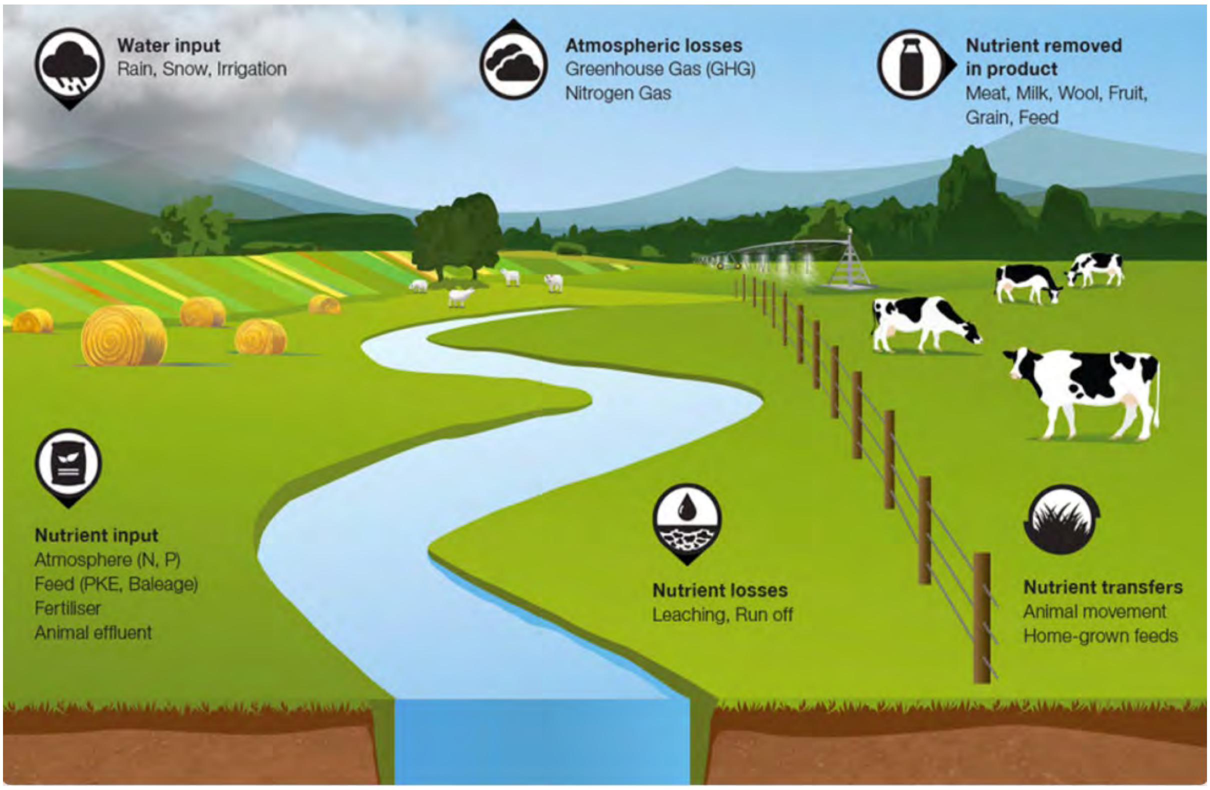
62. Best methods are tailored FEPs that focus on identifying and managing CSA, reducing at risk activities (e.g. cropping, animal access to

waterways, fertiliser management, fence-line pacing and wallowing, irrigation, effluent pond storage and application).

SUMMARY OF OVERSEER

63. Overseer is a nutrient budgeting tool that models the nutrient flows in/out and around a farming system. Recently the legacy version of Overseer has been replaced with OverseerFM. The science and algorithms in the model are the same but the user interface has changed. For the purposes of this report use of the terms 'Overseer' and 'OverseerFM' are used interchangeably. Overseer requires user input to describe the farming system (information such as soil type, topography, climate, livestock system and fertiliser). The model then uses internal equations that are calibrated against scientific data to calculate the nutrient inputs, outputs and changes in nutrient soil pools (Figure 4).

Figure 4: Conceptual diagram of the nutrient flows in, out and within the farm system as modelled by OverseerFM (Source: www.overseer.org.nz/our-science)



64. Overseer works at two scales – the farm scale and the block scale. The sum of the losses from blocks does not equal the farm loss because Overseer also accounts for off-paddock facilities, effluent stored and transfer of nutrients between blocks.

65. "Blocking" in Overseer includes separating the farm into areas with similar characteristics including topography, climate, fertiliser, effluent management, and farm management. OverseerFM now provides the ability to have up to three soil types in one block and up to two different irrigation types. This may have implications for P loss risk estimates, which will be addressed later.

66. Key assumptions of Overseer are:

(a) Steady state conditions;

(b) Constant farm management inputs and annual average outputs;

(c) The stated production did occur given the inputs;

(d) Certain Good Management Practices (GMPs) are occurring, e.g. evenly spread fertiliser, sealed effluent ponds; and

(e) Long-term average rainfall and temperature that are based on the location of the farm.

67. The use of long-term climate data combined with annual farm management data (for example annual irrigation applications as was the case for Case Study C) can result in under- or over-estimates in nutrient losses in Overseer. This is because the actual irrigation inputs in a given year are applied in response to the actual conditions (rainfall, soil moisture) and the actual climate may not match the average climate pattern (Wheeler et al., 2014).

Soil type

68. Soils can be easily classified in OverseerFM to the Sibling Soil level, taken from S-Map (Landcare_Research, 2016), which is the most accurate classification. This is done by drawing the farm blocks onto the map imbedded in Overseer. This is useful only if the farm is covered by S-map.

69. The alternative to S-map classification is for the user to enter soil group and soil order. This breaks down all the soils in NZ into seven groups and 14 soil orders.

How the nitrogen sub-models work

70. There are two sub-models that deal with the fate of nitrogen in the pastoral block. These are the urine patch and background loss sub-models. The *background* loss sub-model deals with dung, fertiliser, effluent and organic additives to the non-urine patch areas of the paddock (Selbie et al., 2013). The *urine* sub-model deals with the losses from the urine patches in the paddock.

71. The N leached figure presented by Overseer is the estimate of N that is leached below the root zone (combined *background* and *urine* estimates) and is calculated on a monthly time-step but presented as an annual figure.

72. Overseer does not take into account the fate of nitrogen below the root zone and any attenuation that may occur (Singh et al., 2015).

How the phosphorus sub-model works

73. Compared with urine being the most important source of N for leaching, the important sources of P are: soil movement, fertiliser, effluent, dung and supplements (Selbie et al., 2013).

74. It is important to understand that the P model within Overseer is a calibrated risk model of losses to second order streams based on the work of McDowell *et al* (2005). Stream order is a measure of the relative size of a stream with the smallest tributaries being first order. Thus, a second order stream is one that has two first order tributaries. P losses are due to runoff which includes combined losses from surface and sub-surface flows,

excluding deep drainage, to groundwater (Gray et al., 2016). The overall risk is estimated as the amount of P lost per hectare per year.

75. The P model estimates sources of P from two sources:

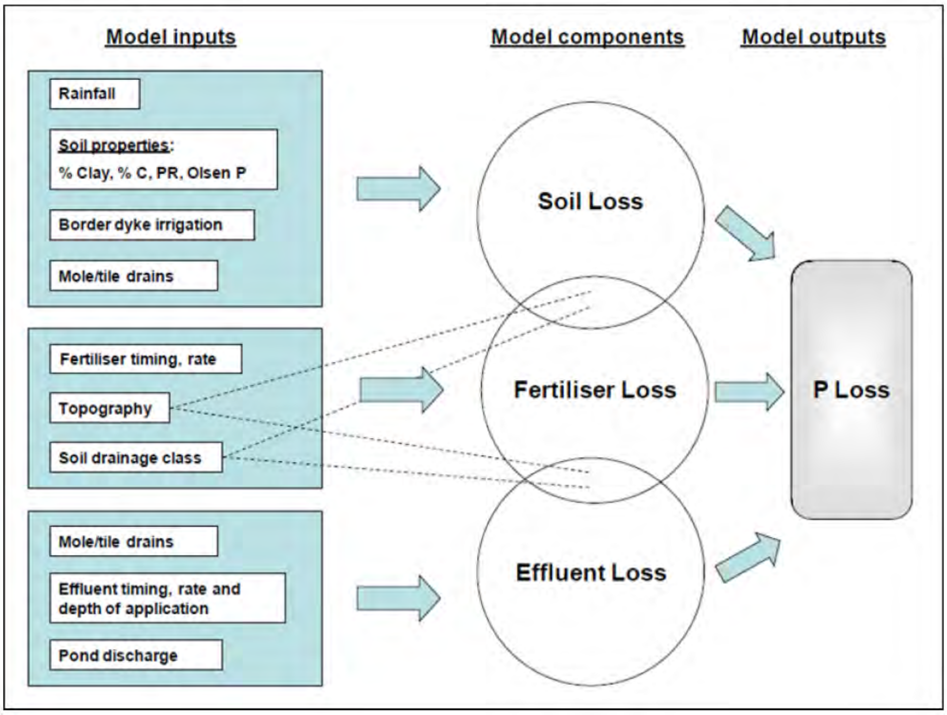
(a) *background* (soil) losses; and

(b) *incidental* losses from fertiliser and effluent.

76. Background losses occur as soil losses where P has had the opportunity to react with soil. These losses are in the form of total phosphorus (TP) and are influenced by site-specific transport mechanisms such as rainfall and topography or management factors, most commonly mole/tile drainage and border dyke irrigation.

77. Incidental P is in the form of particulate and dissolved P in overland flow. These losses occur when a concentrated source of P coincides with a flow event (McDowell *et al.,* 2005). Farm management activities such as the timing of fertiliser or effluent applications can result in incidental losses of P. The model components of the different loss pathways are depicted in the diagram (Figure 5) below sourced from Gray *et al.* (2016).

Figure 5: Conceptual diagram of model structure (Source: Gray *et al.* (2016)).



78. Erosion is an important source of P loss to water. Overseer currently considers contributions of phosphorus from some erosion types such as sheet flow and gully erosion. Factors such as animals having direct access to waterway or deer wallows that are connected to waterways and fence pacing are accounted for in Overseer (McDowell et al., 2008). However, mass events such as landslides or earthflows are not captured (Gray *et al.*, 2016).

79. Overseer is not a spatial tool whereas P losses are spatially variable, therefore, in order to successfully capture P losses from Critical Source Areas (CSAs) the use of blocking in Overseer will be hugely important. It is concerning that the OverseerFM version of the tool has been designed to reduce the number of blocks that the user splits the farm in to. It is possible that this may reduce the accuracy of the P loss estimates and thus care must be taken to identify CSAs and separate them into their own blocks to improve the accuracy of the P model results. In fact, Freeman *et al,.* (2016) state that "*One significant issue with P loss reduction options is that the combination of critical source areas (CSAs)….and normal 'blocking' guidelines… can make it extremely challenging to model mitigation strategies that target CSAs. Development of blocking specifically to target CSAs is currently outside OVERSEER's scope."*

80. In one study, measured in-stream P levels were compared with Overseer predicted results (Burkitt et al., 2016). The authors modelled a P loss of 1.1 kg P/ha/yr for a 85 ha catchment on a sheep and beef hill country farm in th North Island (Overseer version 6.2.1). This compared to in-stream measurements of 0.13 kg P/ha/yr leaving the catchment. The authors attribute this difference to attenuation within the catchment via "landscape features such as wetlands" which slow the flow of water and allow P to be absorbed by plants. This equates to a 0.80 attenuation factor. Assessing the impact of wetlands and grass filter strips on one of our case study files (Farm C) by removing the grass filter strips and wetlands does not dramatically increase the P loss value suggesting that they are not attenuating 80 % of the modelled P from the catchment.

81. In addition, the wetland and grass strip data input fields of Overseer are confusing and complex to fill out and Overseer Ltd itself suggests in their

user manual that it will require expert advice to understand some of the data entry fields (OverseerFM, 2019). As wetlands are well known as nutrient sinks then it will be important that this data is as accurate as possible as it will have a great impact on the nutrient losses from the farm. The complexity of the data entry adds further time and cost to those farms who have already done a lot of mitigation as they will require expert guidance to enter the mitigation data.

Uncertainty in Overseer

82. As with any model there is a degree of uncertainty with the Overseer output values. This uncertainty arises through a number of functions from the model and its use. This degree of uncertainty is highly variable. One metric commonly used is an error of ± 25-30% for N loss, however, this was conducted in 2011 on version 5 of Overseer (Ledgard and Waller, 2001). The PCE report states that "according to Overseer's developers, a similar uncertainty range is likely to apply to the model's predictions of nitrogen loss using the current version (version 6)" (Upton, 2018). P loss uncertainty is also up to 30% based on analysis conducted in 2015 (Upton, 2018). We can only make an educated estimation of the degree of uncertainty that the result may contain. Influencing the degree of uncertainty are several potential factors:

(a) User input error (or differences between users' input of data);

(b) Variation in the quality of the raw data available to represent the farming system;

(c) Errors in the model (bugs);

(d) Similarity of the farm system, the soil type, and the climate to the calibration dataset.

(e) Temporal and spatial variation in the field measurement data used to calibrate the components of the model; and

(f) Version changes where upgrades to some components of the *model* result in changes to nutrient loss estimates. These changes can affect only some farms and can affect farms to differing degrees.

83. The degree of the uncertainty is influenced by which of the above factors are relevant and, importantly, if a farming system combines multiple factors, which could compound the “error”/variability of an estimate. For example, a farm system may have multiple components with less calibration data, plus the raw data may be scarce requiring a large number of assumptions to be incorporated. This has implications for how the model should be used and the weight placed on modelled outputs. In relation to policy, the model should be used with a high degree of caution. At best Overseer can be used to define thresholds for risk, and within a farm system to look at changes over time. However, even in these circumstances version changes significantly challenge the reliability of the model outputs.

Areas of Overseer that have higher uncertainty or are not modelled at all.

84. It is important to be aware that most of the field studies used to calibrate the nitrogen model in Overseer were carried out on flat, pastoral dairy farm systems on primarily free-draining soils and under moderate rainfall (Freeman *et al*, 2016; Watkins & Selbie, 2015). This means that the degree of uncertainty in the predicted N leaching losses is increased on those systems that are:

(a) on hills;

(b) non-dairy;

(c) on heavy or stony soils;

(d) in high or low rainfall areas; and

(e) a combination of all the above.

85. Three specific agricultural systems that are not adequately modelled due to scarcity of data are:

i. Arable cropping blocks;

ii. Cut and carry blocks; and

iii. Fodder (forage) crop blocks.

86. An expert user group asked to report to The Foundation for Arable Research (FAR) on the suitability of Overseer to accurately model nutrient flows in arable crops, had concerns of the ability of Overseer to accurately model long-term nitrate leaching in arable systems (Dunbier et al., 2013). The group found that Overseer had only been tested to a limited extent on arable crops and requires comprehensive testing against both measured leaching values and also leaching estimates from established research models.

87. In addition, as of 2016 there was no experimental data on P loss from arable cropping systems for New Zealand, making it extremely difficult to assess whether the P loss predictions from Overseer are accurate or not for an arable crop (Gray *et al.,* 2016). We are not aware if there has been any data generated since 2016.

88. As of 2016 the P loss from cut and carry blocks was based on the finding of one study (Gray *et al.,* 2016). Again, we are not aware if there has been any data generated since 2016.

89. Fodder cropping is a high-risk practice and while there is some measured data on P losses, the current model relies on only a limited number of data sets (Gray *et al.,* 2016). In addition, Overseer assumes that the topography on a crop or fodder block is flat. This will have significant implications on the predicted P loss risk from fodder crop blocks that are on slopes, where the predicted P loss risk may be lower than actual P loss risk.

90. Gray *et al.* (2016) suggested the following components, related to phosphorus, of the Overseer model could be upgraded:

(a) **Subsurface P losses.** Gray *et al,* suggest this should be improved due to the increasing expansion of irrigation on stony soils and their high P loss risk via leaching. The authors also suggest that the losses are split out into P loss via subsurface flow and surface runoff are reported separately rather than the current reporting of both together as ‘P runoff losses’.

(b) **Irrigation.** Increased runoff and drainage may occur due to non-uniformity in water application across a paddock, or over-irrigating. Gray suggests that further research is required in this area.

(c) **Farm structures.** Gray suggests a review of the structures and the potential for P loss due to attenuation prior to the losses leaving the farm.

(d) **Standardisation of the runoff estimation.** Currently there is a hydrology sub-model within Overseer that is used to provide input to the wetland and riparian sub-model. This works on a daily time-step. In the P loss sub-model (which is different to the hydrology sub-model) surface runoff is calculated on a monthly time-step based on a probability of each months' surplus rainfall, hydrological class, topography and risk months.

91. Some areas not currently captured by Overseer are:

(a) Sediment loss;

(b) *E. coli* or other microbe losses;

(c) Attenuation of nitrogen below the root zone;

(d) Spatial variability. It is widely acknowledged that P loss from farming systems is variable in both space and time with the majority of P losses coming from a small area of the farm, (i.e. a CSA; e.g. McDowell, (2012); McDowell et al. (2014); Monaghan et al. (2016)). Overseer does not work at a spatial level (beyond the level of defining blocks);

(e) Temporal variability. P loss estimates are calculated on a monthly time-step but presented as an annual figure;

(f) Within-stream processes occurring on the farm e.g. stream attenuation or stream bed erosion (Watkins and Selbie, 2015);

(g) Transition periods from one farm system to another;

(h) Not all management activities (including some mitigations) that impact nutrient losses are captured by Overseer – an example of this is sediment traps; and

(i) Components of the model have not been calibrated against measured data from every combination of farm system and environment that Overseer is intended to cover (Watkins and Selbie, 2015).

92. Overseer is a useful tool to gain an understanding of the potential N and P losses for a farm. It can be used to:

(a) highlight areas of the farming system that pose the greatest nutrient loss risk;

(b) investigate the implications on nutrient flows of different scenarios; and

(c) benchmark against other farms (caveat would be that the same data input standards, version of Overseer, availability of data, were available and used by all).

93. However, it has some significant limitations which need to be carefully considered in relation to its application, especially in relation to underpinning catchment modelling, mitigation modelling, and in regulation.

94. The use in policy needs careful consideration to enable the appropriate use of the model to reduce risk and assist with informing on farm management approaches. Given the evidence set out above, there are significant risks associated with utilisation of the model to grandparent farming practices at a particular point in time. Alternative approaches including consideration of thresholds should be considered in relation to establishing outcome or output based risk management frameworks. OVERSEER could be considered a method within a suite of tools to assist farmers to manage risk appropriate to their individual farm, and in its sub catchment/ catchment context.

Specific errors and issues when using OverseerFM to model Case Study Farm C BakerAg Report

95. This farm was a complex mixed cropping property finishing lambs and bull beef. The time required to accurately complete an OverseerFM file was around five working days. The time was long due to:

    (a) The complexity of the farming system;

    (b) The inability of OverseerFM to model some crops and some of the animal grazing practices occurring on the property;

    (c) Error messages with no obvious solution; and

    (d) User interface issues such as data input fields appearing blank.

96. Specific issues included:

    (a) Crops grown but not able to be modelled (hemp);

    (b) Animal grazing practices that cannot be modelled:

        (i) grazing a crop then removing the animals but retaining the crop;

        (ii) Grazing a class of stock (sheep) on crop only (not on pasture) when there are pasture blocks in the system which are grazed by another class of stock (cattle);

    (c) The inability to accurately model the management practices on a grass seed crop (crop residual practices);

    (d) An arror message that stated that stock were over fed by 200+% even though the crop yields were correct, the animal numbers were correct and the areas of the farm the stock were grazing were correct.

97. There were also user interface issues that meant that some data could not be entered until the errors were resolved. This was time consuming and the solutions were not obvious:

    (a) Irrigation events appear that were not entered by the user.

(b) Error saying “Multiple management options are not allowed on block 56 acres, during assessment year 1 of Month September”. Even deleting different managements didn’t clear the error. The only way to solve the problem was to delete the block and re-draw it.

(c) This farm had 42 blocks. In the fertiliser and cropping tabs when viewing on a laptop or small monitor when scrolling down through the blocks it would get to a point where the last blocks in the list were blank. This can be resolved by reducing the size of the screen to 90% or less:

(i) Apparently this is an issue with users who has Chrome as their browser. This could be cause diffilulties with farmers using Chrome.

98. Importantly, this farm has recently undergone development and as Overseer is a steady-state model the N loss values that are a baseline will not accurately represent the actual losses from the property as it undergoes development. This is because such things as transitioning from dryland to irrigation and pasture to cropping will likely cause soil processes that significantly impact the nutrient losses. Losses are likely to be over- or under-estimated during the transition period (Freeman et al., 2016).

The use of Overseer to Grandparent extensive drystock farms

99. Extensive and complex drystock farms will, due to their extensive nature, have low nutrient losses, particularly for nitogen. However, these farms will be greatly disadvantaged by a mandatory requirement to complete an Overseer nutrient budget:

(a) The degree of uncertaintly for their farming systems will be greater than a flatland, pastoral system on a free-draining soil and with a moderate rainfall purely because of the dataset used to calibrate Overseer.

(b) The complexity of their system will mean that the time required to complete a nutrient budget will be longer than a simpler system and due to th complexity less of the initial data entry is likely to be able to be done by the farmer themselves. This results in a greater financial cost for a consultant's time than for a simple system.

OTHER MODELLING TOOLS THAT COULD HAVE BEEN CONSIDERED

100. There are other tools available that may be able to help add to the story of within farm and within catchment N, P, sediment and *E. coli* losses and the associated financial implications of changes in farming systems to meet environmental targets, as well as the environmental outcomes that can be achieved through the appropriate application of a suite of mitigation approaches. These tools were not considered through the HRWO modelling or mitigation scenarios, which significantly reduces the utility of the modelling and limits the economic analyses undertaken. Farmer support tools such as LUCI and MitAgator which are able to function at the catchment and farm scale provide the opportunity to target on farm action through tailored land and environment plans in such a way as to achieve the best environmental outcomes for least cost. More importantly they assist farmers and communities to understand the natural character of their landscape and design interventions including adoption of edge of field mitigation which is suited to their individual needs and aspirations.

101. **AgInform®** Integrated Farm Optimisation and Resource Allocation Model (Rendel et al., 2016). This is a farm financial optimisation tool created by AgResearch. This tool takes into account the natural capital of the land and splits a farm into land management units (LMUs). The user enters farm specific data and the tool them optimises the farm financially. This tool works at a strategic level rather than a tactical level as FARMAX does. This tool is also repeatable. This means that any user, entering the same data, will obtain the same result. With the tool FARMAX, the farm optimisation is very much dependant on the user's concept of the optimal farming system for that property. A strength of AgInform® is that it can identify optimal systems under alternative boundary conditions (for example nitrogen leaching limits) and gives the user an understanding of the financial and system implications of such constraints (Hendy et al., 2018). Another strength is that AgInform is run as a multi-year model. It uses pasture growth over a period of years (around 10) determined from actual climate data over that period of time then the model is optimised for the farm over

that multi-year period. Thus, the resulting optimal farming system takes into account the between-year variation in climate and pasture production. This is something at Overseer and FARMAX as steady-state models do not do.

102. **MitAgator** (Ballance AgriNutrients; Risk [Field] losses. Nitrogen, P and sediment loss predictions are quantified spatially across the landscape (Hendy et al., 2018). This model requires an Overseer nutrient budget for the property combined with spatial information of soil and slope alongside a farm map. Then enables the model to generate spatial risk maps indicating areas of the farm that are high risk. The model also takes into account the financial implications of mitigation strategies.

103. **Land Utilisation and Capability Indicator (LUCI)** (Trodahl et al., 2017). LUCI is a land management decision support framework that investigates the impact of spatially targeted farm-scale environmental mitigations/interventions within the larger catchment. It can assess the cumulative impact of individual farm scale mitigations within the wider receiving catchment (Jackson et al., 2016)

REFERENCES

Beukes, P.C., Chikazhe, T., Edwards, J.P. 2018. Exploring options to reduce nitrogen leaching while maintaining profitability within a Canterbury farm business comprising several distinct enterprises. *Journal of New Zealand Grasslands*, **80**, 191-194.

Bowler, D.G. 1980. *The drainage of wet soils*. Department of Soil Science, Massey University, New Zealand.

Burkitt, L.L., Bretherton, M.R., Singh, R., Hedley, M. 2016. Comparing nutrient loss predictions using Overseer and stream water quality in a hill country sub-catchment. in: *Integrated nutrient and water management for sustainable farming*, (Eds.) L.D. Currie, R. Singh, Vol. Occasional Report No. 29., Fertilizer and Research Centre. Massey University, Palmerston North, New Zealand, pp. 9 pages.

Christensen, C.L., Hanly, J.A., Hedley, M.J., Horne, D.J. 2010. Reducing nitrate leaching losses by using duration-controlled grazing of dairy cows. in: *19th World Congress of Soil Science*, (Eds.) R.J. Gilkes, N. Prakongkep, International Union of Soil Science. Brisbane, Australia, pp. 153-156.

Di, H.J., Cameron, K.C. 2004. Effective reductions in nitrate leaching and nitrous oxide emissions by the use of a nitrification inhibitor, dicyandiamide (DCD), in a grazed and irrigated grassland. in: *Controlling nitrogen flows and losses. 12th Nitrogen Workshop, University of Exeter, UK, 21-24 September 2003*, (Eds.) D.J. Hatch, D.R. Chadwick, S.C. Jarvis, J.A. Roker, Wageningen Academic Publishers. Wageningen, pp. 431-433.

Di, H.J., Cameron, K.C. 2003. Mitigation of nitrous oxide emissions in spray-irrigated grazed grassland by treating the soil with dicyandiamide, a nitrification inhibitor. *Soil Use and Management*, **19**(4), 284-290.

Di, H.J., Cameron, K.C. 2002. Nitrate leaching in temperate agroecosystems: sources, factors and mitigating strategies. *Nutrient Cycling in Agroecosystems*, **64**(3), 237-256.

Di, H.J., Cameron, K.C., Shen, J.P., He, J.Z., Winefield, C.S. 2009. A lysimeter study of nitrate leaching from grazed grassland as affected by a nitrification inhibitor, dicyandiamide, and relationships with ammonia oxidizing bacteria and archaea. *Soil Use and Management*, **25**(4), 454-461.

Drewry, J.J., Cameron, K.C., Buchan, G.D. 2008. Pasture yield and soil physical property responses to soil compaction from treading and grazing — a review. *Soil Research*, **46**(3), 237-256.

Dunbier, M., Brown, H., Edmeades, D., Hill, R., Metherell, A., Rahn, C., Thorburn, P., Williams, R. 2013. A peer review of Overseer in relation to modelling nutrient flows in arable crops. The Foundation for Arable Research.

Dymond, J.R., Ausseil, A.E., Parfitt, R.L., Herzig, A., McDowell, R.W. 2013. Nitrate and phosphorus leaching in New Zealand: a national perspective. *New Zealand Journal of Agricultural Research*, **56**(1), 49-59.

Freeman, M., Robson, M., Lilburne, L., McCallum-Clark, M., Cooke, A., McNae, D. 2016. Using OVERSEER in regulation - technical resources and guidance for the appropriate and consistent use of OVERSEER by regional councils. Freeman Environmental Ltd.

Gray, C.W., Wheeler, D.M., McDowell, R., Watkins, N.L. 2016. Overseer and phosphorus: strengths and weaknesses. in: *Integrated nutrient and water management for sustainable farming*, (Eds.) L.D. Currie, J. Singh, Vol. Occasional Report No. 29, Fertilizer and Research Centre. Massey University, Palmerston North, New Zealand, pp. 9.

Haynes, R.J., Williams, P.H. 1993. Nutrient Cycling and Soil Fertility in the Grazed Pasture Ecosystem. in: *Advances in Agronomy*, (Ed.) L.S. Donald, Vol. Volume 49, Academic Press, pp. 119-199.

Hendy, J., Ausseil, A.E., Bain, I., Blanc, E., Fleming, D., Gibbs, J., Hall, A., Hertzig, A., Kavagnagh, P., Kerr, S., Leining, C., Leroy, L., Lou, E., Monge, J., Reisinger, A., Risk, J.T., Soliman, T., Stroombergen, A., Timar, L., Van der Weerden, T., White, D., Zammit, C. 2018. Land-use modelling in New Zealand: current practice and future needs. Motu Economic and Public Policy Research.

Jackson, B.M., Metherell, A.K., Roberts, A.H.C., Trodahl, M.I., White, M. 2016. Adaptation of the LUCI framework to account for detailed farm management: a case study exploring potential for nutrient mitigation using data from the Southland

Demonstration Farm. in: *Integrated nutrient and water management for sustainable farming*, (Eds.) L.D. Currie, J. Singh, Vol. Occasional Report No. 29, Fertilizer and Lime Research Centre. Massey University, Palmerston North, New Zealand, pp. 10.

James, E., Kleinman, P., Stedman, R., Sharpley, A. 2007. Phosphorus contributions from pastured dairy cattle to streams of teh Cannonsville Watershed, New York. *Journal of Soil & Water Conservation*, **62**, 40-47.

Landcare_Research. 2016. S-map Online. Fast, simple access to New Zealand soils data. in: *Soil Factsheets*.

Ledgard, S.F., Waller, J.E. 2001. Precision of estimates of nitrate leaching in OVERSEER. AgResearch.

Malcolm, B.J., Cameron, K.C., Edwards, G.R., Di, H.J. 2015. Nitrogen leaching losses from lysimeters containing winter kale: the effects of urinary N rate and DCD application. *New Zealand Journal of Agricultural Research*, **58**(1), 13-25.

Malcolm, B.J., Cameron, K.C., Edwards, G.R., Di, H.J., de Ruiter, J.M., Dalley, D.E. 2016. Nitrate leaching losses from lysimeters simulating winter grazing of fodder beet by dairy cows. *New Zealand Journal of Agricultural Research*, 1-10.

McDowell, R.W. 2012. Minimising phosphorus losses from the soil matrix. *Current Opinion in Biotechnology*, **23**(6), 860-865.

McDowell, R.W., Cosgrove, G.P., Orchiston, T., Chrystal, J. 2014. A cost-effective management practice to decrease phosphorus loss from dairy farms. *Journal of Environmental Quality*, **43**(6), 2044-2052.

McDowell, R.W., Drewry, J.J., Muirhead, R.W., Paton, R.J. 2005. Restricting the grazing time of cattle to decrease phosphorus, sediment and E. coli losses in overland flow from cropland. *Soil Research*, **43**(1), 61-66.

McDowell, R.W., Houlbrooke, D.J. 2008. Phosphorus, nitrogen and sediment losses from irrigated cropland and pasture grazed by cattle and sheep. *Proceedings of the New Zealand Grassland Association*, **70**, 77-83.

McDowell, R.W., Monaghan, R.M., Close, M.E., Tanner, C.C. 2016. Agricultural Catchment Restoration. Unpublished., pp. 29.

McDowell, R.W., van der Weerden, T.J., Campbell, J. 2011. Nutrient losses associated with irrigation, intensification and management of land use: A study of large scale irrigation in North Otago, New Zealand. *Agricultural Water Management*, **98**(5), 877-885.

McDowell, R.W., Wheeler, D.M., de Klein, C.A.M., Rutherford, A.J. 2008. Deer and environment: Overseer update. *Proceedings of the New Zealand Grassland Association*, **70**, 95-99.

McDowell, R.W., Wilcock, R.J. 2008. Water quality and the effects of different pastoral animals. *New Zealand Veterinary Journal*, **56**(6), 289-296.

Menneer, J.C., Ledgard, S., Sprosen, M. 2008. Soil N process inhibitors alter nitrogen leaching dynamics in a pumice soil. *Australian Journal of Soil Research*, **46**(4), 323-331.

Monaghan, R.M., Laurenson, S., Dalley, D.E., Orchiston, T.S. 2017. Grazing strategies for reducing contaminant losses to water from forage crop fields grazed by cattle during winter. *New Zealand Journal of Agricultural Research*, **63**(3), 333-348.

Monaghan, R.M., Paton, R.J., Drewry, J.J. 2002. Nitrogen and phosphorus losses in mole and tile drainage from a cattle-grazed pasture in eastern Southland. *New Zealand Journal of Agricultural Research*, **45**(3), 197-205.

Monaghan, R.M., Paton, R.J., Smith, L.C., Drewry, J.J., Littlejohn, R.P. 2005. The impacts of nitrogen fertilisation and increased stocking rate on pasture yield, soil physical condition and nutrient losses in drainage from a cattle-grazed pasture. *New Zealand Journal of Agricultural Research*, **48**, 227-240.

Monaghan, R.M., Smith, L.C. 2004. Minimising surface water pollution resulting from farm-dairy effluent application to mole-pipe drained soils. II. The contribution of preferential flow of effluent to whole-farm pollutant losses in subsurface drainage from a West Otago dairy farm. *New Zealand Journal of Agricultural Research*, **47**(4), 417-428.

Monaghan, R.M., Smith, L.C., Ledgard, S.F. 2009. The effectiveness of a granular formulation of dicyandiamide (DCD) in limiting nitrate leaching from a grazed dairy pasture. *New Zealand Journal of Agricultural Research*, **52**(2), 145-159.

Monaghan, R.M., Smith, L.C., Muirhead, R.W. 2016. Pathways of contaminant transfers to water from an artificially-drained soil under intensive grazing by dairy cows. *Agriculture, Ecosystems & Environment*, **220**, 76-88.

Monaghan, R.M., Wilcock, R.J., Smith, L.C., Tikkisetty, B., Thorrold, B.S., Costall, D. 2007. Linkages between land management activities and water quality in an intensively farmed catchment in southern New Zealand. *Agriculture, Ecosystems & Environment*, **118**(1), 211-222.

OverseerFM. 2019. OverserFM User Guide. in: *User Guide Updated March 2019*, Overseer Limited. New Zealand.

Rendel, J.M., Mackay, A.D., Smale, P.N., Vogeler, I. 2016. Moving from exploring on-farm opportunities with a single to a multi-year focus: Implications for decision making. *Journal of New Zealand Grasslands*, **78**, 57-66.

Selbie, D.R., Buckthought, L.E., Shepherd, M.A. 2015. Chapter Four - The Challenge of the Urine Patch for Managing Nitrogen in Grazed Pasture Systems. in: *Advances in Agronomy*, (Ed.) S. Donald L, Vol. Volume 129, Academic Press, pp. 229-292.

Selbie, D.R., Watkins, N.L., Wheeler, D.M., Shepherd, M.A. 2013. Understanding the distribution and fate of nitrogen and phosphorus in OVERSEER. *Proceedings of the New Zealand Grassland Association*, **75**, 113-118.

Singh, E., Elwan, A., Horne, D., Manderson, A., Patterson, M., Roygard, J. 2015. Prediction of Land-based nitrogen loads and attenuation in the Rangitikei catchment - the model development. in: *FLRC Annual Workshop*, (Eds.) L.D. Currie, J. Singh. Massey University, Palmerston North.

Smith, L.C., Orchiston, T., Monaghan, R. 2012. The effectiveness of the nitrification inhibitor dicyandiamide (DCD) for mitigating nitrogen leaching losses from a winter grazed forage crop on a free draining soil in northern Southland. *Proceedings of the New Zealand Grassland Association*, Gore. Wickliffe Solutions. pp. 39-44.

Sprosen, M.S., Ledgard, S.F., Lindsey, S.B. 2009. Effect of rate and form of dicyandiamide application on nitrate leaching and pasture production from a volcanic ash soil in the Waikato. *New Zealand Journal of Agricultural Research*, **52**(1), 47-55.

Trodahl, M.I., Jackson, B.M., Deslippe, J.R., Metherell, A.K. 2017. Investigating trade-offs between water quality and agricultural productivity using the Land Utilisation nd Capability Indicator (LUCI) - A New Zealand application. *Ecosystem Services*, **26**(B), 338-399.

Upton, S. 2018. Overseer and regulatory oversight: Models, uncertainty and cleaning up our waterways, (Ed.) P.C.f.t. Environment, PCE. Wellington, New Zealand, pp. 138.

Watkins, N., Selbie, D. 2015. Technical Description of OVERSEER for Regional Councils. AgResearch.

Wheeler, D., Shepherd, M., Freeman, M., Selbie, D. 2014. Overseer Nutrient Budgets: Selecting appropriate timescales for inputting farm management and climate information. in: *Nutrient Management for the Farm, Catchment and Community*, (Eds.) L.D. Currie, C.L. Christensen, Fertilizer and Lime Research Centre. Massey University, Palmerston North, New Zealand, pp. 5 pages.

White, T.A., Snow, V.O., King, W.M. 2010. Intensification of New Zealand beef farming systems. *Agricultural Systems*, **103**, 21-35.

Woodward, S.J.R., Barker, D.J., Zyskowski, R.F. 2001. A practical model for predicting soil water deficit in New Zealand pastures. *New Zealand Journal of Agricultural Research*, **44**(1), 91-109.

APPENDIX 7: EVIDENCE IN CHIEF OF MR SIMON STOKES ON BEHALF OF BEEF + LAMB NEW ZEALAND ON WAIKATO REGIONAL COUNCIL PC1

APPENDIX 7

TECHNICAL REPORT OF MR SIMON JOHN STOKES

3 May 2019

IN THE MATTER	of the Beef + Lamb New Zealand submission on the Essential Freshwater Policy document
BY	**BEEF + LAMB NEW ZEALAND LIMITED** **Submitter**

TABLE OF CONTENTS

BACKGROUND

1. My name is Simon John Stokes.

2. I am employed by Beef + Lamb New Zealand (B+LNZ) as the Environment Strategy Manager. I have a Bachelor of Science majoring in environmental science and physical geography from Massey University (1994), Palmerston North and a Diploma in Business Management from Eastern Institute of Technology (2003), Napier. I am a Certified Practising Resource Manager as accredited by the New Zealand Association of Resource Management. I also hold a certificate in Sustainable Nutrient Management in New Zealand Agriculture from Massey University (2006).

3. I have over 22 years' experience in natural resource management, primarily in land, water, biodiversity and catchment operations and management. I worked in regional councils for nearly all those 22 years. My particular areas of expertise are with farm planning and the use of the Land Use Capability Survey technique and application, soils, biodiversity operations and catchment planning and management. I also have expertise in corporate management, governance and the business of regional government.

4. Prior to joining B+LNZ I was the Eastern Catchments Manager for the Bay of Plenty Regional Council. I had previously worked for Manawatu Wanganui Regional Council as a soil conservator, based in Taumarunui, and the Hawke's Bay Regional Council, as a land management officer, based in Napier. I am also a past President of the New Zealand Association of Resource Management and was on the executive for 10 years. I led the New Zealand Deer Farmers Association Environmental Awards programme for 4 years in the mid 2000's where the emphasis of those awards was a triple bottom line assessment and whole of farm systems approach akin to farm planning. I recently resigned as a Trustee of the New Zealand Poplar and Willow Research Trust and the New Zealand Farm Environment Trust which runs the Ballance Farm Environment Awards programme.

5. I am also on the governance group for the Land Use Capability Classification System, managed by Landcare Research, established in 2012. I have also co-authored a guidebook on farm forestry for the Hawke's Bay, which used the land use capability system data of the region as a basis

for anchoring the guides information about the landscape and tree planting options.

6. My most recent work was for the Bay of Plenty Regional Council as the Eastern Catchments Manager tasked with implementing the Annual Plan and ten-year plan programmes. I specifically managed the integrated catchment management programmes for the Rangitāiki River, Ōhiwa Harbour, Waiōtahe, and Eastern river catchments. The management of these programmes were about implementing co-governance strategy's (Ōhiwa Harbour and Rangitaiki catchments); implementing sustainable land use and biodiversity plans on properties as projects with funding; providing an advisory service on a range of natural resource management issues, and building relationships, especially with iwi.

7. I have read the Code of Conduct for Expert Witnesses in the Environment Court's 2014 Practice Note and agree to comply with it. I confirm that the opinions I have expressed represent my true and complete professional opinions. The matters addressed by my evidence are within my field of professional expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

8. I can confirm that I am qualified to provide evidence on the use of the Land Use Capability system, including the Land Use Capability Survey Handbook, the mapping of the land resource inventory system in the field, the use of the Land Resource Inventory Worksheets, Regional classification bulletins and farm planning. This involves the ability to complete a preliminary investigation, mapping (field survey), synthesis and implementation required to undertake an extensive Land Resource Inventory assessment and a Land Use Capability assessment of land, using the methodology set out in the Land Use Capability Survey Handbook (3rd Edition) – A New Zealand handbook for the classification of land. I undertook field work from 1995-2007 using the technique to generate soil conservation plans and latterly comprehensive farm plans.

9. I was involved in the 'Green Project, a Sustainable Business Council funded project, which developed a quality assurance programme for farmers in a form of farm planning approach, incorporating the geo-physical spatial assessment of a farm along with a suite of actions to manage the

environmental issues on farm. The output from that project was then used in the development of the Land and Environment Plan document and programme, still being implemented by B+LNZ currently. Since entering management in 2007, I have used the technique as a basis for catchment scale planning in the Bay of Plenty in the Manawahe coastal area, Waiōtahe, Ōhiwa/Nukuhou, and Rangitāiki catchments. The Land Use Capability system was also used as part of the assessment criteria for riparian management plans in the Bay of Plenty region, supporting a plans approval process.

10. I also ensured that the training requirement for new land management officers at the Bay of Plenty Regional Council required attendance at a Land Use Capability training course so that all staff could use and understand the system. I developed and ran the training courses for Land Use Capability system in the mid 2000's for land management officers from throughout New Zealand. That structured course programme over three days is still in use today.

11. There is no current formally recognised qualification for using the Land Use Capability Survey Handbook and associated skills. The aforementioned training course is delivered by two experienced NZLRI/LUC practitioners when demand requires a course. There is a qualification at Massey University titled Advanced Soil Conservation Module 1, which includes tutoring on the technique. Historically soil conservators were assessed on their on-going capability in its use through their soil conservation certification programme. In development in New Zealand is a farm planning accreditation and certification scheme led by NZIPIM, similar to the sustainable nutrient advisor scheme. Competencies are being developed to validate a provider's ability to produce and audit farm environment plans. The extent to which the Land Use Capability Survey technique will be incorporated requires investigating as I understand it is not a strength of the current core competencies. This would be a critical failing given that the ability to farm plan and have accreditation must contain an ability to be accredited to map the physical resources and understand what advice you are providing or what value is the audit. There is a good farming principle/practice which relates to LUC Class 7 and 8 and there will need to

be some training and competency emphasis on using the Land Use Capability Survey technique.

12. For the purposes of this evidence I will be using and referencing the Land Use Capability Survey Handbook 3rd Edition (2009).

PURPOSE AND SCOPE OF EVIDENCE

13. My evidence explains the New Zealand Land Resource Inventory and Land Use Capability Classification system and it proposes its inclusion within the farm environment plan process for farmers in the Waikato and Upper Waipa river catchments.

14. My evidence will explain the New Zealand Land Resource Inventory and Land Use Capability Classification system through the following topics:

    (a) The New Zealand Land Resource Inventory and Land Use Capability history (in brief);

    (b) The New Zealand Land Resource Inventory and Land Use Capability system; and

    (c) Inclusion of Land Use Capability into PC1.

15. I also provide evidence on the cultivation and grazing rules proposed in PC1 and in relation to the section 42a Officers recommendations.

THE NEW ZEALAND LAND RESOURCE INVENTORY AND LAND USE CAPABILITY HISTORY (IN BRIEF)

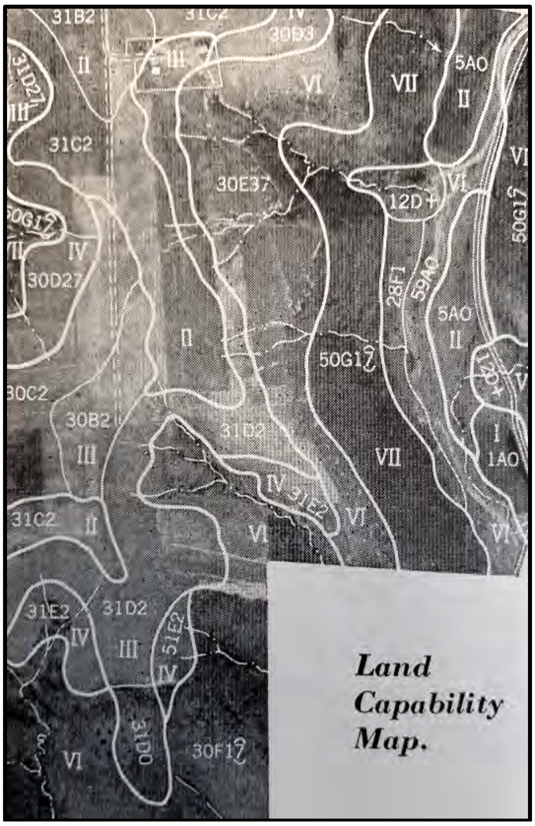
16. There is a long history to the development and use of the land use capability system which requires some explaining to understand why the system was used, how it was used and why it is still in use today.

17. New Zealand started to experience widespread and severe erosion in the early 1900’s and cyclone Thelma in 1938, which devastated the east coast of the North Island, was the catalyst for farmers and politicians to seek some form of legislation to manage landscapes and rivers. In 1941 the Soil Conservation and Rivers Control Act (SCRCA) was passed into legislation,

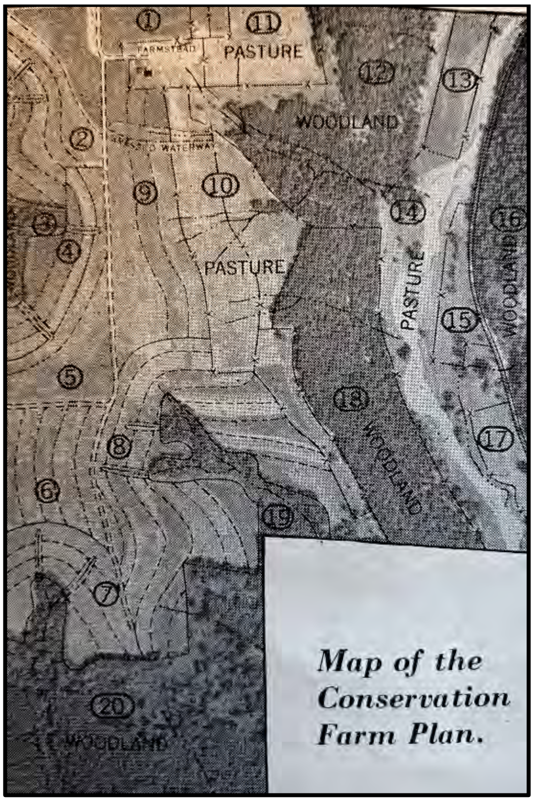
which still exists to this day and is the responsibility of regional councils. Its primary purpose was to manage the erosion problem, including river erosion. To support catchment and river authorities in the implementation of the SCRCA, a land use capability mapping technique was investigated in the United States where it was being used by the United States Department of Agriculture in drafting soil conservation plans. The land resource inventory field mapping and land use capability analysis which were both included in a conservation plan was accepted as an approach for use in New Zealand. The Land Use Capability system is more than just about erosion management, it is a holistic and appropriate tool for investing the long-term sustainable capability of the land, and in understanding its linkages to freshwater. It can be used to inform management decision around the sustainable use of land including pastoral land uses, farm systems, stock holding capacity, land management decision, biodiversity values, retirement, planting, and relationships between land and water resources.

18. An example is "What is a Conservation Farm Plan?", Leaflet No 249, 1948, U.S Department of Agriculture – Van Buren County, Spencer, Tennessee. This document outlines the description of a conservation farm plan based on land use capability mapping.

Figure 1 is an example of a Land Use Capability map and Conservation Farm Plan, page 4 and 5, “What is a Conservation Farm Plan?”, Leaflet No 249, 1948, U.S Department of Agriculture – Van Buren County, Spencer, Tennessee.



Land Capability Map.



Map of the Conservation Farm Plan.

19. This early example of land planning was seen as useful for New Zealand catchment authorities to use as a tool for individual farm and run plans.

20. In the late 1940's and throughout the 1950's, the development of a land resource survey mapping technique suitable for New Zealand was undertaken, based on the introduced United States system. It was a combination of the Pohangina Conservation Survey and the South Canterbury Catchment Board surveys that led to the National Water and Soil Conservation Council adopting the eight-class system in 1952. The application of this system was based on land resource inventory surveying (or examining of the nature of land) enabling an assessment of the land use capability, of an area (polygon), to support the planning of land use at farm scale and latterly regional or catchment scale.

21. The National Water and Soil Conservation Council officially adopted farm planning as part of its national soil conservation programme in 1955-1956. They used pilot and demonstration farms across the country and allegedly the first farm conservation plan was prepared in 1951 near Pohangina, on the Tew property. The plan at the time included a future land use map based on land use capability classifications and proposed land use changes. The purpose of the plan was strongly orientated towards reconciling socio-economic considerations with soil conservation necessities. The intent was to solve erosion problems by changes in land use that did not involve any monetary loss or ensured permanence and maximum productivity. Source Manderson A K, 2003, Farming from the Ground Up, Vol 2, Thesis, Massey University, Palmerston North.

22. From the late 1950's through the 1960's until 1967 the land resource inventory surveys and land use capability analyses were a mixture of soil conservation plans and regional and catchment surveys. National surveys were carried out and approx 9.3 million hectares was surveyed (page 323, Manderson A K, 2003). During this time, a range of farm plans were developed all using the land use capability survey system. Types of plans varied depending on the need; examples were soil conservation plans (general nationwide sheep and beef farms), run conservation plans (South Island high country farms), shelter plans due to wind erosion (Hawke's Bay

and Canterbury), orchard conservation plans (Moutere gravel erosion), and a dairy farm plan.

23. The use of this system grew beyond individual farm analyses to examine problems at catchment scale. The passing of the 1967 Water and Soil Conservation Act (1967) increased the need for the study of land use, land use capability, water management at complete catchments and river systems scale. It was now that it was decided that the entire country be mapped to assist the National Water and Soil Conservation Council with its responsibilities for the development of catchments and promotion of wise land use. The national survey was also to be more widely used to support the Town and Country Planning Act 1977 with comprehensive information about the land they were responsible for.

24. In 1970 progress was again made on the standards for land use inventory mapping and land use capability classification. The first edition of the Land Use Capability Survey Handbook was published (1969) and the emergence of the system as a nationally recognised approach to mapping New Zealand was re-enforced which resulted in the first New Zealand Land Resource Inventory dataset. The Handbook in particular was to be strictly adhered to based on the standards defined when completing a survey. It should be noted here that soil conservators were the only qualified professionals at the time with the ability and capacity to do land resource inventory surveys.

25. To quote A.L Poole, Chairman, Soil Conservation and Rivers Control Council (1971-1978), when describing the benefit of the land use capability technique for the lake Taupo catchment, "*nowhere in this country is the interrelationship between land use and water management better illustrated or of greater significance*". He went on to state "the importance of detailed land resource mapping in providing the basis for district planning has been realised as shown by the recent Hamilton Regional Planning Scheme. A set of eight rural resource policy areas has been defined each sharing some basic characteristics or problem and needing particular management or protection".[1]

[1] Source pages 9 & 10, Our Land Resources, 1979; Bulletin, Water and Soil Division, Ministry of Works and Development, Wellington.

Figure 2 is the Hamilton Regional Planning Authority use of Land Use Capability Class, page 59, Our Land Resources, 1979; Bulletin, Water and Soil Division, Ministry of Works and Development, Wellington.

HAMILTON REGIONAL PLANNING SCHEME: POLICY AREAS

POLICY AREA	LAND USE CAPABILITY CLASS	AGRICULTURAL PRODUCTION	URBAN DEVELOPMENT	FORESTRY	ENVIRONMENT CONSERVATION	PRIORITY FOR ACTION
1 Agricultural Protection	I	Preserve versatility and potential for intensive production.	Prohibit unless exceptional circumstances.	No	Protect high soil productivity	High
2 General Farming	II, III, IV	Conserve as arable farmlands which are suitable for dairy production and crop cultivation.	Allow only under carefully controlled conditions.	No	Conservation supervision important	Medium
3 Hill Country Conservation	VI, VII	Conserve for pastoral farming and afforestation.	Discourage	Yes (commercial)	Conservation supervision very important.	Medium
4 Environmental Protection	VIII	No productive uses.	Prohibit	Yes (protective)	Conservation supervision essential.	Medium
5 Mineral Resources	Any except I	Restore wherever possible.	Control very carefully	No	General supervision very important	High
6 Landscape Interest	Mostly VI, VII	Carefully control farming/forestry	Discourage strongly	Possibly	Environmental control especially significant	Low
7 Regional Recreation	Various	Conserve until public acquisition	Prohibit	Possibly	Conservation and general environmental supervision important	Medium
8 Future Urban Development	Mostly II, III, IV	Conserve until urban need	Staged and structural	No	Encourage good management	High

(Hamilton Regional Planning Authority, 1976) 59

26. Between 1975 and 1988 the foundations of what we use today were developed and set in place. The land resource inventory technique was refined and standardised as being based on the physical factors of rock type, soil type, slope, erosion and vegetation. The Land Resource Inventory Worksheets were completed for New Zealand (330 maps) at 1:50,000 scale, which for the first time gave a complete national picture and the public a view of the countryside as never understood before. There was also the development of the regional classicisation bulletins to represent the information in a way which was useful to land use planning, which contained the first use of regional (geological/landform) suites and sub-suites of land use capability units. For example, in the Bay of Plenty-Volcanic Plateau region you will find a Taupo pumice suite which has 9 sub-suites due to its geological complexity at a more granular level. Only 8 of the 12 Land Use

Capability regions of New Zealand were provided with bulletins. What was very important development during this period was the national standardisation of mapping vegetation, erosion and rock type necessary to provide the nationally consistent application of data for surveying and analysis.

27. Essentially each region has its own unique set of land use capability units that can be correlated to other regional sets of units allowing for a language of landscape interpretation to occur for the use in farm, regional and catchment planning.

28. The current version of the land use capability system is still used today in New Zealand since its original inception in 1952. It has been refined since 1952 with little change occurring since 1988. Primarily in my belief because it is still the only national and regional scale data set with multi-factor information that allows an interpretation of the landscape to be used for a range of purposes. It underpins advanced farm environment planning and as such is a cornerstone to B+LNZ Land Environment Plans, and Horizons Sustainable Land Use Initiative, which is supported and part funded by the Ministry of Primary Industries.

29. It is important to understand that its use is still seen as relevant and important even with the growing list of environmental issues and growing need to see farm management practices applied more robustly. The topographical variation and complexity of farm systems requires an objectively gathered set of geo-bio-physical factors as a starting point, or base set of data, to allow a property/farm to become more precise in achieving potential minimum standards of practice and achieving business goals for economic, environmental, social and cultural reasons. The land use capability system in New Zealand was developed primarily for soil conservation purposes, focusing on erosion. Conservation principles and wider environmental issues have never been left out of the conversation or reflected in the decision making of practitioners. It is planning tool by its simplest definition for which additional information or decision-making layers can be built upon.

30. Some practitioners within regional councils will also be using it for catchment scale analyses or using it within catchment models to provide land resource

information. The national Land Use Capability classification data set is used for understanding the risks of plantation forestry and harvest on soil conservation and associated risks on freshwater ecosystem health, within the National Environment Standards for Plantation forestry (2018). The land has been classified into yellow, orange and red categories based on its susceptibility to erosion which when applied then allows the interpretation of the standards required to be implemented, for example, a consent for planting and harvesting is required on 'red' land, whereas 'green' land is permitted activity for both activities. The Land Use Capability system is also underpinning the emerging landscape and landscape planning tools and models such as the National Sciences Challenge Land Use Suitability Program, which utilises the national LUC inventory as one of its base land inventory layers.

31. Regional and Unitary Authorities use the land use capability data set in regional and district planning. The MitAgator model developed by Ballance Agri-Nutrients uses the national Land Use Capability classification data set within the model to help determine the critical source areas on a farm. Bay of Plenty Regional Council uses it to protect land with versatile land use on Land Use Capability Classes 1, 2, and 3. Gisborne District Council District Plan contains rules for certain land use activity relating to the type of land use capability class. It is also used to outline a good management practice in the Land section for ground cover good management practice. It states: *retire all Land Use Capability Class 8 and either retire, or actively manage, all Class 7e to ensure intensive soil conservation measures and practices are in place.* Source Industry-agreed Good Management Practices relation to water quality, Version 2, September 2015. This practice definition has been carried over into the national list of good farming principles released by the government in 2018.

THE NEW ZEALAND LAND RESOURCE INVENTORY AND LAND USE CAPABILITY SYSTEM

32. The Land Use Capability system has two key components. A land resource inventory (LRI) compiled as an assessment of the physical factors present

in the field and an interpretation of that information into the standardised land use capability (LUC) classification.

33. The basis of the Land Use Capability classification is defined as a systematic arrangement of different kinds of land according to those properties that determine its capacity for long term sustained production. Capability is used in the sense of suitability for productive use or uses after taking into account the physical limitations of the land. Source: page 8, Lynn IH et al 2009, Land Use Capability Survey Handbook – A New Zealand handbook for the classification of land, 3rd Ed, Hamilton - AgResearch, Lincoln - Landcare Research, Lower Hutt – GNS Science.

34. This definition has remained unchanged since the first edition of the handbook. Interpretation of the definition often ends up debating what is meant by the words 'sustained production' and 'productive use or uses'. Their use in the interpretation infers that all land must be used and sustained for productive purposes because it has the capacity to do so, but this is too simplistic an understanding. My own interpretation would infer that the use or uses can include a vegetative state and land use activity, or perceived non-activity, which has no direct link to agricultural production or plantation forestry systems for example. In simple terms a bush clad hill country location is productive within itself and this can be a sustained long-term option. This connects the classification system with the concept of natural capital.

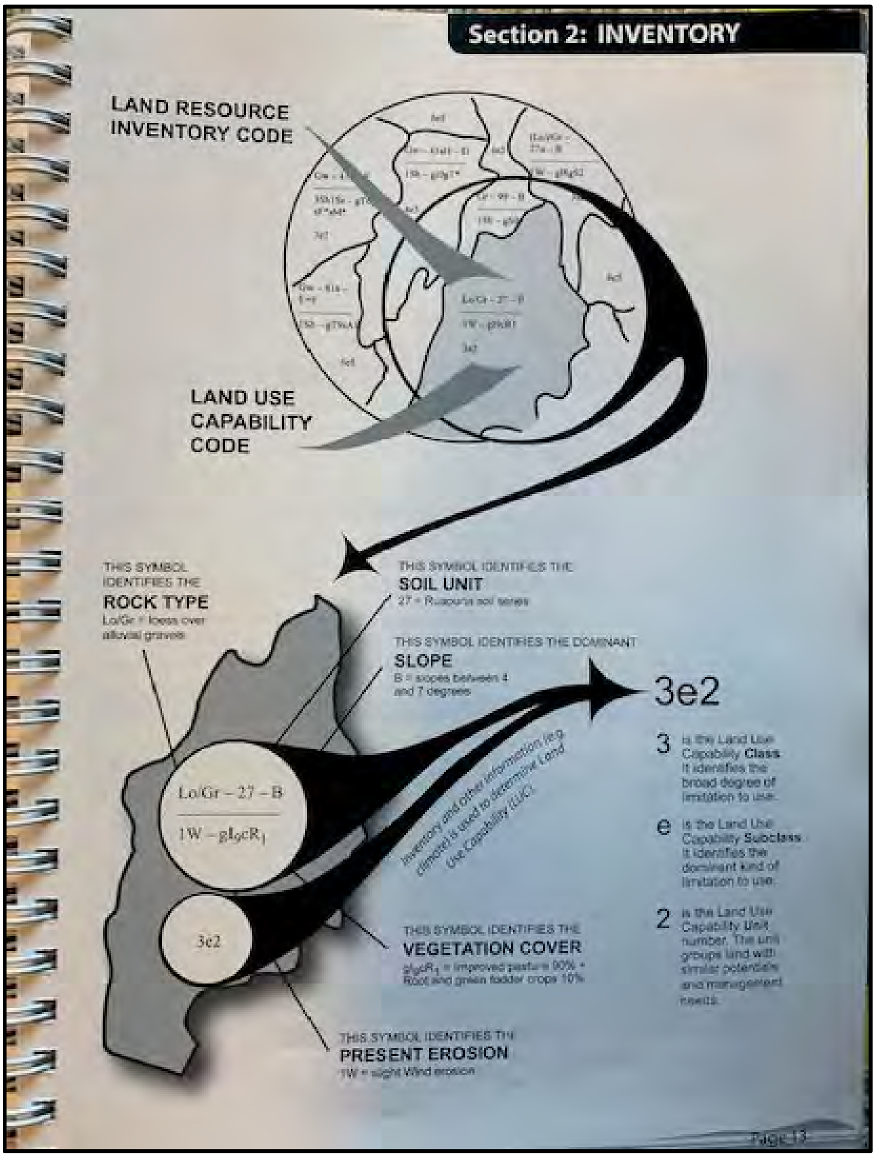
35. The benefit of modern supplementary information such as ecology and biodiversity, climate, archaeology, tectonic data-fault lines, and the greater understanding of the standard limitations (erosion, soils including vulnerability to leaching, wetness and climate) and environmental considerations, are taken into account. This example in figure 3 shows a landscape map in accordance with the standards of the handbooks use – a polygon of land with a wetness limitation and vegetative cover of wetland and estuarine species bordering an estuary. The physical factors mapped are the land resource inventory facts and would correlate to a known Land Use Class, sub class and land use capability unit. The land use option for the polygon in a farm plan could then be subjectively assessed and framed as an area unsuitable for any other use than retirement or a critical source

area. It doesn't have to have an industrial use. That is still a sustained long-term use considering our greater understanding of the benefits of this type of land use from an economic, environmental, cultural and possibly social perspective in this example. The point being that no matter what the land resource inventory and or the associated land use capability unit, not all land has to be thought of for industrial use. If there are rules relating to the land polygon which need to be complied with then the process of mapping the land resources and understanding that lands potential is a solid basis for more precise decision making for the plan owner.

36. The land resource inventory is used by the land use capability system as a basis for interpreting long term sustainable land use and water management, Source; page 12, Lynn IH et al 2009, Land Use Capability Survey Handbook – A New Zealand handbook for the classification of land, 3rd Ed, Hamilton - AgResearch, Lincoln - Landcare Research, Lower Hutt – GNS Science. There are five factors mapped; rock type, soil type, slope angle, erosion type and severity and vegetation cover. These physical factors are the focus due to their relative importance, either individually or in combination, in relation to how the land behaves under various uses. Add in climate, knowledge about current and past land use and other supplementary information and the capability of the land can be assessed for permanent sustained production.

37. The key difference between a land resource inventory approach and other land assessments is the multi-factor field technique versus single factor analysis. In my opinion a single factor field analysis cannot determine alone the land planning required. The natural resources present and land use activities (present or future) consist of a complex series of interrelationships crossing for example geo-physical, bio-physical, and ecological boundaries for instance. Understanding this concept places single factor analysis as useful and important, but not 'complete' enough to plan farm systems or land use management. Yet I would fully agree that a single factor such as rock type or soil type could have predominance in the subjective determination of a land use which is why the land resource inventory has an impact on the land use capability class, sub class and unit decision.

Figure 3 is an example of Coded Land Resource Inventory recorded as a formula', and the accompanying Land Use Capability code (adapted from NWASCO 1979). Page 13, Lynn IH et al 2009, Land Use Capability Survey Handbook – A New Zealand handbook for the classification of land, 3rd Ed, Hamilton - AgResearch, Lincoln - Landcare Research, Lower Hutt – GNS Science.



38. Rock type is recorded because it gives information on the geology and lithology present. This information can be used for giving background information to understand and plan for land stabilisation-erosion control and the nature and rate of run off. Rock type is underestimated in the process of land planning. It has major influence on slope angle, soil stability and the natural fertility of our landscape. New Zealand's geological and geomorphological landscape is complicated further with various aerial and alluvial deposits occurring from loess and volcanic activity and river plain deposition. Another aspect of rock type mapping often mis-understood and mis-mapped are faultlines. Tectonics plays a large part in shaping New Zealand's landscape and the faultlines in our landscape are often associated with increased erosion levels where the resulting tectonic activity has crushed the bedrock causing massive scale slump or earthflow structures. This erosion activity can then be the source of huge volumes of sediment which can reshape and redefine catchment waterways and receiving environment.

39. Soil type is recorded for a multitude of reasons but primarily to understand what type of soil (soil order) exists where, and therefore, how can that soil be best managed and protected for example from degradation, for production or informing irrigation requirements. The mapping of the soils on a farm at farm scale provide for a higher level of precision in management which can reduce the impact of compaction, pugging, and erosion. The current soil knowledge provided by S map and other publications also enables the plan holder to understand soil drainage and soil water holding capacity and therefore provides key characteristics that impact on the soils leaching potential. This knowledge is just so critical for the future management of soils and land in relation to the environmental issues that prevail.

40. Slope angle is recorded as a factor to support the understanding of the land's suitability and capability for use and the risk of surface erosion and mass movement erosion. In the context of PC1 LUC predominant slope could be used to determine management interventions at the land parcel scale such as stock exclusion provisions, which would reduce subjectivity and uncertainty for farmers and land management officers in determining when standards should apply.

41. Erosion type is recorded because of our landscapes propensity to erode and that effect on our economy and environment. It is the fundamental reason legislation was required in New Zealand to conserve our landscape and environment and why the land use capability system was introduced. It is the key limitation associated with the land use capability sub classes. It is mapped as present and potential erosion and by erosion severity. Decisions about land use and land management should always consider or be influenced by this factor, particularly in hill country. There are thirteen erosion types and one deposition category as defined in the 3rd Ed Handbook in New Zealand. The classification and definition of erosion types has been refined over 50 years of the use of the land resource inventory technique with the current definitions based on The New Zealand Land Resource Inventory Erosion Classicisation publication No85, Eyles G O, 1985, National Water and Soil Conservation Authority, Palmerston North. Each erosion type has its own guideline for mapping its severity which is then described within the land use capability code. This is an important assessment as it gives the mapper and farmer an understanding of the active or potential natural erosion activity under a certain landcover or land use, and the actual and potential effect of the land management occurring to cause or accelerate erosion. In effect it allows a farmer to manage thier natural resource more precisely.

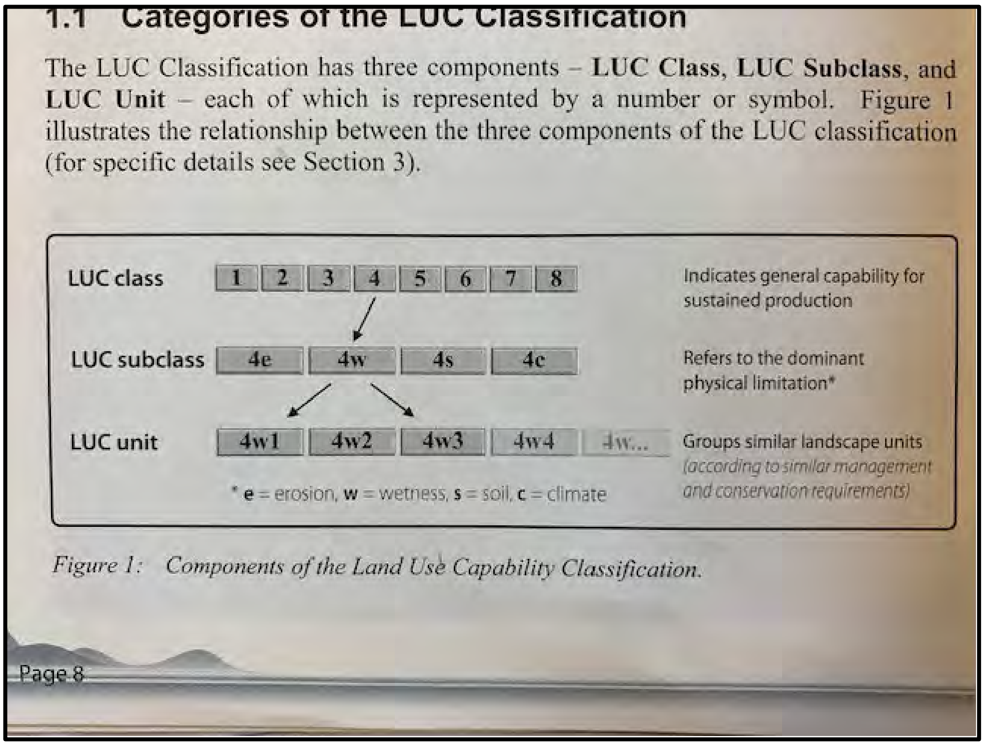
42. Vegetation cover is classified and mapped to provide knowledge of the current land cover and land use and to indicate possible future vegetation cover options. There are many vegetation cover classes to choose from within the Land Use Capability Survey Handbook and they are grouped into five major groups; grass, crop, scrub, forest and herbaceous. The vegetation classes have also been correlated approximately with Overseer® pasture classes, in 2006, page 46, Lynn IH et al 2009, Land Use Capability Survey Handbook – A New Zealand handbook for the classification of land, 3rd Ed, Hamilton - AgResearch, Lincoln - Landcare Research, Lower Hutt – GNS Science. Mapping the vegetation cover can sometimes result in more than one vegetation class mapped within an area, as it is often difficult to map one type of vegetation. This is an important element of the polygon assessment as it can identify for the farmer changes in vegetation cover mapped to the extent of requiring different management or use, but not because of a change in land use capability unit. For example,

an area of land mapped on rolling landscape at farm scale (1:10,000 scale) may be mostly high producing pasture but may also contain herbaceous vegetation located in infilled gullies and a significant area of gorse or blackberry. Recording this information is another benefit of the land resource inventory mapping as it can help with a planning the land use and land management requirements. Mapping at farm scale often provides the property or farm with a very accurate picture of the vegetative cover dominance aligned within the boundary of a land use capability unit. This helps the farmer clearly define the options and management requirements for their business.

43. Simply the land resource inventory mapped and recorded in the field is described in a code form – the land use capability code. This information is then interpreted into a land use capability classification. This assessment of the information outlined in lines on a map creating polygons or areas, is going to define its capacity for sustained productive use, taking into account the physical limitations, management requirements and land resource management needs. As mentioned previously this is where supplementary information is very important and useful.

44. The Land use capability classification has three components – land use capability class, sub-class and unit. Each is represented by a number or symbol.

Figure 4 is an example of the three components from page 8, Lynn IH et al 2009, Land Use Capability Survey Handbook – A New Zealand handbook for the classification of land, 3rd Ed, Hamilton - AgResearch, Lincoln - Landcare Research, Lower Hutt – GNS Science



1.1 Categories of the LUC Classification

The LUC Classification has three components – **LUC Class**, **LUC Subclass**, and **LUC Unit** – each of which is represented by a number or symbol. Figure 1 illustrates the relationship between the three components of the LUC classification (for specific details see Section 3).

Figure 1: Components of the Land Use Capability Classification.

Page 8

45. The land use capability class is the broadest grouping of the capability classification. It gives an indication of the lands versatility for sustained production taking into account the mapped inventory and therefore the general degree of limitation to use. There are eight classes ranging from class 1-8. This eight-level system was modified from the original brought from the United States. The scale ranges from Class 1 which is the most versatile land with the least limitation, to use, to Class 8 which has the least versatility and highest level of limitation, to use.

Figure 5 is an example of the often-shown table showing – Increasing limitations to use and decreasing versatility of use from LUC class 1 to LUC class 8 (modified from SCRCC 1974). *t* Includes vegetable cropping. Page 9 Lynn IH et al 2009, Land Use Capability Survey Handbook – A New Zealand handbook for the classification of land, 3rd Ed, Hamilton - AgResearch, Lincoln - Landcare Research, Lower Hutt – GNS Science.

Increasing limitations to use ↓

LUC Class	Arable cropping suitability†	Pastoral grazing suitability	Production forestry suitability	General suitability
1	High	High	High	Multiple use land
2	↓	↓	↓	
3				
4	Low			
5	Unsuitable			Pastoral or forestry land
6				
7		Low	Low	
8		Unsuitable	Unsuitable	Conservation land

Decreasing versatility of use ↓

Figure 2: Increasing limitations to use and decreasing versatility of use from LUC Class 1 to LUC Class 8 (modified from SCRCC 1974). † Includes vegetable cropping.

LUC Classes 1 to 4 are suitable for arable cropping (including vegetable cropping), horticultural (including vineyards and berry fields), pastoral grazing, tree crop or production forestry use. Classes 5 to 7 are not suitable for arable cropping but are suitable for pastoral grazing, tree crop or production forestry use, and in some cases vineyards and berry fields. The limitations to use reach a maximum with LUC Class 8. Class 8 land is unsuitable for grazing or production forestry, and is best managed for catchment protection and/or conservation or biodiversity.

46. The land use capability sub-class is added to the code because it divides the land by its major kind of physical limitation or hazard to use. Four physical limitations are prescribed in the 3rd Ed Handbook – erodibility where susceptibility to erosion is dominant; wetness where a high-water table, slow internal drainage, and or flooding constitute the dominant limitation; soil where dominant limitation is in the rooting zone. This can occur from shallow soil profiles, subsurface pans, stoniness, rockiness, low soil water holding capacity, low fertility and salinity and toxicity; climate where the climate is the dominant limitation. This can occur from consistent drought, excessive rainfall, frost and snow and exposure to strong or salt spray. Only one dominant limitation can be used in a map polygon or area. When one or more of the limitations are mapped which can occur on non-arable land, a

sub class hierarchy exists in the Handbook, whereby erosion has precedence over wetness and soil as the dominant limitation who both in turn have precedence over climate. The primary principle when prescribing a sub class is the permanency of the physical limitation, so even with management to improve or reduce the impact of the limitation, such as a land practice to improve fertility, remove stones, install permanent irrigation or erosion control, the limitation remains.

47. The land use capability unit is the most detailed part of the land use capability classification and provides a management prescription for its long-term sustained use. The development of this part of the classification system was primarily to enable a more precise application of the system at farm scale for the farm-soil conservation planning programme. While a land use capability class and sub-class can be mapped, similarities and differences within the land area or polygon needed codifying to enable more precise application of the land use capability analysis. Such as similarities or differences in soil conservation management, suitability for cultivation, pasture dry matter growth, crop types or forestry species. This provides a more specific level of detail about the land use capability unit, which is provided in the extended legends in the national land resource inventory worksheets. For example, two land use capability units, 6e1 and 6e6 in pumice hill country. Based on their inventory both have been classified as land use capability class 6, both have a dominant erosion limitation, but due to a subtle change in slope angle, soil type, vegetative productivity variance, and possibly other factors, they are not the same in relation to their capability for long term sustained productive use. But neither are they significantly different by land use capability class or sub class – therefore the allocation of a unit descriptor defines their difference which can then be managed accordingly. This is why the land use capability unit is called the ‘management level’ within the land use capability system. Source: page 87, Lynn IH et al 2009, Land Use Capability Survey Handbook – A New Zealand handbook for the classification of land, 3rd Ed, Hamilton - AgResearch, Lincoln - Landcare Research, Lower Hutt – GNS Science. So, within the national data set there are several land use capability units, listed numerically, based on their assessment of degree of versatility and degree of limitation to use. At a farm plan scale the land use capability unit is necessary to fully maximise the land resource inventory assessment. The

application of this within farm plans is supported by the development and use of the land use capability suites mentioned previously, which tie land use capability units into a landscape picture based on a geomorphological, geological or regionally distinguishable feature e.g. Banded Mudstone suite or Taupo flow tephra and water sorted tephra suite.

48. The following is an example of what a land and environment planning (Level 3) exercise would look like. The two maps highlight the detailed and tailored benefit of a land use capability survey providing a land use capability (unit) map and the ability to provide a possible recommended land use management plan to be actioned by the farmer.

Figure 6 is an example of a land use capability assessment map. Source: Hawke’s Bay Regional Council Plan No 3778.

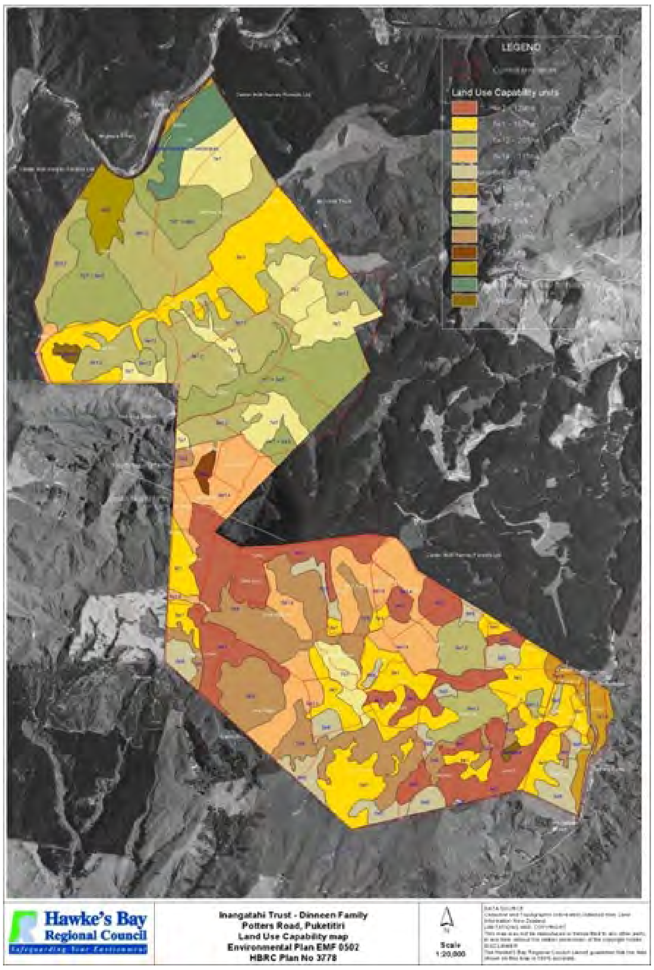
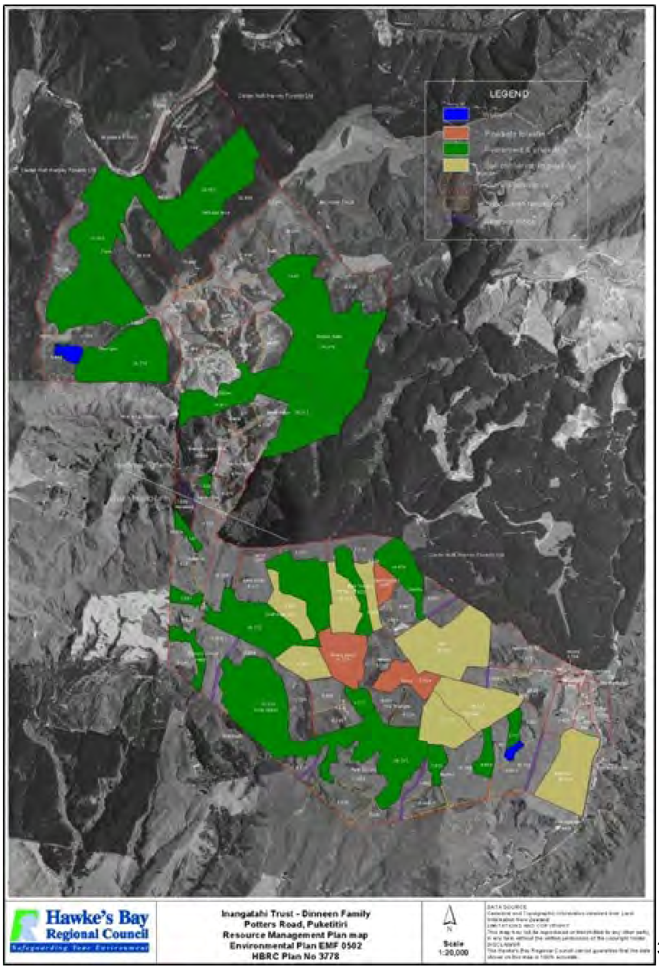


Figure 7 is an example of a recommended land use map derived from a land use capability assessment[2].



3

These types of visual drivers for a farmer translate into the two supporting photos. Both photos display the mosaic land cover of farms that have been managing the farms from a planned approach[4].

---

[2] Source: Hawke's Bay Regional Council Plan No 3778.

[3] Source: Hawke's Bay Regional Council Plan No 3778.

5

6

49. While both photos and the farm plan map examples are not from the Waikato, the principles of farm planning, its implementation, and result would not be dissimilar.

5 Photo source: Hawke's Bay Regional Council

6 Photo source: Hawke's Bay Regional Council

50. There is much scientific research and papers published nationally and internationally outlining the robustness and place of LUC within sustainable natural resource kete. Regional councils, primarily, find a common language and scientifically robust process of analysis, to manage and protect land and water in farm planning. The fact that the breadth of environmental issues and risks associated with a piece of landscape, whether in agricultural or horticultural or conservation management use, has grown to match the needs of the community and landowners, does not affect the validity of using the system nor undermine its role in providing a clearly understood platform of analysis to manage issues and risks into the future.

51. In the last decade new tools for interpreting our natural resources and mitigating effects on the natural resources have been developed like lidar, geo-magnetic surveying, catchment modelling – e source, land models – MyLand, Mitigator, LUCI, GIS, S-map, riparian planner, and the many varied farm environmental plan options, to name a few. These tools are all beneficial participants to achieving the overarching outcome of managing natural resources sustainably, however much of their utility comes from enhancing the use of LUC or its application, and many tools such as MitAGATOR continue to rely on LUC as a fundamental building block within its model. The complexity of the natural ecosystem and economic system cannot be measured in single factor steps even when trying to focus on a issue such as water quality, but must be built on integrated platforms that assess the complexities of the natural environment.

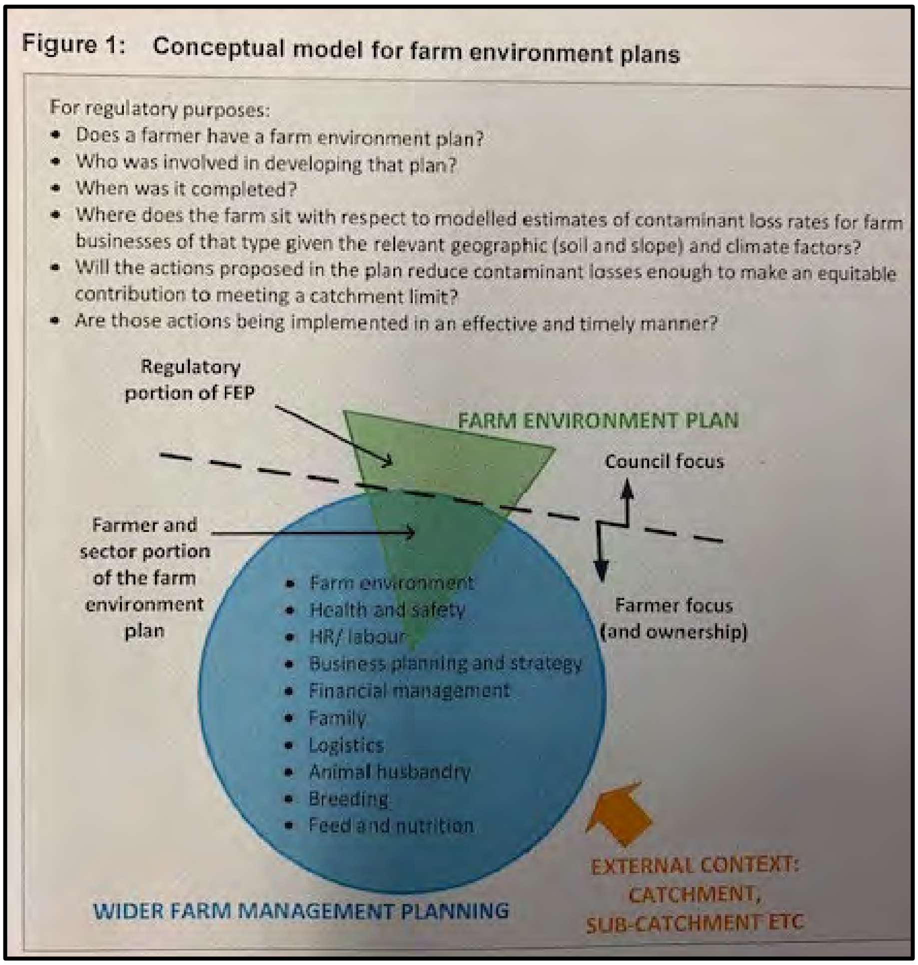
INCLUSION OF LAND USE CAPABILITY INTO PC1

52. B+LNZ has been implementing its Land and Environment Plan programme for over a decade. Farm planning, as defined by its many versions over the last 70 years and in the last decade more often termed farm environment plan, has been an ongoing consistent approach to managing natural resource issues. Even though different regions and different agencies have faced different pressures and drivers with different planning backdrops, everyone turns towards some form of planning document or process tailored to achieve the required end result. The Farm Environment Plans National Collaborative Working Group's final report in 2015 commented that "Farm environment plans are a long-standing risk management and capacity

building tool. They are used by “farmers to understand the impact that they have on the environment and to shift practice to mitigate this impact, and by some sectors as part of a strategy for extracting additional market value” Source, page 1, Farm Environment Plans National Collaborative Working Group - Final Report, 23 June 2015, Martin Jenkins, Wellington.

53. The Working Group also commented that “Resilience and resilient farming systems present a great opportunity for long term focus. However, while farmers have long term business strategy, the immediate regulatory need to manage within limits while increasing profitability requires hard business calls to be made to ensure the viability of their farming enterprise. The best possible short-term result through this process is the co-production of decision support tools that accounts for all of our natural capitals – environment (ecological, biodiversity), economic, social, cultural – to enable farmers and growers to make the best decisions for their farm.” Source, page 2, Addendum to the Martin Jenkins Final Report: Farm Environment Plans National Collaborative Working Group, 23 June 2015, Martin Jenkins, Wellington. Figure 6 highlights the Working Group’s conceptual model they saw, which in their minds provides access to actions on-farm and a recording mechanism, to give the user and regulator/auditor confidence and credibility in relation to the benefit of a farm environment plan.

Figure 8 is the conceptual model for farm environment plans, from page 15, Martin Jenkins Final Report: Farm Environment Plans National Collaborative Working Group, 23 June 2015, Martin Jenkins, Wellington.



54. A Ministry for the Environment report in its summary statements also recommend the ongoing use of farm environment plans as an effective approach to meet future challenges in resource management. The report, Review of New Zealand Environmental Farm Plans, May 2003, Blaschke P & Ngapo N, published report by the Ministry for the Environment, provides two clear statements from its executive summary that helps to underpin why B+LNZ support farm planning in a mixed regulatory-non-regulatory approach. Executive summary No 6 states “that many regional councils recognise that environmental farm plans are an effective method of achieving good environmental outcomes in a non-regulatory way”, and No7 elaborates on their potential use by stating “there is also the potential to integrate environmental farm planning with other on-farm objectives, as well

as wider catchment goals. They can be an ideal mechanism for implementing catchment schemes".

55. In my opinion, the use of a tailored farm environment planning approach in PC1, underpinned by a robust stock take of the farms natural resource and the identification and management of critical source areas will deliver sustainable and enduring outcomes in the integrated management of land and water resources. These farm environment plan requirements, however, should require a land resource inventory assessment interpreted into a land use capability unit at farm scale, essentially using the Land Use Capability Survey technique, which provides a multi-factor assessment to understand the natural capital (resources), their opportunities and their limitations. There may be alternative ways of mapping the five physical factors for example using geo-magnetic aerial survey for soil mapping versus a spade or using lidar versus a clinometer. Ultimately though the benefit of a multi factor assessment will outweigh a single factor assessment. Farm environment planning based on prescriptive practice standards controlled by the Waikato Regional Council will not result in the farm system change required to significantly reduce emissions for current farming systems and practice.

56. A fundamental principle for B+LNZ is to support farming excellence and to support a sense of purpose that has a tangible impact for their farmers. I support this principal. An enduring benefit that a tailored farm environment plan provides is not just the plan itself, but in the process of plan development, the knowledge connections that the farmer makes in relation to their natural resources and their long-term sustainable management. It is process of reviewing and where required changing farming systems and practices to realise the opportunities provided by these resources while avoiding and remedying their limitations, that deliver on the ground change and shape diverse and resilient landscapes. At its most fundamental level, a farm environment plan is critical to this sense of purpose because it can be a capability and culture building tool on farm and maintain a level of

credibility in the eyes of a farmer in being effective in supporting them to meet future challenges, be they environmental or about productivity.

57. Figure 9 shows the current table in the Land Use Capability Survey Handbook, 3rd Edition. This is a clearly outlined standard for mapping that can and should be used by a practising land use capability mapper. The scale of mapping should correlate with the management purposes. For tailored farm or land environment planning, and in particular in diverse landscapes the appropriate scale to support the land resource inventory field assessment and mapped land use capability units is 1:10,000 (1cm-100m). This is because it is necessary to map a farm at the level of the land use capability unit. J Wallace Ramsay's paper on Conservation Farm Planning in the Soil Conservation and the Planning of Land Use proceedings of the 10th New Zealand Science Congress, August 1962, on page 18 he states that "In conservation farm and run planning greater use is made of sub classes designated by the chief limitation factor; and units, designated by a land management factor". The current national worksheets containing the land resource inventory and land use capability units is at 1:50,000 (1cm-500m), which is appropriate for regional or catchment planning and the identification of vulnerability or opportunity at a broader scale, and to use the national worksheets to provide background information to the mapping and land resource inventory analysis.

Figure 9: Table 18: Guidelines to selection of appropriate scales for extensive LRI/LUC surveys (modified from McRae & Burnham 1981 and Jessen 1987), Source: page 100, Lynn IH et al 2009, Land Use Capability Survey Handbook – A New Zealand handbook for the classification of land, 3rd Ed, Hamilton - AgResearch, Lincoln - Landcare Research, Lower Hutt – GNS Science.

Table 18: Guidelines to the selection of appropriate scales for extensive LRI/LUC surveys (modified from McRae & Burnham 1981 and Jessen 1987).

Scale level[1]	National	Regional	District and catchment	Farm
Scale[2]	1:250,000 to 1:100,000	1:100,000 to 1:50,000	1:50,000 to 1:15,000	1:<15,000
Scale size[3]	Small ←		→	Large
Map detail[3]	General ←		→	Detailed
Smallest area[4]	40–250 ha	10–40 ha	1–10 ha	≤ 1 ha
LUC level	Dominant capability class or subclass	LUC unit (regional)	LUC unit (regional)	LUC unit (regional and farm[5])
Common application examples	Strategic overview, broad planning, prioritising or targeting projects for detailed investigations.	Land use planning, targeting of regional priorities and projects, reference for more detailed survey.	Catchment projects, small district/community projects, farm planning for large properties.	Farm planning (detailed), nutrient budgeting, farm development projects, precision agriculture.

[1] Scale levels are subjective. Meaning is often dependent on context (e.g. a 'detailed' scale in a farming context is different from a 'detailed' scale in a regional context).

[2] Recommendations are based on common NZ scales used in soil, geology and LRI/LUC surveys.

[3] Large and small scale terminology is confusing. A 'large' scale (e.g. 1:5,000) is actually more detailed than a 'small' scale (e.g. 1:500,000). Scales are essentially fractions, and fractions with large denominators are smaller numbers (e.g. 1:5,000 is the same as 1/5000 or 0.0002, which is a larger number than 1:500,000 = 0.000002).

[4] The smallest area of interest represents the minimum legible area (MLA) that can be displayed on a paper map at a given scale. Any smaller and labelling becomes illegible, and line boundaries become disproportionate. Modern digital printing can accommodate a minimum legible area as small as 0.4 cm^2 (after Forbes *et al.* 1982).

[5] Occasionally regional LUC Units may require adaptation at the farm scale (see Section 4.4).

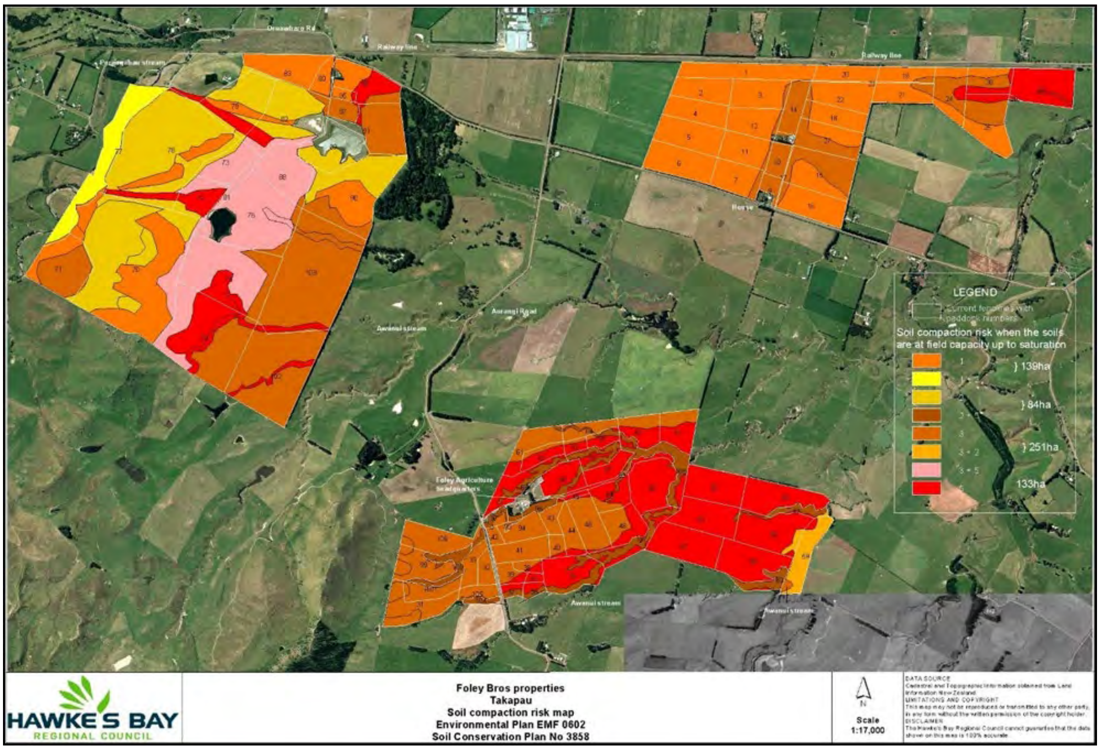
58. A sheep and beef farmer, or any landowner, with a professional land resource inventory field assessment can use that information within a land and environment plan, farm environment plan, or other version of farm plan, to more precisely manage their business. This is necessary due to the increasing precision being requested of landowners in relation to stock exclusion, stocking rates, cultivation management, erosion and sediment control in a landscape which is not flat and contiguous, but complex. When asked to comply or implement rules relating to the activities on the farm or other land uses, having farm scale or higher mapped inventory and land use capability units provides a consistent approach to ensuring those rules or

minimum standards or good management practices are applied more robustly and precisely.

59. Having a consistent approach to farm environment planning will help data collection, reporting, auditing and compliance. Having a visual guide such as a map is very useful for all involved in any land activities as it connects everyone visually to the landscape. This is important because connection with the land is a characteristic of sheep and beef landowners in a way which is more than just ownership. The mapped property can also be spatially interrogated on computer and easily managed for update or recording. This means that sheep and beef farmers and agencies and rural professionals can use the same language to communicate. As modern technology transforms how we see and map the land using drones, it will be important to standardise how we approach 'reading' the landscape and then managing and protecting it.

60. An example of the multiple and flexible use of a land use capability assessment can be to develop risk maps for various environmental or production-based requirements. In a paper to the titled "Working with Farmers to Implement Sustainable Farm systems", Stokes S et al showed the use of the land use capability system and land use capability units to support additional land use management in implementing sustainable farm systems. A soil compaction risk map was developed for the Foley Bros properties in Hawke's Bay which was used for managing the effect of their grazing system for the winter. Soils were derived from the land resource inventory field assessment and then used as the GIS field to highlight their risk. Soil drainage classes were used for each soil which provided the basis for each soils risk. This process of highlighting a single factor from within a suite of land resource factors is an underutilised usage of the land use capability unit. This approach does not mean the other land resource inventory factors have been isolated from the specific analysis, if anything they re-enforce the risk decision making process comes from a more complete ecosystem footprint analysis.

Figure 10 is a Foley Bros property soil compaction risk map. Source: Working with Farmers to Implement Sustainable Farm systems, Stokes S, Eyles G O, Clouston T G & R G,8-9 February 2007, Designing Sustainable Farms – Critical aspects of soil and water management, Proceedings of Fertiliser and Lime Centre Conference, Massey University, Palmerston North



61. A farm environment plan with a land use capability system in place can also be used to support the allocation of nutrients. Land Use Capability provides a well-known and scientifically robust approach for planning land use and providing detail on land management required to conserve the natural capital of the landscape which can be linked to nutrients, pathogens, and erosion loss risk. Both phosphorous and nitrogen are not isolated from general farm use or activity in how they impact on the environment. Their impact on waterways and other receiving environments is dependent on many factors in relation to the landscape and farm system. In my opinion the development of the natural capital allocation approach and the use of Land Use Capability as a proxy for appropriate approach to the allocation of nutrients within a farm business or combination of businesses within a catchment or sub-catchment is robust. This approach enables allocation to

be decoupled from current land uses and linked, instead, directly to the underlying natural biophysical resources in the catchment.

62. A farm environment plan with a land use capability system can be used in models such as Overseer or Farmax, for example, ensuring greater precision in the input and output data. Overseer and Farmax both can create 'blocks' within their models which should be correlated to a property's land use capability units. Once a land use capability unit has been mapped, even in several locations on a farm, it is the same land and can be treated as a 'block'. A farm could then manage its allocation standard more accurately via a combination of more precise land resource inventory data, nutrient management input and output and pasture/crop type and dry matter production and harvest. This would give the farmer a greater level of ability to mitigate the problems associated with nutrients.

63. Tied inexplicably to meeting the challenge of nutrient allocation is also the running of the farm system, especially the intensity of stocking on a farm as an overall average or as a practice in grazing management. As set out in the evidence in chief of Dr Chrystal and Dr Dewes stocking rate and stock type are primary divers in nitrogen leaching risk. In combination with my previous comments in para 46, an additional advantage of the farm scale map with land use capability units is understanding more precisely stock carrying capacity, and the appropriateness of stock type and weight in relation to the natural characteristics of the land. A farmer can learn and derive the present average carrying capacity (this they will know from their own records), the carrying capacity of a top farmer and the attainable physical potential carrying capacity from the region's overall assessment from the LUC extended legend. The inclusion of this type of data in the land resource inventory worksheets started in 1978 as a cooperative exercise involving the Ministry of Agriculture and Fisheries – specifically the Economic Division and Regional Advisory Officers, New Zealand Forest Service (for site indexing of *Pinus radiata*) and the Ministry of Works and Development's land resource inventory scientists. The farmer will have much more up-to-date information along with the data collected for the worksheets, where both can contribute towards the subjective analysis of the land use capability units. This data would not change the land resource inventory mapped except possibly where there is a variation to vegetation

type that has occurred. Further detail as to the development and application of the stock carrying capacity data within the national land resource inventory data set is available.

64. In drafting farm plans over the years, I have referenced the stock carrying capacity by land use capability unit to give the farmer a sense of the potential stock carrying capacity, or site indexing for forestry potential. From that experience and anecdotally, many farmers were not surprised at the carrying capacity potential provided by the worksheet data, but more importantly, in combination with a greater understanding of the land use capability mapped and presented in a planned context, they were able to better grasp improving their farm system by paddock sub-division or realignment, implementation of erosion control of their soil, or provision of other values such as biodiversity. It is a pathway towards continual improvement and behavioural change.

65. A paper titled "Deriving pasture growth patterns for Land Use Capability Classes in different regions of New Zealand", Cichota R, Vogeler I, Li F.Y, and Beautrias J, 2014, AgResearch Grasslands, to Grasslands Association conference provides researched validation that the assessed productivity levels of pasture within the land use capability data associated with stock carrying capacity as agreeing well with researched pasture growth patterns and yields. The papers abstract states, "Farm system models are increasingly being used to assess the implications of land use and practice changes on profitability and environmental impacts. Exploring implications beyond individual farms requires the linkage of such models to land resource information, which for pastoral systems includes forage supply. The New Zealand Land Resource Inventory (LRI) and associated Land Use Capability (LUC) database includes estimates of potential stock carrying capacity across the country, which can be used to derive annual, but not seasonal, patterns of pasture growth. The Agricultural Production Systems Simulator (APSIM) was used, with generic soil profiles based on descriptions of LUC Classes to generate pasture growth curves (PGC's) in three regions of the country. The simulated pasture yields were similar to the estimates in the LRI spatial database and varied with LUC Class within and across regions. The simulated PGC's also agreed well with measured data. The approach can be used to obtain spatially discrete estimates of

seasonal pasture growth patterns across New Zealand, enabling investigation of land use and management changes at regional scales". Source: page 203, Grasslands Conference Proceedings, 2014. This researched example gives confidence to using the land use capability units as a basis for correlating a level of stock carrying capacity to potential nutrient inputs and outputs, understanding that for that land use capability to be sustained in long term use in must be managed accordingly to that unit's management prescriptions. There is nothing in the 3rd Edition Handbook to suggest that new management requirements could not be added to existing land use capability units' management practices.

66. In summary, allocation of nutrients within a farm system or aligned to the land is not easy. However, the close alignment between the concept of natural capital and the land use capability system allows for a more appropriate and tailored application of potential minimum standards for land use practices, which may affect land use change. Modernisation of mapping techniques or data collection process for the land use capability classification system will not change the basic process of collecting land resource inventory or how that is interpreted into a land use capability unit. If anything, this will help refine the data and its accuracy in mapping which makes it more precise to be measured against a minimum standard or target.

67. Issues with nitrogen leaching and losses of phosphorus arise through the vulnerability of the soil to leaching, and erosion, shaped by the underlying geology, and vegetation cover, and stocking rate and intensity. As such management approaches/ frameworks should appropriately focus on holistic and integrated approaches to managing land and water resources including the use of tools which appropriately reflect this diversity including the combination of natural capital and land management activities. The use of land use capability systems within regulatory frameworks is applicable and provides a framework which is able to be implemented practically and creates the framework which shapes land use and management practices

to deliver resilient, integrated, and healthy functioning ecosystems within productive landscape.

68. Dr MacKay further discusses the role of LUC as a proxy for natural capital and its function in regulatory frameworks. I support his conclusions in this regard.

RULE FOR CULTIVATION AND GRAZING

69. I would like to comment on Rule 3.11.5.2(4)(c) in the Section 42A Report, Proposed Waikato Regional Plan Change 1 – Block 2, Parts C1-C6: Policies, Rules and Schedules (most). Specifically, officer's advice from para 724-741 on the provision of an upper slope limit of 15 degrees on cultivation and grazing. Both the upper slope limit of 15 degrees along with restrictions on grazing of land above 15 degrees should be deleted.

70. While I support the notion that a proportion of the Waikato region is vulnerable to erosion as estimated from analysis of the National Land Resource Inventory survey, it is not appropriate nor scientifically justified to extrapolate this to regulatory restrictions on the use of land as proposed by the officers. Within the survey any reference to hectares "affected to some degree by erosion" will be based on the mapped inventory erosion types established within the standards of the Land Use Capability Survey Handbook 3rd Ed. This suite of erosion types does not include grazing or cultivation specifically. It does include sheet erosion, a form of areal or surface erosion type which can occur from cultivation and tracks or areas of heavy stock concentration. This highlights the need for further analysis of the Waikato land use capability units where surface/sheet erosion has been mapped to provide a more substantive understanding of the area involved.

71. For the remaining para's 727-741 I would like to comment in general on the officer's comments. I have reviewed Environment Waikato Regional Councils Technical reports for changes in soil stability (Sources; Changes in soil stability in the Waikato region from 2002 to 2007 Environment Waikato Technical Report 2009/30 – referenced in the S42 report and; and Soil stability in the Waikato region - 2012. Waikato Regional Council Technical Report 2016/20).

72. In summary, both reports highlight the relevance of natural erosion occurrence as being significant. Focusing on the most recent report from 2012 as opposed to the 2009 version used in the officer's comments, out of 2661 sample points across the region analysed for soil stability, 48.7% were erosion prone but inactive, fresh erosion or had extensively disturbed soil. Therefore approx. half of all sample points have been assessed as having eroding characteristics and highlights the not only the relationship between an eroding landscape and its potential to be unstable and contribute sediment but the scale of the problem in the Waikato. Where that erosion is a large earthflow or slump structure or is related to riverbank or streambank erosion there is a large long-term flux of sediment deposited directly into a receiving environment. The erosivity of the region needs further analysis to be more precise in understanding the types of erosion occurring and the management required by sub-catchment or catchment – this analysis would be supported by a farm scale planning approach to the issue and risk of sediment movement, which is what we propose. As opposed to a rule on grazing which has less impact. Managing erosion will impact on grazing management of a property as a result.

73. When each site was assessed for soil disturbance across the entire sample 23.2% had soil disturbed by land use related activities with 6.8% of that disturbed area related to drystock, (sheep and beef and deer sector). The erosivity of the landscape is again highlighted with 9.1% related to natural processes such as mass movement, and only 4.8% is indicated to come from the drystock.

74. What is pointed out is that tracking is highlighted as a major contributor to the bare ground analysis in relation to soil disturbance. Bare ground is a known significant contributor of eroded material as the officers allude to. Tracking alone contributes 0.89% of the 1.93% of the regions area, assessed as soil, sediment or rock exposed by all forms of disturbance. In addition, cultivation, harvest (related to forestry), earthworks, rural roads and drain excavation are also contributors making up the remaining percentage with grazing assessed at 0.05% of the regions area. The 2012 report also notes that 0.38% of the 1.93% of the regions area is causing bare ground by natural processes of erosion. Of this 0.2% is linked to surface erosion processes which include sheetwash, sandblow, geothermal

activity and rockfalls. These erosion types arise for numerous reasons and are not attributed to grazing pressure. Sheetwash erosion for example is due to the cultivation practices which have been consistently carried out over the last decade with pasture renewal and green feed cropping.

75. The report goes on to outline that the rural land uses were observed at approx. 64% of the sample points. About half of these bare soil sites were located on dairy pasture (0.32%) with only 0.22% on drystock. The report states that across the three rural land use sectors (dairy, forestry and drystock), the bare soil caused by soil disturbance was mostly due to tracks, page x, 2012 report.

76. In my opinion, I agree with the statements in para's 724-741 with regards to the impact of cultivation, but I do not agree that land over 15 degrees should be singled out in relation to targeted restrictions. Land considered at <15 degrees is vulnerable or accelerated by natural or anthropogenic erosion activity, as highlighted below. Management frameworks which simply rely on slope as is proposed here are not effects based. While it is difficult to determine the area cultivated in the Waikato, I would estimate that the majority cultivated was on landscape at <15 degrees. Therefore, its contribution towards soil disturbance and the presence of bare ground would be a significant contributor to sediment loss into waterways. The Council's 2012 report on soil stability supports this comment. Cultivation should be managed using best management practices irrespective of slope.

Figure 11 is an example of land <15 degrees with extreme gully erosion on a river terrace with the regolith composed of material known as water sorted Taupo flow tephra, present at depth. This erosion occurred because of the intensive farming of cattle over several years compacting the shallow topsoil causing ponding on the paddock surface, which was then subsequently drained away by the landowner, resulting in extreme gully erosion. Source: S Stokes, 1997

Figure 12 is an example of gully erosion that occurred on land at <15 degrees, where the regolith was composed of layering's of volcanic eruptive material. The land was in pasture with no apparent reason for the erosion to occur – other than the impact of the intense rainfall at the time. Source: Bay of Plenty Regional Council, 2013.

77. Both photos highlight that the angle of slope is not a methodology on its own, to fully understand and appreciate the erosivity of a landscape by natural occurrences or anthropogenically derived. To truly understand erosion types and their management, including surface/sheet erosion you

need to understand the multi-factor complexity of the landscape and ecosystem – in essence, the natural capital.

78. I do not agree that grazing requires a rule to manage erosion or reduce soil disturbance at any relevant slope angle. There is no clear researched relationship between grazing and soil instability in the hill country or on land >15 degrees, presented by the officers' comments. There is a reference in para 739 to Appendix 1, page 137 of the Land Use Capability Survey Handbook 3rd Ed, "that the formation of cross slope stock tracks tends to occur above 25 degrees, indicating a visible level of soil instability". What the Handbook on page 137 actually states is, "Above 25 degrees some soil movement and the formation of stock tracks across the slope are common". What I think the officer is noting is that soil creep, which is a known process, is topographically highlighted by the cross-slope movement of stock which is a visible reference point for many observers of hill country of soil creep, but it does not unrefutably mean that the landscape has soil instability. What soil creep highlights is a function of the regolith and its mass holding it to a slope angle which can be affected by rainfall and water infiltration, creating a physical change in the dynamics of the soil mass relative to being held at that slope angle. This is particularly noticeable in mudstone and siltstone hill country and indicates a potential for mass movement erosion such as a soil or earth slip and earthflow.

79. Soil stability in the councils own 2012 report is defined and identified at sample points that are on stable or unstable surfaces. Unstable surfaces include; erosion prone, recently eroded or freshly eroded surfaces. Surface and rill erosion associated with cultivated sites, as stated in my evidence, could potentially occur mostly on land at <15 degrees. Soil disturbance is defined in the 2012 report as identifying bare soil which has the potential to move. The report again uses land use related activities such as cultivation and harvest, not grazing, or natural process such as landslides.

80. I agree with the officer's comments in para 739 where they doubt that there is sufficient evidence to support restrictions on grazing hill country slopes. Natural erosion occurrences, tracking, and cultivation all creating soil instability, soil disturbance and bare ground are more responsible for sediment moving into receiving environments than grazing. Rules are

already provided for in the Regional Plan for such activities. Active and potential erosion can be managed very effectively through a land use capability assessment at farm scale.

SUMMARY

81. Farm planning from the 1950's until 1987 was a requirement of government policy and the national monitoring of farm plans was a numerical tally of completed plans. Since that time farm planning has been variable in its application by regional councils and unitary authorities, depending on their history in the use of farm plans and or their interest in it as a method for implementing policy under the RMA 1991. While there has been a renewed interest in farm planning since the late 1990's, it is still of variable use, even in the shape of a farm environment plan. Because it has not been monitored nationally or regionally and assessed in a way which shows its effectiveness, there is much debate about the certainty a farm planning approach provides. This may be true in relation to a lack of certainty, but that uncertainty is due to its variable application and mixed policy approach. It is not a measure to suggest a decline in the effectiveness of the tool itself. Quite the opposite is occurring with the growth in farm environment planning nationwide. I applaud the growth in farm environment planning and general farm planning, but as my evidence alludes to, the tools effectiveness must be based on including a land use capability system assessment or some version thereof such as physiographics which provides a robust foundation on which to manage from. There is also a difference between what is now being used as a basis for a farm environment plan or freshwater module which is focused on practice compliance versus a more comprehensive use of the tool to support farm business planning.

82. Farm plans with a land use capability classification analysis identify the fundamental base upon which a sustainable farm can be defined. This process, identifies, assesses, and matches the capability of the land in the sense of suitability for productive use or uses to sustain a socioeconomically sustainable system of land use for the long term. Taking into account the physical limitations of the land.

I believe farm planning provides the following benefits;

- It creates direct liaison with farmers on a one-to-one basis which helps to establish a long-term relationship with the farm planner, regional council or other authority.

- It provides an evaluation of farm specific land capability, sustainable land management issues and risks and requirements and the farmers capabilities

- They address constraints to use and management through assistance towards integrated and long-term sustainable management of land. For example, they encourage and re-enforce the need for farmers to consider long term dimension to their farming operation well beyond the yearly focus on production management.

- They provide a high degree of effectiveness towards addressing on-farm sustainable land management concerns – primarily by using the knowledge contained within the assessment to integrate environmental management into everyday farm management.

- Lastly a farm plan provides a system for assessing a farms sustainable land management progress and if a consistent approach to the lands assessment is used e.g. LUC units, then a farmer or farmers in a catchment have comparable background, analyses, and results to discuss and report on. A farm plan also provides for a legitimate approach to applying a funding intervention which is shown using farm plans in the Horizons region and their SLUI plans which obtain grant funding.

83. There are also disadvantages which are well known such as the cost of the activity, the commitment required by all involved for long periods of time, and the difficulty of farmers realising the relative advantage a farm plan and the information it gives them. However, at this time in New Zealand, the necessity of a farm plan is greater than ever. A farm environment plan as a regulatory tool could be more effective when strengthened with spatially defined land resource inventory assessments and land use capability unit classification to support its implementation. However, in doing this I contradict myself, as you cannot use it as a regulatory tool because it overreaches into detail irrelevant to the main focus of a farm environment

plan, which is compliance (under the RMA); and because of the level of detail and honest appraisal of a farm business, which is private.

84. In my opinion, the farm environment plan proposal within PC1 will be ineffective if it does not have a land use capability system as a baseline dataset, presented spatially and used at land use capability unit management level, to manage and protect the environment and add the additional benefits to a landowners economic, social and cultural dimensions. LUC provides a framework and system to enable and assist farmers to meet policy requirements in complex landscapes with complex ecosystems.

S J Stokes

3 May 2019

APPENDIX 8: BEEF + LAMB NEW ZEALAND LEP II GUIDELINES AND WORKBOOK

LEVEL 2

beef+lamb new zealand

LAND AND ENVIRONMENT PLAN GUIDELINES

Version two

Resource Book 2

0800 BEEFLAMB (0800 233 352) | WWW.BEEFLAMBNZ.COM

BY FARMERS. FOR FARMERS

steps

PREPARE FARM MAP

Map fences, waterways, etc. on to an aerial photo

MAP LAND RESOURCES

Identify areas of similar landform, slope, soil type etc

GENERATE LMUs (A)

Group similar requirements into Land Management Units (LMUs)

STRENGTHS AND WEAKNESSES (B)

RESOURCE CHART (C)

Describe resources by land type

NUTRIENT BUDGET

Quantify nutrient balances using Land Managament Units

PRODUCTIVE POTENTIAL

Assess productive potential for Land Management Units

RESPONSE PLANNING

Plan what, how, when and how much

IMPLEMENT

Carry out activities, review and update

REVIEW

Review and update at least annually

Level 2 LEP guidelines

These guidelines provide a step-wise approach for the preparation of Level 2 Land and Environment Plans. The principal aim is to identify Land Management Units (LMUs), which are used as a basis for nutrient budgeting, assessing strengths and weaknesses, and estimating farm yield gap.

To complete this Level 2 LEP you will need an aerial photo for mapping purposes—refer to farm map section 1a).

Instructions

Preparing a Level 2 LEP involves mapping land into units, and then assessing those units for land and environment purposes. Key steps are summarised as:

- Stocktake the farm's land and soil resources
- Develop Land Management Units (LMUs)
- Use LMUs as a basis for nutrient budgeting, strengths and weaknesses analysis, and yield gap appraisal
- Summarise opportunities for more sustainable farming as a three-year response plan.

While Level 2 may be more challenging than a Level 1 LEP, you do not have to do it all on your own. Help and resources are available from a range of sources e.g. some regional councils, or rural consultants can be contracted.

This LEP should be reviewed each year to assess progress, carry over any incomplete activities, and to consider new issues if and when they arise.

Contact your local Beef + Lamb New Zealand Extension Manager for assistance or further information about land and environment planning. Contacts are provided on the back page.

By completing this Level 2 LEP you will be joining the growing number of farmers using good management tools to future-proof their farms.

1) Prepare a farm map

Create a farm map that shows sites of interest for land and environment planning.

a) Obtain an aerial photo (copy)

- Many farmers already have an aerial photo or an orthophoto of their farm. These can be obtained online (e.g. Google Earth), from commercial suppliers, rural practitioners, or your local regional council may be able to help. Photography outlets, printers, copy centres and desktop publishers can provide large format copies and resizing. Some regional council's will provide you with suitable aerial photos or mapping. The Beef + Lamb New Zealand Mapping Reference may help you.
- Orthophotos are strongly recommended because they have been digitally corrected to remove distortions caused by camera tilt, lens curvature, and terrain uneveness.
- Make at least three copies of the farm photo. Minimum size should be A3 (297 x 420 mm), but bigger is always better for farm mapping. Spanning the farm photo across two or three A3 size pages achieves a detailed scale but also retains manageability.
- Increasingly there are electronic mapping or planning packages available so you can create your map on your computer, including separate layers for different features e.g. waterways, fences, pipelines. Most packages can be integrated with other software such as Overseer® for nutrient budgeting, or farm business planning packages.

b) Map relevant features

- Mark in a North arrow and give the map a name (e.g. Smith's Farm Map).
- Map features of interest. These can be natural (e.g. wetlands, waterways) or constructed (e.g. buildings, tracks). Minimum features to map include:
  1. The farm boundary.
  2. All fencelines, including those adjacent to waterbodies.
  3. Key structures like buildings, storage sheds and yards, raceways, tracks, bridges, crossings or fords.
  4. Permanent and intermittent water courses, streams, drains (including tile drains), lakes, ponds or wetlands.
  5. Silage, offal or refuse pits, feeding or stock holding areas, effluent storage ponds, effluent blocks.
  6. Location of riparian vegetation adjacent to waterways, areas of significant indigenous biodiversity (identified in your local District Plan) or protected (covenanted or fenced) bush or landscapes.
  7. Woodlots or forestry, and sizeable areas of bush and scrub.
  8. Any other relevant features, such as those listed below.
- Use symbols, lines, hatching and colour to differentiate features.
- Create a legend that lists and describes what each map symbol represents.

Additional features for consideration

- Riparian zones
- Wetlands
- Fenced bush (QE II)
- Shelterbelts
- Stock fords
- Bores
- Waterways and unprotected riparian areas
- Conservation trees
- Woodlots/forestry
- Detention dams and other structures
- Dumps, offal holes
- Prevailing wind direction
- Archaeological sites
- Chemical storage sheds
- Runoff points to water (dips, yards, tracks)
- Power pylons, pipelines, easements
- Cultural sites
- Pest control areas

The endpoint of this step is a Farm Map for LEP purposes. An optional refinement is to make the map into an electronic format for presentation purposes.

2) Map the land resource

Create a stock take of your farm's natural capital.

a) Divide the farm into primary landforms

- Primary landforms are easy-to-recognise differences in the landscape associated with changes in geology, morphology (shape and form), slope, and other physical factors.
- Map out primary landforms on a separate aerial photo copy or layer (if using electronic mapping). Start with the obvious, such as separating flat land from hilly areas. Then focus on each primary landform and break it down further. For example, it may be possible to break hilly areas into gorges, valley floors, steepland, rolling hills, etc.
- If only one landform is evident (e.g. a completely flat farm) then move onto the next step.

Landform examples

- Mountain land
- Hill country
- Alluvial flats
- Terraces
- Gorges
- Steepland
- Rolling hills
- Valley floors
- Scarp slopes
- Ridge tops
- Swamps
- Basins
- Glacial moraine
- Dunes
- Flood plains

b) Focus and refine

- Focus on a single landform. Are there areas within the landform that have other physical differences? Consider soil types, drainage, dryness, pasture production, and other physical characteristics and qualities. Examples are given below.
- Repeat the same exercise for each landform, mapping each major difference as a new land type.
- Create a legend with names that describe each land type.

Land characteristics and qualities to consider

- Natural drainage
- Dryness
- Iron or clay pans
- Changes in geology
- P retention status
- Soil depth
- Erosion—existing and at risk areas
- Aspect
- Stoniness
- Flooding frequency
- Elevation
- Contour and slope
- Workability
- Soil texture (e.g. clayey, sandy, etc.)

Alternative methods

Some farms already have detailed land resource maps. This may be a soil map, or a Land Resource Inventory (LRI) and Land Use Capability (LUC) map surveyed by a regional council or catchment board at the farm scale (e.g. 1:5,000 to 1:20,000). These can be used as an alternative, rather than preparing a new land resource map.

All of New Zealand has been surveyed at the regional scale (1:50,000 and 1:63,360). While the level of detail is too coarse for farm management purposes, maps at this scale are useful starting points for further investigation. Soil maps are available for most areas. Land Resource Inventory Worksheets and the NZ LRI database are available for all of New Zealand. Copies or extracts may be obtainable from local libraries, on-line through Crown Research Institutes such as LandcareResearch, farm mapping companies, fertiliser companies, and regional councils.

Coarse-scale soil and LRI information can be useful in most cases. However, when using at a farm level it is important to validate these maps, and refine the detail so they better reflect differences within the farm.

The endpoint of this step is a map of farm land resources which will be used as a basis for generating Land Management Units (LMU).

Example landform mapping

Each farm will be different in how it can be broken down into landforms. For this Waikato example, the following steps were used.

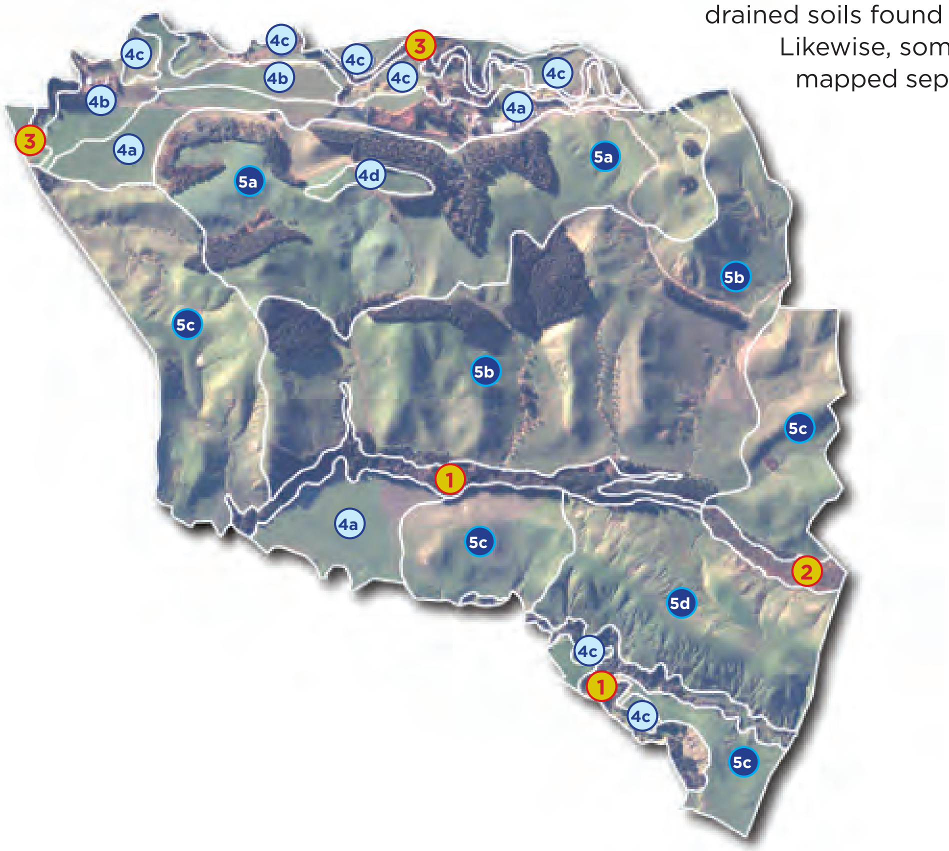
a) The most distinctive landforms were mapped.

1. Ungrazed gully systems.
2. A large wetland area retired from grazing.
3. River bed and adjacent areas that flood regularly.

These areas were easy to identify. Once they had been mapped out, the remaining land could be focused on more clearly.

b) Flat areas were mapped.

- 4 Firstly, all flat areas were mapped as one unit. They were then broken down further according to the following differences:
- 4a Extensive elevated terrace that never floods, and has very deep and well drained soils.
- 4b Slightly lower river terrace that has flooded. Finer textured soils with relatively poor drainage.
- 4c Low river terraces that often flood. Sandy and droughty soils, and some patches of gravel.
- 4d High terrace +100m above the river. Absolutely flat and has river stones in the soil profile.



c) Hill country was divided into best and worse land

- 5a Front sandstone hill country. Easy rolling for the most part with deep free draining soils. Particularly good for winter brassicas. Catches the winter sun and less droughty than the back hills (5b).
- 5b Back sandstone hill country. Much steeper than the front hill country, with shallower and drier soils. Only one paddock can be cultivated. Slightly softer sandstone base because water channels can cut down quickly in heavy rain.
- 5c Strongly rolling hill country. Sandstone is mostly uncemented, and in places it is more like deep raw sand. High soil P levels and it grows good grass, but very prone to slumping and pugging in winter. This hill country has the highest local site index for growing radiata pine.
- 5d Steep, unstable hill country. Has the same sandy base rock as 5c, but the extra steepness makes erosion particularly active. Only thin soils remaining on the steepest parts. Unusual profile because it's very wet in winter (lots of rushes), but it's the first part of the farm to dry out in summer.

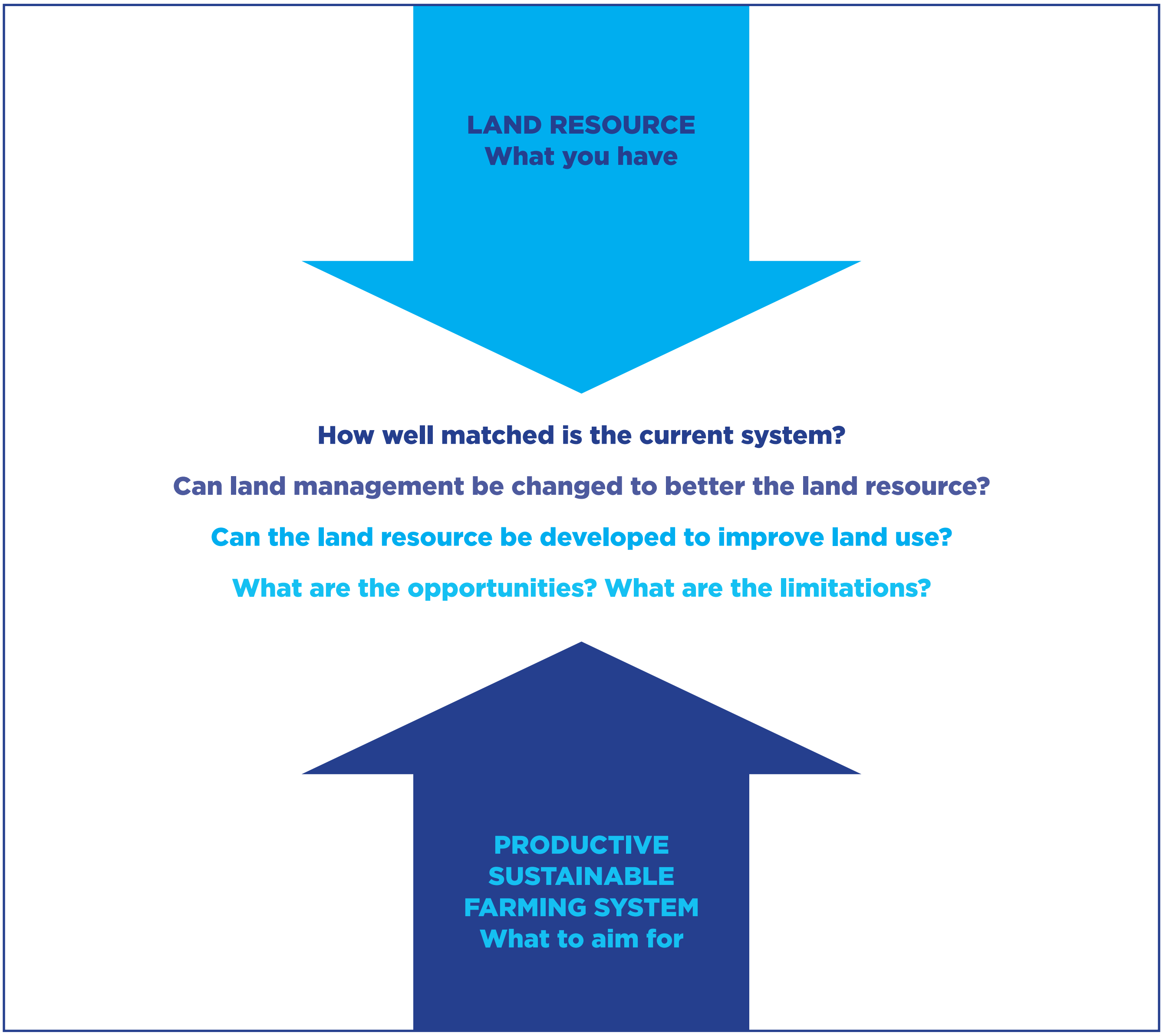
This map was refined further to identify all the potentially arable hill country, and patches of poorly drained soils found throughout the terrace flats. Likewise, some of the steepest slopes were mapped separately as potential woodlot sites.

3) Land Management Units (LMUs)

Land Management Units (LMUs) are areas of land that can be farmed or managed in a similar way because of underlying physical similarities. They can represent a static snapshot of how land is currently used, or an insight into how land could be used if all physical opportunities were realised.

Designing new LMUs involves three steps. These include grouping similar land types (Step 3a), evaluating strengths and weaknesses (Step 3b), and developing a summary resource chart (Step 3c). Read through all the steps before starting on LMU design.

LMUs represent farming's interaction with the physical landscape. The idea is to better clarify what you have (the land resource) so it can be better matched with what you need (a productive sustainable farming system).



3a) Design Land Management Units (LMUs)

Create a map of Land Management Units.

Group similar land types into LMUs

- Aim to aggregate the many different land types into a more manageable set of LMUs.
- Firstly, name all tree blocks (e.g. forestry, bush) as one or two LMUs. These areas require different management by default. Many small areas can be grouped as one LMU (e.g. patches of bush).
- For the remainder, consider each land type individually. What makes it different? Does it have favourable qualities? Unfavourable qualities? Can it be grouped with other similar land types?
- You may already have different management blocks. There may be a lambing block, beef unit block, cropping block, back country block, and so on. Map these existing management blocks against your Land Resource Map. Based on the resources, strengths and weaknesses identified, are there any opportunities or constraints in the current management blocks that could be changed to better use your land?
- Now is a good time to start a strength and weakness analysis (Step 3b) and resource chart (Step 3c). This is a 'chicken or egg' process because it requires describing the LMU, and assessing strengths and weaknesses of the LMU, as part of the actual LMU development process.
- LMUs are meant to be practical so use existing fencelines to define unit boundaries (unless you identify an opportunity that requires changes to fence lines). Other factors to consider when drafting LMUs are listed opposite.

Other considerations for the design of LMUs

- Riparian zones
- Areas at different stages of development
- Erosion management areas
- Areas that flood
- North and south facing slopes
- Wetlands
- Fragile soils
- Pugging management areas
- Weed or pest control areas
- Size: Is it big enough to be managed differently?
- Stock risk areas (gorges, liver fluke, tutu, tomos)
- Climate: Does exposure to wind limit options for use?
- Accessibility: Does access limit use?
- Distance from services and facilities

3b) Strengths and weaknesses

Evaluate the strengths and weaknesses of each LMU. You can use the template provided or your own.

List strengths and weaknesses of each LMU

- A strength is a favourable land quality, while a weakness is a not-so-favourable quality.
- What is defined as a strength or a weakness depends on the management purpose being considered. For example, stoniness may be a weakness for cropping, but it may represent a strength for winter grazing of cattle (to avoid pugging).
- Prepare a draft table of strengths and weaknesses for each (developing) LMU. As you work through the table you may identify opportunities that require LMUs to be modified. Examples of possible strengths and weaknesses are listed below.
- When LMUs are finalised, strengths and weaknesses are recorded in the resource chart (Step 3c).

Examples of possible strengths

- Free draining
- Deep topsoil
- Good soil moisture- holding ability
- High natural fertility
- Good soil structure
- Balanced soil texture (e.g. loam)
- Resistant to pugging
- Well aerated
- Optimum P,K,S levels
- Optimum pH
- Flat land
- Naturally sheltered
- Warm aspect
- Stable (no erosion)
- New pasture
- Good pasture quality
- Well sheltered by trees
- Artificially drained
- Low insect risk
- Low in weeds
- Good stock access to water
- Good machinery access

Examples of possible weaknesses

- Poorly drained
- Shallow topsoil
- Poor soil moisture- holding ability
- Low natural fertility
- Poor soil structure
- Too much clay or sandy
- Susceptible to pugging or compaction
- High water table
- High nutrient leaching
- High runoff risk
- Excessive stoniness
- Hot dry aspect
- Wet cold aspect
- Droughty
- Erosion prone
- Flooding risk
- Low quality pasture
- Excessively steep
- Exposed
- Weeds or pests are a problem
- Poor stock access to water
- Small or fragmented
- Poor machinery access

3c) Resource chart

Describe and record the characteristics, strengths, and weaknesses of each LMU.

Describe the physical characteristics of each LMU

- Prepare a resource chart. An example is provided.
- Refer back to the farm resource-map to describe physical characteristics of each LMU.

Record strengths and weaknesses

- Record strengths and weaknesses under the appropriate headings.

The endpoint of Step 3 is a map of Land Management Units and a resource chart describing characteristics, strengths and weaknesses.

Example of a resource chart

LMU	DESCRIPTION	STRENGTHS	WEAKNESSES	USES AND MANAGEMENT
1. Bush Blocks	Scattered bush fragments unfenced	• Shade and shelter • Aesthetics	• Possum refuge • Trees are not pasture	• Fence off and protect • Possum control
2. River flats	Flat sandy soils, stones in patches	• Cultivable • Sheltered • High K reserves • Well drained and resilient to pugging	• Dry • Patchy production • Minor flood risk • Small area away from main access	• Irrigation • Deer • Lamb finishing • Intensive beef
3. Gorge block	Steep sided gorge with sandstone bluffs and scrub	• Sheltered and dry • Accessible	• Steepness • Possums • Difficult to muster • Erosion prone • Flash floods in creek	• Emergency feed • Retire • Emergency protection for ewes after shearing
4. Stoney hills	Rolling hills with well developed but dry soils on gravels	• Well drained • Resilient to pugging • Easy contour	• Tunnel gullying • Dry • Poor pasture species • Gorse • Exposed	• Grapes • Cattle wintering • Requires shelter belts • K line irrigation
5. Wet hill country	Developed mudstone hill country	• Large area • Holds on through summer • High natural fertility	• Rushes • Earthflow erosion in spots • Pugs up in winter	• No cattle in winter • Add space planted trees

LAND AND ENVIRONMENT PLAN

Level 2 Resource Chart

Characteristics, strengths and weaknesses, and relative pasture yield of each Land Management Unit (refer to page 9 for example)

LMU	DESCRIPTION	STRENGTHS	WEAKNESSES	USES AND MANAGEMENT
Example: Bush blocks	Scattered bush fragments unfenced	• Shade and shelter • Aesthetics	• Possum refuge • Trees are not pasture	• Fence off and protect • Possum control
1.				
2.				

LMU	DESCRIPTION	STRENGTHS	WEAKNESSES	USES AND MANAGEMENT
3.				
4.				
5.				

4) Nutrient budget

Quantify farm nutrient balances using Land Management Units.

Overseer® nutrient budgets are a standard component of good management practice in modern farming, ensuring continuous improvement through efficient fertiliser use and helping minimise nutrient losses from the farm.

Fertiliser companies and some farm advisors can create nutrient budgets with Overseer®. It is important to have someone who is trained in operating Overseer® to ensure the results are valuable and as accurate as possible.

Your nutrient budget should be updated annually. The outputs in a nutrient budget will help you target areas for development and nutrient savings on your farm. The information it provides is key to understanding your nutrient management risks and opportunities.

Review the nutrient budget

1. Is nutrient loss from specific LMUs a risk which is not currently well managed? It is important to recognise that even if farm average nutrient loss is low, there may be blocks where it is high. These 'hotspots' are common and can be managed to best practice to minimise risk.
2. Is your nutrient budget up to date? Do the blocks in Overseer® match your LMUs? If not, the next time you review your Overseer® nutrient budget with your advisor, you might want to update it so that it reflects your LMUs better.
3. If actions are required, include these in your response plan.

Examples of good management practices to manage nutrient loss in hotspots

- Key sites for phosphorus and sediment losses identified
- Alternative sources of stock water in each paddock
- Strategic vegetated-buffer areas where runoff converges, and around waterways in intensely farmed areas)
- Where conditions allow, use slow release P-fertiliser
- No super-phosphate application when heavy rainfall is forecast
- Olsen-P maintained at optimum levels
- Regular soil tests
- Calibration of equipment used for fertiliser application and/or precision application where possible from external providers
- Avoid winter applications of N-fertiliser
- Ensure other nutrients are non-limiting (maximise N-uptake opportunity)
- Deep soil N tests used as basis of N application to crops
- N application rates set to match growth cycle of pasture or crop
- Cultivation practices and timing adjusted to minimise N losses
- Crop rotation designed to utilise residual nitrogen in soil, e.g. cereals following fodder crops.
- Erosion is managed/minimised
- Direct drilling or minimum tillage used

5) Productive potential

Generally, highly efficient and well-run farming businesses are also good for the environment.

Make an assessment of your productive potential

- Consider each of your Land Management Units in the context of your whole farm system, are you operating at optimum for all of these areas (optimum may mean reducing stocking rates or retiring land)?

Consider actions to improve productive potential

- You will have a good grasp of the productive potential for your property. Are there any actions you can take to help reach that potential if you are not there already? Below are some aspects to consider and tools that can help to assess them.

Aspects to consider

- Lambing/calving percentage
- Reducing lamb/calf losses
- Reproductive efficiency—maternal liveweight; hogget lambing/heifer calving
- Changing genetics
- Improving pastures
- Using high value forages/crops
- Controlling weeds
- Controlling pests
- Using rotational grazing and increasing internal sub-division
- Strategic use of N fertiliser
- Reticulated water
- Retiring areas that are costing money to manage or hindering ability to manage other areas better
- Optimising the business—using tools such as Farmax or the B+LNZ Benchmarking tool
- Monitoring performance e.g. pasture cover, liveweight of finishing stock, body condition score of breeding stock.

Management activities to overcome physical limitations

- Achieve optimal pH
- Establish shelter
- Irrigation
- Ripping
- Appropriate stocking rates
- Fully effective pugging management
- Artificial drainage
- Flipping
- Aeration
- Achieve optimal nutrient status
- Optimal subdivision
- Stone picking
- Stopbanks
- Full stock access to fresh water, shelter and shade
- New pasture species
- Fully effective weed and pest control
- Fully effective erosion control.

List each new estimate of potential production in the table, and total to see what it may mean for whole-farm production. If there are realistic opportunities to improve production build them into the response plan (next section).

Tools to help

- Beef + Lamb New Zealand Lambing Calculator: portal.beeflambnz.com/tools/lambs
- Beef + Lamb New Zealand and Farmax Pasture Growth Forecaster: apps.farmax.co.nz/pasture/BeefLambNZ
- Beef + Lamb New Zealand Benchmarking tool: portal.beeflambnz.com/tools/benchmarking-tool
- Beef + Lamb New Zealand Sheep calendar: portal.beeflambnz.com/tools/sheep-calendar/
- AgPest (weed and pest identification, biology, impact and management): agpest.co.nz/
- Farmax
- Employ an advisor or consultant to assist with business planning, production assessment, optimising the farming system or environmental planning
- Yield gap analysis in appendix 1.

6) Develop a response plan

This step brings it all together to develop a three-year response plan.

Summarise opportunities and environmental issues

- Use the template provided to draw up a Response Plan or use your own. A sample response plan is shown.
- Review opportunities and environmental issues identified at each preceding step. List each opportunity or issue then describe how it will be managed, addressed, or capitalised upon. Spread the responses across three years if necessary. Elaborate responses so they are SMART (**S**pecific, **M**easurable, **A**chievable, **R**elevant, and **T**ime-bound).
- Rank priority (which response will be implemented first, second, etc.).
- Include an estimate of cost.

RESPONSE PLAN

Issue or opportunity	**Priority** Rank each in order of priority	**Responses** Year 2015	Year 2016	Year 2017
Ongoing soil slip erosion in back country and Sam's paddock.	1	Plant 25 Kawa poplar poles with sleeves starting in Sams. Minimum 10 metre spacings. Focus around the wet part of the track. Approx. cost $200.	Another 30 poles + sleeves. Start planting across the slope heading towards back country. Approx. cost $230.	Another 30 poles + sleeves destined for the worst parts of back country. Approx. cost $230.
Wind erosion in the front paddocks (James, Corden and No.2) when cultivated.	4	No cultivation this year. Avoid hard grazing if soils go dry, and especially keep the bulls out.	Plant October Barkant turnips. Avoid over cultivating, especially the headlands, and sow early when soils still damp. It is not possible to have zero tillage in this area. Sow back into pasture before the NW winds start.	Same as 2015
Old man willows along stream have raised the bed and cause flooding and washouts along main access track.	2	Find out if the council is supposed to be dealing with the willows. If not find out if willows can be sprayed.	Aim to spray all willows with a helicopter in late summer. Find out cost and if a resource consent is needed. Keep an eye on regrowth throughout the year.	Aim to hire a digger in summer 2016 to clear the stream bed, rip out the willows, and pile the dead wood. Time it so the top two dams can also be de-silted.

LAND AND ENVIRONMENT PLAN

Level 2 Response Plan

CHALLENGE OR OPPORTUNITY	PRIORITY	RESPONSES		
	Rank each in order of priority	Year 1	Year 2	Year 3

CHALLENGE OR OPPORTUNITY	PRIORITY Rank each in order of priority	RESPONSES		
		Year 1	Year 2	Year 3

7) Implement, monitor and review

- Implement each response as indicated
- Monitor and record all your achievements
- Remember to review and reassess each year or earlier if your situation changes
- Register your completed plan at www.beeflambnz.com. This way you can be sure to receive the latest news on LEPs and be notified of the latest modules on topics relevant to on-farm land and environment issues.

Congratulations on designing a **Land and Environment Plan** specifically for your farm.

For full integration with farm business planning you may wish to refer to this LEP when making decisions about farm development and financial planning.

Taking your management to the next level

Level 3 LEP

The Level 3 Land and Environment Plan draws on standards and methods used by professional farm planners. The aim is to continuously improve your management performance and produce a LEP that you can audit (e.g. Audited Self Management) or someone else (2nd or 3rd party auditing). This enables you to provide demonstrable evidence of good management practices in action on your farm.

Appendix 1: Yield gap

Consider the difference between current and potential pasture production levels.

Estimate whole-farm pasture yield (current)

Calculate total stock units for the farm. The *Lincoln University Farm Technical Manual (2011)* states, “A stock unit is based on an animal that requires 6000MJME per annum. If pasture has an average annual ME of 10.8 then 555kgsDM are required to produce 6000 MJME”. There are several stock unit conversions available, but the ones below keep the exercise brief. Use your own conversion factors if required.

Calculate total stock units for the farm

Stock class	Enter Stock numbers		Conversion factor		Stock Units
Beef cows		×	5.3	=	
Beef dry		×	4.7	=	
Beef replacements		×	3.5	=	
Dairy cows		×	7	=	
Dairy replacements		×	3.4	=	
Other cattle		×	5.5	=	
Breeding ewes		×	1	=	
Sheep dry		×	0.8	=	
Sheep replacements		×	0.8	=	
Other sheep		×	0.8	=	
Hinds		×	1.9	=	
Deer for meat		×	1.8	=	
Stags for velvet		×	2.1	=	
Other Deer		×	1.8	=	
			Stock units for the whole farm =		

Convert stock units to dry matter demand

- Estimate the pasture utilisation factor. Sheep and beef farms generally achieve around 70–75% utilisation on average. Hard hill, low-quality pasture utilisation may be as low as 60–65%, while intensive cell grazing of beef may achieve upwards of 80–85% utilisation. Divide the % by 100 to calculate the utilisation factor (e.g. 80% utilisation = 80/100 = utilisation factor of 0.8).
- Calculate dry matter demand by multiplying total stock units by 550 kg DM/yr and the utilisation rate (%). This represents the minimum amount of pasture the farm must be growing to sustain current stock numbers.

Calculate whole farm pasture production (/ha)

Stock units			Utilisation factor*		Whole farm yield		Effective area (ha)		Yield per ha
	× 550	÷		=		÷		=	
			*Utilisation % divided by 100		kg DM/yr				kg DM/ha/yr

Estimate relative yield between LMUs

- Multiply the pasture yield estimate (kg DM/ha/yr) by farm effective area to calculate whole farm pasture yield.
- Distribute whole-farm yield between LMUs. There are several options:
    1. Repeat the stock unit calculations using stock numbers for each LMU. Most farmers are able to approximate where different stock are grazed across the farm. This option takes some time, but provides the best estimate.
    2. Use pasture cuts if available. It may be possible to transfer local pasture monitoring results according to similar land types.
    3. Use experience to estimate relative productivity as a percentage (%). For example, 70% of the farm's production may be coming from the flats, while the remaining 30% comes from the hill country.
- Either use the template provided or your own. Build a table that lists each LMU (refer to 3c Resource Chart) and the estimate for current pasture yield. Add another column with the heading "Potential yield".

Speculate potential pasture yield

- What could each LMU produce if all physical limitations were overcome? Think about how pasture yields or stocking rates could increase for each LMU if limitations could be removed. Examples are provided below.

LAND AND ENVIRONMENT PLAN

Level 2 Relative Yield

Take the pasture yield calculated on page 12 and multiply by farm effective area to get whole farm pasture yield.

YIELD PER HA		FARM EFFECTIVE AREA		WHOLE FARM PASTURE YIELD
	X		=	

1. Distribute whole farm pasture yield between LMUs – template below for the calculation. Page 12 shows 2 other options.
2. Estimate what the potential yield for each LMU could be if limitations could be removed.

LMU	STOCK UNITS			UTILISATION FACTOR*		LMU YIELD (kgDM/yr)		EFFECTIVE AREA (ha)		YIELD PER HECTARE (kgDM/ha/yr)	POTENTIAL YIELD (kgDM/ha/yr)
1.		X 550	÷		=		÷		=		
2.		X 550	÷		=		÷		=		
3.		X 550	÷		=		÷		=		
4.		X 550	÷		=		÷		=		
5.		X 550	÷		=		÷		=		

* Utilisation % divided by 100

NOTES

Beef + Lamb New Zealand Regional Offices

Beef + Lamb New Zealand
51 Norfolk St, Regent
PO Box 5111
Whangarei 0112
Phone: 09 438 0672

Beef + Lamb New Zealand
Lvl 4, 169 London St
PO Box 9062
Hamilton 3240
Phone: 07 839 0286

Beef + Lamb New Zealand
75 South Street
PO Box 135
Feilding 4740
Phone: 06 324 0390

Beef + Lamb New Zealand
Farming House,
211 Market St South
PO Box 251
Hastings 4156
Phone: 06 870 3495

Beef + Lamb New Zealand
140 Dixon Street
PO Box 487
Masterton 5840
Phone: 06 370 2389

Beef + Lamb New Zealand
1/585 Wairakei Rd, Harewood
PO Box 39085
Christchurch 8545
Phone: 03 357 0693

Beef + Lamb New Zealand
465 Cormacks-KiaOra Road
16 C Road
PO Box 390
Oamaru 9444
Phone: 03 433 1392

Beef + Lamb New Zealand
69 Tarbert Street
PO Box 37
Alexandra 9340
Phone: 03 448 9176

APPENDIX 9: BEEF + LAMB NEW ZEALAND LEP FACTSHEET

Environment planning for sheep and beef farmers

There are approximately 12,500 sheep and beef farms in New Zealand, covering a total area of 9.3 million hectares (1/3 of New Zealand's land area). Beef + Lamb New Zealand (B+LNZ) is the farmer-owned, industry organisation representing New Zealand's sheep and beef farmers. It invests farmer levies in programmes that grow the sheep and beef industry and provide sustainable returns now and for future generations.

Summary

A major priority for B+LNZ over the last couple of years has been supporting farmers to develop a land environment plan.

The following paper provides an overview of the work that has been done, the progress that has been made, and plans for building on this.

In 2018, B+LNZ set the objective of every farmer having a farm environment plan by the end of 2021. This is a stretch goal that recognised how important the process of farm planning is to the ongoing environmental and economic sustainability of the sheep and beef sector.

The nature and coverage of farm environment plans is not kept or recorded by a single agency.

A recent survey by UMR, however, indicates approximately 49 per cent of sheep and beef farmers currently have a plan.

Over the last eight years, B+LNZ has run 277 events with approximately 3750 farmers aimed at developing environment plans to a variety of levels, under our Land and Environment Plan programme.

The Land and Environment programme has been successful in introducing farmers to the concepts and value of farm environment planning. There is significant value in farmers attending a workshop to support the development of their plan, connect strongly to why, and build knowledge to match their farming system to the landscape and use of natural resources. It provides for peer to peer learning and matching of farm based goals to wider catchment outcomes.

B+LNZ has undertaken a lot of thinking in 2018 to understand how we can accelerate the uptake of farm environment planning.

There are many different environment plans already out there. Rather than creating another option on top of that, B+LNZ is developing a “process standard” focused on supporting farmers to get started on the environment journey and to continue to develop and improve.

This new process will be aligned with B+LNZ’s work with catchments around the country, as this as a major and growing channel for farmer engagement on the environment.

B+LNZ Organisational and Environmental Vision

There are a number of critical elements of B+LNZ's organisational and environment strategies that relate directly to the wider goals of farm environment planning. Enhancing our environmental position is one of four organisation priorities and our vision and goals contained within the environment strategy strongly emphasise profitable farming, thriving sustainable communities and directly reference farmers contributions to healthy freshwater, biodiversity, climate and soils. There are two critical goals in the environment strategy that support our vision:

1. **All sheep and beef farmers to have and be actively implementing a farm environment plan by the end of 2021;**
2. **Farmers are actively working together in catchment communities and farm environment plans and actions are aligned to catchment priorities.**

B+LNZ's Land and Environment Plan programme has been central to improving awareness of farmers of the benefits of farm environment planning and providing a structure and support on how to go about it. The programme was devised in 2008 and rolled out in 2011. Uptake by farmers improved in 2013, when workshops were developed. It is a voluntary programme, with the decision to participate entirely at the discretion of farmers. More recently workshops have increased in frequency, particularly in regions where farm plans are required by regional councils.

Environment Strategy 2018-22

OUR VISION:

To be world-leading stewards of the natural environment and sustainable communities

He kaitiakitanga mo te tai ao

WE WILL HAVE SUCCEEDED WHEN:

NZ farmers optimise the natural resources of their farms to produce high quality food and fibre
Every farmer has a plan for managing the environmental risks and opportunities on their farm
The sector is open about our challenges and talks about how we are addressing them
Farming landscapes are biologically diverse, freshwater quality is protected, our soils are healthy, and the sector has a carbon footprint that is sustainable in the long term
NZ farmers' commitment to the environment is unquestioned

CLEANER WATER

Goal: *Sheep and beef farmers actively manage their properties to improve freshwater. New Zealanders can gather food from and swim in freshwater surrounding our farms.*

TOWARDS CARBON NEUTRAL

Goal: *Sheep and beef farmers continue to reduce carbon emissions to achieve, at a minimum, a 50% reduction in net emissions below 1990 levels by 2050.*

THRIVING BIODIVERSITY

Goal: *Sheep and beef farms provide pest-controlled habitats that support biodiversity and protect our native species.*

HEALTHY PRODUCTIVE SOILS

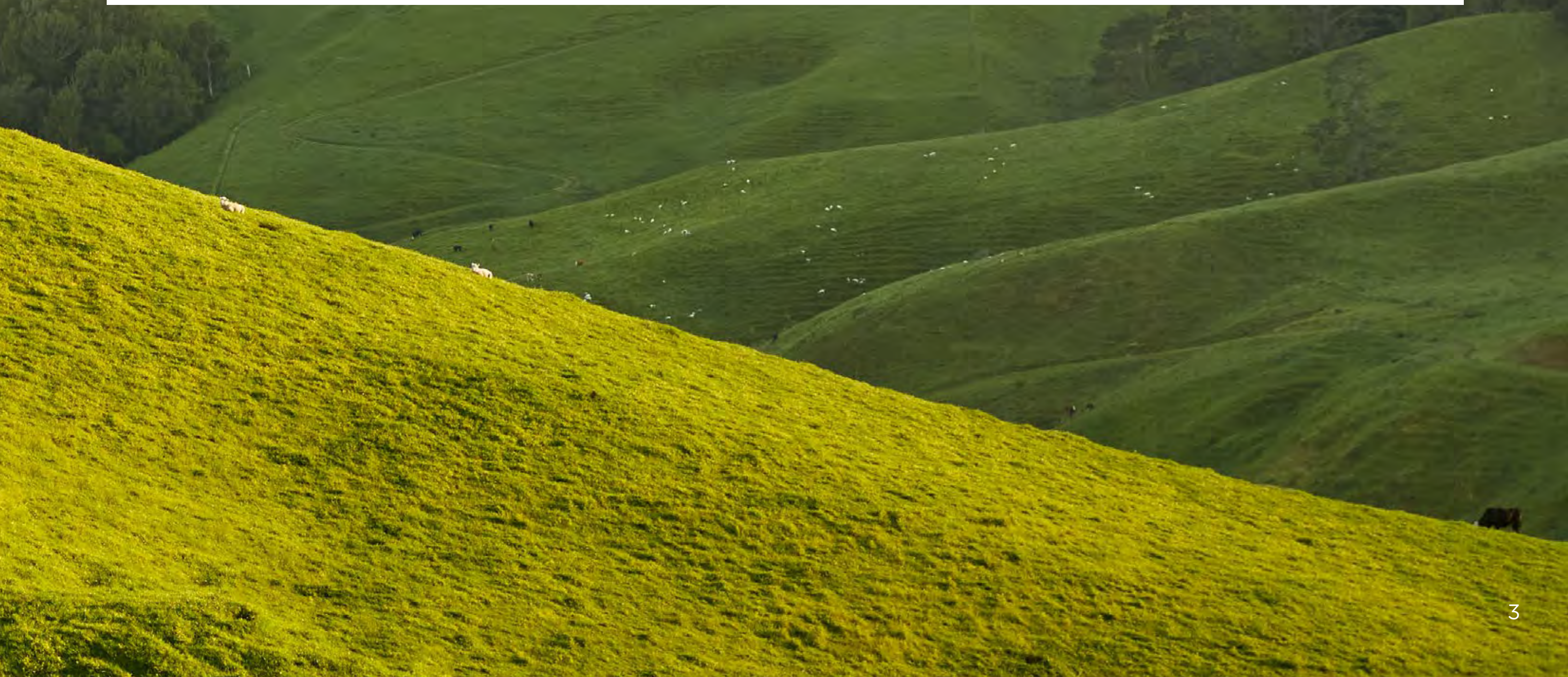
Goal: *Land use is closely matched to soil potential. Soil health, carbon content and productivity will improve in tandem. Soil erosion and loss to water is minimised.*

HOW WE WILL WORK:

It starts with the individual farmer—the farmer is the person who will make the change so our starting point is to equip our farmers with the knowledge and tools to best manage their resources and make change if that is required.

Catchment programmes are a critical tool for scaling up impact—farmers working together with a wider community of stakeholders and with expert support is a proven method to make change at greater scale.

All of us are stakeholders—we will involve the wider NZ community and our customers in our programmes to share the problems, identify opportunities, work together to implement solutions, and take pride in our success.



What is a Land and Environment Plan (LEP)?

An LEP is a tool that guides farmers through a recorded assessment of a farm's natural capital assets such as geology, soil, water, and climate, and assists farmers to understand the vulnerabilities and opportunities provided by these natural assets. An LEP helps farmers to develop a written plan outlining how these natural capital assets will be sustainably managed. It involves a stock-take of land, soil and water resources, an assessment of production opportunities and environmental risks, and development of a written plan showing what actions are going to be undertaken, where they are being targeted, and when they will be implemented. A strong focus of the LEP is to assist farmers to make the knowledge connections between their underlying natural assets, and how their farming systems and enterprise can be optimised to fit the capability of the land.

The key environmental issues actively identified and managed through LEPs include those contaminants which can flow overland to be discharged to surface waterbodies such as phosphorus, sediment, and pathogens, as well as identifying areas of the farm which may be susceptible to erosion and nitrogen losses. The LEP can also help identify areas of the farm which have high biodiversity values such as native vegetation, or other values such as cultural values.

A well prepared LEP captures stewardship and sustainability in relation to the farming enterprise. It provides an understanding of the natural resources on a farm and allows all those involved with the farm business to understand the plan to manage them for the long term.

The benefits of a LEP include:

- Provides a stock take of a farms natural capital assets such as soil, geology, climate, biodiversity, and freshwater resources along with on farm Land Use Capability Mapping (1:5,000 to 1:10,000);
- Identify land management units and their strengths and limitations;
- Can help identify areas where resources are not being fully utilised and production opportunities are being lost;
- Identify sensitive habitats and critical source areas[1];
- can identify improvements in farming practice that will enhance production, future-proof the business and foster access to environmentally discerning markets;
- can provide evidence for on-farm sustainable practices to consumers, regulators and others;
- if actions and timeframes for their achievement are written down, they are more likely to be done;
- can add value to a farm;
- can be integrated with farm business plans;
- can help meet regional council requirements to manage threats to water quality'

[1] Critical Source Area is defined as "A landscape feature like a gully, swale or a depression that accumulates runoff from an adjacent immediate area, and delivers it to surface waterways such as rivers and lakes, artificial waterways and field tiles; and areas which arise through land use activities and management approaches such as tracks, yards, offal pits, cultivation and winter grazing which result in contaminants being discharged from the area or activity and being delivered to surface waterways".

How are LEP Produced?

A foundation of the LEP programme is that a farmer can produce an LEP Level 1 or 2 for their own property. Professional one-on-one support from a farm advisor or consultant is required to prepare a LEP Level 3.

B+LNZ has produced workbooks, and hosts facilitated workshops, to support farmers to do this.
The process is well described in a B+LNZ video:

beeflambnz.com/knowledge-hub/video/land-and-environment-plans-overview

The workbook and workshop guide farmers through the process of identifying on-farm environmental risks, with industry Good Management Practice (GMP) guides used to assist farmers to determine the most appropriate responses to address those risks.

There are three levels of LEP (in increasing order of sophistication):

LEP—LEVEL 1

An introduction to farm environmental planning that sets out how to manage a farm's natural resources. LEP Level 1 guides the farmer through an assessment of their farm's environmental risks and land management opportunities. It involves a stocktake of land, soil and water resources, and results in the development of a personalised, written plan—identifying actions to be undertaken, where they might be targeted, and when they will be implemented.

LEP—LEVEL 2

The key difference between a LEP Level 1 and Level 2 is the identification of Land Management Units (LMU) on a farm map, which are used to tailor land and farm systems management on a property, and the inclusion of a basic nutrient budget. The key steps involved are:

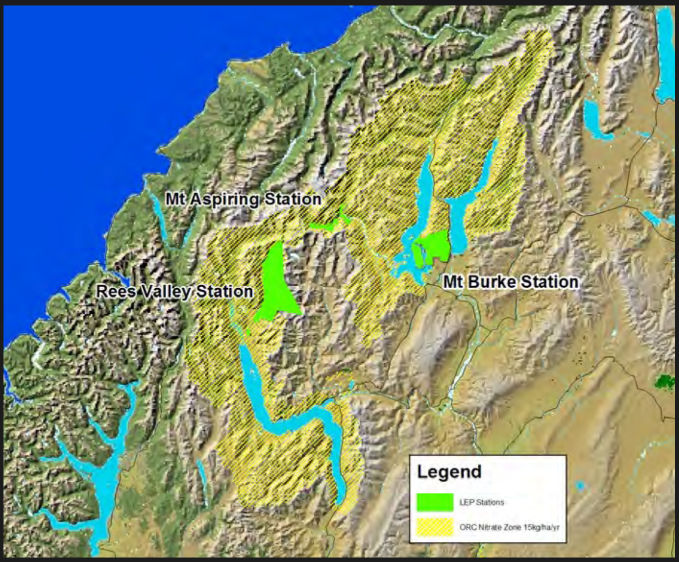
1. Stocktake of a farm's land and soil resources;
2. Develop Land Management Units (LMU)
3. Use LMUs as a basis for nutrient budgeting, strength and weakness analysis, and productive potential assessment;
4. Identification of critical source areas and mitigation actions;
5. Summarise opportunities for optimising sustainable farming as a three-year response plan.

LEP—LEVEL 3

A LEP Level 3 builds on a LEP Level 2. The steps involved are similar to those for a LEP Level 2, but with a greater emphasis on specifications and methods used by professional farm planners, including:

- An accurate and up-to-date paddock-scale map showing features relevant to land and environmental management;
- A paddock-scale inventory describing the land resource according to published standards for either soil mapping or Land Use Capability (LUC);
- Overseer® farm nutrient budget prepared by a qualified operator;
- A "Works Programme" prepared with input from a resource management specialist.

Achievements are recorded and changes in freshwater quality, soil condition and natural biodiversity are monitored at least 3-yearly.



High Country Lake Catchments Environment Project

LEP III—and equivalent

LEP III represents the current gold standard in tailored farm environment planning, and have largely been up taken by the sector's farmer leaders and earlier adopters. While B+LNZ does not keep formal records of the coverage of LEP III, we estimate that their are around 840 LEP III or equivalent plans nationally.

The level 3 plans have been used to support extension through demonstrating how the use of farm environment planning can enhance environmental outcomes, optimize the farm system and increase profitability. There are a number of cases where individual farmers have championed this approach that have supported farmers around them to attend farm plan workshops.

B+LNZ ran a project in the southern lakes region where three farmers around Lake Wanaka were supported to develop a level 3 farm plan and extension events were run to outline how those plans had enhanced each individual farm business. As a result of that project 18 other farmers around the Lake are working with a consultant to develop their own plans and sharing challenges and opportunities presented through that process with their peers.

In addition to these projects there are a number of other farm environment plans that are equivalent to the LEP level 3. In the Horizons region over 700 sustainable land use whole farm plans covering over 525,000 ha, were developed and are being implemented and around 30 Whanganui catchment Strategy Plans covering around 18,000 ha (upper Whanganui, Ohura catchment).

Landcorp/Pamu Farms have developed 64 LEP level III equivalent plans across their sheep and beef farms.

Beef + Lamb New Zealand Farm Environment events

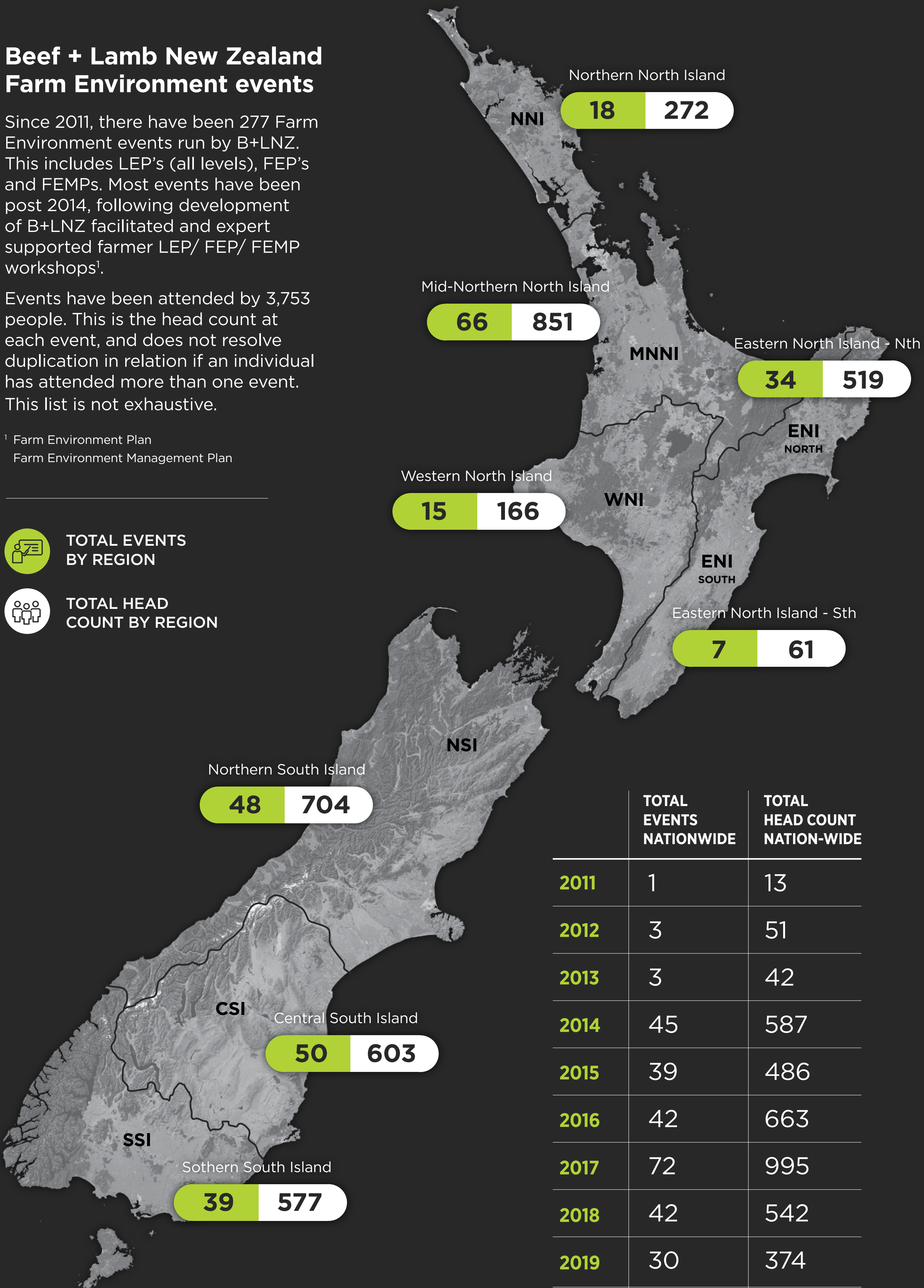
Since 2011, there have been 277 Farm Environment events run by B+LNZ. This includes LEP's (all levels), FEP's and FEMPs. Most events have been post 2014, following development of B+LNZ facilitated and expert supported farmer LEP/ FEP/ FEMP workshops[1].

Events have been attended by 3,753 people. This is the head count at each event, and does not resolve duplication in relation if an individual has attended more than one event. This list is not exhaustive.

[1] Farm Environment Plan
Farm Environment Management Plan

TOTAL EVENTS BY REGION

TOTAL HEAD COUNT BY REGION



	TOTAL EVENTS NATIONWIDE	TOTAL HEAD COUNT NATION-WIDE
2011	1	13
2012	3	51
2013	3	42
2014	45	587
2015	39	486
2016	42	663
2017	72	995
2018	42	542
2019	30	374
Total	**277**	**3753**

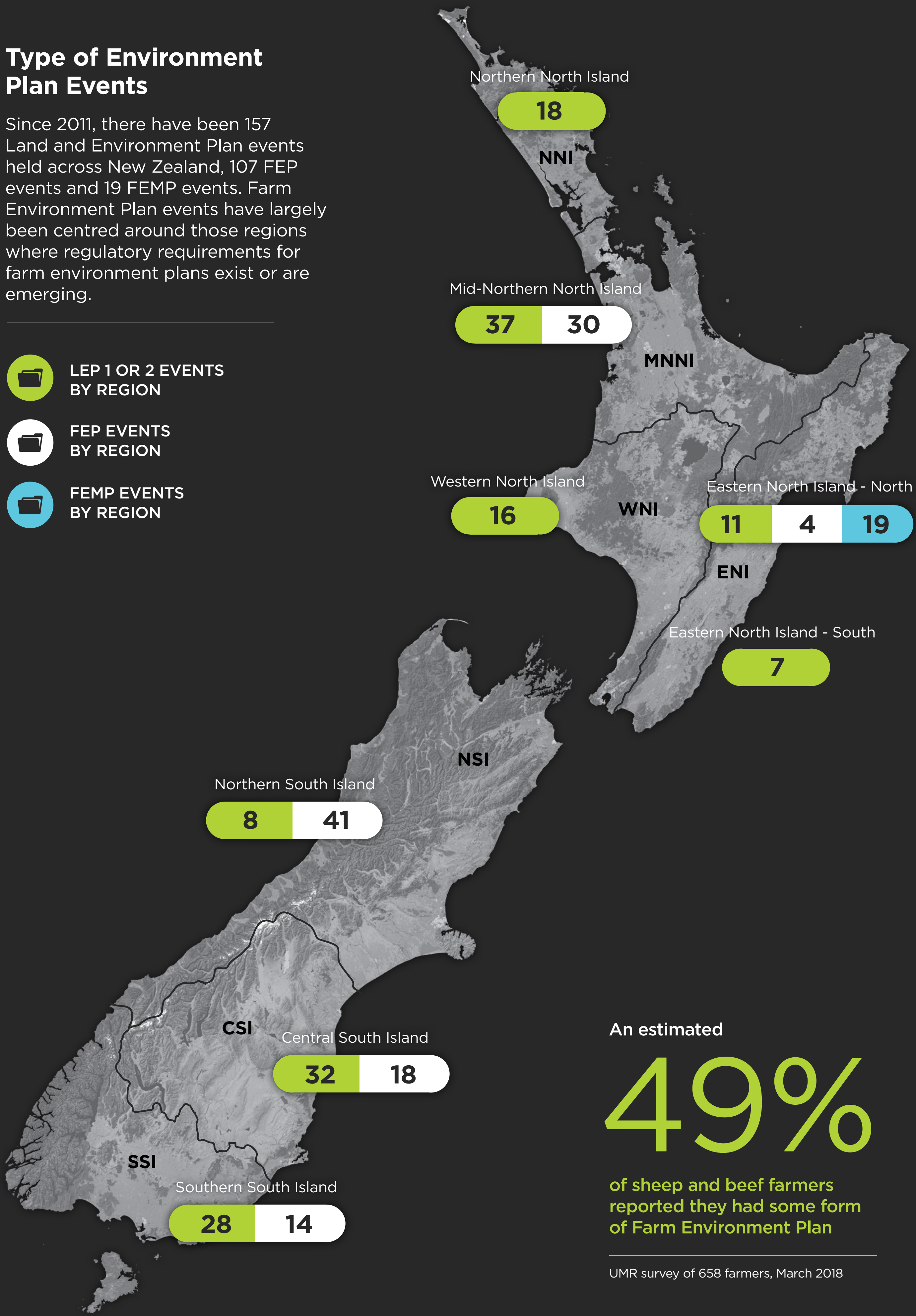
Type of Environment Plan Events

Since 2011, there have been 157 Land and Environment Plan events held across New Zealand, 107 FEP events and 19 FEMP events. Farm Environment Plan events have largely been centred around those regions where regulatory requirements for farm environment plans exist or are emerging.

LEP 1 OR 2 EVENTS BY REGION

FEP EVENTS BY REGION

FEMP EVENTS BY REGION



An estimated

49%

of sheep and beef farmers reported they had some form of Farm Environment Plan

UMR survey of 658 farmers, March 2018

Total numbers of farmers with farm plans

In addition to B+LNZ, Horizons SLUI plans and Landcorp farms there are a number of other providers now supporting farmers to develop farm environment plans. These include the two major fertiliser companies and large agricultural consultancy firms. Groups of farmers working together are also developing and supporting their own farm plans such as those around catchment groups and irrigation companies.Regional councils such as Environment Southland, Taranaki Regional Council and Greater Wellington Regional Council all have varying degrees of interaction with farmers and support farm planning. When combined this would suggest that a significant per centage of sheep and farmers have some kind of active farm environment plan. This aligns strongly with results from a B+LNZ survey of farmers conducted by UMR research that reported that 49 per cent of sheep and beef farmers reported that they had some form of farm environment plan.

Taking our farmers to 100 per cent coverage of FEPs—An Environment Management System for the sheep and beef sector

Following the launch of the Environment Strategy in 2018, B+LNZ has been undertaking a significant re-design of how it supports farm planning.

Based on research and feedback from farmers, B+LNZ is developing an Environment Management System (EMS).

The EMS will break down the steps farmers need to take to develop an environment plan and will support them with implementation and with continuous improvement.

The focus will be on getting farmers started on the environment journey and helping them to continue to develop and improve. Rather than create a new FEP template, under the EMS we will identify existing farm plan templates across the agricultural sector that meet the standard.

To drive uptake by farmers, we will be looking to work with catchments and with the Red Meat Profit Partnership Action Network.

A major driver for the environment strategy is to support the red meat sector's Taste Pure Nature Origin brand. Farm Environment Planning can play an important role in ensuring the sector is able to verify, provide transparency and underpin the brand.

The TPN brand is underpinned by the National Farm Assurance Programme. B+LNZ's farm environment plan refresh intends to ensure alignment between farm environment planning and the national farm assurance programme.

APPENDIX 10: PAN SECTOR INTENSIVE GRAZING REPORT

INTENSIVE WINTER GRAZING

PAN SECTOR POLICY GUIDELINES

beef+lamb new zealand
AGFIRST
Ballance agri-nutrients
ravensdown
AGRICOM Pastures for Profit
Deer Industry New Zealand
Seed Force the power to grow
H&T

ACKNOWLEDGMENTS

We would like to acknowledge the contribution of the following organizations and individuals as part of the 'Pan Sector Intensive Winter Grazing Group'. The commitment to work in a genuinely collaborative way, tackle issues and differences of opinion in a constructive manner, in order to deliver an integrated solutions package for the sector, is very much appreciated. The collective wisdom and positive attitude was great to be part of and I'd like to thank you and your organizations for contributing to this piece of work designed to benefit the pastoral sector.

Facilitator

(AgFirst), Erica van Reenen—Great facilitation and management of the group, forthright and to the point with great outcomes and quality report.

We would like to thank the following people and organizations who were consulted during the process.

Farmers

Dave Diprose—Dairy farmer, Riverton

Scott Linklater—Sheep and beef farmer

Will Morrison—Sheep and beef farmer/ Farmer Council National Chair

Charlie Duncan—Sheep and beef farmer

Roger Dalrymple - Sheep and beef farmer

Martin Coup—Sheep and beef farmer, B+LNZ Board Member, Mid Northern North Island Farmer Council

On farm application and sentiment to ensure practicable outcomes resulted.

Industry Sector

Helen Beattie—Chief Veterinary Officer NZVA and Mark Bryan—Vet (Southland)

Paul Oliver; Duncan Thomas; Freddy Milford-Cottam—H&T

Allister Moorhead—Agricom

Laura Keenan—Agricom

Ian Tarbotton—Ballance Agri-nutrients

Warwick Catto—Ballance Agri-nutrients

Richard Allen—Fonterra

Charlotte Wright—DairyNZ

Richard Kyte—DairyNZ

Anna Wilkes—Ravensdown

Turi McFarlane—Ravensdown

James White—Seedforce

Lindsay Fung—Deer Industry New Zealand

Chris Allen—Federated Farmers of New Zealand

Ewan Kelsall—Federated Farmers of New Zealand

Gavin Forrest—Federated Farmers of New Zealand

Ange McFetridge—B+LNZ

Rowena Hume—B+LNZ

Jane Chrystal—B+LNZ

Corina Jordan—B+LNZ

Matt Harcombe—B+LNZ

Julia Beijeman—B+LNZ

Simon Stokes - B+LNZ

Matt Ward—B+LNZ

Martin Coup - B+LNZ Board member

Ministry Staff [don't want to list just acknowledge]

Mark Fisher—MPI

Mary-Anne Baker—MfE (HBRC) Kay Baxter—MPI

Nicola Scott– MFE

Milly Strong - MfE

Irene Parminter—MfE

Martin Workman—MfE

Jennie McMurran - MPI

Local Government [don't want to list just acknowledge the regions]

Hawkes Bay Regional Council

ECAN

Environment Southland

DEVELOPING POLICY OPTIONS: INTENSIVE GRAZING SYSTEMS

BACKGROUND TO INTENSIVE GRAZING SYSTEMS

During winter, plant growth is reduced as a result of lower soil temperatures and shortened day length, and in some regions pasture may be difficult for stock to access because of snow. This provides a management challenge for farmers in ensuring that their stock have access to adequate feed. This challenge often results in farmers relying on supplementary sources of feed to sustain their stock in the winter months. Supplementary feed can come in the form of on-farm forage crops, balayage, silage, and hay, as well as importing feed to the farm.

The need for and type of intensive grazing varies across the country with areas that are colder with higher winter rainfall, such as those experienced in Southland, being different from what is experienced in the more temperate climates of Hawke's Bay. Intensive grazing can be hugely valuable to farming businesses, particularly where it allows the retention of stock over winter in anticipation of the flush of spring growth, feeding stock during periods of low grass growth, feeding stock when they lamb and calve in spring, and providing the ability to take on additional stock, such as dairy cows to supplement income streams.

However, if not appropriately managed intensive winter grazing systems can impact on the environment and may also impact on animal health and wellbeing. Methods such as the use of 'sacrifice' paddocks, strip grazing, or the use of unsealed stand-off areas, can result in exposed soil and losses of nutrients, pathogens, and sediment that can run into waterways. Animal health and wellbeing can be impacted as stock are exposed to weather events and have nowhere clean and dry to rest and ruminate, as well as being exposed to pathogens.

Pugging results from the trampling of the soil by heavy animals in wet conditions creating mud. This, together with soil compaction by animals, as well as heavy equipment and machinery can affect soil health, including its form and structure. These impacts can affect the ability of the soil to drain, inhibit plant growth, and can result in the exposure of bare soil increasing the likelihood of runoff into waterways. Traditional use of free-draining, stony areas for the feeding of stock has been desirable due to the ability to avoid pugging and soil loss, as well as to improve animal welfare, however it is now widely recognized that soils of this nature present the greatest risk of leaching to groundwater due to their highly permeable nature.

Potential impacts are summarized below:

- Soil damage
- Nitrogen leaching
- Phosphorus, sediment, and faecal microbe losses to water
- Erosion
- Reduced pasture production in following season
- Animal welfare issues.

As such intensive winter grazing systems need to be understood, well planned, and sustainably managed.

Whilst the primary impetus behind and focus of this report is on the environment and particularly developing policy which supports practices and systems to ensure that the environment is appropriately considered and managed, animal welfare considerations should not be overlooked. The Animal Welfare Act (1999) establishes a duty of care for animals, defining 'physical, health, and behavior needs' as the provision of:

- Proper and sufficient food and water
- Adequate shelter
- The opportunity to display normal patterns of behavior
- Appropriate physical handling
- Protection from, and rapid diagnosis of, injury and disease.

It is recommended that an animal welfare plan be established when planning for intensive winter grazing practices, this should include provision of clean water and adequate feed, appropriate transnational practices when moving animals from pasture to crop diets, provision of loafing and cudding areas, and shelter. There are a number of Industry good management practice (GMP) guides that include animal health and wellbeing[1]. Veterinary advise should be sought if there is any uncertainty or concern.

[1] Animal Welfare Codes www.mpi.govt.nz/protection-and-response/animal-welfare/codes-of-welfare/

Regarding general animal welfare there is a learning module here: www.beeflambnz.com/knowledge-hub/module/animal-welfare-farms

Specifically regarding shelter for livestock there is a fact sheet here: www.beeflambnz.com/knowledge-hub/PDF/FS174-shelter

For further general animal welfare guidance there is the Code of Welfare for Sheep and Beef Cattle: www.mpi.govt.nz/dmsdocument/1450-sheep-and-beef-cattle-animal-welfare-code-of-welfare

DEVELOPING INDUSTRY ENDORSED FRAMEWORKS FOR INTENSIVE GRAZING SYSTEMS

Beef + Lamb New Zealand (B+LNZ) ran a series of cross sector Industry workshops on Intensive Grazing Management, over the later part of 2018 and the early part of 2019. The intent of the workshops was to bring together Agricultural experts and industry leaders, called the Primary Industries Pan Sector Intensive Grazing Systems Group, to explore synergies and differences in positions relating to those activities associated with the intensive grazing of animals, either on crop, as break fed on pasture, or associated with the majority of feed being bought in. To develop collaborative policy solutions, and to build ongoing farmer extension support services and guidance.

The Primary Industries Pan Sector Intensive Grazing Systems Group specifically focused on:

1. Defining the range of practices commonly employed by farmers
2. Summarizing the current scientific research around these practices and in particular understanding their potential environmental impacts
3. Summarizing methods including adoption of good management practices which, when implemented, avoid or significantly reduce the potential impacts of these activities on the environment
4. Developing potential policy approaches to ensure the sustainable management of land and water resources with a focus on activities which are deemed to be of a higher potential environmental risk
5. Informing ongoing development of farmer facing extension services and support.

The report titled 'Intensive Grazing Management Workshop" by AgFirst[2] provides a synopsis of the first Primary Industries Pan Sector Intensive Grazing Systems workshop, and outlines the key findings in relation to the points set out above. In summary the following key conclusions were reached, based around understanding and managing whole farm systems, which were then elaborated and expanded on through subsequent workshops.

These include:

1. Ensuring that land use and farming systems fit within the Natural Capital of the land, and the suitability of the land to support production levels including investment in infrastructure
2. The utilization of an effects-based matrix to guide decisions around the management of intensive grazing activities
3. Development of minimum practice standards including the identification and management of critical source areas and the application of strategic winter grazing practices
4. Development of industry frameworks and farmer extension to support continual improvement within the sector
5. Supporting the role of expert on farm advisors working one on one with farmers to effectively manage environmental risks
6. Identification and support for pathways which empower a whole farm systems approach to sustainably managing land and water resources such as through tailored farm specific whole farm plans.

These findings are expanded on through the following sections.

UNDERSTANDING INTENSIVE GRAZING SYSTEMS

There are a wide range of stock grazing strategies with different perceived potential environmental risks. In some cases, the same strategy has a different name depending on individual perception and locality. This means one of the first challenges in considering appropriate policy interventions, is to first consider the range and scale of these activities.

Wintering systems can either constitute 'on paddock systems' or 'off paddock systems'. These systems are briefly summarized below.

On Paddock Systems

The most common wintering systems in New Zealand are 'on paddock systems', that is systems which largely feed animals on pasture, but which may during periods of low pasture growth, supplement the diet with silage, hay, and/or forages fed in situ. Other less common systems may bring in imported feed such as grain or palm kernel. Farmers will also use terms like 'techno grazing', 'set stocking', and 'stand-off pads' to describe differences in their approach to overwintering stock with various levels of intensity.

Extensive grazing on paddock

Animals stocked at low density per hectare of land, and free to roam/graze across the paddock(s). Primary stock diet is pasture, but may include some supplementary feed being brought to the animals (e.g. hay or silage). Feed is typically produced on farm. Pasture cover is maintained (i.e. the paddock is not grazed to the ground, leaving exposed soil).

Intensive Grazing on paddock

Animals stocked at high density per hectare of land, either on pasture or on crop, using break fed areas or part of the paddock. Supplementary feed may be provided.

Hill county cropping

Hill country cropping is described as cropping being practiced on land with a predominate slope of greater than 20 degrees, where existing vegetation is removed/sprayed and/or soil is exposed at some point. Pasture is replaced by a forage crop, as part of pasture renewal and/or to provide a food source for stock during periods of low pasture growth.

Off Paddock Systems

Off paddock systems are where stock are held for a part of, or all of, a 24 hour period off pasture or crop (i.e. an off paddock confinement area). They can:

- Be used in winter or outside of the winter months
- Be with, or without a roof
- Incorporate a feeding area such as a feedpad/ animal shelter where bought in feed is provided
- Be used in conjunction with restricted duration, rotation grazing on paddock (such as pasture or crop).

Systems should provide a loafing area. Effluent is captured either in a specifically designed effluent system or in bedding/surface material.

Off paddock systems may include:

- Feedlot
- Feed pad
- Wintering pad
- Barn—can be used for the winter period only or for periods outside of winter.

Feedlot

Feedlots where animals are housed or kept for extended periods are uncommon in New Zealand. A feedlot can be described as an off-paddock confinement system that is used to house animals for the purpose of achieving increased liveweight gains and stock finishing and is not confined to the winter months. Good management practice includes provision of a sealed surface, and the collection of effluent.

The description includes:

- Stock being maintained within the area for a period longer than 80 days
- Majority of feed is brought to animals
- Usually for animal finishing purposes.

It is important to use an internationally consistent definition to ensure alignment between New Zealand feedlot systems and those adopted internationally. The recommended definition is Feedlot: "An area of land in which the construction of the holding area or stocking density precludes maintenance of pasture or vegetative ground-cover, and livestock are confined for more than 80 days in a six-month period, and are completely hand-or mechanically-fed. This includes both covered and uncovered yards".

[2] Intensive Grazing Management Workshop Summary. Prepared for Beef + Lamb New Zealand. Erica van Reenen. AGFIRST. December 2018.

Feed pad

A specially built area for holding animals for a few hours a day for the purposes of feeding only. Not necessarily only during the winter. Animals then return to a loafing[3] or grazing area for the remainder of the day (this could be a pasture or crop paddock or a loafing/wintering pad). Provides an off paddock feeding area, to supplement daily feed intake. Used to protect pasture/soils, increase utilization of supplementary feeds and reduce contaminant losses, also for animal welfare.

Combining the points above, the following definition could be used: 'Feedpad: A sealed or permeable area used to move animals onto to protect soils and pastures and increase the utilization of supplementary feeds where that feed is brought to the animals for a period of time (can be hours, days, months), can be used at any time of the year.'

Wintering pad

A confined area (with no roof) to hold animals during the winter months. Variations of current systems include:

- Animals held for a proportion of the day for loafing/resting purposes and leave the pad to feed elsewhere (in the dairy industry this is called a loafing pad)
- Animals may graze crops or pasture during the day and return to the wintering pad overnight to help protect soils and provide a comfortable area for animals to lie on. Effluent may be captured in the bedding and possibly by an effluent storage system
- Animals held 24 hours a day during the winter and fed on the pad, often via an adjacent feeding alley or a self-feeding area. Again, effluent may be captured in the bedding and there may possibly be an effluent storage system (most likely for dairy animals);
- Bedding materials may include woodchip, river stone, sawdust, concrete, or straw
- Good practice is for the bedding to sit on a sealed surface, and any leachate directed into an effluent storage system
- Often there will be some form of shelter for the animals—perhaps a tree shelter belt, in the shelter of a building, or the natural topography of the land;
- Animals provided with access to water during confinement.

Barn

A roofed building for the purposes of housing stock. The dairy industry has many purpose-built facilities and has done some good work on describing these systems[4]. The dry stock sector may have purpose-built facilities like those used by the dairy industry, or they may use buildings already on the property and alter them for stock housing purposes.

Some specific points in relation to barns are:

- Feed is brought to the animals and fed in a range of systems from balayage feeders in the barn to a concreted feeding alley along the outside or center of the barn
- They are more likely to house animals 24 hours a day than using the hybrid system of combining confinement with grazing—although some may do this
- In purpose-built facilities, effluent will be stored in the bedding and potentially in an effluent system;
- Altered existing buildings are less likely to have an associated effluent system. Effluent will be captured in the bedding
- Bedding materials include woodchip, sawdust, straw, rubber mats, concrete, and soil
- Animals should have access to water and have enough area per animal to ensure natural lying behaviors are not restricted.

[3] Loafing areas provide a place for sheep or cows to ruminate and rest following feeding. They can be used to "stand off" animals from pasture or forage crops during wet conditions; reducing pasture pugging and resulting in more grass in spring.

[4] Dawn Dalley, FLRC. Which Wintering System is Good for you?

DEVELOPING GOOD PRACTICE GUIDELINES AND SUPPORTING POLICY FRAMEWORKS

In its Environment Strategy, one of the key outcomes sought by working group member Beef + Lamb New Zealand is "Healthy Productive Soils" with the goal being that "Land use is closely matched to soil potential and capability. Farmers are working to improve soil health, carbon content and productivity while minimizing soil loss". A second key outcome of relevance from this strategy when discussing intensive grazing is the desire from the Strategy for "Cleaner Water" which seeks that "Sheep and beef farmers actively manage their properties to improve freshwater. New Zealanders can gather food from and swim in freshwater surrounding our farms". Intensive grazing can have implications on the health of both soils and waterbodies and its management is key to achieving the goals of the Environment Strategy.

The Primary Industries Pan Sector Intensive Grazing Systems group, in providing industry leadership in relation to intensive grazing practices, are aware that a one size fits all approach to management of intensive grazing across the country is not likely to be successful. Instead, a tailored management approach to intensive grazing is needed specific to the farm, to ensure that the type of intensive grazing is suitable for the variables of the particular location and management needs.

The Primary Industries Pan Sector Intensive Grazing Systems group in undertaking this work was also aware of development of national policy on intensive winter grazing as part of the governments Essential Freshwater Program. This report will provide an industry consensus position, where possible, on Good Practice Standards, and other practical measures to address the issues associated with intensive grazing.

THE PRIMARY INDUSTRIES PAN SECTOR INTENSIVE GRAZING SYSTEMS GROUP'S POLICY POSITION IS:

Farmers are dedicated to protecting the water quality of streams, rivers, wetlands and lakes and the coastal environment in particular, to ensure the recreation and food gathering activities associated with water are protected. Poorly designed or unmitigated Intensive grazing activities can have adverse effects on water quality from sediment and nutrient runoff into waterways. It can also have adverse effects on the ability of soils to drain, plants to grow, and may reduce the bioavailability of nutrients. A planning framework for the management of intensive grazing needs to enable a site-specific assessment of suitable locations for intensive grazing based on the unique characteristics of each farm through a Land and Environment Plan (LEP) or Farm Environment Plan (FEP).

SUSTAINABLE MANAGEMENT OF INTENSIVE GRAZING SYSTEMS

There are a number of techniques that can be used to mitigate the effects of intensive grazing on the environment, many at no to little additional cost for farmers. While some of these approaches won't be available in all instances, the following methods provide some agreed minimum practice principals.

Agreed minimum practice principals for intensive winter grazing include:

- Paddock assessment and development of a crop and grazing plan, including per-crop establishment, cultivation techniques, cropping and grazing, and post crop management
- No mechanical cultivation above 20º slope when establishing a fodder crop, without consent
- Critical Source Areas[5] (CSA's) (connected to receiving water bodies) are not to be mechanically cultivated. If the CSA is cropped, it should only be grazed when the area is dry[6]
- Stock are excluded from permanent flowing waterways and CSA's (connected to receiving water bodies) during crop grazing
- If strip grazing, adopt strategic grazing practices such as graze top-down/toward the CSA's or freshwater body
- A buffer strip of ungrazed pasture or riparian vegetation is maintained between a permanently flowing waterway and animals which are being break-fed, or a cropped area. The buffer strip should be at least 5m. Greater setback distances may be required depending on slope and soil type
- Indoor wintering systems have managed effluent disposal
- Providing adequate food and clean water away from CSA's and waterbodies
- Providing loafing areas for stock
- Ensuring stock have access to adequate shelter, and a plan is in place to address stock health and wellbeing during extreme weather events[7]
- Areas of indigenous flora and fauna are recognized and protected.

[5] Critical Source Areas are parts of a farm that are particularly susceptible to the loss of high levels sediment and which have a high the potential to result in discharges of nutrients to water greater than other areas of the farm.

Critical Source Area is defined as: a landscape feature like a gully, swale or a depression that accumulates runoff from an adjacent immediate area, and delivers it to surface waterways such as rivers and lakes, artificial waterways and field tiles; and areas which arise through land use activities and management approaches which result in contaminants being discharged from the area or activity and being delivered to surface waterways.

Critical sources areas on a farm could be:

- Streams and waterways—particularly those which stock can access and where there are no vegetated buffer areas to 'catch' sediment and nutrient runoff. These include intermittently flowing waterbodies or ephemeral waterbodies
- Low-lying areas of paddocks including gully and swale areas—these areas can accumulate sediment and often are more directly connected to waterways through overland flow
- Subsurface drains—these often provide a fast track for contaminants into waterways.

[6] Consider leaving CSA's under pasture or woody vegetation such as native plantings.

[7] From the Sheep and Beef Cattle Code of Welfare (2018), Part 4, minimum standard 6:

(a) All sheep and beef cattle must have access to shelter to reduce the risk to their health and welfare caused by exposure to cold

(b) Sheep and beef cattle giving birth must be provided with an environment affording the newborn protection from any reasonably expected climatic conditions likely to compromise their welfare and survival

(c) Sheep and beef cattle must be provided with means to minimize the effects of heat stress

(d) Where animals develop health problems associated with exposure to adverse weather conditions, priority must be given to remedial action that will minimize the consequences of such exposure.

The code also provides recommended best practice guidelines including: Sheep and beef cattle should have access to areas free of surface water and excessive mud at all times, particularly where conditions can become very muddy such as on crops or small areas of pasture during wet weather.

There are many factors that contribute to whether a particular paddock or area of a paddock is suitable to be used for intensive grazing including:

- Stock type and weight to be grazed
- Stocking rate
- Rainfall events—annual averages and extremes
- Time of the Year/Climate
- Slope
- Land Use Classification (LUC)
- Distance to waterbodies and existence of CSA's
- The duration of soil exposure following grazing.

There are also other factors such as the cultivation technique used, crop establishment methodology, whether animals are grazed on the crop or crop is cut and carried to them, and the duration that a grazed paddock is left with exposed soil that also contribute to whether it is suitable to intensively graze. It is acknowledged that no two farms are likely to be dealing with the same set of factors and that a unique and tailored on farm approach to managing intensive grazing is needed.

The Pan Sector Intensive Winter Grazing Working Group see individual Land and Environment Plans (LEP) or Farm Environment Plans (FEP) as an ideal opportunity to identify the opportunities and vulnerabilities of a farm to intensive grazing through understanding the 'natural capitals' on farm including information around soil types, geology, climate, topography, identification of critical source areas, and the other factors that contribute to whether intensive grazing can be carried out in a way that does not result in adverse effects on the environment, and animal health and wellbeing.

While the issues with intensive grazing are generally most widespread in winter time, it is acknowledged that any intensive grazing activity can result in potential adverse effects on the environment if not sustainably managed. Therefore, good management practices should be applied irrespective of the time of year, and should consider the specific characteristic of the site along with the feeding type and method.

PROVISIONS TO SUPPORT THE SUSTAINABLE MANAGEMENT OF INTENSIVE GRAZING SYSTEMS

Objectives

Objective 1

1. Fresh water bodies and the water bodies in the coastal marine area, are managed to:
   a. Safeguard aquatic ecosystem health
   b. Recognize and provide for the values of the catchment or FMU
   c. Provide for contact recreation
   d. In the case of fresh water, provide for the health needs of people.
2. The soil resource is managed to safeguard its life supporting capacity.

Objective 2

1. Land use activities are managed to:
   a. Avoid significant adverse effects on water quality
   b. Safeguard the life-supporting capacity of soils
   c. Safeguard aquatic ecosystem health
   d. Safeguard mahinga kai
   e. Provide for contact recreation
   f. Provide for Māori customary use
   g. In the case of fresh water, provide for the health needs of people.

Policies

Policy 1

1. To use non-regulatory methods in support of regulatory methods for addressing the adverse effects of discharges including:
   a. In consultation with landowners, undertake the identification of priority areas along the margins of rivers, lakes and wetlands, which should be retired in order to provide a buffer against the effects of runoff from land use activities.
   b. Actively promoting self-regulation by land owners, assisting with the formation of Catchment community Groups, preparing Land and Environment Plans, providing information about sustainable land management practices, and responding to requests for advice.
   c. To provide financial assistance to landowners to implement measures to prevent stock access to streams, rivers, lakes and wetlands where there is benefit to the regional community and to facilitate the retirement of these riparian areas and pest management.
   d. The preparation and distribution of educational material regarding the benefits of retaining, establishing and enhancing appropriate riparian vegetation.

Policy 2

1. Adverse effects on natural character, water quality, bank and dune stability, or riparian vegetation cover arising from intensive grazing activities on water bodies are avoided or mitigated to the extent that there are no more than minor adverse effects on water quality.
2. To promote the use of Land and Environment Plans that enable a risk-based approach to intensive grazing activities and:
   a. Provide a farm-specific approach to the identification of appropriate sites for the intensive grazing of stock that considers the following criteria:
      i. The type of livestock being farmed, their weight and the stocking density
      ii. Annual average rainfall events and the likelihood of extreme weather events
      iii. The season and climate
      iv. The topography of the site
      v. The land use classification of the site
      vi. The location of waterbodies near the site
      vii. The location of critical source areas within the site
      viii. The duration of time following grazing that the site will be re-vegetated
      ix. The ability of stock to access reticulated water supply from the site.
2. Avoid, remedy or mitigate the adverse effects of intensive grazing to protect aquatic ecosystm health.
3. When establishing riparian margins, including those to mitigate runoff from intensive grazing activities, the following matters should be considered:
   a. The appropriate width and planting density shall take account of:
      i. The purpose(s) for establishing the riparian margin
      ii. The surrounding terrain and soil type;
      iii. The type of livestock being farmed
      iv. The contaminants required to be managed to provide for catchment values
      v. The appropriateness of riparian plant species, with a priority given to planting indigenous species.
   b. The requirement for routine maintenance of the riparian planting area, including undertaking weed and pest control, for the purposes of protecing aquatic ecosystem health, human health for recreation and any other catchment-specific values.

Standards

Policy frameworks should be effects based and incorporate as appropriate Industry endorsed 'Good Management Practices' which cover all classes of stock: sheep, cattle, and deer, and which are largely based around—how animals are grazed; set back distances from waterbodies; and empowering farmers to establish systems which match their farm management and farming systems to the natural capital of their land and its suitability for intensive grazing.

The following provides a list of good management practices proposed to be included within policy frameworks:

1. Grazing management plan must be developed, implemented, and provided to the council on request.
2. Stock are to be excluded from permanently flowing waterbodies at all times, and critical source areas when being grazed on crop.
3. Stock are to be excluded from the riparian margins of waterbodies of 8m on land with a slope less than 20 degrees.
4. All animal effluent collected from feed-pads must be treated and discharged through consent.
5. Feedpads[9] need to be sealed.
6. Nutrient budget for the farm, showing the contribution of the intensive grazing area, is to be undertaken and provided to the regional Council on request.
7. The activity shall not result in the following effects on receiving waterbodies:
   a. The production of conspicuous oil or grease films, scums or foams, or floatable or suspended materials
   b. Any conspicuous change in the colour or visual clarity
   c. Any emission of objectionable odor
   d. The rendering of fresh water unsuitable for consumption by farm animals
   e. Any significant adverse effects on aquatic life.

Provision of a Grazing Management Plan and its implementation

Part A—Grazing Management Plan can be based on either of:

1. The material set out under Part B below; or
2. Industry prepared grazing management plan templates and guidance material, with national standards specific supplementary material added where relevant, so that it includes the material set out in Part B below, and for clauses (1), and (2) is
3. Reviewed at least once every 12 months by the landholding owner or their agent and the outcome of the review is documented; and
4. Provided to the Regional Council upon request.

Part B—Grazing Management Plan Content includes:

1. The following landholding details:
   a. Physical address;
   b. Description of the landholding ownership and the owner's contact details
   c. Legal description(s) of the landholding
   d. A list of all resource consents held for the landholding and their expiry dates.
2. The following map(s) or aerial photograph(s) of the landholding at a scale that clearly shows the locations of:
   a. All proposed land preparation areas over the next 12-month period
   b. All land including land boundaries that may be intensively winter grazed (1 May to 30 September)
   c. For these land management units provide:
      i. Soil types and slope (or alternatively land use capability units)
      ii. Identification of gully, landslide and earthflow erosion within the farm boundary including land use capability classes 6e, 7e, and 8
      iii. Natural wetlands, lakes, permanently flowing river(s) or stream(s), or permanently flowing artificial watercourse
      iv. Known subsurface drainage system(s) and the locations of the drain outlets
      v. Critical Source Areas[10]
      vi. All existing and proposed riparian vegetation
      vii. All existing or proposed fences (or other stock exclusion methods) adjacent to waterbodies
      viii. Places where stock access or cross water bodies (including bridges, culverts and fords)
      ix. Areas of indigenous vegetation
      x. Wāhi tapu sites
      xi. Mapped Sites and Areas of Significance to Tangata Whenua (refer Regional Council Regional Plans).
3. The following Good Management Practices shall be implemented:
   a. Strategic grazing principals and good management as set out by Industry[11]
   b. The provision of, and location of pastoral areas, or loafing pads, for stock to rest
   c. The provision of and location of reticulated stock drinking water
   d. The provision of and location of stock shelter
   e. The location, timing and prioritization of measures to control or mitigate erosion, sediment, pathogen, and nutrient losses from the landholding, including time-frames for implementation. These must include the following considerations:
      vi. Avoid, remedy, or mitigate sediment, nutrient, and faecal losses from grazed areas, particularly those associated with overland flow
      vii. Riparian areas (including those from which stock are excluded), extent, and the type of riparian vegetation
      viii. Management, including as appropriate enhancement, and protection of areas of indigenous vegetation
   f. Evidence to support the recommendations in item (1) to (3) above; including but not limited to:
      i. Risk assessment; and/or
      ii. Measures to control or mitigate erosion and sediment loss from the landholding; and
      iii. Measures to control or mitigate losses of phosphorus, nitrogen and faecal material from the landholding.

Examples of general good management practices are provided on the DairyNZ[12], Beef + Lamb New Zealand[13] and Deer Industry New Zealand[14] websites and in the document titled "Good Farming Practice Action Plan for Water Quality, 2018".

---

8 Commonly used setbacks in regulation are 3m, 5m, and 10m. Policy generally prefers to specify the setback distance, however scientific approaches to determining appropriate setback distances are related to slope, soil and geoligy.

9 Feedpad: A sealed or permeable area used to move animals onto to protect soils and pastures and increase the utilization of supplementary feeds where that feed is brought to the animals for a period of time (can be hours, days, months), can be used at any time of the year.

NON-REGULATORY TOOLS: EXTENSION RESOURCES

Primary sector organizations already have useful resources available for farmers on their websites relating to good management practice for intensive grazing. Primary sector organizations and leaders should continue to work with farmers to build sector capability and capacity in sustainably and responsibly managing intensive grazing systems and providing for animal health and wellbeing.

Appendix 1 sets out a stock take of resources including industry fact sheets and farmer support material on Intensive grazing Systems and Industry supported good management principals and practices.

[10] Critical Source Areas are defined as is a landscape feature like a gully, swale or a depression that accumulates runoff from an adjacent immediate area, and delivers it to surface waterways such as rivers and lakes, artificial waterways and field tiles, which discharge to a natural waterbody.

[11] Examples of general good management practices are provided on the DairyNZ, Beef + Lamb New Zealand, and Deer Industry New Zealand websites and in the document titled "Good Farming Practice Action Plan for Water Quality, 2018".

[12] www.dairynz.co.nz/feed/seasonal-management/winter-management/

[13] www.beeflambnz.com/winter-grazing

[14] www.deernz.org/deer-hub/farm-environment/environmental-management-code-practice

APPENDIX 1: STOCK TAKE OF WINTER GRAZING MATERIALS

P21 Research Papers

Chrystal et al (2016): Volumes and nutrient concentrations of effluent products generated from a loose-housed wintering barn with woodchip bedding

Chrystal et al (2016): Effects of applying dairy wintering barn manure of differing C:N ratios directly to pasture on N mineralization and forage growth

Gray et al (2017): Cadmium losses in overland flow from an agricultural soil

Laurenson et al (2017): Assessing the environmental implications of applying dairy cow effluent during winter using low rate and low depth application methods

Monaghan et al (2017): Grazing strategies for reducing contaminant losses to water from forage crop fields grazed by cattle during winter

Chrystal, J., Monaghan, R., Hedley, M., Horne D., 2016. Design of a low cost winter stand-off pad for reducing nutrient losses to water from winter forage crops grazed by dairy cows. **www.massey.ac.nz/~flrc/workshops/16/Manuscripts/Paper_Chrystal_1_2016.pdf**

Other Research Papers

"Winter Grazing versus Supplements—Cheaper dairying systems (NZGA, 1988): **www.grassland.org.nz/publications/nzgrassland_publication_1040.pdf**

"The effects of hillslope forage crop grazing in winter on soil erosion (NZGA, 2016): **www.grassland.org.nz/publications/nzgrassland_publication_2783.pdf**

B+LNZ Web pages

Winter Grazing: **www.beeflambnz.com/winter-grazing**

B+LNZ Fact sheets

FS 127: Winter Forage Crops—management before grazing **www.beeflambnz.com/knowledge-hub/PDF/winter-forage-crops-management-grazing**

FS 128: Winter Forage Crops—Management during grazing: **www.beeflambnz.com/knowledge-hub/PDF/winter-forage-crops-management-during-grazing**

FS 129: Winter forage Crops—Management after grazing: **www.beeflambnz.com/knowledge-hub/PDF/winter-forage-crops-management-after-grazing**

FS 215: 10 Top Tips for Winter Grazing of Crops: **www.beeflambnz.com/knowledge-hub/PDF/ten-top-tips-winter-grazing-crops**

FS 68: Feed planning in a tough Winter: **www.beeflambnz.com/knowledge-hub/PDF/feed-planning-tough-winter**

FS 174: Shelter—maintaining the welfare and productivity of sheep and cattle on Dry stock farms. **www.beeflambnz.com/knowledge-hub/PDF/shelter-maintaining-welfare-and-productivity-sheep-and-cattle-drystock-farms**

Winter Cropping Paddock Warrant of Fitness: Correct paddock selection and management **www.beeflambnz.com/knowledge-hub/PDF/FS222-paddock-wof**

Biosecurity Warrant of Fitness: **www.beeflambnz.com/knowledge-hub/PDF/biosecurity-wof-checklist**

B+LNZ Videos

Strategic Grazing of Winter Crops. **www.youtube.com/watch?v=r5DHYU-jNQI**

Best practice winter feeding cattle: **www.beeflambnz.com/knowledge-hub/video/best-practice-winter-feeding-cattle**

Profitable crop for cattle wintering. **www.beeflambnz.com/knowledge-hub/video/profitable-crop-cattle-wintering**

What is winter grazing and why do farmers use it? **www.youtube.com/watch?v=_3zSgf6KjNs&feature=youtu.be**

B+LNZ Podcasts

“Good management practice for winter grazing: Ross Monaghan, Ag-research” **www.beeflambnz.podbean.com/e/good-management-practice-for-winter-grazing-ross-monaghan-soil-scientist-agresearch/**

Managing the risk of *Mycoplasma bovis* during the winter grazing season: Richard Laven of Massey University
www.beeflambnz.podbean.com/e/managing-the-risk-of-mycoplasma-bovis-during-the-winter-grazing-season-richard-laven-of-massey-university/

Catch Crops: A way to reduce N leaching after winter crops, with Dr Brendon Malcolm, Plant & Food Research
www.beeflambnz.com/knowledge-hub/podcast/PC34-catch-crops-a-way-to-reduce-n-leaching-after-winter-crops

Making positive changes at scale, with the Catchment Community Group Programme
www.beeflambnz.podbean.com/e/making-positive-changes-at-scale-with-the-catchment-community-group-programme/

‘Protecting your patch’—the key biosecurity actions for your farm
www.beeflambnz.podbean.com/e/protecting-your-patch-the-key-biosecurity-actions-for-your-farm/

Hill Country Farming in 2040: Panel discussion at B+LNZ’s FarmSmart 2018 **www.beeflambnz.podbean.com/e/hill-country-farming-in-2040-panel-discussion-at-blnz%e2%80%99s-farmsmart-2018/**

Eradicating Mycoplasma bovis—how to keep your farm free from the disease **www.beeflambnz.podbean.com/e/eradicating-mycoplasma-bovis-%e2%80%93-how-to-keep-your-farm-free-from-the-disease/**

B+LNZ’s Environment Strategy
www.beeflambnz.podbean.com/e/beef-lamb-new-zealand%e2%80%99s-environment-strategy/

Feeding Lambs on Fodder Beet **www.beeflambnz.podbean.com/e/%e2%80%98break-feed%e2%80%99-feeding-lambs-on-fodder-beet-with-scott-linklater/**

Mike Barton: Farming with limits—the Lake Taupo experience **www.beeflambnz.podbean.com/e/farming-with-limits-the-lake-taupo-experience/**

Jim Gibbs: Making the most of fodder beet
www.beeflambnz.podbean.com/e/jim-gibbs-making-the-most-of-fodder-beet/

B+LNZ Resource books

Management practices for forage brassicas
www.beeflambnz.com/knowledge-hub/PDF/management-practises-forage-brassicas-book In revision 2018/2019; will include P21 outputs

B+LNZ Workshops

Full list here:
www.beeflambnz.com/your-levies-at-work/workshops-farmers

Beef Cow Body Condition Scoring: assess cow nutrition, thrift, health, wellbeing and welfare

FeedSmart: teaches participants to assess the quality of feed and estimate its metabolisable energy, plus introduces you to some handy tools.

Freshwater: This interactive workshop will help to introduce you to some simple tools to measure key indicators of freshwater quality and ecosystems.

Land Environment Plans/Regional Farm Environment Plans: develop a full picture of the farm, identify Land Management Units and the farm’s resources and create an ongoing plan that can be reviewed annually. Identify risks and threats and implement processes to avoid/remedy/mitigate

Winter Grazing: plans and processes for good management practice before, during and after winter grazing. Addresses people, animal health and welfare, and strategic grazing to avoid or minimize environmental impacts. Emphasis on paddock selection to avoid risk, and management of paddocks after grazing as well.

B+LNZ app

FeedSmart app **www.feedsmart.co.nz** Instant calculation of animal feed intake requirements for productivity and well-being, along with break-feeding calculators to ensure enough feed is offered in paddock to meet those requirements.
www.beeflambnz.com/news-views/feedsmart-app-making-feed-management-easier

FeedSmart User Guide **www.beeflambnz.com/knowledge-hub/PDF/feedsmart-user-guide**

DairyNZ Fact sheets/ Resource Books

Reducing surface runoff from grazed winter forage crop paddocks by strategic grazing management
www.dairynz.co.nz/media/3207637/strategic-grazing-management.pdf

Wintering Standard Operating Procedures
www.dairynz.co.nz/media/5791486/wintering-standard-operating-procedure.pdf

Wintering on crop and pasture
www.dairynz.co.nz/media/5790989/wintering-on-crops-in-the-south-island-booklet-2019.pdf

Feeding and transitioning onto winter brassicas
www.dairynz.co.nz/media/253806/1-75_Winter_brassica_crops.pdf

Catch Crop guidelines **www.dairynz.co.nz/media/5791668/catch-crop-guidelines.pdf**

DairyNZ web pages

Wintering cows on crops **www.dairynz.co.nz/feed/crops/wintering-cows-on-crops/**

Pastoral 21 research programme:
www.dairynz.co.nz/about-us/research/pastoral-21/ Includes a number of research summaries

Winter management **www.dairynz.co.nz/feed/seasonal-management/winter-management/**

Grazing the winter crop **www.dairynz.co.nz/feed/crops/wintering-cows-on-crops/grazing-the-winter-crop/**

Insight into winter on dairy farms **www.dairynz.co.nz/news/latest-news/insight-into-winter-on-dairy-farms/**

Transition onto fodder beet **www.dairynz.co.nz/feed/crops/fodder-beet/fodder-beet-transitioning/**

Catch Crops **www.dairynz.co.nz/feed/crops/catch-crops/**

Forages for Reduced Nitrate Leaching (FRNL)

Website Lists 10 technical articles on the project’s outputs: **www.dairynz.co.nz/about-us/research/forages-for-reduced-nitrate-leaching/**

FRNL Research Reports: 5 summaries and one published paper on research to date.
www.dairynz.co.nz/about-us/research/forages-for-reduced-nitrate-leaching/frnl-research-reports/

Deer Industry New Zealand (DINZ) web pages

Wintering Feed Systems—Deer Industry New Zealand (DINZ): **www.deernz.org/deerhub/farm-environment/water-soils/land-environment-planning/wintering-feed#.WtVUqaYUmUk**

Farm and Environment—Deer Industry New Zealand (DINZ): **www.deernz.org/deerhub/farm-environment/water-soils/land- environment-planning/wintering-feed#.WtVUqaYUmUk**

Environmental Code of Practice - Deer Industry New Zealand (DINZ): **www.deernz.org/deer-hub/farm-environment/environmental-management-code-practice**

B+LNZ Media

Multiple stories at **www.beeflambnz.com/search?term=winter&type%5B%5D=5**

Examples:
Farmers strongly encouraged to follow best practice for winter grazing **www.beeflambnz.com/news-views/farmers-strongly-encouraged-follow-best-practice-winter-grazing**

Ten Top Tips for Winter Grazing on Crops, July 2017.
www.beeflambnz.com/news-views/ten-top-tips-winter-grazing-crops

3 Tips for Winter Soil Management, June 2017.
www.beeflambnz.com/news-views/three-tips-winter-soil-management

Beef Trial: 30 versus 60 day winter rotations, May 2017. **www.beeflambnz.com/news-views/beef-trial-30-versus-60-day-winter-rotations**

Preparing for winter grazing **www.beeflambnz.com/winter-grazing/per-grazing**

Soil friendly bull wintering system **www.beeflambnz.com/news-views/soil-friendly-bull-wintering-system**

Other Publications

Landcare Research “Wintering practices of dairy farmers across New Zealand” **www.landcareresearch.co.nz/__data/assets/pdf_file/0005/125816/Policy-Brief-16-Winter-Grazing-Practices.pdf**

Greater Wellington Regional Council “Reducing the impacts of winter grazing on soil and water quality”
www.gw.govt.nz/assets/Land-Management/Reducing-the-impacts-of-winter-grazing-factsheet.pdf

Waikato Regional Council “Outline of Waikato Regional Council sheep and beef farming—grazing management practices research”
www.waikatoregion.govt.nz/assets/PageFiles/28959/4/66%20-%203027629.pdf

Gisborne District Council “Fresh Water Fact Sheet: Winter Intensive Grazing”**www.gdc.govt.nz/freshwater-plan-winter-intensive-grazing/**

Other web pages

Winter intensive grazing—Gisborne District Council:
www.gdc.govt.nz/freshwater-plan-winter-intensive-grazing

APPENDIX 11: SELECTION OF ARTICLES ILLUSTRATING THE DEPTH AND BREADTH OF CONCERN ABOUT GRANDPARENTING

Appendix 11: Selection of articles illustrating the depth and breadth of concern about grandparenting.

Throughout the consultation process, Ministers have consistently said that the proposed essential freshwater policies will not affect those that are doing the right thing.

There is widespread concern, however, amongst environmental NGOs and sheep and beef farmers that the proposed policies will have the opposite effect. Their view is that the various "grandparenting" proposals actually let the highest polluting operations off the hook and disproportionately affect those that have the lighted environmental footprint and those that have been doing the right thing.

The following is a collection of articles that illustrate some of the practical implications for farmers of the various grandparenting provisions that are in the current essential freshwater proposals, and articles that illustrate the widespread environmental group concerns as well about these proposals.

Ministerial comments:

18 September: Parker recognises that sheep and beef farmers are concerned about the land use constraints being grandparenting and sharing their concerns:

http://www.scoop.co.nz/stories/PA1909/S00140/speech-parker-water-nz-conference-2019.htm

1 October: "For the vast majority of them it won't be any change at all"

https://www.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=12272509

Environmental perspectives:

17 October: Statement by 9 organisations including Forest and Bird, Fish and Game, EDS and Greenpeace opposing the various grand-parenting provisions in the EFW proposals and mandatory farm environment plans

https://www.forestandbird.org.nz/resources/groups-unite-freshwater-policies-healthy-water
http://img.scoop.co.nz/media/pdfs/1910/Healthy_Water_Healthy_Future__joint_statement_on_freshwater_policy_2019.pdf

9 October: Dr Death reflections on the Essential Freshwater proposals includes the following comment: *"Sheep and beef farmers have a right to be aggrieved. They are being restricted to extremely low nutrient leaching levels limiting their future options, while dairy farmers, who are the main culprits of current low water quality, retain their future flexibility being "constrained" to their very high leaching. So I can understand their concern".*

https://thespinoff.co.nz/politics/09-10-2019/why-dont-new-zealand-farmers-want-to-look-after-their-golden-goose/

25 October: Bruce Bisset, environmentalist, agreeing with farmer concerns about the land-use change and other grandparenting provisions having more impact on low emitters than high emitters:

https://www.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=12279276

Farmer concerns about grandparenting and practical examples about how it will impact on them:

9 October: https://www.interest.co.nz/rural-news/102048/unintended-consequence-farmers-who-have-invested-long-term-fresh-water-remediation

10 October: Rick Burke, Sheep and Beef Farmer in Waikato impacts of grandparenting proposals:

https://www.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=11850058

13 October: 1 News: Farmers hit out at the grandparenting protection proposals as consultation continues:

https://www.tvnz.co.nz/one-news/new-zealand/farmers-hit-waterway-protection-proposals-consultation-continues

17 October: Sam McIvor, comments about grandparenting based on consultation with over 3,000 farmers:

https://www.nzherald.co.nz/the-country/sheep-and beef/news/article.cfm?c_id=802&objectid=12277019

22 October: Hales family talk about the potential impact of the various grandparenting proposals based on the changes they have made on their farm: https://farmersweekly.co.nz/section/agribusiness/view/water-policy-stymies-green-work

22 October: Whanganui farmers discuss freshwater proposals:

https://www.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=12277793

25 October: Dani Darke, sheep and beef farmer Northland impacts of the grandparenting proposals on land prices and communities:

https://www.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=12279611