BEFORE COMMISSIONERS APPOINTED
BY THE WAIKATO REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the First Schedule to the Act
AND	
IN THE MATTER	of Waikato Regional Plan Change 1- Waikato and Waipā River Catchments and Variation 1 to 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 JANE MARIE CHRYSTAL
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

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BACKGROUND

1. My name is 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).

8. In preparing this evidence I have reviewed:

    (a) The reports and statements of evidence of other experts giving evidence relevant to my area of expertise, including:

        (i) Mr Andrew Burtt

        (ii) Mr Richard Parkes

        (iii) Mr Richmond Beetham

    (b) The officers s42A report;

    (c) Plan change 1 and Variation 1;

    (d) The section 32 report.

(e) A number of reports commissioned by the Technical Leaders Group relating to the Healthy Rivers Wai Ora Project. These include document numbers:

(i) HR/TLG/2015-2016/1.4;

(ii) HR/TLG/2015-2016/4.1;

(iii) HR/TLG/2015-2016/4.2;

(iv) HR/TLG/2015-2016/4.6;

(v) HR/TLG/2015-2016/4.8;

(vi) HR/TLG/2016-2017/4.4;

(vii) HR/TLG/2016-2017/4.5.

9. 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 EVIDENCE

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

(a) Why nutrient management is important;

(b) The Overseer tool and how it works; and

(c) Alternative farmer support tools that can assist in the delivery of water quality outcomes.

11. I have been asked to undertake case studies of the sheep and beef and dairy sectors to determine their nutrient emissions profiles, to assist with delineating at-risk activities, and in order to review the modelling that underpins PC1. This includes providing:

(a) A summary of the sheep and beef sector in Waikato from 38 farms that are part of the B+LNZ Sheep and Beef Farm Survey;

(b) A summary of the N leaching losses pertaining to the dairy sector in Waikato; and

(c) How nutrient losses have changed over time.

12. I have reviewed and provided comment on the modelling, underpinning PC1, and its assumptions and recommended corrections.

13. The evidence will be extrapolated as required through hearing stream 2 (HS2) to focus on the matters relevant to that hearing stream.

14. I am aware of the directions of the Hearing Panel to allocate blocks of time for particular topics. My evidence addresses matters relating to the technical modelling and data on farm systems and nutrient discharge profiles which underpin PC1, which is to be addressed through hearing stream 1 under science and economic modelling. I also address the overall direction of the Plan, and in particular the tools that are available to farmers in the region to manage their nutrient discharges. For the purpose of hearing stream 1 I have outlined the methods I consider are the most appropriate for the management of those discharges by the sheep and beef sector. These methods have the following matters in common:

a) They are identified in relation to those activities which potentially have a higher environmental risk;
b) Are spatially appropriate, and tailored to the farm system;
c) Enable flexibility, adaptation and innovation;
d) Acknowledge the benefits and limitations in farm system decision support tools (in particular OVERSEER).

EXECUTIVE SUMMARY

15. 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.

16. 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.

17. Some farming activities pose a higher risk of contaminant losses to water than others. These include:

    (a) irrigation;

    (b) effluent storage, land application, and management;

    (c) cropping;

    (d) high stocking rates and densities; and

    (e) fertiliser use, including type, timing, and load.

18. Mitigation approaches, which are tailored to the farm and the catchment and include 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 and provide for the ongoing viability of dryland agricultural land uses compared to prescriptive input type standards and rules.

19. As presented in Mr Burtt's evidence, since 1990 sheep and beef stocking rates have decreased from 14 to just under 12 stock units (SU)/ha while dairy has significantly increased both in relation to land area and intensity. There has been an increase in the national average of cow/ha: 2.3 cows/ha in 1985/86 to 2.85 in 2015/16 (DairyNZ, 2016). This means there has been an increase in stock units (SU; assuming 7.5 SU/cow) from 17.3 to 21 SU/ha.

20. Understandably effects arising from intensification of land use raise concerns about the health of freshwater ecosystems. However, it is important the decision makers on PC1 are confident that the range and magnitude of policy intervention proposed is justified. The contribution of the agricultural sector to the state and tends in water quality and impacts on aquatic ecosystem health needs to be considered.

21. The Healthy Rivers Plan for Change: Waiora He Rautaki Whakapaipai (HRWO) Project utilises the HRWO economic model ('The HRWO model')

at the farm and catchment scale to establish targets and limits for nutrient, sediment and *E. coli* (Doole, 2016). The HRWO model utilises Overseer® Nutrient Budgets (Overseer) to establish leaching profiles at the farm level for each of the major land uses. This is then aggregated for each sub-catchment, which then informs model development and scenario testing including economic assessments of the implication of PC1. The nitrogen and phosphorus leaching values used for sheep and beef and dairy farms were found by Dr Cox to be flawed, along with the land use information that was used. These flaws mean that the model is unreliable at best and could significantly misrepresent the relationship between current land uses and water quality, including significantly underestimating the amount of nitrogen that can be allocated in relation to the freshwater objectives, and inaccurately represent the implications of PC1 on land owners and the environment.

22. Overseer can be a useful tool when it is used with an understanding of its purpose, strengths and weaknesses.

23. Overseer was originally designed as a fertiliser support tool 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):

    (a) "data input uncertainty;

    (b) version change;

    (c) the inability of Overseer to represent farm systems in particular regions; and

    (d) uncertainty in a compliance setting."

24. 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.

25. 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.

26. The level of uncertainty in the model outputs come from a number of sources including: user error, bugs in the model, sub-models with less data to validate the model against, temporal and spatial variation in validation data, and Overseer version changes.

27. This evidence presents alternative values for N and P losses from sheep and beef farms and dairy farms in the Waikato derived from Overseer (v6.3.0), which are a closer representation to actual farm systems than those used through the HRWO modelling.

28. Due to the sampling methodology that I have employed I believe that this data provides a more accurate representation of the sheep and beef farms in the region than that used within the technical reports which underpin the development of PC1, including the HRWO model and economic analyses.

29. Recalculated N leaching rates show on average a 50% increase in dryland farming (sheep and beef and dryland dairy) over the rates used in the HRWO model. These changes represent changes in the model and not intensification of the sheep and beef sector. On average N leaching from dairy is 240 to 450% higher than those from sheep and beef farming.

30. This means that the basis to PC1 in relation to the modelling is flawed, including misrepresenting the relationship between land use and water quality outcomes. Significant issues arise in relation to the use of Overseer in this context, and conclusions around 'attenuation' which is used to link land use to water quality. These issues have corresponding implications for scenario testing including modelled assumptions around mitigation applied across the sectors and corresponding outcomes in relation to water quality. These uncertainties render the model unfit to inform or underpin PC1.

31. I believe that a recalibration of the nitrogen losses from base farms is required using actual farm data and not 'average' farms, along with updated land use information which is verifiable. Further, I believe that there may be the potential to incorporate other modelling tools such AgInform to help provide a more accurate picture of the nutrient losses from the sectors, farm

optimisation opportunities, and provide useful assistance to the decision process on PC1.

WHY NUTRIENT MANAGEMENT IS IMPORTANT

32. 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

33. 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.

34. 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).

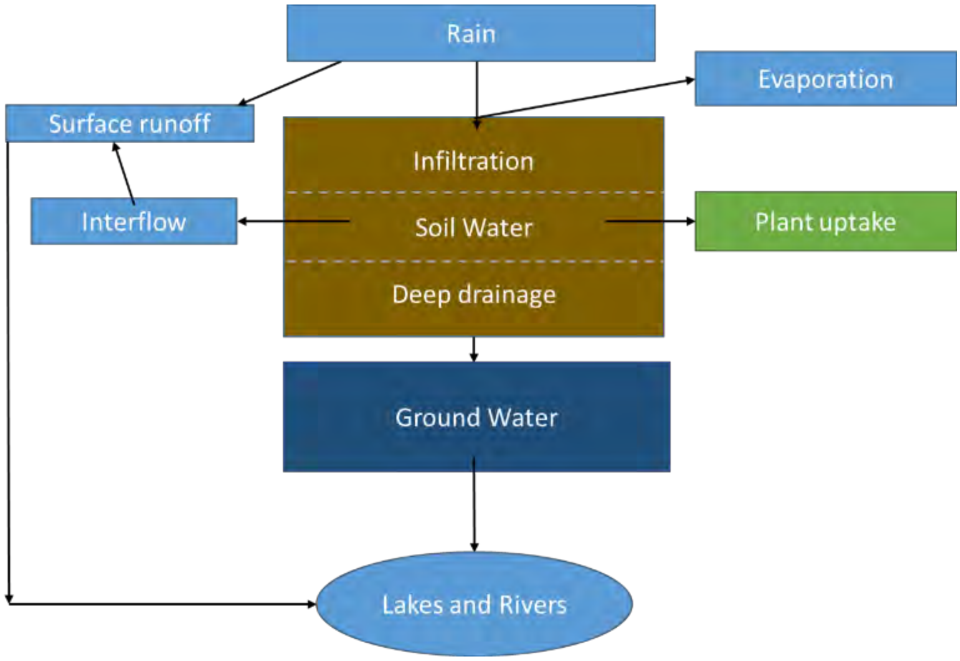

Figure 1: Components of the hydrological cycle that relate to soil water.

Drainage in permeable soils – matrix flow

35. 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 farmers had the same farming system, the same water inputs and climate, they could have a different drainage (and thus nutrient loss) profile due to the soil structure.

Preferential flow

36. Preferential (or bypass flow) flow occurs when water moves through the soil profile in a non-uniform way. This can be through natural cracks in the soil, worm holes, or 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).

Nutrient movement - pathways of N, P, sediment and pathogen (e.g *E. coli*) loss to receiving waters

37. 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.

38. This is discussed further in the evidence of Mr Parkes who specifically addresses the externalities of concern from the red meat sector, CSAs, and methods to manage the potential impacts on water quality. I have reviewed Mr Parkes evidence and support his conclusions on these matters. I provide further evidence below in relation to CSA management on farm.

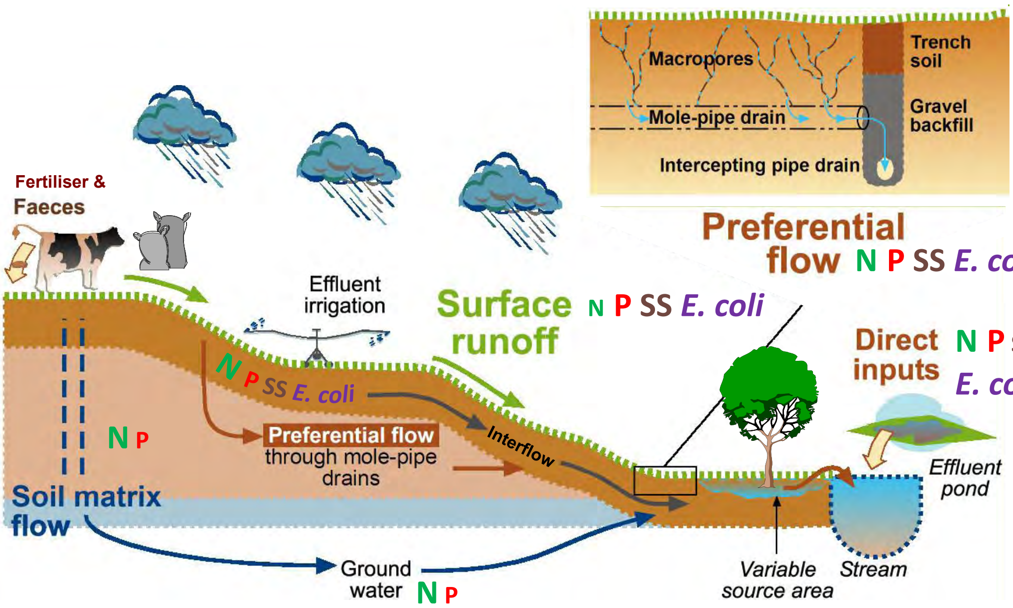

Figure 2: Conceptual diagram of the transport pathways involved in the transfer of contaminants (N, P, SS, and *E. coli*) from land to water. The presence and relative size of each of the contaminants indicates the importance of the pathway to contaminant-specific loss (McDowell et al., 2016).

Nitrogen loss to receiving waters

39. 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), fertiliser N (mostly applied to pastures as urea) or NH_4 based fertiliser. The nitrogen cycle is shown in Figure 3.

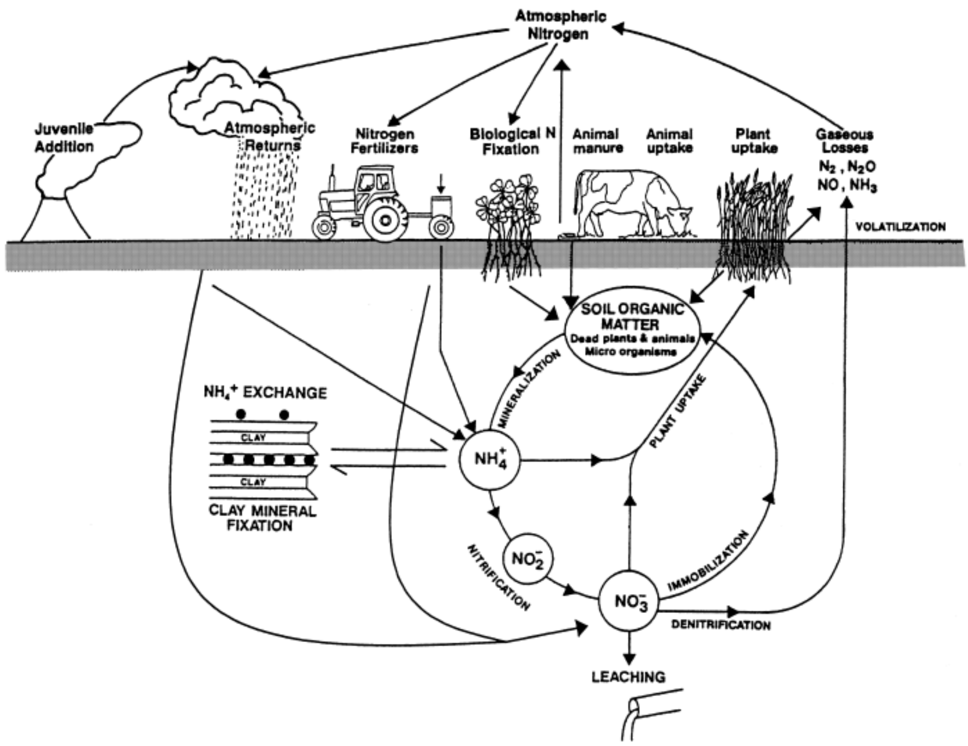

Figure 3: The Nitrogen Cycle in agricultural systems (Di & Cameron, 2002, Figure 1)

40. 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.

41. McDowell and Wilcock (2008) found, in assessing 32 studies conducted since 1975, that significantly more N was lost from dairy catchments than other catchments.

42. The ranking of median N loads from 32 studies was (McDowell and Wilcock, 2008):

Dairy > deer = mixed > sheep > non-agricultural

43. 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

44. 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).

45. 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 incorporates 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

46. 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.

47. 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.

48. Losses of P are very site specific and occur from a small percentage of the landscape from areas commonly referred to as CSAs.

49. 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)*.

50. 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.

51. 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*).

52. 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

53. 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.

54. 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.

55. The impact of this on PC1 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. This will be elaborated on in HS2 and HS3.

56. 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.

57. 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

58. 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

59. 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.

60. 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.

61. 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.

62. 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

63. 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

64. 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

(e) Mole and tile drainage provide a pathway for topsoil to enter streams and waterways.

(f) Olsen P level. Olsen P above the optimum range for the pasture or crop results in increased risk of P loss.

(g) Management of critical source areas (CSAs).

(i) Most P loss is from CSAs because these areas are where high concentrations of P are found. Examples include deer wallows and 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).

65. 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 that 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.

66. 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).

67. 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

68. Overseer is a nutrient budgeting tool that models the nutrient flows in/out and around a farming system. It 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).

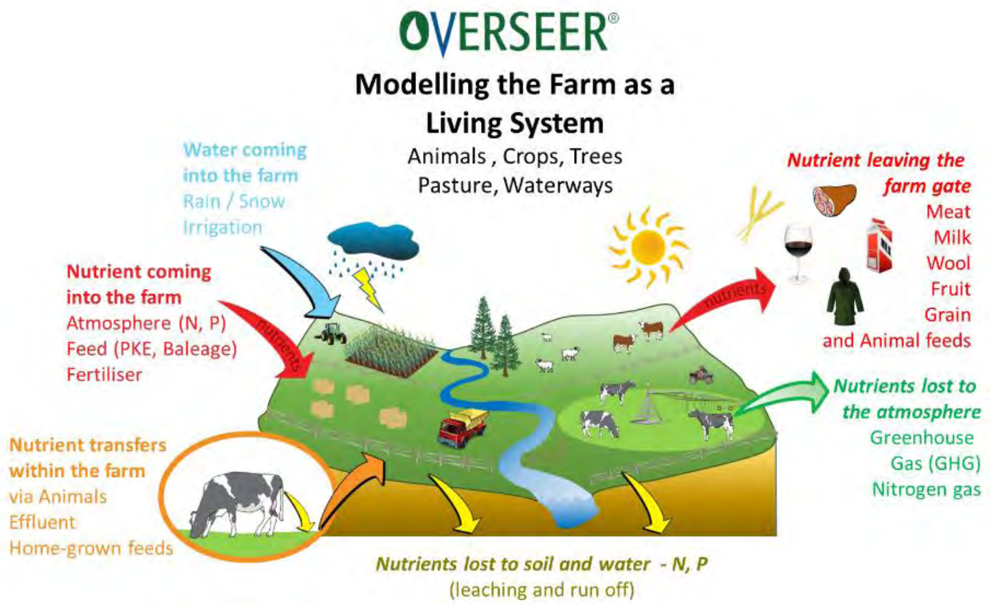

Figure 4: Conceptual diagram of the nutrient flows in, out and within the farm system as modelled by Overseer.

69. 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.

70. “Blocking” in Overseer traditionally includes separating the farm into areas with similar characteristics including topography, climate, soil type, fertiliser, irrigation and effluent management, and farm management.

71. OverseerFM, which is the latest version of Overseer, 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.

72. 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.

Soil type

73. Soils can be classified into different levels in Overseer.

(a) Soil group, this breaks down all the soils in NZ into seven groups e.g. sedimentary and volcanic soils;

(b) Soil Order breaks all the soils in NZ into 15 orders. This is the level required by the Waikato Regional Council and the level used for the analysis described here;

(c) Soil Series breaks all the soils in NZ into just under 2000 series; and

(d) Sibling Soil, taken from S-Map, which is the most accurate classification.

How the nitrogen sub-models work

74. 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.

75. 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. In the older online version of Overseer it is possible to generate a graph of the nitrogen leaching losses on a monthly basis which highlights the monthly loss values and the high-risk months.

76. Overseer does not take into account the fate of nitrogen below the root zone and any attenuation that may occur (Singh et al., 2015). This issue is addressed in the evidence of Tim Cox.

77. The use of Overseer to model nutrient losses at a catchment scale must be done with caution. There are 4 methods described in the document "Using

Overseer in Regulation" (Freeman et al., 2016). The authors provide a table that lists the main strengths and weaknesses of the different approaches. It is provided here as Appendix 1.

78. There are a number of challenges outlined for the methodology of using anecdotal case studies as used for the HRWO Projects (Appendix 1, example 2). These include:

(a) Characteristics and assumptions of the anecdotal systems may not be valid for the whole catchment and subsequent impact on loss rates is compounded with extrapolation to catchment losses;

(b) Confidentiality issues can hinder close scrutiny of input data. This is what I have found in trying to understand the base line data and the assumptions used to generate the figures presented;

(c) Anecdotal files are based on a single year and provide a 'snap-shot';

(d) It can be unclear what assumptions have been used in modelling. Again this is something I have encountered;

(e) If files were built by multiple modellers it may be difficult to get a constant level of practice and input standards; and

(f) Risk of variable quality of information.

79. The likely uncertainty of data inputs and ability to manage uncertainty given by Freeman et al. (2016) is given as:

"High uncertainty of data inputs. Low ability to manage uncertainty".

80. These flaws mean that the model is less reliable than if actual farm data had been used and could significantly misrepresent the relationship between current land uses and water quality. This includes significantly underestimating the amount of nitrogen that can be allocated in relation to the freshwater objectives, and inaccurately representing the implications of PC1 on land owners and the environment.

81. B+LNZ used the methodology of using representative farms, while this is a more robust approach to investigating the implications of land uses on receiving environments and potentially policy implications, as with the use of anecdotal case studies, there are a number of challenges outlined by

Freeman et al. (2016) for the methodology (Appendix 1, example 3). These include:

(a) Characteristics and assumptions of representative farm systems may not be valid for the whole catchment and subsequent impact on loss rates is compounded with extrapolation to catchment losses.

(b) The virtual farms are catchment specific.

(c) Additional modelling may be needed for the representative farms to be plausibly extrapolated across soils and climates in the catchment.

(d) The full range of current land uses in the catchment may not be represented.

82. The likely uncertainty of data inputs and ability to manage uncertainty given by Freeman et al. (2016) is given as:

"**<u>Moderate</u> uncertainty of data inputs. <u>Moderate</u> ability to manage uncertainty**".

83. I believe that the methodology of selecting B+LNZ survey sheep and beef farms gives us the ability to reduce some of the uncertainty in the data inputs, and therefore improves model representation and reliability, from the HWRO model. However, all modelling results should be treated with caution.

How the phosphorus sub-model works

84. 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).

85. 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.

86. The P model estimates sources of P from two sources:

(a) *background* (soil) losses; and

(b) *incidental* losses from fertiliser and effluent.

87. 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.

88. 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, 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).

89. Erosion is an important source of P loss to water. Overseer currently takes into account 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).

90. Overseer is not a spatial tool whereas P losses are spatially variable, therefore, in order to successfully capture P losses from CSAs the use of blocking in Overseer will be hugely important. I am concerned that the latest version of Overseer, OverseerFM, has been designed to reduce the number of blocks that the user has to split the farm into. 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.

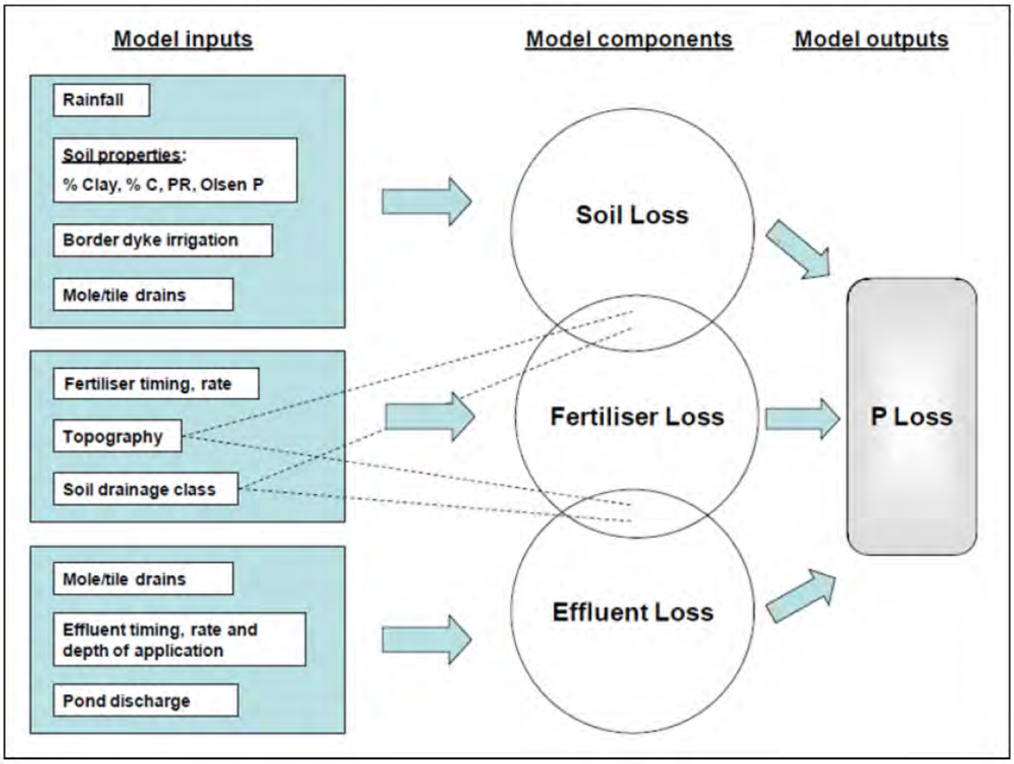

Figure 5: Conceptual diagram of model structure (Source: Gray *et al.* (2016).

91. 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 (version6)” (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. Adding to the degree of uncertainty are a number of 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) Components of the model with less raw data with which to generate algorithms thus the extrapolation to other factors/characteristics, e.g. soil types, may result in a greater level of uncertainty;

(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 effect only some farms and can effect farms to differing degrees.

92. The degree of the uncertainty is influenced by which of the above factors are relevant and, importantly, if a scenario combines multiple factors, which could compound the "error"/variability of an estimate. For example, a scenario may have multiple components with less raw 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. This will be elaborated on through HS2.

Areas of Overseer that have higher uncertainty or are not modelled at all.

93. Three specific agricultural systems that are not adequately modelled due to scarcity of data are:

(a) Arable cropping blocks;

(b) Cut and carry blocks; and

(c) Fodder (forage) crop blocks.

94. B+LNZ acknowledges fodder cropping is a high risk practice and while there is some measured data on P losses, there needs to be more. In addition, Overseer assumes that the topography on a crop or fodder block is flat. This will have 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.

95. 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.

96. 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 (Watkins and Selbie, 2015) that Overseer is intended to cover.

97. 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).

98. 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. I am not proposing that Overseer is not used at all in regulation given that alternatives such as input controls on stock numbers for example, have significant issues of their own. This will be considered further in HS2.

99. However, the use in policy needs careful consideration to enable the appropriate use of the model to reduce risk and assist with informing farm management approaches. Given the evidence set out above, there are

significant risks associated with utilisation of the model to grandparent farming practices to a particular number 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.

OTHER MODELLING TOOLS THAT COULD HAVE BEEN CONSIDERED

100. There are other tools available that may help add to the consideration 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 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).

104. The downside to the methodology of modelling analysis that was conducted for the initial PC1 work is that it does not incorporate actual farm data but rather a user defined 'average' farm and therefore tools such as MitAgator and LUCI cannot be used as there is no spatial data to represent the modelled 'farm'.

105. It also modelled on a steady-state basis and thus did not account for between-year variation. AgInform® modelling showed that using a steady-state approach for a sheep and beef property resulted in a 30% over estimation of earnings before interest, tax, depreciation, depreciation and amortization (EBITDA; Rendel, J (2019) pers comms) compared to a multi-year version taking into account a 10-year variation in climate and pasture data.

106. Going forward tools such as AgInform®, MitAgator and LUCI could be hugely valuable as part of a suite of tools to help aid in the generation of an

individual Farm Environment Plan (FEP). They would add value to the Overseer results, identify critical source areas (CSAs) on farm, show the optimal farm system and financial outcome (EBITDA), and aid in understanding the implications of individual farm emissions (leaching, GHG, contaminant loss) ona wider catchment scale.

107. Tools such as AgInform®, LUCI and MitAgator will help farmers and communities to understand their natural capital stocks and nutrient flow pathways at both a catchment and farm-level in order to build tailored FEPs.

SUMMARY OF SHEEP AND BEEF FARMS IN WAIKATO

108. This work was conducted to obtain information on the nutrient profile of sheep and beef farms in Waikato that are in the B+LNZ Sheep and Beef Farm Survey (the "Survey") in order to:

(a) review the data used in the HRWO modelling and economic assessments which underpin PC1; and

(b) undertake further analysis on the implications for sheep and beef farmers of application of the PC1 provisions as well as to test alternative approaches, which will be presented as part of hearing streams 2 and 3.

109. B+LNZ Survey farms undergo a comprehensive interview, data-collection and analysis process each year. The data obtained in the Survey includes all physical and financial data, livestock numbers and transactions, revenue and expenditure, fertiliser purchases and application, supplementary feed, and cropping rotations.

110. In addition to the regular survey data, each farm is visited in order to gather further data for the purpose of generating a nutrient budget. This included blocking of the farm into land management units (LMUs) for Overseer, obtaining information on stock management policy, fertiliser applications to the different LMUs, and crop rotations.

111. Soil types were taken from Landcare Research's S-map database (https://smap.landcareresearch.co.nz/).

112. The data discussed here comes from analysis using the Overseer version 6.3.0.

113. This evidence is within my area of expertise as I have worked with the Overseer model for the past 10 years, including testing new versions prior to release.

114. A total of 38 farms were modelled for the 2015/16 year. These consisted of; six Hard Hill Country or Farm Class 3, 21 Hill Country (Farm Class 4), and 11 Intensive Finishing (Farm Class 5) farms.

115. Mr Burtt's evidence describes the Survey as a sample survey randomly selected to reflect the country's livestock base. For this reason, I believe that the figures we present are representative of the nutrient losses from sheep and beef farms in Waikato when using Overseer version 6.3.0.

Modelled N loss from Sheep and Beef Survey farms

116. Weighted average nitrogen leaching losses were 17 kg N/ha/yr and farm class averages were 14, 18 and 21 kg N/ha/yr for Hard Hill Country, Hill Country and Finishing farms, (Farm Classes 3, 4 and 5) respectively. This figure is similar to the average of 18 kg N/ha/yr estimated as part of the Southland Economic Project for 43 Southland farms using Overseer v6.2.0 (Anon., 2017)

117. Nitrogen leaching losses are influenced by a number of factors including: soil type, stocking rate (i.e. the carrying capacity of an area of the farm), the classes of livestock, stocking density, and farm management practices (e.g. grazing of crops in winter). These are outlined in more detail below.

118. Of the 15 New Zealand Soil Orders 14 are included in Overseer. Of these, seven are represented in the Survey modelled farms. These are: Allophanic, Brown, Granular, Organic, Pumice, Recent and Ultic. Farms modelled will have one or more of these soil orders present.

119. Soil type has an influence on nitrogen losses from below the root zone with excessively free-draining soils more prone to leaching losses. However, with the Soil Orders present there is more variation in nitrogen leaching caused by stocking rate than soil type.

Stocking rate

120. Stocking rate influences are evidenced in Figure 6. This shows an increase in nitrogen losses below the root zone as farm stocking rate increases beyond around 12 su/ha (RSU/ha total farm area).

121. It can be seen that those farms with a higher N leaching loss (above 23 kg N/ha/yr) have one or more of the following farm management practices;

(a) Dairy grazing,

(b) Wintering livestock on a brassica crop,

(c) Maize cash crops, or

(d) A combination of them.

122. The farm with the highest leaching loss is farm 2 which has dairy wintering, winter cropping and a higher stocking rate (20 RSU/ha).

123. Mr Burtt outlines in his evidence that there is minimal dairy grazing on sheep and beef farms in Waikato with around three-quarters of farms in Waikato-BOP not earning any revenue from dairy grazing. The majority of the dairy grazing that does occur is on Hill Country (Farm Class 4) and Finishing farms (Farm Class 5) with nearly none on Hard Hill Country (Farm Class 3).

124. Of the 38 B+LNZ Sheep and Beef Farm Survey farms modelled none of the Farm Class 3 farms had dairy grazing, six of the 21 Farm Class 4 farms had dairy grazing and two of the 11 Farm Class 5 farms had dairy grazing. This was 79% of the farms with no dairy grazing.

125. In addition, Mr Burtt also points out that approximately 70% of sheep and beef farms did not have any winter grazing in 2016-17 and that of those farms that did conduct winter grazing it was on less than six percent of their effective area.

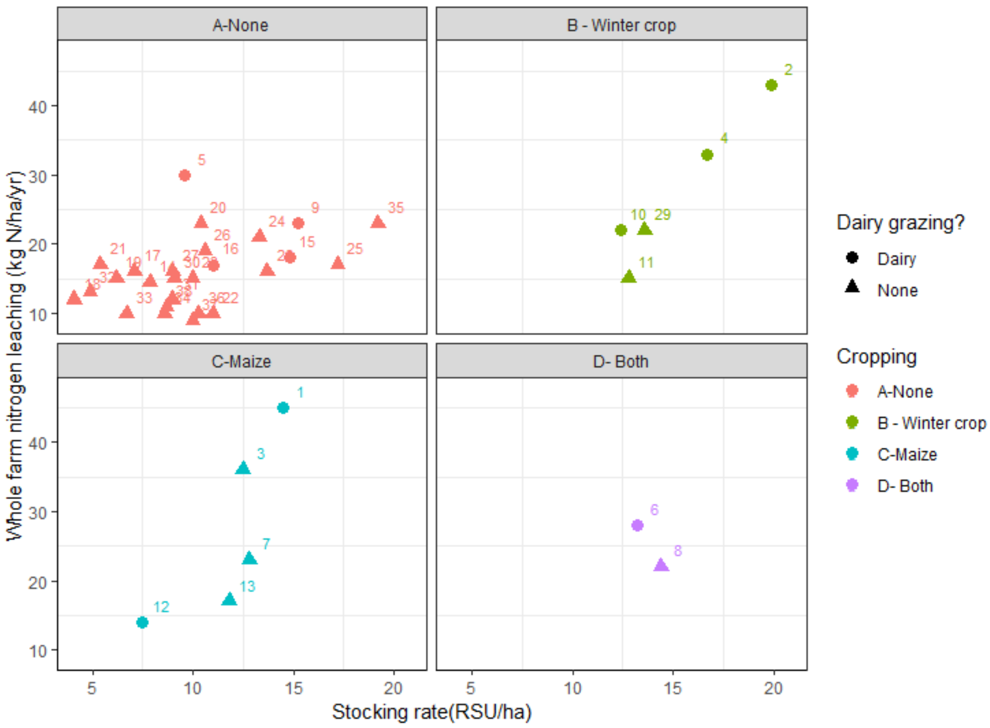

Figure 6: Nitrogen leaching figures for Overseer modelled Waikato B+LNZ Sheep and Beef Survey Farm farms for the 2015/16 year

Stock class

126. In addition to stocking rate, the size of the animals has an impact on nitrogen leaching loss. This is because larger animals (e.g adult cattle) have larger urination events and their urine patches can contribute as much as the equivalent of 1000 kg N/ha per event. This compares to around 500 kg N/ha in a sheep urine patch (Haynes and Williams, 1993).

127. Larger animals also have a greater impact on soil damage during wet weather events.

Stocking density

128. Stocking rate is a description of the annual number of stock units a farm can carry. Stocking density relates to the number of stock units on an area of land at any one time.

129. Farming practices that are high in stocking density include intensive winter grazing on crops where stocking density can be 300-600 cows/ha (2,250-4,500 su/ha; Drewry et al., 2008).

N losses by block

130. Looking further into N losses by block that result in the overall farm N loss values depicted in Figure 7 we can see that there are particular blocks that have considerably higher losses than the overall average or the pasture blocks. Whole farm N leaching losses range from 9-45 kg N/ha/yr with individual block losses ranging from 2.8 kg N/ha/yr for trees to 212 kg N/ha/yr for rape.

131. N losses on pasture blocks average 17.5 kg N/ha/yr (8-33 kg N/ha/yr), whereas N losses from crop range from 49 kg N/ha/yr to 213 kg N/ha/yr for rape.

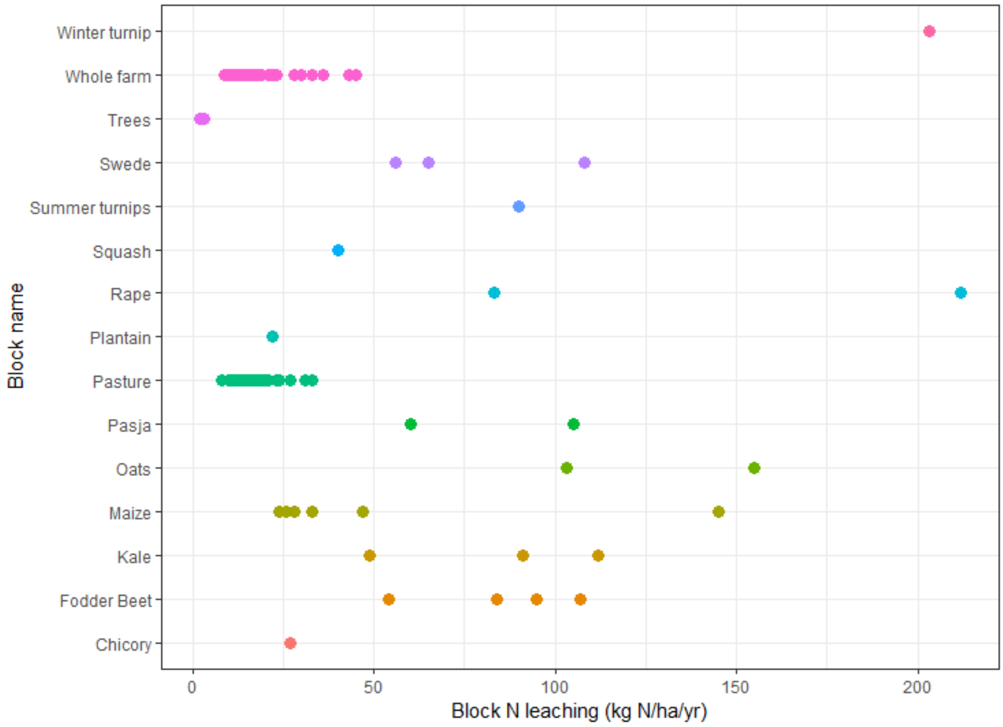

Figure 7: Overseer predicted N leaching block losses across the 38 modelled Waikato B+LNZ Sheep and Beef Survey Farm farms for the 2015/16 season.

132. Losses from crops can be higher than pasture for a number of reasons including: Relatively high stocking density as explained above in paragraph 130, a period of high rainfall which, when combined with high stocking density, moves the nitrogen deposited in urine down through the soil profile below the root zone where it is then leached, and bare soil following grazing

which is vulnerable to nitrogen leaching losses because there are no plants available to take up the nitrogen in the soil.

133. It is important, however, to note that cropping plays an important part in the sheep and beef farming system. It is used for pasture renewal and to provide adequate feed over the winter months when pasture supply maybe low.

134. Often the cropping component on a sheep and beef farm (be it a winter brassica crop, or a maize silage crop) is grown to provide a valuable source of income for sheep and beef farmers while supporting the dairy industry. Overall the impact on the whole farm N and P loss may be minimal depending on the proportion of the farm cropped.

135. There are ways that the contaminant losses from crop paddocks can be reduced. Appropriate management responses for cropping include:

(a) Paddock selection so that high risk paddocks are not cropped

(b) Crop establishment methods:
   (i) Minimum tillage;
   (ii) Sowing across slopes so that crop rows act as buffers for sediment, P and *E.* coli capture during grazing;
   (iii) Soil testing and fertiliser applications based on those soil tests and crop requirements.

(c) CSA management:
   (i) Identify and then void sowing CSAs in crop;
   (ii) Fence stock out of CSAs;
   (iii) If CSAs are cropped, graze them last when weather conditions allow.

(d) Crop grazing management:
   (i) Grazing from the top of a slope down;
   (ii) Have lower stocking densities;
   (iii) Have younger stock or smaller stock types on higher risk areas;
   (iv) Back fence to avoid stock going back over bare soil.

(e) Planting a catch crop as soon after winter grazing as possible to 'mop' up any nitrogen in the soil profile.

Modelled P loss from survey farms

136. Average phosphorus losses were 1.4, 1.5 and 1.4 kg P/ha/yr for Hard Hill Country, Hill Country and Finishing farms respectively. The range in losses were 0.8 - 4.1, 0.4 - 4.0, and 0.2 - 4.6 kg P/ha/yr.

137. However, farm class itself is not a determinant of P loss. Soil type is a better predictor of farm P loss. The average losses for each soil type are shown in Table 1.

Table 1: Soil order and P loss for 38 Sheep and Beef Farm Survey farms in Waikato for the 2015/16 season.

Soil Order	**P loss (kg P/ha/yr)**	**Farms in sample (no.)**
Allophanic	1.0	20
Recent	1.0	1
Brown	1.1	4
Organic	1.2	3
Ultic	2.3	6
Pumice	2.6	2
Granular	2.8	2

138. The predominant soil class on a property has a strong influence on predicted phosphorus loss risk. Figure 8 shows that the high-risk soil classes for P loss are Ultic, Granular and Pumice.

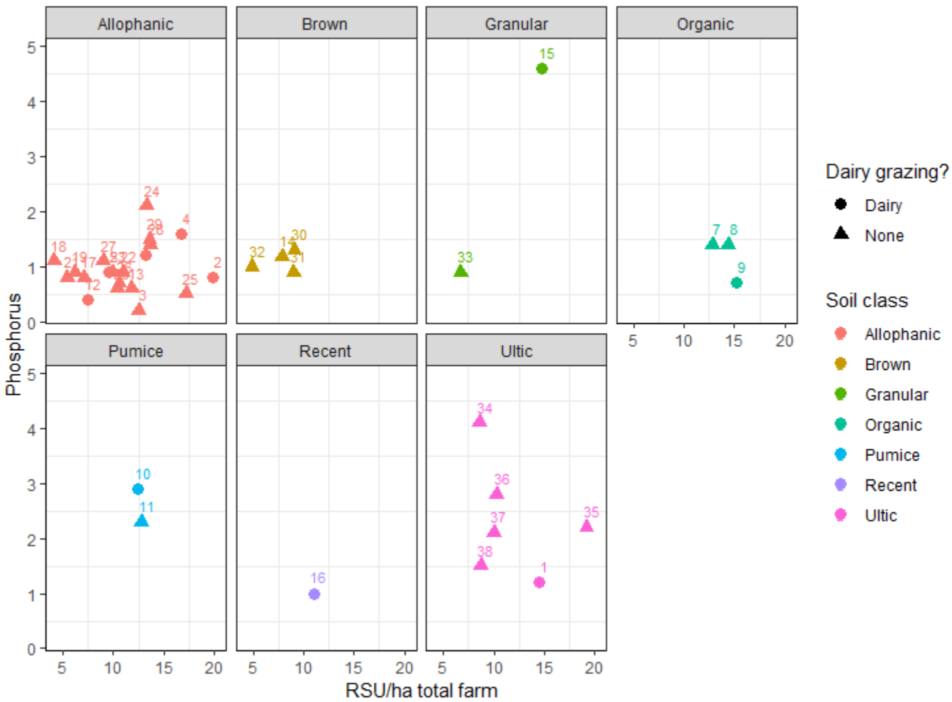

Figure 8: P loss risk estimates as predicted by Overseer v6.3.0 of 38 Sheep and Beef Farm Survey farms in Waikato for the 2015/16 season.

139. Investigating further the farm with the highest P loss (farm 15) also has dairy grazing and a higher stocking rate (Figure 8). All these factors combine with the risky granular soil to result in a high P loss.

140. In comparison, farm 2 has dairy grazers and the highest stocking rate of all the farms modelled but is on a low-risk Allophanic soil, thus the P losses are low. It's N leaching losses, however, are the second highest in the group (see paragraph122).

141. When looking at the N and P losses to water it can be seen that not all farms with high P losses have high N losses and vice versa (Figure 9). Thus, it is important to take into consideration the receiving environment.

142. This is why I support the use of farm environment plans (FEPs) that take into account the receiving environment, the farm system, the soil type, and tailor mitigation strategies to maximise the farm profitability, while working within the constraints of the natural capital of the land.

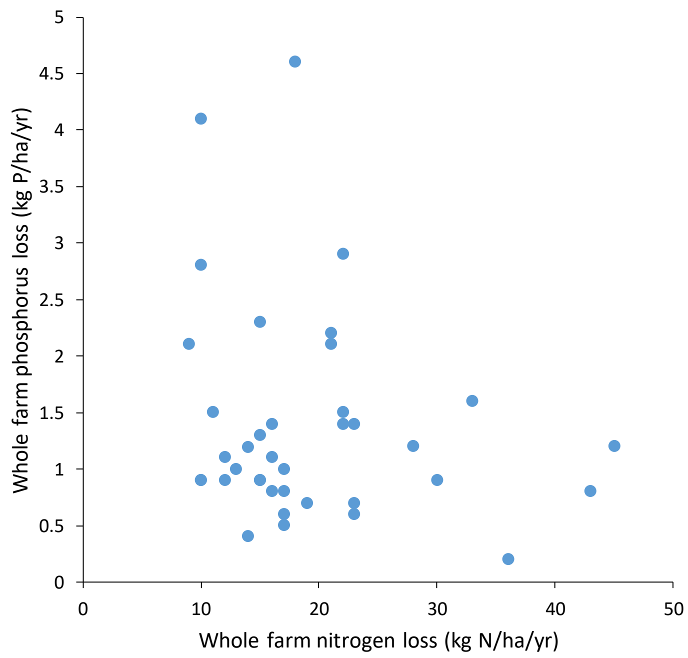

Figure 9: Relationship between N and P loss for the 38 Sheep and Beef Farm Survey farms in Waikato as modelled by Overseer v 6.3.0 (2015/16 season)

143. In summary, the majority of the sheep and beef sector is extensively farmed with low inputs and low N leaching losses. Of the modelled Sheep and Beef Survey Farm farms those with a SR below 15 SU/ha had an average leaching loss of 17 kg N/ha/yr (range 9 to 23 kg N/ha/yr).

144. The farming practices that have a higher risk of high N leaching losses are:

(a) Winter crop grazing;

(b) Cropping (without grazing e.g. maize);

(c) Intensive grazing (above around 20 SU/ha); and

(d) Mature cattle

145. It would, therefore, be effective, efficient, and equitable, where policy intervention was required, that the focus be on potentially higher environmental risk activities. Policy intervention shoulddeal with those contaminants which are discharged via overland flow pathways, such as sediment, through identifying and mitigating CSAs and provide flexibility for low input systems (say below 15 SU/ha average N loss of 17 kg N/ha/yr).

This could be provided in relation to the farms geology and soil to provide a more effective measure of risk in relation to a farm system. This will be elaborated on through HS 2.

SUMMARY OF N AND P LOSSES FROM DAIRY AND SHEEP AND BEEF FARMS – PUBLISHED DATA

146. Obtaining nutrient leaching information from actual dairy farms in Waikato is very difficult. Most of the information published uses an 'average model' farm rather than modelling a range of actual farms and presenting an average result, which implies there is a range of outcomes. Figures from actual farm survey are shaded grey in Table 2. The remainder of the data sets use data from a range of sources including MAF monitor farms, Dexel, and Dairy Base to 'build' an 'average' farm.

147. This methodology is common due to the difficulty in surveying a true representation of the population combined with the cost to do this work and the time required to build up a trusting relationship with the farmers and a labour force skilled in the level of detail required to gather such information. The use of model farms is common practice for comparing scenarios rather than gaining a true understanding of the actual losses of a sector. To gain a true understanding of the losses of a sector it is best to model a representation of actual farms (as I have done).

Table 2: Estimates of Waikato dairy and sheep/beef farm N leaching in the literature (grey shading are actual farms rather than 'average' farms).

Region/ Location	Year/ season	N Leaching	Range	P loss to water	Range	Overseer version	Ref
Dairy							
National average		44	36-61	1.1	0.5-2.3	6.2.1	A
Upper Waikato	12/13	40				6.1.2[1]	B
Waipā-Franklin	12/13	30				6.1.2[1]	B

Region/ Location	Year/ season	N Leaching	Range	P loss to water	Range	Overseer version	Ref
Waikato – 247 farms		39	16-112[3]				D
Waikato (MAF)	97/98	33	18-68	1.0	0.1-2.3	5.0.10	E
Waikato (Dexel)	97/98	32	24-39	1.3	1.0-1.3	5.0.10	E
Waikato (MAF)	02/03	42	30-53	1.0	0.2-1.8	5.0.10	E
Waikato (Dexel)	02/03	40	31-51	1.3	1.3-1.5	5.0.10	E
Waikato	97/98	32	26-39	0.8	0.7-0.9	5.4.3	F
Waikato	99/00	31	25-39	0.8	0.6-0.9	5.4.3	F
Waikato	00/01	34	25-42	0.8	0.7-.09	5.4.3	F
Waikato	01/02	38	30-51	0.8	0.7-0.9	5.4.3	F
Waikato	02/03	39	42-48	0.8	0.7-0.9	5.4.3	F
Waikato	03/04	39	31-49	0.8	0.8-0.9	5.4.3	F
Waikato	04/05	39	32-49	0.8	0.7-0.9	5.4.3	F
Waikato	05/06	41	34-44	0.8	0.7-0.9	5.4.3	F
Waikato	06/07	45	37-60	0.8	0.7-0.9	5.4.3	F
Waikato	07/08	38	33-47	0.8	0.7-0.9	5.4.3	F
Waikato		37.7	31.8-43.6[4]			APSIM	G
Upper Waikato	06/07	45	31-52	2.2	0.7-4.3	5.3.6	H
Waikato	00/01	36				Not given	I
Waikato	08/09	47				Not given	J
Scott Farm	11/12	56				Not given[5]	K, L
Toenepi	01-10	32[6]				Various	M
Toenepi	2001	22				Not given	N
Toenepi	2009	28				Not given	N

Region/ Location	Year/ season	N Leaching	Range	P loss to water	Range	Overseer version	Ref
Sheep and Beef							
Waikato		Unclear[8]	10-28		0.3-1.0	6.1.2[1]	C
Waikato	16/17	17 14/18/21	9-45	1.4	0.2-4.6	6.3.0	This report[7]
National average		16	11-31	1.0	0.2-5.3	6.2.1	A
Waikato	97/98	8	4-19	1.0	0.2-1.8	5.0.10	E
Waikato	02/03	10	5-19	1.7	0.8-3.3	5.0.10	E
Waikato	95/96	10/13/16[2]		2/2/2[2]		5.4.3	F
Waikato	96/97	10/13/15[2]		2/2/2[2]		5.4.3	F
Waikato	97/98	10/13/15[2]		2/2/2[2]		5.4.3	F
Waikato	98/99	10/13/17[2]		2/2/2[2]		5.4.3	F
Waikato	99/00	10/13/16[2]		2/2/1[2]		5.4.3	F
Waikato	00/01	9/13/16[2]		2/2/1[2]		5.4.3	F
Waikato	01/02	9/13/16[2]		2/2/1[2]		5.4.3	F
Waikato	02/03	9/14/15[2]		2/2/1[2]		5.4.3	F
Waikato	03/04	9/14/17[2]		2/2/1[2]		5.4.3	F
Waikato	04/05	10/14/17[2]		2/2/1[2]		5.4.3	F
Waikato	05/06	10/14/17[2]		2/2/1[2]		5.4.3	F
Waikato	06/07	10/14/16		2/2/1[2]		5.4.3	F
King Country	08/09	12				Not given	J

A -(Shepherd et al., 2016b)
B - (DairyNZ, 2014)
C- (Olubode-Awosla et al., 2014)
D - (Beukes et al., 2012)
E - (Judge and Ledgard, 2004)
F - (Judge and Ledgard, 2009)
G - (Romera et al., 2017)
H - (Longhurst and Smeaton, 2008)
I - (Ledgard et al., 2003)
J - (Smeaton et al., 2011)
K -(Chapman et al., 2012)
L - (Beukes et al., 2014)
M - (Monaghan et al., 2008)
N - (Monaghan and De Klein, 2014)
[1] (Doole et al., 2015)
[2]Farm classes 3/4/5
[3]Taken from Figure 1 Farm gate N surplus vs N leached

[4]Range is for same farm modelled over 10 years of climate data
[5]Includes measurements using ceramic cups
[6]Average figure over the 10 years of measurements
[7]B+LNZ survey data
[8]Unclear, see paragraph 168

148. Earlier versions of Overseer had an accuracy of N leaching prediction of approximately ± 25-30% (Ledgard and Waller, 2001). Thus, there is potential for the Overseer generated figures in Table 2 to vary up or down by up to 20% depending on what version of Overseer was used and whether components of the farm modelled are those components of the Overseer model with large uncertainties. Examples would be:

(a) irrigation in versions prior to version 6.2;

(b) effluent management systems prior to version 6; and

(c) phosphorus losses prior to version 5.2.

149. References E and F in Table 2 present results for both the dairy and sheep & beef sectors over time using the same version of Overseer (5.4.3) for analysis. This enables interpretation of the trends in N and P loss without the data being compromised by changes in Overseer version.

150. Dairy losses presented by Judge and Ledgard (2004, 2009) show an increasing trend in N losses from the 1997/98 to the 2006/07 seasons. N losses trend upwards from 32 to 45 kg N/ha/yr. The 07/08 loss is 38 kg N/ha/yr. P losses remain static for the same period at 0.8 kg P/ha/yr.

151. Sheep and beef losses presented by Judge and Ledgard (2009) are presented by Farm Class. For the years from 1995/96 to 2006/07 the N losses for Farm Class 3 fluctuate between 9 and 10 kg N/ha/yr. Farm Class 4 losses are 13 kg N/ha/yr until 2002/03 than then they remain at 14 kg N/ha/yr. Farm Class 5 losses fluctuate between 15 and 17 kg N/ha/yr over the time. P losses for farm classes 3 and 4 are 2 kg P/ha/y and for farm class 5 they drop from 2 kg in the first 4 years to 1 kg P/ha/yr for the remainder of the monitoring period.

152. These data sets of Judge and Ledgard (2004, 2009) highlight the large difference in N leaching losses between the dairy and sheep & beef sectors in the Waikato. Average nitrogen leaching from the dairy sector is 194 to

450% higher than that of the sheep and beef sector (Judge and Ledgard, 2009).

Table 3. Percentage difference in N leaching losses between dairy and sheep & beef farms in published data from 1997/98 –2006/07 using Overseer v5.0.10 and v5.4.3 and estimated 2015/16 dairy N leaching calculated by applying the 97/98-06/07 percentages differences to 2015/16 B+LNZ survey data using Overseer v6.3.0.

Year	**Dairy N loss (kg N/ha/yr) v5.0.10 & v5.4.3**	**Sheep and beef N loss (kg N/ha/yr) v5.0.10 & 5.4.3**	**Difference in N leaching (% that dairy is higher than sheep and beef)**	**Sheep and Beef Farm class N value used for comparison**	**Dairy 16/17 calculated from B+LNZ (kg N/ha/yr) V6.3.0**
97/98[1]	33	8	413%	Ave 3/4/5	70 kg N/ha/yr
02/03[1]	42	10	420%	Ave 3/4/5	71
97/98[2]	32	10	330%	3	46
97/98[2]	31	13	238%	4	45
97/98[2]	34	15	226%	5	46
99/00	31	10	310%	3	43
99/00	31	13	238%	4	43
99/00	31	16	194%	5	41
02/03[2]	39	9	433%	3	60
02/03[2]	39	14	278%	4	50
02/03[2]	39	15	260%	5	55

06/07[2]	45	10	450%	3	63
06/07[2]	45	14	321%	4	58
06/07[2]	45	16	281%	5	59

[1]Judge & Ledgard, 2004 [2]Judge & Ledgard, 2009

153. If I take the B+LNZ figures for 16/17 of 14/18/21 kg N/ha/yr for farm classes 3/4/5 then the losses using the % difference between the sectors presented in Table 3 would be between 45 and 63 kg N/ha/yr (see orange column in Table 3).

154. The ability of Overseer to accurately predict N leaching values improves over time as more research data becomes available to improve the model. Thus, it would be expected that estimates in more recent versions of the model are more accurate than older versions.

155. Overseer assumes best management practice (BMP). One key factor is effluent pond management. Overseer assumes that effluent ponds are sealed and have adequate storage. Waikato Regional Council monitoring flights have found non-compliance in the range of 10-20% (Anon., 2011). Thus, actual losses are likely higher than those modelled under BMP.

156. Nutrient losses change with changing versions of Overseer. An example for actual farms is given below (these farms are whole farm systems so include support blocks for young stock. Milking platform losses are given in brackets).

157. Analysis of the change in N loss from the same file in versions 5.4.8 and 6.3.0 of Overseer shows an increase in N leaching loss between 44 and 95%.

158. This percentage increase in N leaching loss due to version change is of more concern for systems with an already high N leaching figure. For example, the milking platform on dairy farm in Table 4 increased by 73% from 26 kg N to 45 kg N/ha/yr. Which is an extra 19 kg N/ha/yr. If the extensive Farm Class 3 farms from Judge and Ledgard (2009) that were modelled using version 5.4.3 of Overseer increased by 73% this would take them from an average of 10 to 17.3 kg N/ha/yr which is an increase of 7.3

kg N/ha/yr, less than half the actual increase in per hectare N leaching loss of the dairy farm.

159. This percentage increase is huge and represents a major issue when using Overseer to give a N leaching figure for regulatory purposes. A farm system that may be under a limit in one version of Overseer may be greatly exceeding the limit in a later version with no changes whatsoever to the farming system or Overseer file.

160. In addition, the impact of the increase in N leaching loss is far greater on intensive farms (for example dairy farms) with an already high N leaching loss.

161. Further modelling analysis to support paragraph 156 will be presented in HS2 for the pastoral livestock sectors.

Table 4: Comparison of nitrogen leaching losses for the same Overseer files in two different versions of Overseer (v5.4.8 and v6.3.0)

Farm ID	**Description**	**Nitrogen leaching loss (kg N/ha/yr)**	
		Overseer v5.4.8	**Overseer v6.3.0**
A	Dairy in Southland (crop wintering)	24 (MP = 26)	(MP = 45)
B	Dairy in Southland – deep litter barn plus crop	19 (MP = 15)	37 (MP = 29)
C	Dairy in Southland – herd home	12 (MP = 18)	22 (MP = 26)

DIFFERENCES BETWEEN PREDICTED LOSSES FOR SHEEP AND BEEF FARM SURVEY FARMS AND DAIRY FARMS

162. Trying to find the base data used for the modelling in the HRWO Project is extremely difficult. It seems that the Dairy Base farms were taken from a report completed by DairyNZ after modelling over 200 farms and then reducing these to a subset of 26 to represent Waikato. Doole et al. (2015) mentions that Overseer v6.1.2 was used for the modelling and refers readers to the Waikato Dairy Farm Nitrogen Mitigation Impacts report (DairyNZ, 2014) for further information. This report presents average N leaching values for Upper Waikato (40 kg N/ha/yr) and for Waipā-Franklin

(30 kg N/ha/yr) with a range given, across the two catchments, of 10 – 60 kg N/ha/yr.

163. In terms of the base sheep and beef N and P loss figures used for the HRWO analysis, Doole directs the reader to a paper by Olubode titled "Improving water quality in Waikato-Waipā Catchment: Options for dry stock and dairy support farms" (Olubode-Awosla et al., 2014). This breaks down the sheep and beef sector to five different farm types. N and P loss figures are given for four of these (Table 5).

Table 5: N and P loss values for 5 scenario sheep and beef farms as presented by Olubode-Awosla et al. (2014)

Farm type	**N Loss (kg N/ha/yr)**	**P loss (kg P/ha/yr)**
Small lamb finishing	13	1.0
Hill country some finishing	?	?
Hill country with Maize & dairy	28	0.3
Hill country with dairy support	10	0.5
Bull and beef finishing	12	0.5

164. No information is given on the version of Overseer used to determine these results. No information is given on the overall regional N loss or the relative proportion of each of these property types within the region.

165. It is exceedingly difficult to have confidence in the scenarios and modelling presented in the modelling conducted in the HRWO Project in the absence of clarity around the figures used for the base scenario farms in relation to baseline N and P loss calculations and how those figures were generated.

166. As common methodology means all scenario testing must be conducted on a base file, and there is no clarity in the baseline values for the livestock sectors used in the base file, it follows that the values presented for the scenarios cannot be regarded with confidence either. I suggest that the percentage <u>change</u> from the baseline value to the different scenario values could be the figure used rather than actual values as there is no confidence

in the original baseline value. For example, a farm with a baseline value of 40 kg P/ha/yr and a scenario value of 29 kgN/ha/yr should be represented as a decrease in N leaching of 27. 5%. This means that if the baseline figure differs from the 40 kg N/ha/yr used the difference between the baseline is still relevant. If the baseline was actually 50 kg N and scenario testing meant that policy stated losses had to meet a target of 29 kg N then the actual percentage reduction would be 42%. The implications on farmers is huge if the baseline value is incorrect.

167. The figures provided in this report vary to those presented by Doole et al. (2015) via Olubode-Awosla et al. (2014). This represents the difference in modelling a farm from 'averaged data' and modelling a range of actual farms that are statistically representative of the farms in the region. As the same methodology was used in the HRWO Project to estimate the losses from the dairy sector then it could be assumed that the losses predicted by Overseer would be higher than those presented if a statistically significant representation of actual dairy farms was modelled.

168. Doole et al. (2016) state, in regard to the methodology of aggregating data into representative farms, that it "*is a pragmatic "half-way house" that is likely to introduce some precision error, in terms of estimating both contaminant losses and mitigation costs*". They also say that there is "*a shortage of data of a sufficient quality and quantity [which] restricts our capacity to represent individual farms with any precision*". In response to this I have presented data from, and analysis of, the individual farms in the B+LNZ Sheep and Beef Farm Survey which contains a statistically representative sample of farms in the region and that we strongly believe is of sufficient quality and quantity to provide a robust insight into the nutrient loss profiles for sheep and beef farms in the region.

169. In order to gain some clarity around the figures used for the base modelling B+LNZ sent a request to WRC, who sent it on to NIWA. NIWA provided a table with the raw data. B+LNZ then sent a request to WRC and NIWA for the input data to the table. The response was that DairyNZ held that data. A request was put to DairyNZ for the data and no response was received.

170. A spreadsheet was provided showing the breakdown of N and P losses per hectare by catchment for all the land use types (Table 6). Sheep and beef nutrient losses ranged between 10.2 and 11.8 kg N/ha/yr and 0.8 and 0.9

kg P/ha/yr. Dairy losses ranged between 18 and 44.3 kg N/ha/yr and 0.6 to 2.7 kg P/ha/yr while dairy support losses were intermediary at 15.6 to 27.2 kg N/ha/yr and 0.2 to 1.1 kg P/ha/yr. An assumed area of 61,602 ha was modelled under dairy support bring the combined dairy area to 308,008 ha which compares to 370,355 ha under sheep and beef. Urban and forestry figures were the same over all catchments modelled which is likely due to the scarcity of available data to suggest otherwise.

Table 6: Summary of nitrogen and phosphorus figures used for the HRWO Project

	Dairy	**Dairy Support**	**Sheep & Beef**	**Hort**	**Forest**	**Urban**
Total Ha	246,406	61,602	370,355	6,103	169,478	24,418
Ave N (kg N/ha/yr)	33.5	22.1	10.9	65.0	4	12
Max N (kg N/ha/yr)	44.3	27.2	11.8	66.8	4	12
Min N (kg N/ha/yr)	18	15.6	10.2	64.5	4	12
Ave P (kg P/ha/yr)	1.3	0.7	0.8	1.2	0.3	0.6
Max P (kg P/ha/yr)	2.7	1.1	0.9	1.3	0.3	0.6
Min P(kg P/ha/yr)	0.6	0.2	0.8	1.2	0.3	0.6

171. To the best of my knowledge the input data to this data set has not been published and has not been through the peer review process.

172. The dairy data modelled for the Waipā-Franklin and Upper Waikato has a small component of irrigation, although the farm level leaching losses are not given for irrigated land. The modelling assumed 5% of the area under dairying in Waipā-Franklin and Upper Waikato catchments was irrigated (DairyNZ, 2017). I am unsure if this is an accurate representation of the irrigated area in those sub-catchments or if the 5% can be extrapolated to the whole Waikato region.

173. The data I present from B+LNZ's Sheep and Beef Farm Survey farms show a higher N leaching profile for sheep and beef farms than that presented by the data provided by NIWA. I believe that this is the result of two factors:

(a) The methodology used - individual farms vs what were considered by the modeller to be 'typical'.

(b) The version of Overseer used - v6.3.0 vs version unclear.

174. The average N leaching value for sheep and beef properties in the spreadsheet obtained from NIWA is 10.9 kg N/ha/yr whereas the average of the values we calculated is 17 kg/N/ha/yr. Thus, our prediction is nearly 60% higher than the figure supplied by NIWA and used by Doole for the scenario analysis. This difference is a combination of the methodology used and the version of Overseer used, because as presented by Mr Burtt, the sheep and beef sector has not intensified in the intervening period.

175. Review of the NIWA nitrogen leaching profiles for dairy revealed that the profiles were low. Based on published literature along with my experience modelling actual farms the HRWO figures look to significantly underestimate the N leaching from the sector.

176. Modelled figures for 41 dairy farms in Southland (using similar methodology to the HRWO project) found an average N leaching loss (using Overseer v6.2.0) of 38 kg N/ha/yr and a range of 19 to 90 kg N/ha/yr (Anon., 2017). This compares to the range of 12 to 59 kg N/ha/ha for the Waipā-Franklin and Upper Waikato sub-catchments modelled (DairyNZ, 2014).

177. If we assume that a survey of a statistically significant representation of dairy farms would result in the same percentage increase in the dairy figures presented in the NIWA spreadsheet, then the average N leaching figure of 33.5 kg N/ha/yr would actually be 52.6 kg N/ha/yr. The same methodology takes dairy support land from an average of 22.1 kg N/ha/yr to 34.7 kg N/ha/yr (Table 7).

Table 7: NIWA N leaching values used in base file analysis compared with B+LNZ values

	N leaching presented by NIWA[1] (kg N/ha/yr)	**N leaching presented by B+LNZ (kg N/ha/yr)**
Sheep and Beef	10.9	17.0
Dairy	33.5	*52.6
Dairy support	22.1	*34.7

[1]Weighted average value

*Estimated assuming the same increase as observed in the B+LNZ Sheep and Beef Farm Survey data

178. Table 7 and paragraph 153 present two alternative methods for estimating a more accurate average N leaching figure for dairy farms in Waikato. The average value in Table 3 using the data from reference F is 53.5 kg N/ha/yr which is extremely close to the value of 52.6 kg N/ha/yr in Table 7. These figures were calculated from different dairy data sets but came up with the same N loss value.

179. There is one scenario where the percentage increase may be significantly higher than this 57% and that is irrigated land. This is due to changes in the Overseer model from version 6.1.3 to version 6.2.0 in 2015 (Anon., 2019). In 2015 there was a significant upgrade to the irrigation sub-model which would likely increase losses significantly. This will be addressed further in HS2.

Mitigation options for Dairy and Sheep and Beef farms modelled in the HRWO Project

180. Mitigation options for the HRWO Project for sheep and beef farms were modelled using the HRWO Model (Doole, 2015; Appendix 2):

(a) Reducing stocking rate for a small lamb-finishing farm.

(b) Planting areas of a steep slope in forestry and reducing stocking rate for a traditional hill-country farm with lamb finishing.

(c) Reducing maize area for a hill country farm with beef-breeding and maize for dairy support. Unclear if dairy animals are grazed on the property or the maize is exported.

(d) Increasing the sheep:cattle ratio for a hill county farm with a beef-breeding enterprise (no sheep) and maize silage for dairy support. Unclear if dairy animals are grazed on the property or the maize is exported.

(e) Substituting older cattle for younger cattle for a bull and prime-beef finishing operation

181. Scenario 1. Reducing the stocking rate by 25% for a small lamb finishing operation reduced the N leaching by only 2.5 kg N/ha/yr from an already low 11.5 to 9.0 kg N/ha/yr. The same reduction had a significant negative impact on farm profit reducing it from $502/ha to $325/ha. Phosphorus levels remained unchanged.

182. Scenario 2. Planting plantation forestry on steep slopes of the farm. This has almost no impact on an already low nitrogen leaching figure (7.8 to 7.5 kg N/ha/yr) and a slight reduction in P from 0.97 to 0.82 kg P/ha/yr. Farm profit was reduced from $423/ha to $404/ha (5% reduction in profit).

183. Scenario 3. Significant N losses were achieved by reducing the area of maize by 20 – 100% and replacing the maize with imported pasture silage. The loss removing all the maize was from 27.9 to 18.6 kg N/ha/yr with P remaining almost the same (0.31 increased to 0.33 kg P/ha/yr). Profit was reduced from $2,802/ha to $2,411/ha.

184. Scenario 4. This scenario was the one scenario that represented a win:win situation. By increasing the sheep:cattle ratio from a base line of 0:100 (with a female:male ratio of 80:20 for the cattle) to a sheep:cattle ratio of 70:30 the N leaching loss decreased from 10.1 to 8.2 kg N/ha. Profit increased from $370/ha to $710/ha and P remained the same.

185. Scenario 5. This farm has all male cattle and a stocking rate of 11.75 SU/ha. The scenarios were to gradually replace 2 yr or older cattle with less than 2 yr cattle and keep the stocking rate the same. Nitrogen leaching reduced from an already low 12.3 to 9.8 kg/ha/yr, P loss remained the same and farm profit decreased significantly from $382/ha to $151/ha.

186. The scenarios tested for sheep and beef primarily focused on N loss mitigations (with the exception of scenario 2). However, in the majority of sheep and beef farms N loss is not high and P and sediment losses would be of greater concern.

187. Scenario 2 looks at forestry planation. There was no scenario testing done looking at within farm CSA management (which can be modelled using tools such as MitAgator and LUCI).

188. Scenario 4 which increased the sheep:cattle ratio from 0:100 to 70:30 resulted in an increase in profit. However, it is important to note that the N leaching of the original scenario is already low at 12.3 kg N/ha/yr and it is an expensive process to increase your stock ratio so dramatically. It is unclear whether this analysis takes into account the cost of purchasing capital stock, shearing costs, tailing costs, sheep yards etc.

189. It can be seen from the scenarios above that there are very few drivers for dry stock farmers to reduce N leaching from already low levels (particularly for the more extensive farms with lower SRs; modelled here as 8.6 SU/ha) without having significant negative implications on profit.

190. In addition, those sheep and beef farms modelled with higher N leaching losses have a component of dairy support (Scenarios 3 & 4, leaching 27.9 and 10 kg N/ha/yr respectively) or have a high stocking rate incorporating adult cattle (Scenario 5, leaching 12.3 kg N/ha/yr).

191. Information for the dairy mitigation scenarios modelled in the HRWO model was provided by DairyNZ (DairyNZ, 2014; Doole, 2015).

192. Farm data was based on the 2012-13 season and involved the physical and financial data from 500 farms. This was reduced to 26 farms that covered a range of locations, systems, financial performance, N loss/ha and bio-physical characteristics (DairyNZ, 2014).

193. For each of the 26 farms they looked at de-intensification and restricted grazing mitigations. The flow diagram of mitigation options is attached in Appendix 3.

194. Results for de-intensification show a reduction of the Waipā-Franklin farm from 30 to 22 kg N/ha/yr by reducing the stocking rate from 3.1 to 2.7. The profit decreases from $2,566/ha to $2,288/ha. Incorporating restricted

grazing plus reducing stocking rate reduces N from 25 to 18 kg N/ha/yr. Profit reduces from $2,229/ha to $1,896/ha.

195. The base line leaching for the restricted grazing plus reduced stocking rate is lower than the original baseline (25 compared to 30 kg N/ha/yr). This was because “not all farms had a stage 2 scenario run as they could make significant reductions in N leaching without it” (DairyNZ, 2014). However, the N leaching values are still significantly higher than those of extensive sheep and beef and their profit/ha is significantly higher. The lowest N leaching value after mitigations have been applied is 24 kg N/ha/yr for the Upper Waikato and 18 kg N/ha/yr for the Waipā-Franklin farm.

196. A comparison of the level of intensification of the systems modelled requires the stocking rate for the dairy farms to be converted from cows/ha to stock units/ha. A value of 7.5 stock units/cow has been used as a midpoint in the range (6.5 for Jersey cows and 8.5 for Friesian cows) used by the Economic Service as a stock unit conversion (https://beeflambnz.com/data-tools/benchmarking-tool).

197. Table 8 shows that the stocking rate on dairy farms is significantly higher than that of sheep and beef farms. In the HRWO base farms, the dairy farms modelled are between 88 and 274% higher than the sheep and beef farms. Comparing the reduction in stocking rate scenarios modelled for both sheep & beef and dairy (without a stand-off) the dairy farms are still between 159 and 271% higher in stocking rate than the sheep and beef farms. Comparing the reduction in stocking rate scenarios for sheep & beef and dairy (with a stand-off) the dairy farms are between 59 and 260% higher in stocking rate than the sheep & beef farms.

198. The most profitable scenario (Scenario 3) of all those outlined in Table 8 is a baseline beef property with no sheep, a beef-breeding enterprise, and the use of maize-silage crops for dairy support. The profit of this scenario is $2,802 and the N leaching is 27.9 kg N/ha. The stocking rate is 8.6 SU/ha. The scenario test modelled was to reduce the maize area by up to 100% which reduced the profit by $391 to $2,411/ha and reduced the N leaching by 9.3 to 18.6 kg N/ha/yr.

199. Scenario 4 is another hill-country farm involving no sheep and a beef-breeding enterprise, also using maize-silage crops for dairy. In that scenario the N reducing scenario tested was to increase the sheep:beef

ratio from 0:100% to 70:30%. This increased the profit by $340/ha from $370 to $710/ha. The stocking rate was 8.6 SU/ha

200. It could then be assumed that for the Scenario 3 farm (no sheep and beef-breeding) the mitigation of altering the sheep:beef ratio from 0:100% to 70:30% would both increase profit and reduce N leaching. Combining the mitigations of changing the sheep:beef ratio and reducing the area in maize silage could significantly reduce the N leaching without significantly altering the profit. This scenario was not tested.

Table 8: Comparison in stocking rate, N leaching and profit per hectare of scenarios modelled in the HRWO model as presented by Doole (2015)

	Base SU	Base N leach (kg N/ha/yr)	Base profit/ha		Scenario SU	Scenario N leach (kg N/ha/yr)	Scenario profit/ha
Sheep and Beef							
Scenario 1	10 to 15	11.5	$502		7.5 to 11.25	9.0	$325
Scenario 2	8.5	7.8	$423		No change	7.5	$404
Scenario 3	8.6	27.9	$2,802		No change	18.6	$2,411
Scenario 4	8.6	10.1	$370		No change	8.2	$710
Scenario 5	11.8	12.3	$382`		No change	9.8	$151
Dairy without stand-off							
Waipā-Franklin	23.3 (3.1 cows)	30	$2,566		20.3 (2.7 cows)	22	$2,288
Upper Waikato	21 (2.8 cows)	40	$2,377		18.8 (2.5 cows)	30	$2,056
Dairy with stand-off							
Waipā-Franklin	22.5 (3 cows)	25	$2,229		19.5 (2.6 cows)	18	$1,896

Upper Waikato	19.5 (2.6 cows)	30	$1,960		18 (2.4 cows)	24	$1,768

201. The implications of this for PC1 are that sheep and beef farmers have limited options regarding reducing stocking rate for reduced N leaching. Sheep and beef farms already run stocking rates considerably lower than dairy farms (modelled in the HRWO project as up to 274% lower).

202. In addition, N leaching losses are already considerably lower for sheep and beef farms (particularly those farms without a component of dairy support, cropping to provide feed for dairy, or intensive beef operations). Baseline leaching losses for sheep and beef farms are below N leaching losses of the most extreme dairy scenario

SUMMARY OF HOW NUTRIENT LOSSES HAVE CHANGED OVER TIME – SHEEP AND BEEF

203. This work will be addressed in detail in HS2 where data will be presented for a subset of the survey farms who have been in the B+LNZ survey since 1990 and how their emissions profiles have changed over time.

204. As presented in the evidence of Mr Burtt sheep numbers in Waikato have declined by about 60% since 1990 and beef cattle number by about 20%. At the same time dairy number have increased by nearly 30%.

SUMMARY OF THE USE OF OVERSEER AND GRANDPARENTING TO 2014/15 OR 2015/16 YEARS AND THE IMPLICATIONS OF GP TO THOSE YEARS

205. A summary of the implications of grandparenting to 2014/15 or 2015/16 years and the implications of that grandparenting will be presented in HS2.

206. Extensive sheep and beef farms (the average SU for the Farm Class 3 and 4 farms in the B+LNZ Survey was 10 SU/total ha/yr or 12 SU/effective ha/yr) or farming below the natural capital of their land, have very few levers to pull in relation to reducing N leaching further. This is because these systems already have low inputs, including low fertiliser use and lower stocking rates, as they are farming to their grass curve or below it, and generally are net exporters of feed. These farming systems have already made significant eco efficiency gains as discussed in the evidence of Mr Burtt, such as

focussing on improving per animal performance, rather than in increasing stocking rates.

207. Conversely more intensive farming operations have greater ability to reduce nitrogen leaching significantly while still retaining flexibility in farming systems and viability. There have been a number of research papers and reports illustrating this. This is because these systems are higher input, with high fertiliser use, and high stocking rates, operating beyond their grass curve using bought in feed to fill surplus feed requirements. Therefore they have the ability to reconfigure their systems including dropping stocking rate while still retaining profitability. The Pasture21 programme showed that it is possible to reduce losses of N (and P) on dairy farms by up to 40% with little impact on production (Shepherd et al., 2016a). Modelling conducted by Shepherd (2016a) suggested that dairy N losses could be reduced by 10-20% without requiring infrastructure, but it would be required to reach a 40% loss. Their sheep and beef analysis showed that ongoing productivity gains were possible by the sector by improving per animal performance and focusing mitigations on sensitive areas of land to reduce the losses of sediment and P. This will be elaborated on further through HS2.

CONCLUSION

208. I believe that the base farm information on which all further modelling and scenario testing was conducted was incorrect.

209. I have shown that the nitrogen leaching figure for sheep and beef properties was under estimated by around 57% with a figure of 10.9 kg N/ha/yr used for the base analysis for HRWA which compares to B+LNZs figure of an average loss of 17 kg N/ha/yr.

210. I have shown via two different pathways that the actual N leaching loss for the dairy industry is more likely to be around 50 kg N/ha/yr than the 33.5 kg N/ha/yr average figure that was used for the HRWA analysis.

211. Dairy N leaching is between 240 and 450% higher than that of sheep and beef.

212. Overseer is a valuable tool in estimating N and P losses but it must be used with the knowledge that it has limitations.

213. I have presented data from actual farms modelled in different versions of Overseer and have shown the N losses increased by between 44 and 96%, just related to version change.

214. There are other tools available that provide spatial detail of farm N and P losses that can improve the estimates of whole farm losses (MitAgator), tools that provide information on the combined impacts of individual farm decisions at the catchment scale (LUCI), and tools that provide information on farm optimisation (AgInform).

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APPENDIX 1: EXAMPLES OF APPROACHES TO ESTIMATING NUTRIENT LOADS USING OVERSEER (FREEMAN ET AL., 2016)

Table 4
Examples of different approaches to estimating source nutrient loads using OVERSEER

Example 1. Use generic or literature nutrient loss values

Description	Industry average or typical nutrient losses are extrapolated to a catchment scale
Main strengths	▪ Easy access to information ▪ Can generate source load estimates quickly
Main challenges	▪ Generic estimates are not specific to the systems, soils and climates in the catchment and therefore may not reflect actual systems, soils or climates ▪ Can be unclear what level of practice has been modelled and what assumptions have been used in modelling ▪ Mitigations can be problematic to apply to these generic estimates if underlying assumptions are unknown
Resourcing implications	Few resources needed
Likely uncertainty of data inputs and ability to manage uncertainty (Appendix 5)	High uncertainty of data inputs. Low ability to manage uncertainty

Example 2. Use anecdotal case studies

Description	Some existing individual OVERSEER budget nutrient losses are extrapolated to a catchment scale
Main strengths	▪ Relatively easy access to information ▪ Can generate source load estimates quickly ▪ If anecdotal (individual) files are available, these can be updated with model version change ▪ Can be used to estimate current source loads
Main challenges	▪ Characteristics and assumptions of the anecdotal systems may not be valid for the whole catchment and subsequent impact on loss rates is compounded with extrapolation to catchment losses ▪ Confidentiality issues can hinder close scrutiny of input data ▪ Anecdotal files are often based on a single year i.e., a snapshot. This can be problematic if the year was atypical (see Section 8 - Averaging) ▪ Anecdotal systems may not cover all of the soils, climates, and systems in the catchment ▪ Current farm management practice encompasses everything from very poor to best management practice. The level of practice would need to be normalised for use in testing policy options and future scenarios ▪ If files were built by multiple modellers, may be difficult to get a consistent level of practice and data input standards ▪ Can be unclear what assumptions have been used in modelling ▪ Mitigations can be problematic to apply to these anecdotal files if underlying assumptions are unknown ▪ Risk of variable quality of information

Resourcing implications	Few resources needed
Likely uncertainty of data inputs and ability to manage uncertainty (Appendix 5)	High uncertainty of data inputs Low ability to manage uncertainty

Example 3. Use representative farms (few)

Description	Some virtual farm nutrient budgets are created to represent the mix of catchment characteristics and are extrapolated to a catchment scale
Main strengths	• Can engage farmers/ industry representatives in deriving information for models • As farms are virtual, they can be consistent with OVERSEER assumptions e.g., long-term climate (see Section 8 - Averaging) • Can produce reference files that can be updated with model version change • Can apply consistent level of practice and data input standards
Main challenges	• Characteristics and assumptions of few representative farm systems may not be valid for the whole catchment and subsequent impact on loss rates is compounded with extrapolation to catchment losses • The virtual farms are catchment specific • Additional modelling may be needed for the representative farms to be plausibly extrapolated across soils and climates in the catchment • The full range of current land uses in the catchment may not be captured
Resourcing implications	Moderate resources needed
Likely uncertainty of data inputs and ability to manage uncertainty (Appendix 5)	Moderate uncertainty of data inputs Moderate ability to manage uncertainty

Example 4. Use representative farms (many)

Description	Many virtual nutrient budgets are created to cover a range of farm systems, soils, and climates
Main strengths	• Can engage farmers/industry representatives in deriving information for models • As farms are virtual, they can be consistent with OVERSEER assumptions e.g., long-term climate (see Section 8 - Averaging) • Can produce reference files that can be updated with model version change • Can apply consistent level of practice and data input standards • Farm systems not confined to a particular catchment
Main challenges	• The full range of current land uses in the catchment may not be captured • Farms may need to be aggregated for use in testing policy options and future scenarios

Resourcing implications	Significant resources needed
Likely uncertainty of data inputs and ability to manage uncertainty (Appendix 5)	Low uncertainty of data inputs Moderate ability to manage uncertainty
Additional information	Software has been developed that allows many (hundreds) of OVERSEER files to be generated, run and summarised in very short times (minutes). These tools considerably reduce the resource implications of this approach, but require expert input for initial set up and checking of information produced

Example 5. Use actual farm budgets

Description	All farm nutrient budgets are collected for a catchment
Main strengths	• Can be used to assess current source load • Files can be updated with model version change • More closely represents what is occurring in the catchment than representative farms
Main challenges	• Current practice encompasses everything from very poor to best management practice – this approach can accommodate this in estimating source loads. The level of practice would need to be normalised for use in testing policy options and future scenarios • If there are many farms, they may need to be aggregated for use in testing policy options and future scenarios • Risk of variable quality of information • If only a single year is collected, this can be problematic if the year was atypical or for systems in transition (see Section 8 - Averaging) • Confidentiality issues can hinder close scrutiny of input data
Resourcing implications	Significant resources needed
Likely uncertainty of data inputs and ability to manage uncertainty (Appendix 5)	Low/Moderate uncertainty of data inputs (Low if model users are experienced, a consistent input standard is used (e.g., BPDIS, 2016) and high-quality data sources are used). Moderate-high ability to manage uncertainty.
Additional information	Software has been developed that allows a consistent set of modelling proxies (intended to represent industry agreed Good Management Practice) to be applied to existing OVERSEER files. This could overcome the challenge of unknown levels of practice with this approach[20].

[20] ECan Farm Portal: https://farmportal.ecan.govt.nz/. GMP tool: https://farmportal.ecan.govt.nz/GMPTool/Auth/Login?ReturnUrl=%2fGMPTool

APPENDIX 2: DOOLE, G. (2015) DESCRIPTION OF MITIGATION OPTIONS DELIVERED WITHIN THE ECONOMIC MODEL FOR HEALTHY RIVERS WAI ORA

8. Sheep and beef mitigations

Abatement-cost relationships were determined for drystock farms in the Waikato region. Based on a recent WRC survey of 450 drystock farms in the region (Kaine, 2013), 20 farms were selected for case-study analysis, to provide an adequate representation of farm system and spatial diversity within the catchment. Biophysical and financial information were collected for each farm during the case-study survey. These data were extrapolated to different spatial regions within the catchment also, using regional climate and financial data, for the purpose of generalisation. Utilising this information, FARMAX and OVERSEER were employed to identify the relationship between nitrogen leaching and farm profit for different scenarios on five representative farms. The farm-level data were validated through comparison with previous research and review by farmers, industry representatives, rural consultants, and scientists. Further information is provided in Olubode et al. (2014).

The first farm type for the drystock operations (DRY1) represented small lamb-finishing farms with some beef finishing. Average farm size ranged from 50 to 100 ha, with a high sheep: cattle ratio of 70: 30% and a high stocking rate of 10–13 stock units (SU) per ha. The primary mitigation practice evaluated for this farm type was a reduction in stocking rate. Most of the soils are well-drained, except for Puniu and Okupata soil types that are poorly-drained. Data regarding the levels of profit, nitrogen loss, and phosphorus loss computed for the different mitigation scenarios simulated for this farm are presented in Table 4. All N and P loss figures presented in Tables 5–9 are reported to two decimal places, given that these precise figures are those that arise as output from OVERSEER. However, it is recognised that small differences in these decimals are spurious, given the difficulty associated with estimating N and P loss from agricultural and horticultural enterprises. In particular, it is highly evident that there is incredibly small changes in P loss arising from the selected mitigations, in line with most scope for P management on drystock farms accruing to improved P fertiliser management (Section 4) and better soil conservation (Section 7).

Table 4. Levels of profit, nitrogen loss, and phosphorus loss for small lamb-finishing farms with some beef finishing (DRY1).

Soil types	Te Kuiti, Tumutumu, Otorohanga, Okupata, Puniu.		
Rainfall (mm/yr)	1,674		
Farm profit ($ ha^{-1})	**N loss to water (kg N ha^{-1})**	**P loss to water (kg P ha^{-1})**	**Mitigation practice utilised**
502	11.53	0.94	None (baseline)
464	10.82	0.94	Reduce stocking rate by 5%
416	10.34	0.93	Reduce stocking rate by 10%
388	9.82	0.93	Reduce stocking rate by 15%
354	9.31	0.93	Reduce stocking rate by 20%
325	9.03	0.92	Reduce stocking rate by 25%

The second farm type for the drystock operations (DRY2) represented traditional hill-country farms with lamb finishing. This farm involves a free-draining soil in a high-rainfall area. Average farm size ranged from 165 to 450 ha, with a high sheep: cattle ratio of 70: 30% and a low stocking rate of 8.5 SU/ha. The effective area of the farm that consists of steep slopes is assumed to be 10%. The primary mitigation practice evaluated for this farm type was the planting of the steep area in plantation forest. The cost and benefits of forestry management are included in the evaluation of this activity. Data regarding the levels of profit, nitrogen loss, and phosphorus loss computed for the different mitigation scenarios simulated for this farm are presented in Table 5.

Table 5. Levels of profit, nitrogen loss, and phosphorus loss for traditional hill-country farms with lamb finishing (DRY2).

Soil type	Waingaro		
Rainfall (mm/yr)	1,470		
Farm profit ($ ha^{-1})	**Nitrogen load (kg N ha^{-1})**	**Phosphorus load (kg P ha^{-1})**	**Mitigation practice utilised**
423	7.81	0.97	None (baseline)
420	7.76	0.94	Plant 20% of steep slope area and maintain original stocking rate elsewhere
412	7.69	0.91	Plant 40% of steep slope area and maintain original stocking rate elsewhere
404	7.61	0.88	Plant 60% of steep slope area and maintain original stocking rate elsewhere
399	7.55	0.85	Plant 80% of steep slope area and maintain original stocking rate elsewhere
404	7.52	0.82	Plant 100% of steep slope area and maintain original stocking rate elsewhere

The third farm type for the drystock operations (DRY3) represented a hill-country farm involving no sheep, a beef-breeding enterprise, and the use of maize-silage crops for dairy support. Average farm size ranged from 35 to 250 ha, with a female: male ratio for cattle of 80: 20% and a low stocking rate of 8.6 SU/ha. The primary mitigation practice evaluated for this farm type was the reduction in the area of maize-silage crop used for dairy support, with its replacement with imported pasture silage. The soil type is a well-drained soil, under a moderate-rainfall environment. Data regarding the levels of profit, nitrogen loss, and phosphorus loss computed for the different mitigation scenarios simulated for this farm are presented in Table 6.

Table 6. Levels of profit, nitrogen loss, and phosphorus loss for a hill-country farm that has a beef-breeding enterprise and utilises maize-silage crops for dairy support (DRY3).

Soil types	Otorohanga		
Rainfall (mm/yr)	1,246		
Farm profit ($ ha^{-1})	**Nitrogen load (kg N ha^{-1})**	**Phosphorus load (kg P ha^{-1})**	**Mitigation practice utilised**
2,802	27.91	0.31	None (baseline)
2,715	25.69	0.31	Reduce maize area by 20%
2,642	25.00	0.31	Reduce maize area by 40%
2,569	22.19	0.33	Reduce maize area by 60%
2,497	20.39	0.33	Reduce maize area by 80%
2,411	18.63	0.33	Reduce maize area by 100%

The fourth farm type for the drystock operations (DRY4) represented a hill-country farm involving no sheep, a beef-breeding enterprise, and the use of maize-silage crops for dairy support. Average farm size ranged from 35 to 250 ha, with a female: male ratio for cattle of 80: 20% and a low stocking rate of 8.6 SU/ha. The primary mitigation practice evaluated for this farm type was the introduction of sheep to reduce the nitrogen loss experienced on-farm. The farm involves moderate rainfall and well-drained soil types. Data regarding the levels of profit, nitrogen loss, and phosphorus loss computed for the different mitigation scenarios simulated for this farm are presented in Table 7.

Table 7. Levels of profit, nitrogen loss, and phosphorus loss for a hill-country farm that has a beef-breeding enterprise and utilises maize-silage crops for dairy support (DRY4).

Soil types	Tirau, Pukerata		
Rainfall (mm/yr)	1,239		
Farm profit ($ ha^{-1})	**Nitrogen load (kg N ha^{-1})**	**Phosphorus load (kg P ha^{-1})**	**Mitigation**
370	10.09	0.52	None (baseline)
425	9.85	0.52	Increase sheep: cattle ratio to 30: 70%
502	9.63	0.51	Increase sheep: cattle ratio to 40: 60%
575	8.70	0.51	Increase sheep: cattle ratio to 50: 50%
664	8.32	0.50	Increase sheep: cattle ratio to 60: 40%
710	8.15	0.50	Increase sheep: cattle ratio to 70: 30%

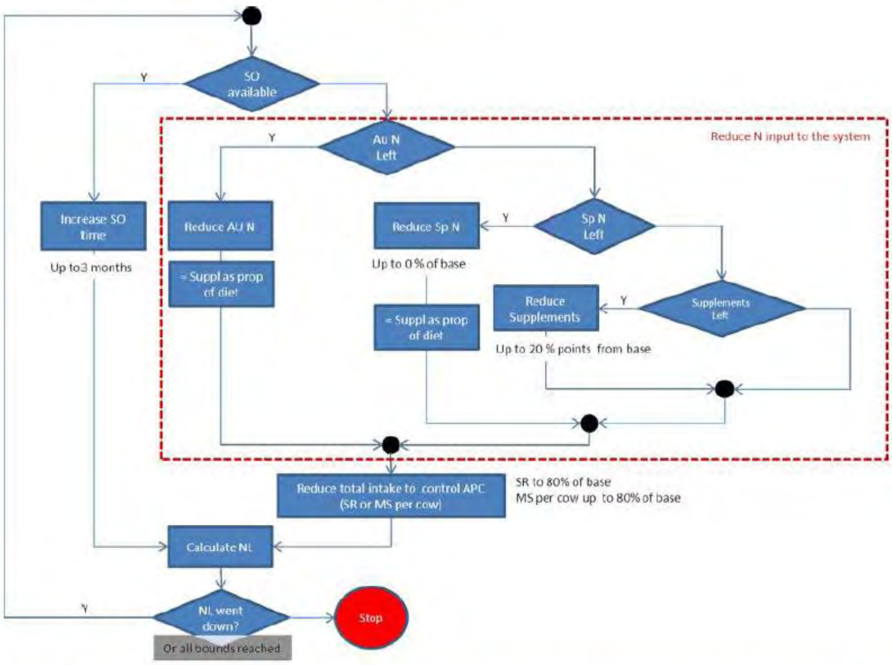
The last farm type for the drystock operations (DRY5) represented a bull- and prime-beef finishing operation. Average farm size ranged from 35 to 250 ha, comprised all male cattle and a high stocking rate of 11.75 SU/ha. The primary mitigation practice evaluated for this farm type was the substitution of older stock with younger cattle (under 2 years old), maintaining a constant stocking rate. The farm involves moderate rainfall on a well-drained soil type. Data regarding the levels of profit, nitrogen loss, and phosphorus loss computed for the different mitigation scenarios simulated for this farm are presented in Table 8.

Table 8. Levels of profit, nitrogen loss, and phosphorus loss for a bull- and prime-beef finishing operation (DRY5).

Soil types	Ohaupo, Otorohanga, Hamilton		
Rainfall (mm/yr)	1,286		
Farm profit ($ ha^{-1})	**Nitrogen load (kg N ha^{-1})**	**Phosphorus load (kg P ha^{-1})**	**Mitigation**
382	12.29	0.49	None (baseline)
275	11.46	0.49	Substitute 30% of 2 year or older cattle for less than 2 year old cattle at constant stocking rate
311	12.03	0.49	Substitute 40% of 2 year or older cattle for less than 2 year old cattle at constant stocking rate
309	12.12	0.49	Substitute 50% of 2 year or older cattle for less than 2 year old cattle at constant stocking rate
197	11.95	0.49	Substitute 60% of 2 year or older cattle for less than 2 year old cattle at constant stocking rate
151	9.83	0.48	Substitute 70% of 2 year or older cattle for less than 2 year old cattle at constant stocking rate

APPENDIX 3: FLOW DIAGRAM OF MITIGATION OPTIONS

Figure 13: Flow diagram of mitigation options



Legend- Au N: autumn applications of nitrogen fertiliser, Sp N: spring applications of nitrogen fertiliser, SO: standoff pad, NL: nitrogen leaching, SR: Stocking Rate, MS: Milksolids, APC: Average pasture cover