Waikato Dairy Farm Nitrogen Mitigation Impacts

Analysis of Waipa-Franklin and Upper Waikato Dairy Farms

Report November 2014

DairyNZ Economics Group

Contents

1 Background

The Government introduced the National Policy Statement for Freshwater Management in 2011. This statement sets out objectives and policies that instruct regional councils on how to manage their region's water resources in an "integrated and sustainable way, while providing for economic growth within set water quantity and quality limits" (National Policy Statement on Freshwater Management, 2011, p.3). It is designed to help the understanding of freshwater resources, the threats to them and in turn manage these resources for the benefit of New Zealand.

As a result regional councils are starting to design policies to improve water quality. This involves establishing the current state of all freshwater bodies in the region, collaborating with the community to define desired water quantity and quality outcomes, and then determining the appropriate water quality policies to achieve these. Water quality attributes include nutrient loads (for example, nitrogen and phosphorous) amongst others.

This project, carried out by DairyNZ is part of the Waikato Economic Impact Joint Venture (JV) project. In this JV project, studies are carried out to support decision-making by central government, local government and the wider community on the potential impacts of setting freshwater objectives and limits in the Waikato River Catchment. The Waikato River Catchment includes the Waipa-Franklin Catchment (Lower Waikato) and the Upper Waikato Catchment.

DairyNZ has investigated the impact of various nitrogen loss restrictions on milk production, profit and viability for dairy farms in the Waikato River Catchment. This report also describes the changes in phosphorous loss resulting from the mitigations to lower nitrogen loss, but no specific mitigations were applied for phosphorous. This analysis involves the use of Farmax[1] to model the farm system, in conjunction with Overseer[2], to determine the impact of reducing nitrogen leached on some key performance indicators of various dairy farms. The overall aim of this research is to gain a better understanding of nitrogen loss on dairy farms in the Waikato River Catchment and the associated economic impacts of reducing nitrogen loss. There are similar studies for other land uses in the catchment as well as analysis for municipal and industrial discharges. These studies will help the JV Group provide economic information to the Healthy Rivers project and in turn assist with policy design.

More specifically this project aims to determine the distribution of nitrogen leached per hectare for dairy farms in the Waipa-Franklin and Upper Waikato regions. This will then be scaled up to feed into a catchment model to examine the wider impact of potential nitrogen leaching policies. This project estimates the physical and financial impacts of reducing nitrogen leaching per hectare. It also models the impact of building a standoff pad on each farm in order to reduce nitrogen leaching beyond changes farmers could make within their current farm systems.

This study was undertaken to provide information for the development of a catchment-scale model, which could then be used to assess the possible effects of policy changes. Specifically, this study

[1] Farmax is an energy based farm system model.

[2] OVERSEER® is an agricultural management tool that assists in examining nutrient use and movements within a farm to optimise production and environmental outcomes.

provides abatement cost curves for dairy farms in the Waipa, Franklin and Upper Waikato areas of the Waikato region. It excludes the land area that feeds into the Hauraki Gulf which includes the Matamata-Piako area.

This report comments on the first stage of this project only, the initial modelling of the impacts from reducing nitrogen loss on 14 case study dairy farms within the Waipa-Franklin region and 12 case study dairy farms in the Upper Waikato area. It also briefly describes the impact of these mitigation measures on phosphorus losses. These farms were selected to represent different bio-physical (soils, drainage and rainfall) and farm system differences amongst dairy farms. The next stage of work will be compiling the various study findings into a catchment model.

2 Methodology

2.1 Region

Thirty three per cent of the land in the Waipa-Franklin and Upper Waikato catchments is occupied by dairy farms. This area has approximately 2,800 herds with an average of 133 effective hectares and 329 cows[3]. The Waikato region hosts a range of soils types suitable for dairy and a temperate climate ideal for pasture production, making it (along with Taranaki) one of the historic primary areas for dairying. Herds are predominantly spring calving with the highest pasture growth seen between September and December. The wider Waikato Region employs 6,785 people on-farm and a further 4,845 people in processing and wholesaling. Dairy contributed 9.8% of Waikato regional GDP in 2012; making the dairy industry the largest contributor to GDP in the Waikato Region.[4]

The Waipa-Franklin and Upper Waikato River Catchments are areas contributing to the Waikato River (as defined by the Regional Council boundaries). It does not include the entire Waikato region (e.g. excludes Matamata Piako) but includes some of the Rotorua District which is usually considered outside the Waikato region.

The rainfall[5] in the Waikato region is varied between 900mm per year in drier parts of the Matamata Piako district to over 2,000mm a year in areas around Waipa and Mt Pirongia. The Waipa-Franklin area has less variation with only small pockets of low rainfall (1,000mm) around Hamilton City, Cambridge and Te Kauwhata. The west side of State Highway One in the Waipa-Franklin Catchment receives around 1,400mm a year north of Hamilton City (this is shown in Figure 3). The Upper Waikato area receives the heaviest rain around Tokoroa (1,500mm per year). The Taupo township area is the driest with only 1,100mm per year, this drier zone continues along State Highway Five between Taupo and Rotorua.

There is a diverse range of soils in the Waikato region from well drained to poorly drained. In the Waipa-Franklin area there is predominantly moderately well drained soils however there is still a wide range (as shown in Figure 5). The Upper Waikato area consists largely of well drained pumice soils. The exception is an area of poorly drained soils along State Highway Five by Reporoa (Figure 6).

There is a range of nitrogen leaching levels throughout the Waikato River Catchment (Waipa-Franklin and Upper Waikato) as shown in Figure 1. According to our estimates, the range is between 10kg N/ha and 60kg N/ha, with a third of the dairy area leaching between 30 and 40kg N/ha.

[3] New Zealand Dairy Statistics 2012-13 (includes all of the 12 TLA's listed in sections 1.1.1 and 1.1.2)
[4] NZIER 2012
[5] NIWA Waikato Median Annual Total Rainfall (1981-2010)

Figure 1: Waikato River Catchment dairy farm nitrogen leaching range

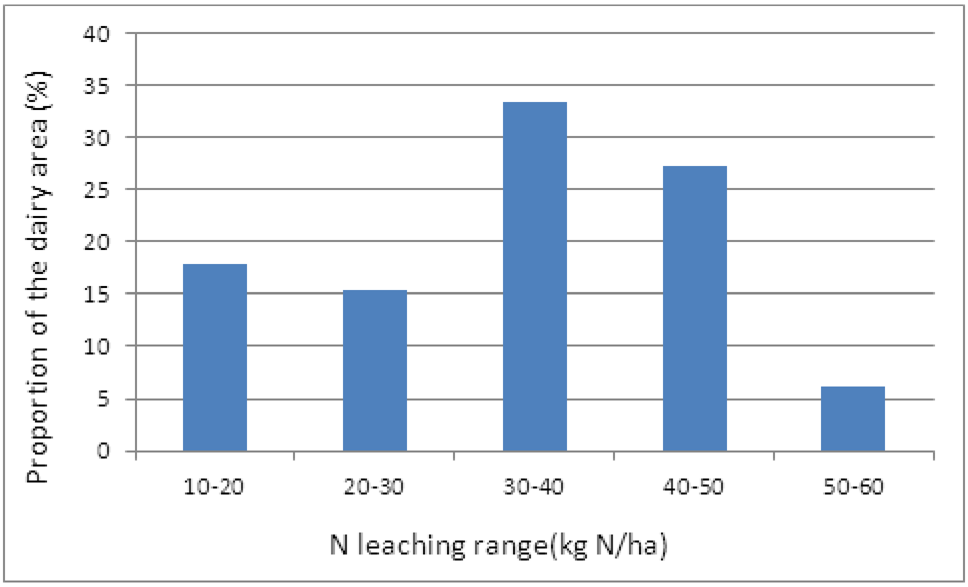
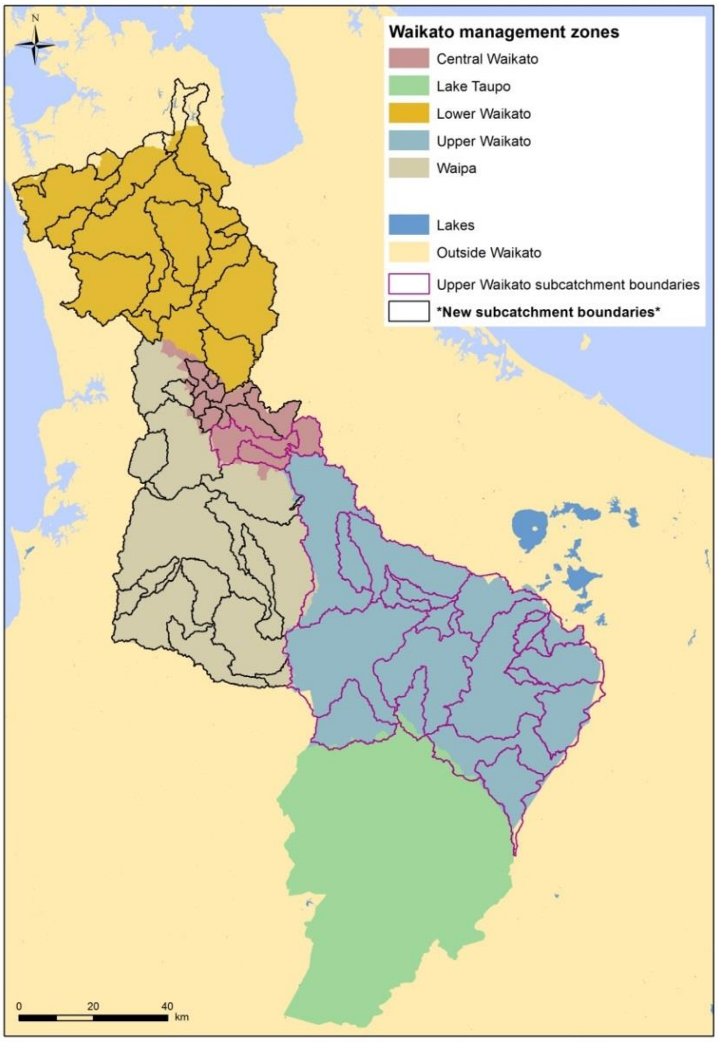


Figure 2: Waipa-Franklin and Upper Waikato catchment area.



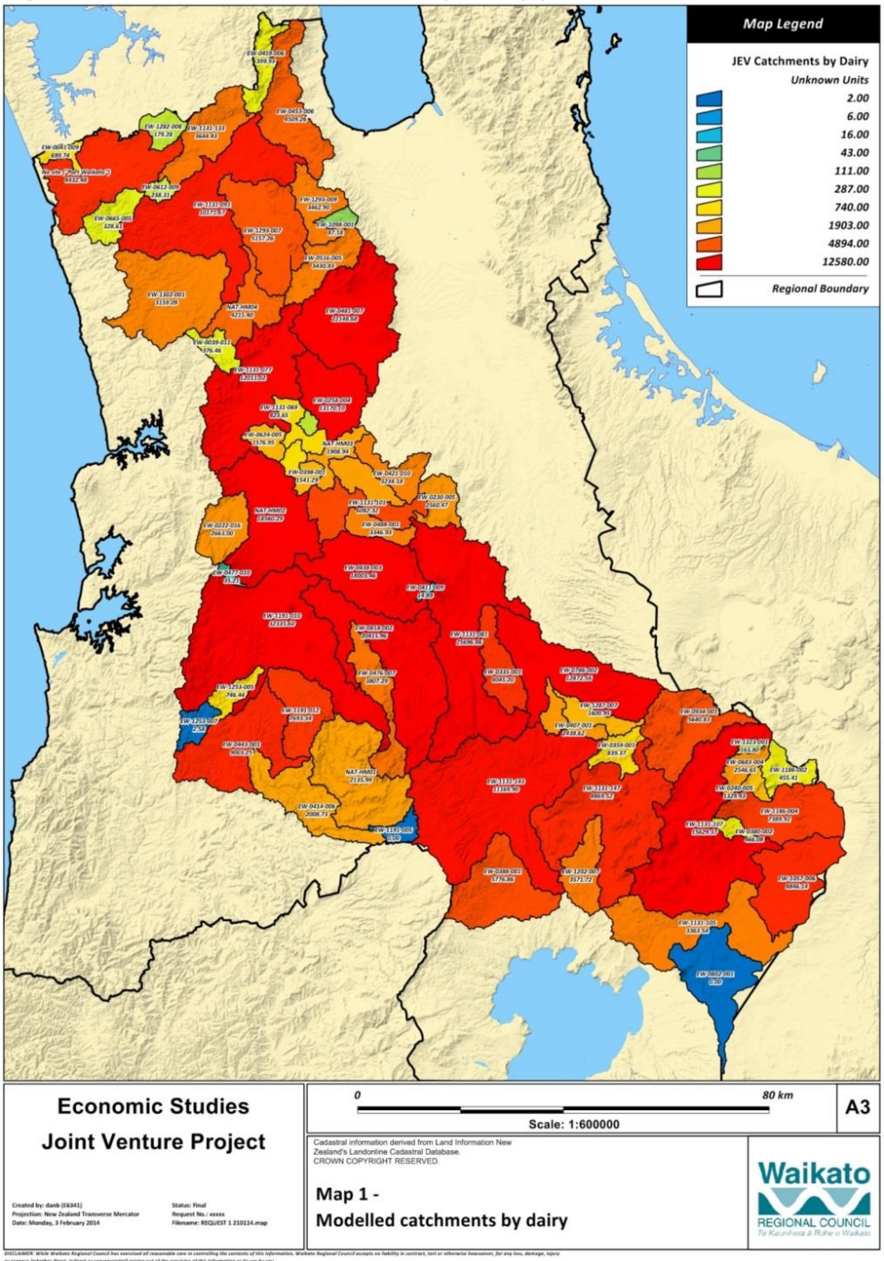
Source: MPI

Figure 2 shows the Waikato River Catchment area that was included in this study. The red boundaries indicate sub catchments within the Waipa-Franklin area; the black boundaries indicate the Upper Waikato area and sub catchments.

The decision was made to include the sub catchments located around Cambridge as Waipa-Franklin sub catchments due to the availability of farm data when modelling was carried out.

The proportion of dairy within the sub catchments is shown in Figure 3. The areas coloured red have a larger portion of dairy land use. These sub catchments have more than 20% of the sub catchment area used for dairying and this represents an area of more than 6,000 hectares.

Figure 3: Modelled catchments by dairy presence



Source: Waikato Regional Council

2.1.1 Waipa-Franklin

The Waipa-Franklin area sits within the Waikato region and includes all, or part of, the following Territorial Local Authorities (TLA's): Franklin, Waikato, Hamilton City, Waipa, Otorohanga and Waitomo. The Waipa-Franklin area has nearly 2,000 herds with an average herd size of 335 cows run on 106 effective milking platform hectares (3.2 cows per hectare)[6]. However the area examined in this report is based on the water catchment area for the lower Waikato River, from the Karapiro Dam to the mouth of the Waikato River, and does not exactly align with council boundaries.

The boundary of the Waipa-Franklin Catchment examined in this study has been set by the Waikato Regional Council. It includes a total of 661,507 hectares, of which 237,291 hectares is dairy land (36%) the next most prevalent land use is pastoral farming which accounts for 31% of total catchment area[7].

2.1.2 Upper Waikato

The Upper Waikato area sits within the Waikato region and includes all, or part of, the following TLA's: Taupo, Rotorua and South Waikato. These TLA's combined have 852 herds with an average herd size of 461 cows on 164 effective hectares (2.8 cows per hectare)[8]. However these statistics include all herds in the TLA's and the Upper Waikato Catchment boundary does not include all the land in these TLA's.

The boundary of the Upper Waikato Catchment examined in this study has been set by the Waikato Regional Council. It includes a total of 440,796 hectares, of which 126,713 hectares is dairy land (29%) the next most prevalent land use is pastoral farming which accounts for 20% of total catchment area[9].

2.2 Case study approach

Nitrogen leaching is influenced by a range of factors including production system, imported feed, nitrogen fertiliser use, stocking rate, soil, and rainfall. Where there is a large variation in some of these key factors, a case study approach is the best option in order to investigate a range of these farming types. A case study approach ensures relevant empirical data is used to describe the farms. The downfall of this method is that it can be challenging to find farms that are typical of the whole area and so in some areas two or three farms were chosen to balance each other, for example, where there was a large range of soil types or farm systems in an area. The use of actual farm data collected through DairyBase provides data that is realistic, checked for errord and is treated consistently between farms. This method was chosen rather than a survey of farms due to perceived transparency.

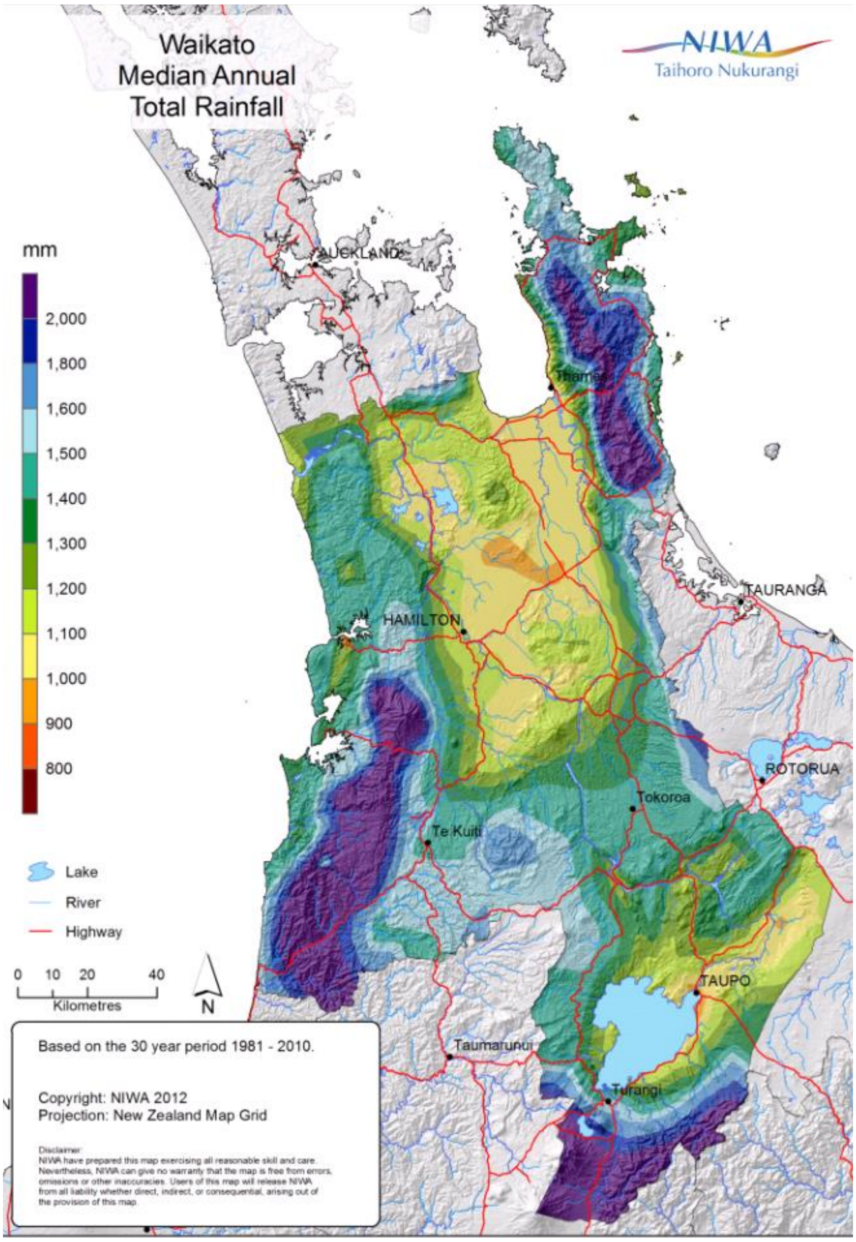
[6] New Zealand Dairy Statistics 2012-13
[7] MPI
[8] New Zealand Dairy Statistics 2012-13
[9] MPI

2.3 Representation

The area covered under this study consists of 66 sub catchments (Appendix 1), 45 in Waipa-Franklin and 21 in Upper Waikato. There is a diverse range of rainfall across these catchments and also soil types and drainage vary throughout the zone.

The area was grouped into six representative sub regions in Waipa-Franklin and four in Upper Waikato based on similar characteristics in rainfall and soil. The 66 sub catchments were grouped into these 10 sub regions. Median annual total rainfall for the area (Figure 4) was one variable that was overlaid with sub catchment boundaries to determine which sub catchments were similar in rainfall and could be grouped together.

Figure 4: Waikato median rainfall map



Source: NIWA

The soil drainage of each sub catchment was also considered as drainage is a key factor in nitrogen leaching, however soil drainage often varies within sub catchments and as a result more than one farm typically represents any of the grouped sub regions.

Attributes such as farm system, stocking rate, herd size, and production per cow or hectare from the large dataset of farm information for each Territorial Local Authority was used to help group sub catchments together as were biophysical features (soil and rainfall).

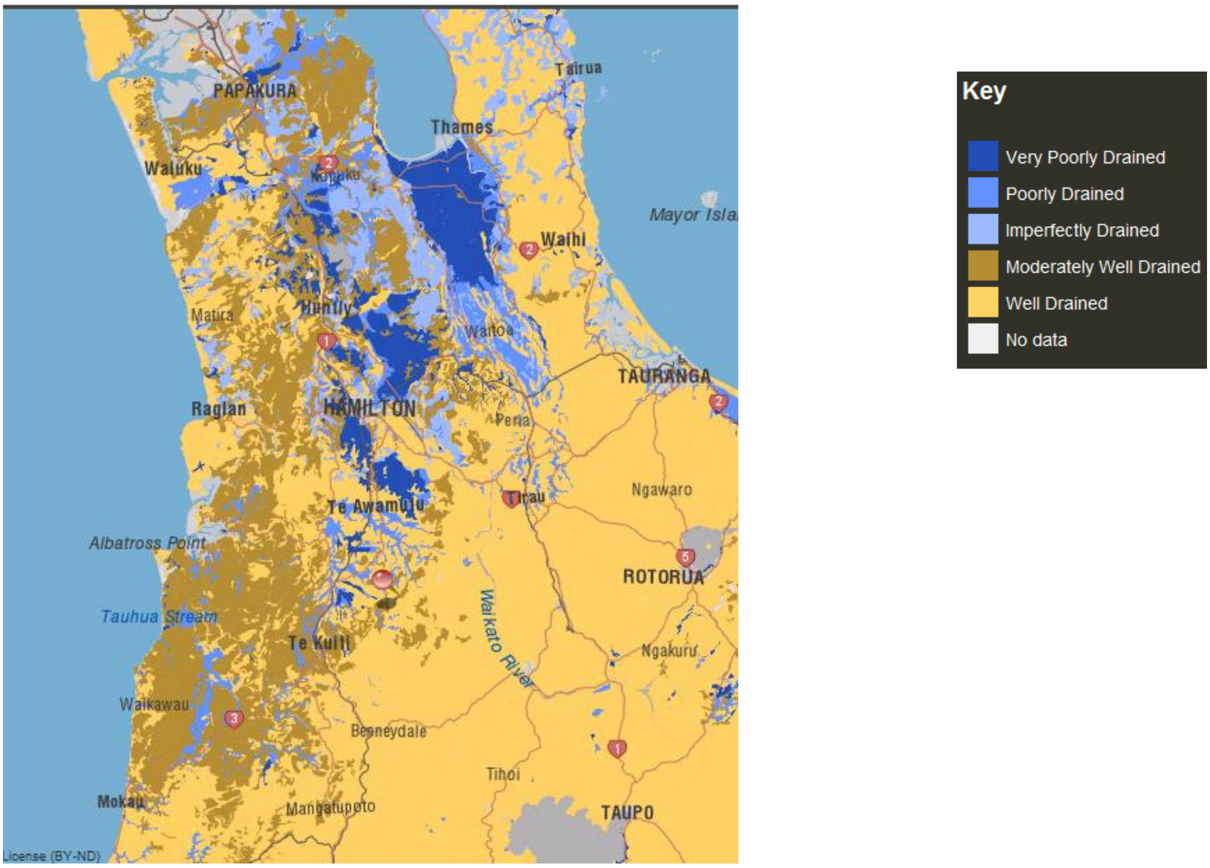
The case study farms were then chosen based on their physical location and how well they represented variables (including biophysical, production system, farm characteristics and key performance indicators) within each sub region. Comparing each farm to district data allowed the project team to consider the suitability of farms for inclusion and to then work with local DairyNZ Consulting Officers on likely representation of farms.

The next stage was to weight the representation of each farm within a sub region as they would then represent a proportion of the dairy population across sub catchments within a sub region (Table 1 and 2); this was done for the Waipa-Franklin and Upper Waikato areas separately. Weightings for each farm depended on the farm's relative position within the various distributions described above and vigorous discussions with DairyNZ Consulting Officers who have local knowledge of topography and farms within the sub regions. This weighting, along with the abatement curve for each farm, was used to construct a catchment model.

The number of farms represented in each cluster should be based on the trade-off between the reasonable representation of the farm types present in the sub catchments, the region as a whole and the resources available, especially time.

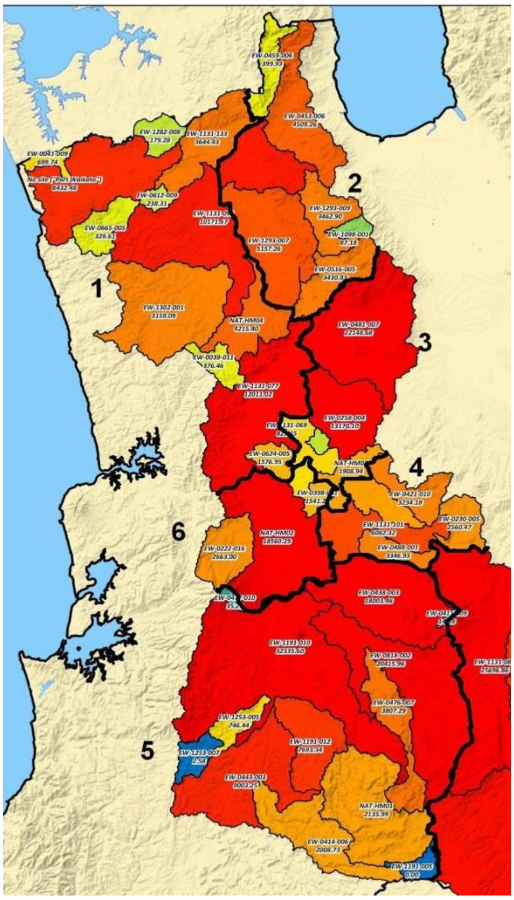
2.3.1 Waipa-Franklin Representation

Figure 5: Soil drainage map for Waipa-Franklin



Source: Landcare Research

Figure 6: Map of Waipa-Franklin sub region boundaries



The six sub regions (Figure 6) were created based on the following observations:

1. North of Hamilton and West of State Highway 1 has relatively higher rainfall than East of State Highway 1. Soils tend to be moderately well drained in this area with some poorly drained soils. Much of the moderately well drained soils are hilly and more likely to be occupied by sheep, beef or forestry.
2. North of Te Kauwhata and East of State Highway 1 relatively lower annual average rainfall occurs with a tendency towards summer dry periods. Soils are predominately poorly or less well-drained.
3. Lower relative rainfall is found South of Te Kauwhata and East of Hamilton, however the soils become very poorly drained in parts (as distinct to sub catchment 2).
4. The sub region between Hamilton to Cambridge has mostly well drained soils and relatively low rainfall persists (compared to West of Hamilton/State Highway 1).
5. The largest sub region stretches from Cambridge in the North to the bottom of the catchment excluding the area around Pirongia, Ohaupo and Te Awamutu. This area is characterised by relatively higher rainfall, with a mixture of both well drained and poorly drained soils.
6. The wettest sub region is found around Mt Pirongia, Ohaupo and Te Awamutu with a range of soil types and drainage in the area.

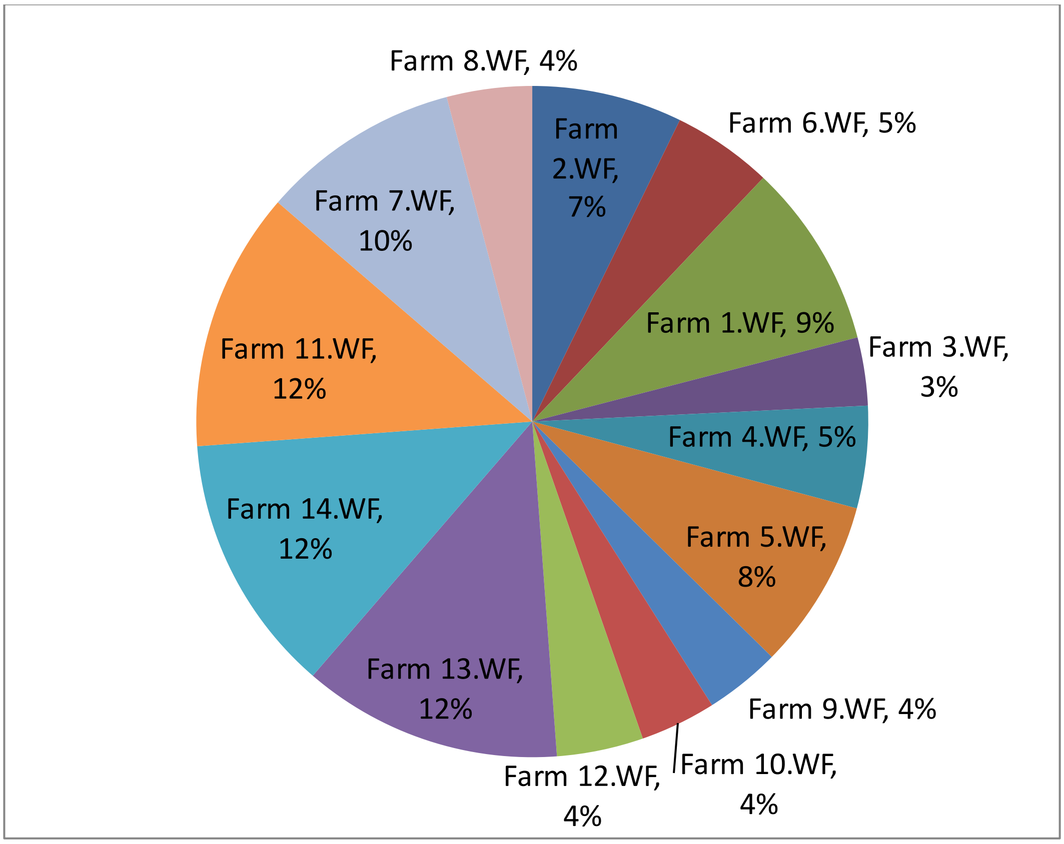
Table 1: Farm representation of the Waipa-Franklin sub regions

Group	Representation of sub-catchment				Comments
	Farm	Percentage of sub region	Hectares represented	Farm system[10]	
1	Farm 2.WF	60%	17,175	Low	Farm 2.WF well-draining soil. Farm 6.WF poor draining soil.
	Farm 6.WF	40%	11,450	Medium	
2	Farm 1.WF	100%	21,116	High	Farm on less well draining soil. Farm typical scale for area.
3	Farm 3.WF	20%	7,786	High	Farm 3.WF is on well-drained soils which are less typical for the catchments. Farm 4.WF is on poorly drained soils. Farm 5.WF is on poor draining peat.
	Farm 4.WF	30%	11,679	Low	
	Farm 5.WF	50%	19,465	Low	
4	Farm 9.WF	50%	19,966	Medium	Farms 9.WF and 10.WF balance each other in scale for the sub catchments.
	Farm 10.WF	50%	19,996	Medium	
5	Farm 11.WF	30%	76,478	Medium	Range of soil types for the four farms. Farm 12.WF is weighted lower than the others due to higher stocking rate and irrigation (minority of farms irrigated).
	Farm 12.WF	10%	25,493	High	
	Farm 13.WF	30%	76,478	High	
	Farm 14.WF	30%	76,478	Low	
6	Farm 7.WF	70%	54,222	Low	Farm 7.WF well-draining soil, Farm 8.WF poorly drained.
	Farm 8.WF	30%	23,238	High	

The representation of the farms was considered across the hectares for the entire area to ensure no particular modelled farm or farm type was over-represented. This representation across the entire catchment was part of the discussions with Consulting Officers (see section 1.3). Farms 11.WF, 13.WF and 14.WF have the largest weight with 12% of the total dairy land each (Figure 7), combined these account for more than a third of the dairy hectares in the catchment. These three farms are all in sub region 5. The modelled farms are balanced across the 45 sub catchments with a range of farm systems, herd sizes, soil types, and nitrogen leaching.

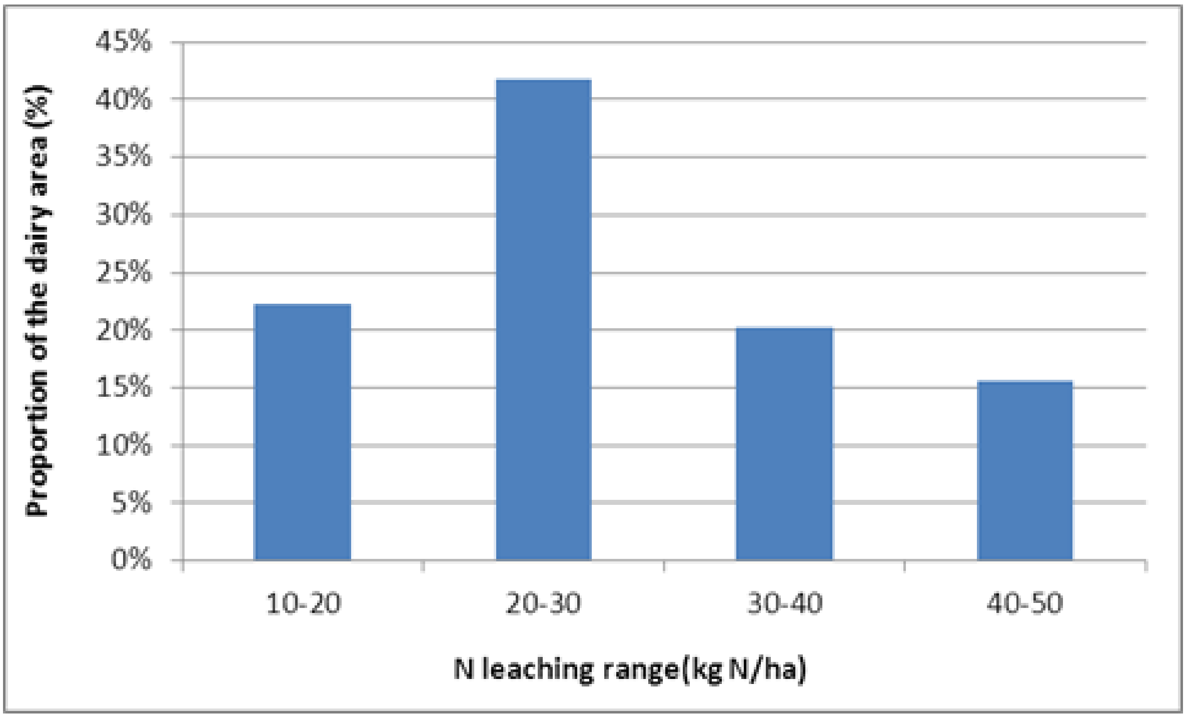
[10] Five production systems described by DairyNZ primarily on the basis of when imported feed is fed to dry or lactating cows during the season and secondly by the amount of imported feed and/or off farm grazing. www.dairynz.co.nz/farm/farm-systems/the-five-production-systems/

Figure 7: Waipa-Franklin farm representation by proportion of dairy hectares in catchment



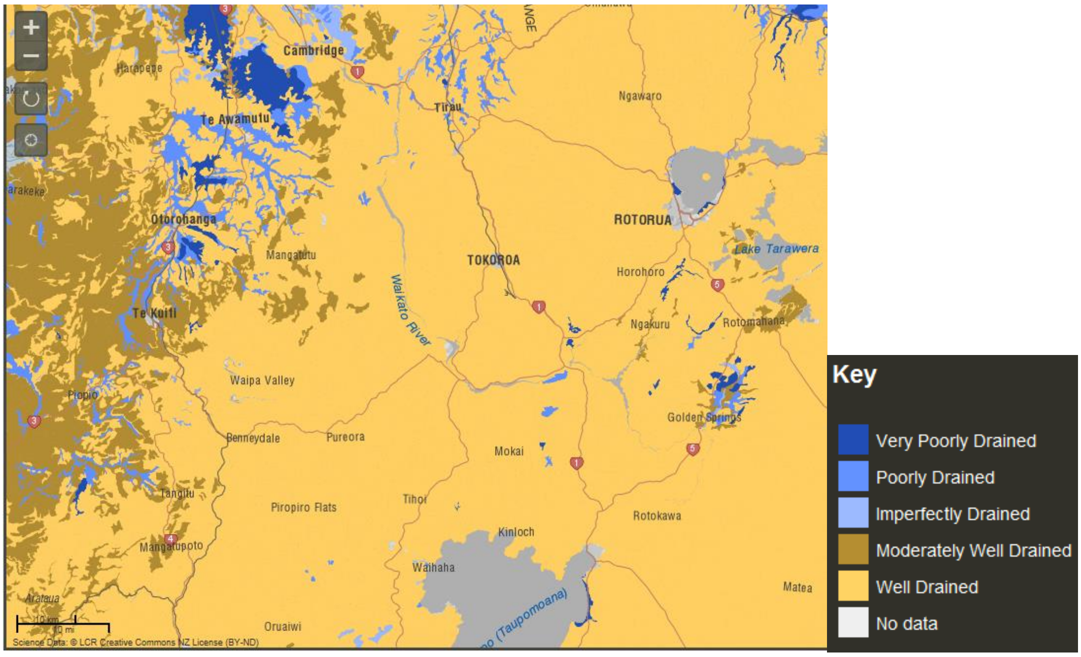
Based on the representation of the farms in the sample, Figure 8 shows the distribution of nitrogen leaching per hectare for dairy farms in the Waipa-Franklin region. The weighted average (weighted by the representation described in section 1.3) was 30.3 kg N/ha. There was a range of 12 kg N/ha to 50 kg N/ha. Over 60% of farms have a nitrogen leaching figure between 20 and 40 kg N/ha, nearly a quarter have less than 20 kg N/ha while 15% of farms have over 40 kg N/ha.

Figure 8: Distribution of nitrogen leaching in the Waipa-Franklin region



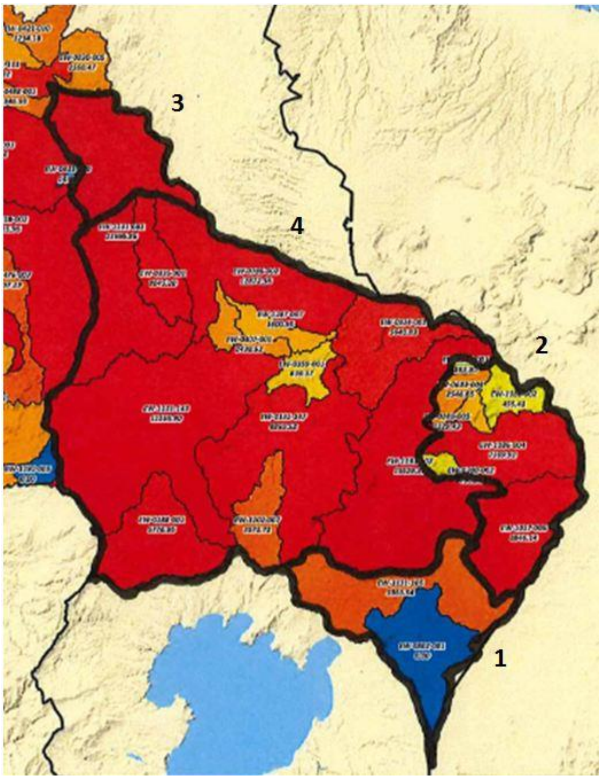
2.3.2 Upper Waikato Representation

Figure 9: Soil Drainage map for Upper Waikato



Source: Landcare Research

Figure 10: Map of sub region boundaries, Upper Waikato



The four sub regions (Figure 10) were created based on the following observations:

1. This sub region includes an area with a relatively low proportion of dairying land; it includes the township of Taupo and the area along the Napier Taupo Road that falls within the Upper Waikato River catchment. It has moderate rainfall and well drained soils. This zone is considered to have a micro-climate distinct from the rest of the Upper Waikato catchment due to colder temperatures, higher wind and lower pasture growth rates.
2. This sub region includes the area of lower rainfall that runs between Taupo and Reporoa along State Highway Five, it encompasses some well drained soils, but also some poorly drained soils around Reporoa. In the Upper Waikato area, this is the largest grouping of poorly drained soils. Farms around Reporoa are often smaller in size but slightly more intensively farmed than farms in sub regions 1 or 4. The area is sheltered and has a milder climate than sub region 4. This area encompasses the majority of the moderate to low nitrogen leaching vulnerability[11] in the Upper Waikato area.
3. Sub region 3 is the area in the North of the Upper Waikato catchment boundary. Please note that it does not include some of the area around Cambridge that was included in the Waipa-Franklin study (see Section 1.1). Rainfall is lower than sub catchment 4 and soils tend to be moderately well drained; it therefore has a lower nitrogen leaching vulnerability than sub region 4.
4. This sub region encompasses the majority of the Upper Waikato catchment both in total land area and dairy farm area. It has higher rainfall than the other three sub regions and is dominated by very well drained pumice soils. It has a high nitrogen leaching vulnerability. It

[11] Nitrogen leaching vulnerability index map for the Upper Waikato River Catchment, report May 2013 prepared by Landcare Research.

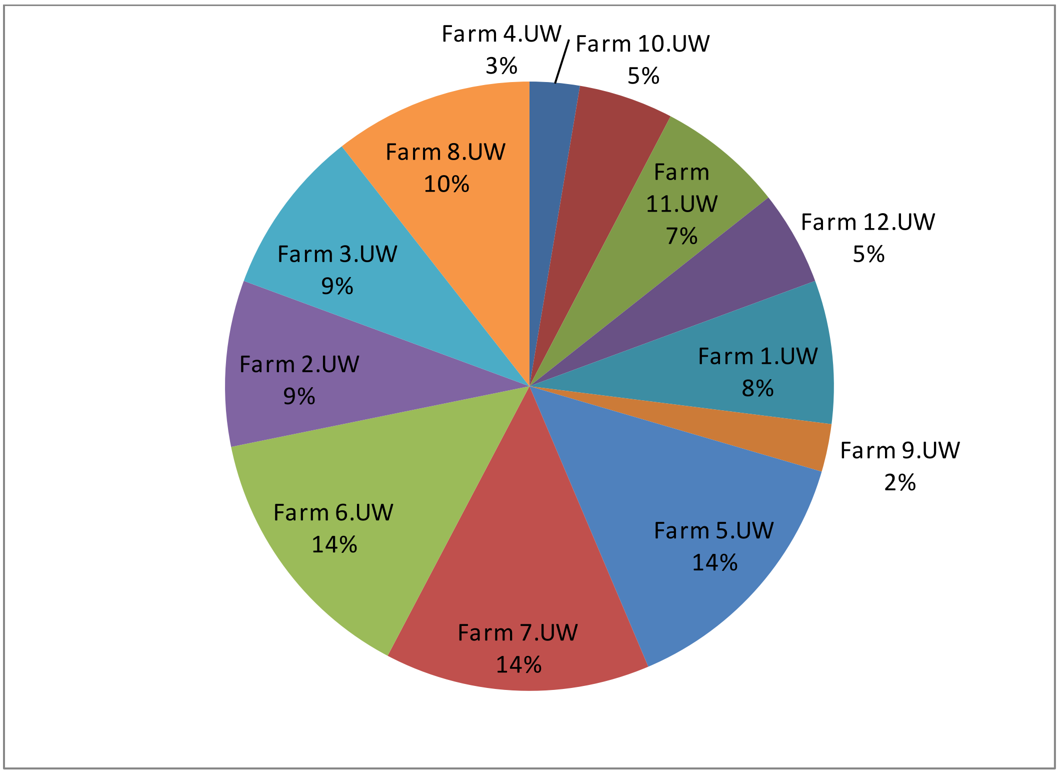
includes a range of dairy farm types from newer large-scale, but lower intensity, forestry conversions, to older, smaller more intensive farms around Tokoroa.

Table 2: Farm representation of Upper Waikato sub regions

Group	Representation of sub-catchment				Comments
	Farm	**Percentage of sub region**	**Hectares represented**	**Farm system**	
1	Farm 4.UW	100%	3,364	Low	This property is a typical large scale farm in this area on well drained soils
2	Farm 10.UW	30%	6,359	Medium	Farm 10.UW is on well drained soils. Farms 11.UW and 12.UW are on less well drained soils, farm 12.UW is higher input and more intensive than farm 11.UW, who is typical for the area.
	Farm 11.UW	40%	8,479	Low	
	Farm 12.UW	30%	6,359	Medium	
3	Farm 1.UW	75%	9,636	Low	Farm 1.UW is fairly typical of this small area. Farm 9.UW represents the small proportion of farms with some irrigation use.
	Farm 9.UW	25%	3,212	Medium	
4	Farm 5.UW	20%	17,861	Medium	All farms are on well drained soils as per the area. Farm 5.UW is a medium input farm with good production. Farm 7.UW is a relatively typical conversion on more marginal land. Farm 6 has an existing standoff pad and is slightly smaller than some farms around Tokoroa but has typical production. Farm 8.UW is lower input, farm 2.UW is higher input and production, while farm 3.UW is larger scale.
	Farm 7.UW	20%	17,861	High	
	Farm 6.UW	20%	17,861	Low	
	Farm 2.UW	13%	11,163	Medium	
	Farm 3.UW	13%	11,163	Medium	
	Farm 8.UW	15%	13,395	Low	

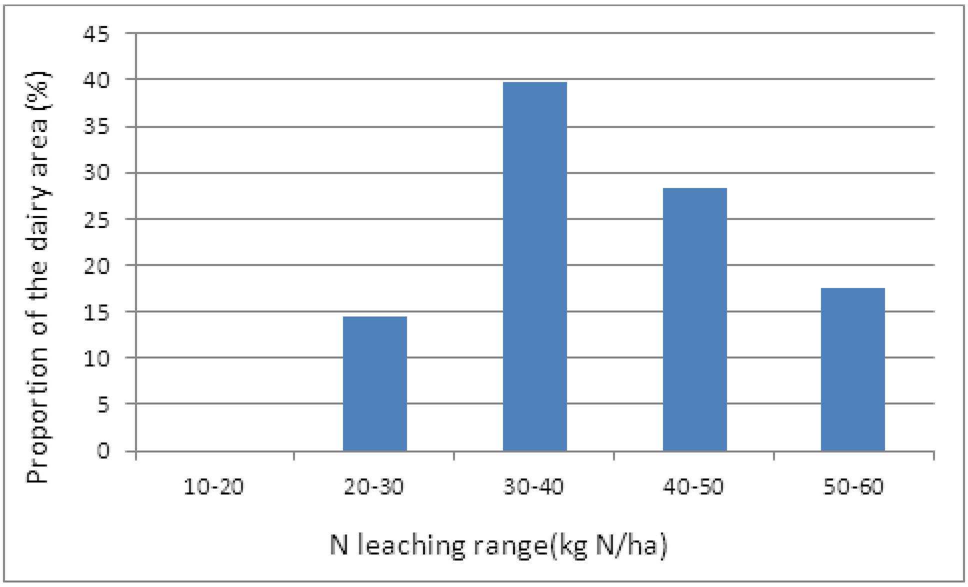
The representation of the farms was checked across the hectares for the entire area to ensure no particular modelled farm or farm type was over-represented. Farms 5.UW, 6.UW and 7.UW have the largest weight with 14% of the total dairy land each, combined these account for more than a third. These three farms are all in sub region 4. The modelled farms are well-balanced across the 21 sub catchments in the Upper Waikato Catchment with a range of farm systems, herd sizes, soil types, and nitrogen leaching.

Figure 11: Upper Waikato farm representation by proportion of dairy hectares in catchment



Based on our representation and the farms in our sample, Figure 12 shows the distribution of nitrogen leaching per hectare for dairy farms in the Upper Waikato region. The weighted average (weighted by the representation described in section 1.3) was 39.6 kg N/ha, this is higher than in the Waipa-Franklin area. There was a range of 27 kg N/ha to 59 kg N/ha, this is a tighter range than in the Waipa-Franklin area.

Figure 12: Distribution of nitrogen leaching in the Upper Waikato region



Two-thirds of farms have a nitrogen leaching figure between 30 and 50 kg N/ha, 17% of farms have over 50kg N/ha while a similar proportion have below 30kg N/ha.

2.4 Modelling and mitigation strategies

Farm data was gathered from a range of farms within the Waikato River Catchment as part of the DairyNZ National Baseline project. This project has involved the collection of 500 farms' physical and financial data for the 2012-13 season and the subsequent creation of Overseer files using Dairy Industry protocol. Following this, 26 farms from the Waikato River Catchment were chosen based on the range of farm types that they represented. These 26 farms were chosen because they covered a range of locations with different bio-physical characteristics and they represented a range of systems as well as differing financial performance and N loss/ha. More specifically, this range of farm types included consideration of farm production system, amount of nitrogen fertiliser used, milk production per hectare, infrastructure, soil types, rainfall levels and nitrogen leaching per hectare.

The Overseer files that were created as part of the Baseline project were checked and where a support block had been modelled in conjunction with a milking platform this was removed. The basis for this was the data that will feed into the catchment modelling treats milking platforms and dairy support as separate enterprises. Once the farm's base Overseer file was adjusted a base Farmax file was created with the physical and financial data collected for each farm.

Overseer (Version 6.1.2) and Farmax were used simultaneously as Farmax allows the user to ensure that viable farm scenarios are being represented and the impact of mitigation options on farm financials is clear, while Overseer allows the impact of mitigation options on nitrogen loss to be modelled.

From this stage mitigation options were discussed with the team and a mitigation strategy was documented so that all farms followed the same overall process. However, there were subtle differences in the mitigations between farms due to their individual characteristics. Mitigations were applied to two stages (see below for details) for each of the 26 farms. The mitigation strategies were developed based on experience and farm systems knowledge from the modelling team. Similar mitigation strategies have been applied and critiqued over time in other nitrogen mitigation projects.

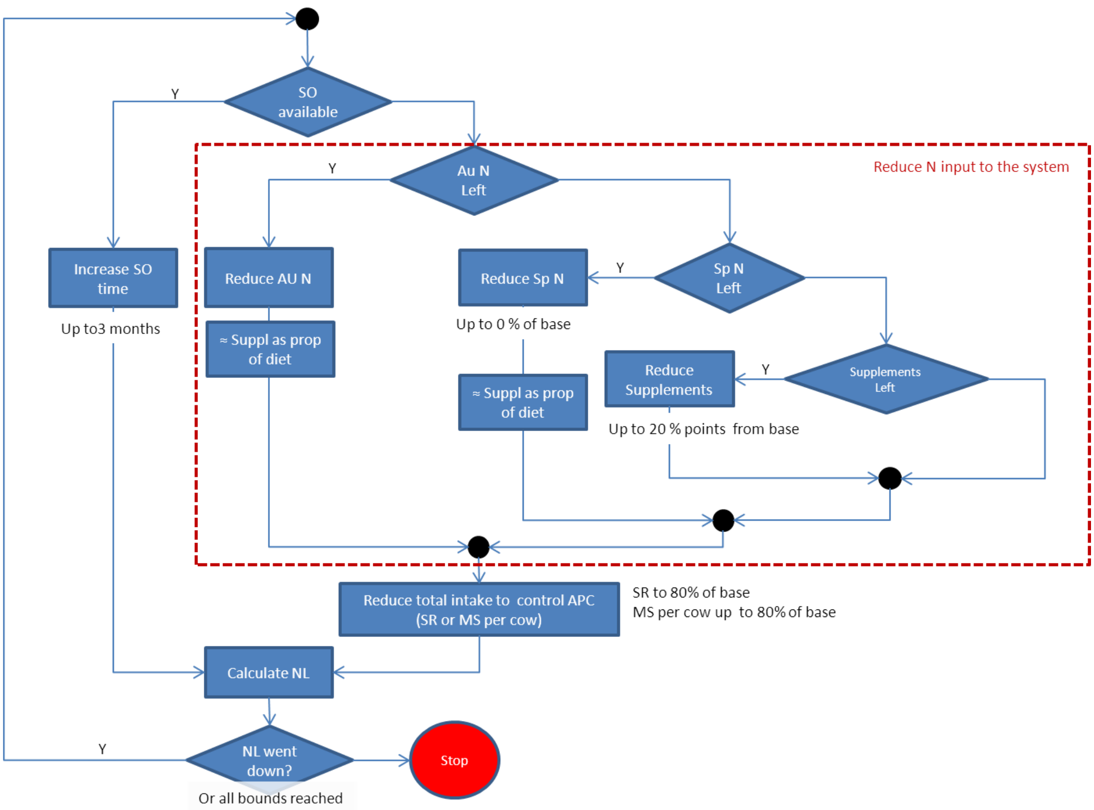
The mitigation strategies can be broadly described as management changes within the current farm system first, followed by an infrastructure change.

Stage 1.0	De-intensification: A stepwise process in which reductions in farm inputs are sequentially applied on the Base farm.
Stage 2.0	Restricted grazing: A stand-off pad is incorporated on each of the scenarios modelled in Stage 1.

It is important to note that all mitigation measures are cumulative, i.e. mitigations applied in run 1.1 are carried forward to run 1.2.

The specific mitigation measures applied to each farm are discussed in more detail in section 3 of this report. The mitigation strategies can be broadly described by Figure 13.

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

Stage 1 follows a standardised sequence, where agreed measures are applied:

1. If the farm has an existing feed pad or standoff pad the use of this is optimised.
2. Autumn nitrogen fertiliser applications are reduced and then removed.
3. Spring nitrogen fertiliser applications are reduced and then removed
4. Reduce supplements imported (up to a 20% reduction from the base).

5. Reduce stocking rate (up to 20% reduction of cow numbers from the base).

If the farm has an existing standoff pad, its use time is increased up to 3 months per year (12 hours per day) to augment the proportion of nitrogen excretion that can be captured[12]. The extent of utilisation of this mitigation option depends on the characteristics of the existing facilities. Where nitrogen fertiliser is reduced, autumn applications are targeted first followed by spring fertiliser applications[13]. This is done in steps of 25% or removing whole dressings. Up to here, the use of purchased feed is maintained constant as a proportion of the total DM intake, however high nitrogen content feeds are replaced by low nitrogen content alternatives. Finally, the proportion of purchased feed in the diet is reduced by up to 20 % relative to baseline.

If a farm has a large crop area used to winter cows, crops with a lower nitrogen leaching risk factor (as per Overseer) can be used as a mitigation option. This was applied to some case study farms.

Each of these steps reduces feed supply further and further, and it is accompanied by a reduction in feed demand to achieve appropriate pasture covers and avoid feed gaps throughout the year in Farmax. This is done either by reducing stocking rate or the amount of feed eaten per cow, according to the judgment of the modeller. Either way milk production per hectare will decline, which may or may not impact on the farm profit but will have a much larger economic consequence for the sub-catchment and region.

The process stops when all the bounds (see Figure 13) have been reached. There are constraints on the amount of supplement feed as a proportion of total feed offered, stocking rate and production per cow that can be altered from the base farm system. This is because drastic changes in either of these variables are likely to disrupt farm management considerably, and it would be difficult to predict how farmers would cope. Having said that, there may be some farmers who might change systems over time due to nutrient management and reduction requirements.

The results from these mitigation options are then analysed, particularly the impact on profit (measured by operating profit per hectare), production and nitrogen leaching. These points are then used to create abatement curves. Abatement curves estimate the impacts of change between nitrogen leached and farm operating profit per hectare (EBIT) from the original base point for each farm.

2.5 Modelling Assumptions

Underpinning this modelling is a range of assumptions. While each farm may have individual assumptions, there are some key assumptions built into the modelling that are consistent across all farms. One is the milk price, for all the modelling for both this and the Upper Waikato report a milk price of $6.50 was used. This reflects a longer-term average price expectation. Fertiliser and feed prices were standardised across all farms and based on the volume and type each farm used

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[12] BEUKES, P., ROMERA, A.J., CLARK, D., DALLEY, D.E., HEDLEY, M.J., HORNE, D.J., MONAGHAN, R.M., LAURENSON, S., 2013. Evaluating the benefits of standing cows off pasture to avoid soil pugging damage in two dairy regions of New Zealand. New Zealand Journal of Agricultural Research, 56, 1-15.

[13] ROMERA, A.J., LEVY G., BEUKES, P., CLARK, D., GLASSEY, C. 2012. A urine patch framework to simulate nitrogen leaching on New Zealand dairy farms. Nutrient Cycling in Agroecosystems 92, 329-346.

multiplied by a standard price for different inputs. Standard feed and fertiliser prices are important as mitigation options change these farm inputs and farm financials are adjusted accordingly. For farms to be comparable the base Farmax file must have the same assumptions behind it.

Another important assumption adopted was that in the mitigation runs the size of the effluent area would not increase. This decision was based on the lack of reliable data on the cost of extending the effluent area. While this may be a valid mitigation option on some farms, the effect on N leaching is likely to be small, and modelling it without a cost associated would lead to results that underrepresent the cost of mitigation options. More work and agreement is required on this mitigation technique before it can be incorporated.

Changes in labour requirements for a dairy farm are non-linear and therefore labour was treated as a fixed cost unless cows dropped significantly resulting in one full time equivalent employee being removed from the farm system. This means that if the number of cows is only reduced by a small amount, the farm would not reduce the number of labour units or their hours significantly.

When a new standoff pad was simulated it was concrete with a bark covering. Consequences of all farms utilising a standoff pad and changing regional demand for bark and other inputs have not been considered in this modelling. The use of the standoff pad was allowed to be up to 12 hours a day during lactation and 18 hours a day for dry cows. If all cows were off the milking platform for winter the standoff pad was just used between the return date and the calving date for dry cows. Cows were not fed on the standoff pad but the effluent collected was treated as dairy shed effluent and spread back on the existing effluent area.

When a standoff pad was constructed, costs were adjusted accordingly. Additional costs for running and maintaining the stand-off pad were incorporated on a per cow basis. These costs included depreciation, repairs and maintenance (R&M), fuel and increasing the effluent holding pond size. The cost of increasing the effluent area was not considered in this modelling. Depreciation was based on dollars per farm and was from each farm's accounts. Depreciation was included over 25 years. R&M included costs related to the changing of the bark covering, treatment and spreading of solid and liquid effluent. The additional cost of incorporating a standoff pad into the farm system was calculated at $113 per cow.

3 Waipa-Franklin Conclusions

This section provides the overall findings and conclusions for the Waipa-Franklin catchment, while the description and detailed results for each individual farm have been removed from this report. Table 3 and Figure 14 show the results for the composite farm in the Waipa-Franklin region, the composite farm is weighted by the total area represented by each farm type (see section 1.3). These results include runs 1.0 to 1.4 as not all farms had mitigations applied beyond this point. Runs beyond 1.4 pushed mitigation options further to try and achieve larger reductions in nitrogen loss, however they still followed the same process as shown in Figure 13.

At the base the composite farm had 118 effective hectares and milked 360 cows, on average, slightly larger than all the farms in the catchment (335 cows and 106ha). The composite farm applied 116 kg of nitrogen fertiliser and leached 30 kgN/ha.

Table 3: Results for the composite Waipa-Franklin farm

Stage 1	**1.0 Base**	**1.1**	**1.2**	**1.3**	**1.4**
N leaching kg/ha	**30**	**27**	**25**	**23**	**22**
P Loss (kgP/ha)	0.8	0.8	0.8	0.8	0.7
Stocking Rate (cows/ha)	3.1	3.0	2.9	2.8	2.7
Nitrogen Use(kg N/ha)	116	88	60	29	14
Milk Solids total (kg)	131,048	127,675	123,675	119,146	115,995
Milk Solids (kg/ha)	1,098	1,072	1,033	997	970
Milk Solids (kg/cow)	360	360	360	360	360
Bought Feed / Feed Offered (%)	17	17	16	15	15
Operating Profit ($/ha)	**2,566**	**2,506**	**2,417**	**2,332**	**2,288**
% Redn in N leaching		-10%	-19%	-25%	-27%
% Redn in operating profit		-2%	-6%	-9%	-11%
% Redn in production		-3%	-6%	-9%	-11%

Stage 2[14]	**2.0 Base**	**2.1**	**2.2**	**2.3**	**2.4**
N leaching kg/ha	**25**	**22**	**20**	**19**	**18**
P Loss (kgP/ha)	0.8	0.8	0.7	0.7	0.7
Stocking Rate (cows/ha)	3.0	2.8	2.7	2.6	2.6
Nitrogen Use(kg N/ha)	111	84	58	29	16
Milk Solids total (kg)	131,048	124,659	120,461	116,358	113,304
Milk Solids (kg/ha)	1,088	1,029	997	964	935
Milk Solids (kg/cow)	360	345	345	345	345
Bought Feed / Feed Offered (%)	16	17	16	15	15
Operating Profit ($/ha)	**2,229**	**2,069**	**1,996**	**1,926**	**1,896**
% Redn in N leaching	-16%	-26%	-33%	-38%	-40%
% Redn in operating profit	-13%	-19%	-22%	-25%	-26%
% Redn in production		-5%	-8%	-11%	-14%

Note: the percentage reductions seen in runs 2.n are in relation to the 1.0 base run. For example the base farm built a standoff pad and this reduced their nitrogen leaching from the base by 16%.

[14] Not all farms had Stage 2 run as they could make significant reductions in Nitrogen leaching without it.

This is a composite farm and the mitigations refer to the changes in the weighted average of specific KPI's.

1.0 Stage 1.

1.1 Nitrogen fertiliser use was reduced by 28 kg N/ha and peak cows milked were reduced by 9. Because this was a composite farm this was a total amount removed from the farm system, not a specific application. However because autumn fertiliser is always removed first, this 28 kg N/ha would also be removed through the autumn period.

1.2 Nitrogen fertiliser use was again reduced by 28 kg N/ha, peak cows milked were reduced by 13. Bought in feed as a percentage of total feed offered was reduced by 1% (from 17% to 16%).

1.3 Nitrogen fertiliser use was reduced by 31 kg N/ha and peak cows milked were reduced by 13. Total nitrogen use was now 29 kg N/ha and peak cows were now 325 (-35 cows from Base).

1.4 Nitrogen fertiliser use was halved and ended up at 14kgN/ha, 6 more cows were removed leaving a herd size of 319 and imported supplements as a portion of total feed offered was reduced to 15%.

2.0 The use of a Base standoff pad reduced Nitrogen leaching by about 18% relative to the equivalent level of intensification in Stage 1. This composite farm used 111 kg N/ha and peak cows milked were 356.

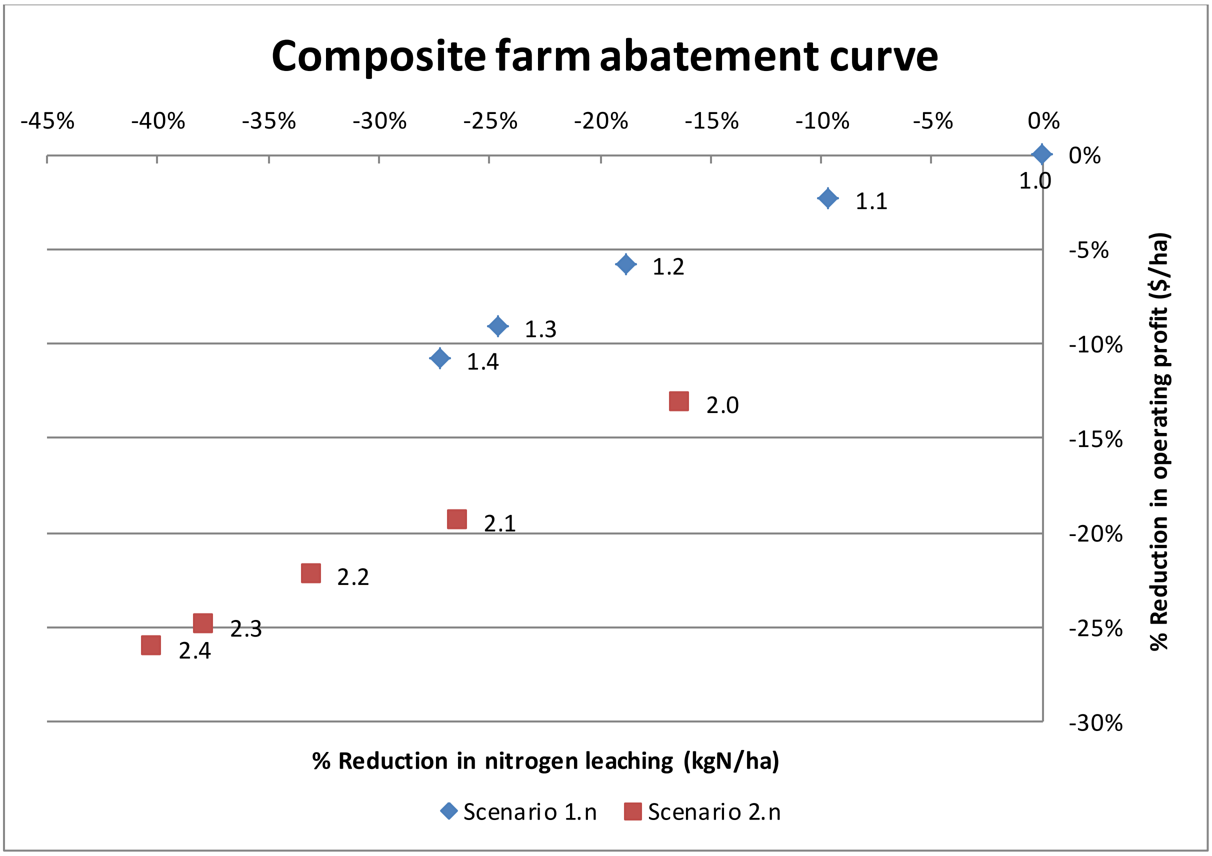
2.1 Peak cows were reduced by 23 and 27 kg of nitrogen fertiliser was removed from the system.

2.2 Another 26 kg of nitrogen fertiliser was removed from the farm system and peak cows were reduced by 12.

2.3 28 kg of nitrogen fertiliser was removed from the farm system and peak cows were reduced by 14.

2.4 Half of the remaining nitrogen fertiliser was removed from the farm system, taking remaining nitrogen fertiliser to 16 kg N/ha and peak cows were reduced by 4 (peak cows milked was 304).

Figure 14: Abatement curve for the composite farm in the Waipa-Franklin region



Average nitrogen leaching was 30 kg N/ha. Based on the above mitigations this farm can achieve a 10% reduction in nitrogen leaching per hectare with a minimal impact on profit and production. This level of nitrogen reduction would reduce operating profit per hectare by 2% and production in milksolids by 3%. Any further mitigation measures beyond this 10% level of nitrogen reduction impacts operating profit and production more significantly. Reductions in nitrogen leaching of greater than 20% generally have an impact on operating profit and production of more than 10%. Mitigation strategies involving de-intensification would allow the farm to achieve a reduction in nitrogen leaching of 27%. This level of reduction in nitrogen through the strategies used in this modelling would reduce operating profit per hectare and production by 11%.

Operating profit was 13% lower with a standoff pad, reflecting the capital cost and the operating expenses. The use of a standoff pad allows nitrogen loss to be reduced further than what occurred under the mitigation strategies in 1.4. Nitrogen loss can be reduced by 40%; however this would reduce operating profit by 26% and milk production by 14%.

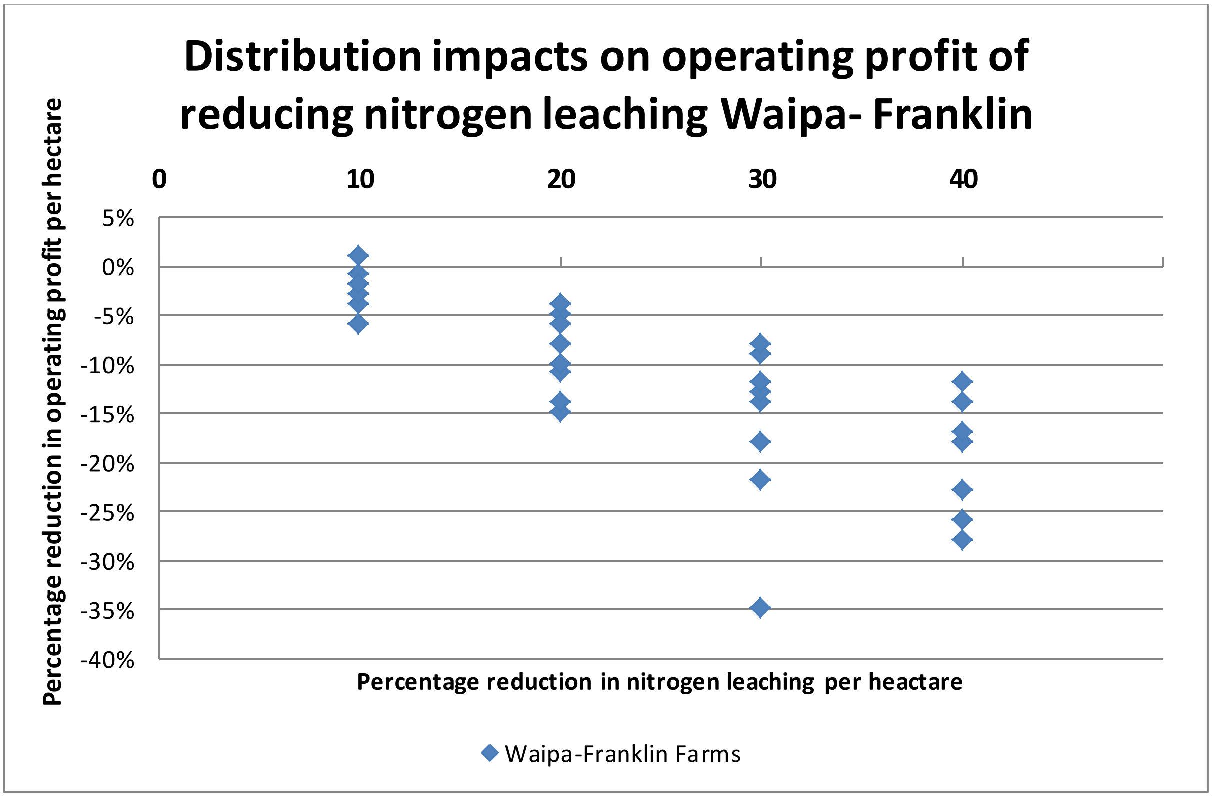
While reductions in phosphorous losses were not directly targeted through the mitigation options used in this report, some reductions occurred as collateral effects of the nitrogen leaching mitigation options. Phosphorus loss from the composite farm was 0.8kgP/ha, with a range on case study farms between 0.4kgP/ha and 1.2kgP/ha. On average, farms were able to remove 0.1kgP/ha through the nitrogen mitigation strategies.

Table 4 shows nitrogen loss per hectare and the percentage decrease in operating profit % for each farm in the targeted nitrogen leaching band.

Table 4: Waipa-Franklin Summary: reduction in operating profit per hectare

Farm	Base N leaching (kg N/ha)	Target -10% N leaching	Target -20% N leaching	Target -30% N leaching	Target -40% N leaching
1.WF	18	-4%	-11%	-35%	NA
2.WF	30	-2%	-4%	-9%	-12%
3.WF	42	1%	-5%	-9%	-18%
4.WF	12	1%	-8%	NA	NA
5.WF	41	-2%	-10%	-13%	-18%
6.WF	12	-6%	-15%	NA	NA
7.WF	28	-6%	-14%	-22%	-28%
8.WF	32	-1%	-4%	-9%	-18%
9.WF	35	-2%	-8%	-14%	-23%
10.WF	20	-6%	-10%	-18%	-26%
11.WF	29	-3%	-6%	-8%	-17%
12.WF	50	-3%	-10%	-13%	NA
13.WF	40	-2%	-6%	-12%	-26%
14.WF	31	-2%	-4%	-12%	-14%

Figure 15: Waipa-Franklin Summary: distribution of impacts of operating profit



4 Upper Waikato Conclusions

This section provides the overall findings and conclusions for the Upper Waikato catchment, while the description and detailed results for each individual farm have been removed from this report. Table 5 and Figure 16 show the results for the composite farm in the Upper Waikato region, the composite farm is weighted by the total area represented by each farm type (see section 1.3). These results include runs 1.0 to 1.3 as not all farms had mitigations applied beyond this point. Runs beyond 1.3 pushed mitigation options further to try and achieve larger reductions in nitrogen loss, however they still followed the same process as shown in Figure 13. The composite farm size was 195 effective hectares, 543 cows milked, this is larger than the average of all farms in the Rotorua, South Waikato and Taupo TLA's (461 cows and 164ha[15]), however not all of these TLA's are included in the Upper Waikato River Catchment boundaries. On average farms applied 161 kg N/ha and leached 40 kg N/ha.

The weighted averages for both nitrogen fertiliser applied per hectare and nitrogen leaching per hectare were higher in the Upper Waikato than in Waipa-Franklin. The farms in the Upper Waikato area lost 2.3± kg P/ha to water annually whereas in the Waipa-Franklin area this was 0.8± kg P/ha, the Waipa-Franklin area had a higher stocking rate of 3.1 cows per hectare compared to 2.8 in the Upper Waikato.

Table 5: Results for the composite Upper Waikato farm

Stage 1	**1.0 Base**	**1.1**	**1.2**	**1.3**
N leaching kg/ha	**40**	**36**	**32**	**30**
P Loss (kgP/ha)	2.3	2.3	2.3	2.3
Stocking Rate (cows/ha)	2.8	2.7	2.6	2.5
Nitrogen Use(kg N/ha)	161	137	113	86
Milk Solids total (kg)	201,577	195,686	188,515	182,605
Milk Solids (kg/ha)	1,063	1,030	991	958
Milk Solids (kg/cow)	381	381	382	382
Bought Feed / Feed Offered (%)	13	13	12	13
Operating Profit ($/ha)	**2,377**	**2,263**	**2,158**	**2,056**
% Redn in N leaching		-10%	-18%	-24%
% Redn in operating profit		-5%	-9%	-13%
% Redn in production		-3%	-6%	-9%

[15] New Zealand Dairy Statistics 2012-13

Stage 2	2.0 Base	2.1	2.2
N leaching kg/ha	**30**	**26**	**24**
P Loss (kgP/ha)	2.3	2.3	2.3
Stocking Rate (cows/ha)	2.6	2.5	2.4
Nitrogen Use(kg N/ha)	146	124	101
Milk Solids total (kg)	196,012	1910,119	183,183
Milk Solids (kg/ha)	995	961	926
Milk Solids (kg/cow)	358	357	358
Bought Feed / Feed Offered (%)	12	12	12
Operating Profit ($/ha)	**1,960**	**1,861**	**1,768**
% Redn in N leaching	-24%	-35%	-40%
% Redn in operating profit	-18%	-22%	-26%
% Redn in production	-3%	-6%	-9%

Note: the percentage reductions seen in runs 2.n are in relation to the 1.0 base run. For example the base farm built a standoff pad and this reduced their nitrogen leaching from the base by 18%.

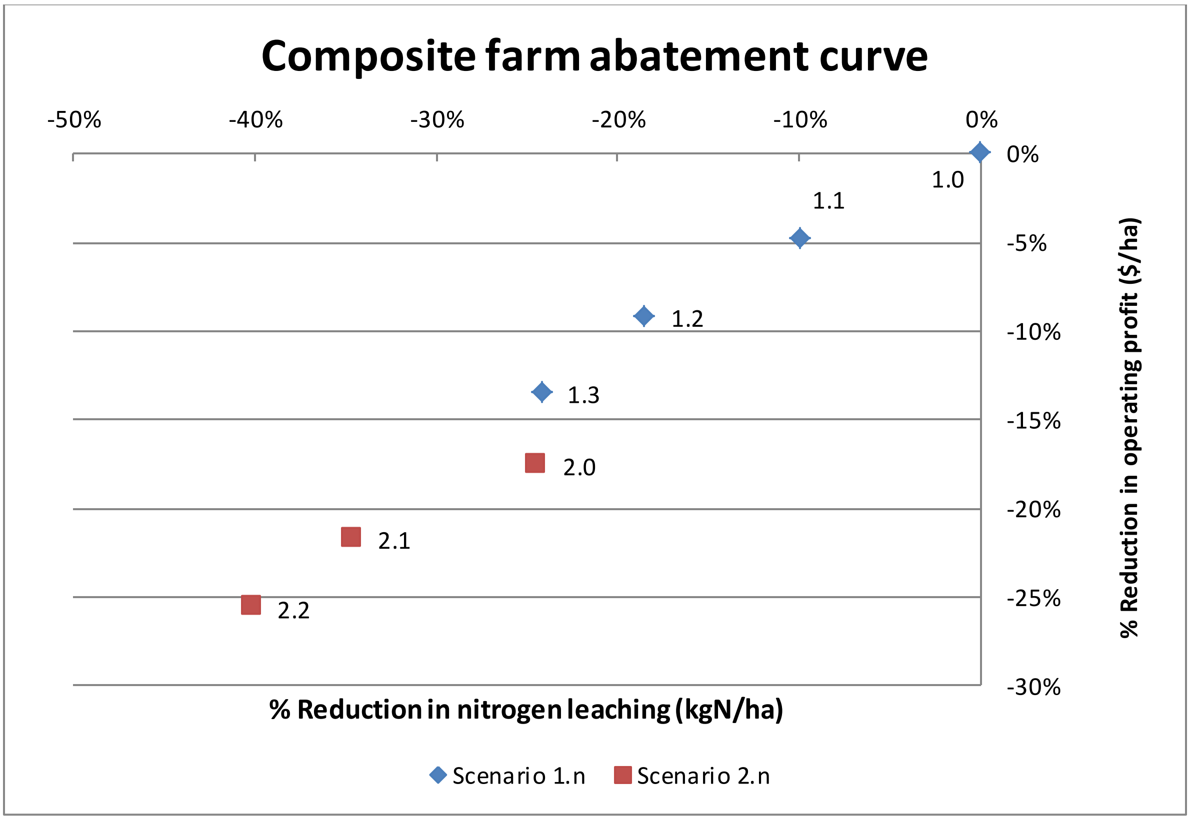
While this is a composite farm and no specific mitigations were undertaken the impact of each farm's mitigation measures can be seen in the KPI's.

1.0 Stage 1.
- 1.1 Nitrogen fertiliser use was reduced by 24 kg N/ha and peak cows milked were reduced by 17 from 543. Because this was a composite farm the 24 kg N/ha of fertiliser was the total amount removed from the farm system, not a specific application. However because autumn fertiliser is always removed first, this 24 kg N/ha would also be removed through the autumn period.
- 1.2 Nitrogen fertiliser use was again reduced by 24 kg N/ha, peak cows milked were reduced by 18.
- 1.3 Nitrogen fertiliser use was reduced by 28 kg N/ha and peak cows milked were reduced by 16. Total nitrogen use was now 86 kg N/ha (-60 Kg N/ha from Base) and peak cows were now 492 (-51 cows from Base, 1.0).

2.0 The addition of a standoff pad reduced N leaching by about 25%, on top of that achieved in Stage 1. This composite farm used 146 kg N/ha and peak cows milked were 500.
- 2.1 Peak cows were reduced by 17 and nitrogen fertiliser reduced by 22 kg/ha.
- 2.2 A further 23 kg of nitrogen fertiliser was removed from the farm system and peak cows were reduced by 16. These mitigations took peak cows milked to 467 and nitrogen use to 101 kg N/ha, milk solids per cow were constant.

No further mitigations were included due to few farms having further runs carried out and the weighted average then became skewed.

Figure 16: Abatement curve for the composite farm in the Upper Waikato region



Average nitrogen leaching was 40± kg N/ha on the baseline. Based on the above mitigations, a 10% reduction in nitrogen leaching per hectare can be achieved with a 5% reduction in profit and 3% reduction in production. A further 10% nitrogen loss reduction impacts operating profit and production by a similar proportion. Reductions in nitrogen leaching of greater than 20% generally have an impact on operating profit and production of more than 10%. Mitigation strategies within the current farm system (i.e. before a standoff pad is introduced in scenario 2.0) would allow the farm to achieve a reduction in nitrogen leaching of 24%. This level of reduction in nitrogen through the strategies used in this modelling would reduce operating profit per hectare by 13% and production by 9%.

The addition of a standoff pad could achieve reductions in nitrogen losses in the order of 7% to 24%, which was the same range as for the Waipa-Franklin region. Scenario 2.0 shows operating profit will be 18% lower with a standoff pad than the base farm scenario reflecting the capital cost and the operating expenses. The use of a standoff pad allows nitrogen loss to be reduced further than what occurred under the mitigation strategies in 1.4. Nitrogen loss can be reduced by 40% with a combination of de-intensification and restricted grazing; however this would reduce operating profit by 26% and milk production by 9%. This percentage reduction in nitrogen leaching caused the same reduction in operating profit (as a percentage reduction from the base) as for the composite Waipa-Franklin farm; however there was a lesser impact on production on the Upper Waikato composite farm.

While reductions in phosphorous leaching were not directly targeted through the mitigation options used in this report, it is often a consequence of the nitrogen leaching mitigation options. The average phosphorus loss was 2.3 kg P/ha, ranging between 0.4 kg P/ha and 6.9 kg P/ha. The measures targeted at mitigations of N leaching losses were also able to remove 0.2 kg P/ha. However this was not achieved until run 2.3 at a 40% reduction in nitrogen loss and the farm had constructed a standoff pad and reduced stocking rate significantly.

The mitigation strategies used had an impact on some farms and not on others in relation to reducing phosphorous loss. Constructing a standoff pad did not always impact on phosphorous losses. There were reductions in phosphorous losses on some farms as a result of nitrogen loss mitigation strategies before a standoff pad was implemented.

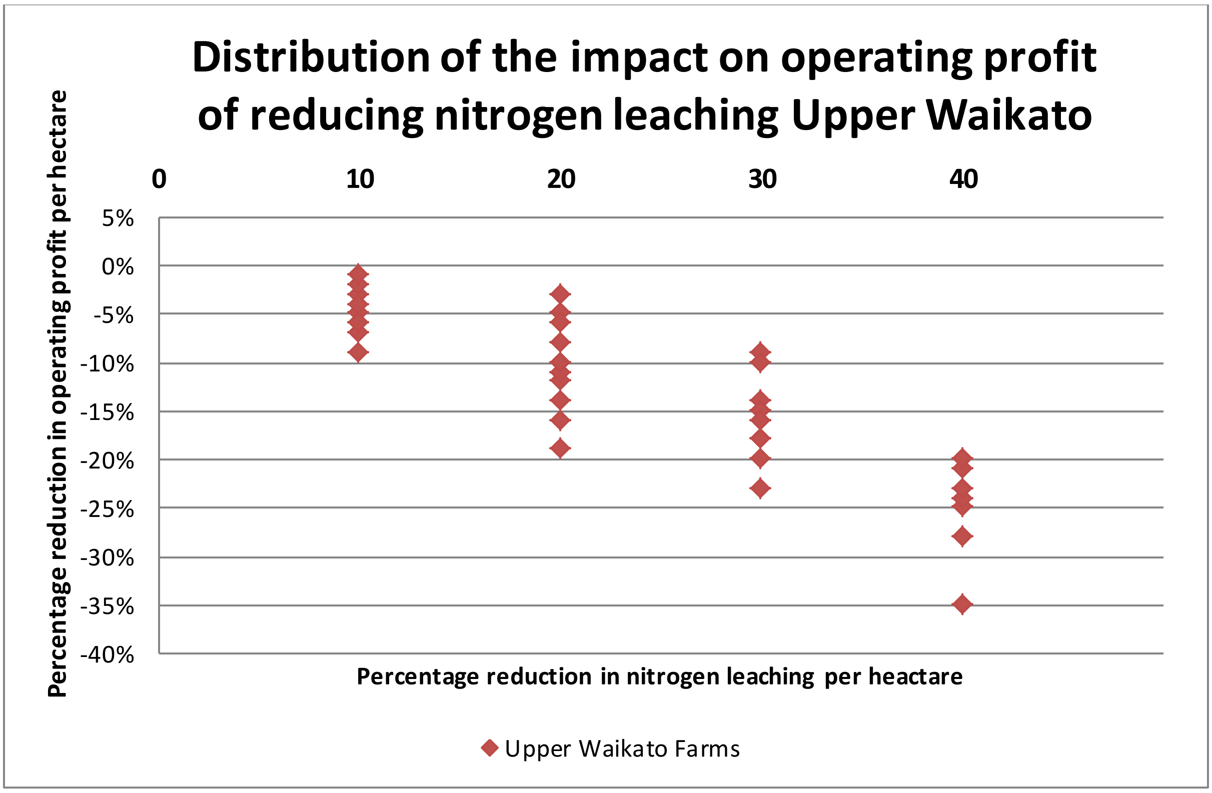
Table 6 shows nitrogen loss per hectare and the percentage decrease in operating profit % for each farm in the targeted N leaching band. Note: the N loss reduction is not exactly 10%, 20%, 30%, and 40% so the percentage is derived by the linear relationship between two points. In general, a 10% reduction in N loss will have a -4% to -8% reduction in operating profit, while a 20% reduction in N loss will reduce profits by -10% to -14%. The impact of achieving a 40% reduction will generally reduce operating profits by a significant 20%-30%.

Table 6: Summary Upper Waikato: Reduction in operating profit per hectare

Farm	Base N leaching (kg N/ha)	Target -10% N leaching	Target -20% N leaching	Target -30% N leaching	Target -40% N leaching
1.UW	33	-3%	-5%	-15%	-21%
2.UW	46	-7%	-19%	-20%	-35%
3.UW	59	-6%	-12%	-18%	-28%
4.UW	30	-5%	-8%	-9%	-24%
5.UW	34	-6%	-16%	-15%*	-28%
6.UW	41	-4%	-11%	-14%	-20%
7.UW	48	-2%	-6%	-10%	-21%
8.UW	38	-6%	-10%	-18%	-25%
9.UW	37	-1%	-3%	-23%	-24%
10.UW	33	-9%	-11%	-15%	-20%
11.UW	26	-7%	-14%	-15%	-23%
12.UW	27	-6%	-10%	-16%	NA

* The impact on operating profit is lower for a 30% reduction in nitrogen leaching than the impact on operating profit for a 20% reduction in nitrogen leaching. This is due to the introduction of a standoff pad which is needed to reduce nitrogen leaching by more than 20%.

Figure 17: Upper Waikato Summary: distribution of impacts of operating profit



5 Appendices

5.1 Waipa-Franklin sub catchment groupings (sub regions)

Group	Farms	Sub catchments
1	2, 6	EW-0039-011 EW-0041-009 EW-0612-009 EW-0624-005 EW-1131-133 EW-1282-008 EW-1302-001 NAT-HM04 No site ("Port Waikato") EW-1131-091 **(60%)** **NB** sub-catchment EW-1131-091 we have split 60/40 across two groups due to differences based on rainfall from East to West in the catchment.
2	1	EW-1131-091 **(40%)** EW-0453-006 EW-0459-006 EW-0516-005 EW-1098-001 EW-1293-007 EW-1293-009 **NB** sub-catchment EW-1131-091 we have split 60/40 due to differences based on rainfall from East to West in the catchment.
3	3, 4, 5	EW-0253-004 EW-0258-004 EW-0481-007 EW-1131-069 EW-1236-002 NAT-HM03
4	9, 10	EW-0417-007 EW-0421-010 EW-0230-005 EW-0488-001 EW-1131-101
5	11, 12, 13, 14	EW-0222-016 EW-0411-009 EW-0414-006 EW-0438-003 EW-0443-003 EW-0476-007 EW-0477-010 EW-0818-002 EW-1191-005 EW-1191-010 EW-1191-012 EW-1253-005 EW-1253-007 NAT-HM01 14 sub catchments grouped due to similar rainfall South of Cambridge (not as wet as further West)
6	7, 8	EW-0398-001 NAT-HM02 EW-0665-005 EW-1131-077

5.2 Upper Waikato sub catchment groupings (sub regions)

Group	Farms	Sub catchments
1	4	EW-0802-001 EW-1131-105
2	10, 11, 12	EW-1057-006 EW-0240-005 EW-0380-002 EW-1323-001 EW-1186-002 EW-0683-004 EW-1186-004
3	1, 9	EW-1131-081 **(50%)** **NB** sub-catchment EW-1131-081 we have split 50/50 across two groups due to differences based on farming systems and type through the length of this catchment.
4	2, 3, 5, 6, 7, 8	EW-1131-107 EW-1202-007 EW-1131-081 **(50%)** EW-1131-143 EW-0786-002 EW-0335-001 EW-1287-007 EW-0388-001 EW-0407-001 EW-1131-147 EW-0359-001 EW-0934-001 **NB** sub-catchment EW-1131-081 we have split 50/50 across two groups due to differences based on farming systems and type through the length of this catchment.