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1. Introduction

The Healthy Rivers Plan for Change: Waiora He Rautaki Whakapaipai (HRWO) Project (www.waikatoregion.govt.nz/healthyrivers) will establish targets and limits for nutrients (N and P), sediment, and *E. coli* in water bodies across the Waikato/Waipa catchment. Different targets and limits regarding the level of these contaminants in waterways within this catchment will have diverse impacts on economic outcomes observed throughout the greater Waikato region. Accordingly, a central contribution of the Technical Leaders Group to the HRWO process is the development and utilisation of an economic model that will integrate diverse information such that the size and distribution of abatement costs associated with alternative limits and targets can be evaluated.

The primary objective of this document is to outline the cost and levels of mitigation achieved for each of the four contaminants for a range of management practices across a broad array of land uses. A feature of this report is an extensive sensitivity analysis that is performed to test how profit changes within the catchment-level model utilised within the HRWO process. Catchment-level profit is a variable of socio-economic importance, and is also highly indicative of the stability of a model of this kind: generally, if profit changes a lot, then a lot has changed in the model, and vice versa. Overall, the sensitivity analysis highlights that key model output changes little with broad changes in the assumed parameters regarding the cost and efficacy of the diverse mitigation strategies included in the model.

A key limitation in a study of this kind is that there is no definitive set of assumptions regarding the cost and efficacy of mitigation practices for nitrogen, phosphorus, *E. coli*, and sediment across New Zealand. Indeed, the breadth of potential levels of effectiveness of each mitigation is broad and hence this aspect to subject to significant uncertainty, according to the circumstances in which the abatement strategy is utilised. This document describes a set of assumptions, drawn from expert opinion and broad literature review, which uphold the broad conceptual relationships that characterise the efficacy of mitigations for these pollutants in the Waikato context. These assumptions have now been reviewed and subsequently updated twice over the course of the HRWO project. While the mitigation performance of abatement strategies is difficult to isolate precisely, especially at the catchment scale, it is proposed that the following are consistent with the stylised facts regarding the effectiveness of mitigations in this region. The capacity for broad variation in these assumptions to detrimentally impact model outcomes is also slight, given that an extensive sensitivity analysis below shows that the model is very robust to significant changes in the values that are utilised.

Many costs that require consideration are one-off costs associated with the establishment of an enduring asset. Examples are those associated with the development of streambank fencing or the construction of a stand-off pad. These costs are annualised in the model, at a consistent interest rate of 8% over a 25-year period, to allow an adequate comparison to costs that are imposed annually (e.g. reductions in operating profit).

2. Streambank fencing

Two general types of stream fencing are incorporated in the model.

The first type of stream fencing is for cattle only and involves a 3-wire electric fence with 2.5 mm wire, number 2 quarter round posts, and 7.5 m spacing to keep cattle out of streams. A cost of \$5 m^{-1} for 10 m post spacing was recommended by Duncan Kervell (Northland Regional Council, 21 April 2015). This is also the midpoint of the range of cost for a 3-wire fence (\$4.50–\$5.50) estimated by Bala Tikkisetty within the Waikato Regional Council in June 2015. No cost for water provision is represented, given that average dairy farms within the region have an adequate number of current troughs and do not rely generally on stream water for stock watering. It is also assumed that only one side of the stream needs to be fenced, given the high level of current fencing present on dairy farms. The total cost is therefore \$5 m^{-1} for stream fencing on dairy farms. This cost is annualised because it is an establishment cost and thus is not borne every year. The annualised cost for fencing both sides is \$0.47 m^{-1}, utilising an interest rate of 8% over a 25-year period.

The second type of stream fencing is for sheep and cattle and involves a 5-wire fence with three electrified wires, 2 plain wires, 2.5 mm wire, and number 2 posts at 5 m spacing. A cost of \$12.50 m^{-1} is drawn from information provided by Duncan Kervell (Northland Regional Council, 21 April 2015). This is higher than the cost of \$7.00–\$7.50 estimated by Bala Tikkisetty (Waikato Regional Council) in June 2015, but is more appropriate given the difficulty of the terrain in which such fences will typically be erected. The cost of water reticulation (including maintenance costs, pumping, and installation) to allow animals to access water even though the stream is fenced is estimated at \$10 m^{-1}, based on information drawn from Northland Regional Council. This cost is assumed to also incorporate an annual cost associated with ongoing maintenance, erosion, and livestock damage—a cost that is especially problematic in first-order streams in steeper terrain. The total cost is therefore $35 m^{-1} for fencing both sides of the stream. This cost is annualised because it is an establishment cost and thus is not borne every year. The annualised cost for fencing both sides is \$3.28 m^{-1}, utilising an interest rate of 8% over a 25-year period.

The existing literature contains a broad range of estimates regarding the potential reductions in nutrient and sediment loss that may be achieved through streambank fencing, buffer strips, and riparian planting (Table 1).

Table 1. Reported efficacy levels for streambank fencing, buffer strips of differing widths, and riparian planting.

Description	**Nitrogen (% red.)**	**Phosphorus (% red.)**	**Sediment (% red.)**	**Source:**
Fence out cattle only	-	-	30–90	McKergow et al. (2007)
Fence out all stock	-	-	80	Palmer et al. (2013)
Fence 20 m buffer	Additional 10–20% of mitigation achieved for fencing cattle out	Additional 15–30% of mitigation achieved for fencing cattle out	50–100	McKergow et al. (2007)
Fence out cattle only	7	10	40	Monaghan and Quinn (2010)
Fence out cattle and plant poplars	10	15	55	Monaghan and Quinn (2010)
Fence out all stock	15	15	50	Monaghan and Quinn (2010)
Fence out dairy cattle	20	40	-	Monaghan et al. (2010)

only				
Fence out all stock	10	30	-	Monaghan et al. (2010)
Fence out cattle only	18	39	60	Semadeni-Davies and Elliott (2012)
Fence out all stock	-	-	8	Fernandez, and Daigneault (2015)
Fence out all stock	-	10–30	-	McDowell (2010)
Fence out all stock	23	24	24	Semadeni-Davies and Elliott (2012)
Grass buffer strips on free-draining soil	-	0–20	-	McDowell (2010)
Vegetated buffer strips	-	37–60	-	McDowell (2010)
Fence out all cattle	-	10–30	-	McDowell and Nash (2012)
Fence out all stock	-	55–60	20–25	McDowell et al. (2013)
Fence out all stock	-	29–37	-	McDowell (2014)
Grass buffer strips	-	29–37	-	McDowell (2014)
Fence out all stock and 5 m planted buffer	50	49	-	Zhang et al. (2010)
Fence out all stock and 10 m planted	73	71	-	Zhang et al. (2010)

buffer				
Fence out all stock and 15 m planted buffer	84	81	-	Zhang et al. (2010)
Fence out all stock and 5 m planted buffer	9	-	46	Sweeney and Newbold (2014)
Fence out all stock and 10 m planted buffer	18	-	63	Sweeney and Newbold (2014)
Fence out all stock and 15 m planted buffer	26	-	72	Sweeney and Newbold (2014)

The value of streambank fencing for nitrogen mitigation is generally low for two reasons. First, streambank fencing can prevent direct urinary deposition to water ways, but these inputs are generally limited (McKergow et al., 2007). Second, while some research has indicated the efficacy of buffers for nitrate removal (Dosskey, 2001; Zhang et al., 2010), there is a well-established concern that these areas will likely act as a source of nitrogen, if vegetation is not regularly cut and removed (e.g. through silage cutting) (Bedard-Haughn et al., 2004; Collier et al., 2013). Given the practicalities of regularly cutting and removing riparian vegetation, it is assumed conservatively here that the sole benefit of fencing is therefore preventing the direct deposition of urine (McKergow et al., 2007), in line with the research used to guide the development of the nitrogen-mitigation options evaluated by Monaghan and Quinn (2010) (Ross Monaghan, AgResearch, pers. comm.).

The use of 5 m buffer strips consisting solely of pasture allows the mitigation of some nitrogen and phosphorus before it reaches waterways. The assumed rates of reduction in total nitrogen are 15% and 5% for dairy and drystock farms, respectively (Ross Monaghan, pers. comm., 7/8/2015). The higher rates for dairy reflect the greater propensity of cattle to enter waterways, relative to sheep, and deposit urine there (Ross Monaghan, pers. comm., 28/1/2015). The first estimate, provided for dairy farms, is closely equivalent to the 16%, 17%, and 26% estimates for dairy farms located on freely-drained, poorly-drained, and peat soils in the Waikato study of Monaghan and Quinn (2010), while also being close to the 18% estimate of Semadeni-Davies and Elliott et al. (2012). The second estimate (10%), provided for drystock farms, is close to the 7% and 15% estimates identified for restricting access by beef cattle and both sheep and beef cattle, respectively, in the Waikato study of Monaghan and Quinn (2010).

The capacity for buffer strips to reduce phosphorus loadings to water courses is well known (Zhang et al., 2010). However, they have only a minor benefit for reducing the delivery of dissolved forms of phosphorus to streams, unless riparian vegetation is harvested regularly (Shepherd et al., Dorioz et al., 2006; McDowell et al., 2004, 2008). Indeed, Sharpley et al. (2001) went so far as to state that there is no benefit of riparian fencing for the removal of dissolved phosphorus. However, the abatement of direct phosphorus input arising from faeces deposited by livestock into water courses is a key benefit of streambank fencing. Given that benefits for sediment reduction are dealt with separately (see below), only modest levels of reduction (10% and 5% for dairy and drystock farms, respectively) in estimated losses of Total Phosphorus are assumed for the mitigation of this nutrient arising from dung deposition directly into the stream and the interception of lateral flows of dissolved forms. Indeed, these levels of reduction are well below those estimates of 40%/30% (Monaghan et al., 2010) and 39%/24% (Semadeni-Davies and Elliott, 2012) for dairy/drystock farms in previous studies, but reflect that the mitigation of particulate phosphorus is dealt with elsewhere. Once again, a higher rate for dairy is assumed—consistent with the estimates provided by Monaghan et al. (2010) and Semadeni-Davies and Elliott (2012)—given the greater propensity for these animals to spend more time in waterways (see above), relative to sheep.

Reductions in particulate phosphorus are achieved through reductions in sediment loss achieved through streambank fencing. Reductions of 40% and 50% in sediment loss due to streambank erosion on dairy and drystock farms are assumed, respectively (Monaghan and Quinn, 2010). These rates are intermediate of the broad range identified during the review, are included in the intervals proposed by McKergow et al. (2007), and are closely equivalent to the efficacy (46%) of the narrow-buffer option (5 m) mentioned in Sweeney and Newbold (2014). The rate of mitigation (80%) for streambank erosion identified by Palmer et al. (2013) is potentially too high, given that most other New Zealand studies suggest that lower rates of abatement are more realistic (Andrew Hughes, NIWA, pers. comm.).

There exists a broad literature regarding river engineering, in which vegetated riparian margins have been shown to have significantly greater stability than those without vegetation (e.g. Smith, 1976). However, these benefits are difficult to establish in practice, due to the narrowing of many small streams under pastoral development that will lead to a pulse of streambank erosion in the near term, and the expectation that they will widen to a new stable equilibrium width under riparian shading, which will lead to a subsequent reduction in streambank erosion (Collier et al., 2001). Riparian vegetation options are not represented in the model due to the difficulty of representing this period of transition and a distinct lack of New Zealand studies—see Boothroyd et al. (2004) for a rare exception—that suggests that planting trees on banks actually reduces rates of streambank erosion (Andrew Hughes, NIWA, pers. comm.). Indeed, the large majority of studies attribute most reductions in streambank erosion to livestock exclusion (Andrew Hughes, NIWA, pers. comm.).

Table 2 draws together a broad range of estimates regarding the efficacy of streambank fencing for reducing the delivery of *E. coli* to water ways. The assumed rates of streambank-fencing efficacy for *E. coli* reduction are 58% and 65% for median and 95th percentile dairy and drystock loads, respectively. These estimates are drawn from a discussion with Ross Monaghan and Richard Muirhead, following reflection on their most-recent set of estimates regarding the efficacy of streambank fencing for reducing microbial loadings to waterways (Table 2). The efficacy of riparian planting for removing microbial loadings is not represented, because experimental research has shown that there is little benefit to riparian planting, compared with the presence of just pasture. This is primarily because the absorptive capacity of riparian plants can be overloaded by high delivery rates, especially during storm events, or high subsurface conveyance of microbes can occur when infiltration is significant (Parkyn et al., 2003; Collins et al., 2004).

Table 2. Reported efficacy levels for streambank fencing for reducing *E. coli* loadings, drawn from the literature.

Reduction in *E. coli* delivery (%)	**Land use**	**Reference**
20–35%	Cattle	McKergow et al. (2007)
40%	Cattle	Monaghan and Quinn (2010)
60%	Dairy and drystock	Monaghan and Quinn (2010)
25%	Dairy	Muirhead et al. (2011), Table 2
20%	Dairy	Longhurst (2012)
24%	Drystock	Longhurst (2012)
30–65%	Dairy and drystock	Quinn (2012)
20%	Dairy Drystock	Semadeni-Davies and Elliott (2012)
24%	Dairy and drystock	Semadeni-Davies and Elliott (2012)
20%	Dairy and drystock	Semadeni-Davies and Elliott (2013)
50%	Dairy and drystock	Semadeni-Davies and Elliott (2013)
20%	Dairy and drystock	Elliott et al. (2013)
50%	Dairy and drystock	Elliott et al. (2013)
50–60%	Drystock	McDowell et al. (2013)
20%	Dairy	Ross Monaghan (pers. comm., 2015)
30%	Median reductions in	Ross Monaghan (pers. comm., 2015)
58%	dairy and drystock	Richard Muirhead (pers. comm., 2015)
65%	95th percentile reductions in dairy and drystock	Richard Muirhead (pers. comm., 2015)

3. Effluent management

A proportion of farms within the catchment still utilise 2-pond effluent treatment systems. Upgrading these systems, such that (high-rate) land application is utilised, allows for improved abatement of nutrients and microbial loads. The benefits for this action are assumed to be an 8% and 80% decrease in TN and TP loads, respectively (Semadeni-Davies and Elliott, 2012). (These benefits of land application are scaled according to the (low) number of cows for which 2-pond systems are still in place.) Moving to high-rate land application reduces the losses of microbes from effluent application by 100% and 85% for median and 95th percentile loadings, respectively (Muirhead, 2015). There is no cost of moving to land application from a 2-pond system, given that the total cost of labour and extra infrastructure is closely equivalent to the money saved through not having to apply additional nutrients through fertiliser application (Ross Monaghan, AgResearch, pers. comm.).

Converting from high-rate effluent application to the use of deferred, low rates of effluent application is a mitigation technique available on dairy farms located on poorly- to imperfectly-drained soils. There is little evidence of broad adoption of this mitigation practice throughout the Waikato region (Semadeni-Davies and Elliott, 2012). The use of delayed, low-rate effluent application is assumed to have a 10% benefit for the mitigation of phosphorus (Semadeni-Davies and Elliott, 2012). This may be closer to 2–5% on farms with well-drained soils (Ross Monaghan, AgResearch, pers. comm.), but is maintained at 10% in this study, given that low-rate effluent application is primarily suited to farms where soils are poorly- to imperfectly-drained.

Applying low rates of effluent to land usually requires an expansion of effluent storage and switching from a travelling irrigator to a low-rate effluent applicator. The cost of this practice is assumed to be an annualised cost of \$26 cow^{-1}, based on data from Ross Monaghan (AgResearch). This consists of an annualised establishment cost of \$10 cow^{-1} for additional pond storage, an annualised capital cost of \$13 cow^{-1} for an upgrade from an existing travelling irrigator to low-rate irrigation infrastructure, and \$3 cow^{-1} for annual, ongoing maintenance. Moving from high-rate land application to deferred, low-rate application is assumed not to change median microbial losses arising from effluent management, which are effectively zero under high-rate effluent land application, relative to the high numbers present with a 2-pond treatment system (Muirhead, 2015). Additionally, a 99.9% reduction in 95th percentile levels of *E. coli* loads arising from effluent application is simulated, drawn from Muirhead (2015).

4. Improved phosphorus management

The improved management of applied phosphorus is a key strategy to achieve reduced levels of phosphorus loss from New Zealand farms. There are three key strategies involved in this aggregated scenario. First, there is an opportunity for farmers to optimise their application of phosphatic fertiliser in response to measurements of plant-available phosphorus levels (McDowell and Nash, 2012). Second, there is an opportunity to reduce rates of phosphorus loss through use of less-soluble forms of phosphatic fertiliser, such as Reactive Phosphate Rock (RPR) (McDowell, 2010; McDowell and Smith, 2012). Last, there is the opportunity to employ best management practice for applying phosphatic fertiliser; for example, applying these only when surface runoff is unlikely (McDowell and Nash, 2012). The last option remains important, relative to the other two options, given that only around 60%, 73%, and 75% of drystock, dairy, and horticulture farms, respectively, currently utilise this practice nationally (Brown, 2013).

These three options are considered as one aggregated mitigation option within the economic model. They are combined for a number of reasons:

1. The degree to which each strategy is applicable to each of the heterogeneous farms present across the catchment is broadly disparate. For example, there is broad heterogeneity in the levels of plant-available phosphorus and amount of phosphatic fertiliser applied on dairy farms within the catchment (DairyNZ Economics Group, 2014). This exists despite Semadeni-Davies and Elliott (2012) suggesting that 80%/40% of intensive/extensive farms currently possess optimal levels of plant-available phosphorus in their soils.
2. Solely representing mitigation through the maintenance of lower levels of plant-available phosphorus on horticultural farms is problematic since reducing maintenance applications can have a significant effect on yield in horticultural enterprises, especially on soils typical of the Lower Waikato region that have high levels of phosphorus fixation (Mike Beare, personal communication, 28 January 2015). Additionally, a more-significant driver of phosphorus loss in horticulture systems in the Lower Waikato is related to the loss of phosphorus bound to sediment (Mike Beare, personal communication, 28 January 2015).
3. The suitability of alternative forms of phosphatic fertiliser (e.g. superphosphate versus RPR that has low solubility) for use within different agricultural enterprises varies, depending on rainfall, soil pH, and the stage of farm development (McDowell and Nash, 2012; McDowell and Smith, 2012).

Results from a literature review of the efficacy levels of these different mitigation options are set out in Table 3. Here, the higher values probably reflect the greater benefits expected for poorly-drained or sloping soils. Based on these results, the broad strategy of improving the management of applied phosphorus is assumed to achieve a 10% reduction in phosphorus loss. These gains are assumed to be achievable at zero cost (Monaghan et al., 2008), given that their adoption will likely benefit farmers through improved pasture and crop yield, if the same rate of application is maintained, or reduced input costs, if lower rates of application are appropriate. The potential bias to model output associated with an assumption of zero cost is effectively bound by the low level of the benefit associated with the action and the focus of this practice on only one pollutant. Additionally, this sensitivity is explored below in an extensive sensitivity analysis carried out with the model.

Table 3. Reported efficacy levels for the improved management of phosphatic fertiliser application, drawn from the literature.

Description	Phosphorus (% red.)	Source
Optimum P fertiliser use based on soil test	5–20	McDowell (2010)
Optimum P fertiliser use based on soil test	5–20	McDowell and Nash (2012)
Optimum P fertiliser use based on soil test	10–12	McDowell et al. (2013)
Low-solubility phosphorus fertilisers	0–20	McDowell (2010)
Low-solubility phosphorus fertilisers	0–20	McDowell and Nash (2012)
Low-solubility phosphorus fertilisers	18–22	McDowell et al. (2013)

5. Stand-off management

Benefits of a stand-off pad for nitrogen and phosphorus mitigation are drawn from OVERSEER. Thus, it is assumed that 10% of *E. coli* are removed through the adoption of stand-off pads in this analysis (Semadeni-Davies and Elliott, 2012). Stand-off pads capture a significant proportion of the microbes deposited on their surface. However, their overall capacity to reduce total loadings is constrained by the limited period that cows spend there—for example, a maximum of three months per year is simulated in this study, based on typical practice in the Waikato region—and the substantial numbers of bacteria that still enter drainage from stock maintained on the pad (Luo et al., 2006). Indeed, a poorly-managed stand-off pad can increase *E. coli* losses to water above those rates experienced on pasture; however, a net benefit is more likely, overall (Richard Muirhead, AgResearch, pers. comm.).

6. Benefits of afforestation

The profitability of forestry in each diverse subcatchment is drawn from SCION modelling. Benefits of forest for nitrogen and phosphorus mitigation are drawn from OVERSEER. Benefits for reducing microbial losses, due to transition from pastoral to forested land, are represented through changing the level of loading for this land from that estimated for the current land-use to that estimated for pine forest (Semadeni-Davies et al., 2015).

Afforestation with pine trees has been shown to achieve significant reductions in sediment loss in past studies (Fahey et al., 2003; Basher, 2013). For example, Dymond et al. (2006) assume that full afforestation can achieve a 90% reduction in erosion, while Hicks (1990)—as cited in Basher (2013)—highlights that a 95% level of reduction is attainable. Decreases in sediment loss from afforestation, relative to pasture, are assumed to be 78% in the economic model (Elliott et al., 2008). This is lower than the high estimates presented by Dymond et al. (2006), but is close to the maximum bound of a 50–80% reduction identified across most studies (Blaschke et al., 2008; Basher, 2013). Thus, it is reasonably intermediate of the broad range identified in previous work (a 50–95% reduction).

There is broad evidence that forest harvest leads to high sediment losses—greater than those emanating from pasture—during harvest and in the subsequent year (Ritchie, 2012). However, the level of mitigation for sediment loss achieved by pine afforestation is retained at 78% because:

1. The sediment loss during harvest is highly episodic. While sediment levels rise during and immediately after harvest, these quickly (i.e. within 2–6 years) return to pre-harvest levels under standard practice (Ritchie, 2012; Baillie and Neary, 2015).
2. The economic model utilised here is an equilibrium model, representing a stationary state. The standard approach to describing such temporal events in an equilibrium model is to annualise the load contribution. This effectively translates to allocating the

pulse of sediment loss accruing to harvest activity across the 28-year harvest regime represented within the model, which would greatly diminish its contribution.

3. The estimate of 78% is drawn from a regression model that aims to predict annual sediment yield; thus, it explicitly includes a consideration of losses during the harvest phase.
4. Increased recognition of the adverse impact of clear-cut harvesting on sediment losses has promoted a focus of the New Zealand forestry industry on improving management practices (NZFOA, 2015). With the use of a broad range of strategies, as outlined by NZFOA (2015), the sediment losses encountered during felling can be effectively mitigated (Baillie and Neary, 2015).

7. Farm plans – soil conservation

It is recognised both in the Waikato (Palmer et al., 2013) and other regions, such as the Manawatu (Dymond et al., 2010), that farm plans provide a coherent and pragmatic tool to model and address erosion losses from agricultural land in New Zealand. Farm plans involve the development of a tailored strategy for each farm, regarding specific actions to achieve sediment mitigation across the different parcels of land present within it. The main justification for using this approach, in modelling and policy development for addressing sediment loss, is the high uncertainty regarding the efficacy of alternative mitigation strategies for this pollutant.

It would be useful to determine the extent that different mitigation technologies (e.g. space-planted poplar trees) reduce sediment loss from different types of erosion (e.g. landslide and earthflow), and then use these to moderate the estimated levels of each source from the New Zealand Empirical Erosion Model (Dymond et al., 2010). However, there is little reliable information that can be used to draw together this information, especially given the localised nature of most field research (John Dymond, Landcare Research, pers. comm., 13/4/2015). Accordingly, upon review with Reece Hill (Waikato Regional Council) on 22 May 2015, it was felt that farm plans were appropriate to define as the primary mitigation instrument for hillslope erosion in this study. This is also consistent with earlier research carried out in the Waipa catchment (Palmer et al., 2013), a primary source of sediment for the Waikato River. Farm plans are assumed to achieve a 70% reduction in sediment loss, once all actions have been adopted (Dymond et al., 2010).

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

9. Horticulture mitigations

The mitigation options to reduce the risk of nitrogen loss from the horticulture farms considered in the study (Agribusiness Group, 2014) are set out below. Lease costs of $2000 ha^{-1} were included in their estimation; however, these had to be removed in this assessment to make them comparable to the profit figures computed for the other industries.

Table 9 outlines the mitigation options for an extensive rotation (HOR1) incorporating potato (summer)–onions–carrots–squash–oats and rye–barley–and oats and rye. This rotation is assumed to cover around half of the horticultural area in the Lower Waikato. N loss goes up for the second scenario in Table 9 due to the use of other strategies adopted to help reduce concomitant cost when monthly N application is limited.

Table 9. Levels of profit, nitrogen loss, and phosphorus loss for an extensive horticultural rotation in the Lower Waikato (HOR1).

Farm profit (\$ ha^{-1})	**Nitrogen load (kg N ha^{-1})**	**Phosphorus load (kg P ha^{-1})**	**Mitigation practice utilised**
5,591	58	1.1	None (baseline)
5,578	60	1.1	Limiting monthly nitrogen application to 80 kg N ha^{-1}
3,870	54	1.1	Reduction of total nitrogen applied by 10%
1,213	52	1.1	Reduction of total nitrogen applied by 20%
-397	49	1.1	Reduction of total nitrogen applied by 30%
-1,884	46	1.1	Reduction of total nitrogen applied by 40%
2,611	54	1.3	Active management of irrigation water

Table 10 outlines the mitigation options for an intensive rotation (HOR2) incorporating squash–broccoli–oats and rye–lettuce (summer)–mustard–onions–oats and rye–and potatoes (winter). This rotation is assumed to cover 45% of the horticultural area in the Lower Waikato.

Table 10. Levels of profit, nitrogen loss, and phosphorus loss for an intensive horticultural rotation in the Lower Waikato (HOR2).

Farm profit ($ ha^{-1})	Nitrogen load (kg N ha^{-1})	Phosphorus load (kg P ha^{-1})	Mitigation practice utilised
6,540	65	1.3	None (baseline)
6,527	61	1.3	Limiting monthly nitrogen application to 80 kg N ha^{-1}
3,348	57	1.3	Reduction of total nitrogen applied by 10%
1,079	54	1.3	Reduction of total nitrogen applied by 20%
-1,593	51	1.3	Reduction of total nitrogen applied by 30%
-3,496	47	1.3	Reduction of total nitrogen applied by 40%
3,560	63	1.3	Active management of irrigation water

Table 11 outlines the mitigation options for a traditional market-garden rotation (HOR3) incorporating broccoli–mustard–lettuce–cabbage–mustard–spinach–cauliflower–cabbage–and mustard. This rotation is assumed to cover 5% of the horticultural area in the Lower Waikato.

Table 11. Levels of profit, nitrogen loss, and phosphorus loss for an intensive horticultural rotation in the Lower Waikato (HOR3).

Farm profit ($ ha^{-1})	Nitrogen load (kg N ha^{-1})	Phosphorus load (kg P ha^{-1})	Mitigation practice utilised
5,274	73	1.9	None (baseline)
5,137	69	1.9	Limiting monthly nitrogen application to 80 kg N ha^{-1}
3,110	65	1.9	Reduction of total nitrogen applied by 10%
1,334	59	1.9	Reduction of total nitrogen applied by 20%
-497	51	1.9	Reduction of total nitrogen applied by 30%
-1,940	44	1.9	Reduction of total nitrogen applied by 40%
2,294	65	1.8	Active management of irrigation water

A range of mitigation activities exist for reducing sediment loss from horticultural farms. These are described in more detail in Barber (2014). The assumed levels of efficacy and cost used here are taken from this source, with midpoints representing any ranges presented by Barber (2014) (Table 12).

Table 12. The efficacy and cost of mitigation strategies for sediment loss on horticultural farms in the Lower Waikato region.

Mitigation strategy for sediment	Effectiveness (%)	Cost ($/ha)
Buffer strip	65	175
Wheel track ripping or dyking	65	35
Contour drains	50	75
Benched headlands	65	75
Super silt fence	87.5	380
Decanting earth bund	87.5	130

The relative adoption of these diverse strategies varies. Contour drains have not been broadly adopted, as these increase the risk of large storm events leading to widescale soil loss. In contrast, there has been broad-scale adoption of wheel-track ripping, dyking, and sediment traps.

10. Dairy mitigations

Data pertaining to the cost of dairy-farm mitigation is provided by DairyNZ. It is summarised in Appendix 1.

11. Edge-of-field mitigations

Chris Tanner (NIWA) has provided information regarding the suitable location (Table 13) of different edge-of-field mitigation strategies, and the efficacy (Table 14) and cost (Table 15) of these structures when they are sited in these locations. The set of strategies and parameters utilised are based on an extensive review of available technologies at a workshop held in early 2015. The density of structures reported in Table 14 is dampened in the model, according to the productivity of the land that is lost (Table 15). This allows the computation of a more-refined estimate of the opportunity cost of land lost when these options are adopted.

Table 13. The siting of the edge-of-field mitigation strategies utilised within the economic model.

Mitigation	Hydrological flow path	Catchment slope applicability	Soil characteristics applicability	Proportional areal applicability (% of area)	Proportion of load intercepted (% of load)
Detention bund	Upland/rolling country Moderately well-drained soils. Ephemeral channels/1st-order catchments	>7 deg <25 deg	Drainage classes 4-5	80%	30%
Detention bund and wetland	Upland/rolling country Poorly-drained soils Ephemeral channels/1st-order catchments	>7 deg <25 deg	Drainage classes 1-3	80%	80%
Sedimentation pond and wetland combination	Lowland drains and first-order streams	<7 deg	Drainage classes 1-3	80%	80%
Small constructed wetland	Base of 1st-3rd order streams	<15 deg	All	80%	80%
Medium constructed wetland	Base of 1st-3rd order streams	<15 deg	All	80%	80%

Table 14. The efficacy of the edge-of-field mitigation strategies utilised within the economic model.

Mitigation	Efficacy for sediment (% load reduction)	Efficacy for N (% load reduction)	Efficacy for P (% load reduction)	Efficacy for *E. coli* (% load reduction)	Density of mitigation (numbers or area per ha)
Detention bund	70%	10%	30%	50%	One per 20ha = 0.05 systems/ha
Detention bund and wetland	70%	10%	50%	50%	One per 20ha = 0.05 systems/ha
Sedimentation pond and wetland combination	70%	10%	30%	50%	0.25% of catchment area
Small constructed wetland	60%	20%	35%	75%	Occupy 1% of area = 0.01ha/ha or 1 ha wetland per 100 ha of contributing catchment
Medium constructed wetland	80%	40%	70%	90%	Occupy 2.5% of area = 0.025ha/ha or 2.5 ha wetland per 100 ha of contributing catchment

Table 15. The cost of the edge-of-field mitigation strategies utilised within the economic model.

Mitigation	Components of cost 1. Construction	Components of cost 2. Planting	Components of cost 3. Fencing	Components of cost 4. land area occupied	Components of cost 5. Maintenance
Detention bund	$5000 each = $250/ha of land mitigated	Nil	Nil	Nil	General maintenenace = $0.30 per ha of land mitigated/year, plus pipework replacement and some sediment removal @ $2000 after 25 years
Detention bund and wetland	$5000 each = $250/ha of land mitigated	0.02 ha wetland planting per system @ $20,000/ha = $400/system =$20/ha of land mitigated	0.02ha fenced per system, assume need 80m fencing /system @ $6/m installed and materials = $480 plus gate and hinges @$220= $700/system = $35/ha of land mitigated	Loss of lower value grazing, in 0.02ha permanent wetland/system or 0.01 ha/ha of mitigated land, earning around 40% of average farm income/ha	General maintenenace = $0.60 per ha of land mitigated/year, plus pipework replacement and some sediment removal @ $2000 after 25 years
Sedimentation pond and wetland combination	0.25% of average 20 ha catchment = 0.05 ha = 500 m2 @ $120,000/ha of planting, a gate and fencing = $6000/system = $300 /ha of land mitigated	Included in construction costs	Gate and fences included in construction costs	0.25% of catchment, but in many cases likely to be constructed on normal productive agricultural value, earning around 80% of average farm income/ha	$0.75 per ha of land mitigated per year
Small constructed wetland	$100,000/ha of actual wetland inclusive of planting, a gate and	Included in construction costs	Gate and fences included in construction costs	1% of catchment but likely to be constructed in water-	$200 per ha of wetland per year = $2/year/ha of land

	fencing $1,000/ha of farmland mitigated			logged and flood-prone areas with reduced agricultural value, earning around 40% of average farm income/ha	mitigated per year @ 1% wetland coverage
Medium constructed wetland	$100,000/ha of actual wetland inclusive of planting, a gate and fencing $2,500/ha of farmland mitigated	Included in construction costs	Gate and fences included in construction costs	2.5% of catchment but likely to be constructed in water-logged and flood-prone areas with reduced agricultural value, earning 40% of average farm income/ha	$200 per ha of wetland per year = $5/year/ha of land mitigated per year @2.5% wetland coverage

12. Sensitivity analysis

The economic model used in the HRWO process is of significant size, consisting of more than 10,000 equations and 50,000 decision variables. Also, the cost and efficacy parameters are not known with certainty. Thus, this section explores how key model output changes when the cost and efficacy parameters for each mitigation are varied from their standard value. The overall aim is to identify how sensitive catchment-level profit is to broad changes in these parameter values. Catchment-level profit is a variable of socio-economic importance, and is also highly indicative of the stability of a model of this kind: generally, if profit changes a lot, then a lot has changed in the model, and vice versa.

The sensitivity analysis is structured according to two classification criteria. First, the full set of mitigations is divided among the different primary types of mitigation practice represented within the model. Second, the parameters are classified according to whether they are cost or efficacy parameters. The latter (efficacy) concerns rates of mitigation across the abatement practices for each of the four contaminants studied in the HRWO process (nitrogen, phosphorus, *E. coli*, and sediment). The sensitivity analysis is carried out for all mitigations and for all cost and efficacy parameters.

Broad changes in the parameters are simulated. The set of changes consist of -50, -25, +25, and +50% perturbations. These ensure that the impacts of sizeable changes in the baseline values of the parameters are explored. Changes regarding the effectiveness of each mitigation strategy are assumed to simultaneously affect their capacity to reduce all contaminant loadings to the same degree. This is to improve the clarity and focus of the sensitivity analysis, while also being broadly indicative of a general misspecification of the parameter values concerning the impact of a given abatement option.

Scenario 1 determined by the Collaborative Stakeholder Group (CSG) is characterised by substantial improvement in water quality for swimming, taking food, and healthy biodiversity. The water-quality attribute set that is the focus of Scenario 1 includes limits defined across a broad range of attributes: chlorophyll *a* (median and maximum), total nitrogen, total phosphorus, nitrate (median and 95^{th} percentile), *E. coli* (median and 95^{th} percentile), and water clarity. A step of *x*% towards Scenario 1 means that all limits defined across the catchment move x% from their current state to that state defined under Scenario 1. For example, if the current state median-nitrate level for a site is 2 g m^{-3} and the Scenario 1 goal for this site is a median-nitrate level of 1 g m^{-3}, then a 10% movement would mean that the simulated limit is 1.9 m^{-3}. Likewise, a 25% movement would mean that the simulated limit is 1.75 m^{-3}. The sensitivity analysis is performed for 10, 25, and 50% steps towards Scenario 1, to explore how the sensitivity of the model framework changes as greater demands are placed on mitigation activity, as determined through more-stringent attribute limits.

Some mitigation practices have a zero value in the baseline model. These are the cost of 2-pond system remediation and improved phosphorus management. The former (2-pond system remediation) is assumed to have costs of $5, $10, $15, and $20 per cow outside of the baseline, instead of changes consisting of -50, -25, +25, and +50% perturbations. The latter (improved phosphorus management) is assumed to have costs of $25, $50, $75, and $100 per ha outside of the baseline, instead of changes consisting of -50, -25, +25, and +50% perturbations.

The profitability of forestry changes across space in the model, according to the biophysical characteristics of each sub-catchment and its location relative to processing facilities. Moreover, there is no abatement-cost option defined for this land use; rather, plantation forest is a single land-use option that can be utilised on a given area of land. Thus, only changes in its effectiveness as a mitigation option are evaluated. In any case, a change in efficacy broadly approximates a change in cost. The important relationship for a mitigation practice within a model of this kind, is the relationship between cost and efficacy (i.e. the abatement-cost relationship). If a parameter regarding mitigation efficacy is changed, this changes the abatement-cost relationship, as would a change in the cost parameter.

The abatement-cost relationships for point sources, dairy farms, drystock farms, and horticulture farms encompass both mitigation efficacy and cost data. It is difficult to develop an informative set of simulations to test the sensitivity of the model to changes in these relationships, especially because a broad range of mitigation activities are encompassed in each data point located on the abatement-cost relationship. Accordingly, only a change in cost is explored, but in a way that reflects the importance of the abatement-cost relationships defined in the model; explicitly recognising the importance of mitigation efficacy, together with its cost. Abatement cost is the difference in profit between the baseline state within a given activity (e.g. current management on a given representative dairy farm) and a state in which mitigation occurs (e.g. current management but with removal of nitrogen-fertiliser application on a given representative dairy farm). Sensitivity analysis for point sources, dairy farms, drystock farms, and horticulture farms is performed through manipulating all such differences by -50, -25, +25, and +50%. A reduction in such a difference between the baseline and mitigation scenarios reflects cheaper abatement, while an increase in such a difference reflects more-expensive abatement, in line with the changes tested for the other cost parameters.

The results of the sensitivity analysis are reported in Table 16 below. The numbers in the table show the percentage change in catchment-level profit for a 1% change in a cost or efficacy parameter for each mitigation strategy, across different steps taken towards achieving Scenario 1. They are computed through dividing the total percentage change in catchment-level profit, relative to the baseline, by the total percentage change in the cost or efficacy parameter (-50, -25, +25, or +50%). (These numbers are specifically called *arc elasticities* in economic analysis.)

<u>The model is very robust to significant changes in cost and efficacy parameters for the set of mitigations reported in the model.</u> The maximum size of any output reported in Table 16 is 0.124%, denoting that the maximum change for a 1% change in cost or efficacy—across a 50% decrease/increase in these parameter values—is 0.124% in catchment-level profit. This highlights that the model is highly robust (i.e. highly inelastic) to broad changes in the cost/efficacy assumptions. Indeed, economists usually classify a relationship as sensitive (i.e. elastic) if the computed number is above 1%; here, the highest value is 0.124%, which shows that the model is very robust to broad-scale changes in the key assumptions for each mitigation. This outcome is intuitive for several reasons. First, movements towards Scenario 1 focus on a broad range of contaminants, thereby reducing the chance that one mitigation practice is solely relied upon in the suite of abatement options selected. (A lower probability that one mitigation practice is relied upon to perform most abatement reduces the chance that the model will be highly sensitive to broad changes in its cost or efficacy.) Second, a broad range of mitigation activities exist, both in reality and in the model, such that other mitigations can cost-effectively substitute for more costly or less-effective options.

The model becomes more sensitive to changes in cost and efficacy as the scenarios become closer to Scenario 1. For example, the elasticity for the cost of streambank fencing increases across 0, 0.003, and 0.011% as steps towards Scenario 1 move to 10, 25, and 50%, respectively (Table 16). This outcome reflects the fact that greater mitigation activity is required as model runs move closer to Scenario 1, and the model is thus more sensitive to changes in the cost and efficacy of abatement options.

Overall, Table 16 highlights that the most-sensitive parameters regard the cost of mitigation performed by medium wetlands, point sources, dairy farms, drystock farms, and horticulture farms, for the 50% step towards Scenario 1. Medium wetlands are costly, but provide a highly-effective mitigation practice across all contaminants (Table 14). Additionally, on-farm abatement is important to reduce nitrogen loss and is reasonably costly in the baseline, given the degree of mitigation required. Accordingly, it is not surprising that these relationships have the greatest impact on the sensitivity of catchment-level profit in the runs performed. Nevertheless, the scale of the output in Table 16 reinforces that the model is very robust to broad changes in the cost and/or efficacy of these practices.

Table 16. The change (%) in catchment-level profit for a 1% change in the parameter representing the cost or efficacy of a given mitigation strategy. Results are reported to three decimal places; thus, numbers reported as zero actually denote changes that are between 0–0.0009%.

Action	**% change**	**10% step to S1**		**25% step to S1**		**50% step to S1**	
		Cost	**Efficacy**	**Cost**	**Efficacy**	**Cost**	**Efficacy**
Streambank fencing	-50%	0	-0.004	0.003	-0.011	0.011	0.003
	-25%	0	-0.002	0.003	-0.004	0.014	0.011
	+25%	0	0.002	0.001	0.008	0.02	0.034
	+50%	0	0.004	0.001	0.014	0.023	0.046
2-pond system remediation (% change is cost/efficacy)	$5/-50%	0	0	0.002	0.002	0.025	0.02
	$10/-25%	0	0	0.002	0.002	0.026	0.024
	$15/+25%	0	0	0.001	0.002	0.026	0.028
	$20/+50%	0	0	0.001	0.002	0.025	0.028
Low-rate effluent application	-50%	0	0	0.002	0.002	0.026	0.027
	-25%	0	0	0.002	0.002	0.026	0.027
	+25%	0	0	0.002	0.002	0.027	0.027
	+50%	0	0	0.002	0.002	0.027	0.027
Improved P management (% change is cost/efficacy)	$25/-50%	0	0	0.001	0.002	0.025	0.026
	$50/-25%	0	0	0.001	0.002	0.025	0.026
	$75/+25%	0	0	0.001	0.002	0.025	0.027
	$100/+50%	0	0	0.001	0.002	0.025	0.027
Farm plans	-50%	0	0	0.002	0.002	0.038	0.028
	-25%	0	0	0.002	0.002	0.032	0.026
	+25%	0	0	0.002	0.002	0.021	0.027
	+50%	0	0	0.002	0.002	0.015	0.027
Forestry	-50%	0	0.037	0	0.069	0	0.06
	-25%	0	0.021	0	0.061	0	0.045
	+25%	0	-0.034	0	-0.121	0	0.003

	+50%	0	-0.081	0	-0.153	0	-0.023
Horticulture erosion control	-50%	0	0	0.002	0.004	0.023	0.023
	-25%	0	0	0.003	0.004	0.023	0.023
	+25%	0	0	0.004	0.004	0.023	0.023
	+50%	0	0	0.004	0.004	0.023	0.023
Detention bund	-50%	0.002	-0.002	0.007	-0.003	0.027	0.017
	-25%	0.001	0	0.005	0.001	0.025	0.02
	+25%	-0.001	0.002	0.002	0.007	0.022	0.027
	+50%	-0.001	0.003	0.001	0.009	0.02	0.031
Detention bund and wetland	-50%	0.002	0	0.006	-0.001	0.026	0.02
	-25%	0.001	0	0.005	0.001	0.025	0.022
	+25%	0	0.001	0.004	0.007	0.022	0.027
	+50%	0	0.002	0.003	0.01	0.021	0.031
Sediment trap	-50%	0.002	-0.001	0.006	0	0.026	0.019
	-25%	0.001	0	0.005	0.002	0.025	0.021
	+25%	0	0.001	0.003	0.007	0.022	0.025
	+50%	0	0.002	0.003	0.009	0.021	0.027
Small wetland	-50%	0.004	0.001	0.008	0.002	0.048	0.008
	-25%	0.002	0.001	0.006	0.003	0.035	0.01
	+25%	0.001	0.002	0.002	0.006	0.014	0.031
	+50%	0.001	0.004	0.003	0.009	0.012	0.039
Medium wetland	-50%	0.014	-0.022	0.024	-0.072	0.067	0.005
	-25%	0.007	-0.008	0.013	-0.031	0.042	0.016
	+25%	-0.002	0.009	-0.004	0.029	0.008	0.033
	+50%	-0.005	0.018	-0.013	0.048	-0.003	0.048
Point sources	-50%	0.004	0	0.008	0	0.093	0
	-25%	0.005	0	0.016	0	0.114	0
	+25%	0.004	0	0.014	0	0.1	0
	+50%	0.002	0	0.008	0	0.066	0
Dairy farms	-50%	0.023	0	0.04	0	0.124	0
	-25%	0.011	0	0.023	0	0.095	0
	+25%	-0.006	0	-0.006	0	0.037	0
	+50%	-0.013	0	-0.02	0	0.013	0
Drystock farms	-50%	0.02	0	0.034	0	0.094	0
	-25%	0.01	0	0.021	0	0.08	0
	+25%	-0.004	0	-0.005	0	0.052	0
	+50%	-0.01	0	-0.018	0	0.038	0
Horticulture farms	-50%	0.002	0	0.009	0	0.074	0
	-25%	0.002	0	0.009	0	0.07	0
	+25%	0.002	0	0.007	0	0.062	0
	+50%	0.002	0	0.006	0	0.057	0

13. Conclusions

The development of an economic model to predict the farm-, catchment-, regional-, and national-level economic outcomes associated with alternative environmental limits is a broad-ranging task, which seeks to integrate diverse information into a consistent framework so that it can be considered altogether during policy evaluation. A key component of the economic model is the representation of the relationships between the use of mitigations and the concomitant reduction achieved in the loss of the four contaminants that are studied within the HRWO project. Moreover, the cost of these actions must also be considered, in order to assess the total cost of reducing contaminant loadings across the scales of interest. The primary objective of this document is therefore to outline the assumptions regarding the cost and levels of mitigation achieved for each of the four contaminants for a range of management practices across a broad array of land uses. These assumptions provide a fair basis for the assessment of alternative water-quality improvement scenarios, particularly given that extensive experimentation with the model shows that it is very robust to broad changes in key parameters regarding the cost and efficacy of the main mitigation strategies.

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APPENDIX ONE

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

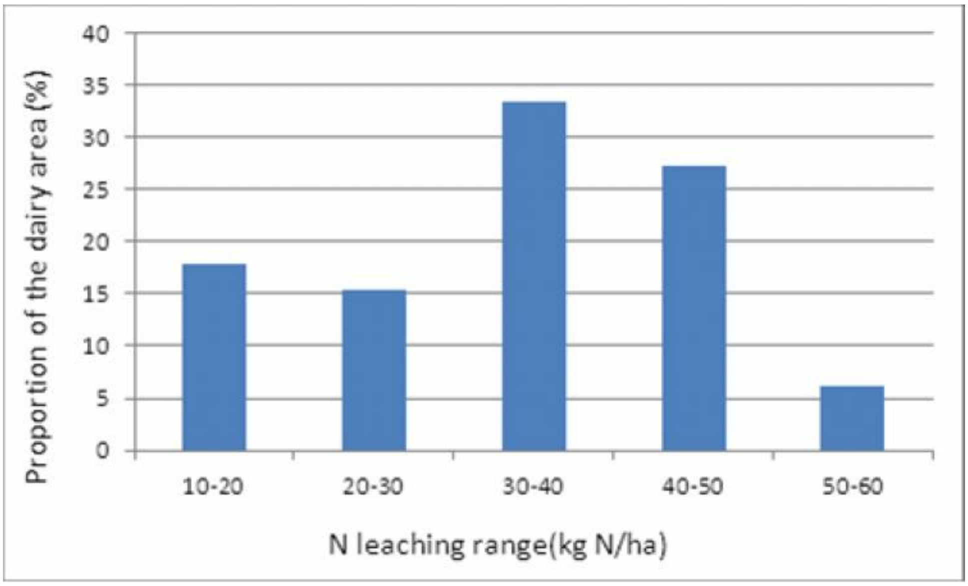
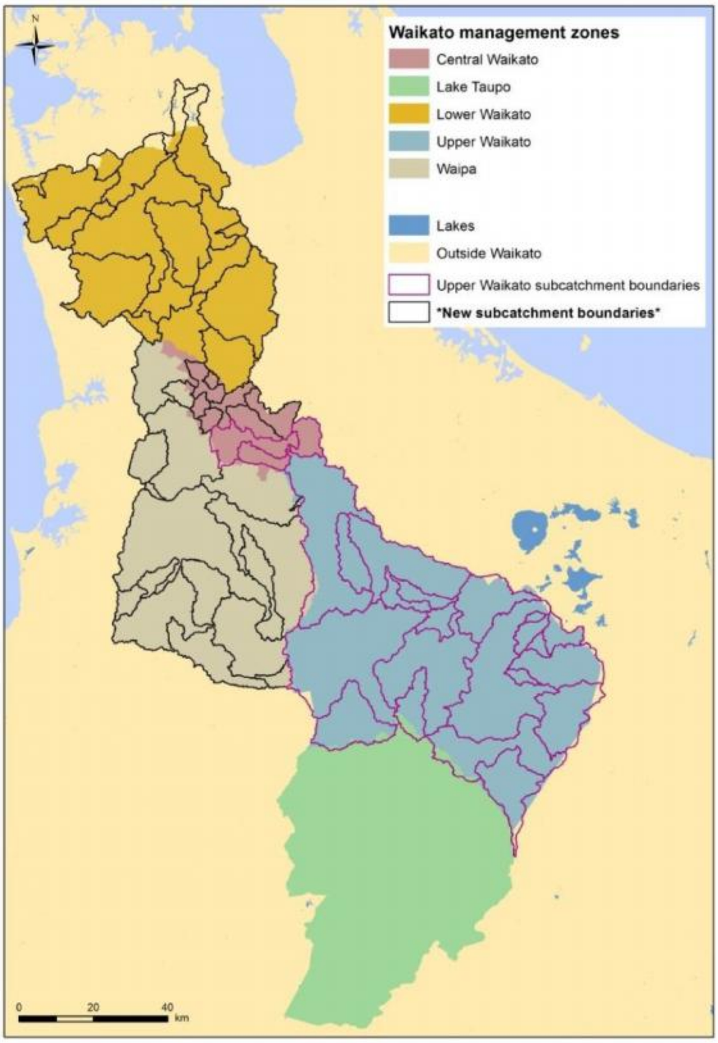


Figure 2: Waipa-Franklin and Upper Waikato catchment area.



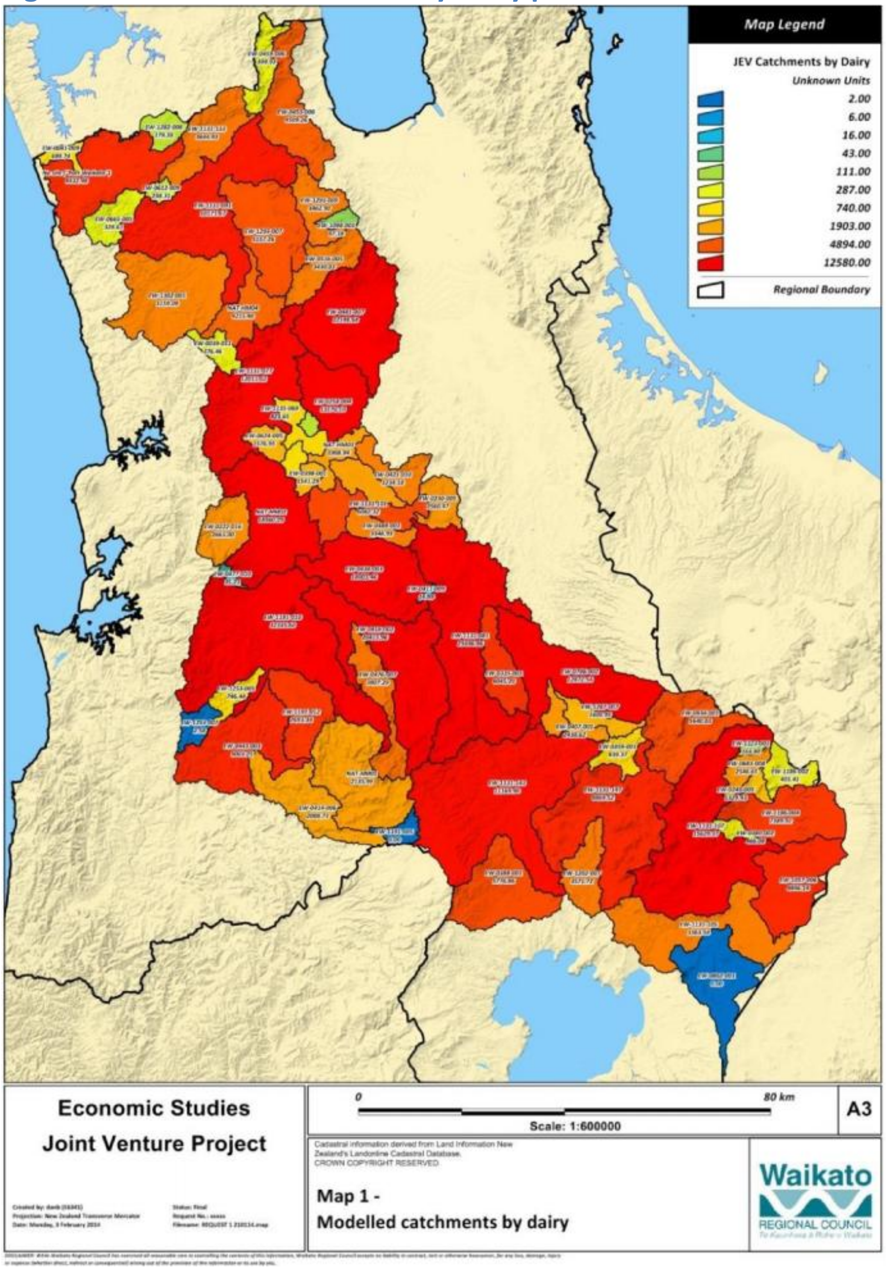
Source: MPI

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.

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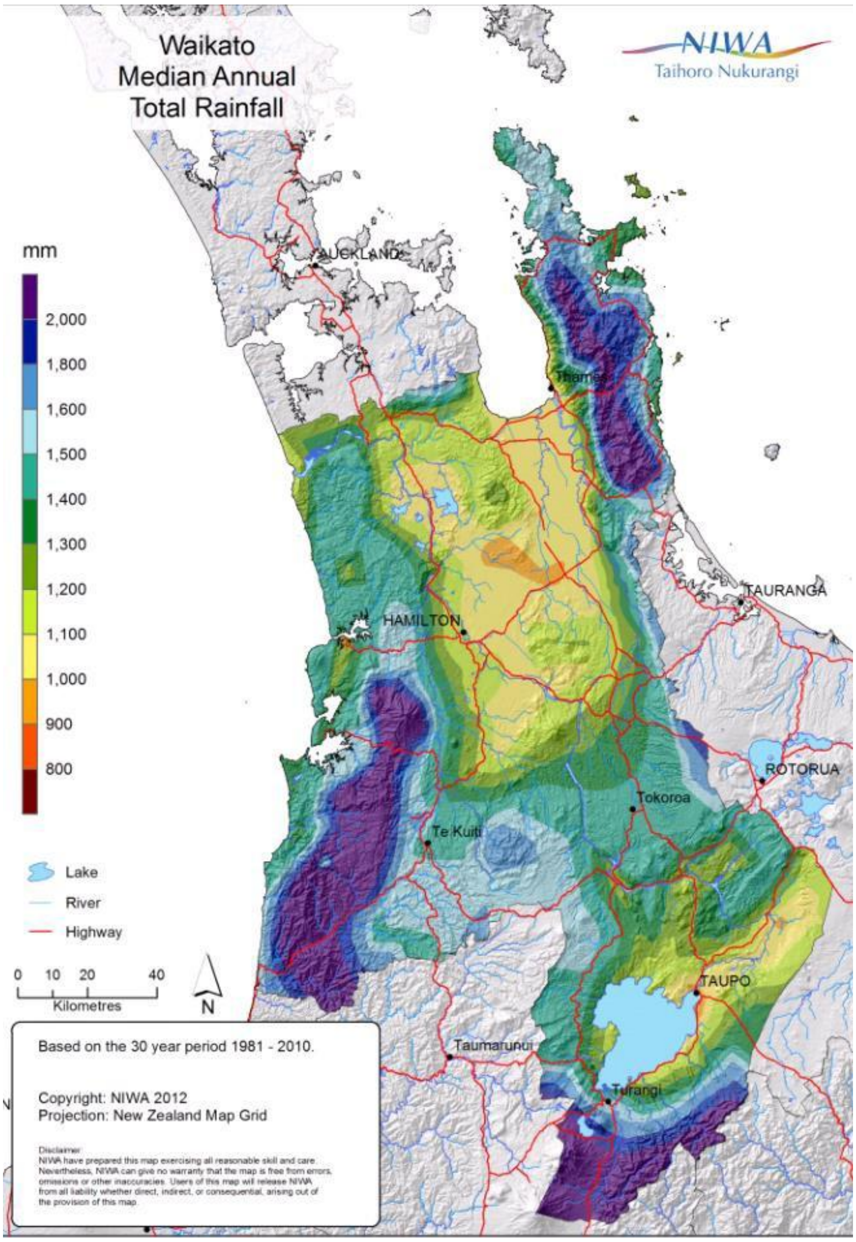
[6] New Zealand Dairy Statistics 2012-13
[7] MPI
[8] New Zealand Dairy Statistics 2012-13
[9] MPI

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).

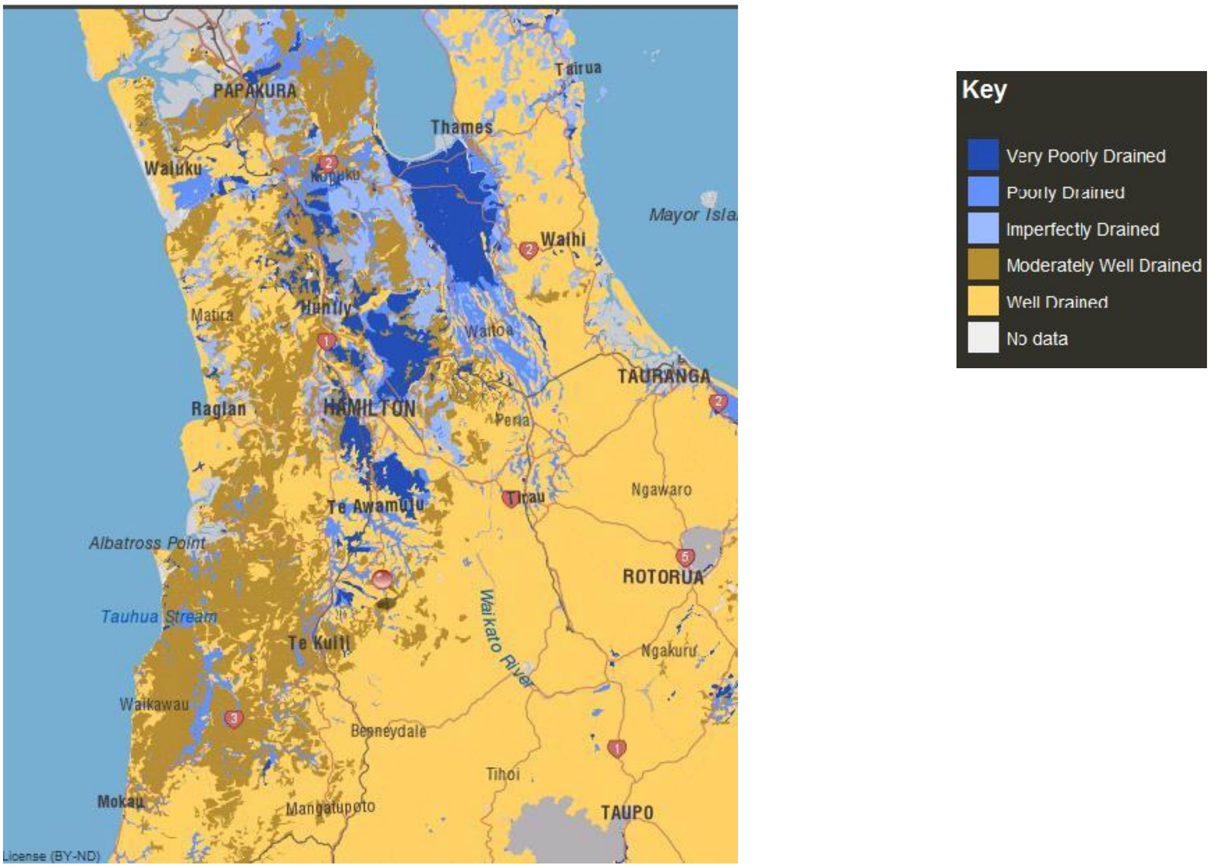
The case study farms were then chosen based on their physical location and how well they represented variables (including biophysical, production system, farm characteristics and key performance indicators) within each sub region. Comparing each farm to district data allowed the project team to consider 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.

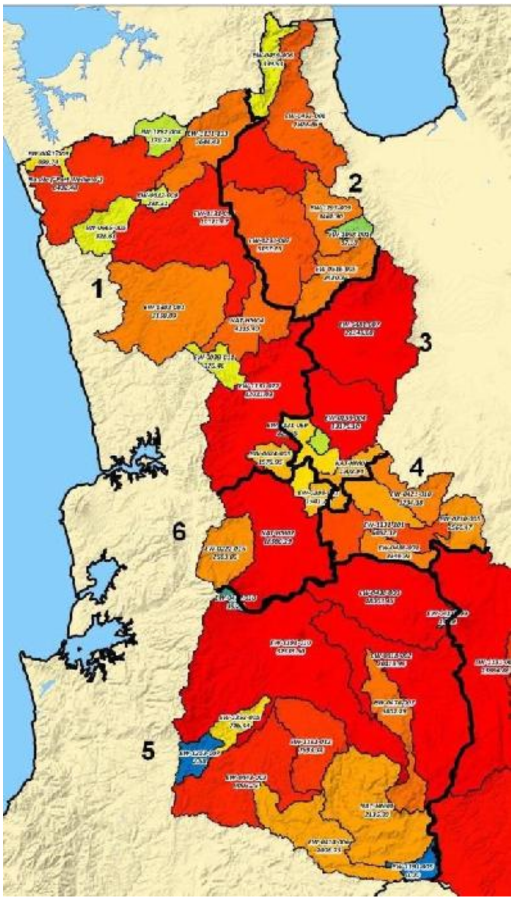
2.3.1 Waipa-Franklin Representation

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.

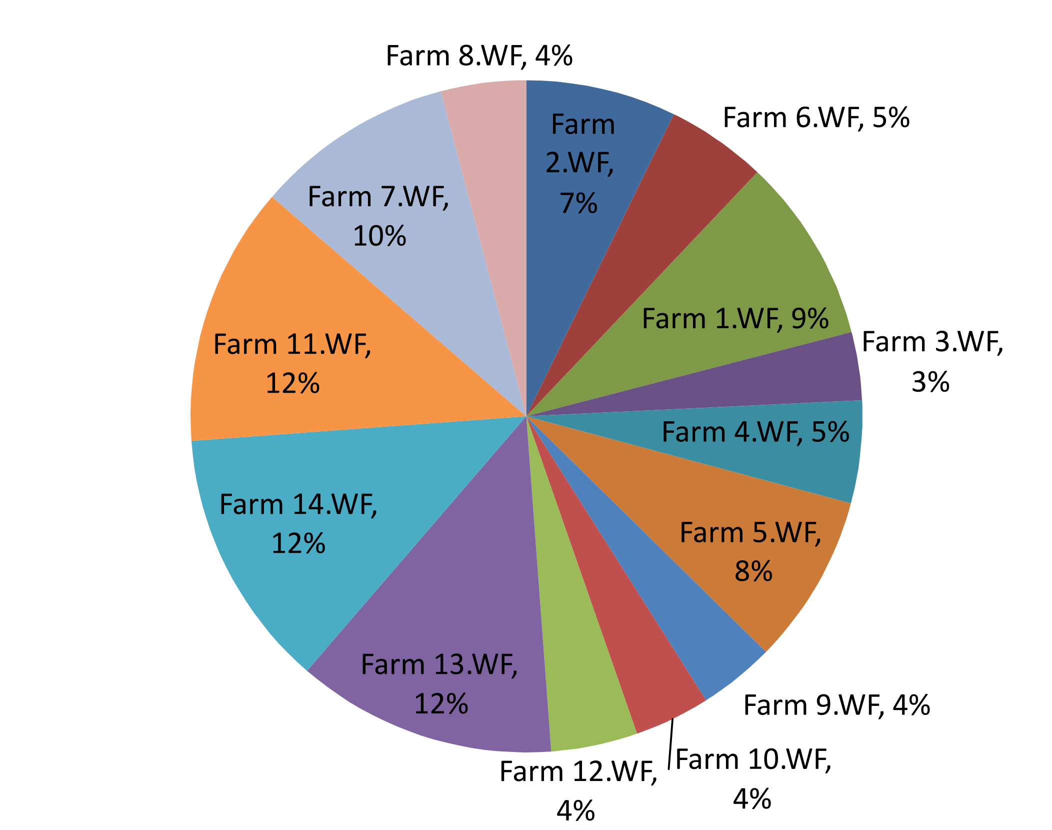
Table 1: Farm representation of the Waipa-Franklin sub regions

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.

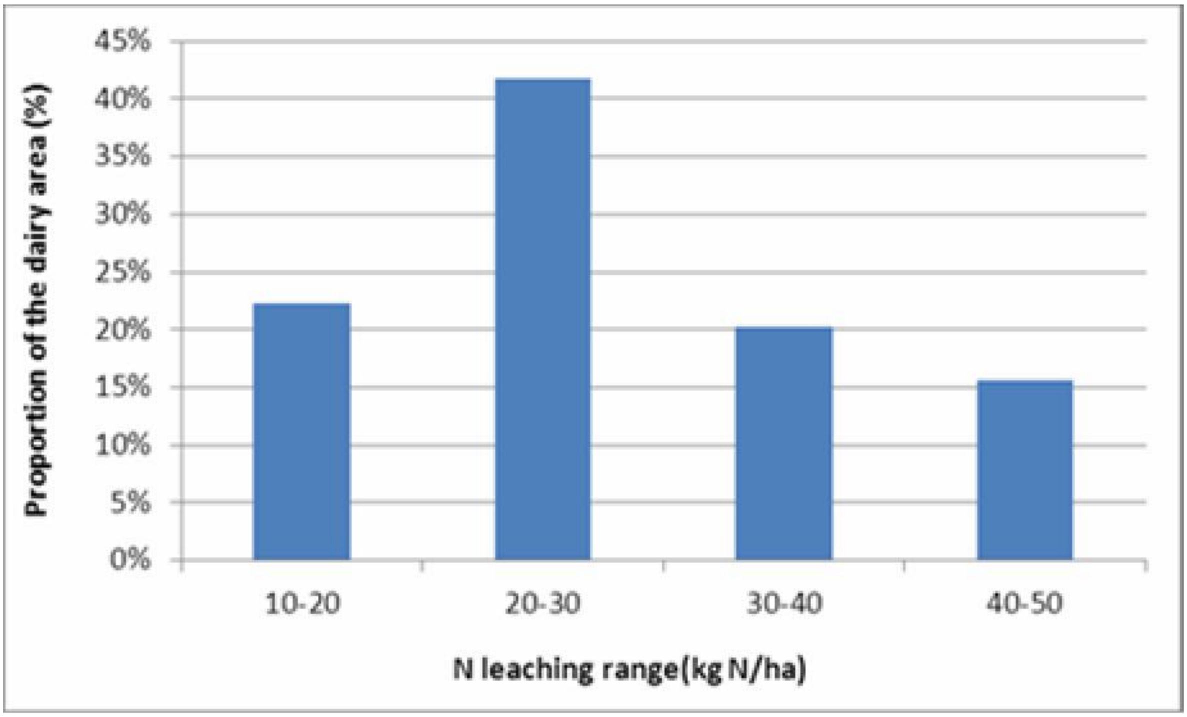
[10] Five production systems described by DairyNZ primarily on the basis of when imported feed is fec to dry or lactating cows during the season and secondly by the amount of imported feed and/or off farm grazing. www.dairynz.co.nz/farm/farm-systems/the-five-production-systems/

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



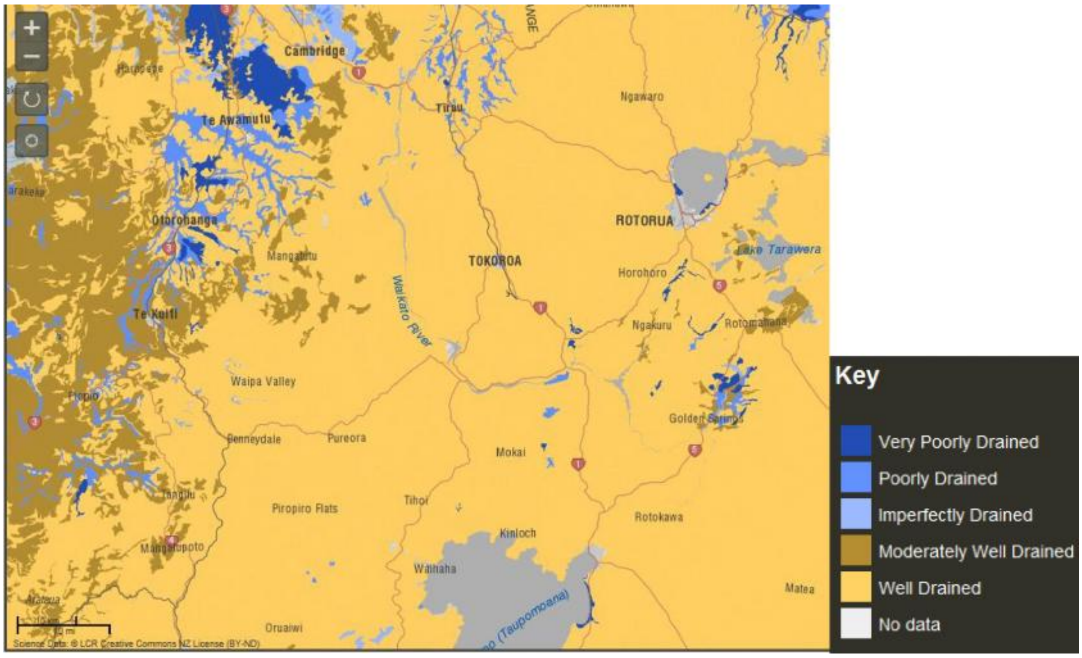
Based on the representation of the farms in the sample, Figure 8 shows the distribution of nitrogen leaching per hectare for dairy farms in the Waipa-Franklin region. The weighted average (weighted by the representation described in section 1.3) was 30.3 kg N/ha. There was a range of 12 kg N/ha to 50 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



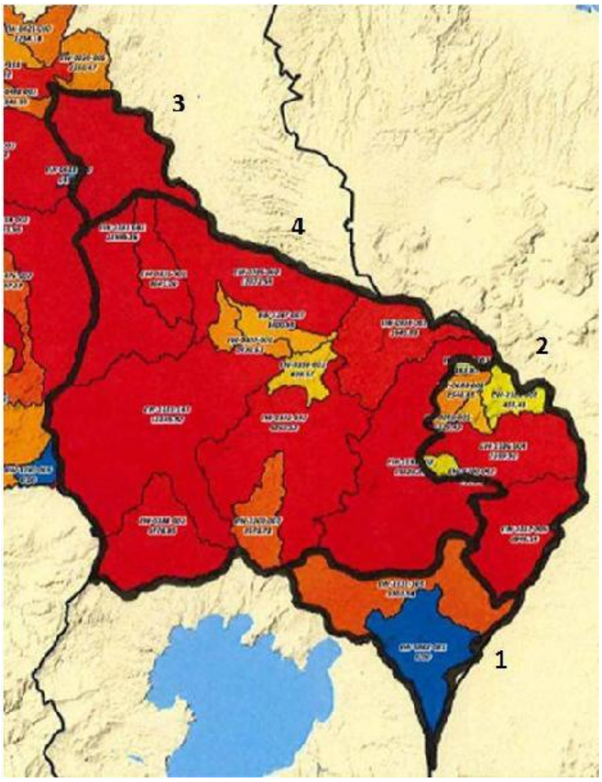
2.3.2 Upper Waikato Representation

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.

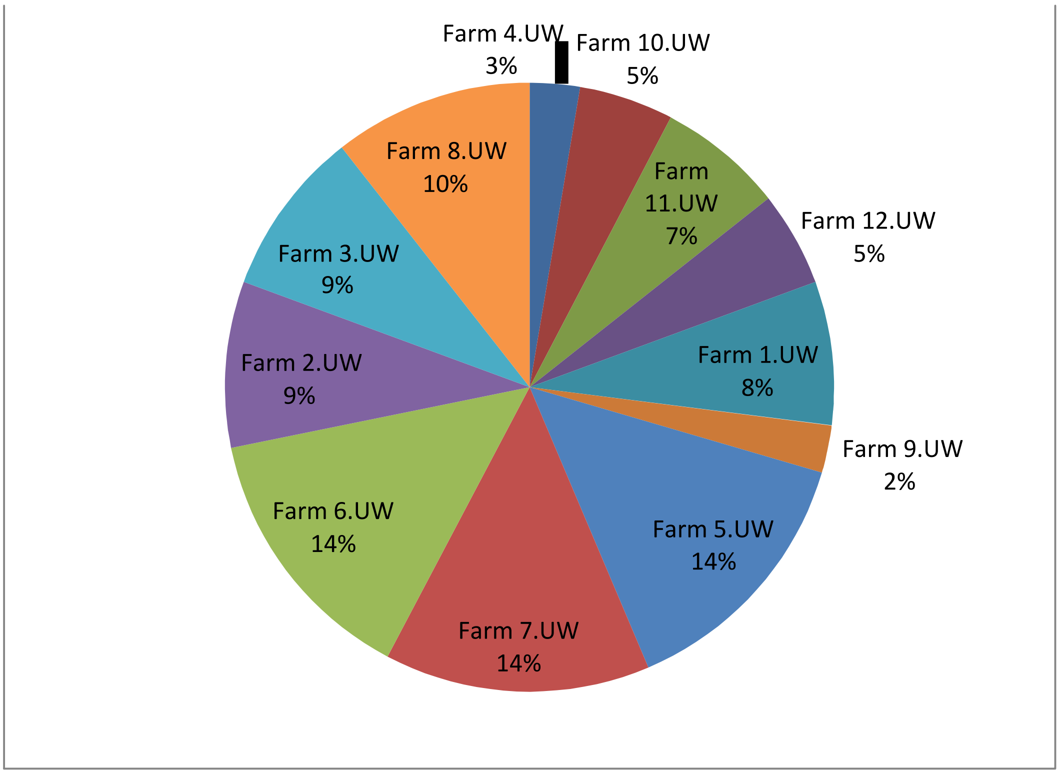
includes a range of dairy farm types from newer large-scale, but lower intensity, forestry conversions, to older, smaller more intensive farms around Tokoroa.

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	

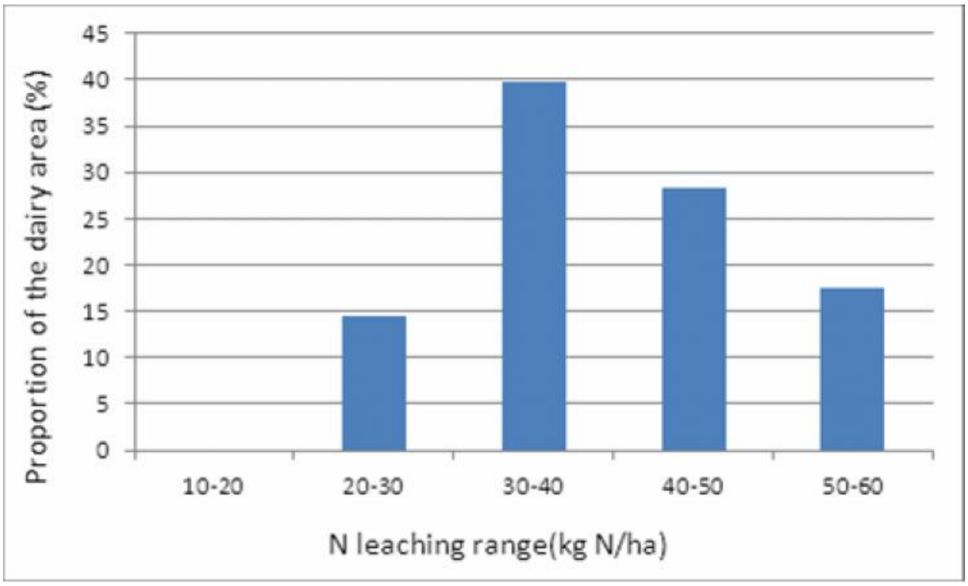
The representation of the farms was checked across the hectares for the entire area to ensure no particular modelled farm or farm type was over-represented. Farms 5.UW, 6.UW and 7.UW have the largest weight with 14% of the total dairy land each, combined these account for more than a third. These three 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.

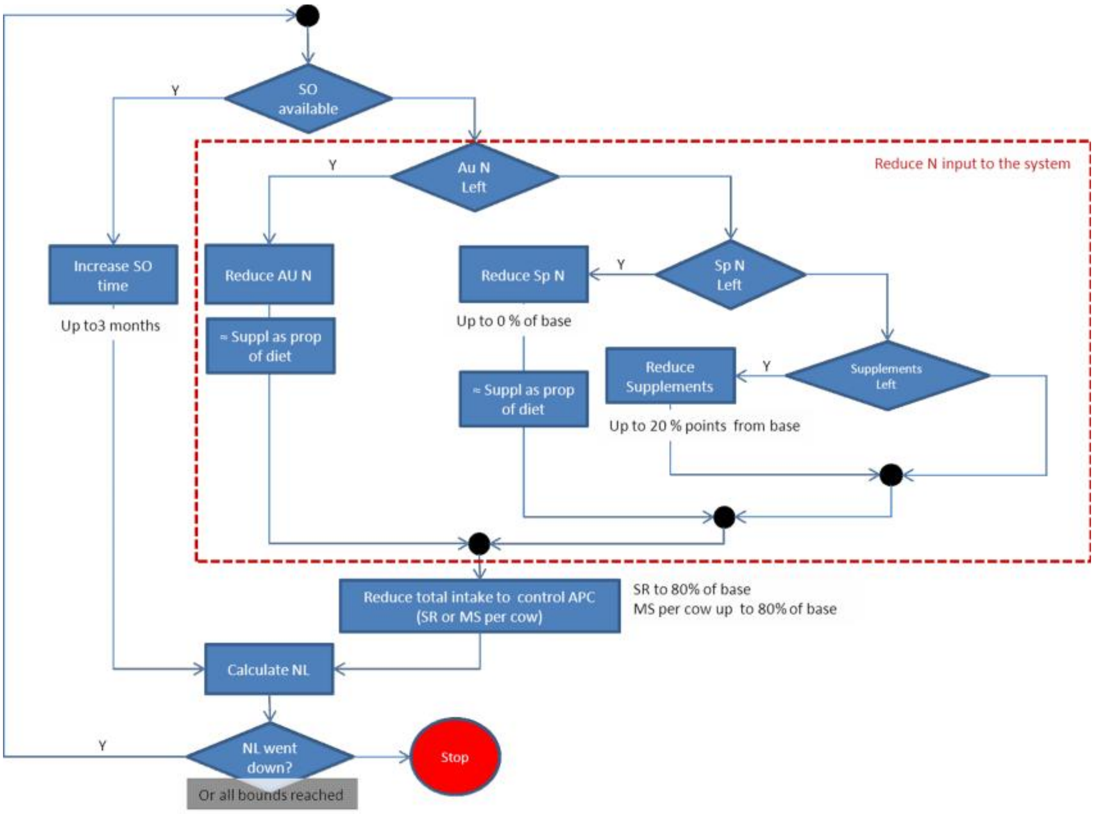
The mitigation strategies can be broadly described as management changes within the current farm system first, followed by an infrastructure change.

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

[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.

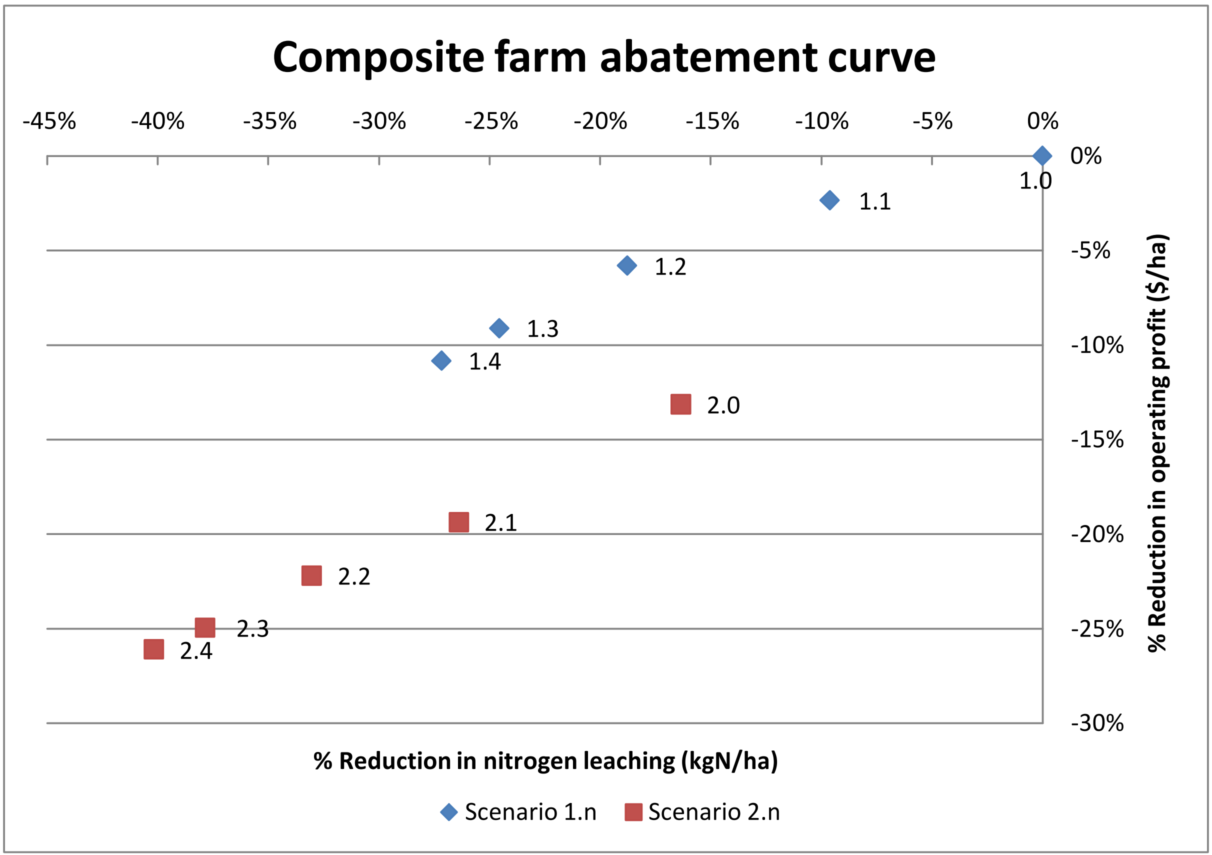
2.1 Peak cows were reduced by 23 and 27 kg of nitrogen fertiliser was removed from the system.

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%.

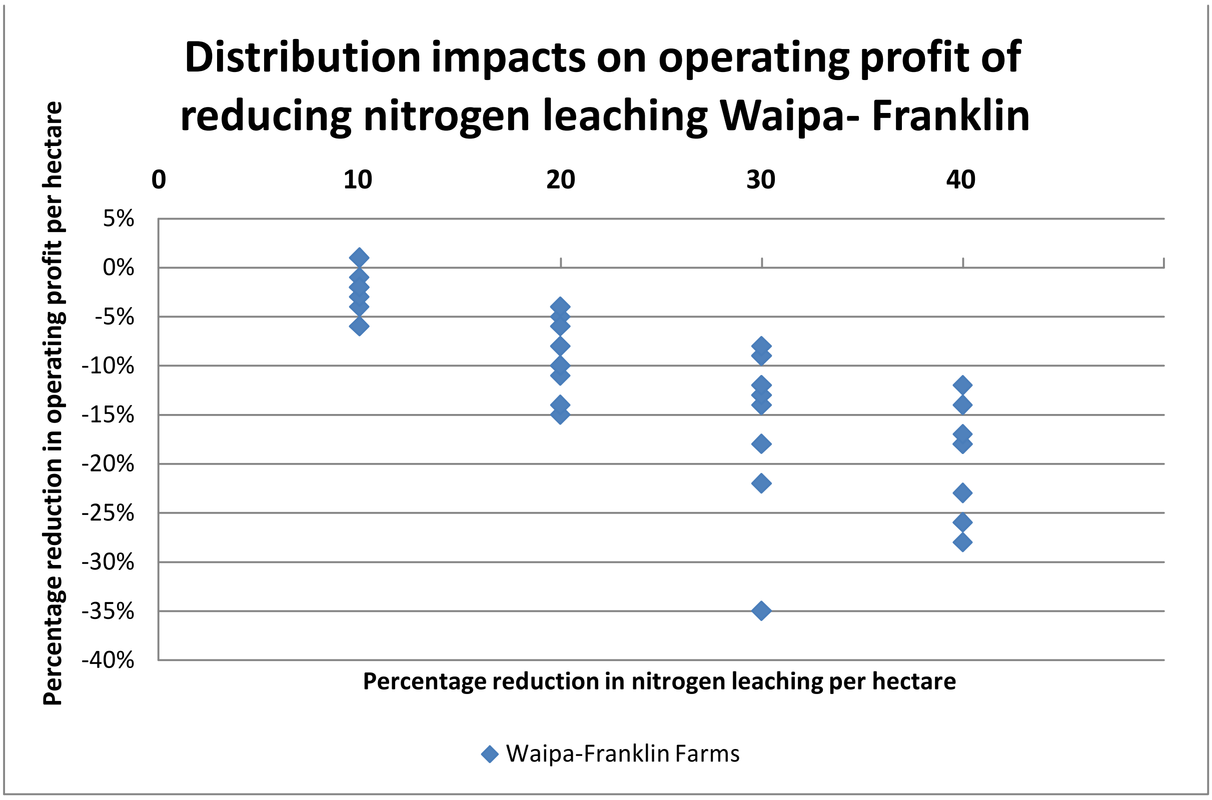
While reductions in phosphorous losses were not directly targeted through the mitigation options used in this report, some reductions occurred as collateral effects of the nitrogen leaching mitigation options. Phosphorus loss from the composite farm was 0.8kgP/ha, with a range on case study farms between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

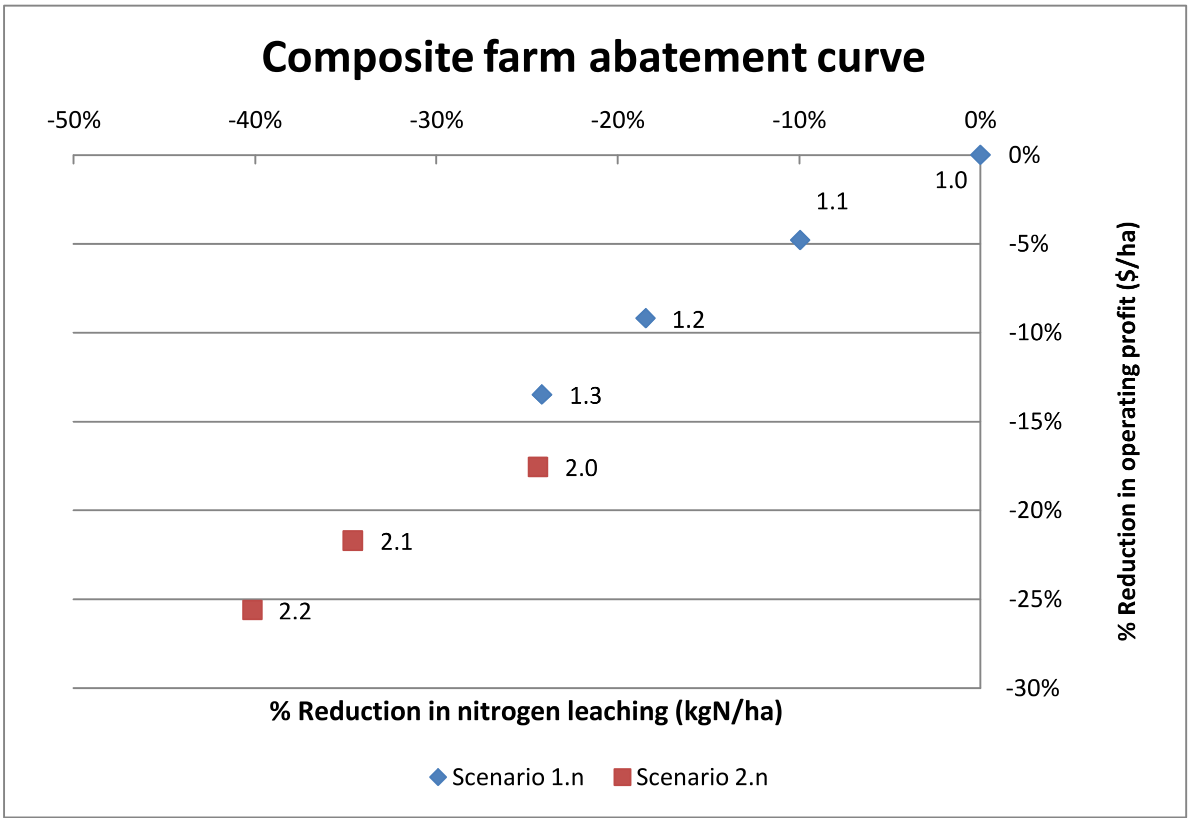
- 1.1 Nitrogen fertiliser use was reduced by 24 kg N/ha and peak cows milked were reduced by 17 from 543. Because this was a composite farm the 24 kg N/ha of fertiliser was the total amount removed from the farm system, not a specific application. However because autumn fertiliser is always removed first, 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.

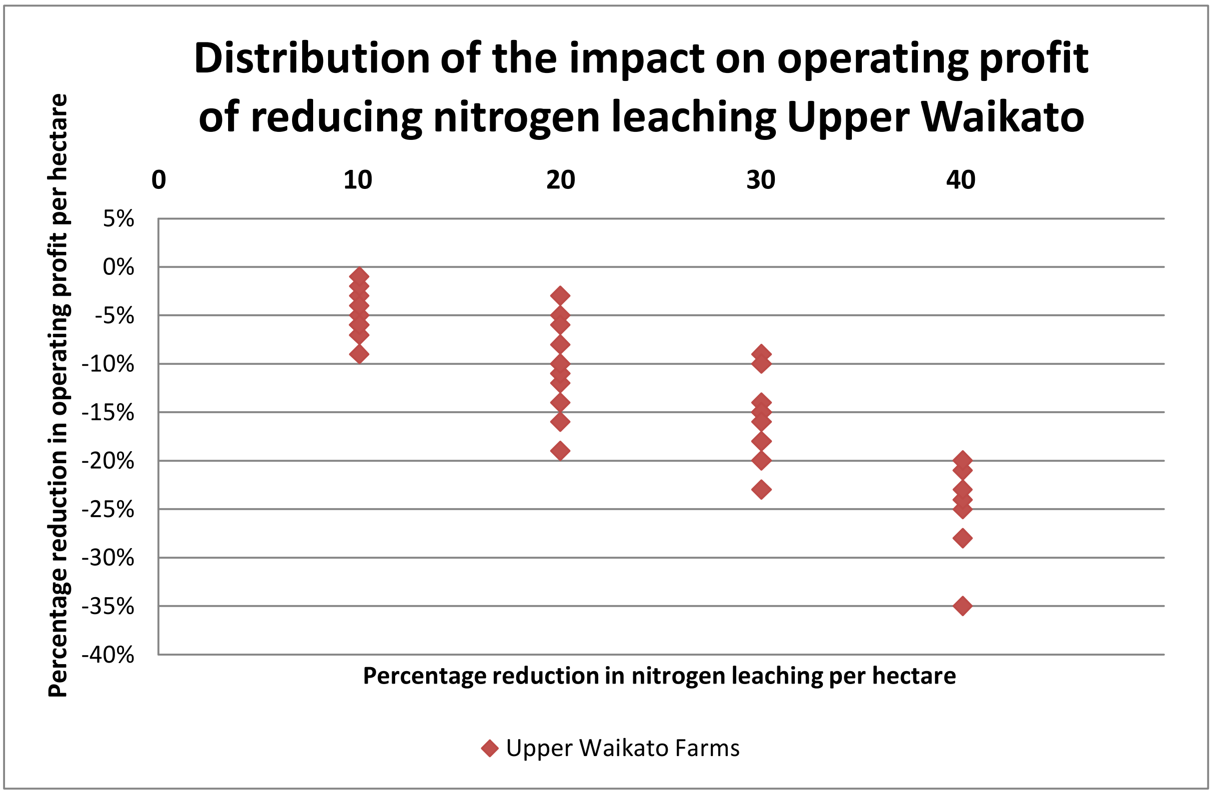
Table 6 shows nitrogen loss per hectare and the percentage decrease in operating profit % for each farm in the targeted N leaching band. Note: the N loss reduction is not exactly 10%, 20%, 30%, and 40% so the percentage is derived by the linear relationship between two points. In general, a 10% reduction 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.