Nutrient Trading in Lake Rotorua: Choosing the Scope of a Nutrient Trading System

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Abstract

A nutrient trading system is one mechanism that is currently being considered to control and reduce nutrient loss into Lake Rotorua. However this may not be the best mechanism for controlling nutrient loss from all sources. A more comprehensive system improves efficiency and decreases market power opportunities, but it can also bring increased compliance and administrative costs. This paper discusses which sources should be included in a nutrient trading system for Lake Rotorua. It examines existing systems and presents an empirical analysis to estimate the impact of including different nutrient sources.

JEL classification
Q53, Q57, Q58

Keywords
Water quality, nutrients, trading, Lake Rotorua

Contents

1 Introduction

A variety of policies can be used to control nutrient loss into waterways, including direct controls on land use activities, compulsory implementation of mitigation options and nutrient trading systems. Each policy will be more effective in controlling nutrient loss from some sources than others. Thus, when implementing a policy, it is important to identify the types of nutrient sources that the policy will be able to effectively control.

A nutrient trading system is one mechanism that is currently being considered to control and reduce nutrient loss into Lake Rotorua. This is likely to be a cost effective method of controlling and reducing nutrient loss from a number of nutrient sources including pastoral farming. However, it may not be an effective mechanism for all sources in the catchment.

For water quality in Lake Rotorua to improve, the total amount of nutrients entering the lake from all sources needs to be controlled. The system design needs to consider sources both within and outside the trading system to ensure that the total nutrient cap is not exceeded (see Kerr et al (2007)). The sources within the nutrient trading system will have their nutrient loss limited by the trading cap, but sources outside the trading system may or may not have their nutrient loss controlled. If these sources are ignored by regulation then this is a lost opportunity to reduce nutrient loss. If they are regulated under separate regulations then we are not ensuring that the marginal cost of the reductions equals the market price or that we achieve the efficiency benefits possible from a comprehensive nutrient trading system. Thus these reductions undertaken outside the nutrient trading system might be much more expensive than reductions undertaken by sources within the system.

This paper discusses which sources should be included in a nutrient trading system for Lake Rotorua. We present benefits and costs associated with a more comprehensive trading system. We then examine existing systems to identify the sources that have (and have not) been included in each system. This includes two New Zealand trading systems (Lake Taupo nutrient trading system and the Quota Management System (QMS) for managing commercial fisheries) and a brief look at international nutrient trading systems. Finally, we discuss the options for the Lake Rotorua catchment. We use data provided by Environment Bay of Plenty (EBOP) to analyse land-based sources of nutrients and provide insight into the impact of including particular types of land-based sources in the system.

This paper is part of a series of papers on various aspects of design of a nutrient trading system for Lake Rotorua. These papers can be found at www.motu.org.nz/nutrient_trading.

1.1 Benefits of a comprehensive system

A comprehensive nutrient trading system is likely to have a number of benefits as a result of greater opportunities for trade. These benefits could include improved efficiency, improved market liquidity and decreased market power opportunities.

1.1.1 Provides greater opportunity for efficiency benefits.

Nutrient trading systems allow the required nutrient loss reductions to take place in the most cost effective time periods and locations, but only from the sources that are included in the system. The greatest flexibility and efficiency will be achieved in a system that includes all sources.

For example, suppose that the cost of reducing nutrient loss through storm water system upgrades was high but that golf courses could reduce their nutrient loss at a low cost. If we included both of these sources in the system, instead of undertaking the expensive nutrient loss reduction option of upgrading the storm water system, the council could instead pay the golf courses to reduce their nutrient loss, through purchasing allowances from the golf course. This would enable the same level of nutrient reductions to be achieved at a much lower cost. But if storm water and/or golf courses were excluded from the system, the nutrient reductions cannot move between sources. Thus, the council would face higher costs to achieve the same level of nutrient loss reductions.

To date, EBOP has identified a number of reduction actions that will and may be undertaken to reduce nutrient loss and their likely costs (Table 1). For example, the community wastewater reticulation projects could cost up to $460 per kg of nitrogen reduction while the storm water upgrade in Rotorua urban areas is estimated to cost $348 per kg of nitrogen and $2,098 per kg of phosphorus reduced. Other actions however, such as Tikitere geothermal, are able to achieve nutrient loss reductions at a much lower cost ($4 per kg). In contrast, it was estimated in an earlier version of the draft Lake Rotorua Action Plan (Table 2, Draft Lake Rotorua and Rotoiti Action Plan, Draft 5, February 2007) that nutrient reductions through land use and land management change would cost, on average, $6 per kg.[1] This figure has been removed from later drafts of this report but it does give us a rough estimate of the cost of nutrient reductions achieved through a nutrient trading system. Even if this prediction of $6 per kg was incorrect by an order of magnitude and should actually be $60 per kg, a nutrient trading system would be able to achieve nutrient reductions much more cost effectively than some of the options already agreed to by the council. For example, at $60 per kg a nutrient trading system would achieve nutrient reductions for less than 20% of the cost of achieving the same reductions through the storm water upgrades.[2] If stormwater is not included in the nutrient trading system, the Council does not have the automatic option of not upgrading the storm water but achieving equivalent gains by purchasing allowances from others. It would have to justify its decision on the upgrade in a separate, non-market process which may lead to an expensive capital project going ahead irrespective of cheaper alternatives.

[1] $6 per kg-N was calculated by Environment Bay of Plenty as a budgeted average for expected costs over 10 years. The nutrient reductions from land use/land use management changes are expected to continue beyond 10 years, but total costs are assumed to be capped at $10 million.

[2] There may be other reasons for upgrading the storm water system that would lead policy makers to decide to undertake this investment. But in this paper we are only considering the investment that is undertaken to reduce nutrient loss only.

Table 1 Comparison of nutrient reductions actions for Lake Rotorua

	Action	N reduction (T/yr)	P reduction (T/yr)	Cost ($)		Time-frame
				Per year	Per kg	
Council approved actions	Rotorua Wastewater Treatment Plant upgrade	15	0	$1,484,320	$99 (N)	By 2006
	Community wastewater reticulation or OSET upgrade for Rotorua	10.8	0.25	$4,990,637	$460 (N) max	By 2014
	Storm water upgrades within Rotorua urban	3	0.5	$1,046,080	$348 (N) $2,092 (P)	By 2017
	Tikitere geothermal	30	0	$108,200	$4 (N)[3]	By 2009
	[P flocculation in the Utuhina Stream]	[0][4]	[2]	$420,000	$210 (P)	By 2006
Potential actions	[P flocculation in two other streams]	[0]	[4]	$840,000	$210 (P)	~
	Constructed wetlands	N reductions, costs and timeframes will depend on the site and proposal. Further evaluation is required				
	In-lake/in-stream nutrient removal using biomass	N reductions, costs and timeframes will depend on the site and proposal. Further evaluation is required				
	Lakebed sediment treatment	0[5]	25	$25 million estimated total cost	~	By 2011
	Hamurana Stream diversion to the Ohau Channel	53 (2005)[6] 92 (2055)[7]	6.3	$3,030,000[8]	$57 ('05) $33 ('55) $481 (P)	After 2011
	Land use management and land use change	170	6	~	~	By 2017
Total		228.8 + 53/92 Hamurana	12.75 (inc flocculants) + 25 (lakebed tmt) + 6.3 (Hamurana)			

Source: Proposed Lakes Rotorua & Rotoiti Action Plan. Environment Bay of Plenty Environmental Publication 2007/11. Available from www.envbop.govt.nz

[3] This cost per kg-N is lower than other actions because the Tikitere geothermal flow has a high nitrogen concentration and low volume, and is close to existing reticulation infrastructure.
[4] [#] means that the action is only temporary until long-term land use change/management actions can take effect.
[5] Lakebed sediment treatment will reduce N releases, however these are not calculated towards the N reduction target as sediment N releases are excluded (see sections [7] and [9.9] of the draft Action Plan).
[6] The 'true' N and P reduction for Lake Rotorua is expected to be lower than this. A Hamurana diversion would increase the lake water residence time and decrease oxygenation of bottom waters, thereby increasing the influence of other nutrient sources on in lake nutrient concentration. The actual impact of a Hamurana diversion on Lake Rotorua's water quality needs a full assessment.
[7] This load is expected to increase to 92 tonnes-N/year in 50 years time, and 118 tonnes at 'steady state' (> year 2200). See section 5.5 of the draft Lakes Rotorua and Rotoiti Action Plan for more information.
[8] Presuming mid-range capital cost = $25 million, maintenance costs $30,000 p.a., 50 year lifespan.

1.1.2 Improves the liquidity of the market

In an ideal market, participants would be able to buy and sell allowances when they wished without affecting the market price (i.e. the market is perfectly liquid). In reality, we are unlikely to be able to achieve such an outcome but we do need to ensure that there is sufficient liquidity in the market so that it functions adequately.

Two key things are necessary for the nutrient allowance market to work effectively. First, participants need to be able to find willing buyers and sellers when they wish to trade. Second, allowances need to have a relatively stable value to give allowance holders confidence in their asset. Each of these requirements is more likely to be achieved in a more comprehensive system simply because there will be more traders and more trades will occur.

1.1.3 Limits market power

Increasing the number of participants and their heterogeneity will reduce each participant's market power. Market power could negatively affect a nutrient trading system in three ways. First, it could allow a participant to affect the market price (Hahn (1984)). For example, an individual with a large number of allowances to sell may be able to push the market price up by holding back allowances. Second, if low liquidity leads to dependence on bilateral trade, unequal bargaining power may eventuate. Thus the price may reflect the relative bargaining power of the parties. For example, if there was a well informed buyer in the catchment, they could hold down the price when dealing with less informed sellers allowing them to take all of the surplus in the transaction. This could lead to equity concerns, but is unlikely to affect the efficiency of the system, unless weaker parties choose not to engage in trades. Third, participants may be able to exclude others from entering a product market by withholding allowances from them (Misiolek and Elder (1989)). This form of market power is unlikely to play a role in this catchment. Nearly all of the production from the catchment is sold outside the catchment and thus there is limited benefit from excluding an additional producer.

1.2 Costs of a comprehensive system

While there are benefits associated with a comprehensive system, there are also costs in making the system as comprehensive as possible. These costs can be put into three main categories – costs to undertake necessary research, costs to individual firms of complying with the system and the administrative costs of running the system including verifying data and enforcing the system.[9]

1.2.1 Increases research costs

Within a nutrient trading system, the modelled nutrient loss and corresponding allowance requirements from each source in the trading system is calculated using a model (see Kerr and Rutherford (2008)). This model needs to provide a reasonable estimate of nutrient loss for each type of nutrient source contained in the system. If the model does not currently provide a reasonable estimate of the nutrient loss from a particular land use, either the current model will need to be enhanced so that it does or a new model will need to be developed. Scientists would need to be funded to complete this work, increasing the research costs associated with the system.

But by including the additional sources in the nutrient trading system, it will also increase the information that we have about their nutrient loss. This could be used improve the ability of catchment models to estimate nutrient loss from these sources leading to better informed choices of environmental goals.

1.2.2 Increased participant's compliance costs

Once the nutrient trading system is in place, all nutrient sources will need to collect and report sufficient information to calculate their nutrient loss. While large nutrient sources may already collect much of the information required, smaller sources may not. They may have to collect additional information, leading to higher costs to comply with regulation. If these costs are going to be very high for some sources, such as small landowners, it may be better

[9] The cost to individual sources of undertaking mitigation options are not considered in this paper as these cost will need to be borne by sources within the catchment regardless of the nutrient control regulation used. The implementation of a nutrient trading system means that the total cost of undertaking mitigation options will be less as the system allows the mitigation costs to move to the most cost effective periods and places.

to exclude them from the nutrient trading system. Alternatively, these sources could be included in a way that has lower compliance costs such as using default values for the model.

1.2.3 Increases administrators' costs

While most people will do their best to comply with a system that they see as reasonable, some individuals will want to cheat any system that restricts their actions. Thus, in a nutrient trading system, verification and enforcement systems need to be in place to decrease this incentive (For more information on system compliance for a Lake Rotorua nutrient trading system see Kerr et al (2008)). As the system becomes more comprehensive, the cost of verifying data and enforcing the system will increase.

The verification and enforcement costs associated with each type of nutrient source depend on the number of sources involved and the complexity of information required to estimate the nutrient loss. Some sources, such as the Tikitere diversion, can be included in the system without greatly increasing costs. But when a type of source is included that has a large number of individuals with a low nutrient loss or requires a significant amount of detailed data to run the model, the verification and enforcement costs associated with including them in the system may be prohibitive. In this case, more random audits may be needed to maintain the same probability that a property is audited.

For the nutrient trading system to work, a registry of allowance holdings needs to be maintained and compliance forms need to processed. As the system becomes more comprehensive, the number of participants and consequently the number of compliance forms requiring processing will increase. This will lead to increased administrative costs of running the system.

2 Scope of other trading systems

Since a number of trading systems are already in place, we can look to these systems to gain some insight into the preferred scope of the Lake Rotorua nutrient trading system. We focus on two New Zealand trading systems – the Lake Taupo nutrient trading system and New Zealand Quota Management System

(QMS) for controlling commercial fisheries - and look at the scope of nutrient trading systems that have been set up overseas.

2.1 Lake Taupo Nutrient Trading System

The Lake Taupo nutrient trading system is being introduced to control the amount of nitrogen entering the lake and is still in the early stages of implementation.[10] This system includes only pastoral farmers who must hold sufficient nutrient allowances to cover their nutrient loss unless their nutrient loss is below the permitted activity level. Permitted activity levels are low thresholds which ensures that only small properties with low nutrient loss, such as lifestyle blocks, do not need to be involved in the system. Non-pastoral farming land uses, such as forestry, are not part of the system and do not need to hold nutrient allowances. But if they wish to convert to pastoral farming, they must purchase nutrient allowances. So properties with a small amount of pastoral farming (e.g. lifestyle blocks) and properties involved in non-pastoral land uses are excluded from the system. Other nutrient sources, such as wastewater discharges, are controlled with separate regulation.

2.2 Quota Management System

While the QMS is used for managing commercial fishery harvest, not nutrient loss, this system can give us insight into how trading systems work in a New Zealand context where some sectors are excluded from the trading system.

Fisheries regulation in New Zealand focuses on two main goals – fish stock sustainability and the utilisation of the fish stocks. Thus the regulations aim to maintain fish stock populations without limiting harvest levels more than necessary. Other than natural fluctuations, the sustainability of fish stocks is affected by three main activities – commercial fishing, recreational fishing and customary fishing. It is necessary to control the combined harvest level, the total allowable catch (TAC), to achieve the above goal of sustainability.[11] But while the

[10] Information on the scope of the Lake Taupo system was provided by Kelly Forster, Environment Waikato (pers. comm., 19th June 2007). For more information on the Lake Taupo system see http://www.ew.govt.nz/Policy-and-plans/Protecting-Lake-Taupo/.
[11] The TAC is set by the Minister at a level which will ensure that the fish stock remains at a size that is able to sustain the maximum sustainable yield or move the stock towards this size.

combined harvest needs to be capped, each of the sectors is managed under different regulations.

Customary fishing is given first priority under fishing regulations to satisfy customary fishing rights. As a matter of policy, customary fishing should be allocated a share of the TAC by the Minister of Fisheries, which is sufficient to fully satisfy customary interests. This share must include sufficient harvest levels of fish and seafood for use in events on marae as well as other traditional, non-commercial uses. The Minister can limit the customary fishing harvest only if he believes that the sustainability of the fish stock is threatened.

While the process for determining the level of customary harvest required is clearly defined, there are no strict guidelines that the Minister has to follow to split the remaining harvest between recreational and commercial fishers. Neither sector has priority in the legislation and the harvest limit for each sector must be considered simultaneously. Thus the Minister must use his discretion and implicit ranking of the value of each sector. This has lead to contention between the two sectors in some fish stocks where both sectors lobby the Minister to increase their share of the TAC.[12] In some fisheries, this is not a major concern as there is no (or limited) recreational fishing. For example, in the deepwater species such as orange roughy, the required investment in fishing boats and equipment means that recreational fishermen do not participate in catching this species. In contrast, species such as paua and snapper are popular with both recreational and commercial fishermen, which can lead to conflict between the two sectors about their share of the harvest.

While the harvest from the customary, recreational and commercial fishing sectors should not exceed the TAC, there is limited information on the level of both recreational and customary catch levels.[13] There is also uncertainty

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Guidance is provided to the Minister through the annual Plenary Reports but recommendations given in this report do not have to be followed through.

[12] The Ministry is currently investigating policy options which will improve the relationship between commercial and recreational fishers including increased involvement of the recreational fishing sector more in management decisions and the creation of Fisheries Plans (see Lock and Leslie (2007)).

[13] To the authors' knowledge only two studies (Teirney et al (2007) and Kearney (2002b)) have estimated recreational catch in New Zealand in the last 15 years. These studies have large

around the sustainable harvest levels, as was shown in September 2007 when substantial adjustments were made to commercial and recreational harvest limits in a number of fish stocks (Anderton (2007)). These adjustments included cutting the North Island eel commercial catch limit by up to 78%, reducing the hoki commercial catch limit by close to 50% in some areas and effectively closing fishing for orange roughy in some locations. So while the Minister needs to aim for sustainability, there is a large amount of uncertainty in the system. Despite this uncertainty and the tension between the sectors, this system has been functioning for the last 20 years and is generally considered to be a success story around the world.

The QMS shows that trading systems can be implemented and continue to function when some of the sources are excluded from the trading system. This suggests that a nutrient trading system for Lake Rotorua could probably function, even if some sources are excluded. However, there may be tension between those parties that are included in the system and those excluded especially if they are not making equal nutrient loss reductions.

2.3 International nutrient trading markets

Internationally, nutrient trading systems are increasingly being considered as a method to reduce and/or control nutrient loss (The World Resources Institute (2007)). The systems implemented vary in a number of ways: who is included, what nutrients are controlled, and how nutrient loss is calculated. Many of these systems do not include diffuse (non-point source) nutrient loss, such as agriculture. Even in the majority of the systems that do include non-point sources, the ability of these sources to participate in the system is limited and their participation is voluntary. Such systems basically use agriculture as an offset mechanism with credits relative to an estimated baseline, to allow for increases in nutrient loss from point sources.

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differences despite being carried out only a few years apart (Kearney (2002a)). There is also very little information on the level of customary harvest in many parts of the country. In the absence of this data, the Minister bases the customary allowance on a variable proportion of the recreational harvest. But as new customary fishing regulations are applied throughout more of the country, the level of information on customary harvest is expected to increase. See Lock and Leslie (2007) for more information on estimating recreational and customary catch levels.

Only two systems have regulated non-point sources and allowed them to trade. These systems were relatively simple trading systems where the participants traded the right to apply manure to the land. While both of the systems are now inactive, they were considered to be successful.[14] In one, the Upper Maquoketa and South Fork Maquoketa Watersheds Nutrient Trading Directory programme, sediment loads were reduced by 25% in the five years that the pilot system was operating. These two systems did not allow for trades between point sources and non-point sources in the catchment as only non-point sources were included.

To the authors' knowledge no system currently in place, or previously implemented, fully includes point sources and non-point sources and allows nutrient allowances to be bought and sold between all parties. This appears to be driven by an unwillingness to regulate agriculture.

3 What do we want to do in the Lake Rotorua Catchment?

Choosing the appropriate scope of a nutrient trading system for the Lake Rotorua catchment is not simple. Some sources, such as dairy farmers, should clearly be included in the system. Other sources, such as residential properties, should clearly be excluded from direct participation. For many sources, it is less clear.

3.1 Sources of nutrients entering Lake Rotorua

Nutrients enter Lake Rotorua from several types of sources. By assessing the nutrient contribution of a particular land use, we can get an idea of how important these land uses are to the water quality problem currently and in the future. The contribution of nutrients from each of the different land uses has been calculated by EBOP (Table 2).

[14] The Upper Maquoketa and South Fork Maquoketa Watersheds Nutrient Trading Directory programme was introduced as a five-year pilot programme. No permanent scheme has been introduced since the pilot finished in December 2005. The Dutch Nutrient Quota System was cancelled in 1998 when separate legislation was passed that was considered prior to the introduction of this system.

Table 2 Sources of nutrient loss into Lake Rotorua and their nutrient export levels.

Land use	Area (ha)	N loss coefficient (kg/ha/yr)	N load (t/yr)	% of total N	P loss coefficient (kg/ha/yr)	P load (t/yr)	% of total P
Native forest and scrub	10,588	4	42.1	5.4	0.12	1.31	3.3
Exotic forest	9,463	3	28.4	3.6	0.1	0.95	2.4
Cropping and horticulture	282	60	16.9	2.2	2	0.56	1.4
Pasture [p]	20,112	See table below	563	71.9	0.84	16.93	42.5
Lifestyle	556	20	11.1	1.4	0.9	0.5	1.3
Urban [u]	3,267	See table below	50.1	6.4	1.17	3.82	9.6
Springs	13	32.7					
Geothermal		42.2	5.4			1.4	3.5
Waterfowl		1.4	0.2			0.8	2
Rain	8079	3.659	29.2	3.7	0.16	1.33	3.3
Total Catchment Inflows	5,234,760		783.1	100	0.76	39.8	100

Breakdown of nutrient loss from pastoral land uses

Pasture [p] land use includes:	Area (ha)	N loss coefficient (kg/ha/yr)	N load (t/yr)	% of N	P loss coefficient (kg/ha/yr)	P load (t/yr)	% of P
Beef	1,196	35	41.9	7.4	0.9	1.08	6.4
Sheep	28	16	0.5	0.1	1	0.03	0.2
Sheep and beef	10,240	18	184.3	32.7	0.9	9.22	54.4
Deer	418	15	6.3	1.1	0.9	0.38	2.2
Deer/sheep/beef	1,294	18	23.3	4.1	0.9	1.16	6.8
Dairy	5,883	50	294.1	52.2	0.7	4.12	24.3
Grassland	425	12	5.1	0.9	0.9	0.38	2.2
Other	628	12	7.5	1.3	0.9	0.57	3.4
Total	20,112	28	563	100	0.8	16.93	100

Breakdown of nutrient loss from urban land uses

Urban[*u*] land use includes:	N (t/yr)	% of *u*	P (t/yr)	% of *u*
Sewage	28.0	55.9	1.00	26.2
Septic tanks	12.0	23.9	0.53	13.9
Storm water	10.1	20.2	2.29	59.9
Total	50.1	100	3.82	100

Source: Proposed Lakes Rotorua & Rotoiti Action Plan. June 2007. Environment Bay of Plenty Environmental Publication 2007/11

The nutrient sources listed above can be classified into two categories – point source and non-point source. This classification can have distinct implications for the way nutrient loss is regulated and the transaction costs of including particular sources in the system.

3.1.1 Point sources

Some nutrient sources enter Lake Rotorua from a single identifiable point, for example urban sewerage and septic tanks. At such sources it relatively simple to identify the level of nutrients that are entering the lake. Consequently you may wish to have all of these sources within the trading system. However there are a large number of small contributors to nutrient loss from sewerage treatment plants. To make each of these households responsible for their nutrient loss is likely to be inefficient. Instead the Rotorua District Council could be responsible for holding sufficient allowances to cover the nutrient loss from the sewerage treatment plant on behalf of the residents. Storm water, septic tanks and geothermal sources could be treated in the same way. Models to estimate nutrient flows from these sources already exist. The Council could regulate these sources in whatever way they choose.

3.1.2 Non-point sources

While it is more difficult to identify the exact level of nutrients lost from non-point sources, such as run-off from pastoral farming, this should not be a barrier to including non-point sources in the system. Existing models are able to model nutrient loss with reasonable accuracy and landowners are not able to manipulate the remaining uncertainty to their advantage. It is especially important to include non-point sources in the Lake Rotorua catchment as they make up a majority of nutrient sources. However we may not want to include all non-point sources because modelling nutrient loss for individual land uses is complex, and excluding small properties with minimal nutrient loss from the trading system would avoid high administrative and compliance costs. But excluding such properties would also decrease the efficiency benefits of the trading system. The following section empirically explores appropriate thresholds for including properties in the Lake Rotorua nutrient trading scheme.

3.2 Thresholds for including different land uses in the trading system

In an ideal world, properties would be included in a nutrient trading system if they had sufficiently high nutrient loss and/or low compliance costs. Properties that had large nutrient loss would be included in the trading system while properties with very little nutrient loss would be excluded or covered by a larger body. Properties that have low compliance costs associated with being included in the system will be included while those with high compliance costs will be excluded. By identifying the nutrient loss of each property, we could determine whether they were included in the system or not.

Such a system is not practical. One of the main costs of being included in a nutrient trading system is the cost to the landowner of collecting sufficient data to be able to run the model and calculate their nutrient loss. Thus, if every source is required to collect sufficient data to assess whether they are included in the system, the additional costs of participation in the system are minimal, and therefore all sources could be included. But including all sources in the system as direct participants is likely to be very inefficient. A number of small sources in the catchment have minimal nutrient loss. The additional compliance costs of having these properties included is likely to be much higher than the additional benefits of including the nutrient loss from these properties.

Since we cannot use the nutrient loss by property to identify which properties are included in the nutrient trading system, a rule, or set of rules, needs to be developed to determine which properties are included in the system. These rules aim to ensure that properties with a large amount of nutrient loss and/or low compliance costs are included in the system while those with low nutrient loss and/or high compliance costs are excluded. To achieve this, we need to develop proxies that are simple but linked to the nutrient loss from the property.

Two factors play a large role in determining the nutrient loss off a particular property: the property size and the land use. Larger properties are likely to have more nutrient loss than smaller properties, however this depends on the land use. Horticulture, for example, has more nutrient loss than plantation forestry. Therefore a large property covered in plantation forests may have lower nutrient loss than a much smaller horticulture property. Different land uses also face differences in compliance costs. If a land use has a relatively high compliance cost, the threshold for inclusion in the system could be set at a higher level to account for the increased cost of compliance. Alternatively, for properties that are likely to have low nutrient loss, compliance could be made simpler. Where possible, it is better not to base thresholds on current land use as this can change from year to year and it is complex if parcels enter and exit the system.

3.3 Analysis of nitrogen distribution from land use sources across parcels

To identify appropriate rules based on land use and property size, we first identified the sources of nutrients in the catchment so we could better understand the implications of including or excluding different types and sizes of parcels. For simplicity, in this analysis we have focused on the non-urban, non-conservation estate sources of nitrogen loss. Sources of phosphorus may be different to sources of nitrogen. To assess this, a similar analysis could easily be carried out for phosphorus.

3.3.1 Dataset creation

To undertake this analysis we used a map of 2003 land use in the Lake Rotorua catchment provided by EBOP. This map was based on the Land Cover Database (LCDB) 2003 satellite imagery and then improved by the land resources staff at EBOP. EBOP staff allocated land use areas to the map, defining land uses for the pastoral areas and correcting mistakes in the map using their knowledge and records for the rural properties in the area (Andrew Wharton, EBOP, pers. comm., 12th February 2008).[15]

The land use map was combined with the cadastral map to identify the areas of each land use located on each parcel in the catchment.[16] By incorporating the nutrient loss coefficients from the Action Plan we were able to estimate the

[15] The LCDB only provides land cover data such as forest or pasture. It does not distinguish between dairy and sheep/beef properties. This information was added in by the EBOP staff.
[16] The cadastral map only gives us parcel boundaries, not the property boundaries. In many cases a property consists of multiple parcels and are likely to be managed together. Unfortunately, it is impossible to identify which parcels are managed together given the data that is available.

total nutrient loss from each parcel as these coefficients provide the nutrient loss per hectare by land use.[17]

The analysis showed a number of discrepancies between the final dataset that was developed using the above methodology and the levels of nutrient loss given by EBOP (Table 3). This was not unexpected. While the table produced the nutrient loss for recent land use, the available map provided land use information for 2003. Land use has changed significantly during this time (Andrew Wharton, EBOP, pers. comm., 12th February 2008), which may significantly alter the amount of nutrient loss from some parcels and in total. Also the two analyses are based on different data. In our analysis, conservation land and urban areas are excluded. In the EBOP data only urban areas are excluded.

Table 3 Comparison of nutrient loss and areas by land use between EBOP data and calculated data

Land use	EBOP Area (ha)	Calculated Area (ha)	EBOP N load (t/yr)	Calculated N load (t/yr)
Native forest and scrub	10,588	7,580[18]	42.1	30.5
Forestry	9,463	8,277	28.4	24.8
Cropping and horticulture	282	418	16.9	24.9
Dairying	5,883	6,805[19]	294	327.1
All other pastoral uses	14,229	12,147	268.9	249.6
Total	41,000[20]	35,227	661.4	656.9

These discrepancies do not make the current analysis uninformative. Through time the land uses areas will change. Thus the rules developed now need

[17] Some land use categories in the land use map did not have nutrient loss coefficients listed for them. All of the pastoral land uses, such as horses and alpacas, that did not have a nutrient loss coefficient assigned, were assigned a nutrient loss coefficient of 12 kg/ha/yr, which is the ‘other’ category in the nutrient loss table. Bare ground was identified in the land use map only. We assigned this a nutrient loss coefficient of 3.3 kg/ha/yr, which is the nutrient loss from plantation forestry (the lowest emitter) plus ten percent. This assumes that there may be more nutrients lost from bare ground than plantation forestry, as no nutrients are taken up by the plants. As bare ground only covers 149 ha in the catchment, small inaccuracies in this coefficient are unlikely to have a large impact on the analysis.

Some areas of the catchment were allocated multiple land uses such as ‘deer, beef and horses’ or ‘sheep and dairy grazers’. These categories did not match the categories for which we had nutrient loss coefficients. We assumed that this land was evenly split between the land uses listed when calculating the nutrient loss levels and included ‘dairy grazing’ as ‘dairy’. For example, if 100 ha of land was allocated to the category ‘sheep and dairy’, 50 ha was assumed to be sheep farming and 50 ha was assumed to be dairy farming. The nutrient loss was then calculated accordingly.

[18] This data excludes conservation land.

[19] This data includes dairy grazing land as dairy.

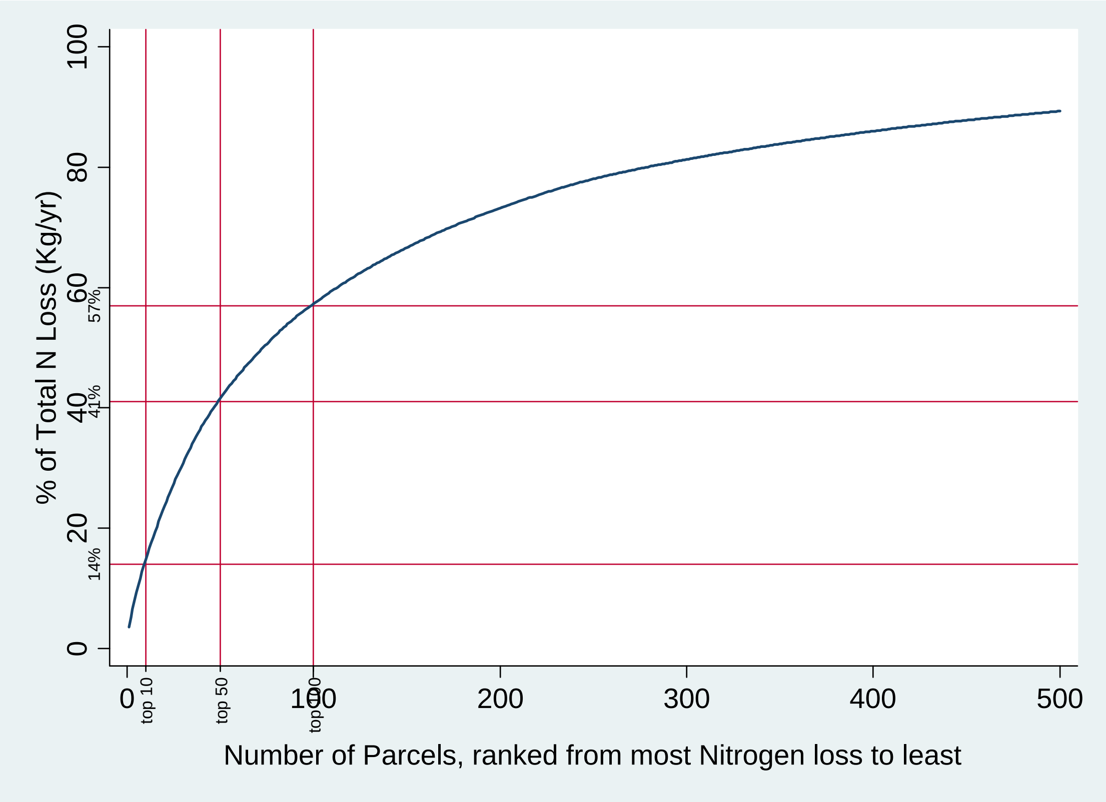
[20] This data includes urban areas.

to be robust to changes in the future. This analysis provides insight into the nutrient loss levels from different land uses and different sized parcels at a point in time, allowing appropriate thresholds to be identified.

3.4 Identifying appropriate thresholds

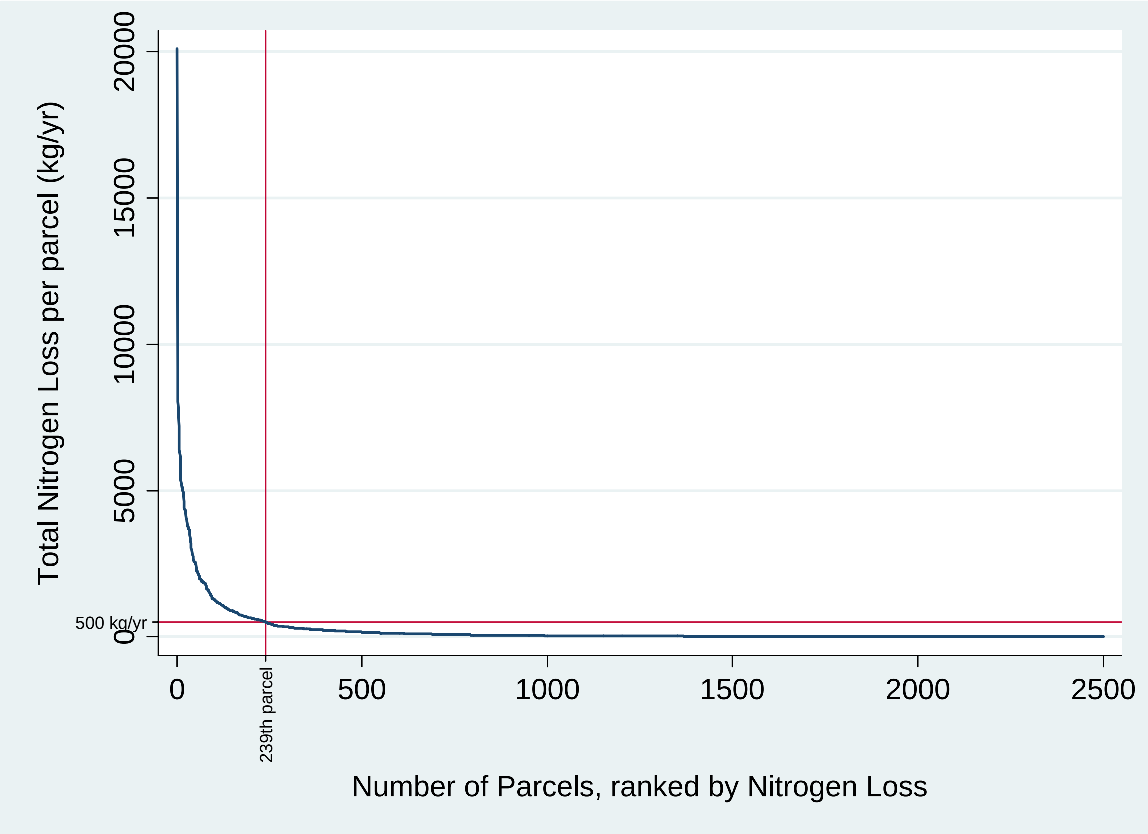
As outlined earlier, in an ideal world, thresholds would be set to ensure that individual sources with high levels of nutrient loss would be included in the system. Since in our analysis the nutrient loss by parcel is known, a threshold, in terms of nutrient loss, can be identified. Within this catchment, a few privately owned parcels contribute a significant proportion of the nutrient loss (Figure 1). The top 10, 50 and 100 nitrogen losing parcels contribute 14%, 41% and 57% of the total nitrogen loss respectively.

Figure 1 Distribution of nitrogen loss across parcels ranked by total nitrogen loss



Only 239 parcels have nutrient loss above 500 kg/yr and most of the remaining properties have much lower losses (Figure 2). The potential gain from including parcels with over 500 kg/yr seems likely to justify reasonably careful monitoring, while for other parcels we may find that the gains from inclusion do not justify the transaction costs of participating in the system.

Figure 2 Nitrogen loss per parcel and a potential threshold for inclusion in the system



This 500 kg/yr threshold provides a first cut for identifying thresholds based on parcel area and land use. Using the EBOP nutrient loss per hectare for each of the land uses, it is easy to convert this threshold based on nitrogen loss into a threshold based on land use and area (Table 4). For example, all parcels that had at least 10 ha of dairy land would be included in the system. In contrast, a plantation forests might need to be at least 167 ha before it is included in the system.

Different land uses in the catchment have different costs of complying with the system. For example, very little data is required to measure nutrient loss from plantation forestry. In contrast, the calculation of nutrient loss from livestock farming involves the collection of much more data and consequently the costs of complying with the system are much higher.

Table 4 Potential inclusion thresholds based on a 500 kg/yr nitrogen loss threshold and the nitrogen loss coefficients

Land use	Nitrogen loss coefficient (kg/ha/yr)	Land use area threshold (ha)
Horticulture and cropping	60	8.3
Dairy	50	10
Non-Dairy Pastoral farming	19[21]	26
Native bush	4	125
Exotic forestry	3	167

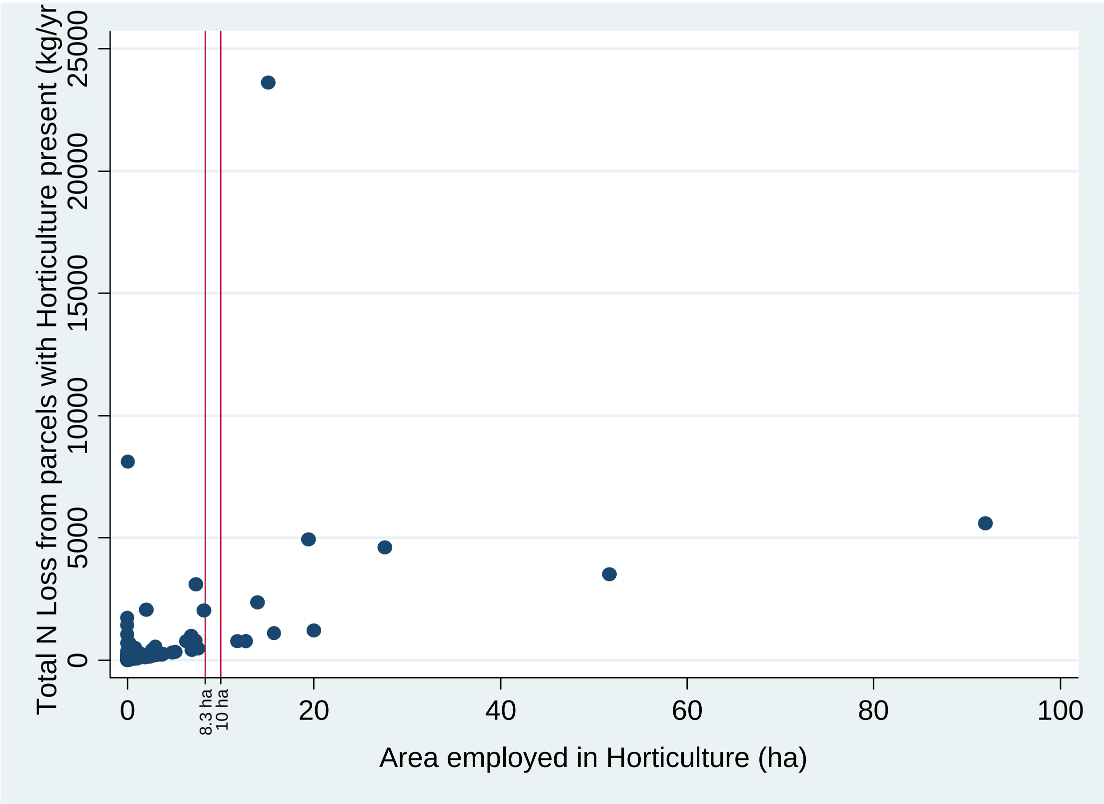
3.4.1 Horticulture and cropping land

While horticulture and cropping have the largest nutrient loss coefficient, this land use contributes only 2.2% of the nutrient loss in the catchment because of the small land area it occupies. Given the small impact on nutrient loss that this land use has, it might not be worth including horticulture and cropping land in the system if existing models cannot be used to calculate their nutrient loss. Given the high per hectare nutrient loss however, it may be appropriate to include them even in a very crude way. One option is to require landowners to report their total horticulture land area and use existing EBOP nutrient loss coefficients to estimate nutrient loss.

To include horticulture and cropping in the nutrient trading system, an appropriate threshold for identifying which parcels are included is required. If the 500 kg threshold identified above were used, all parcels with at least 8.3 ha of horticultural or cropping land would be included. Based on our analysis, only 11 parcels would meet this criterion and consequently would be included in the nutrient trading system (Figure 3). This corresponds to 1.7 tonnes of nitrogen loss each year.

[21] This coefficient was calculated as the weighted averaged N loss coefficient based on the data provided in Table 2.

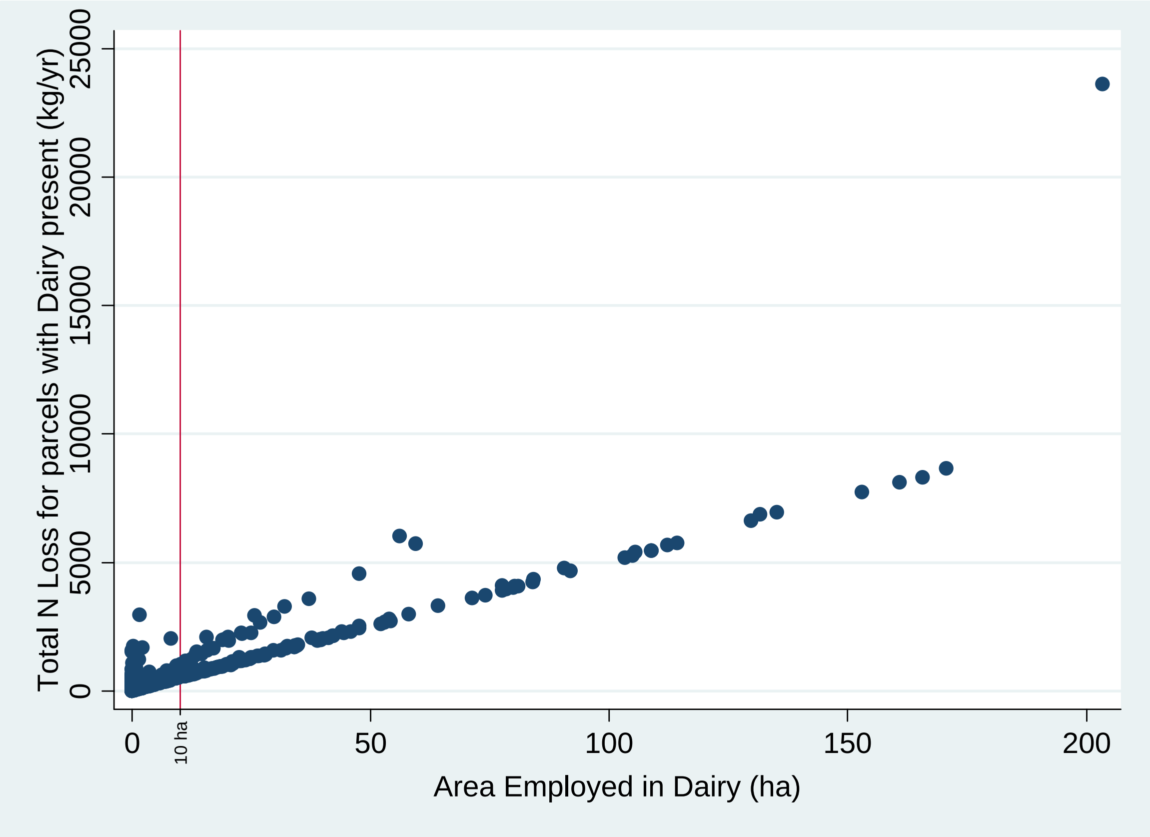
Figure 3 Total N loss from parcels with horticultural and cropping areas



3.4.2 Dairy land

545 parcels within the catchment contain dairy and dairy grazing land. Given the high nutrient loss from dairy land, it is important to ensure that large dairy farms are included in the nutrient trading system. Based on the simple thresholds developed above, all parcels with at least 10 ha of dairy land would be included in the nutrient trading system. This would lead to an additional 159 parcels being included in the system (Figure 4) covering over 310 tonnes of nitrogen loss.

Figure 4 Total N loss from parcels with dairy and dairy grazing areas



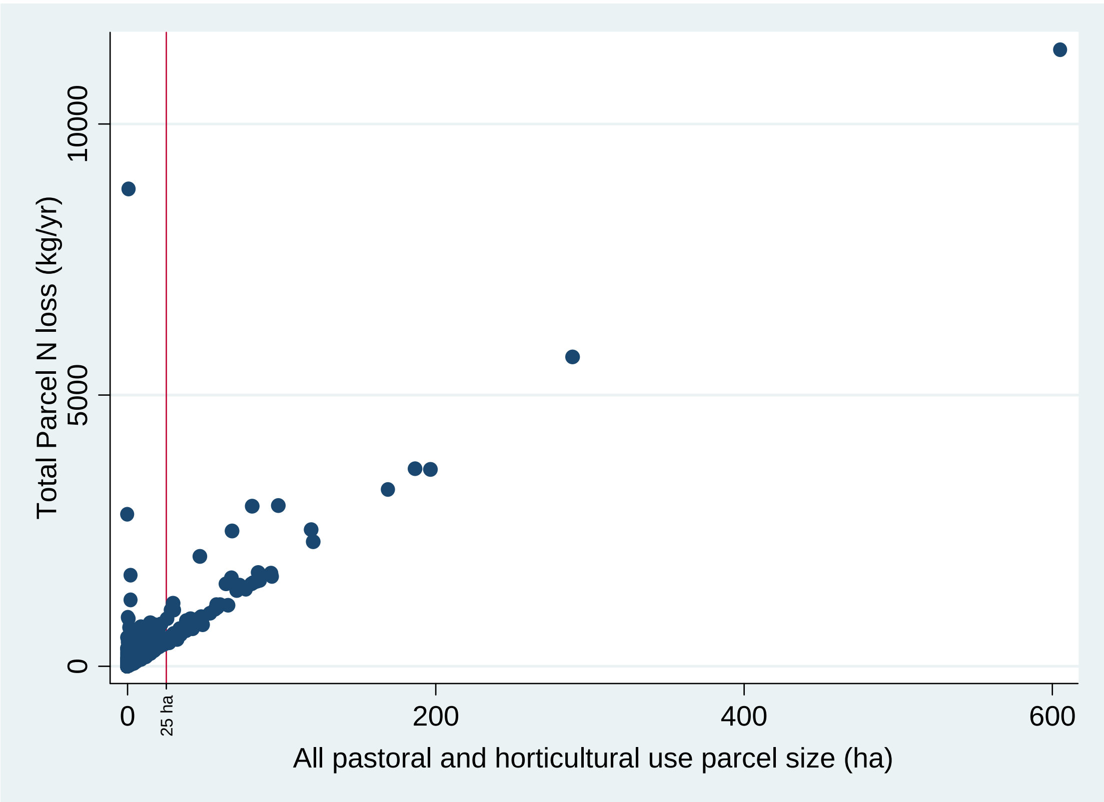
To be able to support either horticulture and cropping or dairy farming, the land must be highly productive. These are also the two land uses that have the highest nutrient losses per hectare and thus it is important that land under these land uses are included in the system. Therefore we propose that all parcels with at least 10 ha of dairy and/or horticulture and cropping land be included in the nutrient trading system.[22] The owners of these parcels will be responsible for collecting sufficient information and running the nutrient loss model to calculate their nutrient loss and surrendering sufficient allowances to cover their nutrient loss. They may also be eligible for any initial free allocation of allowances (For more information on the allocation of allowances see Kerr (2008)). This threshold also ensures that parcels with a small amount of horticulture, for example, are not automatically included in the nutrient trading system and required to collect detailed data.

[22] This threshold is slightly higher than the threshold discussed above for horticulture and cropping. We used 10 ha for simplicity.

3.4.3 Pastoral land

1758 parcels have non-dairy pastoral land uses including sheep, beef, deer and horses (Figure 5). Based on the 500 kg/yr threshold, all parcels that have at least 26 ha of non-dairy pastoral land should be included in the system. To capture parcels that have small amount of dairy land and/or horticulture and cropping land, we suggest that all parcels that have at least 25 ha of land in pastoral farming, horticulture and/or cropping (referred to as 'pastoral and horticulture' for the remainder of the paper) be included. Therefore parcels with 9 ha of dairy and 16 ha of sheep/beef farming are included. This adds an additional 101 parcels and 94.8 tonnes of nutrient loss to the system.

Figure 5 Total N loss from parcels with pastoral, horticulture and cropping areas excluding parcels with high quality land greater than 10 ha.[23]



3.4.4 Avoiding undesirable changes in participation over time

Under these thresholds, parcels with at least 10 ha of combined dairy, horticulture and cropping land or at least 25 ha of 'pastoral and horticulture' land are included in the system. We also want to avoid adding parcels to the system when their land use changes. Doing so would require annual adjustments to the cap and could create perverse incentives across land uses. To avoid this complexity, we propose that all parcels 10 ha or larger are included in the system, regardless of the land use. This will lead to parcels being included that have smaller amounts of pastoral or horticultural land than specified by the above thresholds and parcels with plantation forestry and native bush being included in the system. It is important that the compliance costs to these parcels are not crippling.

Compliance costs for plantation forestry and native bush areas will be low. Landowners will not be responsible for the first 3 kg/ha that is lost from their land as they cannot reduce nutrient loss below this level. Therefore, nutrient loss from plantation forestry does not need to be covered by allowances each year and only 1 kg/ha is required for land that is covered in native bush. Landowners could simply report the total area that they have in plantation forestry and native bush to allow their nutrient loss to be calculated and thus the default values are not needed.

To minimise compliance costs for parcels with less than 10ha of combined dairy, horticulture and cropping and less than 25 ha of pastoral and horticultural farming, default values could be used to calculate their nutrient loss from pastoral land uses. This would require the landowner to supply information on the area in each land use but default values supplied by EBOP could be used to calculate the total nutrient loss from pastoral, horticultural and cropping land uses. But if the landowner wished to use the actual information from their parcel, they could use this instead of the default values.

By ensuring that all parcels above 10 ha are included in the system, parcels will only stop participating directly in the system when they are subdivided to be less than 10 ha. Under the rules outlined above, when parcels change land use they will not move into or out of the nutrient trading system, but

[23] The two data points with a high total nutrient loss and a small amount of pastoral area are large plantation and native bush blocks with only a small amount of pastoral land.

the level of information that they are required to collect may change. For example, if the total pastoral area falls below 25 ha, the landowner will now have the option to use default values.

3.4.5 What about other parcels?

The above rules include 88.5% of nitrogen loss from the catchment. The excluded parcels are either urban parcels, smaller than 10ha or owned by the Department of Conservation.

To achieve the most flexibility in the system, all sources of nutrient loss should be included. The land owned by the Department of Conservation (DoC) should be included in the system with DoC responsible for reporting and holding sufficient allowances to cover nutrient loss from all of their land. As this land is managed as an estate, DoC could complete a single report of the nutrient loss from all of the conservation land in the catchment. The Rotorua District Council (RDC) and EBOP should be made responsible for surrendering sufficient allowances to cover the nutrient loss from parcels smaller than 10 ha. The parcels that each council is responsible for should follow their jurisdiction. RDC should hold allowances on behalf of urban parcels while EBOP should be responsible for the small non-urban parcels such as lifestyle blocks.[24] The councils will be required to report and estimate the total nutrient loss off the parcels they are responsible for and surrender sufficient allowances. To control nutrient loss they can undertake mitigation options or use regulations to limit nutrient loss.

3.4.6 Why use parcels?

We propose that land use areas in parcels rather than properties should be used to determine whether land is included in the nutrient trading system because parcel size are relatively unchanging through time. Farmers often manage their parcels simultaneously. This means a landowner can jointly report on all of their parcels at once, including opting to have parcels smaller than 10ha in the system. Once a parcel enters the nutrient trading system it can only leave the

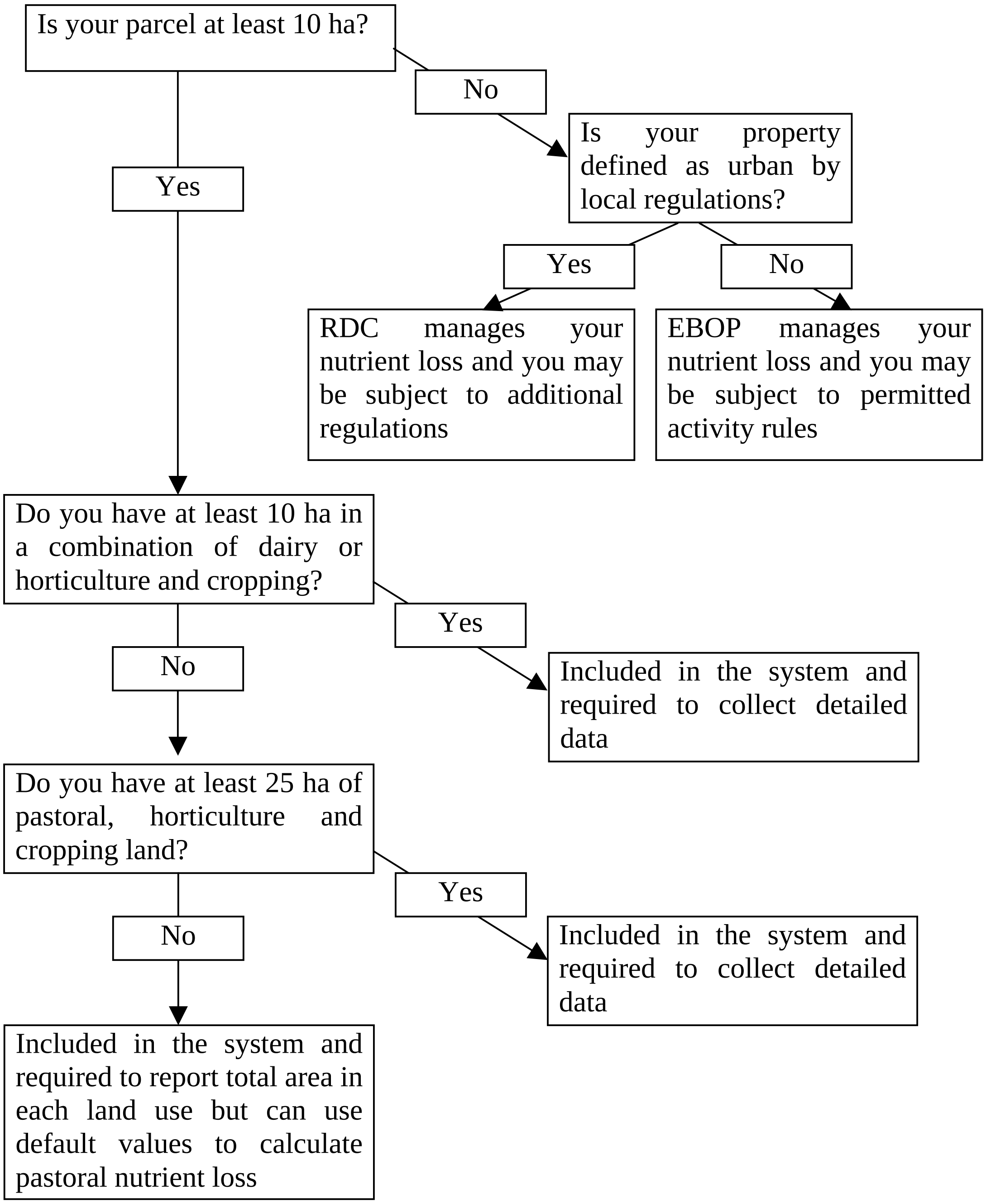
[24] Urban land is defined in EBOP's Regional Water and Land Plan as "an area which contains an aggregation of more than 50 lots or sites of an average size of no more than 1000m^2". The same definition should be used here.

system if the parcel is sold, providing the new owner the option of including or excluding the parcel in the nutrient trading system. This stops parcels entering and leaving the system annually but avoids locking in small parcels.

4 Summary

Based on an analysis of the distribution of nutrient loss from parcels in the Lake Rotorua catchment, a set of rules have been developed to identify which parcels are included in the nutrient trading system (Figure 6). The thresholds developed in this analysis are only indicative of the values that should be used.

Figure 6 Rules for determining how a parcel is included in the Nutrient Trading System



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