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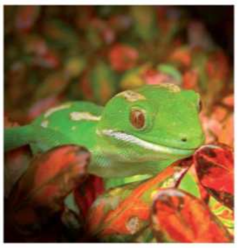

Evaluation of the impact of different policy options for managing to water quality limits

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Landcare Research
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Executive Summary

New Zealand has a diverse range of aquatic environments from mountain springs to coastal estuaries, connected by an intricate network of rivers, lakes, wetlands, estuaries and groundwater systems. Its freshwater bodies are of good quality by global standards and are a pivotal resource for agriculture, recreation, tourism, energy and industry. It is a source of life and food, and it is a central part of everyday life. Water has a strong cultural and spiritual presence in New Zealand, and Maori value water highly because it is central to their identity.

Despite being relatively clean and abundant at the national scale, deteriorating water quality is a pressing issue for a number of catchments around New Zealand. Diffuse discharges, including nutrient discharges, are a significant factor in this deterioration (Ministry for the Environment 2007; Land and Water Forum 2010). The Land and Water Forum was established to develop a common direction for freshwater management in New Zealand, and provided its first set of recommendations to the Government in early 2011. In response, the Government announced a package of initiatives, including the National Policy Statement (NPS) for Freshwater Management that sets out objectives and policies that direct local government to manage water in an integrated and sustainable way, while providing for economic growth within set water quantity and quality limits. The Land and Water Forum was subsequently asked by the Government to develop further recommendations on how to manage within quality limits, and is due to report in September 2012. The Ministry for Primary Industries commissioned this research to support the Forum process and to assist in the evaluation of cost-effective policy options for managing to targets.

This report focuses primarily on the costs and benefits of policies designed to manage nutrients from rural diffuse or non-point sources, specifically total nitrogen (N) and total phosphorus (P). The bulk of the report is dedicated to estimating the impacts on rural landowners of various policy approaches to reducing nutrient discharges in three important New Zealand catchments: the Hurunui and Waiau Rivers, the Manawatu River, and Lake Rotorua. The policy impacts are assessed using a combination of quantitative analysis and qualitative discussion. A majority of the costs and benefits are estimated using two catchment-level, agri-environmental, partial equilibrium economic models – the New Zealand Forest and Agricultural Regional Model (NZFARM) and NManager. These models allow for detailed representation of practices, economics and environmental impacts for two key primary industries, agriculture and forestry. Each model has a unique structure and parameterisation and thus its own set of strengths and weaknesses. An overview of the key components of the models is show in Table 1.

Table 1 Overview of economic modelling for water quality policy case studies

Catchment	Economic Model	Scale	Key Land Uses	Key Environmental Outputs
Hurunui and Waiau	NZFARM	Spatial: 6 sub-catchment zones Temporal: Annual	Dairy, sheep and beef, deer, pigs, forestry, arable, horticulture, scrub, conservation land	N leaching P loss GHG emissions
Manawatu	NZFARM	Spatial: 4 sub-catchment zones Temporal: Annual	Dairy, sheep and beef, deer, forestry, arable, horticulture, scrub, conservation land	N leaching P loss GHG emissions
Rotorua	NManager	Spatial: 1 catchment Temporal: Annual	Dairy, sheep and beef, forestry	N leaching GHG emissions

The economic models used for this analysis include several practices for managing nutrients at the farm-level, such as reducing nitrogen fertiliser application, applying nitrification inhibitors (DCD), or wintering off dairy cows. At least two other important management options tracked in this analysis, stream fencing and riparian planting, are not currently included in either of the economic models. As a result, we also investigate the potential costs and benefits of adopting these measures outside of the model simulations.

The management practices that can contribute to reductions in nutrients tracked in this analysis are listed in Table 2, and does not cover all feasible options to reduce N and P. First, we do not include all possible nutrient sources or options to mitigate nutrient leaching from diffuse sources into waterways. Second, we do not track or account for nutrient mitigation from point sources within the catchment. Including additional management options and sources of mitigation would potentially reduce the estimated costs of each of the policies assessed in this report.

Table 2 Management practices used in this analysis for reducing N and P

Management Practice	NZFARM	NManager	Outside Models
Stock Exclusion via Fencing Streams			√
Reduced N Fertiliser	√	√	
Apply Nitrification Inhibitors (DCD)	√	√	
Wintering Off Dairy Cows	√	√	
Construct Dairy Feed Pad	√		
Riparian Planting			√
Change Stocking Rate	√	√	
Using High Fertility Ewes		√	
Use Imported Feed	√	√	
Feasible Combinations of Above	√	√	√

We consider a number of policies that could improve water quality, primarily through the maintenance or reduction in nutrient loads from land-based operations. The first option we consider is having landowners implement the set of 'good management practices' (GMP) listed in Table 2 that would result in a lower level of nutrient leaching. We consider both voluntary adoption of GMP and adoption in response to regulatory requirements. The second set of policies we consider is a nutrient cap-and-trade programme. This places a regulatory limit on total nutrient leaching from all major sources in the form of nutrient discharge permits but allows for the trading of permits between the regulated sources. We assess the cap-and-trade policy under several allocation options[1] and spatial restrictions for trading to estimate the range of likely costs and changes in land use and land management. The final option we consider is a direct tax on nutrient discharges.

For each policy scenario, we report the mitigation costs of achieving the nutrient reduction target to improve water quality and the resulting changes in farm profit,[2] represented by net revenues in the catchment. Where appropriate, the predicted land-use change resulting from each scenario is also reported. We do not quantify all the costs and benefits of each policy in monetary terms, rather we report the relative changes in the catchment's nutrient discharges and revenue streams resulting from each policy scenario.

There are several other important factors and metrics to consider for a policy assessment beyond estimating the economic impacts of reducing N and P from diffuse sources. These are outside the scope of this report. Sediment and faecal coliform, for example, can have a strong influence on water quality. The economic and biophysical models used for this analysis are currently not able to assess the impacts of these factors from changes in land use and/or land management. However, the on-farm land management practices and options to mitigate N leaching and P losses often improve micro-organism and sediment contamination as well. The models used in this analysis also estimate changes in greenhouse gas emissions (GHG), thereby highlighting some of the other "co-benefits" that could arise from implementing policies that promote the reduction of nutrient discharges from diffuse sources. Acknowledging this concept of co-benefits is important as there are often multiple pollutants and policies being discussed simultaneously at the central government and regional council level.

This analysis also does not account for the broader impacts of changes in land use and land management beyond the farm gate. The flow on effects from some of the policies investigated in this report could produce a significant change in regional employment and GDP. There could also be social and cultural impacts as well. The estimates presented in this report provide just a subset of possible metrics that could be used to determine the best policy to manage nutrients at the catchment-level.

Many other important aspects of reducing nutrients from rural diffuse sources not covered by the economic models are addressed through additional quantitative analysis and supplemented by qualitative discussion. This additional analysis includes assessing the likely

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[1] Allocation options are how the regulatory limit is translated into individual discharge permits for each source.

[2] Farm profit is measured as annual earnings before interest and taxes, or the net revenue earned from output sales less fixed and variable farm expenses.

changes in water quality from implementing (or not) a particular nutrient reduction target, the likely administrative and transaction costs of a policy, and how the costs and benefits could impact different stakeholders in the community. A list of key caveats, assumptions, and limitations for this analysis is included in Box 1.

Box 1: Key caveats, assumptions, and limitations of this analysis

- We define a 'cost-effective policy' as a modelled policy that achieves the nutrient target in the catchment at the least cost to the landowners, given the specified management options.
- Our economic analyses depend on the datasets and estimates provided by biophysical models like OVERSEER and SPASMO, and farm budgeting models such as FARMAX. Estimates derived from other data sources may provide different results for the same catchment. Thus, the tools and analysis presented here should be used in conjunction with other information during the decision making process.
- Data and model limitations prevent this analysis from including all possible N and P mitigation strategies that could be implemented in a given catchment. Some mitigation options not explicitly included are some farm-level mitigation options (e.g. optimum soil test P) and catchment-wide solutions (e.g. series of constructed wetlands). Tracking additional mitigation options could lower both the overall cost of the policy and the cost to individual landowners.
- The economic models do not track or account for nutrient mitigation from point sources. Incorporating the costs of mitigating point sources may change the relative cost-effectiveness of the policies. The Hurunui-Waiau and Manawatu case studies assume a constant nutrient attenuation rate across the entire catchment area and that nutrients from diffuse sources will all reach the waterway of concern within 10 years. The Rotorua case study assumes that there are several groundwater lag zones within the catchment, and that nutrients exported from some farms can take up to 200 years to reach the lake.
- The economic models do not explicitly account for all administrative and transaction costs of the various policies. Doing so could alter the estimates for the distributional impacts to farmers, land use change, and overall cost of the different policies.
- The models are static and assume that technology, climate, input costs, and output are all constant for the duration of the policy. However, the aim of the models is to compare a range of policy options at a given point in time.
- NZFARM tracks both N and P while NManager only tracks changes in N. We acknowledge that there are other important factors and metrics to consider beyond N and P for assessing changes in water quality, such as sediment and faecal coliform.
- With the exception of the voluntary GMP scenarios, the analysis assumes full compliance for each nutrient reduction policy. Actual outcomes will differ if individuals do not understand the policy or choose not to comply.
- Each case study uses catchment-specific economic data, biophysical data, options for land management, and policy assumptions. In addition the Hurunui-Waiau and Manawatu catchment studies use the same economic model but the Rotorua case study uses a different model. Thus, the estimates from one case study are not directly comparable with another, although limited comparisons can legitimately be made between the Hurunui-Waiau and Manawatu cases because they use the same economic model.

The three catchments investigated in detail are:

1. The Hurunui-Waiau catchment, Canterbury. This is a South Island river catchment with predominant land uses being hill country grazing, lowland irrigated pastures and plantation forests. Water quality is currently acceptable to the community, but is an increasing concern in the catchment, particularly given the on-going expansion of irrigation in the Hurunui Plains. This catchment has shallow stony soils with high nitrogen leaching rates, and has a large irrigation scheme proposal under development. The water quality and water quantity limits for the catchment have been developed by the local zone committee.

2. The Manawatu catchment. This is a North Island river catchment with longstanding extensive and intensive land uses. Intensive pastoral systems are predominantly rain-fed with a mix of dairy and sheep and beef farming. Significant water quality problems already exist in the catchment due to point and non-point source discharges. Water quantity and quality limits are specified in the Horizons Regional Council's (HRC) Proposed One Plan.[3]

3. Lake Rotorua. This is a North Island lake catchment with a mix of pastoral and forestry land uses on volcanic soils. Water quality is poor (BoPRC 2012) and is likely to deteriorate further as there are long lag times between nutrient discharges and impacts on the lake. There are also large tracts of Maori land within the catchment. This catchment has extensive information on groundwater flows and a limit-setting policy is in place through Bay of Plenty Regional Council's (BoPRC) Regional Land and Water Plan.

A discussion of the important findings for each catchment is included below, and a summary of the key impacts on N for each policy scenario is listed in Table 3. The main report provides more detail on these findings, while the appendices include additional policy scenarios that demonstrate the range of impacts from several different nutrient targets and tax levels.

Hurunui-Waiau Catchment

The water quality limits being discussed for the Hurunui-Waiau catchment are intended to maintain nutrient loads at 2010 levels (Environment Canterbury 2011a). There is also an irrigation scheme being proposed for the Hurunui Plains area of the catchment that could more than double the area of irrigable land in the catchment (Environment Canterbury 2012). The policy scenarios are all compared to a baseline where there is no additional irrigation scheme. Our modelling indicated the following:

- At the catchment level, adding a large irrigation scheme would raise net catchment revenue by 10% through increased production, but would also increase N leaching by 24%, P loss by 4% and GHG emissions by 72% in the catchment, in the absence of any additional policies to manage water quality and GHG impacts. For the Hurunui Plains,

[3] Schedule D (December 2010 version). The One Plan was appealed to the Environment Court, and at the time of writing this report, the Environment Court decision had not been released.

where the irrigation scheme will operate, there would be productivity benefits and increased profits for dairy, sheep and beef, and arable crop farmers that increase their access to water, but N leaching and P loss could both increase by nearly 60%.

- If landowners in the catchment maintained their current land use and adopted GMPs such as applying nitrification inhibitors (DCD), riparian planting, and installing dairy feed pads, it is unlikely that the 2010 catchment nutrient loads would be maintained if a large irrigation scheme were implemented (policy #1a–b). The estimated average costs of implementing GMPs are around $50/tN, primarily because of the relatively high cost of these practices for sheep and beef farmers in the catchment.
- Of the policy options modelled, a catchment-wide trading programme with a grandparenting allocation proved to be the most cost-effective[4] for landowners to maintain 2010 catchment nutrient loads with the irrigation scheme implemented. Compared with the baseline, a cap-and-trade programme that allocates permits to landowners based on their 2010 N leaching and P loss levels (i.e. grandparenting) increases net catchment income by 5% (policy #2a). With catchment-wide trading there may still be water quality issues (e.g. localized 'hotspots') in the Hurunui Plains because N leaching is estimated to increase by 16% and P loss by 44% for over baseline levels in that area.
- Restricting trading of discharge permits to a specific area of the catchment may reduce the likelihood of 'hotspots', but net revenues only increase by 4% over the baseline (policy #2b).
- We modelled a modified equal allocation approach (policy #2c) where an average permit level per hectare was established and then adjusted for the productive capacity of the land. This generated similar results as a grandfathering allocation with area-restricted trading (policy #2b). Allowing farmers in the more productive Hurunui Plains to purchase permits from landowners in the lower productivity areas (i.e. foothills) would provide flexibility for landowners to increase their own level of nutrient discharges while still meeting 2010 nutrient loads.
- Theoretically, an optimally implemented nutrient tax (policy #3) would produce similar impacts to a catchment-wide cap-and-trade programme (policy #2a, #2c). The N and P tax could, if desired, be varied across different parts of a catchment to meet different water quality limits (policy #2b).
- The optimal N tax rate to maintain nutrients at 2010 levels was to charge all landowners in the catchment $23/kg N and $119/kg P (policy #3). Although this is an 'optimal' solution from a catchment-wide perspective, there could be distributional impacts as not all landowners who would be required to pay the tax would benefit from the new irrigation scheme.
- The marginal costs of abatement for taxes are non-linear making it difficult to establish an optimal tax ex–ante. Providing flexibility to adjust the tax over time would better ensure that nutrient load limits are maintained over the long run. If policy makers have

[4] In this report, a 'cost-effective policy' is defined as a modelled policy that achieves the nutrient target in the catchment at the least cost to the landowners. It does not necessarily account for administrative and transaction costs that could make the policy more costly in reality.

to frequently adjust the tax rate, then this could generate more economic and social disruption in the transition than a cap-and-trade approach.

Manawatu Catchment

The water quality limits modelled for the Manawatu catchment would require a reduction of N leaching by 53% and P losses by 49%, similar to those specified by Horizons Regional Council (Ausseil & Clark 2007). We assume that the entire limit would have to be achieved through mitigation from the land-use sector based on the fact that 90% of nitrogen in the Manawatu River is from two main types of non-point sources – dairy, and sheep and beef farming (Clothier et al. 2007). Part of the policy outlined in the December 2010 version (the Decisions Version) of the proposed Horizons One Plan required that new dairy farms demonstrate compliance with cumulative nitrogen leaching maxima that vary with Land Use Capability (LUC) classification (i.e. natural capital approach). For the model scenarios, We evaluate a policy option slightly different from the One Plan where *all* dairy farms must comply with LUC based nitrogen leaching caps,[5] plus other options such as implementing GMPs, various cap-and-trade schemes, and a nutrient discharge tax. The baseline scenario modelled assumed that the proposed water quality policy had yet to be implemented. As a result of the policy assumptions presented in this report, the estimates are *not* directly comparable with analyses of the One Plan. The key findings from the policies modelled for the Manawatu catchment are:

- A GMP approach that assumed the most effective voluntary practices (i.e. DCD and riparian planting) would be implemented on 50% of the eligible land in the catchment could reduce N leaching by 7%, and P losses by 14% relative to the baseline (policy #1a). This would not achieve the specified nutrient reductions.
- If all pastoral landowners were required by regulation to implement the GMPs of applying DCDs and undertaking riparian planting, and all dairy farmers also had to implement the GMP of wintering their cows off the farm, then N leaching and P loss is estimated to decrease by 15% and 27%, respectively (policy #1b). This would be done at a low average cost ($2/kgN) to the landowner, primarily because applying DCDs could improve productivity, but would not achieve the water quality limits specified by the Regional Council.
- A catchment-wide cap-and-trade programme with a grandparenting-based allocation (policy #2a) proved to be one of the most cost-effective policies of those options modelled to meet the water quality limits at the catchment-level. Net revenue for landowners in the catchment declined by 17% and adding administration and transaction costs further reduced revenues to 22% below 2007 baseline revenues.
- Allocating discharge permits based on LUC is intended to intensify the use of high productivity land while simultaneously reducing nutrient loads. This is referred to as a natural capital allocation approach. Only requiring existing dairy enterprises in each LUC to meet specified nutrients discharge levels results in a 6% reduction in total N compared to the modelled baseline (policy #2c), and less than a 1% reduction in net

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[5] This policy option is not the same as the policies for diffuse discharges in the notified version, neither is it the same as that in the decisions version of the Proposed One Plan.

revenue. This is because (1) most dairy farms are already located on the LUCs with permitted discharges of 18 kgN/ha/yr or more and thus required little change to meet the specified leaching rates stated in the December 2010 version of the Horizons One Plan, and (2) dairy farms comprise less than 20% of the catchment, and therefore dairying does not have a large enough share of the land mass to achieve a 53% reduction in N discharges on its own.

- A natural capital approach could still be a feasible policy to meet nutrient reduction targets if (1) discharge permits based on LUC are allocated to *all* pastoral, arable and horticultural land uses (not just dairy) and (2) *all* landowners are required to collectively meet the HRC's nutrient targets of reducing N by 53%, and P by 49% through a catchment-wide trading scheme (similar to policy #2a). In this case, net revenue for landowners in the catchment was estimated to decline by 17% and adding administration and transaction costs further reduced revenues to 22% below baseline revenues.
- The grandparenting (policy #2a) and natural capital approaches (policy #2d) for allocating nutrient discharges have similar estimated impacts at the catchment level when all landowners are covered, given that the policies are designed to (1) cover nutrient losses from all landowners and (2) cap nutrients at the levels necessary to meet the HRC water quality limits. However, impacts could vary at the farm-level between grandparenting and natural capital based approaches because landowners may receive different amounts of permits, depending on allocation criteria used.
- Restricting trades to smaller areas within the Manawatu catchment would reduce the possibility of localized water quality 'hotspots'. However, spatially restricting trades resulted in a modelled decline in revenue of about 43% when accounting for changes in farm profit, administration and transaction costs (policy #2b). This is because farmers in the 'flats' area of the catchment must reduce nutrients in their own area of the catchment rather than purchasing discharge permits from farmers in the 'hills' that may be able to reduce their N and P discharges at a lower cost.
- The cap-and-trade programme and nutrient discharge tax policies assessed could result in significant changes in land use in the Manawatu catchment with land converting from pasture to arable, forests, scrub, or fallow.
- Theoretically, a nutrient tax (policy #3), implemented optimally, will provide similar impacts as a catchment-wide cap-and-trade programme (policy #2a). We estimate that charging landowners a tax of $36/kgN that leaches from their land should achieve the desired nutrient loads set at the catchment-level. The average cost of reducing N was estimated to be $23/kgN, which is significantly lower than the tax rate because many landowners can implement changes in land management that reduce N at costs lower than the specified tax.
- In all likelihood there would be no need to tax P as the land use and land management changes implemented in response to the N tax will also achieve the required P loss reductions in the catchment.
- Varying the N and P tax across different parts of the catchment to meet different nutrient reduction goals has similar outcomes as policy #2b. Estimates reveal that the N tax could range from $18.70/kgN in the Manawatu Hills to $89.70/kgN in the Tararua Flats.

- The marginal costs of abatement for a tax are non-linear, which could make it difficult to establish the optimal tax ex ante. Providing flexibility to adjust the tax over time would better ensure that nutrient reduction goals are achieved over the long run but could generate more economic and social disruption in the transition than a cap-and-trade approach if policy makers have frequently to adjust the tax rate.

Rotorua Catchment

The provisional water quality target proposed for the Rotorua catchment is to reduce the annual N load to the lake from 755 tN to 435 tN in the long run, with agricultural N loss to fall by approximately 60% by 2022. The agricultural sector is expected to reduce 270 tN of the desired 320 tN. The remainder will come from non-agricultural sources. The water quality target for total N in the Rotorua catchment is significantly lower than the two river catchments modelled because it is a much smaller catchment. The baseline assumes there is no additional water quality policy over and above current settings. The key findings from the policy options modelled for the Rotorua catchment are:

- Implementing a mix of GMPs on pastoral land such as applying DCDs, reducing N fertiliser, importing feed, and adjusting the mix and level of stock would decrease the N loads arriving at Lake Rotorua relative to baseline, but by less than the 270 t reduction required to achieve the regional council's long run environmental goal of 435 tN/yr (policy #1a & b). In over-allocated catchments such as Lake Rotorua land use change as well as management changes may be required to meet environmental goals.
- Even when nutrient exports decrease by 270 tN in 10 years, the loads of N reaching the lake do not achieve the long run sustainable load goal of 435 tN per year until approximately 2100 due to unmanageable legacy loads. These long delays between costly N export cuts and N load outcomes could be an issue in any catchment where some N travels through groundwater and the groundwater lags are long.
- Reducing N discharges by 270 tN by 2022 was estimated to cost $3.2 million per year (policy #2a). A large amount of this cost would be spent on mitigation efforts on dairy land, relative to the land area occupied by dairy farms. If agriculture had to meet all the required N leaching reductions (i.e. 320 tN) it will cost an additional $1million per year (policy #2b). This equates to a 30% increase in costs for only an additional 18% decrease in nutrients.
- A reduction of 270 tN could also be achieved by a $30/kg N tax. Setting the tax at $27/kg N only achieves a reduction of 240 tN, while a $33/kg N tax gave a reduction of 303 tN (policy #3a, b & c).
- The distribution of costs in a cap-and-trade programme is determined by the choice of allocation scheme. Allocating permits based on current discharges (i.e. grandparenting) and then buying sufficient permits back to achieve the N reduction target would cost the regulatory agency a modelled $5.4 million/year with farm profits increasing by more than 10%. Conversely, auctioning all permits would net the regulatory agency $5.3million and farm profits would fall by 39–70%.

Generalized Findings

While the impacts of water quality policies will differ between catchments there are some findings that we can generalize from the three case studies. These include:

- The policy scope and stringency of the nutrient reduction goals affects the economic impact of the policy. If nutrient limits are established prior to major declines in water quality occurring then the economic burden of reaching the specified limits is significantly lower. This is illustrated in the difference in estimates of the total costs of policies #2 and #3 for the Hurunui-Waiau and Manawatu catchments. The proposed policy to maintain current water quality in the Hurunui-Waiau allowed the flexibility to increase their intensity and net revenues by about 5%, while the large reductions in nutrients proposed for the Manawatu meant that landowners had a reduction in profit by 22% or more.
- The economic impact of large reductions in nutrients, while large, was less in percentage terms than the required nutrient reduction, e.g. achieving a 53% reduction of N in the Manawatu catchment would reduce catchment net revenue by 22% (under optimal policy settings that enable a dynamically efficient adjustment to limits; and assuming well-informed economically-rational decision making by land users). This, of course, depends on mitigation technologies available and the willingness and ability to invest in the adoption of GMPs, change land use, or participate in a trading programmes.
- In catchments where the nutrient load is significantly above the limit (e.g. Manawatu or Rotorua), it is unlikely that a policy to voluntarily or mandatorily implement GMP will achieve the necessary reduction in discharges. Our simulations suggest that additional policy instruments may be required and it is likely that some level of land use change will be needed, though this will depend on the severity of the problem and individual catchment characteristics.
- The average cost of nutrient reductions can vary both within and across modelled catchments. Key reasons include current land use and land management, feasible mitigation options, and biophysical aspects such as soil type and topography.
- The modelled costs of reducing P loss are significantly larger than N leaching on a per unit basis. This is likely due to the small amount of P in the catchment relative to N, and hence that the value of output per unit of P is also higher to mitigate than the same unit of N. There are also limited management practices included in the model that are specific for controlling P loss.
- The marginal abatement costs (i.e. the cost of reducing an additional unit of N or P at the limit) are also different between the three catchments. This also indicates that there is likely to be a high level of variation in mitigation potential across catchments in New Zealand.
- Economic theory shows that a pollution tax and cap-and-trade programmes should result in equally efficient nutrient reductions provided there is perfect information about the pollution sources and how landowners would react to alternative instruments that put a price on nutrient outputs. We find this in the three catchments assessed for this report. The cost savings may be somewhat undercut though by the administration and setup costs of establishing a tax or nutrient trading programme. Additional transitional costs are likely in a tax regime if policy makers cannot set the optimal tax rate ex ante, and adjust the tax rate frequently.
- Although tax and trading scheme can theoretically achieve the same level of nutrient reductions at the same cost at the catchment-scale, the two approaches can have different distributional implications. Some landowners would face lower costs from a

cap-and-trade programme from selling excess nutrient reduction permits. In the tax case, the government receives tax revenue from the landowners and has the ultimate decision on how to utilise the funds, such as by decreasing other taxes or investing in research, education, or alternative mitigation options to assist with the policy.

- If all the revenue collected from the nutrient tax were recycled back to landowners in the form of a dividend or reduction of other taxes, then the changes in net catchment revenue would be similar to the grandparented cap-and-trade policy. This is the assumption that we use in when presenting catchment-wide estimates for the tax policies in this report. If not all of the taxes collected were recycled back to the landowner, however, the total costs to farmers would be higher under this policy approach. Furthermore, landowners that might not have the ability to implement more cost-effective management practices on their farm could face a potentially high price of maintaining their current operation.
- How discharge permits are allocated does not have large economic impacts at the catchment level. However, different allocation systems can lead to significantly different distributional impacts. For instance, in the Manawatu catchment, the natural capital allocation approach would reduce the cost of meeting the nutrient limit for those located in high-productive land by 11% compared with a grandparenting allocation. At the same time, those located in less productive areas would face 16–17% higher costs to meet the limit with a natural capital allocation. If landowners were able to trade permits, the equilibrium result at the catchment level will be similar regardless of how the permits were distributed (i.e. natural capital, grandparenting, etc.). These findings are based on the assumption that an efficient trading market exists and all landowners are profit maximisers. Impacts may differ where there are high transaction costs, spatially restricted trading, or there is an unwillingness to buy and sell permits even if it is economically efficient to do so.
- The larger the geographical area for trading, the more cost-efficient the programme is likely to be. This results from a more diverse set of land-uses, landowners, and tradable permits. However, there may be a greater possibility of localised water quality ‘hotspots’ with catchment-wide trading than where trades are restricted to smaller areas.
- Land-use change in response to changes in market conditions is typically a slow process. Evidence suggests that adjusting land use quickly will be costly, and may justify slower transition pathways to minimize cost.

Table 3 Estimated Impacts of Nutrient Reduction Policies

Catchment[a]	Scenario	N Target (tonnes)[b]	Total N in 2022 (tonnes)	% N Target Achieved by 2022[c]	% N Target Achieved by 2100[c]	Average Mitigation Cost ($/kg N)	Time to Achieve (years)	Total Annual Cost ($ million)[d]	Profit[e] Change from Baseline (%)
Hurunui-Waiau	Baseline without Waitohi Irrigation Scheme	2930	2930	100%	100%	n/a	0	n/a	0%
	Baseline with Voluntary GMP (Policy #1a)	2930	2710	108%	108%	$52	10	$11.2	-5%
	Baseline with Regulatory GMP (Policy #1b)	2930	2300	127%	127%	$46	10	$29.3	- 12%
	Waitohi Irrigation- No Water Quality Policy	2930	3620	76%	76%	n/a	Not	-$24.4	+10%
	Waitohi-Catchment-wide Trading (Policy #2a)	2930	2930	100%	100%	n/a	10	-$11.0	+5%
	Waitohi-Region-restricted Trading (Policy #2b)	2930	2930	100%	100%	n/a	10	-$9.3	+4%
	Waitohi-Equal Allocation Trading (Policy #2c)	2930	2930	100%	100%	n/a	10	-$9.8	+4%
	Waitohi-N Tax at $23/kgN and P Tax at $119/kgP (Policy #3)	2930	2930	100%	100%	n/a	10	-$11.0	+5%
Manawatu	Baseline	2536	5400	0%	0%	n/a	0	n/a	0%
	Voluntary GMP (Policy #1a)	2536	5019	13%	13%	$2	Not	$0.8	0%
	Regulatory GMP (Policy #1b)	2536	4591	28%	28%	$2	Not	$1.8	-1%
	Catchment-wide Trading (Policy #2a)	2536	2536	100%	100%	$23	10	$64.7	-22%
	Region-restricted Trading (Policy #2b)	2536	2520	101%	101%	$45	10	$129.4	-43%
	Natural Capital Allocation Trading – Dairy Only (Policy #2c)	2536	5076	11%	11%	$4	10	$1.2	-0.4%
	Natural Capital Allocation Trading – Pasture and Arable (Policy #2d)	2536	2536	100%	100%	$23	10	$66.2	-22%
	Tax at $36/kgN (Policy #3)	2536	2536	100%	100%	$23	10	$66.2	-22%
Rotorua	Baseline	435	755	100%	100%	n/a	0	n/a	0%
	BoPRC GMP (Policy #1a)	435	539	68%	58%	$7	Not	$0.8	-5%
	Stringent GMP (Policy #1b)	435	472	88%	91%	$11	Not	$2.6	-18%
	Catchment-wide Trading - 270tN reduction (Policy #2a)	435	454	94%	100%	$9	92	$3.2	-22%
	Catchment-wide Trading - 320tN reduction (Policy #2b)	435	479	86%	100%	$5	147	$4.2	-29%
	Tax at $30/kgN (Policy #3a)	435	454	94%	100%	$4	92	$3.2	-22%
	Tax at $27/kgN (Policy #3b)	435	472	88%	91%	$9	Not	$2.6	-18%
	Tax at $33/kgN (Policy #3c)	435	436	100%	109%	$11	16	$3.9	-27%

n/a: not applicable

[a] Each case study catchment uses different economic data, biophysical data, options for land management, and policy assumptions. The Hurunui-Waiau and Manawatu catchment scenarios were modelled using NZFARM while Rotorua was modelled NManager. Thus, the estimates from each case study are not directly comparable.

[b] Nutrient reduction targets are set simultaneously for N and P for Hurunui-Waiau and Manawatu. Rotorua targets are only for reductions in N leaching.

[c] Values greater than 100% indicate that additional nutrient reductions beyond the target have been achieved. In the case when the policy requires a simultaneous reduction in N and P, the economically optimal solution could be to change land use or land management in a manner that reduces one nutrient beyond the target level.

[d] Negative costs in the Hurunui-Waiau catchment imply that there is an increase in net revenue from increase in intensity due to implementation of Waitohi Irrigation Scheme

[e] Farm profit is measured as annual earnings before interest and taxes, or the net revenue earned from output sales less fixed and variable farm expenses.