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Te Papa Atawhai




Southland:
Overview of studies assessing the potential impacts of scenarios for setting water quality objectives

October 2013

New Zealand Government

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Preface

Southland is the southernmost region in New Zealand, extending from Fiordland in the West to the Catlins on the East Coast, and includes Stewart Island. The region is the second largest geographically, covering around 3,176,000 ha, or around 12.5 per cent of New Zealand's total land area, with just over half managed as public conservation land. Within the region there are four major river catchments, the Mataura, Oreti, Aparima and Waiau. The main stems of these rivers have particularly high cultural values, and are Crown statutory acknowledgements under the Ngāi Tahu Claims Settlement Act (1998). At the bottom of these catchments are a range of estuaries, coastal lakes and lagoons with high recreational and ecological values, including the Waituna Lagoon, which is designated as a Ramsar Wetland of International Importance.

Around 93,300 people live in Southland, or 2.2 per cent of New Zealanders, and it is expected to remain a relatively stable, aging population over the next 25 years. In contrast, the region has one of the fastest growing economies, experiencing 23.3 per cent growth in regional gross domestic product (GDP) in the four years from 2007 to 2010. In the year ended March 2010 the Southland economy, driven by agriculture and manufacturing, generated around 2.3 per cent of New Zealand's GDP. A quarter of the population live in rural areas, reflecting the central importance of agriculture to the Southland economy. Agriculture production and processing are both major users of water, via takes and discharges, and are expected to require 87 per cent of additional future demand for water. The agricultural industry has significant flow-on effects to the service sectors in urban areas such as Gore, Winton and Te Anau, and Invercargill.

Southland is becoming more reliant on the use of fresh water and is highly sensitive to changes in freshwater management. Southlanders are well aware of this situation. In the *Our Way Southland Quality of Life Survey (2013)*, around half of respondents expressed significant concerns about water quality, while securing economic development was identified as the single most important issue facing the region.

This report is a summary of a series of reports commissioned by central government that consider the potential environmental, economic, social and cultural impacts of choices for setting freshwater quality objectives and limits in Southland (see Table 1 for a list of the studies). The Southland economic impact studies assessed a range of scenarios for managing water quality. The results are generated from a series of interdependent models, each with limitations, and need to be interpreted with care. The purpose of these studies is to integrate environmental and economic information in a way that will support community discussions about the potential impacts of freshwater management choices across all sectors in Southland. The results are not intended to direct the choices that the Southland community will make in managing water quality.

The National Policy Statement for Freshwater Management 2011 requires councils to set freshwater objectives and limits in their regional plans. The March 2013 *Freshwater reform 2013 and beyond* document details the proposals currently under consideration, which include changes to the National Policy Statement (NPS) to facilitate a National Objectives Framework (NOF), including national bottom lines or minimum states for all freshwater bodies. The results of the Southland studies contributed to central government understanding of the potential impacts of a National Objectives Framework with national bottom lines for ecosystem and human health.

The studies consider a range of scenarios to manage freshwater quality to see what the magnitude of the costs and benefits to the community's value for water might be; they cover a range of policies along a spectrum from 'realistic' to 'less likely'. Some of the scenarios modelled are at the extreme ends of a spectrum, and are not likely to be realistically considered. The scenarios attempt to use current mitigation practices in Southland as a starting point. In isolation the scenarios are artificial, and they do not represent current policy proposals or intentions.

In the real world, tools will be more targeted than those used in the scenarios modelled. Communities would likely choose an integrated package of management measures that would be put in place over time. One generation – the 25 years modelled in these studies – may not be long enough to achieve a community's desired water quality outcomes because of the adjustment timeframes chosen and required. It is reasonable to expect that improving environmental outcomes will almost certainly require managing impact and responses to those impacts over many years, perhaps over generations. The scenarios modelled have not looked at how economic impacts would vary with different adjustment timeframes.

One aspect that the studies have not been able to cover is the potential impact of freshwater quality on the health of estuaries, coastal lakes and lagoons. Understanding ecosystem responses in the face of changing water quality presents a significant challenge for Environment Southland and the community to address. The changes required to meet community expectations for these coastal water bodies will have big implications for how freshwater resources and land-based activities may be managed in the future. Overall, and putting the estuaries to one side for the moment, Southland's economy can continue to develop within a limited range of environmental, social and cultural constraints. The amount of future development and level of environmental outcomes achieved will depend on the objectives chosen by the community.

The national bottom lines for rivers assessed in the reports are minimum states to test the relative performance of scenarios for setting freshwater objectives and should not be interpreted as a community's objectives for water quality in Southland because they are unlikely to be sufficient to meet estuary water quality requirements. The studies provide Environment Southland with both a starting point and lessons for undertaking a fuller economic analysis, which can be used alongside regional initiatives that are planned or underway.

Executive summary

Economic impact studies

Central government (Ministry for the Environment (MfE), Ministry of Primary Industries (MPI), Department of Conservation (DOC)) is running an 'Economic Impact Studies' workstream, and commissioning a series of interlinked economic and scientific studies to assess the potential impacts of scenarios for setting freshwater quality objectives and limits.

The purpose of these studies is to help inform community discussions and support policy making by regional councils on the potential economic, environmental, social and cultural impacts of freshwater management options. The studies also inform national policy development on the potential impacts of setting freshwater objectives and limits, including proposed national bottom lines, under the National Policy Statement for Freshwater Management 2011.

Why Southland was chosen

The Southland region was chosen as an appropriate region to carry out the economic impact study as:

- water quality is an important regional issue
- the region was at an appropriate stage of developing regional plan changes
- It was considered likely that Southland would be one of the most impacted regions by proposed national bottom lines both now and in the future.

Water quality in Southland

Environment Southland have stated that they are concerned that rivers and streams in the developed areas of Southland generally have high levels of nitrogen and phosphorus, and that they see worsening nitrogen trends in both groundwater and surface water. Sediment and faecal bacteria levels across the region are also a concern to the council. The most sensitive parts of catchments (the estuaries, lagoons and coastal lakes) are showing signs of stress with deterioration due to excess sediment and nutrients.

National Policy Statement for Freshwater Management 2011 and freshwater reform

The National Policy Statement for Freshwater Management 2011 requires regional councils to set freshwater objectives and limits in their regional plans. This policy statement requires regional councils to safeguard the life-supporting capacity of fresh water (Objectives A1 and B1) and to set freshwater objectives and limits that maintain or improve overall water quality within a region (Objective A2).

Objective A2 recognises that maintaining all aspects of water quality everywhere is not possible. It does not require every degraded water body will be cleaned up, some will remain in their current state; and the objective-setting process will determine which ones. The objective allows for some variability in water quality as long as the overall water quality is maintained in a region.

The March 2013 consultation document *Freshwater reform 2013 and beyond*[1] proposed a series of reforms to support communities to make better planning decisions, set freshwater objectives and limits for their water bodies, and manage land and water use within those limits. The document detailed options for delivering the proposals including potential changes to the National Policy Statement.

The proposals include:

- establishing a regulated National Objectives Framework to support regions to set freshwater objectives and limits under the National Policy Statement
- requiring freshwater objectives and limits to be set in an integrated way, allowing for the impacts of limits and adjustment timeframes to be well understood and factored into decision-making
- including a set of values a water body can be managed for with associated minimum states (e.g. minimum states for bacterial contamination when a river is managed for swimming)
- requiring that all water bodies meet the minimum states for attributes to measure ecosystem health and human health for secondary contact, effectively establishing some national bottom lines.

Overview of the Southland economic impact study

This summary report provides an overview of the component economic impact studies relevant to the Southland Region. The series of studies assess the potential economic, environmental, social and cultural costs and benefits of setting freshwater quality objectives and limits, including proposed bottom lines for ecosystem health and human health, under the National Policy Statement for Freshwater Management. The studies evaluate the potential impacts on the agricultural, industrial and municipal sectors and on non-market values in Southland. In the studies, ecosystem health in rivers is based on the attributes of median nitrate toxicity and

[1] Ministry for the Environment. 2013. *Freshwater reform 2013 and beyond*. Wellington: Ministry for the Environment.

periphyton (slime) and human health is based on *E. coli* concentrations. Other attributes for ecosystem health and human health also need to be considered going forward.

The economic impact studies provide Environment Southland with a useful starting point for assessing the potential impacts of objectives and limit-setting under the National Policy Statement. Environment Southland will be able to build on the work carried out, taking the time to do this with the community. Future work will need to consider both adjustment timeframes and the wider economic impacts on local communities, both of which are essential parts of the freshwater reform programme. Such an approach will be key to informing community discussions on shared values for water, minimising impacts on existing users of water and ensuring environmental outcomes are achieved across the region.

Results of the Southland study suggest that communities would have a wide range of economic and environmental choices in managing freshwater quality of rivers. The findings are region specific and cannot be extrapolated to other regions.

Results of the Southland studies – Achieving proposed national bottom lines

A range of potential national bottom lines are being considered, for potential inclusion of minimum quality states in a National Objectives Framework. In addition to bottom lines, water quality bands A – D have been identified (where A is the highest quality and the boundary between C and D represents the proposed bottom line), to allow analysis of improvements in water quality at levels above the proposed minimum states.

The Southland case study reports have found that the proposed bottom lines for ecosystem health in rivers for the two attributes tested in Southland are currently met and do not impose costs. Water quality will be maintained above bottom lines for median nitrate toxicity and periphyton (slime) under all scenarios tested.[2] Although the ecosystem health in rivers will decline, the proposed national bottom lines tested will be met without undertaking additional mitigation both now and in 2037.

The National Policy Statement for Freshwater Management and existing regional policy currently requires councils to maintain or improve overall water quality in the region, which would require further policy response. Maintained or improved overall water quality could be achieved in Southland's rivers. Growth in agricultural production could be achieved while maintaining or improving overall water quality, although it is likely have economic impacts.

The proposed national bottom line for *E. coli*, the attribute tested for human health, in rivers is currently breached at five of the 73 sites monitoring sites tested in Southland. Predicted future (2037) water quality in a 'no additional mitigation' scenario show little change in *E. coli* levels. The study considers existing mitigation levels as a starting point for the analysis. The findings are driven by the assumption of a small decrease in the amount of agricultural land area, and the assumption that dairy and non-dairy pasture uses impose similar nutrient loads.

The reports investigate the potential impacts of a range of different scenarios (with related agricultural (farm-level) mitigation bundles), on freshwater quality. The mitigation bundles are focused on reducing nitrogen and phosphorus levels in rivers and therefore most mitigation bundles have little effect on *E. coli* levels.

Specific on-farm mitigation practices aimed at reducing *E. coli* concentrations are required to meet the bottom line for human health. In Southland, mitigation measures on dairy farms only will not be sufficient to ensure that the *E. coli* bottom line is met at the five sites where it is currently

[2] After the Southland study was completed, the nitrate toxicity bottom line was strengthened by the addition of a criterion around nitrate levels at the 95th percentile (in addition to the median). The potential impact of meeting the bottom line at the one site in Southland which breaches the updated threshold has not been assessed.

breached. However, fencing of waterways on surrounding sheep and beef farms as well as on dairy farms would address *E. coli*. The majority of these costs could fall on sheep and beef farms, as most dairy farms already have fencing in place.

The Southland studies do not provide information on the water quality and associated economic impacts of limits for achieving national bottom lines for lakes, as most lakes in Southland fall within the Conservation Estate, with Lake Te Anau being the exception.

Ecosystem health of estuaries is likely to be a more constraining water quality issue than rivers in Southland, as water quality thresholds for estuaries are more challenging to meet. Results suggest that estuaries in Southland are more sensitive receiving environments than rivers and that contaminant loss from land-use activities in the region has its most marked effect on estuaries. Therefore, the proposed bottom lines for rivers are unlikely to be sufficient to maintain and improve water quality in the estuaries. The science around the appropriate thresholds for estuaries in New Zealand is limited. Objectives set for fresh water will also need to consider the impact on estuaries and the requirements of the Coastal Policy Statement.

Results of the Southland studies – Potential impacts of scenarios to manage freshwater quality

The Southland economic impact studies assessed a range of scenarios for managing water quality. The results are generated from a series of interdependent models, each with limitations, and need to be interpreted with care. The purpose of these studies is to integrate environmental and economic information in a way that can support community discussions about the potential costs and benefits of freshwater management choices across all sectors in Southland. The results are not intended to direct the choices that the Southland community will make in managing water quality. The findings emphasise the importance of councils testing a range of scenarios when setting objectives and limits, in terms of the level those objectives and limits are set, the regime for managing within limits and the timeframe for adjustment.

The following sections provide an overview of the potential impacts of scenarios for setting water quality objectives on the agricultural, municipal and industrial sectors and on non-market values. The potential impacts of minimum flow requirements on electricity generation are also summarised.

Potential impact of scenarios for setting freshwater quality objectives and limits for rivers[3] on agriculture

A range of scenarios[4] for setting freshwater quality objectives and limits were tested to assess the potential costs and benefits to agriculture in Southland (see table 5 and table 14 for more detail on scenarios). The scenarios to reduce nutrient discharges are hypothetical and they do not represent policy proposals or intentions. In the real world, policy responses are likely to be more targeted than the scenarios modelled and will need to occur in an integrated way. However, the results of the scenarios provide a first step in informing community discussions on the potential impacts of options and choices they may face when managing land and water use to improve water quality.

Under the modelling carried out in these studies, it has been found that maintained or improved overall water quality may be achievable for rivers in Southland, with some scenarios allowing for dairy growth.

[3] As noted previously, achieving water quality objectives for rivers may not be sufficient to maintain or improve water quality in estuaries.

[4] A combination of mitigation bundles under a number of scenarios including uniform nutrient discharge caps; non-uniform nutrient discharge caps; grandparenting with proportionately equal reductions in discharges and mandated mitigation actions across all dairy, sheep and beef farms.

The modelling indicates that dairy growth and gains in aggregate gross margin could be achieved with non-uniform caps and mandated mitigation while meeting the bottom lines for ecosystem health and human health and maintaining or improving overall water quality in rivers.

The most cost effective scenarios tested in terms of nitrogen mitigation are the non-uniform caps where all dairy farms adopt the mitigation bundle including stock exclusion, improved nutrient management and improved animal productivity. However, while aggregate gross margin is maintained in both non-uniform cap scenarios, the reduction in production entailed in scenario 18 would have downstream economic impacts on the processing industries in Southland. These wider impacts are not considered in the studies. Furthermore, practices such as fencing aimed at reducing *E. coli* to meet the proposed bottom lines for human health result in costs, but these costs are hidden in the overall benefit of the mitigation bundles that mainly focus on reducing nitrogen and phosphorus losses.

This result of a gain in gross margin under the non-uniform cap scenarios is heavily dependent on the modelled benefits of improved animal productivity, which deliver both improved profitability and reduced nutrient loss. This result differs from other New Zealand research which suggests that on farm nutrient loss reduction of the order of 20 per cent per hectare is achievable at relatively minimal cost but mitigation costs rise steeply after this point[5].

Potential impacts of improved water quality on the municipal and industrial sectors

The case studies assess the potential mitigation costs to reduce contaminant losses at industrial and municipal sites that are point sources of contaminants. If deemed cost effective, these mitigation measures may be considered within a wider package of measures to achieve a specific water quality objective such as bottom lines.

Proposed bottom lines would not result in costs to Invercargill municipal water supply, as the Ministry of Health standards for drinking water are more stringent. In contrast, the effects of reducing key contaminants on stormwater could be more than $1,800 per ratepayer household per year. This reduces to $240 if only stormwater from the industrial area is treated or $526 per year if the industrial and CBD areas are treated. The Winton case study estimates wastewater treatment costs ranging from $460 and $700 per household or business annually on average over the next 25 years.

The study assumes all financial and capital costs are funded through loans and paid off through rates. This study takes no account of the wider range of funding options open to local governments including rates differentials, development contributions, grants and others. Utilising a mix of these funding mechanisms is the likely approach councils will take and will have a significant bearing on the results. Moreover, the timing of implementation of water quality limits impacts significantly on councils' ability to afford the infrastructure required to meet any new standards.

The potential costs associated with an upgrade to the Alliance Meatworks wastewater processing facility are significant. Should the upgrade be developed in time to be fully operational by 2017 and meet the current published water quality standards it may cost the company over $41 million (in NPV terms).

However, it is worth noting that a range of scenarios have been considered to develop the cost estimates for the Alliance Meatworks wastewater processing facility. Alliance Meatworks was in the early stages of investigating costs and processes when such scenarios were developed and thus the scenarios do not necessarily correspond to the reality on the ground. Moreover, the Net

[5] For example, see Doole, Agricultural Water Management, Volume 104, February 2012, Pages 10–20 "Cost-effective policies for improving water quality by reducing nitrate emissions from diverse dairy farms: An abatement–cost perspective".

Present Value has been calculated over a 25 year time period (at a 6% rate) so the investment would not necessarily have to happen in one go. A staged approach would mean the costs could almost be halved, however the efficacy of such approach is not known and therefore the costs are rough estimates at this stage. Furthermore, the wastewater upgrade does not provide Alliance Meatworks with improvements to operational efficiency which may allow Alliance Meatworks to recoup some of these costs.

While the potential mitigation costs could run into the tens or even hundreds of millions of dollars, it is difficult to draw any region-wide conclusions on the impact of proposed bottom lines on the municipal and industrial sectors. To do so, further data on contaminant discharges, facility standards and upgrade requirements and costs would be necessary across the region.

Potential Impacts of improved water quality on non-market values

The non-market values[6] study is a first step in assessing the marginal impact of improved water quality on non-market values in Southland. The total marginal impact is unknown as not all values could be quantified. The results indicate that, for the values that could be quantified, improving water quality with uniform nutrient discharge caps[7] would result in a marginal benefit for recreational uses (fishing, swimming and kayaking) and existence value of between $0.1 and $2.3 million per year in 2037 (in 2012 dollars).

The total marginal benefit of improved water quality to meet bottom lines would be greater than the estimated results for two reasons:

- Whilst the marginal benefit quantified appears to be relatively small, it does not include the marginal impact on a number of significant non-market values, including ecosystem health and diversity, aesthetics and amenity, and cultural and spiritual values (including unique Māori values[8]) that have not been quantified due to data limitations. As the latter values are greater in scope than the values of recreation and existence values quantified, and as they are likely to be positively correlated with improved water quality, it can reasonably be expected that these values would have greater marginal benefits than those quantified.
- The results are based on improvements to water quality resulting from uniform nutrient discharge caps at farm level, which represents only an incremental improvement in water quality. This scenario meets the bottom line for ecosystem health and results in maintained or improved ecosystem health in rivers overall. This scenario does not meet the bottom line for human health at a small number of sites, but results in improvements in *E. coli* levels overall. As it is likely that an improvement in *E. coli* would lead to an increase in non-market values for recreation and kayaking, it is expected that meeting the bottom line for human health at all sites would result in a greater non market benefit.

Potential impacts of minimum flow requirements on electricity generation

Minimum flow requirements imposed on rivers may create economic impacts on electricity generation. In implementing or increasing minimum flow requirements, actual costs (primarily due to reduced generation system efficiency) depend on a range of factors including: the size of any minimum flow imposed, the location of the minimum flow on a particular scheme and the unique characteristics of the river. While the costs would need to be balanced against

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[6] Non-market values include recreational and cultural values, existence values, option values and bequest values.

[7] Other scenarios were not analysed due to time constraints.

[8] Covec (2013) worked closely with Ngāi Tahu in Southland to understand Māori values associated with fresh water. For Ngāi Tahu, and potentially other iwi, there are three uniquely iwi values related to water, which have been identified as additional to the non-market values captured by the overall theoretical framework. These values are: reciprocity; knowledge gained from sustainable use; and cultural identity associated with water bodies.

environmental, social and cultural outcomes, an economic cost on the electricity system may have flow-on effects for national consumers, regardless of where the minimum flow limit is implemented or increased. Costs to the electricity system will primarily arise from the following drivers:

- Loss of generation: reduced diversions into rivers used for electricity generation arising from increasing the minimum flow requirements in waterways from which water has been diverted. To a lesser extent, there may also be a loss of generation output from increased spill as generators have to keep storage lakes higher than they otherwise would in order to ensure they have sufficient water to meet minimum flow rates.
- Loss of flexibility: from reduced ability for hydro generators to store water at low value times for use at high value times.

For Southland's Manapouri scheme, increasing current consented minimum flows for the lower Waiau has a relatively small marginal impact on electricity generation as the current consented flows are significantly lower than natural minimum flows. A 10 per cent and 40 per cent increase in consented flows has been estimated to cost of $8.6m and $36.2m respectively. Setting consented flows along the Waiau at a fixed percentage of natural Mean Average Low Flow (MALF) would have a significantly greater marginal impact on electricity generation. For example, a 40 per cent and 80 per cent increase in 7dayMALF was estimated to cost $683m and $1,647m respectively.

It is critical to note that the marginal change assessed within the report on the electricity sector is in terms of changes to availability of water quantity, rather than considering change in water quality directly. As such, the findings of this report stand alone, and cannot be considered alongside the impacts identified in the parallel studies. However, the ecosystem health of aquatic habitats in the Lower Waiau River is extremely dependent on a flow regime based on a range of flows that includes medium to large floods for flushing of the system, and not just minimum flows.

Limitations of the Southland economic impact studies

A risk with any modelling exercise is that models are by definition a simplification of reality. All models are a predictive tool that forecast expected outcomes, rather than a tool that allows perfect foresight. These studies do not represent the 'answer' as such, and instead are a 'lego', and at times 'duplo' reflection of reality, that is nonetheless a better guide of the potential impacts of setting freshwater objectives than if not using any logical analytical model.

Whilst no scientific nor economic model can perfectly replicate the reality on the ground, the outputs of the modelling work gives a clear indication as to the relevant impact categories, and magnitude of those impacts, on the agricultural, municipal and industrial sectors and on non-market values – a critical piece of evidence in the assessment of policy proposals. The results cannot be extrapolated to other regions or at a national level, due to differences in geographies, climates, types of freshwater bodies, farming practices and the assumptions made in the modelling which are unique to Southland.

The key limitations of the Southland studies include:

- Overall: It was not possible to gather primary data for most of the studies, given the timeframe to carry out such assessment. Further work is required.
- Farm level modelling: Mitigation bundles used in the modelling include practices such as improved nutrient management and improved animal productivity which are aimed at reducing nutrients levels (N and P). Most mitigation actions have little effect on *E. coli* levels. Practices such as fencing, aimed at reducing *E. coli* to meet the human health bottom line result in costs, but these costs are hidden in the overall benefit of the mitigation bundles.

- The farm level modelling has found that under some scenarios, farms could both reduce nutrient discharges and improve profitability by adopting certain mitigation bundles. However, in reality this situation may not be possible, as it would require increased efficiency at farm level, which would impose mitigation costs on existing as well as new farms. The result differs from other New Zealand research which suggests that on farm nutrient loss reduction of the order of 20 per cent per hectare is achievable at relatively minimal cost but mitigation costs rise steeply after this point. Therefore, it must be noted that these findings are specific to the modelling assumptions made in the modelling, and that in reality some sectors/farmers will not have the capability to carry out these mitigations at a low or no cost.
- Non-market value: Not all non-market values were quantified due to significant gaps in the data. The study is based on secondary data sources, and values have been transferred from sites in different parts of New Zealand. There are a number of limitations that result from such a benefit transfer process and primary research is required for a more complete understanding of non-market values. The total economic value (TEV) framework may not be suited to evaluate iwi non-market values.
- Municipal and industrial: The approach of the municipal and industrial study evaluates the impact of reducing contaminant losses at industrial and municipal sites that are point sources of contaminants. The study does not directly assess the impact of achieving a specific water quality objective or proposed bottom lines. The results are based on four case studies and do not reflect the potential impacts on the sectors at a regional level.

Section 1: Introduction

The National Policy Statement for Freshwater Management 2011 requires councils to set freshwater objectives and limits in their regional plans. The March 2013 consultation document *Freshwater reform 2013 and beyond* proposed a National Objectives Framework including national bottom lines for water quality standards.

Central Government (MfE, MPI, DOC) is investigating the potential impacts of scenarios for setting water quality objectives and limits through a series of interlinked economic and scientific studies. The purpose of these studies is to support and help inform community decision making on freshwater management options. The studies also inform national policy development on the potential impacts of setting freshwater objectives and limits, including proposed national bottom lines for ecosystem health and human health, under the proposed National Policy Statement for Freshwater Management 2011.

By taking a Total Economic Value and marginal impact approach, the studies attempt to identify, and where feasible quantify, the costs and benefits of scenarios for setting freshwater quality objectives across environmental, economic, social and cultural water values. Carrying out component case studies relevant to the Southland region has enabled a preliminary region-specific assessment of the feasibility of scenarios for setting water quality objectives.

1 Introduction

1.1 The importance of water

1. Fresh water matters to all New Zealanders. It is central to the environment, the economy and our identity. It is a key aspect of who New Zealanders are and what they bring to the world. For Māori, it is a taonga, essential to life and identity.

2. Fresh water is one of New Zealand's key economic assets. Directly and indirectly, rivers, lakes and groundwater resources support the creation of wealth, whether growing crops and livestock, generating electricity, thrilling jet boating tourists, allowing minerals to be mined, or through a host of other activities. In 2012, primary industries that depend on fresh water – such as livestock farming, horticulture and forestry – delivered more than 12 per cent of our GDP and over 52 per cent of overall exports (70 per cent of merchandise exports). Tourism, which also draws on the beauty of New Zealand's fresh water, accounts for a further 10 per cent of GDP and 15 per cent of overall exports. Approximately 58 per cent of New Zealand's electricity comes from hydro-power stations, with other power stations dependent on fresh water for cooling.

1.2 Background to this study

1.2.1 The regulatory framework governing freshwater management

3. The Resource Management Act 1991 (RMA) is the key legislation governing the management of New Zealand's freshwater resources. Under the RMA, regional and unitary councils are responsible for making decisions on the allocation and use of water within their boundaries and for managing water quality. Central Government can guide and direct regional councils

under the RMA using tools such as National Policy Statements and National Environmental Standards.

1.2.2 Proposals for reform

4. The National Policy Statement for Freshwater Management 2011 requires regional councils to set freshwater objectives and limits in their regional plans. This policy statement requires regional councils to safeguard the life-supporting capacity of fresh water (Objectives A1 and B1) and to set freshwater objectives and limits that maintain and improve overall water quality within a region (Objective A2).

5. Objective A2 recognises that maintaining all aspects of water quality everywhere is not possible. It does not require every degraded water body to be cleaned up, some will remain in their current state; the objective-setting process will determine which ones. The objective allows for some variability in water quality as long as the overall water quality is maintained in a region.

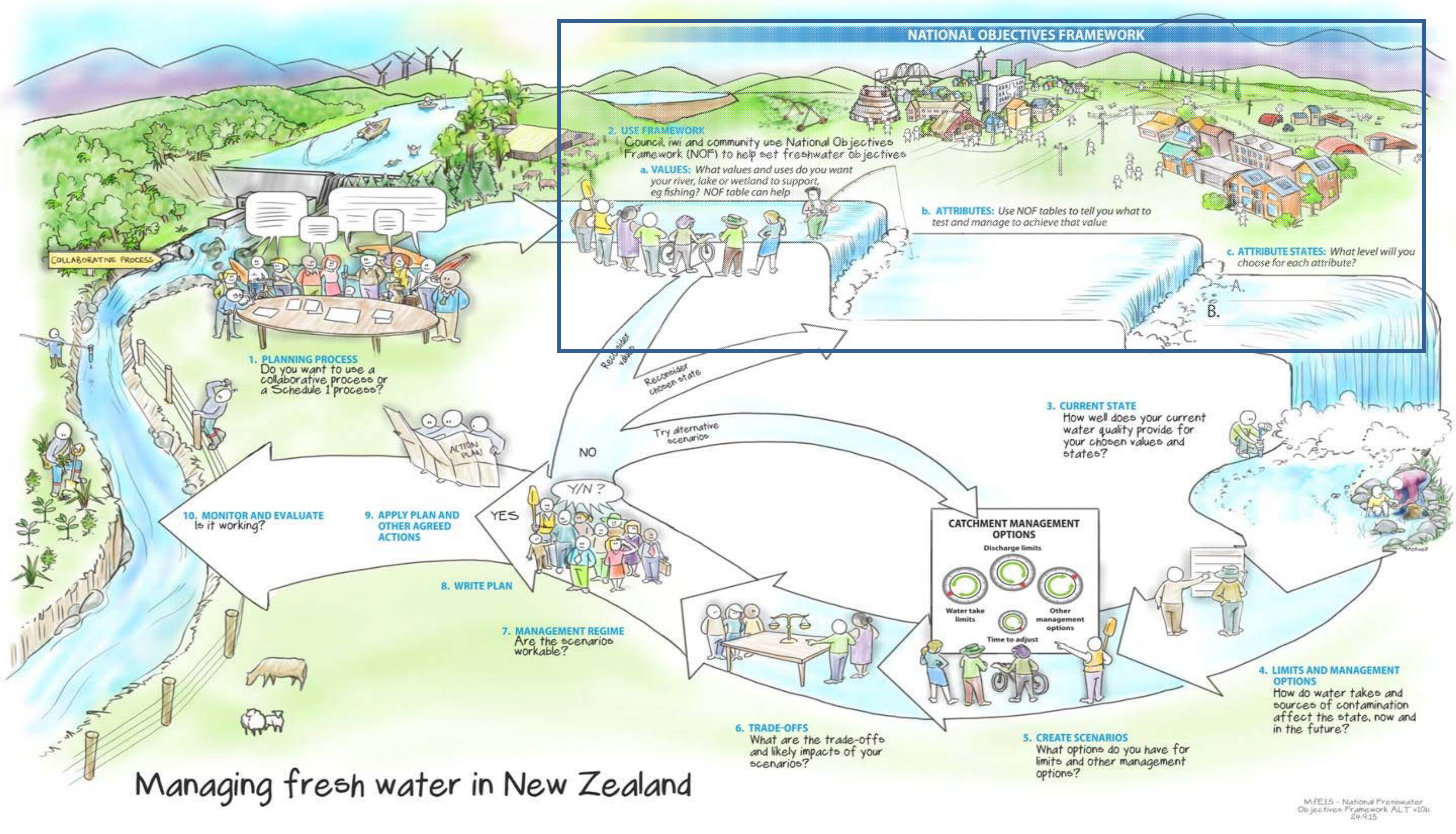
6. The March 2013 consultation document *Freshwater reform 2013 and beyond* proposed a series of reforms to support communities to make better planning decisions, set freshwater objectives and limits for their water bodies, and manage land and water use within those limits. The document detailed options for delivering the proposals including potential changes to the National Policy Statement, as illustrated in Figure 1.

7. The proposals include:

   - establishing a regulated National Objectives Framework to support regions to set freshwater objectives and limits under the National Policy Statement
   - requiring freshwater objectives and limits to be set in an integrated way, allowing for the impacts of limits and adjustment timeframes to be well understood and factored into decision-making
   - including a set of values a water body can be managed for with associated minimum states (e.g., minimum states for bacterial contamination when a river is managed for swimming)
   - requiring that all water bodies meet the minimum states for attributes to measure ecosystem health and human health for secondary contact, effectively establishing some national bottom lines.

8. The concept of a National Objectives Framework, including some national bottom lines and direction and guidance on setting freshwater objectives and limits, was a key aspect of the Land and Water Forum's recommendations.

Figure 1: Proposals for managing fresh water in New Zealand, including a National Objectives Framework with water quality bands and national bottom lines.



9. The framework will:

- specify which quality and quantity attributes of the freshwater body would need to be managed to allow for that value to be provided for
- for each attribute, provide a series of bands – for example, A, B, C or D which represent a range of environmental states. A region may choose to manage to band A, B or C (i.e., to maintain or improve) depending on the local context and on national and community aspirations. Choosing the D band would not be acceptable
- for each band, the framework will specify where possible, the minimum acceptable state. For example, band C for *E. coli* bacteria concentrations for swimming could be between 260/100mL and 550/100mL. Where it is not possible to specify numeric states nationally, the framework would direct regional councils and unitary authorities to determine these numbers at a regional level
- allow for tāngata whenua values to inform decision-making, using the Mana Atua Mana Tāngata Framework which shows the relationship between tāngata whenua values and the values identified in the preamble of the National Policy Statement for Freshwater Management
- allow regionally-decided timeframes for management.

1.3 Evidence-based analysis on impacts of proposed reforms

10. Central Government (Ministry for the Environment (MfE), Ministry of Primary Industries (MPI), Department of Conservation (DOC)) is running an ‘Economic Impact Studies’ workstream, and commissioning a series of interlinked economic and scientific studies to assess the potential impacts of scenarios for setting freshwater objectives and limits.

11. The purpose of these studies is to help inform community discussions and support policy making by regional councils on the potential economic, environmental, social and cultural impacts of freshwater management options. The studies also inform national policy development on the potential impacts of setting freshwater objectives and limits, including proposed national bottom lines, under the National Policy Statement for Freshwater Management 2011.

12. This summary report provides an overview of the component studies relevant to the Southland Region, that assess the potential economic, environmental, social and cultural costs and benefits of setting water quality objectives and limits, including proposed bottom lines for ecosystem health and human health, under the National Policy Statement for Freshwater Management. The studies evaluate the potential impacts on the agricultural, industrial and municipal sectors and on non-market values in Southland. In the studies, ecosystem health is based on the attributes of median nitrate toxicity and periphyton (slime) and human health is based on *E. coli* concentrations.

1.3.1 Southland economic impact studies – Analytical approach

1.3.1.1 Information inputs

13. Information has been collected from a range of sources, including data on regional economic performance, water consents, actual water takes, agricultural information on the impact of mitigation actions on land run-off, the costs and effectiveness of on-farm mitigation actions, point source water quality monitoring data, landowner behavioural responses, and municipal and industrial uses of water.

14. Sources include Environment Southland, the CRIs AgResearch, Landcare Research and NIWA, the Ministry of Business, Innovation and Employment, and information and datasets already compiled by scientists at Aqualinc, and economists at NZIER, Market Economics, Nimmo-Bell, Covec and Lincoln and Waikato University. Datasets provided have been rigorously checked for internal completeness and consistency by external experts in data analysis prior to use.

1.3.1.2 Total economic value

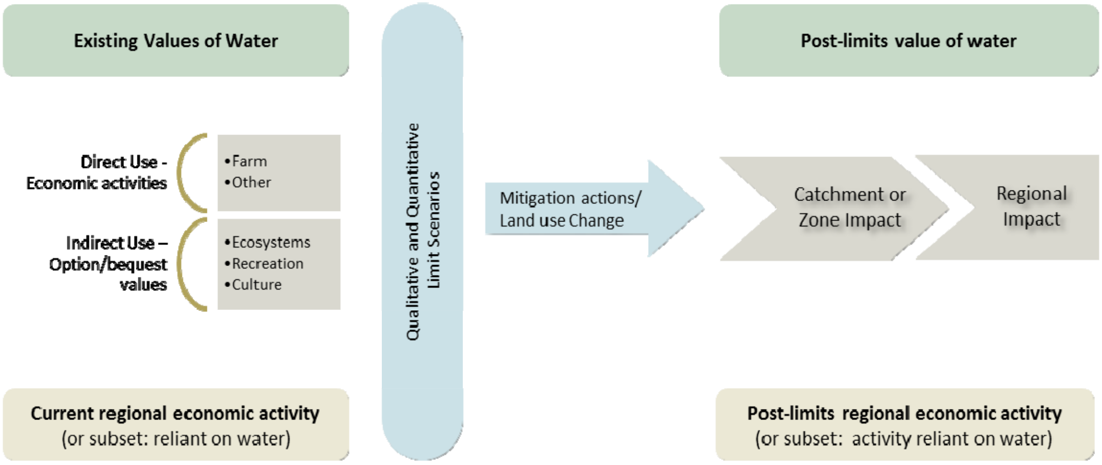
15. The studies use a total economic value (TEV) approach which takes into account all values of water, including consumptive (volumetric) water use, and non-consumptive use. Non-consumptive use includes volumetric use when water is immediately returned to a water flow, using water's assimilative capacity when discharging nutrients or effluent, and when water is not consumed but nonetheless a value is placed on water's existence and quality, e.g. for recreation or cultural activities.

16. The TEV approach was used as the overall framework for the Southland economic impact studies. TEV identifies and quantifies (where possible) the marginal impacts of setting water quality limits on economic, environmental, social and cultural values of fresh water. The TEV approach was considered broad enough to give an appropriate order of magnitude for cost and benefit estimates of scenarios for setting water quality objectives and meeting proposed national bottom lines for ecosystem and human health in the Southland region.

1.3.1.3 Assessing marginal impact of policy proposals

17. The national bottom lines for water quality proposed under the National Objectives Framework (NOF) may require changes water usage – in terms of both volumetric water quantity used and nutrient and other contaminant discharges into soil and waterways. Assessing the impact of water quality objectives and limits requires identifying the *marginal* impact of requiring water use changes across all parties that use water, discharge into water or otherwise place value on water. The analytical approach is shown in Figure 2 below.

Figure 2: Total economic value framework to assess marginal impact of a change in water policy



1.3.1.4 Component studies

18. A series of sector and subject studies have been undertaken. The regional study in Southland has involved a multi-part process involving the following consultant studies.

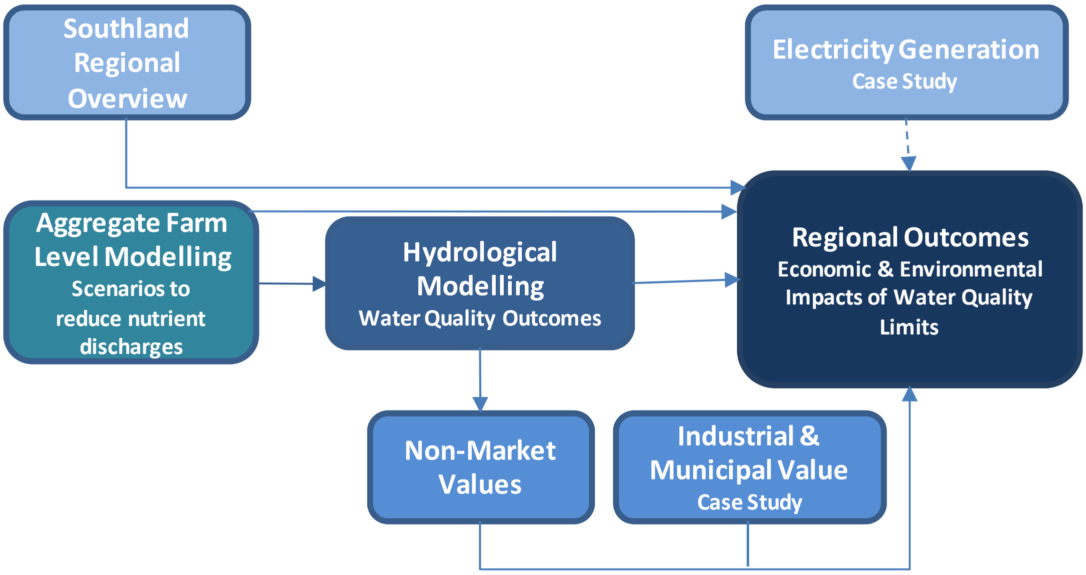
Table 1: Studies contributing to the assessment of the potential impacts of scenarios for setting water quality objectives in Southland

Summarised in this Report's Section #	Study	Description	Consultant(s)
1	**Regional overview**	An overview of the value categories of water in the region and the contribution of water to the outputs and value of each sector.	Market Economics and Nimmo-Bell
2	**Aggregate farm-level model**	Evaluates the marginal costs and benefits to agriculture of scenarios (applied via farm level mitigation tools) to limit nutrient discharges and the resultant changes in nitrate (N) and phosphorous (P) loss.	NZIER & AgResearch
3	**Hydrological modelling**	Aggregates the estimated farm level and point source nutrient discharges to downstream water quality concentrations for 73 monitored sites in Southland, to determine whether nutrient discharge limits can feasibly achieve national bottom lines.	NIWA and Aqualinc
4	**Non-market value study**	The non-market values study is a first step in assessing the marginal impact of maintaining or improving water quality on non-market values of freshwater.	Covec
5	**Industrial and municipal value**	Identifies the value of industrial and municipal use of water and the marginal impacts of improving water quality on those values.	Market Economics
6	**Electricity generation**	Evaluates the potential economic impacts on electricity generation if hypothetical *minimum flow requirements* were imposed on the upper and lower Waiau river. This study is based on *quantity* limits.	Concept Consulting

19. The final section (8) of this summary report collates the potential impacts identified in each of the economic impact studies above and the water quality outcomes predicted by the hydrological modelling to present an overall evaluation the potential economic and environmental impacts of scenarios for setting water quality objectives and meeting national bottom lines in Southland.

20. The inter-related structure of analyses carried out for Southland is shown in Figure 3 below.

Figure 3: Southland framework of studies to assess the potential impacts across direct market and non-market values



21. It is important to understand the logic of how the studies fit together. The series of marginal impact analyses were undertaken as follows:

- Twenty scenarios[9] to reduce nutrient discharges at farm level were tested, and farm-level responses and associated costs (and benefits) modelled. The 20 scenarios were divided into 7 groups (A – H) depending on the outcomes for farm contaminant loss rates.
- Hydrological modelling combined farm-level discharge, point source discharges and naturally occurring leaching to establish contaminant loads at 73 sites for 2012. Contaminant loads were also predicted forward to 2037 under the current policy regime and under each of the 20 scenarios. Nitrogen loading was also estimated for each of the nine Southland estuaries. Predicted contaminant loadings were then converted into water quality attributes identified under the proposed National Objectives Framework for each of the 73 river sites and nine estuaries for all scenarios, and compared these to the thresholds (bands) proposed for the National Objectives Framework, including the national bottom lines.
- The non-market value study took the downstream improvements in water quality achieved via one of the scenarios modelled (uniform nutrient discharge caps) tested as given, and assessed the marginal impact of improved water quality on non-market values.

[9] The scenarios include a range of nutrient discharge caps, allowing grandfathering of existing discharge rights with equally proportionate reductions, and mandating mitigation actions.

- The industrial and municipal case studies assessed the costs to industry and municipalities of achieving an improvement in discharge, or stormwater runoff, quality. It is important to note that the approach of the municipal and industrial study evaluates the impact of reduced contaminant losses and does not directly assess the impact of achieving a specific water quality objective or proposed bottom lines.
- A study into the impact of changes to water quantity restrictions on electricity generation was also carried out. However the results of this study cannot be combined with the above studies in an assessment of water quality objectives and limits. The above studies assess the impact of a change in quality standards, whilst the study on the electricity sector assesses the impact of changes in available water quantity. An assessment of the interrelationship between water quality and flow rates (quantity) was not feasible within the given timeframe.

22. The timeframe under which the studies had to be completed meant we were restricted to using existing models to undertake the series of partial impact analyses described above. Thus we have been unable to assess optimal mitigation strategies across all sectors under the scenarios modelled.

1.3.1.5 Modelling reality

23. A risk with any modelling exercise is that models are by definition a simplification of reality. All models are a predictive tool that forecast expected outcomes, rather than a tool that allows perfect foresight. These studies do not represent the 'answer' as such, and instead are a 'lego', and at times 'duplo' reflection of reality, that is nonetheless a better guide of the potential impacts of policy decisions than if not using any logical analytical mode. We have worked with sectors and undertaken peer review to ensure the analysis is as robust as practical.

24. Whilst no scientific nor economic model can perfectly replicate the reality on the ground, the outputs of the modelling work gives a clear indication as to the relevant impact categories, and magnitude of those impacts, across all water values – a critical piece of evidence in the assessment of policy proposals.

25. The results cannot be extrapolated to other regions or at a national level, due to differences in geographies, climates, types of freshwater bodies, farming practices and the assumptions made in the modelling which are unique to Southland.

Section 2: Southland regional overview

This section provides an overview of the value categories of water in the Southland region and the contribution of water to the outputs and value of key economic sectors in the region.

The economic future of the Southland region, under a business as usual demand driven scenario, is closely aligned to economic activities with high water abstraction, discharge and nutrient loadings. The analysis has considered the period 2000 to 2012, projected a business as usual scenario, and quantified the value of water through the use of ecological multipliers of the environment-economy interface.

2 Southland regional overview

2.1 Southland's economic profile

26. Southland's population is expected to decline over the next 20 years from the current level to around 88,000 by 2031. Compared to the national average of 86 per cent, the proportion of the Southland population living within urban areas is low, at 70 per cent. Twenty five per cent of Southland residents are classified as living within rural areas and 5 per cent within rural centres.

27. Agricultural sectors, with their combination of high employment, export focus and value added contributions to the region dominate the list of key sectors in Southland. The dairy sector is expected to continue to show growth as more farms undergo conversion to dairy. The primary sectors of the economy employ 23 per cent of Southland's total labour force. Livestock and cropping farming account for almost half of this, although this is decreasing because of the number of dairy farm conversions, with many workers switching jobs between farming sectors.

28. Southland has a well-established manufacturing base, although the economic recession has placed pressure on manufacturing industries. Meat and meat product manufacturing had a value added contribution of $652m, and is a key sector in Southland, although it is facing pressure from pricing trends and the conversion from livestock to dairy farming. Basic metal production and metal related machinery and equipment manufacturing, although less dominant, represents another important cluster of industrial activity. These industries, which include the NZAS Tiwai Aluminium Smelter, make up a relatively small proportion of the economy in value added terms, but have strong linkages to other economic sectors and play an important support role in the Southland economy. Tourism is also important as reflected by the water and rail transport and accommodation, restaurants and bars sectors.

2.2 Value added

29. In 2012 the Southland economy generated around NZ$4bn[10] in value added,[11] and provided over 55,000 employment positions in some in 13,600 businesses. The agricultural sectors combined contributed 17 per cent to total value added, with livestock and crop farming contributing 7 per cent ($280m) and dairy cattle farming contributing 9 per cent ($373m). The relative contributions of these two agricultural sectors will probably change in the future, given the trend of converting

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[10] All values are presented in constant 2012 NZ dollar terms.

[11] Value added is similar to GDP with the main difference being how tax is treated. Value added excludes tax on products (eg,. GST) whereas GDP includes tax on products.

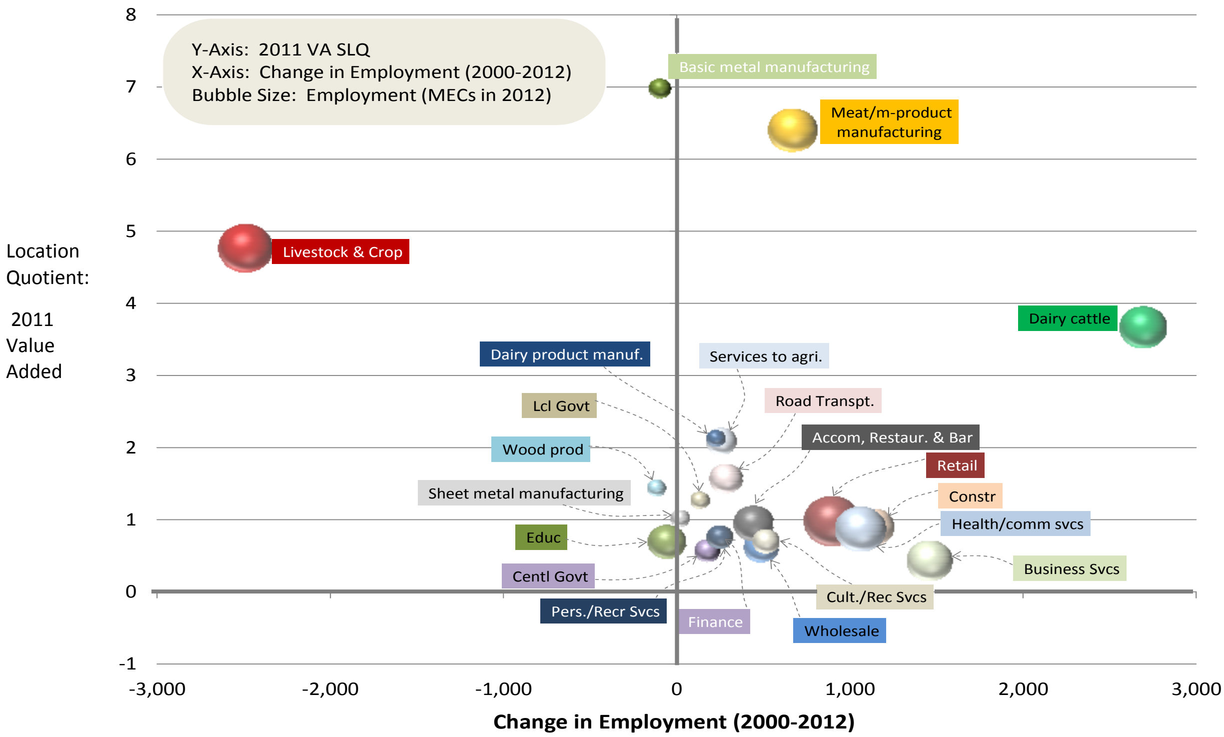
from livestock farming to dairy farming. Other primary sector activities (including fishing, forestry and mining) contributed a further $120m to Southland's value added.

30. The importance of agriculture is further evident in the flow on effects to the manufacturing sector. Meat and meat product manufacturing is the largest single economic sector in Southland, with a value added contribution of $625m (15 per cent of the region's value added). This sector is coming under pressure from the large amount of dairy farm conversions. There are also significant other manufacturing industries in Southland. Southland's manufacturing contributed around $1.4bn of value added to the region's economy.[12] Manufacturing has been under pressure due to the economic recession. Basic metal manufacturing is a key manufacturing activity. This industry has a number of downstream linkages with the rest of the Southland economy.

2.3 Key economic sectors

Figure 4 shows Southland's 20 largest sectors using the three key parameters of relative size: Simple location quotient (SLQ)[13] for value added (on the y-axis), the total change in employment between 2000 and 2012 (on the x-axis), and the total number of employees in 2012 (bubble size). Note that the sectors included in this figure account for around 90 per cent of Southland's total employment.

Figure 4: Change in Southland's employment between 2000 and 2012



31. Fourteen key sectors were identified for Southland, based on a shift-share framework that considered each sector's: economic contribution (using value added and employment); recent

[12] Note this is all manufacturing including meat processing and dairy processing.

[13] A SLQ is a measure of an industry's concentration in an area relative to a reference area (New Zealand in this instance). It compares an industry's share of local employment (or another indicator, we used Value Added) with its share of national employment. A SLQ greater than one means the industry is comparatively more important in the local region than the reference region, while a SLQ less than 1 implies that the industry's importance in the local region is relatively low.

employment performance (using change in employment MECs between 2000 and 2012); comparative advantage (using Simple Location Quotient as indicator), and contribution to regional exports.

32. The key sectors are:[14]

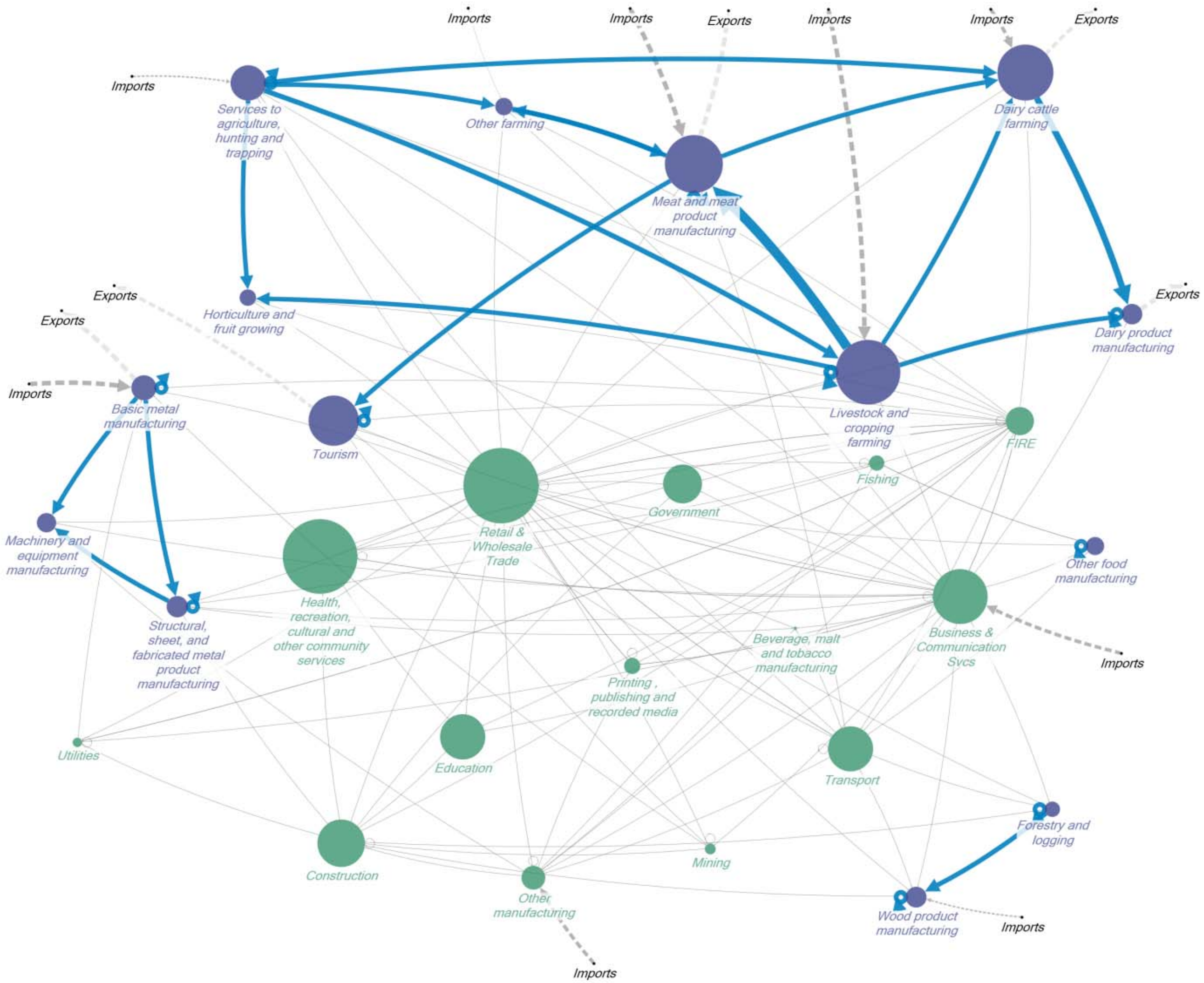
1. Dairy product manufacturing
2. Meat and meat product manufacturing
3. Other food manufacturing
4. Sheet and fabricated metal product manufacturing
5. Basic metal manufacturing
6. Livestock and cropping farming
7. Dairy cattle farming
8. Accommodation, restaurants and bars
9. Wood product manufacturing
10. Forestry and logging
11. Machinery and equipment manufacturing
12. Services to agriculture, hunting & trapping
13. Water and rail transport
14. Other farming.

2.3.1 Economic linkages

33. In an interconnected economic system, the activities occurring within one economic sector ultimately (through direct and indirect production chains) impact on all other sectors within that economy. Backward linkages are demand related, whilst forward linkages relate to sector supply. Figure 5 provides a visual representation of the backward linkages existing between Southland's identified key sectors (blue bubbles) and other sector groups in the region (green bubbles).

[14] Tourism is also an important industry in Southland. It does not exist as a stand-alone sector per se in the model. It is represented in the key sectors by water and rail transport and accommodation, restaurants and bars.

Figure 5: Southland key sectors' backward (demand) linkages

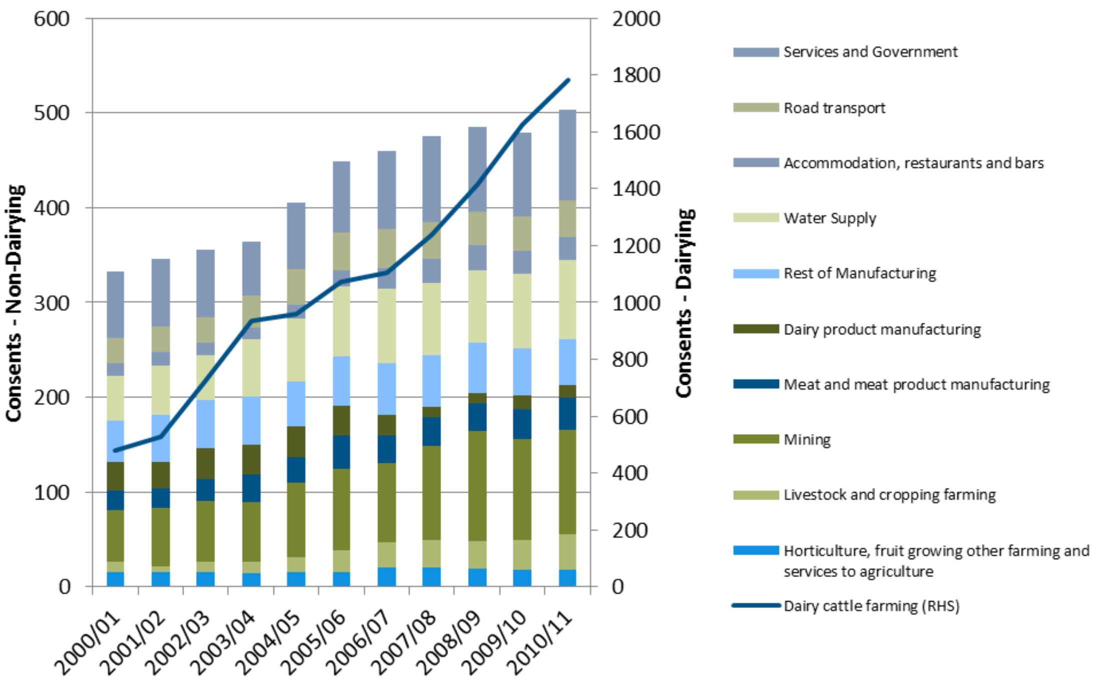


2.4 Water abstraction, discharge and nutrient loadings

Abstraction

34. Demand for the region's water resource has been increasing over the past decade.[15] Most sectors' demand for water (as expressed using the number of consents issued) increased since 2000/1. While most sectors' water demand increased, dairy farming's growth and its demand for water dominate the consenting pattern. The number of dairy farming consents dwarfs the other sectors (hence the distinctive scale for dairy farming on the right hand side of Figure 6.

Figure 6: Consents per broad economic sector (All consents; Dairying on RHS)



Source: Environment Southland Consent Database

35. Dairying accounted for over three quarters of consents in 2010/11 up from around 60 per cent of consents in 2001/2. This shows the increase in demand for Southland's water from dairy farming. Manufacturing accounts for between 4 – 5 per cent of water consents. Manufacturing, including meat and meat product manufacturing, dairy product manufacturing and basic metals has a slightly larger share of discharge consents than abstraction consents.

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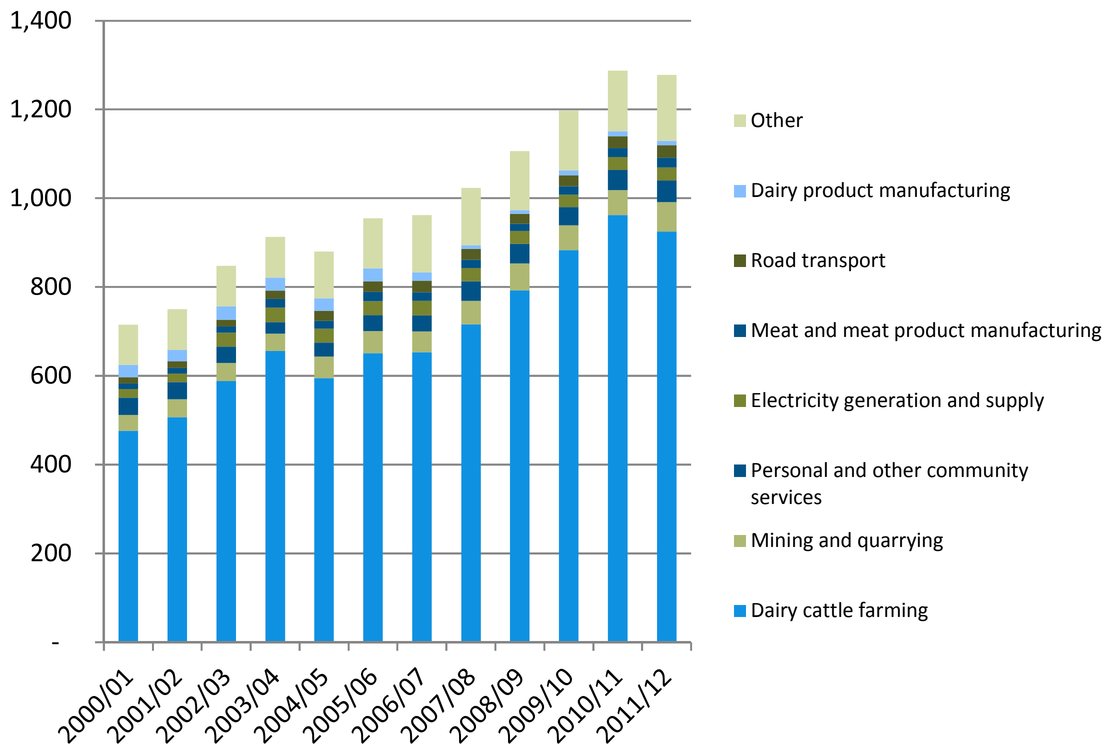
[15] Environment Southland manages the region's water resource using the provisions of the Resource Management Act 1991 (RMA). Water can be taken from surface or from groundwater. A consent is required for both, if the amount taken is over a daily limit (Environment Southland, 2013). Environment Southland's consent database, covering almost 12,000 consents, was reviewed and over 6,000 water related consents were selected/extracted for this study. The final list contained over 3,500 individual consents covering both water takes (abstractions) and water discharges. This list included the period from April 2000 to March 2012.

Discharge

36. Water discharges are dominated by dairy farming, with non-dairy discharges characterised by a few consents with very large volumetric flows. In particular, meat processing and dairy processing are responsible for an increasing share of regional discharge. Importantly, dairy cattle farming discharges are growing through time. Mining and quarrying discharges are another key discharger, but this includes mine de-watering.

Figure 7: Discharge consents per sector



2.5 Economic and ecological multipliers

37. Ecological multipliers demonstrate the extent to which production and consumption of economic goods and services depends on the provision of different types of ecological goods and services, both directly and indirectly. Essentially the multipliers measure all of the downstream or upstream ecological impacts that are 'embodied' in the production of a particular economic good or service.

38. The goods produced by the manufacturing sectors responsible for immediate processing of raw primary products (particularly meat and meat product manufacturing and dairy product manufacturing) embody the greatest demands on water resources. This is because these industries are both significant direct users of water, and major purchasers of primary goods that are also produced with significant water inputs. All economic sectors within the Southland economy depend on the provision of water and water-related services – even those for which no consented abstraction, discharge and residual production data is available. While service industries generally require relatively little direct water resources, some of these industries (particularly real estate services, construction, wholesale trade and retail trade and accommodation, restaurants and bars) appropriate relatively substantial water resources. This occurs through their production chains.

39. Through the supply of raw and manufactured dairy products, it is likely that Southland is a significant exporter of embodied water-related ecological services, both to the rest of the New Zealand and other nations.

2.6 Limitations

40. This research provides some insight into the scale of the issues that Southland region may face in water terms by looking at the economy-environment interface using abstraction, discharge and nutrient loadings. To expand and complete this picture it would be necessary to consider the dynamic feedbacks which exist between the economy and environment. These feedbacks are characterised by non-linearities, lags and complex cause-effect relationships which may produce emergent behaviour not captured in business as usual trends.

41. The study relied heavily on Environment Southland's resource consent and monitoring datasets.

42. This study used an Input-Output (IO) model to show the economic linkages within and between sectors in Southland, the rest of the South Island and the rest of New Zealand. IO models have a number of assumptions, and in the context of this study the main assumptions are:

    - the results are based on approximations of Southlands economic/sectoral input-output results and it is assumed that these relationships are constant
    - the economic structure and relationships are based on the 2006/7 Supply-Use tables. This is the best available data but it is getting dated
    - the IO model does not account for price changes that may result from increased competition for scarce resource
    - it was assumed that all firms within a sector have common production processes
    - in the context of this study we assumed that the all resources needed to operate are available i.e., the model is demand driven and not constrained.

Section 3: Agriculture: aggregate farm-level modelling

This section presents the aggregate farm-level analysis that tested a range of potential scenarios, applied via on-farm mitigation actions, to reduce the contribution of nitrogen, phosphorus and microbiological contaminants (*E. coli*) to freshwater.

Farm-level responses and associated costs (and benefits) were modeled. The 20 scenarios were divided into 7 groups (A – G) depending on the outcomes for farm contaminant loss rates.

Under the modelling carried out in these studies, it has been found that maintained or improved overall water quality in rivers may be achievable in Southland, with some scenarios allowing for dairy growth. The modelling indicates that dairy growth and gains in aggregate gross margin could be achieved with non-uniform caps and mandated mitigation while meeting bottom lines for ecosystem health and human health and maintaining or improving overall water quality.

The most cost effective scenarios in terms of nitrogen mitigation are the non-uniform caps. However, while aggregate gross margin is maintained in both non-uniform cap scenarios, the reduction in production entailed in scenario 18 would have downstream economic impacts on the processing industries in Southland. These wider impacts are not considered in the study. Furthermore, there is a cost to meet E. coli bottom lines, which is hidden in the overall benefit of mitigation bundles.

3 Agriculture: aggregate farm-level modelling

43. NZIER and AgResearch investigated the economic and environmental impacts of a range of scenarios, implemented on-farm via nutrient caps and mandated farm practices, in the Southland region.

44. The main tool for the farm-level analysis is the Rural Futures MAS model. It is a multiagent simulation (MAS) model that has been developed over the last five years in the Rural Futures programme led by AgResearch to model multiple pressures on farming systems. It models the behaviour of representative farmers on a landscape defined using data from actual regions, such as Southland. These farmer-agents are subjected to drivers and changes like drought, price fluctuations, and new policies, and their reactions produce outputs from the model.

45. A tailored Multi-Agent Simulation (MAS) model was used to evaluate explicitly how individual farmers respond to per hectare maximum nutrient discharge levels and mandated mitigation activities. The model includes:

- biophysical – pasture productivity and nutrient discharges that vary by soil and land characteristics
- behavioural – farmer decision making that accounts for differences across age groups and other factors, so that farmers can be expanding, maintaining, or contracting their farms
- economic – financial results that are based on biophysical potential and the decisions by farmers.

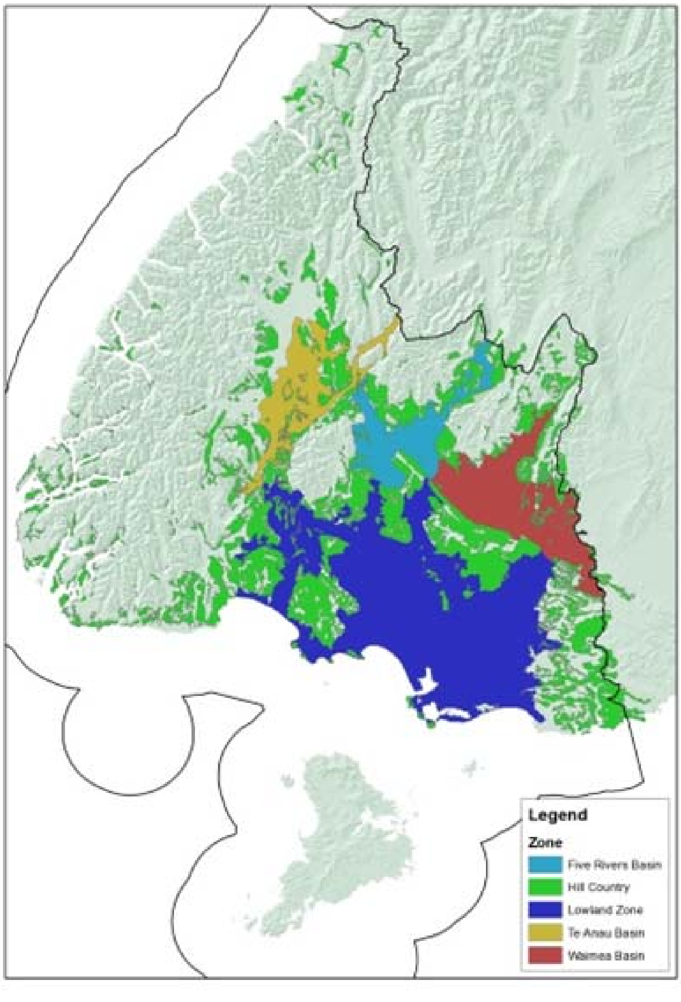
3.1 Method

46. The farm-level modelling covers most farms (over 3,000) in the three catchment zones (lowlands, inland basin and hill country) of Southland.

47. NZIER examined the impact of strict limits or caps on the level of nutrient discharges from individual farms. Because of the state of scientific knowledge and the analytical tools available, the model scenarios were specified in terms of N and P discharges from the farm. Each combination of N and P caps formed a different scenario. They were used as inputs for the MAS model; the model was run with each scenario.

48. The levels of N and P caps were driven by a desire to have a wide range of final impacts, to get a sense for the full scope of possible economic and environmental outcomes. The higher limits were expected to have little effect on farming, but would allow the modelling to produce results that could be analysed for their impacts on water quality indicators. The stricter limits, on the other hand, might be required in order to reach specific water quality targets. It was therefore important to model their potential economic impacts.

Figure 8: Southland's water management zones



Source: AgResearch

49. The caps are applied within each of three water management zones, shown in Figure 8:
    - Lowland
    - Basin – Five Rivers Basin, Te Anau Basin, Waimea Basin
    - Hill.

50. The MAS model assessed each zone separately, so caps could be applied either across all of Southland or by zone. The caps are applied only to pastoral farms and managed forestry blocks in the water management zones, so were not applied to any other parcels of land in the zones, such as national parks or arable farms. The final land dataset includes over 1 million hectares.

51. A baseline out to 2037 was modelled, using scenarios that are combinations of limits on nitrate leaching and phosphorus loss, or mandated mitigation activities, applied across the agriculture sector. These scenarios were modelled to investigate a range of possible water quality outcomes that will inform to national and regional policy development on setting freshwater objectives and limits. The study results compare costs to the agriculture sector, and nutrient discharge outcomes in Southland in 2037 with and without additional mitigation.

52. It is important to note that the impact of adjustment timeframes has generally not been considered in all the studies focused on Southland. Farmers are assumed to be immediately compliant with mitigation requirements. This simplification nonetheless allows valid comparison of the various mitigation policy tool options. The farm level modellers assume that with a delayed compliance requirement, farm-level compliance will not occur sooner than required. Thus the impacts would remain similar in the year of implementation and be delayed until compliance is required. Although delaying action would need to be balanced against the risk associated with delaying environmental outcomes, spreading the costs of adjustment across time would reduce the costs of a policy when these costs are discounted back to a net present value. Furthermore, where the mitigation practices involve capital costs, longer adjustment times allow these costs to be absorbed with less impact on year-to-year profitability – profitability which can be precarious for some in the region.

3.1.1 Nutrient discharge mitigation scenarios

53. Scenarios were specified in terms of maximum N and P discharges by hectare, and used as inputs for the MAS model. Outcomes are grouped for those mitigation scenarios with similar farm-level responses and so cost impacts. The modelling examined the scenarios set out in Table 2.

54. Scenarios modelled include:
    - 'uniform caps', and 'non-uniform caps'[16] on nutrient leaching per hectare across all parties
    - 'grandparenting' (in this case with ratcheting down), so an equally proportionate reduction in discharge across all parties; and

[16] It is worth noting that a practical application of a 'non-uniform caps' mitigation scenario is the Horizon regional council's OnePlan model, which proposed varying allowable nutrient discharge levels by soil type. This is one of many potential uniform cap scenarios, and does not explicitly state the objective of ensuring marginal mitigation costs are equalized across all participants. Equalising marginal costs implies more mitigation for those parties for whom it costs less to do so.

- ‘mandated actions’ whereby actions to reduce nutrient leaching are mandated by farm type.

55. Finally, all 20 scenarios were re-analysed to estimate the impacts of allowing inclusion of using DCD-based mitigation practices.

56. For the modelling, the N and P caps are enforced in 2013 and remain in place. The choice of 2013 is arbitrary, and was chosen to allow the policies to have full effect. The model runs from 2012 until 2037 and assumes the nutrient caps are actively enforced across all farms, not just those farms converting to dairying. The model assumes all farms are compliant with the nutrient discharge caps.

Table 2: Scenarios tested, applied via on-farm mitigation bundles

Mitigation Scenario	Scenario numbers in NZIER's analysis	Description	Responses allowed
Uniform caps	1 - 16	Same nutrient discharge cap across all dairy, sheep & beef	*Farms chose the most cost effective mitigation bundles to meet cap*
Non-uniform caps	17 & 18	Nutrient discharge cap varies by farm type and also by characteristic eg, soil type	
Grand parenting with ratcheting down	19	Equally proportionate reductions in discharge mandated across all farms	
Mandated actions	20	Certain mitigation bundles mandated for farm types - focuses on farm practices rather than nutrient limits.	*Farms mitigate as directed*

3.1.2 Farm-level responses meet mitigation scenarios

57. Farm-level responses to the scenarios tested covered a choice of three mitigation bundles (low, medium and high bundles), as shown in

Table 3. Farm profitability and productivity improvements resulting from mitigation activities are also considered. The mitigation bundles are cumulative, so that M3 includes both M1 and M2.

Table 3: Mitigation bundles analysed[17]

Bundle	Bundle "name"	Activities	Description
M1 **Low**	Good management practices	Stock exclusion Improved nutrient management Improved farm dairy effluent management.	Minor improvements in efficiency
M2 **Medium**	M1 + stocking rates	Improved animal productivity ('less cows and fatter cows')	Major productivity improvements
M3 **High**	M1 + M2 + capital expenditure	Grazing strategies, e.g. feed pad Grass buffer strips	Capital investments that deliver mitigation at a cost

Source: NZIER, 2013

** Explanatory Note: Mitigation bundles are cumulative, i.e. M2 includes M1, and M3 includes both M2 and M1.*

3.2 Key findings

3.2.1 The to-2037 baseline includes increased dairying

58. Results are aggregated across all Southland dairy farms, and those that face hypothetical gains or losses within the aggregate have not been identified.

➢ *Baseline projections indicate growth in total agricultural production and in dairying for 25 years to 2037, without additional action to reduce nutrient losses.*

59. Without action to reduce nutrient losses, the total value of agricultural production is forecast to increase across Southland in real terms to $4.6 billion per annum by 2037. Dairying could increase by 127,000 hectares over the period. Sheep and beef farming is expected to decrease.

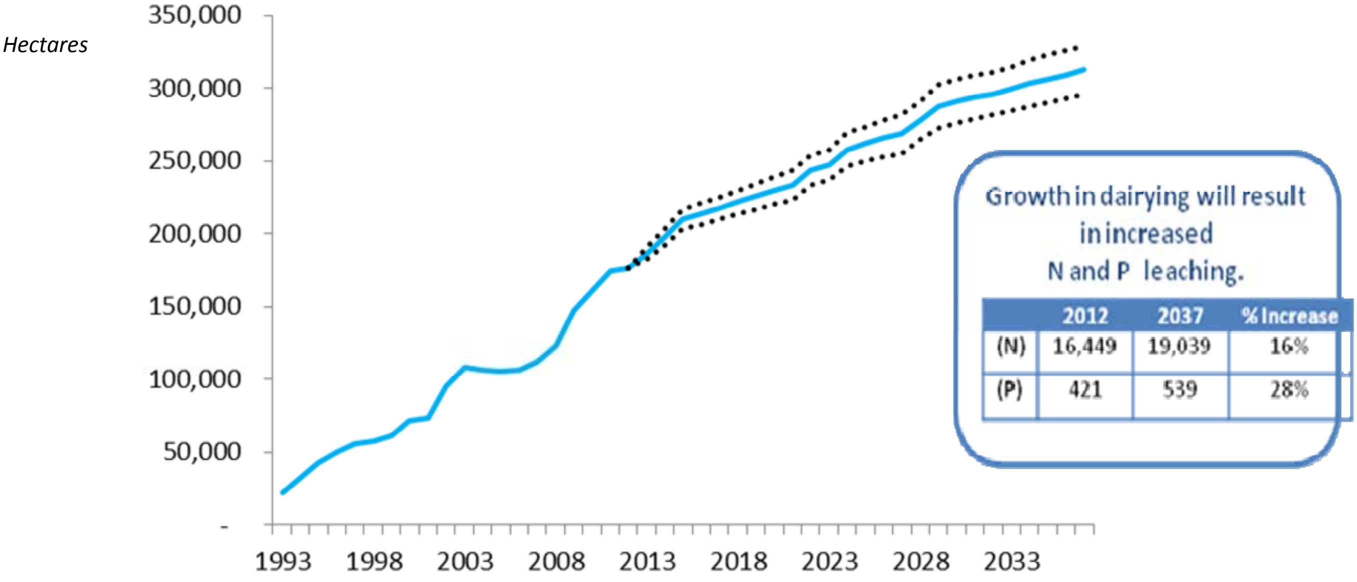
➢ *Baseline projections indicate that unconstrained growth in dairying will result in increased N and P nutrient loss.*

60. N and P nutrient loss is projected to increase by 16 per cent and 28 per cent respectively under the baseline scenario which assumes unconstrained dairy growth and no change to mitigation activities.

[17] For more detailed information on the mitigation bundles, see Appendix A.3 in NZIER report – 'Potential impacts of water-related policies in Southland'.

Figure 9 illustrates the projected growth of Southland's dairy sector, if unconstrained by changes to water policy.

Figure 9: Projected dairy sector growth in Southland, without action to reduce nutrient loss



Source: NZIER, Environment Southland (ES)

Explanatory note: Dotted lines = 1 standard deviation

Understanding the farm-level analysis findings

2012 vs 2037 dollars

The farm-level modelling works in nominal figures. However, a dollar in 2037 is not equivalent to a dollar in 2012. When discussing future dollars, it is necessary to distinguish two concepts: deflating and discounting. **Deflating** is a calculation that removes the effect of inflation. **Discounting** is a calculation that accounts for time preferences (having money now rather than later) and opportunity cost (what you could do with the money in the meanwhile).

Findings are reported in 2012 dollars, calculated by dividing 2037 results by 1.64, or 1.02. This factor accounts for 2 per cent inflation over 25 years. The 2 per cent figure is the mid-range of the Reserve Bank of New Zealand's inflation target band.

Key metrics used to compare farm level discharge mitigation scenario set outcomes in 2037 with baseline

1. The results presented are 'comparative static': they compare the baseline outcomes in 2037, 25 years from the assumed implementation, with the outcomes in 2037 under each of the scenarios. The difference is the impact of the scenario in 2037.
2. The following key metrics are reported:
   - gross margin – this is total revenue minus total costs, excluding any depreciation, income taxes or family drawings. Gross margin is analogous to the economic measure of value-add, which is the impact of a farm on Gross Domestic Product
   - total gross margin – this is the sum of the gross margins of all the farms in the area being considered
   - value of agricultural production – this is the value of the farms' agricultural production. Value of production is important because it includes payments to suppliers, so it gives an indication of potential impacts beyond the farm gate
   - total value of agricultural production – this is the sum of the agricultural production of all the farms in the area being considered
   - N and P loss to water – this is the sum of all the N and P discharges from all the farms (dairy, sheep and beef, forestry) in the area being considered. This does not include leaching from areas outside the farm hectares such as natural scrub
   - cost-effectiveness – this is the total cost of the scenario divided by the kilograms of N mitigated. The higher the dollars per kilogram of N mitigated, the less cost-effective the scenario is. The cost-effectiveness of P is not reported, because P did not tend to be the limiting factor in most scenarios.

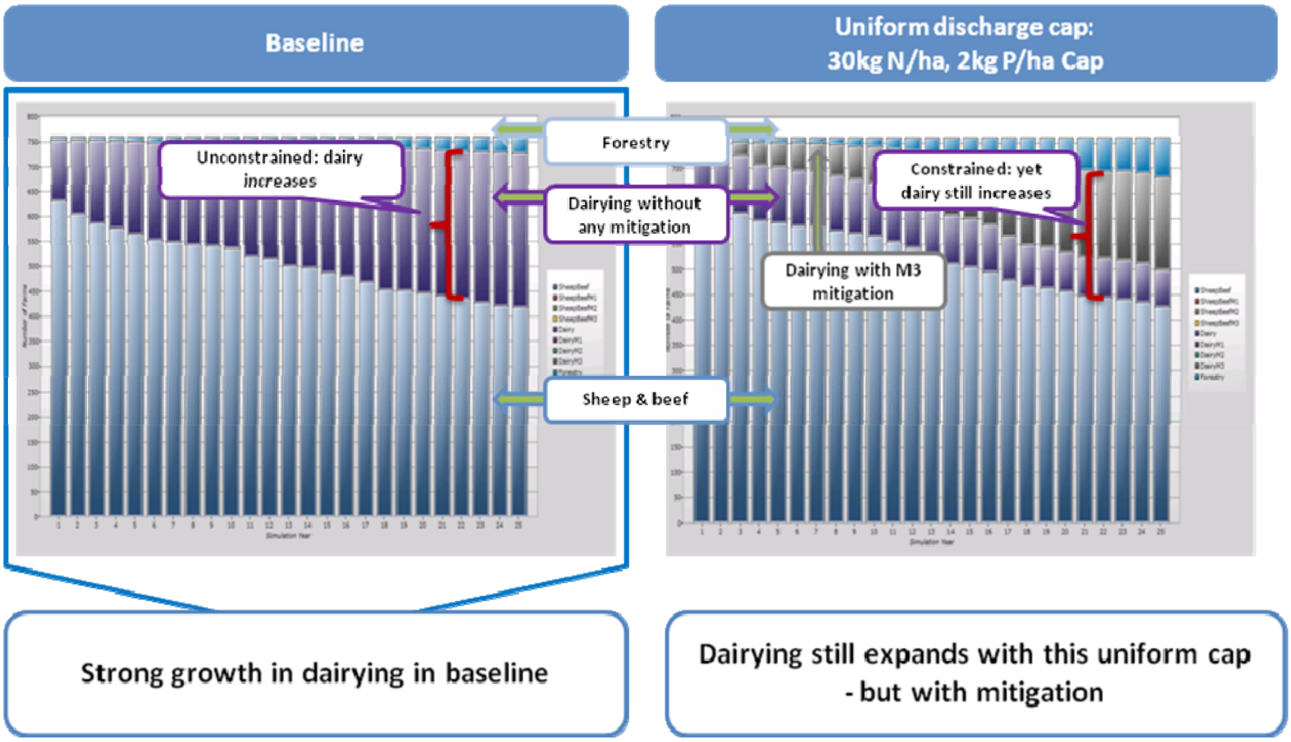
Effective Farm Surplus, farmer drawings, or Farm Surplus for Reinvestment are not calculated. These metrics account for additional items, such as taxes and living costs. Calculating these amounts properly would require additional modelling assumptions about the business and tax structure of Southland farms.

In addition, including taxes or consumption/drawings is inappropriate from an economic perspective: earnings from productive activity (value-add) are expected to fund taxes and consumption.

3.2.2 Environmental and economic impacts of uniform nutrient discharge caps

61. Figure 10 shows an example of possible outcomes when testing a uniform discharge cap of 30kg N/ha, 2kg P/ha across all dairy sheep and beef farms in Southland's Basin zone. This figure does not demonstrate the actual results of the modelling but has been included for illustrative purposes to demonstrate the level of detail feasible within the analysis.

Figure 10: Impact of a uniform discharge cap in the Basin zone



62. Aggregate farm-level responses to discharge caps are shown in Table 4 below:

Table 4: Aggregate farm-level responses to uniform discharge caps across whole of Southland

Bundle	Change in dairy hectares vs. baseline 2037	Dairy practices	Description
A	0	No change	No change in land use
B	0	64% of dairy farmland uses M2	No change in land use
C	-84,000 (-28%)	All farms adopt M2	Some land-use change
D	-84,000 (-28%)	All farms adopt M3	Some land-use change
E	-303,000 (-100%)	Dairying unable to comply with discharge caps	Largest land-use change

- *As uniform nutrient discharge caps become more stringent, costs arise due to mitigation activities and forgone dairy conversions.*

63. Nutrient caps applied uniformly across farms have a very minor direct impact on sheep and beef and forestry land-uses, as these activities have N and P loss rates per hectare that are mostly below even the most stringent of the nutrient caps. Therefore only dairying would be impacted under uniform caps.

- *Expansion of dairying would occur with most uniform nutrient caps, albeit at a slower rate and with a negative impact on aggregate gross margins but a positive impact on productivity.*

64. Expansion of dairying occurs under all but the tightest discharge caps; however cost effectiveness varies across nutrient caps and mitigation bundles chosen. As nutrient caps become more stringent dairy farmers are likely to choose more effective mitigation actions, some of which can be both more effective in reducing nutrient losses and more cost effective, thus improving productivity and profits. Table 5 provides explanations of the impacts of each set of nutrient discharge cap scenarios.

3.2.3 Non-uniform caps, grandfathering and mandated mitigation practices – findings

- *Policy tools that would require mitigation to occur on farms where mitigation is less costly, or more effective, are likely to achieve reductions in nutrient loss and have a lower cost impact on the dairy sector compared to uniformly applied nutrient discharge caps.*

3.2.3.1 Non-uniform caps

65. Uniformly applied nutrient caps are a blunt and expensive farm-level policy tool. They affect only a subset of total farms – farms with discharges above the cap. Other tools, such as non-uniform caps based on soil type, could achieve similar mitigation results at an aggregate marginal benefit to farmers. Non-uniform caps can help to broaden the scope (the number of farms affected) of any cap by making the cap specific to the farm. Farms in Southland have different N leaching rates, as shown in Figure 11. N leaching varies by industry (dairy, sheep and beef, forestry) as well as by farming intensity, adoption of mitigation practices and status of soil drainage. So for example, a cap could be defined according to a farm's current practice, the soil class or drainage.

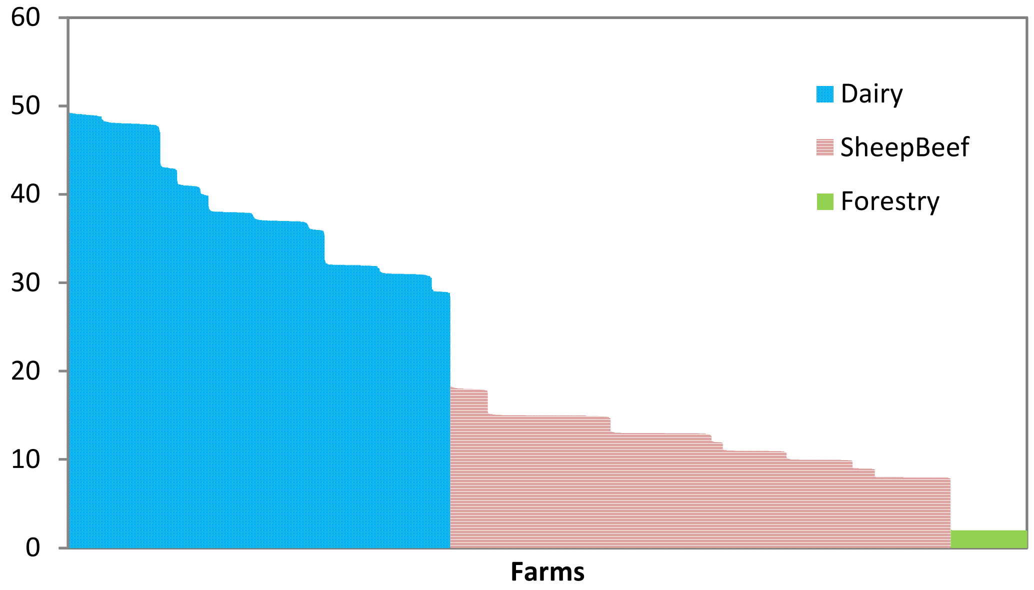
66. Compared to the uniform cap scenarios 5-7, the non-uniform cap scenario 17 mitigates 400 tonnes more of N and reduces P loss by 50 tonnes, while at the same time increasing total regional gross margin by $180m, which is $60m more than the gross margin impact of scenarios 5 – 7.

67. Compared to the uniform cap scenarios 9-12, the non-uniform cap scenario 18 mitigates 2,400 tonnes less of N and increases P loss by 35 tonnes. However, scenario 18 costs much less than scenarios 9 – 12 in lost production ($60m versus $1,200m), and actually improves gross margins by $30m, whereas the uniform cap scenarios cost $850m. Thus, while scenario 18 mitigates less in total terms than scenarios 9 – 12, it is much more cost effective.

68. These modelling scenarios provide two findings about non-uniform nutrient caps:

- non-uniform caps have the potential to be more cost-effective than uniform caps because they tailor the discharge cap to the potential of the farm for mitigation. In some situations, non-uniform caps can achieve significant reductions in nutrient discharges for no economic cost
- non-uniform caps encourage the use of lower-cost options, but across a wider range of farms. As a result, non-uniform caps help lower the overall cost of meeting a given total N or P load.

Figure 11: Distribution of N leaching by farm type (kg N/ha; 2037 baseline)



Source: NZIER

69. Similarly, negotiating transfer of a portion of a discharge cap to a neighbour for whom it costs less to mitigate could deliver similar overall mitigation at a greatly reduced cost to farmers. The theoretical point here is important: a given overall level of mitigation can be achieved at *least* aggregate mitigation cost if marginal mitigation costs are equalised across all participants.

3.2.3.2 Grandparenting

70. Grandparenting refers to a type of policy that bases limits on current practice. This is distinct from uniform caps, which apply a blanket limit across the region. It is also distinct from non-uniform caps, which apply limits based on the farm physical characteristics such as LUC and soil drainage, but apply to all farms regardless of past activities.

71. Scenario 19 modelled 'grandparenting with ratcheting down'. This sets N and P discharge limits for all dairy farms that are 25 per cent below current practice. This can be achieved by adoption of mitigation bundle M3 (which mitigates 25-42 per cent of N and 45 – 51 per cent of P).

72. Results suggest that this scenario, i.e., equally proportionate discharge reduction across all farm types, is less cost-effective than most mitigation scenarios. Widespread adoption of mitigation

actions by both dairy and sheep and beef farms is more cost-effective than most mitigation tools while achieving a comparatively high level of mitigation.[18]

73. The modelling on the impacts of grandparenting suggests the following:

- grandparenting that limits conversion to dairying imposes large opportunity costs. These are higher than the economic costs of all uniform nutrient caps except set E
- grandparenting that limits conversion to dairying is less cost-effective than model scenarios that improve farm practices without limiting land-use change.

3.2.3.3 Mandated mitigation practices

74. NZIER estimate the potential gains from mandating or encouraging mitigation practices across both the dairy and the sheep and beef sector. Dairy farming is currently estimated at 17 per cent of land use and is projected to grow to 28 per cent. Most of the rest of the agricultural land is in sheep and beef. NZIER compare the outcome of widespread adoption of mitigation practices to the uniform cap scenarios modelled previously. The specific design mechanisms or transaction costs are not considered, thus the estimates can be thought of as the total potential impact from some system that encourages widespread mitigation, with the costs yet to be deducted.

75. One way to estimate the potential impacts is to calculate the costs and mitigation that would be possible if all farms adopted mitigation bundle M3, which NZIER modelled in scenario 20. The cost of mitigating using these bundles is relatively similar between sheep and beef and dairy.

76. NZIER calculate that if all dairy and sheep and beef farms were to use mitigation bundle M3, 6,300 tonnes of N leaching (a third of total 2037 baseline) could be mitigated at a cost of $190 million in total gross margins. This equates to a cost of $30/kg N mitigated – or about one-fifth the cost of group D tools which deliver 4,900 tonnes of N mitigation at a cost of $170/kg N mitigated. Because of the widespread use of mitigation, the average reduction in *E. coli* per hectare is 57 per cent.

77. This approach is cost effective because it utilises the lowest cost options for mitigation. Under the uniform caps, sheep and beef farms do not mitigate N leaching. These farms already have low levels of N leaching relative to dairy farms, and nearly all sheep and beef farming activities were compliant under even the strictest cap of 15kg N/ha that was considered. However, it is predicted that sheep and beef farms make up 65 per cent of land use in 2037 and to contribute 39 per cent of N leaching. Mitigation options on sheep and beef farms can mitigate over a third of their N leaching. Scenario 20 makes use of the mitigation potential on sheep and beef farms to reduce or eliminate the amount of mitigation required through land-use change.

3.2.4 Overview of aggregate farm-level findings

78. Table 5 below presents the projected impacts of the scenarios tested aggregated across Southland farms, and clustered into groups of scenario sets that achieve similar impacts. The impact of each set of scenarios is compared to the baseline (no additional nutrient mitigation) in 2037.

[18] Whether widespread adoption would be achieved via voluntary means (eg. educational programme) or regulatory means (eg, mandating across all farms) was beyond the scope of this study.

Table 5: Environmental and economic impacts of scenarios tested 2037 vs. baseline 2037, Southland dairy sector

							Environmental		Economic		
							N losses (tonnes)	P losses (tonnes)	Aggregated farmer gross margin (2012 $m)		Dairy hectares
Baseline 2012							16,449	421	940		176,000
Baseline 2037 (no mitigation)							**19,039**	**539**	**2,700**		**303,000**
Description	Scenario Set	Nutrient cap scenarios (kg /ha) #	N	P	Dairy practices	Comment	N mitigation (tonnes)	P mitigation (tonnes)	Impact on aggregated farmer gross margin (2012 $m)	Cost effectiveness of mitigation ($gross margin/kg N mitigated	Change in dairy hectares
Marginal impacts of Farm Level Mitigation Actions to meet Nutrient Discharge Limits 2037 vs. Baseline 2037											
Uniform Nutrient Discharge Caps	A	1	60	2	No change	No foregone dairy conversions or dairy practices	0	0	0	0	0
		2	60	1.5							
	B	3	60	1	64% of farms adopt M2	No foregone dairy conversions; some change in dairy practices	1,000 (-5%)	125 (-23%)	+120 (+5%)	120	0
		5	45	2							
		6	45	1.5							
		7	45	1							
	C	4	60	0.5	All farms adopt M2	Foregone dairy conversions; change in dairy practices to medium mitigation bundle	3,500 (-19%)	215 (-40%)	-670 (-24%)	-190	-84,000 (-28%)
		8	45	0.5							
	D	9	30	2	All farms adopt M3	Foregone dairy conversions; change in dairy practices to high mitigation bundle	4,900 (-25%)	215 (-40%)	-850 (-31%)	-170	-84,000 (-28%)
		10	30	1.5							
		11	30	1							
		12	30	0.5							
	E	13	15	2	No dairy farms	Dairying no longer viable under tightest caps	8,500 (-45%)	315 (-59%)	-2,200 (-82%)	-260	-303,000 (-100%)
		14	15	0.5							
		15	15	1							
		16	15	0.5							
Non-Uniform Caps	F	17	45/ 38	0.6/1. 2	All farms adopt M2	No foregone dairy conversions; complete change in practices	1,400 (-7%)	175 (-33%)	+180 (+6%)	130	0
		18	37/ 30	0.6/1. 2	M2 and M3 adopted	No foregone dairy conversions; complete change in practices	2,500 (-13%)	180 (-33%)	+30 (+1%)	10	0
Grandparenting	G	19	-25%	-25%	All currently existing farms adopt M3	Foregone dairy conversions: dairy does not expand beyond 2012 area. Complete change in dairy practices	4,700 (-25%)	-225 (-41%)	-980 (-36%)	-210	-135,000 (-45%)
Mandated Mitigation	H	20	N/A	N/A	All farms adopt mitigation bundle M3	No foregone dairy conversions; complete change in practices. Scenario also includes complete change to sheep and beef practices.	6,300 (-33%)	254 (-47%)	-190 (-7%)	-30	0

Key Findings

1. **Total value of agricultural production is forecast to increase by 2037** in real terms to $4.6 billion per year, without action to reduce nutrient discharges .

2. **Concurrent N and P nutrient loss would increase by 16% and 28% respectively.**

3. **Dairying will continue to grow under all but the tightest uniform nutrient discharge cap.**

4. **Least stringent uniform caps** (set B) deliver the lowest N Mitigation (-5%) but can improve farm gross margin by $120/kg N with mitigation bundle 2 (M2).

5. **Although nutrient caps become more stringent between scenarios sets C and D,** farmers would choose more effective mitigation actions under D which are both more effective for nutrient losses and costs and improve productivity and profits.

6. **Non-uniform caps** (set F) could achieve similar mitigation results as uniform caps at a benefit to aggregate farmer gross margin.

7. **Grandparenting with racheting down** (set G), i.e. equally proportionate discharge reduction by all, is less cost-effective than most mitigation tools.

8. **Promoting widespread adoption of mitigation** (set H), primarily by fencing off both sheep and beef farms and dairy farms, is more cost-effective than most tools while achieving a comparatively high level of mitigation.

Source: NZIER, 2013

Explanatory Notes: *(-24%) implies a 24% lower aggregate gross margin than the baseline 'no caps' scenario, meaning the dairy sector would still expand, albeit at a slower rate than with no caps.

3.3 Impact of including DCD mitigation options

79. DCD is a chemical nitrification inhibitor. It is a possible option for mitigating N discharges, and it was not included in initial farm-level modelling because of potential trade concerns that arose in 2012. The results presented above do not include the use of DCD as a mitigation option. This section provides an overview of NZIER's findings when including DCD in mitigation bundles.

80. The modelling of DCD using Farmax and Overseer shows that:

- DCD adds between 2.6 and 7.2 kg N/ha of mitigation to the M2 and M3 bundles
- DCD adds more mitigation to well-drained soils than to poorly-drained soils
- DCD adds costs of between $144/ha and $196/ha.

81. In summary, DCD is a cost-effective mitigation option that can lower the cost of meeting a given environmental objective. The specific implications for each scenario depend on where the caps fall relative to the leaching rates with and without DCD.

3.3.1 Uniform caps

82. In scenarios 1 and 2 there is no change to farming practices, with or without DCD, as the caps are not binding.

83. In scenarios 3 to 8, there is widespread adoption of mitigation bundle M2. Overall, the inclusion of DCD delivers around 5 per cent reduction in N leaching because M2 with DCD delivers much higher levels of mitigation relative to M2 without DCD. However this comes at a cost to gross margins which are 3 to 4 per cent lower due to the higher costs of DCD.

84. In scenarios 9 to 11 without DCD, some dairy farms would be non-compliant at a cap 30kg N/ha even after adopting mitigation M3. These farms had to change out of dairying. Adopting M3 with DCD allows these farms to remain in dairying. Similarly, other dairy farms needed to adopt mitigation M3 to be compliant with a cap of 30kg N/ha. When DCD is included, many of these farms need only adopt M2. As a result, when DCD is included, scenarios 9 to 11 leach about 5 per cent more N and 12 per cent more P than when DCD was excluded. This is because more land remains in dairying. *By contrast, gross margins and value of production are about 40 per cent higher with DCD included.* Thus while the total mitigation under these scenarios falls, the cost per mitigation changes from a cost in agricultural production losses of $408 per kg N mitigated, to a gain of $24 per kg N mitigated.

85. In scenario 12, the inclusion of DCD allows dairy farms to use M2 instead of M3. However the P cap of 0.5 kg/ha is still binding on some farms, as DCD has no impact on P loss. Overall the N and P mitigation in scenario 12 is the same with and without DCD, as mitigation M2 with DCD is comparable to mitigation M3 without DCD. However M2 with DCD saves farmers some money while M3 without DCD is a $315/ha cost. Thus gross margins are in scenario 12 are about 5 per cent higher when DCD is included.

3.3.2 Non-uniform caps

86. In the original scenario 17, the non-uniform caps induce all dairying into the use of mitigation bundle M2. With the inclusion of DCD about 20 per cent of dairying is now compliant using mitigation bundle M1, with the remainder still using mitigation bundle M2. However, M2 with DCD generates both more mitigation and higher costs. Overall the N leaching is reduced by 9 per cent, while the total gross margin falls by 4 per cent.

87. In the original scenario 18, the non-uniform caps induce dairying to move to M2 (55 per cent) and M3 (45 per cent). With the inclusion of DCD, dairy farms are compliant with M1 (20 per cent) and M2 (80 per cent). Overall, the N leaching is reduced by 2 per cent while the total gross margin increases by 2 per cent as M2, even with extra DCD costs, is more profitable than M3.

3.3.3 Grandparenting

88. In scenario 19, grandparenting allocations force all dairy farms into M3 and limit conversion to dairying. With DCD, M3 generates both more mitigation and higher costs. Overall the N leaching decreases by 4 per cent while the total gross margin falls by 3 per cent when DCD is included.

3.3.4 Mandated mitigation practices

89. In scenario 20, all farms adopt mitigation bundle M3. Without DCD, this reduced 2037 N leaching from the baseline 19,000 tonnes to 12,700 tonnes – a reduction of 33 per cent. With the inclusion of DCD, N leaching drops to 11,400 tonnes, a reduction of 40 per cent versus baseline. With or without DCD, there is no significant impact on the value of agricultural production in the region.

3.4 Limitations

90. The MAS model has been validated against land use change in Southland over the last 20 years, as described in NZIER's Appendix A.2.9. The results in their report should be interpreted in their proper context:

- they are based specifically on Southland data, and the applicability to other regions has not been assessed
- the model scenarios are broad-brush attempts to understand a range of future possibilities rather than specific recommendations
- the mitigation scenario tools have been modelled without consideration of how they would be implemented
- the results are not intended to be specific predictions, but to help us understand the magnitude of impacts and the relationships amongst different parts of the regional agricultural system.

91. This analysis has provided information on the potential costs and impacts of nutrient discharge caps on Southland, but the following limitations should be acknowledged:

- Wintering-off – the approach to analysing wintering-off does not account for decisions by farmers to participate in dairy support, nor does it account for geographic concentration of dairy support. Managing the three- to five-month winter period could be a part of the farm system where future mitigation strategies focus.

- System change as a mitigation option – in this modelling, if a nutrient cap requires more mitigation than the highest mitigation level, then farmers resort to land-use change. The modelling does not include the potential for radical system change in dairying methods, particularly de-intensification.
- Bundling mitigation options – mitigation options were grouped into three bundles, whereas farmers will actually be able to choose from a number of specific options. The impact is that the modelling overstates the total impact of each tool, because farmers are mitigating somewhat more than they need to be to meet the caps. The net impacts of bundling on price per kg of N and P reduction are ambiguous, because they depend on the costs of specific practices and their individual and aggregate efficacy.
- Mitigation bundles used in the modelling include practices such as improved nutrient management and improved animal productivity which are aimed at reducing nutrients levels (N and P), Most mitigation actions have little effect on *E. coli* levels. Practices such as fencing, aimed at reducing *E. coli* to meet the human health bottom line result in costs, but these costs are hidden in the overall benefit of the mitigation bundles.
- Barriers to adoption – the model does not account for hurdles or barriers to adoption that affect the total cost of selecting new farm practices or changing land use. For example, some potential practices seem to be both economically profitable and efficient with nutrients. We would expect those practices to be more widespread than they actually are, suggesting that there exist some constraints to adoption for which we have not accounted.
- Farmer behaviour – the modelling extends analysis of environmental policy from a single, average, profit maximising farmer, to multiple, heterogeneous farmers with differing objectives. If our description of those behaviours is incorrect, we could be biasing the model results in unknown ways.
- Corporate farms – are not explicitly considered within the model, so the model may understate the amount of profit maximising or financially driven decision making.
- Capacity of regional resources – the capacity of regional resources, including water to sustain the growth in dairying in the baseline, has not been explicitly considered. The projected growth path for dairying is in line with past levels of conversions, and therefore does not account for geographic areas in which water availability already is, or may become, restricted.
- Farmer debt and stranded assets – debt and access to credit will affect a farmer's ability to adopt new practices, however debt and assets are not explicitly included in the model. The impact of credit constraints and debt are implicitly captured in the 'aversion-to-change' parameter that limits farmers from changing land use that has been calibrated on the historical behaviour of farmers.
- Technological improvements over time – growth in agricultural productivity based on the gains over the last 20 years is included. Growth in the performance of current mitigation practices or any possible new 'silver bullets' that significantly reduce agriculture's environmental footprint have not been included.

92. A risk with any modelling exercise is that models are by definition a simplification of reality. This simplification risks attracting criticism. The results are not intended to be specific predictions of

exact benefits and costs. These provide an indication of the magnitude of impacts on the agricultural sector, which feed into a wider assessment of the potential impacts water quality objectives and limits across all market and non-market values.

93. It is also important to recognise that the findings reported here relate to one study carried out by NZIER for the Southland region. The farm level modelling has found that under some scenarios, farms could both reduce nutrient discharges and improve profitability by adopting certain mitigation bundles. However, in reality this situation may not be possible, as it would require increased efficiency at farm level, which would impose mitigation costs on existing as well as new farms. The result differs from other New Zealand research which suggests that on farm nutrient loss reduction of the order of 20 per cent per hectare is achievable at relatively minimal cost but mitigation costs rise steeply after this point. Therefore, it must be noted that these findings are specific to the modelling assumptions made in the modelling, and that in reality some sectors/farmers will not have the capability to carry out these mitigations at a low or no cost.

94. For further detail on the farm-level modelling assumptions, the reader is referred to the NZIER report.

Section 4: Hydrological water quality modelling

The NIWA and Aqualinc reports provide an assessment of the water quality outcomes associated with a range of scenarios modeled at farm level. The water quality variables determine the state of environmental attributes: nitrate toxicity, periphyton (algae) abundance, and *E. coli* concentrations in rivers. The attributes for rivers are currently being considered for inclusion in the proposed NOF.

The Southland case study reports have found that the proposed bottom lines for ecosystem health in rivers for the two attributes tested in Southland are currently met. Water quality will be maintained above bottom lines for median nitrate toxicity and periphyton (slime) under all scenarios tested. Although the ecosystem health in rivers will decline, the proposed national bottom lines tested will be met without undertaking additional mitigation both now and in 2037.

The proposed national bottom line for *E. coli*, the attribute tested for human health, in rivers is currently breached at five of the 73 sites monitoring sites tested in Southland. Predicted future (2037) water quality in a 'no additional mitigation' scenario show little change in *E. coli* levels. The findings are driven by the assumption of a small decrease in the amount of agricultural land area, and the assumption that dairy and non-dairy pasture uses impose similar loads.

Results suggest that estuaries in Southland are more sensitive receiving environments than rivers and that contaminant loss from farming activities in the region has its most marked effect on estuaries. Therefore, the proposed bottom lines for rivers are unlikely to be sufficient to maintain and improve water quality in the estuaries.

4 Hydrological water quality modelling

95. Hydrological water quality modelling has been undertaken by NIWA and Aqualinc, with information inputs also provided by AgResearch. The NIWA and Aqualinc reports provide an assessment of the water quality outcomes associated with different scenarios and evaluate the results in terms of levels of acceptability (bands) proposed by the National Objectives Framework (NOF).

96. The water quality modelling aggregates estimated farm-level and point source discharges to downstream water quality outcomes, the essential step in determining whether the scenarios modelled at farm level can feasibly achieve national bottom lines.

97. Arguably, an ideal approach to assessing water quality limits would start by defining the desired outcomes in the receiving environments and determine the resource use limits that would achieve this. This approach is technically difficult from a scientific perspective, partly because there are many ways that catchment land use and land management could be organised to meet a desired water quality outcome. The approach used in the NIWA and Aqualinc studies was to work from the source to receiving environment in three steps.

98. The first step modelled the consequences of a range of scenarios that would be implemented in Southland using regulatory or non-regulatory tools. This work was undertaken by NZIER, as described in Section 3 of this summary report. The outputs described the economic consequences and the loss rates for total nitrogen (TN) and total phosphorus (TP) for all (~3000) farms in Southland for the current ("Baseline") policy settings and a range of 20 farm-level discharge

mitigation scenarios. This modelling work also produced information that allowed the loss of *E. coli* to be estimated from farms at the subsequent step.

99. The second step modelled catchment loads and concentrations by combining the modelled farm losses with other catchment contaminant contributions, both natural and human derived, and accumulated these down the region's river systems. This work was undertaken by NIWA. The catchment model estimated the annual loads of *E. coli*, TN and TP at 73 long-term State of Environment (SOE) river monitoring sites in Southland. The catchment model was calibrated to the observed loads at these 73 sites. The farm losses that were estimated by the NZIER model were then used as input to the NIWA model. The annual loads for all scenarios were used to calculate the corresponding median concentrations of *E. coli*, TN and TP plus nutrient species of nitrogen and phosphorus including dissolved inorganic nitrogen (DIN), nitrate (NO_3N) and dissolved reactive phosphorus (DRP) at the 73 SOE sites. These concentrations were calculated based on the assumption that the observed ratio of the annual load to the concentrations would be preserved for all scenarios. The catchment modelling was also used to estimate the annual load of TN for each of nine estuaries in the Southland region.

100. The third step, carried out by Aqualinc, comprised the assessment of environmental outcomes for water quality. This step used the predicted river water quality (concentrations of *E. coli* and nutrients at the 73 SOE sites) to evaluate performance against some of the objectives that are currently under consideration as part of the proposed NOF.

4.1 Catchment model for calculating N and P load

101. The NIWA report describes the catchment model used to obtain median concentrations of TN (total nitrogen), TP (total phosphorus) and *E. coli* at the monitored sites in the region and the loads of these contaminants to the estuaries in the region, as shown in Figure 12.

102. The 'representativeness' analysis of the 73 SOE sites that have been used as a basis for the modelling indicates that they over-represent the lowland pasture category of rivers. This category represents the rivers in Southland that are generally the most degraded from a water quality perspective. These river types also drain the landscapes that are most likely to undergo intensification of land use. This means that the overall results (ie, the regionally aggregated results presented) are likely to give pessimistic estimates of overall water quality in the region (ie, on average it is better than represented by the SOE sites).

103. The catchment model used in this study was spreadsheet-based and a simplified adaptation of the SPARROW (Spatially Referenced Regressions On Watershed) model (Smith et al. 1997).[19] Within each reach's sub-catchment, there are a number of sources. The load of contaminant generated for a particular source type (source load) is the product of the amount of source (area of land cover, load from point sources, or pasture losses from a separate model) times a source coefficient (yield for diffuse sources, a dimensionless source coefficient for point sources[20] and pasture).

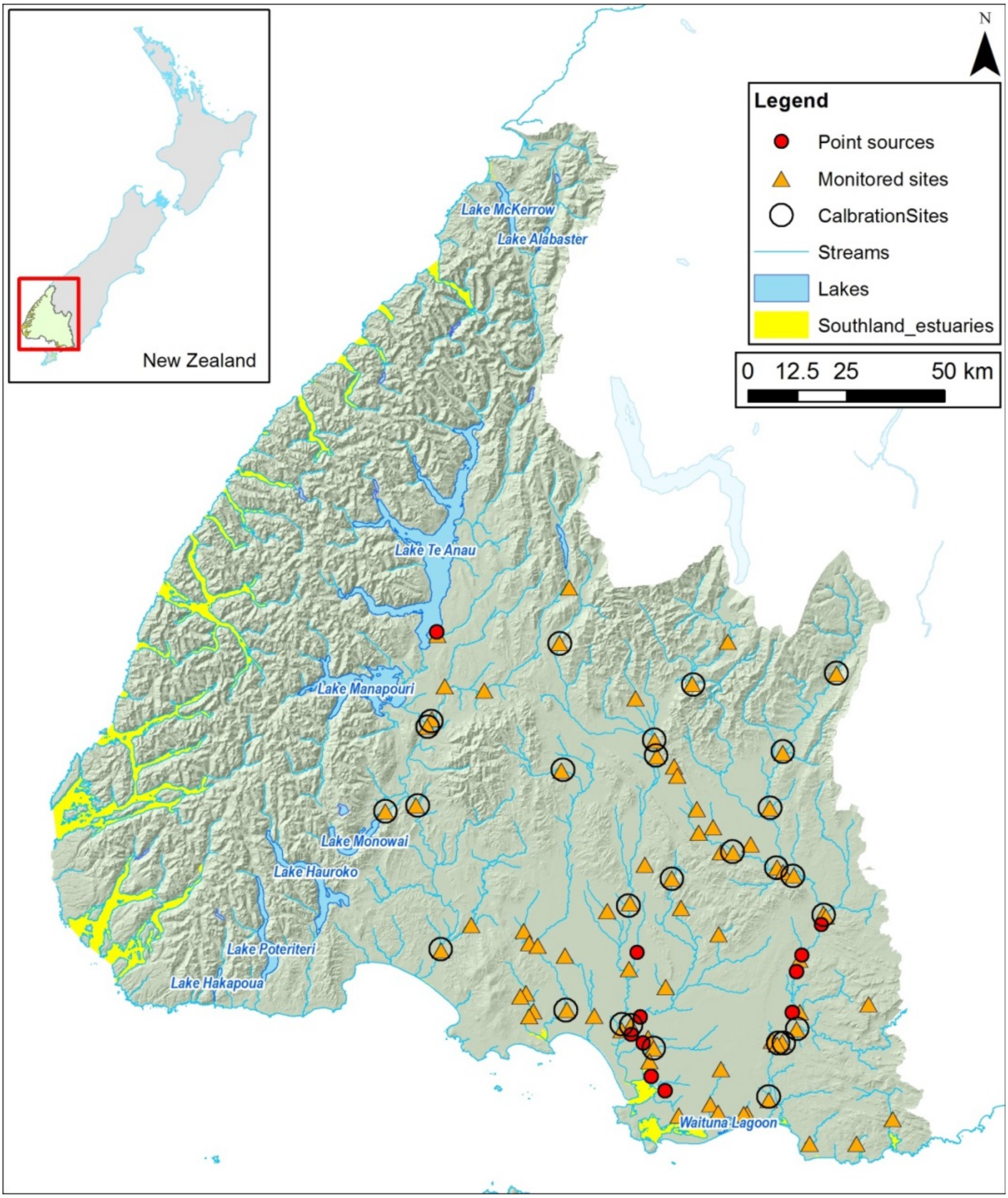
[19] This model, originating from the U.S. Geological Survey, has been used in New Zealand for the Waikato River Basin (Alexander et al. 2002) and for the whole country (Elliott et al. 2005) to predict mean annual loads of TN and TP in streams. It is also the catchment model used in CLUES (Elliott et al. 2008) and E. coli modelling capabilities (prediction of mean annual load) have also been added to the SPARROW model in CLUES.

[20] We only consider point sources that discharge directly into waterways, ie, point sources that discharge to land are not accounted for.

104.This source load is then modified by a land-to-water delivery term, which is an exponential function of a number of delivery variables (such as rainfall or land drainage class) and delivery coefficients. The modified sources are then summed for a given sub-catchment to give the total load entering the associated stream reach.

105.In-stream losses are modelled by a first-order decay term, and the load is then accumulated and attenuated during movement down the reach or stream network. A separate attenuation factor for reservoirs (eg, lakes), is also calculated (Elliott et al. 2005). The result of the calculations is the mean annual load for each stream reach.

Figure 12: Southland region showing streams of order ≥ 4, estuaries, lakes, point sources, monitored and calibration sites



Treatment of *E. coli*

106.Quantitative analysis of mitigations for *E. coli* is an emerging area of science. AgResearch provided current best estimates stipulating the potential effectiveness of the different farm-level discharge mitigation scenarios in reducing in-stream median *E. coli* concentrations.

107.The list of current mitigation practices included in the *E. coli* risk index are: direct animal access to streams, stream crossings as a ford, use of flood irrigation systems and farm dairy effluent (FDE) management. The risk index was then calibrated against measured data from the five dairying focus catchments (Wilcock et al. 2007). The catchment average risk index was plotted against the water quality data to determine the relationship between the risk index values and in-stream *E. coli* concentrations.

4.1.1 Informational inputs

108.Input information for NIWA's modelling included the following:

- Output from NZIER's MAs model consists of mean annual Nitrate and Phosphate loads from farms, percentage reduction in *E. coli* load, farm areas and pasture enterprise type (dairy or sheep/beef) for each of the 3290 farms modelled in the region.[21]
- The losses from non-farm uses were determined from the areas of different land uses (LCDB3). The LCBD3 data from AgResearch has 33 land cover categories.
- The conversion of the remaining 31 land cover areas (diffuse sources) to loads was achieved by ascribing a yield (t km^{-2} y^{-1}) to each of them.
- The yields for the other non-pasture land covers were either based on expert knowledge, previous SPARROW modelling, or estimated in the calibration process.
- Data on 11 point sources were obtained from Environment Southland.

4.1.2 Key findings on stream N, P and *E. coli* concentrations

109.The probability distribution of median concentration for TN, TP and *E. coli* were calculated for the 73 monitored sites. Included are the measured concentrations and predictions for the various tool sets. Concentrations generally increased from the current situation (Baseline2012) to Baseline2037, reflecting increased conversions to dairying. The lowest concentrations were for mitigation scenario Set E, reflecting the scenarios under which dairying could not comply with required discharge limits, which approximately halved the concentrations for a given percentile.

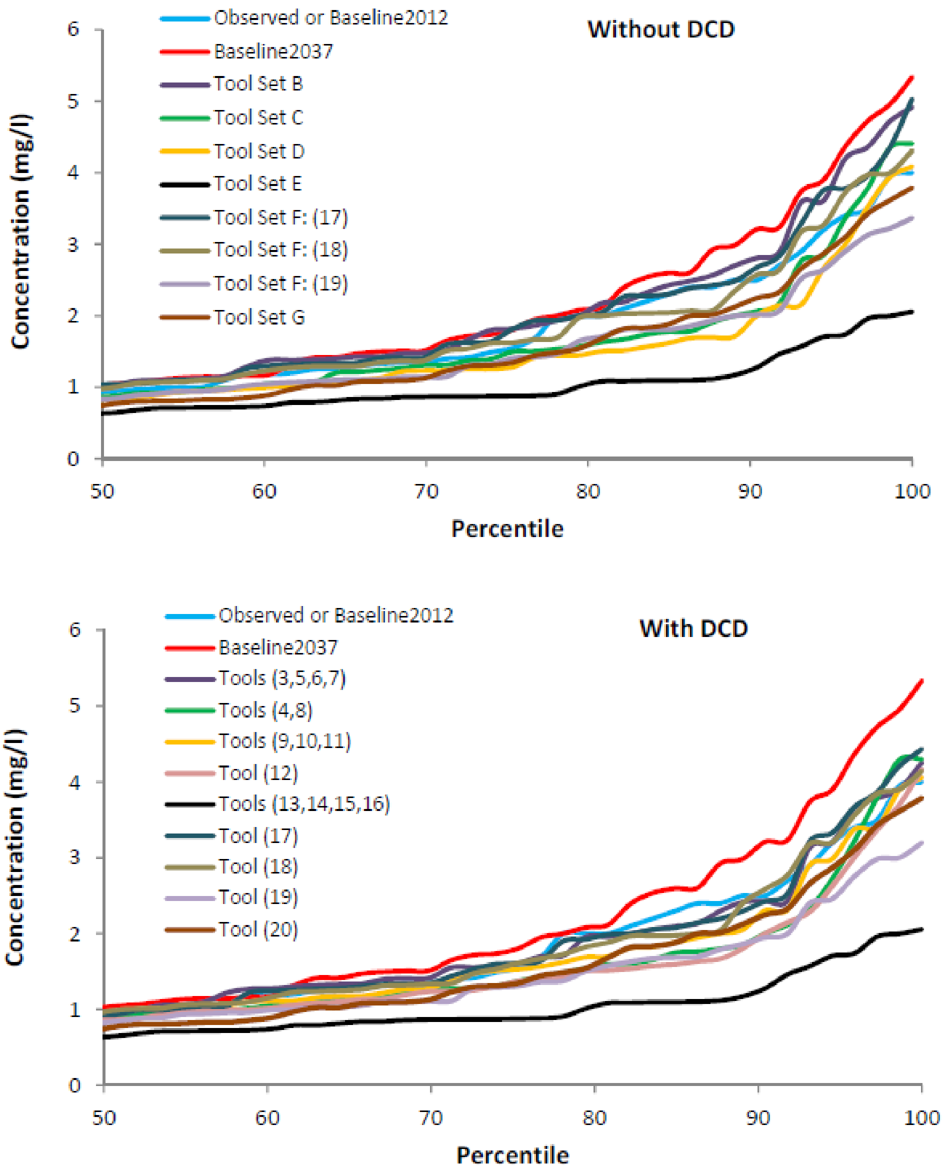
110.For *E. coli* there was not much sensitivity to the mitigation scenario sets, which reflects the equal loading given in the model to dairy and non-dairy pasture (so that land use change between pasture classes has no effect). The effect of mitigations on dairy land was fairly minor, because non-dairy pasture produces a large proportion of the loading. Mitigation scenario Set G did result in significant reductions, however, because in that scenario, mitigations were applied to both dairy and non-dairy areas.

[21] Only farms with area > 20 ha are considered (Josef Beautrais and Chris Schilling, AgResearch and NZIER respectively, *pers. comm.*).

111.The introduction of DCD had a small effect on the TN concentrations and loads, but very little effect on TP and *E. coli* concentrations and loads.

112.The modelled probability distribution of median concentration for TN is shown in Figure 13 for the 73 monitored sites. Included are the measured concentrations and predicted concentrations for the various scenarios/tool sets. The figures show the percentage of sites with median concentrations less than the value on the vertical axis. For example, for Baseline 2037, 80 per cent of the sites have a median TN concentration less than 2.0 mg/L. The figure summarises the distribution across sites, rather than the more variable increases or decreases on a site-by-site basis. This way of summarising the results is for convenience and clarity, and does not influence subsequent stages of assessment of effects.

Figure 13: The modelled probability distribution of median concentration for TN across Southland's 73 monitored sites



Source: NIWA

4.2 Assessing water quality outcomes against NOF water quality objectives

113. The policy proposals for a National Objectives Framework (NOF) include a graduated range of acceptable values for attributes that are associated with the objectives that define bands that are denoted A, B, C and D. These bands express the extent to which values are supported including ecosystem health and human health. The Aqualinc study used objectives, attributes and bands that are currently under consideration by the NOF to assess the water quality outcomes.

114. Aqualinc took as inputs the water quality predictions made by NIWA and tested these against numerical thresholds of acceptability for specific attributes that are currently being considered as part of the development of the NOF. Results for the river SOE sites based on three groupings were aggregated for: the whole region; the four major catchments (Matuara, Oreti, Aparima and Waiau); and proposed water quality management zones (Lowland and three Inland Basins).

115. For each grouping, Aqualinc summarised the results by counting the number of sites in the possible NOF bands (A, B, C and D). Aggregation of the results in this manner has two advantages. First, it allows broad conclusions to be drawn about the consequences under each scenario. Second, the water quality predictions for individual sites are associated with uncertainties, however, as a group, the predictions were strongly correlated with the observations. This means the broad conclusions drawn from the aggregate results can be treated with greater confidence than predictions for individual sites.

4.2.1 Key findings

4.2.1.1 River human health: microbiological contamination

116. The NOF objectives for human health seek to protect people from infection by waterborne pathogens such as the protozoan *Cryptosporidium parvum*. The associated attribute that is proposed by the NOF is the concentration of the indicator bacterium *Escherichia coli* (*E. coli*). The concentration bands proposed by the NOF are for human "secondary contact". Secondary contact implies being in contact with the water but not immersion in it (eg, fishing, boating, and wading but not swimming). The bands are defined in terms of the risk of contracting an illness given a secondary contact occasion and are shown in Table 6.

Table 6: Thresholds that define the NOF bands for *E. coli* and the associated risk of infection.

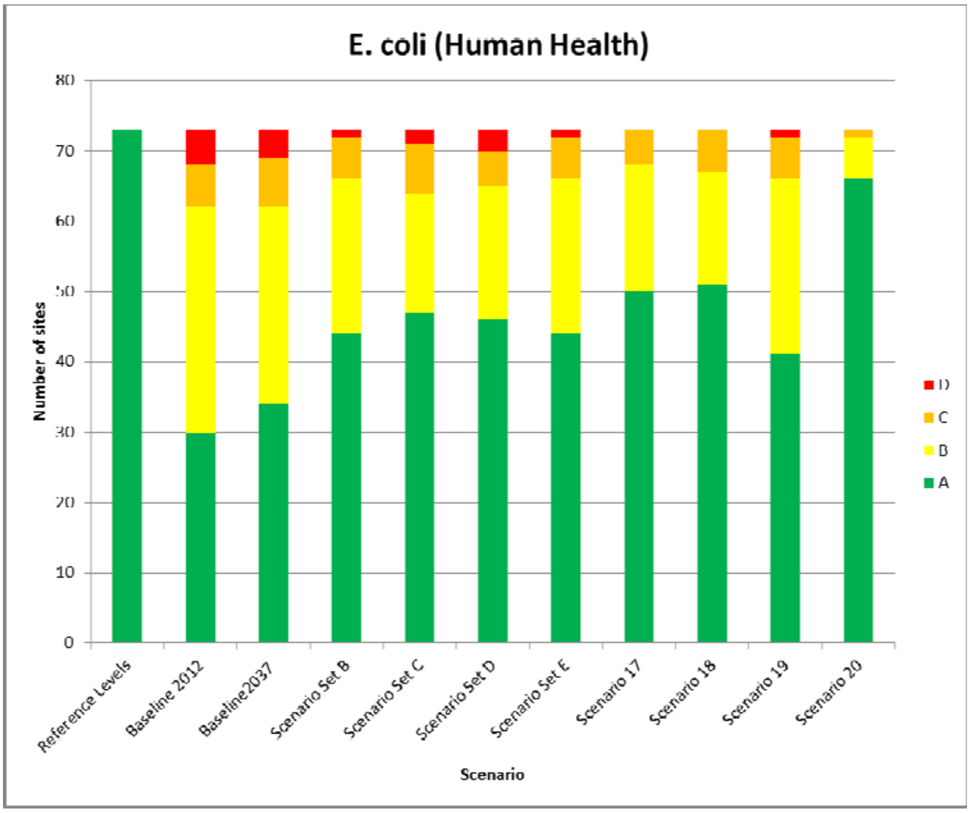
Thresholds (*E. coli*/100ml)	Band	Infection risk
<260	A	<0.1%
<540	B	0.1-1%
<1000	C	1-5%
>1000	D	>5%

117. The analysis of the river human health objective under "reference state" water quality (ie, water quality in the absence of human pressures) indicated that all SOE sites would be in the A (ie, excellent) state. The regionally aggregated results for the Baseline 2012 scenario indicated 5 sites (5 per cent) had *E. coli* values in the D category (ie, below the bottom line) and 6 were in the C (ie,

above the bottom line but only in a fair state). The remaining 62 sites (ie, 85 per cent of the SOE sites) were in either an A or B category. Results for the Baseline 2037 scenario showed little change to the 2012 scenario with a slight decrease in the number of sites in the D category and increase in sites in the C and A categories. This outcome occurs because the percentage of agricultural land area (either dairy or sheep/beef) was lower for Baseline2037 (dairy 28 per cent, sheep/beef 65 per cent, total of 93 per cent) than Baseline2012 (dairy 15 per cent, sheep/beef 82 per cent, total of 97 per cent), and the *E. coli* yields for dairy and sheep/beef were equal (NIWA 2013). The dairy yields for TN and TP are greater than those for sheep/beef, so that the increase in dairy land area for Baseline 2037 leads to greater TN and TP concentrations and loads when compared to the 2012 baseline (NIWA 2013).

118. The predicted *E. coli* values for the mitigation scenarios indicated small improvements in meeting the proposed NOF bottom line compared to the Baseline 2012 scenario. The improvements are small because for most scenarios the mitigations have most impact on loss of contaminants from dairy farms but *E. coli* loss rates from sheep and beef farms are assumed to be equivalent by the NZIER model; therefore non-dairy pasture produces a large proportion of the loading. Scenario 20, however, was associated with a large improvement in *E. coli* values across the region. This is because this scenario mandates mitigations to all farm types and therefore reduces the loads from sheep and beef farming, which represents the dominant source of *E. coli* regionally. (NZIER 2013).

Figure 14: Regionally aggregated results of the analysis the river human health objective based on predicted *E. coli* concentrations and proposed NOF bands.



Source: Aqualinc

4.2.1.2 River ecosystem health: Nitrate toxicity

119. The NOF objectives for ecosystem health seek to support biological communities and ecological processes. An associated attribute that is proposed by the NOF is the concentration of nitrate. Nitrate is toxic to some species when its concentration exceeds specific thresholds. The concentration bands proposed by the NOF are defined in terms of the proportion of test species that are protected at that concentration (Figure 10). It is important to note that after the Southland study was completed, the nitrate toxicity bottom line was strengthened by the addition of a criterion around nitrate levels at the 95th percentile (in addition to the median), which has not been assessed.

Table 7: Thresholds that define the NOF bands for nitrate toxicity and the associated proportion of test species that are protected.

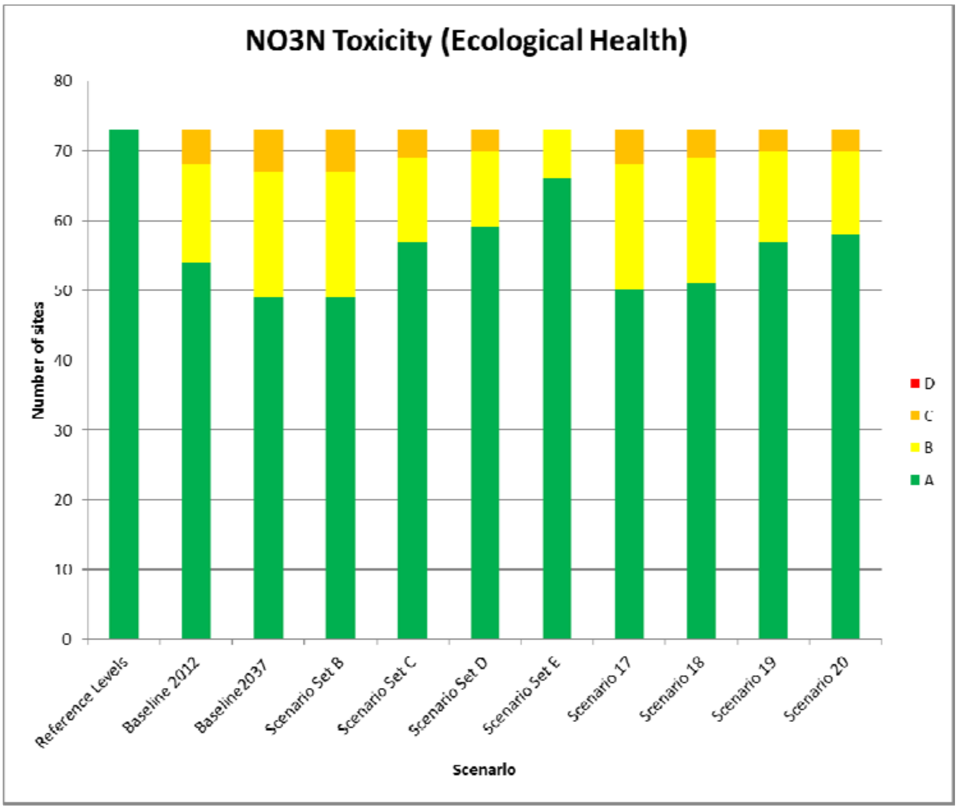
Thresholds (mg Nitrate m^{-3})	Band	Species Protected
<1000	A	99%
<2400	B	95%
<6900	C	80%
>6900	D	>80%

120. All SOE sites were predicted to be in the A (ie, excellent) condition for the river ecosystem health objective (nitrate toxicity attribute) under "reference state" water quality (ie, water quality in the absence of human pressures) (Figure 15). The regionally aggregated results for the 2012 Baseline scenario indicated that five sites (7 per cent) had nitrate concentrations in the C category (ie, above the bottom line but in only fair condition). Of the remaining sites 74 per cent and 19 per cent were in the A and B categories respectively.

121. The regionally aggregated results for the Baseline 2037 scenario in showed an increase in the number of sites in the C and B categories to 8 per cent and 25 per cent respectively and a decrease in sites in the A category. This outcome is expected because the baseline scenario envisages further intensification of land use and no change to mitigation practices.

122. Scenario A, which included mitigation measures, did not show an improvement in the river ecosystem health outcome over the Baseline 2037 scenario and indicated some degradation of water quality relative to the Baseline 2012 scenario. The remaining scenarios indicated an increase in attainment of the river ecosystem health outcome relative to the Baseline 2012 scenario. This suggests that the land use intensification envisaged under these scenarios could occur with improvements in overall water quality outcomes if mitigation measures were adopted.

Figure 15: Results of the analysis the river ecosystem health objective based on predicted nitrate concentrations and proposed NOF bands (see Table 7).



Source: Aqualinc

4.2.1.3 River ecosystem health: Periphyton

123.The NOF objectives for ecosystem health seek to support biological communities and ecological processes. A key attribute of rivers with suitable substrate is the abundance of algae (ie, slime) growing on the bed. Algae growing on the bed of rivers are known as periphyton and are a primary source of food for invertebrate insects, which in turn are food for fish and birds. The growth of periphyton is determined primarily by light, temperature and the concentration of nitrogen and phosphorus. If nutrient concentrations exceed certain values, the abundance of algae can become excessive. Excessive or 'nuisance' growth of periphyton can smother habitat, alter invertebrate communities, and produce adverse fluctuations in dissolved oxygen and pH. Excess periphyton can also cause changes to water colour, odour and the general physical nature of the river bed, which has flow-on detrimental effects on aesthetics and human uses (MFE 2000).

124.Periphyton abundance bands could be expressed in the NOF by an index that measures the proportion of the bed covered by periphyton. To use these bands in this study Aqualinc needed to convert the predicted nutrient concentrations to this index. A national scale model of periphyton cover (Snelder et al., In press) was used to estimate the cover index at the 73 SOE sites. However, when the model was tested against periphyton cover observations made by Environment

Southland the model was found to perform poorly. The reasons for this were unclear but further investigation was beyond the scope of this study.

125. Environment Southland also monitor the concentration of benthic Chlorophyll-*a*, which is an alternative measure of periphyton abundance to cover. This data was used to develop a predictive model of benthic Chlorophyll-*a* as a function of nutrient concentration.[22] The model developed for the present study included variables that describe the flow regime at sites to maximise the accuracy of the regional predictions. Because flow regimes are spatially variable, the periphyton abundance is a function of both nutrient concentrations and the variables used to describe variation in flow regimes.

126. The mean annual maximum of benthic Chlorophyll-*a* is used as a guideline in New Zealand (MFE 2000). Aqualinc adopted this guideline and associated thresholds as a basis for developing periphyton bands for this study (Table 8). The Chlorophyll-*a* concentration bands adopted are also shown in Table 8.

Table 8: Periphyton biomass thresholds for mean summer Chlorophyll-a and equivalent mean annual maximum thresholds.

Thresholds (Chlorophyll-a mg m^{-2})	*Band*	*Equivalent mean annual maximum threshold* **(Chl-*a* mg m^{-2})**
<31	A	<50
<75	B	<100
<124	C	<200
>124	D	>200

127. The analysis for the river ecosystem health objective (periphyton attribute) under "reference state" water quality (ie, water quality in the absence of human pressures) indicated that the majority of SOE sites (62 per cent) would be in the A band (ie, excellent) condition and the remainder would be in the B band (Figure 16) due to natural discharges. The regionally aggregated results for the 2012 Baseline scenario indicated that four sites (5 per cent) had Chlorophyll-*a* concentrations in the C category (ie, above the bottom line but in only fair condition). Of the remaining sites, 37 per cent and 58 per cent were in the A and B categories respectively.

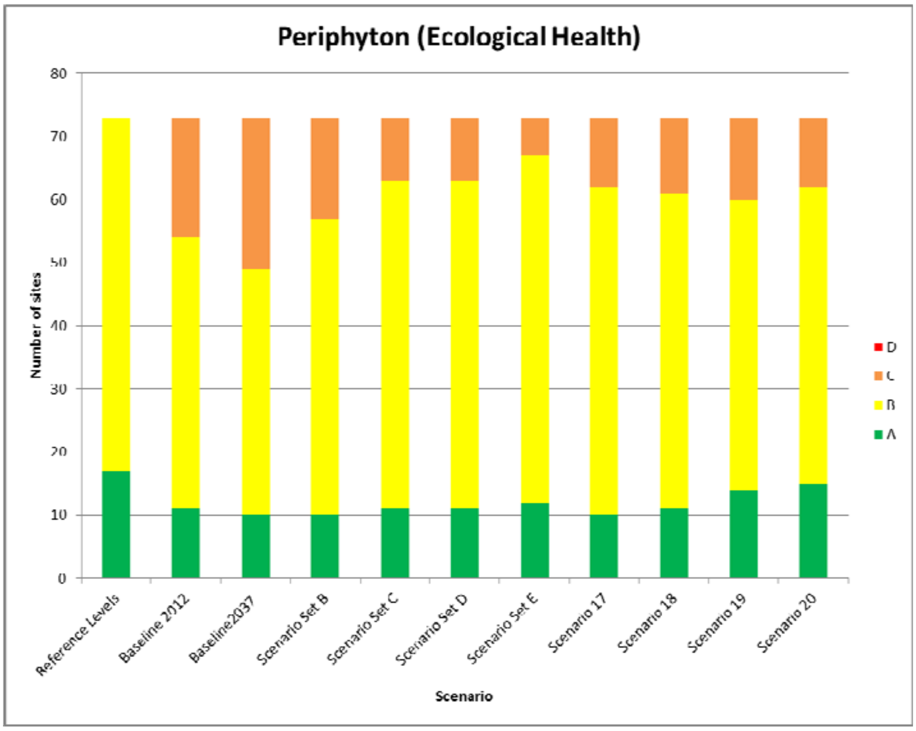
128. The regionally aggregated results for the Baseline 2037 scenario in showed an increase in the number of sites in the C category to 10 per cent and a decrease in the number of sites in the A category (Figure 16). This outcome indicates a small decrease in attainment of the river ecosystem health outcome relative to the Baseline 2012 scenario. This is expected because the baseline scenario envisages further intensification of land use and no change to mitigation practices.

129. The regionally aggregated results for all scenarios that included mitigation measures indicate either maintaining river ecosystem health outcomes relative to the Baseline 2012 scenario or improving the attainment of these objectives (Figure 16). This suggests that the land use

[22] Previous work (eg, Biggs, 2000; Snelder et al., in press), has shown that, apart from nutrient concentrations, hydrological regime (eg, the magnitude of low flows and the frequency of change in flow) is an important determinant of periphyton abundance.

intensification envisaged under these scenarios could occur with either maintaining or improving the water quality outcomes if mitigation measures were adopted.

Figure 16: Results of the analysis the river ecosystem health objective based on predicted Chlorophyll-a concentrations (ie, measure of periphyton biomass) and nominated bands



Source: Aqualinc

4.3 Conclusions

4.3.1 Rivers

130. Overall the analysis suggests that the existing river water quality in Southland achieves a high level of attainment of the proposed NOF bottom lines that were considered in this analysis (ie, *E. coli*, nitrate toxicity and periphyton).

131. The baseline 2012 scenario indicates that a few sites are below the bottom line for the human health objective (*E. coli*) and all sites are above the bottom line for the ecosystem health objectives (nitrate toxicity and periphyton).

132. Overall the analysis indicates that the current level of attainment of the proposed NOF water quality objectives would be maintained or improved under the scenarios with improvements increasing as the contaminant loss rates decreased.

133. However, the analysis indicated that the improvements in water quality at the regional level under all scenarios would not be large. This is because the mitigation measures modelled mainly affect dairy farming, and dairy farming currently makes up only 17 per cent of the region's agricultural land use. This means that mitigations are making reductions in contaminant losses in only a relatively small proportion of the agricultural landscape.

134. A particular exception to this general pattern was Scenario 20, for which large improvements in the human health objective (reductions in *E. coli*) was predicted. This occurs because Scenario 20 mandates specific mitigations for all farm types.

135. With regards to the impact of including DCD as an on-farm mitigation option, in general terms, NIWA and Aqualinc's work found that compliance with NOF thresholds for tools that included DCD were very similar to those that did not include DCD. This is because the farm-level scenarios were generally based on achieving specified nutrient caps; DCD simply provides another way of complying with the cap. An important distinction is the economic implications associated with the option of DCD as a mitigation method, as described in Section 0 above.

4.3.2 Estuaries

136. Ecosystem health of estuaries is likely to be a more constraining water quality issue than rivers in Southland, as water quality thresholds for estuaries are more challenging to meet. Results suggest that estuaries in Southland are more sensitive receiving environments than rivers and that contaminant loss from farming activities in the region has its most marked effect on estuaries. Therefore, the proposed bottom lines for rivers are unlikely to be sufficient to maintain and improve water quality in the estuaries.

137. The science around the appropriate thresholds for estuaries in New Zealand is limited. Objectives set for fresh water will also need to consider the impact on estuaries and the requirements of the Coastal Policy Statement.

4.4 Limitations

138. There are three principal limitations to consider when reviewing the results of this report:

- Uncertainties present in the NZIER and NIWA models inevitably impact upon Aqualinc's analysis – findings on achievability of national bottom lines are subject to the limitations of the 'upstream' analysis.
- Aqualinc's results are based on proposed NOF attributes and associated thresholds, which are likely to be revised before being adopted.
- For example the bands tested for periphyton in this study were preliminary and are subject to on-going revision as part of the process of developing the NOF. These results should therefore be treated as indicative. Moreover, the certainty of the model for evaluating periphyton abundance is limited by available data. In addition, in applying the model, Aqualinc assumed that all sites are suitable for periphyton. However, not all rivers and streams have suitable habitats for periphyton growth.
- It is important to note that only two of the national bottom line indicators being considered for ecosystem health could be assessed by Aqualinc.

139. The Southland studies do not provide us with any information on the water quality and associated economic impacts of limits for achieving national bottom lines for lakes. This is because most of Southland's lakes fall within the Conservation Estate.

140. Little is yet known about the age of the groundwater in the Southland region although data collection and modelling are currently being done and the results from this work are expected soon (Clint Rissmann, Environment Southland, pers. comm.). The SPARROW model assumes groundwater lags are zero (i.e., that stream concentrations reflect current land use) and adjusts

key coefficients (eg, TN and TP yields from farmland and stream attenuation coefficients) to match current observations. If there are significant groundwater lags in the region, then the SPARROW model results are likely to under-predict stream concentrations and estuary loads in 2037.

141. Whilst not strictly a limitation, it is nonetheless important to note that the farm-level and hydrological water quality studies have identified only incremental river water quality improvements arising from the range of nutrient mitigation scenarios modelled. This improvement is the 'change' factor that feeds into the assessment of impacts on non-market values and the case studies on industrial and municipal values. The critical 'change' factor being *small* is a key driver of the *small* changes in values found in the non-market, municipal and industrial studies.

Section 5: Industrial and municipal

The case studies present an introduction to the potential mitigation costs of reducing contaminant losses associated with industrial and municipal water use if necessary to improve water quality in the Southland environment.

Proposed bottom lines would not result in costs to Invercargill municipal water supply, as the Ministry of Health standards for drinking water are more stringent. In contrast, the effects of quality limits on stormwater could cost more than $1,800 per ratepayer household per year.

The costs associated with an upgrade to the Alliance Meatworks wastewater processing facility are large. Should the upgrade be developed in time to be fully operational by 2017 and meet the current published water quality standards it may cost the company $41.4 million in NPV terms over its lifetime.

While the potential mitigation costs could run into the tens or even hundreds of millions of dollars, it is difficult to draw any region-wide conclusions on the impact of proposed bottom lines on the municipal and industrial sectors. To do so, further data on contaminant discharges, facility standards and upgrade requirements and costs would be necessary across the region.

5 Industrial and municipal

142. The aim of the project undertaken by Market Economics is to present an introduction to the potential costs of reducing contaminant losses associated with industrial and municipal water use if necessary to improve water quality in the Southland environment. The approach adopted is to identify the current values associated with water use in the municipal and industrial sectors, test the system by applying water quality limits and assess the effects these are likely to have in qualitative terms, and quantitative terms where feasible. The study does not directly assess the impact of achieving a specific water quality objective or proposed bottom lines.

143. The focus of other studies has been on the effects of reductions in nutrient runoff brought about through land use and farm management practice changes. These reductions have then been traced through the freshwater network.

144. A key restriction on the work feasible with respect to costs of water quality improvements to the industrial and municipal sectors is the current lack of data, and therefore it is difficult to identify water quality improvements to be made. Moreover, the analysis carried out on Southland's industrial and municipal water uses is based on four case studies, and therefore must be viewed as such. The findings cannot be interpreted as the total marginal cost to the whole of Southland's municipal and industrial sectors of setting objectives to maintain or improve water quality.

5.1 Method

5.1.1 Method and estimations

145. Case studies were undertaken in Invercargill and Winton, with Invercargill being the focus of water and storm water and Winton being the focus of wastewater assessment.

146. For the Invercargill water studies this meant identifying the following:

- Water use by sector of the economy. This is based on data provided by Invercargill City Council matched via land use category and location to economic sector. Water use has then been tied to economic output and employment to provide an estimate of the productive values associated with water.
- Future water use is then estimated by utilising the Economic Futures Model (EFM) Market Economics developed for the wider Southland Regional Water assessment study, once factored down to reflect the Invercargill specifics. The EFM generates estimates of future output, value added and employment by sector for the economy under a set of assumptions about the key drivers for economic growth (population growth, export performance, gross fixed capital formation rates and factor productivity change), and the end result is a view of future requirements for water by Invercargill residents and businesses.
- The final water quality issue is that associated with the quality of the raw water Invercargill draws from the environment for purification and distribution. If quality limits are placed on freshwater this may have implications for further purification processing by council prior to distribution. In reality, the quality limits are lower than the drinking water standards applicable in New Zealand. This means that in all likelihood that reductions in cost will be minimal. It has been investigated and reported on below in the Invercargill Water Section.

147. If quality limits that are set that constrain pollutants contained in stormwater, it is likely to have significant cost implications for councils and therefore residents and businesses. To assess these and the practical effects and impacts of treating stormwater required the following:

- Discussion with council officers who identified that the most pragmatic approach to reduction of pollutants was to promote tidy workplaces such that significant industrial pollutants (mostly heavy metals and hydrocarbons) are contained on-site.
- Identification of three scenarios of potential treatment that focus on initially industrial areas, then industrial and the central business district and finally all of the urban area.
- The water modelling then estimated the percentage of pollutants contained in the Invercargill stormwater, and the effects of imposing specified treatment scenarios.

148. In addition to assessing the effects of storm water runoff from Invercargill City's urban area, an assessment of the contribution to freshwater quality from non-reticulated on-site treatment plants was carried out. In the Southland environment, the majority of these are simple septic tanks that discharge to ground via field tiles to disposal fields. There are a few more modern secondary processing systems that utilise aeration or special filters (textile of sand) to remove a significantly higher proportion of pollutants and produce a far higher quality of output to ground. Given the very limited data available on the types and numbers of systems in Invercargill City and the very site specific nature of the level of processing that is undertaken by the topsoil, it is beyond the scope of this report to present a definitive estimate of the freshwater outcomes of changes to on-site systems in total. Rather this report estimates the changes in discharges to land from upgrading to secondary systems as well as placing the current discharges to land into context.

149. Winton was chosen as the location to model the effects of changes required of a waste-water system on a small community. The changes have not been modelled in response to a set of quality limits imposed by Government, rather a cost abatement curve approach has been taken. This means that for each of the major pollutants, targets in the form of percentage reductions have been set; plant has been designed and costed to achieve these. These costs are then divided across ratepayers.

150.The final case study focuses on the Alliance Meatworks at Lorneville. This lies outside the Invercargill City boundary, but given the scale of the operation and the fact that it employs a significant number of Invercargill residents, plus the scale of the inputs to the Oreti River it was important to understand its current and future industrial discharge profile.

5.2 Key findings

151.The key findings of this report relate to the financial implications of changes to meet higher water quality standards. The costs are likely to be distributed in an uneven manner and the wider implications of investment in additional plant to meet higher standards or the implications of plant closure if standards cannot be met due to high costs have not been explored in this report. Nor does this report definitively answer the question, "What are the costs to a small rural community of meeting higher water quality standards?" This is simply because those standards have not been set and the cost to the community is fully dependent on the difference between the status quo and the higher standards.

152.What this report does do is outline the range of potential costs the community might face to meet higher water quality standards. Results are reported on as additional costs per ratepayer be that per household or per business.

153.Table 9 combines a range of outcomes from all the individual case studies contained in this report. The individual case study results cannot be combined, rather they are presented here together for convenience.

Table 9: Summary of Key Financial Impact Results ($2012)

Scenarios	Water Supply	Stormwater ($/hhld, bus.)	Wastewater		
			Winton ($/hhld, bus.)	Alliance Meatworks	On-site Wastewater Systems* ($/hhld, bus.)
Lowest Cost		$ 240	$ 463		
Low - Medium Cost			$ 477	$27,581,000	$14,405
Medium Cost		$ 526	$ 534		
Med - High Cost			$ 666	$41,368,000	$16,462
Highest Cost		$ 1,819	$ 697		
			** For the Invercargill Study Area Only*		
	Note: Alliance Meatworks costs and Septic Tank Costs in NPV terms at 6%				

154.In summary:

- Proposed bottom lines would not result in costs to Invercargill municipal water supply, as the Ministry of Health standards for drinking water are more stringent.
- The effects of quality limits on storm water are likely to be significant. In order to address all stormwater in Invercargill, to reduce the key pollutants (50 per cent reduction in Phosphorous, 80 per cent reduction in heavy metals, 80 per cent reduction in hydrocarbons and solids) is expected to cost more than $1,800 per ratepayer household per year. This reduces to $240 if only the industrial area is treated or $526 per year if the industrial and CBD areas are treated. Note that these costs are not divided according to any differential.

- In Winton, additional waste water treatment costs increase in relation to the percentage of pollutant removed. The figures presented here are based on combining the costs of individual processes allowing for a 25 per cent efficiency saving if individual processes are combined during the build phase. In reality, the actual system built will be tailored to meet the specific water quality standards at the time. Therefore these figures can be seen as a guide to potential cost structures. The Winton case study estimates waste water treatment costs ranging from $460 and $700 per household or business annually on average over the next 25 years.

- The study assumes all financial and capital costs are funded through loans and paid off through rates. This study does not take account of the wider range of funding options open to local governments including rates differentials, development contributions, grants and others. Utilising a mix of these funding mechanisms is the likely approach councils will take and will have a significant bearing on the results. Moreover, the timing of implementation of water quality limits impacts significantly on councils' ability to afford the infrastructure required to meet any new standards. It is understood that Regional Councils will set the timeframes but it is the territorial authorities who will have to meet these timeframes.

- The costs associated with the upgrade to the Alliance Meatworks wastewater processing facility are significant. Should the upgrade be developed in time to be fully operational by 2017 and meet the current published water quality standards it could cost the company over $41.4 million in Net present Value (NPV) at 6 per cent, terms over its lifetime.

- However, it is worth noting that a range of scenarios has been considered to develop the cost estimates for the Alliance Meatworks wastewater processing facility. Alliance was in the early stages of investigating costs and processes when such scenarios were developed and thus the scenarios do not necessarily correspond to the reality on the ground. Moreover, the NPV has been calculated over a 25 years' time period (at a 6 per cent rate) so the investment would not necessarily have to happen in one go. If it is possible to stage the development and develop the new system in two stages approximately five years apart the costs are almost halved ($27.6m in NPV terms). Note that the level of efficacy of the staged approach is not known, and the costs are rough estimates. Furthermore, the waste water upgrade does not provide alliance with improvements to operational efficiency which may allow Alliance to recoup some of these costs.

- On-site waste water treatment systems are common in Invercargill. They have the potential to be significant contributors to pollutants in freshwater systems if they are poorly maintained, are too close to open water, are highly concentrated in number, or if they are poorly designed for the soil types. However, they are likely to be a minor contributor to water quality issues currently due to the small volumes of pollutants involved (on average) over a wide area. The limited data available indicates that some 1,070 are pre 1992 a further 414 are pre-2000 with the rest post-2000. In order to bring the older type up to higher standards is likely to cost between $14,000 and $16,000 per household. In doing so the volume of key pollutants drops significantly. The key point is that it is beyond the scope of this study to identify the role soil plays in further processing these wastes prior to them entering the freshwater system. Differences between sites are likely to be large so further investigation would be required if setting binding policy.

- While the potential mitigation costs could run into the tens or even hundreds of millions of dollars, it is difficult to draw any region-wide conclusions on the impact of proposed bottom lines on the municipal and industrial sectors. To do so, further data on contaminant discharges, facility standards and upgrade requirements and costs would be necessary across the region.

5.3 Limitations

155. This study is a first step in understanding the effects of water quality limits on municipal and industrial water values. The study is limited by the available data, the time required to prepare this report plus the limited number of other studies in New Zealand that have focused on these issues. The key limitations to this study are as follows:

- In the absence of specified water quality standards, a definitive impact has not been able to be estimated. The study does not directly assess the impact of achieving a specific water quality objective or proposed bottom lines. Once policy is set and the standards determined it will be necessary to repeat aspects of this study to determine the actual effect of those limits on Invercargill and Winton or similar communities nationally.
- Where practical, the case studies have been generalised to ensure they have meaning when applied more widely than the actual study area. This means that some specific characteristics of the study areas may not have been taken into account. The effect of this is that the findings must be seen as a general outcome – accurate specific studies of these areas will be needed once actual limits and standards have been set.
- Currently there is no way of identifying in the Winton situation the relative contributions of the commercial or industrial discharges from the residential ones. This makes modelling meaningful change impossible as it is not possible to isolate these specific discharges.
- In respect of Invercargill's water supply, there are potentially reductions in processing costs associated with higher freshwater quality standards. The estimation of the effects of those are beyond the scope of this report, they are not known as they will be specific to the standards themselves.
- In terms of quantity of water, Invercargill currently losses around 25 per cent to leakage or is unaccounted for. This is more than enough to cater for growth. What is not clear, is the costs involved in reducing that leakage relative to sourcing new water supplies (such as Lake Hauroko).
- Where possible the most likely solution to treating wastewater and stormwater is to target the key pollutants that have the greatest impact on both the freshwater networks and the Coastal Marine Environments (these being nitrogens and phosphorous), rather than looking to address every pollutant equally. It is likely that other treatment system options exist, than covered in this report. This study does not pretend to be exhaustive in terms of the solutions assessed.
- Throughout this study, estimates of cost are simply based on dividing the total cost stream over time by the numbers of likely ratepaying units (households plus businesses). This study assumes all financial and capital costs are funded through loans and paid off through rates. This study takes no account of the wider range of funding options open to local governments including rates differentials, development contributions, grants and so on. Utilising a mix of these funding mechanisms is the likely approach councils will take and will have a significant bearing on the results.
- This study takes no account of households ability to pay or any affordability aspects of these modelled changes nor any account of the distributional effects of new charges.
- This study has not identified the potentially positive effects of new investment in infrastructure in Southland that might flow from quality limits in terms of additional construction sector activity.

Section 6: Non-market values

This section presents the analysis and discussion of the non-market values that individuals and communities hold for freshwater in Southland. Non-market values are those that are not usually expressed in monetary terms or associated with commercial activities from which monetary values can be derived.

The total marginal impact is unknown as not all values could be quantified. The results indicate that, for the values that could be quantified, improved water quality would result in a marginal benefit for recreational use (fishing, swimming and kayaking) and existence value of between $0.1 and $2.3 million per year.

Whilst the quantified marginal benefit appears to be relatively small, it does not include the marginal impact on a number of significant non-market values, including ecosystem health and diversity, aesthetics and amenity, and cultural and spiritual values (including unique Māori values) that have not been quantified due to data limitations.

As the latter values are greater in scope than the values of recreation and existence values quantified, and as they are likely to be positively correlated with improved water quality, it can reasonably be expected that these values would have marginal benefits that significantly exceed those quantified. Therefore, total marginal benefit of improving water quality would be significantly greater than estimated results.

6 Non-market values

156. This section presents Covec's analysis and discussion of the non-market values that individuals and communities hold for fresh water in Southland. This is a first step in assessing the marginal impact of improved water quality on non-market values in Southland. Non-market values are those that are not usually expressed in monetary terms or associated with commercial activities from which monetary values can be derived. They include recreational uses, scenic qualities, food gathering and the values that people place on natural environments just because they exist.

157. Whilst the marginal benefit to non-market values from improved water quality appears to be relatively small, it does not include the marginal impact on a number of significant non-market values, including aesthetics and amenity, ecosystem health and diversity and cultural and spiritual values that have not been quantified due to data limitations. As the latter values are greater in scope than the small proportion of values quantified, and as they are likely to be positively correlated with improved water quality,[23] it can reasonably be expected that these values would have marginal benefits that significantly exceed those quantified.

158. Moreover, the non-market values study results are based on improvements to water quality resulting from uniform nutrient discharge caps at farm level[24]. This scenario meets the bottom line for ecosystem health and results in maintained or improved ecosystem health in rivers overall. This scenario does not meet the bottom line for human health at a small number of sites, but results in improvements in *E. coli* levels overall. As it is likely that an improvement in *E-coli* leads to an increase in non-market values for recreation and kayaking, it is expected that meeting the bottom line for human health at all sites would result in a greater non market benefit.

159. Therefore, the total marginal benefit of improving water quality would be significantly greater than the preliminary results presented in this report.

[23] Aesthetics, ecosystem health and cultural uses are likely to increase as water becomes cleaner.

[24] Other scenarios were not analysed due to time constraints.

160. It is important to recognise non-market values as a significant influencing factor in community based decision-making on the trade-offs between environmental and economic impacts of freshwater management. However, communities may face challenges in quantifying the marginal impact of maintaining or improving water quality on non-market values as it is technically difficult and resource intensive. It is also difficult to quantify and assess marginal impacts on unique Māori values such as reciprocity, knowledge and cultural identity. While the approach could be used to support community based decision-making, communities will require subjective assessments of values that cannot be quantified.

161. Fresh water is recognised as one of New Zealand's key economic assets. However, water quality is declining in some catchments, which could result in potential environmental and public health impacts, and potential risks for future direct economic uses of water (eg, agriculture, electricity), as well as non-market values of water. Non-market value is a 'catch-all concept' that captures all water values that are not associated with the direct economic use of water, ie, the values of water that are not traded in a market and are not readily valued in monetary terms.

Table 10: Non-market values attributed to water

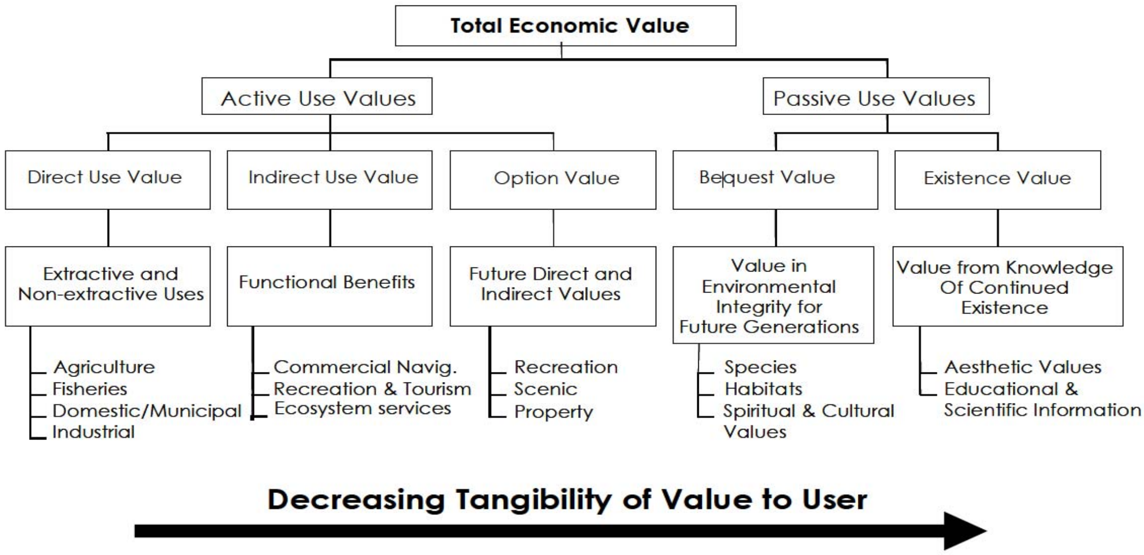
Non-market value of water	Description and examples
Recreational and cultural use values	Swimming, fishing, canoeing, kayaking, mahinga kai, hiking and picnicking along a waterway.
Option values	Potential for future economic uses (eg, manufacturing) and recreational uses.
Existence values	Value from knowledge of continued existence (eg, aesthetic values, ecosystem health and biodiversity (water purification and soil cycling)).
Bequest values	Value in environmental integrity for future generations (eg, cultural values).

162. Māori values include both market and non-market values. This study focuses on non-market Māori values associated with water in order to provide a complete picture of the non-market values of water in New Zealand. Māori have strong associations with water bodies based on social, cultural, economic and spiritual world-views. This relationship gives rise to distinct interests in respect of fresh water. Māori values related to water such as whakapapa (genealogy), mauri (life supporting capacity of water), and mahinga kai (food and resource gathering) may be valued differently by individual iwi.

163. There are challenges in integrating Māori values, as with all cultural and spiritual values, into microeconomic frameworks that assess the impact of changes in water quality. While there is some overlap between Māori values and non-market values captured by the TEV framework used (explained below), there are unique Māori non-market values of water which are not reflected and are difficult to quantify.

164. This study feeds into the overall TEV framework which identifies and quantifies (where possible) the impacts of water quality limits across economic, environmental, social and cultural water values. Figure 17 presents the framework with a focus on non-market values. The categories considered in the non-market study are all values except the direct market use values.

Figure 17: Total Economic Value Framework for non-market study



6.1 Method

6.1.1 Informational inputs

165. This study takes inputs from the hydrological modelling undertaken by Aqualinc and NIWA that estimated the impacts of water quality limits at 73 different locations in Southland.

6.1.2 Analytical method

166. The approach used to estimate the marginal impacts of improving water quality on non-market values is a first step in linking a change in water quality outcomes to non-market values.

167. In this study Covec uses scenarios of changes in water quality and:

- identifies the components or attributes of water that enable it to be used or that provide direct value. For example, this would include water clarity, the presence of certain fish species and the absence of pathogens that cause health problems for swimmers. The relationship between changes in water quality and these valued attributes is estimated
- identifies non-market values for water and the way in which these values change as a result of changes in water quality. These are marginal values, expressed as how total value changes as a result of a small change in a factor that affects that value, for example the change in recreational value of one more metre of water visibility
- compiles and makes use of Southland data that enables combination of the generic values (applicable to water bodies throughout New Zealand) with the results of the Southland scenario analysis to estimate effects in Southland. For example, this includes data on current levels of recreational activity, and
- combines the different components to estimate the effects on non-market values.

6.1.2.1 Using the TEV framework

168.The TEV categories are:[25]

- Active use and passive use values, where:
    - *active use* values derive from actual use of the water resource via extraction (eg, for irrigation) or for in-stream use for recreation or simply as a back-drop for other activities beside the river. In other words, the physical presence of the water is vital to the realisation of the value. In contrast
    - *passive use* values are values that pertain more to the fact of existence of the water resource.
- Amongst active use values there are those that derive from:
    - *extractive* use of the water that involves taking the water out of the river. This includes use of water for agriculture (irrigation or stock water), municipal use (drinking water and other household uses), industrial use. Hydro-electricity is also included here
    - *in-situ use* where the water resource may be used directly (eg, swimming) or indirectly (eg, recreation beside the river)
    - *option values* which represent the value of retaining an option to use a resource in the future.
- Passive use values, which are independent of the individual's present use of the resource and are variously described as "existence value", the value from knowing that a particular environmental assets exists (eg, endangered species); and "bequest value", the value arising from the desire to bequeath certain resources to one's heirs or future generations (eg, habitat preservation).

169.In practice people have difficulty in separating out some of these different elements of value including the components of passive use and the difference between passive use and option values. For practical reasons we group these categories together under the catch-all of existence value. Thus Covec examine:

- *in-situ use values* – recreational and other uses of water at a particular site
- *existence values* – values that do not require a person to be present at the site.

170.Despite identifying the different elements of value, studies do not exist that enable us to quantify all of them in monetary terms.

171.The TEV concept isolates individual elements of value. In reaction to this approach, it has been suggested to use that Ngāi Tahu see the value of the environment more holistically with values being interlinked and would not differentiate extractive resource use, or its effects, from the other use values because any use can have associated non-market values to both whānau and hapū. This is likely to apply to many other people also. The TEV approach is not attempting to describe how people think about the values of water bodies; most people do not isolate the individual values obtained. What the TEV approach is suggesting is that, if one factor is changed (eg, the ability of

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[25] Although the categories are changed somewhat, the descriptions are taken largely from Sharp and Kerr, Option and Existence Values for the Waitaki Catchment and EVRI (2009) in Nimmo-Bell (2009) Biodiversity Valuation Manual. A technical manual for MAF BNZ.

the water body to provide water for irrigation), but nothing else changes, there is a loss of total value of the water body.

6.1.2.2 Māori values

172. Māori have some additional and distinct values as recognised under the Treaty of Waitangi. There is a legal requirement to address these values in decision-making under the Resource Management Act, the Local Government Act and the Conservation Act.

173. For Ngāi Tahu the values associated with water are numerous and relate directly to many core Ngāi Tahu values. Some of these values are likely to be shared by other whanau around the country. These associations show how fundamentally important water is the Ngāi Tahu as a taonga. Specifically for Ngāi Tahu as tāngata whenua of Southland, Covec concentrate on the following values that result in different or additional values to those discussed with respect to TEV:

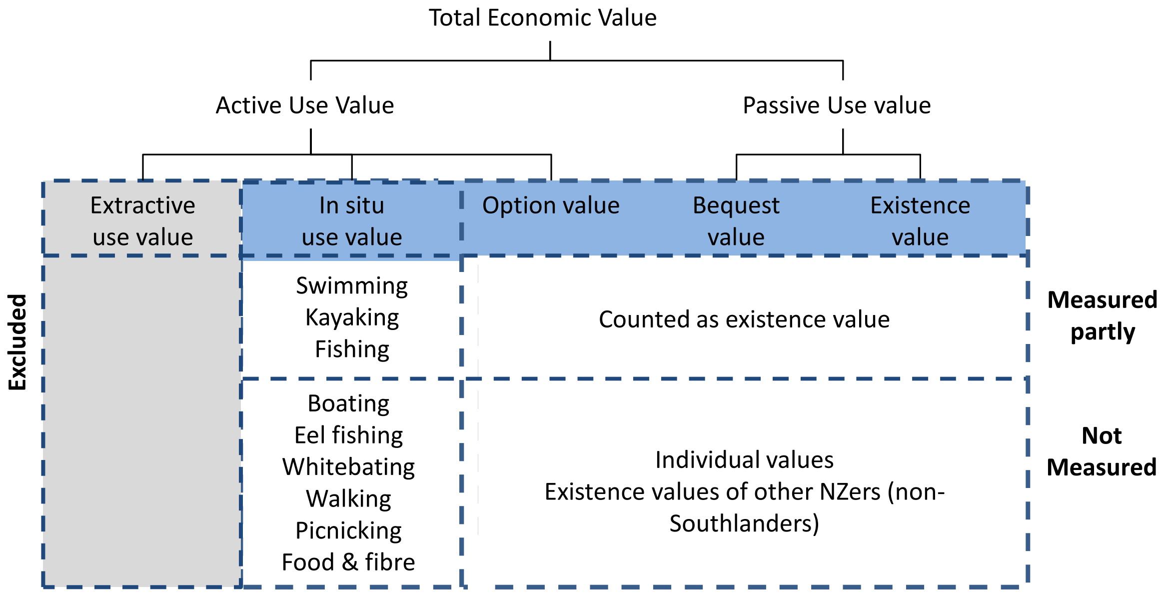
- The concept of *reciprocity* in which anything taken (food or other resources) is balanced by giving. This means that there is a requirement for restoration to ensure the on-going functioning and wholeness of the environment. This concept is based upon elements of the Māori values of Kaitiakitanga, Mahinga kai, Mauri and Whānaungatanga. Failure to look after the local environment may be seen as a loss of mana. Any deterioration in quality may be reflected in the inability to produce traditional food or other resources iconic to a local environment.
- The importance of *knowledge* (*mātauranga*) and the sharing of it with future generations (whakapapa). Management and use of water, and the relationship with the water body, provides resources for the group but also builds knowledge and provides educational experiences that can be passed on to future generations. Thus there is a marginal increase in knowledge with an increase in water quality because there is an increase in the opportunities for use of a resource that yields opportunities for education.
- The importance of specific environment and its use to the *cultural identity* of the group. Whānau and hapū are defined with respect to the environment and resources that they relate to, whereby the loss of ability to use a resource reduces their identity as a group.

174. These concepts would be expected to result in Māori holding and expressing a greater value for sustainable use of water or enhancement of water quality.

6.1.2.3 Applying the TEV framework

175. There are a number of components of the TEV which haven't been measured (or only partially addressed) because of challenges associated with collecting suitable information or data, as illustrated in Figure 18.

Figure 18: Components of TEV included in the study



Source: Adapted from Sharp B and Kerr G (2005) Option and Existence Values for the Waitaki Catchment and EVRI (2009) in Nimmo-Bell (2009) Biodiversity Valuation Manual. A technical manual for MAF BNZ.

176.Covec estimates values for some recreational uses of water bodies, and specifically fishing, kayaking and swimming, but have not provided values for others including whitebaiting, boating or walking/picnicking. They also do not have estimates of the value of Mahinga kai (traditional food) or other food gathered from water bodies, or of fibre, eg, flax.

177.Option values are not included specifically, but as noted above, Covec did not attempt to differentiate between option and existence value, or between existence values and bequest values. Existence values measured include the values accruing to Southlanders, but not to other New Zealanders.

178.The additional values noted by Māori would be expected to result in greater preferences for (and valuations of) existence and of sustainable uses of water that provide for the passing on of knowledge and/or maintain cultural identity. Thus they will be taken into account to some extent in surveys used to obtain values.[26] The legislative requirement to address these values does not change the values, but suggests that they are considered separately from the valuation exercise discussed in this report.

6.2 Key findings

179.The analysis undertaken for Southland estimated the marginal impacts of improving water quality for a limited number of non-market values of fresh water, including recreational values of fishing, swimming, kayaking and existence value, as baseline information on these activities was available. Other significant non-market values including aesthetics and amenity, ecosystem health and diversity and cultural and spiritual values have not been individually analysed due to data limitations, but these are partly covered in existence value. Results for non-market values examined are presented in Table 11.

[26] Covec did not have data on the separate existence values of Māori which might, for example, be used to weight the values to represent the Māori population in Southland versus the study sites. However, views and preferences may differ between Māori populations in different parts of the country, but so will the preferences of all people.

180.The total marginal impact of improved water quality on non-market values is unknown as not all values could be quantified. The results indicate that, for the values that could be quantified, improved water quality would result in a marginal benefit for recreational use (fishing, swimming and kayaking) and existence value of between $0.1 and $2.3 million per year in 2037 (in 2012 dollars). The findings indicate that non-market values of water generally increase (for all except fish numbers[27]) as water quality improves with the implementation of nutrient discharge caps.

181.That the marginal benefit of improved water quality appears to be relatively small is contributed to by three key factors:

- The water quality improvements modelled in the farm-level and hydrological water quality modelling studies has resulted in only very incremental improvements to the water quality in rivers.
- The results are based on improvements to water quality resulting from uniform nutrient discharge caps at farm level[28], which represents only an incremental improvement in water quality. This scenario meets the bottom line for ecosystem health and results in maintained or improved overall freshwater quality. This scenario does not meet the bottom line for human health at a small number of sites, but results in improvements in *E. coli* overall. As it is likely that an improvement in *E. coli* leads to an increase in non-market values for recreation and kayaking, it is expected that meeting the bottom line for human health at all sites would result in a greater non market benefit.
- Moreover, this study has not been able to include the marginal impact of improved water quality for a number of significant non-market values, including ecosystem health and diversity, aesthetics and amenity, and cultural and spiritual values (including unique Māori values[29]) that have not been quantified due to data limitations. As the latter values are greater in scope than the values of recreation and existence values quantified, and as they are likely to be positively correlated with improved water quality (eg, aesthetics, ecosystem health and cultural uses are likely to improve as water becomes cleaner), it can reasonably be expected that these values would have greater marginal benefits than those quantified.

Therefore, the total marginal benefit to non-market water values of improving water quality would be significantly greater than the preliminary results presented in Table 11.

[27] At low levels of periphyton, increased periphyton can result in increased trout density. The tipping point is currently unknown.

[28] Other scenarios were not analysed due to time constraints.

[29] Covec (2013) worked closely with Ngāi Tahu in Southland to understand Māori values associated with fresh water. For Ngāi Tahu, and potentially other iwi, there are three uniquely iwi values related to water, which have been identified as additional to the non-market values captured by the overall theoretical framework. These values are: reciprocity; knowledge gained from sustainable use; and cultural identity associated with water bodies.

Table 11: Impact of an improvement in water quality associated with the non-uniform cap scenario on non-market values

Non-market values		Marginal Impacts of Improved Water Quality resulting from Uniform Nutrient Discharge Caps			
		Scenario Set B ($m)	Scenario Set C ($m)	Scenario Set D ($m)	Scenario Set E ($m)
Recreation value	Benefit to water clarity for fishing	$0.1 to $0.2	$0.3 to $0.7	$0.3 to $0.7	$0.5 to $1.1
	(Potential) cost in terms of fish numbers	-$0.1 to $0.0	-$1.2 to -$1.0	-$1.4 to -$1.2	-$2.4 to -$2.2
	Benefit to swimming visits	$0.1 to $0.4	$0.0	$0.0 to $0.1	$0.1 to $0.3
	Benefit to kayaking visits	$0.1 to $0.1	$0.0	$0.0	$0.0
	Benefit to other recreation	*Not assessed quantitatively*			
Existence value	Benefit to existence Value (includes some option value)	$0.3 to $0.6	$1.0 to $1.8	$1.0 to $1.9	$1.7 to $3.2
	Benefit to aesthetics and amenity values	*Not assessed quantitatively but may be included partially in existence Value*			
	Benefits to current ecosystem health and biodiversity	*Not assessed quantitatively but may be included partially in existence Value*			
Cultural & spiritual values	Benefits to current cultural and spiritual activities, including unique Maori values	*Not assessed quantitatively*			
Bequest value	Benefits to future ecosystem health and biodiversity	*Not assessed quantitatively but may be included partially in existence Value*			
	Benefits to future cultural and spiritual values, including unique Maori values	*Not assessed quantitatively*			
	Sub-total of marginal change *(incomplete – as only some marginal impacts assessed quantitatively)*	**$0.6 to $1.2**	**$0.2 - $1.2**	**$0.1 - $1.2**	**$0.2 - $2.3**
	Sub-total of marginal change (ignoring fishing days) *(incomplete – as only some marginal impacts assessed quantitatively)*	**$0.6 to $1.3**	**$1.2 to $2.4**	**$1.3 to $2.6**	**$2.4 to $4.7**
	Total marginal change to non-market value of water	Unknown and likely to be far greater than estimates of this study			

Key Findings

1. **This study is a first step in assessing the marginal impact of maintaining or improving water quality on non-market values.**
2. **Total marginal impact is unknown** due to data limitations.
3. **Benefits to fishing, swimming kayaking and existence values range from $0.1m to $2.3m per year in 2037 (in 2012 dollars).**
4. **Whilst the marginal benefit appears to be relatively small,** it is based on quantifying the impact of an *incremental* predicted water quality improvement, and does not include the marginal impact on a number of significant non-market values, that have not been quantified due to data limitations.
5. **Total marginal benefit would be significantly greater than the results presented** as it can reasonably be expected that the unquantified values are likely to be positively correlated with improved water quality.

6.3 Limitations

182.The analysis is limited in its scope because there are significant gaps in data and a number of simplifying assumptions. Data gaps include the following:

- values of water are missing for a significant number of categories of TEV. This includes several recreational uses, option values applied to other use categories (including extractive use), and existence values for southland rivers for people outside of Southland
- relationships between changes in water quality and changes in factors that are valued. For example, we do not know how the water quality changes will affect whitebating or eel fishing
- the limitation of the analysis to the rivers and streams included in the modelling by NIWA and Aqualinc. This ignores the impacts on estuaries and other wetlands where nutrients and other contaminants may accumulate
- distinct values expressed by Māori – although Covec have identified some differences, they are unable to quantify them.

6.3.1 Māori values

183.The report notes three distinct differences that apply to Māori values of water bodies. These are the changes to value as a result of reciprocity, knowledge gained from sustainable use and cultural identity from management and use of the water resource. These would be expected to result in increased expressions of existence value and the values of other activities consistent with sustainable use of water. These additional values are taken into account to some limited extent via Māori participation in surveys that have produced measurements of value, but they have not been isolated. The legislative requirement for separate consideration of Māori values is a separate issue from valuation; it has implications both for approaches to decision making and partnership processes that go beyond the issues discussed in this report.

6.3.2 New Zealand's reputation risk

184. Covec has not analysed any impact on New Zealand's reputation for its pristine environment as a result of impacts on water quality. This is always a difficult consideration when assessing marginal changes in environmental values at a specific site, as the reputational impact is likely to be cumulative as a result of numerous impacts in different locations. However, it is noted that this is an unvalued component in this study.

6.3.3 Uncertainty

185. In addition to the data gaps there are uncertainties associated with all of the values used. In all cases the values used have been transferred from different sites in different parts of New Zealand. In particular, it was assumed that the values will transfer to other rivers and to different communities. There are a number of limitations that result from such a benefit transfer process. In particular, the rivers are not the same as those at the study sites from which the values have been obtained, and the communities are different also. The results are based largely on values obtained from stated preference studies that often suffer from hypothetical bias in which people over-state their willingness to pay compared with what they would actually pay.

Section 7: Electricity generation

This section describes the potential nature and scale of economic impacts on electricity generation if hypothetical minimum flow requirements were imposed on selected rivers.

If councils and communities implement or increase minimum flow requirements, then actual costs will depend on a range of factors including: the size of any minimum flow imposed, the location of the minimum flow on a particular scheme and the unique characteristics of the river.

For Southland's Manapouri scheme, increasing current consented minimum flows for the lower Waiau has a relatively small marginal impact on electricity generation as the current consented flows are low compared with natural minimum flows.

It is critical to note that the marginal change assessed within the report on the electricity sector is in terms of changes to availability of water quantity, rather than a change in water quality. As such, the findings of this report stand alone, and cannot be considered alongside the impacts identified in the parallel studies.

7 Electricity generation

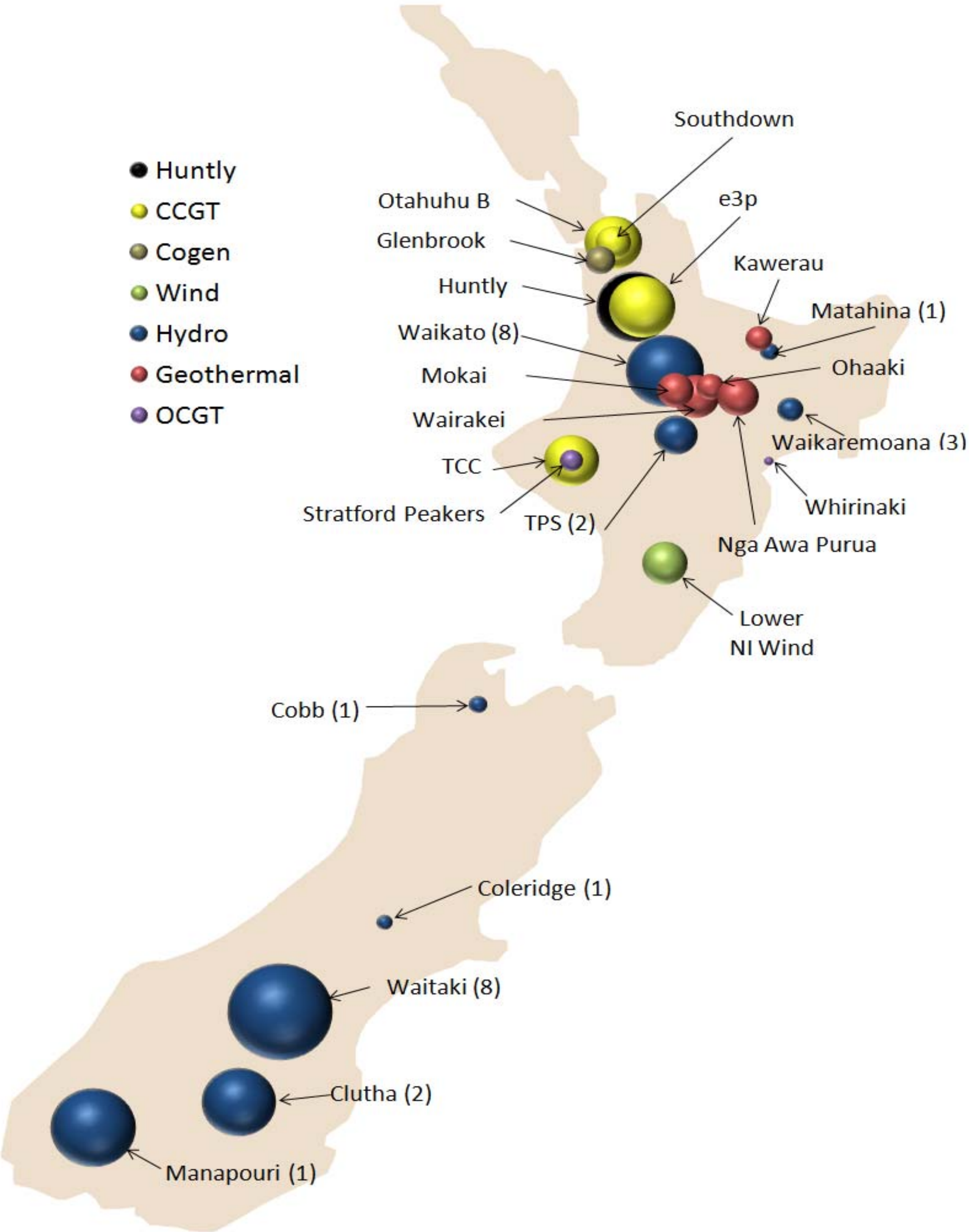
186. The report carried out by Concept Consulting describes the potential nature and scale of economic impacts on electricity generation if hypothetical minimum flow requirements were imposed on selected rivers. It is critical to note that the marginal change assessed within the report on the electricity sector is in terms of changes to availability of water *quantity*, rather than a change in water *quality.* As such, the findings of this report stand alone, and cannot be considered alongside the impacts identified in the parallel studies.

187. The National Policy Statement for Freshwater Management requires regional councils to set freshwater objectives and water quality limits. It is conceivable that regional councils may consider imposing minimum flow regimes on selected rivers in order to meet these objectives. Consistent with the overall TEV approach, this study seeks to test potential scale of economic impacts from hypothetical minimum flows on selected rivers. These economic impacts can be aggregated to give a preliminary indication of potential national level impact if amending minimum flows.

7.1 Electricity in New Zealand

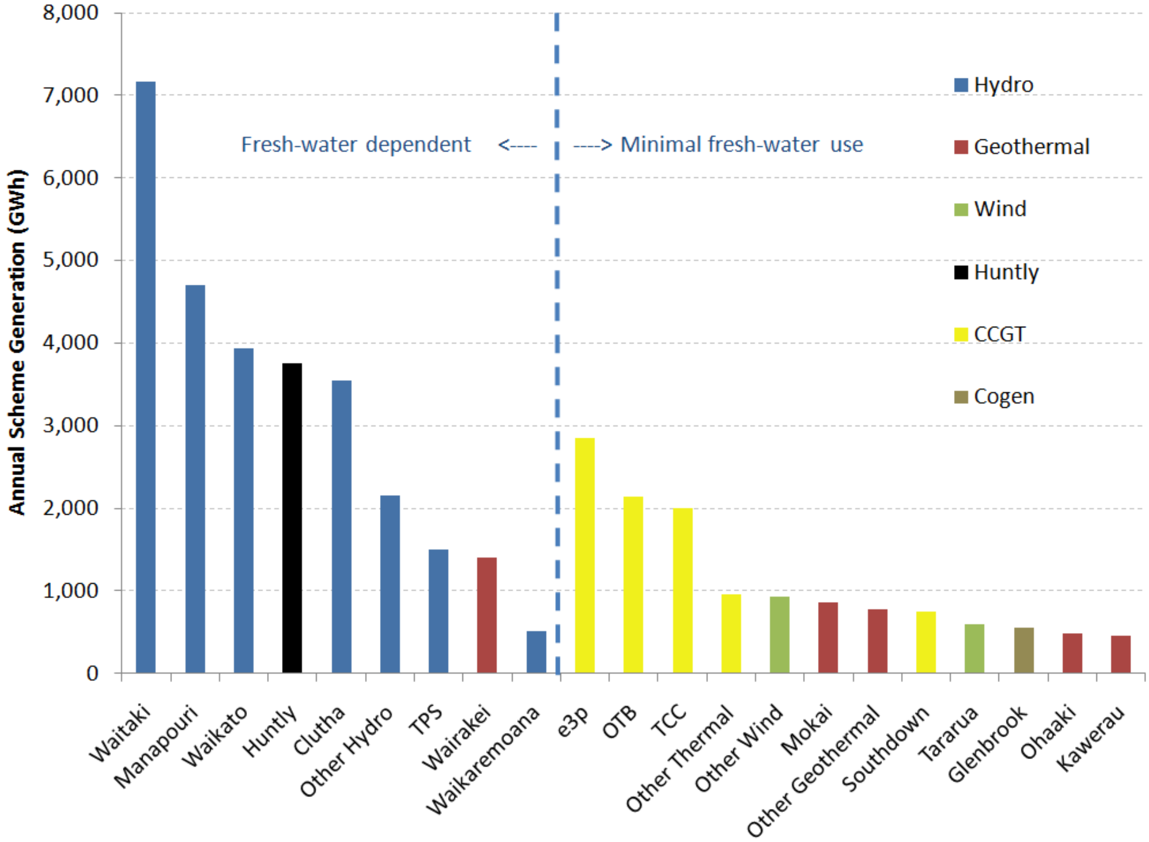
188. New Zealand's electricity is generated by a variety of renewable and fossil-fuelled power stations. Figure 9 shows the location of the main power stations in New Zealand.

Figure 19: Location of main generation schemes in New Zealand[30]



[30] The size of the circle indicates the average annual amount of electricity generated by the scheme. For hydro generation, the number of individual stations is shown in brackets.

Figure 20: Average annual generation categorised by fresh water dependence



In addition to hydro stations, fresh water is also critical to the operation of some of New Zealand's thermal and geothermal power stations where it is used as a cooling source.[31]

[31] Thermal stations work by heating and cooling a fluid (usually steam), and extracting useful energy from the fluid's change in temperature. The larger the temperature difference, the more efficient the plant will be. Access to a source of cooling is therefore important. This can be provided by the atmosphere (air cooling) or a river, lake or sea (water cooling). From an energy efficiency perspective, water cooling is generally preferred because of water's higher heat capacity.

189. Figure 20 shows the average annual generation of power stations grouped into those that are dependent on fresh water, and those that are not.[32]

190. On average, approximately three-quarters of all electricity generated in New Zealand is dependent on access to fresh water, and hydro-electric stations alone account for 60 per cent of total power production.

191. While New Zealand's hydro generation schemes share the same basic technology, there is significant variation in many key characteristics including:

- size (being a function of the head of the scheme, the volume of water available for generation, and the capacity of stations in the scheme)
- the amount of hydro storage in each scheme
- the timing of typical within-year hydro inflows into the scheme[33]
- whether the scheme consists of a single power station, or a chain of interconnected power stations
- the extent to which water is diverted from one river to another to increase hydro generation
- the electrical 'location' within the national grid
- the specific ecological characteristics of the river system (noting that there can be significant differences in flora and fauna, and the volume and variability of flows along the river)
- other specific environmental factors including tāngata whenua, cultural, amenity, recreational, landscape and natural character values, and
- the nature and scale of other potential uses for water in a catchment.

192. One of the consequences of such diversity of characteristics is that the consents governing the use of such water for electricity generation are themselves very diverse to reflect the situation-specific nature of the water bodies. The situation-specific complexity of the issues, coupled with the extensive community and science-based consultative nature of the consenting process, results in consent conditions which often run to hundreds of pages in length, and which cover a range of ecological, cultural, recreational, and economic requirements and phenomena.

Southland electricity generation – Manapouri power scheme

193. The Manapouri hydro station diverts water from Lake Manapouri through the power station and tailrace tunnels to Deep Cove. Subject to water quality (turbidity), water is also diverted into Lake Manapouri from the Mararoa River. Lakes Te Anau and Manapouri provide storage. Figure 21 illustrates the scheme, including showing where water is diverted away from original water-ways into the scheme, and which points in the scheme are currently subject to minimum flow requirements. Notably, all of Manapouri's generation capacity comes from consumptive flows.

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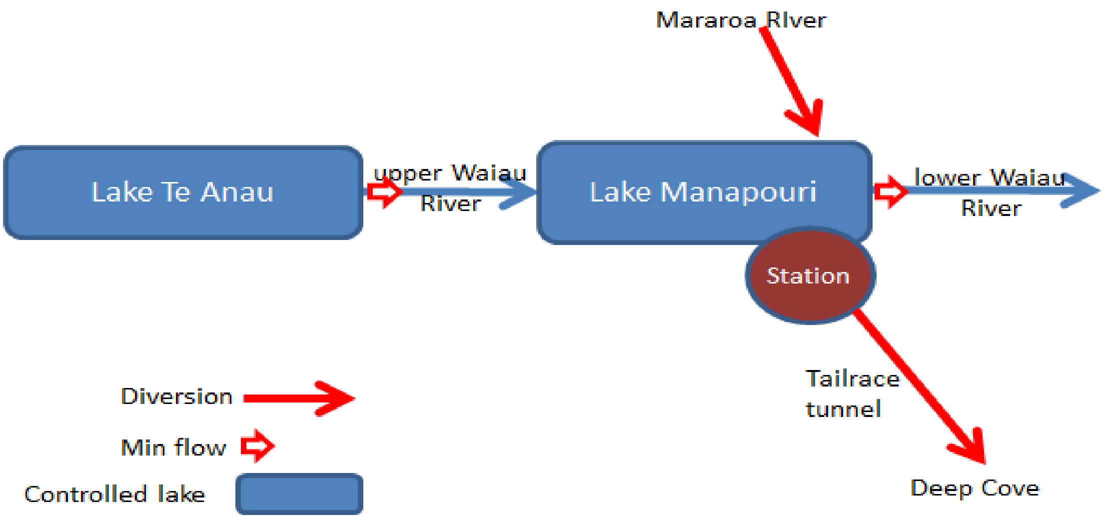
[32] The 'water dependent' list only includes hydro generation stations and thermal or geothermal stations that use fresh water for cooling purposes. Other thermal stations may require fresh water for use in boilers, or for water injection. While still significant, the volume of water required for these uses is much less than for cooling purposes, and these stations have not been classified as 'water dependent' in the chart.

[33] For example, Waikato monthly inflows are broadly correlated with national demand in that highest inflows tend to occur in the winter months, whereas Waitaki inflows are more anti-correlated with demand as the winter months tend to have the lowest inflows.

Figure 21: Schematic of Manapouri hydro scheme



194.The management of Manapouri storage and generation is constrained by complex lake operating rules (which aim to mimic natural lake level patterns over time), relatively small lake operating ranges compared to inflows, which can be very volatile, and minimum flow requirements in the Waiau River. Water from the Mararoa River is also diverted into Lake Manapouri provided water quality (turbidity) meets requirements.

7.2 Method

195.A scenario-based approach has been adopted to evaluate the potential electricity sector outcomes from altered minimum flow regimes. Specifically a sample of eight hydro schemes was selected for examination, and, where possible, the same type of altered minimum flow requirements was modelled for each scheme. The eight schemes selected account for approximately 93 per cent of New Zealand's hydro generation, plus they span the range of different hydro scheme characteristics in terms of: scale (large to small), storage capabilities, numbers of stations along the river, and water sources.

196.Modelling was undertaken for each scheme to determine the likely outcomes that would occur from altering the minimum flows in the rivers associated with each scheme. The modelling was done on a scenario basis, with similar altered minimum flow scenarios applied to each scheme. Two types of scenario were considered:

- Increasing minimum flows above existing consented levels by a set percentage (10 per cent or 40 per cent). In some cases such scenarios were infeasible given the physical characteristics of the scheme.[34] Accordingly no model runs were done for such situations.
- Setting minimum flows at a fixed percentage of natural minimum flows (40 per cent or 80 per cent). In some cases this would have resulted in a reduction in minimum flows relative to the current situation. Accordingly, such instances were not included in the study.

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[34] Situations where increasing minimum flows would be infeasible are where minimum flows at a point in the river are already close to natural minimum flow levels, and the scheme does not have large amounts of storage which can be used to raise minimum flows above these natural levels. This applied to minimum flows at the bottom of the Clutha (hence only altered minimum flows further up the Clutha scheme were considered), and the Waikato scheme.

7.2.1 Analytical method

197.Two different approaches have been adopted to estimate the cost to the New Zealand electricity system of the hypothetical minimum flow outcomes modelled by the generators:

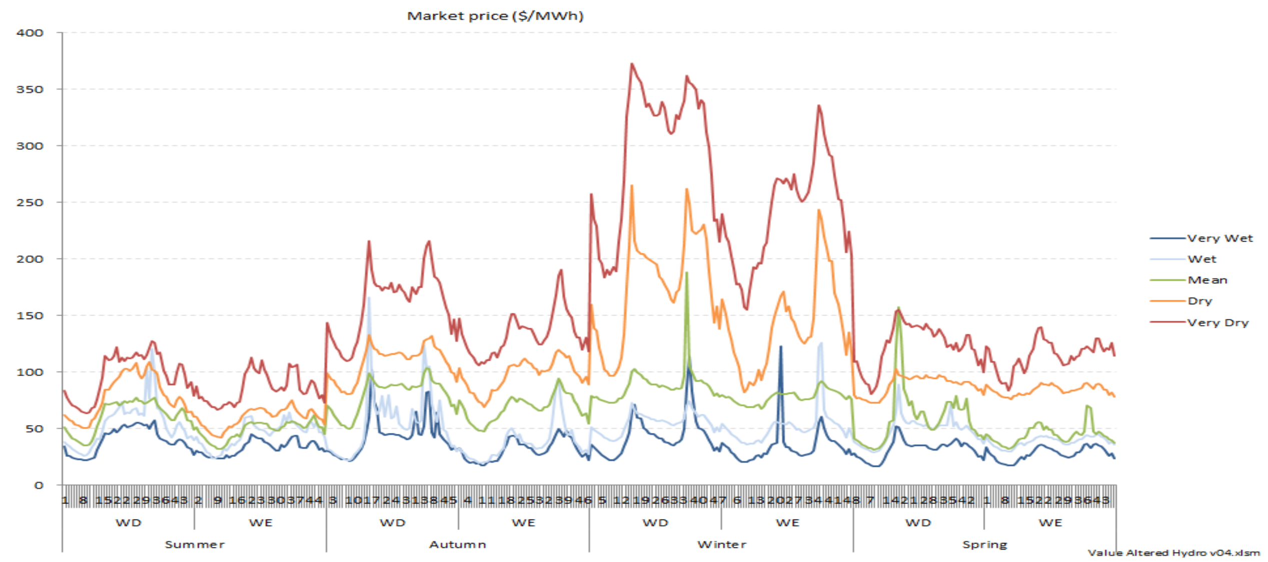
- A market price-based approach.
- Residual non-hydro generation cost-based approach.

7.2.1.1 Market price-based approach

198.Modelling undertaken by the generators has produced projections of altered quantities of hydro generation (based on minimum flow requirements) for different times of the day and year, and for different hydrology states (very dry, dry, mean, wet, very wet). The market price-based approach has been to value this altered quantity outcome at the market price associated with the particular time-of day and year and hydro state. For example, the loss of 1 MWh of hydro generation during the middle of the night during a very wet summer will be valued significantly less than 1 MWh of hydro generation lost during the evening peak during a very dry winter.

199.Figure 22 below shows the array of market prices used to value such altered hydro generation outcomes. This price array has been derived from the observed historical distribution of prices associated with different times of day and year, and different hydrological states for the years 1998 to 2011. However, it has been artificially factored to ensure the time-weighted average price across all such periods equals $85/MWh which is estimated to be the approximate long-run marginal cost of new baseload generation at the present time. This price-based approach is considered to be a reasonable estimate of the resource cost implications of losing (or indeed gaining) a MWh of hydro generation at different times of the day and year and for different hydro states – although probably a lower bound. A fuller description of why it is believed likely to be a lower bound is included in the limitations section.

Figure 22: Synthetic market price array used to value altered hydro generation outcomes ($MW/h)



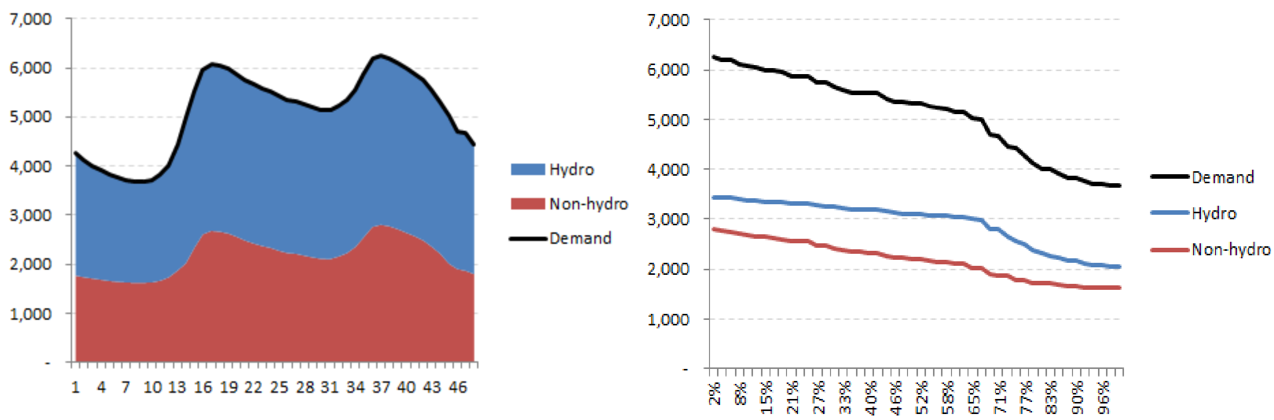
7.2.1.2 Residual non-hydro generation cost-based approach

200.The second approach has been to estimate the likely impact of altered hydro generation profiles on the requirements for non-hydro plant – both in terms of altered operations (and hence altered fuel burn, carbon dioxide and other variable costs), and altered investment (and hence capital and fixed operating costs). A simple approach has been undertaken to achieve this based on the concept of the 'residual demand' for non-hydro plant. This approach is as follows:

- The modelling framework considers typical within-day profiles of demand and hydro generation for business days and non-business days for each of the four seasons, as well as distinguishing between five different hydro inflow states (Very Wet, Wet, Mean, Dry, Very Dry) based on national inflow sequences. Each hydro state is a quintile of the overall population of historical inflow series.
- A hydro state has been assigned to each historical season (ie, Summer, Autumn, Winter, Spring) rather than a historical year. This is because, as set out above, New Zealand has limited seasonal hydro storage capability. Accordingly, dry and wet events are most significant when measured over a timescale of three to five months, rather than over a period of a year.
- This combination of different demand and hydro generation profiles for the different days and hydro states are combined to produce a residual non-hydro demand duration curve.

201.Figure 23 shows the concept of how a residual non-hydro demand duration curve is constructed.

Figure 23: Illustration of how to determine residual non-hydro duration curve



202.A change in hydro generation for a particular scheme can be fed into this framework in order to estimate the change in the residual demand for non-hydro generation, and thus the impact of such altered hydro generation outcomes on the wider New Zealand system. The cost of these altered requirements for non-hydro generation are calculated as follows:

- Changes in the amount of baseload non-hydro generation required are valued at the long-run marginal cost of such baseload generation – the central estimate of which is $85/MWh.
- Changes in the amount of non-hydro peaking generation required are valued as follows:
  - The carrying cost associated with requiring a greater amount of peaking capacity on the system is valued at $145/kW/yr. This is an estimate of the levelised capital and fixed operating and maintenance (O&M) costs associated with a new OCGT.

- The variable costs of increased GWh of peaking operation are based on the variable O&M plus fuel and CO_2 costs of such generation.

- Changes in the amount of non-hydro mid-merit generation are predominantly costed on a variable cost basis, being the average of the fuel and CO_2 costs of a gas-fired CCGT and the coal-fired Huntly power station. Any increase in the amount of capacity required for mid-merit generation is assumed to be met through building a new OCGT, rather than a new CCGT.

Potential Impact on consumer prices

203. The impact on electricity consumers was also considered. This impact differs from the economic efficiency cost. This difference arises because consumers would not only pay a higher price for any new generation that is required. They would also be likely to pay higher prices for other existing generation over time.[35]

204. The key driver of this price increase is the fact that each successive new baseload generator that is built is likely to be slightly higher cost than the previous generator.[36]

7.2.2 Informational inputs

205. The prime source of information for these inputs has been modelling work undertaken by the five major generators – Contact, Genesis, Meridian, Mighty River Power and TrustPower. Data points are from a combination of publically available hydrological inflow information and pricing information as well as proprietary information on generation scenarios as determined by the electricity generators.

206. The modelling exercise consisted of two main parts:

- Firstly, the owners of the schemes (namely the five main generators in New Zealand), each undertook modelling of the likely altered pattern of generation for their individual schemes as a result of the altered minimum flow scenarios.
- Concepts then modelling the potential electricity system costs arising as a result of these altered generation patterns.

7.3 Key findings

207. The analysis in this study demonstrates that increasing the minimum flow requirements on rivers used for electricity generation will impose costs on the electricity system.

208. Such costs will primarily arise from two main phenomena:

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35 This phenomenon is common to most goods and services in the economy. For example, if the cost of constructing new houses were to increase, this would be expected to feed through to the price of new houses and existing houses over time.

36 This means that if all new generators cost exactly the same amount to build, there would be no price impact from the loss of any generation, as there would be no change to the prices required to cover the cost of replacement generation. There would, however, be an economic cost impact.

That said, it is possible in such a scenario that there could be some short-term price impact if the loss of generation were sudden and unanticipated, and the market had insufficient time to build new generation to restore the supply / demand balance into equilibrium.

- *Reduced diversions* into rivers used for electricity generation arising from increasing the minimum flow requirements in waterways from which water has been diverted. This will have an effect on electricity generation output.
- *Loss of flexibility* from reduced ability for hydro generators to store water at low value times for use at high value times. This loss of flexibility arises because generators:
    - Will need to release more water at some low value times in order to meet increased minimum flow requirements at such times. This released water will therefore no longer be available for use at higher value times; and
    - Will need to hold more water back in their reservoirs to ensure they can meet increased minimum flow requirements if inflows over the subsequent days/weeks/months turn out to be low – ie, in case of a 'dry' inflow sequence. In general this water will be held back during higher value periods than those during which it is subsequently released. Operating the reservoirs more conservatively in this fashion may also result in increased spill if subsequent inflows turn out to be very wet.

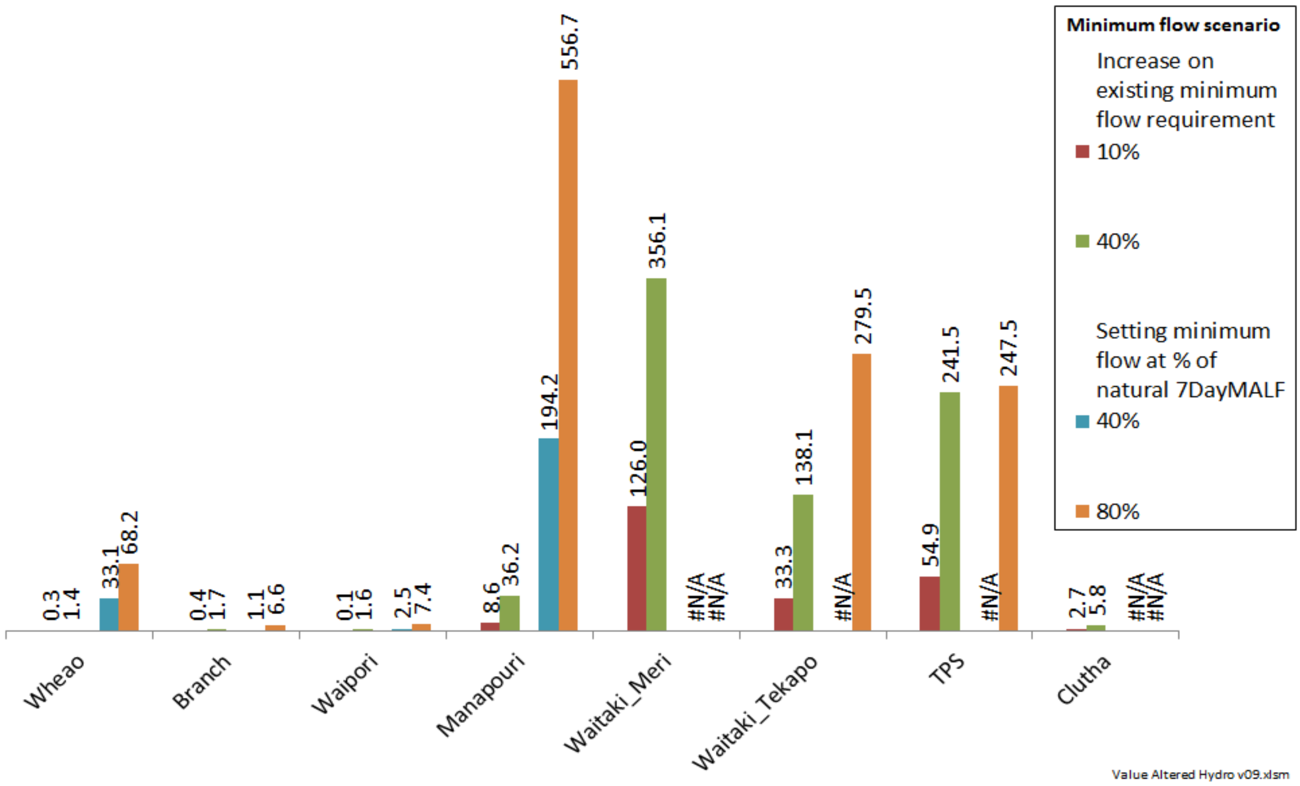
209. Actual costs will depend on a range of factors including the size of any minimum flow imposed, the location of the minimum flow on a particular scheme and the unique characteristics of the river.

7.3.1 Quantitative findings

210. Figure 24 demonstrates a high level view of the potential economic impacts, modelled across various minimum flow scenarios.

211. To achieve these estimates Concept developed, in conjunction with generators, several hypothetical minimum flow scenarios to be tested. They included increasing minimum flows above existing consented levels by a set percentage (10 per cent or 40 per cent) and by setting minimum flows at a fixed percentage of natural minimum flows (40 per cent or 80 per cent). The eight schemes selected were considered a reasonable representation as they account for approximately 93 per cent of New Zealand's hydro generation, plus they span the range of different hydro scheme characteristics in terms of: scale (large to small), storage capabilities, numbers of stations along the river, and water sources.

Figure 24: Estimated scale of impact on electricity system costs for different hydro schemes and minimum flow increases (25 yr $m NPV cost)



7.3.1.1 Impact on consumers' bills

212.The principal focus of this study has been to consider the economic cost impacts on New Zealand – ie, estimating the cost of altered fuel burn, other operating costs, and capital investment requirements. However, it is also the case that altered hydro generation outcomes could impact on consumers' bills through higher consumer prices. Such an outcome could arise if the loss of any hydro generation requires the building of progressively more expensive replacement generators. In other words:

- if each new generator costs more to build than the last, there would likely be a consumer price impact in addition to the economic cost impact, whereas
- if each new generator costs the same to build as the last, there would only be an economic cost impact, but no consumer price impact .

213.Analysis indicates that New Zealand does face an upward sloping new generation cost-supply curve as there is considerable variation in the cost of New Zealand's new generation options – particularly driven by variations in the characteristics of the different new renewable generation options. The slope of this cost-supply curve suggests that the $m magnitude of an increase in all New Zealand consumers' bills will be very similar to the $m magnitude of the economic cost impacts shown in Figure 20 above, with the scale of impact depending on which hydro schemes face altered minimum flows and by how much.

214.Thus, the impact on consumer bills of a 40 per cent increase in minimum flows for the Wheao scheme will be relatively insignificant (approximately a 0.002 per cent increase on domestic consumers' bills), whereas for the Waitaki scheme the impact of a 40 per cent increase in minimum flows would start to become more material (approximately a 0.35 per cent increase on domestic consumers' bills). It is considered that the cumulative impact on consumers' bills of several schemes facing altered minimum flows would be additive rather than multiplicative.

7.3.2 Southland findings – High level implications of altering minimum flows

215. Increasing lower Waiau minimum flows or reducing Mararoa diversions would reduce energy supply from the scheme. Increasing lower and upper Waiau minimum flows would complicate storage management and affect seasonal supply flexibility. Therefore, Meridian's modelling considered:

- increasing consented minimum flows for the lower Waiau. Because current consented flows are low compared with natural minimum flows, an increase in such consented flows has a relatively small percentage impact on generation.
  - 10 per cent increase in consented flows resulted in $8.6m cost.
  - 40 per cent increase in consented flows resulted in $36.2m cost.
- Meridian also considered scenarios where consented flows along the Waiau were set at a fixed percentage of natural MALF. As can be seen, the percentage loss of generation is significantly greater.
  - 40 per cent increase in 7dayMALF resulted in $683m cost.
  - 80 per cent increase in 7dayMALF resulted in $1,647m cost.

216. This study cannot identify the formal impacts of altered minimum flows, because water quality management decisions are ultimately made by councils and communities on a catchment-by-catchment basis.

7.3.3 Qualitative findings

217. Assuming that regional councils decide to increase or implement minimum flow limits to achieve water quality objectives, the key preliminary findings from the electricity study are as follows:

- There will be an economic cost on the electricity system (primarily due to reduced efficiency of electricity system. This will have flow-on effects for national consumers, regardless of where the minimum flow limit is implemented or increased.
- The unique nature of each scheme – size, amount of storage, hydrological inflows and position in a chain for example – ensures that:
  - the scale and nature of the economic cost varies significantly from river to river and from scheme to scheme.
  - there is no linear relationship between minimum flow rates and costs of electricity generation.
- A case by case approach will be needed when regional councils assess potential impacts of minimum flow rates on electricity generators.

218. Such costs will primarily arise from two main phenomena:

- Reduced diversions into rivers used for electricity generation arising from increasing the minimum flow requirements in waterways from which water has been diverted. This will have an effect on electricity generation output.

- Loss of flexibility from reduced ability for hydro generators to store water at low value times for use at high value times. This loss of flexibility arises because generators:
    - Will need to release more water at some low value times in order to meet increased minimum flow requirements at such times. This released water will therefore no longer be available for use at higher value times, and
    - Will need to hold more water back in their reservoirs to ensure they can meet increased minimum flow requirements if inflows over the subsequent days / weeks / months turn out to be low – ie, in case of a 'dry' inflow sequence. In general this water will be held back during higher value periods than those during which it is subsequently released. Operating the reservoirs more conservatively in this fashion may also result in increased spill if subsequent inflows turn out to be very wet.

219. Increasing or introducing minimum flows may also jeopardise existing mitigations associated with awards of consents. Such as recreational releases and provisions around fish migration.

220. Increasing or introducing minimum flows may have a positive impact on thermal generators as this will improve the assimilative capacity of the river to accept discharges. However, there may be negative impacts, as is the case with TPS and Waikato relationship, as diversions into rivers may be altered. Again, in assessing the impact of implemented or increased minimum flows on thermal generators, a case by case assessment is required.

7.4 Limitations

221. This analysis is designed to give an indication of the scale and nature of impacts from minimum flow scenarios. In reality, considerably more analysis involving interrelated models would be required to give a more accurate reflection of the impacts.

222. This analysis is therefore useful for understanding the scale and nature of potential economic costs, but does not profess to be a view of the expected quantitative costs.

Counter-balancing effects and of un-served energy

223. The annex of the Concept report discusses limitations of counter-balancing effects and of un-served energy. Both are relevant considerations. Additionally, there are a range of other factors which must be taken into account when interpreting the results of this study. These include, but are not limited to the following:

- Existing consents: Many of the river schemes have existing consents in place. The analysis has intentionally ignored the costs and impacts of breaking or amending these consents to accommodate the hypothetical minimum flow rates chosen.
- Market structure: This analysis is based on the existing market structure, and does not consider any sensitivity analysis of altered supply or demand dynamics.

224. Ultimately this analysis makes estimations about the potential economic cost of hypothetical minimum flow decisions to electricity generators across a range of river schemes. These economic costs will be realisable over a long period of time – during which, significant change may or may not occur to all input variables, including market structure, existing supply and demand dynamics, changes to existing consents and hydrological inflows.

Transitional impacts

225.The cost estimates set out above are based on the altered resource cost implications once the market has shifted to a new supply-demand equilibrium.

226.However, immediately following any change to altered minimum flow regimes the market may be in a situation of dis-equilibrium which could give rise to different cost outcomes – at least until demand growth and generation new-build / retirement transitions the market to a situation of supply-demand equilibrium again.

227.It is very difficult to assess the likely nature and scale of such short-term impacts as they are heavily dependent on:

- whether the cycle of new-build and retirement means the market is in a situation of over- or under-supply when such changes occur, and
- how much advance notice is given of a change in minimum flows, and thus the extent to which such information can be factored into new-build / retirement decisions ahead of time.

228.Despite these inherent uncertainties, in general it would be expected that these short-term impacts would result in higher $/MWh costs than the long-term costs as the market would move into a situation of relative scarcity.

A wider perspective

229.Linking assessments of the impact of water quality changes with water quantity changes to build an overall picture of potential cross-sector impacts is a challenge that will be faced by councils that has not been addressed in the Southland studies.

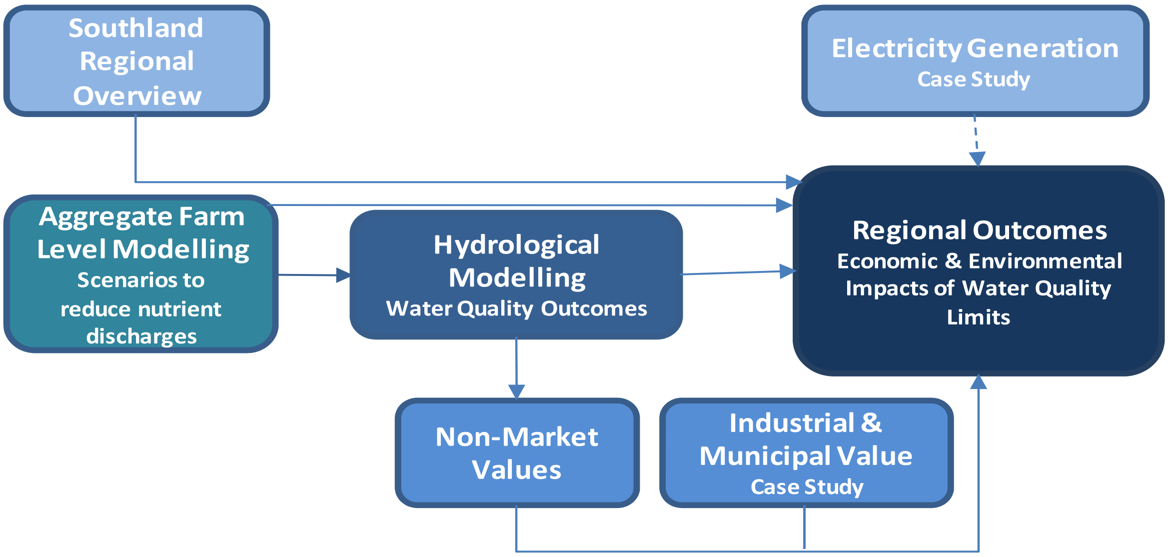
230.Assessing the marginal impacts of bottom lines across those sectors constrained by water quality limits (eg, dairy, industry) at the same time as those sectors that are constrained by water quantity limits (eg, hydro) is a critical area of further research.

8 Southland: Overview of the potential impacts of scenarios for setting water quality objectives

231.This section collates the key findings of the component studies relevant to the Southland region, that assess the potential economic, environmental, social and cultural costs and benefits of scenarios for setting water quality objectives and limits, including proposed bottom lines for ecosystem health and human health, under the National Policy Statement for Freshwater Management.

232.The studies evaluate the potential impacts on the agricultural, industrial and municipal sectors and on non-market values in Southland. In the studies, ecosystem health is based on the attributes of median nitrate toxicity and periphyton (slime) and human health is based on *E. coli* concentrations. The findings are region specific and cannot be extrapolated to other regions. A study into the impact of changes to water quantity restrictions on electricity generation was also carried out. However the results of this study cannot be combined with the above studies in an assessment of water quality objectives and limits.

Figure 25: Southland framework of studies which assess the potential impacts of scenarios for setting water quality objectives across environmental, economic, social and cultural values of fresh water



8.1 Impact analysis of scenarios for setting water quality objectives

8.1.1 Achieving proposed national bottom lines

233.The Southland case study reports have found that the proposed bottom lines for ecosystem health in rivers for the two attributes tested in Southland are currently met and do not impose costs. Water quality will be maintained above bottom lines for median nitrate toxicity and periphyton (slime) under all scenarios tested[37]. Although the ecosystem health in rivers will decline, the proposed national bottom lines tested will be met without undertaking additional mitigation both now and in 2037.

234. Maintained or improved overall water quality could be achieved in Southland's rivers. Growth in agricultural production could be achieved while maintaining or improving overall water quality, although it is likely to have economic impacts.

235. The proposed national bottom line for *E. coli*, the attribute tested for human health, is currently breached at a five river sites in Southland. Predicted future (2037) water quality in a 'no additional mitigation' scenario show little change in *E. coli* levels. Specific on-farm mitigation practices aimed at reducing *E. coli* concentrations are required to meet the bottom line for human health. In Southland, mitigation measures on dairy farms only will not be sufficient to ensure that the *E. coli* bottom line is met at the five sites where it is currently breached. However, fencing of waterways on surrounding sheep and beef farms as well as on dairy farms would address *E. coli*. The majority of these costs could fall on sheep and beef farms, as most dairy farms already have fencing in place.

236. The Southland studies do not provide information on the water quality and associated economic impacts of limits for achieving national bottom lines for lakes, as most lakes in Southland fall within the Conservation Estate, with Lake Te Anau being the exception.

237. Ecosystem health of estuaries is likely to be a more constraining water quality issue than rivers in Southland, as water quality thresholds for estuaries are more challenging to meet. Results suggest that estuaries in Southland are more sensitive receiving environments than rivers and that contaminant loss from land-use activities in the region has its most marked effect on estuaries. Therefore, the proposed bottom lines for rivers are unlikely to be sufficient to maintain and improve water quality in the estuaries.

238. The science around the appropriate thresholds for estuaries in New Zealand is limited. Objectives set for fresh water will also need to consider the impact on estuaries and the requirements of the Coastal Policy Statement.

8.1.2 Key findings from the Southland farm-level modelling

239. The NZIER report tested a range of scenarios to reduce nutrient discharges at farm level. Key findings include:

- Without action to reduce nutrient discharges, the total value of agricultural production is forecast to significantly increase in real terms[38] to $4.6 billion per year by 2037. Nitrogen (N) and Phosphorus (P) nutrient loss are projected to increase by 16 per cent and 28 per cent respectively, assuming dairy growth in the 'no additional mitigation' baseline.

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[37] After the Southland study was completed, the nitrate toxicity bottom line was strengthened by the addition of a criterion around nitrate levels at the 95th percentile (in addition to the median). The potential impact of meeting the bottom line at the one site in Southland which breaches the updated threshold has not been assessed.

[38] 2037 results are deflated by 2% per year for 25 years to determine 2012 real dollars, accounting for inflation.

- Compared to the baseline, dairying will continue to expand under all but the tightest uniform discharge cap, albeit at a slower rate. Aggregate farmer gross margin[39] is impacted by more stringent scenarios, due mainly to the cost of forgone dairy conversions.
- As uniform nutrient caps become more stringent, dairy farmers are likely to choose more effective mitigation actions, some of which can be more cost effective, thus also improving both productivity and profits.
- Uniform nutrient caps are a blunt and expensive farm-level policy tool. Other tools, such as non-uniform caps[40] based on soil type, may achieve similar mitigation results at an aggregate marginal benefit to farmers. Similarly, negotiating transfer of a portion of a discharge cap to a neighbour for whom it costs less to mitigate could deliver similar overall mitigation at a greatly reduced cost to farmers. The theoretical point here is important: a given overall level of mitigation can be achieved at *least* aggregate mitigation cost if marginal mitigation costs are equalised across all participants.
- Results suggest that grandparenting with ratcheting down, i.e., equally proportionate discharge reduction across all farm types, is less cost-effective than most mitigation scenarios. Widespread adoption of mitigation actions by both dairy and sheep and beef farms is more cost-effective than most mitigation tools while achieving a comparatively high level of mitigation.[41]
- Best management practices that drive efficiency gains can incentivise more efficient resource use and production, and may potentially create headroom for further development to expand and grow sectors requiring nutrient discharges, while maintaining or improving water quality. Growth and expansion could occur through existing farmers or new conversions.

8.1.3 Potential impacts of scenarios for setting freshwater quality objectives and limits on agriculture

240. Under the modelling carried out in these studies, it has been found that maintained or improved overall water quality may be achievable for rivers in Southland, with some scenarios allowing for dairy growth.

- The modelling indicates that dairy growth and gains in aggregate gross margin could be achieved with non-uniform caps and mandated mitigation while meeting the bottom lines for ecosystem health and human health and maintaining or improving overall water quality in rivers.
- The most cost effective scenarios tested in terms of nitrogen mitigation are the non-uniform caps where all dairy farms adopt the mitigation bundle including stock exclusion, improved nutrient management and improved animal productivity. However, while aggregate gross margin is maintained in both non-uniform cap scenarios, the reduction in production entailed in scenario 18 would have downstream economic impacts on the processing industries in Southland. These wider impacts are not considered in the studies.

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[39] Gross margin is a farm-level metric that is aggregated across Southland farms to compare uniform nutrient discharge cap scenarios. Gross margin aggregated across Southland farms, is similar to value-add or GDP for Southland agriculture.

[40] Nutrient caps tailored to farms' productive capacity and potential discharge rates.

[41] Whether widespread adoption would be achieved via voluntary means (eg, educational programme) or regulatory means (eg, mandating across all farms) was beyond the scope of this study.

- Furthermore, practices such as fencing aimed at reducing *E. coli* to meet the proposed bottom lines for human health result in costs, but these costs are hidden in the overall benefit of the mitigation bundles that mainly focus on reducing nitrogen and phosphorus losses.

- This result of a gain in gross margin under the non-uniform cap scenarios is heavily dependent on the modelled benefits of improved animal productivity, which deliver both improved profitability and reduced nutrient loss. This result differs from other New Zealand research which suggests that on farm nutrient loss reduction of the order of 20 per cent per hectare is achievable at relatively minimal cost but mitigation costs rise steeply after this point[42]. Therefore, it must be noted that these findings are specific to the modelling assumptions made in the modelling, and that in reality some sectors/farmers will not have the capability to carry out these mitigations at a low or no cost.

8.1.4 Potential impacts of improved water quality on the municipal and industrial sectors

241.The key findings of this report relate to the potential financial implications of reducing contaminant losses at municipal and industrial sites that are point sources of contaminants to meet higher water quality standards. Table 12 combines a range of outcomes from all the individual case studies contained in the report. This means the results cannot be combined, rather they are presented here together for convenience.

Table 12: Summary of key financial impact results ($2012)

Scenarios	Water Supply	Stormwater ($/hhld, bus.)	Wastewater		
			Winton ($/hhld, bus.)	Alliance Meatworks	On-site Wastewater Systems* ($/hhld, bus.)
Lowest Cost		$ 240	$ 463		
Low - Medium Cost			$ 477	$27,581,000	$14,405
Medium Cost		$ 526	$ 534		
Med - High Cost			$ 666	$41,368,000	$16,462
Highest Cost		$ 1,819	$ 697		
			** For the Invercargill Study Area Only*		
	Note: Alliance Meatworks costs and Septic Tank Costs in NPV terms at 6%				

242.In summary:

- Proposed bottom lines would not result in costs to Invercargill municipal water supply, as the Ministry of Health standards for drinking water are more stringent.

- The effects of reducing key contaminants on storm water are likely to be significant. In order to address all storm water in Invercargill, reducing the key pollutants (50 per cent reduction in Phosphorous, 80 per cent reduction in heavy metals, 80 per cent reduction in hydrocarbons and solids) could cost more than $1,800 per ratepayer household per year.

- In Winton, additional waste water treatment costs increase in relation to the percentage of pollutant removed. The Winton case study estimates wastewater treatment costs ranging from $460 and $700 per household or business annually on average over the next 25 years.

[42] For example, see Doole, Agricultural Water Management, Volume 104, February 2012, Pages 10–20 “Cost-effective policies for improving water quality by reducing nitrate emissions from diverse dairy farms: An abatement–cost perspective”.

- The potential costs associated with an upgrade to the Alliance Meatworks waste water processing facility are significant. Should the upgrade be developed in time to be fully operational by 2017 and meet the current published water quality standards it may cost the company over $41 million (in NPV terms).
- While the potential mitigation costs could run into the tens or even hundreds of millions of dollars, it is difficult to draw any region-wide conclusions on the impact of proposed bottom lines on the municipal and industrial sectors. To do so, further data on contaminant discharges, facility standards and upgrade requirements and costs would be necessary across the region.

8.1.5 Potential impacts of improved water quality on non-market values

243. Non-market values include recreational values, cultural and spiritual values, existence values, option values and bequest values. Key findings are as follows:

- The study is a first step in assessing the marginal impact improving water quality on non-market values and provides an indication of the overall marginal changes. The total marginal impact is unknown as not all values could be quantified. Results indicate that, for the values that could be quantified, improving water quality with uniform nutrient discharge caps[43] would result in an aggregate marginal benefit for recreational uses (fishing, swimming and kayaking) and existence values ranging from $0.1m to $2.3m per year in 2037 (in 2012 dollars).
- The total marginal benefit of improved water quality to meet bottom lines would be greater than the estimated results for two reasons:
  - Whilst the marginal benefit quantified appears to be relatively small, it does not include the marginal impact on a number of significant non-market values, including ecosystem health and diversity, aesthetics and amenity, and cultural and spiritual values (including unique Māori values) that have not been quantified due to data limitations. As the latter values are greater in scope than the values of recreation and existence values quantified, and as they are likely to be positively correlated with improved water quality, it can reasonably be expected that these values would have greater marginal benefits than those quantified.
  - The results are based on improvements to water quality resulting from uniform nutrient discharge caps at farm level, which represents only an incremental improvement in water quality. This scenario meets the bottom line for ecosystem health and results in maintained or improved overall water quality. This scenario does not meet the bottom line for human health at a small number of sites, but results in improvements in *E. coli* overall. As it is likely that an improvement in *E. coli* leads to an increase in non-market values for recreation and kayaking, it is expected that meeting the bottom line for human health at all sites would result in a greater non market benefit.

8.1.5.1 Key findings from the electricity generation study

244. Minimum flow requirements imposed on rivers may create economic impacts on electricity generation. In implementing or increasing minimum flow requirements, actual costs (primarily

[43] Other nutrient discharge mitigation scenarios were not analysed due to time constraints.

due to reduced generation system efficiency) depend on a range of factors including: the size of any minimum flow imposed, the location of the minimum flow on a particular scheme and the unique characteristics of the river. While the costs would need to be balanced against environmental, social and cultural outcomes, an economic cost on the electricity system may have flow-on effects for national consumers, regardless of where the minimum flow limit is implemented or increased. Costs to the electricity system will primarily arise from the following drivers:

- Loss of generation: reduced diversions into rivers used for electricity generation arising from increasing the minimum flow requirements in waterways from which water has been diverted.
- Loss of flexibility: from reduced ability for hydro generators to store water at low value times for use at high value times.

245. For Southland's Manapouri scheme, increasing current consented minimum flows for the lower Waiau has a relatively small marginal impact on electricity generation as the current consented flows are low compared with natural minimum flows. A 10 per cent and 40 per cent increase in consented flows has been estimated to cost of $8.6m and $36.2m respectively.[44]

8.1.1 Overview of potential economic, environmental, social and cultural impacts

246. Table 13 summarises the key findings drawn from the series of economic impact studies for Southland which assessed the potential marginal impacts of a range of scenarios for setting water quality objectives and limits.

247. The findings represent the information set enabling a preliminary region-specific assessment of the potential economic, environmental, social and cultural costs and benefits of setting water quality objectives and limits, including proposed bottom lines for ecosystem health and human health, under the National Policy Statement for Freshwater Management. The studies evaluate the potential impacts on the agricultural, industrial and municipal sectors and on non-market values in Southland. The findings are region specific and cannot be extrapolated to other regions.

248. The purpose of these studies is to integrate environmental and economic information in a way that can support community discussions about the potential costs and benefits of freshwater management choices across all sectors in Southland. The results are not intended to direct the choices that the Southland community will make in managing water quality. The findings emphasise the importance of councils testing a range of scenarios when setting objectives and limits, in terms of the level those objectives and limits are set, the regime for managing within limits and the timeframe for adjustment.

249. In Table 13, the corresponding economic impacts, environmental impacts, and performance against water quality objectives for each of the scenarios can be read by following the column down vertically. The lower (blue) rows of Table 13 show the number of sites falling within a water quality band (see section 4) and the lower (green) rows show the proportion of sites that meet the water quality standard to meet the proposed national bottom line. Table 14 summarises the potential impacts on agriculture in absolute values.

44 All costs estimated in the report are based on a 25 year NPV outlook.

Table 13: Summary table of potential marginal impacts in Southland

Reading the Table

For each scenario B-H, the corresponding economic impacts, environmental impacts and performance against policy objectives can be read by following the column down vertically.

		Scenarios	Current State 2012	No mitigation - future baseline 2037	Uniform Caps				Non-Uniform Caps		Grandparenting	Mandated farm-level mitigation
					B	C	D	E	F		G	H
		Scenario Set			3,5,6,7	4 / 8	9,10,11,12	13,14,15,16	17	18	19	20
		N limit (kg/ha)			60 / 45 / 45 / 45	60 / 45	30 / 30 / 30 / 30	15 / 15 / 15 / 15	45/38	37/30	-25%	N/A
		P limit (kg/ha)			1 / 2 / 1.5 / 1	0.5 / 0.5	2 / 1.5 / 1 / 0.5	2 / 1.5 / 1 / 0.5	0.6/1.2	0.6/1.2	-25%	N/A
		Change to dairy practice			64% of farms adopt M2	All farms adopt M2	All farms adopt M3	Dairying unable to comply with caps	All farms adopt M2	M2 and M3 adopted	All currently existing farms adopt M3	All farms adopt mitigation bundle M3
		Description of change			No foregone dairy conversions; some change in dairy practices	Foregone dairy conversions; change in dairy practices to medium mitigation bundle	Foregone dairy conversions; change in dairy practices to high mitigation bundle	Dairying no longer viable under tightest caps	No foregone dairy conversions; complete change in practices	No foregone dairy conversions; complete change in practices	Foregone dairy conversions: dairy does not expand beyond 2012 area. Complete change in dairy practices	No foregone dairy conversions; complete change in practices. Also includes complete change to sheep and beef practices
2037 Marginal Impacts compared to 2037 Baseline (in $2012 per year)												
Economic impacts	Agriculture	Agriculture - Marginal impact on aggregate gross margin (2012 $m)	*$940*	$2,700	$120	($670)	($850)	($2,200)	$180	$30	($980)	($190)
		% change	*n/a*		5%	-24%	-31%	-82%	6%	1%	-36%	-7%
		Cost effectiveness of mitigation ($ gross margin/kg N mitigated)	*n/a*		$120	($190)	($170)	($260)	$130	$10	($210)	($30)
		Change in dairy hectares	176,000	303,000	0	-84,000	-84,000	-303,000	0	0	-135,000	0
		% Change in dairy hectares	*n/a*		0%	-28%	-28%	-100%	0%	0%	-45%	0%
	Municipal & Industial	Industrial	*n/a*	*n/a*	Cannot be analysed at a regional level - see case study analysis				N/A	N/A	N/A	N/A
		Municipal	*n/a*	*n/a*	Cannot be analysed at a regional level - see case study analysis				N/A	N/A	N/A	N/A
	Non-market values of water	Sub-total of marginal impacts on recreational values of fishing, swimming, kayaking and existence value (2012 $m)	*n/a*	*n/a*	$0.6 - $1.2	$0.2 - $1.2	$0.1 - $1.2	$0.2 - $2.3	N/A	N/A	N/A	N/A
		Total marginal impact on non-market values *A number of significant non-market values have not been quantified due to data limitations	*n/a*	*n/a*	Unknown and likely to be far greater than the sub-total estimates				Unknown			
2037 Sites meeting National Bottom Lines (# sites within each band)			A B C D	A B C D	A B C D	A B C D	A B C D	A B C D	A B C D	A B C D	A B C D	A B C D
Environ-mental impacts	Rivers	Periphyton — # sites	27 42 4 0	25 41 7 0	28 39 6 0	27 45 1 0	29 43 1 0	32 40 1 0	29 41 3 0	29 41 3 0	27 43 3 0	25 46 2 0
		NO3N Toxicity — # sites	54 14 5 0	49 18 6 0	49 18 6 0	57 12 4 0	59 11 3 0	66 7 0 0	50 18 5 0	51 18 4 0	57 13 3 0	58 12 3 0
		E. coli (Human Health) — # sites	30 32 6 5	34 28 7 4	44 22 6 1	47 17 7 2	46 19 5 3	44 22 6 1	50 18 5 0	51 16 6 0	41 25 6 1	66 6 1 0
2037 Performance against Policy Objectives												
Ecosystem Health	Periphyton must meet band C	% sites that meet critera	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Nitrate toxicity must meet band C	% sites that meet critera	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Human Health	E.coli must meet band C	% sites that meet critera	93%	95%	99%	97%	96%	99%	100%	100%	99%	100%

Key Findings

Proposed bottom lines for ecosystem health and human health can be achieved in Southland at a low or no cost to agriculture. Headroom for economic growth could be provided whilst maintaining and improving overall water quality.

1. **Ecosystem health:** Southland rivers currently meet the proposed national bottom line for periphyton (slime) and median nitrate toxicity under all scenarios tested– proposed national bottom lines for ecosystem health do not impose costs.

2. **Human health:** 7% of monitored sites currently fail the proposed E. *coli* bottom line. Mitigation measures only on dairy farms will not be sufficient to ensure the *E. coli* national bottom line is met. However, fencing of waterways on surrounding sheep and beef farms, as well as on dairy farms, would address *E. coli*. The majority of the costs would be met by sheep and beef farms, as most dairy farms already have fencing in place.

3. **Maintained or improved overall water quality** in rivers could be achieved in Southland, with some scenarios allowing for dairy growth. The most stringent uniform discharge caps (scenario set E) results in the largest improvements in periphyton and median nitrate toxicity relative to the 2012 baseline, improvement in *E. coli* levels and marginal benefits to non-market values. However, dairying would no longer be viable under this scenario.

4. **Dairy growth and gains in aggregate gross margin** could be achieved with non-uniform caps (scenario set F) and mandated mitigation (scenario set H) while meeting bottom lines for ecosystem health and human health and maintaining or improving overall water quality.

5. **The most cost effective scenarios tested** in terms of nitrogen mitigation are the non-uniform caps where all farms adopt stock exclusion, improved nutrient management and improved animal productivity.
   - However, while aggregate gross margin is maintained in both non-uniform cap scenarios, the reduction in production entailed in scenario 18 would have downstream economic impacts on the processing industries in Southland. These wider impacts are not considered.
   - Furthermore, there is a cost to meet *E. coli* bottom lines, which is hidden in the overall benefit of mitigation bundles.

6. **Headroom for economic growth:** Best management practices that drive efficiency gains can incentivise more efficient resource use and production. This could provide headroom to expand and grow sectors that require discharges, while maintaining or improving water quality overall.

Table 14: Summary table of potential impacts on agriculture in absolute values

Reading the Table

For each scenario B-H, the corresponding economic impacts, environmental impacts and performance against policy objectives can be read by following the column down vertically.

Scenarios	Current State 2012	No mitigation - future baseline 2037	Uniform Caps: B	Uniform Caps: C	Uniform Caps: D	Uniform Caps: E	Non-Uniform Caps: F	Non-Uniform Caps: F	Grandparenting: G	Mandated farm-level mitigation: H
Scenario Set			3,5,6,7	4 / 8	9,10,11,12	13,14,15,16	17	18	19	20
N limit (kg/ha)			60 / 45 / 45 / 45	60 / 45	30 / 30 / 30 / 30	15 / 15 / 15 / 15	45/38	37/30	-25%	N/A
P limit (kg/ha)			1 / 2 / 1.5 / 1	0.5 / 0.5	2 / 1.5 / 1 / 0.5	2 / 1.5 / 1 / 0.5	0.6/1.2	0.6/1.2	-25%	N/A
Change to dairy practice			64% of farms adopt M2	All farms adopt M2	All farms adopt M3	Dairying unable to comply with caps	All farms adopt M2	M2 and M3 adopted	All currently existing farms adopt M3	All farms adopt mitigation bundle M3
Description of change			No foregone dairy conversions; some change in dairy practices	Foregone dairy conversions; change in dairy practices to medium mitigation bundle	Foregone dairy conversions; change in dairy practices to high mitigation bundle	Dairying no longer viable under tightest caps	No foregone dairy conversions; complete change in practices	No foregone dairy conversions; complete change in practices	Foregone dairy conversions: dairy does not expand beyond 2012 area. Complete change in dairy practices	No foregone dairy conversions; complete change in practices. Also includes complete change to sheep and beef practices
2037 Absolute values compared to 2012 Baseline (in $2012 per year)										
Economic impacts – Agriculture – Agriculture - Absolute aggregate gross margin (2012 $m)	*$940*	$2,700	$2,820	$2,030	$1,850	$500	$2,880	$2,730	$1,720	$2,510
Economic impacts – Agriculture – % change in agreggate gross margin from 2012 baseline	*n/a*	187%	200%	116%	97%	-47%	206%	190%	83%	167%
Economic impacts – Agriculture – Ansolute dairy hectares	176,000	303,000	303,000	219000	219000	0	303000	303000	168000	303000
Economic impacts – Agriculture – % Change in dairy hectares from 2012 baseline	*n/a*	72%	72%	24%	24%	-100%	72%	72%	-5%	72%
2037 Sites meeting National Bottom Lines (# sites within each band)	A / B / C / D	A / B / C / D	A / B / C / D	A / B / C / D	A / B / C / D	A / B / C / D	A / B / C / D	A / B / C / D	A / B / C / D	A / B / C / D
Environ-mental impacts – *Rivers* – Periphyton – # sites	27 / 42 / 4 / 0	25 / 41 / 7 / 0	28 / 39 / 6 / 0	27 / 45 / 1 / 0	29 / 43 / 1 / 0	32 / 40 / 1 / 0	29 / 41 / 3 / 0	29 / 41 / 3 / 0	27 / 43 / 3 / 0	25 / 46 / 2 / 0
Environ-mental impacts – *Rivers* – NO3N Toxicity – # sites	54 / 14 / 5 / 0	49 / 18 / 6 / 0	49 / 18 / 6 / 0	57 / 12 / 4 / 0	59 / 11 / 3 / 0	66 / 7 / 0 / 0	50 / 18 / 5 / 0	51 / 18 / 4 / 0	57 / 13 / 3 / 0	58 / 12 / 3 / 0
Environ-mental impacts – *Rivers* – E. coli (Human Health) – # sites	30 / 32 / 6 / 5	34 / 28 / 7 / 4	44 / 22 / 6 / 1	47 / 17 / 7 / 2	46 / 19 / 5 / 3	44 / 22 / 6 / 1	50 / 18 / 5 / 0	51 / 16 / 6 / 0	41 / 25 / 6 / 1	66 / 6 / 1 / 0
2037 Performance against Policy Objectives										
Ecosystem Health – Periphyton must meet band C – % sites that meet critera	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Ecosystem Health – Nitrate toxicity must meet band C – % sites that meet critera	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Human Health – E.coli must meet band C – % sites that meet critera	93%	95%	99%	97%	96%	99%	100%	100%	99%	100%