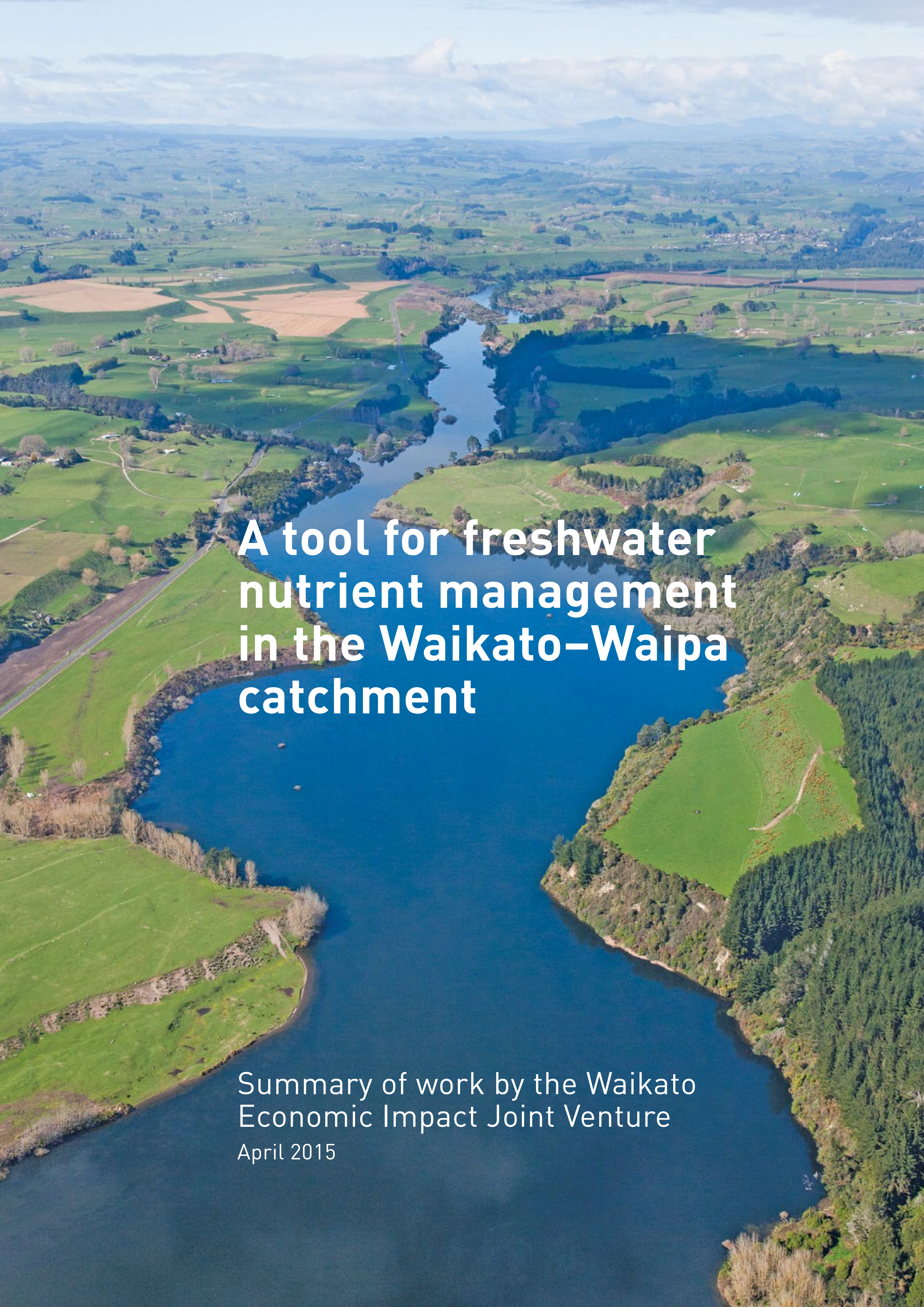


A tool for freshwater nutrient management in the Waikato–Waipa catchment

Summary of work by the Waikato Economic Impact Joint Venture

April 2015

Report prepared by the Joint Venture's Technical Advisory Group, December 2014

Waikato River Authority
Waikato Regional Council
DairyNZ
Ministry for the Environment
Ministry for Primary Industries

This publication is available at:
Waikato Regional Council website: www.waikatoregion.govt.nz
Ministry for Primary Industries website: www.mpi.govt.nz

ISBN No. 978-0-908334-13-1 (print)
ISBN No. 978-0-908334-14-8 (online)

DISCLAIMER

Foreword

This analysis provides a useful contribution to the important discussions about the future of freshwater management that are taking place in our Waikato region.

This study exists because several organisations could see a need and knew that it would take time to address, so they decided to get started.

The hallmark of the Waikato Economic Impact Joint Venture is collaboration. Any organisation could have gone away and done some work, but several parties coming to the table to work on this over an extended period of time has created opportunities for exploring together. This has led to a more robust approach.

Getting a detailed understanding of real-world dynamics, especially in the economy, is critical to setting a policy framework, and it's complex. We as a community need the full picture. We must not ignore any aspect just because it might be hard to understand.

The analysis provides a foundation. It hasn't gone the whole way – there wasn't the time or resource available to do that, and also it's up to the community to determine what it sees as important to investigate further.

We have some important and interesting discussions ahead of us. I look forward to seeing you around the tables and paepae.

I commend this document to all the parties engaged with the Healthy Rivers Plan process and the collaborative stakeholder group in particular.

Bob Penter
Chief Executive
Waikato River Authority

Contents

1 WAIKATO ECONOMIC IMPACT JOINT VENTURE

Introduction

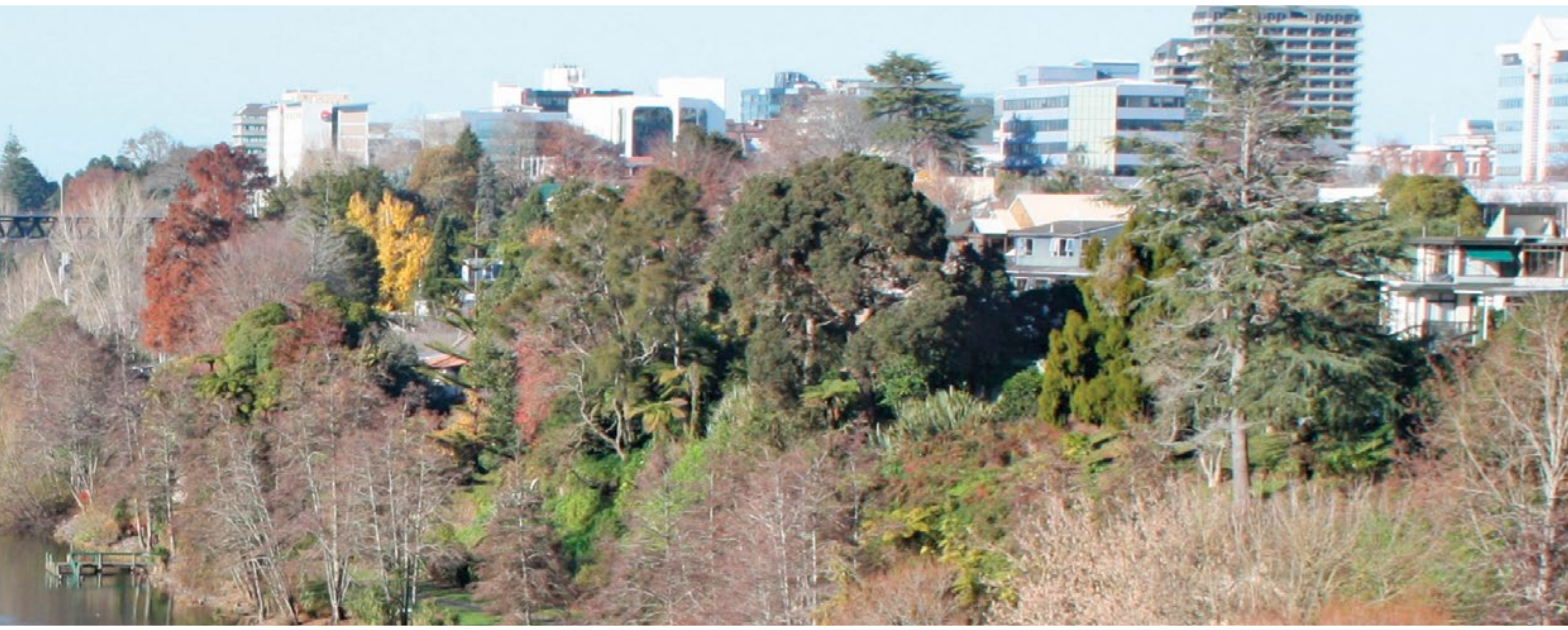
New Zealanders want better management of fresh water and improvements in water quality over time. To achieve this, new tools and analysis is required to help assess what contaminant reduction is possible and what impacts this would have on environmental, social, cultural and economic values.

Water resources are a key part of the fact that Waikato, with its important agriculture, energy generation and tourism sectors, is the fourth-largest regional economy in New Zealand. The freshwater bodies of the Waikato region are valued by its community: for example they are of particular spiritual significance to Māori, provide recreational activities and help drive the economy.

However, quality of fresh water is an increasing concern. Regional Council monitoring shows elevated concentrations of nutrients, sediment and faecal indicator bacteria at sites throughout the region, particularly in areas of urban and agricultural development, and evidence of increasing trends in some indicators, particularly nitrogen. Levels of contaminants in many waterways are likely to be significantly impacting fresh water values (e.g. swimming, food gathering, ecosystem health) across the region.

The Vision and Strategy for the Waikato River/Te Ture Whaimana o Te Awa o Waikato, published in 2008, has become the primary direction-setting document for the Waikato River and its catchments (including the Waipa River). It aims to protect and restore the Waikato and Waipa rivers. The Healthy Rivers/Wai Ora project is now working to implement the intentions of the *Vision and Strategy*.

Recognition of people's values associated with freshwater is implicit in the *Vision and Strategy,* so these perspectives have been included. As part of this, in any assessment of setting water quality limits, it is important that River Iwi values (and non-economic values) are considered in decision-making.



This report describes how baseline information has been collected about the Waikato-Waipa catchment and the value of the waterways to its users. This has been used to develop economic modelling for the catchment. This approach is being presented to help the community assess options for regional water management.

This work has been initiated and led by the Waikato Economic Impact Joint Venture, which was established in early 2013. The primary project partners are the Ministry for Primary Industries (MPI) and Ministry for the Environment (MfE), the Waikato River Authority (WRA), Waikato Regional Council (WRC) and DairyNZ. Several other groups have participated in the process. (Note, the two Ministries formed a joint Water Directorate which has engaged in this work.)

The partners aimed to develop a base of information that would support the Waikato community in its process of collaborative decision-making to set water quality outcomes (objectives and limits) for the Waikato and Waipa Rivers, that is the Healthy Rivers/Wai Ora project. The Joint Venture got started well ahead of this decision-making process, as obtaining information and modelling impacts is complex and time-consuming.

The Joint Venture has built on work previously done by MPI and MfE along with the Department of Conservation when the Government was developing the National Policy Statement for Freshwater Management (NPS). That involved the development of a model linking land-use profitability with working towards water quality targets. That early catchment modelling was done in the upper Waikato and effectively formed a pilot phase for this current work.

This report is a summary of several studies that have been prepared by a range of people for the Joint Venture.

The Joint Venture partners have been careful to ensure that they were all happy with the approach being taken at all times and that the quality of information generated is high: the major reports have all been independently peer-reviewed.

It is intended that the reports will be freely available, and that the Healthy Rivers/Wai Ora project will be able to make use of the information and modelling framework.

The partners aimed to develop a base of information that would support the Waikato community in its process of collaborative decision-making to set water quality outcomes (objectives and limits) for the Waikato and Waipa Rivers, that is the Healthy Rivers/Wai Ora project.

2 THE JOINT VENTURE PROJECT

The Joint Venture's aim has been to develop an information base so that decisions about water quality targets and limits can be taken with a better understanding of the implications of those decisions. While it is not possible to provide complete information about every type of value held for freshwater, it has provided a sample from across the spectrum of economic values associated with fresh water and affected by changes in water quality.

The "economic value" of fresh water encompasses all of the things that people value about fresh water – whether these are "market" values that affect the finances of people, businesses or other organisations, or "non-market" values which may not be readily measured in dollars but have real value to people and can affect their wellbeing.

To support decisions about water quality targets and limits, we as a community need to know what those values are and how they are affected by changes in water quality. Understanding this would make it clear what would be gained or lost by choosing to set particular water quality targets.

To assist with this, the Joint Venture has attempted to cover a range of values of different types.

On the non-market side, we have estimated some of the benefits of improving water quality – for example to recreational users. We have also attempted to collate existing published information about the values that iwi, as co-governors, hold in relation to fresh water.

Also, the group has sought information on the sources of contaminants in the Waikato–Waipa catchment, what changes these sources could have to make to achieve different targets (measured as total loads being discharged) and what such changes could cost. This information has been used to develop a catchment model that can provide an estimate of the cost to land users of achieving certain targets.

3 RIVER IWI VALUES

Introduction

River Iwi have in common a special and interconnected relationship with the rivers and the catchment that is cultural and spiritual as well as physical.

As a first step to informing future work on cultural values, a review of available information was undertaken to indicate values that five River Iwi, Tūwharetoa, Te Arawa, Raukawa, Waikato-Tainui and Maniopoto, hold in relation to the Waikato–Waipa River catchment. It is not the intent to provide an exhaustive list of River Iwi values.

Information gathering

A desktop review was conducted for the Joint Venture, based primarily on a range of publicly available reports, plans, legal documents and presentations by iwi. River Iwi representatives also provided information directly and reviewed the report.

For each of the River Iwi, the review provides an overview of values, the challenges and some of the impacts based on available information. Historical accounts reiterated the importance of these values and how they contributed to iwi aspirations and tribal identity.

Overview

Māori values are understood to stem from traditional Māori beliefs based on mātauranga Māori. For Waikato River Iwi, one research study (undertaken by NIWA, the National Institute of Water and Atmosphere Research, in 2010) found this includes:

> *The historical and spiritual association that iwi have with the river, the range of activities undertaken, the different relationships with the river, the dependence of these activities and relationships on the state of water quality and the health of aquatic ecosystems, and the changes that have been observed over the centuries.*

Other research by Harmsworth and Awatere in 2013, presents some of the internal and external core Māori values that guide behaviour, for example in relation to freshwater and as expressed in the landscape, the rivers, lakes and streams. These include:

Kaitiakitanga
Guardianship or stewardship

Whakapapa
Genealogical connections, relationships, holistic

Tikanga
Customary practices, protocols

Manaakitanga
Caring for, hosting, acts of giving

Wairuatanga
Spiritual wellbeing

Rangatiratanga
Self determination, empowerment

Whānaungatanga
Relationships, family connections

Mana whenua
Authority over land and resources

Wāhi tapu
Sacred sites – such as urupā (burial grounds), caves, ceremonial sites

Wāhi taonga
Treasured sites – such as marae, pā (old fortified villages), kāinga (settlements)

Wāhi tupuna
Ancestral sites – such as aka landings, old battlegrounds, tracks

Mahinga kai
Traditional food gathering sites and resource sites

Taonga
Something treasured, such as native flora and fauna, plants, trees and animals, wetlands, and so on

Landmarks
Mountains, peaks, rivers, lakes, streams, geothermal areas, springs, and so on

Metaphysical
Atua domains

Recreation
Such as swimming, waka ama, rowing, boating, picnics.

The River Iwi also describe values and principles beyond these. The purpose for which the above values were identified (that is, to inform legislation or to provide guidance on iwi objectives and policies on environmental resource management) is not the same as the reason for them being documented here, and therefore the relevant range of values could be wider or different.

As the iwi values review noted, *"Significant historical accounts are provided which share some of the issues experienced in the loss and degradation of taonga but also some of the positive actions being undertaken and the aspirations of iwi in the journey towards restoring and protecting the Waikato and Waipa river catchments."*

While noting differences in values between and within iwi, the reviewer found some commonalities in their perspectives. These included:

» A holistic world view that encompasses both tangible and intangible values
» The significant relationship between the river and iwi
» The negative impacts on the environment and waterways, and the causes
» The importance of sustainability but not being opposed to development
» The commercial and economic interests of iwi.

As illustrated in the review, River Iwi values are holistic, incorporating environmental, social and economic values.

(For information about the particular perspectives of each of the five River Iwi, please see the full review report.)

4 THE USE OF ECONOMIC MODELS

The Joint Venture has used economic techniques for much of its work, because this provides useful tools for decision making. This is for several reasons:

- Economics is one important aspect of any regional decision-making, to ensure that the region can continue to provide opportunities for its residents. Freshwater decision-making is specifically required by law to take account of the economic impacts of policy decisions (Section 32 of the Resource Management Act).
- Economics provides tools to aid community discussions and decision-making. Economic techniques are useful to clearly show relationships between values, activities, benefits, costs and choices. An economic model can be useful in drawing out understandings and assumptions that might not otherwise be expressed.
- Economics can work with and complement information and analysis from other disciplines such as biological and other social sciences.

It should be noted that the Joint Venture work shows some of the linkages and relationships, but further work would be needed to give more accurate, detailed information about aspects covered here as well as other aspects in order to properly assess the likely impacts of various policy settings. This includes the wider regional-level economic impacts.

5 NON-MARKET VALUATION MODEL

Introduction

What is the value to a person of being able to spend an afternoon with a friend walking along a picturesque length of the Waikato River edge, to take their family for a day out swimming and boating on a lake, or to share a meal of fish caught in the river? And what features of the waterway or water body affect these values?

The Joint Venture's non-market valuation study used a range of methods to identify and assess values associated with the rivers that do not have a market price because they do not involve buying or selling directly. This estimation enables linkages to be shown between the (different) values and changes in water quality.

The scope of the non-market work included looking at values such as recreation use, option values for future use, and existence value. It aimed to help quantify the change in these values that might result from policies to improve fresh water in the catchment (in other words, the marginal values).

Three aspects of water quality were used in this work, chosen because they can easily be related to community values, and also can be monitored in the catchment and linked to hydrological models:

» Water clarity.

» Human health risk (contact health risk or swimmability).

» Ecosystem health.

Two types of valuation methods were used: revealed preferences and stated preferences, and these two were combined to form a non-market evaluation model.

The research team conducted two online surveys to gather information.

Analysis methods

REVEALED PREFERENCES

Revealed preference methods analyse real-world behaviour, such as recreation site visits. They enable value to be understood from the travel and other costs that people are willing to pay for the use of freshwater sites.

The first survey respondents, who include people from outside the Waikato region, provided information about themselves and about trips they have made to freshwater sites – if any. They gave details about the distance travelled for a trip, the duration and activities, their perceptions of water quality at the site visited and their preferred site features.

This enabled analysis of destination choices and a trip count:

» Destination choice analysis – analyses how far people travel to visit sites of varying quality and what factors influence why they choose to visit a particular site.

» Trip count analysis – analyses the number of trips people make to freshwater sites.

STATED PREFERENCES

Stated preference techniques involve finding out people's preferences or willingness to pay for a possible change, and this includes an insight into non-use values.

The respondents to the second survey, who include people from local regions most likely to use Waikato freshwater sites, provided information about themselves and completed a choice experiment and some attitudinal questions. For the experiment they were presented with information about the current state of water quality at five sites and were asked to make a series of choices about possible changes to water quality, given a certain level of cost in rates or taxes.

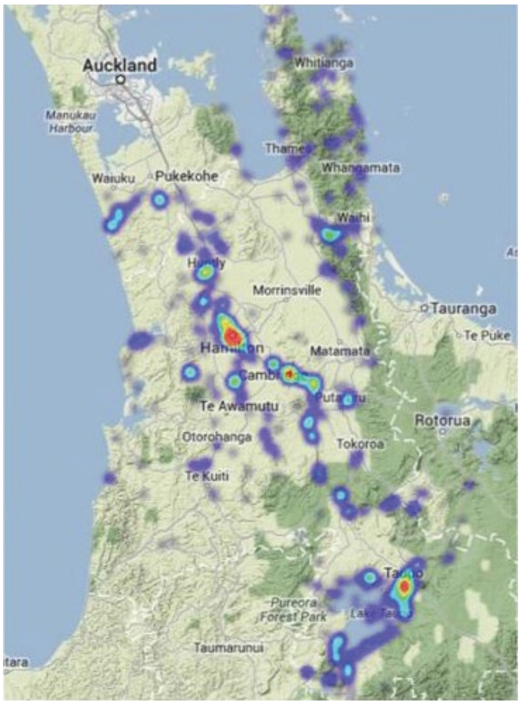
JOINT MODEL

The non-market evaluation model was produced by combining these two. The model brings together the strengths of each approach and also showed how consistent the results were.

For the joint model, the revealed preferences modelling provided a detailed baseline estimate of recreational use of fresh water, and the stated preferences model expanded on this by including non-use values and helping to tease out perceptions about human health risk and ecosystem health from the more visible attribute of clarity.

Figure 1: Heat map of sites visited (weighted by number of visits)

Source: (2014) *Non-market values for fresh water in the Waikato region: a combined revealed and stated preference approach.*



Overview of findings

There are a wide range of recreational uses of fresh water in the Waikato region.

A quarter of the users live in the Hamilton urban area, with a further 18 percent residing in Auckland. Aucklanders more often visit the lower Waikato (close to Auckland), Lake Karapiro and Lake Taupo.

The most common activities at Waikato freshwater sites were walking or jogging or relaxing near the water. Of the in-the-water activities, swimming or paddling are the most popular (48 percent of users), followed by fishing (37 percent). Boating is the most popular on-the-water activity (33 percent). A smaller number of respondents reported doing traditional cultural activities like eeling, mahinga kai, customary and ceremonial uses.

DESTINATION CHOICE

The destination choice analysis shows that the factors that best explain site choice include: travel cost, clarity, land cover (urban and forest), facilities, accessibility, development, perceived site cleanliness, perceived safety of food gathered and flow adequacy.

Water clarity was found to have a significantly positive effect in motivating people to visit a site.

Human health risk and ecosystem health measures were found to be not significant themselves in influencing site choice.

Travel cost has just as large a negative effect as clarity's positive effect. It means that sites further away are less likely to be visited, all else being equal.

However, cleanliness of the site – including the land, as perceived by the user – has the largest single impact overall, having a very positive influence on site visits. This is significant even when water clarity is included as a separate item.

Figure 3 shows the average influence of each factor.

Figure 2: Activities at Waikato freshwater sites

Source: (2014) *Non-market values for fresh water in the Waikato region: a combined revealed and stated preference approach.*

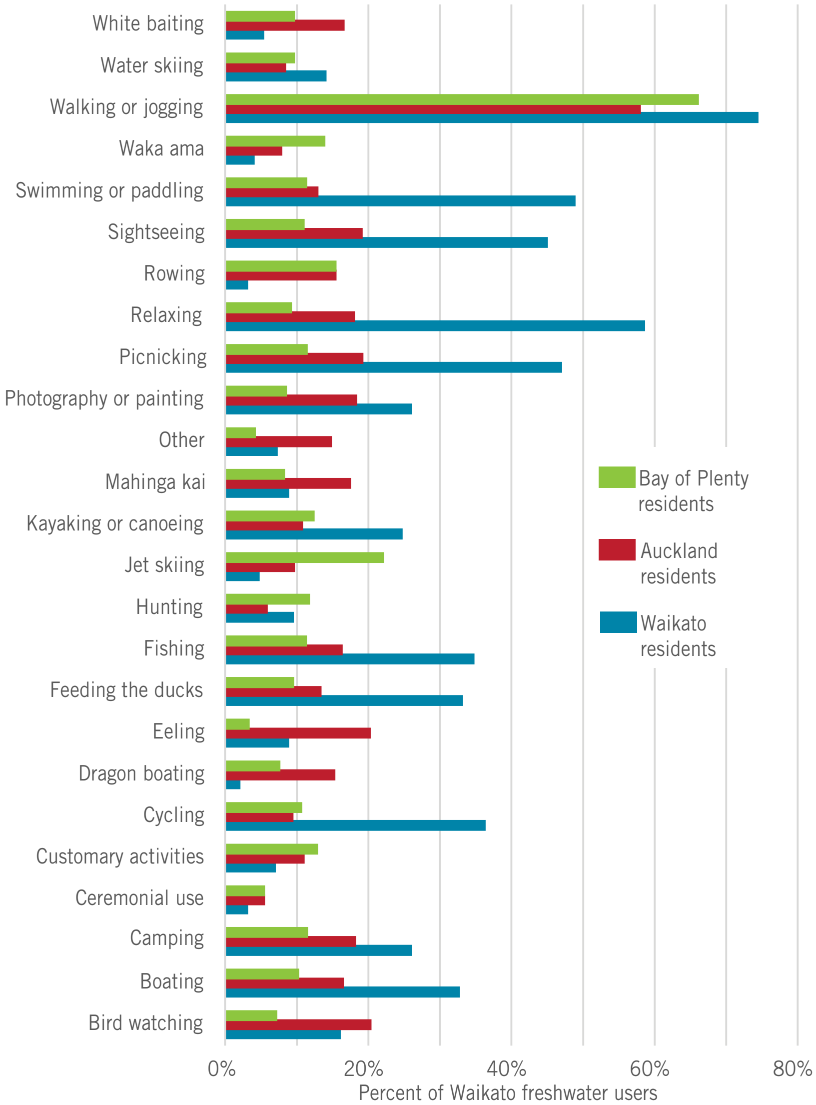
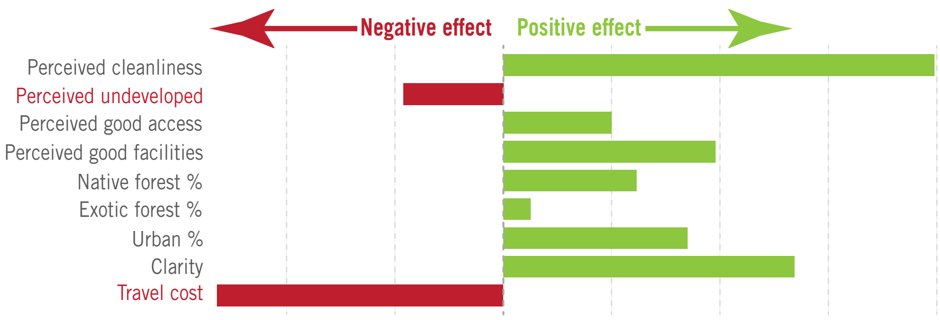


Figure 3: Relative impact of coefficients at average levels of each variable

Source: (2014) *Non-market values for fresh water in the Waikato region: a combined revealed and stated preference approach.*



TRIP COUNT

There is insufficient information to estimate the effect of water quality on the total number of trips, but the results signify that improvements in quality will result in substitutions between sites. People will benefit from being able to visit suitable sites closer to home.

Older and more highly educated people make more trips for freshwater recreation, according to this survey.

STATED PREFERENCES

The stated preference work resulted in a set of data about people's willingness to pay for improved water quality, such as for clarity.

These show there are several factors that have a significant impact on the amount people are willing to pay for water quality, including whether they are currently a user or a non-user, Māori ethnicity, ratepayers versus non-ratepayers, attitude towards water quality and distance they live from the site.

Overall, it showed that a wide range of people expect to experience benefits from improved water quality, whether they currently visit freshwater sites or not.

JOINT MODEL

Merging the two sets of data into a joint model showed that the same underlying preferences for water quality affect both destination choice and willingness to pay. The impact of changes in water quality on the values (that is, the marginal values) was found to be broadly consistent.

USE OF THE MODEL

This model can be used to evaluate the non-market benefits of changing aspects of water quality such as clarity, level of bacteria and levels of nutrients such as nitrogen. The model will give an output regarding how a specific level of water quality is expected to influence people's behaviour and welfare derived from recreation and cultural use.

This can be considered alongside potential costs of improving water quality – from the catchment model (see later section) – to assess different choices or policy options in setting freshwater objectives and limits.

Overall, it showed that a wide range of people expect to experience benefits from improved water quality, whether they currently visit freshwater sites or not.

6 CONTAINANTS THAT IMPACT ON WATER QUALITY

Introduction

Scientific research shows there are several contaminants that reduce water quality in New Zealand waterways when present at elevated levels for sustained periods of time. The main ones are:

» Nutrients (nitrogen and phosphorus).

» Sediment.

» Bacteria *(E.coli)*.

An excess of these can affect ecological health – the health of plants and animals and their freshwater habitat – as well as other values associated with the waterways, such as safe swimming, and in such situations they may need to be reduced.

Monitoring of water quality includes measuring the levels of contaminants and relating them to other water quality measures such as clarity and suitability for swimming – which will be affected by the level of contaminants. A range of physical sciences are used to understand the linkages.

In order to maintain and improve water quality, it is crucial to understand the sources of these contaminants. It's also important to understand how specific land use practices influence the levels of contaminants reaching waterways.

For the Joint Venture work, the researchers have primarily focused on nutrients and specifically nitrogen, as there are well-tested models available for analysing nitrogen. Further work on other contaminants is occurring outside of this project.

More about nitrogen

Nitrogen is needed for the growth of any biological organism. Growers spread nitrogen fertiliser around plants, for example, to assist plant growth.

Nitrogen also occurs in waste. Grazing animals urinating on pastures deposit concentrated nitrogen on to soil, and where this is not taken up by plants, it may leach through the soil. Human sewage is also rich in nitrogen compounds, as can be wastewater from some industrial processes.

Water containing elevated levels of nitrogen compounds is therefore produced as a by-product of farming, growing, industrial processing and municipal sewage treatment, and some of this is leached or discharged to waterways.

Fresh water naturally contains nitrogen. However, excess nitrogen changes the waterway as a habitat for animals and plants and reduces water quality for swimming. High levels of nitrogen can also be toxic for freshwater life. Nitrogen is therefore one contaminant that causes a decline in several aspects of water quality.

7 THE CATCHMENT MODEL

Introduction

The Waikato Economic Impact Joint Venture identified that an economic model was needed that would represent key aspects of land use and management within the Waikato–Waipa River catchment and help evaluate the relative economic impacts of different options for achieving water quality objectives.

The Waikato Land Allocation Model (known as the catchment model or WLAM) has been created as a core model that can be developed further as more information becomes available.

The catchment model represents the land, its management and nitrogen entering the Waikato-Waipa River catchment. This is no small task: movement of contaminants is influenced by the type of land activity, soil and rainfall, and previous research has shown there is a diverse range of land activity, rainfall, soil type and soil drainage in the Waikato region. The catchment model has the potential to show the relationships between activities on land and concentrations of contaminants (nutrients, sediment and *E. coli)* in the water.

Importantly, the model is supported by the organisations that have contributed to its development.

At this stage, the link between land use and movement of contaminants from the area of land being used is the best-developed part of the model (as indicated by the top arrow in the diagram below). The connection between the level or rate of contaminant movement (through and over land) and the quality of the water in the waterway is still to be fully developed.

For each land use, the model has access to information about a range of management systems – with estimates of the associated rate of contaminant loss and economic cost. (See the section on mitigation cost curves.)

In technical terms, the model is an example of a constrained optimisation model. This is because when given a particular water quality outcome, the model can go through a range of options for how contaminant loss from land-based activities can be constrained. It can then identify a combination of land use and management systems that are economically the best (least costly) to achieve the desired outcome. (The outcomes could be freshwater quality objectives and limits set by councils and communities.)

This kind of model has been widely used around the world to look at the relationship between land uses and associated environmental outcomes, although the data, analysis and its set-up are specific to the Waikato River catchment.

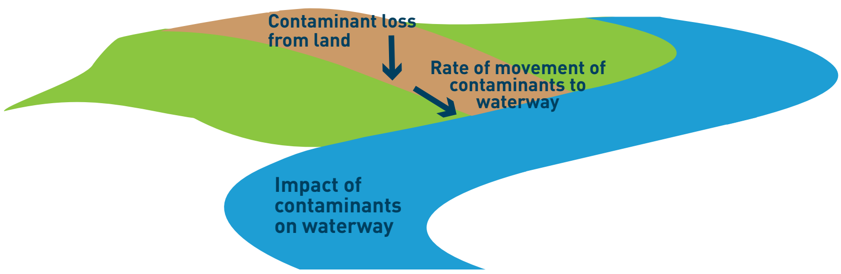
The catchment model comprises several parts:

» Underlying model logic.

» Algorithms – the set of rules for the calculations.

» Baseline data.

» Mitigation information.



A range of carefully-sourced baseline and mitigation information has been used, and the data gathered is explained in further sections of this document. The data gathering was overseen jointly by the governance and technical groups of the Joint Venture.

Sub-catchments

The model recognises 66 sub-catchments: with 22 in Upper Waikato (Lake Taupo to Karapiro), 15 in Waipa (Waipa River Catchment), 10 in Central Waikato (Karapiro Dam to Ngaruawahia) and 19 in Lower Waikato (Ngaruawahia to Tasman Sea) (see Figure 4).

The information about the sub-catchments was developed by NIWA. The analysis has identified the land use mix in each sub-catchment.

Also, for each sub-catchment there is a monitoring site in the Waikato and Waipa Rivers or a tributary, where levels of contaminant can be measured.

Land uses

The Waikato Land Allocation Model incorporates three types of land use:

» Farming and growing, that is: dairy, dairy support, sheep and beef, horticulture and forestry.

» Industrial sites.

» Urban (municipal) sites.

Farming and growing are known as "diffuse" or "non point" sources because contaminants will flow from a relatively wide area as a by-product of their activities (leaching through the soil or flowing over the land). The others are known as "point" sources, where contaminants are typically moved through a pipe or enter at a particular point into the waterway. In general, a lot of work has been done to address point sources in New Zealand and less progress has been made in addressing the diffuse sources.

According to a recent technical report, an estimated 61 percent of nitrogen in the Waikato and Waipa Rivers comes from land uses; 7 percent from point sources and the remainder from natural sources or Lake Taupo. (At mean flows, a little over one-third of the water in the Waikato River – at the mouth – has derived from Lake Taupo. Lake Taupo is subject to a separate plan that aims to reduce nitrogen in its waters.)

As mentioned, for each of these land uses, a series of mitigation cost curves have been produced and these have been built into the catchment model (see the following section).

Use of the catchment model

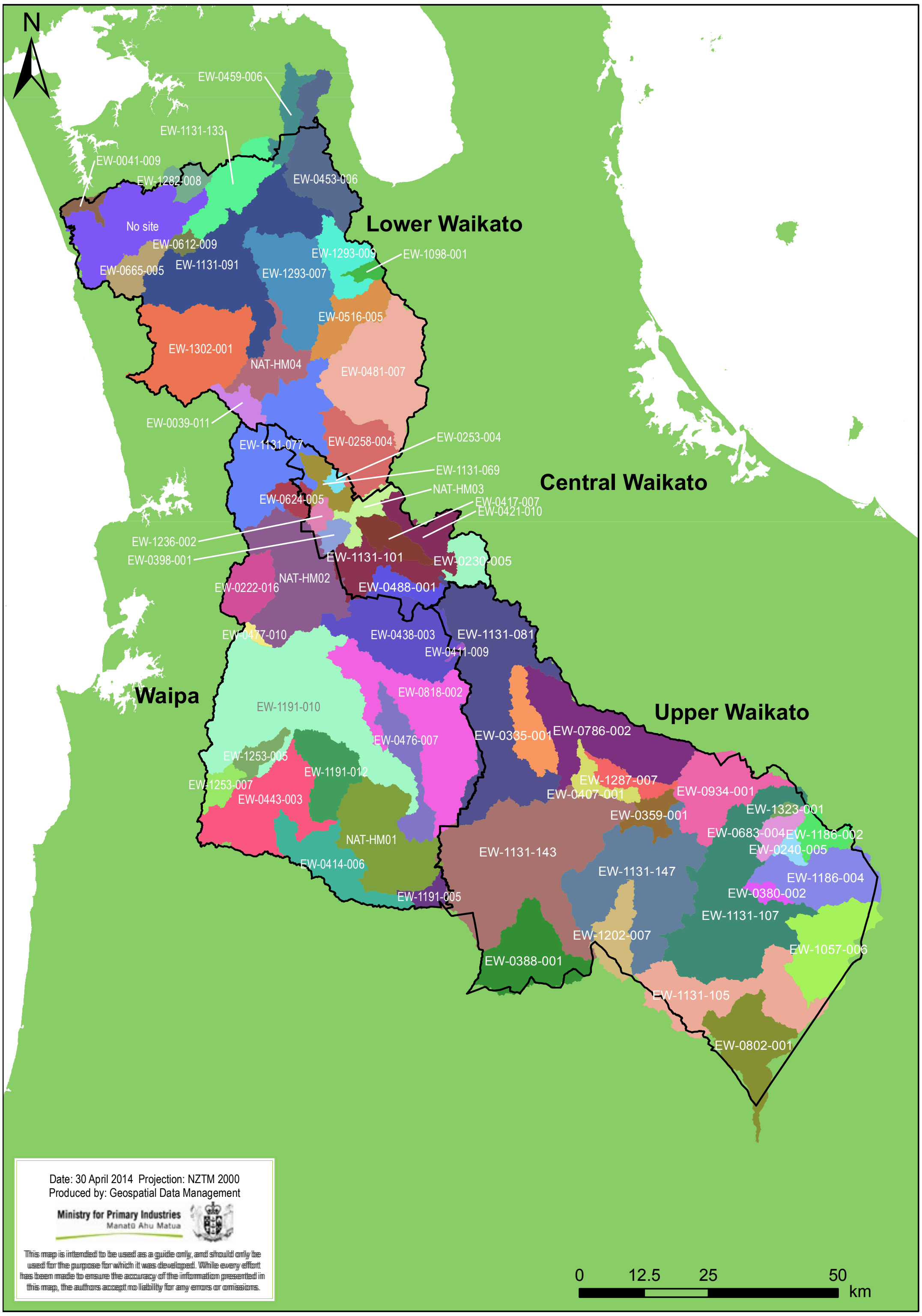
To use the model, a set of input files needs to be prepared, consisting of a target level of overall contaminant loss from farms and other land-based entities.

The model will then run calculations and come up with an output that could meet the required target level. The output file will consist of selected land management options, with costs ascribed to each sector and rate of contaminant loss.

Regarding change of land use, the model has two settings: it can be set to suggest a change of land use for a given area of land in response to a target – currently this only allows a change from pastoral to forestry production, or it can be set to work only within land uses.

This output showing potential costs of mitigation can then be considered alongside the output from the non-market valuation model which shows some potential benefits.

Figure 4: Sub-catchments in Waikato-Waipa River Catchment of Waikato region
Source: MPI.



8 USE OF MITIGATION COST CURVES

Introduction

For the main activities that are known to be losing contaminants into waterways in the catchment, a set of mitigation cost curves has been produced.

A mitigation cost curve is a well-recognised way of showing the relationship between reducing contaminant loss and the cost to entities from making changes to reduce contaminant loss.

The entities that have been studied are:

» Farming and growing enterprises.

» Industrial sites.

» Municipal wastewater treatment sites.

The researchers have undertaken several steps, working with people engaged with these activities and their technical advisers to:

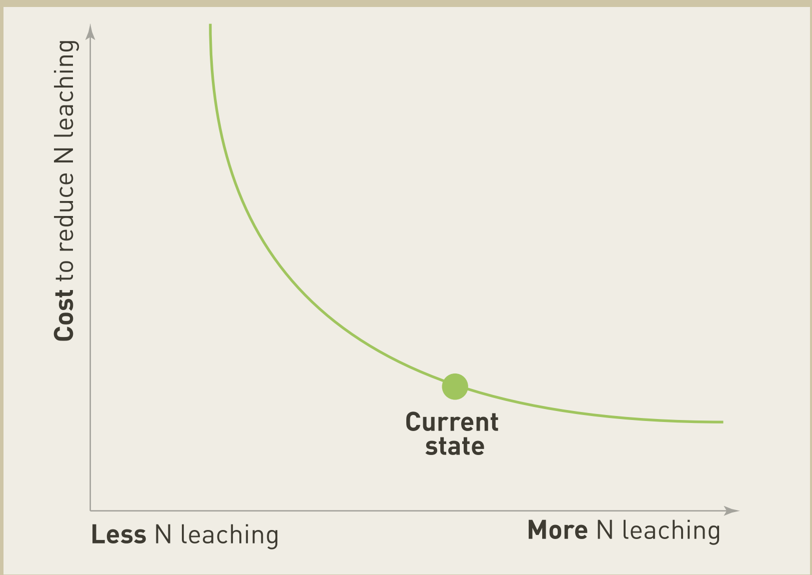
» Identify what options entities have to reduce contaminant loss – known as mitigation options.

» Determine how much reduction in contaminant loss each option could achieve if applied.

» Determine the cost to the entity of applying each option.

» Order the mitigation options by the level of impact they have in reducing loss and cost.

The result of this analysis is sets of figures that can be graphed. A graph (in this case showing the cost of change known as "marginal cost") would typically look like this in shape, though the steepness will vary:



For an entity that is going to make changes to reduce contaminant loss, such as a farm reducing nitrogen leaching, start at a point at the right of the curve that represents the current state – and move left.

From that point it is possible there are some options for reducing nitrogen loss without having much impact on the cost of running the farm, so the curve is flat at the start. (The mitigation strategies have been designed to start with the least-cost options.)

As progress is made, from right to left along the curve – and in effect through the options – it gets to a stage where the cost is becoming a bit higher. Further along, the curve goes up steeply – indicating that less and less reduction is being achieved for a given amount of cost. At some point the operation would no longer be economically viable.

(Economists calculate the area under the curve to give the cost, but the idea is the same as seeing where the line goes.)

It is very important to understand that the economic impact is not linear – that is, it is not straight because some mitigation options will have more impact. This is why the modelling is so important in helping to understand relationships.

How the catchment model uses the curves

The catchment model links to the curve data. For a given water quality level, the catchment model can assess the impact on individual entities, as described by the mitigation cost curves, and select from among them to get the required result. For example, if one curve shows that the impact of reducing contaminant loss is still fairly low for one type of entity, the model would first choose this entity to make some changes – rather than another where the cost impact would be higher.

In this way, the model shows the least-cost or most cost-effective way of achieving a given target across the whole catchment. By doing so, it estimates the lowest possible overall cost of achieving a given water quality result.

A DAIRY ANALYSIS

Introduction

The Waikato region has a temperate climate and a number of soil types that are ideal for pasture production and dairy farming. Research for the catchment model shows that one-third (33 percent) of land in the Waikato–Waipa River catchment is occupied by dairy farms. There are 2800 dairy herds, on average comprising 329 cows run on 133 hectares (effective).

The development of dairy sector data for the catchment model was led by a team of production economists and farm systems specialists at DairyNZ. (This work is part of a wider DairyNZ environmental economics programme.)

Case study farms

The research team's first step was to determine an approach for collecting information that would ultimately give a good representation of dairy farm operations within the region. This encompassed farm physical, financial and environmental information.

Scientific research has shown that nitrogen leaching on a pastoral farm is influenced by a range of factors, including: soil and rainfall, the production system, stocking rate, imported feed and nitrogen fertiliser use. These factors vary significantly on dairy farms across the Waikato region.

In order to represent the differences, it was therefore considered that a case study approach would be best: identifying individual farms that represent the known types of dairy farms in the region and then finding out more about these case study farms. This provides real and relevant farm data, rather than using averaged or modelled farm information.

Given that every dairy farm produces milk as the main output (unlike drystock and horticulture enterprises, for example), the types of farms were distinguished by factors including the location, soil type and rainfall, along with the amount of supplementary or bought-in feed used. Existing dairy industry statistics along with local consultants' and farmers' knowledge were used to determine the weights for each of the 26 dairy farms – 12 in the Upper Waikato area and 14 in the remainder of the catchment. Each type represents between 2 and 14 percent of the dairy farmed area.

With the agreement of the farmers, further information was gathered about the case study farms so that there was a complete set of physical and financial data, including details of farm infrastructure, fertiliser used and milk production per hectare. (Animals that were wintered on a support block are accounted for with standardised grazing costs.) Assumptions and standardised figures were used for factors such as prices for milk, fertiliser and supplementary feed.

For each of the case study farms, files were produced using Overseer® and Farmax software.

OVERSEER® – Overseer® models nutrient flows on a farm. Overseer® was developed by AgResearch and is jointly owned by the Ministry for Primary Industries, AgResearch and the Fertiliser Association. Overseer® version 6.1.2 was used for this work, with the Dairy Industry Input Protocol.

FARMAX – Farmax models animal feed demand and available feed supply. Farmax was developed by AgResearch and is now privately owned. Farmax Dairy Pro was used for the dairy analysis.

Mitigation options

The research team pulled together a range of possible mitigation options that could be used on case study farms to reduce loss of nitrogen from the farm land. They modelled the amount of loss reduction that could be achieved by each option and the economic impacts for the farm. (Mitigation options were limited to what can be modelled in Overseer®.)

A mitigation strategy was developed consisting of a series of options that a dairy farmer could realistically use and given in the order that they would apply the options, based on an understanding of the physical and economic requirements and impacts. Each successive option builds on the work already done – so the effects are cumulative – as would occur on a real farm. (The mitigation strategy was tailored for each case study farm.) A level of constraint is added for some measures, to reflect the reality of how far this aspect of the current farm operation can realistically be changed.

Following the technical advice, there are two initial settings for each case study farm – one as it is and one with a stand-off pad added if one does not already exist. Any scenario can be run for either or both of these settings.

STAND-OFF PAD – A standoff pad is a specially built area where cows can be taken off paddock for periods of time. Stand-off pads are primarily used during wet conditions to protect soils and pastures from damage, and in autumn to reduce urine deposition on paddocks that could be leached during later wetter weather. (Note, a stand-off pad differs from a wintering pad, a feed pad or any kind of barn.)

(The impact of nitrogen mitigation measures on phosphorus loss is included, but specific phosphorus mitigation measures were not pursued.)

MITIGATION STRATEGY – The agreed mitigation strategy for reducing nitrogen loss on the case study dairy farms is:

- If the farm has an existing feed pad or stand-off pad, the use of this is optimised.
- Autumn nitrogen fertiliser applications are reduced, and then removed.
- Spring nitrogen fertiliser applications are reduced, and then removed.
- The level of imported supplements is reduced (up to a 20 percent reduction from the base).
- Reduce stocking rate (up to 20 percent reduction of cow numbers from the base).

Overview of the current picture

While it was not the main purpose of this work, the modelling done during this research gave a picture of current levels of nitrogen leaching from dairy farming activity throughout the catchment. It showed that there is currently a range of leaching between 10kg N/ha and 60kg N/ha, with a third of the dairy area leaching between 30 and 40kg N/ha. (Note, this is the level that Overseer® has calculated is coming out from below the root zone and does not show what is actually going into waterways.)

Overall, from this initial work it appears possible for dairy farmers in the region to achieve some reduction in nitrogen loss without "a huge impact" on their farm operation, but once the reduction is beyond about 15 percent there is significantly more economic impact and the curve starts to get steeper (more expensive).

However, the research team notes that each farm is in fact different – and starts from a different baseline regarding nitrogen leaching, and ultimately an approach that enables solutions to be tailored to individual farm circumstances would help achieve catchment-wide targets in a cost-effective way.

B SHEEP AND BEEF ANALYSIS

Introduction

As noted previously, the Waikato region has a temperate climate and soil types that are favourable for pasture production and some types of cropping. About a third of the Waikato region's agricultural land is used for drystock farming, including sheep, beef, pasture silage and maize production. There are around 3600 drystock farms in the Waikato-Waipa Rivers catchment.

The development of drystock sector data for the catchment model was led by economists at the Waikato Regional Council.

Case study farms

The researchers used results from a previous survey of 450 drystock farms in the Waikato region to get a sense of the specific types of drystock farms and their spread across the sub-catchments. The team then approached 20 drystock farmers to get more detailed farm-level information about their operations.

It was identified that there are five main farm types of drystock enterprises in the region. Thirteen drystock farms that best represent these types were selected to be the focus of case studies. Complete information was collected for each, and this was checked with farmers and farm technical specialists. (Averaged climate and financial information from the wider group was used for the final representative farms to help protect privacy.)

The drystock farm types are:

» Small lamb finishing farms, some with a beef finishing operation.

» Traditional hill country with lamb finishing.

» All cattle on hill country with maize cropping (selling maize silage to dairy farmers).

» All cattle on hill country with a pasture-based dairy grazing operation.

» Bull and prime beef finishing.

One type, the traditional hill country farm with lamb finishing, represents about 60 percent of the total drystock-farmed area in the catchment. Each of the others represents around just under 10 percent.

Realistic, effective options for mitigating nitrate leaching on these farm types were then investigated by the Waikato Regional Council, with consideration of the type of enterprise and the main source of leached nitrate. Beef + Lamb New Zealand and a group of farmers gave feedback on the work.

Farmax software was used to model the baseline farm systems and test the practicality of the proposed mitigation options. Then the software was used to assess the economic impacts of the viable mitigation options.

Mitigation options include:

» Reduce stocking rate on farms with a high stocking rate.

» If the farm has steep slopes, plant trees on steep slopes.

» If producing maize silage for dairy support, substitute with pasture silage.

» For farms running fewer sheep relative to cattle numbers, increase the sheep-to-cattle ratio.

» For farms running a higher ratio of older or heavier cattle, substitute some with younger and lighter cattle.

Finally, Overseer® software (version 6.1.1) was used to predict the level of nutrient leaching that would result from applying the different mitigation options.

Overview of the current picture

The rate of leaching from the current, baseline for drystock enterprises in the catchment ranges from 8 kg/ha/year to 28 g/ha/year.

C HORTICULTURE ANALYSIS

Introduction

The lower Waikato area has a largely frost-free climate and soil types suitable for vegetable growing, particularly around Pukekohe and Pukekawa. Growers produce a range of vegetable crops, from potatoes to leafy greens. Between 6000 and 7000 hectares of land is in horticultural production in this area each year.

The development of horticulture sector data for the Waikato catchment model was a joint project between the Joint Venture, Horticulture New Zealand, the Pukekohe Vegetable Growers Association and combined vegetable grower product groups, with the analysis undertaken by an economist at the AgriBusiness Group. (For the horticulture sector, this is part of wider work on Horticulture New Zealand's Nutrient Management Programme, which is identifying and documenting good nutrient management practices.)

Representative rotations

A survey was conducted of current Lower Waikato growers to find out about crops grown, current management practices, typical yields achieved and the financial data for each individual crop.

In practice, there are generally not standardised crop rotations that would occur in a typical four-year period. However, based on growers' practice and consultation with an expert panel of growers and advisers, three representative four-year rotations for vegetable growing in the Pukekohe growing region were developed.

These are:

- **Large-scale crops –** a relatively extensive rotation of major large-scale crops such as potatoes, onions and carrots, which make up approximately 50 percent of the land in horticulture production in Lower Waikato.
- **Large-scale crops including green crops –** a more intensive rotation with the inclusion of more green crops such as broccoli and summer lettuce, which make up approximately 45 percent of the land in horticulture production.
- **Traditional market garden –** a more traditional market garden rotation, which is significantly more intensive, and which make up approximately 5 percent of land in horticulture production in Lower Waikato.

Mitigation options

Previous research has shown that nitrate leaching from land used for horticulture can result from high use of applied nitrogen, frequent cultivation, relatively short periods of plant growth, low nutrient use efficiency of many vegetable crops – partly because of sparse root systems, and crop residues remaining after harvest. The rates vary fairly widely between crops. The main sources of nitrate leaching in horticulture have been identified as being from fertiliser and crop residue.

Three mitigation techniques were identified, focusing on the timing and volume of nitrogen fertiliser application, as well as careful management of irrigation.

These will reduce the amount of nitrogen (N) leaching and also the output of phosphorus (P).

» **Mitigation 1 – Limiting N application:** limited any one application of N to 80 kg N/ha per month.

» **Mitigation 2 – Reducing N applications:** tested the model against a range of N application reductions from 10 percent to 40 percent and reduced the yield by an amount determined by reference to research reports and grower experience.

» **Mitigation 3 – Active Water Management:** tested the impact of altering the irrigation practices to apply only the amount of water required by the crop.

The effect of these mitigation techniques on each of the representative rotations was analysed using Overseer® nutrient budgeting software (version 6.1) to assess the impact on leaching and a financial model to assess costs. (It should be noted that while Overseer® is considered the best nutrient budgeting option for horticulture, it is still in the early stages of development for assessing horticultural crops.)

This has enabled a mitigation cost curve to be derived for each of the representative rotations, for use by the catchment model.

Overview of the current picture

The rate of nitrate leaching from the three representative models ranges from 58 to 75 kg N/ha, but with significant variation between the years of a four-year cycle – according to the specific crop grown.

D FORESTRY ANALYSIS

Introduction

The Waikato region has a strong forestry industry. The soils of the upper Waikato had trace element deficiencies that made it impossible to run livestock and this led to large areas of forestry planting. Forestry currently covers 12 percent of the region's land area. The Waikato soils and climate are well-suited for growing the main forestry species, *Radiata pine*.

The aim of the forestry analysis was to understand forestry's contribution to income in the catchment and how this might change with changing land use.

Research has shown that areas of commercial forestry production typically leach very low levels of nitrogen – similar to an area of native bush. However, forestry harvesting can cause significant loss of sediment and phosphates, and this could be the subject of a separate economic analysis.

The development of forestry sector data for the catchment model was led by analysts at Scion Research. They have developed estimates for costs of establishing, managing and harvesting a typical commercial pine plantation, as well as for areas of pine trees on steep farmland. The farm setting that has been addressed is a steep sloped area of a typical 450 hectares sheep and beef farm in the Waikato region, which accounts for about 100,000 hectares.

The forestry plantation was based on production of *Radiata pine* for framing wood, initially planted at 900 stems per hectare and thinned to 600 stems, with a rotation length of 28 years.

The calculations have included the value of wood and the value of carbon credits. Costings included consideration of terrain and road access, which can vary widely and have a marked impact on viability.

(The analysts noted that along with wood production and carbon sequestration, pine plantations can provide other benefits such as soil stabilisation, avoidance of erosion, recreation and habitats for native species.)

The forestry data provides a baseline for analysis by the catchment model of a possible change in land use for some areas where existing land uses can no longer operate within new nitrogen loss targets.

Overall, the forestry analysis determined that pine can provide a viable, profitable return and is therefore a potential alternative option when grown in dedicated forestry areas as well as when grown on steep farmland.

E INDUSTRIAL AND MUNICIPAL ANALYSIS

Introduction

There are a number of industrial and municipal sites that use or produce water and have controlled discharge rights, which means they are allowed to put water with a level of contaminants into the Waikato or Waipa Rivers or their tributaries. This includes treated wastewater from urban areas and from industrial processing sites.

The development of initial data about these discharges for the catchment model was led by a team of technical specialists at Opus International Consultants.

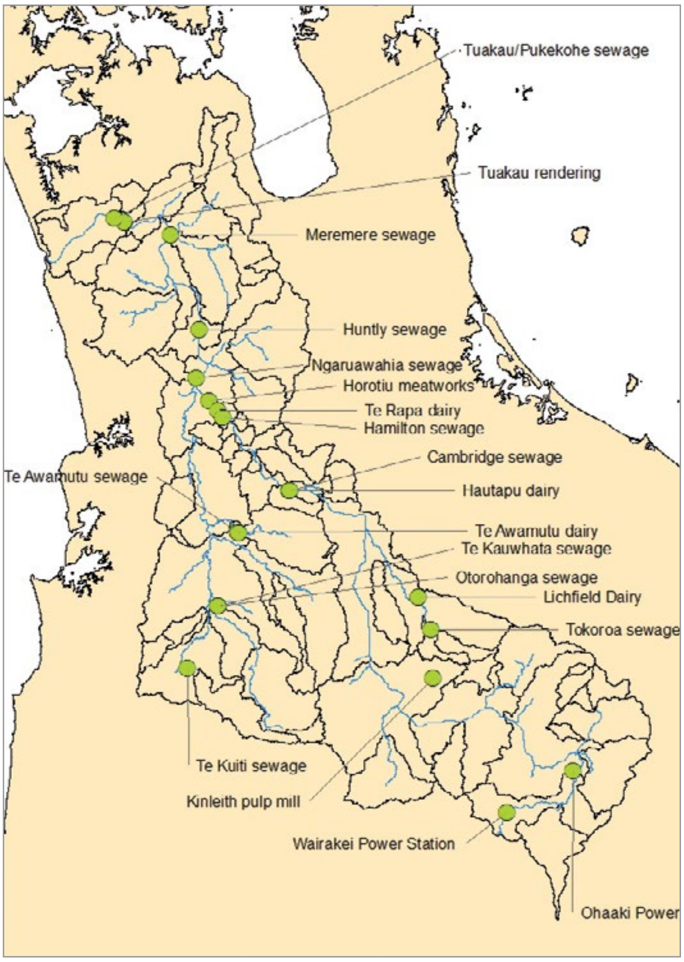
Main sites

Overall, it was identified that there are 4000 point source discharge points in the Waikato River catchment, of which the vast majority (99.5 percent) are for stormwater.

This investigation focused on the 20 largest point sources discharging to the catchment: 11 municipal wastewater treatment plants, which treat urban sewage, and nine industrial wastewater treatment plants. Councils monitor the water quality associated with each point source in their area.

The research team have used site-specific data where publicly available (mainly relating to municipal sites) as well as generalised information about wastewater operations to calculate likely contaminant removal rates and the associated costs. They have used five treatment settings: none, primary, secondary, tertiary and land disposal. This gives an approximate mitigation cost curve for each site, based on existing information.

Figure 5: Wastewater and stormwater discharge points in the Waikato River catchment



Overview of the current picture

The current situation is that the 20 sites have facilities for treating wastewater that are worth approximately $306 million (based on replacement value), and they spend approximately $21 million a year operating and maintaining them.

They are releasing the equivalent of about 1095 tonnes of nitrogen a year in discharges, but if the water was left untreated would be discharging 3576 tonnes a year.

The researchers estimate that should total contaminant removal be required (that is, total disposal to land), expenditures over the next 10 years would need to be nearly four times what is currently planned. Targeting individual contaminants would enable intermediate options.

9 SUGGESTED STEPS

As indicated, this report has described modelling tools that have been developed for use in decision-making around freshwater management in the Waikato-Waipa catchment. The focus of this initial work has been on nitrogen. It has also collated information about values associated with the waterways.

While this work represents a significant step forward, the Joint Venture recognises it does not provide all the information that will be needed for the decision-making.

Following are examples of areas that need further work.

- As noted, further work on the other three contaminants is occurring outside of this project, as part of the Healthy Rivers/ Wai Ora project. This is important to give a full picture of the main impacts on water quality from diffuse discharges in particular.
- The general principle is that the better the data, the more robust the model will be. There are several areas where this type of improvement could be made, including improved land use data. (For example, forestry harvesting could be the subject of a separate economic analysis.) Also, it is expected that new data will become available over time, such as for new mitigation technologies.
- It would be advisable to undertake sensitivity analysis, to understand the potential for change and the impacts of change. For example, an analysis of income should look at the impact of changing input pricing and product returns on the viability of different land uses.
- If targets and limits for freshwater quality are to be set in terms of concentrations of contaminants in the water, there will need to be some way of linking what is happening on land (as indicated by this modelling), with concentrations in the waterways. This work will be undertaken by hydrologists and groundwater researchers.
- This work has drilled down into specific aspects of the regional picture. In order to properly understand the implications of setting targets and limits, the wider economic and social perspective is required. The catchment modelling could be an input into a broader analysis of the regional economy.

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