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Evaluation of the Decision Version of the Proposed Plan Change 1 policy mix

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Waikato Regional Council
Te Kaunihera ā Rohe o Waikato

Prepared by: Femi Olubode-Awosola

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

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Peer reviewed by:	Date
Carla Muller	30 November 2021
Riccardo Scarper	15 September 2021
Guido M Bazzani	15 September 2021

Approved for release by:	Date
Tracey May	21 March 2022

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Abstract

The Collaborative Stakeholder Group (CSG) conceived the initial version of the Proposed Waikato Regional Plan Change 1 (PC1) as a policy mix intending to achieve short term[1] water quality target attribute states (the targets) in the Waikato and Waipā catchments. The policy mix was simulated using scenario modelling by the Technical Leaders Group (TLG) who provided advice for the CSG deliberation. The policy mix included information on the types and extent of mitigations required to meet the water quality target attribute states. It also provided information on the economic and production impacts of those mitigations and policy.

After PC1 was notified, Waikato Regional Council (WRC) received submissions that were heard by an independent Hearings Panel who then made changes to the policy mix, in the 'decision version' reported in Hill et. al. (2020). Using the modelling framework developed by the TLG, an evaluation of the decision version of PC1 was completed and is presented in this report. Implications for policy implementation and monitoring, as well as possible on farm responses to the policy, were also considered. The aim of this evaluation and report is to contribute to the understanding of various contaminant sources, the mitigation options and the extent to which they can help achieve the water quality target attribute states to meet the objectives of Te Ture Whaimana (the Vision and Strategy for the Waikato and Waipā rivers[2]).

The key finding of this modelling of the decision version is that in both the long term (80-year) and short term (now 20% of 80-year target attribute states in the first 10 years) scenarios, more target attribute states are met than breached. The results suggest the impact is specific to nitrogen (N), and localised in two sub-catchments, Upper Waikato and Waipā Freshwater Management Units (FMUs).

To arrive at the level of achievements reported above, the main assumptions are that some mitigations are adopted among the rural sectors such that some farm types are not expected to remain at their baseline level of nutrient loss profiles. This, together with further mitigation options are reflected in the sectors' profits and productions. Overall, there is potential loss of about 18% of catchment-level income in the long term scenario, and about 16% in the short term scenario. The difference is not much because most of the targets are achieved and or exceeded even at the short term scenario based on the modelling assumptions.

An on-farm implication is that options to mitigate contaminant losses could be more effective and efficient with advancements in technology that would maintain or improve productivity and profitability. The results of the long term scenario show possible localised increases in concentrations of specific contaminants ("hot spots") in the catchment. For policy implementation, this suggests that mitigation options should be specific and targeted.

Although time[3] affects the difference between on-farm contaminant loads and concentrations in the rivers, it has not been explicitly incorporated into either this modelling of the decisions version or the original modelling for PC1. Therefore, it is important that WRC's implementation efforts are focused on monitoring the adoption of the mitigation activities along with monitoring of contaminant concentrations in the river. This has the potential to inform updates to, and/or future reviews, of the plan.

[1] Initially, PC1 aimed to achieve 10% of the 80-year water quality targets or limits in the first 10 years of the PC1 being operative. The decision version changed this to 20% of the 80-year targets in 10 years.

[2] "the restoration of water quality within the Waikato River so that it is safe for people to swim in and take food from over its entire length" and consideration of social and economic implications.

[3] There are many other factors that are time dependent such as development and adoption of innovations, changes in prices and costs, climate change, etc.

Executive summary

- The first notified version of the Proposed Waikato Regional Plan Change 1 (PC1) was conceived by the Collaborative Stakeholder Group (CSG) as a policy mix to improve water quality in the Waikato-Waipā Rivers Catchment through a range of mitigations. The policy mix comprised a range of provisions (objectives, policies, rules and methods) to achieve short term target attribute states[4] (the targets), which were 10% of the 80-year target attribute states, and were to be achieved in the first 10 years of the plan being operative. In addition, there was a provision that allowed intensification of tangata whenua ancestral lands.

- PC1 aims to restore and protect the health and wellbeing of the Waikato and Waipā rivers for the benefits of current and future generations, as set out in the Vision and Strategy for the Waikato River, Te Ture Whaimana o Te Awa o Waikato. The desired outcome is for the Waikato and Waipā Rivers to be swimmable and safe for food collection along their entire lengths, a higher goal, at the time, than the National Policy Statement for Freshwater Management (NPS-FW) 2014 requirements for wadeable water bodies (Waikato Regional Council, 2016).

- The Technical Leaders Group (TLG) that advised the CSG undertook scenario-based modelling simulation of the policy mix of the PC1. In the set of scenarios modelled, on farm mitigation strategies were the main factors considered as to whether, and to what extent, the improvement in water quality outcomes being sought were achievable. Also considered were edge-of-field mitigations[5]. The implications of the simulated policy mix are reported in Doole et. al. (2016).

- After the CSG's proposal was notified, Waikato Regional Council (WRC) received submissions that were heard by an independent Hearings Panel who recommended a revised set of provisions. WRC adopted the Hearings Panel's recommendations and notified the 'decisions version' (Hill et. al., 2020) of PC1 in April 2020.

- An important change recommended by the Hearings Panel was to achieve 20% (rather than the initially proposed 10%) of the 80-year target attribute states in the first 10 years of the plan being operative. Also recommended were changes in the method of achieving the water quality improvement. The notified PC1 effectively 'capped' each farm's nitrogen leaching by setting a farm Nitrogen Reference Point (NRP) that farmers needed to farm within. High intensity farms needed to reduce to the 75th percentile nitrogen leaching. The decisions version removes the numerical nitrogen limits for each farm, although retains more nuanced policy directions intended to achieve the same thing. The decisions version requires application of Nitrogen Leaching Loss Rate (NLLR), which is an Overseer modelled nitrogen leaching number, to determine if the farms could be permitted activities, controlled activities or discretionary activities. Another main change recommended was to allow commercial vegetable production (CVP) expansion up to a limit for specific sub-catchments.

- Comparable to the analysis done by the TLG, the Land Allocation Model (LAM) applied by Doole et. al. (2016) was extended and applied to evaluate whether the Hearings Panel's recommendations would likely achieve the water quality attribute targets, and what the economic and production implications could be. Possible implications for policy

[4] For water quality

[5] Mitigation actions or technologies to reduce loss of contaminants from farmland by investing at edge of field either on or off-farm, and includes constructed wetlands, sedimentation ponds and detention bunds.

implementation and monitoring, and on farm response to the policy, were also considered.

- This modelling exercise aims to test if the decision versions of the PC1 can meet the water quality attributes targets and the Vision and Strategy objectives, and the impacts on rural land use sectors.

- In this report, references are made to all relevant reports[6]. Therefore, the results reported here should be read alongside those reports, which provide details on the modelling approach used by the TLG in the proposed version of the PC1. This report describes results of the modelling done for the decision version, but does not assess appropriateness of the model.

- As is always the case with such a modelling exercise, there is a caveat associated with the level of calibration in the model applied in this study. Encouragingly, the model reproduced the land use distribution and patterns observed in the baseline and previous modelling exercises (Olubode et. al. 2014, Doole et al 2015a, 2015b and 2016). Also, other factors outside the model could affect achievement of the target attribute states including nitrogen (N) 'load to come'. For example, based on the N-model, total nitrogen (TN), median nitrate and 95th percentile nitrate in a downstream or hydro-geologically connected sub-catchment could be affected by high N 'load to come' in the surface water even after attenuation[7] (Semadeni-Davies at al. 2015a). Also, there has been evidence of high levels of groundwater N in the upper Waikato (Doole et. al. 2015a, 2015b). However, the model validation is considered reasonable. With the assumptions about the mitigation options and the data inputs, the results are as per *a priori* expectations in terms of the direction of estimated impacts. That is where we expect a scenario or policy provision to have negative impact on meeting targets, such results were found. However, the magnitudes are only an indication as modelling cannot guarantee precision all the time. Some of the magnitudes observed are comparable to the earlier modelling by the TLG and evidence from industry groups.

- In both long and short term scenarios in the decision version, more target attribute states were met than breached. Only two instances of possible increased concentrations of contaminants in the Middle Waikato FMU, three instances in Waipā, and a few (5) instances in the Lower Waikato FMU were indicated. As may be expected, most (23) instances were in the Upper Waikato FMU.

- The level of CVP expansion recommended by the Hearings Panel was estimated to have relatively small negative effects on the prospects of meeting the target attribute states. The results suggest the impact is contaminant specific (relating largely to N) and localised in a couple of specific sub-catchments in the Upper Waikato and Waipā FMUs.

- The results of intensification of iwi land are similar as per the original PC1 version – mainly N in specific sub-catchments (Upper Waikato and Waipā FMUs).

- To arrive at the level of achievement of target attribute states reported above, the main assumption was that mitigations would be adopted in rural sectors in line with the NLLR policy directions. This is reflected in the sectors' profits and production.

- As a result of the assumptions underlying the TLG data collection and analyses to support the CSG deliberations on the costs of mitigation options, the financial cost of land-use

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[6]The reports commissioned by the CSG and produced by the TLG, available on the WRC website: https://www.waikatoregion.govt.nz/council/policy-and-plans/healthy-rivers-plan-for-change/technical-alliance/technical-alliance-documents/

[7]The difference between nutrient losses and loads.

conversion of iwi land is relatively large. Edge-of-field mitigations are also relatively high cost, while erosion control on horticulture land and effluent management on dairy land are the least costly.

- Overall, a potential loss of about 18% of catchment level income was estimated for the long term scenario and only slightly more than the 16% estimate for the short term scenario. The difference is not much because most of the targets are achieved and or exceeded even at the short term scenario based on the modelling assumptions.

- Allowing CVP expansion in the short term could raise the horticulture income by a margin of about 0.14%. However, intensification of iwi land in the short term could reduce the pastoral income by 0.38%, 0.75% and 1.13% under low, medium and high land area development rates respectively. This is because intensification of iwi land may be costly (and would be less probable if those costs outweigh the expected revenue), it is acknowledged that the costs of mitigation would likely decrease over time as technology evolves.

- An evaluation of economic growth and employment implications[8] of the decision version of the PC1 has not been carried out in this modelling exercise because of limited time. This was required in the initial development of the plan change to satisfy section 32 of the Resource Management Act (RMA) 1991.

- In terms of the possible responses from farmers, some mitigation options could involve changes in farm systems that might lead to increased variable costs, as well as fixed costs. Since farmers are generally 'price-takers' (i.e. they cannot influence the price they receive for their products), higher costs imply some adjustments to the level of production. Economic theory suggests that if only cost per unit of output is covered (i.e. output price per unit is only up to the output cost per unit), farmers may stay in business although there would be cash flow deficits and loss of net worth. If costs of mitigating contaminant loss increase, farmers can minimise loss by reducing production, but if costs increase to the point that losses are substantial enough and become permanent, the best way to minimise loss is to go out of business. An option to prevent or turn around a permanent or substantial loss is better technology to improve productivity.

- The long term scenario showed localised instances of increasing concentration of some contaminants suggests contaminant "hot spots", not only on farms (as is usually observed) but also in the catchment. Such instances would benefit from targeted mitigation options, as generalised mitigation options might fail to address "hot spots". In addition, the consideration for intensification, such as CVP expansion and iwi land development, could be targeted to avoid increased concentrations at the "hot spots". This is where farm environment plans, proposed as one of the monitoring tools, would be useful for risk-based monitoring of property characteristics, land use activities and mitigation actions.

- Although time[9] affects the difference between contaminant loads on farm and concentrations in the rivers, yet it has not been explicitly incorporated into the modelling (currently as well as in the earlier PC1 version[10]). Therefore, it is important that WRC's implementation efforts are focused on monitoring the adoption of the mitigation activities

[8] i.e. value added and flow-on impacts of the farm and catchment level productions/economics in terms of gross domestic product (GDP) at regional level. That would require input-output modelling.

[9] There are many other factors that are time dependent such as development and adoption of innovations, changes in prices and costs, climate, etc.

[10] Time was implicitly integrated in the efficacy of the mitigation options using theoretical adoption rate

along with monitoring of the contaminant concentrations in the river. This has the potential to inform updates to, and/or future reviews of the plan.

1 Introduction

The Waikato Regional Council (WRC) has proposed Plan Change 1 (PC1) to its Regional Plan, which involves setting water quality target attribute states to achieve the objectives of Te Ture Whaimana o Te Awa o Waikato for the Waikato and Waipā River catchments. The proposed plan change was initially developed under the *Healthy Rivers Plan for Change: Waiora He Rautaki Whakapaipai* (HRWO) project. This project started in 2015 with the aim to reduce the discharge of nitrogen (N), phosphorus (P), sediment and *E. coli* in the catchment (Waikato Regional Council, 2016).

The notified version of PC1 was conceived by the Collaborative Stakeholder Group (CSG) as a policy mix. The policy mix comprised a set of nine water quality attributes[11] on which target attribute states (the targets) are set to be achieved over 80 years. It was accompanied by rules and policies to achieve 10% of the 80-year target attribute states in the first 10 years of the plan being operative. The Technical Leaders Group (TLG) undertook scenario modelling to simulate the policy mix of PC1, showing the extent to which the target attribute states could be achieved as well as the economic and production implications of PC1. This is reported in Doole et. al. (2016).

After PC1 was notified, WRC received submissions, which were heard by an independent Hearings Panel. The panel developed a revised version of PC1, referred to as the 'decision version', which is reported in Hill et. al. (2020).

An important change recommended by the Hearings Panel was that the plan change should aim to achieve 20% of the 80-year water quality improvement in the first 10 years of being operative (as opposed to the 10% improvement proposed by the CSG). A summary of the baseline states and target attribute states of the nine water quality attributes is presented in Table 1. The concentrations of water quality attributes 1 to 8 are to be maintained or reduced by mitigation actions and the 9th water quality attribute, clarity (i.e. visibility distance), is to be maintained or increased. The target attribute states describe the percentage reduction in the concentration being sought for the first eight attributes, and the increase in clarity for the ninth attribute (10th percentile clarity) compared to their baseline states. The concentrations and clarity numeric values are summarised across the 74 sub-catchments as medians presented in the 4th column of Table 1. For further information, see details in Table 3.11.1a-c in Hill et. al. (2020).

[11]Based on the attributes tables in the National Objectives Framework of the National Policy Statement for Freshwater Management and chosen as part of the Waikato Objectives Framework (Waikato Regional Council, 2015).

Table 1: Summary of baseline/current and proposed target attribute states[12]

#	Water quality attributes	Number of sub-catchments where target attribute states are set	Baseline/current concentration (Median)	% change proposed**	
				20% of 80-year	80-year
1	Median chlorophyll-*a* (mg/m³)*	9	5.67	-4.72%	-17.32%
2	Maximum chlorophyll-*a* (mg/m³)	9	23	-1.25%	-5.65%
3	Median TN (mg/m³)	10	425.5	-2.12%	-12.20%
4	Median TP (mg/m³)	10	32	-3.77%	-17.67%
5	Median nitrate (mg/L)	62	0.63	-1.16%	-6.16%
6	95th percentile nitrate (mg/L)	62	1.21	-1.72%	-8.58%
7	Median *E. coli* (cfu/100mL)	62	215	-7.47%	-37.38%
8	95th percentile *E. coli* (cfu/100mL)	62	2,035.00	-12.06%	-58.14%
9	10th percentile clarity (m)	58	0.44	40.19%	198.53%

Data Source: Author summary from tables 3.11.1 a-c in Hill et. al. (2020)
*current' refers to the water quality statistics for the 2010 – 2014 period (except for *E. coli*, where the period is 2009 – 2014).
** rounding errors in computing average.

Another key change to PC1 recommended by the Hearings Panel was a difference in the method to determine which rules apply to which properties. The notified PC1 effectively 'capped' each farmer's nitrogen leaching by setting a farm Nitrogen Reference Point (NRP) that farmers needed to farm within. High leaching farms needed to reduce to the 75th percentile nitrogen leaching. The decisions version removes the numerical N limits for each farm, although retains more nuanced policy directions intended to achieve the same thing. The decisions version requires an application of the Nitrogen Leaching Loss Rate (NLLR), which is an Overseer[13] modelled nitrogen leaching number, to determine if the farms could be permitted activities, controlled activities or discretionary activities. The following table shows the 'gateway' for determining which rule (permitted, controlled or discretionary) applies to farms as indicated by their NLLR in different FMUs.

Table 2: Proposed nitrogen leaching loss rate levels by FMUs

Freshwater Management Unit	Low (kg N/ha/year)	Moderate (kg N/ha/year)	High (kg N/ha/year)
Lower Waikato River	≤ 21	> 21 and ≤ 29	> 29
Middle Waikato River	≤ 21	> 21 and ≤ 33	> 33
Upper Waikato River	≤ 31	> 31 and ≤ 57	> 57
Waipā River	≤ 30	> 30 and ≤ 43	> 43

Source: Hill et. al. (2020)
Note:
≤ denotes 'less than or equal to'.
> denotes 'greater than'.

Another change recommended was to enable CVP a limited increase in area for specific sub-catchments as presented in Table 3 (compared to a cap in the area under the earlier CSG version of the PC1).

[12] To avoid confusion of terminologies, we are using the term 'target attribute states' which is the term used in the NPS-FW 2020 to imply water quality targets

[13] https://www.overseer.org.nz/

Table 3: Existing and proposed maximum CVP areas

No	Sub-catchment	Existing/ baseline areas (ha)*	Maximum areas recommended (ha)*
Specific sub-catchments where expansions are recommended*			
1	Mangaonua (29)	90	96
2	Waikato at Bridge St Br (27)	200	219
3	Kirikiriroa (23)	0	4
4	Waikato at Horotiu (25)	2	21
5	Waikato at Huntly-Tainui Br (20)	77	155
6	Opuatia (11)	94	108
7	Waikato at Mercer Br (9)	977	1,078
8	Mangatāwhiri (1)	0	4
9	Ohaeroa (7)	123	129
10	Waikato at Tuakau Br (4)	684	712
11	Waikato at Port Waikato (6)	950	1,020
12	Waipā at Waingaro Rd Br (24)	106	146
13	Firewood (21)	0	6
	Total	**3,304**	**3,698**
14	Other sub-catchments with existing CVP***	2,801	
	TOTAL	**6,105**	**6,499**

* There are rounding errors
**Source: the last column data is from Hill et. al. (2020)
*** these are 21 other sub-catchments with existing CVP in the baseline

A comprehensive summary of the recommended changes is presented in Table A1 in Appendix A.

Simulation of the policy mix that comprises water quality attribute states, mitigation options and policies, and the resulting estimates of the economic and production implications thereof, has been completed using the same methodology as the analysis by the TLG. The Land Allocation Model (LAM) by Doole (2015) was extended to simulate the decisions version of the policy mix, including economic and production implications. The results are presented in this report.

This report proceeds with a description of the model and the data input. First, the modelling framework used to help understand the issues and options to achieve the policy objectives is described. This is followed by a brief outline of the model and assumptions - specifically how quantitative changes in the decision version of PC1 were parameterised in the model. The results of the modelling are presented and discussed. Conclusions are presented, highlighting feasibilities and the implications of the quantitative changes recommended. Lastly, policy and on-farm implications based on the results of the modelling are highlighted.

2 The methodology

The methodology employed in the modelling of the PC1 policy scenarios and in this evaluation of the decision version is based on the modelling framework and data inputs from the HRWO project's predecessor, the Waikato Economic Joint Venture Studies project. That project aimed to inform central government's decisions on the original version of the National Policy Statement for Freshwater Management in 2011. The project was a collaboration between central government agencies, Waikato Regional Council, the Waikato River Authority and DairyNZ, with support from other industry groups (Doole, 2013; Olubode et. al., 2014). One of the main outputs of the project was the development of an analytical model based on a land allocation modelling (LAM) framework published in Doole (2015a). In addition, and as part of the project, a baseline database (model input) was compiled. The data are relevant to the analysis of a range of scenarios for water quality attribute states and limit setting specifically in the Waikato-Waipā River catchment. The model and data input formed the basis from which the HRWO TLG supported the CSG's deliberation.

When the TLG was supporting the CSG deliberations during the HRWO project, the TLG extended and applied the version of the model reported in Olubode et. al. (2014) to perform some sets of scenario modelling to advise the CSG.

In this section, a summary of the model, the data input, and the applications[14] of the model are presented. Also mentioned are the references to sources of data input and the models' detailed documentations. The section ends with the presentation of current application of the model and how the scenarios were specified and parameterised in this modelling exercise. Specifically, the extension to the model for the purpose of evaluating the Hearings Panel's recommendations in the decision version of the PC1 were itemised.

2.1 The model

In this section, the base models (LAM and hydrogeological models) and their integration are briefly described. The prototype and framework of the LAM were developed and published in Doole (2015a). The model is an optimisation model that integrates economic and hydrogeological models. Also, the model is a mathematical programming model. Ideally, this type of model is best suited where there is inadequate data for other approaches. However, in the case of PC1, the database and the model have been extended over time from the previous project, the Joint Ventures Economic Studies (Doole, 2013; Olubode et. al*.,* 2014). The integration of six hydrogeological models into LAM has increased the complexity of the model in terms of the numbers of variables represented in the model.

[14] After the base model was developed during the Joint venture projects, the TLG further developed the model and applied to a number of scenarios analysis.

An integrated version of LAM with the hydro-geological models that relate concentrations of contaminants in waterbodies to nutrient losses is presented in Figure 1 below.

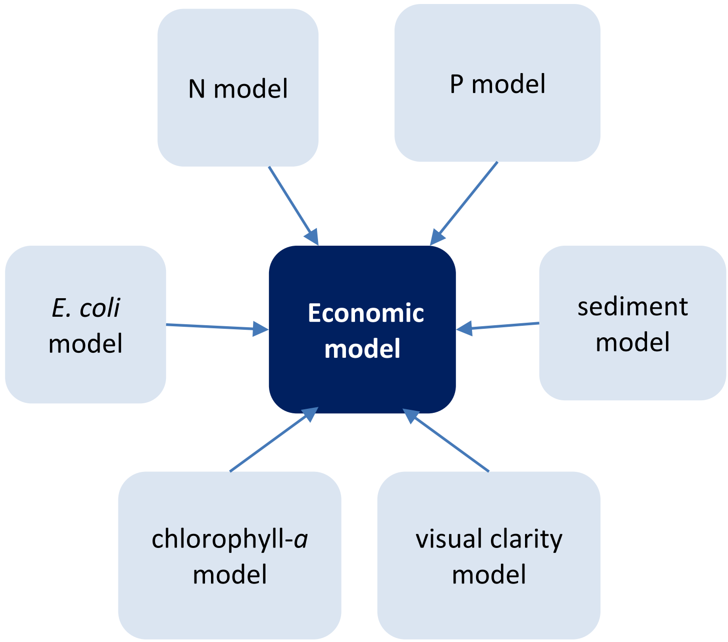

Figure 1: Schematic diagram of the Land Allocation Model and the hydrogeological models

The earlier version of the LAM (Olubode et. Al., 2014) that included only 2 contaminants, nitrogen (N) and phosphorus (P) was further developed by the TLG to include 2 additional contaminants, microbes and sediments. The TLG then applied the model to help the CSG understand how the current states of the water quality attributes relate to mitigation options, efficacies and possible adoption rate of the mitigations, as well as the tributaries and mainstem attenuations.

The base model has features to optimise abatement costs across land use types, farm systems, level of intensification, edge-of-field mitigations as well as point source remediation from both industry and municipal water treatment plants (Doole, 2016). Details of the mitigations included in the model are presented in Doole (2015b) and Keenan (2015).

The model and database have the four contaminants represented as nine water quality attributes in the hydrogeological models. For example, the sediment model captures the attenuations in the Waikato River hydro-reservoirs (Hughes, 2015). Median and 95th percentile loads of *E. coli* (microbial[15] loads) are affected differently by the mitigation options (Semadeni-Davies et. al., 2015b). Median and maximum chlorophyll-*a* concentrations and water clarity, and how they relate to their sources, are represented in the model (Yalden and Elliott, 2015). These hydrogeological models are catchment level, relating farm level nutrient losses to contaminant concentrations measured in water bodies within the network of the Waikato-Waipā main-stem rivers and tributaries (Doole et. al., 2016).

The model has features to evaluate the costs of achieving environmental objectives by running the model to test the feasibility of achieving the water quality target attribute states and what policy variables would be required to achieve a target.

[15] These are microorganisms capable of inducing illness in humans.

The level of aggregation in the model is at the sub-catchment level, where each of the 74 sub-catchments[16] in the Waikato and Waipā River catchments contains varying numbers of farm types (representative farms) at different levels of intensification, reflecting their soil types, land use capabilities and climate variations. Also incorporated are point sources in the catchment – 24 major industrial and wastewater treatment plants that hold consents to discharge contaminants to waterbodies (Opus International Consultants, 2013; Vant, 2014; Keenan, 2015).

In addition, significant heterogeneity in terms of farm systems is represented in the model. Non-point and point sources of contaminants are represented, as are numerous options to mitigate discharges, including edge-of-field mitigations and hydro-reservoirs. Broad-scale diversity in attenuation of on farm nutrient loss both within the tributaries and across the mainstem rivers of Waikato and Waipā are also incorporated (Dymond et. al., 2010; Hughes, 2015).

Also represented are surface water linkages and complex groundwater legacies that are incorporated in the six different hydrogeological models, namely the NIWA models for N, *E. coli*, P, chlorophyll-*a*, sediment and visual clarity (Figure 1). All these models sit behind an economic model that seeks the least cost combination of mitigation options for achieving water quality improvements. Sources of sediment loss are represented in the model to capture hill slope and stream bank erosion. This was specified within the sediment model, using the New Zealand Empirical Erosion model (Dymond et. al. 2010; Hughes, 2015). This diverse representation involves many stakeholders, who expect a reasonable description of their sectors and the implications for them. This complicates the level of aggregation and representation in the model specification and the data inputs (the database).

At catchment level, LAM maximises production per unit profit minus costs of mitigation activities and penalties for breaching any water quality constraints (target attribute states). Specifically, the profits are represented for dairy, dairy support, drystock, horticulture and forestry activities. Transition costs are also specified as saved costs or added revenue that may arise from converting from one land use to another. Details are presented in Matheson (2015). Represented in LAM are details of production activities, such as the number of mixed age (MA), rising one-year (A1), rising two-year-old (A2) cows and cows grazed off and on farms, including dairy-support blocks and drystock farms within and outside of the catchments.

As the water quality attributes are specified in the model as a set of exogenous variables, water quality target limits are fed into the model as inputs with a set of constraints to the model which maximises profit from the farming activities subjected to the constraints.

The LAM can predict the feasibility of achieving the water quality target attribute states by optimising mitigations and land-use conversion, especially to de-intensify such that the area allocated to a farm type under a certain mitigation level is equal to the baseline land allocation plus or minus the area converted to another farm type and/or land use. However, there are some restrictions on conversion between land uses to reflect land use capabilities. For example, the dairy area can only be converted to drystock or forest operations; horticulture can also convert to drystock or forest operation; and drystock can convert to forestry. The model was specified to constrain the land use change within the historical land use patterns observed between 1972 and 2012 as reported in Hudson et. al. (2015). This is to reflect that

[16] This poses a challenge of aggregation error as some sub-catchments are dependent in some respects (e.g. hydro-geological models) and independent in others. Efforts have been made to minimise this error as there are attenuation matrices that capture the dependencies between sub-catchments. Another challenge is that some land uses are dependent on others such as dairy, dairy support, and drystock land uses.

land use is relatively inflexible[17] in the short term and restricted by spatial biophysical factors and land use capability (Kerr and Olssen, 2012).

Overall, the complexity in the model has been moderated by the introduction of penalty functions that turn the 'hard'[18] constraints (the environmental constraints) into soft[19] constraints. That is, the constraints were specified as soft constraints. This means that there are constraints that can be breached or violated, but at high cost. These costs are related to the catchment level profits across the farming sectors that are being maximised. Details of this technique (elastic programming or penalty function) are reported in Gill et. al. (2015). The technique allows the water quality attribute constraints to be violated but at a high penalty cost. This analytical technique has applications in real life policy making, like determining fines for infringing a rule that cannot be strictly enforced. However, its application in this study is limited to turning the target constraints into soft constraints. This helped the model to converge i.e. find a solution. The solutions also mimic practical possibilities i.e. the model's solutions could either i. meet and or exceed target; ii. fall short of achieving the target or iii. result in increased attribute concentration. This approach reflects the reality of how difficult it could be to achieve water quality improvements by enforcing compliance. The inclusion of penalty functions means that, in seeking to maximise land use profitability, the model will avoid violations of constraints wherever possible (since this would incur large 'penalty costs' and so reduce profitability). However, violations *are* possible, if they are necessary to enable the model to find a solution.

In summary, the model is a complex mathematical programming tool that has wide applications in applied economic analysis (Bazaraa et. al., 2006). It is a standard model applied in behavioural economics to understand and predict behaviour of economic agents, especially in response to policy changes. It is also a static, equilibrium optimisation model that has proven useful to study the efficiency of economic activities (Throsby, 1967; Throsby and Rutledge, 1977; Bazaraa et. al*.,* 1990; McCarl, 1992; Klein-Haneveld and Stegeman, 2005; Olubode-Awosola, 2006; Olubode-Awosola et. al., 2008; Minot, 2009; Olubode-Awosola, 2010; Daigneault et. al., 2012). The biggest advantage of this type of modelling is its flexibility in allowing integration of complex hydrogeological models of which some are non-linear constraints. That has a disadvantage. Like any other nonlinear programming model, for each scenario run, the LAM did find local optimal solutions which may or may not be global optimal solutions. That is, the solutions found when the model is run may not be the best possible. But they are 'good enough' solutions compared to no solutions. A model like this is regarded as a 'black box'; useful for managing lack of, or sparse, data in policy analysis. However, in this case, the model could be arguably regarded as a 'grey box' as the amount of information has increased greatly and it is difficult to present all the details without being distracted from the big picture[20].

The caveats, like in many modelling exercises, include that it is a catchment-level static model that has not captured the dynamics of transition across time, although other temporal measures are assumed to be captured in the attenuation parameters as well as the efficacies of the mitigation options. These limitations in the model suggest a future research area would

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[17] It is acknowledged that this modelling approach has neglected the possibility of a new evolution of different land use pattern. For instance, areas in plantation forestry have been increasing, arguably driven by carbon price. Yet, the modelling approach is justified based on the premise that policy makers don't want to assume that the policy will be the driver of land use change. It is expected that the policy scenarios should reflect the costs of mitigating nutrient loss rather than afforestation. We have a specification in the model that allows afforestation of marginal lands as a mitigation option.

[18] strict i.e. constraints that cannot be breached or violated.

[19] not strict i.e. constraints that can be breached or violated.

[20] What the panel's recommendations mean for meeting the environmental targets and the economics and productions implications.

be to identify empirically how land users/managers adapt to policy changes and/or adopt mitigation practices over time, and how to quantitatively determine the spatial pattern and time path of water quality responses to mitigation actions. This has implications for the implementation and strategies to enforce and/or monitor PC1 policies.

2.2 The data inputs

The model data inputs have grown over time. The model is populated with data from the major land use types (farm types), representative systems within each land use, level of nutrient use and nutrient loss, a variety of nutrient mitigation options and scenarios in terms of level of mitigation. This information/data is at farm-type[21] level, but regional agricultural statistics and other industry databases (DairyBase, Agribase, agricultural census data, etc.) are used to scale the representative farm-type level data up to catchment level.

For each of the dairy and drystock land use types, the economic and farm systems of the farm types and mitigation options have been modelled and estimated with a farm management tool, FARMAX®. The nutrient budgets were then generated with a nutrient budget tool, Overseer. These tools, when used together have a library of information on soil and climate from which management practices, including mitigation options, were evaluated. The tools used farm information such as specific fertiliser use and rates, crop and pasture yields, and number and classes of animals, etc. These are farm level tools that are used to determine the abatement costs curves for different farm types represented in the model. Forestry Investment Finder (a forestry model) was used by the New Zealand Forestry Institute (known as SCION) to estimate the costs and returns to forestry land use and by CSG as a proxy for on-farm tree planting (Harrison and Yao 2014; Yao and Harrison 2014). Regarding point source discharges, the LAM model includes the sources of discharge, the wastewater treatment plants, the industries and their means of treating the contaminants before discharging into a water body, as well as the spatial distribution of these sources.

Different but coherent means were used to estimate the land use profitability close to the base year (2011/12 to 2012/13) data. For dairy and dry stock farming, these were determined using FARMAX® and Overseer modelling by DairyNZ and WRC, respectively. For horticulture, the AgriBusiness Group, with input from HortNZ, used Gross Margin analysis and Overseer (Agribusiness Group 2014). For the point sources, the input data (nutrient loads and mitigation cost) were obtained from Opus International Consultants (2013) but updated with input from point source plant operators identified in further work at WRC.

The farm-level data was extrapolated with secondary processed regional data to scale up to the catchment level. This allows for generalisation without losing the specific focus. Although production functions with technical input-output coefficients are not available yet, there is scope for incorporating these later[22]. The data input includes technical information on current states of the four contaminants, represented by nine different water quality attributes across the 74 sub-catchments (Figure 2). Other data and information include different sources of land use types, and their baseline production and environmental profile for different levels of intensification.

The scope of the model has improved with the data[23], most of which were gathered and contributed by industries and stakeholders represented in the projects (Joint Venture studies and HRWO). For example, the data on production, management and nutrient loads associated with each land use and management option were supplied by different organisations. As is always the case with such a modelling exercise, there is a limit to the level of calibration in the

[21] Each land use type e.g. dairy has multiple farm-types defined in the supporting reports and modelling.

[22] This is an important data missing in the LAM. Input-Output coefficients can represent better farm management and production possibility functions

[23] Based on the accumulated work from the Joint Venture projects, TLG analyses, and the current modelling extension and data from literature as referenced in this report.

model. Relative to the baseline data and results presented in the earlier modelling exercises[24], the model did, however, reproduce the land use distribution and patterns observed in the baseline year, 2012. The base year of 2012 was used as the most recent data available when the project started, which means the model was specified to calibrate to the land use distribution observed in 2012. Currently, the most recent land use database is the recently released 2018 data. The 2018 data suggests the pattern/distribution of areas remain the same as in 2012, as do trends over time. Full details on the input data, the model and associated documentation is on the WRC website:
https://www.waikatoregion.govt.nz/council/policy-and-plans/healthy-rivers-plan-for-change/technical-alliance/technical-alliance-documents/.

[24] Joint venture project (Olubode *et. al.,* 2014) and HRWO TLG modelling reports (Doole et. al., 2015a; 2015b; 2016)

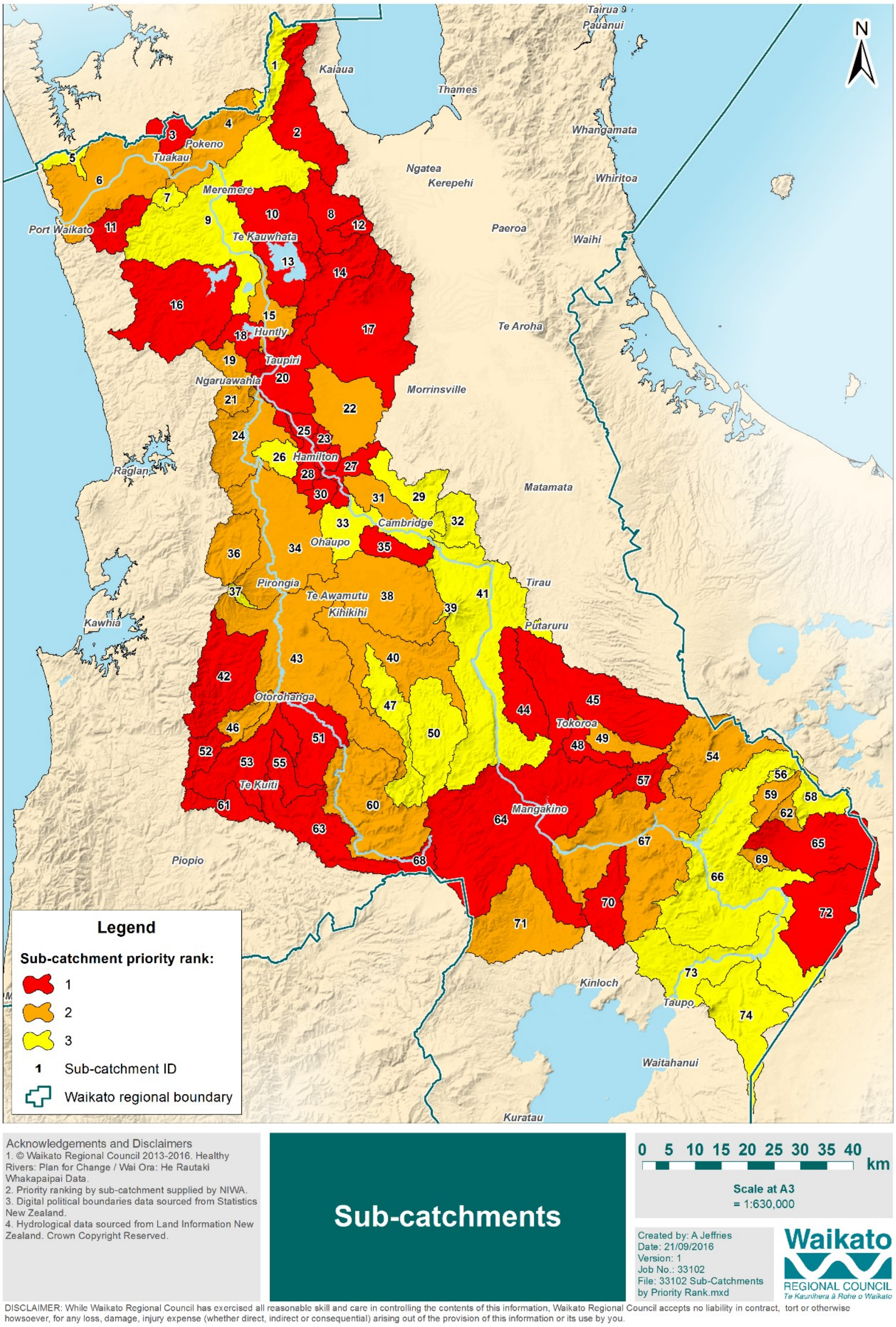

Figure 2: Sub-catchments in the Waikato-Waipā Rivers catchment

2.3 The model extension and application in this study

The version of LAM with the database that was received from the TLG was the version that produces the TLG's second set of the scenarios modelling report, Doole et. al. (2015b). Then, in this modelling exercise to evaluate the decision version of the PC1, the model with the database was extended and applied to evaluate the changes being recommended by the Hearings Panel using scenario modelling. That is, the scenarios were specified with new equations and parameters added to the model, to represent the variables and parameters that reflect the recommended changes (such as new areas for CVP expansion, the new level of water quality attribute targets, etc).

In terms of testing how sensitive the model is to the changes been evaluated; a parametric analysis approach was followed by implementing the Hearing Panel's recommendations as quantitative variables in the model. The process, including the scenario definitions and assumptions, as well as how Hearings Panel's recommendations were reflected in the model and data in this current modelling exercise, is presented in the following sub-sections.

2.3.1 The scenarios

The first model run was a baseline scenario (scenario 1) to reproduce the activity levels in terms of land use, land distribution and pattens observed in the base year, 2012. In this scenario, there are no mitigations at all or water quality target attribute states being set. This scenario run was to check the calibration of the model before applying it to other policy scenarios, since the model being applied is a static model. This baseline scenario is the one against which the long (scenario 2) and short term (scenario 3) scenarios were compared. The short term scenario is used as a base for considering the impacts of the last four scenarios namely CVP expansions (scenario 4) and low (scenario 5), medium (scenario 6) and high (scenario 7) level of iwi land developments.

Of the seven scenarios, the last six scenarios are policy scenarios and specified and implemented as follows:

- In the scenario 2, the model was run to examine the feasibility of achieving the 80-year water quality target attribute states and the resulting land use, including the economic production implications thereof. This is referred to as the long-term target toward the Vision and Strategy objectives. The earlier modelling of the PC1 policy mix by the TLG did not involve the long term, 80-year scenario. Rather the modelling was focused on the short term target attribute states. In this study, however, both long and short term target attribute states were modelled, partly to serve as a model validation exercise by comparing the model's responses to both long and short term scenarios, and partly to consider the results of the short term scenario in relation to the long term scenario, as the modelling lacks an explicit dynamic feature.

- In the scenario 3, the model was run to examine the feasibility and economic implications of achieving 20% of the 80-year target attribute states within the first 10 years of the plan becoming operative. This is in recognition of the ambitious nature of the target attribute states, and the fact that the efforts required will be inter-generational, which means that progressive steps towards the target attribute states are rational. Again, it is a key difference of the decision versions to the notified version which was 10% of the 80 year targets.

The four variations of the short-term scenario (scenario 3) have been modelled as scenarios 4, 5, 6 and 7. These variants show land use change being proposed as permitted activities including CVP expansion; and allowing iwi land development at low; medium; and high scale[25] within 10 years of PC1 becoming operative. The variations from the short-term scenario were modelled as follows:

- Scenario 4 – CVP in the short term, which is specified as conversion of miscellaneous land that is assumed suitable for horticulture, is allowed as a permitted activity within the first 10 years of the proposed plan being operative. The bulk (76%) of the CVP expansion recommended are in the Lower Waikato FMU, and the remaining are evenly shared between the Middle Waikato and Waipā FMUs.

- Scenario 5 - low level of iwi land development in the short term. This is specified exactly as in the previous PC1 model such that about one third of about 9,200ha of iwi land that are currently in forestry and drystock farming, but suitable for conversion into intensive drystock and dairy farming, were assessed in terms of impacts on achieving short term water quality target attribute states.

- Scenario 6 - medium level of iwi land development in the short term. Here, two thirds of about 9,200ha of iwi land that are currently in forestry and drystock farming, but suitable for conversion into intensive drystock and dairy farming, were assessed in terms of impacts on achieving short term water quality attribute targets.

- Scenario 7 - high level of iwi land development in the short term, in which all 9,200ha of iwi land that are currently in forestry and drystock farming, but which are suitable for conversion into intensive drystock and dairy farming, were assessed in terms of impacts on achieving short term water quality target attribute states.

To each of the scenarios, the feasibility algorithm (MsNLP and CONOPT4) solvers were applied using the General Algebraic Modelling System (GAMS) Modelling software (GAMS Development Corporation, 2021) and the farm management mitigation options were adjusted iteratively in a parametric and sensitivity analysis to find a feasible point. That is, the land use management practices were adjusted to their highest level of mitigation to find a solution as described in the next section.

2.3.2 Parametric and sensitivity analysis

Parametric analysis involves changing some parameters in a model that are directly or indirectly related to a policy provision(for example, how water quality attribute limits are related to mitigation options in the LAM specification). In this modelling exercise, efforts were made to understand the differences between the notified PC1 and decision version to be able to identify the Hearings Panel's recommendations that are applicable to modelling. A detailed comparison of the earlier version of the PC1 and the decision version is presented in Table A1 in Appendix A.

In modelling the changes to PC1 as recommended by the Hearings Panel, the model and the underlying data inputs received from the TLG were studied to understand how various hydrogeological models are integrated into the economic model (land allocation model), including how different mitigation options were previously specified (Scarpa and Bazzani, 2019). The model was next extended to represent the Hearing Panel's recommendation as described in this section. Using the model and data received from the TLG, the first step was to replicate the baseline model run as reported in Olubode et. al. (2014), Doole et. al., (2015a), (2015b) and (2016). This step helped to reproduce the baseline results as a test of the model and data consistencies over time and across the HRWO project modelling exercises and the predecessor's projects – Joint venture project.

[25] There is provision for flexibility of land use for iwi land that has not been able to be developed due to historical and legal impediments (Hill et. al., 2020).

Then, additional specifications were added to incorporate the recommended changes to PC1, to reflect the decision version recommendations. Where there are no direct or quantitative measures of a mitigation and/or policy variable, assumptions were made to reflect possible impacts of such variables/policies, especially in terms of feasibility of achieving the target attribute states.

Some new parameters were introduced to reflect the Hearings Panel's recommendation. Namely

- an average cost of pond remediation estimated at $84 per cow based on average effluent management and capital costs from Foote (2014: Table 10.3, p190),
- cost of improved phosphorous management at $94/ha from Olubode-Awosola (2014),
- cost of CVP expansion at $390/ha, conversion from forestry to dairy at $3,305/ha, conversion from forestry to drystock at $1,448/ha and lastly conversion from drystock to dairy at $1,805/ha all estimated based on Matheson (2015)'s land use conversion costs for the HRWO project and own assumption of 12 monthly annual interest rate of 8% over capital life of 30 years.

The provision for capping the maximum area for CVP meant easing the constraint at the catchment from the 2012 baseline data of about 6000ha as was modelled in the notified PC1 to more than 6,396ha under the Hearings Panel's recommendations.

Further mitigations[26] such as fencing, effluent management and erosion control are specified in the model with two types of iterations. The first iteration serves to evaluate the policy scenarios and the second to solve the model successfully until convergence (i.e. a technically feasible solution) is achieved[27]. As in the previous policy mix modelling, two different types of feasibility algorithms and solvers (CONOPT4 and MsNLP) based on GAMS software (Brooke et. al., 2014) were used to find the feasibilities of achieving the water quality attribute target attribute states given a range of combined on-farm mitigation options.

A list of relevant parameters is presented in Table A2 in Appendix A. These parameters are consistent with the PC1 earlier modelling with the new parameters mentioned in the earlier paragraph. Table A3 in Appendix A presents a range of model's decision variables[28] that represent mitigation options applied to find model solutions, that is, mitigation practices that allow a maximum number of water quality attribute target attribute states to be met along with maximum catchment level profitability of land use sectors.

The scenario runs iterations were started with the mitigation levels based on the variables in Table A3 that satisfy environmental constraints at the minimum violation of those constraints. These are variables that affect the achievement of the target attribute states. Some are set as initial, lower and upper values to help the solver find feasible solutions. Specifying the lower and upper values helps to speed up the solver's iteration process. Several of these variables are also useful when working with variables that are undefined if another variable becomes zero in the model specification.

[26] Including the industry agreed and approved practices and actions undertaken on a property or enterprise that reduce or minimise the risk of contaminants entering a water body.

[27] That is repeatedly running the model to find the level of mitigations for which the model provides a solution without breaking any constraints.

[28] These are variables that represent policy options

Efforts were made to retain the initial and minimum values, and the bounds that were pre-defined for the hydrogeological models[29]. These include the median concentration in each sub-catchment after linkage, the percentage change in beam attenuation, the denominator for the logistic function in chlorophyll-*a* regressions, to name a few. This process was repeated iteratively as a sensitivity analysis, which yielded a wide range of feasibilities. However, because the range of feasibility is so wide, the options were limited to the optimal solutions presented in this report[30].

For example, there are point sources of contaminants (where the municipalities and industries have consent to discharge their contaminants) in the Waipā catchment, yet these point sources are not remediated in this modelling exercise. These point source discharges will be addressed at their next consent renewals, so are not subject to PC1. Also, the hearing panel's recommendation to allow expansion of CVP areas in 13 specific sub-catchments was specified in the model as relaxing land availability constraints in the scenarios. In such cases, miscellaneous lands are converted to CVP areas as specified in the 10:9:1 ratio based on the baseline distribution of the three different farm types[31] representing horticulture. This ratio was part of the earlier modelling by Doole (2016).

Some parameters and/or variables, such as the extent of mitigations, are adjusted incrementally as a sensitivity analysis, but others are specified in the scenarios. For example, the recommendation by the hearing panel to incorporate a maximum area allowed for CVP in specific sub-catchments (according to Table 1 Rule 3.11.4.8), amounts to an additional 396ha on top of the existing area. The areas of iwi land modelled in scenarios five to seven are the areas under the Central North Island (CNI) forestry lands and those under multiple-ownership (MO) are up to about 3,067ha, 6,133ha and 9,200ha in scenarios five, six and seven, respectively.

In summary, taking this modelling approach allows for integration of diverse processes involved in achieving the water quality objectives. It also helps in evaluating the impacts of achieving multiple water quality target attribute states. This process was repeated for 7 scenarios to evaluate the hearing panel's recommendations. The range of assumptions and mitigation options applied is presented in the sub-section below.

2.3.3 The mix of mitigation options and extent assumed

To evaluate the water quality attribute targets achievements, two main features of the model were applied. First, in the short and long term scenarios and relative to the baseline scenario, the farm types in each land use sector were specified in the model to move along their abatement costs curves without changes in the areas of land use. These are mitigation options that reduce the level of contaminant loss mainly by changes in farm systems plus additional[32] mitigation options that shift the abatement costs curves. Second and in addition, in the last 4 scenarios (variant of short term scenario) some land use sectors have land areas changed to reflect some policy provisions (i.e. iwi land developments) and the Hearings Panel's recommendations (i.e. CVP expansion).

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[29] These bounds are directly from the reports on hydro-geological models. They were as specified in the basic model and none of the scenarios in this modelling exercise warranted changing them.

[30] Presenting the range of results would have been ideal but for simplicity and management of the project, those details have not been presented.

[31] Rotation 1, the extensive rotation of major large scale crops – potatoes, onions and carrots, which make up approximately 50% of the land in horticulture production in the Lower Waikato; Rotation 2, intensive rotation with the inclusion of more green crops such as broccoli and summer lettuce, which make up approximately 45% of the land in horticulture production; and the traditional market garden, which is significantly more intensive and make up approximately 5% of land in horticulture production in the Lower Waikato.

[32] such as stock exclusion, edge-of-field mitigations, etc

The feasibility of achieving the targets (water quality target attribute states) was optimised in model runs for the scenarios described above.

In terms of how much contaminant reduction could be achieved (based on the modelling) in the different land use activities, several mixes of mitigation options and extent were assumed in a form of parametric and sensitivity analysis described in the earlier sections. Since the Hearing Panel's recommendations have a different approach to applying rules to nitrogen loss levels, comparable assumptions were made to represent the Hearing Panel's recommendations (the nitrogen leaching loss rate (NLLR) (as presented in Table 2 earlier) in the model. Specifically, for the 6 policy scenarios in the modelling, the farm types were prevented from continuing at their baseline level of nutrient loss in order to meet water quality target attribute states while maximising catchment-level profit. The optimisation[33] feature of the model then determined how much areas of high NLLR moved to moderate NLLR, and from moderate to low, for different land use activities in the model.

The approach to find some level of mitigations expected from different land uses is based on the predominant contaminants from each land use activity. For example, N, P, and microbial pathogens are the contaminants most usually associated with dairy farming. For drystock farming, sediments, P and microbial pathogens are also common. For horticulture, N, P and sediments are a focus (Waikato Regional Council, 2016).

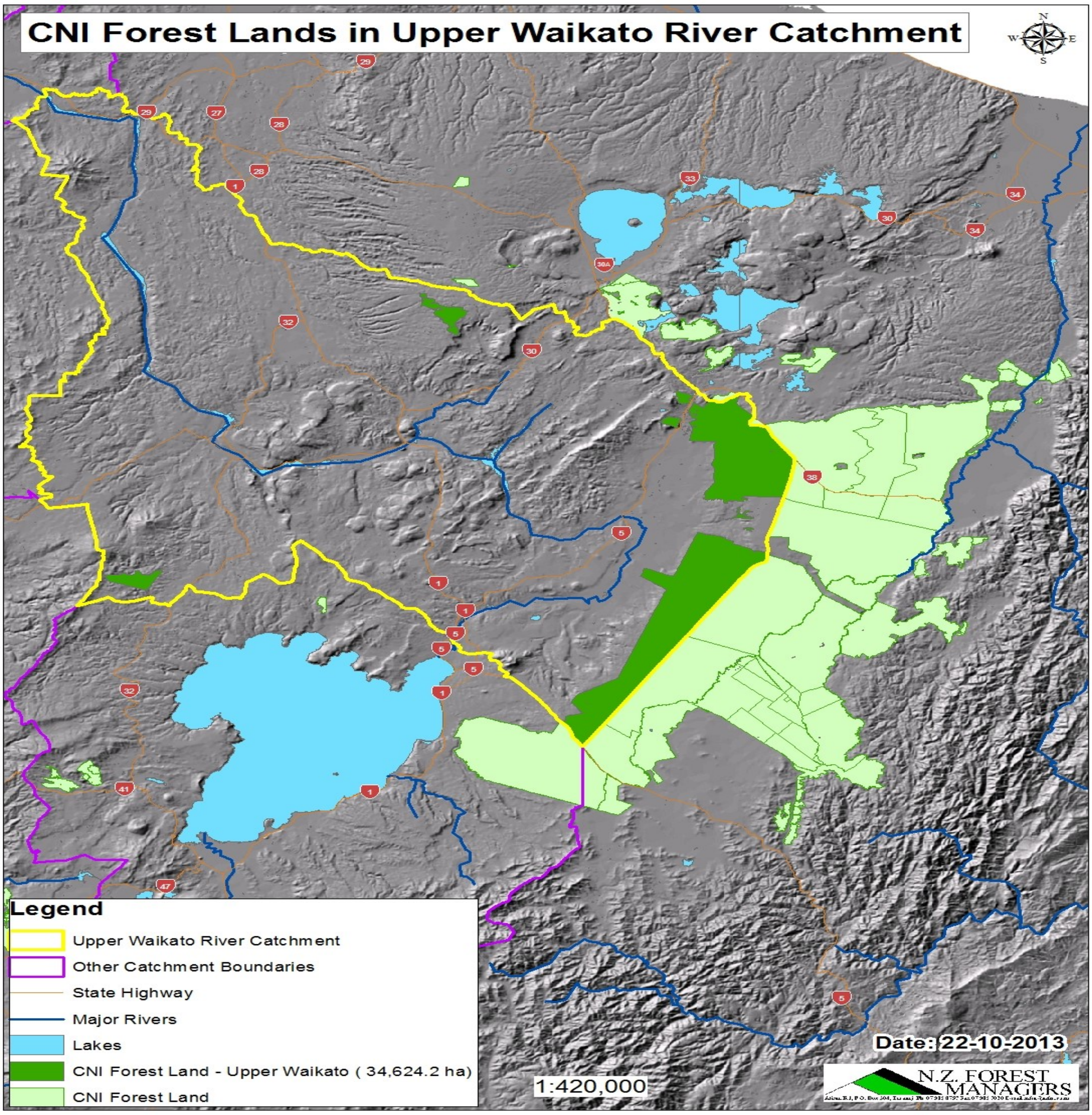
The other assumptions and extent of mitigations that return model solutions include:

- point source remediation was exempted across the scenarios tested in this study;
- across the scenarios tested, the areas under each farm type on which edge-of-field mitigations can occur are specified as 10% of maximum land areas suitable for each type of edge-of-field-mitigation. In the long and short term scenarios, the areas of land allocated to edge-of-field mitigations are about 29,000ha of dairy land and 36,000ha of drystock land;
- there are 25 sub-catchments where 2-pond systems are being used and the proportion of the systems remediated to reduce microbial loads are specified to the minimum. The proportion of cows for which low-rate effluent application is utilised is about 5% and applied in very few sub-catchments. The proportion of cows managed on farms with a stand-off pad averages about 17%.
- the proportion of MA (mixed age), R1 (rising 1 year old) and R2 (rising 2 year old) cows that could be grazed out of the catchment was specified as 95%;
- the proportion of 2-pond systems remediated to reduce microbial loads was specified as 33% for the long term scenario and 26% for the short term scenarios;
- the proportion of streambank fenced on accord streams[34] in dairy and dairy support areas was specified as 26% across the scenarios;
- the proportion of streambank fenced on non-accord streams in dairy and dairy support areas was specified at an average of 2.3% for the long term scenario and an average of 2% for the short term scenarios;
- the proportion of streambank fenced on drystock land was specified as an average of 22% for the long term scenario and an average of 16% in the short term scenarios;
- the proportion of streambanks on dairy farms fenced with a 5m buffer was specified at an average of 54% in the long term scenario and about 50% in the short term scenario;
- similarly, the proportion of streambanks on drystock farms fenced with a 5m buffer was specified as an average of 55% in the long term scenario and about 48% in the short term scenarios; and

[33] The caveat is optimisation is based on rationality assumptions. That is, the land use decision makers are rational in their decisions which may not be so all the time.
[34] Streams that are about 1m wide and 15 to 20cm deep (Ministry for the Environment, 2003).

- the extent of wheel track ripping and decanting earth bunds on horticultural land was specified at an average of about 74% across the scenarios.

It should be acknowledged that the above mitigation options and their extents are only feasible[35] mitigation levels in the model and not necessarily maximum technically possible on farm. Factors such as adoption rate could influence the extent to which any of these options can be realised on the farm and consequently could give different results compared to those being presented in the next section.



Source: *CNI Iwi Holdings Ltd (2015)*

Figure 3: Distribution of the CNI iwi lands in the Upper Waikato

[35] i.e. the levels of mitigations where the model successfully runs without any errors based on the data inputs.

3 Results and discussion

In this section, the results are presented and summarised in a series of tables, to take a stepwise approach to understanding the findings. Tables 4, 5 and 6 summarise how many target attribute states are met and how many are breached (i.e. shortfalls or where there could be some increase (even from the baseline) in contaminant concentrations).

Notable results (water quality attributes states, sub-catchments and FMUs) and their significance, are presented in another set of tables (Tables B1 to B6) in Appendix B. Tables B1 to B6 are colour-coded to reflect the elastic programming feature applied in this modelling exercise, as mentioned earlier. That is, the water quality constraints were specified in the model as constraints that can be violated but with penalty costs. This means that for each water quality attribute target/limit at each sub-catchment (sub-catchment), if the target is met, the percentage by which the target is exceeded is presented in green. That is, 0% means the target is just met, and not exceeded while 25% means the target is met and exceeded by 25%. Similarly, blue is used to represent how much more percentage increase is required to meet a water quality target. That is, 15% means the model solution is an 85% improvement towards meeting the target, which implies it falls only 15% short of meeting the target. Lastly, red is used to report the percentages by which water quality attribute concentrations could increase from the baseline/current level. That is, 50% means the contaminant concentration could increase by 50% from the baseline.

To summarise in terms of water quality target attribute states, Tables 7-10 give an indication of how the four contaminants (N, P, sediments and microbes) are related to the different scenarios (long term, short term, CVP expansion and iwi land development levels of low, medium and high).

Lastly, Tables 11-14 present the land use distribution, changes in areas under N leaching loss rate, and economic and production implications of the predicted level of achieving the water quality target attribute states presented in Tables 1-10. The rest of this section provides a discussion of the results by scenarios.

3.1 Scenario 2 - Long term scenario

Across the 74 sub-catchments in the study area (the Waikato-Waipā River Catchment), for the nine different water quality attributes (representing the four contaminants) being considered, there are 336 target attribute states for which there are enough data for the scenario modelling in this study.

From Table 4 (and the corresponding Table A1 in Appendix A), of the 336 target attribute states across the 9 water quality attributes and 74 sub-catchments, the modelling solutions to the long term scenario suggest that about half (163) of the target attribute states could be met and exceeded by a median 15%. Of the other half of the sub-catchments (where target attribute states are not met), 140 have a median shortfall of about 60% with respect to the target attribute states. The other 33 sub-catchments not only breach the target attribute states, but the water quality attributes could be worse than the baseline by a median 7%. These are concentrated (23) in the Upper Waikato FMU, with 1 in the Middle Waikato and 3 in Waipā FMUs and 6 in the Lower Waikato FMU. Also, the breaches are mostly in relation to nitrates and total N, which are all in the Upper Waikato FMU, especially in the mainstem of the Waikato River (see Details in Table A1 in Appendix A).

Across the sub-catchments, most of the target attribute states for chlorophyll-*a* are met, followed by nitrates, and breaches are mostly observed for TN and TP. The breaches of TN and TP are concentrated in the Upper Waikato FMU. Most chlorophyll-*a*, TP, *E. coli* and water clarity target attribute states are met in the Upper Waikato FMU. Most nitrate target attribute states are met in the Waipā FMU.

Of the nine sub-catchments where median chlorophyll-*a* target attribute states are set, the target attribute states are shortfall from the target by about 89% at Waikato River at Tuakau bridge, 60% at Waikato River at Mercer Bridge and 10% at Waikato at Horotiu. The maximum chlorophyll-*a* target is only short by 1% from the target at Waikato River at Tuakau bridge.

Similarly, of the 10 sub-catchment where TN target attribute states are set, the target attribute states are only met in the Waikato river at Horotiu and Narrows, both in the Middle Waikato FMU. The target attribute states are short at the Lower Waikato FMU but there could be an increase in concentration at Waikato at Ohaki, Ohakuri, Waipapa and Whakamaru, all mainstem sub-catchments in the Upper Waikato FMU.

The TP target attribute states are all met in the Upper Waikato FMU sub-catchments (Waikato at Ohaaki, Ohakuri, Waipapa and Whakamaru), and also met at Waikato at Narrows but short by only 2% at Waikato at Horotiu in the Middle Waikato FMU, but fall short by 4% at Waikato at Narrows in the Middle Waikato FMU. They all fall short in the Lower Waikato FMU.

Median and 95th percentile nitrate target attribute states are mostly met in Waipā FMU with a shortfall only at Mangapiko by about 9% and 36%, respectively. There are only a few shortfalls in the middle Waikato FMU. Similar results are observed in the Lower Waikato, except that there could be an increase in concentration at Mangatawhiri where median nitrate concentration could increase by about 3% from the baseline. However, in the Upper Waikato, the result is about 50:50, that is, about 50% of the target attribute states are met and 50% are breached, the latter mainly increases in concentration.

However, *E. coli* target attribute states are mostly met in the Upper Waikato with only some shortfalls from the target attribute states and no increase in concentration from the baseline. A few target attribute states are met in the other FMUs which show a couple of instances of increases in concentration.

Some (22) of the 10th percentile water clarity target attribute states are met across the sub-catchments, with most target attribute states met in the Upper Waikato FMU. The results are mixed in the other FMUs, but there is no decrease in water clarity at any sub-catchment. There are 8 sub-catchments where some data required in the model to estimate the water clarity attribute limits were lacking (including parameters such as existing measurement for the beam attenuation coefficient, etc.). It is specified in the model that where such data are missing, the target attribute states should be zero. The source (Yalden and Elliott 2015) of these data/parameters (in the database behind the model) specifically reported that sub-catchments that do not have these data/parameters were not associated with monitoring sub-catchments. This observation applies to all the scenarios modelled and the sub-catchments of Komakorau and Whangape in the Lower Waikato; Mangakara, Waikato at Ohaaki and Waikato at Whakamaru in the Upper Waikato and Kaniwhaniwha, Mangauika and Ohote in Waipā.

3.2 Scenario 3 - Short term scenario

From the lower part of Table 4 (and the corresponding detailed Table B2 in Appendix B), compared to scenario 2, the long term target attribute states, about three quarters of the 336 target attribute states across the 9 water quality attributes and 74 sub-catchments are met and could be exceeded by a median 14%. Of the remaining one quarter where target attribute states are not met, 53 have a median shortfall of about 9% from meeting the target attribute states.

Like the long term scenario, the breaches of the other 33 target attribute states, which are also an increase in the concentration of the water quality attributes by a median 7%, persist even in the short term scenario.

As expected, in the short term scenario, across the sub-catchments more target attribute states are met and where there are breaches, the shortfalls in meeting the target attribute states are lower compared to long term scenario results.

Looking at each water quality attribute, all the chlorophyll-*a* and median TP target attribute states are met across the catchment. Most of the 10th percentile water clarity target attribute states are met with few shortfalls in the Lower Waikato FMU. Only one sub-catchment in the Middle Waikato FMU shows a shortfall. Specifically, the target attribute states for median and 95th percentile chlorophyll-*a* are met and exceeded by a median 11% and 27%, respectively. All the median TP target attribute states are met and exceeded by a median 14% across the whole catchment. Of the 10 sub-catchments where median TN target attribute states are set, the target attribute states are only short by about 9% in Whangamarino at Island Block Road in the Lower Waikato FMU. It is, however, noteworthy that the concentrations could get worse not only in the short term, but also in the long term scenario at Waikato at Ohaki, Ohakuri, Waipapa and Whakamaru, all in the Upper Waikato FMU.

For the median and 95th percentile nitrate attributes, the target attribute states are all met in the Lower Waikato, Middle Waikato and Waipā, except at one sub-catchment (Mangatāwhiri in the Lower Waikato FMU) where the concentration could increase as already observed in the long term scenario described earlier.

Again, more of the *E. coli* target attribute states are met in the Upper Waikato with fewer shortfalls from the target attribute states and no increase in concentration from the baseline compared to the long term scenario. Many (46) of the 10th percentile water clarity target attribute states are met across the sub-catchments with a couple of shortfalls in the Lower Waikato FMU and only one in the middle Waikato FMU.

Table 4: Summary of instances where target attribute states are met or breached

Scenarios and water quality attributes	Total number of sub-catchments where target attribute states are set*	No. of sub-catchments where target attribute states are met and/or exceeded	Number of sub-catchments where target attribute states are breached	
			with shortfall from target attribute states	with increase in contaminant concentration
Scenario 2 - 80-year scenario				
Median chlorophyll-*a* (mg/m^3)	9	6	3	0
Maximum chlorophyll-*a* (mg/m^3)	9	8	1	0
Median TN (mg/m^3)	10	2	4	4
Median TP (mg/m^3)	10	5	5	0
Median nitrate (mg/L)	62	44	8	10
95th percentile nitrate (mg/L)	62	40	12	10
Median *E. coli* (cfu/100mL)	62	22	37	3
95th percentile *E. coli* (cfu/100mL)	62	14	42	6
10th percentile clarity (m)*	50	22	28	0
Total	**336**	**163**	**140**	**33**
Scenario 3 - Short term (20% of 80-year) scenario				
Median chlorophyll-*a* (mg/m^3)	9	9	0	0
Maximum chlorophyll-*a* (mg/m^3)	9	9	0	0
Median TN (mg/m^3)	10	5	1	4
Median TP (mg/m^3)	10	10	0	0
Median nitrate (mg/L)	62	51	1	10
95th percentile nitrate (mg/L)	62	52	0	10
Median *E. coli* (cfu/100mL)	62	38	21	3
95th percentile *E. coli* (cfu/100mL)	62	30	26	6
10th percentile clarity (m)*	50	46	4	0
Total	**336**	**250**	**53**	**33**

* Otherwise referred to as instances

3.3 Scenario 4 - CVP expansion

Horticulture is a land use activity that, although it occupies a small area of the catchment, has the potential for high per-hectare discharge of sediments and nutrients. In the data input into the modelling, three farm types of horticulture were represented: Rotation 1, the extensive rotation of major large scale crops – potatoes, onions and carrots, which makes up approximately 50% of the land in horticulture production in the Lower Waikato; Rotation 2, intensive rotation with the inclusion of more green crops such as broccoli and summer lettuce, which makes up approximately 45% of the land in horticulture production; and the traditional market garden, which is significantly more intensive and make up approximately 5% of land in horticulture production in the Lower Waikato. Among these farm types, seven different types of mitigation were considered, ranging from limiting N application (i.e. limit monthly N application to 80kg or less per ha) to active irrigation water management. It is acknowledged that the modelling tools currently available do not capture the diversity of farm types in terms of rotation, farm systems and mitigation options practiced by the growers.

The relative intensity of horticulture and the consequent effects on water quality are some of the reasons why the CSG essentially proposed a cap on CVP area (conversions to CVP had to be offset by equivalent reductions in area elsewhere). However, the hearing panel recommended expansion be allowed in 13 sub-catchments. Looking at the proposed and baseline areas in those sub-catchments, the recommended expansion areas are a maximum of approximately 396ha. In the modelling, these areas have been apportioned to the three farm types represented in the proportion observed in the baseline as described above. In terms of land use capability, it was thought that dairy land would be more suitable for CVP expansion in terms of land use capability. However, it was discovered that in some of the sub-catchments, there was not enough existing dairy area to convert to represent the amount of expansion recommended by the Hearings Panel. In addition, there is indication that CVP is becoming more extensive in some parts of the region. This implies increase in land demand by vegetable growers. Therefore, it was assumed that the new expansion had come from 'miscellaneous' lands in the respective sub-catchment. This is because this land area is represented in the model and also has data (environmental profile) in terms of nutrient loss. It is noted that this may imply overestimation of the additional environmental impacts of CVP expansion if expansion comes from land use that has a higher contaminant profile compared to the miscellaneous land.

On top of the assumptions behind scenario 3, the short term scenario, expansion of CVP area was allowed to the maximum recommended level by the Hearings Panel for the specific sub-catchments. The impacts on the feasibility of the short term target attribute states are presented in the following paragraphs. In Table 5[36] below (and corresponding detailed Table B3 in Appendix B), the impact of these assumptions is that in addition to the short term scenario (scenario 3)[37], the 95th percentile nitrate target that was met in the short term scenario would now be breached at the Mangatāwhiri (Lyons Rd at Buckingham Br) in the Lower Waikato FMU. The breach is marginal, though, with a concentration increase by 0.17% from the baseline. The number of shortfalls remains the same as does the level of achievements. This again suggests negative impacts of CVP expansion could be managed if 'hot spot' sub-catchments are avoided, even though only 4ha of expansion is being recommended in the Mangatāwhiri sub-catchment (Hill et. al. 2020). It is noteworthy that only *E. coli* and sediment are priority contaminants in the Mangatāwhiri, and the sub-catchment was also judged priority zone 3[38] in the CSG deliberation.

[36] The table simply presents the results of CVP expansion i.e. to understand the impact of CVP expansion, we need to compare the table with the lower part of Table 4 mentioned earlier.

[37] i.e. achieving 20% of the 80-year targets in 10 years.

[38] The 74 sub-catchments are prioritised for time to take mitigation actions required under the PC1 such that Priority Zone 1 sub-catchments have the highest (compared to Zones 2 and 3) gap between existing contaminant discharges and that required to achieve the desired water quality to account for 'load to come' of N.

Table 5: Impacts of scenario 4, CVP expansion on the short term water quality attribute states

Water quality attributes	Total number of sub-catchments where target attribute states are set*	No. of sub-catchments where target attribute states are met and/or exceeded	Number of sub-catchments where target attribute states are breached	
			with shortfall from target attribute states	with increase in contaminant concentration
Median chlorophyll-*a* (mg/m^3)	9	9	0	0
Maximum chlorophyll-*a* (mg/m^3)	9	9	0	0
Median TN (mg/m^3)	10	5	1	4
Median TP (mg/m^3)	10	10	0	0
Median nitrate (mg/L)	62	51	1	10
95th percentile nitrate (mg/L)	62	51	0	11
Median *E. coli* (cfu/100mL)	62	38	21	3
95th percentile *E. coli* (cfu/100mL)	62	30	26	6
10th percentile clarity (m)*	50	46	4	0
Total	**336**	**249**	**53**	**34**

3.4 Scenarios 5, 6 and 7 - Iwi land development

In terms of how the iwi land areas allowed for intensification are distributed across FMUs, 86% of the iwi land are in Upper Waikato, about 12% in Waipā, and only 2% in the Lower Waikato FMU. Based on the TLG and CSG deliberation (Doole 2016), almost 100% of the forestry to dairy conversion is in the Upper Waikato FMU, as is about 98% of conversion from forestry to drystock. In addition, approximately 46% of conversion from drystock to dairy is in the Upper Waikato and about 47% in Waipā, with only about 6% in the Lower Waikato FMU.

From Table 6 (and the corresponding detailed Tables B4 to B6 in Appendix B), compared to scenario 3, the short term scenario, intensification on iwi lands could be expected to increase the extent of breaches slightly, especially where there are already breaches. Few new breaches in other sub-catchments would be expected.

At a low level of development (scenario 5 where one-third of the 9,200ha of iwi lands are developed in the short-term), 3 of the 250 target attribute states that have been met will now be a breach. One additional sub-catchment would have a shortfall; the 95th percentile *E. coli* target that was just met in the short term will now be narrowly short (by 0.01%) at Waikato at Huntly-Tainui Br. This is a marginal effect, and only P and sediment are priority contaminants in this sub-catchment. Also, median and 95th percentile nitrates would increase in Waipā at Mangaokewa Rd in the Waipā FMU. These target attribute states were narrowly met under the short term scenario. Only *E. coli* is a priority contaminant in this sub-catchment, but this result suggests nitrogen may also be an issue there.

At a medium level of iwi land development (scenario 6 where two-third of the 9,200ha of iwi lands are developed in the short-term), an additional two breaches are possible compared to the low scenario described above – in particular, maximum chlorophyll-*a* and median nitrate at Waikato at Ohakuri in the Upper Waikato FMU. These target attribute states were narrowly met under the short term scenario, although their concentration would also increase narrowly, by 0.48% and 1.63% from the baseline. While there has not been any priority contaminant in this sub-catchment, this result may suggest chlorophyll-*a* and nitrate becoming issues there unless the development is well targeted.

And finally, at a high level of iwi land development (scenario 7 where all the 9,200ha of iwi lands are developed in the short-term), the modelling shows the impact would further increase by an additional three breaches causing an increase in contaminant concentration from the baseline levels. These breaches are median *E. coli* at Pueto, Torepatutahi and Waiotapu at Homestead, all in the Upper Waikato FMU. Again, only P and N are priority contaminants at these sub-catchments but again, a targeted increase of iwi land development could avoid issues of more and new contaminant coming up in the catchment as a whole.

Table 6: Impacts of iwi land development on the short term water quality attribute states

Scenarios	**Total number of sub-catchments where target attribute states are set**	**No. of sub-catchments where target attribute states are met and/or exceeded**	**No. of sub-catchments where target attribute states are breached**	
			with shortfall from target attribute states	**with increase in contaminant concentration**
Scenario 5 - Short term (20% of 80-year) + low iwi land development scenario				
Median chlorophyll-*a* (mg/m^3)	9	9	0	0
Maximum chlorophyll-*a* (mg/m^3)	9	9	0	0
Median TN (mg/m^3)	10	5	1	4
Median TP (mg/m^3)	10	10	0	0
Median nitrate (mg/L)	62	50	1	11
95th percentile nitrate (mg/L)	62	51	0	11
Median *E. coli* (cfu/100mL)	62	38	21	3
95th percentile *E. coli* (cfu/100mL)	62	29	27	6
10th percentile clarity (m)*	50	46	4	0
Total	**336**	**247**	**54**	**35**
Scenario 6 - Short term (20% of 80-year) + medium iwi land development scenario				
Median chlorophyll-a (mg/m^3)	9	9	0	0
Maximum chlorophyll-a (mg/m^3)	9	8	0	1
Median TN (mg/m^3)	10	5	1	4
Median TP (mg/m^3)	10	10	0	0
Median nitrate (mg/L)	62	49	1	12
95th percentile nitrate (mg/L)	62	51	0	11
Median *E. coli* (cfu/100mL)	62	38	21	3
95th percentile *E. coli* (cfu/100mL)	62	29	27	6
10th percentile clarity (m)*	50	46	4	0
Total	**336**	**245**	**54**	**37**
Scenario 7 - Short term (20% of 80-year) + high iwi land development scenario				
Median chlorophyll-*a* (mg/m^3)	9	9	0	0
Maximum chlorophyll-*a* (mg/m^3)	9	8	0	1
Median TN (mg/m^3)	10	5	1	4
Median TP (mg/m^3)	10	10	0	0
Median nitrate (mg/L)	62	49	1	12
95th percentile nitrate (mg/L)	62	51	0	11
Median *E. coli* (cfu/100mL)	62	35	21	6
95th percentile *E. coli* (cfu/100mL)	62	29	27	6
10th percentile clarity (m)*	50	46	4	0
Total	**336**	**242**	**54**	**40**

3.5 Summary results

In terms of how the concentrations of the nine water quality attributes add up to the concentrations of the four contaminants at catchment level, the scenario results are summarised for the four contaminants and presented in the next few paragraphs.

Looking across the scenarios in Table 7, the contribution of N load at a catchment level from dairy land use activities could drop by about 33% in the short term scenario, and relative to that could increase slightly by 1%, 3% and 4% in the low, medium, and high level of iwi land development scenarios, respectively. The contribution from the drystock land use could drop by about 5% in the long term scenario and about 3% in the short term scenario and could marginally increase by about 1% under high iwi land development. The contribution of horticulture to N load could reduce by up to 8% in the long term scenario, and by up to 5% in the short term scenario. However, with the CVP expansion in the short-term, the N load contribution could increase by 9% relative to the short term scenario level.

Table 7: Scenario impacts on Nitrogen load (tonne)

Land uses and point sources	Current	80 years	Short term	Short term + CVP expansion	Short term + impact of iwi land development		
					Low	Medium	High
Dairy	9,619	6,424	6,439	6,439	6,524	6,609	6,694
Drystock	4,019	3,826	3,915	3,915	3,922	3,929	3,936
Forestry	678	678	678	678	666	653	641
Horticulture	402	369	381	415	381	381	381
Miscellaneous	948	948	948	946	948	948	948
Point sources	1,077	1,077	1,077	1,077	1,077	1,077	1,077
Total	**16,742**	**13,321**	**13,438**	**13,470**	**13,517**	**13,597**	**13,676**

Similarly, from Table 8, across the scenarios, the contribution of P load at catchment level from dairy land use activities could drop by about 34% in the long term scenario and 31% in the short term scenario. P load is not affected by low level of iwi land development but increases by 3% and 6% in the medium and high level of iwi land development scenarios, respectively. The contribution from the forestry land use could drop by about 2% and 4% under the medium and high iwi land development scenarios. However, with the CVP expansion in the short term, the P load contribution could increase by 6%, which corresponds to a 0.2% drop in contribution from miscellaneous land.

Table 8: Scenario impacts on Phosphorous loads (tonne)

Land uses and point sources	Current	80 years	Short term	Short term + CVP expansion	Short term + impact of iwi land development		
					Low	Medium	High
Dairy	223.6	147.0	154.5	154.5	159.6	164.0	167.2
Drystock	300.8	291.1	296.4	296.4	296.7	297.0	297.4
Forestry	50.8	50.8	50.8	50.8	49.9	49.0	48.1
Horticulture	7.5	7.5	7.5	8.0	7.5	7.5	7.5
Miscellaneous	107.4	107.4	107.4	107.2	107.4	107.4	107.4
Point sources	198.4	198.4	198.4	198.4	198.4	198.4	198.4
Total	**888.5**	**802.3**	**815.0**	**815.3**	**819.5**	**823.3**	**825.9**

Table 9 shows the impact on sediments across the scenarios. The contribution of sediment load at catchment level from dairy land use could drop by about 6% in both short and long term scenarios, not affected by any level of iwi land development scenarios. The contribution of sediment load from the drystock land use could drop by about 7% in the long term scenario and about 5% in the short term scenario but is not affected noticeably by the CVP expansion or any level of iwi land development. The contribution of horticulture to sediment load is the highest, and could reduce by up to 40% in either long or short term scenarios, but is not affected noticeably by CVP expansion in the short term nor by iwi land developments, where at least drystock areas increase. Collectively, these sum up to a decrease of about 7% and 6% in the long and short term scenarios, respectively, and no changes with either CVP expansion or iwi land development.

Table 9: Scenario impacts on total streambank sediment loads (tonne)

Land uses	Current	80 years	Short term	Short term + CVP expansion	Short term + impact of iwi land development		
					Low	Medium	High
Dairy	176,579.6	165,284.9	165,274.7	165,274.7	165,274.7	165,274.7	165,274.7
Drystock	392,351.5	363,172.0	372,359.0	372,359.0	372,359.0	372,359.0	372,359.0
Horticulture	945.4	571.3	571.3	571.3	571.3	571.3	571.3
Total	569,876.4	529,028.2	538,205.0	538,205.0	538,205.0	538,205.0	538,205.0

Looking at the impacts on microbe loads by land use contribution at the catchment level in Table 10, the contribution of microbe load at catchment level from dairy land use could drop by about 18% in both the short and long term scenarios. It is unaffected by CVP expansion, but increases slightly by 0.4%, 0.9% and 1.3% in the low, medium and high level of iwi land development scenarios, respectively. The contribution from the drystock land use could drop by about 12% in the long term scenario, and about 9% in the short term scenario. This is not affected by the CVP expansion but could marginally decrease by about 0.1% under high iwi land development. All this sums up to a total decrease in microbe load by up to 13% in the long term scenario, and up to 11% in the short term scenario. However, with iwi land development in the short term, the microbe loads could increase (relative to the short term scenario level) only marginally by 0.2%, 0.3% and 0.5% in the low, medium and high level of iwi land development, respectively.

Table 10: Scenario impacts on the median loads (load) of microbes

Land uses	Current	80 years	Short term	Short term + CVP expansion	Short term + impact of iwi land development		
					Low	Medium	High
Dairy	36,184.2	29,861.1	29,867.0	29,867.0	29,997.6	30,128.2	30,258.8
Drystock	42,674.6	37,385.3	38,960.8	38,960.8	38,952.4	38,944.0	38,935.6
Point source	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Other sources	10,581.5	10,581.5	10,581.5	10,581.5	10,581.5	10,581.5	10,581.5
Total	**89,442.2**	**77,829.9**	**79,411.2**	**79,411.2**	**79,533.4**	**79,655.6**	**79,777.8**

3.6 Land use activities

The distribution of land use areas by sector and the changes in areas by scenarios are presented in Table 11. In the baseline, most land area is drystock farming followed by dairy and dairy support, while the area in forestry is about half that of dairy, and horticulture has the smallest land area of about 6,000ha. The land area under 'miscellaneous' is broadly defined in the original data source, which is Ministry for the Primary Industries (2012). This land is predominantly classified as 'other' types of land use. Lifestyle blocks are another significant proportion of the miscellaneous land area.

While it is acknowledged that there are considerable amounts of dairy areas and lifestyle blocks in the sub-catchments where CVP expansion is recommended, there are still some sub-catchments where there are not dairy areas that could convert to CVP. However, there are typically many lifestyle blocks in those sub-catchments, and hence the assumption that the CVP expansion areas could come from miscellaneous areas. As mentioned earlier, this assumption could imply overestimation of the impact of CVP as the nutrient loss from miscellaneous land use is less than that from dairy or other pastoral land use.

Therefore, we have modelled the recommended CVP expansion to investigate the impacts on water quality target attribute states. This potentially enables the expansion of existing CVP operations to compensate the industry for the loss of land for urban expansion, and it may also allow for new growers and or the need for more land for crop rotations. It is however acknowledged that depending on the extent of urban expansion that takes land from vegetable production, the impacts of CVP expansion might be an overestimation.

Looking at how this compared with evidence presented during the hearing by Horticulture New Zealand (HortNZ), Baker (2019) identified lands with class 1 and 2 as potential development for CVP expansion. The evidence estimated that some 716ha of expansion would have a negligible effect on water quality at a catchment scale. Miscellaneous areas are amongst those that the evidence of HortNZ identified as potential growth areas (for CVP expansion) based on the Waikato District Plan Change. The results reported in Baker (2019) are somewhat comparable to the results observed and presented earlier in this study.

In the hearing panel's recommendation, unless the lifestyle blocks which are assumed converted to CVP are as highly productive as baseline dairy or other pastoral land, the estimated additional nutrients due to expansion would be an overestimate compared to the conversion from dairy or pastoral lands.

As assumed in the model, the solutions for the different scenarios are as expected in terms of land use distributions and changes. For example, for the long and short term scenarios, the land use distribution remains largely the same as in the baseline. For the CVP expansion scenario, the additional areas of land converted to CVP have come from miscellaneous land and this is about 396ha. In the iwi land development scenarios, the specified amount of lands under low, medium, and high areas are reflected as expected. In terms of iwi land areas being converted, this means conversion of about 5,314ha of forestry to dairy, 1,519ha from forestry to drystock and 2,367ha from drystock to dairy across 53 sub-catchments. These are estimated pro-rata as one-third, two-third, and all (9,200ha), under the scenarios low, medium, and high land development of iwi land at about 3,067ha, 6,133ha and 9,200ha, respectively. This is land currently in production forest and multiple ownership and they can potentially be intensified. This assumption is same as in the earlier TLG modelling of PC1.

Table 11: Scenario impacts on land allocation

Areas by sector	Current	80 years	Short term	Short term + CVP expansion	Short term + impact of iwi land development		
					Low	Medium	High
Dairy and dairy support area (ha)	308,008	308,008	308,008	308,008	310,569	313,129	315,689
Drystock area (ha)	370,355	370,355	370,355	370,355	370,862	371,368	371,874
Horticulture area (ha)	6,103	6,103	6,103	6,499	6,103	6,103	6,103
Forestry area (ha)	169,478	169,478	169,478	169,478	166,412	163,345	160,278
Miscellaneous area (ha)	248,358	248,358	248,358	247,963	248,358	248,358	248,358
Total (ha)	**1,102,303**	**1,102,303**	**1,102,303**	**1,102,303**	**1,102,303**	**1,102,303**	**1,102,303**
Horticulture expansion							
New CVP (from miscellaneous area) (ha)		-	-	396	-	-	-
Iwi land development							
New dairy from forestry (ha)					1,771	3,543	5,314
New dairy from drystock (ha)					789	1,578	2,367
New drystock (from forestry) (ha)					506	1,012	1,519
Total iwi land development (ha)					**3,067**	**6,133**	**9,200**

3.7 Land use areas and nitrogen leaching loss rate (NLLR)

The concept of an 'N leaching loss rate' (NLLR) mitigation approach also implies that achieving the improved water quality objectives is not dependent on afforestation of pastoral land. Rather, it implies reductions in land use areas of high NLLR to moderate or low NLLRs by categorising a land use activity's NLLR into permitted, controlled or discretionary activities in terms of policy implementation[39]. The summary of the resulting land use activities in terms of areas under different land uses and changes in areas under different NLLR categories is presented in Table 12 (and see also the corresponding detailed results in Table C1 in Appendix C). In the modelling this result is driven simply by the optimisation feature of the model.

Looking at dairy and dairy support activities, to achieve the long term target attribute states, the areas in high NLLR could drop by about 70% in the Lower Waikato, 90% in the middle Waikato and 100% in Waipā and Upper Waikato. Overall and across the catchment, this implies a drop in areas under high NLLR by 87%. To achieve the short term target attribute states, that is, 20% of the long term target in the first 10 years of the operational plan, the areas in high NLLR could drop by about 21% in the Lower Waikato, 64% in the middle Waikato, about 100% in the Upper Waikato whilst there is no change in the Waipā. This amounts to just over a 50% drop in areas under high NLLR in the whole Waikato-Waipā river catchment.

Under the iwi land development scenarios, the areas in high NLLR could increase marginally at a rate of about 0.15%, 0.30% and 0.45% across the catchment under the low, medium, and high levels of development. As the areas being allowed to develop are FMU-specific, the pattern is not uniform, which means that the policy could lead to increases in areas under

[39] The nitrogen leaching loss rate (NLLR) approach may be interpreted as high N leaching farms to substantially reduce leaching, and for moderate leaching farms to ensure leaching is as low as practicable. Reducing leaching means reducing areas under high NLLRs. Higher leaching farms are to be manged by discretionary activity consent, moderate leaching farms by controlled activigty consent and low leaching farms by permitted activities.

moderate NLLR in some FMUs and high NLLR in other FMUs, as detailed in Table C1 in Appendix C.

With respect to horticulture, total areas under high NLLR from horticulture could reduce by up to 3.6% towards the long term target attribute states but only about 1.2% in the short term scenario. The provision to allow CVP expansion will increase the areas under high NLLR by about 5% overall in the catchment. Looking at the detailed results in Table C1 in Appendix C, horticulture areas are under high NLLR across the catchment in the baseline. The overall 5% increase in high NLLR areas is from CVP scenario areas of 6,342ha compared to the short term scenario area of 6,029ha. Again, this result is driven simply by the optimisation feature of the model and reflects the distribution of horticulture areas among the FMUs in the catchment. That is, 70% of horticulture area is in the Lower Waikato, 10% in the Middle Waikato, 8% in Upper Waikato and the rest 12% in the Waipa. Of the 396ha CVP expansion areas allowed, 299ha expansion in Lower Waikato FMU implies 7% increase in the existing areas under high NLLR; 49ha expansion in Middle Waikato implies 8% increase in the existing areas under high NLLR; 46ha expansion in Waipa implies 6% increase in the existing areas under high NLLR and only 2ha expansion in Upper Waikato means more of the existing areas in Upper Waikato could go into moderate NLLR reflecting Upper Waikato FMU having more water quality attribute targets to meet compared to the rest of the FMUs.

The 5% increase in high NLLR area could be avoided by allowing the expansion in areas of less N risk, at least where N is not a priority contaminant. However, N is a priority contaminant in 4 out of the 13 sub-catchments where CVP expansion was recommended namely Mangaonua and Kirikiriroa sub-catchments in the Middle Waikato FMU and Opuatia and Ohaeroa sub-catchments in the Lower Waikato FMU. This is also reflected in terms of impacts on the numbers of sub-catchments where the environmental target attribute states are not met because of this provision. That is, there is an additional sub-catchment where the median nitrate was not only breached, but the expansion could lead to increase in concentration (although neither N nor P was a priority contaminant in that sub-catchment (Mangatāwhiri), which is also not a mainstem sub-catchment).

This indicator of sectors' contributions to the reduction in N loss could be compared to the CSG's proposals for sectors' contributions to managing contaminants (in which they proposed using the 75th percentile for dairy and 10% reduction in N discharge from horticulture). However, the CSG decided to focus on predominant contaminants by activity as well as the policy selection criterion of proportionality (i.e. those contributing to the problem contribute to the solution). Again, these observed changes in areas under high and moderate NLLR are being driven by the optimisation feature[40] of the model which could also imply policy direction. For example, Policy 2a and b require moderate NLLR land use activities to demonstrate that their leaching is as low as practicable while high NLLR land use activities to reduce N leaching 'significantly'.

Table 12: Scenario impacts on proportion (%) of areas under High N leaching loss rate (NLLR)

Sector	80 years	Short term	Short term			
			Plus CVP expansion	Plus iwi land development		
				Low	Medium	High
Dairy and dairy support	-86.63%	-51.16%	0.00%	0.15%	0.30%	0.45%
Drystock	0	0	0	0	0	0
Horticulture	-3.61%	-1.22%	5.19%	0.00%	0.00%	0.00%
Forestry	0	0	0	0	0	0

[40] That is, meeting the environmental objectives while maximising the catchment-level income.

3.8 Sector profits

As expected, the mitigation approach also has implications for sector profitability and the specific costs of mitigation, as presented in the following paragraphs. From Table 13, with the level of mitigations among the different land uses as presented earlier, the implication is a shift in sector profit based on the distribution of the costs associated with the level of mitigations assumed. It is expected that there will be a loss of production income from horticulture, dairy and drystock. The decline in horticulture income is highest in the long term scenario, which sees more than 60% loss in horticulture income compared to about 20% in the short term scenario.[41] There is a marginal difference between the long term and short term scenarios for drystock, and the difference is even smaller for dairy, although there is about 20% loss in dairy profitability for either of the scenarios. This reflects the optimisation feature in the model.

The CVP expansion also implies some cost is possible (about $1.5m due to expansion into new area) and the cost of iwi land development is significant, at about $8m, $16m and $24m under low, median, and high level of iwi land development. The other costs associated with mitigations vary. Edge-of-field mitigation options could cost about $5.4m across the scenarios. Erosion control in the horticultural land is estimated at about $1m for either short or long term scenarios, but could increase slightly with CVP expansion in the short term scenario.

Stream fencing could be a substantial cost at more than $5m in the long term scenario and about $4m in the short term scenarios. Effluent system update is another cost estimated at about $1.8m in the long term scenario and about $1.4m in the short term scenarios.

Overall, there is potential loss of about 18% of income for the long term scenario, and about 16% for the short term scenario. The difference is not much because most of the targets are achieved and or exceeded even at the short term scenario based on the modelling assumptions. While allowing for CVP expansion could increase the sector income by about 0.14%, allowing for intensification of iwi land may not be profitable due to cost of conversion, as predicted in the modelling, which assumed sector averages for the environmental footprint and profitability of this land. This was the original TLG assumption in the previous modelling of PC1 (Doole 2018).

[41]This is also being driven by the optimisation feature of the model which is to reflect rationality in land user's behaviour. For example, in the case of horticulture, some of the farm types were operating at a loss in the baseline.

Table 13: Scenario impacts on catchment-level annual profits ($m) by sectors

	Current	80 years	Short term	Short term + CVP expansion	Short term + impact of iwi land development		
Sector profits					Low	Medium	High
Dairy	617.54	489.03	489.06	489.06	494.89	500.72	506.56
Drystock	210.15	203.01	207.86	207.86	208.26	208.67	209.07
Horticulture	28.21	15.82	22.25	24.96	22.25	22.25	22.25
Forest	58.86	58.86	58.86	58.86	57.75	56.65	55.54
Total	***914.76***	***766.72***	***778.03***	***780.74***	***783.15***	***788.29***	***793.42***
Mitigation costs							
Expansion/conversion ($m)				1.54	8.01	16.03	24.04
Stream fencing ($m)		5.32	4.03	4.03	4.03	4.03	4.03
Effluent update ($m)		1.83	1.39	1.39	1.39	1.39	1.39
Erosion control ($m)		1.01	1.01	1.07	1.01	1.01	1.01
Edge of field ($m)		4.99	4.99	4.99	4.99	4.99	4.99
Total	***0***	***13.15***	***11.42***	***13.02***	***19.43***	***27.45***	***35.46***
NET ($m)	**914.76**	**753.57**	**766.61**	**767.72**	**763.72**	**760.84**	**757.96**
Scenarios impacts							
Change in profit ($m)		*-161.19*	*-148.15*	*1.11*	*-2.89*	*-5.77*	*-8.65*
Change in profit (%)		*-17.62%*	*-16.20%*	*0.14%*	*-0.38%*	*-0.75%*	*-1.13%*

3.9 Sector production

The other implication is the level of production across sectors. The sector outputs are expected to reflect the types and level of mitigations assumed for the different land use types in terms of different farming systems within each land use type. The level and potential impacts of the assumed mitigations on key production outputs by sectors are presented in Table 14 below.

Milk solid production could drop by a little over 20% in the long term scenario, which is not much different from the short term scenario. Most of the drystock products are relatively stable, except a marginal reduction in carcass beef. This is because the mitigation options in drystock land use are farm system specific, which means they are also product specific. This also stems from the assumption that some of the environmental impacts of farm systems that are dominated by heavy animals point to mitigation options that include shifting to smaller or younger animals (Olubode-Awosola et. al. 2014).

Horticulture products also dropped by about 11% in the long term scenario, but only about 7% in the short term scenario. However, the CVP expansion assumed only raises production volumes by about 2%. While the model seemed to have captured the intent of allowing expansion, the profitability of the CVP as represented in the baseline data is low and negative for some rotations (farm types). This could jeopardise the intended impacts of expansion, depending on market conditions. The product volumes from forestry are stable, and only marginally decrease with iwi land development.

Additional iwi land development into dairy and drystock sectors has noticeable upward impact on milk solid production, and marginal impacts on drystock farming products, especially on beef products.

Table 14: Scenario impacts on catchment-level annual productions

Production outputs	Current	80 years	Short term	Short term + CVP expansion	Short term + impact of iwi land development		
					low	medium	high
Total milk solids (tonne)	248,699.27	191,341.20	191,358.06	191,358.06	193,915.56	196,473.06	199,030.57
Wool production (tonne)	7,224.41	7,225.21	7,301.02	7,301.02	7,307.97	7,314.91	7,321.86
Carcass mutton production (tonne)	15,194.43	15,342.52	15,531.67	15,531.67	15,549.78	15,567.89	15,586.00
Carcass lamb production (tonne)	12,333.70	12,205.69	12,290.81	12,290.81	12,296.67	12,302.52	12,308.38
Carcass beef production (tonne)	26,058.83	23,577.49	24,722.84	24,722.84	24,789.71	24,856.58	24,923.45
Carcass bull beef production (tonne)	15,776.94	15,648.59	15,649.04	15,649.04	15,681.17	15,713.29	15,745.42
Horticulture crops (tonne)	251.45	223.42	233.77	254.52	233.77	233.77	233.77
S1 logs (m^3)	18.44	18.44	18.44	18.44	18.09	17.75	17.40
S2 logs (m^3)	48.79	48.79	48.79	48.79	47.91	47.02	46.14
S3 logs (m^3)	51.51	51.51	51.51	51.51	50.59	49.67	48.74
Pulp (m^3)	33.48	33.48	33.48	33.48	32.87	32.26	31.66
Waste (m^3)	2.31	2.31	2.31	2.31	2.27	2.23	2.18

4 Summary, conclusions and implications

As is always the case with modelling exercises, limitations to the level of calibration in the model apply to this study. Although the model reproduced the same land use distribution and patterns as the ones observed in the baseline and reported in previous studies (Olubode et. al., 2014, Doole et. al., 2015a, 2015b and 2016), it only reproduced the current level of water quality attributes with some gaps.

In addition, the assumptions have not captured any possible benefits of contaminant mitigation actions that are in place already. This may mean the simulated negative impacts on the environment (breaches of the water quality attribute target attribute states), and the estimated economic implications, are being overestimated. Also, the speed at which groundwater transmits nitrogen leached below the root zone to surface water, and the likely attenuation rate of nitrogen between the root zone and surface waterway, provides a time factor that is difficult to capture. This time factor has not been represented in the model, although the implied linkages have been represented as far as possible. This is related to the fact that another factor affecting the achievement or not of the target attribute states is N load to come. For example, based on the N model, total nitrogen (TN), median nitrate and 95th percentile nitrate in a downstream or hydro-geologically connected sub-catchment could be affected by high N load to come in the surface water even after attenuation. Also, there has been evidence of high levels of groundwater N in the upper Waikato, which is due to past intensification (Doole et. al., 2016).

As for the appropriateness of the main modelling methodology and concepts in this study, aggregation is the main challenge. This is to acknowledge Policy 10 of the proposed plan that highlights the spatial variability in land use, contaminant losses and the effect of contaminant discharges in different parts of the catchment. However, the aggregation of the rural properties into farm types within each sub-catchment is not only inevitable due to lack of property specific data, but also aligns with Policy 9 of the proposed plan change, which alludes to collective groups of property owners and other stakeholders working together which could be a reflection of sub-catchment having different properties. It is however acknowledged that some instances would not lend themselves to land owners working together. Also, the level of optimisation[42] in the model, has been significantly limited to the bio-physical models, since most assumptions about the policies were specified as constraints. The results suggest that the modelling approach and the specifications in the models have provided the closest fit for the way land users may, in aggregate (at the catchment and sub-catchment levels) make decisions, at least given the environmental target attribute states in the model.

For example, in terms of model validation, the model results are consistent across the scenarios when it comes to showing *a priori* relationships with the level of improvement in water quality attributes required (long term and short term scenarios) as well as with intensification (i.e. horticulture activity expansion and iwi land intensification). Moreover, the patterns and changes in the N leaching loss rate areas among the land use activities, the changes in the contaminant concentration across the scenarios, and sectoral profits and production, all show expected impacts across the scenarios given the optimisation and simulation techniques applied in the model.

With the assumptions about the mitigation options and the data inputs, the results are as expected, *a priori,* in terms of direction of impacts. That is where we expect a scenario or policy provision to have negative impact on meeting targets, such results were found.

[42] Optimisation is based on rationality assumptions. Yet, changes in economic conditions and components of the model are possible as prices and costs can vary. Using single year and or average data also exacerbates this caveat.

However, the magnitudes are only an indication as modelling cannot guarantee precision all the time. Although the magnitudes of the results are considered reasonable compared to the earlier modelling by the TLG and evidence from the industry groups. In both the long and short term scenarios, more target attribute states are met than breached across much of the catchment, with only two instances of possible increase in concentration of contaminants in the Middle Waikato FMU, three instances in Waipā, and a few instances in the Lower Waikato FMU. The Upper Waikato, however, has more of such instances, as expected.

The results for the long term scenario were used to compare the results for the short term scenario in terms of model validation by looking at the proportional impacts. More (almost double) of the short term target attribute states could be achieved. Although, there is a caveat, a 10-year time frame is assumed. That is, time is not explicitly modelled. The number of shortfalls in meeting the target attribute states is about one third of the long term scenario.

CVP expansion may have relatively small negative effects on meeting the target attribute states. Similarly, iwi land development may make things only slightly worse. The results suggest the impact is localised and specific to N and nitrates contaminants, and only in a couple of specific sub-catchments in the Upper Waikato and Waipā FMUs.

In the short term scenario, more of the N related attributes are breached compared to median TP target attribute states which are all achieved, and it is notable that both chlorophyll-*a* target attribute states are achieved. Meanwhile, in the long term scenario, some of both the N and P related target attribute states are breached - markedly so for P – and this may explain why the median chlorophyll-*a* target attribute states are breached. This is in line with the argument that N and P interact to cause the problem of algae growth in some sub-catchments of the region (Doole et. al., 2016). It may also suggest that both the target attribute states for the chlorophyll-a target attribute states could be met in all sub-catchments and scenarios.

To arrive at the level of achievement of target attribute states reported above, the main assumptions are that some mitigations are assumed for each land use and farm type, such that some farm types are not expected to remain at the baseline level of contaminant loss profile. For example, more intensive sectors such as dairy, dairy support and horticulture have substantial land areas shifted from high N leaching loss rate (NLLR) to moderate and low NLLR. This, together with more substantial, though costly mitigation options, is reflected in the sectors' profits and productions.

For example, there will be a loss of production income from horticulture, dairy, and drystock. The decline in horticulture income is highest in the long term scenario. There is a marginal difference between the long term and short term scenarios for dairy and drystock incomes. The costs of mitigations vary, and the effects on income will depend on what mitigations are required to be deployed. The cost of intensification of iwi land is relatively large. Edge-of-field mitigations also have relatively high costs, while erosion control on horticulture land and effluent management on dairy are the least costly methods.

Overall, there is potential loss of about 18% of income for the long term scenario and 16% for the short term. The difference is not much because most of the targets are achieved and or exceeded even at the short term scenario based on the modelling assumptions. Allowing CVP expansion and intensification of iwi land may see some land use change, but it is noted that mitigation costs would be required too. If additional costs are sufficiently high, these land use changes may not eventuate given that price of carbon is already slowing down forestry-to-pasture conversion and the carbon price could continue to rise. It is acknowledged though, that the costs would decrease over time as technology evolves, making such land use changes possible in the future.

There are downward changes to production across most of the land uses. For example, milk solid production will decrease slightly, but all the drystock products will only increase marginally. The impacts of these estimates in horticulture production and income may be inconclusive and hard to interpret in terms of the initial database that shows that some horticulture farm types have negative income in the baseline, including the CVP farm types. On the other hand, the scenarios indicate products from forestry would decrease, though marginally. Finally, additional development of iwi land into dairy and drystock land causes an increase in milksolid production and marginal impacts on drystock farming products, especially on beef products that could witness negative impacts from the main scenarios (long and short term).

In terms of the possible responses from farmers, some stringent mitigation options could involve changes in farm systems that could lead to not only increase in variable costs, but also fixed costs. Since farmers are generally 'price-takers' (i.e. they cannot influence the price they receive for their product), higher costs imply some adjustments to the level of production. Economic theory (Salvatore, 1983) suggests that if only cost per unit of output is covered (i.e. output price per unit is only up to the output cost per unit), farmers may stay in business though there may be cash flow deficits and loss of net worth. But if costs of mitigating contaminant loss increase, farmers can minimise loss by reducing production, however if costs increase such that losses get big enough and become permanent, the best way to minimise loss is to go out of business. An option to prevent or turn around a permanent or a big enough loss is better technology to improve productivity.

In terms of policy implementation and monitoring of progress towards the Vision and Strategy[43] objectives, the results of the long term scenario showing the possibility of a few localised instances of increasing concentration of some contaminants suggest there are "hot spots" not only on farms (as usually observed) but also in the catchment. Such specific water quality attributes and FMUs/sub-catchments would benefit from specific mitigation options. This suggests generalised mitigation options might fail to address such "hot spots". In addition, the considerations for intensification, such as CVP expansion and iwi land development, could potentially also be targeted to address the "hot spots". This is where the proposed farm environment plans would be useful as one of the tools for risk-based monitoring of property characteristics, land use activities and mitigation actions.

In addition, since time[44], though critical to the difference between contaminant loads on farm and concentrations in the rivers, has not been explicitly incorporated into the modelling, it is important that more efforts are focused on monitoring adoption of mitigation activities and implementation of the policy as well as monitoring contaminant concentrations in the rivers. This has potential to inform updates to and/or review of the plan.

[43] "… improvement everywhere, even if already meeting minimum acceptable states…"

[44] There are many other factors that are time dependent such as development and adoption of innovations, changes in prices and costs, climate, etc.

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APPENDIX A – PC1 and Decision version highlights and some parameters

Table A1: Highlights of the PC1 and decision versions

No	Variable	PC1	Decision	Comments/Implementation in the model
1	Nitrogen Reference Point	• Highest N emitters to reduce (75th percentile on per sector basis. Drystock sector will need to benchmark before this can be determined); • Those below 75th percentile make some reductions that represent GMP relating to the risk factors on their property[45] • Where NRP exceeds 75th percentile, must reduce to or below 75thpercentile. • 10% for CVP	• Nitrogen Reference Point is being substituted with Nitrogen leaching loss rate (NLLR). The NLLR determines which rules are applicable to the land, rather than determining a limit that cannot be exceeded. • Farms with a "moderate" NLLR need to reduce their N loss to as "low as practicable". • Farms with a "high" NLLR need to make "significant" reductions to their N loss.	• The results of the areas under different NLLR have been interpreted based on the optimisation feature of the model • The areas under high NLLR for policy scenarios were compared with baseline land areas under high NLLR by sectors in each FMU

2	Stock exclusion	• Stock exclusion (cattle, horses, deer, pigs). 1m setback for slopes <15^0 and 3m for 15^0 - 25^0. "alternative" mitigations required on slopes above 25 degrees.
		• Fencing must be completed by:
		  ○ 1 July 2023 for farms within priority 1 sub-catchments
		  ○ 1 July 2026 for priority 2 and 3 sub-catchments
			• Cattle, horses, deer, pigs must be excluded from water bodies on land:
			○ With a slope of up to 15^0
			○ With a slope over 15^0 where the adjoining paddock has a stocking rate of over 18su/ha
			• Setback distances must be:
			  ○ 3m from any wetland
			  ○ 3m from any waterbody
			  ○ 1m from any drain, except where the width of the drain is less than 2m in which case no setback is required
			• For farms that are permitted, fencing must be completed:
			  ○ Within 2 years of PC1 becoming operative or;
				• Stock exclusion was specified in the economic model as fencing of water ways with 3m grazing setback and 5m cultivation setback. This has been applied across all farm types for all sectors. It is acknowledged that his would more likely be specifics such as
				○ Farms more than 20ha must be fenced except CVP.
				○ 3m buffer is required broadly.
				○ When to fence by depends on permitted activities.
				○ However, new conversion would be expected to be fully fenced.
				• 100% fencing in sub-catchments sensitive to *E. coli* in Table 3.11.2

[45] Note: the amount of reduction in contaminants other than N is more difficult to estimate at farm level, so clear guidance is needed as to appropriate levels of action that should be achieved through these property management plans in order to meet water quality targets. This guidance will be developed further by the CSG. Source: Restoring and protecting our water. Overview of collaborative Stakeholder Group's Recommendations for Waikato Regional Plan Change No. 1 – Waikato and Waipā River Catchments March 2016. Doc #3351821 CSG recommendations – not council policy

			○ In sub-catchments identified as sensitive to *E. coli* in Table 3.11.2, within 1 year after PC1 becomes operative • Farms operating under resource consent can stage fencing in line with a tailored timeframe specified in their FEP.	
3	CVP expansion	• No increase in CVP area	• Limited increase provided for in 13 sub-catchments.	• The area limit in Table 3.11.4.8 has been applied for the 13 sub-catchments. • The area amounts to a maximum of 396ha increase in total. This was assumed to be an expansion from miscellaneous land rather than conversion from current pastoral land use because there were not dairy activities in all the sub-catchments where expansion was recommended. However, it is acknowledged that some expansion could be a conversion from dairy activities.
4	Iwi land development	• Flexibility for development of tangata whenua ancestral lands under the land use change non-complying activity rule. This is to recognise that flexibility has been restricted in the past due to legal and/or historical impediments. Other rules apply to this land use change.	• same	• The area is about 9,200ha, which has been modelled exactly as in PC1 modelling.
5	Land use change	• Land use change constrained for the first stage but in the second stage of change, property-level allocations will be set in place to achieve further reductions	• Same	• That is land use held constant at its baseline (Doole et. al. 2015a).
6	Farm environment plan/property management plan	• The CSG conceived FEP as a property management plan tool to document actions and practices for mitigating contaminants. • Small properties (such as 'ten-acre block') and low intensity farming properties (less than 6 SU) are exempted	• Same	• The mitigation options that were embedded in the baseline data and the abatement costs curves for each sources of contaminants are itemised as follow: • The management practices also cover all four Heathy Rivers Wai Ora contaminants.

7	Mitigation options and means of achieving water quality attributes	• The CSG expected proportionality of contributions and optimisation of environmental, social and economic outcomes as an approach to setting the target attribute states	• same	○ Each land use has a set of mitigation options in terms of farm systems by way of reduced intensity of nutrient use, stocking rate, effluent management, autumn N, de-intensification, change in capital structure, etc. These were the underlying data inputs used to develop the abatement costs curves. For example, dairy follows the mitigation protocol for N by DairyNZ, horticulture includes reducing N application by 10%, 20%, 30%, 40% and active water management. ○ These mitigation options are as follows: **Dairy** • Reduce stocking rate • Reduce nitrogen fertiliser use • Reduce supplement use • Use a stand-off pad • Reduce use of crops with high N loss risk **Sheep and beef** • Small lamb-finishing farm - reduce stocking rate by 5, 10, 15, 20 or 25% • Traditional hill-country with lamb finishing - afforest 20, 40, 60, 80,or 100% of steep slope area and maintain original stocking rate elsewhere • Beef-breeding with maize-silage crops for dairy support - reduce maize area by 20, 40, 60, 80 or 100% • Beef-breeding with maize-silage crops for dairy support - increase sheep: cattle ratio to 30:70%, 40:60%, 50:50%, 60:40%, 70:30% • Bull- and prime-beef finishing - substitute 30, 40, 50, 60 or 70% of 2-year or older cattle for less than 2-year-old cattle at constant stocking rate **Horticulture** • Limit monthly nitrogen application to 80 kg N/ha or less • Reduce total nitrogen applied by 10, 20, 30, or 40% • Active management of irrigation water • Wheel track ripping or dyking

				Edge of field and collective area[46] • Fence out stock (dairy, dry stock) • Fence and include buffers of 5m • Detention bunds • Detention bund + wetland (0.4% of catchment) • Sedimentation pond (0.2% of catchment) • Small, constructed wetland (0.4% of catchment) • Medium constructed wetland (1% of catchment)

[46] These mitigation options are comparable to MARs application in the Canterbury Plan Change 2. Environment Canterbury decided on this option after their consideration that some 'advanced' (highly stringent) mitigation options could bankrupt the dairy sector.

Table A2: Some modelling parameters[47]

	Cost items	Parameter
1	Cost of streambank fencing on dairy farms ($/km)	470
2	Cost of sheep streambank fencing on drystock farms ($/km)	3,280
3	*Cost of pond remediation ($/cow)*	*83.5*
4	Cost of low-rate effluent application ($/cow)	26
5	*Cost of improved phosphorus management ($/ha)*	*94*
6	Cost of wheel track ripping on horticultural land($/ha)	35
7	Cost of earth bund on horticultural land ($/ha)	130
8	Cost of dairy farm plans for sediment remediation($/ha)	335
9	Cost of drystock farm plans for sediment remediation ($/ha)	280
10	Cost of conversion from dairy to forestry ($/ha)	-1,257
11	Cost of conversion from dairy to drystock ($/ha)	-823
12	Cost of conversion from dairy support to forestry ($/ha)	0
13	Cost of conversion from dairy support to drystock ($/ha)	240
14	Cost of conversion from drystock to forestry ($/ha)	-128
15	Cost of conversion from horticulture to drystock ($/ha)	446
16	*Cost of conversion from forestry to dairy ($/ha)*	*3,305*
17	*Cost of conversion from forestry to drystock ($/ha)*	*1,448*
18	*Cost of conversion from drystock to dairy ($/ha)*	*1,805*
19	*Cost of expansion – miscellaneous land to horticulture ($/ha)*	*390*
	Opportunity cost land	
20	Area lost to fencing from grazing for dairy (ha/km)	0.5
21	Area lost from grazing for drystock (ha/km)	1
	Efficacy of mitigation options	
22	Efficacy of low-rate effluent application on median microbial load (%)	100
23	Efficacy of low-rate effluent application on 95th percentile microbial load (%)	100
24	Efficacy of low-rate effluent application on phosphorus load (%)	10
25	Efficacy of stream fencing for reducing nitrogen loading on dairy farms (%)	15
26	Efficacy of stream fencing for reducing nitrogen loading on drystock farms (%)	5
27	Efficacy of stream fencing for reducing phosphorus loading on dairy farms (%)	10
28	Efficacy of stream fencing for reducing phosphorus loading on drystock farms (%)	5
29	Efficacy of dairy streambank fencing on median microbial load (%)	58

[47]The parameters in this list were from the relevant reports done by the TLG to support the CSG deliberations. The reports are available online at the WRC's website, https://www.waikatoregion.govt.nz/council/policy-and-plans/healthy-rivers-plan-for-change/technical-alliance/technical-alliance-documents/.
The ones in italics are new parameters introduced to reflect some of the changes in the Hearings Panel's recommendations. Namely

- an average cost of pond remediation estimated at $84 per cow based on average effluent management and capital costs from Foote (2014: Table 10.3, p190),
- cost of improved phosphorous management at $94/ha from Olubode-Awosola (2014). The costliest option for N and P loss mitigation is Cluster IV farm type (bull and prime beef finishing farm having mostly beef cattle, no sheep, 100% male cattle ratio, high stocking rate (11.75SU/ha) and average N used of 3.5kg/ha/yr and mainly finishing 2+ year old cattle. Baseline is 75% older/heavier animals); Doing mitigation scenario 5 which is substituting 2yr and older cattle with younger cattle from 75% to 30%). This has the highest mitigation potential of 2.47kgN/ha and 0.01kgP/ha assumed $94/ha from Olubode-Awosola (2014),
- cost of CVP expansion at $390/ha, conversion from forestry to dairy at $3,305/ha, conversion from forestry to drystock at $1,448/ha and lastly conversion from drystock to dairy at $1,805/ha all estimated from Matheson (2015)'s land use conversion costs for the HRWO project and own assumption of 12 monthly annual interest rate of 8% over capital life of 30 years.

30	Efficacy of sheep streambank fencing on median microbial load (%)	58
31	Efficacy of dairy streambank fencing on 95thpercentile microbial load (%)	65
32	Efficacy of sheep streambank fencing on 95th percentile microbial load (%)	65
33	Efficacy of streambank fencing on sediment load in dairy enterprises (%)	40
34	Efficacy of pond remediation for reducing median microbial load (%)	100
35	Efficacy of pond remediation for reducing 95th percentile microbial load (%)	85
36	Efficacy of pond remediation for reducing phosphorus (%)	80
37	Efficacy of pond remediation for reducing nitrogen (%)	8
38	Efficacy of stand-off pad for reducing microbial load (%)	10
39	Efficacy of improved phosphorus management (%)	10
40	Efficacy of farm plans for sediment remediation (%)	70
41	Efficacy of wheel track ripping on horticultural land (%)	50
42	Efficacy of decanting earth bund on horticultural land (%)	80
43	Efficacy of afforestation for sediment reduction (%)	78

Table A3: The model's variables[48]

N	**Variables**
1	Point source remediation (yes/no)
2	Area of farm type on which an edge of field mitigation is used (ha)
3	Proportion of farm type on which each edge of field mitigation is used (%)
4	Proportion of MA (mixed age) cows grazed out of catchment (%)
5	Proportion of R1 (rising 1-year-old) cows grazed out of catchment (%)
6	Proportion of R2 (rising 2-year-old) cows grazed out of catchment (%)
7	Improved phosphorus management on dairy land (%)
8	Improved phosphorus management on drystock land (%)
9	Improved phosphorus management on horticultural land (%)
10	Proportion of 2-pond systems remediated to reduce microbial loads (%)
11	Proportion of cows for which low-rate effluent application is utilised (%)
12	Proportion of farms using low-rate effluent application (%)
13	Proportion of cows managed on farms with a stand-off pad (%)
14	Total number of cows in each sub-catchment (head)
15	Proportion of streambank fenced on accord streams in dairy and dairy support areas (%)
16	Proportion of streambank fenced on non-accord streams in dairy and dairy support areas (%)
27	Positive variable - Proportion of streambank fenced on drystock land (%)
18	Proportion of streambanks on dairy farms fenced with a 5m buffer (%)
19	Proportion of streambanks on drystock farms fenced with a 5m buffer (%)
20	Extent of wheel track ripping on horticultural land (%)
21	Extent of decanting earth bunds on horticultural land (%)

48 That is model's inputs that are changed to observe changes in water quality attributes targets

APPENDIX B – Detailed results - water quality target attribute states

Table B1: Detailed results of 80-year, long term scenario*

Sub-catchment	Zone	Priority contaminant	Median chlorophyll-*a* (mg/m3)*	Maximum chlorophyll-*a* (mg/m^3)	Median TN (mg/m^3)	Median TP (mg/m^3)	Median nitrate (mg/L)	95th percentile nitrate (mg/L)	Median *E. coli* (cfu/100mL)	95th percentile *E. coli* (cfu/100mL)	10th percentile clarity (m)
Lower Waikato											
Awaroa (Rotowaro) at Harris/Te Ohaki Br (18)	1	E. coli, sediment									
Awaroa (Rotowaro) at Sansons Br (19)	2	*E. coli*, sediment					9.19%	9.18%	120.61%	6.91%	19.92%
Awaroa (Waiuku) (5)	3	*E. coli*, sediment, N					15.40 %	36.40%	62.91%	72.04%	57.35%
Komakorau (22)	2	*E. coli*, sediment, N					40.85 %	10.42%	556.80%	403.05%	nd
Mangatangi (2)	1	*E. coli*, sediment, P					10.64 %	10.24%	163.27%	912.11%	38.91%
Mangatāwhiri (1)	3	*E. coli*, sediment					3.08%	0.60%	46.08%	939.25%	61.18%
Mangawara (17)	1	*E. coli*, sediment, N, P					35.91 %	43.13%	536.81%	721.32%	69.01%
Matahuru (14)	1	*E. coli*, sediment, N, P					9.41%	15.04%	313.40%	1025.09%	69.57%
Ohaeroa (7)	3	*E. coli*, sediment, N, P					29.01 %	8.00%	124.08%	818.25%	18.93%
Opuatia (11)	1	*E. coli*, sediment, N					5.82%	5.83%	2.35%	0.40%	49.93%
Waerenga (12)	1	*E. coli*, sediment, N, P					5.38%	5.37%	274.48%	7.78%	19.63%
Waikato at Huntly-Tainui Br (20)	**1**	**Sediment, P**	**3.60%**	**19.30%**	**1.14%**	**11.29%**	**14.74 %**	**14.41%**	**15.34%**	**212.08%**	**0.60%**
Waikato at Mercer Br (9)	**3**	**Sediment, P**	**60.09%**	**11.20%**	**14.56%**	**3.42%**	**13.48 %**	**14.45%**	**14.92%**	**142.19%**	
Waikato at Tuakau Br (4)	**2**	**Sediment**	**89.10%**	**1.30%**	**2.98%**	**6.05%**	**14.80 %**	**14.43%**	**14.92%**	**148.40%**	**44.38%**
Whakapipi (3)	1	*E. coli*, sediment, N, P					33.76 %	40.21%	144.52%	251.08%	16.34%
Whangamarino at Island Block Rd (10)	1	*E. coli*, sediment, P			121.74 %	83.00%	10.80 %	10.25%	25.05%	10.63%	79.35%
Whangamarino at Jefferies Rd Br (8)	1	*E. coli*, sediment, P					12.06 %	46.57%	313.04%	745.47%	49.16%
Whangape (16)	1	*E. coli*, sediment, N					25.00 %	13.90%	65.00%	6.13%	nd
Waikare (13)	1	Sediment, N, P									
Waikato at Rangiriri (15)	**2**	**no current state water quality data**									
Waikato at Port Waikato (6)	2	no current state water quality data									
Karapiro (32)	3	*E. coli*, sediment, P					17.06 %	2.68%	91.65%	13.45%	8.50%

Middle Waikato											
Kirikiriroa (23)	1	*E. coli*, sediment, N, P					12.11 %	15.72%	290.44%	545.03%	58.54%
Mangakotukutuku (30)	1	*E. coli*, sediment, N, P					20.36 %	24.77%	204.00%	2049.53%	57.69%
Mangaone (31)	2	*E. coli*, N, P					11.53 %	18.33%	494.32%	275.82%	4.30%
Mangaonua (29)	3	*E. coli*, sediment, N					16.22 %	8.11%	833.25%	1058.97%	7.36%
Mangawhero (35)	1	*E. coli*, sediment, P					55.97 %	34.68%	234.10%	402.28%	68.82%
Waikato at Horotiu (25)	**1**	**P**	**10.24%**	**26.85%**	**3.04%**	**1.94%**	**4.88%**	**4.80%**	**11.07%**	**10.59%**	**5.41%**
Waikato at Narrows (33)	**3**		**12.67%**	**33.49%**	**4.32%**	**4.00%**	**4.34%**	**5.21%**	**12.31%**	**8.63%**	**9.34%**
Waitawhiriwhiri (28)	1	*E. coli*, sediment, N, P					15.01 %	15.00%	326.14%	4.73%	58.67%
Waikato at Bridge St Br (27)	1	no current state water quality data									
Upper Waikato											
Kawaunui (62)	2	*E. coli*, P, N					39.92 %	44.54%	29.02%	307.30%	41.38%
Little Waipā (44)	1	N, P					4.55%	4.55%	17.22%	4.35%	58.62%
Mangaharakeke (57)	1	*E. coli*, P					8.95%	8.96%	12.18%	13.43%	16.79%
Mangakara (69)	2	*E. coli*, P, N					1.86%	15.70%	22.41%	181.32%	nd
Mangakino (71)	2	P					14.68 %	14.67%	20.43%	22.90%	79.11%
Mangamingi (48)	1	*E. coli*, N, P					0.15%	14.16%	292.76%	216.68%	13.34%
Otamakokore (59)	2	*E. coli*, P					30.28 %	30.28%	39.37%	25.10%	16.19%
Pokaiwhenua (45)	1	*E. coli*, N, P					61.96 %	35.35%	0.92%	115.39%	39.94%
Pueto (74)	3	P					15.71 %	15.60%	10.02%	17.21%	87.65%
Tahunaatara (54)	2	P					16.43 %	16.44%	15.96%	5.69%	27.92%
Torepatutahi (72)	1	P					70.92 %	70.92%	13.89%	15.17%	
Waikato at Karapiro (41)	**3**	**no current state water quality data**									
Waikato at Ohaaki (73)	**3**		**100.00%**	**100.00%**	**4.78%**	**0.00%**	**0.51%**	**1.05%**	**16.09%**	**15.98%**	nd
Waikato at Ohakuri (66)	**3**		**11.36%**	**1.21%**	**6.94%**	**17.06%**	**3.14%**	**4.41%**	**16.78%**	**34.02%**	**2.79%**
Waikato at Waipāpa (64)	**1**	**P**	**8.92%**	**48.81%**	**5.68%**	**13.20%**	**2.13%**	**5.69%**	**17.01%**	**16.75%**	**20.15%**
Waikato at Whakamaru (67)	**2**		**100.00%**	**100.00%**	**8.27%**	**18.00%**	**6.14%**	**8.25%**	**27.67%**	**19.43%**	Nd
Waiotapu at Campbell (58)	3						14.74 %	14.75%	60.15%	9.86%	32.09%
Waiotapu at Homestead (65)	1	P, N					14.77 %	26.37%	14.10%	15.51%	

Waipāpa (70)	1	P, N					22.50%	22.50%	23.59%	38.70%	23.19%
Whakauru (49)	2	*E. coli*, P					8.85%	8.85%	228.54%	219.70%	13.56%
Whirinaki (56)	3	P					9.01%	9.01%	26.27%	29.44%	
Waipā											
Firewood (21)	2	no current state water quality data									
Mangarapa (55)	1	no current state water quality data									
Moakurarua (42)	1	no current state water quality data									
Puniu at Wharepapa (50)	3	N									
Waipā at Waingaro Rd Br (24)	2	no current state water quality data									
Kaniwhaniwha (36)	2	*E. coli*, sediment					18.20%	18.20%	76.89%	250.32%	nd
Mangaohoi (39)	3	P					5.30%	5.33%	19.06%	51.17%	63.92%
Mangaokewa (63)	1	*E. coli*, sediment					8.74%	8.75%	273.21%	1155.43%	0.55%
Mangapiko (38)	2	*E. coli*, sediment, P, N					8.78%	36.30%	108.31%	1087.98%	38.21%
Mangapu (53)	1	*E. coli*, sediment, P, N					13.79%	13.82%	212.80%	684.03%	14.07%
Mangatutu (47)	3	*E. coli*					19.89%	19.94%	11.37%	29.05%	55.64%
Mangauika (37)	3						11.10%	11.26%	9.40%	88.80%	nd
Ohote (26)	3	*E. coli*, sediment, P					22.10%	22.09%	90.39%	304.52%	nd
Puniu at Bartons Corner Rd Br (40)	2	*E. coli*, P					19.00%	19.00%	13.10%	344.91%	2.57%
Waipā at Mangaokewa Rd (68)	1	*E. coli*					1.82%	1.80%	61.46%	385.84%	6.23%
Waipā at Pirongia-Ngutunui Rd Br (43)	2	*E. coli*, sediment					18.92%	17.02%	96.06%	670.16%	13.65%
Waipā at Otorohanga (51)	1	*E. coli*, sediment					17.32%	17.32%	14.61%	545.86%	12.45%
Waitomo at SH31 Otorohanga (46)	2	*E. coli*, sediment					11.50%	11.50%	132.57%	183.59%	39.10%
Waitomo at Tumutumu Rd (52)	1	*E. coli*, sediment, N					9.60%	9.44%	3.55%	3.91%	0.11%
Mangarama (61)	1	no current state water quality data									
Waipā at Otewa (60)	2	*E. coli*, sediment					12.46%	11.77%	76.98%	257.43%	122.15%
Waipā at SH23 Br Whatawhata (34)	2	*E. coli*, sediment, N					18.95%	14.72%	151.93%	534.10%	35.68%

Note:

1. *The content of this Table is colour coded. For each water quality attribute target/limit at each sub-catchment (sub-catchment), if the target is met and or exceeded, the percentage by which the target is exceeded is presented in green. That is, 0% means the target is just met but not exceeded, while 25% means the target is met and exceeded by 25%. Similarly, blue is used to report the short-fall percentages to represent further improvements required to meet a water quality target. That is, 15% means the model solution is 85% improvement towards meeting the target, which implies only 15% short of meeting the target. Lastly, red is used to report the percentages by which water quality attribute concentrations could increase from the baseline/current level. That is, 50% means the contaminant concentration could increase by 50% from the baseline.
2. Sub-catchments in **bold** are the mainstem of the Waikato River
3. ***nd*** = These sub-catchments are lacking some data (including parameters such as existing measurement for beam attenuation coefficient, etc.), which are required in the model to estimate the water clarity attribute limits. It is specified in the model that where such data are missing, the target attribute states should be zero. The source (Yalden and Elliott, 2015) of these data/parameters (in the database behind the model) reported that sub-catchments that do not have these data/parameters were not associated with monitoring sub-catchments.
4. The table is colour-coded to reflect the elastic programming feature applied in this modelling exercise as mentioned in the section earlier. That is, the water quality constraints have been specified in the model as constraints that can be violated but with penalty costs. This means that for each water quality attribute target/limit at each sub-catchment (sub-catchment), the percentages by which the target attribute states are met and exceeded are presented in green. Similarly, blue is used to report the short-fall percentages to represent improvements required to meet a water quality target in a sub-catchment. And lastly, red is used to report the percentages by which water quality attribute concentrations can increase from the baseline/current level.
5. N = Nitrogen, P = Phosphorous

Table B2: Detailed results of short term scenario*

Sub-catchment	Zone	Priority contaminant	Median chlorophyll-*a* (mg/m3)*	Maximum chlorophyll-*a* (mg/m^3)	Median TN (mg/m^3)	Median TP (mg/m^3)	Median nitrate (mg/L)	95th percentile nitrate (mg/L)	Median *E. coli* (cfu/100mL)	95th percentile *E. coli* (cfu/100mL)	10th percentile clarity (m)
Lower Waikato											
Awaroa (Rotowaro) at Harris/Te Ohaki Br (18)	1	*E. coli*, sediment									
Awaroa (Rotowaro) at Sansons Br (19)	2	E. coli, sediment					7.41%	7.42%	11.16%	6.91%	77.96%
Awaroa (Waiuku) (5)	3	*E. coli*, sediment, N					11.52%	9.42%	2.85%	3.63%	25.44%
Komakorau (22)	2	*E. coli*, sediment, N					40.34%	35.99%	1.94%	10.67%	nd
Mangatangi (2)	1	*E. coli*, sediment, P					9.36%	8.98%	3.71%	9.13%	42.07%
Mangatāwhiri (1)	3	*E. coli*, sediment					3.08%	0.60%	6.69%	22.00%	250.39%
Mangawara (17)	1	*E. coli*, sediment, N, P					35.23%	27.19%	0.22%	0.65%	8.85%
Matahuru (14)	1	*E. coli*, sediment, N, P					9.41%	5.39%	6.21%	9.98%	17.76%
Ohaeroa (7)	3	*E. coli*, sediment, N, P					6.87%	9.35%	9.51%	17.84%	47.40%
Opuatia (11)	1	*E. coli*, sediment, N					3.22%	3.22%	2.35%	0.40%	11.27%
Waerenga (12)	1	*E. coli*, sediment, N, P					5.38%	5.37%	14.28%	7.78%	46.13%
Waikato at Huntly-Tainui Br (20)	1	Sediment, P	14.90%	17.98%	13.12%	15.24%	14.16%	13.83%	14.21%	0.00%	99.28%
Waikato at Mercer Br (9)	3	Sediment, P	11.80%	21.33%	8.29%	16.73%	12.71%	13.70%	12.52%	0.02%	
Waikato at Tuakau Br (4)	2	Sediment	7.93%	25.77%	9.77%	14.29%	14.00%	13.64%	12.36%	0.21%	13.31%
Whakapipi (3)	1	*E. coli*, sediment, N, P					0.67%	0.00%	12.72%	15.88%	115.44%
Whangamarino at Island Block Rd (10)	1	*E. coli*, sediment, P			9.16%	21.82%	10.80%	10.25%	4.37%	29.31%	31.17%
Whangamarino at Jefferies Rd Br (8)	1	*E. coli*, sediment, P					12.06%	4.41%	6.12%	7.48%	30.36%
Whangape (16)	1	*E. coli*, sediment, N					22.50%	11.70%	6.19%	0.84%	nd
Waikare (13)	1	Sediment, N, P									
Waikato at Rangiriri (15)	2	no current state water quality data									
Waikato at Port Waikato (6)	2	no current state water quality data									
Middle Waikato											
Karapiro (32)	3	*E. coli*, sediment, P					15.08%	12.49%	4.90%	13.45%	98.91%
Kirikiriroa (23)	1	*E. coli*, sediment, N, P					12.07%	7.62%	5.31%	15.95%	9.11%
Mangakotukutuku (30)	1	*E. coli*, sediment, N, P					20.25%	14.04%	7.23%	10.25%	11.34%
Mangaone (31)	2	*E. coli*, N, P					16.19%	17.48%	16.01%	7.72%	65.56%
Mangaonua (29)	3	*E. coli*, sediment, N					16.10%	16.99%	1.04%	9.34%	62.53%
Mangawhero (35)	1	*E. coli*, sediment, P					13.99%	15.41%	12.78%	2.12%	2.56%
Waikato at Horotiu (25)	1	P	4.32%	26.50%	2.79%	8.86%	4.65%	4.56%	9.02%	2.52%	50.43%

Waikato at Narrows (33)	3		10.90%	33.41%	4.12%	11.11%	4.13%	4.99%	9.91%	5.93%	59.95%
Waitawhiriwhiri (28)	1	*E. coli*, sediment, N, P					14.49%	14.49%	8.62%	4.73%	5.97%
Waikato at Bridge St Br (27)	1	no current state water quality data									
Upper Waikato											
Kawaunui (62)	2	*E. coli*, P, N					43.67%	44.54%	9.82%	2.97%	91.05%
Little Waipā (44)	1	N, P					4.55%	4.55%	17.22%	59.77%	88.83%
Mangaharakeke (57)	1	*E. coli*, P					8.95%	8.96%	9.98%	8.31%	44.19%
Mangakara (69)	2	*E. coli*, P, N					20.85%	22.90%	26.91%	3.48%	nd
Mangakino (71)	2	P					14.68%	14.67%	20.43%	22.59%	108.27%
Mangamingi (48)	1	*E. coli*, N, P					11.64%	14.16%	4.20%	13.28%	42.07%
Otamakokore (59)	2	*E. coli*, P					30.28%	30.28%	10.31%	39.18%	43.44%
Pokaiwhenua (45)	1	*E. coli*, N, P					0.97%	1.44%	11.78%	8.56%	79.41%
Pueto (74)	3	P					15.71%	15.60%	10.02%	17.21%	101.77%
Tahunaatara (54)	2	P					16.43%	16.44%	15.96%	24.51%	50.49%
Torepatutahi (72)	1	P					70.92%	70.92%	13.89%	15.17%	
Waikato at Karapiro (41)	3	no current state water quality data									
Waikato at Ohaaki (73)	3		100.00%	100.00%	4.78%	0.00%	0.51%	1.05%	16.09%	15.98%	nd
Waikato at Ohakuri (66)	3		9.36%	0.00%	6.94%	14.12%	3.14%	4.41%	16.78%	34.02%	51.34%
Waikato at Waipāpa (64)	1	P	6.95%	48.13%	5.68%	10.80%	2.13%	5.69%	17.01%	16.75%	27.26%
Waikato at Whakamaru (67)	2		100.00%	100.00%	8.27%	16.50%	6.14%	8.25%	27.67%	19.43%	nd
Waiotapu at Campbell (58)	3						14.74%	14.75%	60.15%	9.86%	40.52%
Waiotapu at Homestead (65)	1	P, N					33.67%	32.33%	14.10%	15.51%	
Waipāpa (70)	1	P, N					22.50%	22.50%	23.59%	69.35%	66.47%
Whakauru (49)	2	*E. coli*, P					8.85%	8.85%	4.17%	10.64%	41.70%
Whirinaki (56)	3	P					9.01%	9.01%	26.27%	29.44%	
Waipā											
Firewood (21)	2	no current state water quality data									
Mangarapa (55)	1	no current state water quality data									
Moakurarua (42)	1	no current state water quality data									
Puniu at Wharepapa (50)	3	N									
Waipā at Waingaro Rd Br (24)	2	no current state water quality data									
Kaniwhaniwha (36)	2	*E. coli*, sediment					17.40%	17.40%	1.75%	7.24%	nd
Mangaohoi (39)	3	P					4.83%	4.84%	19.06%	9.10%	88.41%
Mangaokewa (63)	1	*E. coli*, sediment					6.86%	6.85%	16.07%	21.23%	86.20%
Mangapiko (38)	2	*E. coli*, sediment, P, N					17.50%	14.91%	5.31%	1.06%	31.47%

Mangapu (53)	1	*E. coli*, sediment, P, N					12.27%	12.30%	0.82%	9.46%	104.60%
Mangatutu (47)	3	*E. coli*					19.18%	19.22%	5.99%	2.67%	110.32%
Mangauika (37)	3						10.81%	10.94%	9.40%	6.64%	nd
Ohote (26)	3	*E. coli*, sediment, P					20.73%	20.72%	0.61%	11.22%	nd
Puniu at Bartons Corner Rd Br (40)	2	*E. coli*, P					18.00%	18.00%	18.13%	5.41%	47.62%
Waipā at Mangaokewa Rd (68)	1	*E. coli*					0.42%	0.42%	8.19%	18.82%	92.36%
Waipā at Pirongia-Ngutunui Rd Br (43)	2	*E. coli*, sediment					17.88%	17.50%	4.18%	3.76%	100.81%
Waipā at Otorohanga (51)	1	*E. coli*, sediment					16.19%	16.19%	12.36%	16.88%	124.90%
Waitomo at SH31 Otorohanga (46)	2	*E. coli*, sediment					9.98%	9.99%	10.34%	13.27%	52.25%
Waitomo at Tumutumu Rd (52)	1	*E. coli*, sediment, N					8.00%	7.84%	3.55%	3.91%	113.00%
Mangarama (61)	1	no current state water quality data									
Waipā at Otewa (60)	2	*E. coli*, sediment					11.05%	10.32%	7.01%	3.22%	283.02%
Waipā at SH23 Br Whatawhata (34)	2	*E. coli*, sediment, N					17.99%	17.58%	3.68%	3.45%	39.83%

Note:

1. *The content of this Table is colour coded. For each water quality attribute target/limit at each sub-catchment (sub-catchment), if the target is met and or exceeded, the percentage by which the target is exceeded is presented in green. That is, 0% means the target is just met but not exceeded, while 25% means the target is met and exceeded by 25%. Similarly, blue is used to report the short-fall percentages to represent further improvements required to meet a water quality target. That is, 15% means the model solution is 85% improvement towards meeting the target, which implies only 15% short of meeting the target. Lastly, red is used to report the percentages by which water quality attribute concentrations could increase from the baseline/current level. That is, 50% means the contaminant concentration could increase by 50% from the baseline.
2. Sub-catchments in **bold** are the mainstem of the Waikato River
3. ***nd*** = These sub-catchments are lacking some data (including parameters such as existing measurement for beam attenuation coefficient, etc.), which are required in the model to estimate the water clarity attribute limits. It is specified in the model that where such data are missing, the target attribute states should be zero. The source (Yalden and Elliott, 2015) of these data/parameters (in the database behind the model) reported that sub-catchments that do not have these data/parameters were not associated with monitoring sub-catchments.
4. The table is colour-coded to reflect the elastic programming feature applied in this modelling exercise as mentioned in the section earlier. That is, the water quality constraints have been specified in the model as constraints that can be violated but with penalty costs. This means that for each water quality attribute target/limit at each sub-catchment (sub-catchment), the percentages by which the target attribute states are met and exceeded are presented in green. Similarly, blue is used to report the short-fall percentages to represent improvements required to meet a water quality target in a sub-catchment. And lastly, red is used to report the percentages by which water quality attribute concentrations can increase from the baseline/current level.
5. N = Nitrogen, P = Phosphorous

Table B3: Detailed results of short term + CVP expansion scenario*

Sub-catchment	Zone	Priority Contaminant	Median chlorophyll-a (mg/m3)*	Maximum chlorophyll-a (mg/m3)	Median TN (mg/m3)	Median TP (mg/m3)	Median nitrate (mg/L)	95th percentile nitrate (mg/L)	Median E. coli (cfu/100mL)	95th percentile E. coli (cfu/100mL)	10th percentile clarity (m)
Lower Waikato											
Awaroa (Rotowaro) at Harris/Te Ohaki Br (18)	1	*E. coli*, sediment									
Awaroa (Rotowaro) at Sansons Br (19)	2	*E. coli*, sediment					7.41%	7.42%	11.16%	6.91%	77.96%
Awaroa (Waiuku) (5)	3	*E. coli*, sediment, N					11.40%	9.30%	2.85%	3.63%	25.44%
Komakorau (22)	2	*E. coli,* sediment, N					40.31%	35.96%	1.94%	10.67%	nd
Mangatangi (2)	1	*E. coli*, sediment, P					9.36%	8.98%	3.71%	9.13%	42.07%
Mangatāwhiri (1)	3	*E. coli*, sediment					3.85%	0.17%	6.69%	22.00%	250.39%
Mangawara (17)	1	*E. coli*, sediment, N, P					35.23%	27.19%	0.22%	0.65%	8.85%
Matahuru (14)	1	*E. coli*, sediment, N, P					9.41%	5.39%	6.21%	9.98%	17.76%
Ohaeroa (7)	3	*E. coli*, sediment, N, P					3.96%	6.52%	9.51%	17.84%	47.40%
Opuatia (11)	1	*E. coli*, sediment, N					1.66%	1.67%	2.35%	0.40%	11.27%
Waerenga (12)	1	*E. coli*, sediment, N, P					5.38%	5.37%	14.28%	7.78%	46.13%
Waikato at Huntly-Tainui Br (20)	1	Sediment, P	14.88%	17.97%	13.02%	15.24%	14.05%	13.73%	14.21%	0.00%	99.26%
Waikato at Mercer Br (9)	3	Sediment, P	11.79%	21.32%	8.13%	16.53%	12.58%	13.54%	12.52%	0.02%	
Waikato at Tuakau Br (4)	2	Sediment	7.88%	25.73%	9.58%	14.29%	13.82%	13.45%	12.36%	0.21%	13.29%
Whakapipi (3)	1	*E. coli*, sediment, N, P					0.67%	0.00%	12.72%	15.88%	115.44%
Whangamarino at Island Block Rd (10)	1	*E. coli*, sediment, P			8.35%	22.27%	11.47%	10.91%	4.37%	29.31%	31.17%
Whangamarino at Jefferies Rd Br (8)	1	*E. coli*, sediment, P					12.27%	4.65%	6.12%	7.48%	30.36%
Whangape (16)	1	*E. coli*, sediment, N					22.50%	11.70%	6.19%	0.84%	nd
Waikare (13)	1	Sediment, N, P									
Waikato at Rangiriri (15)	2	no current state water quality data									
Waikato at Port Waikato (6)	2	no current state water quality data									
Middle Waikato											
Karapiro (32)	3	*E. coli*, sediment, P					14.98%	12.39%	4.90%	13.45%	98.91%
Kirikiriroa (23)	1	*E. coli*, sediment, N, P					11.45%	6.98%	5.31%	15.95%	9.11%
Mangakotukutuku (30)	1	*E. coli*, sediment, N, P					20.16%	13.94%	7.23%	10.25%	11.34%
Mangaone (31)	2	*E. coli*, N, P					15.86%	17.15%	16.01%	7.72%	65.56%
Mangaonua (29)	3	*E. coli*, sediment, N					15.59%	16.48%	1.04%	9.34%	62.53%
Mangawhero (35)	1	*E. coli*, sediment, P					13.85%	15.27%	12.78%	2.12%	2.56%

Waikato at Horotiu (25)	1	P	4.29%	26.48%	2.74%	8.86%	4.62%	4.51%	9.02%	2.52%	50.41%
Waikato at Narrows (33)	3		10.88%	33.40%	4.12%	11.11%	4.13%	4.99%	9.91%	5.93%	59.93%
Waitawhiriwhiri (28)	1	*E. coli*, sediment, N, P					14.49%	14.49%	8.62%	4.73%	5.97%
Waikato at Bridge St Br (27)	1	no current state water quality data									
Upper Waikato											
Kawaunui (62)	2	*E. coli*, P, N					43.67%	44.54%	9.82%	2.97%	91.05%
Little Waipā (44)	1	N, P					4.55%	4.55%	17.22%	59.77%	88.83%
Mangaharakeke (57)	1	*E. coli*, P					8.95%	8.96%	9.98%	8.31%	44.19%
Mangakara (69)	2	*E. coli*, P, N					20.85%	22.90%	26.91%	3.48%	nd
Mangakino (71)	2	P					14.68%	14.67%	20.43%	22.59%	108.27%
Mangamingi (48)	1	*E. coli*, N, P					11.64%	14.16%	4.20%	13.28%	42.07%
Otamakokore (59)	2	*E. coli*, P					30.28%	30.28%	10.31%	39.18%	43.44%
Pokaiwhenua (45)	1	*E. coli*, N, P					0.97%	1.44%	11.78%	8.56%	79.41%
Pueto (74)	3	P					15.64%	15.54%	10.02%	17.21%	101.77%
Tahunaatara (54)	2	P					16.43%	16.44%	15.96%	24.51%	50.49%
Torepatutahi (72)	1	P					70.92%	70.92%	13.89%	15.17%	
Waikato at Karapiro (41)	3	no current state water quality data									
Waikato at Ohaaki (73)	3		100.00%	100.00%	4.63%	0.00%	0.26%	0.92%	16.09%	15.98%	nd
Waikato at Ohakuri (66)	3		9.36%	0.00%	6.85%	14.12%	3.26%	4.35%	16.78%	34.02%	51.34%
Waikato at Waipāpa (64)	1	P	6.94%	48.13%	5.65%	10.80%	2.13%	5.66%	17.01%	16.75%	27.26%
Waikato at Whakamaru (67)	2		100.00%	100.00%	8.19%	16.50%	6.04%	8.21%	27.67%	19.43%	nd
Waiotapu at Campbell (58)	3						14.74%	14.75%	60.15%	9.86%	40.52%
Waiotapu at Homestead (65)	1	P, N					33.67%	32.33%	14.10%	15.51%	
Waipāpa (70)	1	P, N					22.26%	22.26%	23.59%	69.35%	66.47%
Whakauru (49)	2	*E. coli*, P					8.85%	8.85%	4.17%	10.64%	41.70%
Whirinaki (56)	3	P					9.01%	9.01%	26.27%	29.44%	
Waipā											
Firewood (21)	2	no current state water quality data									
Mangarapa (55)	1	no current state water quality data									
Moakurarua (42)	1	no current state water quality data									
Puniu at Wharepapa (50)	3	N									
Waipā at Waingaro Rd Br (24)	2	no current state water quality data									
Kaniwhaniwha (36)	2	*E. coli*, sediment					17.40%	17.40%	1.75%	7.24%	nd

Mangaohoi (39)	3	P					4.83%	4.84%	19.06%	9.10%	88.41%
Mangaokewa (63)	1	*E. coli*, sediment					6.86%	6.85%	16.07%	21.23%	86.20%
Mangapiko (38)	2	*E. coli*, sediment, P, N					17.48%	14.89%	5.31%	1.06%	31.47%
Mangapu (53)	1	*E. coli*, sediment, P, N					12.27%	12.30%	0.82%	9.46%	104.60%
Mangatutu (47)	3	*E. coli*					19.18%	19.22%	5.99%	2.67%	110.32%
Mangauika (37)	3						10.81%	10.94%	9.40%	6.64%	nd
Ohote (26)	3	*E. coli*, sediment, P					20.69%	20.69%	0.61%	11.22%	nd
Puniu at Bartons Corner Rd Br (40)	2	*E. coli*, P					17.88%	17.88%	18.13%	5.41%	47.62%
Waipā at Mangaokewa Rd (68)	1	*E. coli*					0.42%	0.42%	8.19%	18.82%	92.36%
Waipā at Pirongia-Ngutunui Rd Br (43)	2	*E. coli*, sediment					17.82%	17.45%	4.18%	3.76%	100.81%
Waipā at Otorohanga (51)	1	*E. coli*, sediment					16.19%	16.19%	12.36%	16.88%	124.90%
Waitomo at SH31 Otorohanga (46)	2	*E. coli*, sediment					9.98%	9.99%	10.34%	13.27%	52.25%
Waitomo at Tumutumu Rd (52)	1	*E. coli*, sediment, N					8.00%	7.84%	3.55%	3.91%	113.00%
Mangarama (61)	1	no current state water quality data									
Waipā at Otewa (60)	2	*E. coli*, sediment					11.05%	10.32%	7.01%	3.22%	283.02%
Waipā at SH23 Br Whatawhata (34)	2	*E. coli*, sediment, N					17.95%	17.53%	3.68%	3.45%	39.83%

Note:

1. *The content of this Table is colour coded. For each water quality attribute target/limit at each sub-catchment (sub-catchment), if the target is met and or exceeded, the percentage by which the target is exceeded is presented in green. That is, 0% means the target is just met but not exceeded, while 25% means the target is met and exceeded by 25%. Similarly, blue is used to report the short-fall percentages to represent further improvements required to meet a water quality target. That is, 15% means the model solution is 85% improvement towards meeting the target, which implies only 15% short of meeting the target. Lastly, red is used to report the percentages by which water quality attribute concentrations could increase from the baseline/current level. That is, 50% means the contaminant concentration could increase by 50% from the baseline.
2. Sub-catchments in **bold** are the mainstem of the Waikato River
3. ***nd*** = These sub-catchments are lacking some data (including parameters such as existing measurement for beam attenuation coefficient, etc.), which are required in the model to estimate the water clarity attribute limits. It is specified in the model that where such data are missing, the target attribute states should be zero. The source (Yalden and Elliott, 2015) of these data/parameters (in the database behind the model) reported that sub-catchments that do not have these data/parameters were not associated with monitoring sub-catchments.
4. The table is colour-coded to reflect the elastic programming feature applied in this modelling exercise as mentioned in the section earlier. That is, the water quality constraints have been specified in the model as constraints that can be violated but with penalty costs. This means that for each water quality attribute target/limit at each sub-catchment (sub-catchment), the percentages by which the target attribute states are met and exceeded are presented in green. Similarly, blue is used to report the short-fall percentages to represent improvements required to meet a water quality target in a sub-catchment. And lastly, red is used to report the percentages by which water quality attribute concentrations can increase from the baseline/current level.
5. N = Nitrogen, P = Phosphorous

Table B4: Detailed results of short term scenario + low level of iwi land development*

Sub-catchment	Zone	Priority contaminant	Median chlorophyll-a (mg/m3)*	Maximum chlorophyll-*a* (mg/m^3)	Median TN (mg/m^3)	Median TP (mg/m^3)	Median nitrate (mg/L)	95th percentile nitrate (mg/L)	Median *E. coli* (cfu/100mL)	95th percentile *E. coli* (cfu/100mL)	10th percentile clarity (m)
Lower Waikato											
Awaroa (Rotowaro) at Harris/Te Ohaki Br (18)	1	*E. coli*, sediment									
Awaroa (Rotowaro) at Sansons Br (19)	2	*E. coli*, sediment					7.40%	7.40%	11.16%	6.91%	77.96%
Awaroa (Waiuku) (5)	3	*E. coli*, sediment, N					11.52%	9.42%	2.85%	3.63%	25.44%
Komakorau (22)	2	*E. coli*, sediment, N					40.34%	35.99%	1.94%	10.67%	nd
Mangatangi (2)	1	E. coli, sediment, P					9.36%	8.94%	3.71%	9.13%	42.07%
Mangatāwhiri (1)	3	*E. coli*, sediment					3.08%	0.60%	6.69%	22.00%	250.39%
Mangawara (17)	1	*E. coli*, sediment, N, P					35.20%	27.15%	0.22%	0.65%	8.85%
Matahuru (14)	1	*E. coli*, sediment, N, P					9.38%	5.36%	6.21%	9.98%	17.76%
Ohaeroa (7)	3	*E. coli*, sediment, N, P					6.86%	9.34%	9.51%	17.84%	47.40%
Opuatia (11)	1	*E. coli*, sediment, N					3.22%	3.21%	2.35%	0.40%	11.27%
Waerenga (12)	1	*E. coli*, sediment, N, P					5.38%	5.37%	14.28%	7.78%	46.13%
Waikato at Huntly-Tainui Br (20)	1	Sediment, P	14.39%	17.65%	12.61%	14.52%	13.64%	13.32%	14.19%	0.01%	98.94%
Waikato at Mercer Br (9)	3	Sediment, P	11.29%	20.97%	7.81%	16.12%	12.27%	13.25%	12.51%	0.02%	
Waikato at Tuakau Br (4)	2	Sediment	7.41%	25.43%	9.32%	13.67%	13.57%	13.20%	12.35%	0.20%	13.17%
Whakapipi (3)	1	*E. coli*, sediment, N, P					0.67%	0.00%	12.72%	15.88%	115.44%
Whangamarino at Island Block Rd (10)	1	*E. coli*, sediment, P			9.20%	22.27%	10.80%	10.22%	4.37%	29.31%	31.17%
Whangamarino at Jefferies Rd Br (8)	1	*E. coli*, sediment, P					12.02%	4.37%	6.12%	7.48%	30.36%
Whangape (16)	1	*E. coli*, sediment, N					22.50%	11.67%	6.19%	0.84%	nd
Waikare (13)	1	Sediment, N, P									
Waikato at Rangiriri (15)	2	no current state water quality data									
Waikato at Port Waikato (6)	2	no current state water quality data									
Middle Waikato											
Karapiro (32)	3	*E. coli*, sediment, P					15.08%	12.49%	4.90%	13.45%	98.91%
Kirikiriroa (23)	1	*E. coli*, sediment, N, P					12.07%	7.62%	5.31%	15.95%	9.11%
Mangakotukutuku (30)	1	*E. coli*, sediment, N, P					20.25%	14.04%	7.23%	10.25%	11.34%
Mangaone (31)	2	*E. coli*, N, P					16.19%	17.48%	16.01%	7.72%	65.56%
Mangaonua (29)	3	*E. coli*, sediment, N					16.00%	16.89%	1.04%	9.34%	62.53%
Mangawhero (35)	1	*E. coli*, sediment, P					13.99%	15.41%	12.78%	2.12%	2.56%
Waikato at Horotiu (25)	1	P	3.54%	26.07%	1.90%	8.00%	3.77%	3.69%	8.96%	2.49%	49.88%
Waikato at Narrows (33)	3		10.02%	32.97%	3.24%	10.00%	3.23%	4.13%	9.84%	5.90%	59.17%
Waitawhiriwhiri (28)	1	*E. coli*, sediment, N, P					14.49%	14.49%	8.62%	4.73%	5.97%

Waikato at Bridge St Br (27)	1	no current state water quality data									
Upper Waikato											
Kawaunui (62)	2	*E. coli*, P, N					43.67%	44.54%	9.82%	2.97%	91.05%
Little Waipā (44)	1	N, P					4.57%	4.57%	17.21%	59.77%	88.83%
Mangaharakeke (57)	1	*E. coli*, P					8.95%	8.96%	9.97%	8.30%	44.19%
Mangakara (69)	2	*E. coli*, P, N					20.85%	22.90%	26.91%	3.48%	nd
Mangakino (71)	2	P					13.86%	13.86%	20.07%	22.36%	108.27%
Mangamingi (48)	1	*E. coli*, N, P					11.64%	14.16%	4.20%	13.28%	42.07%
Otamakokore (59)	2	*E. coli*, P					30.28%	30.28%	10.31%	39.18%	43.44%
Pokaiwhenua (45)	1	*E. coli*, N, P					1.08%	1.33%	11.60%	8.46%	79.41%
Pueto (74)	3	P					21.76%	21.64%	5.94%	17.18%	101.77%
Tahunaatara (54)	2	P					17.12%	17.11%	15.80%	24.46%	50.49%
Torepatutahi (72)	1	P					89.12%	89.13%	8.22%	14.78%	
Waikato at Karapiro (41)	3	no current state water quality data									
Waikato at Ohaaki (73)	3		100.00%	100.00%	6.19%	0.00%	1.79%	2.50%	14.43%	15.94%	nd
Waikato at Ohakuri (66)	3		9.36%	0.00%	9.58%	14.12%	0.81%	6.95%	14.55%	33.83%	51.34%
Waikato at Waipāpa (64)	1	P	6.98%	48.14%	7.26%	10.80%	3.66%	7.25%	16.82%	16.68%	27.27%
Waikato at Whakamaru (67)	2		100.00%	100.00%	10.33%	16.50%	8.12%	10.36%	27.22%	19.36%	nd
Waiotapu at Campbell (58)	3						10.80%	10.79%	58.10%	7.12%	40.52%
Waiotapu at Homestead (65)	1	P, N					29.12%	27.69%	8.68%	14.72%	
Waipāpa (70)	1	P, N					24.55%	24.55%	23.51%	69.32%	66.47%
Whakauru (49)	2	*E. coli*, P					8.85%	8.85%	4.17%	10.64%	41.70%
Whirinaki (56)	3	P					8.92%	8.92%	26.17%	29.34%	
Waipā											
Firewood (21)	2	no current state water quality data									
Mangarapa (55)	1	no current state water quality data									
Moakurarua (42)	1	no current state water quality data									
Puniu at Wharepapa (50)	3	N									
Waipā at Waingaro Rd Br (24)	2	no current state water quality data									
Kaniwhaniwha (36)	2	*E. coli*, sediment					17.37%	17.38%	1.75%	7.24%	nd
Mangaohoi (39)	3	P					4.83%	4.84%	19.06%	9.10%	88.41%
Mangaokewa (63)	1	*E. coli*, sediment					5.70%	5.69%	16.08%	21.24%	86.20%
Mangapiko (38)	2	*E. coli*, sediment, P, N					17.49%	14.90%	5.31%	1.06%	31.47%
Mangapu (53)	1	*E. coli*, sediment, P, N					11.50%	11.53%	0.81%	9.47%	104.60%

Mangatutu (47)	3	*E. coli*					19.13%	19.17%	5.99%	2.67%	110.32%
Mangauika (37)	3						10.81%	10.94%	9.40%	6.64%	nd
Ohote (26)	3	*E. coli*, sediment, P					20.71%	20.70%	0.61%	11.22%	nd
Puniu at Bartons Corner Rd Br (40)	2	*E. coli*, P					17.94%	17.93%	18.13%	5.41%	47.62%
Waipā at Mangaokewa Rd (68)	1	*E. coli*					5.24%	5.24%	8.20%	18.83%	92.36%
Waipā at Pirongia-Ngutunui Rd Br (43)	2	*E. coli*, sediment					17.52%	17.15%	4.18%	3.77%	100.81%
Waipā at Otorohanga (51)	1	*E. coli*, sediment					15.51%	15.51%	12.35%	16.88%	124.90%
Waitomo at SH31 Otorohanga (46)	2	*E. coli*, sediment					9.29%	9.29%	10.37%	13.30%	52.25%
Waitomo at Tumutumu Rd (52)	1	*E. coli*, sediment, N					7.79%	7.62%	3.55%	3.91%	113.00%
Mangarama (61)	1	no current state water quality data									
Waipā at Otewa (60)	2	*E. coli*, sediment					9.87%	9.15%	7.02%	3.22%	283.02%
Waipā at SH23 Br Whatawhata (34)	2	*E. coli*, sediment, N					17.74%	17.32%	3.67%	3.45%	39.83%

Note:

1. *The content of this Table is colour coded. For each water quality attribute target/limit at each sub-catchment (sub-catchment), if the target is met and or exceeded, the percentage by which the target is exceeded is presented in green. That is, 0% means the target is just met but not exceeded, while 25% means the target is met and exceeded by 25%. Similarly, blue is used to report the short-fall percentages to represent further improvements required to meet a water quality target. That is, 15% means the model solution is 85% improvement towards meeting the target, which implies only 15% short of meeting the target. Lastly, red is used to report the percentages by which water quality attribute concentrations could increase from the baseline/current level. That is, 50% means the contaminant concentration could increase by 50% from the baseline.
2. Sub-catchments in **bold** are the mainstem of the Waikato River
3. ***nd*** = These sub-catchments are lacking some data (including parameters such as existing measurement for beam attenuation coefficient, etc.), which are required in the model to estimate the water clarity attribute limits. It is specified in the model that where such data are missing, the target attribute states should be zero. The source (Yalden and Elliott, 2015) of these data/parameters (in the database behind the model) reported that sub-catchments that do not have these data/parameters were not associated with monitoring sub-catchments.
4. The table is colour-coded to reflect the elastic programming feature applied in this modelling exercise as mentioned in the section earlier. That is, the water quality constraints have been specified in the model as constraints that can be violated but with penalty costs. This means that for each water quality attribute target/limit at each sub-catchment (sub-catchment), the percentages by which the target attribute states are met and exceeded are presented in green. Similarly, blue is used to report the short-fall percentages to represent improvements required to meet a water quality target in a sub-catchment. And lastly, red is used to report the percentages by which water quality attribute concentrations can increase from the baseline/current level.
5. N = Nitrogen, P = Phosphorous

Table B5: Detailed results of short term scenario + medium level of iwi land development*

Sub-catchment	Zone	Priority contaminant	Median chlorophyll-*a* (mg/m3)*	Maximum chlorophyll-*a* (mg/m^3)	Median TN (mg/m^3)	Median TP (mg/m^3)	Median nitrate (mg/L)	95th percentile nitrate (mg/L)	Median *E. coli* (cfu/100mL)	95th percentile *E. coli* (cfu/100mL)	10th percentile clarity (m)
Lower Waikato											
Awaroa (Rotowaro) at Harris/Te Ohaki Br (18)	1	*E. coli*, sediment									
Awaroa (Rotowaro) at Sansons Br (19)	2	*E. coli*, sediment					7.40%	7.40%	11.16%	6.91%	77.96%
Awaroa (Waiuku) (5)	3	*E. coli*, sediment, N					11.52%	9.42%	2.85%	3.63%	25.44%
Komakorau (22)	2	*E. coli*, sediment, N					40.34%	35.99%	1.94%	10.67%	nd
Mangatangi (2)	1	*E. coli*, sediment, P					9.27%	8.89%	3.71%	9.13%	42.07%
Mangatāwhiri (1)	3	*E. coli*, sediment					3.08%	0.60%	6.69%	22.00%	250.39%
Mangawara (17)	1	*E. coli*, sediment, N, P					35.16%	27.11%	0.22%	0.65%	8.85%
Matahuru (14)	1	*E. coli*, sediment, N, P					9.36%	5.33%	6.21%	9.98%	17.76%
Ohaeroa (7)	3	*E. coli*, sediment, N, P					6.85%	9.34%	9.51%	17.84%	47.40%
Opuatia (11)	1	*E. coli*, sediment, N					3.20%	3.20%	2.35%	0.40%	11.27%
Waerenga (12)	1	*E. coli*, sediment, N, P					5.38%	5.37%	14.28%	7.78%	46.13%
Waikato at Huntly-Tainui Br (20)	1	Sediment, P	13.97%	17.37%	12.08%	14.05%	13.15%	12.80%	14.18%	0.02%	98.68%
Waikato at Mercer Br (9)	3	Sediment, P	10.88%	20.68%	7.33%	15.71%	11.81%	12.79%	12.50%	0.01%	
Waikato at Tuakau Br (4)	2	Sediment	6.98%	25.14%	8.85%	13.27%	13.14%	12.76%	12.34%	0.20%	13.02%
Whakapipi (3)	1	*E. coli*, sediment, N, P					0.67%	0.00%	12.72%	15.88%	115.44%
Whangamarino at Island Block Rd (10)	1	*E. coli*, sediment, P			9.24%	22.27%	10.80%	10.20%	4.37%	29.31%	31.17%
Whangamarino at Jefferies Rd Br (8)	1	*E. coli*, sediment, P					11.98%	4.33%	6.12%	7.48%	30.36%
Whangape (16)	1	*E. coli*, sediment, N					22.50%	11.65%	6.19%	0.84%	nd
Waikare (13)	1	Sediment, N, P									
Waikato at Rangiriri (15)	2	no current state water quality data									
Waikato at Port Waikato (6)	2	no current state water quality data									
Middle Waikato											
Karapiro (32)	3	*E. coli*, sediment, P					15.08%	12.49%	4.90%	13.45%	98.91%
Kirikiriroa (23)	1	*E. coli*, sediment, N, P					12.07%	7.62%	5.31%	15.95%	9.11%
Mangakotukutuku (30)	1	*E. coli*, sediment, N, P					20.25%	14.04%	7.23%	10.25%	11.34%
Mangaone (31)	2	*E. coli*, N, P					16.18%	17.47%	16.01%	7.72%	65.56%
Mangaonua (29)	3	*E. coli*, sediment, N					15.90%	16.79%	1.04%	9.34%	62.53%
Mangawhero (35)	1	*E. coli*, sediment, P					13.99%	15.41%	12.78%	2.12%	2.56%
Waikato at Horotiu (25)	1	P	2.87%	25.71%	1.00%	7.14%	2.92%	2.80%	8.91%	2.47%	49.41%
Waikato at Narrows (33)	3		9.27%	32.59%	2.37%	8.89%	2.38%	3.27%	9.77%	5.87%	58.50%
Waitawhiriwhiri (28)	1	*E. coli*, sediment, N, P					14.49%	14.49%	8.62%	4.73%	5.97%

Waikato at Bridge St Br (27)	1	no current state water quality data									
Upper Waikato											
Kawaunui (62)	2	*E. coli*, P, N					43.67%	44.54%	9.82%	2.97%	91.05%
Little Waipā (44)	1	N, P					4.59%	4.59%	17.21%	59.77%	88.83%
Mangaharakeke (57)	1	*E. coli*, P					8.97%	8.97%	9.97%	8.29%	44.19%
Mangakara (69)	2	*E. coli*, P, N					20.85%	22.90%	26.91%	3.48%	nd
Mangakino (71)	2	P					13.05%	13.04%	19.71%	22.12%	108.27%
Mangamingi (48)	1	*E. coli*, N, P					11.64%	14.16%	4.20%	13.28%	42.07%
Otamakokore (59)	2	E. coli, P					30.28%	30.28%	10.31%	39.18%	43.44%
Pokaiwhenua (45)	1	*E. coli*, N, P					1.20%	1.23%	11.43%	8.35%	79.41%
Pueto (74)	3	P					27.80%	27.69%	1.87%	17.15%	101.77%
Tahunaatara (54)	2	P					17.80%	17.80%	15.65%	24.41%	50.49%
Torepatutahi (72)	1	P					107.34%	107.35%	2.56%	14.38%	
Waikato at Karapiro (41)	3	no current state water quality data									
Waikato at Ohaaki (73)	3		100.00%	100.00%	7.69%	0.00%	3.33%	3.82%	12.76%	15.89%	nd
Waikato at Ohakuri (66)	3		8.57%	0.48%	12.22%	12.94%	1.63%	9.55%	12.33%	33.63%	50.77%
Waikato at Waipāpa (64)	1	P	6.59%	48.01%	8.81%	10.00%	5.18%	8.81%	16.63%	16.62%	27.08%
Waikato at Whakamaru (67)	2		100.00%	100.00%	12.44%	15.50%	10.20%	12.43%	26.76%	19.29%	nd
Waiotapu at Campbell (58)	3						6.84%	6.85%	56.06%	4.38%	40.52%
Waiotapu at Homestead (65)	1	P, N					24.58%	23.05%	3.26%	13.93%	
Waipāpa (70)	1	P, N					26.60%	26.60%	23.42%	69.30%	66.47%
Whakauru (49)	2	*E. coli*, P					8.85%	8.85%	4.17%	10.64%	41.70%
Whirinaki (56)	3	P					8.82%	8.82%	26.06%	29.23%	
Waipā											
Firewood (21)	2	no current state water quality data									
Mangarapa (55)	1	no current state water quality data									
Moakurarua (42)	1	no current state water quality data									
Puniu at Wharepapa (50)	3	N									
Waipā at Waingaro Rd Br (24)	2	no current state water quality data									
Kaniwhaniwha (36)	2	*E. coli*, sediment					17.37%	17.37%	1.75%	7.24%	nd
Mangaohoi (39)	3	P					4.83%	4.84%	19.06%	9.10%	88.41%
Mangaokewa (63)	1	*E. coli*, sediment					4.51%	4.52%	16.08%	21.25%	86.20%
Mangapiko (38)	2	*E. coli*, sediment, P, N					17.49%	14.90%	5.31%	1.06%	31.47%
Mangapu (53)	1	E. coli, sediment, P, N					10.73%	10.76%	0.80%	9.48%	104.60%

Mangatutu (47)	3	*E. coli*					19.08%	19.13%	5.99%	2.67%	110.32%
Mangauika (37)	3						10.81%	10.94%	9.40%	6.64%	nd
Ohote (26)	3	*E. coli*, sediment, P					20.67%	20.67%	0.61%	11.22%	nd
Puniu at Bartons Corner Rd Br (40)	2	*E. coli*, P					17.86%	17.87%	18.13%	5.41%	47.62%
Waipā at Mangaokewa Rd (68)	1	*E. coli*					10.89%	10.89%	8.21%	18.83%	92.36%
Waipā at Pirongia-Ngutunui Rd Br (43)	2	*E. coli*, sediment					17.19%	16.80%	4.17%	3.78%	100.81%
Waipā at Otorohanga (51)	1	*E. coli*, sediment					14.84%	14.84%	12.35%	16.88%	124.90%
Waitomo at SH31 Otorohanga (46)	2	*E. coli*, sediment					8.58%	8.58%	10.40%	13.33%	52.25%
Waitomo at Tumutumu Rd (52)	1	*E. coli*, sediment, N					7.57%	7.39%	3.55%	3.92%	113.00%
Mangarama (61)	1	no current state water quality data									
Waipā at Otewa (60)	2	*E. coli*, sediment					8.68%	7.96%	7.02%	3.22%	283.02%
Waipā at SH23 Br Whatawhata (34)	2	*E. coli*, sediment, N					17.49%	17.06%	3.67%	3.46%	39.83%

Note:

1. * The content of this Table is colour coded. For each water quality attribute target/limit at each sub-catchment (sub-catchment), if the target is met and or exceeded, the percentage by which the target is exceeded is presented in green. That is, 0% means the target is just met but not exceeded, while 25% means the target is met and exceeded by 25%. Similarly, blue is used to report the short-fall percentages to represent further improvements required to meet a water quality target. That is, 15% means the model solution is 85% improvement towards meeting the target, which implies only 15% short of meeting the target. Lastly, red is used to report the percentages by which water quality attribute concentrations could increase from the baseline/current level. That is, 50% means the contaminant concentration could increase by 50% from the baseline.
2. Sub-catchments in **bold** are the mainstem of the Waikato River
3. ***nd*** = These sub-catchments are lacking some data (including parameters such as existing measurement for beam attenuation coefficient, etc.), which are required in the model to estimate the water clarity attribute limits. It is specified in the model that where such data are missing, the target attribute states should be zero. The source (Yalden and Elliott, 2015) of these data/parameters (in the database behind the model) reported that sub-catchments that do not have these data/parameters were not associated with monitoring sub-catchments.
4. The table is colour-coded to reflect the elastic programming feature applied in this modelling exercise as mentioned in the section earlier. That is, the water quality constraints have been specified in the model as constraints that can be violated but with penalty costs. This means that for each water quality attribute target/limit at each sub-catchment (sub-catchment), the percentages by which the target attribute states are met and exceeded are presented in green. Similarly, blue is used to report the short-fall percentages to represent improvements required to meet a water quality target in a sub-catchment. And lastly, red is used to report the percentages by which water quality attribute concentrations can increase from the baseline/current level.
5. N = Nitrogen, P = Phosphorous

Table B6: Detailed results of short term scenario + high level of iwi land development*

Sub-catchment	Zone	Priority Contaminant	Median chlorophyll-*a* (mg/m3)*	Maximum chlorophyll-*a* (mg/m^3)	Median TN (mg/m^3)	Median TP (mg/m^3)	Median nitrate (mg/L)	95th percentile nitrate (mg/L)	Median *E. coli* (cfu/100mL)	95th percentile *E. coli* (cfu/100mL)	10th percentile clarity (m)
Lower Waikato											
Awaroa (Rotowaro) at Harris/Te Ohaki Br (18)	1	*E. coli*, sediment									
Awaroa (Rotowaro) at Sansons Br (19)	2	*E. coli*, sediment					7.39%	7.39%	11.16%	6.91%	77.96%
Awaroa (Waiuku) (5)	3	*E. coli*, sediment, N					11.52%	9.42%	2.85%	3.63%	25.44%
Komakorau (22)	2	*E. coli*, sediment, N					40.33%	35.98%	1.94%	10.67%	nd
Mangatangi (2)	1	*E. coli*, sediment, P					9.27%	8.84%	3.71%	9.13%	42.07%
Mangatāwhiri (1)	3	*E. coli*, sediment					3.08%	0.60%	6.69%	22.00%	250.39%
Mangawara (17)	1	*E. coli*, sediment, N, P					35.12%	27.07%	0.22%	0.65%	8.85%
Matahuru (14)	1	*E. coli*, sediment, N, P					9.33%	5.30%	6.21%	9.98%	17.76%
Ohaeroa (7)	3	*E. coli*, sediment, N, P					6.85%	9.33%	9.51%	17.84%	47.40%
Opuatia (11)	1	*E. coli*, sediment, N					3.19%	3.19%	2.35%	0.40%	11.27%
Waerenga (12)	1	*E. coli*, sediment, N, P					5.38%	5.37%	14.28%	7.78%	46.13%
Waikato at Huntly-Tainui Br (20)	1	Sediment, P	13.75%	17.23%	11.57%	13.81%	12.63%	12.29%	14.16%	0.03%	98.52%
Waikato at Mercer Br (9)	3	Sediment, P	10.69%	20.55%	6.86%	15.51%	11.37%	12.35%	12.49%	0.00%	
Waikato at Tuakau Br (4)	2	Sediment	6.74%	24.99%	8.40%	13.06%	12.68%	12.33%	12.32%	0.19%	12.96%
Whakapipi (3)	1	*E. coli*, sediment, N, P					0.67%	0.00%	12.72%	15.88%	115.44%
Whangamarino at Island Block Rd (10)	1	*E. coli*, sediment, P			9.27%	22.35%	10.80%	10.16%	4.37%	29.31%	31.17%
Whangamarino at Jefferies Rd Br (8)	1	*E. coli*, sediment, P					11.94%	4.28%	6.12%	7.48%	30.36%
Whangape (16)	1	*E. coli*, sediment, N					22.50%	11.62%	6.19%	0.84%	nd
Waikare (13)	1	Sediment, N, P									
Waikato at Rangiriri (15)	2	no current state water quality data									
Waikato at Port Waikato (6)	2	no current state water quality data									
Middle Waikato											
Karapiro (32)	3	*E. coli*, sediment, P					15.08%	12.49%	4.90%	13.45%	98.91%
Kirikiriroa (23)	1	*E. coli*, sediment, N, P					12.07%	7.62%	5.31%	15.95%	9.11%
Mangakotukutuku (30)	1	*E. coli*, sediment, N, P					20.25%	14.04%	7.23%	10.25%	11.34%
Mangaone (31)	2	E. coli, N, P					16.18%	17.47%	16.01%	7.72%	65.56%
Mangaonua (29)	3	*E. coli*, sediment, N					15.80%	16.69%	1.04%	9.34%	62.53%
Mangawhero (35)	1	*E. coli*, sediment, P					13.99%	15.41%	12.78%	2.12%	2.56%
Waikato at Horotiu (25)	1	P	2.52%	25.52%	0.11%	6.86%	2.04%	1.93%	8.86%	2.44%	49.17%
Waikato at Narrows (33)	3		8.91%	32.41%	1.49%	8.52%	1.49%	2.39%	9.70%	5.83%	58.20%
Waitawhiriwhiri (28)	1	*E. coli*, sediment, N, P					14.49%	14.49%	8.62%	4.73%	5.97%
Waikato at Bridge St Br (27)	1	no current state water quality data									
Upper Waikato											
Kawaunui (62)	2	*E. coli*, P, N					43.67%	44.54%	9.82%	2.97%	91.05%
Little Waipā (44)	1	N, P					4.61%	4.61%	17.21%	59.77%	88.83%

Mangaharakeke (57)	1	*E. coli*, P					8.97%	8.97%	9.96%	8.29%	44.19%
Mangakara (69)	2	*E. coli*, P, N					20.85%	22.90%	26.91%	3.48%	nd
Mangakino (71)	2	P					12.23%	12.23%	19.34%	21.89%	108.27%
Mangamingi (48)	1	*E. coli*, N, P					11.64%	14.16%	4.20%	13.28%	42.07%
Otamakokore (59)	2	*E. coli*, P					30.28%	30.28%	10.31%	39.18%	43.44%
Pokaiwhenua (45)	1	*E. coli*, N, P					1.31%	1.12%	11.26%	8.25%	79.41%
Pueto (74)	3	P					33.87%	33.73%	2.20%	17.12%	101.77%
Tahunaatara (54)	2	P					18.47%	18.47%	15.50%	24.37%	50.49%
Torepatutahi (72)	1	P					125.56%	125.55%	3.11%	13.99%	
Waikato at Karapiro (41)	3	no current state water quality data									
Waikato at Ohaaki (73)	3		100.00%	100.00%	9.18%	0.00%	4.62%	5.26%	11.10%	15.85%	nd
Waikato at Ohakuri (66)	3		7.18%	1.33%	14.86%	10.59%	3.95%	12.15%	10.11%	33.43%	49.77%
Waikato at Waipāpa (64)	1	P	5.99%	47.80%	10.39%	9.20%	6.65%	10.38%	16.44%	16.56%	26.79%
Waikato at Whakamaru (67)	2		100.00%	100.00%	14.50%	14.50%	12.28%	14.50%	26.31%	19.22%	nd
Waiotapu at Campbell (58)	3						2.90%	2.89%	54.02%	1.64%	40.52%
Waiotapu at Homestead (65)	1	P, N					20.03%	18.41%	2.16%	13.14%	
Waipāpa (70)	1	P, N					28.65%	28.66%	23.34%	69.27%	66.47%
Whakauru (49)	2	*E. coli*, P					8.85%	8.85%	4.17%	10.64%	41.70%
Whirinaki (56)	3	P					8.73%	8.73%	25.96%	29.13%	
Waipā											
Firewood (21)	2	no current state water quality data									
Mangarapa (55)	1	no current state water quality data									
Moakurarua (42)	1	no current state water quality data									
Puniu at Wharepapa (50)	3	N									
Waipā at Waingaro Rd Br (24)	2	no current state water quality data									
Kaniwhaniwha (36)	2	*E. coli*, sediment					17.34%	17.35%	1.75%	7.25%	nd
Mangaohoi (39)	3	P					4.83%	4.84%	19.06%	9.10%	88.41%
Mangaokewa (63)	1	*E. coli*, sediment					3.35%	3.36%	16.09%	21.25%	86.20%
Mangapiko (38)	2	*E. coli*, sediment, P, N					17.48%	14.90%	5.31%	1.06%	31.47%
Mangapu (53)	1	*E. coli*, sediment, P, N					9.97%	10.00%	0.79%	9.49%	104.60%
Mangatutu (47)	3	*E. coli*					19.05%	19.09%	5.99%	2.67%	110.32%
Mangauika (37)	3						10.81%	10.94%	9.40%	6.64%	nd
Ohote (26)	3	*E. coli*, sediment, P					20.65%	20.65%	0.61%	11.22%	nd
Puniu at Bartons Corner Rd Br (40)	2	*E. coli*, P					17.80%	17.80%	18.13%	5.41%	47.62%

Waipā at Mangaokewa Rd (68)	1	*E. coli*					16.53%	16.54%	8.21%	18.84%	92.36%
Waipā at Pirongia-Ngutunui Rd Br (43)	2	*E. coli*, sediment					16.83%	16.45%	4.17%	3.78%	100.81%
Waipā at Otorohanga (51)	1	*E. coli*, sediment					14.16%	14.17%	12.35%	16.88%	124.90%
Waitomo at SH31 Otorohanga (46)	2	*E. coli*, sediment					7.88%	7.88%	10.43%	13.36%	52.25%
Waitomo at Tumutumu Rd (52)	1	*E. coli*, sediment, N					7.35%	7.18%	3.56%	3.92%	113.00%
Mangarama (61)	1	no current state water quality data									
Waipā at Otewa (60)	2	*E. coli*, sediment					7.50%	6.77%	7.02%	3.22%	283.02%
Waipā at SH23 Br Whatawhata (34)	2	*E. coli*, sediment, N					17.22%	16.80%	3.66%	3.46%	39.83%

Note:

1. * The content of this Table is colour coded. For each water quality attribute target/limit at each sub-catchment (sub-catchment), if the target is met and or exceeded, the percentage by which the target is exceeded is presented in green. That is, 0% means the target is just met but not exceeded, while 25% means the target is met and exceeded by 25%. Similarly, blue is used to report the short-fall percentages to represent further improvements required to meet a water quality target. That is, 15% means the model solution is 85% improvement towards meeting the target, which implies only 15% short of meeting the target. Lastly, red is used to report the percentages by which water quality attribute concentrations could increase from the baseline/current level. That is, 50% means the contaminant concentration could increase by 50% from the baseline.
2. Sub-catchments in **bold** are the mainstem of the Waikato River
3. ***nd*** = These sub-catchments are lacking some data (including parameters such as existing measurement for beam attenuation coefficient, etc.), which are required in the model to estimate the water clarity attribute limits. It is specified in the model that where such data are missing, the target attribute states should be zero. The source (Yalden and Elliott, 2015) of these data/parameters (in the database behind the model) reported that sub-catchments that do not have these data/parameters were not associated with monitoring sub-catchments.
4. The table is colour-coded to reflect the elastic programming feature applied in this modelling exercise as mentioned in the section earlier. That is, the water quality constraints have been specified in the model as constraints that can be violated but with penalty costs. This means that for each water quality attribute target/limit at each sub-catchment (sub-catchment), the percentages by which the target attribute states are met and exceeded are presented in green. Similarly, blue is used to report the short-fall percentages to represent improvements required to meet a water quality target in a sub-catchment. And lastly, red is used to report the percentages by which water quality attribute concentrations can increase from the baseline/current level.
5. N = Nitrogen, P = Phosphorous

APPENDIX C – Details results - N leaching loss rate (NLLR)

Table C1: Areas and percentage change under high N leaching loss rate (NLLR)

Sector and FMU	baseline	Long term[49]	% change from baseline	Short term[50]	% change from baseline	Short term + CVP expansion	% change from short term	Short term + low level of iwi land development	% change from short term	Short term + medium level of iwi land development	% change short term	Short-term + high level of iwi land development	% change from short term
Dairy and dairy support													
Lower Waikato													
Low	35,275	42,344	20.04%	38,634	9.52%	38,634	0.00%	38,634	0.00%	38,634	0.00%	38634	0.00%
Moderate	15,751	30,713	94.99%	18,742	18.99%	18,742	0.00%	18,742	0.00%	18,742	0.00%	18742	0.00%
High	30,946	8,914	-71.20%	24,595	-20.52%	24,595	0.00%	24,642	0.19%	24,689	0.38%	24736	0.57%
Middle Waikato													
Low	10,178	10,178	0.00%	10,178	0.00%	10,178	0.00%	10,178	0.00%	10,178	0.00%	10178	0.00%
Moderate	1,653	8,919	439.73%	6,620	300.56%	6,620	0.00%	6,620	0.00%	6,620	0.00%	6620	0.00%
High	7,792	526	-93.26%	2,825	-63.74%	2,825	0.00%	2,831	0.18%	2,836	0.36%	2841	0.55%
Waipā													
Low	56,000	82,170	46.73%	59,847	6.87%	59,847	0.00%	59,847	0.00%	59,847	0.00%	59847	0.00%
Moderate	47,326	28,207	-40.40%	43,479	-8.13%	43,479	0.00%	43,847	0.85%	44,215	1.69%	44583	2.54%
High	7,052		-100.00%	7,052	0.00%	7,052	0.00%	7,052	0.00%	7,052	0.00%	7052	0.00%
Upper Waikato													
Low	29,620	55,302	86.71%	56,701	91.43%	56,701	0.00%	56,701	0.00%	56,701	0.00%	56701	0.00%
Moderate	41,634	40,735	-2.16%	39,337	-5.52%	39,337	0.00%	33,882	-13.87%	36,022	-8.43%	38163	-2.99%
High	24,784		-100.00%		-100.00%								
Change in total areas under High NLLR			**-86.63%**		**-51.16%**		**0.00%**		**0.15%**		**0.30%**		**0.45%**
Drystock													
Lower Waikato													
Low	105,861	105,861	0.00%	105,861	0.00%	105,861	0.00%	105,862	0.00%	105,863	0.00%	105865	0.00%
Moderate	10,303	10,303	0.00%	10,303	0.00%	10,303	0.00%	10,303	0.00%	10,303	0.00%	10303	0.00%
High													
Middle Waikato													
Low	17,449	17,449	0.00%	17,449	0.00%	17,449	0.00%	17,449	0.00%	17,449	0.00%	17449	0.00%
Moderate	1,667	1,667	0.00%	1,667	0.00%	1,667	0.00%	1,667	0.00%	1,667	0.00%	1667	0.00%
High													
Waipā													
Low	109,978	109,978	0.00%	109,978	0.00%	109,978	0.00%	109,985	0.01%	109,993	0.01%	110001	0.02%
Moderate													
High													
Upper Waikato													
Low	125,098	125,098	0.00%	125,098	0.00%	125,098	0.00%	125,595	0.40%	126,092	0.80%	126590	1.19%
Moderate													
High													
Change in total areas under High NLLR			**0**		**0**		**0**		**0**		**0**		**0**
Horticulture													
Lower Waikato													
Low													

[49] 80 years to achieve the vision and strategy objective - restoration of water quality within the Waikato River so that it is safe for people to swim in, and take food from, over its entire length and consideration for social and economic implications.

[50] Achieving 20% towards the 80-year water quality attribute targets in the first 10 years of the plan being operative.

Moderate													
High	4,268	4,268	0.00%	4,268	0.00%	4,567	7.01%	4,268	0.00%	4,268	0.00%	4268	0.00%
Middle Waikato													
Low													
Moderate													
High	612	612	0.07%	612	0.07%	661	7.93%	612	0.00%	612	0.00%	612	0.00%
Waipā													
Low													
Moderate													
High	734	734	-0.03%	734	-0.03%	780	6.30%	734	0.00%	734	0.00%	734	0.00%
Upper Waikato													
Low													
Moderate		220		74		157	111.71%	74	0.00%	74	0.00%	74	0.00%
High	490	270	-44.98%	415	-15.24%	334	-19.58%	415	0.00%	415	0.00%	415	0.00%
Change in total areas under High NLLR			**-3.61%**		**-1.22%**		**5.19%**		**0.00%**		**0.00%**		**0.00%**
Forestry													
Lower Waikato													
Low	13,862	13,862	0.00%	13,862	0.00%	13,862	0.00%	13,814	-0.35%	13,766	-0.70%	13717	-1.04%
Moderate													
High													
Middle Waikato													
Low	595	595	0.00%	595	0.00%	595	0.00%	589	-0.86%	584	-1.73%	579	-2.59%
Moderate													
High													
Waipā													
Low	12,239	12,239	0.00%	12,239	0.00%	12,239	0.00%	11,863	-3.07%	11,487	-6.14%	11112	-9.21%
Moderate													
High													
Upper Waikato													
Low	142,783	142,783	0.00%	142,783	0.00%	142,783	0.00%	140,145	-1.85%	137,508	-3.69%	134870	-5.54%
Moderate													
High													
Change in total areas under High NLLR			**0**		**0**		**0**		**0**		**0**		**0**