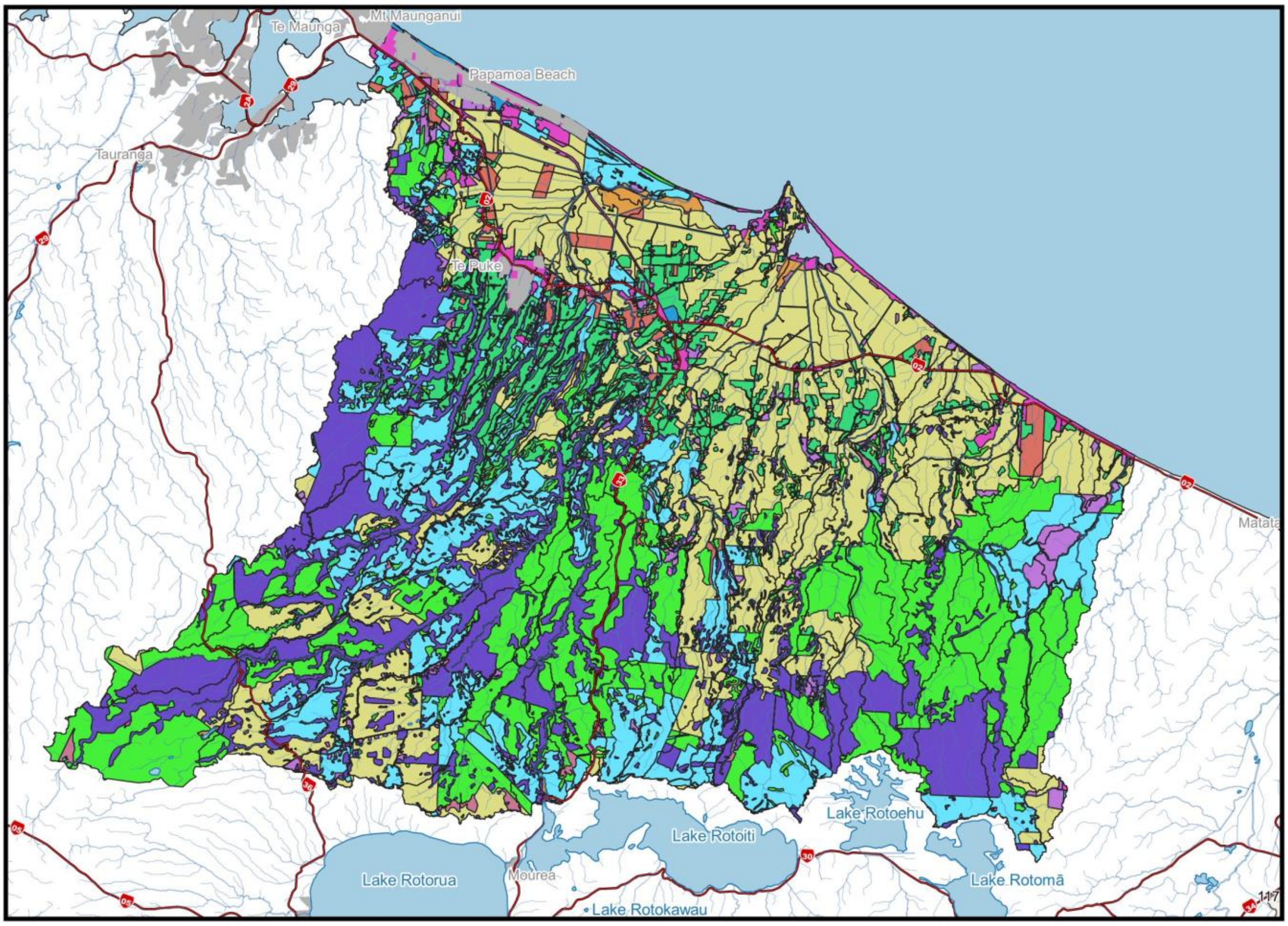
# Bay of Plenty Regional Council

# Kaituna-Pongakawa-Waitahanui & Rangitāiki Catchment Models

## Scenarios Report

BAY OF PLENTY REGIONAL COUNCIL

WWA0033 | Rev. 2



# Kaituna-Pongakawa-Waitahanui & Rangitāiki Catchment Models

| | |
|---|---|
| Project no: | WWA0033 |
| Document title: | SOURCE Catchment Modelling Analysis |
| Revision: | 2 |
| Date: | 18 Dec 2020 |
| Client name: | Bay of Plenty Regional Council |
| Project manager: | Jon Williamson |
| Author(s): | Elise Legarth, Jessie Loft, Josh Mawer |
| File name: | G:\Shared drives\Projects\BOPRC\WWA0033_SOURCE Models\Deliverables\Scenarios Report\BOP Catchment SOURCE Model_Scenarios Report_Rev2.docx |

**Williamson Water & Land Advisory**

PO Box 314,
Kumeu 0841,
Auckland
T +64 21 654422

## Document history and status

| Rev | Date | Description | By | Review | Approved |
|---|---|---|---|---|---|
| 1 | 02 Oct 2020 | First issue for client review | Elise Legarth | Josh Mawer | |
| 2 | 18 Dec 2020 | Updated following client feedback | Elise Legarth | Josh Mawer | Jon Williamson |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

## Distribution of copies

| Rev | Date issued | Issued to | Comments |
|---|---|---|---|
| 1 | 02 Oct 2020 | Bay of Plenty Regional Council | First issue for client review |
| 2 | 18 Dec 2020 | Bay of Plenty Regional Council | Updated following client feedback |
| | | | |
| | | | |
| | | | |
| | | | |

# Contents

**1. Introduction ..... 6**
1.1 Modelling Tools ..... 6
1.2 Report Structure ..... 7
**2. Scenario Descriptions ..... 8**
2.1 Land Use Change Scenarios ..... 8
2.2 Mitigation Scenarios ..... 10
2.3 Summary of Scenarios ..... 12
**3. Scenario Modelling ..... 13**
3.1 Climate Data ..... 13
3.2 Flow ..... 13
3.2.1 SMWBM Parameter Disaggregation ..... 14
3.2.2 Disaggregation Example ..... 15
3.2.2.1 Lakes Adjustment ..... 17
3.3 Land Use ..... 17
3.4 Stresses (Takes and Discharges) ..... 20
3.5 Mitigation Measures ..... 21
3.5.1 Implementation in SOURCE ..... 21
**4. Land Use Change Scenario Results ..... 23**
4.1 Kaituna-Pongakawa-Waitahanui ..... 23
4.1.1 TN Results ..... 23
4.1.2 TP Results ..... 26
4.1.3 TSS Results ..... 28
4.1.4 E. coli Results ..... 30
4.2 Rangitāiki ..... 32
4.2.1 TN ..... 32
4.2.2 TP ..... 34
4.2.3 TSS ..... 36
4.2.4 E. coli ..... 38
4.3 Scenario Analysis ..... 39
4.3.1 Kaituna-Pongakawa-Waitahanui ..... 40
4.3.2 Rangitāiki ..... 44
**5. Mitigation Scenario Results ..... 48**
5.1 Kaituna-Pongakawa-Waitahanui ..... 48
5.1.1 TN Cumulative Results ..... 48
5.1.2 TP Cumulative Results ..... 51
5.1.3 TSS Cumulative Results ..... 53
5.1.4 E. coli Cumulative Results ..... 55
5.2 Rangitāiki ..... 57
5.2.1 TN Cumulative Results ..... 57
5.2.2 TP Cumulative Results ..... 59

5.2.3 TSS Cumulative Results ........ 61
5.2.4 E. coli Cumulative Results ........ 63
5.3 Scenario Analysis ........ 65
5.3.1 Kaituna-Pongakawa-Waitahanui ........ 65
5.3.2 Rangitāiki ........ 69
**6. Summary and Conclusions ........ 73**
**7. References ........ 74**

## Table of Figures

Figure 1. Kaituna Land Use Scenarios (Refer A3 attachment at rear). ..... 9
Figure 2. Rangitāiki Land Use Scenarios (Refer A3 attachment at rear). ..... 9
Figure 3. Comparison of flow hydrographs for calibrated (aggregated) and disaggregated models at Raparapahoe River. ..... 16
Figure 4. Disaggregated land use flow contributions for SC#42. ..... 16
Figure 5. Kaituna WMA – key reporting and model output locations. (Refer A3 attachment at rear). ..... 23
Figure 6. Rangitāiki WMA – key reporting and model output locations. (Refer A3 attachment at rear). ..... 23
Figure 5. Discrete TN yields (T/ha/yr) for the Kaituna WMA. (Refer A3 attachment at rear). ..... 23
Figure 6. Discrete TP yields (T/ha/yr) for the Kaituna WMA. (Refer A3 attachment at rear). ..... 26
Figure 7. Discrete TSS yields (T/ha/yr) for the Kaituna WMA. (Refer A3 attachment at rear). ..... 28
Figure 8. Discrete *E. coli* yields (CFU/ha/year) for the Kaituna WMA. (Refer A3 attachment at rear). ..... 30
Figure 9. Discrete TN yields (T/ha/yr) for the Rangitāiki WMA. (Refer A3 attachment at rear). ..... 32
Figure 10. Discrete TP yield (T/ha/yr) for the Rangitāiki WMA. (Refer A3 attachment at rear). ..... 34
Figure 11. Discrete TSS yield (T/ha/yr) for the Rangitāiki WMA. (Refer A3 attachment at rear). ..... 36
Figure 12. Discrete *E. coli yield (CFU*/ha/year) for the Rangitāiki WMA. (Refer A3 attachment at rear). ..... 38

# 1. Introduction

Bay of Plenty Regional Council (BOPRC) commissioned Williamson Water Advisory (WWA), Hydrology and Risk Consulting (HARC), and Eco Logical Australia (ELA) to develop two integrated catchment models for the Kaituna-Pongakawa-Waitahanui (Kaituna) and Rangitāiki Water Management Areas (WMAs). The goal of these hydrological models was to simulate the water quantity and quality of the rivers and streams to support policy development under the National Policy Statement for Freshwater Management (NPS-FM).

WWLA's specific engagement comprised technical work to build the SOURCE model, calibrate the model to the measured flow and water quality constituents, and simulate various historical and potential future land management scenarios. BOPRC staff were heavily involved in data provision, assistance and support roles, particularly with regard to monitoring data collected by BOPRC and the development of analysis scenarios.

This report outlines the development and results of modelling water quality scenarios of various land use and mitigation practises within the Kaituna and Rangitāiki WMA's. The water quality constituents assessed were:

- Total Nitrogen (TN);
- Total Phosphorus (TP);
- Total Suspended Solids (TSS); and
- Escherichia coli (E. coli).

In addition to the models results and outputs (tabulated summary statistics and figures) presented in this report, raw and processed model outputs for all sub-catchment and each of the four constituents were provided to BOPRC as a series of Excel and csv output files. It is understood BOPRC are currently preparing a technical report to present the model's results and findings in greater detail than presented here, and at various spatial scales, with a focus on supporting policy decision-making.

## 1.1 Modelling Tools

The modelling was primarily undertaken using the SOURCE catchment model developed in Australia by eWater Ltd. SOURCE provides a framework for simulation and accounting of flows and constituents on a catchment-by-catchment basis. It comprises a range of models and tools that have been incorporated into a single flexible adaptable environment that recognises the practical and technical issues in developing water policy and the need for transparency and sustainability. It was designed to be customisable by users to address specific local problems or can be pre-configured for typical integrated water resource management (IWRM) situations.

The Soil Moisture Water Balance Model (SMWBM_VZ), developed by WWLA, was used to simulate catchment flow. Dynamic SedNet (dSedNet) developed by the CSIRO in Australia was used to generate sediment runoff, and functions as a plugin to SOURCE. To enable assessment of water quality effects associated with land use the Agricultural Production System Simulator (APSIM) was used to generate Total Nitrogen leaching loss from the sub-soil. APSIM comprises several separate modules that simulate biophysical processes in agricultural systems including water balance, N and P transformations, soil pH, erosion and a full range of management controls.

APSIM was run independently of the SOURCE model with outputs imported into the SOURCE model to enable simulation of the effects of nutrient losses associated with agricultural land use on the quality of receiving waters.

The SOURCE model was calibrated to available river flow and water quality monitoring data. In general, calibration of flow, TN, a TP was considered Satisfactory or better. While calibration to measured TSS and *E. coli* data was not as successful, the model constituent generation parameters were linked to physical catchment characteristics, and therefore still provides a useful tool for simulating relative change between scenarios.

Model refinements of TN and TSS were based on industry information and stakeholder feedback provided prior to December 2019. Data or information received after that time has not been incorporated due to practical reasons.

Full details of the development and calibration of these models can be found in the SOURCE and APSIM reports (WWLA, 2020a,b).

## 1.2 Report Structure

The modelling and analysis undertaken for this for project is detailed across a suite of three technical reports, which are:

- **WWLA, 2020a.** ***Kaituna-Pongakawa-Waitahanui & Rangitāiki Catchment Models*** – details the development of the water quantity and quality catchment models;
- **WWLA, 2020b*. Kaituna-Pongakawa-Waitahanui & Rangitāiki APSIM Modelling Report*** – details the development of the APSIM Models.
- **WWLA, 2020c*. Kaituna-Pongakawa-Waitahanui & Rangitāiki Scenarios Modelling Report*** (this report) – presents the development and analysis of land use change and mitigation scenarios.

This scenario modelling report is structured around the following sections:

- **Section 1** –- introduction and project overview;
- **Section 2** – description of scenarios;
- **Section 3** – description of scenario model adjustments;
- **Section 4** – results from land use scenarios;
- **Section 5** – results from mitigation scenarios; and
- **Section 6** – summary and conclusions from the work undertaken.

# 2. Scenario Descriptions

Scenario modelling enables the outcomes from a range of potential future scenarios to be assessed. Although modelling cannot predict the exact future outcomes, testing a range of potential scenarios provides useful insight for decision making and planning policy.

Seven scenarios were assessed, representing four land use change scenarios (**Section 2.1**), and three scenarios where nutrient generation / loss mitigation measures were applied to three of the of the land use change scenarios (**Section 2.2**).

## 2.1 Land Use Change Scenarios

Four land use change scenarios were developed and provided to WWLA by BOPRC, representing the WMAs current state, the naturalised state of the WMAs (i.e. assuming land uses prior to human modification), and two potential future development scenarios. The four land use scenarios are referenced as follows:

- **Scenario 1** – Base Case
- **Scenario 2** – Reference State
- **Scenario 3** – Development C
- **Scenario 4** – Development D

The hypothetical future land use change scenarios were developed with input from local stakeholders and feedback from community workshops. The scenarios were provided to WWLA as a series of GIS shapefiles displaying the location and extent of land use classes across the Kaituna and Rangitāiki WMAs

To allow for direct comparisons to the Reference State, Development C and Development D scenarios, an additional scenario was included in the assessment (Scenario 1b – Current State). This Current State scenario was similar to the Base Case, except the water takes applied were developed similar to those applied in the development scenarios (WWLA, 2020a). A description of each of the scenarios assessed is provided in **Table 1**.

**Table 1. Scenario Descriptions for Rangitāiki and Kaituna WMA**

| Scenario Name | Description |
|---|---|
| Scenario 1 – Base Case | The calibrated flow and constituent model, reflecting the current state of the environment.<br>Used rainfall from 1980 – 2016. |
| Scenario 1b – Current State | The calibrated model with irrigation water use based on area rather than consented volume.<br>Provides a like-with-like reference for comparison to the development scenarios (C and D).<br>Used historical rainfall relabelled as 2020 – 2056. |
| Scenario 2 – Reference State | Flow and constituent simulation under a naturalised land use (native forest and wetlands)<br>Used rainfall from 1980 – 2016. |
| Scenario 3 – Development C | Flow and constituent simulations to assess the effect of a possible future land use scenario:<br>Rangitāiki - an increase in kiwifruit; and<br>Kaituna - an increase in kiwifruit and plantation forest.<br>Used historical rainfall relabelled as 2020 – 2056. |
| Scenario 4 – Development D | Flow and constituent simulations to assess the effect of a possible future land use scenario:<br>Rangitāiki - an increase in dairy; and<br>Kaituna - an increase in kiwifruit, plantation forest and dairy.<br>Used historical rainfall relabelled as 2020 – 2056. |

The differences in land use classification between scenarios for the Kaituna and Rangitāiki WMAs are presented in **Figure 1** and **Figure 2**, respectively.

The Base Case and Current State scenarios are both representative of the present-day land use. The Reference State scenario represents the land use prior to human modification, where catchments consisted of almost entirely native forest and wetlands.

The Development C and Development D scenarios represent varying levels of development with increases in kiwifruit and plantation forest in the Kaituna WMA, and increased kiwifruit and dairy in the Rangitāiki WMA, respectively. It should be noted, these scenarios represent hypothetical future land use changes for the purposes of “what if” testing and analysis, and were developed in conjunction with key stakeholders.

**Figure 1. Kaituna Land Use Scenarios** (Refer A3 attachment at rear).

**Figure 2. Rangitāiki Land Use Scenarios** (Refer A3 attachment at rear**).**

The area and proportional composition of land uses within each scenario are tabulated in **Table 1** and **Table 2** for the Kaituna and Rangitāiki WMAs, respectively.

**Table 2. Comparison of land use classification between scenarios – Kaituna WMA.**

| Land use | Current State (ha) | Reference State (ha) | Development C (ha) | Development D (ha) |
|---|---|---|---|---|
| Arable | 1,605<br>(1.4%) | | 839<br>(0.7%) | 747<br>(0.6%) |
| Dairy | 31,545<br>(27.5%) | | 10,340<br>(9.0%) | 25,902<br>(22.5%) |
| Forest | 21,862<br>(19.1%) | 99,190<br>(87%) | 26,560<br>(23.1%) | 26,956<br>(23.5%) |
| Plantation Forest | 25,281<br>(22.1%) | | 39,724<br>(34.6%) | 39,877<br>(34.7%) |
| Hydro & Wetland | 1,028<br>(0.9%) | 14,642<br>(13%) | 4993<br>(4.3%) | 2,621<br>(2.3%) |
| Kiwifruit and Orchards | 8,402<br>(7.3%) | | 18,347<br>(16.0%) | 8,377<br>(7.3%) |
| Lifestyle | 3,062<br>(2.7%) | | 2,507<br>(2.2%) | 2,538<br>(2.2%) |
| Parks and Reserves | 177<br>(0.2%) | 134<br>(0.1%) | 119<br>(0.1%) | 119<br>(0.1%) |
| Scrub | 629<br>(0.5%) | 684<br>(0.5%) | 293<br>(0.3%) | 190<br>(0.2%) |
| Sheep and Beef | 16,549<br>(14.4%) | | 4,992<br>(4.3%) | 1,739<br>(1.5%) |
| Urban, Road, Rail & Unknown | 4,498<br>(3.9%) | | 6,121<br>(5.3%) | 5,837<br>(5.1%) |
| Vegetables | 2<br>(<0.1%) | | 2.1<br>(<0.0%) | 0.4<br>(<0.1%) |

**Table 3. Comparison of land use classification between scenarios – Rangitāiki WMA.**

| Rangitāiki land use | Current State (ha) | Reference State (ha) | Development C (ha) | Development D (ha) |
|---|---|---|---|---|
| **Arable** | 1,656<br>(1.0%) | | 530<br>(0.2%) | 225<br>(0.1%) |
| **Dairy** | 25,180<br>(9.0%) | | 20,939<br>(7.1%) | 39,736<br>(13.5%) |
| **Forest** | 82,132<br>(28.0%) | 284,614<br>(97.0%) | 84,505<br>(28.8%) | 84,110<br>(28.7%) |
| **Hydro** | 2,654<br>(1.0%) | 1,699<br>(0.6%) | 1,552<br>(0.5%) | 1,674<br>(0.6%) |
| **Kiwifruit and Orchards** | 590<br>(<0.1%) | | 19,574<br>(6.7%) | 6,167<br>(2.1%) |
| **Lifestyle** | 1,193<br>(<0.1%) | | 1,193<br>(0.4%) | 1,215<br>(0.4%) |
| **Parks and Reserves** | 155<br>(<0.1%) | 152<br>(0.1%) | 134<br>(<0.1%) | 155<br>(0.1%) |
| **Plantation Forest** | 156,464<br>(53.0%) | | 141,772<br>(48.3%) | 140,506<br>(47.9%) |
| **Scrub** | 1,307<br>(<0.1%) | 1,284<br>(0.4%) | 895<br>(0.3%) | 717<br>(0.2%) |
| **Sheep and Beef** | 19,728<br>(7.0%) | | 18,095<br>(6.2%) | 15,915<br>(5.4%) |
| **Urban, Road, Rail, Unknown** | 2,275<br>(1.0%) | | 2,021<br>(0.7%) | 1,933<br>(0.7%) |
| **Vegetables** | 105<br>(<0.1%) | | 105<br>(<0.1%) | 105<br>(<0.0%) |
| **Wetlands** | Combined with Hydro for Current State. | 5,691<br>(1.9%) | 2,124<br>(0.7%) | 980<br>(0.3%) |

## 2.2 Mitigation Scenarios

Perrin Ag Consultants (2018) were commissioned by BOPRC to undertake an assessment of the farm/orchard-gate economic impact of applying a range of mitigation practices to reduce losses of nitrogen, phosphorus, E. coli and sediment, to support freshwater planning for the Kaituna and Rangitāiki WMAs as part of BOPRC Plan Change 12 process.

As part of the assessment, three mitigation bundles were developed and evaluated at community groups and separate industry meetings. The final list of bundles was refined and compiled by the project management team, and progressed for economic modelling.

The three mitigation bundles represent a cumulative, three-layer framework. The bundles were primarily determined based on cost at the farm gate, filtered for effectiveness at reducing constituent loss. The mitigation strategy bundles were designed to be applied cumulatively to farm and orchard systems, and included:

- **M1 Bundle:** Low barrier to adoption, primarily defined by being of low cost (equivalent to less than 10% of Earning Before Interest and Tax (EBIT) with at least a low effectiveness for reducing constituents in comparison to other bundles.
- **M2 Bundle:** Moderate barrier to adoption, primarily defined by direct costs and or reduced revenue equivalent to more than 10%, but less than 25% of EBIT, with a medium effectiveness for targeted constituent loss.
- **M3 Bundle:** High barrier to adoption, primarily defined by significant reductions in pre-mitigation profitability (i.e. reduction in >25% of EBIT) and high effectiveness at constituent reduction.

Only the M1 Mitigation Bundle has been considered and modelled at present, and therefore is the only bundle detailed throughout the remainder of this report. The mitigation measured included in the M1 Mitigation Bundle are summarised in **Table 4**.

It should be noted, not all of the mitigation practices apply to every farming / growing system for various land uses, or locations. Full details of where mitigation practices were considered applicable is presented in Perrin Ag Consultants (2018).

**Table 4. Summary of the M1 Mitigation Bundle.**

| Land Use | Mitigation measures included |
|---|---|
| Dairy | • Placement of feeding equipment<br>• Timing of effluent application in line with soil moisture levels<br>• Reduced tillage practices<br>• Improved nutrient budgeting<br>• Laneway run-off diversion<br>• Grow maize on effluent blocks<br>• Elimination of summer cropping<br>• Reduction in seasonal stocking rate<br>• Efficient fertiliser use technology<br>• Efficient irrigation practices<br>• Use of plant growth regulators<br>• Adoption of low N leaching forages<br>• Relocation of troughs<br>• Slow-release phosphorus fertiliser RPR<br>• Reduce autumn N application<br>• Vegetated buffer around water bodies |
| Drystock | • Improved nutrient budgeting<br>• Efficient fertiliser use technology<br>• Stock class management within landscape<br>• Adopt M1 arable cultivation practices for winter cropping<br>• Laneway run-off diversion<br>• Relocation of troughs<br>• Appropriate gate, track and race placement<br>• Targeted space planting of poles<br>• Slow-release phosphorus fertiliser |
| Arable farming | • Grass or planted buffer strips |

| Land Use | Mitigation measures included |
|---|---|
| | • Complete protection of existing wetlands<br>• Maintain optimal Olsen P<br>• Efficient fertiliser use and technology<br>• Cover crops between cultivation cycles<br>• Manage risk from contouring<br>• Reduced tillage practices |
| Kiwifruit orchard systems | • Complete protection of existing wetlands<br>• Maintain optimal Olsen P<br>• Laneway run-off diversion<br>• Efficient fertiliser use and technology<br>• Efficient irrigation practices<br>• Grass swards under canopy, minimise bare ground and vegetated buffers around waterways |

## 2.3 Summary of Scenarios

As described in the sections above, seven scenarios were modelled and presented in this report. They are referred to throughout this report as follows:

- **Scenario 1** – Current State;
- **Scenario 2** – Reference State;
- **Scenario 3** – Development C;
- **Scenario 4** – Development D;
- **Scenario 5** – Current State with M1 Mitigation Bundle;
- **Scenario 6** – Development C with M1 Mitigation Bundle; and
- **Scenario 7** – Development D with M1 Mitigation Bundle.

# 3. Scenario Modelling

The SOURCE modelling framework was used for the development of the catchment models. SOURCE is a hydrological modelled platform designed to simulate all aspects of the water resource systems and support the planning and management of catchment to river scale freshwater resources. SOURCE integrates flow and constituent generation processes in each sub-catchment and simulates these variables through the defined downstream network.

Within SOURCE, WWLA's Soil Moisture Water Balance Model (SMWBM_VZ) was used to simulate water quantity (converting rainfall to surface water and groundwater flow). The catchment flow models were calibrated to fifteen primary flow gauging sites and a range of spot gauge sites used to provide a secondary level of calibration.

Four water quality constituents were simulated; TN, TP, E. Coli, and TSS. Individual constituent generation models were developed using a combination of third-party modelling tools, SOURCE plugins, and derived catchment specific constituent generation relationships, which related catchment and land use characteristics to generated constituent concentrations. These constituent generation models were calibrated against eight and six primary monitoring sites in the Kaituna and Rangitāiki WMAs, respectively.

Full details on the development and calibration of both the water quantity and water quality components of the Kaituna and Rangitāiki SOURCE catchment models are provided in WWLA (2020a).

The following section details the general adjustments made to model configuration and setup for the simulation of the land use change and mitigation scenarios. It is noted a number of technical processes and specific model parameters are discussed below, these are briefly explained where appropriate, however this section should be read in conjunction with WWLA (2020a), to provide a full understanding of model adjustments made for scenario simulation.

## 3.1 Climate Data

The calibrated Base Case model was simulated for the period 1976 to 2016. In order to easily distinguish between current state and potential future development scenario outputs, the rainfall evaporation data, and thus model simulation period, was re-labelled to the period 2016 to 2056. It is assumed that on average the rainfall for the period 2016 – 2056 will be generally similar to that which occurred during the previous 40 years. Therefore, the results presented are the direct result of changes in land use and do not include any potential changes in rainfall regime associated with climate change.

Simulation and analysis of water quantity and quality changes associated with potential changes in rainfall and evaporation regimes associated with climate change are planned for the next phases of this project.

## 3.2 Flow

To simulate changes in catchment flow associated with land use change, the Base Case (calibrated) SMWBM_Vz parameter values were adjusted to reflect the hydrological responses of the differing land use classifications for each scenario. The method below details the characterisation of new SMWBM_Vz parameter values based on the change in land use.

The flow models developed for the Base Case were calibrated to available observed flow data, as described in the SOURCE Modelling report (WWLA, 2020a). Using the calibrated flow models, the area weighted average SMWBM_Vz parameters assigned to each sub-catchment were disaggregated based on the composition of individual land uses within each sub-catchment. The disaggregated parameters provided a representation of the relative parameters for each individual land use within the sub-catchment. This disaggregation was based on an assumed relative ratio for each model parameter.

The process applied to disaggregate averaged SMWBM_Vz parameters to individual land uses is provided below, along with an example for a selected sub-catchment.

### 3.2.1 SMWBM Parameter Disaggregation

To disaggregate sub-catchment average parameters (i.e. parameters that represent a specific combination of underlying physical characteristics), SMWBM_Vz parameters were determined relating the relative change in magnitude of the key model parameters (ST, Zmax, FT and PI) for each of the individual land use classifications. These key parameters are briefly summarised as follows:

- **ST** (Maximum soil water content) – defines the depth (capacity) of the soil water store.
- **Zmax** (Maximum Infiltration rate) – defined the maximum infiltration rate of surface water into the soil water store.
- **FT** (Maximum sub-soil drainage rate) – controls the rate of percolation of water from the soil water store, to the groundwater store.
- **PI** (Canopy interception storage capacity) – defines the storage capacity of rainfall that that is intercepted by the overhead canopy or vegetation and does not reach the soil zone.

The ratios defined for each land use type, reflect the land use practices for each sub-catchment. For example, the ratios applied for pasture reflect the compact soils in pasture zones, compared with forest land which typically have less compact soils, and typically also associated with increased infiltration into the soil zone. The ratios between land use and SMWBM_Vz parameters are displayed in **Table 5**. Pasture was selected as the benchmark land use (i.e. all parameters have a ratio of 1), and the ratio values for all other land uses represent the change in parameter relative to pastural land use.

**Table 5. SMWBM parameter ratios between differing land uses.**

| Land use | Parameter Ratio | | | |
|---|---|---|---|---|
| | ST | Zmax | FT | PI |
| Pasture | 1 | 1 | 1 | 1 |
| Forest | 2 | 2 | 1 | 2 |
| Plantation Forest | 2 | 2 | 1 | 2.5 |
| Kiwifruit and Orchards | 1 | 1 | 1 | 1.75 |
| Dairy | 1 | 1 | 1 | 1 |
| Sheep and Beef | 1.2 | 1.2 | 1 | 1 |
| Vegetables | 1.4 | 1.4 | 1 | 0.5 |
| Urban (Including Road, Rail and Unknown) | 0.25 | 0.25 | 0.5 | 0.5 |
| Arable | 1.3 | 1.3 | 1 | 1 |
| Lifestyle | 2 | 2 | 1 | 2 |
| Hydro and Wetland | 3 | 2 | 0.5 | 2 |
| River, Lake and Pond | 0.01 | 0.01 | 0.01 | 0.01 |
| Hydro | 0.01 | 0.01 | 0.01 | 0.01 |
| Wetlands | 3 | 2 | 0.5 | 2 |

| Land use | Parameter Ratio | | | |
|---|---|---|---|---|
| | ST | Zmax | FT | PI |
| Scrub | 2 | 2 | 1 | 2 |
| Parks and Reserves | 2 | 2 | 1 | 2 |

Using the land use ratios outlined above and the future land use classification scenarios provided by BOPRC, the following steps were carried out to disaggregate the calibrated SMWBM_Vz parameters into parameters representative of the individual land uses:

1. The total area of each land use classification was calculated for each sub-catchment using GIS.
2. The weighted average of the land use ratio was calculated as the sum product of the land use area and function unit ratio, divided by the total sub-catchment area.
3. The weighted average of the land use ratio was then divided by the calibrated SMWBM_Vz parameter value of the sub-catchment to provide the multiplier.
4. The ratio for each corresponding land use area and the multiplier are then multiplied together to produce the disaggregated value for the given land use.

As a check, the sum product of the new disaggregated SMWBM_Vz value and the area of the sub-catchment were calculated to confirm they equal the calibrated SMWBM parameter value.

To convert the disaggregated SMWBM_Vz parameters for each land use back to a value representative of the sub-catchments in the assessment scenarios, the sum product of the disaggregated values for each land use and the area of each land use were calculated to produce the scenario SMWBM_Vz parameter value.

The disaggregation process described above is based on the following assumptions:

- The calibrated values within SMWBM_Vz reflect an area weighted average of all land uses within the sub-catchment.
- The ratios between each land use were based on a logical estimate. For example, the soil moisture ratio used for forested areas (ST) is twice as large as the original parameter for pasture. The assumption is that forested areas have larger root depths and thus are able to store large volumes of water in the soil moisture zone.

An example of disaggregating a sub-catchments flow into its individual contributions for each land use is provided below.

### 3.2.2 Disaggregation Example

To provide confirmation that the disaggregation process described above produces appropriate SMWBM_Vz parameters for individual land use types, a test was undertaken whereby the Raparapahoe River gauge catchment was simulated as individual land uses, rather than using the aggregated area weighted average sub-catchment parameters.

**Figure 3** compares the Raparapahoe River gauge as simulated using the calibrated SMWBM_Vz parameter values against those simulated using the disaggregated land use parameter values for the sub-catchment. A comparison of summary flow statistics is provided **Table 6**. The time series plot and summary statistics show the two simulations produce very similar flows.

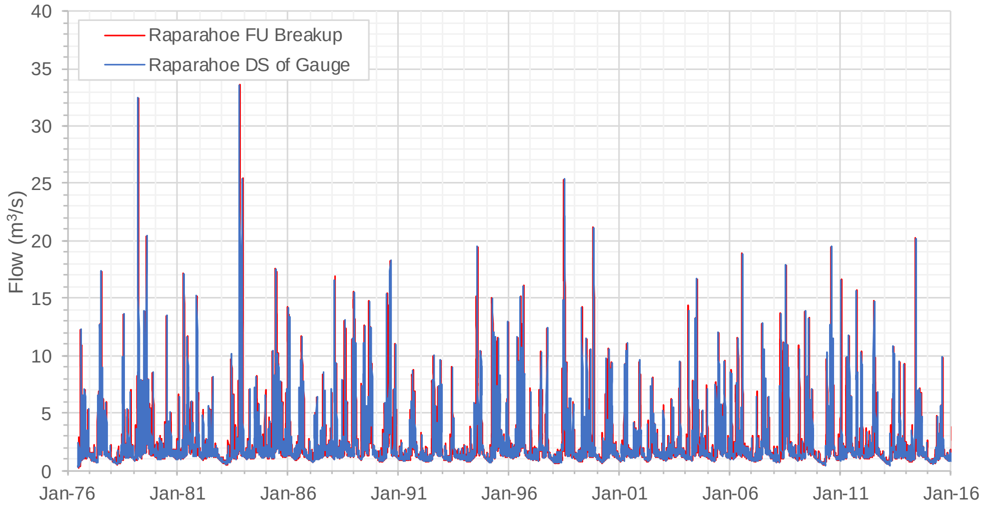


**Figure 3. Comparison of flow hydrographs for calibrated (aggregated) and disaggregated models at Raparapahoe River.**

**Table 6. Statistics for the disaggregation of SMWBM_Vz values per land use against the calibrated value for the SMWBM_Vz at Raparapahoe River.**

| | Calibrated (aggregated) Model ($m^3/s$) | Disaggregated Land use Model ($m^3/s$) |
|---|---|---|
| Minimum | 0.2 | 0.2 |
| Maximum | 33.6 | 33.6 |
| Mean | 2.3 | 2.3 |
| Median | 1.4 | 1.4 |

Within the Raparapahoe catchment Model, sub-catchment 42 (SCID42) was further analysed to show the effect that different land uses have on flow. **Figure 4** and **Table 7** show the individual contributions from each land use to the total catchment flow. The Forest land use accounts from approximately 70% of the total land use within this sub-catchment, and therefore has the largest contribution to the total flow.

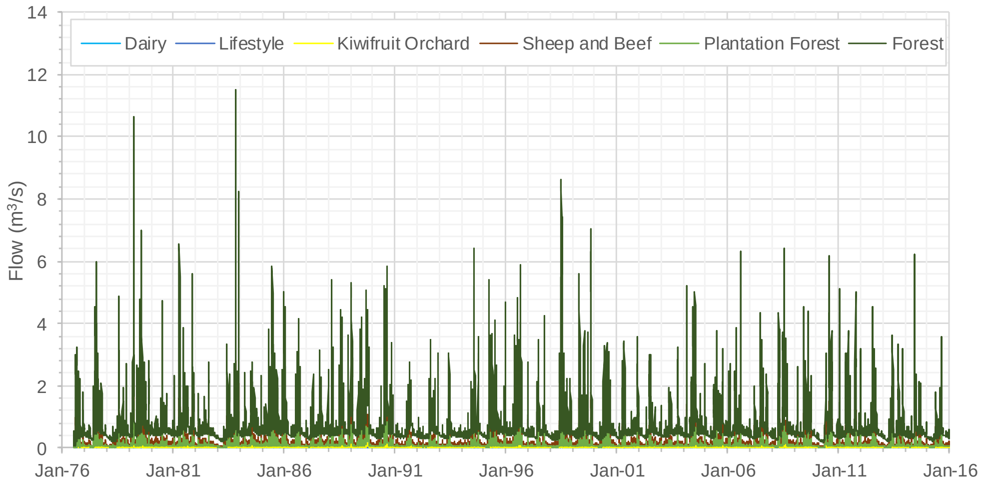


**Figure 4. Disaggregated land use flow contributions for SC#42.**

**Table 7. Disaggregated land use flow contribution statistics for SC#42.**

| | Dairy ($m^3/s$) | Forest ($m^3/s$) | Kiwifruit Orchard ($m^3/s$) | Lifestyle ($m^3/s$) | Plantation Forest ($m^3/s$) | Sheep and Beef ($m^3/s$) |
|---|---|---|---|---|---|---|
| Minimum | 0.00 | 0.06 | 0.00 | 0.00 | 0.01 | 0.02 |
| Maximum | 0.07 | 11.50 | 0.36 | 0.15 | 1.61 | 2.83 |
| Mean | 0.01 | 0.78 | 0.03 | 0.01 | 0.11 | 0.20 |
| Median | 0.00 | 0.49 | 0.02 | 0.01 | 0.07 | 0.13 |

### 3.2.2.1 Lakes Adjustment

In the Base Case and Current State scenarios, constant flow and constituent concentration values were applied to represent contributions from the upstream lakes based on a trend analysis of available measured water quality data (WWLA, 2020a). However, with the hypothetical future land use scenarios these values required adjustment to reflect these changes in land use.

A percentage adjustment was applied based on the simulation of the constituent at the nearest downstream gauge. This was calculated as the proportional difference between the Current State and the new Scenario (with the lake discharge turned off). This reduction was then applied to the constituent discharge for the new scenarios.

## 3.3 Land Use

As part of the constituent model development for the Base Case and Current State scenarios, relationships were developed and calibrated between catchment characteristics (e.g. slope, vegetation cover and stocking density) and constituent generation rates (WWLA, 2020a – Section 7). These calibrated relationships were applied in the scenario assessments, with the catchment characteristics representative of the modified land use for the various scenarios simulated when calculating the constituent generation index.

An overview of the constituent generation and decay change between the Base Case and other land use change scenarios is provided in **Table 8**.

**Table 8. Constituent Generation and Decay for all Scenarios.**

| | Generation | | Decay | |
|---|---|---|---|---|
| | Current State | Scenarios | Current State | Scenarios |
| TN | Baseflow TN - APSIM simulated daily TN leaching for each land use. Individual land uses were aggregated to provide an average sub-catchment leaching rate.<br>Quick Flow TN – A sub-catchment index based on vegetation cover, stocking rate and slope was used to determine the quick flow TN concentration. A power curve relationship was applied to the attenuated surface runoff which controlled the amount of TN released each day depending on | Baseflow TN – APSIM was used to simulate TN leaching for each land use, and outputs aggregated based on the composition of land uses within each sub-catchment for each scenario.<br>Quick Flow TN - The generation index changed based on a different composition of land uses between scenarios. The attenuated surface runoff also changed based on the | A Catchment Attenuation Factor (CAF) accounts for the difference between the APSIM simulated and measured TN loads in the stream network.<br>Bulk mechanism accounting for natural denitrification and biosphere uptake processes. | The catchment attenuation factors that applied to each sub-catchment in the Base Case Scenario remained the for each land use change scenario. This assumes that the amount of TN biological uptake for a given area remains the same irrespective of land use. |

| | **Generation** | | **Decay** | |
|---|---|---|---|---|
| | **Current State** | **Scenarios** | **Current State** | **Scenarios** |
| | the amount of attenuated surface runoff occurring on each day. | changes in land use. Therefore, the amount of quick flow TN generated for each sub-catchment will differ between scenarios. | | |
| TP | Surface Load TP – Generated as a fraction (TN:TP ratio) of TN from APSIM.<br>Event Surface Load TP – defied by the PLSC (soil acid soluble phosphorus, slope, and vegetation cover values) index, and represents the additional supply of TP delivered via surface processes during storm events.<br>Natural Load TP – defined by Acid Soluble Phosphorus (ASP) content of rock material, representing the natural background levels of TP found leaching from the parent soil. | Surface Load TP – Changed based on changes in the APSIM generated TN between scenarios.<br>Event Surface Load TP – Changes as the C (vegetation cover) value of PLSC changes with land use.<br>Natural Load TP – the ASP value for each sub-catchment changed with changing land uses due to changes in percolation rate. | Not applicable – No decay was applied to TP. | Not applicable – No decay was applied to TP. |
| TSS | Catchment Erosivity, Length, Slope and Vegetation Cover (KLSC) govern the amount of sediment generated in each sub-catchment.<br>The rainfall threshold (R) defined the minimum rainfall required before sediment can be mobilised.<br>The Hill Slope Delivery Ratio (HSDR) determined the percentage of sediment generated that is delivered in-stream.<br>The Dry Weather Concentration (DWC) represents the concentration of TSS present during dry weather conditions. | KLSC – K and LS are linked to the physical characteristics of a catchment (soil type and slope), therefore do not change between scenarios. However, the vegetation cover (C) changed as each land use has a different vegetation density assigned.<br>HSDR – did not change between scenarios as it is linked to slope (a physical characteristic).<br>R Threshold – Changed as it was based off the vegetation cover for each sub-catchment.<br>DWC - Changed as it was defined using a relationship based on KLSC. | Not applicable – No decay was applied to TSS. | Not applicable – No decay was applied to TSS. |
| *E. coli* | Relationship considers Vegetation Cover, Stocking Rates and Slope.<br>The larger the index the higher the concentration of *E. coli* generated within the sub-catchment. | The index changed due to the different composition of land uses between scenarios. | Based on sub-catchment elevation as a proxy for temperature.<br>Assumes areas which have cooler climates (higher elevations) have higher decay rates compared to those with warmer climates (lower elevations). | Decay for each sub-catchment remains the same, as sub-catchment elevation does not change between scenarios. |

| | **Generation** | | **Decay** | |
|---|---|---|---|---|
| | **Current State** | **Scenarios** | **Current State** | **Scenarios** |
| Lake Contributions | Based on observed data. | A percentage change was applied to constituent concentrations from Lake Rotoiti based on the percentage change in downstream concentrations from a scenario that excluded the lake. Therefore, the percentage change in lake constituent concentrations were based on the change in land use of the catchment downstream, effectively assuming the same changes occur in the upstream catchment of the lake. | Not applicable. | Not applicable. |

## 3.4 Stresses (Takes and Discharges)

The Base Case scenario model was configured with takes and discharges, including irrigation demands, which were based on consented data (i.e. if a land parcel does not have a legal right to water, no water use is simulated). In addition, permitted activity takes (e.g. for stock drinking water) were included in each sub-catchment.

As it is not possible to know what takes and discharges will be consented in the future, assumptions were made on future takes and discharges based on land use area. An overview of how the various takes and discharges were determined in the Base Case and Development Scenarios is provided in **Table 9**.

**Table 9. Water Take implementation into the model for Scenarios.**

| Water Use | Base case | Scenarios |
|---|---|---|
| Irrigation | Consented limits – Disaggregated to a daily value using the Irrigation Model. | Irrigation requirements were determined based on land use (80% of horticulture and dairy) area, rather than consented amounts. |
| Non-Municipal Demands: Industrial, Domestic, Commercial | Non-municipal consents were configured based on consented limits.<br>The annual maximum abstraction volume was disaggregated into a daily rate over the full consented period. | Same takes as applied for the Base Case model. |
| Municipal Takes | Defined based on actual use metered data.<br>Data gaps were filled by disaggregating the consented annual volume to a daily rate. | Two additional takes were added to the Kaituna and Rangitāiki Models – the Waiari Take and Paul Rd takes, respectively.<br>The Waiari take was configured based on forecast future water use requirements (for 2048 onwards), supplied by BOPRC from discussions with Tauranga City Council and Western Bay of Plenty District Council.<br>The Paul Rd take was configured based on available measured data for the period 13 September 2017 to 3 December 2017. The average daily take was estimated as the 75th percentile of measured data to account for lower water use in winter.<br>A monthly water use pattern was applied to both takes to represent increased demand in summer and a lower demand during winter. |
| Wastewater Facility Takes and Discharges | Base Case and Current State Models - the Te Puke WWTP, Fonterra Factory, and the AFFCO Factory consents have been configured.<br>Actual metered use data implemented.<br>Data gaps filled by disaggregating the consented annual volume to a daily rate.<br>AFFCO also had constituent information assigned based on provided measured water quality data. | The Te Puke Wastewater system was increased by 33% to reflect a larger municipal take in future. The 33% increase was determined based on the percentage difference between the current Waiari take and the future Waiari take (as assigned in the model). This was then applied to the wastewater discharge.<br>The AFFCO factory discharges remained the same. |
| Permitted Activities | In the Base Case Model, permitted activity takes were based on the assessment carried out by Aqualinc (Rutter, H., 2015. Water Management Report: Assessing Unconsented or Permitted Water Use in the Bay of Plenty Region, Aqualinc). | The domestic takes remained the same as within the base case model, however the agricultural takes were changed.<br>This is based on the agricultural land use area found within each sub-catchment taken from the Aqualinc report (2015). |

## 3.5 Mitigation Measures

In order to represent the reduction in constituent generation associated with mitigation practices, a mitigation effectiveness factor was calculated for each SOURCE model sub-catchment, for each land use scenario, for both the baseflow and quickflow constituent generation components. The mitigation effectiveness factor was defined as a percentage reduction in constituent concentration, relative to the corresponding non-mitigation land use scenario. Mitigation effectiveness factors were developed for each individual M1 bundle mitigation practice (**Table 4**).

The method for developing, and calculation of the mitigation effectiveness factors was undertaken by BOPRC (BOPRC, 2019) and considered the effectiveness of each mitigation practice, the level of existing uptake, and the proportional area of each land use over which the mitigation practice would apply (i.e. only near water bodies, or on land of certain slopes etc). The method for calculating the mitigation effectiveness factors and how they were applied to the SOURCE models are briefly described below.

Gross baseflow mitigation effectiveness factors for TN and TP were defined based on OVERSEER modelling undertaken by Perrin Ag Consultant (2018b). Mitigation of baseflow contributions of E. coli and TSS were not modelled, as baseflow is not considered a major transportation pathway for these constituents.

Gross quickflow mitigation effectiveness factors for TN, TP, TSS and E. coli were defined based on a literature review of relevant studies and refined through teleconferences between Perrin Ag, AgResearch, NIWA, and BOPRC staff. Mitigation effectiveness estimates were based on literature where available, and professional judgement of teleconference participants.

Estimates of baseline levels of implementation of each mitigation practice for the Base Case scenario were determined based on BOPRC Land Management Officers' local catchment knowledge, community group feedback, feedback from industry groups and advice from farm consultants familiar with the local area. These estimates of baseline implementation levels were subtracted from the gross mitigation effectiveness factors, in order to ensure the effect of existing mitigation practices were not double counted. The resulting mitigation effectiveness factors were referred to as the net mitigation effectiveness factors.

### 3.5.1 Implementation in SOURCE

The mitigation effectiveness factors represented the reduction in constituent generation for each individual mitigation practice, for each land use. As the SOURCE model operates on a distributed sub-catchment spatial scale, rather than an individual land use scale, an area weighted sub-catchment average net mitigation effectiveness factor was calculated for each SOURCE model sub-catchment, for both the baseflow and quickflow constituent components. This represented the average reduction in constituent generation for each sub-catchment, proportionally weighted based on the composition of land use within each sub-catchment.

A spreadsheet listing the baseflow and quickflow net sub-catchment average mitigation effectiveness factor for each sub-catchment was provided to WWLA by BOPRC, and used for the basis of representing the mitigation measures in the SOURCE catchment model.

The reduction in baseflow TN resulting from the M1 Bundle mitigation practices was incorporated into the model by multiplying the daily TN leaching mass (simulated from APSIM – WWLA, 2020a Section 7.2.5) by the inverse of the net sub-catchment average mitigation effectiveness factor (i.e. applying a percentage reduction). Similarly, the reduction in baseflow TP was incorporated by multiplying the simulated baseflow TP concentration (WWLA, 2020a – Section 7.3) by the inverse of the net sub-catchment average mitigation effectiveness factor for TP.

The reduction in quickflow TN, TP, and E. coli resulting from the M1 Bundle mitigation practices were incorporated into the SOURCE model by multiplying the assigned quickflow concentrations by the inverse of the corresponding net sub-catchment average mitigation effectiveness factor. The reduction in TSS was incorporated by applying the net sub-catchment average effectiveness mitigation factor as a percentage reduction to the dSedNET Hillslope Delivery Ratio (HSDR) parameter (WWLA, 2020a – Section 7.4.2.3).

# 4. Land Use Change Scenario Results

The sub-sections below present the results of the land use change scenario for each constituent for the Kaituna and Rangitāiki WMAs in **Section 4.1** and **4.2**, respectively. The results are presented as a series of maps displaying the spatial variation in annual average constituent yield generated from each individual catchment and tables of summary statistics of constituent concentrations at the three key monitoring locations in each WMA.

Constituent yield is defined as the mass (load in kg/year) of a given constituent normalised by (divided by) the area over which it was generated (e.g. a single sub-catchment (discrete), or all upstream sub-catchment (continuous)). Normalising constituent load by area (yield) allows constituent generation rates to be compared against sub-catchments of different size (area).

The results presented are an analysis of the last five years of the assessment period (January 2011 to December 2015, and January 2051 to December 2055).

Discrete results refer to the yield of a given constituent generated from a single (discrete) sub-catchment. The cumulative results refer to the yield or concentration of a given constituent generated from all sub-catchments and the river network upstream of a specified location, usually a catchment gauge or monitoring location. It should be noted, the cumulative results include the effect of water takes and point source discharges, whereas the discrete results only include the constituent mass generated from land uses within each sub-catchment.

Further analysis of the results and descriptions of the changes between scenarios is provided in **Section 4.3**.

In addition to the tabulated summary statistics and figures presented in this report, raw and processed (e.g. summary statistics) model outputs for all sub-catchments and each of the four constituents were provided to BOPRC as a series of Excel and csv output files.

An overview of key reporting and model output locations referred to throughout this report for the Kaituna and Rangitāiki WMAs are presented in **Figure 5** and **Figure 6**, respectively.

**Figure 5. Kaituna WMA – key reporting and model output locations.** (Refer A3 attachment at rear).

**Figure 6. Rangitāiki WMA – key reporting and model output locations.** (Refer A3 attachment at rear).

## 4.1 Kaituna-Pongakawa-Waitahanui

The following sections present the results of each constituent for the four modelled scenarios in the Kaituna WMA.

### 4.1.1 TN Results

#### 4.1.1.1 Discrete

A comparison of the discrete TN yields from each individual sub-catchment between the four scenarios is presented in **Figure 7**. The largest change in discrete TN yield from the Current State occurred in the Reference State Scenario, as a large proportion of the catchment was converted to native forest. Reductions in TN yield were also predicted in the Development C and Development D scenarios in sub-catchments where dairy was replaced by kiwifruit and plantation forest.

**Figure 7. Discrete TN yields (T/ha/yr) for the Kaituna WMA.** (Refer A3 attachment at rear).

#### 4.1.1.2 Cumulative

A comparison of the cumulative TN concentration statistics between scenarios for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site are presented in **Table 10** to **Table 12**.

A decrease in TN concentrations were predicted between the Current State scenario and the three scenarios. The percentage change in mean concentration between the Current State and Reference scenarios was a decrease of 65%, 47% and 60% for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site respectively. There was a predicted decrease in mean concentration of 30%, 65% and 46% between the Current State and Development C scenario, and a decrease of 30%, 57% and 34% between the Current State and Development D scenarios respectively between the three monitoring sites.

**Table 10. Cumulative concentration statistics for Kaituna River at Te Matai gauge (mg/L).**

| Modelled TN Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.74 | 0.26 | 0.52 | 0.63 |
| Standard Deviation | 0.16 | 0.16 | 0.17 | 0.17 |
| Minimum | 0.52 | 0.16 | 0.30 | 0.43 |
| 5th Percentile | 0.60 | 0.17 | 0.37 | 0.48 |
| 25th Percentile | 0.65 | 0.18 | 0.43 | 0.54 |
| 50th Percentile | 0.71 | 0.19 | 0.48 | 0.59 |
| 75th Percentile | 0.77 | 0.25 | 0.53 | 0.66 |
| 95th Percentile | 1.05 | 0.59 | 0.85 | 0.95 |
| Maximum | 2.38 | 1.88 | 2.19 | 2.27 |

Table 11. Cumulative concentration statistics for Pongakawa River at Old Coach Rd gauge (mg/L).

| **Modelled TN Concentration (mg/L)** | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 1.52 | 0.28 | 0.53 | 0.66 |
| Standard Deviation | 0.16 | 0.18 | 0.18 | 0.17 |
| Minimum | 1.30 | 0.21 | 0.44 | 0.53 |
| 5th Percentile | 1.37 | 0.21 | 0.45 | 0.56 |
| 25th Percentile | 1.43 | 0.22 | 0.46 | 0.58 |
| 50th Percentile | 1.48 | 0.23 | 0.48 | 0.61 |
| 75th Percentile | 1.55 | 0.27 | 0.53 | 0.67 |
| 95th Percentile | 1.75 | 0.55 | 0.79 | 0.92 |
| Maximum | 4.19 | 3.46 | 3.65 | 3.70 |

Table 12. Cumulative concentration statistics for Waitahanui River at SCID114 site (mg/L).

| **Modelled TN Concentration (mg/L)** | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.87 | 0.35 | 0.47 | 0.57 |
| Standard Deviation | 0.32 | 0.30 | 0.31 | 0.30 |
| Minimum | 0.53 | 0.20 | 0.27 | 0.33 |
| 5th Percentile | 0.58 | 0.21 | 0.30 | 0.36 |
| 25th Percentile | 0.70 | 0.22 | 0.34 | 0.43 |
| 50th Percentile | 0.79 | 0.24 | 0.38 | 0.48 |
| 75th Percentile | 0.92 | 0.34 | 0.47 | 0.57 |
| 95th Percentile | 1.45 | 0.89 | 1.04 | 1.10 |
| Maximum | 4.38 | 3.79 | 3.97 | 3.99 |

### 4.1.2 TP Results

#### 4.1.2.1 Discrete

A comparison of the discrete TP yields from each individual sub-catchment between the four scenarios is presented in **Figure 8**. The largest change in discrete TP yield from the Current State scenario occurred in the Reference scenario, where 87% of the catchment was converted to native forest, resulting in decreased TP yields. Reductions in TP yield were also predicted in the Development C and Development D scenarios in sub-catchments, typically where dairy was replaced by kiwifruit and plantation forest.

Total phosphorus yields remained comparatively high in the headwater sub-catchments under the Reference scenario, as these sub-catchments are influenced by spring inflows, which remain present in the naturalised scenario as they are a physical feature of the catchment, and not linked to the changes in land use between scenarios.

**Figure 8. Discrete TP yields (T/ha/yr) for the Kaituna WMA.** (Refer A3 attachment at rear).

#### 4.1.2.2 Cumulative

A comparison of the cumulative TP concentration statistics between scenarios for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site are presented in **Table 13** to **Table 15**.

A decrease in TP concentrations were predicted between the Current State and the other scenarios. The percentage change in mean concentration between the Current State and Reference scenario was a decrease of 60%, 14% and 10% for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site respectively. There was a decrease in mean concentration of 20%, 14% and 9% and a concentration decrease of 20%, 14% and 9% between the Current State and Development C and Development D scenarios respectively.

**Table 13. Cumulative concentration statistics for Kaituna River at Te Matai gauge (mg/L).**

| Modelled TP Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.05 | 0.02 | 0.04 | 0.04 |
| Standard Deviation | 0.01 | 0.00 | 0.01 | 0.01 |
| Minimum | 0.03 | 0.02 | 0.03 | 0.03 |
| 5th Percentile | 0.03 | 0.02 | 0.03 | 0.04 |
| 25th Percentile | 0.04 | 0.02 | 0.04 | 0.04 |
| 50th Percentile | 0.04 | 0.02 | 0.04 | 0.04 |
| 75th Percentile | 0.05 | 0.03 | 0.04 | 0.05 |
| 95th Percentile | 0.07 | 0.03 | 0.06 | 0.06 |
| Maximum | 0.19 | 0.04 | 0.14 | 0.17 |

Table 14. Cumulative concentration statistics for Pongakawa River at Old Coach Rd gauge (mg/L).

| Modelled TP Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.14 | 0.11 | 0.12 | 0.12 |
| Standard Deviation | 0.04 | 0.00 | 0.01 | 0.01 |
| Minimum | 0.12 | 0.11 | 0.11 | 0.11 |
| 5th Percentile | 0.12 | 0.11 | 0.11 | 0.11 |
| 25th Percentile | 0.12 | 0.11 | 0.11 | 0.11 |
| 50th Percentile | 0.12 | 0.11 | 0.12 | 0.12 |
| 75th Percentile | 0.14 | 0.11 | 0.12 | 0.12 |
| 95th Percentile | 0.20 | 0.12 | 0.13 | 0.14 |
| Maximum | 0.62 | 0.13 | 0.24 | 0.29 |

Table 15. Cumulative concentration statistics for Waitahanui River at SCID114 site (mg/L).

| Modelled TP Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.11 | 0.09 | 0.10 | 0.10 |
| Standard Deviation | 0.02 | 0.00 | 0.01 | 0.01 |
| Minimum | 0.09 | 0.07 | 0.09 | 0.09 |
| 5th Percentile | 0.09 | 0.08 | 0.09 | 0.09 |
| 25th Percentile | 0.10 | 0.08 | 0.10 | 0.10 |
| 50th Percentile | 0.10 | 0.09 | 0.10 | 0.10 |
| 75th Percentile | 0.11 | 0.09 | 0.10 | 0.10 |
| 95th Percentile | 0.14 | 0.09 | 0.11 | 0.12 |
| Maximum | 0.26 | 0.10 | 0.15 | 0.18 |

### 4.1.3 TSS Results

#### 4.1.3.1 Discrete

A comparison of the discrete TSS loads from each individual sub-catchment between the four scenarios is presented in **Figure 9**. The largest change in discrete TSS loads from the Current State occurred in the Reference scenario, resulting from the widespread reversion to native forest. Smaller changes are reflected on a sub-catchment basis where changes in land use occur in the Development C and Development D scenarios.

**Figure 9. Discrete TSS yields (T/ha/yr) for the Kaituna WMA.** (Refer A3 attachment at rear).

#### 4.1.3.2 Cumulative

A comparison of the cumulative TSS concentration statistics between scenarios for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site are presented in **Table 16** to **Table 18**.

The percentage change in mean concentration between the Current State and Reference scenario was a decrease of 66%, 58% and 60% for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River (SCID114) respectively. There was an increase in mean concentration of 10%, 55% and 15% and a similar concentration increase of 10%, 55% and 15% between the Current State and Development C and Development D scenarios respectively.

**Table 16. Cumulative concentration statistics for Kaituna River at Te Matai gauge (mg/L).**

| Modelled TSS Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 9.06 | 3.11 | 9.94 | 9.96 |
| Standard Deviation | 8.08 | 0.45 | 9.40 | 9.16 |
| Minimum | 1.75 | 1.38 | 1.77 | 1.88 |
| 5th Percentile | 3.24 | 2.42 | 3.24 | 3.40 |
| 25th Percentile | 3.64 | 2.81 | 3.64 | 3.82 |
| 50th Percentile | 4.02 | 3.04 | 4.03 | 4.21 |
| 75th Percentile | 14.38 | 3.38 | 16.14 | 16.08 |
| 95th Percentile | 25.79 | 3.95 | 29.35 | 28.85 |
| Maximum | 44.24 | 4.67 | 51.12 | 49.94 |

Table 17. Cumulative concentration statistics for Pongakawa River at Old Coach Rd gauge (mg/L).

| Modelled TSS Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | Current State | Reference State | Development C | Development D |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 19.21 | 8.15 | 29.73 | 29.71 |
| Standard Deviation | 18.58 | 1.41 | 34.57 | 34.55 |
| Minimum | 2.18 | 2.55 | 2.44 | 2.43 |
| 5th Percentile | 6.94 | 6.98 | 7.11 | 7.11 |
| 25th Percentile | 7.36 | 7.37 | 7.48 | 7.48 |
| 50th Percentile | 7.44 | 7.44 | 7.56 | 7.56 |
| 75th Percentile | 31.13 | 8.93 | 52.76 | 52.74 |
| 95th Percentile | 58.81 | 11.12 | 103.55 | 103.51 |
| Maximum | 86.35 | 13.29 | 154.47 | 154.37 |

Table 18. Cumulative concentration statistics for Waitahanui River at SCID114 site (mg/L).

| Modelled TSS Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | Current State | Reference State | Development C | Development D |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 15.04 | 6.05 | 17.29 | 17.29 |
| Standard Deviation | 14.13 | 0.70 | 17.46 | 17.45 |
| Minimum | 1.16 | 1.41 | 1.38 | 1.39 |
| 5th Percentile | 5.41 | 4.92 | 5.67 | 5.69 |
| 25th Percentile | 6.18 | 5.77 | 6.28 | 6.25 |
| 50th Percentile | 6.42 | 6.02 | 6.51 | 6.52 |
| 75th Percentile | 23.96 | 6.35 | 28.42 | 28.58 |
| 95th Percentile | 45.46 | 7.22 | 54.54 | 54.44 |
| Maximum | 69.94 | 7.88 | 85.83 | 85.61 |

### 4.1.4 E. coli Results

#### 4.1.4.1 Discrete

A comparison of the discrete *E. coli* yields from each individual sub-catchment between the four scenarios is presented in **Figure 10**. The largest change in discrete *E. coli* yields from the Current State occurred in the Reference State scenario, resulting from the widespread reversion to native forest. Smaller changes are reflected on a sub-catchment basis where changes in land use from dairy to kiwifruit and plantation forest occur in the Development C and Development D scenarios.

**Figure 10. Discrete *E. coli* yields (CFU/ha/year) for the Kaituna WMA.** (Refer A3 attachment at rear).

#### 4.1.4.2 Cumulative

A comparison of the cumulative *E. coli* concentration statistics between scenarios for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site are presented in **Table 19** to **Table 21**.

A decrease in *E. coli* concentrations was predicted between the Current State scenario and the other scenarios. The percentage change in mean concentration between Current State and Reference State scenario was a decrease of 27%, 20% and 37% for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River (SCID114) respectively. There was a decrease in mean concentration of 10%, 16% and 34% and a concentration decrease of 16%, 15% and 30% between the Current State and Development C and Development D scenarios.

**Table 19. Cumulative concentration statistics for Kaituna River at Te Matai gauge (CFU/100 mL).**

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 37 | 27 | 33 | 31 |
| Standard Deviation | 74 | 50 | 64 | 70 |
| Minimum | 7 | 7 | 7 | 5 |
| 5th Percentile | 9 | 9 | 9 | 6 |
| 25th Percentile | 12 | 11 | 11 | 7 |
| 50th Percentile | 14 | 13 | 13 | 9 |
| 75th Percentile | 23 | 18 | 21 | 18 |
| 95th Percentile | 166 | 105 | 144 | 152 |
| Maximum | 1029 | 695 | 882 | 967 |

**Table 20. Cumulative concentration statistics for Pongakawa River at Old Coach Rd gauge (CFU/100 mL).**

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 83 | 66 | 70 | 70 |
| Standard Deviation | 113 | 84 | 89 | 90 |
| Minimum | 29 | 29 | 29 | 29 |
| 5th Percentile | 29 | 29 | 29 | 29 |
| 25th Percentile | 30 | 29 | 29 | 29 |
| 50th Percentile | 36 | 32 | 33 | 33 |
| 75th Percentile | 79 | 61 | 65 | 65 |
| 95th Percentile | 296 | 224 | 238 | 241 |
| Maximum | 1441 | 1160 | 1192 | 1206 |

**Table 21. Cumulative concentration statistics for Waitahanui River at SCID114 site (CFU/100 mL).**

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 82 | 52 | 54 | 58 |
| Standard Deviation | 182 | 128 | 134 | 139 |
| Minimum | 9 | 9 | 9 | 9 |
| 5th Percentile | 11 | 11 | 11 | 11 |
| 25th Percentile | 15 | 13 | 13 | 14 |
| 50th Percentile | 24 | 16 | 16 | 17 |
| 75th Percentile | 54 | 26 | 27 | 31 |
| 95th Percentile | 389 | 246 | 272 | 278 |
| Maximum | 2040 | 1530 | 1584 | 1651 |

## 4.2 Rangitāiki

The following sections present the results of each constituent for the four modelled scenarios in the Rangitāiki WMA.

### 4.2.1 TN

#### 4.2.1.1 Discrete

A comparison of the discrete TN yields from each individual sub-catchment between the four scenarios is presented in **Figure 11**. The largest change in discrete TN yield from the Current State occurred in the Reference State scenario, resulting from widespread reversion to native forest. Smaller changes are reflected on a sub-catchment basis where conversion from, or to, dairy occurred in the Development C and Development D scenarios.

**Figure 11. Discrete TN yields (T/ha/yr) for the Rangitāiki WMA.** (Refer A3 attachment at rear).

#### 4.2.1.2 Cumulative

A comparison of the cumulative TN concentration statistics between scenarios for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 site are presented in **Table 22** to **Table 24**.

A decrease in TN concentrations was predicted between the Current State scenario and the other three scenarios. The percentage difference between the Current State and Reference State scenario was a decrease of 44%, 0% and 12% for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 sites. There was an increase of 11%, 0% and 12% and a concentration increase of 16%, 0% and 24% between the Current State and Development C and Development D scenarios, respectively.

**Table 22. Cumulative concentration statistics for Rangitāiki River at Murupara gauge (mg/L).**

| Modelled TN Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.98 | 0.55 | 1.09 | 1.14 |
| Standard Deviation | 0.08 | 0.06 | 0.10 | 0.10 |
| Minimum | 0.79 | 0.42 | 0.84 | 0.88 |
| 5th Percentile | 0.84 | 0.46 | 0.91 | 0.96 |
| 25th Percentile | 0.91 | 0.50 | 1.02 | 1.06 |
| 50th Percentile | 0.99 | 0.56 | 1.11 | 1.16 |
| 75th Percentile | 1.04 | 0.61 | 1.17 | 1.23 |
| 95th Percentile | 1.10 | 0.65 | 1.23 | 1.28 |
| Maximum | 1.15 | 0.67 | 1.29 | 1.34 |

Table 23. Cumulative concentration statistics for Whirinaki River at Galatea gauge (mg/L).

| Modelled TN Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | Current State | Reference State | Development C | Development D |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.13 | 0.13 | 0.13 | 0.13 |
| Standard Deviation | 0.08 | 0.08 | 0.08 | 0.08 |
| Minimum | 0.02 | 0.02 | 0.02 | 0.03 |
| 5th Percentile | 0.03 | 0.03 | 0.03 | 0.03 |
| 25th Percentile | 0.06 | 0.06 | 0.06 | 0.06 |
| 50th Percentile | 0.12 | 0.11 | 0.11 | 0.11 |
| 75th Percentile | 0.18 | 0.18 | 0.18 | 0.18 |
| 95th Percentile | 0.28 | 0.27 | 0.27 | 0.27 |
| Maximum | 0.50 | 0.49 | 0.48 | 0.48 |

Table 24. Cumulative concentration statistics for Rangitāiki River at SCID34 site (mg/L).

| Modelled TN Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | Current State | Reference State | Development C | Development D |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.59 | 0.33 | 0.66 | 0.73 |
| Standard Deviation | 0.06 | 0.04 | 0.04 | 0.06 |
| Minimum | 0.51 | 0.30 | 0.58 | 0.64 |
| 5th Percentile | 0.52 | 0.30 | 0.61 | 0.66 |
| 25th Percentile | 0.55 | 0.31 | 0.63 | 0.69 |
| 50th Percentile | 0.57 | 0.32 | 0.66 | 0.71 |
| 75th Percentile | 0.61 | 0.34 | 0.68 | 0.75 |
| 95th Percentile | 0.71 | 0.42 | 0.73 | 0.83 |
| Maximum | 0.97 | 0.54 | 0.92 | 1.10 |

### 4.2.2 TP

#### 4.2.2.1 Discrete

A comparison of the discrete TP yields from each individual sub-catchment between the four scenarios is presented in **Figure 12**. The largest change in discrete TP yield from the Current State scenario occurred in the Reference State scenario, resulting from widespread reversion to native forest. The high TP yield in the Murupara catchment in the Reference State scenario is due to the spring inflow load of TP in these sub-catchments. Smaller changes are reflected on a sub-catchment basis where conversion from or to dairy occur in the Development C and Development D scenarios.

**Figure 12. Discrete TP yield (T/ha/yr) for the Rangitāiki WMA.** (Refer A3 attachment at rear).

#### 4.2.2.2 Cumulative

A comparison of the cumulative TP concentration statistics between scenarios for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 site are presented in **Table 25** to **Table 27**.

The percentage change in TP concentrations between the Current State scenario and Reference State scenario was a decrease of 25%, 0% and 25% for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 sites respectively. There was a change in mean concentration of 0%, between Current State and Development C and a concentration increase of 25%, 0% and 0% between Current State and Development D scenarios, for the same gauges as above.

**Table 25. Cumulative concentration statistics for Rangitāiki River at Murupara gauge (mg/L).**

| Modelled TP Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.04 | 0.03 | 0.05 | 0.05 |
| Standard Deviation | 0.01 | 0.00 | 0.01 | 0.02 |
| Minimum | 0.02 | 0.02 | 0.02 | 0.03 |
| 5th Percentile | 0.03 | 0.03 | 0.03 | 0.03 |
| 25th Percentile | 0.03 | 0.03 | 0.03 | 0.03 |
| 50th Percentile | 0.04 | 0.03 | 0.04 | 0.04 |
| 75th Percentile | 0.05 | 0.03 | 0.06 | 0.06 |
| 95th Percentile | 0.06 | 0.04 | 0.07 | 0.07 |
| Maximum | 0.10 | 0.05 | 0.10 | 0.11 |

**Table 26. Cumulative concentration statistics for Whirinaki River at Galatea gauge (mg/L).**

| Modelled TP Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | Current State | Reference State | Development C | Development D |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.03 | 0.03 | 0.03 | 0.03 |
| Standard Deviation | 0.01 | 0.00 | 0.00 | 0.01 |
| Minimum | 0.02 | 0.02 | 0.02 | 0.02 |
| 5th Percentile | 0.02 | 0.02 | 0.02 | 0.02 |
| 25th Percentile | 0.03 | 0.03 | 0.03 | 0.03 |
| 50th Percentile | 0.03 | 0.03 | 0.03 | 0.03 |
| 75th Percentile | 0.03 | 0.03 | 0.03 | 0.03 |
| 95th Percentile | 0.04 | 0.03 | 0.04 | 0.04 |
| Maximum | 0.05 | 0.04 | 0.04 | 0.05 |

**Table 27. Cumulative concentration statistics for Rangitāiki River at SCID34 site (mg/L).**

| Modelled TP Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | Current State | Reference State | Development C | Development D |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.04 | 0.03 | 0.04 | 0.04 |
| Standard Deviation | 0.01 | 0.00 | 0.01 | 0.01 |
| Minimum | 0.02 | 0.02 | 0.02 | 0.02 |
| 5th Percentile | 0.03 | 0.02 | 0.03 | 0.03 |
| 25th Percentile | 0.03 | 0.03 | 0.04 | 0.04 |
| 50th Percentile | 0.04 | 0.03 | 0.04 | 0.04 |
| 75th Percentile | 0.04 | 0.03 | 0.04 | 0.05 |
| 95th Percentile | 0.05 | 0.03 | 0.05 | 0.05 |
| Maximum | 0.05 | 0.03 | 0.06 | 0.07 |

### 4.2.3 TSS

#### 4.2.3.1 Discrete

A comparison of the discrete TSS yields from each individual sub-catchment between the four scenarios is presented in **Figure 13**. The largest change in discrete TSS yields from the Current State scenario occurred in the Reference State scenario, resulting from widespread reversion to native forest.

**Figure 13. Discrete TSS yield (T/ha/yr) for the Rangitāiki WMA.** (Refer A3 attachment at rear).

#### 4.2.3.2 Cumulative

A comparison of the cumulative TSS concentration statistics between scenarios for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 site are presented in

**Table** 28 to **Table 30**.

There was a decrease in TSS concentration between the Current State and Reference State scenarios, and an increase in the two development scenarios. The mean concentration decreased between the Current State and Reference State scenarios by 51%, 61% and 63% for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 site respectively. There was a decrease in mean concentration of 1%, an increase of 1% and a decrease of 0.5% between the Current State and Development C scenario, and a decrease of 1%, an increase of 1% and a decrease 25% between Current State and Development D scenarios for the same gauges as above, respectively.

**Table 28. Cumulative concentration statistics for Rangitāiki River at Murupara gauge (mg/L).**

| Modelled TSS Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 7.65 | 3.74 | 7.55 | 7.55 |
| Standard Deviation | 5.94 | 0.95 | 5.80 | 5.79 |
| Minimum | 0.54 | 0.49 | 0.54 | 0.54 |
| 5th Percentile | 2.50 | 2.00 | 2.46 | 2.47 |
| 25th Percentile | 3.93 | 3.09 | 3.92 | 3.91 |
| 50th Percentile | 4.97 | 3.94 | 4.96 | 4.96 |
| 75th Percentile | 10.52 | 4.46 | 10.33 | 10.29 |
| 95th Percentile | 20.70 | 5.01 | 20.15 | 20.13 |
| Maximum | 33.72 | 6.07 | 32.95 | 33.21 |

Table 29. Cumulative concentration statistics for Whirinaki River at Galatea gauge (mg/L).

| Modelled TSS Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | Current State | Reference State | Development C | Development D |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 16.13 | 6.26 | 16.32 | 16.30 |
| Standard Deviation | 22.25 | 6.23 | 22.58 | 22.59 |
| Minimum | 0.15 | 0.16 | 0.15 | 0.16 |
| 5th Percentile | 1.03 | 1.03 | 1.03 | 1.03 |
| 25th Percentile | 2.31 | 2.21 | 2.31 | 2.30 |
| 50th Percentile | 4.27 | 3.95 | 4.27 | 4.26 |
| 75th Percentile | 24.17 | 7.86 | 24.43 | 24.43 |
| 95th Percentile | 65.16 | 20.20 | 65.88 | 65.46 |
| Maximum | 129.47 | 38.27 | 131.41 | 133.32 |

Table 30. Cumulative concentration statistics for Rangitāiki River at SCID34 site (mg/L).

| Modelled TSS Concentration (mg/L) | | | | |
|---|---|---|---|---|
| | Current State | Reference State | Development C | Development D |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 3.47 | 1.29 | 3.45 | 2.61 |
| Standard Deviation | 3.39 | 0.54 | 3.52 | 2.49 |
| Minimum | 0.11 | 0.09 | 0.11 | 0.08 |
| 5th Percentile | 0.79 | 0.55 | 0.71 | 0.60 |
| 25th Percentile | 1.37 | 0.95 | 1.24 | 1.06 |
| 50th Percentile | 1.79 | 1.23 | 1.63 | 1.41 |
| 75th Percentile | 4.85 | 1.42 | 5.08 | 3.64 |
| 95th Percentile | 11.12 | 2.38 | 11.28 | 8.21 |
| Maximum | 18.69 | 3.59 | 18.77 | 13.72 |

### 4.2.4 E. coli

#### 4.2.4.1 Discrete

A comparison of the discrete *E. coli* yield from each individual sub-catchment between the four scenarios is presented in **Figure 14**.

**Figure 14. Discrete *E. coli yield (CFU*/ha/year) for the Rangitāiki WMA.** (Refer A3 attachment at rear).

#### 4.2.4.2 Cumulative

A comparison of the cumulative *E. coli* concentration statistics between scenarios for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 site are presented in **Table 31** to **Table 33**.

There was a decrease in concentration between the Current State and the Reference State scenarios, and an increase in the two development scenarios. The mean percentage difference between the Current State and Reference State scenario was a decrease of 12%, 2% and 5% for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 site respectively. There was a mean concentration increase of 2%, and a decrease of 1% and increase of 1% between the Current State and Development C scenarios.

**Table 31. Cumulative concentration statistics for Rangitāiki River at Murupara gauge (CFU/100 mL).**

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 25 | 22 | 26 | 26 |
| Standard Deviation | 49 | 45 | 50 | 51 |
| Minimum | 1 | 1 | 1 | 1 |
| 5th Percentile | 2 | 1 | 2 | 2 |
| 25th Percentile | 5 | 4 | 6 | 6 |
| 50th Percentile | 14 | 12 | 14 | 14 |
| 75th Percentile | 26 | 23 | 26 | 26 |
| 95th Percentile | 85 | 76 | 89 | 89 |
| Maximum | 668 | 625 | 671 | 676 |

**Table 32. Cumulative concentration statistics for Whirinaki River at Galatea gauge (CFU/100 mL).**

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 65 | 63 | 64 | 64 |
| Standard Deviation | 99 | 97 | 97 | 97 |
| Minimum | 1 | 1 | 1 | 1 |
| 5th Percentile | 6 | 6 | 6 | 6 |
| 25th Percentile | 19 | 19 | 19 | 19 |
| 50th Percentile | 33 | 33 | 33 | 33 |
| 75th Percentile | 63 | 62 | 63 | 63 |
| 95th Percentile | 244 | 240 | 241 | 241 |
| Maximum | 953 | 941 | 942 | 942 |

**Table 33. Cumulative concentration statistics for Rangitāiki River at SCID34 site (CFU/100 mL).**

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | |
|---|---|---|---|---|
| | **Current State** | **Reference State** | **Development C** | **Development D** |
| Count | 1826 | 1826 | 1826 | 1826 |
| Mean | 33 | 31 | 33 | 34 |
| Standard Deviation | 57 | 54 | 57 | 58 |
| Minimum | 1 | 1 | 1 | 1 |
| 5th Percentile | 2 | 1 | 2 | 2 |
| 25th Percentile | 5 | 5 | 6 | 6 |
| 50th Percentile | 13 | 12 | 13 | 13 |
| 75th Percentile | 33 | 31 | 33 | 34 |
| 95th Percentile | 157 | 149 | 157 | 159 |
| Maximum | 559 | 527 | 558 | 569 |

## 4.3 Scenario Analysis

The following section provides descriptions of the key changes predicted in constituent yield (and concentration) between scenarios. Comparisons are drawn against the Current State scenario rather than the Base Case scenario, as the Current State Scenario included a similar irrigation scheme as the Development Scenarios, where irrigation was based on land use rather than consented takes as applied per the Base Case.

### 4.3.1 Kaituna-Pongakawa-Waitahanui

A summary of the key changes in TN yields resulting from the three scenarios across the main sections of the Kaituna WMA are presented in **Table 34**.

**Table 34. Kaituna discrete TN yields scenario comparison.**

| Discrete TN | Kaituna middle and upper, Waiari water supply | Pongakawa-Waihi middle and upper, Waitahanui | Kaituna lowland, Pongakawa-Waihi lowland |
|---|---|---|---|
| Scenario 1b Current | The dairy, and sheep and beef land uses are the largest contributors to the TN yield in the western section of the Kaituna WMA. In addition, the biological uptake of TN is thought to be low to moderate in the western section, as reflected in the low to moderate CAF required for calibration. | Dairy land use is prevalent in this area and high biological uptake is thought to occur in the Kaikokopu, Puanene and Wharere Rivers, as reflected by the higher CAF required for calibration. However, catchments upstream of the Pongakawa gauge had no attenuation applied. | The TN yields generated within these lowland sub-catchments reflects the predominantly dairy land use. There is a lower TN yield found within the Eastern lowland sub-catchments compared to the Western lowland sub-catchments due to the assumed higher biological uptake (CAF) in the Eastern lowland sub-catchments. |
| Scenario 2 Reference | There is a reduction in TN yields throughout the western section of the Kaituna. Compared to the majority of the western Kaituna WMA, TN yields are higher in the sub-catchments of the Raparapahoe River. The Raparapahoe River is primarily driven by quick flow, due to the physical characteristics of the catchment. The higher TN load delivered to the stream network is a result of the larger quick flow component of the flow regime in this sub-catchment. As a result, there is increased TN generated in this catchment than the rest of the WMA. | There is a reduction in TN load throughout the eastern section of the WMA. This is a result of the reversion of dairy land use in to native forest. | There is a reduction in TN load throughout the lowland section of the WMA. This is a result of the reversion of dairy land use in to native forest and wetlands. |
| Scenario 3 Development C | The decrease in TN yield within the sub-catchments flowing to the Kaituna and Waiari Rivers is a result of the reduction in dairy, and sheep and beef in the highland areas and an increase in plantation forest. | Within this scenario there is an increase in kiwifruit and forested areas and a decrease in dairy. This resulted in a general decrease in TN yields throughout this section. The reduction was greater in areas of dairy converted to forest, in comparison to those converted to kiwifruit. Pockets of dairy found within this section do show an increase in TN yield in some sub-catchments (e.g. SCID96). | A reduction in TN yield was predicted in sub-catchments where significant portions of the sub-catchment have been converted to kiwifruit. However, higher TN loads are still predicted from catchments where dairy dominate. |
| Scenario 4 Development D | The decrease in TN yield within the sub-catchments flowing to the Kaituna River was a result of the decrease in dairy, sheep and beef and increase in plantation forest. Conversely, in the Waiari sub-catchments there was a conversion of sheep and beef (in Current State) to dairy (in Development D) resulting in larger TN yield produced within these sub-catchments. | In this scenario there was an increase in forested areas, and a decrease in dairy. This resulted in a decrease in TN yield throughout this section. There is a larger dairy influence in this scenario compared to Development C, and therefore a higher TN yield in some sub-catchments | A reduction in TN yield was predicted in sub-catchments where significant portions of the sub-catchment have been converted to forest. However, high TN yields are still predicted from catchments where dairy dominate. |

A summary of the key changes in TP yields resulting from the three scenarios across the main sections of the Kaituna WMA are presented in **Table 35**.

**Table 35. Kaituna discrete TP yields scenario comparison.**

| **Discrete TP** | **Kaituna middle and upper, Waiari water supply** | **Pongakawa-Waihi middle and upper, Waitahanui** | **Kaituna lowland, Pongakawa-Waihi lowland** |
|---|---|---|---|
| Scenario 1b Current | The sub-catchments within this section that have high TP yields are dominated by dairy, sheep and beef, and kiwifruit, while the surrounding sub-catchments are largely forested which generate lower TP yields. | A higher TP yield is generated in the eastern sub-catchment compared to the western primarily due to dissolved P component supplied from spring inflows. | The TP yields found within these lowland sub-catchments reflects the overlying land uses, which is predominately dairy, with interspersed areas of kiwifruit orchards. |
| Scenario 2 Reference | TP yields are predominately due to the background (natural) TP load generated from the acid soluble soil types and dissolved P supplied from spring inflows. | TP yields are larger in the eastern catchment compared to the western due to dissolved P component found in the spring waters. | The reversion of dairy to forestry and wetland results in less TP generation. Therefore, reducing the TP loads in these areas. |
| Scenario 3 Development C | The conversion of land from sheep and beef to kiwifruit and orchards results in reduced TP yields from these sub-catchments. | The conversion of land from dairy and sheep and beef to kiwifruit and planation forest results in lower TP yields from these sub-catchments. TP loads are higher in the eastern catchment compared to the western due to dissolved P component supplied from spring inflows. | The conversion of dairy to forestry and wetland results in lower TP generation. Therefore, reducing the TP yield in these areas. |
| Scenario 4 Development D | The widespread conversion of sheep and beef to dairy resulted in increased TP yields in these sub-catchments. | The conversion of land use from dairy and sheep and beef to native forest and plantation forest resulted in lower TP yields in these sub-catchments. TP yields are larger in the eastern catchment compared to the western due to dissolved P component supplied from spring inflows. | The conversion of dairy to forestry and wetland results in lower TP generation. Therefore, reducing TP yields in these areas. |

A summary of the key changes in TSS yields resulting from the three scenarios across the main sections of the Kaituna WMA are presented in **Table 36**.

**Table 36. Kaituna discrete TSS yield scenario comparison.**

| Discrete TSS | Kaituna middle and upper, Waiari water supply | Pongakawa-Waihi middle and upper, Waitahanui | Kaituna lowland, Pongakawa-Waihi lowland |
|---|---|---|---|
| Scenario 1b<br>Current | Sub-catchments with plantation forest areas experience high TSS due to influence of the felling cycle. This is reflected in the high yield catchments in the Kaituna river (SCID18 - SCID20). In addition, catchments with steep slopes (such as SCID42) promote a high delivery of TSS to the river and stream network. | There are large plantation forest areas in the headwater of this section which generate large TSS yields (due to the felling cycle), in addition the steep slopes promote a high delivery of TSS to the river and stream network. | The lowland area is predominately characterised by flat to low slope catchments, and dairy is the main land use in these areas. Therefore, there is comparatively less TSS load generated in these catchments than in the steeper upper catchments where plantation forestry is common. |
| Scenario 2<br>Reference | The reversion of the western section of the WMA to native forest significantly reduced TSS yields. This is due to native forest providing increased vegetation cover, which promotes soil stability and reduces surface runoff. In addition, unlike plantation forests, native forests do not undergo a felling cycle, and therefore generate less TSS. | The large decrease from Current State to Naturalised State is attributed to the change from largely plantation forest to native forest. | The decrease in TSS loads in the lowland area is due to the reversion of predominately dairy with areas of kiwifruit and orchard to native forest and wetland. |
| Scenario 3<br>Development C | The increase in TSS throughout most of the western Kaituna is due to an increase in plantation forestry throughout the head waters of this section. | The increase in TSS throughout most of the eastern Kaituna is due to an increase in plantation forestry throughout the area. | The lowland area is dominated by kiwifruit and wetland land uses which generates less TSS, than plantation forestry. |
| Scenario 4<br>Development D | The increase in TSS throughout most of the Kaituna for this Scenario is due to an increase in plantation forestry throughout the head waters of this section. | The increase in TSS throughout most of the eastern Kaituna is due to an increase in plantation forestry throughout the area. | Similar to the Current State Scenario the lowland area is dominated by dairy land use which in addition to the low sloped catchments, generates lower TSS yields than the western and eastern areas. |

A summary of the key changes in *E. coli* loads resulting from the three scenarios across the main sections of the Kaituna WMA are presented in **Table 37**.

**Table 37. Kaituna discrete *E. coli* yields scenario comparison**

| Discrete E. coli | Kaituna middle and upper, Waiari water supply | Pongakawa-Waihi middle and upper, Waitahanui | Kaituna lowland, Pongakawa-Waihi lowland |
|---|---|---|---|
| Scenario 1b Current | *E. coli* yields are largely reflected in sub-catchment land use, with dairy typically producing the largest loads. | *E. coli* yields are largely reflected in sub-catchment land use, with dairy typically producing the largest loads. | The lowlands are predominately dairy and have higher stocking rates than dairy in the upper catchments, therefore generate higher *E. coli* loads. |
| Scenario 2 Reference | Widespread reversion to native forest significantly reduces *E coli* yields. A small increase was observed in SCID1 as the reversion to native forest produced slightly higher peak flows and therefore *E. coli* loads. | Widespread reversion to native forest significantly reduced *E. coli* yields through this section of the WMA. | Widespread reversion to native forest and wetland significantly reduced *E coli* yields. |
| Scenario 3 Development C | Changes in *E. coli* yield reflect changes in land use between individual sub-catchments. Where dairy and sheep and beef have been converted to forest, *E. coli* yields reduced and vice versa. | Changes in *E. coli* yields reflect changes in land use between individual sub-catchments. Where dairy and sheep and beef have been converted to forest, *E. coli* yields reduced and vice versa. | *E. coli* yields were significantly reduced in the sub-catchments where dairy was converted to kiwifruit and orchards and wetlands. |
| Scenario 4 Development D | Changes in *E. coli* yield reflect changes in land use between individual sub-catchments. Where dairy and sheep and beef have been converted to forest, *E. coli* yield reduced and vice versa. | Changes in *E. coli* yield reflect changes in land use between individual sub-catchments. Where dairy and sheep and beef have been converted to forest, *E. coli* yield reduced and vice versa. | Similar to the Current State scenario the lowland area is dominated by dairy land use, and therefore *E. coli* yields remain similar to the Current State Scenario. |

### 4.3.2 Rangitāiki

A summary of the key changes in TN yields resulting from the three scenarios across the main sections of the Rangitāiki WMA are presented in **Table 38**.

**Table 38. Rangitāiki discrete TN yields scenario comparison.**

| Discrete TN | Middle and upper Rangitāiki | Rangitāiki natural state | Lowland |
|---|---|---|---|
| Scenario 1b<br>Current | The headwaters (SCID1, 5 & 7) in this section comprise dairy and sheep and beef land uses, while the Galatea Plains are primarily dairy. The majority of the remaining Middle section of the Rangitāiki Plains is plantation forest. The spatial variation in land use is reflected in TN yields generated, with higher TN yields reflected in the sub-catchments with dairy and sheep and beef compared to those of plantation forest. | The predominant land use in this section of the WMA is native forest, and therefore TN yields are lower than those generated in the neighbouring dairy and sheep and beef land uses. | TN yields in the Lowland section of the WMA largely reflect the spatial variation in land use, with higher TN yields generated in the sub-catchments dominated by dairy, and lower TN yields in the catchments dominated by arable and plantation forest. |
| Scenario 2<br>Reference | The reversion in land use from dairy to forest reduced TN yields throughout this section on the WMA. | The predominant land use in this section of the WMA remains as native forest in the Naturalised scenario, and therefore TN yields remain similar to those of the Current State Scenario. | Same conclusion as for the middle reach. |
| Scenario 3<br>Development C | The Galatea Plains have a slightly lower TN yield compared to that of Current State Scenario due to the conversion of dairy to kiwifruit and orchards. To the west of the Galatea Plains, large sections of plantation forest were converted to dairy and kiwifruit and orchards, and therefore TN yields increased across these sub-catchments. Land use remained largely the same across the remaining catchments, and therefore also the TN load generated within these sub-catchments. | The predominant land use in this section of the WMA remained as native forest in this scenario, and therefore TN yields remain similar to those of the Current State Scenario. | TN yields increase in sub-catchments where arable land was converted to kiwifruit and remain similar where the existing (Current State Scenario) land use was already dairy. |
| Scenario 4<br>Development D | Land use remained similar in this section of the WMA, with the exception of the conversion of plantation forest to dairy and kiwifruit and orchards to the west of the Galatea Plains. Where land use remains unchanged, TN yield remained unchanged. However, TN yields increased in sub-catchments to the west of the Galatea Plains where conversion to dairy occurred. | The predominant land use in this section of the WMA remains as native forest in this, and therefore TN yields remain similar to those of the Current State Scenario. | Similar to Development C scenario the TN yields increased in sub-catchments where arable land was converted to dairy and remain similar where the existing (Current State Scenario) land use was already dairy. |

A summary of the key changes in TP yields resulting from the three scenarios across the main sections of the Rangitāiki WMA are presented in **Table 39**.

**Table 39. Rangitāiki discrete TP yields scenario comparison.**

| Discrete TP | Middle and upper Rangitāiki | Rangitāiki natural state | Lowland |
|---|---|---|---|
| Scenario 1b<br>Current | The headwaters (SCID1, 5 & 7) in this section comprise of a dairy and sheep and beef, while the Galatea Plains are primarily dairy. The majority of the remaining Middle section of the Rangitāiki Plains is plantation forest. The spatial variation in land use is also reflected in the TP yields, with higher TP yields reflected in the sub-catchments with dairy and sheep and beef compared to those of plantation forest. In addition, spring inflows into the upper Murupara catchment produce elevated TP yields. | The predominant land use in this section of the WMA is native forest. Lower TP yields are generated in these sub-catchments compared to sub catchments in other sections of WMA that contain dairy and sheep and beef. | TP yields in the Lowland section of the WMA largely reflect the spatial variation in land use, with higher TP yields generated in the sub-catchments dominated by dairy, and lower TN yields in the catchments dominated by arable and plantation forest land uses. |
| Scenario 2<br>Reference | The widespread reversion of plantation forest, dairy, and sheep and beef to native forest resulted in reduced TP yields in these sub-catchments. Larger reductions in TP yields occur in sub-catchments where dairy or sheep and beef were reverted to native forest, in comparison to the neighbouring sub-catchments where plantation forest was converted to native forest.<br>TP load produced by spring inflows in the upper Murupara catchment remain the same as for the Current State, as these are not affected by the change in land use. | TP yields generated in individual sub-catchments remain the same as the Current State scenario throughout the majority of this section. The exception is sub-catchment 42 where sheep and beef land use were reverted to native forest, which resulted in a reduction in TP yields in this sub-catchment. | The widespread reversion of land use to native forest and wetlands in this section of the WMA results in reduced TP yields, especially in sub-catchments where dairy was previously the predominant land use. |
| Scenario 3<br>Development C | The Galatea Plains have a lower TP yield compared to that of Current State Scenario as the dairy land use was converted to kiwifruit and orchards. To the west of the Galatea Plains, large sections of plantation forest were converted to high intensity beef or dairy grazing, and kiwifruit and orchards, which produced an increase in TP yields across these sub-catchments. Land use remained largely the same across the remaining catchments, and therefore also the TP load generated within these sub-catchments.<br>The TP load produced by spring inflows in the upper Murupara catchment remain the same as in the Current State Scenario. | TP loads generated in individual sub-catchments remain the same as Current State Scenario throughout the majority of this section. | TP loads are generally reduced in the lowlands under Development C. The variation in reduction of TP loads between sub-catchments follows the variation in land use change. For example, the largest reduction in TP load occurs in SCID110 where a significant portion of the sub-catchment was converted from dairy to wetland. Smaller reductions in TP occur in sub-catchments such as SCID37 where a portion of arable land was converted to native forest. |

| **Discrete TP** | **Middle and upper Rangitāiki** | **Rangitāiki natural state** | **Lowland** |
|---|---|---|---|
| Scenario 4 Development D | Land use remain similar in this section of the WMA with the exception of the conversion of plantation forest to dairy and kiwifruit and orchards to the west of the Galatea Plains. Where land use remains unchanged, TP yields remain unchanged. However, TP yield increased in the sub-catchments to the west of the Galatea Plains where conversion to dairy and kiwifruit and orchards occurred. | TP yields generated in individual sub-catchments remain the same as the Current State Scenario throughout the majority of this section. The exception is SCID42 where a small parcel of sheep and beef land use was converted to dairy, resulting in an increase in TP yield for this sub-catchment. | TP yields are generally increased in the lowlands under Development D. The spatial variation in increased TP yields followed the spatial variation in land use. For example, an increase in TP yield was seen in SCID13, 14 & 15 where small portions of plantation forest were converted to dairy. An increase in TP yield was all seen in SCID37 where the arable land was largely converted to dairy. |

A summary of the key changes in TSS yields resulting from the three scenarios across the main sections of the Rangitāiki WMA are presented in **Table 40**.

**Table 40. Rangitāiki discrete TSS yields scenario comparison.**

| **Discrete TSS** | **Middle and upper Rangitāiki** | **Rangitāiki natural state** | **Lowland** |
|---|---|---|---|
| Scenario 1b Current | The headwaters (SCID1, 5 & 7) in this section comprise of a dairy and sheep and beef land use, while the Galatea Plains are primarily dairy. The majority of the remaining Middle section of the Rangitāiki Plains is plantation forest. Higher TSS yields occur in SCID59, 61, 63, 65, 67 and 68 due to the steeper topography in these sub-catchments in comparison to those further south in this section. | The main land use in this section of the WMA is native forest. Higher TSS yields are often produced in this section in comparison to the plantation forest in the Middle (Murupara to Lake Matahina) due to the significantly steeper topography. | TSS yields in the Lowland section of the WMA largely reflect the spatial variation in land use, with higher TSS yields generated in the sub-catchments dominated by plantation forest land use, and lower TN yields in the catchments dominated by dairy. |
| Scenario 2 Reference | Under the Reference State scenario, the reversion of plantation forest to native forest reduced TSS yields generated within this section. The largest reduction in TSS yield occurred in sub-catchments to the west of the Galatea Plains, where the topography is generally steeper than the sub-catchments to the south. | Under the Reference State Scenario, the pocket of sheep and beef is converted to native forest, and therefore, the TSS yield from this sub-catchment decreases. This is due to the native forest providing greater soil stability than the previous land use. In the sub-catchments were the land use was already entirely native forest, TSS yields remain the same. | The widespread reversion of land use to native forest and wetlands in this section of the WMA results in reduced TSS yields, especially in sub-catchments where plantation forest was previously the predominant land use. |
| Scenario 3 Development C | Under Development C, the land use in this section remains largely unchanged in comparison to the Current State Scenario. The exception is the sub-catchments to the west of the Galatea Plains, which were converted from plantation forest to high intensity beef or dairy grazing, and kiwifruit and orchards. In these sub-catchments, TSS yields generated decreased. | Under Development C, the land use in this section remains largely unchanged in comparison the Current State Scenario. | Under Development C, the conversion of a portion of dairy to wetland in SCID110 resulted in a reduced TSS yield, and the conversion of arable land to kiwifruit in SCID108 resulted in small decrease in TSS yield. |
| Scenario 4 | Under Development D, the land use in this section remains largely unchanged | Under Development D, the land use in this section remains largely unchanged | Under Development D, the conversion of a portion of arable land |

| Discrete TSS | Middle and upper Rangitāiki | Rangitāiki natural state | Lowland |
|---|---|---|---|
| Development D | in comparison Current State Scenario. The exception is the sub-catchments to the west of the Galatea Plains, which were converted from plantation forest to dairy, and kiwifruit and orchards. In these sub-catchments, TSS yields decreased. | in comparison to the Current State Scenario. The exception is SCID42 where sheep and beef land use was converted to dairy. This resulted in a small decrease in TSS yield from SCID42. | to dairy in SCID37 & 38 resulted in a small decrease in TSS yield in these sub-catchments. |

To highlight the potential magnitude of changes in TSS load which can occur when converting native forest to plantation forest, SCID17 was analysed in detail. Under the Current State scenario SCID17 comprises 94% native forest and 6% plantation forest, and generated an average of 931 tonnes/year TSS over the assessment period. Under the Reference State scenario, the plantation forest was converted to native forest, and the sub-catchment was predicted to generate an average of 296 tonnes/year TSS. This highlights a 68% reduction in TSS load due to a change in land use in only 6% of the sub-catchment.

A summary of the key changes in *E. coli* yield resulting from the three scenarios across the main sections of the Rangitāiki WMA are presented in **Table 41**.

**Table 41. Rangitāiki discrete *E. coli* yield scenario comparison.**

| Discrete *E. coli* | Middle and upper Rangitāiki | Rangitāiki natural state | Lowland |
|---|---|---|---|
| Scenario 1b<br>Current | *E. coli* yields in this section of the WMA are typically low due to predominately plantation forestry land use and generally flat topography. The higher yields predicted in SCID69, 70, and 73 are due to the steeper topography in this area in comparison to the sub-catchments to the south. | The main land use in this section of the WMA is native forest, with a small parcel of sheep and beef. This results in low *E. coli* yield. | The high *E. coli* yield are reflective of the predominately dairy land use and high stocking rates. |
| Scenario 2<br>Reference | *E. coli* yields throughout most of this section in the WMA remain similar to the Current State scenario, with the exception of SCID1 and 5 where parcels of dairy and sheep and beef land use were converted to native forest. | The main land use in this section of the WMA is native forest. Reductions in *E. coli* yields were predicted in SC42 where the parcel of sheep and beef was converted to native forest. | The widespread reversion of land use to native forest and wetlands in this section of the WMA results in reduced *E. coli* yield. |
| Scenario 3<br>Development C | *E. coli* yields increased in sub-catchments to the west of the Galatea Plains where plantation forestry was converted to high intensity beef or dairy grazing, and remained the same in the rest of this section of the WMA. | Land use in this section remains similar to the Current State Scenario, and therefore so are the *E. coli* yields. | The high *E. coli* yields are reflective of sub-catchments with predominately dairy land use. Reduction in *E. coli* yield are predicted in sub-catchments where conversion to wetlands occurred. |
| Scenario 4<br>Development D | *E. coli* yields increased in sub-catchments to the west of the Galatea Plains where plantation forestry was converted to dairy, and reduced sub-catchments of the Galatea Plains where dairy was converted to Kiwifruit and orchards. | Land use in this section remains similar to Current State Scenario, and therefore also the *E. coli* yields remain similar. | Increased *E. coli* yields were predicted in sub-catchments where arable land was converted to dairy. |

# 5. Mitigation Scenario Results

The following sections present the outputs of the M1 Mitigation Bundle Scenarios for the Kaituna and Rangitāiki WMAs in **Section 5.1** and **Section 5.2**, respectively. Mitigation Scenario results are presented in the form of cumulative concentration statistics at the key water quality monitoring sites across the Kaituna and Rangitāiki WMAs. The change in cumulative concentrations at these sites (relative to the corresponding non-mitigation scenario) reflect the combined impact of all mitigation measures applied in up-stream reaches of the monitoring site.

In addition to the tabulated summary statistics presented in this report, raw and processed (e.g. summary statistics) model outputs for all sub-catchment and each of the four constituents were provided to BOPRC as a series of Excel and csv output files.

## 5.1 Kaituna-Pongakawa-Waitahanui

The following sections present the cumulative concentration results for the three scenarios with the M1 Mitigations Bundle applied for the Kaituna WMA. Cumulative concentrations for the four land use change (i.e. no mitigations) are also presented within the tables for comparison.

### 5.1.1 TN Cumulative Results

A comparison of the cumulative TN concentration statistics between the land use change scenarios and scenarios with the M1 Mitigation Bundle applied (excluding Scenario 2) for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site are presented in **Table 42** to **Table 44**.

A decrease in TN concentration was predicted between each scenario and its corresponding mitigation scenario. The percentage change in mean concentration between the Current State and Current State Mitigation scenarios was a decrease of 2%, 2% and 3% for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site, respectively. There was a predicted decrease in mean concentration of 9%, 0% and 5% between the Development C and Development C Mitigation scenario, and a decrease of 3%, 5% and 4% between the Development D and Development D mitigation scenarios respectively between the three monitoring sites.

### Table 42. Cumulative concentration statistics for Kaituna River at Te Matai gauge (mg/L).

| | Modelled TN Concentration (mg/L) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.26 | 0.74 | 0.72 | 0.52 | 0.51 | 0.63 | 0.61 |
| Standard Deviation | 0.16 | 0.16 | 0.16 | 0.17 | 0.16 | 0.17 | 0.16 |
| Minimum | 0.16 | 0.52 | 0.51 | 0.30 | 0.30 | 0.43 | 0.41 |
| 5th Percentile | 0.17 | 0.60 | 0.58 | 0.37 | 0.36 | 0.48 | 0.46 |
| 25th Percentile | 0.18 | 0.65 | 0.63 | 0.43 | 0.42 | 0.54 | 0.52 |
| 50th Percentile | 0.19 | 0.71 | 0.68 | 0.48 | 0.46 | 0.59 | 0.57 |
| 75th Percentile | 0.25 | 0.77 | 0.75 | 0.53 | 0.52 | 0.66 | 0.63 |
| 95th Percentile | 0.59 | 1.05 | 1.02 | 0.85 | 0.83 | 0.95 | 0.93 |
| Maximum | 1.88 | 2.38 | 2.32 | 2.19 | 2.14 | 2.27 | 2.22 |

### Table 43. Cumulative concentration statistics for Pongakawa River at Old Coach Rd gauge (mg/L).

| | Modelled TN Concentration (mg/L) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.28 | 1.52 | 1.38 | 0.53 | 0.53 | 0.66 | 0.63 |
| Standard Deviation | 0.18 | 0.16 | 0.16 | 0.18 | 0.18 | 0.17 | 0.17 |
| Minimum | 0.21 | 1.30 | 1.20 | 0.44 | 0.38 | 0.53 | 0.51 |
| 5th Percentile | 0.21 | 1.37 | 1.25 | 0.45 | 0.44 | 0.56 | 0.54 |
| 25th Percentile | 0.22 | 1.43 | 1.30 | 0.46 | 0.46 | 0.58 | 0.56 |
| 50th Percentile | 0.23 | 1.48 | 1.35 | 0.48 | 0.47 | 0.61 | 0.59 |
| 75th Percentile | 0.27 | 1.55 | 1.41 | 0.53 | 0.52 | 0.67 | 0.64 |
| 95th Percentile | 0.55 | 1.75 | 1.59 | 0.79 | 0.78 | 0.92 | 0.89 |
| Maximum | 3.46 | 4.19 | 4.02 | 3.65 | 3.62 | 3.70 | 3.65 |

Table 44. Cumulative concentration statistics for Waitahanui River at SCID114 site (mg/L).

| Modelled TN Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.35 | 0.87 | 0.81 | 0.47 | 0.47 | 0.57 | 0.55 |
| Standard Deviation | 0.30 | 0.32 | 0.32 | 0.31 | 0.30 | 0.30 | 0.30 |
| Minimum | 0.20 | 0.53 | 0.50 | 0.27 | 0.27 | 0.33 | 0.32 |
| 5th Percentile | 0.21 | 0.58 | 0.55 | 0.30 | 0.30 | 0.36 | 0.36 |
| 25th Percentile | 0.22 | 0.70 | 0.65 | 0.34 | 0.33 | 0.43 | 0.42 |
| 50th Percentile | 0.24 | 0.79 | 0.73 | 0.38 | 0.37 | 0.48 | 0.47 |
| 75th Percentile | 0.34 | 0.92 | 0.85 | 0.47 | 0.46 | 0.57 | 0.55 |
| 95th Percentile | 0.89 | 1.45 | 1.38 | 1.04 | 1.03 | 1.10 | 1.08 |
| Maximum | 3.79 | 4.38 | 4.22 | 3.97 | 3.93 | 3.99 | 3.93 |

### 5.1.2 TP Cumulative Results

A comparison of the cumulative TP concentration statistics between the land use change scenarios and land use change scenarios with the M1 Mitigation Bundle applied (excluding Scenario 2) for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site are presented in **Table 45** to **Table 47**.

A decrease in TP concentration was predicted between each scenario and its corresponding mitigation scenario. The percentage change in mean concentration between the Current State and Current State Mitigation scenarios was a decrease of 0%, 7% and 9% for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site, respectively. There was no change in between the Development C and Development C Mitigation or Development D and Development D Mitigation Scenarios between the three monitoring sites.

**Table 45. Cumulative concentration statistics for Kaituna River at Te Matai gauge (mg/L).**

| Modelled TP Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.02 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 |
| Standard Deviation | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Minimum | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 5th Percentile | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 |
| 25th Percentile | 0.02 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| 50th Percentile | 0.02 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| 75th Percentile | 0.03 | 0.05 | 0.05 | 0.04 | 0.04 | 0.05 | 0.04 |
| 95th Percentile | 0.03 | 0.07 | 0.07 | 0.06 | 0.05 | 0.06 | 0.06 |
| Maximum | 0.04 | 0.19 | 0.17 | 0.14 | 0.13 | 0.17 | 0.17 |

Table 46. Cumulative concentration statistics for Pongakawa River at Old Coach Rd gauge (mg/L).

| | Modelled TP Concentration (mg/L) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.11 | 0.14 | 0.13 | 0.12 | 0.12 | 0.12 | 0.12 |
| Standard Deviation | 0.00 | 0.04 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 |
| Minimum | 0.11 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 5th Percentile | 0.11 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 25th Percentile | 0.11 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 50th Percentile | 0.11 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| 75th Percentile | 0.11 | 0.14 | 0.13 | 0.12 | 0.12 | 0.12 | 0.12 |
| 95th Percentile | 0.12 | 0.20 | 0.19 | 0.13 | 0.13 | 0.14 | 0.14 |
| Maximum | 0.13 | 0.62 | 0.54 | 0.24 | 0.23 | 0.29 | 0.28 |

Table 47. Cumulative concentration statistics for Waitahanui River at SCID114 site (mg/L).

| | Modelled TP Concentration (mg/L) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.09 | 0.11 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Standard Deviation | 0.00 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Minimum | 0.07 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| 5th Percentile | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| 25th Percentile | 0.08 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| 50th Percentile | 0.09 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| 75th Percentile | 0.09 | 0.11 | 0.11 | 0.10 | 0.10 | 0.10 | 0.10 |
| 95th Percentile | 0.09 | 0.14 | 0.13 | 0.11 | 0.11 | 0.12 | 0.11 |
| Maximum | 0.10 | 0.26 | 0.23 | 0.15 | 0.14 | 0.18 | 0.18 |

### 5.1.3 TSS Cumulative Results

A comparison of the cumulative TSS concentration statistics between the land use change scenarios and land use change scenarios with the M1 Mitigation Bundle applied (excluding Scenario 2) for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site are presented in **Table 48** to **Table 50**.

A decrease in TSS concentration was predicted between each scenario and its corresponding mitigation scenario. The percentage change in mean concentration between the Current State and Current State Mitigation scenarios was a decrease of 1%, 3% and 1% for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site, respectively. There was a predicted decrease in mean concentration of 3%, 5% and 3% between the Development C and Development C Mitigation scenario, and a decrease of 1%, 1% and 0% between the Development D and Development D mitigation scenarios respectively between the three monitoring sites.

**Table 48. Cumulative concentration statistics for Kaituna River at Te Matai gauge (mg/L).**

| Modelled TSS Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 3.11 | 9.06 | 8.95 | 9.94 | 9.67 | 9.96 | 9.87 |
| Standard Deviation | 0.45 | 8.08 | 7.90 | 9.40 | 8.99 | 9.16 | 9.02 |
| Minimum | 1.38 | 1.75 | 1.75 | 1.77 | 1.77 | 1.88 | 1.88 |
| 5th Percentile | 2.42 | 3.24 | 3.24 | 3.24 | 3.24 | 3.40 | 3.40 |
| 25th Percentile | 2.81 | 3.64 | 3.64 | 3.64 | 3.64 | 3.82 | 3.82 |
| 50th Percentile | 3.04 | 4.02 | 4.02 | 4.03 | 4.03 | 4.21 | 4.21 |
| 75th Percentile | 3.38 | 14.38 | 14.20 | 16.14 | 15.65 | 16.08 | 15.91 |
| 95th Percentile | 3.95 | 25.79 | 25.31 | 29.35 | 28.26 | 28.85 | 28.47 |
| Maximum | 4.67 | 44.24 | 43.33 | 51.12 | 48.99 | 49.94 | 49.21 |

Table 49. Cumulative concentration statistics for Pongakawa River at Old Coach Rd gauge (mg/L).

| Modelled TSS Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 8.15 | 19.21 | 18.79 | 29.73 | 28.21 | 29.71 | 29.49 |
| Standard Deviation | 1.41 | 18.58 | 17.91 | 34.57 | 32.15 | 34.55 | 34.18 |
| Minimum | 2.55 | 2.18 | 2.18 | 2.44 | 2.44 | 2.43 | 2.43 |
| 5th Percentile | 6.98 | 6.94 | 6.94 | 7.11 | 7.11 | 7.11 | 7.11 |
| 25th Percentile | 7.37 | 7.36 | 7.36 | 7.48 | 7.48 | 7.48 | 7.48 |
| 50th Percentile | 7.44 | 7.44 | 7.44 | 7.56 | 7.56 | 7.56 | 7.56 |
| 75th Percentile | 8.93 | 31.13 | 30.25 | 52.76 | 49.69 | 52.74 | 52.26 |
| 95th Percentile | 11.12 | 58.81 | 56.92 | 103.55 | 96.91 | 103.51 | 102.50 |
| Maximum | 13.29 | 86.35 | 83.44 | 154.47 | 143.93 | 154.37 | 152.76 |

Table 50. Cumulative concentration statistics for Waitahanui River at SCID114 site (mg/L).

| Modelled TSS Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 6.05 | 15.04 | 14.85 | 17.29 | 16.77 | 17.29 | 17.23 |
| Standard Deviation | 0.70 | 14.13 | 13.82 | 17.46 | 16.62 | 17.45 | 17.34 |
| Minimum | 1.41 | 1.16 | 1.16 | 1.38 | 1.38 | 1.39 | 1.39 |
| 5th Percentile | 4.92 | 5.41 | 5.41 | 5.67 | 5.67 | 5.69 | 5.69 |
| 25th Percentile | 5.77 | 6.18 | 6.18 | 6.28 | 6.28 | 6.25 | 6.25 |
| 50th Percentile | 6.02 | 6.42 | 6.42 | 6.51 | 6.51 | 6.52 | 6.52 |
| 75th Percentile | 6.35 | 23.96 | 23.55 | 28.42 | 27.40 | 28.58 | 28.47 |
| 95th Percentile | 7.22 | 45.46 | 44.59 | 54.54 | 52.30 | 54.44 | 54.17 |
| Maximum | 7.88 | 69.94 | 68.51 | 85.83 | 81.98 | 85.61 | 85.15 |

### 5.1.4 E. coli Cumulative Results

A comparison of the cumulative *E. coli* concentration statistics between the land use change scenarios and land use change scenarios with the M1 Mitigation Bundle applied (excluding Scenario 2) for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site are presented in **Table 51** to **Table 53**.

A decrease in *E. coli* concentration was predicted between each scenario and its corresponding mitigation scenario. The percentage change in mean concentration between the Current State and Current State Mitigation scenarios was a decrease of 3%, 2% and 5% for the Kaituna at Te Matai gauge, Pongakawa at Old Coach Rd gauge and Waitahanui River SCID114 site, respectively. There was no change between the Development C and Development C Mitigation scenarios. However, there was a predicted decrease in mean concentration of 0%, 20% and 2% between the Development D and Development D mitigation scenarios between the three monitoring sites.

**Table 51. Cumulative concentration statistics for Kaituna River at Te Matai gauge (CFU/100 mL).**

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 27 | 37 | 36 | 33 | 33 | 31 | 31 |
| Standard Deviation | 50 | 74 | 72 | 64 | 64 | 70 | 70 |
| Minimum | 7 | 8 | 7 | 8 | 7 | 5 | 5 |
| 5th Percentile | 9 | 9 | 9 | 9 | 9 | 6 | 6 |
| 25th Percentile | 11 | 12 | 12 | 11 | 11 | 7 | 7 |
| 50th Percentile | 13 | 14 | 14 | 13 | 13 | 9 | 8 |
| 75th Percentile | 18 | 23 | 23 | 21 | 21 | 18 | 17 |
| 95th Percentile | 105 | 166 | 160 | 144 | 139 | 152 | 148 |
| Maximum | 695 | 1029 | 991 | 882 | 873 | 967 | 951 |

Table 52. Cumulative concentration statistics for Pongakawa River at Old Coach Rd gauge (CFU/100 mL).

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 66 | 83 | 81 | 70 | 70 | 70 | 70 |
| Standard Deviation | 84 | 113 | 109 | 89 | 89 | 90 | 90 |
| Minimum | 29 | 29 | 29 | 29 | 29 | 29 | 29 |
| 5th Percentile | 29 | 29 | 29 | 29 | 29 | 29 | 29 |
| 25th Percentile | 29 | 30 | 30 | 29 | 29 | 29 | 29 |
| 50th Percentile | 32 | 36 | 36 | 33 | 33 | 33 | 33 |
| 75th Percentile | 61 | 79 | 78 | 65 | 65 | 65 | 65 |
| 95th Percentile | 224 | 296 | 287 | 238 | 238 | 241 | 240 |
| Maximum | 1160 | 1441 | 1363 | 1192 | 1191 | 1206 | 1194 |

Table 53. Cumulative concentration statistics for Waitahanui River at SCID114 site (CFU/100 mL).

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 52 | 82 | 78 | 54 | 54 | 58 | 57 |
| Standard Deviation | 128 | 182 | 175 | 134 | 134 | 139 | 137 |
| Minimum | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| 5th Percentile | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 25th Percentile | 13 | 15 | 15 | 13 | 13 | 14 | 14 |
| 50th Percentile | 16 | 24 | 23 | 16 | 16 | 17 | 17 |
| 75th Percentile | 26 | 54 | 50 | 27 | 26 | 31 | 30 |
| 95th Percentile | 246 | 389 | 373 | 272 | 272 | 278 | 277 |
| Maximum | 1530 | 2040 | 1936 | 1584 | 1580 | 1651 | 1632 |

## 5.2 Rangitāiki

The following sections present the cumulative concentration results for the three scenarios with the M1 Mitigations Bundle applied for the Rangitāiki WMA. Cumulative concentrations for the four land use change (i.e. no mitigations) are also presented within the tables for comparison.

### 5.2.1 TN Cumulative Results

A comparison of the cumulative TN concentration statistics between the land use change scenarios and land use change scenarios with the M1 Mitigation Bundle applied (excluding Scenario 2) for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 site are presented in **Table 54** to **Table 56**.

A decrease in TN concentration was predicted between each scenario and its corresponding mitigation scenario. The percentage difference between the Current State and Current State mitigation scenario was a decrease of 2%, 0%, 3% for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 sites. There was a concentration decrease of 2%, 0% and 3% and a decrease of 3%, 0% and 5% between the Development C and Development C mitigation, Development D and Development D mitigation scenarios, respectively.

Table 54. Cumulative concentration statistics for Rangitāiki River at Murupara gauge (mg/L).

| Modelled TN Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.55 | 0.98 | 0.96 | 1.09 | 1.07 | 1.14 | 1.11 |
| Standard Deviation | 0.06 | 0.08 | 0.08 | 0.10 | 0.11 | 0.10 | 0.10 |
| Minimum | 0.42 | 0.79 | 0.71 | 0.84 | 0.76 | 0.88 | 0.86 |
| 5th Percentile | 0.46 | 0.84 | 0.82 | 0.91 | 0.88 | 0.96 | 0.93 |
| 25th Percentile | 0.50 | 0.91 | 0.89 | 1.02 | 0.99 | 1.06 | 1.03 |
| 50th Percentile | 0.56 | 0.99 | 0.96 | 1.11 | 1.08 | 1.16 | 1.13 |
| 75th Percentile | 0.61 | 1.04 | 1.02 | 1.17 | 1.15 | 1.23 | 1.19 |
| 95th Percentile | 0.65 | 1.10 | 1.08 | 1.23 | 1.20 | 1.28 | 1.24 |
| Maximum | 0.67 | 1.15 | 1.13 | 1.29 | 1.27 | 1.34 | 1.30 |

### Table 55. Cumulative concentration statistics for Whirinaki River at Galatea gauge (mg/L).

| Modelled TN Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| Standard Deviation | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Minimum | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 |
| 5th Percentile | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 25th Percentile | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| 50th Percentile | 0.11 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| 75th Percentile | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| 95th Percentile | 0.27 | 0.28 | 0.27 | 0.27 | 0.26 | 0.27 | 0.27 |
| Maximum | 0.49 | 0.50 | 0.50 | 0.48 | 0.48 | 0.48 | 0.48 |

### Table 56. Cumulative concentration statistics for Rangitāiki River at SCID34 site (mg/L).

| Modelled TN Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.33 | 0.59 | 0.57 | 0.66 | 0.64 | 0.73 | 0.69 |
| Standard Deviation | 0.04 | 0.06 | 0.05 | 0.04 | 0.04 | 0.06 | 0.06 |
| Minimum | 0.30 | 0.51 | 0.50 | 0.58 | 0.57 | 0.64 | 0.61 |
| 5th Percentile | 0.30 | 0.52 | 0.51 | 0.61 | 0.59 | 0.66 | 0.63 |
| 25th Percentile | 0.31 | 0.55 | 0.53 | 0.63 | 0.62 | 0.69 | 0.65 |
| 50th Percentile | 0.32 | 0.57 | 0.55 | 0.66 | 0.64 | 0.71 | 0.68 |
| 75th Percentile | 0.34 | 0.61 | 0.59 | 0.68 | 0.67 | 0.75 | 0.71 |
| 95th Percentile | 0.42 | 0.71 | 0.68 | 0.73 | 0.71 | 0.83 | 0.79 |
| Maximum | 0.54 | 0.97 | 0.93 | 0.92 | 0.90 | 1.10 | 1.06 |

### 5.2.2 TP Cumulative Results

A comparison of the cumulative TP concentration statistics between the land use change scenarios and land use change scenarios with the M1 Mitigation Bundle applied (excluding Scenario 2) for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 site are presented in **Table 57** to **Table 59**.

A decrease in TN concentration was predicted between each scenario and its corresponding mitigation scenario. The percentage difference between the Current State and Current State mitigation scenario was a decrease of 0%, 0%, 25% for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 sites. There was a concentration decrease of 20%, 0% and 0% between the Development C and Development C mitigation scenarios. There was no change between Development D and Development D mitigation scenarios.

**Table 57. Cumulative concentration statistics for Rangitāiki River at Murupara gauge (mg/L).**

| Modelled TP Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.03 | 0.04 | 0.04 | 0.05 | 0.04 | 0.05 | 0.05 |
| Standard Deviation | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 |
| Minimum | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 |
| 5th Percentile | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 25th Percentile | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 50th Percentile | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| 75th Percentile | 0.03 | 0.05 | 0.05 | 0.06 | 0.05 | 0.06 | 0.06 |
| 95th Percentile | 0.04 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 |
| Maximum | 0.05 | 0.10 | 0.09 | 0.10 | 0.10 | 0.11 | 0.10 |

Table 58. Cumulative concentration statistics for Whirinaki River at Galatea gauge (mg/L).

| | Modelled TP Concentration (mg/L) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Standard Deviation | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 |
| Minimum | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 5th Percentile | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 25th Percentile | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 50th Percentile | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 75th Percentile | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 95th Percentile | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Maximum | 0.04 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 |

Table 59. Cumulative concentration statistics for Rangitāiki River at SCID34 site (mg/L).

| | Modelled TP Concentration (mg/L) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 0.03 | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 |
| Standard Deviation | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Minimum | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 5th Percentile | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 25th Percentile | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.04 | 0.03 |
| 50th Percentile | 0.03 | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 |
| 75th Percentile | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 |
| 95th Percentile | 0.03 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Maximum | 0.03 | 0.05 | 0.05 | 0.06 | 0.06 | 0.07 | 0.07 |

### 5.2.3 TSS Cumulative Results

A comparison of the cumulative TSS concentration between the land use change scenarios and land use change scenarios with the M1 Mitigation Bundle applied (excluding Scenario 2) for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 site are presented in **Table 60** to **Table 62**.

A decrease in TN concentration was predicted between each scenario and its corresponding mitigation scenario. The percentage difference between the Current State and Current State mitigation scenario was a decrease of 0%, 0%, 22% for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 sites. Similarly, there was a 1%, 0% and 25% decrease between Development C and Development C mitigation scenarios for each of the three sites. There was a concentration decrease of 1% at the Rangitāiki at Murupara gauge and no change at the other sites between the Development D and Development D mitigation scenarios.

**Table 60. Cumulative concentration statistics for Rangitāiki River at Murupara gauge (mg/L).**

| Modelled TSS Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 3.74 | 7.65 | 7.63 | 7.55 | 7.49 | 7.55 | 7.50 |
| Standard Deviation | 0.95 | 5.94 | 5.90 | 5.80 | 5.71 | 5.79 | 5.73 |
| Minimum | 0.49 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 |
| 5th Percentile | 2.00 | 2.50 | 2.50 | 2.46 | 2.46 | 2.47 | 2.47 |
| 25th Percentile | 3.09 | 3.93 | 3.93 | 3.92 | 3.92 | 3.91 | 3.91 |
| 50th Percentile | 3.94 | 4.97 | 4.97 | 4.96 | 4.96 | 4.96 | 4.96 |
| 75th Percentile | 4.46 | 10.52 | 10.47 | 10.33 | 10.21 | 10.29 | 10.23 |
| 95th Percentile | 5.01 | 20.70 | 20.60 | 20.15 | 19.87 | 20.13 | 19.96 |
| Maximum | 6.07 | 33.72 | 33.56 | 32.95 | 32.47 | 33.21 | 32.88 |

### Table 61. Cumulative concentration statistics for Whirinaki River at Galatea gauge (mg/L).

| Modelled TSS Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 6.26 | 16.13 | 16.11 | 16.32 | 16.30 | 16.30 | 16.28 |
| Standard Deviation | 6.23 | 22.25 | 22.22 | 22.58 | 22.55 | 22.59 | 22.56 |
| Minimum | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.16 |
| 5th Percentile | 1.03 | 1.03 | 1.03 | 1.03 | 1.03 | 1.03 | 1.03 |
| 25th Percentile | 2.21 | 2.31 | 2.31 | 2.31 | 2.31 | 2.30 | 2.30 |
| 50th Percentile | 3.95 | 4.27 | 4.27 | 4.27 | 4.27 | 4.26 | 4.26 |
| 75th Percentile | 7.86 | 24.17 | 24.15 | 24.43 | 24.40 | 24.43 | 24.40 |
| 95th Percentile | 20.20 | 65.16 | 65.08 | 65.88 | 65.81 | 65.46 | 65.38 |
| Maximum | 38.27 | 129.47 | 129.32 | 131.41 | 131.26 | 133.32 | 133.14 |

### Table 62. Cumulative concentration statistics for Rangitāiki River at SCID34 site (mg/L).

| Modelled TSS Concentration (mg/L) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 1.29 | 3.47 | 2.70 | 3.45 | 2.59 | 2.61 | 2.60 |
| Standard Deviation | 0.54 | 3.39 | 2.63 | 3.52 | 2.46 | 2.49 | 2.48 |
| Minimum | 0.09 | 0.11 | 0.09 | 0.11 | 0.08 | 0.08 | 0.08 |
| 5th Percentile | 0.55 | 0.79 | 0.61 | 0.71 | 0.60 | 0.60 | 0.60 |
| 25th Percentile | 0.95 | 1.37 | 1.07 | 1.24 | 1.05 | 1.06 | 1.06 |
| 50th Percentile | 1.23 | 1.79 | 1.40 | 1.63 | 1.40 | 1.41 | 1.41 |
| 75th Percentile | 1.42 | 4.85 | 3.77 | 5.08 | 3.62 | 3.64 | 3.62 |
| 95th Percentile | 2.38 | 11.12 | 8.63 | 11.28 | 8.12 | 8.21 | 8.19 |
| Maximum | 3.59 | 18.69 | 14.52 | 18.77 | 13.56 | 13.72 | 13.67 |

### 5.2.4 E. coli Cumulative Results

A comparison of the cumulative *E. coli* concentration statistics between the land use change scenarios and land use change scenarios with the M1 Mitigation Bundle applied (excluding Scenario 2) for the Rangitāiki at Murupara gauge, Whirinaki at Galatea gauge and Rangitāiki River SCID34 site are presented in **Table 63** to **Table 65**.

A decrease in *E. coli* concentration was predicted between each scenario and its corresponding mitigation scenario. There was no change between the standard and the mitigation scenario for each scenario at the Rangitāiki at Murupara gauge. At the Whirinaki at Galatea gauge there was a -2% percentage difference between the Current State and Current State mitigation scenario and no change between the other scenarios. At the Rangitāiki River SCID34 site there was a 3%, 6%, 3% percentage decrease between the Current state and Current state mitigation, Development C and Development C mitigation and Development D and Development D mitigation results, respectively.

**Table 63. Cumulative concentration statistics for Rangitāiki River at Murupara gauge (CFU/100 mL).**

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 23 | 26 | 26 | 27 | 27 | 27 | 27 |
| Standard Deviation | 47 | 51 | 51 | 52 | 52 | 52 | 52 |
| Minimum | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5th Percentile | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 25th Percentile | 4 | 6 | 6 | 6 | 6 | 6 | 6 |
| 50th Percentile | 12 | 14 | 14 | 14 | 14 | 14 | 14 |
| 75th Percentile | 23 | 27 | 27 | 28 | 27 | 28 | 28 |
| 95th Percentile | 79 | 89 | 89 | 93 | 93 | 94 | 94 |
| Maximum | 625 | 668 | 665 | 671 | 669 | 676 | 673 |

Table 64. Cumulative concentration statistics for Whirinaki River at Galatea gauge (CFU/100 mL).

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 65 | 66 | 65 | 65 | 65 | 65 | 65 |
| Standard Deviation | 99 | 101 | 100 | 99 | 99 | 99 | 99 |
| Minimum | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5th Percentile | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 25th Percentile | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| 50th Percentile | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| 75th Percentile | 63 | 64 | 64 | 64 | 63 | 64 | 63 |
| 95th Percentile | 240 | 246 | 244 | 242 | 241 | 242 | 241 |
| Maximum | 941 | 953 | 949 | 942 | 940 | 942 | 940 |

Table 65. Cumulative concentration statistics for Rangitāiki River at SCID34 site (CFU/100 mL).

| Modelled *E. coli* Concentration (CFU/100 mL) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Reference State** | **Current State** | **Current State M1** | **Development C** | **Development C M1** | **Development D** | **Development D M1** |
| Count | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 | 1826 |
| Mean | 33 | 35 | 34 | 35 | 33 | 35 | 34 |
| Standard Deviation | 56 | 59 | 58 | 59 | 57 | 60 | 58 |
| Minimum | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5th Percentile | 1 | 2 | 1 | 2 | 1 | 2 | 1 |
| 25th Percentile | 5 | 6 | 5 | 6 | 5 | 6 | 5 |
| 50th Percentile | 13 | 13 | 12 | 14 | 12 | 14 | 12 |
| 75th Percentile | 33 | 34 | 33 | 35 | 33 | 35 | 33 |
| 95th Percentile | 156 | 162 | 159 | 162 | 157 | 163 | 159 |
| Maximum | 527 | 559 | 560 | 558 | 551 | 569 | 560 |

## 5.3 Scenario Analysis

The following section provides a summary of land use change scenarios and the relative levels of effectiveness of the mitigations applied, and thus reduction in constituent load (and yield), and concentration, within main sections of the Kaituna and Rangitāiki WMAs.

It should be noted, the Reference State scenario is not presented in this section, as no mitigations were applied in this scenario.

### 5.3.1 Kaituna-Pongakawa-Waitahanui

A summary of the key changes to TN resulting from the three land use and mitigation scenarios across the main sections of the Kaituna WMA are presented in **Table 66**.

**Table 66. Kaituna WMA TN Mitigation Scenario comparisons.**

| **Discrete TN** | **Kaituna middle and upper, Waiari water supply** | **Pongakawa / Waihi middle and upper, Waitahanui** | **Kaituna lowland, Pongakawa / Waihi lowland** |
|---|---|---|---|
| Scenario 1b Current | The land use in this section is predominately kiwifruit, sheep beef, and native forest. Sheep and Beef has a very small baseflow nitrogen mitigation effectiveness factor and no quickflow factor. Forest land use have no mitigations applied, and kiwifruit has a small mitigation effectiveness factor. Therefore, the catchments in this section typically range from having no reduction in nitrogen to a small reduction only. | The eastern sub-catchments are largely dominated by dairy land use, which had a significant reduction in nitrogen due to the large mitigation factor effectiveness factor applied. As no mitigation practices were applied to the forest land use, the overall the large reduction in this area was dominated by the mitigations applied to dairy. | The lowland catchments saw the greatest reduction in TN between the Current State and the Current State Mitigation Scenario as the largest mitigation effectiveness factor was applied due to the catchment being predominately dairy land use. |
| Scenario 3 Development C | The western catchments in Development C and the corresponding mitigation scenario are dominated by kiwifruit and forest / native forest land uses. As forest has no mitigation effectiveness factor applied and kiwifruit only has a small factor, the reduction in these catchments is smaller than in the Current State and Development D Scenario. | The eastern catchments in Development C and the corresponding mitigation scenario are dominated by kiwifruit and forest. As forest has no mitigation effectiveness factor applied and kiwifruit only has a small factor, the reduction in these catchments is smaller than in the Current State and Development D Scenarios. | Lowland catchments in the Development C scenario are largely dominated by kiwifruit interspersed with dairy. As the mitigation effectiveness factors applied to kiwifruit were less than those for dairy, there was less reduction than in the Current State and Development C scenarios, which are dominated by dairy in these areas. |
| Scenario 4 Development D | The amount of reduction in TN between the Development D and Development D mitigation scenarios is dependent on the percentage of dairy within each catchment as that had the largest mitigation effectiveness factor. Catchments in the western region are predominately dairy, and forest. The overall reduction in each sub-catchment was dependant on the proportional composition of these two land uses. | This section of the WMA is largely dominated by forest and native forest land use, interspersed with small pockets of dairy. Small reduction in TN occurred in sub-catchments which included pockets of dairy land use. | In Development D the land use was predominately a mix of dairy and smaller pockets of kiwifruit. The increased prevalence of dairy in the lowland area in comparison to Development C meant there was a larger reduction TN, however, less than the Current State scenario. |

A summary of the key changes to TP resulting from the three land use and mitigation scenarios across the main sections of the Kaituna WMA are presented in **Table 67**.

Table 67. Kaituna TP Mitigation Scenario comparisons.

| **Discrete TN** | **Kaituna middle and upper, Waiari water supply** | **Pongakawa / Waihi middle and upper, Waitahanui** | **Kaituna lowland, Pongakawa / Waihi lowland** |
|---|---|---|---|
| Scenario 1b<br>Current | The land use in these catchments and mainly kiwifruit, sheep beef and forest. Sheep and Beef had a large mitigation effectiveness factor which is similar to that applied to dairy. Forest has no mitigations applied and kiwifruit has a small mitigation factor. Therefore, the catchments in this region range from having no reduction in TP to a large reduction due to mitigation practices of the M1 bundle. | The eastern catchments are dominated by dairy and forest land uses. Dairy had a significant reduction in TP due to a large mitigation effectiveness factor being applied. Mitigations were not applied to the forest land use, and therefore, the overall the reduction in this area was primarily due to the mitigations applied to dairy. | The lowland catchments saw the largest difference in TP between the Current State and the Current State Mitigation Scenario predominately dairy land use, which had large mitigation effectiveness factor. |
| Scenario 3<br>Development C | The western catchments in Development C and the corresponding mitigation scenario are dominated by kiwifruit and forest, with smaller areas of sheep and beef and dairy. As forest has no mitigation effectiveness factor applied and kiwifruit only has a small factor, the reduction in these catchments is smaller than in the Current State and Development D Scenarios. | The eastern catchments in Development C and the corresponding mitigation scenario are dominated by kiwifruit and forest. As forest has no mitigation effectiveness factor applied and kiwifruit only has a small factor, the reduction in these catchments is smaller than in the Current State and Development D Scenarios and the Development C lowland catchments. | Lowland catchments in the Development C scenario are dominated by kiwifruit. No baseflow and a small quickflow mitigation effectiveness factor were applied to these catchments meaning there was less reduction than in Current State. |
| Scenario 4<br>Development D | The magnitude of reduction in TP between the Development D and Development D mitigation scenarios is dependent on the percentage of dairy within each catchment as that had the largest mitigation effectiveness factor. | Development D and the corresponding mitigation scenario are dominated by forest, with smaller areas of dairy. Reductions in TP associated with the M1 Mitigation bundle occurred in sub-catchments where dairy was present. However, given the prevalence of forest in this section, the resulting mitigations were relatively small | In Development D the land use was predominately a mix of dairy and kiwifruit. This resulted in a greater reduction in TP associated with the M1 mitigations than in the upstream catchments. |

A summary of the key changes to TSS resulting from the three land use and mitigation scenarios across the main sections of the Kaituna WMA are presented in **Table 68**.

**Table 68. Kaituna TSS Mitigation Scenario comparisons.**

| Discrete TN | Kaituna middle and upper, Waiari water supply | Pongakawa / Waihi middle and upper, Waitahanui | Kaituna lowland, Pongakawa / Waihi lowland |
|---|---|---|---|
| Scenario 1b<br>Current | The land use in these catchments is predominantly kiwifruit, sheep beef and forest. Sheep and beef had a small TSS mitigation effectiveness factor, and forest had no mitigations applied. Whereas, kiwifruit had a large mitigation factor. Therefore, the catchments in this region ranged from having no reduction in TSS to a large reduction in TSS resulting from the M1 Mitigation Bundle. | The eastern catchments that were dominated by dairy land use had a significant reduction in TSS due to a large mitigation factor being applied. No mitigation factor was applied to forest catchments. Overall, the reduction in this area was dominated by the mitigations applied to dairy. | The lowland catchments exhibited between the Current State and the Current State Mitigation Scenario as the largest mitigation effectiveness factor was applied due to the catchment being predominately dairy land use. |
| Scenario 3<br>Development C | The western section in Development C and the corresponding mitigation scenario are dominated by kiwifruit and forest. Forest has no mitigation effectiveness factor applied but kiwifruit has a large factor resulting in the reduction due to M1 mitigation bundle in this section being larger than in the Current State scenario. | The eastern section in Development C and the corresponding mitigation scenario are dominated by kiwifruit and forest. Forest has no mitigation effectiveness factor applied but kiwifruit has a large factor meaning. | Lowland catchments in the Development C scenario are dominated by kiwifruit. A large quickflow mitigation effectiveness factor was applied to these catchments meaning there was similar reduction than in Current State. |
| Scenario 4<br>Development D | The reduction in TSS between the Development D and Development D mitigation scenarios was dependent on the percentage of dairy within each catchment as that has the highest mitigation effectiveness factor. | As the predominant land use in the eastern section of Development D is forest and native forest, the reduction in TSS between the Development D and Development D mitigation scenarios is dependent on the proportion of dairy within each sub-catchment. | In Development D the land use was predominately a mix of dairy and kiwifruit, similar to the Current State scenario, and therefore similar reductions resulting from the M1 mitigations were seen. |

A summary of the key changes to E. coli resulting from the three land use and mitigation scenarios across the main sections of the Kaituna WMA are presented in **Table 69**.

**Table 69. Kaituna E. coli Mitigation Scenario comparisons.**

| Discrete TN | Kaituna middle and upper, Waiari water supply | Pongakawa / Waihi middle and upper, Waitahanui | Kaituna lowland, Pongakawa / Waihi lowland |
|---|---|---|---|
| Scenario 1b<br>Current | The land use in this section is predominately kiwifruit, sheep beef and forest, with areas of dairy in the upper catchment. Of these land uses, the M1 mitigations only reduce *E. coli* from sheep and beef, and dairy. The largest reductions occurred in the upper sub-catchments containing dairy, with smaller reductions in sub-catchments containing sheep and beef. | The eastern catchments that were dominated by dairy land use had a comparatively large reduction in *E. coli* due the M1 mitigation measures. No mitigation factor was applied to forest catchments so overall the reduction in this area was dominated by the mitigations applied to dairy. | The lowland catchments saw the largest reduction from between the Current State and the Current State Mitigation Scenario due to the significant prevalence of dairy land use throughout this section, and high mitigation effectiveness factor for *E. coli* from dairy land use. |
| Scenario 3<br>Development C | The western catchments in Development C and the corresponding mitigation scenario are dominated by kiwifruit and forest. As both kiwifruit and forest have no mitigation effectiveness factor applied, there was no significant change in these catchments. The small reductions that did occur resulted from the pockets of dairy and sheep and beef land uses. | The eastern catchments in Development C and the corresponding mitigation scenario are dominated by kiwifruit and forest. As both kiwifruit and forest have no mitigation effectiveness factor applied, there was no significant reduction in *E. coli* from these catchments. | Lowland catchments in the Development C scenario is predominately kiwifruit, with dairy and wetlands towards the coastal margin. Therefore, the reduction in *E. coli* in this area was lower than that for the Current State and Development D scenarios. |
| Scenario 4<br>Development D | There is an increased prevalence of dairy land use in the western section of Development D in comparison to Development C, and therefore also larger reduction in *E. coli* due to the M1 mitigation measures. | The eastern section predominately consists of plantation forest interspersed with native forest, and small pockets of dairy. Therefore, the reduction in *E. coli* were comparatively smaller than that of the Current State scenario. | The lowland catchments predominately consist of dairy mixed with kiwifruit, generally similar to the Current State scenario, with the exception of the forested area to the north of Otamarakau Road. |

### 5.3.2 Rangitāiki

A summary of the key changes to TN resulting from the three land use and mitigation scenarios across the main sections of the Rangitāiki WMA are presented in **Table 70**.

**Table 70. Rangitāiki TN Mitigation Scenario comparisons.**

| Discrete TN | Middle and upper Rangitāiki | Rangitāiki natural state | Lowland |
|---|---|---|---|
| Scenario 1b<br>Current | The Galatea Plains are primarily dairy and the headwaters applied are dairy and sheep and beef. The majority of the remaining Middle section of the Rangitāiki Plains is plantation forest which has no mitigation applied. Therefore, reductions in TN resulting from the M1 mitigation measures were only seen in the Galatea Plains and headwaters. There was a larger relative reduction from dairy in comparison to sheep and beef. | The predominant land use in this section of the WMA is native forest. Therefore, there was no change between the Current State and the Current State M1 scenario throughout the majority of this FMU. | The reduction in TN in the Lowland section of the WMA between the current state and current state mitigation scenarios, largely reflect the spatial variation in land use, with greater reduction generated in the sub-catchments dominated by dairy, and lower reduction in the catchments dominated by arable and plantation forest. |
| Scenario 3<br>Development C | The Galatea Plains have a lower TN reduction between the Development C scenarios compared to that of Current State Scenario due to the conversion of dairy to kiwifruit and orchards. To the west of the Galatea Plains, large sections of plantation forest were converted to dairy and kiwifruit and orchards, and therefore the reduction increased across these sub-catchments in comparison to the Current State. In the headwaters there was a larger relative reduction from dairy in comparison to sheep and beef. | The predominant land use in this section of the WMA is native forest. Therefore, there was no change between the Current State and the Development C scenario throughout the majority of this FMU. | The reductions in TN due to the M1 mitigation measures was comparatively lower than under the Current State scenario as large areas of the Lowland section of the WMA had been converted from dairy, to wetland and arable converted to a forest and kiwifruit. |
| Scenario 4<br>Development D | The Galatea Plains are primarily dairy under Development D. The majority of the remaining Middle section of the Rangitāiki Plains is a combination of plantation forest, dairy and kiwifruit. Therefore, reductions from mitigation measures were largest in sub-catchments containing dairy. Comparatively minor reduction occurred in kiwifruit land use, and no reduction in areas of plantation forest | The predominant land use in this section of the WMA is native forest. Therefore, there was no change between the Development D and the Development D M1 scenario throughout the majority of this FMU. | The reduction in TN in the Lowland area of the WMA as a result of the M1 mitigations was comparatively largest in the Development D scenario compared to the other two due to the increased prevalence of daily land use in this scenario. Dairy had a larger mitigation effectiveness factor in comparison to the other land uses. |

A summary of the key changes to TP resulting from the three land use and mitigation scenarios across the main sections of the Rangitāiki WMA are presented in **Table 71**.

**Table 71. Rangitāiki TP Mitigation Scenario comparisons.**

| Discrete TP | Middle and upper Rangitāiki | Rangitāiki natural state | Lowland |
|---|---|---|---|
| Scenario 1b<br>Current | The majority of the Middle section of the Rangitāiki Plains is plantation forest which had no mitigation applied. Therefore, reductions in TP resulting from the M1 mitigation measures were only seen in the Galatea Plains and headwaters where diary and sheep and beef land uses occur. The exception was in where there was a larger relative reduction from sheep and beef in comparison to dairy. | The predominant land use in this section of the WMA is native forest. Therefore, there was no change between the Current State and the Current State M1 scenario throughout the majority of this FMU. | The largest reduction in TP from the Current State to Current State M1 scenario in the Lowland section of the WMA occurred in sub-catchments predominately consisting of dairy and arable land use. These two land uses had similar, and high mitigation effectiveness factors for TP in comparison to surrounding land uses. |
| Scenario 3<br>Development C | In comparison to the Current State scenario, the reduction in TP resulting from the M1 mitigation bundle in the Galatea Plains was lower due to the widespread conversion of dairy to kiwifruit land use. However, to the west, reductions increased, due to the conversion of plantation forest to dairy (which had a greater mitigation effectiveness factor). | The predominant land use in this section of the WMA is native forest. Therefore, there was no change between the Development C and the Development C M1 scenario throughout the majority of this FMU. | The reductions in TP due to the M1 mitigation measures was comparatively lower than under the Current State scenario as large areas of the Lowland section of the WMA had been converted from dairy, to wetland and arable converted to a forest and kiwifruit, both of which had lower mitigation effectiveness. |
| Scenario 4<br>Development D | Reductions in TP across the Galatea Plains in the Development D M1 scenario remained the same as that for the Current State. However, to the west, the proportional reduction in TP due to mitigations increased in areas where plantation forest had been converted to dairy land use. In the headwaters there was a larger relative reduction from sheep and beef in comparison to dairy. | The predominant land use in this section of the WMA is native forest. Therefore, there was no change between the Development D and the Development D M1 scenario throughout the majority of this FMU. | The reduction in TP in the Lowland area of the WMA as a result of the M1 mitigations was similar to that of the Current State, as both diary and arable land use had a similar mitigation effectiveness factor for TP in the Lowland Rangitāiki. |

A summary of the key changes to TSS resulting from the three land use and mitigation scenarios across the main sections of the Rangitāiki WMA are presented in **Table 72**.

**Table 72. Rangitāiki TSS Mitigation Scenario comparisons.**

| Discrete TSS | Middle and upper Rangitāiki | Rangitāiki natural state | Lowland |
|---|---|---|---|
| Scenario 1b<br>Current | The majority of the Middle section of the Rangitāiki Plains is plantation forest which had no mitigation applied. Therefore, reductions in TSS resulting from the M1 mitigation measures were only seen in the Galatea Plains and headwaters, where dairy and sheep and beef land uses occur. Sub catchments with dairy had a large reduction than those with sheep and beef. | No reductions occurred in this WMA as the land use is predominately native forest. | The largest reduction in TSS from the Current State to Current State M1 scenario in the Lowland section of the WMA occurred in sub-catchments predominately consisting of arable land use, and to a lesser extent dairy. |
| Scenario 3<br>Development C | In comparison to the Current State scenario, the reduction in TSS resulting from the M1 mitigation bundle in the Galatea Plains was greater due to the widespread conversion of dairy to kiwifruit land use. In addition, to the west, the proportional reductions increased, due to the conversion of plantation forest to dairy (which had a greater mitigation effectiveness factor). | No reductions occurred in this WMA as the land use is predominately native forest. | The reductions in TSS due to the M1 mitigation measures was comparatively lower than under the Current State scenario as large areas of the Lowland section of the WMA had been converted from dairy, to wetland and arable converted to a forest and kiwifruit, both of which had lower mitigation effectiveness factors. |
| Scenario 4<br>Development D | Reductions in TSS across the Galatea Plains in the Development D M1 scenario remained the same as that for the Current State. However, to the west, the proportional reduction in TSS is due to mitigation measures increased in areas where plantation forest has been converted to dairy land use. | No reductions occurred in this WMA as the land use is predominately native forest. | The reduction in TSS in the Lowland area of the WMA as a result of the M1 mitigations was lower than that of the Current State, as the arable land (which had a large mitigation effectiveness factor for TSS) was converted to dairy. |

A summary of the key changes to E. coli resulting from the three land use and mitigation scenarios across the main sections of the Rangitāiki WMA are presented in **Table 73**.

**Table 73. Rangitāiki E. coli Mitigation Scenario comparisons.**

| **Discrete *E. coli*** | **Middle and upper Rangitāiki** | **Rangitāiki natural state** | **Lowland** |
|---|---|---|---|
| Scenario 1b<br>Current | Reductions in *E. coli* resulting from the M1 Mitigations occurred across the Galatea Plains where dairy land use was prevalent and in the headwaters of this section of the WMA where diary and sheep and beef land uses occurred. | No reductions occurred in the areas entirely covered in native forest. | The largest reduction in *E. coli* from the Current State to Current State M1 scenario in the Lowland section of the WMA occurred in sub-catchments predominately consisting of dairy land use, and to a lesser extent across the small pockets of sheep and beef. |
| Scenario 3<br>Development C | The Galatea Plains have a lower *E. coli* reduction between the Development C scenarios compared to that of Current State Scenario due to the conversion of dairy to kiwifruit and orchards. To the west of the Galatea Plains, large sections of plantation forest were converted to dairy and kiwifruit and orchards, and therefore the reduction increased across these sub-catchments, in comparison to the Current State. The land use and therefore the percentage reduction stayed the same in the headlands. | No reductions occurred in the areas entirely covered in native forest. | The reductions in *E. coli* due to the M1 mitigation measures was comparatively lower than under the Current State scenario as large areas of the Lowland section of the WMA had been converted from dairy, to wetland. |
| Scenario 4<br>Development D | Reductions in *E. coli* across the Galatea Plains in the Development D M1 scenario remained the same as that for the Current State. However, to the west, the proportional reduction in *E. coli* due to mitigation measures increased in areas where plantation forest were converted to dairy land use. The land use and thus percentage reduction in *E. coli* remained the same in the headwaters. | No reductions occurred in the areas entirely covered in native forest. | The reduction in *E. coli* in the Lowland area of the WMA as a result of the M1 mitigations was greater than that of the Current State, as the arable land (which had a mitigation effectiveness factor of 0% for *E. coli*) was converted to dairy. |

# 6. Summary and Conclusions

Catchment wide hydrological models were developed using the eWater SOURCE modelling framework to simulate the water quantity and quality in the Kaituna and Rangitāiki Water Management Areas, as detailed in the SOURCE Catchment Modelling report (WWLA, 2020a). These models were then used to simulate and assess the outcomes from a range of hypothetical future land use scenarios and scenarios with constituent loss mitigation measures implemented, to assist and support policy development under the National Policy Statement for Freshwater Management.

Seven scenarios were modelled, and are summarised as follows:

- **Scenario 1** – Current State;
- **Scenario 2** – Reference State;
- **Scenario 3** – Development C;
- **Scenario 4** – Development D;
- **Scenario 5** – Current State with M1 Mitigation Bundle;
- **Scenario 6** – Development C with M1 Mitigation Bundle; and
- **Scenario 7** – Development D with M1 Mitigation Bundle.

The Current State scenario represents the present-day land use. The Reference State scenario represents the land use prior to human modification, where catchments consisted of almost entirely native forest and wetlands.

The Development C and Development D scenarios represent varying levels of development with increases in kiwifruit and plantation forest in the Kaituna WMA, and increased kiwifruit and dairy in the Rangitāiki WMA, respectively. These hypothetical future land use changes scenarios (Development C and Development D) were developed by BOPRC with input from local stakeholders and feedback from community workshops.

The M1 Mitigation Bundle scenarios represent the implementation of the first tier of mitigation practices of a three-tier framework to reduce losses of nitrogen, phosphorus, E. coli and sediment from dairy, sheep and beef, arable, and kiwifruit land uses. The cumulative (combined total) effect of the M1 Mitigation Bundle was implemented in the catchment models by applying a percentage reduction (referred to as the mitigation effectiveness factor) to the quickflow and baseflow components for the four constituent generation models.

The seven scenarios were simulated over a 44-year period (1972-2016), and the outputs of discrete yields and cumulative concentrations analysed for the 2010-2015 period. High-level outputs and analysis at a broad scale presented in this report. The full suite of raw and processed model outputs were delivered to BOPRC, who are currently preparing a detailed scenario analysis report for internal use by their policy development and planning team.

# 7. References

BOPRC. 2019. Mitigation Scenarios for the Catchment Model. Unpublished memo prepared by BOPRC for WWLA.

Perrin Ag Consultants Ltd & Manaaki Whenua Landcare Research. 2018a. Recommended mitigation bundles for cost analysis of mitigation of sediment and other freshwater contaminants in the Rangitāiki and Kaituna-Pongakawa-Waitahanui Water Management Areas. Consultancy report prepared for the Bay of Plenty Regional Council. Version 1.3

Perrin Ag Consultants Ltd & Manaaki Whenua Landcare Research. 2018b. Economic and contaminant loss impact on farm and orchard systems of mitigation bundles to address sediment and other freshwater contaminants in the Rangitāiki and Kaituna-Pongakawa-Waitahanui Water Management Areas. Consultancy report prepared for the Bay of Plenty Regional Council. Version 1.3

Williamson Water Advisory (WWLA) (2020a) *Kaituna-Pongakawa-Waitahanui and Rangitāiki SOURCE Catchment Modelling Report*. Report prepared for Bay of Plenty Regional Council.

Williamson Water Advisory (WWLA) (2020b) *Kaituna-Pongakawa-Waitahanui and Rangitāiki APSIM Modelling Report*. Report prepared for Bay of Plenty Regional Council.