Ruamāhanga Scenario Modelling

Greater Wellington Regional Council

Human Health *E.coli* Summary

2

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Contents

GLOSSARY

Term	Description
BAU	Business as usual modelling scenario
DWC	Dry weather concentrations that are applied to baseflow generated from various landuses
EMC	Event mean concentrations that are applied to quickflow (rapid runoff) generated from various landuses
GNS	Geological Nuclear Sciences
Gold	Gold modelling scenario
NIWA	National Institute of Water and Atmospheric Research
NPSFM	National Policy Statement for Freshwater Management 2014 (amended 2017)
Percentile	Statistical observation indicating the value which a given percentage of observations in a group fall below.
Silver	Silver modelling scenario
Tier 1, 2 and 3 (M1, M2, M3)	Nutrient and *E.coli* farm management mitigations modelled by agresearch for dairy, dairy support, arable farms and sheep and beef.
WWTP	Waste water treatment plant

1. Introduction

This report provides a technical summary of the scenario modelling undertaken for the Ruamāhanga Whaitua, with a focus on describing the 20 reporting sites (**Section 2.3**) in regards to 'Human Health', driven by *E.coli* as a measure of suitable primary contact conditions at each location and the National Policy Statement for Freshwater Management 2014 (NPSFM) (amended 2017) swimmability standards (**Table 1.1**). Catchment modelling for Ruamāhanga has been undertaken for the baseline condition and nine scenarios.

Table 1.1 : NPSFM *E.coli* swimming categories. Categories blue, green and yellow indicate suitability for primary contact recreation (e.g. swimming)

Category	Percentage of Exceedances over 540 cfu/100 mL	Median *E.coli* per 100 mL	95th percentile *E.coli* per 100 mL	Percentage of exceedances above 260 cfu/100 mL
Blue (Excellent)	< 5 percent	≤ 130	≤ 540	< 20 percent
Green (Good)	5–10 percent	≤ 130	≤ 1,000	20–30 percent
Yellow (Fair)	10–20 percent	≤ 130	≤ 1,200	20–34 percent
Orange (Intermittent)	20–30 percent	> 130	> 1,200	> 34 percent
Red (Poor)	> 30 percent	> 260	> 1,200	>50 percent

1.1 *E.coli* modelling approach

E.coli was modelled within the eWater Source software package. Microbial contamination of water sources are influenced by surrounding land use, and both point and nonpoint sources are of importance. *E.coli* can be generated from a variety of sources within a catchment including.

- Direct access of cattle to waterways;
- Overland flow through grazed paddocks entraining *E.coli*;
- Application of sprayed dairy effluent; and
- Waste water discharge to streams.
- Urban stormwater discharges, including pets, birds and wastewater infiltration and overflows

Representation of the relative source load of *E.coli* from these different sources was a focus in the selection and calibration of the baseline model, in regards to adopting an Event Mean Concentration (EMC) and Dry Weather Concentrations (DWC) load generation approach. Numerous literature sources informed the initial set of EMC/DWC parameters and guided calibration to in-stream monitoring data, including loads used in CLUES for pasture, other rural and urban sources.

The EMC's are applied to 'quickflow' in the model, representative of rapid runoff during rainfall events, primarily through overland flow. DWC's are applied to 'baseflow' in the model and could be considered the base load into the system.

1.2 Landuse types and functional units

Mitigations on *E.coli* sources in scenario modelling were applied to the areas of the functional units (representing a landuse and soil drainage combination) within catchments (for example, where land has been retired to native bush).

1.2.1 Primary landuse areas

The dominant Ruamāhanga catchment landuse types have been summarised in **Table 1.2.** These do not represent the functional unit list, only a summary of the dominant landuses.

The landuse type 'Other' includes water, finishing, poultry, recreation, viticulture and horticulture. The dominant landuse in the catchment is sheep and beef, followed by native forest and dairy. The total catchment area is ~354,311 ha.

Table 1.2 : Ruamāhanga landuse areas

Landuse Type	Area (ha)	% of total catchment
Sheep and Beef	146,962	41.5%
Native Forest	83,888	23.7%
Dairy	30,029	8.5%
Other	17,528	4.9%
Mixed	16,725	4.7%
Lifestyle	12,184	3.4%
Plantation Forest	11,143	3.1%
Dairy Support	9,987	2.8%
Beef	8,974	2.5%
Urban	7,999	2.3%
Sheep	4,491	1.3%
Equine	2,036	0.6%
Arable Land	1,656	0.5%
Deer	709	0.2%

Further analysis of the landuse relative to each reporting site has been summarized in **Table A.1** and **Figure B.2**.

2. Scenarios

2.1 Scenario list

A total of ten different scenario models were run over four different time periods. They are as follows:

- Baseline model (i.e., existing management practices between 1992 and 2014);
- Business as usual (BAU) scenario for 2025, 2040 and 2080;
- Gold scenario for 2025, 2040 and 2080; and
- Silver scenario for 2025, 2040 and 2080.

The baseline model provides the reference point for comparison against scenarios. Each scenario has a number of mitigation 'options' applied within a given scenario. Inherently the discrete influence of specific mitigations on water quality results is difficult to discern at downstream catchments which have had a significant amount of inflows from various tributaries, and should be viewed as the cumulative effectiveness of the BAU, Gold or Silver scenarios.

2.2 Scenario descriptions

The following sections provide an overview of the mitigation options applied in each of the scenarios. These were developed by the Ruamāhanga Whaitua Committee.

Table 2.1 : BAU scenario and mitigation option descriptions

Management Option	Description
Land Retirement	Retirement of very steep slopes and reversion to bush on class 7e and 8 (LUC) land. Retirement at a rate of 18 ha/yr.
Pole Planting	Pole (space) planting on steep slopes (class 7 land and above) at a rate of 135 ha/yr.
WWTP	WWTP are discharging partially to land. Discharge to water is allowed only under certain flow conditions (as described in Jacobs 2017a). Proportion of flow volume to be discharged to land: **Masterton:** - 60% (summer) and 5% (winter) by 2025, 100% (summer) and 80% (winter) by 2040, 100% (summer) and 97% (winter) by 2080 **Carterton:** - 35% by 2025, 60% by 2080. **Martinborough:** - 24% by 2025, 100% by 2040 **Greytown** - 20% by 2025, 100% by 2040 **Featherston** -0% (full course of model)

Management Option	Description
Minimum flow rules	Minimum flow rules (cease takes) were applied to all existing agglomerated surface water consents in the SOURCE model, based off Tables 7.1 and 7.2 in the GWRC Proposed Natural Resources Plan (PNRP). These were applied immediately (evident through 2025-2080 models).
Nutrient Mitigations (Tier 1)	Tier 1 (M1) stock exclusion on dairy, dairy support, sheep and beef was considered to occur immediately (any nutrient, *E.coli* and sediment reductions were therefore consistent across the three BAU scenarios).

Table 2.2 : Silver scenario descriptions

Management Option	Description
Land Retirement	Retirement of very steep slopes and reversion to bush on in Eastern Hill Country on the top 5% of erosion prone land. Retire land by 2040.
Pole Planting	Pole (space) planting on steep slopes (class 6e and 7 land) but not including the top 5% of erosion prone land. Pole planting completed by 2040.
WWTP	WWTP are discharging only to land, includes all sites. 60% of the volume by 2025, 100% by 2040. The 40% of load that is discharged to the river (2025) can only occur when flow is greater than 3x the median flow.
Minimum flow rules	Minimum flow rules (cease takes) are the same as applied in the BAU model (see **Table 2.1**).
Nutrient Mitigations (Tier 1, 2 and 3)	Tier 1 (M1) applied immediately (2025 through to 2080). Tier 2 (M2- fertiliser management, constructed wetlands etc) applied by 2040. Tier 3 (5 m riparian buffer) applied by 2080. Mitigations only applied to dairy, dairy support, sheep and beef and arable farm types.

Table 2.3 : Gold scenario descriptions

Management Option	Description
Land Retirement	Retirement of very steep slopes and reversion to bush on in Eastern Hill Country on the top 5% of erosion prone land. Retire land by 2025.
Pole Planting	Pole (space) planting on steep slopes (class 6e and above) but not including the top 5% of erosion prone land. Pole planting completed by 2040.
WWTP	WWTP are discharging only to land, includes all sites. 100% of the volume by 2025.
Minimum flow rules	Minimum flow rules (cease takes) are the same as applied in the BAU model (see **Table 2.1**).
Nutrient Mitigations (Tier 1, 2 and 3)	Tier 1 (M1) and Tier 2 (M2) applied immediately (2025 through to 2080). Tier 3 (10 m riparian buffer) applied by 2040. Mitigations only applied to dairy, dairy support, sheep and beef and arable farm types.

2.3 Scenario reporting points

Discussions with GWRC identified a total of 25 reporting points in the Ruamāhanga catchment. Five of these were lake reporting sites (Wairarapa and Onoke). The 20 remaining sites that were assessed in the scenario modelling are outlined in **Table 2.4.**

Table 2.4 : Reporting points, catchment area and co-ordinates

Reporting site	Total catchment area (ha)	Co-ordinates (NZTM)	
Huangarua River at Ponatahi Bridge	30,239	1809110.9	5433450.9
Kopuaranga River at Stuarts	16,686	1826760.0	5469569.0
Mangatarere River at SH2	11,947	1809768.0	5452160.0
Ruamāhanga River at Pukio	246,366	1796969.7	5429312.4
Ruamāhanga River at Te Ore Ore	31,078	1825238.6	5462371.0
Taueru River at Gladstone	49,244	1824148.0	5450815.0
Tauherenikau River at Websters	14,481	1794221.8	5438960.8
Waingawa River at South Rd	14,969	1824037.5	5456790.2
Waiohine River at Bicknells	39,320	1810473.9	5446861.2
Waipoua River at Colombo Rd Bridge	17,452	1825118.6	5462371.0
Parkvale Stream at weir	5,006	1813384.6	5448900.9
Ruamāhanga River at Wardells	64,284	1824577.7	5457270.2
Ruamāhanga River at Gladstone Bridge	133,694	1819925.6	5449559.8
Ruamāhanga River at Waihenga	236,089	1804111.3	5435911.3
Whangaehu River at 250m from Rua Confluence	14,578	1826209.0	5459282.0
Otukura Stream at Mouth	9,366	1793829.6	5437578.3
Makahakaha Stream at Mouth	6,192	1821065.6	5448899.5
Ruamāhanga River at U/S Lake Wai Outlet	254,496	1784197.9	5423956.4
Tauanui River at Mouth	4,155	1783915.1	5423674.8
Turanganui River at Mouth	6,740	1779267.6	5419205.8

These reporting points are presented in **Figure B1** in **Appendix B.**

2.4 *E.coli* swimmability metrics

E.coli daily timeseries were processed using the Hazen method to calculate the medians and 95th percentiles at each site based on the 22 years of daily simulated concentration data (cfu/100 mL). These were compared against the NPSFM swimmability criteria as outlined in **Table 1.1**, which includes the percentage of exceedances over 260 and 540 cfu/100 ml and the reporting points corresponding 'category' (from red to blue). These have been represented in **Table 5.4** to **Table 5.23.**

The 'swimmability category' and results in **Table 5.4** to **Table 5.23** are determined as an overall score based on all of the four parameters within that group (median, 95th, % exceedance >260 cfu/100ml and % exceedance>540 cfu/100ml). If one of these four criteria are above the threshold, this would push a site into a worse swimming category (i.e. green to yellow) and the whole category may change.

3. Methods influencing E.coli

3.1 Tier 1 Mitigations (M1)

On farm mitigations (M1, M2 and M3) were modelled against 16 farm types in Overseer by Agresearch (Muirhead *et al.* 2016). Only Tiers 1 and 3 had an effect on *E.*coli. The Tier 1 *E.coli* mitigations were applied to Dairy, Dairy Support and Sheep and Beef land-uses. As described in Muirhead *et al.* 2016, Tier 1 includes:

- Stock exclusion from streams and wetlands
- Deferred and/or low rate effluent irrigation (dairy farms only)

Tier 1 mitigations were applied in every scenario from 2025 through to 2080. In regards to *E.coli*, a percentage reduction was applied to DWC's only, representing the base load of *E.coli* into the streams. The reductions were derived off a number of field studies that evaluated the effectiveness of these mitigations on the appropriate landuse types (Muirhead 2013, Muirhead 2016). These reductions were:

- 69% in E.coli DWC's for Dairy and Dairy Support
- 44% in *E.coli* DWC's for Sheep and Beef.

No reductions were applied to the landuse types described in **Table 1.2**, other than Dairy, Dairy Support and Sheep and Beef.

The surface water model uses a flow partitioning approach to separate baseflows from quickflows. As described in **Section 1.1**, the DWC's are applied to baseflows, and vary depending on landuse type. Any reduction to these DWC generation rates will ultimately effect the modelled 5th and 50th (median) percentiles at a reporting point, with only a minor influence on the 95th percentiles. This is because the modelled 95th percentiles are primarily generated through quickflows (overland flows) that occur during events, where the EMC's would be applied.

95th percentiles are mitigated through Tier 3 mitigations (riparian planting), as described in the following section.

3.2 Tier 3 Mitigations (M3)

Tier 3 (M3) is the application of riparian planting. This was undertaken in Silver and Gold scenarios only. Silver assumed a 5 m buffer strip, Gold a 10 m buffer. For the purposes of applying reductions to *E.coli* EMC's due to riparian planting, the effect of the buffer width has been assumed to be equal .

Email communication with Richard Muirhead on the 22nd of September 2017 indicated that a realistic estimate for riparian buffer planting would be a 10% reduction to event concentrations.

The staging of planting throughout the scenarios has an important effect on the percentage reduction to the *E.coli* EMC's. Planting was not considered spatially (with priority to particular farm types etc), it was assumed to occur across all Dairy, Dairy Support, and Sheep and Beef landuses across the catchment. **Table 3.1** lists the reductions applied in different scenarios.

No reductions to EMC's were undertaken in any of the BAU scenarios, which means minimal change would be expected in the 95th *E.coli* percentiles, except for locations were land treatment of waste water treatment plants (WWTP) is occurring. This may result in the swimmability category of a reporting site not changing in BAU, despite the medians decreasing.

Table 3.1 : *E.coli* EMC percentage reductions due to riparian planting (Tier 3)

Model date	% planting applied to all landuses	% reduction in *E.coli* EMC's
Silver 2025	33	3.3%
Silver 2040	66	6.6%
Silver 2080	100	10.0%
Gold 2025	50	5.0%
Gold 2040/2080	100	10.0%

3.3 Land Retirement

Retirement of land was driven by the Land Use Classification (LUC) for BAU scenarios, and in addition the top 5% of erosion prone land for Gold and Silver scenario's (See **Table 2.1** – **Table 2.3)**. GIS analysis was undertaken to identify the relevant LUC classes for each scenario and retiring land starting with the steepest slope class, by converting the baseline landuse to native Bush FU type. Retirement essentially effects Sheep and Beef farms, given most retirement focused on steep and eroding slopes as per descriptions in **Table 2.1** to **Table 2.3.**

This is undertaken through an area change in the model, i.e. Sheep and Beef decreases by 50 ha, Native Bush increases by 50 ha. Where this occurs, the Native_Bush EMC/DWC input parameters for *E.coli* would be applied to the land that has been retired, thereby decreasing the *E.coli* generation rate. A change to Native_Bush from Sheep and Beef would result in EMC/DWC reductions of >99%, as defined by the literature data used to derive input concentrations (Jacobs 2017).

Retirement was undertaken first, followed by pole planting (also starting on the steepest slopes). Subsequently, the method did not prioritize certain catchments. Pole planting is considered to have no effect on *E.coli*, as grazing will continue underneath the established trees.

The total area of land that is retired upstream of each reporting point is described in **Table C.1** in **Appendix C.** In BAU, this was ~347 ha by 2080 at the most downstream reporting site (Upstream of Lake Wai Outlet), while Silver and Gold retired 11,088 ha by 2080 at the same location. This is equivalent to ~0.1% (BAU) and ~3.1% (Silver and Gold) of the total catchment area.

Retirement of land mitigation option will effect both median (50th) and 95th percentile concentrations.

3.4 WWTP

WWTP mitigations varied depending on the scenario being modelled, as outlined in **Section 2.** However, all scenarios included the following approaches:

- WWTP flow and load were increased based on population growth assessments for the region (from statistics NZ).
- Receiving water flows were assessed to determine when discharge could occur to the river. When it could not, it was assumed to be land treated.
- The proportion of flow that was land treated was multiplied with the WWTP timeseries concentration to create a load. This load was then attenuated based on information gathered from consents, Overseer and literature data that was verified and agreed on with all district councils. I.e. 77% reduction to Nitrogen, 95% reduction *E.coli*.

- The revised 'attenuated' load was then recalculated as a concentration, and imported back into Source model with the revised flow (corrected for population increase). The resulting decrease in load represents land treatment.

The effects of the WWTP mitigations are most evident at the links directly downstream, however their effects propagate throughout the catchment. It is worth noting that there is no reporting point downstream of the Featherston WWTP, so the changes in receiving waters here are only captured in Lake Wairarapa quality.

The attenuation factors applied to *E.coli* in each of the WWTP's are described in **Table 3.2.**

Table 3.2 : *E.coli* reduction due to land treatment

WWTP	% reduction factor due to land treatment	Assumptions	Source
Carterton	95	*E. coli* attenuation rates will be similar to those likely to be observed at the Masterton WWTP (i.e., 95% of *E. coli* will die off within the soil).	Green, 2007
Featherston			
Greytown			
Martinborough			
Masterton			

The primary influence on reducing WWTP *E.coli* loads is whether land treatment is occurring. Throughout BAU there is a mixture of land and water discharge, while Gold and Silver are primarily land treatment at all the WWTP, which would therefore lead to a greater decrease in *E.coli* concentrations (both median and 95th).

4. Assumptions/Limitations

4.1 Baseline model calibration

A good calibration was achieved for the observed means and the 95th percentiles, however generally the final calibration resulted in modelled medians being higher than the observed in many cases, which may indicate some sites are in a lower swimmability category (based off the simulated results) than is the actual reality.

The explicit concentration results generated through the scenarios should be used subjectively, with the focus being on the proportional changes between the scenarios, and narrowing down the values (i.e. 50th, 95th) that change (or don't) and have the biggest influence on the swimming category.

The *E.coli* calibration was based off water quality data from 2000 to 2014, and constrained to the timeseries period of flows modelled by other software packages. This data was provided at the start of the Ruamāhanga modelling project and hence in some locations the number of samples are limited and do not capture any sampling up to the present day. The calibration against this data (and the lumped EMC/DWC method used to model *E.coli*) is a straight forward but simple approach to modelling in-stream pathogen concentrations. A more accurate (but data and time hungry) approach would be to model *E.coli* in a sub-daily catchment model coupled to a 3D hydrodynamic model of the River, which would provide a better estimate of in-stream fate and transport of E.coli.

Modelling was undertaken prior to the change in the national swimmability standards in mid-2017. Subsequently, the amended version of the National Policy Statement for Freshwater Management (NPSFM 2017) includes a requirement for swimmability categories to be determined off the last 5 years of *E.coli* sampling data, with a minimum of 60 samples.

The effect of this means in some situations the model may indicate a baseline swimming category that is different to the swimming category defined from observed data over the last 5 years. In addition, the calibration was focused on the observed means, 95th percentiles and medians, but the calibration did not attempt to replicate the numeric attribute state.

4.2 Riparian planting/Stock Exclusion

Stock exclusion was undertaken from BAU onwards. Excluding stock would lead to an increase in grass growth along the riparian margins, and likely would have some removal of *E.coli* from overland flow, represented as a reduction in EMC. However, the proportion of this was unknown, and for the purposes of scenarios no reductions to EMC's were applied during BAU scenarios, only Silver and Gold. Subsequently, the BAU 95th percentiles of *E.coli* will have a smaller proportionate change than Silver and Gold.

In addition, all riparian planting and stock exclusion was applied across the entire catchment, with no specific focus on a single locality or hot spot. Therefore, the effects could be considered as averaged over the area, when in reality certain catchments may be prioritized for restoration activities.

4.3 Mitigations on other landuse types

The Tier 1 and 3 mitigations were applied to the four landuse types evaluated in the agresearch Overseer trials. Subsequently, no *E.coli* reductions were applied to sheep or beef (as individual land classes, only land classified as 'sheep and beef'). These represent ~4% of the catchment area (**Table 1.2**). This also applies to all other farming types including mixed, lifestyle and deer. Applying mitigations to these landuses would likely increase the *E.coli* reductions observed in a number of catchments.

Additionally, no mitigations have been applied to any urban landuses within Ruamāhanga, representing ~2.3% of the catchment area (**Table 1.2**).

4.4 WWTP mitigations

The single value of 95% has been applied to all the WWTP and is driven by a study on the land treatment of Masterton's effluent water. This efficiency may vary depending on the WWTP loads, land available for treatment and mechanism of distribution. In the absence of data, this value is considered appropriate until new data verifies otherwise.

4.5 Flow calibration

Loads in the water quality model are driven by the flow generation. The Source model used flows from a range of inputs. The flow development framework includes:

- TOPNET (NIWA) provides total stream flow generated from the Hill catchments;
- Irricalc (Aqualinc) provides quickflow inputs from the plains catchments and irrigation surface water demands (unrestricted).
- MODFLOW-SFR-MT3D (GNS) system, developed in parallel to the Source model, provided groundwater flux and nitrate loads for input to river links (reaches);
- Point-source inputs (discharge and effluent concentrations) from five wastewater treatment plants (WWTP) derived from monitoring data and included as inflow nodes within the node-link network
- Surface water abstraction annual allocation and minimum low flow limits were modelled within Source and applied total daily abstraction (agglomerated per subcatchment) along the river links.

The subsequent calibration of these flows series was undertaken by each of the respective parties above, with Jacobs compiling the flow series in Source for the water quality modelling. At a number of sites, calibrations to observed data have often led to an over simulation of flow for many reaches. An accurate flow model is important to ensure generated loads are correctly attenuated. Subsequently, good calibrations of water quality data to observed information are increasingly difficult to achieve if the flows are inaccurate. This can impact on the baseline model and incorporate attenuation factors in catchments that may be higher or lower than in reality, which can then propagate through into scenarios.

In regards to swimmability criteria of a site, locations which have difficulty in calibration of *E.coli* (for the above reasons) can make it challenging to compare the observed data's swimming category against the simulated results. Hence, looking at the relative change between the scenarios is the appropriate way to examine the outcomes of mitigations.

5. Reporting point discussions

The following section describes the most significant results observed in the median and 95th percentiles and the swimming categories. This is described further relative to each of the 20 reporting sites. Descriptions of the results at the reporting sites focuses on the simulated outputs from scenarios, which provides an idea on the relative change due to the various mitigations applied.

In some situations, comparisons have been made against observed data (for sites where it exists), with more detailed analysis considered where the observed data indicates the site has a different swimming category than the simulated models suggest. The purpose of the modelling scenarios is to provide context on how effective the mitigations are relative to each reporting point, and understanding the percentage changes that occur.

5.1 Significant results

Table 5.1 and **Table 5.2** present the relative change of the *E.coli* median and 95th percentiles (derived off simulated concentrations), from the baseline simulation through all scenarios.

Table 5.3 presents the colour coded swimming categories based on the criteria in **Table 1.1** applied to scenario *E.coli* concentrations.

Table 5.1 : Percentage change from baseline for *E.coli* 50th (median) percentile concentrations

Site	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Huangarua Ponatahi Bridge	-14.8	-14.9	-14.9	-23.6	-29.2	-30.9	-28.2	-30.9	-30.9
Kopuaranga at Stuarts	-2.9	-2.9	-2.9	-8.5	-16.7	-19.4	-15.4	-19.4	-19.4
Makahakaha Stream Mouth	-24.7	-24.7	-24.7	-28.3	-31.5	-33.1	-30.8	-33.1	-33.1
Mangatarere at SH2	-63.1	-62.9	-61.5	-63.9	-65.3	-64.7	-65.1	-66.2	-64.7
Otukura Stream Mouth	-11.9	-11.9	-11.9	-14.7	-17.5	-20.4	-16.1	-20.4	-20.4
Parkvale Weir	-24.0	-24.0	-24.0	-24.7	-25.5	-26.3	-25.1	-26.3	-26.3
Rua US LWai Outlet	-18.0	-20.6	-20.6	-24.6	-29.9	-31.5	-28.8	-32.0	-31.5
Rua at Pukio	-19.4	-21.2	-21.2	-25.4	-30.7	-32.5	-29.8	-32.8	-32.5
Rua at Te Ore Ore	-4.2	-4.2	-4.9	-9.6	-16.4	-19.2	-15.2	-19.2	-19.2
Rua at Gladstone	-5.0	-5.0	-5.4	-10.2	-16.6	-19.1	-15.3	-19.2	-19.1
Rua at Waihenga	-18.9	-19.2	-19.1	-23.7	-28.7	-30.7	-27.8	-31.0	-30.7
Rua at Wardells	-5.8	-5.8	-6.0	-10.9	-17.1	-19.7	-15.9	-19.8	-19.7
Tauanui River Mouth	-4.6	-4.6	-4.6	-7.7	-11.3	-14.3	-9.9	-14.3	-14.3
Tauherenikau at Websters	-4.9	-4.9	-4.9	-5.7	-6.4	-7.1	-6.1	-7.1	-7.1
Taueru Gladstone Te Whiti	-4.7	-4.7	-4.7	-10.4	-17.8	-20.5	-16.5	-20.5	-20.5
Turanganui R Mouth	-11.8	-13.6	-13.6	-17.6	-20.3	-22.9	-19.1	-22.9	-22.9
Waingawa at South Rd	-9.3	-9.3	-10.2	-11.4	-13.5	-15.7	-12.5	-15.7	-15.7
Waiohine at Bicknells	-67.1	-66.8	-65.1	-67.8	-69.3	-69.0	-69.2	-70.1	-69.0

Site	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Waipoua at Colombo	-13.8	-13.8	-14.7	-18.3	-21.9	-24.2	-21.0	-24.2	-24.2
Whangaehu 250m Confluence	-0.1	-0.1	-0.1	-4.6	-9.1	-12.2	-7.7	-12.2	-12.2

Table 5.2 : Percentage change from baseline for *E.coli* 95th percentile concentrations

Site	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Huangarua Ponatahi Bridge	1.2	1.0	1.0	-8.8	-13.7	-16.5	-12.4	-16.5	-16.5
Kopuaranga at Stuarts	-0.3	-0.3	-0.3	-5.2	-12.9	-15.9	-11.6	-15.9	-15.9
Makahakaha Stream Mouth	-9.3	-9.3	-9.3	-14.1	-18.6	-21.1	-17.4	-21.1	-21.1
Mangatarere at SH2	-41.8	-40.4	-35.2	-42.5	-74.1	-72.7	-73.7	-74.3	-72.7
Otukura Stream Mouth	-0.9	-0.9	-0.9	-4.1	-7.3	-10.6	-5.8	-10.6	-10.6
Parkvale Weir	0.6	0.6	0.6	-2.6	-5.7	-9.0	-4.2	-9.0	-9.0
Rua US LWai Outlet	-0.3	-0.4	-0.4	-4.9	-9.4	-12.4	-7.9	-12.3	-12.4
Rua at Pukio	-0.4	-0.5	0.0	-5.6	-10.0	-12.6	-8.7	-12.6	-12.6
Rua at Te Ore Ore	-0.2	-0.2	-0.3	-3.2	-9.8	-12.8	-8.3	-12.8	-12.8
Rua at Gladstone	-1.0	-1.0	-1.1	-5.7	-11.6	-14.5	-10.3	-14.5	-14.5
Rua at Waihenga	-3.5	-3.5	-3.2	-9.5	-16.4	-19.1	-15.1	-19.1	-19.1
Rua at Wardells	-0.7	-0.7	-0.8	-5.6	-10.7	-13.4	-9.3	-13.4	-13.4
Tauanui River Mouth	-0.4	-0.4	-0.4	-3.8	-7.8	-11.1	-6.2	-11.1	-11.1
Tauherenikau at Websters	-0.1	-0.1	-0.1	-2.8	-5.5	-8.4	-4.2	-8.4	-8.4
Taueru Gladstone Te Whiti	-0.9	-0.9	-0.9	-6.9	-14.9	-17.9	-13.5	-17.9	-17.9
Turanganui R Mouth	-0.5	-2.5	-2.5	-7.2	-10.6	-13.9	-9.1	-13.9	-13.9
Waingawa at South Rd	-0.7	-0.7	-0.7	-3.1	-5.6	-8.1	-4.4	-8.1	-8.1
Waiohine at Bicknells	-46.3	-45.1	-40.5	-47.0	-70.8	-71.8	-70.3	-71.8	-71.8
Waipoua at Colombo	-0.6	-0.6	-1.4	-6.2	-10.2	-13.2	-8.9	-13.2	-13.2
Whangaehu 250m Confluence	-0.1	-0.1	-0.1	-5.4	-12.6	-15.5	-11.1	-15.5	-15.5

Table 5.3 : MFE swimming category changes at each site through the various scenarios (modelled results only)

Site	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Huangarua Ponatahi Bridge	Orange	Orange	Orange	Orange	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Kopuaranga at Stuarts	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Makahakaha Stream Mouth	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Mangatarere at SH2	Orange	Orange	Orange	Orange	Orange	Green	Green	Green	Green	Green
Otukura Stream Mouth	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
Parkvale Weir	Orange	Orange	Orange	Orange	Orange	Orange	Yellow	Orange	Yellow	Yellow
Rua US LWai Outlet	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Rua at Pukio	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Rua at Te Ore Ore	Orange	Orange	Orange	Orange	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Rua at Gladstone	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Rua at Waihenga	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Rua at Wardells	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Tauanui River Mouth	Orange	Orange	Orange	Orange	Blue	Blue	Blue	Blue	Blue	Blue
Tauherenikau at Websters	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Taueru Gladstone Te Whiti	Red	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
Turanganui R Mouth	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Waingawa at South Rd	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Waiohine at Bicknells	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Waipoua at Colombo	Green	Green	Green	Green	Green	Blue	Blue	Blue	Blue	Blue
Whangaehu 250m Confluence	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
Swimming Category	Blue		Green		Yellow		Orange		Red	

5.2 Huangarua at Ponatahi Bridge

Table 5.4 : Simulated concentrations and swimming category for Huangarua at Ponatahi Bridge

Scenario	50th Percentile (cfu/100mL) ***	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	156	1015	17	35
BAU 2025	133	1028	18	33
BAU 2040	133	1026	18	33
BAU 2080	133	1026	18	33
Silver 2025	119	926	16	29
Silver 2040	110	876	15	27
Silver 2080	110	876	15	27
Gold 2025	112	890	15	27
Gold 2040	108	847	14	26
Gold 2080	108	847	14	26

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

*** All 50th percentiles <130 cfu/100 mL are coloured as 'blue' category in the **Table 5.4** to **Table 5.23**. However, based on **Table 1.1**, this threshold is applied across three swimming categories (blue to yellow). The final simulated swimming category assigns the correct colour coding based on all four criteria.

Table 5.4 indicates that the modelled baseline swimming category at Ponatahi Bridge is considered to be '**orange**'. This is driven by a 50th percentile >130 cfu/100 mL (156 cfu/100 mL) and the percentage (35%) of exceedances >260 cfu/100 mL. The 95th percentiles sit within the 'yellow' swimming category.

The catchment is ~84% sheep and beef, and the remainder primarily native bush. There is no change in swimmability in this site between baseline and BAU scenarios. However, retirement in BAU (of 107 ha) and stock exclusion results in a ~14.9% reduction to the median percentiles (by 2080), with a value of 133 cfu/100 mL (**Table 5.4**). The 95th percentiles have had little change, as no mitigations are applied to the EMC's in BAU.

The median concentrations in BAU (3 cfu/100 mL above the threshold) are the only cause for the site remaining an '**orange**' swimming category. Given the model calibration slightly overestimates the median concentrations, and general inaccuracies with model flow and assumptions described in **Section 4**, it could be assumed the BAU scenarios could change to a '**yellow**' swimming category.

Throughout the Silver and Gold scenarios, this site changes to a '**yellow**' swimming category. Due to 3,239 ha of retirement by 2080 (in both scenarios) and riparian planting (reducing *E.coli* EMC's), a significant reduction in the median and 95th percentiles has been simulated (up to 30.9% and 16.5% respectively). See **Table C.1**, **Table 5.1** and **Table 5.2**.

Subsequently, by 2025 in both scenarios, the medians are within the '**blue**' swimming category and the 95th and percentage of exceedances >260 cfu/100 mL are considered '**green**'. The only value keeping the sites overall category '**yellow**' is the number of exceedances >540 cfu/100 ml (see Table 5.4). A ~5–6% reduction in this value (not achieved in these simulations) would result in the site changing to a '**green**' swimming category in Silver and Gold.

5.2.1 Comparison to observed data

The observed data for the last 5 years has a median and 95th *E.coli* percentile of 80 and 495 cfu/100 mL. Exceedances >540 and 260 cfu/100 mL are 5 and 13.3% respectively. This data indicates the most current water state for Huangarua River is '**green**'.

E.coli was not calibrated for at this site, and was based off inputs and assumptions from other catchments. In addition, flow inputs from Topnet were not always well calibrated for some catchments. Subsequently the model is over-predicting both medians and 95th concentrations.

The criteria which characterizes this site as 'green' is driven by the number of exceedances >540 cfu/100 mL. Applying the proportionate changes observed in **Table 5.1** and **Table 5.2,** BAU 2025 would lower medians by 14.9% while Silver 2025 would lower medians and 95th percentiles by 23.6% and 8.8%. It could be assumed both these scenarios would lead to transition into the '**blue**' swimming category.

5.3 Kopuaranga at Stuarts

Table 5.5 : Simulated concentrations and swimming category for Kopuaranga at Stuarts

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	481	2377	47	61
BAU 2025	467	2369	46	60
BAU 2040	467	2369	46	60
BAU 2080	467	2369	46	60
Silver 2025	440	2253	45	60
Silver 2040	401	2069	42	58
Silver 2080	388	2000	41	58
Gold 2025	407	2102	43	58
Gold 2040	388	2000	41	58
Gold 2080	388	2000	41	58

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

Table 5.5 indicates that the modelled baseline swimming category at Kopuaranga at Stuarts is considered to be '**red**'. This is driven by all four criteria being above the threshold that would move a site into the 'orange' category (see **Table 1.1** for an understanding of the thresholds). The swimmability of Stuarts does not change from the baseline through all scenarios.

The catchment is ~85% sheep and beef, ~8% dairy and dairy support, and the remainder primarily native, plantation bush and 'other' landuse classes (**Table A.1**).

Through the BAU scenarios, there is no retirement occurring within this catchment (see **Table C.1**). Subsequently, the only mitigations are through stock exclusion lowering DWC's, which results in a 2.9%

reduction in median percentiles. The frequent high simulated loads that contribute to the high 95th percentiles buffer out the effectiveness of this mitigation on the median results.

Through Gold and Silver, retired land peaks at 1,068 ha within the catchment. Coupled with a 10% reduction applied to the EMC's through riparian buffer strips (see **Section 3.2**), this contributes to a 15.4–19.4% reduction in medians and up to 15.9% reduction in 95th percentiles (**Table 5.1** and **Table 5.2**).

These reductions in *E.coli* due to mitigations do not lead to a change in any of the simulated swimming criteria required to improve the site to an '**orange**' category in the simulated results.

5.3.1 Comparison to observed data

The observed water quality data for the site from the last 5 years of records has a median of 180 cfu/100 mL and 95th percentile of 1,800 cfu/100 mL. The simulated baseline has a higher median and 95th of 481 cfu/100 mL and 2,377 cfu/100 mL.

In addition, the exceedances above 540 and 260 cfu/100 mL are 21.7% and 33.3%. The observed data would classify the site as an '**orange**' swimming category.

If the overall percentage reductions in in-stream E.coli concentrations (i.e. the 8.5 – 19.4% reductions in 95th percentiles in Gold and Silver scenarios) were applied to the observed data, the high 95th concentrations at this site would not change from the '**orange**' swimming category, similar to the simulated results (albeit a different category).

5.4 Makahakaha Stream Mouth

Table 5.6 : Simulated concentrations and swimming category for Makahakaha Stream Mouth

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	74	122	0	0
BAU 2025	56	111	0	0
BAU 2040	56	111	0	0
BAU 2080	56	111	0	0
Silver 2025	53	105	0	0
Silver 2040	51	100	0	0
Silver 2080	50	96	0	0
Gold 2025	51	101	0	0
Gold 2040	50	96	0	0
Gold 2080	50	96	0	0

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

Table 5.6 indicates that the modelled baseline swimming category at Makahakaha Stream Mouth is considered to be '**blue**'.

It is worth noting that there is no observed data for this site to inform model calibration. Therefore, the simulated loads are based off appropriate input concentrations for similar landuses in nearby catchments. The median and 95th percentiles are low in this catchment and remain low through all scenarios. Significant reductions in *E.coli* are observed in BAU due to stock exclusion, (see **Section 3.1**), applied to ~83% of the catchment area, has reduced median percentiles.

5.5 Mangatarere at SH2

Table 5.7 : Simulated concentrations and swimming category for Mangatarere at SH2

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	212	2174	21	43
BAU 2025	78	1265	8	21
BAU 2040	79	1295	8	21
BAU 2080	82	1409	8	22
Silver 2025	76	1251	8	20
Silver 2040	73	564	5	18
Silver 2080	75	593	5	18
Gold 2025	74	571	5	18
Gold 2040	72	560	5	17
Gold 2080	75	593	5	18

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

Table 5.7 indicates that the modelled baseline swimming category at Mangatarere River at SH2 is considered to be '**orange**'. This category is maintained until Silver 2040 where the swimming category changes to '**green**'.

Throughout the BAU scenarios, three of the four swimming criteria (excluding the 95th percentile) change from an '**orange**' swimming category to '**blue**' and '**green**' (see **Table 5.7**). This is driven by stock exclusion on ~26% of dairy/dairy support and 21% of sheep and beef area in the catchment (**Table A.1**). The remaining >50% of the area is primarily native and plantation forest. While stock exclusion helps lower the medians, the most significant cause for the reductions in *E.coli* concentrations is due to the land treatment of the Carterton WWTP.

As described in **Table 2.1**, the Carterton WWTP had a planned land treatment of 35% of outputs by 2025 and 60% by 2080 in BAU. However, the flow controls that were advised by the committee and applied in the modelling were too restrictive to allow regular discharge to water. When discharge to water could not occur, the output was considered to be land treated.

Ultimately, through BAU 2025 to 2080 the discharge ratio (land to water) was 85:15, meaning the Carterton WWTP has a significant amount of its effluent water treated by land. This is why median percentiles decrease between 63 and 66% through BAU, Silver and Gold scenarios (**Table 5.1**). Reductions of up to 41% are observed in the 95th percentiles through the BAU, however the 95th percentiles remain in the '**orange**' category (>1,200 cfu/100 mL) until Silver 2040. The change in 2040 is due to the 100% land treatment of Carterton WWTP (**Table 2.2**) and the 6.6% reduction to *E.coli* EMC's due to riparian planting (**Table 3.1**).

From Silver 2040 and through all Gold scenarios, the Mangatarere River at SH2 falls into a swimming category of '**green**'. This would fall into a '**blue'** swimming category, if the 95th percentiles decreased a further ~30-50 cfu /100 mL (5-7%). The effects of the land treatment at Carterton propagate downstream and is evident in the Waiohine River at Bicknells (**Section 5.19**).

5.5.1 Comparison to observed data

The observed data for this site results in median concentrations of 140 cfu/100 mL, and the 95th percentiles are 1,050 cfu/100 mL. The baseline calibration overestimates medians and the 95th concentrations (212 and 2,174 cfu/100 mL, respectively). However, the high observed median values >130 cfu/100 mL result in a swimming category of '**orange**', consistent with the scenario modelling.

Applying the median and 95th reductions obtained through the BAU scenario modelling (61% and 40%) to the observed data (**Table 5.1** and Table 5.2), would indicate that the site is likely to transition into a '**green**' swimming category if the land treatment of Carterton WWTP went ahead in that timeframe (and at the rate described). The medians would drop below 130 cfu/100 mL, and the 95th percentile would be ~630 cfu/100 mL.

In Silver 2025, 95th percentiles have declined up to 73% (primarily due riparian planting), which would move the site into a '**blue**' category when the same modelled reductions are applied to observed data.

5.6 Otukura Stream Mouth

Table 5.8 : Simulated concentrations and swimming category for Otukura Stream Mouth

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	24	3592	9	10
BAU 2025	21	3560	9	10
BAU 2040	21	3560	9	10
BAU 2080	21	3560	9	10
Silver 2025	20	3445	8	10
Silver 2040	20	3329	8	9
Silver 2080	19	3211	8	9
Gold 2025	20	3385	8	9
Gold 2040	19	3211	8	9
Gold 2080	19	3211	8	9

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

The Otukura Stream Mouth is an uncalibrated, ungauged catchment in regards to flow and water quality. However the *E.coli* parameters that are applied to this catchment are based off nearby calibrated sites (i.e. Tauherenikau at Websters).

The baseline (**Table 5.8**) modelled swimming category is considered to be '**orange**', due to the high 95th percentiles of 3,592 cfu/100 mL, with the remaining criteria in the **blue** and **green** category. This catchment is ~9,365 ha, predominantly made up of 55.7% dairy/dairy support, 17% sheep and beef, and the remaining area

considered to be 'other', a mixture of landuses such as lifestyle, deer, mixed, equine, sheep and/or beef (**Table A.1**).

BAU simulations primarily influence DWC's and median values, which is why stock exclusion and effluent management only leads to a 0.9% decrease in BAU 95th percentiles from baseline. Silver and Gold results in a decrease in the 95th percentiles of up to 10.6%, however this is not significant enough to drop below the 1,200 cfu/100 mL threshold required to move the site to **yellow** swimming category (**Table 5.2**).

5.7 Parkvale Weir

Table 5.9 : Simulated concentrations and swimming category for Parkvale Weir

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	7	1311	6	6
BAU 2025	5	1319	6	6
BAU 2040	5	1319	6	6
BAU 2080	5	1319	6	6
Silver 2025	5	1277	6	6
Silver 2040	5	1236	6	6
Silver 2080	5	1193	6	6
Gold 2025	5	1256	6	6
Gold 2040	5	1193	6	6
Gold 2080	5	1193	6	6

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

The Parkvale catchment is ~5,000 ha. ~36% of the area is dairy and dairy support, while 19.5% is sheep and beef. The remaining ~44.5% is a mixture of a variety of landuses (mixed, lifestyle, deer, sheep and beef etc) (**Table A.1**). The baseline model simulations (**Table 5.9**) characterize the site as '**orange**', due to the high 95th percentiles.

Throughout BAU, the median concentrations decrease by ~24% due to stock exclusion and dairy effluent management (**Table 5.1**). There is no land retirement in the catchment. There is a slight increase in the 95th percentile (**Table 5.2**), which is most likely due to a reduction in flow in the catchment driven by groundwater model simulations applying maximum abstraction rates (when through the baseline this ramped up over time). Hence, lower flow can lead to higher concentrations.

Riparian planting in Silver and Gold decrease the EMC's and subsequently the 95th percentiles up to 9%. This results in a category change to '**yellow**' in the simulations (**Table 5.3**).

5.7.1 Comparison to observed data

Calibration was undertaken upstream of the weir at Lowes Reserve, which has a significantly lower observed *E.coli* than the weir location (median and 95th of 16 and ~78.5 cfu/100 mL respectively).The observed data at Parkvale Weir shows the median and 95th are ~340 and 1,710 cfu/100 mL.

The baseline model (**Table 5.9**) at Parkvale Weir under-predicts *E.coli,* with a median of 7 cfu/100 mL, and a 95th of 1,311 cfu/100 mL, resulting in an '**orange**' swimming category. Calibration at this site was difficult (see **Section 4.5**) and influences the simulated swimming categories described in **Section 5.7**.

The observed data at Parkvale Weir would be considered a '**red**' swimming category, driven by the high median and also exceedances >260 cfu/100 mL at 62.7%.

If the relative changes (~24% decrease) observed in **Table 5.1** were applied to the observed 50th percentiles at Parkvale Weir, then a value of 258.4 cfu/100 mL would be obtained (under the BAU scenarios). This would lower the median into an 'orange' threshold, however the site is likely to stay in the '**red**' category due to the high amount of observed samples >260 cfu/100 mL. This criteria would require the number of higher concentration *E.coli* samples (>260 cfu/100 mL) to decrease by >12.7%, which may be achievable with reductions in both the median and 95th percentiles observed in Silver and Gold scenarios.

5.8 Ruamāhanga upstream of Lake Wairarapa Outlet

Table 5.10 : Simulated concentrations and swimming category for Ruamāhanga U/S of Lake Wairarapa Outlet

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	54	954	8	16
BAU 2025	44	951	8	15
BAU 2040	43	950	8	15
BAU 2080	43	951	8	15
Silver 2025	41	907	8	14
Silver 2040	38	865	7	13
Silver 2080	37	836	7	13
Gold 2025	38	879	7	13
Gold 2040	37	836	7	13
Gold 2080	37	836	7	13

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

This site is located upstream of the confluence between the Ruamāhanga River and the outflow from Lake Wairarapa (see **Figure B.1**). It is also upstream of the confluence of Tauanui River. It is the most lowland reporting site (excluding Lake Onoke).

The baseline simulation for this site results in a swimming category of '**green**' (see **Table 5.10**). This does not change through all scenarios. Similar trends in concentrations as observed in other reporting sites also occur at this location, with a significant reduction to median percentiles through the BAU to Gold due to stock exclusion, dairy effluent management and WWTP mitigations, while 95th percentiles primarily decrease in Silver and Gold as land retirement (11,088 ha by Silver/Gold 2080) and riparian planting come into effect (**Table C.1**).

Two criteria remain in the '**green**' category through all simulations. These are the 95th percentiles >540 cfu/100 mL and the number of exceedances that exceed 540 cfu/100 mL, 5–10% of the time (see **Table 5.10** as an example).

5.9 Ruamāhanga at Pukio

Table 5.11 : Simulated concentrations and swimming category for Ruamāhanga at Pukio

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	72	851	8	18
BAU 2025	58	847	8	16
BAU 2040	57	846	8	16
BAU 2080	57	850	8	16
Silver 2025	54	803	7	15
Silver 2040	50	766	7	14
Silver 2080	49	743	7	14
Gold 2025	51	777	7	14
Gold 2040	49	743	7	14
Gold 2080	49	743	7	14

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

Pukio is upstream of the Wairarapa Outlet reporting site. This site has a '**green**' swimming category under the baseline simulations and does not change through scenarios (**Table 5.11**).

Through BAU simulations, median *E.coli* reduces by ~19 to 21%, and up to 32.8% in Gold 2040 (see **Table 5.1**). The 95th percentiles change little in BAU, however riparian planting, retirement (of 10,808 ha by Silver/Gold 2080) and WWTP mitigations result in decreases in the 95th of up to 12% (**Table 5.2**). There is no change in the swimming category in simulated scenarios for Pukio (remaining '**green**' throughout the scenarios).

5.9.1 Comparison to observed data

Observed *E.coli* data at Pukio indicate the median and 95th percentiles are 47 and 800 cfu/100 mL respectively. The baseline calibration (**Table 5.11**) resulted in a median of 72 and 95th of 851 cfu/100 mL. The observed data would characterize the site as a '**green**' category, as simulated in the baseline model. Lowering of the observed 95th percentile by 12% (based off the simulated Silver and Gold % reduction in concentrations in **Table 5.2**) would still result in an '**green**' swimming category.

5.10 Ruamāhanga at Te Ore Ore

Table 5.12 : Simulated concentrations and swimming category for Ruamāhanga at Te Ore Ore

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	133	1218	14	32
BAU 2025	128	1215	14	31
BAU 2040	128	1215	14	31
BAU 2080	127	1214	14	31
Silver 2025	121	1179	13	30
Silver 2040	111	1099	12	27
Silver 2080	108	1062	11	27
Gold 2025	113	1116	12	28
Gold 2040	108	1062	11	27
Gold 2080	108	1062	11	27

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

Te Ore Ore has an '**orange**' swimming category in the baseline and BAU simulations (**Table 5.12**), due to median and 95th percentiles of 133 and 1,218 cfu/100 mL. The calibration for this site was good, with a slight overestimation of the median values and underestimation of the 95th percentile.

Only a ~4% reduction is observed in median concentrations through BAU. While ~57% of the area draining to Te Ore Ore is sheep and beef, the 44% mitigation applied to this land-use's DWC's subsequently have minimal impact on the total load (**Table A.1**). Retirement of 1,244 ha in Silver and Gold, and EMC reductions due to riparian planting help to lower the medians up to 19.2%, and the 95th up to 12.8% (**Table 5.1** and **Table 5.2**).

This results in the simulated swimming category changing to '**yellow**' from Silver 2025 onwards, primarily due to the 95th percentile dropping below the 1,200 cfu/100 mL threshold (**Table 5.12**).

5.10.1 Comparison to observed data

The observed data results in a median of 75 cfu/100 mL and 95th percentile of 1,250 cfu/100 mL. This would also be categorized as an '**orange**' swimming site.

If the equivalent Silver and Gold 12.8% reduction in concentrations (see **Table 5.2**) were applied to the observed 95th percentile, a value of 1,090 cfu/100 mL would be obtained. This would result in the site improving to a '**yellow**' category, similarly indicated by the scenario modelling results.

5.11 Ruamāhanga at Gladstone

Table 5.13 : Simulated concentrations and swimming category for Ruamāhanga at Gladstone

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	98	657	7	22
BAU 2025	93	650	7	22
BAU 2040	93	650	7	22
BAU 2080	93	650	7	22
Silver 2025	88	619	6	20
Silver 2040	82	581	6	19
Silver 2080	80	561	5	18
Gold 2025	83	589	6	19
Gold 2040	79	561	5	18
Gold 2080	80	561	5	18

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

Table 5.13 indicates the simulated swimming category at the Gladstone Bridge is considered to be '**green**' throughout the scenarios and in the baseline model.

Silver and Gold scenarios result in a maximum reduction of 19.1% to the medians, and 14.5% to the 95th percentile (**Table 5.1** and **Table 5.2**). The higher reduction in the 95th percentile concentrations is driven by land retirement (6,337 ha in Silver and Gold 2040), riparian planting and also the 100% land treatment of the Masterton WWTP.

While these reductions are significant, they are not sufficient to result in a swimming category change to '**blue**'.

5.11.1 Comparison to observed data

The observed data for this site has a median and 95th percentile of 35 and 2,550 cfu/100 mL. The baseline model overestimates the median and substantially under predicts the 95th percentile concentrations (with values of 98 and 657 cfu/100 mL, respectively). There were difficulties in calibrating this site, given median concentrations are small, however discrete events of high *E.coli* concentrations lead to large 95th percentiles. The observed data would classify this site as a '**orange**', solely due to the high 95th percentiles. The other three observed swimming criteria all fall within a 'green and blue' category.

Applying 14.5% reductions (as simulated in Silver and Gold in **Table 5.2**) to the 95th observed percentiles would indicate and '**orange**' swimming category would remain for this site.

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5.12 Ruamāhanga at Waihenga

Table 5.14 : Simulated concentrations and swimming category for Ruamāhanga at Waihenga

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	73	494	4	17
BAU 2025	59	477	4	14
BAU 2040	59	477	4	14
BAU 2080	59	478	4	14
Silver 2025	56	447	3	13
Silver 2040	52	413	3	12
Silver 2080	50	400	3	11
Gold 2025	53	419	3	12
Gold 2040	50	400	3	11
Gold 2080	50	400	3	11

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

Table 5.14 show that simulations of Waihenga result in a '**blue**' swimming category, which is maintained through all scenarios. The median and 95th simulated baseline percentiles are 73 and 494 cfu/100 mL. **Table 5.1** and **Table 5.2** show median percentiles decrease up to 20% in BAU, and up to 31% in Gold and Silver scenarios. 95th percentiles decrease a maximum of 19.1% in Silver and Gold.

5.12.1 Comparison to observed data

Waihenga is a significant calibration site within the catchment in regards to flow and suspended sediment concentration (SSC). Waihenga also has a limited number of recent *E.coli* samples (~10) that allow for some comparison to observed data.

The observed percentiles are 38 and 440 cfu/100 mL (median and 95th). This is similar to the baseline model calibration, resulting in a '**blue**' category.

5.13 Ruamāhanga at Wardells

Table 5.15 : Simulated concentrations and swimming category for Ruamāhanga at Wardells

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	111	1001	13	29
BAU 2025	105	994	13	29
BAU 2040	105	994	13	29
BAU 2080	105	993	13	29
Silver 2025	99	945	12	27
Silver 2040	92	894	11	26
Silver 2080	89	867	11	25
Gold 2025	94	908	11	26
Gold 2040	89	867	11	25
Gold 2080	89	867	11	25

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

Wardells is downstream of Te Ore Ore and the Masterton WWTP. The close proximity of these sites to one another allow the land treatment mitigations applied to Masterton WWTP to be identified before additional large tributaries flow in and the effects become 'buffered' due to greater volumes.

Table 5.15 indicate Wardells is considered a '**yellow**' swimming category throughout the simulations. This is driven by 95th percentile >1,000 cfu/100 mL and the percentage of exceedances >540 cfu/100 mL.

Unfortunately, no *E.coli* observed data exists at Wardells to compare the swimming categories to simulated results. In regards to scenarios (see **Table 5.1** and **Table 5.2**), the median percentiles decreased by up to 19.8%, and the 95th percentile by 13.4% (Silver and Gold 2040). Lowering of the 95th percentiles was due to 225 ha retirement in BAU, and 3,007 ha of retirement in Gold and Silver (**Table C.1**). In addition, riparian planting and land treatment of the WWTP helped decrease the 95th.

This resulted in the 95th percentiles dropping into the '**green**' category from BAU 2025 onwards (**Table 5.15**), however the number of exceedances >540 cfu/100 mL remained between 10-15% throughout all simulations. This is the primary reason the sites swimming category does not have an overall change to 'green' (remaining '**yellow**'), although is close by Silver 2040 and Gold 2025 (with the exceedances sitting at 11%, on the lower end of the yellow threshold).

The impact of land treatment from the WWTP is evident in BAU, Gold and Silver. Between Te Ore Ore and Wardells, the Whangaehu flows in as a tributary to the Ruamāhanga. Median *E.coli* reductions in BAU are only 0.1% for this site (**Table 5.1**) while the change between Te Ore Ore and Wardells in the median values is ~1.6%. It could be assumed this additional reduction in *E.coli* at Wardells is due to land treatment at Masterton and localized catchment mitigations.

Through Gold and Silver, the difference in *E.coli* reductions between Te Ore Ore and Wardells is smaller, approximately 0.6% (in both median and 95th percentiles). This is likely due to the significant amount of retirement and riparian planting that is occurring upstream of this site, which may buffer out the effects of land treatment by the WWTP that may contribute a smaller load to the river than farming practices.

5.14 Tauanui River Mouth

Table 5.16 : Simulated concentrations and swimming category for Tauanui River Mouth

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	138	525	5	19
BAU 2025	131	523	5	18
BAU 2040	131	523	5	18
BAU 2080	131	523	5	18
Silver 2025	127	505	4	17
Silver 2040	122	484	4	16
Silver 2080	118	467	4	15
Gold 2025	124	492	4	16
Gold 2040	118	467	4	15
Gold 2080	118	467	4	15

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

The Tauanui River Mouth has an '**orange**' swimming category (**Table 5.16**) through baseline and BAU simulations. This changes to '**blue**' (a significant three category change) by Silver and Gold (2025 onwards).

The reason for the **'orange**' category is due to a high median percentile exceeding 130 cfu/100 mL (see **Table 5.16**). The baseline median is 133 cfu/100 mL, and this decreases to 131 cfu/100 mL during BAU, primarily due to stock exclusion (as no land retirement occurs in this catchment).

No observed *E.coli* water quality data exists for this river. The catchment is ~4,155 ha with ~61% Native Bush (**Table A.1**), and it would be expected that given the significant native forest areas, which generally have low *E.coli* concentrations, a greater swimmability category may be expected., however field testing would be required to verify this.

5.15 Tauherenikau at Websters

Table 5.17 : Simulated concentrations and swimming category for Tauherenikau at Websters

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	2	120	4	4
BAU 2025	2	120	4	4
BAU 2040	2	120	4	4
BAU 2080	2	120	4	4
Silver 2025	2	117	4	4
Silver 2040	2	113	4	4
Silver 2080	2	110	3	4
Gold 2025	2	115	4	4
Gold 2040	2	110	3	4
Gold 2080	2	110	3	4

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

This site was a calibration location in the baseline model. The river flows into Lake Wairarapa, and through all the simulations was considered a '**blue**' swimming category (see **Table 5.17**).

Low percentiles are expected for the Tauherenikau River, as the catchment is primarily native forest (>85%), with loads generated mainly from the ~4.6% dairy and 6.5% sheep and beef land areas (**Table A.1**).

The threshold for the median and 95th percentiles for the '**blue**' category allows for values of ≤130 and ≤540 cfu/100 mL. The most likely criteria that would raise this site to a '**green**' category is the percentage of exceedances >540 cfu/100 mL. Through baseline simulations, this was ~4%, where values >5% would result in change in swimming category.

Subsequently, this indicates the site is suitable for swimming in regards to primary contact recreation, however infrequent events can occur which have resulted in observed *E.coli* levels of up to 1,000 cfu/100 mL.

5.15.1 Comparison to observed data

The observed water quality data for this site indicate median and 95th percentiles are 19 and 230.5 cfu/100 mL. The baseline calibration under-predicted these results, with a median and 95th of 2 and 120 cfu/100 mL (**Table 5.17**). However, given the low percentiles exhibited in the observed data, this is considered a good calibration, resulting in the modelled and observed data having the same swimming category.

5.16 Taueru Gladstone Te Whiti

Table 5.18 : Simulated concentrations and swimming category for Taueru River at Gladstone Bridge

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	265	763	14	51
BAU 2025	252	756	13	48
BAU 2040	252	756	13	48
BAU 2080	252	756	13	48
Silver 2025	237	710	11	44
Silver 2040	218	650	9	39
Silver 2080	210	627	8	37
Gold 2025	221	660	9	40
Gold 2040	210	627	8	37
Gold 2080	210	627	8	37

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

The Taueru River at Gladstone Bridge is a large catchment (~493 km^2) with flow generated primarily from TOPNET runoff. Flow calibrations at this site were average to poor, which subsequently made water quality and *E.coli* calibrations difficult.

The baseline calibration produced medians and 95th percentiles of 265 and 763 cfu/100 mL

The baseline simulated median percentiles push this site into a '**red**' category (see **Table 5.18**), due to the median levels exceeding 260 cfu/100 mL and the number of exceedances >260 cfu/100 mL at 51%.

The model is consistently over-predicting the *E.coli* load which leads to the '**red**' swimming category. The catchment is ~80.5% sheep and beef with a mixture of other landuses including plantation and native forest, arable farming and dairy (**Table A.1**).

BAU simulations result in the sites category changing from red to '**orange**', which is maintained for the remainder of the scenarios (**Table 5.18**). Stock exclusion decreases applied to DWC's (see **Section 3.1**) lower the median by ~4.7% (**Table 5.1**) and subsequently the exceedances >260 cfu/100 mL below the red category threshold.

Significant land retirement occurs in Silver and Gold, totaling 3,008 ha by 2080 (**Table C.1**). Coupled with riparian planting lowering EMC's, up to 20.5% and 17.9% reductions are observed on the median and 95th percentiles (**Table 5.1** and **Table 5.2**).

5.16.1 Comparisons to observed data

The observed *E.coli* data at this site indicate a median and 95th percentile of 110 and 1,033 cfu/100 mL. This site would be considered a '**yellow**' swimming category due to 95th percentiles falling within the range of 1000–1200

cfu/100 mL (see thresholds in **Table 1.1**). The remaining observed criteria (median and exceedances >260 and 540 cfu/100 mL) fall into 'blue' and 'green' categories.

Applying the 17.9% reduction derived from Silver and Gold scenario modelling (**Table 5.2**) to the observed 95th percentiles would produce a value of 848 cfu/100 mL. Hence this could indicate the observed 95th percentiles could decrease and the site may improve into the '**green**' category.

5.17 Turanganui River Mouth

Table 5.19 : Simulated concentrations and swimming category for Turanganui River Mouth

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	76	580	7	25
BAU 2025	67	577	7	25
BAU 2040	66	565	6	24
BAU 2080	66	565	6	24
Silver 2025	63	538	5	23
Silver 2040	61	518	4	22
Silver 2080	59	499	3	21
Gold 2025	61	527	4	23
Gold 2040	59	499	3	21
Gold 2080	59	499	3	21

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

Turanganui River Mouth is one of the most southern catchments in the model, draining into Lake Onoke. No water quality data exists for this site for calibration purposes, however the Tauanui River at Whakatomotomo Road (see **Figure B1**) was used as a reference during calibrations.

The river has a '**green**' swimming category throughout all simulations (including the baseline). See **Table 5.19**. During the baseline simulation, only the median percentiles sit within the 'blue' category, with the remaining criteria considered 'green' (**Table 5.19**). The catchment is ~70.5% forest, ~24.5% sheep and beef and ~5% dairy/dairy support (**Table A.1)**.

BAU modelling results in an 11.8% decrease in the median percentiles due to stock exclusion and 152 ha of retirement (**Table C.1**), indicating the significance of these mitigations are greater due to the higher proportion of total load being generated from the smaller amount of dairy and sheep and beef (**Table 5.1**). However, throughout BAU scenario none of the three criteria in the 'green' threshold decrease to 'blue'.

This occurs in Silver and Gold (from 2025 onwards), due to the addition of riparian planting lowering EMC's. Only one criteria remains in the '**green**' threshold for the site; the percentage of exceedances >260 cfu/100 mL (see **Table 5.19**). A decrease of 1-2% for this criteria would mean the entire site would be considered a 'blue' swimming category, based off simulated data.

5.18 Waingawa River at South Rd

Table 5.20 : Simulated concentrations and swimming category for Waingawa River at South Road

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	18	172	3	4
BAU 2025	17	171	3	4
BAU 2040	17	171	3	4
BAU 2080	17	171	3	4
Silver 2025	16	167	3	4
Silver 2040	16	162	3	4
Silver 2080	16	158	3	4
Gold 2025	16	164	3	4
Gold 2040	16	158	3	4
Gold 2080	16	158	3	4

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

The Waingawa River is a '**blue**' swimming site throughout all scenarios (including the baseline). See **Table 5.20**. All criteria remain well below the thresholds that would move the site into a 'green' category.

It should be noted that the reporting site for this location is not located at 'South Road', but is ~5 km downstream at the outlet of the river (where it joins with Ruamāhanga). The reporting point had to be moved to this location as the catchment had been delineated ~2-3 years ago and was used in flow calibrations. Subsequently, the flows, loads and water quality in the model can only be reported at catchment outflow points, which unfortunately did not co-inside with the long term water quality monitoring site. Essentially this additional area covers another 638 ha of lowland farming (and the braided river itself).

The catchment has ~82% native forest, which is the primary mechanism for low *E.coli* percentiles (**Table A.1**).

5.18.1 Comparison to observed data

Observed water quality data at South Road indicate median and 95th percentiles are very low, 14 and 260 cfu/100 mL respectively. This is consistent with the modelled baseline data (downstream), where a slightly lower 95th were simulated (18 and 172 cfu/100 mL). While the model is slightly underestimating the *E.coli* 95th percentiles, overall both the observed and simulated data show this is a '**blue**' swimming category and will improve in terms of water quality through all the scenarios (see **Table 5.1** and **Table 5.2**).

5.19 Waiohine River at Bicknells

Table 5.21 : Simulated concentrations and swimming category for Waiohine River at Bicknells

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	24	677	7	11
BAU 2025	8	363	3	6
BAU 2040	8	372	4	6
BAU 2080	8	403	4	6
Silver 2025	8	359	3	6
Silver 2040	7	198	3	4
Silver 2080	8	191	3	4
Gold 2025	7	201	3	5
Gold 2040	7	191	3	4
Gold 2080	8	191	3	4

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

The Waiohine River at Bicknells is located at the catchment outlet, prior to joining with the Ruamāhanga River. The Mangatarere River at SH2 joins the Waiohine ~5 km upstream of the reporting point. This means the mitigations applied to Carterton WWTP will be captured (albeit diluted) within the *E.coli* results at Bicknells. See **Section 5.5** for a description on Mangatarere at SH2.

The swimmability of this site is '**green**' during the baseline simulation, changing to '**blue**' in BAU (and for the remainder of all scenarios modelled). See **Table 5.21**. The 95th percentiles and the exceedances >540 cfu/100 mL are the primary reason for the sites 'green' category in the baseline results.

Significant reductions of >60% are observed in the median and 95th percentiles at Bicknells, primarily due to the land treatment of the Carterton WWTP. These effects propagate downstream, coupled with fencing in BAU and riparian planting in Gold and Silver. No land retirement occurs upstream of this reporting site.

~4% of the median percentiles changes in BAU are likely due to stock exclusion within the catchment, with the remainder driven by the WWTP mitigations (see **Table 5.1**).

5.19.1 Comparison to observed data

Observed data for Bicknells shows the median and 95th percentiles are 47 and 215 cfu/100 mL. The baseline model produced values of 24 and 677 cfu/100 mL for the same criteria.

Further assessment of the observed data for Bicknells shows the percentage of exceedances >540 and >260 cfu/100 mL are ~1.7% and 3.3%. This indicates that all four swimmability criteria for the 'observed' data would characterize the site as a '**blue**' category, rather than '**green**' as per the baseline.

5.20 Waipoua River at Colombo Road Bridge

Table 5.22 : Simulated concentrations and swimming category for Waipoua River at Colombo Road Bridge

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	62	573	6	23
BAU 2025	54	570	6	22
BAU 2040	54	570	6	22
BAU 2080	53	565	5	22
Silver 2025	51	537	5	20
Silver 2040	49	515	5	19
Silver 2080	47	497	4	18
Gold 2025	49	522	5	20
Gold 2040	47	497	4	18
Gold 2080	47	497	4	18

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

Table 5.22 indicates the Waipoua River is a '**green**' swimming category through baseline, BAU and Silver 2025 scenarios. This site was a model calibration point.

In BAU, a 14.7% reduction in median values is observed by 2080 (**Table 5.1**). This is due to stock exclusion and 163 ha of land retirement (**Table C.1**). Minimal reductions of the 95th percentiles in BAU scenarios (1-2%) are due to the absence of mitigations applied to EMC's, meaning the higher event based loads remain relatively unchanged.

Silver and Gold scenarios incorporate more land retirement (>400 ha) and reduction to EMC's due to riparian planting. By Silver 2040, the site has shifted to a '**blue**' category for the remainder of model simulations (**Table 5.22**).

5.20.1 Comparison to observed data

The observed data results in a median and 95th percentile of 41.5 and 950 cfu/100 mL. While the baseline simulates the median well (62 cfu/100 mL), it tends to under-predict the 95th percentiles (573 cfu/100 mL). The observed data's percentage of exceedances >540 cfu/100 mL is ~8.3%, meaning this criteria (and the 95th percentiles) result in the site being a '**green**' swimming category, in line with the baseline simulation

A maximum reduction of 13.2% is observed on the 95th percentiles in Silver and Gold scenarios (see **Table 5.2**). Applying this proportionate change to the observed 95th values would result in percentiles of 825 cfu/100 mL, meaning this site would remain in the '**green**' category.

5.21 Whangaehu River 250m Confluence

Table 5.23 : Simulated concentrations and swimming category for Whangaehu River at 250 m Confluence

Scenario	50th Percentile (cfu/100mL)	95th Percentile (cfu/100mL)	Exceedances over 540 cfu/100ml (%)	Exceedances over 260 cfu/100ml (%)
Baseline	164	4137	26	36
BAU 2025	164	4133	26	36
BAU 2040	164	4134	26	36
BAU 2080	164	4134	26	36
Silver 2025	156	3912	25	35
Silver 2040	149	3618	24	33
Silver 2080	144	3497	24	33
Gold 2025	152	3676	25	34
Gold 2040	144	3497	24	33
Gold 2080	144	3497	24	33

Final Simulated Swimming Category	Base-line	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080

The Whangaehu River is classified as '**orange**' through all scenarios modelled. There is no change from the baseline simulation (**Table 5.23**). The primary reason for this is the high 95th percentiles ranging from 3,497 to 4,137 cfu/100 mL through baseline to Gold 2080, resulting in the percentage of exceedances >260 and >540 cfu/100 mL remaining high. The catchment is >70% sheep and beef, ~8% dairy/dairy support and the remainder a mixture of land classes with some forestry in the headwaters (**Table A.1**).

Minimal reductions (~0.1%) are observed in the median and 95th percentiles during BAU simulations (**Table 5.1** and **Table 5.2**), likely due to the significant event based loads influencing the high 95th percentiles. This would mean the DWC loads contribute a small proportion to the percentiles, and therefore reductions applied due to stock exclusion would have minimal effects.

Significant land retirement of 1,285 ha in Silver and Gold (**Table C.1**) and reductions of the EMC's due to riparian planting leads to the 95th percentiles decreasing up to 15.5%, with the medians reduced by ~12.2% (see **Table 5.1** and **Table 5.2**). However, this reduction is not large enough to result in a threshold change for the key parameter for this site; median percentiles.

To change from orange to yellow, median percentiles need to drop below 130 cfu/100 mL, which does not occur in any simulations under the current mitigation criteria.

5.21.1 Comparison to observed data

The observed data for this site has a median and 95th percentile of 170 and 6,200 cfu/100 mL. This is similar to the baseline simulation, which predicted the median well, however underestimated the 95th percentile concentrations, with values of 164 and 4,137 cfu/100 mL respectively.

The observed data would result in the site having an '**orange**' swimming category.

If the simulated reductions in 95th percentiles were applied to the observed data, there would be no change in the sites swimming category of '**orange**'.

6. Summary

Tier 1 mitigations (stock exclusion and dairy effluent management) are applied to DWC's through BAU, Gold and Silver. These mitigations primarily lead to a reduction in base load of *E.coli* in receiving water bodies, exhibited through greater reductions in the median concentrations. The 95th concentrations have a greater decrease during the Tier 3 mitigations, where up to 10% reductions are applied to *E.coli* EMC's due to riparian planting (Silver and Gold).

Land retirement effects both median and 95th concentrations, as primarily sheep and beef is retired to native forest (and its subsequent low *E.coli* model input concentrations). Retirement area is significantly larger in Silver and Gold (up to 11,000 ha at the most lowland reporting point), which contributes to greater load reductions.

Land treatment of the WWTP's has a large influence on load reductions in some catchments, particularly in Mangatarere and the receiving Waiohine River. At these locations, Carterton WWTP has had significant land treatment (85:15 land to water) in BAU scenarios, due to flow restrictions on the receiving water body. The impact of the treatment is greater in the Waiohine River due to the generally low *E.coli* concentrations and comparatively small loads out of the large upstream native forest areas. Hence the Carterton WWTP inputs to this river system are proportionately larger than compared to WWTP's discharging to the Ruamāhanga River, which has greater flow and more varied (and intensified) landuse.

The modelled results should be reviewed with the assumptions and limitations of the model in mind. Scenarios provide a useful indication of the relative change that may be observed at a site, in both concentrations and swimming categories. Analysis of the changes in swimmability between all scenarios shows that Silver appears to have a similar amount of category changes as Gold, and significantly more than BAU.

Under each simulated scenario, the following sites have a change in their swimming category:

Business as Usual (BAU)

Two sites change categories:

- Taueru River at Gladstone Bridge (from red to orange in 2025)
- Waiohine River at Bicknells (from green to blue in 2025).

Silver

Eight sites change categories:

- Huangarua at Ponatahi Bridge (from orange to yellow in 2025)
- Mangatarere at SH2 (from orange to green in 2040)
- Parkvale Weir (from orange to yellow in 2080)
- Te Ore Ore (from orange to yellow in 2025)
- Tauanui River Mouth (from orange to blue in 2025)
- Taueru River at Gladstone Bridge (from red to orange in 2025)
- Waiohine River at Bicknells (from green to blue in 2025).

- Waipoua at Colombo (from green to blue in 2040)

Gold

Eight sites change categories, with the primary difference between silver is that this occurs at an earlier timescale.

- Huangarua at Ponatahi Bridge (from orange to yellow in 2025)
- Mangatarere at SH2 (from orange to green in 2025)
- Parkvale Weir (from orange to yellow in 2040)
- Te Ore Ore (from orange to yellow in 2025)
- Tauanui River Mouth (from orange to blue in 2025)
- Taueru River at Gladstone Bridge (from red to orange in 2025)
- Waiohine River at Bicknells (from green to blue in 2025).
- Waipoua at Colombo (from green to blue in 2025)

7. References

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Appendix A. Landuse area table

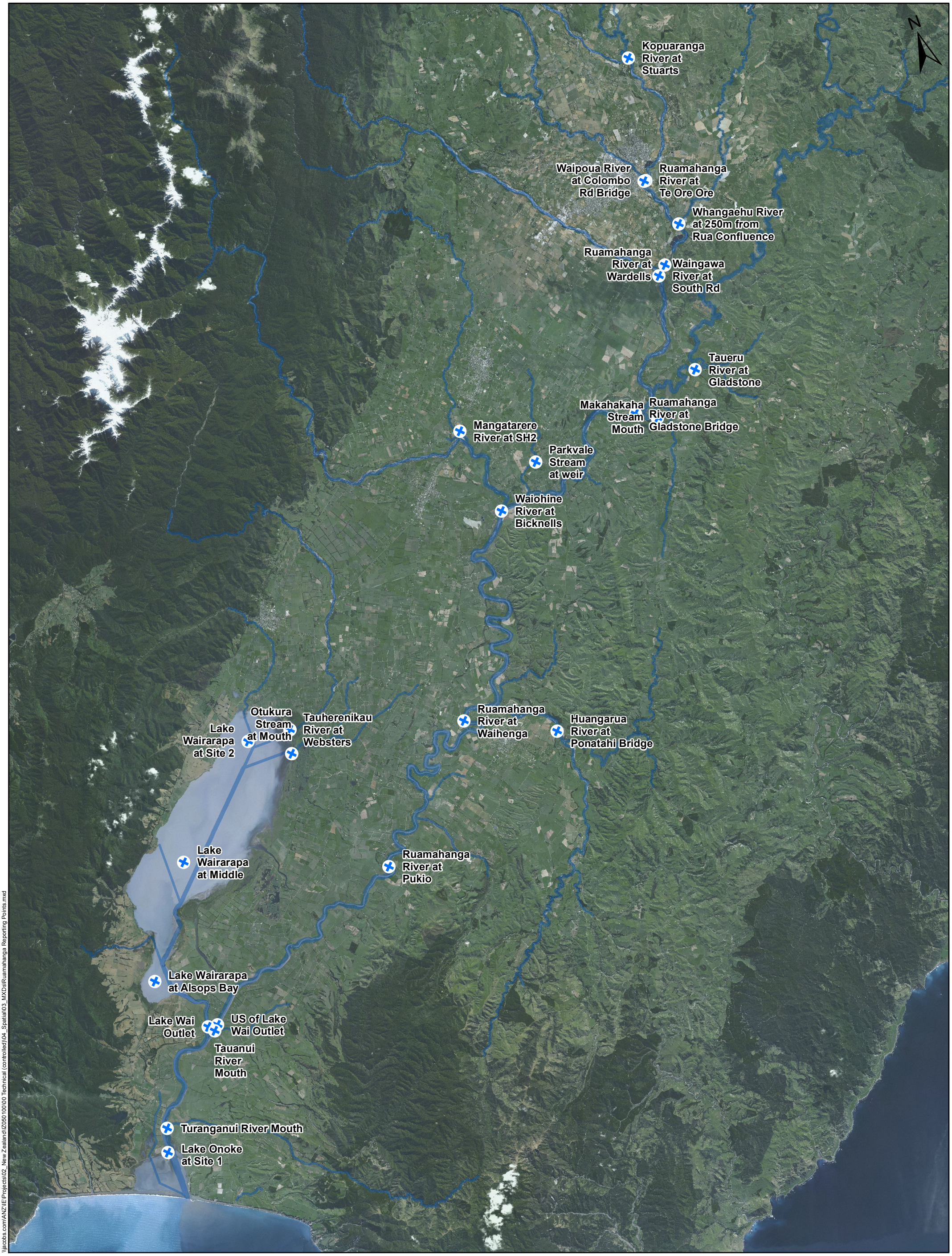
Table A.1 : Landuse area (ha) in the BASELINE model relative to each reporting site.

Reporting Site	Dairy	Dairy Support	Arable	Sheep and Beef	Native Bush	Other**	Total***
Huangarua River at Ponatahi Bridge	-	46.0	-	25581.5	692.7	3918.5	30239
Kopuaranga River at Stuarts	808.4	281.0	-	14103.0	154.5	1339.0	16686
Mangatarere River at SH2	2841.9	356.9	40.4	2514.8	4190.3	2002.5	11947
Ruamāhanga River at Pukio	14437.8	5866.7	1556.3	132684.5	45103.8	46716.9	246366
Ruamāhanga River at Te Ore Ore	1115.1	548.9	2.7	17950.0	7487.1	3973.9	31078
Taueru River at Gladstone	297.7	245.8	586.7	39654.5	242.1	8216.7	49244
Tauherenikau River at Websters	266.7	418.7	-	944.2	11255.2	1596.3	14481
Waingawa River at South Rd	214.6	127.4	-	2388.7	9856.0	2381.9	14969
Waiohine River at Bicknells	6070.0	1036.3	227.1	3595.0	23641.3	4750.1	39320
Waipoua River at Colombo Rd Bridge	173.3	670.2	113.1	9862.3	2801.9	3831.6	17452
Parkvale Stream at weir	1246.2	553.0	-	979.5	42.4	2184.6	5006
Ruamāhanga River at Wardells	2321.9	1518.0	160.9	38490.1	10298.0	11494.9	64284
Ruamāhanga River at Gladstone Bridge	3564.4	2095.1	791.2	81249.4	20400.6	25593.3	133694
Ruamāhanga River at Waihenga	13451.3	5412.6	1486.7	128058.1	44818.2	42861.8	236089
Whangaehu River at 250m from Ruamāhanga Confluence	914.5	298.9	45.2	10335.5	5.2	2978.7	14578
Otukura Stream at Mouth	2790.4	2454.2	-	1611.0	83.2	2427.6	9366
Makahakaha Stream at Mouth	128.8	389.2	37.9	5155.1	3.6	477.3	6192
Ruamāhanga River at U/S Lake Wai Outlet	16145.6	6139.4	1556.3	136133.3	47015.5	47505.7	254496
Tauanui River at Mouth	-	-	-	617.2	2535.3	1002.9	4155
Turanganui River at Mouth	260.4	38.2	-	1809.8	3491.3	1140.7	6740

** 'Other' landuse refers to all remaining landuse types within Ruamāhanga (including forestry, horticulture, urban etc.)

*** The landuse area will change in BAU, Silver and Gold Scenarios due to retirement of land (**Table C.1**). Nearly all retirement occurs on sheep and beef and in some instances 'Other' landuse classes such as sheep farms (on their own). To approximate the area draining to a watershed during scenarios, obtain the retired land area from **Table C.1**, and subtract this off sheep and beef. The retired land is added to the native bush area. An example would be 107 ha of retirement in Huangarua River at Ponatahi Bridge in BAU. Sheep and Beef area would decrease to 25,364 ha (**Table A.1**), and native bush would increase another 107 ha

Appendix B. Figures



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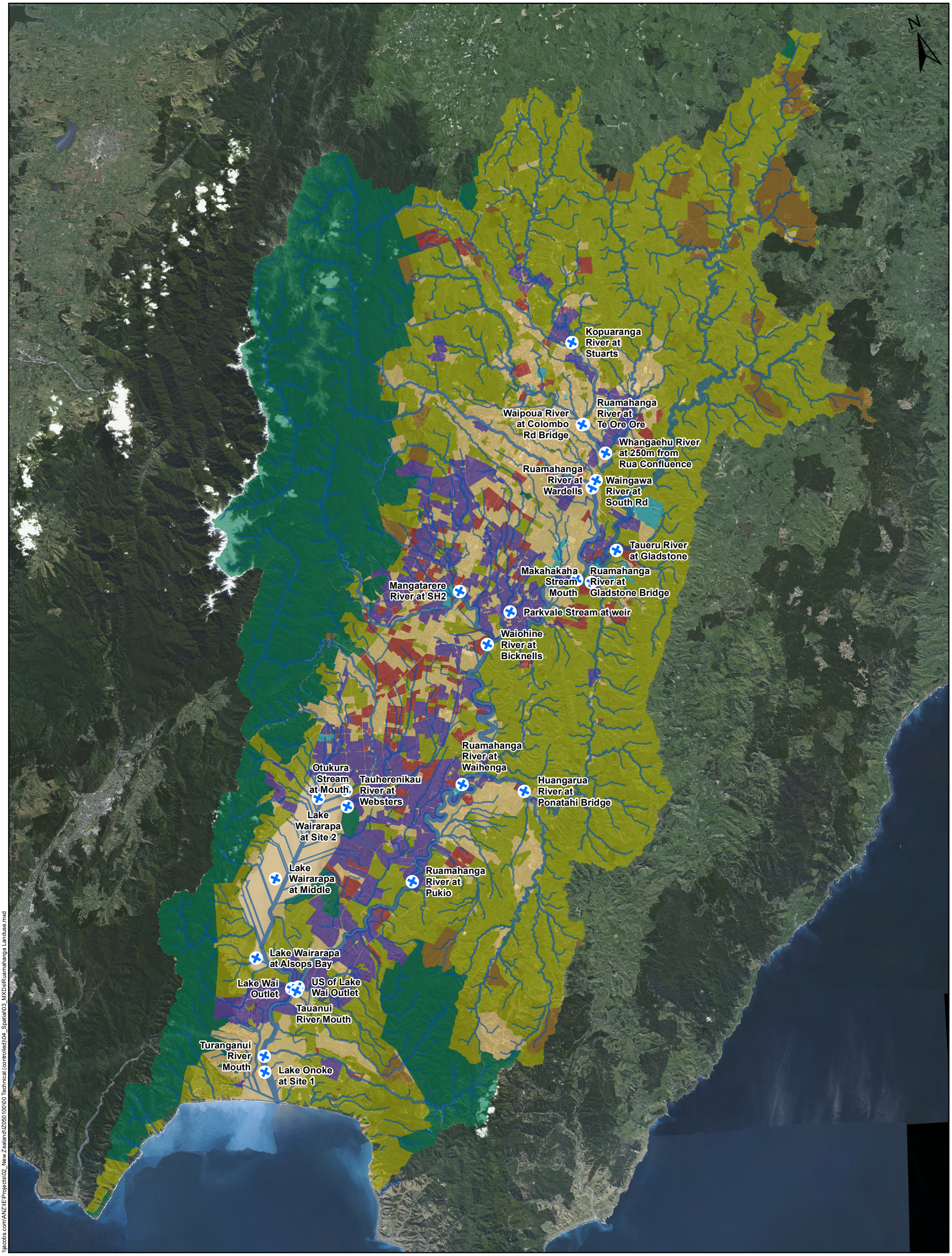
CLIENT: GWRC		**Legend**: River; Reporting Points
PROJECT: Ruamahanga SOURCE Model		**Ruamāhanga Whaitua** **Figure B1. Reporting Points**
SCALE: 1:200,000 @ A3	DATE: 17/10/2017	0 1 2 3 4 5 km JACOBS



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CLIENT: GWRC	
PROJECT: Ruamahanga SOURCE Model	
SCALE: 1:300,000 @ A3	DATE: 17/10/2017

Reporting Points
River
Sheep and Beef Farming
Dairy Farming
Dairy Support
Arable
Native Bush
Forestry
Other

Ruamāhanga Whaitua
Figure B2. Land Use

0 1 2 3 4 5 km

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Appendix C. Retired land

Table C.1 : Retired land (hectares) at each reporting point, in each scenario. The values are cumulative, where lowland sites such as Pukio include all the areas upstream of this site.

Reporting Site	BAU 2025	BAU 2040	BAU 2080	Silver 2025	Silver 2040	Silver 2080	Gold 2025	Gold 2040	Gold 2080
Huangarua River at Ponatahi Bridge	107	107	107	2285	3240	3240	3240	3240	3240
Kopuaranga River at Stuarts	0	0	0	353	1068	1068	1068	1068	1068
Mangatarere River at SH2	0	0	0	0	0	0	0	0	0
Ruamāhanga River at Pukio	107	245	347	5376	10812	10812	10812	10812	10812
Ruamāhanga River at Te Ore Ore	0	52	61	452	1244	1244	1244	1244	1244
Taueru River at Gladstone	0	0	0	1213	3310	3310	3310	3310	3310
Tauherenikau River at Websters	0	0	0	0	0	0	0	0	0
Waingawa River at South Rd	0	7	7	0	5	5	5	5	5
Waiohine River at Bicknells	0	0	0	0	0	0	0	0	0
Waipoua River at Colombo Rd Bridge	0	79	163	314	454	454	454	454	454
Parkvale Stream at weir	0	0	0	0	0	0	0	0	0
Ruamāhanga River at Wardells	0	132	225	1241	3008	3008	3008	3008	3008
Ruamāhanga River at Gladstone Bridge	0	138	231	2468	6340	6340	6340	6340	6340
Ruamāhanga River at Waihenga	107	245	347	5272	10637	10637	10637	10637	10637
Whangaehu River at 250m from Ruamāhanga Confluence	0	0	0	452	1286	1286	1286	1286	1286
Otukura Stream at Mouth	0	0	0	0	1	1	1	1	1
Makahakaha Stream at Mouth	0	0	0	218	341	341	341	341	341
Ruamāhanga River at U/S Lake Wai Outlet	107	245	347	5634	11092	11092	11092	11092	11092
Tauanui River at Mouth	0	0	0	5	8	8	8	8	8
Turanganui River at Mouth	2	67	152	123	131	131	131	131	131

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