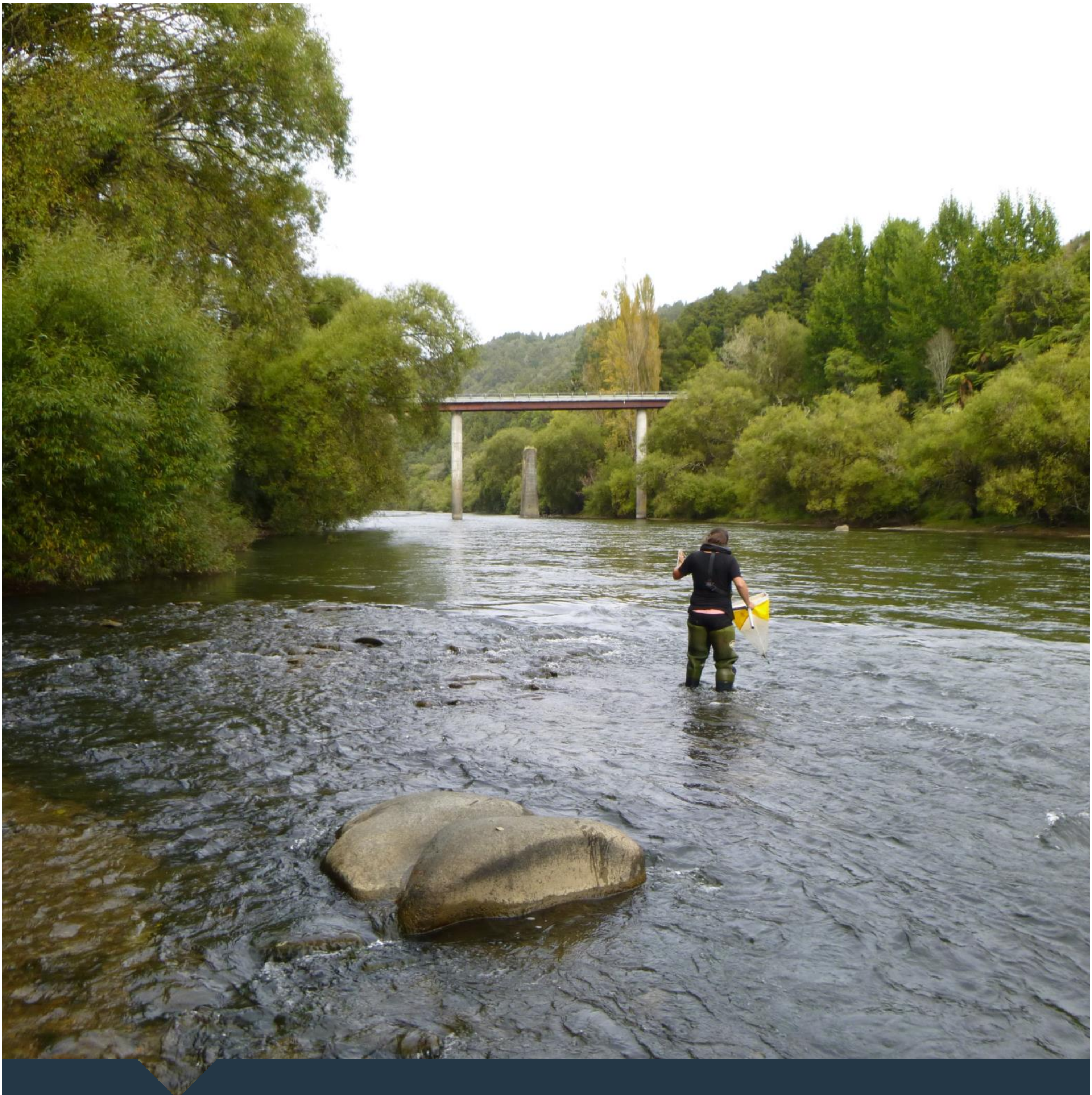

Regional modelling of *E. coli* to support implementation of the NPS-FM

Stage 2 Technical Report

July 2023

horizons REGIONAL COUNCIL

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Maree Patterson
Acting Science Manager

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Prepared by:

Annette Semadeni-Davies, Sandy Elliot, Yvonne Matthews
NIWA Ltd

CONTACT	24 hr freephone 0508 800 80		Help@horizons.govt.nz		www.horizons.govt.nz
SERVICE CENTRES	Kairanga Cnr Rongotea and Kairanga-Bunnythorpe Roads Palmerston North Marton 19 Hammon Street Taumarunui 34 Maata Street	REGIONAL HOUSES	Palmerston North 11-15 Victoria Avenue Whanganui 181 Guyton Street	DEPOTS	Taihape 243 Wairanu Road Taihape Woodville 116 Vogel Street
POSTAL ADDRESS	Horizons Regional Council, Private Bag 11025, Manawatū Mail Centre, Palmerston North 4442				F 06-952 2929

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Climate, Freshwater & Ocean Science

Prepared by:
Annette Semadeni-Davies
Sandy Elliott
Yvonne Matthews

For any information regarding this report please contact:

Sandy Elliott
Principal Scientist
Catchment Processes
+64 7 859 1839
sandy.elliott@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
Private Bag 99940
Viaduct Harbour
Auckland 1010

Phone +64 9 375 2050

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	Formatting checked by:	Jo Downey
	Approved for release by:	Jennifer Gadd, Group Manager Urban Aquatic Environments

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Executive summary

Horizons Regional Council (HRC) is preparing assessments of freshwater microbial concentrations and predictions of the effects of mitigation measures to inform their implementation of the National Policy Statement on Freshwater Management (NPS-FM, New Zealand Government 2023). Here we report on Stage 2 of a three-stage project being undertaken by NIWA for HRC to support these assessments. Stage 1 was a recalibration of the Catchment Landuse for Environmental Sustainability (CLUES) *E. coli* model using data from the Taranaki and Manawatū-Whanganui regions. The objectives of Stage 2, which are addressed in this report, were as follows:

1. To estimate current *E. coli* loads in the region's rivers and streams.
2. To determine, using the CLUES model, the impacts of two future state mitigation scenarios (Scenario 1, further stock exclusion; and Scenario 2, land disposal of farm dairy effluent) on *E. coli* loads and National Objectives Framework (NOF) attribute bands .
3. To undertake an economic analysis of the lifecycle costs and benefits of the two future state mitigation scenarios.
4. To determine, using CLUES, the load reductions required to meet targeted attribute bands for *E. coli* for the NPS-FM human contact value.

Stage 3 of the project is to undertake further future state modelling using yet to be determined scenarios.

CLUES model

CLUES is a catchment-scale, steady-state, mass budget model that estimates mean annual loads of TN, TP and *E. coli* for each segment in the New Zealand Digital River Network (DRN), we used version 2.5 of the network. CLUES has been set-up nationally and is intended as a screening tool to support policy development and catchment planning. This project uses only the *E. coli* model component of CLUES. For each DRN subcatchment, CLUES estimates *E. coli* loads from diffuse sources (represented by different land uses) as the product of the source area within the subcatchment and a calibrated source yield. These loads are modified by calibrated delivery factors that are exponential functions representing the effects of soil drainage, rainfall and annual temperature on *E. coli* loads before delivery to the stream network. The modified load for each subcatchment is added, along with any point sources present, to the instream load for the respective DRN river segment. The instream load is routed downstream and is subject to both calibrated instream attenuation and losses in lakes and reservoirs.

Current state

There are five *E. coli* attribute state bands (i.e., A, B, C, D and E) under the NPS-FM human contact value. The band for a stream segment is determined on the basis of four water quality metrics called numeric attributes. These are the median and 95th percentile concentrations (C_{50}, C_{95}), and the proportion of time concentration thresholds of 260 and 540 *E. coli* 100mL^{-1} are exceeded (G_{260}, G_{540}). The current value for each of the numeric attributes for each DRN segment has been estimated nationally using random forest modelling undertaken by NIWA for the Ministry of the Environment (Whitehead *et al.* 2022). The overall *E. coli* NOF attribute band for each DRN river segment was assigned on the basis of the numeric attribute with the lowest band grading. The NOF band for each

DRN segment was determined with and without the C_{95} numeric attribute. This is because the NPS-FM states that if there is insufficient data to calculate this attribute, it can be removed from the calculation of the NOF band.

Future state modelling

Mitigation in CLUES is modelled by changing the load inputs reaching the stream network either by reducing or removing the load from affected sources. Since CLUES is an annual load model, it cannot estimate the *E. coli* attributes directly. Instead, the current state attribute values were adjusted proportionally to the change in load to obtain future state attribute estimates. The results are reported for stream segments of stream order four or more (i.e., higher order streams)

Scenario 1 – Stock Exclusion

The stock exclusion scenario was developed with reference to spatial information provided by HRC and Manaaki Whenua / Landcare Research. This information was used to estimate the proportion of each DRN stream segment in the region that is currently fenced or is suitable for future fencing. Across the region, around 10 % of streams will have new fencing.

In DRN stream segments with new fencing, the reduction in *E. coli* load was estimated using percent removal efficiencies (PREs) derived from Muirhead (2019). Three removal efficiencies were used relating to low, medium and high removal, to encompass the range of possible impacts.

The mean annual *E. coli* loads had reduced by 3 %, 7.7 % and 11.4 % region-wide for the three removal efficiencies. With the low removal efficiency, the NOF band was predicted to change in around 64 km of streams. The medium and high removal efficiencies resulted in a net change of NOF band classification of around 203 km (4) and 337 km (7), respectively, regardless of whether C_{95} was included in the NOF band classification.

Scenario 2 - Reduction of point source loads

This scenario reduced the point source loads from some wastewater treatment plants to represent improved water treatment. The future point source loads were provided by HRC. The scenario had a negligible impact on overall *E. coli* loads from the region.

Economic analysis

We undertook a lifecycle cost analysis, cost-effectiveness analysis, and benefit-cost analysis of the stock exclusion scenario. The analysis was not undertaken for Scenario 2

Total costs

Costs and assumptions were primarily sourced from technical reports commissioned by the Ministry for Primary Industries and the Ministry for the Environment and validated against other published sources. Cost components for Scenario 1 included capital, maintenance, and retirement opportunity costs for fencing and water reticulation for the different land-use types represented in CLUES. All costs are adjusted to 2023 prices using the Producers' Price Index (PPI) published by Statistics New Zealand.

The estimated capital cost for installing 7,556 kilometres of new fencing ranged from $49.5 million (low estimate) to $132.5 million (high estimate). The opportunity cost resulting from the loss of grazing ranges from $1.1 million to $3.7 million per year. Low-intensity farm systems may have no other stock drinking water apart from streams, so need to install water reticulation systems.

Installation of that water reticulation is expected to cost $6.7 million with maintenance costs of $338,400 per year.

The medium estimate for total annualized lifecycle cost (LCC) was $7.4 million using a 50-year period, 5 per cent discount rate and considering only the costs of fencing. If including opportunity and water reticulation costs the LCC is $11.8 million.

A sensitivity analysis was conducted to consider the impact of cost estimate ranges, assessment period, discount rate, and the inclusion or exclusion of opportunity costs and water reticulation costs and showed the variation in fencing costs had the greatest impact on total cost.

Cost-effectiveness

The cost-effectiveness of the project was evaluated using the metric of change in median *E. coli*/100ml (C_{50}) multiplied by the stream length in kilometres for each segment. This metric assumes that all waterways are equally important and are weighted only by length.

Based on the medium LCC estimate of $6.7 million, the cost per change in C_{50} per kilometre ranged from $13 (high PRE) to $50 (low PRE).

Benefit-cost analysis

The assessed benefits were non-market values for freshwater improvement. Alternative estimates of freshwater non-market values were considered from two different valuation studies. The first study (Tait *et al.* 2016) was based on water quality outcomes and suggests a relatively low benefit per year of $152,000 (low PRE) to $1.2 million (high PRE). The second study (Matthews 2023) was based on the combined effects of restoration activities and suggests the benefit may be significantly higher at $5.1 million per year. The resulting benefit-cost ratios have a very wide range from 0.01 to 0.69.

Unquantified benefits include improved pasture and animal management resulting from fencing of waterways, and recreational and cultural values. In addition, we note that that a benefit-cost ratio need not be greater than one when there is a legal obligation to meet a minimum standard. Rather, the preferred option may be the one that is most cost-effective, or that maximises net benefits while fulfilling legal obligations.

Load reduction analysis

The load reduction analysis assessed the degree to which source loads would need to be reduced to meet the grading targets for each NOF band. The overall process has four steps as follows:

1. Establish the in-stream load reduction factor required to achieve a specified target band for each stream segment of interest given its current state band. The segments of interest were higher order streams (order 4 or more) and segments with an associated water quality monitoring site. For each segment of interest, determine the load reduction required for each of the four numeric attributes to meet the attribute criteria for the target band.

2. For each DRN subcatchment, find the downstream segment with the largest value for the load reduction factor (i.e., the maximum downstream load reduction factor or MDLRF). This is to give an idea of which subcatchments could be implicated in achieving load reductions. The load reductions were expressed as load reduction factors, equal to the current load divided by the load required to meet the target (the

"target load"). In this way, the load reduction factors indicate the value by which the current load must be divided to meet the target.

3. In an iterative process, the maximum load reduction is distributed to the upstream catchment of a segment assuming that the "manageable source load" is reduced by the same proportion in all subcatchments upstream of the segment. The manageable source load for a subcatchment is the current source load minus a reference source load representing natural conditions (i.e., all point sources removed, all developed land use such as urban and pastural crop land converted to native forest).

4. Recalculate attribute bands for all subcatchments after the source load reduction, assuming that instream-concentrations reduce in proportion to the reduction in in-stream load.

The analysis was applied for each of five grade target bands, i.e., NOF bands A to E. The target band E is effectively to maintain the *E. coli* numeric attribute values at their current condition. The analysis was repeated for two cases: including the C_{95} numeric attribute in the overall grading or excluding it. The analysis also included two scenarios to explore the impact of considerable uncertainty in reference source loads in the original calibration: (i) the Full Reference Source scenario (reference yields as in the original calibration) and (ii) a Low Reference Source scenario (whereby the source yields associated with natural land uses were halved). The Low Reference Source scenario gave more scope for reducing loads, and hence the numeric attribute values.

It was found that the required load reductions for all of the target bands are highly variable across the region. This is because of the spatial variability in the difference between the current water quality and the target value, and also because different parts of the catchment have greater manageable source loads (current source load minus reference source load) in relation to the current source loads.

The variability of load reduction within a catchment means that some subcatchments will need a higher load reduction factor, to compensate for areas where there is little or no scope for load reduction (such as in forested areas).

The key findings of the analyses are in the bullet points below. Unless otherwise stated, results are for the Full Reference Source scenario.

- For a target band D, a region-average source load reduction factor of 1.27 (about 21.2 % reduction) was needed. However, this reduction would not be sufficient to meet the NOF 2030 target, because more than 20 % of the length of large streams remain in class D. This result applies regardless of the reference source scenario or whether C_{95} is included.

- For target band C with C_{95} included, a region-average source load reduction factor of just over 3 is needed. These reductions are not distributed evenly over the region, and many areas would need a reduction factor of 5 (80 % reduction) or more. This results in achieving the NOF national 2030 target of <20 % in D-E bands.
  If C_{95} is not included, the region-average load reduction factor is 1.74, with many areas needing reduction factors of 4 or more.

- For target band B with C_{95} included, many streams did not meet the target band even after source load reduction. This is because even if the source load is reduced to

reference levels (the lowest possible level, associated with natural land use such a native vegetation), C_{95} was not reduced sufficiently to achieve the B band. The required load reduction factors in that case are not meaningful because the possible reductions in source loads are not sufficient to meet the target. Despite reducing loads to the reference condition (the lowest level allowed in the model), the load reduction would not be sufficient to reduce the attribute values to their target state. This unexpected result relates to uncertainty of loads and associated concentrations under reference conditions in conjunction with the assumption of proportional decreases, but could also point to difficulties in achieving high gradings under native reversion in lowland areas. The result motivated creation of the Low Reference Source scenario, whereby loads under reference conditions would be lower (as a result of a different source coefficient, not due to mitigation), and precited concentrations could therefore be lower.
If C_{95} is not included, the B target was largely met (0.2 % of streams of interest remained in class C or worse). The region-average load reduction factor was 2.33, with many locations needing a load reduction factor of 3 or more.

- For target band A, the target could not be met for >20 % of streams of interest, with or without C_{95}, and the associated load reduction factors are not meaningful.
- Low Reference Source scenario. The Low Reference Source scenario showed similar results to the Full Reference Source scenario for the D and C targets, but different results for B and A targets. By allowing the reference source to be lower, B and A targets could be met. If C_{95} is considered, the region-average source load reduction factor was 3.70 for grade target B, and 5.97 for target A, while lower factors were required if C_{95} was not included (2.34 and 3.32 for B and A respectively).

The spatially-variable source load reduction factors point to the importance of tuning source reductions to areas where reductions are needed, rather than applying a blanket source load reduction factor across the catchment.

Overall, the results demonstrated that considerable reductions would be needed to meet the C target (which also achieved the 2030 NOF target for D-E bands). The load reductions are generally larger if C_{95} is included. Achieving the B and A targets region-wide would be even more difficult, especially when C_{95} is considered. Further, it is uncertain whether these targets could be achieved due to uncertainty in the source loads and concentrations in reference conditions.

1 Background

Horizons Regional Council (HRC) is preparing assessments of freshwater microbial concentrations and predictions of the effects of mitigation measures to inform their implementation of the National Policy Statement on Freshwater Management (New Zealand Government 2023) as it relates to the NPS-FM compulsory human contact[1] value. This work is being driven by community concerns that many rivers and streams in the region do not meet the National Objectives Framework (NOF) *E. coli* attribute targets for human contact.

This report documents the second stage in a three-stage project being undertaken for HRC. Stage 1 (Semadeni-Davies *et al.* 2023) was to recalibrate the Catchment Land-Use for Environmental Sustainability (CLUES; Elliott *et al.* 2016) *E. coli* model using water quality data from the Taranaki and Manawatū-Whanganui regions to improve the fit of the model for both regions.

The objectives of Stage 2, as reported on here, are as follows:

1. To estimate current *E. coli* loads in the regions' rivers and streams.
2. To determine the impacts on *E. coli* loads and NOF attribute bands of two future state mitigation scenarios (further stock exclusion and reduction of loads from wastewater treatment plants) that have been developed with HRC. The methods used for this analysis are similar to those applied nationally for the Ministry of Primary Industries (MPI) and the Ministry for the Environment (MfE) (Semadeni-Davies and Elliott 2017; Semadeni-Davies *et al.* 2018; Semadeni-Davies *et al.* 2020).
3. To undertake an economic analysis of the lifecycle costs and benefits of the stock exclusion scenario. The cost components for this analysis include capital, maintenance, and opportunity costs.
4. To use the CLUES model to determine the load reductions required to meet target NOF *E. coli* attribute bands required for the NPS-FM human contact value.

Stage 3 will be to undertake any further mitigation modelling required by HRC and is not discussed in this report.

1.1 Report layout

This report is broken into the following sections:

Section 2 presents the estimated current state of streams and rivers in the region as determined by previous modelling undertaken by NIWA for MfE (Whitehead *et al.* 2022).

Section 3 overviews the CLUES model, its underlying data, and how it has been applied in this project.

Section 4 describes the application of the CLUES model for the future state mitigation scenarios (Section 4.1), as well as the methods used to undertake the economic analysis (Section 4.2) and load

[1] The NPS-FM defines Human contact as "the extent to which an FMU or part of an FMU supports people being able to connect with the water through a range of activities such as swimming, waka, boating, fishing, mahinga kai, and water skiing, in a range of different flows or levels."

reduction analysis (Section 4.3). Further information on the methods and data used is given in Appendices A – D.

Section 5 presents and discusses the outputs of the CLUES future state modelling (Section 5.1; additional model outputs are given in Appendices E - G) and the economic (Section 5.2) and load reduction analyses (Section 5.3).

Section 6 provides a set of conclusions relating to each of the analyses separately and together.

2 Current attribute state

There are five NOF *E. coli* attribute state bands (i.e., A – blue, B – green, C - yellow, D – orange and E – red) under the NPS-FM human contact value. The band for a stream segment is determined on the basis of four criteria called numeric attributes states (given in Table 2-1). These are the median and 95th percentile concentrations (C_{50}, C_{95}), and the proportion of exceedances of concentration thresholds of 260 and 540 *E. coli* 100mL^{-1} (G_{260}, G_{540}). The overall *E. coli* NOF band for each DRN river segment was assigned based on the numeric attribute with the lowest rating according Table 2-1. The NOF band was determined both with and without the C_{95} numeric attribute. This is because the NPS-FM states that if there is insufficient data to calculate this attribute, it can be removed from the calculation of the NOF band. Moreover, HRC staff have concerns that C_{95} may dominate the NOF band calculation, which is an issue for the human contact value.

Table 2-1: Criteria used to define the *E. coli* attribute states for the NPS-FM human contact value. Shading refers to the attribute classification colour. Source, Table 9 of New Zealand Government (2023).

Numeric attribute state	A (Blue)	B (Green)	C (Yellow)	D (Orange)	E (Red)
Median *E. coli*/100ml (C_{50})	≤130	≤130	≤130	>130	>260
95th Percentile *E. coli*/100ml (C_{95})	≤540	≤1000	≤1200	>1200	>1200
Proportion of exceedances over 260 *E. coli*/100ml (G_{260})	<20%	20-30%	20-34%	>34%	>50%
Proportion of exceedances over 540 *E. coli*/100ml (G_{540})	<5%	5-10%	10-20%	20-30%	>30%

The current numeric states for *E. coli* estimated for each river segment in the region come from national random forest water quality modelling undertaken by NIWA for MfE (Whitehead *et al.* 2022)[2]. While random forest modelling has been undertaken regionally using SOE data from Taranaki, Waikato and Manawatū-Whanganui (Fraser 2022; Snelder and Fraser 2022), the estimates of the *E. coliI* attributes had poorer fit against measured SOE data compared to the national modelling*.* The national random forest modelling was calibrated against water quality data from State of Environment (SOE) monitoring sites covering the five-year period between January 2016 and December 2020. There are 111 SOE sites in the region that were used in that calibration; these are mapped in Appendix A. For this project, for segments with SOE monitoring, modelled current state attributes were replaced by measured values*.* This is in keeping with the 'best information' principle in the NPS-FM that modelled information should be used in the absence of robust data (which we take to be measurements).

[2] https://shinydev.niwa.local/rec_data_tool/

3 CLUES model description

CLUES is a catchment-scale, steady-state annual budget-type model that estimates mean annual loads of TN, TP and *E. coli* for each segment in the River Environments Classification stream network (Snelder and Biggs 2002; Snelder *et al.* 2010). CLUES has been set-up nationally and is intended as a screening tool to support policy development and catchment planning. The spatial and temporal scales were chosen to allow rapid model setup and scenario creation. The low data requirements and resolution mean that CLUES follows an empirical modelling approach. The model description below is summarised from Appendix 1 of Elliott *et al.* (2016).

The CLUES *E. coli* model is based on the United States Geological Survey SPARROW model (SPAtially-Referenced Regression On Watershed attributes; Smith *et al.* 1997; Schwarz *et al.* 2006a; Schwarz *et al.* 2006b). *E. coli* loads from diffuse sources are calculated for each DRN subcatchment as the product of the source area and associated source yield. Diffuse sources are represented in CLUES by the proportion of each sub-catchment covered by each of 19 land use classes. The land use data used by CLUES relate to the reference year 2018 and are based on the LCDB5 land cover database[3] and the Agribase dataset for the reference year 2017 under licence from AsureQuality[4]. Agribase was used to split grass and cropland land covers from LCDB5 into enterprise types (i.e., stock, crop and horticulture land uses). The breakdown of land uses in Manawatū-Whanganui is given in Table 2-1.

Table 3-1: CLUES land use class percentage areas in Manawatū-Whanganui grouped by type The calibration groupings (see Section 2.2.) are shaded: green = Dairy, yellow = all other stock, red = urban, blue = other land use.

<table>
<tr><th>Land use class</th><th>Calibration group</th><th>Land area (%)</th></tr>
<tr><td>Dairy</td><td>Dairy</td><td>8.0</td></tr>
<tr><td>Sheep and Beef (lowland intensive)</td><td rowspan="3">Sheep and beef</td><td rowspan="3">44.3</td></tr>
<tr><td>Sheep and Beef (hill-country)</td></tr>
<tr><td>Sheep and Beef (high-country)</td></tr>
<tr><td>Deer</td><td rowspan="2">All other stock</td><td rowspan="2">2.2</td></tr>
<tr><td>Other animals</td></tr>
<tr><td>Ground crops</td><td rowspan="5">Crops and horticulture</td><td rowspan="5">0.8</td></tr>
<tr><td>Surface crops</td></tr>
<tr><td>Kiwifruit</td></tr>
<tr><td>Other fruit</td></tr>
<tr><td>Viticulture</td></tr>
<tr><td>Exotic Forest</td><td rowspan="3">Trees</td><td rowspan="3">38.0</td></tr>
<tr><td>Native Forest</td></tr>
<tr><td>Scrub</td></tr>
<tr><td>Water (rivers, lakes)</td><td rowspan="4">Other</td><td rowspan="4">6.0</td></tr>
<tr><td>Tussock</td></tr>
<tr><td>Ungrazed grassland</td></tr>
<tr><td>Other</td></tr>
<tr><td>Urban</td><td>Urban</td><td>0.7</td></tr>
</table>

The generated loads from diffuse sources are modified by a delivery factor that is an exponential function of the mean annual rainfall and the mean annual temperature. Once delivered to the stream network, subcatchment loads are added to the instream load and are routed downstream.

[3] https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/
[4] https://www.asurequality.com/services/agribase/

While the model does have the ability to calculate *E. coli* losses in streams and lakes, the regional recalibration (see Section 3-2) removed these losses from the regional version of CLUES.

3.1 Point sources

The point sources applied in this project represent discharges from wastewater treatment plants that discharge to freshwater located in the Manawatū-Whanganui region. The point source loads for both the current and point source reduction scenarios were supplied to NIWA by HRC – these are listed in Table 3-2.

3.2 Calibration

Recalibration of the CLUES *E. coli* model was undertaken at a regional-scale using data from both Taranaki and Manawatū-Whanganui as described in Semadeni-Davies et al. (2023) and summarised here. The recalibration was done to improve the model's fit (compared with the existing national model) in the two regions by:

- Increasing the number of monitoring sites in the regions used for calibration (compared to calibration for a single region).
- Removing the possibility of bias in the calibrated parameters due to the influence of water quality data from other regions.
- Updating the water quality data used for calibration to a time-frame compatible with current land use and land management practices in the regions.

The model was calibrated against mean annual *E. coli* loads determined for 58 water quality monitoring sites located in the two regions where measured flow data are also available. Loads were determined using the 95^{th} percentile flow record rather than the full record to represent loading occurring during normal and elevated flow, but not storm flow. This is because *E. coli* loads tend to be influenced by infrequent storm conditions (typically occurring less than 1 % of the time), whereas the NOF attributes are mainly related to the normal range of conditions (95 % of the time). We also used CLUES calibrated to loads calculated for the 95^{th} percentile flow record for national swimmability modelling (Semadeni-Davies *et al.* 2018).

It was also assumed that the current level of mitigation is inherently accounted for in the model calibration. The methods used to determine the measured loads and to calibrate the model are described fully in the Stage 1 report along with the full calibration results, limitations and assumptions (Semadeni-Davies *et al.* 2023). Here, the calibration outputs are summarised in Table 3-3 and Table 3-4. The yield for urban land use (0.08 peta organisms/km^2/y) was fixed and was derived from literature.

Table 3-2: CLUES mean annual *E. coli* loads (peta organisms / year) for point sources located in Manawatū-Whanganui. Data provided by HRC

NZSEGMENT	Name	*E. coli* load (peta organisms/y)
7234946	AFFCO Fielding at Industrial Waste water	0.01992
7235055	Dannevirke STP at microfiltered oxpond	0.00044
7247235	Eketahuna STP at Secondary oxpond waste	0.00115
7235811	Feilding STP at Secondary oxpond waste	0.01551
7242126	Foxton STP at Secondary oxpond waste	0.01287
7231319	Halcombe at Secondary oxpond	0.00504
7224518	Hunterville STP at Microfiltration Plant	0.00026
7229177	Kimbolton STP at oxpond waste	0.00084
7230320	Marton STP at Rock filtered oxpond waste	0.04628
7174519	National Park STP at Secondary oxpond	0.00119
7230015	Norsewood STP at oxpond waste	0.00018
7233271	Ohakea STP at Effluent outfall	0.10296
7233271	Riverlands at Industrial wastewater	0.08880
7233271	Bulls STP at Secondary oxpond waste	0.00276
7192527	Ohakune STP at Secondary oxpond waste	0.01284
7231038	Ormondville STP at 2nd oxpond waste	0.00014
7241128	Pahiatua STP at Tertiary oxpond waste	0.00394
7239481	PNCC STP at Tertiary Treated Effluent	0.50374
7244835	Pongaroa STP at 2nd oxpond waste	0.00035
7236160	PPCS Oringi STP at oxpond waste	0.00048
7194503	Raetihi STP at Secondary oxpond waste	0.00194
7193718	Rangataua STP at Secondary oxpond waste	0.00024
7227733	Ratana STP at Secondary oxpond waste	0.000392
7236594	Rongotea STP at Secondary oxpond waste	0.00211
7234275	Sanson STP at Secondary oxpond waste	0.01482
7211096	Taihape STP at oxpond waste	0.07961
7150643	Taumarunui STP at Tertiary treated waste	0.00406
7241792	Tokomaru at oxpond waste	0.00090
7196591	Waiouru STP at oxpond waste	0.36133
7196647	Winstone Pulp WWTP at oxpond waste	0.43282
7238330	Woodville STP at Secondary oxpond waste	0.00332
Regional total point source load		**1.72121**

Table 3-3: CLUES calibrated parameters and their standard errors determined for the Manawatū-Whanganui and Taranaki regions.

Parameter	Value	Uncertainty (Standard Error)
tempCoef	0.50081	0.10390
rainCoef	1.02764	0.14800
yDairy (peta* organisms/km^2/y)	0.00693	0.00249
ySB and other stock (peta organisms/km^2/y)	0.00852	0.00138
yOther (peta organisms/km^2/y)	0.00111	0.00059

Notes: *peta = 10^{15}

Table 3-4: Calibration performance for the natural logs of loads (peta organisms/y) and yields (peta organisms/km^2/y).

Performance metric	Load	Yield
Coefficient of determination, R^2	0.927	0.689
Nash-Sutcliffe Efficiency[5], NSE	0.924	0.689
Root Mean Square Error, RMSE	0.587	0.567

3.3 Representing farm mitigations

Farm mitigation measures to reduce contaminant yields from stock are modelled in CLUES by applying a Percentage Removal Efficiency (PRE) that is representative of the performance of each mitigation modelled. The post-mitigation yield from each affected land use is calculated as the land use's pre-mitigation yield multiplied by (100-PRE) / 100. The PREs are user specified and are set separately for each mitigation type, land use and contaminant. The PREs specific to this study are given in Section 4.1.

There has been some criticism in the determination of PREs due to inconsistent monitoring, sampling and analytical methods used to measure removal efficiencies in different studies as well as the differences in the design and implementation of mitigation (e.g., International Stormwater BMP Database 2007). However, the use of PREs is very common for water quality modelling as they are both simple to understand and apply (e.g., Waidler *et al.* 2011). While more sophisticated, process based methods can be applied in dynamic water quality models, the use of PREs is appropriate in a simple model such as CLUES. To cover the range of PREs possible, we have applied three sets of PREs representing low, medium and high removal efficiencies.

3.4 Modelled area

The model has been applied to all DRN segments in Manawatū-Whanganui. The Freshwater management Units (FMU) and Water Management Subzones (WMS) used by HRC for reporting are shown in Figure 3-1 and listed in Table 3-5. The total length of DRN stream segments by stream order

[5] Nash, J.E. and Sutcliffe, J.V. (1970) River flow forecasting through conceptual models part I — A discussion of principles. *Journal of Hydrology*, 10(3): 282–290.

are given in Table 3-6 for the FMUs and in Appendix B for the WMS. In Table 3-6, higher order streams are defined as those with a stream order of four or more; these are the streams deemed suitable for human activities under the NPS-FM (see Appendix 3 of New Zealand Government 2020).

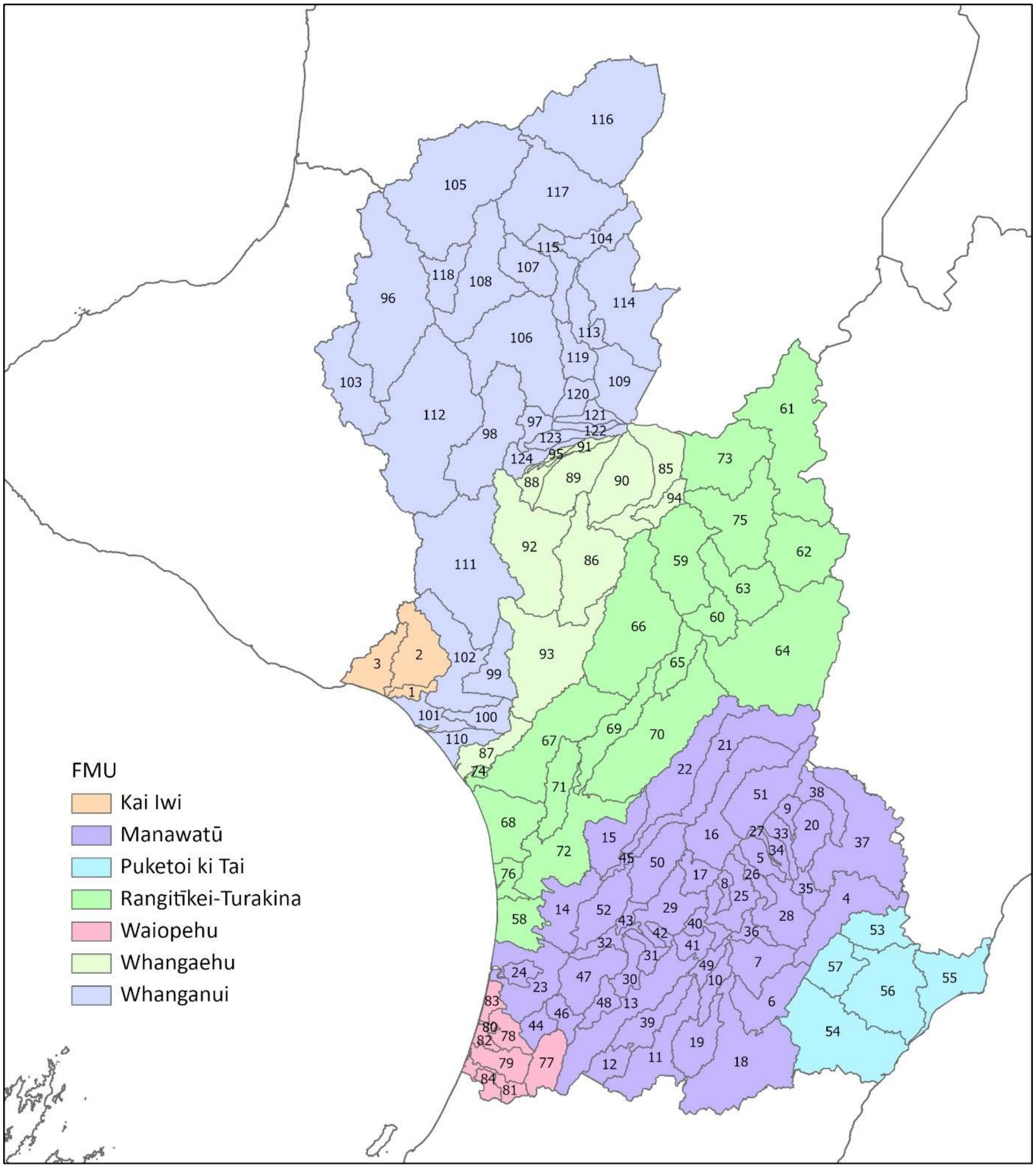


Figure 3-1: Freshwater Management Units and Water Management Subzones in Manawatū-Whanganui. The subzones are labelled numerically and are named in Table 3-5.

Table 3-5: Freshwater Management Units and Water Management Subzones. Map ID refers to Figure 3-1.

FMU	Map ID	Sub_zone	FMU	Map ID	Sub_zone
Kai Iwi	1	Mowhanau	Manawatū cont.	35	Weber - Tamaki
	2	Kai Iwi		36	Hopelands - Tiraumea
	3	Northern Coastal		37	Upper Manawatū
Manawatū	4	Mangatoro		38	Mangatewainui
	5	Oruakeretaki		39	Middle Mangatainoka
	6	Makuri		40	Upper Gorge
	7	Lower Tiraumea		41	Lower Mangahao
	8	Mangapapa		42	Aokautere
	9	Upper Tamaki		43	Lower Mangaone Stream
	10	Mangaramarama		44	Koputaroa
	11	Makakahi		45	Middle Oroua
	12	Upper Mangatainoka		46	Mangaore
	13	Upper Mangahao		47	Lower Tokomaru
	14	Lower Oroua		48	Upper Tokomaru
	15	Makino		49	Lower Mangatainoka
	16	Middle Pohangina		50	Upper Mangaone Stream
	17	Lower Pohangina		51	Upper Pohangina
	18	Upper Tiraumea		52	Main Drain
	19	Mangaone River	Puketoi ki Tai	53	Upper Akitio
	20	Mangatera		54	Owahanga
	21	Upper Oroua		55	Eastern coastal zone
	22	Kiwitea		56	Lower Akitio
	23	Coastal Manawatū		57	Waihi
	24	Foxton Loop	Rangitīkei-Turakina	58	Northern Manawatū Lakes
	25	Mangaatua		59	Upper Hautapu
	26	Raparapawai		60	Lower Hautapu
	27	Upper Kumeti		61	Upper Rangitikei
	28	Tamaki - Hopelands		62	Middle Rangitikei
	29	Middle Manawatū		63	Lower Moawhango
	30	Kahuterawa		64	Pukeokahu - Mangaweka
	31	Turitea		65	Makohine
	32	Lower Manawatū		66	Upper Turakina
	33	Lower Tamaki		67	Lower Turakina
	34	Lower Kumeti		68	Southern Whanganui Lakes

FMU	Map ID	Sub_zone
Rangitīkei-Turakina Cont.	69	Porewa
	70	Lower Rangitikei
	71	Tutaenui
	72	Coastal Rangitikei
	73	Upper Moawhango
	74	Ratana
	75	Middle Moawhango
	76	Tidal Rangitikei
Waiopehu	77	Upper Ohau
	78	Lake Horowhenua
	79	Lower Ohau
	80	Hokio
	81	Waikawa
	82	Lake Papaitonga
	83	Waitarere
	84	Manakau
Whangaehu	85	Upper Whangaehu
	86	Middle Whangaehu
	87	Coastal Whangaehu
	88	Lower Makotuku
	89	Upper Mangawhero
	90	Tokiahuru
	91	Upper Makotuku
	92	Lower Mangawhero
	93	Lower Whangaehu
	94	Waitangi
	95	Makara

FMU	Map ID	Sub_zone
Whanganui	96	Tangarakau
	97	Middle Manganui o te Ao
	98	Lower Manganui o te Ao
	99	Upokongaro
	100	Matarawa
	101	Coastal Whanganui
	102	Lower Whanganui
	103	Whangamomona
	104	Pungapunga
	105	Upper Ohura
	106	Retaruke
	107	Te Maire
	108	Middle Whanganui
	109	Upper Whakapapa
	110	Kaitoke Lakes
	111	Paetawa
	112	Pipiriki
	113	Lower Whakapapa
	114	Upper Whanganui
	115	Cherry Grove
	116	Upper Ongarue
	117	Lower Ongarue
	118	Lower Ohura
	119	Piopiotea
	120	Waimarino
	121	Makatote
	122	Upper Manganui o te Ao
	123	Mangaturuturu
	124	Orautoha

Table 3-6: Length (km) of streams by FMU and stream order. Stream length was determined from the DRN 2.5 stream network data set. Higher order streams are those with a stream order of four or more (shaded).

FMU	Length by stream order							Total length	
	1	2	3	4	5	6	7	Higher order streams	All streams
Kai Iwi	268	147	68	59	22	0	0	81	564
Manawatū	4 774	2 473	1 255	649	436	162	118	1 365	9 867
Puketoi ki Tai	887	443	261	139	71	46	0	256	1 847
Rangitīkei-Turakina	4 342	2 103	1 030	476	288	156	138	1 059	8 535
Waiopehu	313	156	88	36	34	0	0	69	626
Whangaehu	1 665	890	403	223	126	144	0	494	3 452
Whanganui	5 830	2 868	1 392	789	404	166	244	1 603	11 694
Total	**18 080**	**9 079**	**4 499**	**2 371**	**1 381**	**675**	**500**	**4 927**	**36 585**

4 Methods

4.1 Future state modelling

Two scenarios were applied for Stage 2 modelling, these represent stock exclusion (Scenario 1) and the reduction or removal of point source discharges to water listed in Table 3-2 (Scenario 2). The first scenario is an example of an on-farm mitigation while the second is an example of a source change mitigation. In addition to these scenarios, the model was run for current default conditions. The model outputs are reported here in relation to the change in NOF *E. coli* attribute bands for human contact (see Table 2-1) between the current and future state scenarios.

As previously noted, CLUES does not estimate *E. coli* concentrations, and by abstraction, the *E. coli* NOF numeric attributes, directly. For this reason, the future state attributes for each mitigation scenario were estimated by adjusting the *E. coli* current state attribute values from Whitehead *et al.* (2022) proportional to the change in instream *E. coli* mean annual loads estimated for the current and future state scenarios.

The future scenario values of C_{50} and C_{95} are calculated using a delta-change method similar to that used by Semadeni-Davies and Elliott (2017) whereby the percentage difference in the loads simulated for the current and future scenarios was used to adjust the C_{50} and C_{95} values proportionally under the under the assumption that, all else being equal, there is a linear relationship between contaminant loads and concentrations. The calculation of future values of G_{260} and G_{540} is similar but uses an additional statistic, the standard deviation of the concentrations, so that the full range of concentrations (that is, the distribution) can be modelled for every location (Elliott and Whitehead 2016). The method followed to calculate the exceedance attributes is described in Appendix C.

The NOF bands for each future state scenario were determined using the same method described above for the current state. Like the current state, NOF bands were estimated both with and without the C_{95} concentration attribute.

4.1.1 Current scenario

The current scenario is the same as that used for the regional recalibration and uses the default land use and includes all the point sources noted in Section 3.1.

Existing mitigations are assumed to be inherent in the calibration and are not included in the current scenario. However, while not included in the current scenario, the extent of existing stock exclusion was determined to subtract its effect from Scenario 1. Estimates of the current and future extent of stock exclusion for each DRN river segment were determined by Manaaki Whenua / Landcare Research (MW/LC; reference Dr Simon Vale) for HRC. These estimates were provided to NIWA by HRC and are summarised with the future extent of fencing in Table 4-1. The current extent of fencing was estimated by MW/LC from diverse data including the MW/LC Survey of Rural Decision Makers[6] and spatial data (e.g., from the Sustainable Land Use Initiative and the Freshwater Programme) provided to MW/LC by HRC. It is estimated that 4571 km of streams[7] in the region are currently fenced; this is around 13 % of the total stream length in the region.

[6] Survey of Rural Decision Makers » Manaaki Whenua (landcareresearch.co.nz)
[7] Stream length estimated from the REC 2.5 river network.

4.1.2 Scenario 1 – Stock Exclusion

Scenario 1 increases the extent of fencing for stock exclusion across the region in accordance with the implementation of the Resource Management (Stock Exclusion) Regulations 2020[8]. The dataset provided by MW/LC gives the percentage of the total stream length in each DRN river segment in the region suitable for fencing that is not already fenced (Vale and Smith 2023). The future extent was estimated on the basis of land cover (wooded land and urban areas from the Land Cover Database[9] were excluded from the estimation), stream width (wider than 1 m)[10] and slope (low slopes from the MfE low slope spatial layer[11]). The length of streams to be fenced under Scenario 1 for each FMU is given, along with the current extent of fencing, in Table 4-1. Under Scenario 1, an additional 3778 km of streams (10 % of the total stream length) will be fenced. Assuming both sides of the stream is fenced, the length of new fencing will be 7556 km.

Table 4-1: Percentage of streams by FMU that are currently fenced (Current) or will be fenced (Scenario 1). Data provided by HRC to NIWA.

FMU	Current fencing	Additional fencing (Scenario 1)
Kai Iwi	10%	5%
Manawatū	23%	19%
Puketoi ki Tai	13%	7%
Rangitīkei-Turakina	13%	10%
Waiopehu	20%	24%
Whangaehu	7%	3%
Whanganui	5%	6%
Regional total	**13%**	**10%**

The PREs for fencing were applied to dairy, sheep and beef, and deer farming and were derived from a literature review undertaken for national *E. coli* modelling (Muirhead 2016; Semadeni-Davies and Elliott 2017; Semadeni-Davies *et al.* 2018; Muirhead 2019; Semadeni-Davies *et al.* 2020). Low, medium and high estimated PREs were applied in different model runs to give a range of possible future *E. coli* loadings (Table 4-2).

Table 4-2: Range of *E. coli* removal efficiencies for the five different levels of future stock exclusion modelled.

Percentage Removal		
Low	**Medium**	**High**
24%	62%	92%

It was assumed that both sides of streams are fenced and each stock type within a subcatchment has the same weighted PRE and will be equally excluded from streams. Since a river segment can have

8 https://www.legislation.govt.nz/regulation/public/2020/0175/latest/LMS379869.html
9 https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/
10 https://shiny.niwa.co.nz/nzrivermaps/
11 https://data.mfe.govt.nz/layer/111150-stock-exclusion-low-slope-land-2022/

sections of fenced and unfenced banks, the PREs in Table 4-2 were weighted for each DRN subcatchment by the proportion of the total stream bank that is within each stock exclusion class.

4.1.3 Scenario 2 Reduction of point source loads

Scenario 2 reduces or removes estimated loads from selected point sources located in Manawatū-Whanganui. The updated loads used in CLUES for Scenario 2 are shown in Table 4-3 and were provided by HRC. The updated loads represent, for example, changes in proposed consent applications and / or changes to long term plans from city and district councils.

4.2 Economic Analysis

The economic analysis of the stock exclusion scenario uses the following assessment frameworks: lifecycle costing, cost effectiveness analysis (CEA) and benefit-cost analysis (BCA). The analysis of the point source reduction scenario was not undertaken as it is outside the scope of this study.

Lifecycle costing is used to evaluate the costs for both CEA and BCA. It considers all costs associated with a product or project throughout its entire lifecycle, including upfront costs, operational expenses, maintenance costs, and end-of-life costs. Lifecycle cost (LCC) allows the comparison of assets or programmes with different lifespans. For example, the LCC of the stock exclusion scenario may be compared with the LCC of a different freshwater mitigation bundle.

CEA is a method used to compare the costs and outcomes of different interventions, programs, or policies with similar objectives. It assesses the efficiency of alternatives by calculating the cost per unit of a specific outcome or benefit achieved. CEA is appropriate for this assessment because the primary mitigation benefits can be converted to a common unit of impact (*E.coli* load).

BCA, on the other hand, allows the assessment of whether the net benefits of a project outweigh the costs. Given that the benefits derived from reduced pathogen loads are not directly traded in markets, their valuation requires the use of non-market valuation methods. There have been previous non-market valuation studies regarding *E.coli*, but the transfer of values from one context to another may overlook important differences and potentially lead to inaccurate assessments. Therefore, net benefit estimates should be treated with caution. Normally, it is important that the benefit-cost ratio be greater than one. However, when there is a legal obligation to meet the freshwater attribute national bottom line, then a conventional BCA framework does not apply. In this case, BCA may be used to compare options that have varying benefits or costs, with the condition that the chosen option should at least fulfil legal obligations.

4.2.1 Lifecycle analysis period

The life cycle analysis period is the number of years over which the analysis will run. It can sometimes equal the life span of an investment but also requires consideration of policy planning timeframes and long-term objectives. If long-lived investments are assessed over a longer time period, then the annualised cost will be smaller, all else being equal. The National Stock Exclusion Study (Ministry for Primary Industries 2016) used a period of 25 years because that is the average expected lifetime for fencing. However, most councils use a 50-year time-frame; for example, Auckland Council views 50 years as more appropriate for economic assessment (Muller *et al.* 2020; Auckland Council 2021). Accordingly, in this analysis, we adopted a 50-year timeframe for all costs and benefits while also conducting a sensitivity analysis using 25 years.

Table 4-3: Scenario 2 updated point source loads (peta organisms per year) for Manawatū-Whanganui. Data provided by HRC.

NZSEGMENT	Name	Updated load	Reduction	
			Load	%
7234946	AFFCO Fielding at Industrial Waste water	0.0199	0.0000	0
7235055	Dannevirke STP at microfiltered oxpond	0.0004	0.0000	0
7247235	Eketahuna STP at Secondary oxpond waste	0.0003	0.0009	77
7235811	Feilding STP at Secondary oxpond waste	0.0078	0.0078	50
7242126	Foxton STP at Secondary oxpond waste	0.0000	0.0129	100
7231319	Halcombe at Secondary oxpond	0.0000	0.0050	100
7224518	Hunterville STP at Microfiltration Plant	0.0003	0.0000	0
7229177	Kimbolton STP at oxpond waste	0.0000	0.0008	100
7230320	Marton STP at Rock filtered oxpond waste	0.0000	0.0463	100
7174519	National Park STP at Secondary oxpond	0.0012	0.0000	0
7230015	Norsewood STP at oxpond waste	0.0002	0.0000	0
7233271	Ohakea STP at Effluent outfall	0.0000	0.1030	100
7233271	Riverlands at Industrial wastewater	0.0888	0.0000	0
7233271	Bulls STP at Secondary oxpond waste	0.0028	0.0000	0
7192527	Ohakune STP at Secondary oxpond waste	0.0128	0.0000	0
7231038	Ormondville STP at 2nd oxpond waste	0.0001	0.0000	29
7241128	Pahiatua STP at Tertiary oxpond waste	0.0009	0.0030	77
7239481	PNCC STP at Tertiary Treated Effluent	0.0000	0.5037	100
7244835	Pongaroa STP at 2nd oxpond waste	0.0002	0.0001	43
7236160	PPCS Oringi STP at oxpond waste	0.0005	0.0000	0
7194503	Raetihi STP at Secondary oxpond waste	0.0019	0.0000	0
7193718	Rangataua STP at Secondary oxpond waste	0.0002	0.0000	0
7227733	Ratana STP at Secondary oxpond waste	0.0000	0.0004	100
7236594	Rongotea STP at Secondary oxpond waste	0.0000	0.0021	100
7234275	Sanson STP at Secondary oxpond waste	0.0000	0.0148	100
7211096	Taihape STP at oxpond waste	0.0796	0.0000	0
7150643	Taumarunui STP at Tertiary treated waste	0.0041	0.0000	0
7241792	Tokomaru at oxpond waste	0.0000	0.0009	100
7196591	Waiouru STP at oxpond waste	0.3613	0.0000	0
7196647	Winstone Pulp WWTP at oxpond waste	0.4328	0.0000	0
7238330	Woodville STP at Secondary oxpond waste	0.0010	0.0023	70

4.2.2 Discounting

The real discount rate is a percentage rate used to discount future costs and benefits back to their present-day value and reflects the social cost of capital. A higher discount rate places more emphasis on the initial investment outlay relative to ongoing maintenance and leads to a higher annual LCC. The reverse is true for a lower discount rate.

The default public sector discount rate is published by the NZ Treasury[12] and was 5 % at the time of this analysis. We used the default rate of 5 % but also included sensitivity analyses at 3 % and 7 %.

4.2.3 Cost effectiveness analysis criterion

The criterion against which to compare performance should align with policy objectives, be quantifiable, and be sensitive enough to detect variations in performance. A criterion on a continuous scale is preferred to a categorical scale such as NOF bands as it enables finer differentiation between outcomes.

The criteria against which we chose to evaluate cost-effectiveness was median *E. coli*/100ml (C_{50}). As mentioned in Section 3 above, 95th percentile concentration (C_{95}) is not strictly necessary for determination of NOF band so would be a less relevant criterion.

The outcome metric was calculated by multiplying median *E. coli*/100ml (C_{50}) in each segment by stream length in kilometres. The inclusion of length in the metric means that the cost effectiveness result may be compared across different catchments if the same modelling and assessment methods are used.

4.2.4 Data inputs and assumptions

All costs were converted from publication year to 2023 dollars using the seasonally adjusted Producer's Price Index (PPI) published by Statistics New Zealand. An average of the dairy and sheep and beef PPI indices were used. Benefit values were adjusted for inflation using the Consumer Price Index (CPI), also published by Statistics New Zealand.

Costs:

Fencing

The cost of fencing varies significantly, depending on factors such as the terrain and the specific livestock that the fence aims to exclude. As the type of farm was not known for each section of new fencing, fence lengths were assigned livestock according to the proportion of each farm type in the DRN.

Table 1 in the National Stock Exclusion Costs report (Ministry for Primary Industries 2017) lists the minimum, average and maximum costs for different fence and terrain types. Only the costs for flat and rolling terrain were included because the current fencing scenario encompasses slopes of up to 15 degrees. The minimum and maximum costs across flat and rolling terrain were adjusted to 2023 prices using the PPI and mapped to a land-use type in CLUES (Table 4-4). The midpoint of the low and high figures were used for a medium cost scenario.

[12] https://www.treasury.govt.nz/information-and-services/state-sector-leadership/guidance/financial-reporting-policies-and-guidance/discount-rates

Table 4-4: Range of fencing capital costs per metre for flat and rolling land derived from MPI (2017)

CLUES Farm type	Fence type	Cost estimate range ($)		
		Low	High	Midpoint
Dairy	Electric 2-wire	$3.88	$14.11	$9.00
Intensive sheep and beef	Electric 4-wire	$5.87	$16.29	$11.08
Hill/high-country sheep and beef	8-wire or netting	$11.77	$25.12	$18.44
Deer	Deer netting	$18.28	$38.55	$28.41

Excluding sheep requires either electric 4-wire or non-electric 8 wire or netting. Electric fences have lower capital costs but require access to a reliable electricity supply, regular monitoring of electrical components, and regular checks to ensure vegetation is not earthing the wires (Ministry for Primary Industries 2016; p. 22). Electric fences may therefore be less appropriate for hill or high-country sheep and beef farms that tend to be larger and more remote. Netting fences have a lower cost than 8-wire fences on flat terrain, however installation can be challenging on hills (Wiremark 2016).

A review of actual forest restoration costs (Forbes 2022) reported average costs of $14.75 per metre for 2-wire, $16 for 4-wire, and $22 for 8-wire fences, consistent with the high range of costs above. However, the costs in Forbes may include fences on steep slopes. Another source (Waikato River Authority 2022) says $9.20 for 3-wire electric, which is consistent with the midpoint estimate above

Fencing maintenance and replacement

Each type of fence was assumed to have a 25-year average lifetime, and be replaced at the end of year 25 (Muller *et al.* 2020). Any residual value in terms of reusable materials is assumed to be balanced by the cost of disposal of non-reusable materials, so the net disposal cost was zero.

The annual maintenance cost of fencing was assumed to be 1 % of the construction cost (Ministry for Primary Industries 2016; p. 20). While it is believed that electric fences may have higher maintenance costs, figures to support this claim could not be found in published literature. Consequently, the same 1 % maintenance cost was applied to electric fences as well.

Riparian planting

It was assumed that the excluded riparian buffer will not be planted, therefore no planting costs were included in this analysis. Weed control was included in fence maintenance but only to the extent of removing pest plants that may compromise the integrity of the fence.

Water reticulation

The Ministry for Primary Industries (2016; p. 21) estimated a water reticulation system for 50 hectares might cost $13,574 ($362 per hectare in 2023). However, Journeaux and van Reenen (2016) provide a more detailed economic analysis with real case studies. They report an average capital cost of $154 per hectare ($208 in 2023 prices) and an annual maintenance cost of 5%. Unlike fencing, water reticulation does not have a designated lifetime. Rather, worn out fittings are assumed to be replaced as part of regular maintenance.

Journeaux and van Reenen (2016) report that installing water reticulation provided a net benefit and an average payback period of 3 years, due to improved grazing management and stock performance.

If water reticulation provides a net benefit, then it should not be counted as a cost in a stock exclusion scenario. However, the case study farms apparently lacked reliable water prior to installing a system. If a stream provides reliable water, then replacing it with a reticulation system will not necessarily boost productivity. Therefore, we conservatively use only the costs from Journeaux and van Reenen (2016) and not the benefits resulting from reliable water.

There was no information available about the water reticulation propensity in the region. Following a similar approach to Muller *et al.* (2020), it was assumed that intensive farm systems will already have water reticulation so installation will be necessary only for hill country sheep and beef farms. To account for the uncertainty surrounding whether water reticulation already exists, and whether it is truly a net cost, the sensitivity analysis presents results with and without water reticulation expenses.

Retirement opportunity cost

Stock exclusion requires retirement of the riparian area from active grazing. The loss of this grazing is the opportunity cost, which depends on the size and productivity of the excluded area. A particularly wide and flat riparian area may be mowed to produce hay (Matthews and Matheson 2020), but it is assumed that this option will not be feasible for the majority of newly fenced margins. Allowing mowing requires the use of moveable electric fences, which do not contain sheep.

The calculation of the opportunity cost per retired hectare was derived from the operating profit per effective hectare, as presented by Muller *et al.* (2020: table 3). These figures have been adjusted to reflect 2023 prices. Following the methodology employed by the author, we applied a 50 % multiplier to account for the lower productivity of riparian margins, which tend to be frequently saturated.

Table 4-5: Average operating profit and opportunity cost of riparian retirement by land-use type.

CLUES Land-use type	Operating profit per effective hectare ($)	Opportunity cost per retired hectare ($)
Dairy	1 623	812
Sheep and beef intensive	830	415
Sheep and beef hill country	513	256
Deer	598	299

The 2020 Stock Exclusion Regulations require a 3-metre setback for riparian fencing. However, wider setbacks of at least 10 metres are recommended for nutrient reduction, allowing shade plants, and bank stability (Fenemor and Samarasinghe 2020). Therefore, a sensitivity analysis was performed using average buffer widths of 3 and 10 m.

Benefits

Non-market values

The analysis uses the findings of a water quality valuation study (Tait *et al.* 2016) commissioned by the Ministry for the Environment and the Ministry for Primary Industries (MPI) in association with the drafting of national stock exclusion guidelines. That study used a non-market choice experiment methodology and a nationwide survey to evaluate public willingness-to-pay (WTP) for reduced human infection risk, ecological health and clarity. The valuation attributes were presented as percentages of waterways achieving different quality levels. Only WTP for human health risk was used in the MPI cost-benefit analysis (Ministry for Primary Industries 2016). Findings were generally in agreement with earlier non-market valuation studies of ecological health.

The infection risk levels used by Tait *et al.* (2016) align reasonably well with the *E. coli* attribute bands outlined in Table 22 of the 2020 National Policy Statement for Freshwater. In 2023 prices, the median WTP for a 1 % increase in the proportion of sites in band A is $4.10, with a 90% confidence interval ranging from $3.46 to $4.75 (Table 4-6). For band B the median WTP is $1.43. The lowest WTP ($0.87) is applied to both bands C and D because the infection risk level used in the choice experiment falls between these two bands. There is no value associated with the worst band, E.

Table 4-6: Annual willingness-to-pay in 2023 dollars for a percentage point increase in *E. coli* attribute band among residents aged over 17 years.

NOF band	Median	Low	High
A	4.10	3.46	4.75
B	1.43	0.81	2.05
C	0.87	0.27	1.59
D	0.87	0.27	1.59

A limitation of the study (Tait *et al.* 2016) is that the scenarios presented to participants had a much larger change in human health risk than the stock exclusion scenario analysed in this report. For example, the best outcome (equivalent to band A) ranged from 50 % to 80 % of all waterways. Non-market values are critically dependent on the range of outcomes presented to participants, so we might expect values transferred from that study to significantly under-estimate the value of the modest and more realistic outcomes resulting from the scenarios in this report.

Another non-market valuation approach was used in a study by Matthews (2023). That study sought to measure the total WTP for all freshwater restoration activities, and subsequently allocated this value spatially and by water quality attribute based on participant priorities. In 2023 prices, the aggregated median WTP for freshwater restoration in Manawatū-Whanganui is $17.7 million. When this amount is allocated by quality attribute, WTP was $1.59 million for activities to reduce pathogen, $2.1 million to reduce nutrients, and $1.4 million to reduce dissolved sediment. Although stock exclusion does have some benefits for nutrient and sediment reduction, the total of the three ($5.1 million) should be considered a high estimate while $1.59 million is a conservative estimate.

Non-market values are known to be highly dependent on the specific context and presentation of the valuation study. Various factors such as the number of water quality attributes, the spatial scope, the framing of the questions, and the methodological approaches employed can influence respondents' perceptions and, consequently, their stated WTP. Therefore, we performed a sensitivity analysis by considering the lower and upper values of benefits estimated from these two separate studies.

Summary of data and sources

Table 4-7 provides a summary of the key information sources used in the economic analysis.

Table 4-7: Summary list of data sources.

Information	Source
Fence construction cost	Ministry for Primary Industries (2016)
Fence maintenance cost	Ministry for Primary Industries (2016)
Water reticulation cost	Journeaux and van Reenen (2016)
Water reticulation maintenance cost	Journeaux and van Reenen (2016)
Retirement opportunity cost	Muller *et al.* (2020)
Non-market benefits	Tait *et al.* (2016), Matthews (2023)

4.2.5 Limitations and non-quantified values

The accuracy of any economic analysis is dependent mainly on the quality of data utilized. One challenge is the fact that cost information is variable, not site-specific, and rapidly goes out of date. Furthermore, as mentioned above, non-market benefits transferred from a different context are inherently uncertain. In this analysis, the most recent cost and benefit information has been employed, but it is important to exercise caution when interpreting the results.

There is anecdotal evidence that stock exclusion from waterways reduces stock deaths and injuries, makes mustering easier, and enables improved grazing management (Journeaux and van Reenen 2016). However, no quantitative estimates of these benefits could be found.

4.2.6 Data inputs and assumptions

All costs were converted from publication year to 2023 dollars using the seasonally adjusted Producer's Price Index (PPI) published by Statistics New Zealand. An average of the dairy and sheep and beef PPI indices were used. Benefit values were adjusted for inflation using the Consumer Price Index (CPI), also published by Statistics New Zealand.

4.3 Load reduction to meet targets

4.3.1 Method of determining load reduction to meet a target grading band

The load reduction analysis assesses the degree to which source loads under the current scenario would need to be reduced to meet hypothetical grading targets. The overall process follows an iterative procedure as described in Elliott *et al.* (2020) and has four steps:

1. Establish the load reduction factor (LRF) to achieve a specified target grading band for each stream segment of interest given its current state band. This also gives a target load, which is the current load divided by the LRF, and a load reduction to meet the target load. An LRF of two, for instance, means that the instream load would need to be halved to meet the target. A reduction factor of 1 means there is no load reduction required. A reduction factor less than 1 would mean that the load would increase to match the target, but this situation does not arise because water quality is not permitted to degrade under the NPS-FM.

2. The segments of interest in this study were chosen to be those segments with a stream order of four or more (i.e., higher order streams) and segments with an associated SOE water quality monitoring site.

3. For each subcatchment, find the segment downstream with the largest value of reduction factor (the maximum downstream load reduction factor, MDLRF). This is to give an idea of which subcatchments could be implicated in achieving load reductions. Maps of this factor give an indication of the extent and degree of source load reductions, but the MDLRF is not used in the source load reduction calculations.

4. For each river segment of interest, distribute the load reduction at that segment across the upstream catchment of the segment. In other words, determine the reduction of source load from each subcatchment to meet the target load in all downstream river segments (including the segment associated with the subcatchment). This calculation is done in an iterative way.

5. Re-calculate attribute bands after the source load reduction.

These steps are described in more detail below.

Step 1. In-stream load reduction factor and load reduction at each river site of interest

The first step of the process is to establish the reduction in instream loads (loads flowing down the stream or river) that would be needed to meet a specified grading target band for each river segment of interest. This was calculated for each segment of interest by: a) determining a load reduction factor (LRF) from the reduction in concentration or G value to achieve the target grading band; b) multiplying the LRF times the current load to calculate the target load; and c) using the difference between the current load and target load to determine the load reduction. The LRF was constrained to be greater than or equal to 1 so that there are no load increases, only load reductions or stationary loads.

LRF calculation. For each segment of interest, the in-stream LRF was determined for each of the four numeric attributes related to *E. coli* water quality bands in the NOF (C_{50}, C_{95}, G_{260} and G_{540}) to meet the specified target attribute band. For a specified target attribute band, the associated target value of the numeric attribute state was taken as the value at the lower (more degraded) end of the attribute band in Table 9 of the NPS-FM (reproduced here in Table 2-1), for each of the numeric attributes. In the case of a target band of D, the target value in relation to C_{95} was set to a large number, because the overall grade band is determined by the attributes other than C_{95}.

For the concentration (numeric attributes C_{50} and C_{95}), the LRF was calculated as the current state concentration divided by the target concentration for the numeric attribute. For the exceedance (numeric attributes G_{260} and G_{540}), the LRF was determined using the method given in Appendix D. If the current state is already at or better than the target state, then the in-stream load reduction factor was set at 1, to maintain or improve water quality.

Once the LRF was determined for each numeric attribute, the overall reduction factor to meet the target was set as the largest of the values for the individual numeric attributes, because the overall grading for a site is based on the worst grading across the four numeric attributes.

Segments that are not segments of interest (i.e., those that have no target assigned) or have no downstream segment of interest are given a load reduction factor of one to ensure no degradation of water quality.

Step 2. Maximum downstream reduction factor

For each DRN segment all downstream segments were examined to find the segment downstream with the maximum LRF. The associated reduction factor is termed the termed the maximum downstream load reduction factor, (MDLRF). This result is not used directly in later steps, but gives an indication of what source locations are implicated reducing loads at segments of interest.

Step 3. Distribute load reduction to determine source reductions

The in-stream load reduction at a segment of interest is distributed to its upstream catchment by assuming that the manageable source load for each upstream segment is reduced by the same proportion. The manageable source load for a segment is equal to the current source load minus a reference source load representing natural conditions (i.e., all point sources removed and all developed land use such as urban and pastural crop land converted to native forest). Load reduction is done first for the critical segment, which is the segment requiring the largest proportional reduction of accumulated manageable load to meet the load target. The source loads after source reduction are then routed through the network (as described in Section 2). The process of identifying critical points and distributing the load reduction upstream is repeated in an iterative fashion until no further reductions are required. In this way, the method accounts for situations where an upstream segment requires a larger reduction in manageable load than a downstream segment.

Step 4. Determine the attribute band after source load reduction.

After the iterative process described above, the attribute band for each stream segment was determined from the reduced instream loads as described in Section 4.1. This was repeated for two cases: including C_{95} in the overall grading; or excluding it.

4.3.2 Target bands used

The load reduction analysis was applied for each of five hypothetical grade target bands; i.e., NOF bands A to E. The goal of target band E is effectively to maintain concentrations and G values at their current condition. For each of these scenarios, the target band was applied uniformly to all segments of interest (fourth order streams and larger, plus SOE sites).

4.3.3 Low Reference Source scenario

The above scenarios were repeated for an additional Low Reference Source scenario. In assessing load reductions, it was found that it was difficult to get to the target state in some cases (typically when aiming for an A or B band). This was because, despite reducing loads to the reference condition, the load reduction was not sufficient to reduce the concentration or exceedance values to their target state. This could be a manifestation of uncertainty regarding the reference load. To explore the possible impact of such uncertainty, we conducted the load reduction analysis with a Low Reference Source reference scenario, whereby the source coefficients associated with natural land uses were halved. Under this scenario there is more scope for reducing loads, and hence the concentration and exceedance values. The original scenario with calibrated rather than reduced reference loads is referred to as the Full Reference Load scenario.

The analysis was therefore run with four scenarios; i.e., with the calibrated (full) and low references sources, both with and without the C_{95} numeric attribute used in the band determination.

4.3.4 Comparison with national targets

The distribution of stream lengths in each band after load reduction was determined to compare with the national target distribution of grades from Appendix 3 of the NPS-FM (see Figure 4-1) for the nominal year 2030. For the distribution, only stream segments of interest were considered (fourth order or larger, and SOE sites). Under the national grade targets, 80 % of higher order streams are required to be in NOF bands A to C to achieve the target for primary contact. The distribution of grades was repeated for two cases: including C_{95} in the overall grading or excluding it.

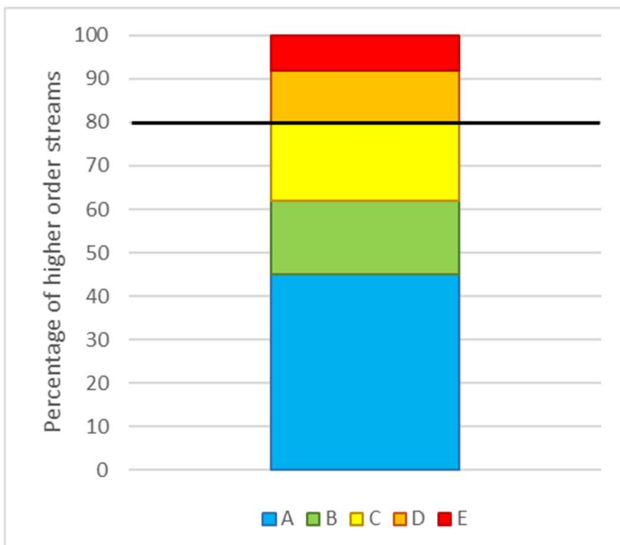


Figure 4-1: National targets for primary contact, reference year 2030. Reproduced from Appendix 3 of the NPS-FM.

4.3.5 Other outputs

Shapefiles of the MDLRF and distribution of source load reduction were created. Results by river segment are provided in supplementary files so further summaries or displays can be generated.

The total source load reduction was calculated by summing the reductions across all subcatchments in the region, and was expressed as a reduction factor in relation to the current total source load (before reduction).

Load reduction factors (D) can be translated into percentage reductions (P) using the formula P = 100 (1 – 1/D), as depicted in Figure 4-2.

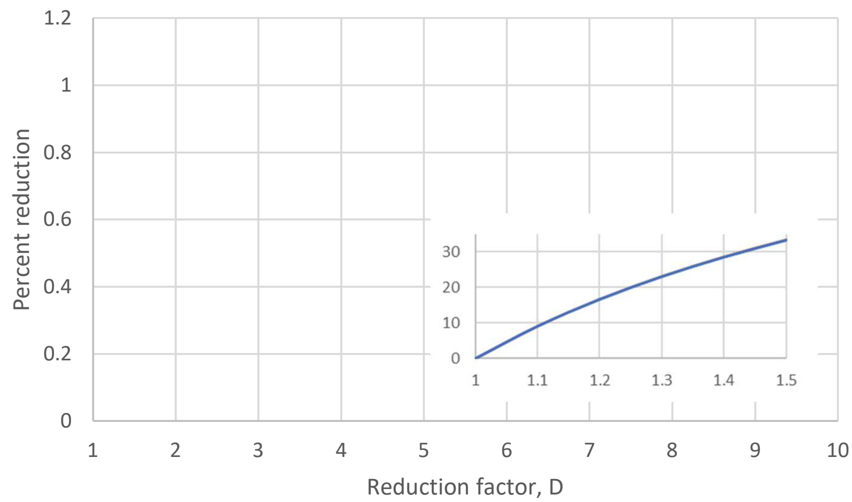


Figure 4-2: Relationship between load reduction factor and percent reduction.

5 Results with discussion

For the current and future state modelling and load analysis, reporting here has been restricted to higher order streams, while the economic analysis was carried out for all stream orders.

5.1 Current and future state modelling

The outputs created for each scenario run of the CLUES *E. coli* model that have been provided to HRC are listed in Table 5-1. The outputs reported here for each scenario are maps of the generated *E. coli* loads and segment NOF bands by DRN stream segment and tables of the stream length within each of the NOF bands calculated for each FMU. The reporting has been restricted to higher order streams as these are the streams deemed suitable for human contact activities under the NPS-FM (see Appendix 3 of New Zealand Government 2020).

Table 5-1: Model output files produced or each scenario and their contents. Scenario in the file name replaced by the scenario name for each model run.

File	Content
NOF_bands_Segments_scenario.csv	Current and future state NOF bands for each DRN river segment derived from the modelled current state attributes determined by Whitehead *et al.* (2022) for MfE.
Segment_scenario.shp	Shapefile containing the same data provided in the NOF_bands_Segments_scenario.csv text file.
Seg_Load_scenario.shp	Shapefile containing the generated and cumulative loads and yields for the baseline and future state scenarios.
NOF_bands_SOE_meas_scenario.csv	Current and future state NOF bands for each DRN river segment containing a SOE monitoring site derived from measured water quality data. The NOF attributes for the sites were calculated by Whitehead *et al.* (2022).
NOF_FMU_Ord_scenario.csv	The length of streams* within each NOF band grouped by FMU and Strahler stream order.
NOF_FMU_Order4Plus_scenario.csv	The length of streams* within each NOF band grouped by FMU and stream order for river segments with an DRN stream order of four or more. These streams are those deemed swimmable under the NPS-FM (see Appendix 3 of New Zealand Government 2020)
NOF_FMU_scenario.csv	The total length of streams* within each NOF band grouped by FMU.
Trace_Segments_scenario.csv	Modelled generated and instream (cumulative) *E. coli* load estimates for each stream segment. The loads are presented for each land use class and as segment totals summed for all land uses and point sources.
Trace_SOE_scenario.csv	As above extracted for reaches containing an SOE monitoring site.

*Stream lengths taken from the DRN 2.5 stream network.

5.1.1 Current scenario

The total mean annual load of *E. coli* delivered to the coast under the current scenario is 121 peta organisms per year. The current generated *E. coli* yields are mapped by DRN segment in Figure 5-1, and the NOF bands calculated with and without the C_{95} numeric attribute are likewise mapped in Figure 5-2. The FMU boundaries and higher order streams are shown in the maps for reference. There is broad agreement between the spatial distribution of *E. coli* yields and the NOF bands with the highest yields coinciding with bands E and D and the lowest yields coinciding with bands A and B. The lowest yields are found in forested areas of the Matemateaonga and Hauhungaroa Ranges in the Whanganui FMU and the Tararua and Ruahine Ranges in the Manawatū FMU. The highest yields are associated with urban land use (i.e., Whanganui, Palmerston North, Dannevirke and Levin) followed by high intensity farming.

The length of streams in each NOF band for the higher order streams is given by FMU in Table 5-2 (with the C_{95} attribute) and in Table 5-3 (without the C_{95} attribute). The percentage of the total length of higher order streams in each class is plotted by FMU with and without the C_{95} attribute in Figure 5-3 for visual comparison. The length of streams in each band for the current and future state scenarios is given in Appendix E by WMS and Appendix F by SOE site.

The tables show the overall or net change in lengths within the NOF bands, which does not necessarily reflect the actual length of streams affected by the change in classification. That is, if a shift in length from band D to C is balanced by a shift from band C to B, there will be no apparent change in the length of streams in band C and an apparent jump from band D directly to band B.

Because there is no band E criterion for C_{95}, there is no change in the length of streams in NOF band E between the model outputs with and without C_{95}. However, there is a net shift in band for around 743 km of higher order streams in the region when excluding C_{95}. There is a small increase in the length of streams in NOF band A (27 km) without the C_{95} attribute, but the greatest increases are in the B (407 km) and C (309 km) bands. The FMUs with the least percentage change in the length of stream in the NOF bands were Puketoi ki Tai (5) and Waiopehu (7), while the FMUs with the greatest change in NOF bands were Whangaehu (27) and Kai Iwi (24).

Removing the C_{95} attribute results in a change of NOF band for 18 SOE sites, 12 from band D to band C (HRC-00063 / Whanganui at Cherry Grove, LAWA-100545 / Hautapu at Papakai Road Bridge, HRC-00058 / Whangaehu at Kauangaroa, HRC-00351 / Mangatewainui at Hardys, HRC-00006 / Kumeti at Te Rehunga, HRC-00040 / Pohangina at Mais Reach, HRC-00018 / Manawatu at Weber Road, HRC-00016 / Manawatu at Hopelands, HRC-00005 / Kahuterawa at Johnstons Rata, HRC-00054 / Tokomaru River at Horseshoe bend, LAWA-101936 / Mangaore at d/s Shannon STP, HRC-00022 / Mangatainoka at Larsons Road) and six from band D to band B (LAWA-100557 / Manganui o te Ao at Ruatiti Domain, HRC-00003 / Hautapu at Alabasters, HRC-00069 / Rangitikei at u/s Bulls STP, LAWA-101957 / Rangitikei at d/s Riverlands, HRC-00043 / Rangitikei at McKelvies, HRC-00004 / Hokio at Lake Horowhenua).

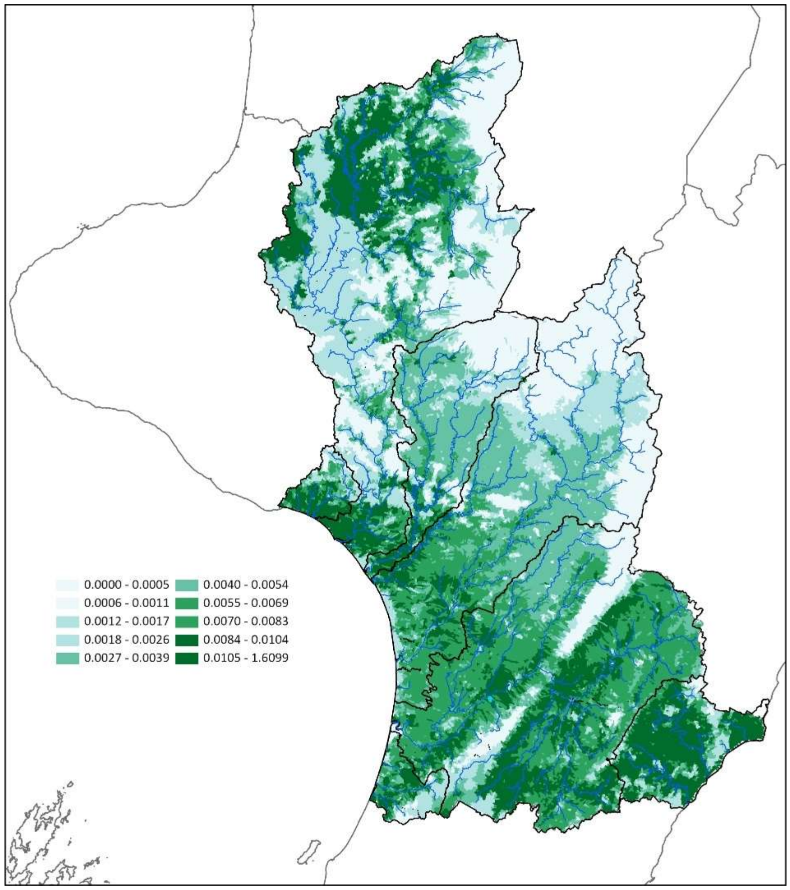


Figure 5-1: Estimated current generated *E. coli* yield (peta/km^2/y). Quantile distribution symbology.

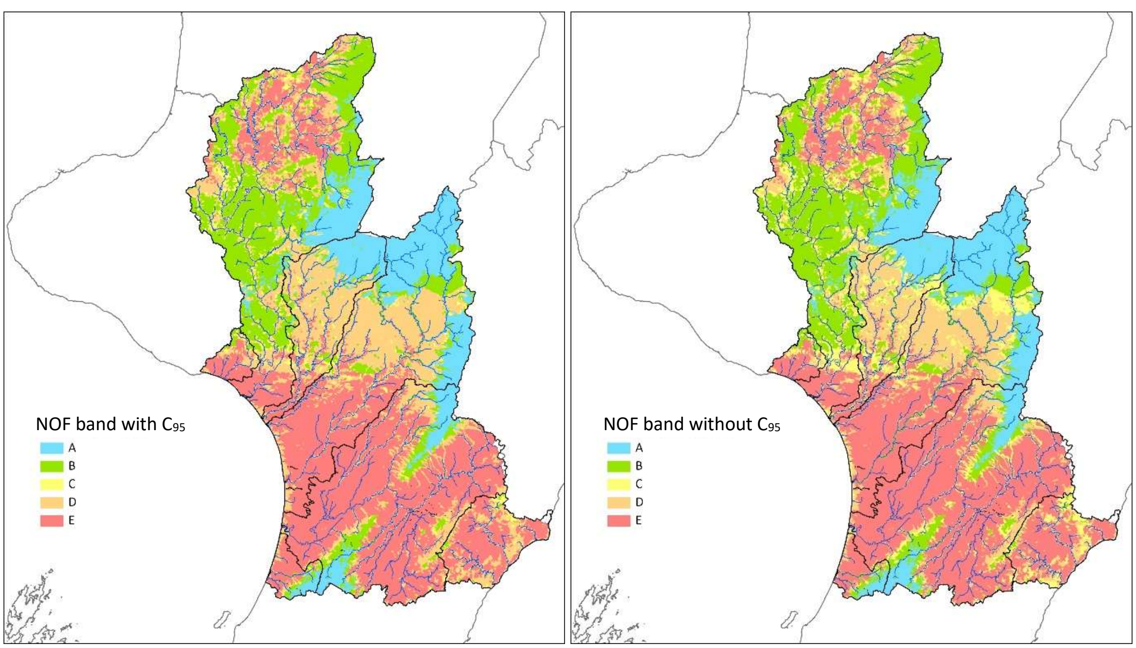


Figure 5-2: Current NOF bands determined from current state water quality attribute estimates with (left) and without (right) the C_{95} concentration attribute. Current state attribute source Whitehead *et al.* (2022).

Table 5-2: Length (km) of DRN 2.5 higher order stream segments in each NOF band determined for the current scenario with C_{95} included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Kai Iwi	0 (0)	0 (0)	1 (1.8)	40 (50)	39 (48.1)
Manawatū	81 (6)	42 (3.1)	11 (0.8)	562 (41.1)	670 (49)
Puketoi ki Tai	0 (0)	0 (0)	0 (0)	192 (74.9)	64 (25.1)
Rangitīkei-Turakina	317 (29.9)	120 (11.4)	51 (4.8)	439 (41.4)	132 (12.4)
Waiopehu	21 (30.7)	15 (21.4)	6 (8.6)	14 (20.3)	13 (19)
Whangaehu	94 (19.1)	38 (7.6)	7 (1.4)	355 (71.9)	0 (0)
Whanganui	149 (9.3)	360 (22.4)	68 (4.2)	952 (59.3)	77 (4.8)
Total	**663 (13.4)**	**575 (11.7)**	**145 (2.9)**	**2555 (51.8)**	**995 (20.2)**

Table 5-3: Length (km) of DRN 2.5 higher order stream segments in each NOF band determined for the current scenario with C_{95} not included in the band calculation. The percentage of the total stream length of higher order streams in each band is in parentheses.

FMU	A	B	C	D	E
Kai Iwi	0 (0)	17 (20.9)	4 (4.9)	21 (26.1)	39 (48.1)
Manawatū	81 (6)	64 (4.7)	122 (8.9)	428 (31.3)	670 (49.1)
Puketoi ki Tai	0 (0)	8 (3)	5 (2)	179 (69.8)	64 (25.1)
Rangitīkei-Turakina	321 (30.3)	262 (24.7)	28 (2.7)	318 (30)	130 (12.3)
Waiopehu	17 (24.8)	23 (33.8)	6 (9.2)	9 (13.1)	13 (19.1)
Whangaehu	114 (23.2)	66 (13.3)	90 (18.2)	223 (45.3)	0 (0)
Whanganui	152 (9.5)	542 (33.8)	202 (12.6)	630 (39.3)	77 (4.8)
Total	**686 (13.9)**	**982 (19.9)**	**458 (9.3)**	**1808 (36.7)**	**994 (20.2)**

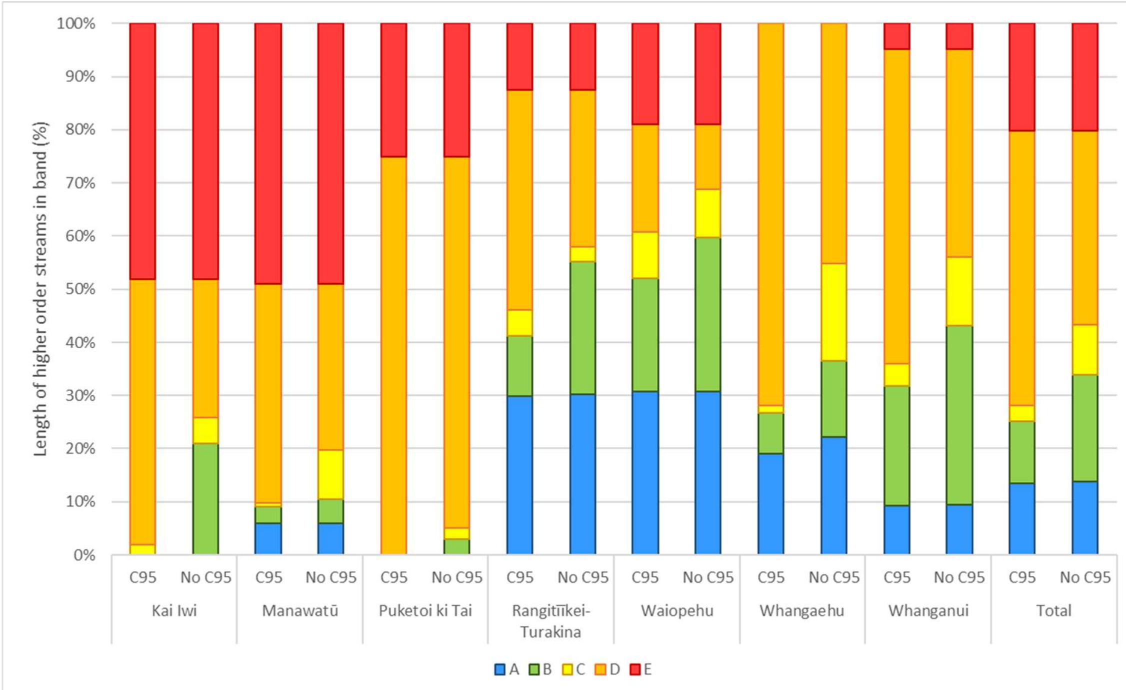


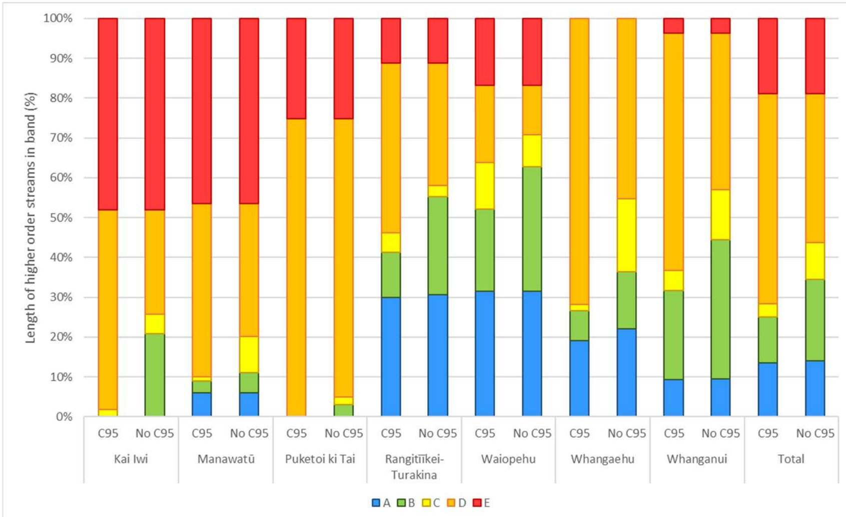
Figure 5-3: Estimated percentage length of higher order streams in each NOF band calculated with and without the C_{95} concentration attribute by FMU for the current scenario.

5.1.2 Scenario 1 – Stock Exclusion

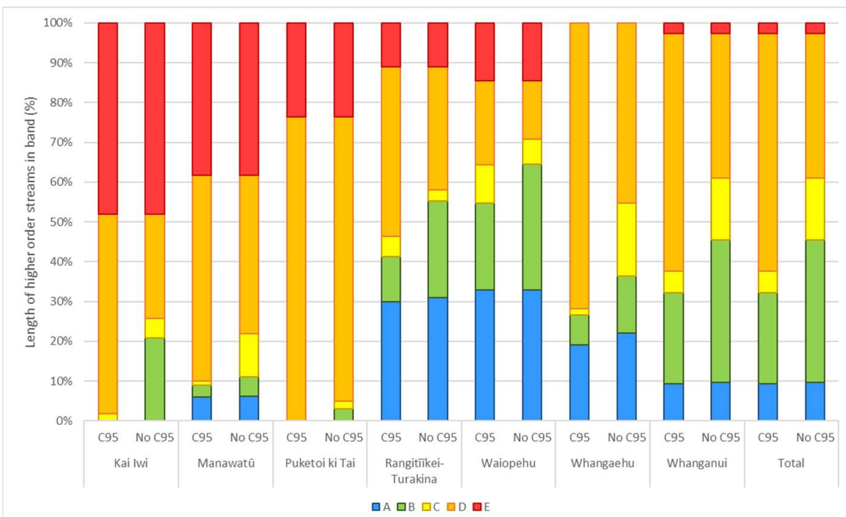
The stock exclusion scenario was undertaken with three sets of PREs representing low, medium and high estimates of removal (see Table 4-2). The mean annual *E. coli* loads delivered to the coast under Scenario 1 are 117, 112 and 107 peta organisms per year, respectively, for the three sets of PREs, which represent region-wide reductions in *E. coli* loads of 3 %, 7.7 % and 11.4 %.

Figure 5-4 shows the percentage of higher order streams in each NOF band modelled using the low, medium and high removal PREs, both with and without the C_{95} concentration attribute included in the NOF classification. The change in the length of streams in each band compared to the current scenario, with and without the C_{95} concentration attribute included in the NOF classification, are given by FMU in Table 5-4 to Table 5-9. Tables by WMS are given in Appendix G. All three scenario sets result in a small upwards shift in NOF bands across the region.

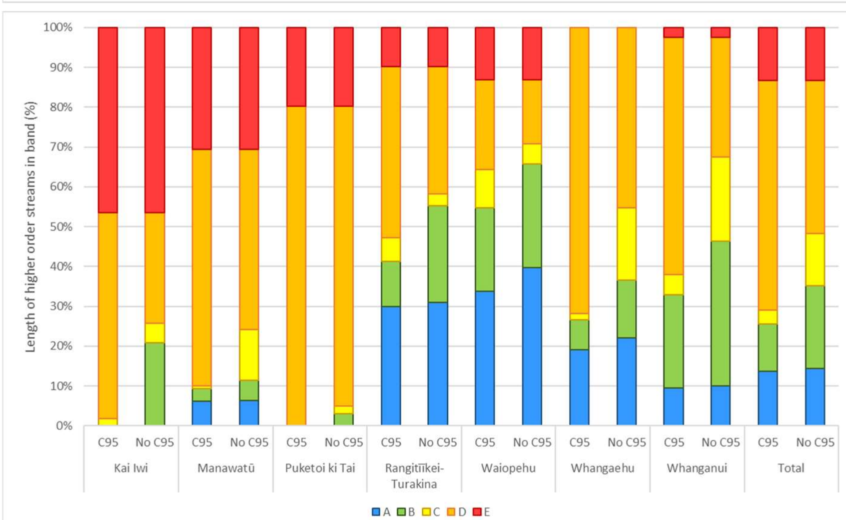
With the low removal PREs (Table 5-4 and Table 5-5), the length of streams with a net change in NOF band is around 64 km, or 1 % of the total length of higher order streams, both with and without the C_{95} attribute. The medium (Table 5-6 and Table 5-7) and high removal PREs (Table 5-8 and Table 5-9) result in a net change in NOF band classification of around 203 km (4) and 337 km (7), respectively, both with and without the C_{95} attribute included in the NOF band classification. The most affected FMUs were Manawatū and Whanganui; the net changes for these FMUs with the low, medium and high PREs amounted to 34 km, 148 km and 253 km for the Manawatū FMU and 16 km, 33 km and 37 km for the Whanganui FMU, both with and without the C_{95} attribute included in the NOF band classification. There were minimal predicted changes in band for the Kai Iwi, Puketoi ki Tai and Whangaehu FMUs.



Low PRE



Medium PRE



High PRE

Figure 5-4: Estimated percentage length of higher order streams in each NOF band calculated with and without the C_{95} concentration attribute under Scenario 1 using the low (top), medium (middle) and high (bottom) PREs.

For all levels of removal efficiency, while the net change in the length of streams with a change in NOF band is similar with and without the C_{95} attribute included in the NOF classification, there is a slight difference in the amount of shift from bands D, C and B to bands C, B and A. This is because the current without C_{95} has more stream lengths in bands C and B and fewer in band D than the current scenario with C_{95}.

The generated segment loads calculated with the medium PREs are shown in Figure 5-5 and the NOF bands estimated both with and without the C_{95} attribute are shown in Figure 5-5. The key discernible change is a move from band E to band D in the northern part of the Whanganui FMU, near the coast in the Rangitīkei-Turakina FMU and along the borders of the Tararua and Ruahine Ranges in the Manawatū FMU.

There are no predicted changes in NOF bands under Scenario 1 for the SOE monitoring sites with the low removal PRE, however there are predicted changes in NOF bands with the medium and high removal PREs, these are shown in Table 5-10.

Table 5-4: Change in the length (km) of higher order streams compared to the current scenario in each NOF band determined for Scenario 1 (low removal efficiency) with C_{95} included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Kai Iwi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Manawatū	0 (0)	0 (0)	2 (0.1)	32 (2.4)	-34 (-2.5)
Puketoi ki Tai	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Rangitīkei-Turakina	0 (0)	0 (0)	1 (0.1)	12 (1.2)	-12 (-1.1)
Waiopehu	1 (0.8)	-1 (-0.8)	2 (3.1)	-1 (-1)	-1 (-2.1)
Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Whanganui	0 (0)	0 (0)	13 (0.8)	3 (0.2)	-16 (-1)
Total	**1 (0)**	**0 (0)**	**17 (0.3)**	**47 (0.9)**	**-64 (-1.3)**

Table 5-5: Change in the length (km) of higher order streams compared to the current scenario in each NOF band determined for Scenario 1 (low removal efficiency) with C_{95} not included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Kai Iwi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Manawatū	1 (0)	5 (0.4)	-1 (0)	28 (2.1)	-34 (-2.5)
Puketoi ki Tai	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Rangitīkei-Turakina	4 (0.3)	-4 (-0.4)	0 (0)	12 (1.2)	-12 (-1.1)
Waiopehu	1 (0.8)	2 (2.2)	-1 (-1.1)	0 (0.2)	-1 (-2.1)
Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Whanganui	1 (0)	21 (0.4)	-5 (-0.1)	-1 (0)	-16 (-0.3)
Total	**6 (0.1)**	**24 (0.5)**	**-6 (-0.1)**	**40 (0.8)**	**-64 (-1.3)**

Table 5-6: Change in the length (km) of higher order streams compared to the current scenario in each NOF band determined for Scenario 1 (medium removal efficiency) with C_{95} included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Kai Iwi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Manawatū	1 (0)	-1 (-0.1)	3 (0.3)	144 (10.6)	-148 (-10.8)
Puketoi ki Tai	0 (0)	0 (0)	0 (0)	4 (1.6)	-4 (-1.6)
Rangitīkei-Turakina	0 (0)	0 (0)	2 (0.2)	14 (1.3)	-15 (-1.4)
Waiopehu	2 (2.2)	0 (0.4)	1 (1)	1 (1)	-3 (-4.5)
Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Whanganui	1 (0)	6 (0.4)	19 (1.2)	7 (0.4)	-33 (-2.1)
Total	3 (0.1)	6 (0.1)	24 (0.5)	170 (3.4)	-203 (-4.1)

Table 5-7: Change in the length (km) of higher order streams compared to the current scenario in each NOF band determined for Scenario 1 (medium removal efficiency) with C_{95} not included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Kai Iwi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Manawatū	4 (0.3)	4 (0.2)	22 (1.6)	118 (8.7)	-148 (-10.8)
Puketoi ki Tai	0 (0)	0 (0)	0 (0)	4 (1.7)	-4 (-1.6)
Rangitīkei-Turakina	8 (0.7)	-8 (-0.8)	0 (0)	15 (1.4)	-15 (-1.4)
Waiopehu	2 (2.2)	2 (2.7)	-2 (-2.9)	2 (2.6)	-3 (-4.5)
Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Whanganui	2 (0.1)	37 (2.3)	41 (2.5)	-47 (-2.9)	-33 (-2.1)
Total	**16 (0.3)**	**34 (0.7)**	**61 (1.2)**	**92 (1.9)**	**-203 (-4.1)**

Table 5-8: Change in the length (km) of higher order streams compared to the current scenario in each NOF band determined for Scenario 1 (high removal efficiency) with C_{95} included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Kai Iwi	0 (0)	0 (0)	0 (0)	1 (1.6)	-1 (-1.6)
Manawatū	3 (0.2)	1 (0.1)	-1 (0)	249 (18.3)	-253 (-18.5)
Puketoi ki Tai	0 (0)	0 (0)	0 (0)	14 (5.4)	-14 (-5.4)
Rangitīkei-Turakina	0 (0)	0 (-0.1)	11 (1.1)	17 (1.6)	-28 (-2.6)
Waiopehu	2 (3.1)	0 (-0.4)	1 (1)	2 (2.3)	-4 (-5.9)
Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Whanganui	4 (0.3)	14 (0.9)	13 (0.9)	5 (0.3)	-37 (-2.3)
Total	**10 (0.2)**	**15 (0.3)**	**24 (0.5)**	**288 (5.8)**	**-337 (-6.8)**

Table 5-9: Change in the length (km) of higher order streams compared to the current scenario in each NOF band determined for Scenario 1 (high removal efficiency) with C_{95} not included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Kai Iwi	0 (0)	0 (0)	0 (0)	1 (1.6)	-1 (-1.6)
Manawatū	5 (0.3)	7 (0.5)	49 (3.6)	191 (14)	-253 (-18.5)
Puketoi ki Tai	0 (0)	0 (0)	0 (0)	14 (5.4)	-14 (-5.4)
Rangitīkei-Turakina	8 (0.8)	-8 (-0.8)	2 (0.2)	26 (2.4)	-28 (-2.6)
Waiopehu	6 (9)	-2 (-3)	-3 (-4.1)	3 (4)	-4 (-5.9)
Whangaehu	0 (0)	1 (0.2)	-1 (-0.2)	0 (0)	0 (0)
Whanganui	8 (0.5)	45 (2.8)	131 (8.1)	-147 (-9.2)	-37 (-2.3)
Total	**28 (0.6)**	**42 (0.9)**	**179 (3.6)**	**88 (1.8)**	**-337 (-6.8)**

Table 5-10: SOE monitoring sites with predicted changes in NOF bands under Scenario 1 (high removal efficiency). Changes in NOF band compared to the current state are highlighted

Site	Current		Low PRE		Medium PRE		High PRE	
	With C_{95}	Without C_{95}	With C_{95}	Without C_{95}	With C_{95}	Without C_{95}	With C_{95}	Without C_{95}
NRWQN-00019_NIWA (WA4 Whanganui @ Paetawa)	D	D	D	D	D	C	D	C
HRC-00044 (Rangitikei @ Onepuhi)	B	B	B	B	B	A	B	A
HRC-00351 (Mangatewainui @ Hardies)	D	C	D	C	D	C	D	B
LAWA-101923 (L Horowhenua Inflow @ Lindsay Road)	D	D	D	D	D	D	D	C
HRC-00010 (Makuri @ Tuscan Hills)	E	E	E	E	E	E	D	D
HRC-00343 (Mangatainoka @ Scarborough Konini Rd)	D	D	D	D	D	C	D	C
HRC-00031 (Ohau @ Haines Property)	B	B	B	B	B	B	B	A
HRC-00008 (Makakahi @ Hamua)	E	E	E	E	D	D	D	D
HRC-00015 (Manawatu @ Teachers College)	E	E	E	E	D	D	D	D

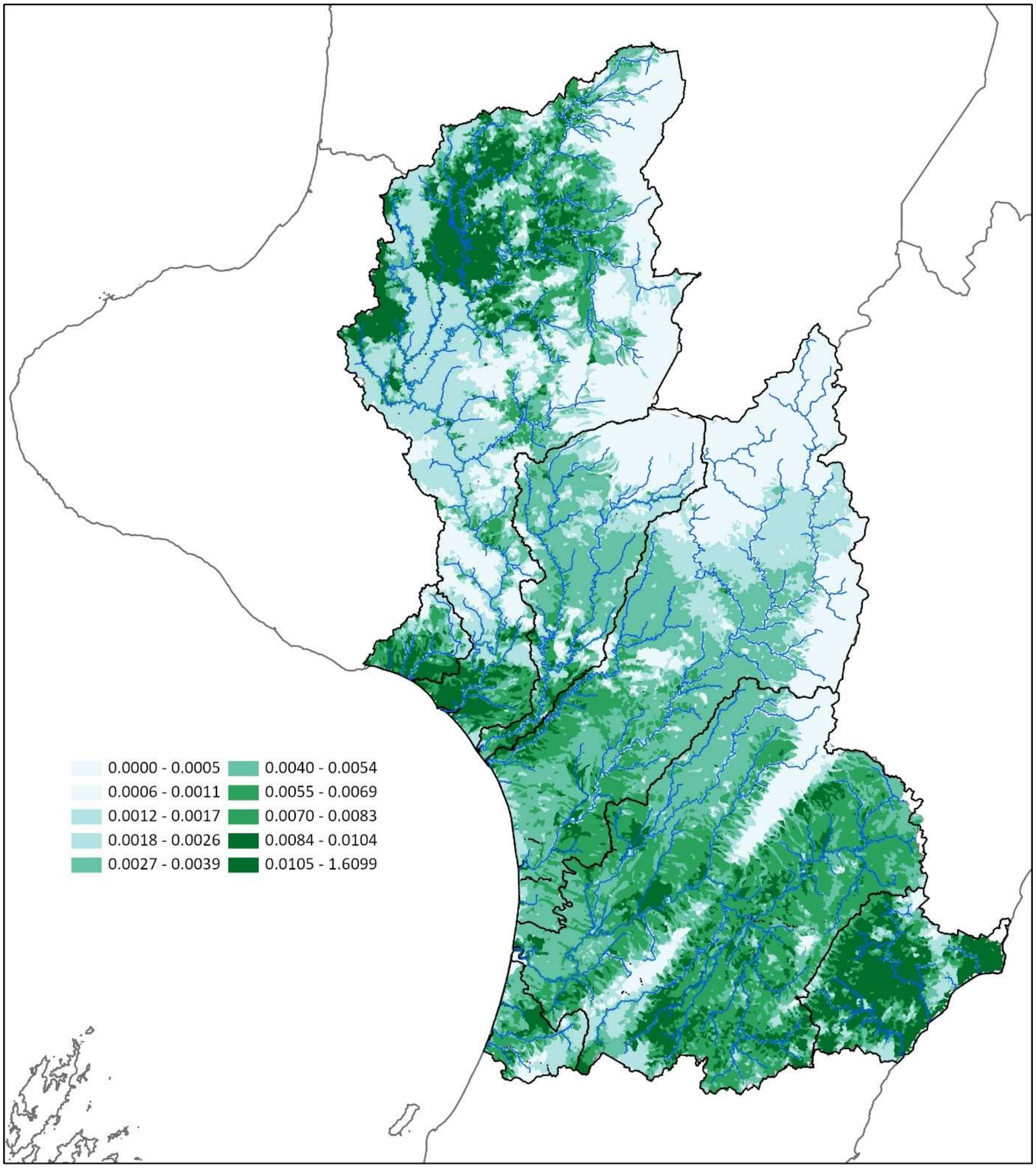


Figure 5-5: Estimated generated *E. coli* yield (peta/km^2/y) for Scenario 1 (medium PREs) mapped by DRN2 subcatchment. FMU boundaries and DRN streams with an order of 4 or more are shown for reference. Symbology is the same as that in Figure 5-1.

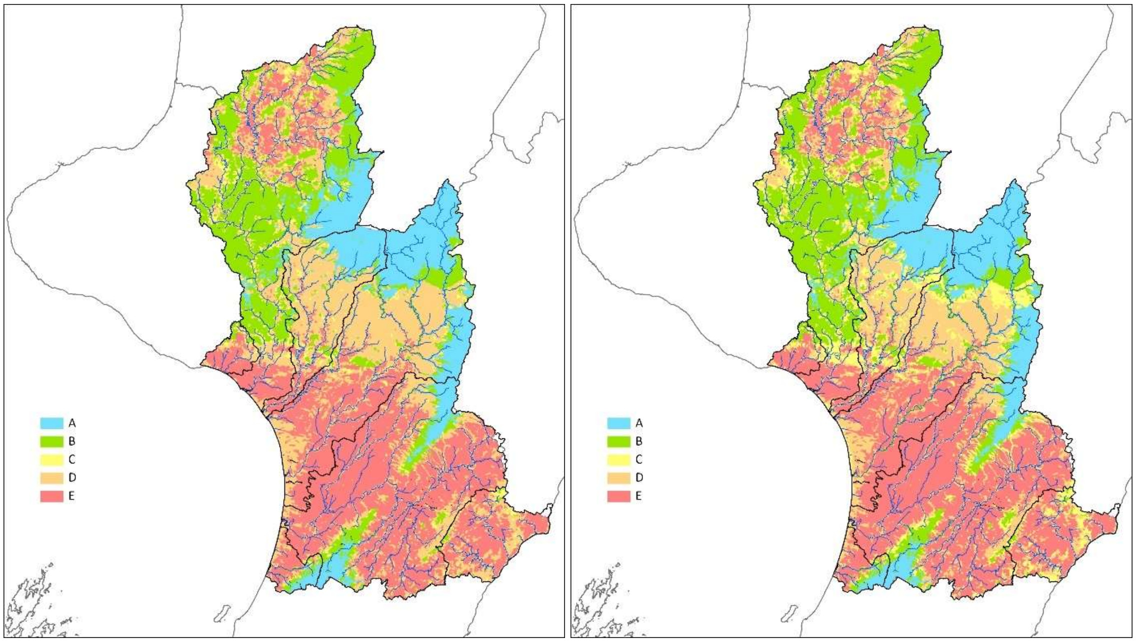


Figure 5-6: NOF bands by DRN 2 segment estimated for Scenario 1 (medium PREs) with (left) and without (right) the C_{95} concentration attribute.

5.1.3 Scenario 2 – Reduction of point source loads

The reduction of point source loads resulted in an estimated reduction of 0.7 peta organisms per year across the region, which represents around 0.5 % of the total regional load. The point source loads are compared to the total load generated within the subcatchment they are located in and the instream loads in the river segment they discharge to are shown in Table 5-11. The table shows that while the reduction in point source can result in a sizable reduction in the generated load delivered to the stream network, their effect on instream loads is marginal for all but three sources (Rongotea, Sanson and Woodville). The reductions in load are not enough to change the NOF band for the river segments they discharge to.

5.2 Economic analysis for Scenario 1

5.2.1 Lifecyle costs

The estimated capital cost for 7556 km of new fencing ranges from $49.5 million to $132.5 million depending on whether low or high unit costs are used. The medium estimate is $91 million. Including 1 % annual maintenance and replacement in year 25, the annualised LCC for 50 years at a 5 % discount rate is between $4 million and $10.7 million. Most of the cost is incurred in first and second order streams (Table 5-12).

If the average buffer width is three metres, the total area retired from grazing is 2,216 hectares. If the average buffer width is ten metres this increases to 7387 hectares. The associated opportunity cost of foregone grazing is therefore $1.1 million or $3.7 million respectively (Table 5-13).

Table 5-11: Effect of change in point source loads on the generated and instream yields for the subcatchments within which they are located.

Point source	Estimated loads (peta org. / y)				Load difference (%)		Concentration attributes (*E. coli* 100mL^{-1})				Exceedence attributes (proportion of time exceeded)				NOF bands			
	Generated		Instream				C50		C95		G260		G540		With C95		Without C95	
	Current	Future	Current	Future	Generated	Instream	Current	Future	Current	Future	Current	Future	Current	Future	Current	Future	Current	Future
Eketahuna	0.008	0.007	0.574	0.573	13%	0%	250	250	8179	8165	0.47	0.47	0.26	0.26	D	D	D	D
Feilding	0.017	0.009	2.523	2.514	46%	0%	200	199	3600	3587	0.44	0.44	0.20	0.20	D	D	D	D
Foxton	0.013	0.000	0.432	0.419	98%	3%	454	440	7909	7672	0.58	0.57	0.41	0.40	E	E	E	E
Halcombe	0.007	0.002	0.299	0.294	71%	2%	510	501	5165	5079	0.78	0.78	0.46	0.45	E	E	E	E
Kimbolton	0.003	0.002	0.033	0.032	35%	3%	440	427	4050	3926	0.68	0.67	0.41	0.40	E	E	E	E
Marton	0.050	0.004	0.937	0.891	91%	5%	620	590	5475	5206	0.83	0.82	0.56	0.54	E	E	E	E
Ohakea /.Riverlands / BullsSTP	0.204	0.101	8.534	8.426	50%	1%	62	61	1410	1392	0.12	0.12	0.08	0.08	D	D	B	B
Pahiatua	0.096	0.093	0.105	0.102	3%	3%	627	609	6333	6152	0.76	0.75	0.56	0.55	E	E	E	E
PNCC	0.505	0.001	28.749	28.239	100%	2%	340	334	12394	12174	0.53	0.53	0.36	0.36	E	E	E	E
Ratana	0.017	0.017	0.017	0.017	2%	2%	610	596	50500	49342	0.65	0.64	0.51	0.50	E	E	E	E
Rongotea	0.022	0.020	0.022	0.020	9%	9%	636	578	7331	6665	0.75	0.72	0.54	0.51	E	E	E	E
Sanson	0.037	0.022	0.129	0.114	41%	12%	355	314	4200	3713	0.56	0.52	0.36	0.33	E	E	E	E
Tokomaru	0.035	0.034	0.035	0.034	3%	3%	670	651	9236	8976	0.72	0.71	0.56	0.55	E	E	E	E
Woodville	0.005	0.003	0.005	0.003	40%	40%	533	322	7825	4723	0.73	0.59	0.47	0.32	E	E	E	E

Table 5-12: Length of new fencing, capital cost, and annualised LCC by stream order.

Stream order	New fencing (km)	Capital cost ($million)			Annualised LCC ($million/yr) 50 years @5%		
		Low	Medium	High	Low	Medium	High
1	2 921	17.86	33.65	49.45	1.45	2.72	4.00
2	2 272	14.96	27.46	39.96	1.21	2.22	3.23
3	861	6.07	10.88	15.68	0.49	0.88	1.27
4	567	4.24	7.45	10.67	0.34	0.60	0.86
5	400	2.79	5.02	7.25	0.23	0.41	0.59
6	321	2.12	3.89	5.66	0.17	0.31	0.46
7	215	1.46	2.66	3.87	0.12	0.22	0.31
Total	7 556	49.50	91.01	132.53	4.01	7.37	10.73

Table 5-13: Retired area hectares and opportunity cost for average buffer widths of 3 and 10 metres.

Stream order	Retired area (ha)		Opportunity cost ($million/yr)	
	3 m buffer	10 m buffer	3 m buffer	10 m buffer
1	858	2 861	0.46	1.52
2	666	2 221	0.33	1.11
3	254	848	0.12	0.38
4	167	557	0.07	0.24
5	117	391	0.05	0.18
6	92	307	0.05	0.15
7	61	202	0.03	0.11
Total	**2 216**	**7 387**	**1.11**	**3.69**

The total area potentially requiring new water reticulation (Table 5-14) is 32,556 hectares, equivalent to 1.4 % of the total catchment area. The installation cost is $6.8 million and annual maintenance would cost $336,400. The annualised LCC is therefore $709,200.

Table 5-14: Area serviced by new water reticulation and associated costs.

Stream order	New reticulation service area (ha)	Reticulation capital cost ($million)	Reticulation maintenance ($million /yr)	Annualised LCC @5 ($million /yr)
1	12 434	2.59	0.13	0.27
2	9 207	1.91	0.10	0.20
3	4 372	0.91	0.05	0.10
4	3 318	0.69	0.03	0.07
5	1 756	0.37	0.02	0.04
6	973	0.20	0.01	0.02
7	496	0.10	0.01	0.01
Total	**32 556**	**6.77**	**0.34**	**0.71**

Total cost and sensitivity analysis

The following sensitivity analysis (Table 5-15) presents the impact on LCC of using the different cost estimates, assessment periods and discount rates. The lowest estimate is $3.3 million using low per-unit costs for fencing, a 50-year assessment period, and 3 % discount rate. The highest estimate is $17.3 million using high unit costs, a 25 year period, a 7 % discount rate, and including opportunity and water reticulation costs.

The variance around per-unit fencing costs has the largest impact on total cost. Using the high (low) cost estimates increases (decreases) total cost by 46 % relative to medium costs. Including opportunity and water reticulation increases the total cost by up to 100 %. The choice of discount rate also has a large impact on total cost. Changing from a 5 % to 7 % discount rate increases the annualised cost by up to 18 %. The choice of a 25- or 50-year assessment period has no impact on fencing costs because fences are assumed to be replaced after 25 years.

Table 5-15: Sensitivity of LCC to cost range, time, discount rate, and inclusion of opportunity and water costs.

Cost estimate	Assessment Period (years)	Discount rate	LCC fencing + planting ($mill/yr)	LCC fencing + planting + opportunity + water ($mill/yr)
Low	25	3%	3.34	7.75
Low	25	5%	4.01	8.51
Low	25	7%	4.74	9.35
Low	50	3%	3.34	7.62
Low	50	5%	4.01	8.40
Low	50	7%	4.74	9.26
Medium	25	3%	6.14	10.55
Medium	25	5%	7.37	11.87
Medium	25	7%	8.72	13.33
Medium	50	3%	6.14	10.42
Medium	50	5%	7.37	11.76
Medium	50	7%	8.72	13.24
High	25	3%	8.94	13.35
High	25	5%	10.73	15.23
High	25	7%	12.70	17.30
High	50	3%	8.94	13.22
High	50	5%	10.73	15.12
High	50	7%	12.70	17.21

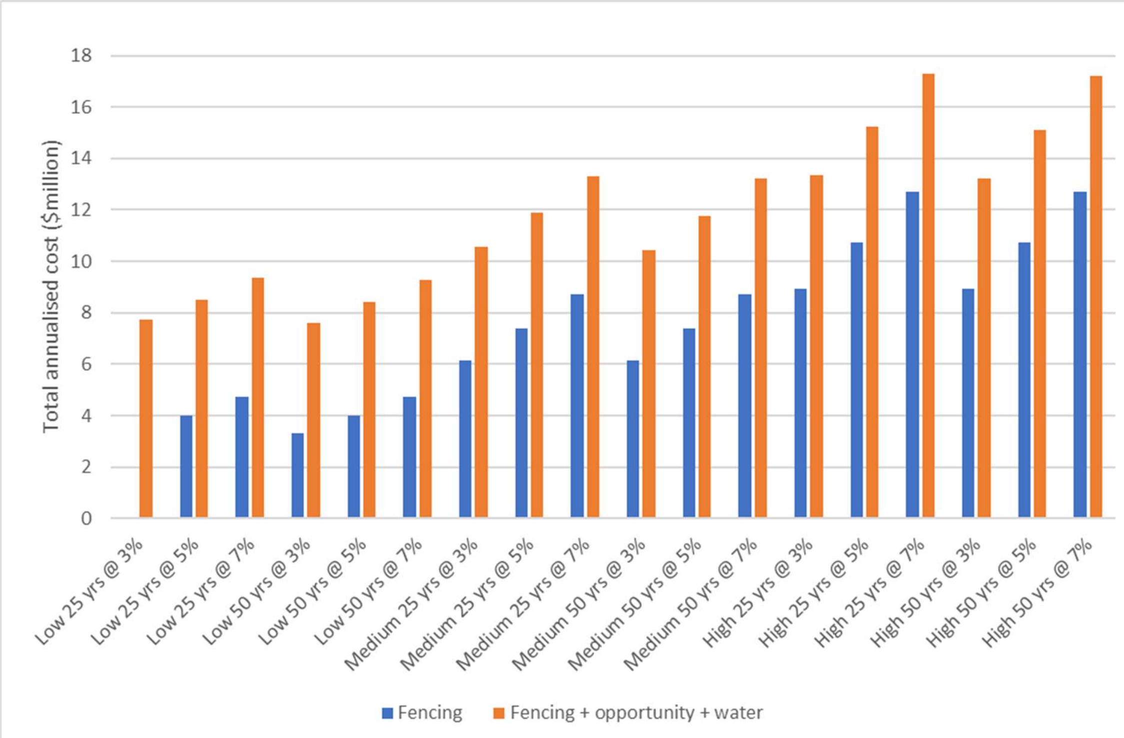


Figure 5-7: **Total costs given different cost estimates, periods and discount rates.**

5.2.2 Cost-effectiveness analysis

The current C_{50} in each segment multiplied by stream kilometres is 6.7 million (Table 5-16). The low, medium, and high PRE outcomes are 6.5 million, 6.1 million, and 5.8 million respectively. Cost-effectiveness is calculated based on a total LCC of $11.8 million using medium cost estimates, a 50-year assessment period, a 5 % discount rate, and including fencing, opportunity and water reticulation costs. Cost per concentration reduction per kilometre ranges from $13 for the high PRE scenario to $50 for the low PRE scenario.

Table 5-16: **LCC (50 years @ 5%) per unit reduction in C_{50} times stream length.**

Scenario	C_{50} x stream length (km)	Change in C_{50} x stream length (km)	LCC per unit reduction ($/$C_{50}$/km/yr)
Current	6 738 541	0	0
Low PRE	6 502 870	- 235 671	50
Medium PRE	6 129 985	- 608 556	19
High PRE	5 834 993	- 903 548	13

Due to inter-dependencies between cumulative loads in different segments it is inappropriate to report cost-effectiveness by stream order or FMU for a single stock exclusion scenario. However, if additional CLUES scenarios were conducted, specifically targeting fencing of only certain stream orders or FMUs, it would be valid to compare the resulting cost effectiveness with the current scenario. Such comparisons could provide valuable insights into the relative cost effectiveness of targeting different FMUs.

5.2.3 Benefit-cost analysis

The CLUES model results show that the stock exclusion scenarios result in small changes in the proportion of segment lengths in each attribute band (Table 5-17). The proportion in band E decreases from 37.1 % to 36.2 %, 33 % or 29.7 % under the low, medium and high PRE scenarios respectively. The largest increase is in band D, with smaller increases in bands A, B and C.

Table 5-17: Percent of stream length in attribute band for low, medium and high PRE scenarios.

Scenario	*E. coli* attribute band				
	A	B	C	D	E
Current	14.2%	17.2%	2.8%	28.6%	37.1%
Low PRE	14.2%	17.2%	2.9%	29.5%	36.2%
Medium PRE	14.3%	17.3%	2.9%	32.5%	33.0%
High PRE	14.3%	17.4%	3.0%	35.7%	29.7%

The change in band percentage is multiplied by the inflation-adjusted marginal WTP reported by Tait et al. (2016). The individual WTP is then aggregated (multiplied) by the adult population of the Manawatū-Whanganui region, which was 183,363 according to the 2018 census. Total WTP ranges from $152,000 for the Low PRE scenario, to $1.29 million for the high PRE scenario (Table 5-18).

Table 5-18: Annual WTP for low, medium, and high PRE outcomes.

Non-market value estimate	*E. coli* attribute band				
	A	B	C	D	Total
Individual WTP for 1% increase ($)	4.10	1.43	0.87	0.87	
Benefit - Low PRE ($)	1 200	4 500	9 600	136 700	152 000
Benefit - medium PRE ($)	26 400	11 100	13 900	619 100	670 400
Benefit - high PRE ($)	53 000	35 100	19 600	1 121 000	1 228 700

Using the upper confidence interval for WTP reported by Tait et al. the total WTP is approximately 80 % higher. The high estimate is $275,400, $1.2 million, and $2.2 million for the low, medium and high PRE scenarios respectively.

The benefit estimated with the value transferred from Tait et al. (2016) is significantly lower than even the lowest annual LCC. Using the conservative LCC of $5 million for fencing only, the benefit-cost ratio (BCR) ranges from 0.03 to 0.44. However, as mentioned in Section 4.2.6), the values transferred from Tait et al. (2016) are likely to underestimate the value of modest improvements.

The alternative benefit estimation approach is to transfer values from a non-market valuation study of restoration activities rather than outcomes (Matthews, 2023). The inflation-adjusted WTP for activities that only reduce pathogens is $1.6 million per year. For activities that reduce pathogens, nutrients and suspended sediment in waterways the WTP is $5.1 million per year. Considering that fenced buffers can filter nutrients and sediment as well as *E. coli*, we consider the latter value a reasonable estimation of benefits. The benefit-cost ratio ranges from 0.01 to 0.69 depending on which assumptions are used for costs and benefits (Table 5-19).

Table 5-19: Benefit-cost ratios estimated with transferred values for restoration activity.

Benefit value transferred	LCC fencing ($7.4 million/yr)	LCC fencing + opportunity ($11.1 million/yr)	LCC fencing + opportunity + water ($11.7 million/yr)
Percent change in *E.coli* attribute bands[a]	0.01 - 0.30	0.01 - 0.20	0.01 - 0.19
Activities reducing pathogens[b] ($1.6 million)	0.22	0.14	0.14
Activities reducing pathogens, nutrients and sediment ($5.1 million)[b]	0.69	0.46	0.44

[a] Transferred from Tait et al. 2016 [b] Transferred from Matthews 2023, [c] Refer to Table 5-15

The wide range of possible benefit-cost ratios illustrates the challenges of doing benefit-cost analysis when the benefits are non-market values. Non-market values are highly sensitive to the specific context and circumstances in which they are assessed, making it difficult to obtain a universally applicable estimate. Various factors such as the method, framing of the valuation study, the spatial scope, the number, and range of attributes presented, and current events affecting respondent priorities all influence estimated values.

5.3 Load reduction to meet targets

5.3.1 Maximum downstream reduction factor

The Maximum downstream reduction factor (MDRF) to meet water quality grade targets is mapped by subcatchment in Figure 5-8 for bands C and B. This gives an overall impression of the degree of load reduction and which source areas might be implicated in achieving the reduction. If an DRN subcatchment has an MDLRF factor greater than one, there is some location downstream that violates the target (including potentially the local stream), but it does not necessarily mean that the water quality in the local stream violates the target. The maps also indicate the overall reduction factor in the catchment associated with a downstream site, but the load reduction to meet the target is likely to vary spatially within the catchment because some parts of the catchment are unlikely to be able to have their source load reduced (e.g., areas in native forest). A factor of one indicates there is no load reduction needed in any downstream river segment. This might apply if all of the segments downstream meet the target grade band, or if there are no downstream segments with a stream order of four or greater.

The maps in Figure 5-8 show that there is a marked difference in the factors calculated with and without the C_{95} numeric attribute. In each case, the MDLF varies spatially, reflecting variations in water quality across the region. Note that within a river catchment, a considerable upstream area can be associated with a single downstream site not meeting the target. The MDLF becomes larger as the target band becomes more stringent because lower concentrations are required. The MDLF is generally larger if C_{95} is included in the grading metric because the overall grading for a site is influenced by C_{95} in many cases.

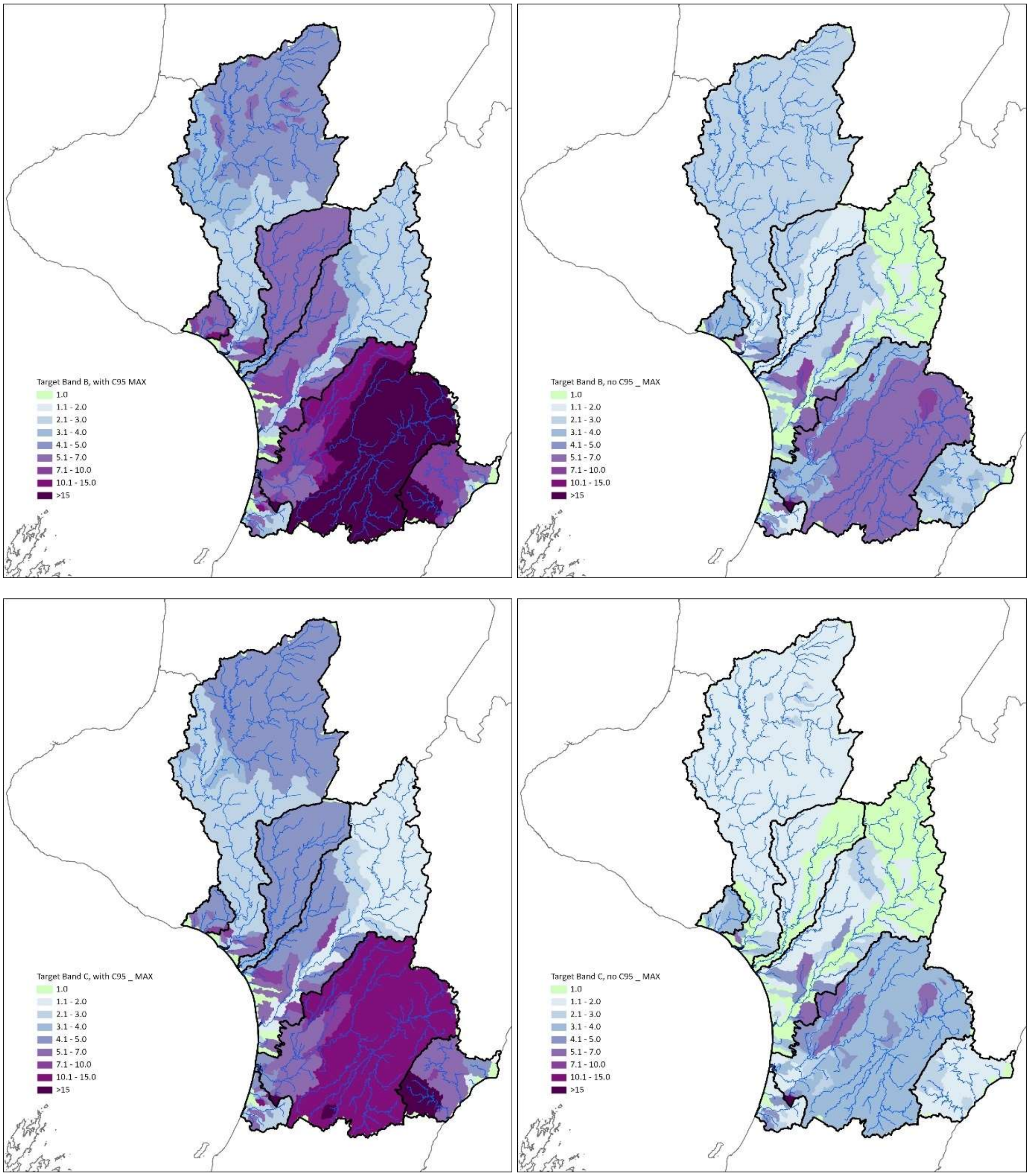


Figure 5-8: Maximum downstream load reduction factors calculated for selected targets with full source yeilds Target band B with C_{95} (top left), Target band B without C_{95} (top left), Target band C with C_{95} (bottom left), Target band C without C_{95} (bottom left).

5.3.2 Load reduction to meet targets, and resulting grade banding

Maps of the distribution of load reductions required to meet NOF targets are shown in Figure 5-9 for bands B and C. Overall load reduction across the region are summarised in Figure 5-10 and in Table 5-20. The resulting distribution of grading is summarised in Figure 5-11 and is tabulated Table 5-21.

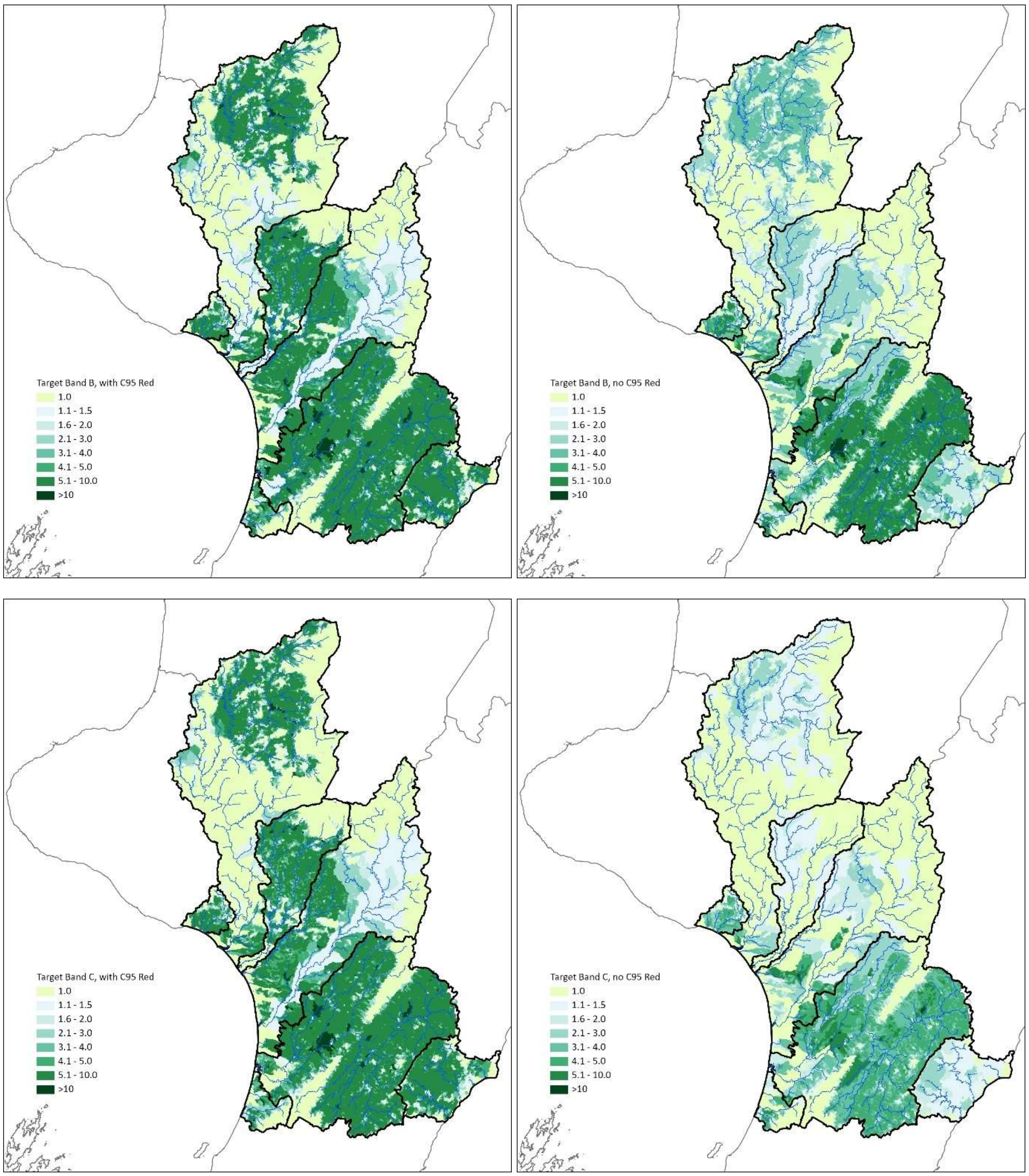


Figure 5-9: Maps of load reductions to meet selected target bands (full yields). Target band B with C_{95} (top left), Target band B without C_{95} (top right), Target band C with C_{95} (bottom left), Target band C without C_{95} (bottom right).

Table 5-20: Tabulated region-wide load reduction to meet targets. Grey italics denote situations where the target is not reached to a significant degree.

Reference Source Model	IncludeC95	Grade Target	Reduction Factor	Percent Reduction
Full Source	Yes	E	1.00	0.0
Full Source	Yes	D	1.27	21.2
Full Source	Yes	C	3.07	67.4
Full Source	Yes	B	*3.43*	*70.8*
Full Source	Yes	A	*4.51*	*77.8*
Full Source	No	E	1.00	0.0
Full Source	No	D	1.27	21.2
Full Source	No	C	1.74	42.4
Full Source	No	B	2.33	57.1
Full Source	No	A	3.19	68.6
Low Source	Yes	E	1.00	0.0
Low Source	Yes	D	1.28	21.7
Low Source	Yes	C	3.28	69.5
Low Source	Yes	B	3.70	73.0
Low Source	Yes	A	5.97	83.3
Low Source	No	E	1.00	0.0
Low Source	No	D	1.28	21.7
Low Source	No	C	1.76	43.2
Low Source	No	B	2.34	57.3
Low Source	No	A	3.32	69.9

The maps of load reduction are highly variable. This is because of the spatial variability in the difference between the current water quality and the target value, and also because different parts of the catchment have greater manageable source load (current load minus reference load) in relation to the current source loads.

There are some large factors in the reductions (e.g., factors greater than 10), largely associated with point sources or urban areas, because these have a large manageable load in relation to the current load. Reductions from such areas are needed to meet the overall load reduction in a catchment.

In contrast, areas with native forest or other natural land use have a reduction factor of one, because it was assumed that there can be no reductions in the source load for such areas. There are also near-coastal areas with reduction factors of one, because the terminal reaches of these coastal streams have a stream order less than four.

The variability of load reduction within a catchment means that some subcatchments will need a higher load reduction factor, to compensate for areas where there is little or no scope for load reduction (such as in native areas).

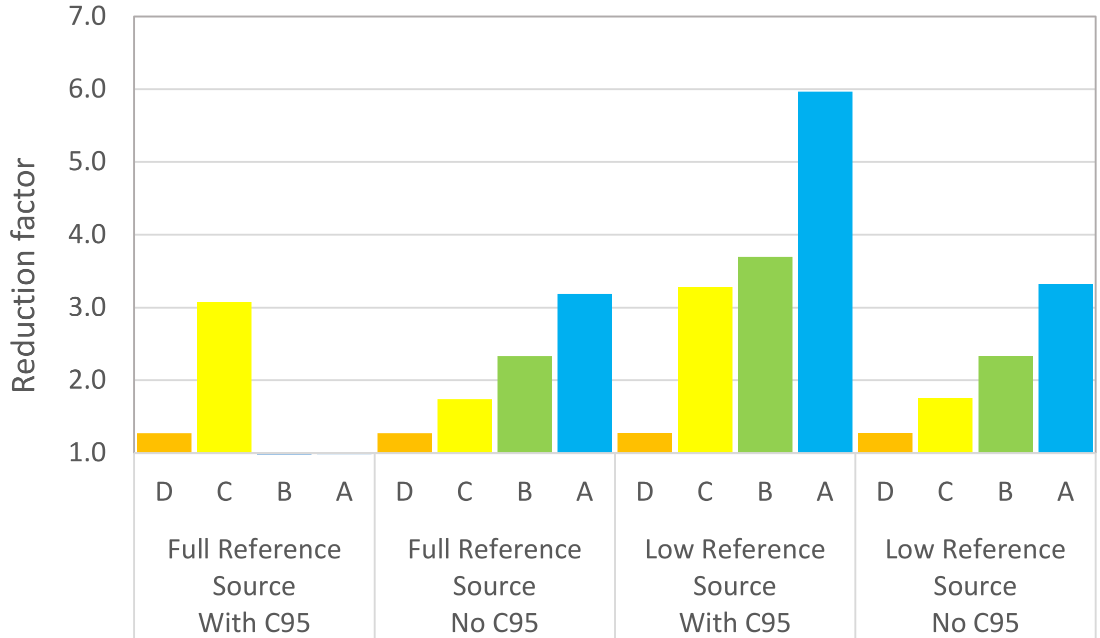


Figure 5-10: Region-wide load reduction factor to meet targets. Bars are not shown for situations where, after the maximum possible source reduction, the target is not reached to a significant degree (more than 20 % of stream length not meeting the target). Bars are not shown for target band E, because there is no reduction (factor of 1) in that case.

The details of the spatial distribution of load reductions within are only indicative because they rely on assumptions about how the required load reduction is distributed among sources in the catchment upstream of a location of interest. There are alternative ways that reductions could be reduced, which would result in different spatial spreads of the reductions within a catchment. Hence the maps should not be relied on as a definitive representation of how the sources need to be reduced.

The overall reduction in load across the region (Figure 5-10) varies with the grade target, whether C_{95} is included or not, and whether the original or reduced reference source is used. The related graphs of the grades achieved after adjusting loads (Figure 5-11) demonstrate the shifting bands in response to these different scenarios.

The key findings of the analysis are:

- Full Reference Source scenario, D band target:
  - There is a modest source load reduction factor of 1.27 for the D band target (21.2 % reduction). This results in all stream segments of interest in the E band being reclassified as D band. There is an associated increase in the proportion of stream length in the D band. There is also a slight increase in the A-B band proportion because the load reductions made to avoid the E band in some cases influence segments that are graded higher than D.

    Although there are no E band segments, there are 70.4 % of streams in the D band, which is much greater than the NOF national 2030 target of only 20 % in combined D and E bands. Hence the target D scenario does not meet the national target.

- Removing the C_{95} values for grading does not have any effect because the difference between D and E gradings is only influenced by numeric attributes other than C_{95}.
- For the D target, there is very little difference between the full-source and low-source scenarios, because the reductions in load are only small.

Table 5-21: Tabulated resulting grade distributions for higher order streams and SOE monitoring sites.

Reference Source Model	Grade Target	With C_{95} For Grade	Percentage in band				
			A	B	C	D	E
Full Source	E	Yes	13.4	11.7	2.9	51.8	20.2
Full Source	D	Yes	14.0	11.8	3.8	70.4	0.0
Full Source	C	Yes	25.6	42.3	24.8	7.3	0.0
Full Source	B	Yes	29.7	52.3	10.8	7.3	0.0
Full Source	A	Yes	38.4	43.5	10.8	7.3	0.0
Full Source	E	No	13.9	19.9	9.5	36.5	20.2
Full Source	D	No	14.9	24.2	12.1	48.8	0.0
Full Source	C	No	24.3	36.9	38.7	0.0	0.0
Full Source	B	No	44.0	55.7	0.2	0.0	0.0
Full Source	A	No	90.8	8.9	0.2	0.0	0.0
Low Source	E	Yes	13.4	11.7	2.9	51.8	20.2
Low Source	D	Yes	14.1	11.8	3.9	70.2	0.0
Low Source	C	Yes	36.6	40.9	22.1	0.4	0.0
Low Source	B	Yes	43.4	55.3	0.9	0.4	0.0
Low Source	A	Yes	81.1	17.5	0.9	0.4	0.0
Low Source	E	No	13.9	19.9	9.5	36.5	20.2
Low Source	D	No	15.0	24.0	12.2	48.7	0.0
Low Source	C	No	26.0	35.7	38.3	0.0	0.0
Low Source	B	No	44.9	55.0	0.1	0.0	0.0
Low Source	A	No	97.1	2.8	0.1	0.0	0.0

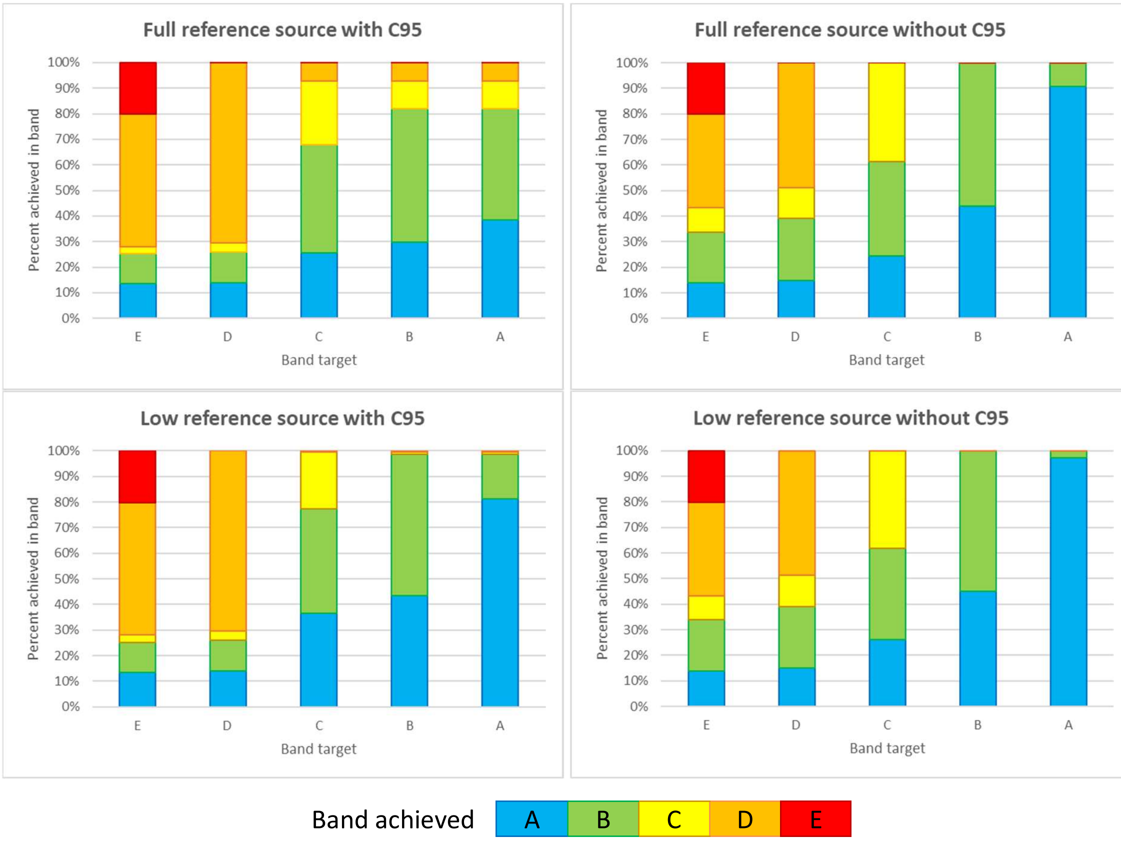


Figure 5-11: Resulting grade distribution after load reduction.

- Full Reference Source scenario, C band target:
  - Increasing the target band to C with C_{95} included requires an three-fold reduction in the regional source load.

    The three-fold reduction is a regional average. To achieve this overall reduction, some areas will need to have their load reduced by more than a factor of 3 (Figure 5-8 and Figure 5-9). It may be challenging to achieve such localised reductions, given that there would need to be greater than a halving of source load. If everywhere in the region had its source load reduced uniformly by a factor of 3, there would be less of an improvement in the proportion of streams in D-E bands (result not shown), compared with reductions that are more targeted to areas that do not meet the target; this result suggests the benefits of targeting reductions to the areas that have downstream areas in D-E bands rather than applying uniform source reductions.

    Making these reductions (C target) results in most streams (92.7%) being classified in the A-C bands, achieving the NOF national 2030 target of <20 % in D-E bands. The NOF target for A-B bands (>62) is achieved (67.9 % in A-B bands), but the A band target (>45) is not achieved (25.6 % achieved) This is due to the focus on addressing areas with water quality in D and E bands in the modelling. To achieve those other bands would require additional load reductions targeted more at A and B bands.

With C_{95} included, there are still 7.3 % of streams in the D band. This is because in some cases, reducing the land use back to reference conditions does not result in sufficient load reduction to take the concentration to the C band or better. This is largely driven by the difficulty of achieving the C band threshold for C_{95}. The relevant threshold is 1200 per 100 ml, yet 16 % of segments of interest have a concentration >6,000 per 100 ml, suggesting that a reduction factor of 5 is needed, averaged over the relevant catchment. With the source coefficient for pasture and non-pasture varying by only a factor of 7, and most catchments having a mix of land use, it becomes difficult in some cases to achieve a C band. This situation is more pronounced for the A and B targets as discussed later.

  - If C_{95} is not included, then the region-wide load reduction factor associated with the C target is reduced, from 3.07 to 1.74. Moreover, there are no streams that remain in the D band. This highlights the importance of whether C_{95} is included in the bands. There is still a similar proportion in A and B bands, because the reductions were targeted to remove streams from the D-E bands.

- Full Reference Source, B and A band targets:
  - Increasing the target to B and then A requires larger source load reductions. The required load reduction factors in that case are not meaningful because the possible reductions in source loads are not sufficient to meet the target. The reductions with C_{95} are not meaningful, because the source loads reduction to reference levels is not sufficient to meet the target (61.6 % of streams would remain in bands B-E despite aiming for all being in band A – see top left panel of Figure 5-11), so the results are not shown in Figure 5-10). Despite reducing loads to the reference condition (the lowest level allowed in the model), the load reduction would not be sufficient to reduce all the attribute values to their target state. This unexpected result relates to uncertainty of loads and associated concentrations under reference conditions in conjunction with the assumption of proportional decreases, but could also point to difficulties in achieving high gradings under native reversion in lowland areas.
  - Without C_{95}, the load reduction factor increases from 1.74 to 3.19 going from C to A target. While the B target is achieved when C_{95} is not considered, the A target was not fully realised, so the relevant point is not shown in the graph. The B target scenario clearly achieves the NOF national 2030 target of >62 % in A-B bands, and the NOF target for the A band is nearly met. The A target scenario meets the NOF national 2030 target for the A band, despite a proportion of streams remaining in the B band.

- Full Reference Source scenarios:
  - Investigation of the difficulties with achieving the higher grades for the original full-source scenario prompted creation of the reduced-source reference scenario. Such a scenario is not unreasonable considering the uncertainty in reference source loads in the original calibration.
  - The reduced-source scenario resulted in similar load reduction factors for the D and C targets. Once the target proceeded to B and A grades, there was divergence

in results for the low-reference source scenario (at the B and A levels when C_{95} was included, and for the A level when C_{95} was not included.

- While the differences in load reduction factor were not large, the differences in resulting grade bands were significant. This is because a small change in source load compared with the current estimated load can result in a large change in grading at the higher grading levels. For the Low Reference Source scenario, the load reduction factor increased as the B and A levels were targeted, with a 3.70 region-average factor reduction for level B, and 5.97 for level B, if C_{95} is considered.
  If C_{95} is not considered, the reduction for the A target scenario is a factor of 3.31, with greater achievement of the A level.

These results highlight the potential difficulty of achieving high grades, especially when C_{95} is considered. This is partly associated with uncertainty about how low concentrations can go as the degree of pasture in a catchment approaches zero. As an illustration of these uncertainties, Figure 5-12 shows how C_{95} varies with the proportion of pasture in the upstream catchment, for the combined Taranaki and Horizons regions, including separation into DRN lowland and 'not-lowland' topography classes. There is little data for low-pasture lowland sites, hence uncertainty around the concentrations that could be achieved for reference conditions of zero pasture for lowland sites. Even for non-lowland sites, it is unclear whether a target C_{95} of 260 per 100 ml is realistic for all sites – a proportion of even non-lowland sites might be expected to exceed a C_{95} of 260 per 100 ml with not pasture. It is also expected that lowland sites will have higher concentrations at reference conditions (e.g., McDowell *et al.* 2013).

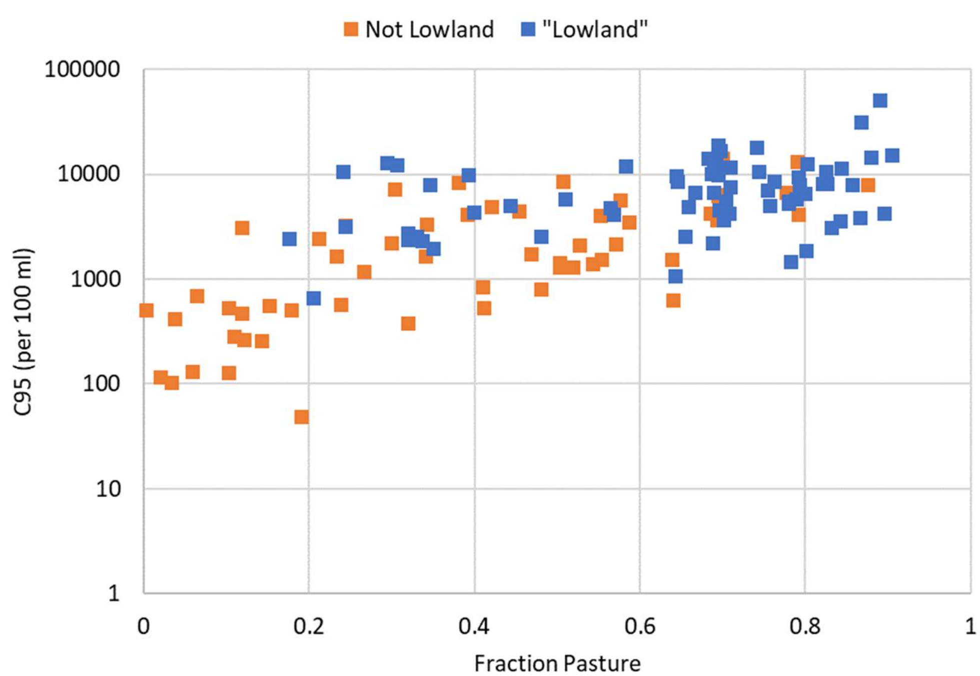


Figure 5-12: Variation of C_{95} with fraction of pasture in the catchment for monitoring sites in the combined Taranaki-Horizons regions.

6 Conclusion

This report presents the outcomes of three related analyses based on the results of *E. coli* load modelling using the CLUES *E. coli* model. The first two analyses looked at the impacts, costs and benefits of implementing two mitigation scenarios. The third analysis investigated the load reductions that would be required to meet bands A to D target gradings for the NOF attribute related to the value Human contact.

The two mitigation scenarios were developed using data provided by HRC and are for further stock exclusion using new fencing (Scenario 1) and reduction of *E. coli* discharge loads from some wastewater treatment plants (Scenario 2). Scenario 1 had a variable effect on the predicted loads and NOF gradings for *E. coli* in higher order streams depending on the PRE used. The region-wide reductions in *E. coli* loads were 3 %, 7.7 % and 11.4 % for low, medium and high removal respectively. The medium removal PRE results in an upwards change of NOF band classification for stream lengths of around 203 km and 337 km, respectively, with and without the inclusion of C_{95} attribute in the NOF band classification. Scenario 2 had a negligible effect on regional loads and there was no change in NOF bands in any of the river segments.

The economic analyses for Scenario 1 found that the cost per concentration reduction per kilometre ranged from $13 for the high PRE scenario to $50 for the low PRE scenario.

The load reduction analysis used the CLUES model to determine the reduction in load that would be required to meet the NOF band targets for bands A-D. Even to achieve the target grade for band C would require a three-fold reduction of the load from the region if the C_{95} attribute is included in the grading. If C_{95} is not included, then the load reduction associated with the C target is reduced, from 3.0 to 1.7. The results highlight the high load reductions required to achieve high *E. coli* grades, especially when C_{95} is considered. It is clear from the scenario modelling that neither of the mitigation scenarios could achieve that level of reduction.

7 Acknowledgements

Thank you to Dr Simon Vale at Manaaki Whenua / Landcare Research for providing the spatial data required to construct Scenario 1.

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Appendix A SOE monitoring sites in the region used for random forest modelling

The following maps show the locations of SOE water quality maps used in the random forest modelling (Whitehead *et al.* 2022) that forms the basis of the current scenario. The names of the sites are given in Table A-1.

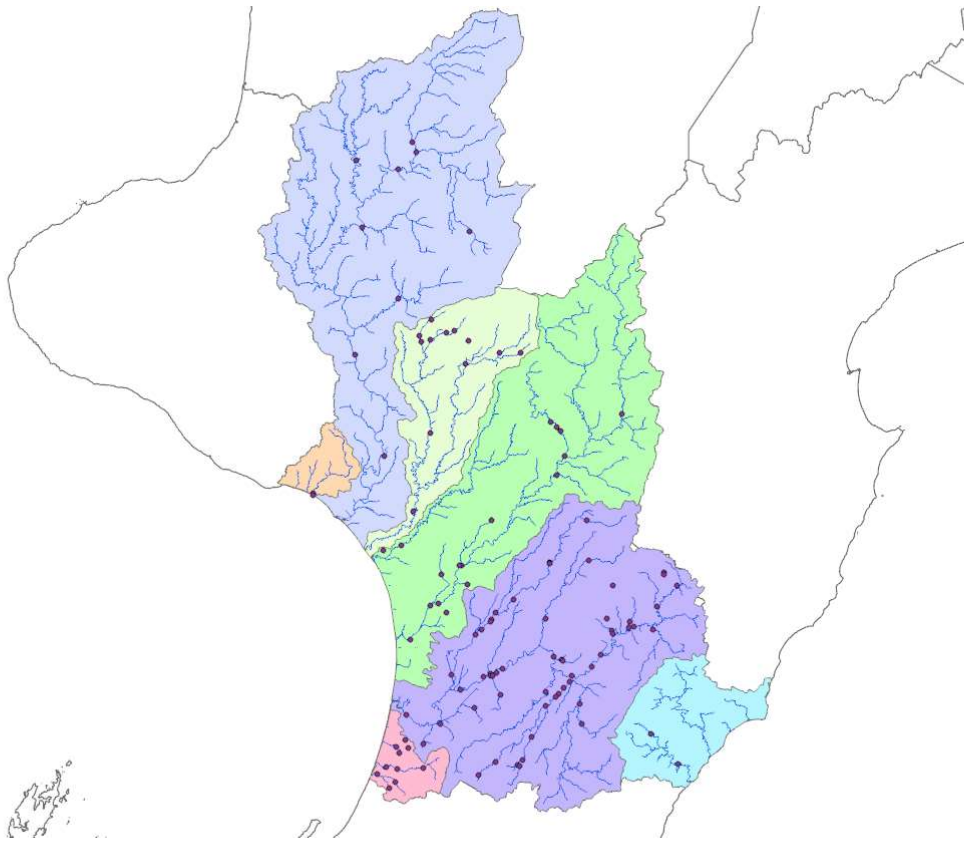

Figure A-1: SOE monitoring sites in the region used for random forest current state modelling. Sites are labelled in the following maps. FMU boundaries and higher order streams are shown for reference.

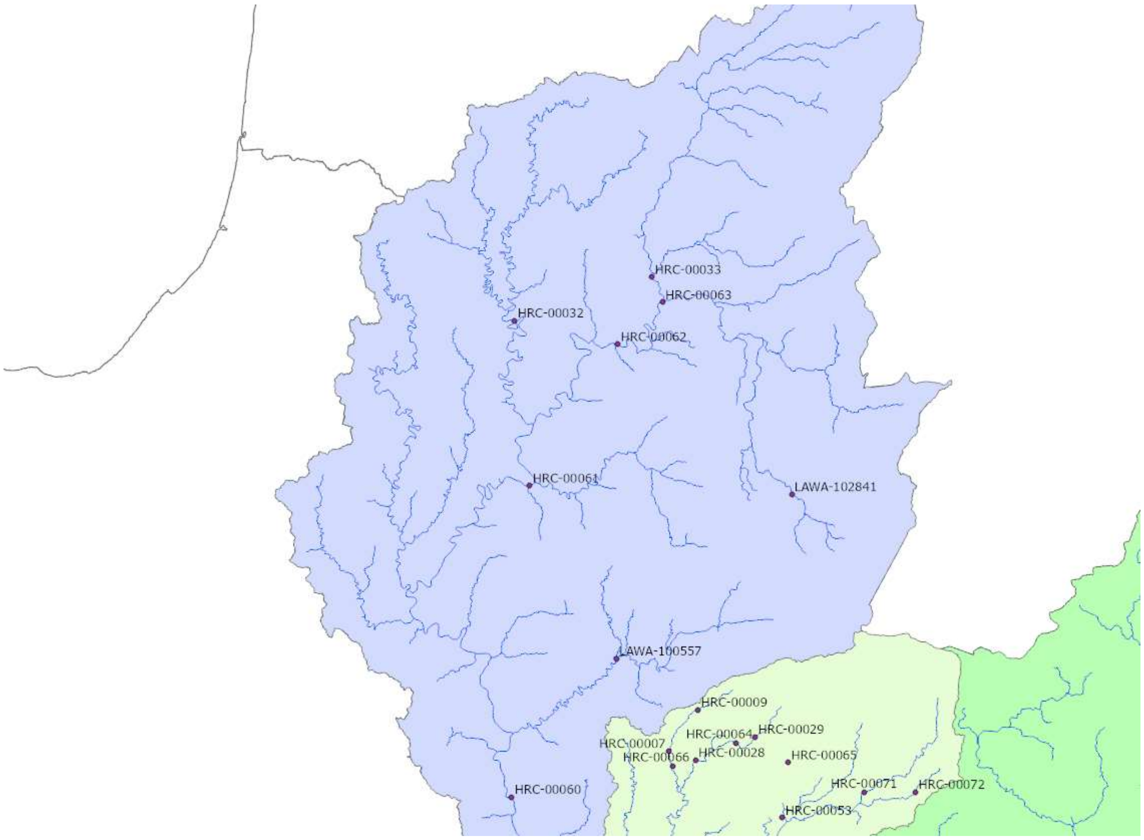

Figure A-2: SOE monitoring sites in the upper Whanganui FMU used for random forest current state modelling. Sites are labelled in the following maps. FMU boundaries and higher order streams are shown for reference.

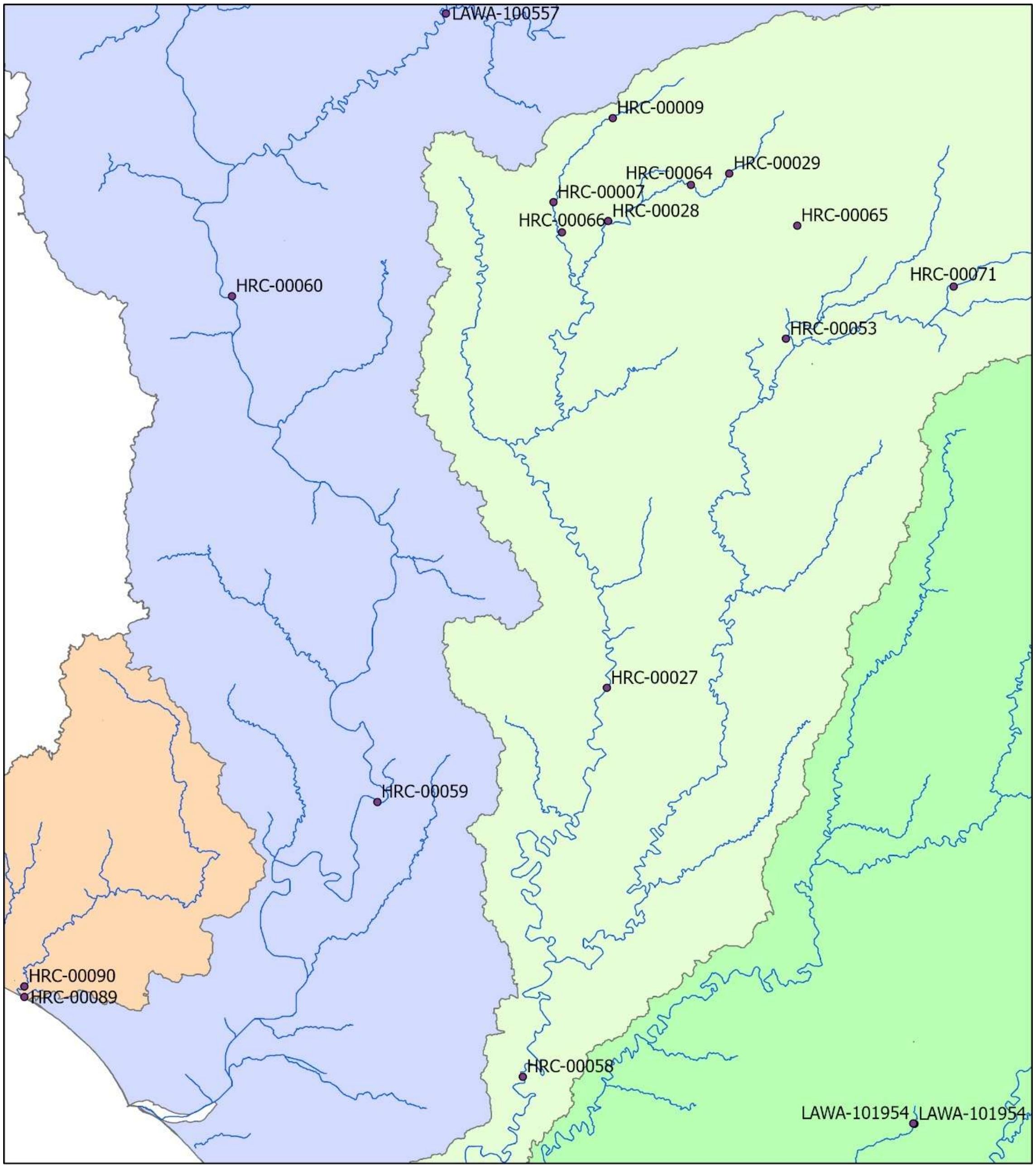

Figure A-3: SOE monitoring sites in the Kai Iwi, lower Whanganui and Whangaehu FMUs used for random rorest current state modelling. Sites are labelled in the following maps. FMU boundaries and higher order streams are shown for reference.

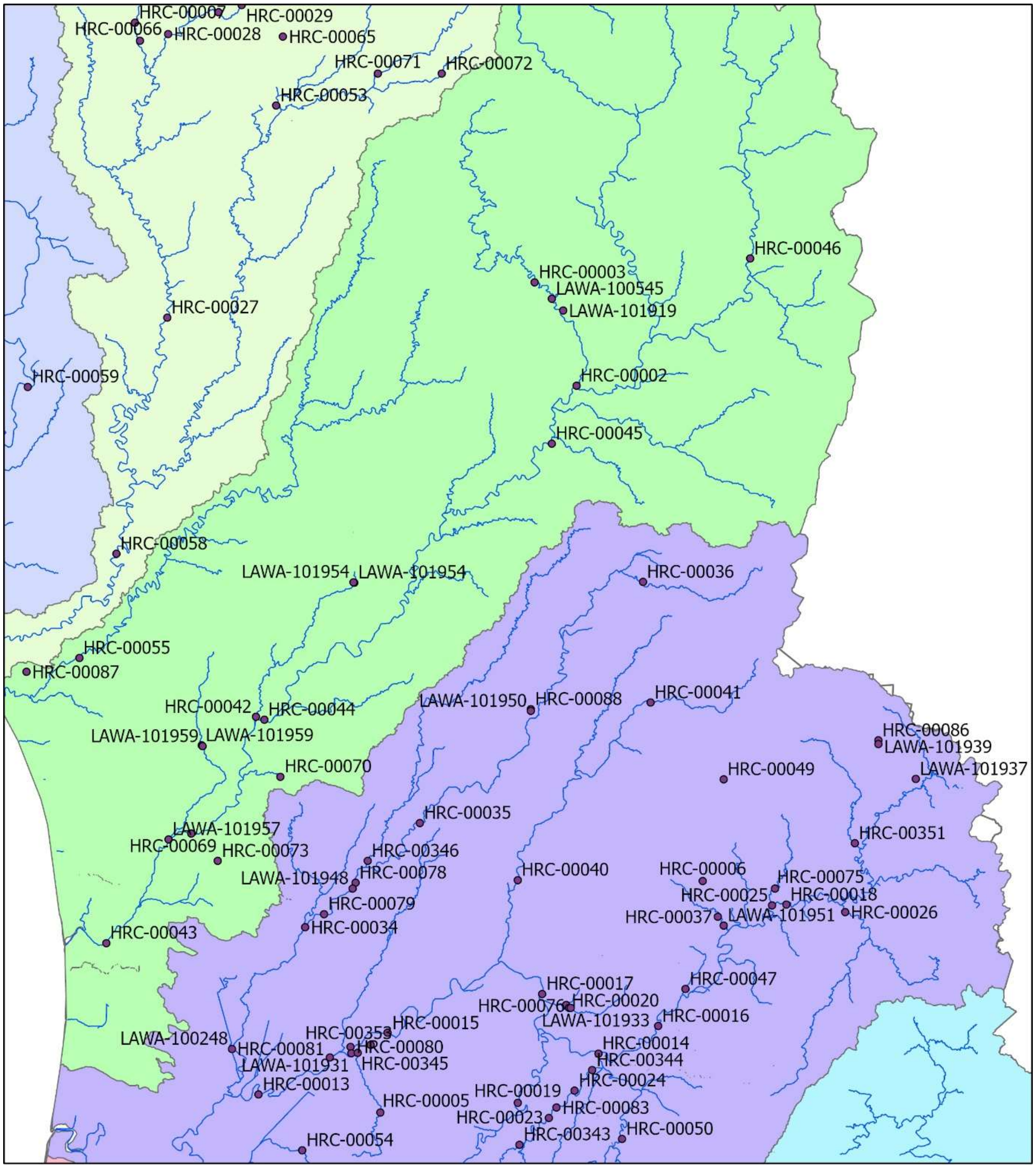

Figure A-4: SOE monitoring sites in the Rangitīkei-Turakina and Manawatū FMUs used for random rorest current state modelling. Sites are labelled in the following maps. FMU boundaries and higher order streams are shown for reference.

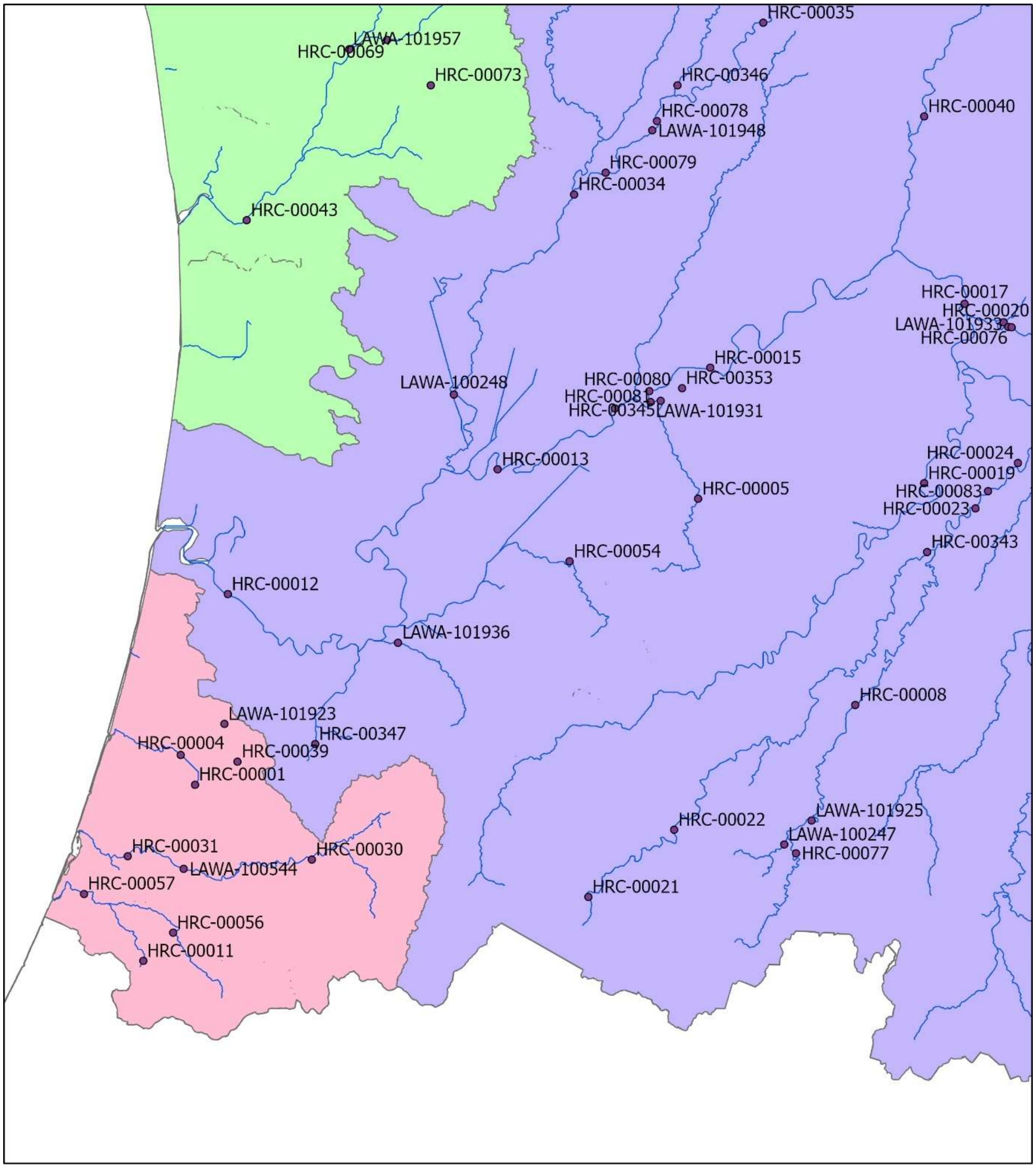

Figure A-5: SOE monitoring sites in the Waiopehu and lower Manawatū FMUs used for random forest current state modelling. Sites are labelled in the following maps. FMU boundaries and higher order streams are shown for reference.

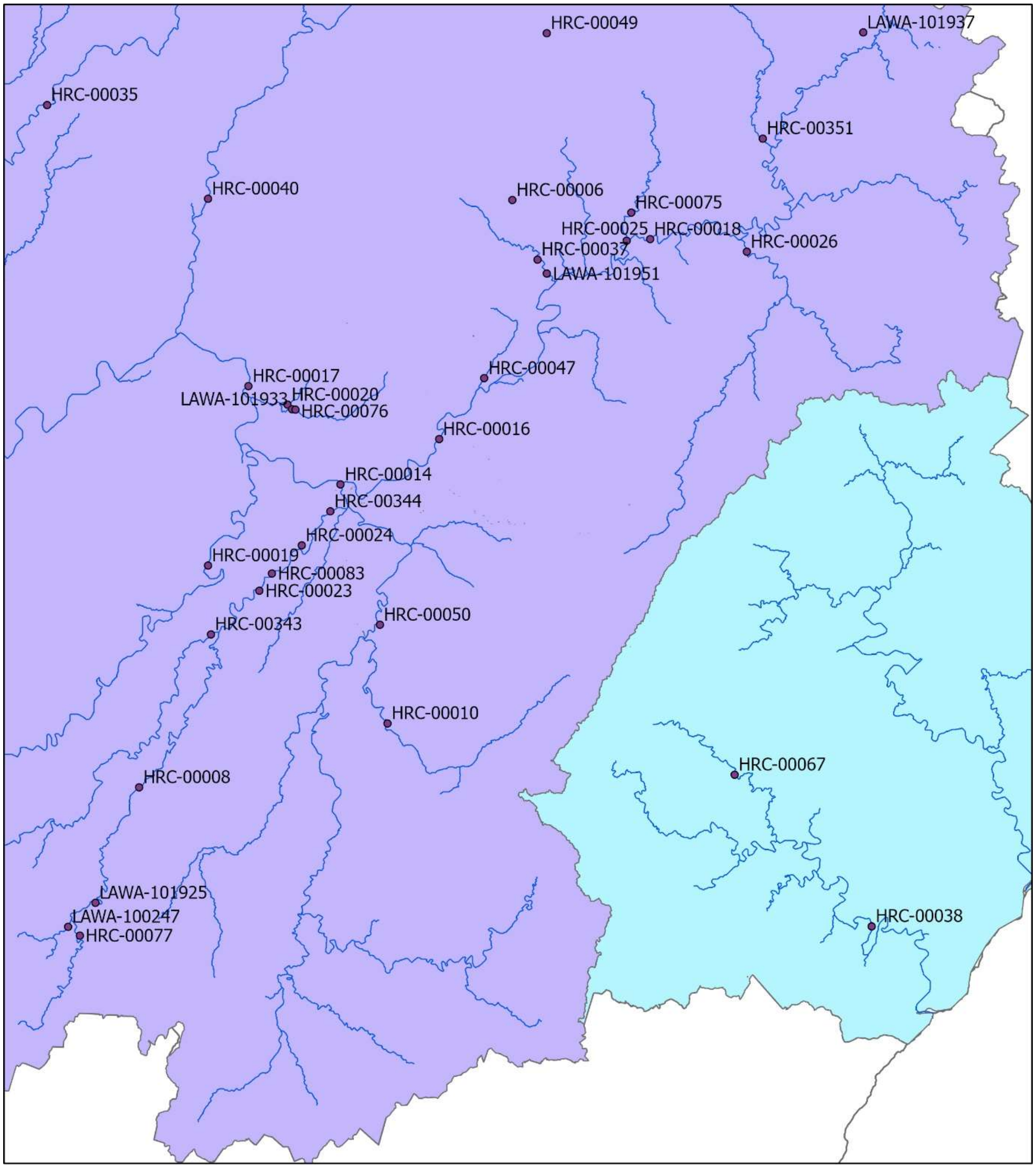

Figure A-6: SOE monitoring sites in the lower Manawatū and Puketoi ki Tai FMUs used for random forest current state modelling. Sites are labelled in the following maps. FMU boundaries and higher order streams are shown for reference.

Table A-1: SOE site names.

NZsegment	Site ID	Site Name
7246119	HRC-00001	Arawhata Drain @ Hokio Beach Road
7209566	HRC-00003	Hautapu @ Alabasters
7211096	LAWA-101919	Hautapu @ D/S Taihape Stp
7210283	LAWA-100545	Hautapu @ Papakai Road Bridge
7215080	HRC-00002	Hautapu @ Us Rangitikei River Conf
7245739	HRC-00004	Hokio @ Lake Horowhenua
7241259	HRC-00005	Kahuterawa @ Johnstons Rata
7239687	HRC-00345	Kahuterawa @ Keebles Farm
7220928	HRC-00090	Kai Iwi @ Handley Road
7234007	HRC-00346	Kiwitea @ Kimbolton Rd
7245566	HRC-00347	Koputaroa @ Tavistock Rd
7234284	HRC-00006	Kumeti @ Te Rehunga
7245285	LAWA-101923	L Horowhenua Inflow @ Lindsay Road
7246929	LAWA-101925	Makakahi @ D/S Eketahuna Stp
7244807	HRC-00008	Makakahi @ Hamua
7247523	HRC-00077	Makakahi @ U/S Eketahuna Stp
7194503	HRC-00066	Makotuku @ Above Sewage Plant
7194503	LAWA-101929	Makotuku @ D/S Raetihi Stp
7193268	HRC-00007	Makotuku @ Raetihi
7189858	HRC-00009	Makotuku @ Sh49a
7243830	HRC-00010	Makuri @ Tuscan Hills
7249277	HRC-00011	Manakau @ S.H.1 Bridge
7239702	LAWA-101931	Manawatu @ D/S Pncc Stp
7239663	LAWA-101932	Manawatu @ Ds Fonterra Longburn
7238779	HRC-00016	Manawatu @ Hopelands
7239689	HRC-00014	Manawatu @ Ngawapurua Bridge
7240461	HRC-00013	Manawatu @ Opiki Br
7239110	HRC-00015	Manawatu @ Teachers College
7239481	HRC-00080	Manawatu @ U/S Pncc Stp
7237871	HRC-00017	Manawatu @ Upper Gorge
7239663	HRC-00081	Manawatu @ Us Fonterra Longburn
7235487	HRC-00018	Manawatu @ Weber Road
7243000	HRC-00012	Manawatu @ Whirokino
7238369	LAWA-101933	Mangaatua @ D/S Woodville Stp

NZsegment	Site ID	Site Name
7238376	HRC-00076	Mangaatua @ U/S Woodville Stp
7193718	LAWA-101934	Mangaehuehu @ D/S Rangataua Stp
7193718	HRC-00065	Mangaehuehu @ U/S Rangataua Stp
7240715	HRC-00019	Mangahao @ Ballance
7185582	LAWA-100557	Manganui O Te Ao @ Ruatiti Domain
7243893	LAWA-101936	Mangaore @ D/S Shannon Stp
7238188	HRC-00020	Mangapapa @ Troup Rd
7231038	LAWA-101937	Mangarangiora @ D/S Ormondville Stp
7231038	LAWA-101938	Mangarangiora @ U/S Ormondville Stp
7230394	LAWA-101939	Mangarangiora Trib @ Ds Norsewood Stp
7230015	HRC-00086	Mangarangiora Trib @ Us Norsewood Stp
7240726	HRC-00024	Mangatainoka @ Brewery - S.H.2 Bridge
7241121	LAWA-101941	Mangatainoka @ D/S Pahiatua Stp
7246861	HRC-00022	Mangatainoka @ Larsons Road
7241237	HRC-00023	Mangatainoka @ Pahiatua Town Bridge
7248192	HRC-00021	Mangatainoka @ Putara
7242238	HRC-00343	Mangatainoka @ Scarborough Konini Rd
7241121	HRC-00083	Mangatainoka @ U/S Pahiatua Stp
7240042	HRC-00344	Mangatainoka @ U/S Tiraumea Confluence
7235055	LAWA-101942	Mangatera @ D/S Dannevirke Stp
7235055	HRC-00075	Mangatera @ Dannevirke
7235280	HRC-00025	Mangatera @ U/S Manawatu Confluence
7235055	LAWA-101943	Mangatera @ U/S T.D.C. Ox Ponds
7233345	HRC-00351	Mangatewainui @ Hardies
7235636	HRC-00026	Mangatoro @ Mangahei Road
7192527	LAWA-101944	Mangawhero @ D/S Ohakune Stp
7192145	HRC-00029	Mangawhero @ Doc Headquarters
7194090	HRC-00028	Mangawhero @ Pakihi Rd Bridge
7211554	HRC-00027	Mangawhero @ Raupiu Road
7192527	HRC-00064	Mangawhero @ U/S Ohakune Stp
7221195	HRC-00089	Mowhanau Stream @ Footbridge
7247234	LAWA-100247	Ngatahaka Stream @ U/S Makakahi Confl
7247560	HRC-00030	Ohau @ Gladstone Reserve
7247544	HRC-00031	Ohau @ Haines Property
7247769	LAWA-100544	Ohau @ State Highway Bridge

NZsegment	Site ID	Site Name
7152279	HRC-00032	Ohura @ Tokorima
7147944	HRC-00033	Ongarue @ Taringamotu
7232687	HRC-00035	Oroua @ Almadale Slackline
7224737	HRC-00036	Oroua @ Apiti
7236108	HRC-00034	Oroua @ Awahuri Bridge
7234946	LAWA-101948	Oroua @ D/S Affco Feilding
7235811	LAWA-101949	Oroua @ D/S Feilding Stp
7239168	LAWA-100248	Oroua @ Mangawhata
7234651	HRC-00078	Oroua @ U/S Affco Feilding
7235811	HRC-00079	Oroua @ U/S Feilding Stp
7229177	HRC-00088	Oroua Trib @ U/S Kimbolton Stp
7229253	LAWA-101950	Oroua Tributary @ D/S Kimbolton Stp
7236160	LAWA-101951	Oruakeretaki @ D/S Ppcs Oringi Stp
7235868	HRC-00037	Oruakeretaki @ S.H.2 Napier
7247269	HRC-00038	Owahanga @ Branscombe Bridge
7245888	HRC-00039	Patiki Stream @ Kawiu Road
7234275	LAWA-101952	Piakatutu @ D/S Sanson Stp
7234275	HRC-00073	Piakatutu @ U/S Sanson Stp
7234641	HRC-00040	Pohangina @ Mais Reach
7228989	HRC-00041	Pohangina @ Piripiri
7244835	LAWA-101953	Pongaroa @ D/S Pongaroa Stp
7244835	HRC-00067	Pongaroa @ U/S Pongaroa Stp
7224660	LAWA-101954	Porewa @ D/S Hunterville Stp Site A
7229125	HRC-00042	Porewa @ Onepuhi Road
7224660	HRC-00068	Porewa @ U/S Hunterville Stp Site A
7231319	LAWA-101956	Rangitawa Stream @ Ds Halcombe Oxpond
7231319	HRC-00070	Rangitawa Stream @ Us Halcombe Oxpond
7233234	LAWA-101957	Rangitikei @ D/S Riverlands
7218183	HRC-00045	Rangitikei @ Mangaweka
7236501	HRC-00043	Rangitikei @ Mckelvies
7229603	HRC-00044	Rangitikei @ Onepuhi
7208135	HRC-00046	Rangitikei @ Pukeokahu
7233271	HRC-00069	Rangitikei @ U/S Bulls Stp
7233271	LAWA-101958	Rangitikei @ Us Riverlands Stp
7237817	HRC-00047	Raparapawai @ Jackson Rd

NZsegment	Site ID	Site Name
7231345	HRC-00049	Tamaki @ Tamaki Reserve
7241723	HRC-00050	Tiraumea @ Ngaturi
7239689	HRC-00051	Tiraumea U/S Manawatu Confluence
7198731	HRC-00053	Tokiahuru @ Junction
7242415	HRC-00054	Tokomaru River @ Horseshoe Bend
7154460	HRC-00062_NIWA	Tu1 Whanganui @ Te Maire
7227401	HRC-00055	Turakina @ Oneills Bridge
7239293	HRC-00353	Turitea @ No1 Dairy
7230320	LAWA-101959	Tutaenui Stream @ D/S Marton Stp
7230320	HRC-00085	Tutaenui Stream @ U/S Marton Stp
7227733	LAWA-101960	Unnamed Trib Of Waipu @ Ds Ratana Stp
7227733	HRC-00087	Unnamed Trib Of Waipu @ Us Ratana Stp
7215564	NRWQN-00019_NIWA	Wa4 Whanganui @ Paetawa
7218183	HRC-00045_NIWA	Wa5 Rangitikei @ Mangaweka
7235487	HRC-00018_NIWA	Wa7 Manawatu @ Weber Rd
7239110	HRC-00015_NIWA	Wa8 Manawatu @ Teachers College
7240461	HRC-00013_NIWA	Wa9 Manawatu @ Opiki Br
7248148	HRC-00057	Waikawa @ Huritini
7248627	HRC-00056	Waikawa @ North Manakau Road
7196591	LAWA-101962	Waitangi @ D/S Waiouru Stp
7196591	HRC-00072	Waitangi @ U/S Waiouru Stp
7170971	LAWA-102841	Whakapapa @ Footbridge
7196647	LAWA-101963	Whangaehu @ D/S Winstone Pulp
7223467	HRC-00058	Whangaehu @ Kauangaroa
7196647	HRC-00071	Whangaehu @ U/S Winstone Pulp
7150443	HRC-00063	Whanganui @ Cherry Grove
7197112	HRC-00060	Whanganui @ Pipiriki
7154460	HRC-00062	Whanganui @ Te Maire
7215327	HRC-00059	Whanganui @ Te Rewa
7169416	HRC-00061	Whanganui @ Wades Landing

Appendix B Length of streams by stream order and water management sub-zone

Table B-1: Length (km) of streams by stream order and Water Management Sub-zone.

Sub-zone	Stream order							Total length	
	1	2	3	4	5	6	7	Higher order streams	All streams
Aokautere	12	8	8	0	0	0	0	0	29
Cherry Grove	98	47	15	13	0	22	0	34	194
Coastal Manawatū	167	82	39	3	1	0	46	50	339
Coastal Rangitikei	281	142	87	15	6	0	38	58	568
Coastal Whangaehu	81	42	11	0	0	37	0	37	171
Coastal Whanganui	71	40	10	3	0	0	8	10	132
Eastern coastal zone	128	59	36	25	0	0	0	25	248
Foxton Loop	31	18	10	8	0	0	0	8	66
Hokio	6	1	0	6	0	0	0	6	13
Hopelands - Tiraumea	33	21	7	0	0	10	0	10	71
Kahuterawa	54	22	9	19	0	0	0	19	104
Kai Iwi	152	89	29	40	14	0	0	54	325
Kaitoke Lakes	59	31	17	4	0	0	0	4	112
Kiwitea	213	108	48	65	11	0	0	77	446
Koputaroa	46	30	8	6	6	0	0	12	95
Lake Horowhenua	58	26	8	0	0	0	0	0	94
Lake Papaitonga	20	9	4	0	0	0	0	0	33
Lower Akitio	234	136	81	21	5	46	0	72	523
Lower Hautapu	86	45	15	0	15	0	0	15	161
Lower Kumeti	41	22	8	3	0	0	0	3	74
Lower Makotuku	54	27	4	14	0	0	0	14	98
Lower Manawatū	33	20	2	0	0	0	27	27	81
Lower Mangahao	51	23	9	0	13	0	0	13	96
Lower Manganui o te Ao	257	118	65	35	41	0	0	75	516
Lower Mangaone Stream	12	10	5	0	11	0	0	11	38
Lower Mangatainoka	32	21	3	0	0	17	0	17	73
Lower Mangawhero	340	146	63	52	53	0	0	105	653
Lower Moawhango	172	80	39	16	0	26	0	42	333
Lower Ohau	59	41	25	1	21	0	0	23	147
Lower Ohura	82	40	18	1	0	32	0	32	173

Sub-zone	Stream order							Total length	
	1	2	3	4	5	6	7	Higher order streams	All streams
Lower Ongarue	417	194	83	47	11	33	0	92	785
Lower Oroua	107	76	38	4	11	29	0	45	266
Lower Pohangina	62	28	11	1	10	0	0	11	111
Lower Rangitikei	421	207	88	56	0	0	70	126	842
Lower Tamaki	29	25	10	12	0	0	0	12	77
Lower Tiraumea	107	52	27	14	0	17	2	33	219
Lower Tokomaru	143	65	38	18	10	0	0	28	274
Lower Turakina	353	180	83	27	0	84	0	111	726
Lower Whakapapa	96	34	13	0	12	18	0	30	173
Lower Whangaehu	345	172	54	37	44	59	0	140	710
Lower Whanganui	214	84	48	32	0	0	36	68	415
Main Drain	93	73	44	13	3	0	0	15	224
Makakahi	162	95	38	19	35	0	0	54	349
Makara	10	10	5	0	0	0	0	0	26
Makatote	45	28	6	8	0	0	0	8	87
Makino	160	70	16	31	6	0	0	37	283
Makohine	78	36	19	21	0	0	0	21	155
Makuri	137	66	36	14	17	0	0	31	270
Manakau	25	13	7	6	0	0	0	6	50
Mangaatua	102	55	47	10	2	0	0	13	218
Mangaone River	93	56	27	18	17	0	0	35	212
Mangaore	45	18	14	11	0	0	0	11	87
Mangapapa	22	13	10	3	0	0	0	3	49
Mangaramarama	52	25	14	15	0	0	0	15	106
Mangatera	95	58	31	15	0	0	0	15	200
Mangatewainui	66	29	30	21	0	0	0	21	146
Mangatoro	198	94	37	43	14	0	0	57	386
Mangaturuturu	50	33	31	2	0	0	0	2	115
Matarawa	69	30	17	15	5	0	0	20	135
Middle Manawatū	142	63	42	3	0	0	28	30	278
Middle Manganui o te Ao	47	14	9	7	16	0	0	23	93
Middle Mangatainoka	93	49	27	14	25	0	0	39	209
Middle Moawhango	277	131	49	13	32	17	0	62	519
Middle Oroua	8	2	0	0	0	12	0	12	21

Sub-zone	Stream order							Total length	
	1	2	3	4	5	6	7	Higher order streams	All streams
Middle Pohangina	226	133	61	29	20	0	0	49	469
Middle Rangitikei	208	107	55	16	25	0	0	42	412
Middle Whangaehu	255	131	55	26	0	47	0	73	513
Middle Whanganui	241	115	56	27	0	0	42	69	481
Mowhanau	21	8	18	2	0	0	0	2	49
Northern Coastal	95	49	21	17	8	0	0	25	190
Northern Manawatū Lakes	90	71	23	3	3	0	0	7	190
Orautoha	63	32	12	9	0	0	0	9	117
Oruakeretaki	51	31	15	11	0	0	0	11	108
Owahanga	328	148	88	62	42	0	0	104	669
Paetawa	461	229	105	50	19	0	51	121	915
Piopiotea	84	39	19	11	5	0	0	17	159
Pipiriki	561	299	118	56	25	0	90	172	1150
Porewa	135	57	37	22	9	0	0	31	260
Pukeokahu - Mangaweka	568	278	137	85	30	19	25	159	1142
Pungapunga	84	51	12	23	4	0	0	27	175
Raparapawai	39	15	14	8	0	0	0	8	77
Ratana	10	3	2	0	0	0	0	0	15
Retaruke	389	169	103	33	16	28	0	77	739
Southern Whanganui Lakes	162	76	66	6	0	0	0	6	309
Tamaki - Hopelands	131	45	56	14	0	23	0	37	269
Tangarakau	461	228	109	98	72	10	0	181	979
Te Maire	91	51	20	17	0	0	18	35	197
Tidal Rangitikei	38	28	8	5	0	0	5	10	84
Tokiahuru	181	160	57	26	5	0	0	31	429
Turitea	37	13	16	0	0	0	0	0	67
Tutaenui	159	66	14	28	0	0	0	29	268
Upokongaro	111	42	36	23	0	0	0	23	212
Upper Akitio	96	44	26	14	13	0	0	27	194
Upper Gorge	42	19	6	1	0	0	15	16	83
Upper Hautapu	243	96	62	12	52	0	0	64	465
Upper Kumeti	7	4	10	0	0	0	0	0	21
Upper Makotuku	15	10	17	8	0	0	0	8	51
Upper Manawatū	300	160	81	33	43	20	0	95	636

Sub-zone	Stream order							Total length	
	1	2	3	4	5	6	7	Higher order streams	All streams
Upper Mangahao	205	113	54	7	58	0	0	65	437
Upper Manganui o te Ao	26	23	10	1	0	0	0	1	60
Upper Mangaone Stream	161	76	31	11	17	0	0	28	296
Upper Mangatainoka	56	20	13	15	0	0	0	15	104
Upper Mangawhero	162	84	62	18	10	0	0	29	337
Upper Moawhango	217	100	69	29	17	0	0	46	432
Upper Ohau	80	35	29	9	6	0	0	15	159
Upper Ohura	510	251	107	127	65	10	0	203	1070
Upper Ongarue	501	272	141	64	56	12	0	133	1047
Upper Oroua	253	147	35	33	66	0	0	99	534
Upper Pohangina	176	89	53	29	7	0	0	36	355
Upper Rangitikei	402	185	83	64	46	0	0	110	780
Upper Tamaki	25	12	13	0	0	0	0	0	50
Upper Tiraumea	339	157	77	58	33	28	0	119	691
Upper Tokomaru	49	18	15	8	0	0	0	8	88
Upper Turakina	442	216	93	58	53	11	0	122	872
Upper Whakapapa	168	109	47	15	9	0	0	24	348
Upper Whangaehu	176	83	65	26	15	1	0	42	367
Upper Whanganui	340	160	102	30	20	0	0	50	652
Waihi	101	56	29	18	11	0	0	28	214
Waikawa	36	17	6	12	6	0	0	18	77
Waimarino	73	23	22	9	0	0	0	9	127
Waitangi	46	26	9	15	0	0	0	15	96
Waitarere	30	14	9	1	0	0	0	1	54
Weber - Tamaki	41	23	10	8	0	8	0	15	89
Whangamomona	162	81	42	27	27	0	0	54	339
Total	**18 080**	**9 079**	**4 499**	**2 371**	**1 381**	**675**	**500**	**4 927**	**36 585**

Appendix C Future adjustment of exceedance frequencies

This appendix outlines the method used adjust the current attribute states to the future attribute states under Scenarios 1 and 2.

For each reach, the new non-exceedance frequencies are calculated assuming that the concentrations are characterized by a log-normal distribution with μ = ln(median) and σ = ln(standard deviation). We use a fixed value of σ = 1.34 (Elliott and Whitehead, 2016)[13]. The calculations are as follows:

1. Calculate the non-exceedance frequencies for the current scenario as:

$$F_{260,0} = 1 - G_{260,0}$$

or

$$F_{540,0} = 1 - G_{540,0}$$

where $F_{260,0}$ and $G_{260,0}$ are, respectively, the non-exceedance and exceedance frequencies of concentration 260 per 100 ml under Scenario 0, and $F_{540,0}$ and $G_{540,0}$ are the non-exceedance and exceedance frequencies of concentration 540 per 100 ml under Scenario 0.

2. Calculate an estimate of μ from the current non-exceedance frequency:

$$\mu_{260} = \ln(260) - \sqrt{2}\sigma \mathrm{erf}^{-1}\left(2F_{260,0} - 1\right)$$

or

$$\mu_{540} = \ln(540) - \sqrt{2}\sigma \mathrm{erf}^{-1}\left(2F_{540,0} - 1\right)$$

respectively, where erf^{-1} is the inverse of the error function (implemented from the Python Scipy library[14]).

3. Calculate the new non-exceedance frequency using

$$F_{260,1} = \frac{1}{2} + \frac{1}{2}\mathrm{erf}\left(\frac{\ln 260 - \mu_{260} - \ln D}{\sqrt{2}\sigma}\right)$$

or

$$F_{540,1} = \frac{1}{2} + \frac{1}{2}\mathrm{erf}\left(\frac{\ln 540 - \mu_{540} - \ln D}{\sqrt{2}\sigma}\right)$$

where $F_{260,1}$ and $F_{540,1}$ are, respectively, the non-exceedance frequencies of concentrations 240 per 100 ml and 540 per 100 ml under Scenario 1 (or 2), $D = L_1/L_0$ is the ratio of loads between Scenario 1 (or 2) and Scenario 0 and erf is the error function (implemented from the Python SciPy library[15])

4. Convert the non-exceedance frequencies back into <u>exceedance</u> frequencies for reporting using $G_{260,1} = 1 - F_{260,1}$ or $G_{540,1} = 1 - F_{540,1}$

[13] Elliott S., Whitehead A. (2016) Effect of *E. coli* Mitigation on the Proportion of Time Primary Contact Minimum Acceptable State Concentrations Are Exceeded: Technical Note. .

[14] https://docs.scipy.org/doc/scipy-0.14.0/reference/generated/scipy.special.erfinv.html (date of access, 9 March 2018)

[15] https://docs.scipy.org/doc/scipy-0.14.0/reference/generated/scipy.special.erf.html (date of access, 9 March 2018)

Appendix D Load reduction for exceedance numeric attributes

This appendix addresses the question of how much the load needs to be changed to achieve a target exceedance probability (G) value, give an initial value of G. Here G could be $G260$ or $G540$, indicating the exceedance probability of concentrations 260 per 100 ml or 540 per 100 ml, respectively. The methodology is very similar to that given in Appendix A for mitigation modelling. The method assumes that a) the distribution of concentrations follows a log-normal distribution, and that for a given load reduction factor D, all concentrations are reduced by a factor D. These are the same assumptions as in Elliott and Whitehead (2016).

The formula for the cumulative distribution function, F, of concentrations in a log-normal distribution is

$$F(\ln C\,;\sigma,\mu) = 0.5 + 0.5\mathrm{erf}\left(\frac{\ln C - \mu}{\sqrt{2}\sigma}\right)$$

where C denotes the concentration, σ is the log-standard deviation parameter, and μ is the log-mean parameter.

Also, by definition, the non-exceedance probability is $G = 1 - F$.

Solving for the log-mean,

$$\mu = \ln C - \sqrt{2}\sigma\mathrm{erf}^{-1}(1 - 2G)$$

For an initial value of $G540$ denoted by subscript 0, the associated value of μ is

$$\mu_0 = \ln 540 - \sqrt{2}\sigma\mathrm{erf}^{-1}(1 - 2G540_0)$$

The value of σ is taken to be 1.34, as established in Whitehead (2016). We examinined alternatives for estimating σ, such as us using measured or predicted $G540$ and $G260$, but the approach proved to be problematic due to uncertainty in measurements and predictions. Therefore, the simple approach of assuming a constant σ was used.

Similarly, for the target conditions denoted by subscript 1,

$$\mu_1 = \ln 540 - \sqrt{2}\sigma\mathrm{erf}^{-1}(1 - 2G540_1)$$

Since all concentrations are reduced by a factor D, and the median concentration is $\exp(\mu)$,

$$D = \exp(\mu_0)\,/\,\exp(\mu_1)$$

or

$$D = \exp(\mu_0 - \mu_1)$$

the new exceedance probability for the target conditions can then be calculated as

$$G540_1 = \frac{1}{2} - \frac{1}{2}\mathrm{erf}\left(\frac{\ln 540 - \mu_0 + \ln D}{\sqrt{2}\sigma}\right)$$

These equations have been written for $G540$, but similar equations apply for $G260$.

There are some special conditions for the equations that need to be handled:

If G_0 is zero (this could arise if the G values are determined from monitored data and all the samples are less than 260, or 540, depending on the G numeric attribute of interest) then there is no way of calculating the required reduction factor. The formulas above will give a required load reduction factor of zero (can increase concentrations without limit). That is okay because the load reduction calculations in the capacity model apply a minimum D value of 1 to maintain or improve the state.

If G_0 is 1 (all the samples are greater than 260 or 540, depending on the G numeric attribute of interest) then the above approach does not work – the calculations will return a value of infinity (the load reduction factor would be infinitely large). For the Horizons/Taranaki model, this situation did not arise, so it was not an issue in practice. There are some potential methods to handle this situation: the result could be set as 1 (in which case other numeric attributes would dominate the load reduction); modelled G values could be used instead of measured ones; or the estimated median concentration (from measurements) could be used in place of μ_0 in the above equations. We don't apply the last approach in general (for general G values) because it would give an implied G_0 inconsistent with the measurements.

Appendix E Current State NOF bands by Water Management Sub-zone

Table E-1: Length of higher order streams in each NOF band calculated with the C_{95} concentration attribute by Water Management Subzone.

WMS	A (%)	B (%)	C (%)	D (%)	E (%)
Cherry Grove	4 (12.5)	7 (20)	2 (5.9)	15 (44.9)	6 (16.7)
Coastal Manawatū	0 (0)	0 (0)	0 (0)	0 (0)	50 (100)
Coastal Rangitikei	0 (0)	1 (1)	1 (1.5)	36 (62.4)	20 (35)
Coastal Whangaehu	0 (0)	0 (0)	0 (0)	37 (100)	0 (0)
Coastal Whanganui	0 (0)	0 (0)	0 (0)	8 (74.7)	3 (25.3)
Eastern coastal zone	0 (0)	0 (0)	0 (0)	25 (100)	0 (0)
Foxton Loop	0 (0)	0 (0)	0 (0)	0 (0)	8 (100)
Hokio	0 (0)	0 (0)	0 (0)	6 (100)	0 (0)
Hopelands - Tiraumea	0 (0)	0 (0)	0 (0)	10 (100)	0 (0)
Kahuterawa	0 (0)	0 (0)	0 (0)	19 (100)	0 (0)
Kai Iwi	0 (0)	0 (0)	1 (2.7)	36 (65.5)	17 (31.8)
Kaitoke Lakes	0 (0)	0 (0)	0 (0)	0 (0)	4 (100)
Kiwitea	0 (0)	0 (0)	0 (0)	68 (88.6)	9 (11.4)
Koputaroa	0 (0)	0 (0)	0 (0)	0 (0)	12 (100)
Lake Horowhenua	0 (0)	0 (0)	0 (0)	0 (0)	0 (100)
Lower Akitio	0 (0)	0 (0)	0 (0)	60 (83.5)	12 (16.5)
Lower Hautapu	0 (0)	1 (8.6)	0 (0)	12 (80.5)	2 (10.9)
Lower Kumeti	0 (0)	0 (0)	0 (0)	1 (26.4)	2 (73.6)
Lower Makotuku	0 (0)	3 (25.1)	2 (15.7)	8 (59.2)	0 (0)
Lower Manawatū	0 (0)	0 (0)	0 (0)	4 (14.4)	23 (85.6)
Lower Mangahao	0 (0)	0 (0)	0 (0)	13 (100)	0 (0)
Lower Manganui o te Ao	7 (9.6)	50 (66.9)	14 (18.1)	4 (5.4)	0 (0)
Lower Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	11 (100)
Lower Mangatainoka	0 (0)	0 (0)	0 (0)	17 (100)	0 (0)
Lower Mangawhero	1 (1.1)	0 (0)	1 (0.8)	103 (98.1)	0 (0)
Lower Moawhango	0 (0)	26 (60.8)	0 (0)	16 (39.2)	0 (0)
Lower Ohau	7 (30.2)	9 (39.3)	0 (1.3)	5 (22.8)	1 (6.4)
Lower Ohura	0 (0)	0 (0)	0 (0)	32 (100)	0 (0)
Lower Ongarue	0 (0)	4 (4.4)	0 (0)	77 (83.9)	11 (11.7)
Lower Oroua	0 (0)	0 (0)	0 (0)	8 (16.9)	37 (83.1)
Lower Pohangina	0 (0)	0 (0)	0 (0)	10 (89.4)	1 (10.6)
Lower Rangitikei	0 (0)	2 (1.5)	35 (27.8)	50 (39.5)	39 (31.2)
Lower Tamaki	0 (0)	0 (0)	0 (0)	12 (100)	0 (0)

WMS	A (%)	B (%)	C (%)	D (%)	E (%)
Lower Tiraumea	0 (0)	0 (0)	0 (0)	6 (16.9)	27 (83.1)
Lower Tokomaru	0 (0)	0 (0)	0 (0)	7 (22.9)	22 (77.1)
Lower Turakina	0 (0)	0 (0)	0 (0)	100 (90.4)	11 (9.6)
Lower Whakapapa	30 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whangaehu	0 (0)	0 (0)	0 (0)	140 (100)	0 (0)
Lower Whanganui	0 (0)	3 (4)	17 (25.5)	38 (56.4)	10 (14.1)
Main Drain	0 (0)	0 (0)	0 (0)	0 (0)	15 (100)
Makakahi	0 (0)	0 (0)	0 (0)	18 (32.7)	36 (67.3)
Makatote	8 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Makino	0 (0)	0 (0)	0 (0)	0 (0)	37 (100)
Makohine	0 (0)	0 (0)	0 (0)	21 (100)	0 (0)
Makuri	0 (0)	0 (0)	0 (0)	25 (79.9)	6 (20.1)
Manakau	0 (0)	0 (0)	0 (0)	0 (0)	6 (100)
Mangaatua	0 (0)	0 (0)	0 (0)	0 (0)	13 (100)
Mangaone River	0 (0)	0 (0)	0 (0)	0 (0)	35 (100)
Mangaore	0 (0)	0 (0)	0 (0)	10 (90.4)	1 (9.6)
Mangapapa	0 (0)	0 (0)	0 (0)	0 (0)	3 (100)
Mangaramarama	0 (0)	0 (0)	0 (0)	0 (0)	15 (100)
Mangatera	0 (0)	0 (0)	0 (0)	0 (0)	15 (100)
Mangatewainui	0 (0)	0 (0)	0 (0)	21 (100)	0 (0)
Mangatoro	0 (0)	0 (0)	0 (0)	23 (40.2)	34 (59.8)
Mangaturuturu	2 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Matarawa	0 (0)	0 (0)	0 (0)	0 (0)	20 (100)
Middle Manawatū	0 (0)	0 (0)	0 (0)	18 (57.7)	13 (42.3)
Middle Manganui o te Ao	16 (70.8)	7 (29.2)	0 (0)	0 (0)	0 (0)
Middle Mangatainoka	0 (0)	0 (0)	0 (0)	35 (89.8)	4 (10.2)
Middle Moawhango	48 (77.4)	11 (17.9)	0 (0)	3 (4.7)	0 (0)
Middle Oroua	0 (0)	0 (0)	0 (0)	12 (100)	0 (0)
Middle Pohangina	0 (0)	0 (0)	0 (0)	49 (100)	0 (0)
Middle Rangitikei	26 (63.3)	7 (17.3)	4 (10.2)	4 (9.2)	0 (0)
Middle Whangaehu	0 (0)	18 (25.1)	3 (3.9)	52 (71)	0 (0)
Middle Whanganui	0 (0)	0 (0)	0 (0)	66 (94.7)	4 (5.3)
Mowhanau	0 (0)	0 (0)	0 (0)	0 (0)	2 (100)
Northern Coastal	0 (0)	0 (0)	0 (0)	5 (19.2)	20 (80.8)
Northern Manawatū Lakes	0 (0)	0 (0)	0 (0)	4 (57.6)	3 (42.4)
Orautoha	0 (0)	0 (0)	0 (0)	9 (100)	0 (0)
Oruakeretaki	0 (0)	0 (0)	0 (0)	11 (100)	0 (0)
Owahanga	0 (0)	0 (0)	0 (0)	75 (72.2)	29 (27.8)

WMS	A (%)	B (%)	C (%)	D (%)	E (%)
Paetawa	5 (4.3)	50 (41.2)	3 (2.7)	63 (51.9)	0 (0)
Piopiotea	0 (0)	17 (100)	0 (0)	0 (0)	0 (0)
Pipiriki	0 (0)	81 (47.4)	0 (0)	90 (52.6)	0 (0)
Porewa	0 (0)	0 (0)	0 (0)	12 (37.6)	19 (62.4)
Pukeokahu - Mangaweka	87 (54.9)	32 (20.2)	9 (5.8)	30 (19.1)	0 (0)
Pungapunga	5 (18.4)	10 (34.9)	0 (0)	13 (46.6)	0 (0)
Raparapawai	0 (0)	0 (0)	0 (0)	0 (0)	8 (100)
Retaruke	3 (3.6)	26 (33.8)	9 (11.4)	39 (51.2)	0 (0)
Southern Whanganui Lakes	0 (0)	0 (0)	0 (0)	1 (22.4)	5 (77.6)
Tamaki - Hopelands	0 (0)	0 (0)	0 (0)	23 (62.1)	14 (37.9)
Tangarakau	0 (0)	0 (0)	7 (3.7)	163 (90.2)	11 (6.1)
Te Maire	0 (0)	0 (0)	0 (0)	26 (73.7)	9 (26.3)
Tidal Rangitikei	0 (0)	0 (0)	0 (0)	5 (53.6)	5 (46.4)
Tokiahuru	28 (90.4)	3 (9.6)	0 (0)	0 (0)	0 (0)
Tutaenui	0 (0)	0 (0)	0 (0)	0 (0.7)	28 (99.3)
Upokongaro	0 (0)	2 (6.7)	1 (5.8)	20 (87.5)	0 (0)
Upper Akitio	0 (0)	0 (0)	0 (0)	19 (71.2)	8 (28.8)
Upper Gorge	0 (0)	0 (0)	0 (0)	8 (48.3)	8 (51.7)
Upper Hautapu	13 (20.6)	27 (41.9)	2 (3)	22 (34.5)	0 (0)
Upper Makotuku	5 (62.4)	3 (37.6)	0 (0)	0 (0)	0 (0)
Upper Manawatū	0 (0)	0 (0)	0 (0)	50 (52)	46 (48)
Upper Mangahao	33 (50.6)	12 (18.8)	5 (7.2)	11 (16.6)	4 (6.8)
Upper Manganui o te Ao	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	28 (100)
Upper Mangatainoka	7 (45.4)	3 (20)	0 (1)	5 (33.6)	0 (0)
Upper Mangawhero	9 (32.8)	6 (20.2)	1 (4.3)	12 (42.7)	0 (0)
Upper Moawhango	46 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Ohau	8 (52.9)	2 (12.4)	4 (25.3)	1 (9.4)	0 (0)
Upper Ohura	0 (0)	6 (3.1)	5 (2.6)	191 (94.4)	0 (0)
Upper Ongarue	0 (0)	86 (64.9)	8 (6)	39 (29)	0 (0)
Upper Oroua	22 (22.5)	10 (9.6)	1 (1.5)	63 (63.8)	3 (2.6)
Upper Pohangina	19 (53.5)	12 (32.3)	4 (11.4)	1 (2.9)	0 (0)
Upper Rangitikei	96 (87.5)	14 (12.5)	0 (0)	0 (0)	0 (0)
Upper Tiraumea	0 (0)	0 (0)	0 (0)	0 (0)	119 (100)
Upper Tokomaru	0 (0)	6 (74.8)	1 (11)	1 (14.2)	0 (0)
Upper Turakina	0 (0)	0 (0)	0 (0)	122 (100)	0 (0)
Upper Whakapapa	24 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whangaehu	40 (94.1)	0 (0)	0 (0)	2 (5.9)	0 (0)

WMS	A (%)	B (%)	C (%)	D (%)	E (%)
Upper Whanganui	36 (71.3)	9 (18)	0 (0)	5 (10.7)	0 (0)
Waihi	0 (0)	0 (0)	0 (0)	12 (43.7)	16 (56.3)
Waikawa	6 (35.7)	4 (22.4)	2 (10.2)	0 (0)	6 (31.7)
Waimarino	9 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Waitangi	11 (71.3)	4 (28.7)	0 (0)	0 (0)	0 (0)
Waitarere	0 (0)	0 (0)	0 (0)	1 (100)	0 (0)
Weber - Tamaki	0 (0)	0 (0)	0 (0)	8 (50)	8 (50)
Whangamomona	0 (0)	3 (6.2)	2 (3.5)	49 (90.3)	0 (0)
Total	663 (13.5)	575 (11.7)	145 (2.9)	2549 (51.7)	994 (20.2)

Table E-2: Length of higher order streams in each NOF band calculated without the C_{95} concentration attribute by Water Management Subzone.

WMS	A (%)	B (%)	C (%)	D (%)	E (%)
Cherry Grove	4 (12.5)	16 (47.3)	1 (3.6)	7 (19.9)	6 (16.7)
Coastal Manawatū	0 (0)	0 (0)	0 (0)	0 (0)	50 (100)
Coastal Rangitikei	0 (0)	38 (65)	0 (0)	0 (0)	20 (35)
Coastal Whangaehu	0 (0)	0 (0)	37 (100)	0 (0)	0 (0)
Coastal Whanganui	0 (0)	0 (0)	8 (74.7)	0 (0)	3 (25.3)
Eastern coastal zone	0 (0)	0 (0)	0 (0)	25 (100)	0 (0)
Foxton Loop	0 (0)	0 (0)	0 (0)	0 (0)	8 (100)
Hokio	0 (0)	1 (15.8)	0 (0)	5 (84.2)	0 (0)
Hopelands - Tiraumea	0 (0)	0 (0)	0 (0)	10 (100)	0 (0)
Kahuterawa	0 (0)	0 (0)	12 (61.1)	8 (38.9)	0 (0)
Kai Iwi	0 (0)	17 (31)	4 (7.3)	16 (30)	17 (31.8)
Kaitoke Lakes	0 (0)	0 (0)	0 (0)	0 (0)	4 (100)
Kiwitea	0 (0)	0 (0)	0 (0)	68 (88.6)	9 (11.4)
Koputaroa	0 (0)	0 (0)	0 (0)	0 (0)	12 (100)
Lake Horowhenua	0 (0)	0 (0)	0 (0)	0 (0)	0 (100)
Lower Akitio	0 (0)	0 (0)	0 (0)	60 (83.5)	12 (16.5)
Lower Hautapu	0 (0)	1 (8.6)	1 (6.7)	11 (73.7)	2 (10.9)
Lower Kumeti	0 (0)	0 (0)	0 (0)	1 (26.4)	2 (73.6)
Lower Makotuku	0 (0)	6 (40.8)	0 (0)	8 (59.2)	0 (0)
Lower Manawatū	0 (0)	0 (0)	0 (0)	4 (14.4)	23 (85.6)
Lower Mangahao	0 (0)	0 (0)	0 (0)	13 (100)	0 (0)
Lower Manganui o te Ao	7 (9.6)	68 (90.3)	0 (0)	0 (0.1)	0 (0)
Lower Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	11 (100)
Lower Mangatainoka	0 (0)	0 (0)	0 (0)	17 (100)	0 (0)

WMS	A (%)	B (%)	C (%)	D (%)	E (%)
Lower Mangawhero	1 (1.1)	4 (3.8)	1 (1.2)	98 (93.8)	0 (0)
Lower Moawhango	0 (0)	26 (60.8)	0 (0)	16 (39.2)	0 (0)
Lower Ohau	7 (30.2)	11 (50.1)	2 (8)	1 (5.3)	1 (6.4)
Lower Ohura	0 (0)	0 (0)	0 (0)	32 (100)	0 (0)
Lower Ongarue	0 (0)	4 (4.4)	16 (17.2)	62 (66.7)	11 (11.7)
Lower Oroua	0 (0)	0 (0)	0 (0)	8 (16.9)	37 (83.1)
Lower Pohangina	0 (0)	0 (0)	6 (57.5)	4 (31.9)	1 (10.6)
Lower Rangitikei	0 (0)	70 (55.9)	0 (0)	16 (13)	39 (31.2)
Lower Tamaki	0 (0)	0 (0)	6 (50.3)	6 (49.7)	0 (0)
Lower Tiraumea	0 (0)	0 (0)	0 (0)	6 (16.9)	27 (83.1)
Lower Tokomaru	0 (0)	0 (0)	7 (22.9)	0 (0)	22 (77.1)
Lower Turakina	0 (0)	0 (0)	0 (0)	100 (90.4)	11 (9.6)
Lower Whakapapa	30 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whangaehu	0 (0)	12 (8.6)	49 (34.9)	79 (56.5)	0 (0)
Lower Whanganui	0 (0)	15 (21.8)	43 (62.8)	1 (1.3)	10 (14.1)
Main Drain	0 (0)	0 (0)	0 (0)	0 (0)	15 (100)
Makakahi	0 (0)	0 (0)	3 (6.3)	14 (26.4)	36 (67.3)
Makatote	8 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Makino	0 (0)	0 (0)	0 (0)	0 (0)	37 (100)
Makohine	0 (0)	0 (0)	0 (0)	21 (100)	0 (0)
Makuri	0 (0)	0 (0)	0 (0)	25 (79.9)	6 (20.1)
Manakau	0 (0)	0 (0)	0 (0)	0 (0)	6 (100)
Mangaatua	0 (0)	0 (0)	0 (0)	0 (0)	13 (100)
Mangaone River	0 (0)	0 (0)	0 (0)	0 (0)	35 (100)
Mangaore	0 (0)	0 (0)	3 (25.6)	7 (64.9)	1 (9.6)
Mangapapa	0 (0)	0 (0)	0 (0)	0 (0)	3 (100)
Mangaramarama	0 (0)	0 (0)	0 (0)	0 (0)	15 (100)
Mangatera	0 (0)	0 (0)	0 (0)	0 (0)	15 (100)
Mangatewainui	0 (0)	1 (4.8)	17 (81.1)	3 (14.1)	0 (0)
Mangatoro	0 (0)	0 (0)	0 (0)	23 (40.2)	34 (59.8)
Mangaturuturu	2 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Matarawa	0 (0)	0 (0)	0 (0)	0 (0)	20 (100)
Middle Manawatū	0 (0)	0 (0)	0 (0)	18 (57.7)	13 (42.3)
Middle Manganui o te Ao	16 (70.8)	7 (29.2)	0 (0)	0 (0)	0 (0)
Middle Mangatainoka	0 (0)	0 (0)	10 (24.8)	25 (65)	4 (10.2)
Middle Moawhango	51 (83.3)	7 (12)	0 (0)	3 (4.7)	0 (0)
Middle Oroua	0 (0)	0 (0)	0 (0)	12 (100)	0 (0)
Middle Pohangina	0 (0)	0 (0.8)	26 (53.5)	22 (45.7)	0 (0)

WMS	A (%)	B (%)	C (%)	D (%)	E (%)
Middle Rangitikei	26 (63.3)	11 (27.5)	3 (7.1)	1 (2.1)	0 (0)
Middle Whangaehu	9 (12.4)	38 (52.2)	0 (0)	26 (35.4)	0 (0)
Middle Whanganui	0 (0)	0 (0)	0 (0)	66 (94.7)	4 (5.3)
Mowhanau	0 (0)	0 (0)	0 (0)	0 (0)	2 (100)
Northern Coastal	0 (0)	0 (0)	0 (0)	5 (19.2)	20 (80.8)
Northern Manawatū Lakes	0 (0)	0 (0)	0 (0)	4 (57.6)	3 (42.4)
Orautoha	0 (0)	0 (0)	0 (0)	9 (100)	0 (0)
Oruakeretaki	0 (0)	0 (0)	0 (0)	11 (100)	0 (0)
Owahanga	0 (0)	0 (0)	2 (1.5)	73 (70.7)	29 (27.8)
Paetawa	6 (5.4)	57 (47.5)	6 (5)	51 (42.2)	0 (0)
Piopiotea	0 (0)	17 (100)	0 (0)	0 (0)	0 (0)
Pipiriki	2 (1.1)	80 (46.4)	0 (0)	90 (52.6)	0 (0)
Porewa	0 (0)	0 (0)	0 (0)	12 (37.6)	19 (62.4)
Pukeokahu - Mangaweka	87 (54.9)	41 (26)	20 (12.4)	11 (6.6)	0 (0)
Pungapunga	5 (18.4)	10 (36)	7 (24.4)	6 (21.2)	0 (0)
Raparapawai	0 (0)	0 (0)	0 (0)	0 (0)	8 (100)
Retaruke	3 (3.6)	46 (59.8)	18 (22.7)	11 (13.8)	0 (0)
Southern Whanganui Lakes	0 (0)	0 (0)	0 (0)	1 (22.4)	5 (77.6)
Tamaki - Hopelands	0 (0)	0 (0)	1 (3)	22 (59)	14 (37.9)
Tangarakau	0 (0)	70 (38.7)	40 (22.2)	60 (33)	11 (6.1)
Te Maire	0 (0)	0 (0)	2 (5.5)	24 (68.2)	9 (26.3)
Tidal Rangitikei	0 (0)	5 (50.6)	0 (0)	0 (3)	5 (46.4)
Tokiahuru	31 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Tutaenui	0 (0)	0 (0.7)	0 (0)	0 (0)	28 (99.3)
Upokongaro	0 (0)	4 (17.2)	2 (9.2)	17 (73.6)	0 (0)
Upper Akitio	0 (0)	8 (28.3)	4 (13.6)	8 (29.3)	8 (28.8)
Upper Gorge	0 (0)	0 (0)	0 (0)	8 (48.3)	8 (51.7)
Upper Hautapu	13 (20.6)	49 (76.5)	0 (0)	2 (2.9)	0 (0)
Upper Makotuku	5 (62.4)	3 (37.6)	0 (0)	0 (0)	0 (0)
Upper Manawatū	0 (0)	0 (0)	1 (1.2)	48 (50.8)	46 (48)
Upper Mangahao	33 (50.6)	17 (26)	4 (6.3)	7 (10.2)	4 (6.8)
Upper Manganui o te Ao	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	28 (100)
Upper Mangatainoka	7 (45.4)	5 (33.7)	3 (20.9)	0 (0)	0 (0)
Upper Mangawhero	12 (43.4)	4 (14)	0 (0)	12 (42.7)	0 (0)
Upper Moawhango	46 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Ohau	8 (52.9)	2 (12.4)	5 (29.4)	1 (5.4)	0 (0)
Upper Ohura	0 (0)	23 (11.4)	12 (5.8)	168 (82.8)	0 (0)

WMS	A (%)	B (%)	C (%)	D (%)	E (%)
Upper Ongarue	0 (0)	92 (69.3)	32 (24)	9 (6.7)	0 (0)
Upper Oroua	22 (22.5)	15 (14.8)	27 (26.9)	33 (33.2)	3 (2.6)
Upper Pohangina	19 (53.5)	17 (46.5)	0 (0)	0 (0)	0 (0)
Upper Rangitikei	96 (87.5)	14 (12.5)	0 (0)	0 (0)	0 (0)
Upper Tiraumea	0 (0)	0 (0)	0 (0)	0 (0)	119 (100)
Upper Tokomaru	0 (0)	8 (100)	0 (0)	0 (0)	0 (0)
Upper Turakina	0 (0)	0 (0)	6 (4.6)	116 (95.4)	0 (0)
Upper Whakapapa	24 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whangaehu	40 (94.1)	0 (0)	2 (5.9)	0 (0)	0 (0)
Upper Whanganui	36 (71.3)	9 (18)	3 (5.1)	3 (5.6)	0 (0)
Waihi	0 (0)	0 (0)	0 (0)	12 (43.7)	16 (56.3)
Waikawa	6 (35.7)	6 (32.6)	0 (0)	0 (0)	6 (31.7)
Waimarino	9 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Waitangi	11 (71.3)	4 (28.7)	0 (0)	0 (0)	0 (0)
Waitarere	0 (0)	0 (0)	0 (0)	1 (100)	0 (0)
Weber - Tamaki	0 (0)	0 (0)	0 (0)	8 (50)	8 (50)
Whangamomona	0 (0)	24 (43.4)	15 (28.4)	15 (28.2)	0 (0)
Total	**685 (13.9)**	**982 (19.9)**	**464 (9.4)**	**1802 (36.6)**	**994 (20.2)**

Appendix F Current State NOF bands at SOE sites

Table F-1: NOF bands calculated from SOE water quality data with and without the C_{95} concentration numeric attribute. Bands were determined using attributes obtained from measured data (Whitehead *et al.* 2022).

NZSEGMENT	SOE Site	With C_{95}	No C_{95}
7147944	HRC-00033	D	D
7152279	HRC-00032	D	D
7170971	LAWA-102841	A	A
7150443	HRC-00063	D	C
7154460	HRC-00062	D	D
7169416	HRC-00061	D	D
7189858	HRC-00009	B	B
7185582	LAWA-100557	C	B
7192145	HRC-00029	A	A
7193268	HRC-00007	D	D
7193718	HRC-00065	B	B
7192527	HRC-00064	B	B
7194503	HRC-00066	D	D
7194090	HRC-00028	D	D
7196647	HRC-00071	A	A
7196591	HRC-00072	A	A
7197112	HRC-00060	D	D
7198731	HRC-00053	A	A
7208135	HRC-00046	A	A
7209566	HRC-00003	D	B
7210283	LAWA-100545	D	C
7211554	HRC-00027	D	D
7211096	LAWA-101919	E	E
7215080	HRC-00002	B	B
7215327	HRC-00059	D	D
7215564	NRWQN-00019_NIWA	D	D
7220928	HRC-00090	E	E
7221195	HRC-00089	E	E
7218183	HRC-00045	B	B
7223467	HRC-00058	D	C
7224660	LAWA-101954	E	E
7224737	HRC-00036	A	A
7227733	HRC-00087	E	E

NZSEGMENT	SOE Site	With C_{95}	No C_{95}
7227401	HRC-00055	D	D
7229125	HRC-00042	D	D
7229177	HRC-00088	E	E
7229253	LAWA-101950	E	E
7230015	HRC-00086	E	E
7228989	HRC-00041	B	B
7230320	LAWA-101959	E	E
7229603	HRC-00044	B	B
7230394	LAWA-101939	E	E
7231038	LAWA-101937	D	D
7231345	HRC-00049	A	A
7231319	HRC-00070	E	E
7232687	HRC-00035	D	D
7233345	HRC-00351	D	C
7233271	HRC-00069	D	B
7233234	LAWA-101957	D	B
7234007	HRC-00346	D	D
7234284	HRC-00006	D	C
7234651	HRC-00078	D	D
7234275	HRC-00073	E	E
7234946	LAWA-101948	D	D
7235055	HRC-00075	E	E
7235280	HRC-00025	E	E
7234641	HRC-00040	D	C
7235811	HRC-00079	D	D
7236108	HRC-00034	D	D
7235868	HRC-00037	D	D
7236160	LAWA-101951	D	D
7236501	HRC-00043	D	B
7237817	HRC-00047	E	E
7238188	HRC-00020	E	E
7239168	LAWA-100248	E	E
7238376	HRC-00076	E	E
7238369	LAWA-101933	E	E
7235636	HRC-00026	D	D
7235487	HRC-00018	D	C
7238779	HRC-00016	D	C
7239293	HRC-00353	E	E

NZSEGMENT	SOE Site	With C_{95}	No C_{95}
7241259	HRC-00005	D	C
7239687	HRC-00345	D	D
7244835	HRC-00067	E	E
7245285	LAWA-101923	D	D
7242415	HRC-00054	D	C
7245888	HRC-00039	E	E
7243830	HRC-00010	E	E
7243893	LAWA-101936	D	C
7246119	HRC-00001	E	E
7245566	HRC-00347	E	E
7245739	HRC-00004	D	B
7247269	HRC-00038	D	D
7247234	LAWA-100247	E	E
7248192	HRC-00021	A	A
7246861	HRC-00022	D	C

Appendix G Scenario 1 NOF bands summarised by Water Management Sub-zone

Table G-1: Change in the length (km) compared to the current scenario in each NOF band determined for Scenario 1 (low removal efficiency) with C_{95} included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Cherry Grove	0 (0)	0 (0)	0 (0)	3.54 (10.4)	-3.54 (-10.3)
Coastal Manawatū	0 (0)	0 (0)	0 (0)	0.56 (1.1)	-0.56 (-1.1)
Coastal Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coastal Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coastal Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Eastern coastal zone	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Foxton Loop	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hokio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hopelands - Tiraumea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kahuterawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kai Iwi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kaitoke Lakes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kiwitea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Koputaroa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lake Horowhenua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Akitio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Kumeti	0 (0)	0 (0)	0 (0)	2.29 (73.6)	-2.29 (-73.6)
Lower Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Manawatū	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangahao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Manganui o te Ao	0 (0)	0 (0)	4.02 (5.4)	-4.02 (-5.3)	0 (0)
Lower Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangatainoka	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Ohau	0.54 (2.3)	-0.54 (-2.3)	2.19 (9.5)	-2.19 (-9.5)	0 (0)
Lower Ohura	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Ongarue	0 (0)	0 (0)	0 (0)	0.83 (0.9)	-0.83 (-0.9)
Lower Oroua	0 (0)	0 (0)	0 (0)	1.22 (2.7)	-1.22 (-2.7)
Lower Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Rangitikei	0 (0)	0 (0)	0.53 (0.5)	-0.53 (-0.4)	0 (0)

FMU	A	B	C	D	E
Lower Tamaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Tiraumea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Tokomaru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Turakina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Main Drain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makakahi	0 (0)	0 (0)	0 (0)	9.61 (17.9)	-9.61 (-17.9)
Makatote	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makohine	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makuri	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Manakau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaatua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaone River	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaore	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaramarama	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangatera	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangatewainui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangatoro	0 (0)	0 (0)	0 (0)	2.45 (4.4)	-2.45 (-4.4)
Mangaturuturu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Matarawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Manawatū	0 (0)	0 (0)	0 (0)	2.22 (7.3)	-2.22 (-7.3)
Middle Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Mangatainoka	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Oroua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Whanganui	0 (0)	0 (0)	0 (0)	1.88 (2.7)	-1.88 (-2.7)
Mowhanau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Northern Coastal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Northern Manawatū Lakes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Orautoha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Oruakeretaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Owahanga	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Paetawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Piopiotea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Pipiriki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Porewa	0 (0)	0 (0)	0 (0)	3.27 (10.6)	-3.27 (-10.6)
Pukeokahu - Mangaweka	0.06 (0)	-0.06 (0)	0 (0)	0 (0)	0 (0)
Pungapunga	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Raparapawai	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Retaruke	0 (0)	0.19 (0.2)	0.06 (0)	-0.25 (-0.3)	0 (0)
Southern Whanganui Lakes	0 (0)	0 (0)	0 (0)	4.58 (74.9)	-4.58 (-74.9)
Tamaki - Hopelands	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tangarakau	0 (0)	0 (0)	7.23 (4)	2.6 (1.4)	-9.83 (-5.4)
Te Maire	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tidal Rangitikei	0 (0)	0 (0)	0 (0)	4.63 (46.4)	-4.63 (-46.4)
Tokiahuru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tutaenui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upokongaro	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Akitio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Gorge	0 (0)	0 (0)	0 (0)	4.77 (29.5)	-4.77 (-29.5)
Upper Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Manawatū	0 (0)	0 (0)	0 (0)	9.57 (10.1)	-9.57 (-10.1)
Upper Mangahao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangatainoka	0 (0)	0 (0)	1.55 (10.1)	-1.55 (-10.1)	0 (0)
Upper Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Ohau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Ohura	0 (0)	0 (0)	1.1 (0.5)	-1.1 (-0.6)	0 (0)
Upper Ongarue	0 (0)	0 (0)	0.34 (0.3)	-0.34 (-0.2)	0 (0)
Upper Oroua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Tiraumea	0 (0)	0 (0)	0 (0)	1.26 (1.1)	-1.26 (-1.1)
Upper Tokomaru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Turakina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Upper Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waihi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waikawa	0 (0)	0 (0)	0 (0)	1.47 (8.2)	-1.47 (-8.2)
Waimarino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitangi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitarere	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Weber - Tamaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Whangamomona	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total	**0.6 (0)**	**-0.41 (0)**	**17.02 (0.3)**	**46.79 (0.9)**	**-63.99 (-1.3)**

Table G-2: Change in the length (km) compared to the current scenario in each NOF band determined for Scenario 1 (low removal efficiency) with C_{95} not included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Cherry Grove	0.64 (1.9)	-0.64 (-1.9)	0 (0)	3.54 (10.3)	-3.54 (-10.3)
Coastal Manawatū	0 (0)	0 (0)	0 (0)	0.56 (1.1)	-0.56 (-1.1)
Coastal Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coastal Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coastal Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Eastern coastal zone	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Foxton Loop	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hokio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hopelands - Tiraumea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kahuterawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kai Iwi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kaitoke Lakes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kiwitea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Koputaroa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lake Horowhenua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Akitio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Kumeti	0 (0)	0 (0)	0 (0)	2.29 (73.6)	-2.29 (-73.6)
Lower Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Manawatū	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangahao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Lower Mangatainoka	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Ohau	0.54 (2.3)	-0.54 (-2.4)	1.21 (5.3)	-1.21 (-5.3)	0 (0)
Lower Ohura	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Ongarue	0 (0)	0 (0)	4.98 (5.4)	-4.15 (-4.5)	-0.83 (-0.9)
Lower Oroua	0 (0)	0 (0)	0 (0)	1.22 (2.7)	-1.22 (-2.7)
Lower Pohangina	0 (0)	0 (0)	1.81 (16.4)	-1.81 (-16.4)	0 (0)
Lower Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Tamaki	0 (0)	0 (0)	1.84 (15.6)	-1.84 (-15.6)	0 (0)
Lower Tiraumea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Tokomaru	0 (0)	1.59 (5.6)	-1.59 (-5.6)	0 (0)	0 (0)
Lower Turakina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whanganui	0 (0)	0 (0)	0.86 (1.3)	-0.86 (-1.3)	0 (0)
Main Drain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makakahi	0 (0)	0 (0)	1.13 (2.1)	8.48 (15.8)	-9.61 (-17.9)
Makatote	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makohine	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makuri	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Manakau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaatua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaone River	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaore	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaramarama	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangatera	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangatewainui	0 (0)	0 (0)	0.81 (3.8)	-0.81 (-3.8)	0 (0)
Mangatoro	0 (0)	0 (0)	0 (0)	2.45 (4.4)	-2.45 (-4.4)
Mangaturuturu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Matarawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Manawatū	0 (0)	0 (0)	0 (0)	2.22 (7.3)	-2.22 (-7.3)
Middle Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Mangatainoka	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Oroua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Middle Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Whanganui	0 (0)	0 (0)	0 (0)	1.88 (2.7)	-1.88 (-2.7)
Mowhanau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Northern Coastal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Northern Manawatū Lakes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Orautoha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Oruakeretaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Owahanga	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Paetawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Piopiotea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Pipiriki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Porewa	0 (0)	0 (0)	0 (0)	3.27 (10.6)	-3.27 (-10.6)
Pukeokahu - Mangaweka	3.98 (2.5)	-3.98 (-2.5)	0 (0)	0 (0)	0 (0)
Pungapunga	0 (0)	0.52 (1.9)	0.96 (3.5)	-1.49 (-5.5)	0 (0)
Raparapawai	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Retaruke	0 (0)	2.79 (3.6)	-2.79 (-3.6)	0 (0)	0 (0)
Southern Whanganui Lakes	0 (0)	0 (0)	0 (0)	4.58 (74.9)	-4.58 (-74.9)
Tamaki - Hopelands	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tangarakau	0 (0)	14.78 (8.2)	-8.72 (-4.8)	3.77 (2.1)	-9.83 (-5.4)
Te Maire	0 (0)	0 (0)	0.07 (0.2)	-0.07 (-0.2)	0 (0)
Tidal Rangitikei	0 (0)	0 (0)	0 (0)	4.63 (46.4)	-4.63 (-46.4)
Tokiahuru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tutaenui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upokongaro	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Akitio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Gorge	0 (0)	0 (0)	0 (0)	4.77 (29.5)	-4.77 (-29.5)
Upper Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Manawatū	0 (0)	0 (0)	0 (0)	9.57 (10)	-9.57 (-10.1)
Upper Mangahao	0 (0)	3.66 (5.7)	-3.66 (-5.6)	0 (0)	0 (0)
Upper Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangatainoka	0.99 (6.5)	-0.65 (-4.2)	-0.34 (-2.2)	0 (0)	0 (0)
Upper Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Ohau	0 (0)	2.11 (13.7)	-2.11 (-13.8)	0 (0)	0 (0)

FMU	A	B	C	D	E
Upper Ohura	0 (0)	1.85 (0.9)	-1.85 (-0.9)	0 (0)	0 (0)
Upper Ongarue	0 (0)	0 (0)	3.21 (2.4)	-3.21 (-2.4)	0 (0)
Upper Oroua	0 (0)	0.84 (0.8)	-0.75 (-0.7)	-0.08 (-0.1)	0 (0)
Upper Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Tiraumea	0 (0)	0 (0)	0 (0)	1.26 (1.1)	-1.26 (-1.1)
Upper Tokomaru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Turakina	0 (0)	0 (0)	0.45 (0.4)	-0.45 (-0.4)	0 (0)
Upper Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waihi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waikawa	0 (0)	0 (0)	0 (0)	1.47 (8.2)	-1.47 (-8.2)
Waimarino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitangi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitarere	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Weber - Tamaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Whangamomona	0 (0)	2.09 (3.8)	-2.09 (-3.8)	0 (0)	0 (0)
Total	**6.14 (0.1)**	**24.42 (0.5)**	**-6.54 (-0.1)**	**39.97 (0.8)**	**-63.99 (-1.3)**

Table G-3: Change in the length (km) compared to the current scenario in each NOF band determined for Scenario 1 (medium removal efficiency) without C_{95} included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Cherry Grove	0 (0)	0 (0)	0 (0)	5.73 (16.7)	-5.73 (-16.7)
Coastal Manawatū	0 (0)	0 (0)	0 (0)	32.08 (63.8)	-32.08 (-63.8)
Coastal Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coastal Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coastal Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Eastern coastal zone	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Foxton Loop	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hokio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hopelands - Tiraumea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kahuterawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kai Iwi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kaitoke Lakes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kiwitea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Koputaroa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Lake Horowhenua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Akitio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Kumeti	0 (0)	0 (0)	0 (0)	2.29 (73.6)	-2.29 (-73.6)
Lower Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Manawatū	0 (0)	0 (0)	0 (0)	2.15 (7.9)	-2.15 (-7.9)
Lower Mangahao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Manganui o te Ao	0 (0)	1.64 (2.2)	2.38 (3.2)	-4.02 (-5.3)	0 (0)
Lower Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangatainoka	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Ohau	0.54 (2.3)	-0.54 (-2.3)	2.19 (9.5)	-2.19 (-9.5)	0 (0)
Lower Ohura	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Ongarue	0 (0)	0 (0)	0 (0)	5.23 (5.7)	-5.23 (-5.7)
Lower Oroua	0 (0)	0 (0)	0 (0)	9.14 (20.3)	-9.14 (-20.3)
Lower Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Rangitikei	0 (0)	0 (0)	1.64 (1.3)	0.56 (0.4)	-2.2 (-1.8)
Lower Tamaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Tiraumea	0 (0)	0 (0)	0 (0)	1.2 (3.6)	-1.2 (-3.6)
Lower Tokomaru	0 (0)	0 (0)	0 (0)	2.46 (8.7)	-2.46 (-8.7)
Lower Turakina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Main Drain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makakahi	0 (0)	0 (0)	0 (0)	26.48 (49.2)	-26.48 (-49.2)
Makatote	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makohine	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makuri	0 (0)	0 (0)	0 (0)	5.4 (17.6)	-5.4 (-17.6)
Manakau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaatua	0 (0)	0 (0)	0 (0)	1.18 (9.3)	-1.18 (-9.3)
Mangaone River	0 (0)	0 (0)	0 (0)	5.66 (16)	-5.66 (-16)
Mangaore	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaramarama	0 (0)	0 (0)	0 (0)	0.43 (2.8)	-0.43 (-2.8)
Mangatera	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Mangatewainui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangatoro	0 (0)	0 (0)	0 (0)	9.61 (17)	-9.61 (-17)
Mangaturuturu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Matarawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Manawatū	0 (0)	0 (0)	0 (0)	6.34 (20.9)	-6.34 (-20.9)
Middle Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Mangatainoka	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Oroua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Whanganui	0 (0)	0 (0)	0 (0)	1.88 (2.7)	-1.88 (-2.7)
Mowhanau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Northern Coastal	0 (0)	0 (0)	0 (0)	0.02 (0)	-0.02 (0)
Northern Manawatū Lakes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Orautoha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Oruakeretaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Owahanga	0 (0)	0 (0)	0 (0)	1.85 (1.8)	-1.85 (-1.8)
Paetawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Piopiotea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Pipiriki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Porewa	0 (0)	0 (0)	0 (0)	3.69 (11.9)	-3.69 (-11.9)
Pukeokahu - Mangaweka	0.06 (0)	-0.06 (0)	0 (0)	0 (0)	0 (0)
Pungapunga	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Raparapawai	0 (0)	0 (0)	0 (0)	1.5 (19.7)	-1.5 (-19.7)
Retaruke	0.59 (0.8)	0.82 (1)	-1.16 (-1.5)	-0.25 (-0.3)	0 (0)
Southern Whanganui Lakes	0 (0)	0 (0)	0 (0)	4.74 (77.6)	-4.74 (-77.6)
Tamaki - Hopelands	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tangarakau	0 (0)	4.04 (2.2)	14.29 (7.9)	-7.31 (-4.1)	-11.02 (-6.1)
Te Maire	0 (0)	0 (0)	0 (0)	9.16 (26.2)	-9.16 (-26.2)
Tidal Rangitikei	0 (0)	0 (0)	0 (0)	4.63 (46.4)	-4.63 (-46.4)
Tokiahuru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tutaenui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upokongaro	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Akitio	0 (0)	0 (0)	0 (0)	0.85 (3.1)	-0.85 (-3.1)
Upper Gorge	0 (0)	0 (0)	0 (0)	6 (37.1)	-6 (-37.1)
Upper Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Upper Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Manawatū	0 (0)	0 (0)	0 (0)	16.62 (17.5)	-16.62 (-17.5)
Upper Mangahao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangatainoka	0.99 (6.5)	-0.83 (-5.4)	2.14 (13.9)	-2.29 (-14.9)	0 (0)
Upper Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Ohau	1 (6.5)	-1 (-6.5)	0.31 (2)	-0.31 (-2)	0 (0)
Upper Ohura	0 (0)	0 (0)	2.83 (1.4)	-2.83 (-1.4)	0 (0)
Upper Ongarue	0 (0)	0 (0)	0.34 (0.3)	-0.34 (-0.2)	0 (0)
Upper Oroua	0 (0)	0 (0)	1.09 (1.1)	-0.93 (-1)	-0.16 (-0.2)
Upper Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Tiraumea	0 (0)	0 (0)	0 (0)	18.71 (15.7)	-18.71 (-15.7)
Upper Tokomaru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Turakina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waihi	0 (0)	0 (0)	0 (0)	1.43 (5)	-1.43 (-5)
Waikawa	0 (0)	1.83 (10.2)	-1.83 (-10.2)	3.16 (17.6)	-3.16 (-17.7)
Waimarino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitangi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitarere	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Weber - Tamaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Whangamomona	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total	**3.17 (0.1)**	**5.9 (0.1)**	**24.21 (0.5)**	**169.71 (3.4)**	**-202.98 (-4.1)**

Table G-4: Change in the length (km) compared to the current scenario in each NOF band determined for Scenario 1 (medium removal efficiency) with C_{95} not included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Cherry Grove	1.33 (3.9)	-1.33 (-3.9)	0 (0)	5.73 (16.6)	-5.73 (-16.7)
Coastal Manawatū	0 (0)	0 (0)	0 (0)	32.08 (63.8)	-32.08 (-63.8)
Coastal Rangitikei	0.6 (1)	-0.6 (-1)	0 (0)	0 (0)	0 (0)
Coastal Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coastal Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Eastern coastal zone	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Foxton Loop	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hokio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hopelands - Tiraumea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kahuterawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kai Iwi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kaitoke Lakes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kiwitea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Koputaroa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lake Horowhenua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Akitio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Kumeti	0 (0)	0 (0)	0 (0)	2.29 (73.6)	-2.29 (-73.6)
Lower Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Manawatū	0 (0)	0 (0)	0 (0)	2.15 (7.9)	-2.15 (-7.9)
Lower Mangahao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangatainoka	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Ohau	0.54 (2.3)	-0.54 (-2.4)	1.21 (5.3)	-1.21 (-5.3)	0 (0)
Lower Ohura	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Ongarue	0 (0)	0 (0)	8.52 (9.2)	-3.29 (-3.5)	-5.23 (-5.7)
Lower Oroua	0 (0)	0 (0)	0 (0)	9.14 (20.3)	-9.14 (-20.3)
Lower Pohangina	0 (0)	0 (0)	3.35 (30.3)	-3.35 (-30.4)	0 (0)
Lower Rangitikei	0 (0)	0 (0)	0 (0)	2.2 (1.7)	-2.2 (-1.8)
Lower Tamaki	0 (0)	0 (0)	5.79 (48.8)	-5.79 (-48.8)	0 (0)
Lower Tiraumea	0 (0)	0 (0)	0 (0)	1.2 (3.6)	-1.2 (-3.6)
Lower Tokomaru	0 (0)	1.59 (5.6)	-1.59 (-5.6)	2.46 (8.7)	-2.46 (-8.7)
Lower Turakina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whanganui	0 (0)	0 (0)	0.86 (1.3)	-0.86 (-1.3)	0 (0)
Main Drain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makakahi	0 (0)	0.62 (1.2)	1.14 (2.1)	24.72 (45.9)	-26.48 (-49.2)
Makatote	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Makohine	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makuri	0 (0)	0 (0)	0 (0)	5.4 (17.6)	-5.4 (-17.6)
Manakau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaatua	0 (0)	0 (0)	0 (0)	1.18 (9.3)	-1.18 (-9.3)
Mangaone River	0 (0)	0 (0)	0 (0)	5.66 (16)	-5.66 (-16)
Mangaore	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaramarama	0 (0)	0 (0)	0 (0)	0.43 (2.8)	-0.43 (-2.8)
Mangatera	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangatewainui	0 (0)	0 (0)	1.3 (6.1)	-1.3 (-6.1)	0 (0)
Mangatoro	0 (0)	0 (0)	0 (0)	9.61 (17)	-9.61 (-17)
Mangaturuturu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Matarawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Manawatū	0 (0)	0 (0)	0 (0)	6.34 (20.9)	-6.34 (-20.9)
Middle Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Mangatainoka	0 (0)	0 (0)	10.46 (26.7)	-10.46 (-26.7)	0 (0)
Middle Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Oroua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Pohangina	0 (0)	0 (0)	1.7 (3.5)	-1.7 (-3.5)	0 (0)
Middle Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Whanganui	0 (0)	0 (0)	6.26 (9)	-4.38 (-6.3)	-1.88 (-2.7)
Mowhanau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Northern Coastal	0 (0)	0 (0)	0 (0)	0.02 (0)	-0.02 (0)
Northern Manawatū Lakes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Orautoha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Oruakeretaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Owahanga	0 (0)	0 (0)	0 (0)	1.85 (1.8)	-1.85 (-1.8)
Paetawa	0 (0)	0 (0)	20.73 (17.2)	-20.73 (-17.2)	0 (0)
Piopiotea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Pipiriki	0 (0)	0 (0)	1.56 (0.9)	-1.56 (-0.9)	0 (0)
Porewa	0 (0)	0 (0)	0 (0)	3.69 (11.9)	-3.69 (-11.9)
Pukeokahu - Mangaweka	7.67 (4.8)	-7.67 (-4.8)	0 (0)	0 (0.1)	0 (0)
Pungapunga	0 (0)	1.76 (6.4)	1.35 (4.9)	-3.1 (-11.4)	0 (0)
Raparapawai	0 (0)	0 (0)	0 (0)	1.5 (19.7)	-1.5 (-19.7)
Retaruke	0.59 (0.8)	3.22 (4.2)	-3.81 (-4.9)	0 (0)	0 (0)
Southern Whanganui Lakes	0 (0)	0 (0)	0 (0)	4.74 (77.6)	-4.74 (-77.6)
Tamaki - Hopelands	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Tangarakau	0 (0)	19.48 (10.8)	2.88 (1.6)	-11.34 (-6.3)	-11.02 (-6.1)
Te Maire	0 (0)	0 (0)	7.3 (20.9)	1.86 (5.3)	-9.16 (-26.2)
Tidal Rangitikei	0 (0)	0 (0)	0 (0)	4.63 (46.4)	-4.63 (-46.4)
Tokiahuru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tutaenui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upokongaro	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Akitio	0 (0)	0 (0)	0 (0)	0.85 (3.1)	-0.85 (-3.1)
Upper Gorge	0 (0)	0 (0)	0 (0)	6 (37.1)	-6 (-37.1)
Upper Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Manawatū	0 (0)	0 (0)	3.69 (3.9)	12.93 (13.5)	-16.62 (-17.5)
Upper Mangahao	1.58 (2.5)	2.08 (3.3)	-2.42 (-3.7)	-1.23 (-1.9)	0 (0)
Upper Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangatainoka	2.46 (16)	-2.12 (-13.8)	-0.34 (-2.2)	0 (0)	0 (0)
Upper Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Ohau	1 (6.5)	2.4 (15.6)	-3.4 (-22.2)	0 (0)	0 (0)
Upper Ohura	0 (0)	4.9 (2.4)	-3.96 (-2)	-0.94 (-0.5)	0 (0)
Upper Ongarue	0 (0)	0 (0)	6.9 (5.2)	-6.9 (-5.2)	0 (0)
Upper Oroua	0 (0)	1.62 (1.6)	-1.53 (-1.5)	0.07 (0)	-0.16 (-0.2)
Upper Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Tiraumea	0 (0)	0 (0)	0 (0)	18.71 (15.7)	-18.71 (-15.7)
Upper Tokomaru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Turakina	0 (0)	0 (0)	0.45 (0.4)	-0.45 (-0.4)	0 (0)
Upper Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whanganui	0 (0)	0 (0)	0.84 (1.7)	-0.84 (-1.7)	0 (0)
Waihi	0 (0)	0 (0)	0 (0)	1.43 (5)	-1.43 (-5)
Waikawa	0 (0)	0 (0)	0 (0)	3.16 (17.6)	-3.16 (-17.7)
Waimarino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitangi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitarere	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Weber - Tamaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Whangamomona	0 (0)	8.86 (16.2)	-7.97 (-14.6)	-0.89 (-1.6)	0 (0)
Total	**15.75 (0.3)**	**34.27 (0.7)**	**61.26 (1.2)**	**91.7 (1.9)**	**-202.98 (-4.1)**

Table G-5: Change in the length (km) compared to the current scenario in each NOF band determined for Scenario 1 (high removal efficiency) with C_{95} included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Cherry Grove	0 (0)	1.82 (5.3)	-1.82 (-5.3)	5.73 (16.7)	-5.73 (-16.7)
Coastal Manawatū	0 (0)	0 (0)	0 (0)	48.37 (96.1)	-48.37 (-96.1)
Coastal Rangitikei	0 (0)	0 (0)	2.32 (4)	-2.32 (-4)	0 (0)
Coastal Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coastal Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Eastern coastal zone	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Foxton Loop	0 (0)	0 (0)	0 (0)	1.58 (19.6)	-1.58 (-19.6)
Hokio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hopelands - Tiraumea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kahuterawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kai Iwi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kaitoke Lakes	0 (0)	0 (0)	0 (0)	0.28 (6.5)	-0.28 (-6.5)
Kiwitea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Koputaroa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lake Horowhenua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Akitio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Kumeti	0 (0)	0 (0)	0 (0)	2.29 (73.6)	-2.29 (-73.6)
Lower Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Manawatū	0 (0)	0 (0)	0 (0)	10.49 (38.5)	-10.49 (-38.5)
Lower Mangahao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Manganui o te Ao	0 (0)	1.87 (2.5)	2.15 (2.9)	-4.02 (-5.3)	0 (0)
Lower Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangatainoka	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Ohau	1.13 (4.9)	-1.13 (-4.9)	2.19 (9.5)	-1.9 (-8.2)	-0.29 (-1.2)
Lower Ohura	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Ongarue	0 (0)	0 (0)	0 (0)	5.99 (6.5)	-5.99 (-6.5)
Lower Oroua	0 (0)	0 (0)	0 (0)	10.6 (23.6)	-10.6 (-23.6)
Lower Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Rangitikei	0 (0)	0 (0)	8.69 (6.9)	-6.2 (-4.9)	-2.49 (-2)
Lower Tamaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Tiraumea	0 (0)	0 (0)	0 (0)	1.42 (4.3)	-1.42 (-4.3)
Lower Tokomaru	0 (0)	0 (0)	0 (0)	9.89 (34.9)	-9.89 (-34.9)

FMU	A	B	C	D	E
Lower Turakina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Main Drain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makakahi	0 (0)	0 (0)	0 (0)	27.08 (50.3)	-27.08 (-50.3)
Makatote	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makohine	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makuri	0 (0)	0 (0)	0 (0)	6.18 (20.1)	-6.18 (-20.1)
Manakau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaatua	0 (0)	0 (0)	0 (0)	1.18 (9.3)	-1.18 (-9.3)
Mangaone River	0 (0)	0 (0)	0 (0)	33.52 (94.8)	-33.52 (-94.8)
Mangaore	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaramarama	0 (0)	0 (0)	0 (0)	0.43 (2.8)	-0.43 (-2.8)
Mangatera	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangatewainui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangatoro	0 (0)	0 (0)	0 (0)	11.7 (20.7)	-11.7 (-20.7)
Mangaturuturu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Matarawa	0 (0)	0 (0)	0 (0)	2.72 (13.7)	-2.72 (-13.7)
Middle Manawatū	0 (0)	0 (0)	0 (0)	10.27 (33.8)	-10.27 (-33.8)
Middle Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Mangatainoka	0 (0)	0 (0)	0 (0)	0.9 (2.3)	-0.9 (-2.3)
Middle Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Oroua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Whanganui	0 (0)	0 (0)	0 (0)	1.88 (2.7)	-1.88 (-2.7)
Mowhanau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Northern Coastal	0 (0)	0 (0)	0 (0)	1.29 (5.2)	-1.29 (-5.2)
Northern Manawatū Lakes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Orautoha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Oruakeretaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Owahanga	0 (0)	0 (0)	0 (0)	3.23 (3.1)	-3.23 (-3.1)
Paetawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Piopiotea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Pipiriki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Porewa	0 (0)	0 (0)	0 (0)	9.56 (30.8)	-9.56 (-30.8)
Pukeokahu - Mangaweka	0.27 (0.2)	-0.27 (-0.2)	0 (0)	0 (0)	0 (0)
Pungapunga	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Raparapawai	0 (0)	0 (0)	0 (0)	1.5 (19.7)	-1.5 (-19.7)
Retaruke	2.93 (3.8)	-1.52 (-2)	-1.16 (-1.5)	-0.25 (-0.3)	0 (0)
Southern Whanganui Lakes	0 (0)	0 (0)	0 (0)	4.74 (77.6)	-4.74 (-77.6)
Tamaki - Hopelands	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tangarakau	0 (0)	13.62 (7.5)	10.39 (5.8)	-13 (-7.2)	-11.02 (-6.1)
Te Maire	0 (0)	0 (0)	0 (0)	9.2 (26.3)	-9.2 (-26.3)
Tidal Rangitikei	0 (0)	0 (0)	0 (0)	4.63 (46.4)	-4.63 (-46.4)
Tokiahuru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tutaenui	0 (0)	0 (0)	0 (0)	6.42 (22.4)	-6.42 (-22.4)
Upokongaro	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Akitio	0 (0)	0 (0)	0 (0)	5.14 (19)	-5.14 (-19)
Upper Gorge	0 (0)	0 (0)	0 (0)	6.48 (40)	-6.48 (-40)
Upper Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Manawatū	0 (0)	0 (0)	0 (0)	20.45 (21.5)	-20.45 (-21.5)
Upper Mangahao	1.58 (2.5)	-0.45 (-0.7)	-1.12 (-1.7)	0 (0)	0 (0)
Upper Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangatainoka	1.74 (11.3)	0.71 (4.6)	-0.16 (-1)	-2.29 (-14.9)	0 (0)
Upper Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Ohau	1 (6.5)	-1 (-6.5)	0.31 (2)	-0.31 (-2)	0 (0)
Upper Ohura	0 (0)	0 (0)	3.44 (1.7)	-3.44 (-1.7)	0 (0)
Upper Ongarue	1.54 (1.2)	-1.54 (-1.1)	0.34 (0.3)	-0.34 (-0.2)	0 (0)
Upper Oroua	0 (0)	0 (0)	1.09 (1.1)	1.49 (1.5)	-2.58 (-2.6)
Upper Pohangina	0 (0)	0.75 (2.1)	-0.75 (-2.1)	0 (0)	0 (0)
Upper Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Tiraumea	0 (0)	0 (0)	0 (0)	44.79 (37.6)	-44.79 (-37.6)
Upper Tokomaru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Turakina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waihi	0 (0)	0 (0)	0 (0)	5.47 (19.3)	-5.47 (-19.3)

FMU	A	B	C	D	E
Waikawa	0 (0)	1.83 (10.2)	-1.83 (-10.2)	3.82 (21.3)	-3.82 (-21.4)
Waimarino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitangi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitarere	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Weber - Tamaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Whangamomona	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total	**10.17 (0.2)**	**14.71 (0.3)**	**24.07 (0.5)**	**286.61 (5.8)**	**-335.56 (-6.8)**

Table G-6: Change in the length (km) compared to the current scenario in each NOF band determined for Scenario 1 (high removal efficiency) with C_{95} not included in the band calculation. The percentage of the total stream length in each band is in parentheses.

FMU	A	B	C	D	E
Cherry Grove	1.33 (3.9)	-1.33 (-3.9)	0 (0)	5.73 (16.6)	-5.73 (-16.7)
Coastal Manawatū	0 (0)	0 (0)	0 (0)	48.37 (96.1)	-48.37 (-96.1)
Coastal Rangitikei	0.6 (1)	-0.6 (-1)	0 (0)	0 (0)	0 (0)
Coastal Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coastal Whanganui	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Eastern coastal zone	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Foxton Loop	0 (0)	0 (0)	0 (0)	1.58 (19.6)	-1.58 (-19.6)
Hokio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hopelands - Tiraumea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kahuterawa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kai Iwi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kaitoke Lakes	0 (0)	0 (0)	0 (0)	0.28 (6.5)	-0.28 (-6.5)
Kiwitea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Koputaroa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lake Horowhenua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Akitio	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Kumeti	0 (0)	0 (0)	0 (0)	2.29 (73.6)	-2.29 (-73.6)
Lower Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Manawatū	0 (0)	0 (0)	0 (0)	10.49 (38.5)	-10.49 (-38.5)
Lower Mangahao	0 (0)	0 (0)	4.09 (32)	-4.09 (-32)	0 (0)
Lower Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangatainoka	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Lower Ohau	5.27 (22.9)	-5.27 (-23)	1.21 (5.3)	-0.92 (-4)	-0.29 (-1.2)
Lower Ohura	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Ongarue	0 (0)	0 (0)	13.57 (14.7)	-7.59 (-8.2)	-5.99 (-6.5)
Lower Oroua	0 (0)	0 (0)	0 (0)	10.6 (23.6)	-10.6 (-23.6)
Lower Pohangina	0 (0)	0 (0)	3.35 (30.3)	-3.35 (-30.4)	0 (0)
Lower Rangitikei	0 (0)	0 (0)	0 (0)	2.49 (1.9)	-2.49 (-2)
Lower Tamaki	0 (0)	0 (0)	5.79 (48.8)	-5.79 (-48.8)	0 (0)
Lower Tiraumea	0 (0)	0 (0)	0 (0)	1.42 (4.3)	-1.42 (-4.3)
Lower Tokomaru	0 (0)	1.59 (5.6)	-1.59 (-5.6)	9.89 (34.9)	-9.89 (-34.9)
Lower Turakina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lower Whangaehu	0 (0)	0.78 (0.6)	-0.78 (-0.6)	0 (0)	0 (0)
Lower Whanganui	0 (0)	0 (0)	0.86 (1.3)	-0.86 (-1.3)	0 (0)
Main Drain	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makakahi	0 (0)	2.16 (4)	5.42 (10)	19.51 (36.2)	-27.08 (-50.3)
Makatote	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makohine	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Makuri	0 (0)	0 (0)	0 (0)	6.18 (20.1)	-6.18 (-20.1)
Manakau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaatua	0 (0)	0 (0)	0 (0)	1.18 (9.3)	-1.18 (-9.3)
Mangaone River	0 (0)	0 (0)	0 (0)	33.52 (94.8)	-33.52 (-94.8)
Mangaore	0 (0)	0.22 (2.1)	1.05 (10)	-1.27 (-12.1)	0 (0)
Mangapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangaramarama	0 (0)	0 (0)	0 (0)	0.43 (2.8)	-0.43 (-2.8)
Mangatera	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mangatewainui	0 (0)	2.33 (11)	-1.02 (-4.9)	-1.3 (-6.1)	0 (0)
Mangatoro	0 (0)	0 (0)	0 (0)	11.7 (20.7)	-11.7 (-20.7)
Mangaturuturu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Matarawa	0 (0)	0 (0)	0 (0)	2.72 (13.7)	-2.72 (-13.7)
Middle Manawatū	0 (0)	0 (0)	0 (0)	10.27 (33.8)	-10.27 (-33.8)
Middle Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Mangatainoka	0 (0)	0 (0)	25.46 (65)	-24.57 (-62.7)	-0.9 (-2.3)
Middle Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Oroua	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Pohangina	0 (0)	0 (0)	1.7 (3.5)	-1.7 (-3.5)	0 (0)
Middle Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Middle Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

FMU	A	B	C	D	E
Middle Whanganui	0 (0)	0 (0)	7.17 (10.4)	-5.29 (-7.6)	-1.88 (-2.7)
Mowhanau	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Northern Coastal	0 (0)	0 (0)	0 (0)	1.29 (5.2)	-1.29 (-5.2)
Northern Manawatū Lakes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Orautoha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Oruakeretaki	0 (0)	0 (0)	2.77 (24.6)	-2.77 (-24.6)	0 (0)
Owahanga	0 (0)	0 (0)	0 (0)	3.23 (3.2)	-3.23 (-3.1)
Paetawa	0 (0)	0 (0)	43.62 (36.1)	-43.62 (-36.2)	0 (0)
Piopiotea	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Pipiriki	0 (0)	0 (0)	58.49 (34.1)	-58.49 (-34.1)	0 (0)
Porewa	0 (0)	0 (0)	0 (0)	9.56 (30.8)	-9.56 (-30.8)
Pukeokahu - Mangaweka	7.87 (4.9)	-7.87 (-4.9)	0 (0)	0 (0.1)	0 (0)
Pungapunga	0 (0)	1.76 (6.4)	2.56 (9.4)	-4.31 (-15.8)	0 (0)
Raparapawai	0 (0)	0 (0)	0 (0)	1.5 (19.7)	-1.5 (-19.7)
Retaruke	4.87 (6.4)	0.69 (0.9)	-5.57 (-7.2)	0 (0)	0 (0)
Southern Whanganui Lakes	0 (0)	0 (0)	1.57 (25.7)	3.17 (51.9)	-4.74 (-77.6)
Tamaki - Hopelands	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tangarakau	0 (0)	25.85 (14.3)	-0.7 (-0.4)	-14.13 (-7.8)	-11.02 (-6.1)
Te Maire	0 (0)	0 (0)	12.56 (35.9)	-3.36 (-9.6)	-9.2 (-26.3)
Tidal Rangitikei	0 (0)	0 (0)	0.11 (1.2)	4.51 (45.3)	-4.63 (-46.4)
Tokiahuru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tutaenui	0 (0)	0 (0)	0 (0)	6.42 (22.4)	-6.42 (-22.4)
Upokongaro	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Akitio	0 (0)	0 (0)	0 (0)	5.14 (19)	-5.14 (-19)
Upper Gorge	0 (0)	0 (0)	0 (0)	6.48 (40)	-6.48 (-40)
Upper Hautapu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Makotuku	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Manawatū	0 (0)	0 (0)	4.41 (4.7)	16.04 (16.8)	-20.45 (-21.5)
Upper Mangahao	2 (3.1)	1.66 (2.6)	-1.38 (-2.1)	-2.28 (-3.5)	0 (0)
Upper Manganui o te Ao	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangaone Stream	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Mangatainoka	3.23 (21)	-2.89 (-18.8)	-0.34 (-2.2)	0 (0)	0 (0)
Upper Mangawhero	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Moawhango	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Ohau	1 (6.5)	3.2 (20.8)	-4.2 (-27.4)	0 (0)	0 (0)
Upper Ohura	0 (0)	6.4 (3.2)	-2.04 (-1)	-4.35 (-2.2)	0 (0)
Upper Ongarue	1.54 (1.2)	-1.54 (-1.2)	6.9 (5.2)	-6.9 (-5.2)	0 (0)
Upper Oroua	0 (0)	1.62 (1.6)	-0.21 (-0.2)	1.17 (1.1)	-2.58 (-2.6)

FMU	A	B	C	D	E
Upper Pohangina	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Rangitikei	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Tiraumea	0 (0)	0 (0)	0 (0)	44.79 (37.6)	-44.79 (-37.6)
Upper Tokomaru	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Turakina	0 (0)	0 (0)	0.45 (0.4)	-0.45 (-0.4)	0 (0)
Upper Whakapapa	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whangaehu	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Upper Whanganui	0 (0)	0 (0)	2.71 (5.4)	-2.71 (-5.4)	0 (0)
Waihi	0 (0)	0 (0)	0 (0)	5.47 (19.3)	-5.47 (-19.3)
Waikawa	0 (0)	0 (0)	0 (0)	3.82 (21.3)	-3.82 (-21.4)
Waimarino	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitangi	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Waitarere	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Weber - Tamaki	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Whangamomona	0 (0)	13.21 (24.2)	-8.75 (-16.1)	-4.46 (-8.2)	0 (0)
Total	**27.71 (0.6)**	**41.97 (0.9)**	**179.24 (3.6)**	**86.65 (1.8)**	**-335.56 (-6.8)**

horizons
REGIONAL COUNCIL

horizons.govt.nz

24 hour freephone 0508 800 800
fax 06 952 2929 | **email** help@horizons.govt.nz
Private Bag 11025, Manawatu Mail Centre, Palmerston North 4442