Technical Memorandum

To:	Rachel Pawson	**From:**	Claire Conwell
Company:	Greater Wellington Regional Council	**SLR Consulting NZ**	
cc:		**Date:**	13 October 2023
		Project No.	820.V14291.00001

RE: Baseline (2017) and current (2023) *E. coli* attribute states for primary contact sites across the Wellington region

Background

This memorandum sets out the baseline state (calculated as of September 2017) and current state (calculated up to the 30 March 2023), for 24 primary contact sites identified for Plan Change 1 (**PC1**), across the Wellington Region (Kapiti, Wellington and Hutt Valley, and the Wairarapa region).

Under the National Policy Statement for Freshwater Management (2020) (**NPS-FM,** updated February 2023), a primary contact site is defined as '*a site identified by a regional council that it considers is regularly used, or would be regularly used but for existing freshwater, for recreational activities such as swimming, paddling, boating, or watersports, and particularly for activities where there is a high likelihood of water or water vapour being injected or inhaled'.*

To date, baseline and current states have not been calculated for the NPS-FM 2020 *E. coli* attribute for primary contact sites (as per Table 22 of the NPS-FM 2020). This work is needed to set target attribute states for this attribute in future plan changes.

Assessment against the NPS-FM 2020 Table 22 *E. coli* attribute should be based on weekly samples taken during a pre-defined bathing season (see Clause 3.27 Primary Contact Sites, NPS-FM 2020). The bathing period is generally for 17-20 weeks, from November through to the end of March, and may vary between regional/unitary council authorities.

In 2018, Greater Wellington Regional Council (**GWRC**) shifted the sampling regime to:

- Implement a daily risk criteria model (based on a combined weighting of historical Microbiological Assessment Category (**MAC**) grades with daily forecast rainfall, to provide a daily risk assessment of whether sites are safe to swim; and
- Conduct fortnightly sampling across primary contact sites, the results of which are used to update the MAC grade of sites at the end of each season.

An unintended consequence of this shift was that against the current requirements set out in the NPS-FM, the full weekly surveillance data period across the bathing season became reduced, and the inability to apply weekly data to assign a current state. Therefore, there is a need to explore a 'best available' alternative approach to assigning current state on the basis of the available data.

Scope

The scope of the assessment as request from GWRC includes:

- An assessment of the baseline state (at September 2017) calculated from weekly freshwater sampling collected over the standard council period for grading contact recreation sites (three years);
- Assessment of current state for all sites in two ways:
  - o Fortnightly sampling data collected over the standard council period for grading contact recreation sites (three years); and
  - o Fortnightly sampling data collected over whatever period is necessary to achieve the minimum number of data points set out in the latest guidance, detailed below (five years).

The results of GWRC's daily risk model were initially considered in the methodology to define the current state, but this was not considered appropriate for the purpose of attribute state assessment. This is discussed below.

Methodology

E. coli data were accessed via GWRC's Hilltop URL link, and also double checked against available data as listed on GWRC's Environmental Data Dashboard[1]. Several data sets that could not be accessed via these links were requested directly from GWRC. All data were cross checked against the summary of Recreational Water Quality Bathing Programme Network Summary (F. Drummond, supplied via email, 24/3/23).

E. coli data for each site were sorted by monitoring season, to ensure minimum data requirements for calculating baseline state could be achieved.

Data were sorted to identify any routine surveillance samples that exceeded a value of >260 cfu/100mL. This triggered additional sampling to be taken over subsequent days, until monitoring returns to below 260 cfu/100mL. This was to ensure that only routine surveillance data were analysed for the calculation of baseline states.

Data requirements

It is noted that Table 22 (*E. coli* for primary contact sites) of the NPS-FM does not specify minimum data requirements for the calculation of numeric attribute states. In the absence of this, guidance was taken from the following:

- GWRC's Natural Resources Plan, Table 3.1 Primary contact recreation and Māori customary use objectives in freshwater bodies:
  - o Minimum of 30 data points, collected over a minimum of 3 years;
- Recommended data requirement for Table 9 (*E.coli*) of the NPS-FM (August, 2020)[2] of:
  - o Monthly monitoring of sites visited on a regular basis regardless of weather and flow, grading a site is based on 5 years. This infers 60 data points is recommended for grading attribute state assessment.
- LAWA 'Is it Safe to Swim' module:
  - o Minimum of 50 data points collected over a maximum time period of 5 years[3], sites must have had monitoring undertaken in the 2 most recent bathing seasons to be included.

[1] https://graphs.gw.govt.nz/#dataViewer
[2] National Policy Statement for Freshwater Management 2020 (environment.govt.nz)
[3] https://www.lawa.org.nz/learn/factsheets/coastal-and-freshwater-recreation-monitoring/

For the baseline state assessment, to achieve the minimum data requirements (as per the NPS-FM guidance) of 60 data points, this generally meant data from 1 January 2014 up to the 1 September 2017 was required.

However, for achieving consistency across bathing seasons, only data applicable for the full bathing season were applied. This meant that data from September 2014 to the end of March 2017 was applied. This accounted for three full bathing seasons across 2014/15, 2015/16, and the 2016/17 bathing periods. Whilst this meant a reduction in sample points (to just below 60), it still met the minimum data criteria as defined in the NRP and LAWA.

For the current state, the number of samples for analyses varies per site. Analyses were conducted using fortnightly data collected over the 3 time periods.

- 2017 baseline state:
  - 3-year baseline state, from 1 September 2014 to 31 March 2017 (2014/15, 2015/16, 2016/17 bathing seasons);
- 2023 current state:
  - 3-year current state, 1 September 2020 to 31 March 2023 (20/21, 21/22, 22/23 bathing seasons);
  - 4-year current state, 1 September 2019 to 31 March 2023 (2019/20, 20/21, 21/22, 22/23 bathing seasons);
  - 5-year current state (2018/19, 2019/20, 20/21, 21/22, 22/23).

Data were assessed to calculate the Hazen 95th percentile for the selected data range. Outputs were tabulated and benchmarked against Table 22 of the NPS-FM to identify attribute states for the selected data range.

Results

Table 1 lists the *E. coli* baseline attribute state, calculated up to the end of the summer bathing season in 2017 for 21 primary contact sites in the Wellington Region. The location of the primary contact sites are listed in Appendix 1 and mapped in Figure 1.

Due to the absence of available data (as monitoring was established after 2017), baseline states for 2017 could not be assessed for the following three sites listed in **Table 1**:

- Pākuratahi River at Kaitoke Campground (monitoring established in 2021);
- Hutt River upstream of Silverstream Bridge (monitoring established in 2017); and
- Hutt River at Taita Rock (monitoring established in 2022).

Table 2 lists the *E. coli* current (2023) attribute state, calculated up to the end of the summer bathing season in 2023 for 24 primary contact sites in the Wellington Region. The minimum data requirement for Pākuratahi River at Kaitoke Campground and Hutt River at Taita Rock was not achieved due to these two sites being newly established. The 95th percentile statistic and grade are indicative only.

Table 3 shows the summary of attribute state assessments across the 2017 and 2023 periods.

Table 1: Wellington Region primary contact swimming site *E. coli* baseline attribute state at September 2017.

Site Name	Data available / range	No. Sample points	Hazen 95th percentile	Attribute State (Table 22)
Kāpiti Coast (3 sites)				
Ōtaki River at State Highway One	Weekly data	57	315	Fair
Waikanae River at State Highway One	Weekly data	57	366	Fair
Waikanae River at Jim Cooke Park	Weekly data	57	379	Fair
Wellington & Hutt Valley (11 sites)				
Pākuratahi River at Hutt Forks	Weekly data	57	199	Good
Pākuratahi River at Kaitoke Campground	Fortnightly from Nov 2021	NA (2017 baseline state could not be calculated, data not available)		
Akatarawa River at Hutt Confluence	Monthly data 05/09/2012 – 14/08/2017*	60	420	Fair
Hutt River at Birchville	Weekly data	57	122	Excellent
Hutt River at Maoribank Corner	Weekly data	57	123	Excellent
Hutt River at Poets Park	Weekly data	57	117	Excellent
Hutt River at Silverstream Bridge	Weekly data to 2017	57	164	Good
Hutt River upstream Silverstream Bridge	Weekly / fortnightly data from 2017	Refer to baseline state for Hutt River at Silverstream Bridge		
Hutt River at Taita Rock	Weekly from 2022	NA (2017 baseline state could not be calculated, data not available)		
Hutt River at Melling Bridge	Weekly data	57	704	Poor
Wainuiomata River at Richard Prouse Park	Weekly data	57	966	Poor
Ruamāhanga (10 sites)				
Ruamāhanga River at Double Bridges	Weekly data	57	158	Good
Ruamāhanga River at Te Ore Ore	Weekly data	57	960	Poor
Waipoua River at Colombo Road	Weekly data	57	240	Good
Waingawa River at South Road	Weekly data	57	89	Excellent
Ruamāhanga River at The Cliffs	Weekly data	57	110	Excellent
Ruamāhanga River at Kokotau	Weekly data	57	153	Good
Ruamāhanga River at Waihenga	Weekly data	57	157	Good
Ruamāhanga River at Morrisons Bush	Weekly data	57	157	Good

Site Name	Data available / range	No. Sample points	Hazen 95th percentile	Attribute State (Table 22)
Waiohine River at State Highway 2	Weekly data	57	282	Fair
Tauherenikau River at Websters[1]	Monthly data	58	140	Good

*Monthly under River Water Quality and Ecology Programme, 5 years of available data required to meet sample numbers.

Table 2: Wellington Region primary contact swimming site *E. coli* current attribute state at 31 March 2023.

Site Name	Data available / range	3Y Hazen 95th percentile (No. Sample points)	3Y Attribute State (Table 22)	4Y Hazen 95th percentile (No. Sample points)	4Y Attribute State (Table 22)	5Y Hazen 95th percentile (No. Sample points)	5Y Attribute State (Table 22)
Kāpiti Coast							
Ōtaki River at State Highway One	Weekly/fortnightly	342 (48)	Fair	308 (60)	Fair	283 (69)	Fair
Waikanae River at State Highway One	Weekly/fortnightly	982 (48)	Poor	785 (60)	Poor	700 (69)	Poor
Waikanae River at Jim Cooke Park	Weekly/fortnightly	1352 (48)	Poor	1030 (60)	Poor	1084 (69)	Poor
Wellington & Hutt Valley							
Pākuratahi River at Hutt Forks	Weekly/fortnightly	992 (38)	Poor	902 (48)	Poor	863 (57)	Poor
Pākuratahi River at Kaitoke Campground#	Weekly/fortnightly since Nov 2021	3450 (23)	Poor	NA	NA	NA	NA
Akatarawa River at Hutt Confluence**	Monthly	564 (38)	Poor	1200 (48)	Poor	1200 (59)	Poor
Hutt River at Birchville	Weekly/fortnightly	1472 (38)	Poor	1922 (49)	Poor	1912 (58)	Poor
Hutt River at Maoribank Corner	Weekly/fortnightly	1088 (38)	Poor	1342 (49)	Poor	1284 (58)	Poor
Hutt River at Poets Park	Weekly/fortnightly	1072 (38)	Poor	1105 (49)	Poor	1012 (58)	Poor
Hutt River at Silverstream Bridge	Weekly data to 2017	NA					
Hutt River upstream Silverstream Bridge	Weekly / fortnightly data from 2017-2021	NA					
Hutt River at Silverstream Bridge (Combined data)	Bridge site combined with upstream site	888 (38)	Poor	929 (49)	Poor	780 (58)	Poor
Hutt River at Taita Rock#	Weekly from 2022	178 (12)	Good	NA	NA	NA	NA
Hutt River at Melling Bridge	Weekly/fortnightly	860 (30)	Poor	1127 (41)	Poor	1145 (55)	Poor

Site Name	Data available / range	3Y Hazen 95th percentile (No. Sample points)	3Y Attribute State (Table 22)	4Y Hazen 95th percentile (No. Sample points)	4Y Attribute State (Table 22)	5Y Hazen 95th percentile (No. Sample points)	5Y Attribute State (Table 22)
Wainuiomata River at Richard Prouse Park	Weekly/fortnightly	664 (38)	Poor	1050 (48)	Poor	1325 (57)	Poor
Ruamāhanga							
Ruamāhanga River at Double Bridges	Fortnightly	480 (38)	Fair	300 (48)	Fair	272 (57)	Fair
Ruamāhanga River at Te Ore Ore	Fortnightly	1845 (37)	Poor	1064 (49)	Poor	898 (56)	Poor
Waipoua River at Colombo Road	Fortnightly	1437 (37)	Poor	1329 (49)	Poor	1254 (56)	Poor
Waingawa River at South Road	Fortnightly	87 (37)	Excellent	64 (49)	Excellent	59 (56)	Excellent
Ruamāhanga River at The Cliffs	Fortnightly	1577 (36)	Poor	529 (48)	Fair	346 (55)	Fair
Ruamāhanga River at Kokotau	Fortnightly	1850 (35)	Poor	860 (46)	Poor	2033 (53)	Poor
Ruamāhanga River at Waihenga	Fortnightly	2175 (35)	Poor	1635 (47)	Poor	2220 (54)	Poor
Ruamāhanga River at Morrisons Bush	Fortnightly	1218 (35)	Poor	1020 (47)	Poor	1234 (54)	Poor
Waiohine River at State Highway 2	Fortnightly	378 (35)	Fair	203 (47)	Good	144 (54)	Good
Tauherenikau River at Websters**	Monthly	213 (35)	Good	196 (46)	Good	190 (54)	Good

* Fortnightly – generally sampled weekly up to 31 December, then sampled fortnightly Jan – March (no follow ups).

** Monthly sampling under the RWQE Programme, data range April 2018 to March 2023.

Does not meet the minimum data requirements for the NRP, LAWA or NPS-FM

Table 3: Summary of baseline and current attribute state assessments

Site Name	3Y Baseline State	3Y Attribute State	4Y Attribute State	5Y Attribute State
Kāpiti Coast				
Ōtaki River at State Highway One	Fair	Fair	Fair	Fair
Waikanae River at State Highway One	Fair	Poor	Poor	Poor
Waikanae River at Jim Cooke Park	Fair	Poor	Poor	Poor
Wellington & Hutt Valley				
Pākuratahi River at Hutt Forks	Good	Poor	Poor	Poor
Pākuratahi River at Kaitoke Campground	NA (2017 baseline state could not be calculated, data not available)	Poor#	NA	NA
Akatarawa River at Hutt Confluence**	Fair	Poor	Poor	Poor
Hutt River at Birchville	Excellent	Poor	Poor	Poor
Hutt River at Maoribank Corner	Excellent	Poor	Poor	Poor
Hutt River at Poets Park	Excellent	Poor	Poor	Poor
Hutt River at Silverstream Bridge	Good			
Hutt River upstream Silverstream Bridge	NA (Refer to baseline state for Hutt River at Silverstream			
Hutt River at Silverstream Bridge (Combined data)	NA	Poor	Poor	Poor
Hutt River at Taita Rock	NA (2017 baseline state could not be calculated, data not available)	Good#	NA	NA
Hutt River at Melling Bridge	Poor	Poor	Poor	Poor
Wainuiomata River at Richard Prouse Park	Poor	Poor	Poor	Poor
Ruamāhanga				
Ruamāhanga River at Double Bridges	Good	Fair	Fair	Fair
Ruamāhanga River at Te Ore Ore	Poor	Poor	Poor	Poor
Waipoua River at Colombo Road	Good	Poor	Poor	Poor
Waingawa River at South Road	Excellent	Excellent	Excellent	Excellent

Site Name	3Y Baseline State	3Y Attribute State	4Y Attribute State	5Y Attribute State
Ruamāhanga River at The Cliffs	Excellent	Poor	Fair	Fair
Ruamāhanga River at Kokotau	Good	Poor	Poor	Poor
Ruamāhanga River at Waihenga	Good	Poor	Poor	Poor
Ruamāhanga River at Morrisons Bush	Good	Poor	Poor	Poor
Waiohine River at State Highway 2	Fair	Fair	Good	Good
Tauherenikau River at Websters**	Good	Good	Good	Good

* Fortnightly – generally weekly up to 31 December, then fortnightly Jan – March (no follow ups).

** Monthly sampling under the RWQE Programme, data range April 2018 to March 2023.

[#] Does not meet the minimum data requirements for the NRP, LAWA or NPS-FM

Summary

For long term monitoring sites established prior to 2017, there is generally a consistent amount of data available for the calculation of baseline states. Data requirements across all sites complied with the minimum data requirements as defined in the NRP (30 sample points across a minimum of 3 years), and met the minimum data requirements used by LAWA (minimum of 50 sample points).

Sample numbers generally fell short of the suggested minimum indicated in Table 9 of the NPS-FM[4] – however it is again noted that for the assessment of bathing season data (rather than routine monthly data to which the Table 9 assessment applies), minimum data requirements are not specified for the calculation of attribute states.

For the 2023 current attribute state assessment, the suggested minimum data requirements for the NRP were met for sites across the three most recent full bathing seasons. Data requirements only fell short for sites that are newly established. These sites did not achieve the minimum sample size to enable the 95th percentile statistic to be calculated with some certainty, thus should be regarded as 'indicative' only (i.e. Pākuratahi River at Kaitoke Campground with 23 sample points since 2021, and Hutt River at Taita Rock with 12 sample points since 2022).

The comparison of attribute states across the 2023 period (**Table 2**), assessed on the basis of 3-year, 4-year or 5-year bathing season data demonstrates the marked influence of individual samples collated across a bathing season on the overall attribute state. For example, the past two bathing seasons (2021/22 and 2023/22) were notable for a series of high *E. coli* counts (in the 1000s) resulting in significant shifts in attribute state since the 2017 baseline. These elevated counts are often associated with rainfall either immediately prior to, or during routine surveillance monitoring. These elevated counts have a high influence on the 95th percentile calculation, thus the elevated attribute state may take several seasons to reduce.

Given the influence of wetter than usual seasonal effects, removing or only partially including data from a single bathing season is not recommended to achieve minimum data requirements. This was avoided for this current assessment to avoid any bias within the bathing season itself. Thus, the attribute states presented here represent the water quality across the full bathing season range, and not parts or seasons themselves.

Across the 3, 4 and 5 yearly attribute state assessment for 2023, only two sites recorded differences in the attribute state:

- Ruamāhanga River at The Cliffs – shifted from 'Poor' (3Y assessment) to 'Good (4Y and 5Y assessment); and
- Waiohine River at State Highway 2 – shifted from 'Fair' (3Y assessment) to 'Good' (4 and 5Y assessment).

This shift reflects the combination of the higher sample size to lessen the influence of elevated *E. coli* counts for the 95th percentile calculation, but this was not apparent for the majority of sites.

Applicability of the Risk Criteria Model

The risk model was introduced in the 2018/19 bathing season and was intended to overcome the problems faced in communicating the suitability for swimming based on data

[4] Table 9 of the NPS-FM refers to '*a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years*', thus inferring 60 data points is recommended.

that was out of date by the time is was publicly available. The intention was not to calculate or substitute numerical modelling outputs as the design is too simplistic.

GWRC's daily risk model is based on a series of criteria that combines the following information:

- Long term MAC grade (calculated based on the last three years of weekly or fortnightly sampling data);
- Rainfall, as measured from the most proximate rain gauge to the site, as measured in the past 24h); and
- Daily forecast rainfall.

The criteria are weighted to produce an overall rank of suitability for swimming.

The output is updated daily and gives a high level, daily risk assessment with one of the key messages: Suitable for Swimming, Caution Advised, Unsuitable for swimming.

Given the input data and simplistic weighting system, it does not reproduce a numerical *E. coli* count. The derivation or extrapolation of the results of the model are not appropriate to generate *E. coli* count data as the overall risk message is based on a range of the weighted score only. Any methods to derive or extrapolate numerical output would require a more sophisticated relationship between rainfall depth, source of contamination, and river hydrodynamics to inform a numerical output. This has been addressed to some extent under the Whaitua modelling programmes, but accurate modelling would require intensive sampling effort under a range of wet weather conditions to calibrate and validate any numerical model.

For the purpose of the attribute state assessment to inform PC1, the criteria model is not an appropriate tool to inform this process.

Monitoring effort

The current sampling effort applied across bathing water seasons meets the minimum data requirements for the NRP, even with the reduced sampling effort introduced in the 2018/19 season. It is acknowledged here, that whilst the NPS-FM (Section 3.27(4)) requires weekly sampling to be undertaken across the bathing season, the timing of the bathing season itself is not stipulated. The scheduling of bathing seasons itself may vary between council authorities carrying out primary contact site monitoring, which in turn may influence the final sample size available for analysis. Issues concerning the timing of the bathing season, and resourcing monitoring effort to give effect to Section 3.27(4) are not in the scope of this current assessment.

Given the reduced sample size, increasing the analyses to 4 or 5 bathing seasons overcomes any constraints, or perceptions of biases or misrepresentation of data across a shorter time frame that may be apparent with a 3-year assessment period. The analyses of 5 bathing seasons is consistent with the timeframes referenced in both the NPS-FM and LAWA approach. There is no indication that having a slightly reduced sampling effort, based on 3 bathing seasons, significantly changes the attribute state assessments across the board. Only two sites were shown to be affected by changes to the bathing season periods whereby attribute states were lower on the basis of a 3-year assessment, compared with a 4 or 5-year assessment.

If a 3-year attribute state is to be maintained across sites, sampling effort should be maintained and not reduced further.

Regards

Dr Claire Conwell

Principal consultant

Reviewed by C. Lockyer , Principal Consultant

Appendix 1: Freshwater primary contact sites for Plan Change 1 (PC1).

Whaitua	Site Name	E	N
Kāpiti Coast			
Kāpiti Coast	Ōtaki River at State Highway One	1781309	5484406
Kāpiti Coast	Waikanae River at State Highway One	1773752	5472296
Kāpiti Coast	Waikanae River at Jim Cooke Park	1772155	5472377
Wellington & Hutt Valley			
Wellington & Hutt Valley	Pākuratahi River at Hutt Forks	1784288	5452620
Wellington & Hutt Valley	Pākuratahi River at Kaitoke Campground	1784573	5451743
Wellington & Hutt Valley	Akatarawa River at Hutt Confluence	1776183	5449184
Wellington & Hutt Valley	Hutt River at Birchville	1776196	5449091
Wellington & Hutt Valley	Hutt River at Maoribank Corner	1775882	5446696
Wellington & Hutt Valley	Hutt River at Poets Park	1771462	5446092
Wellington & Hutt Valley	Hutt River at Silverstream Bridge	1767598	5443172
Wellington & Hutt Valley	Hutt River upstream Silverstream Bridge	1768396	5443805
Wellington & Hutt Valley	Hutt River at Taita Rock	1764779	5440885
Wellington & Hutt Valley	Hutt River at Melling Bridge	1759906	5436831
Wellington & Hutt Valley	Wainuiomata River at Richard Prouse Park	1764536	5429141
Ruamāhanga			
Ruamāhanga	Ruamāhanga River at Double Bridges	1824350	5471775
Ruamāhanga	Ruamāhanga River at Te Ore Ore	1825529	5462917
Ruamāhanga	Waipoua River at Colombo Road	1824996	5462889
Ruamāhanga	Waingawa River at South Road	1820756	5460858
Ruamāhanga	Ruamāhanga River at The Cliffs	1821476	5452180
Ruamāhanga	Ruamāhanga River at Kokotau	1815756	5447191
Ruamāhanga	Ruamāhanga River at Waihenga	1804604	5436519
Ruamāhanga	Ruamāhanga River at Morrisons Bush	1808918	5441108
Ruamāhanga	Waiohine River at State Highway	1809662	5451705
Ruamāhanga	Tauherenikau River at Websters	1797082	5439942

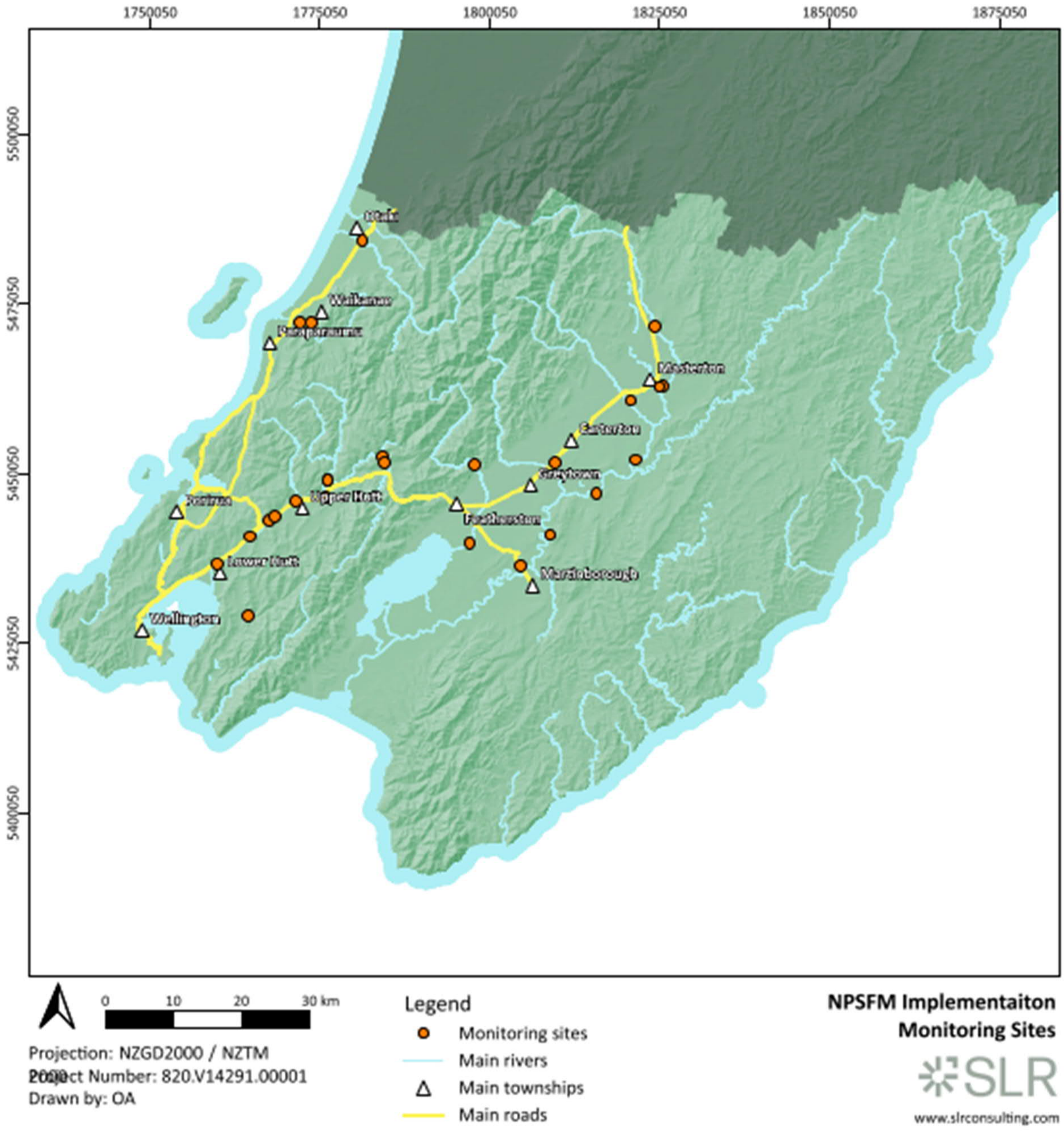

Figure 1: Primary contact sites across the Wellington Region

Threatened Freshwater Species Mapping Technical Guide for the Wellington Region

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The report may be cited as:

Crisp P. 2023. *Threatened freshwater species mapping technical guide for the Wellington region.* Greater Wellington Regional Council, Publication No. GW/ESCI-T-23/9, Wellington.

Executive summary

The National Policy Statement for Freshwater Management 2020 (NPS-FM) requires regional councils to identify the critical habitats and conditions of nationally Threatened freshwater species and to set limits and targets for Threatened freshwater species in each Freshwater Management Unit. This report identifies the Threatened freshwater-dependent species and their critical habitats and conditions in the Wellington Region.

The list of Threatened freshwater species was based on the lists of nationally Threatened species that have been located in the Wellington Region. Freshwater-dependence was determined by considering the critical elements of the life-cycle and habitat-use of each species. The locations of Threatened species were determined from a wide variety of data sources. Each location was sense-checked from aerial imagery but field checks have not been made.

A total of 30 species were identified as meeting the criteria, including: eleven plant, nine invertebrate, seven bird, two fish and one bat species. There were 260 observations used to determine the location of these Threatened species. Some observations covered a number of sites (eg, bittern habitat includes wetlands and streams within 15km of a breeding site). It is noted that there are data limitations because of the lack of search effort for some species across the region.

Recommendations for next steps include mapping and workshopping the development of limits and targets with other regional councils.

Contents

1. Introduction

The National Policy Statement for Freshwater Management 2020 (NPS-FM) provides local government authorities with direction on how they should manage freshwater under the Resource Management Act 1991. One of the requirements of the NPS-FM is that each regional council is to identify within each Freshwater Management Unit (FMU):

- the location of habitats of Threatened species, and to
- set an environmental outcome for Threatened species in each FMU.

Threatened species have been defined in the NPS-FM as any indigenous species of flora or fauna that:

- relies on fresh water bodies for at least part of its life-cycle, and
- meets the criteria for Nationally Critical, Nationally Endangered or Nationally Vulnerable species in the *New Zealand Threat Classification Manual* (Townsend et al. 2008).

The aim of the NPS-FM is to identify the extent to which an FMU or part of an FMU that supports a population of Threatened species has the critical habitats and conditions necessary to support the presence, abundance, survival and recovery of the Threatened species. All the components of ecosystem health must be managed, as well as (if appropriate) specialised habitat or conditions needed for only part of the life-cycle of the Threatened species. Habitat is defined in the NPS-FM as: the physical form, structure, and extent of the water body, its bed, banks and margins, its riparian vegetation and its connections to the floodplain and to groundwater.

2. Objectives

The goal of this report is to identify which nationally Threatened species in the Wellington Region meet the criteria for inclusion as a 'freshwater-dependent' species, to identify where they are located and to provide information about the critical habitat and conditions required for the species to persist.

3. Methodology

3.1 Species Identification

The Department of Conservation (DOC) publishes the New Zealand Threat Classification Series (NZTCS) lists on its website (Department of Conservation 2022). These lists for animal, plant, and fungal groups detail which species are nationally Threatened (Nationally Critical, Nationally Endangered or Nationally Vulnerable). The process for assessing species conservation status is detailed in the NZTCS manual 2008 (Townsend et al 2008), but some categories were revised in a 2021 amendment (Michel 2021). In the 2021 amendment, the nationally Threatened categories were expanded to include a 'Nationally Increasing' status. Species listed in this new Nationally Increasing status have been included in this analysis, as they meet the intention of the NPS-FM to protect nationally Threatened freshwater species.

The process used for identifying which species are relevant to the requirements of the NPS-FM was as follows:

1. All of the latest published national species conservation assessments were searched to extract the Nationally Critical, Nationally Endangered, Nationally Vulnerable or Nationally Increasing species.

2. Whether or not a species was present in the Wellington Region was determined by using the regional conservation assessments that have been undertaken for vascular plants (Crisp 2020a, based on de Lange et al 2013), birds (Crisp 2020b) and freshwater fish (Crisp et al. 2022, based on Dunn et al. 2017). Updated national conservation lists for bats and birds were used (O'Donnell et al. 2022; Robertson et al. 2021). For other species groups, such as freshwater invertebrates (Grainger et al. 2018), mosses (Rolfe et al. 2014) and marine invertebrates (Freeman et al. 2014), national experts (Brian Smith, Tom Drinan, Jessica Beever and Geoff Read *pers comm*) were contacted to find out which species were present in the region.

3. A decision was made as to whether or not the species fitted the criteria of being 'freshwater-dependent' as discussed in section 3.2 below.

The latest national conservation assessments for amphibians, bats, birds, butterflies and moths, earthworms, fleas, freshwater fish, freshwater invertebrates, frogs, fungi, hornworts and liverworts, Hymenoptera, lichens, macroalgae, marine invertebrates, marine mammals, mites and ticks, Orthoptera, reptiles, sharks and rays, slugs and snails, spiders, stick insects, vascular plants, and velvet worms were considered. Only Nationally Threatened species in the bat, bird, freshwater fish, freshwater invertebrate, marine invertebrate, hornworts and liverworts, and vascular plant lists were determined to fit the criteria of being 'freshwater-dependent' and were present in the Wellington Region.

3.2 Identification of 'freshwater-dependent' species

There was a need to identify whether or not a species met the criteria of being 'freshwater-dependent', as the NPS-FM defined a 'freshwater-dependent' Threatened species as being reliant on water bodies for at least part of its life-cycle. This raised two questions about (1) what is regarded as 'freshwater' and (2) how to determine which species are 'dependent' on freshwater.

The NPS-FM applies to all freshwater environments (including groundwater), and to receiving environments to the extent they are affected by freshwater (which may include estuaries and the wider coastal marine area). This meant that defining 'freshwater' species has challenges for some coastal bird species that mainly use the coast as habitat but also make use of freshwater habitats during their lifecycle (particularly estuaries). Taranui / Caspian tern is relevant to that determination. Similarly, the habitat of the large-egged polychaete (*Boccardiella magniovata*) is brackish but the species is present 0.5 km upstream in the Hutt River. Those species have been included in this report.

Identifying whether or not a species met the criteria of 'relying on water bodies for at least part of its life-cycle' was more challenging. Many species rely on water bodies for their life-cycles, as water is essential to life. However, for the purpose of this exercise, there was a need to identify which species were the most relevant to the intent of the NPS-FM. Guidance was taken from the approach applied to determining the extent of natural inland wetland vegetation where wetland species have been identified as Obligate (OBL- almost always require wet conditions for their habitat) or Facultative Wet (FACW - usually require wet conditions for their habitat). Species that can live in wet conditions but are also found in drier sites were excluded. Consideration was given to the inclusion of bat species that require food supplies from waterways for survival.

To make that determination, information was obtained from Clarkson et al. 2021 for wetland plant indicator status and from McArthur 2020 for freshwater biostatus of bird species in the Wellington Region, as well as bird species associated with freshwater environments listed in Storey et al. 2018. The Obligate status for fish, freshwater invertebrates and marine invertebrates was clear, while the status of the moss species had been detailed in Champion 2021. Long-tailed bats were considered to be freshwater-dependent, as they require freshwater invertebrates as a food source.

3.3 Determination of the locations of species in the Wellington Region

The NPS-FM requires the use of the best information available at the time and to use, if practicable, complete and scientifically robust data. Sources of information that provide the greatest level of certainty are preferred. It should be noted that species' locations are not static and that this report provides information gathered up until the end of 2022.

Identifying the locations of Threatened species has been largely dependent on observers who are experts in their field. Location data was derived from the following sources:

- Birds – data collected by Greater Wellington Regional Council Te Pane Matua Taiao (GWRC) or Department of Conservation Te Papa Atawhai (DOC) (including: GWRC wetland bird survey data, GWRC/DOC Wairarapa Moana wetland bird monitoring, GWRC/DOC Lake Wairarapa lake-edge bird monitoring, GWRC coastal bird survey data, GWRC river bird survey data), Birds New Zealand Te Kāhui Mātai Manu o Aotearoa surveys, eBird (where the observer is a known expert).

- Plants – Paul Champion from the National Institute of Water and Atmospheric Research Taihoro Nukurangi (NIWA) (Champion 2021, uses data from Allan and Auckland Museum Herbaria, and verified iNaturalist records), GWRC data (Wellington regional threatened plant database), Museum of New Zealand Te Papa Tongarewa records.

- Freshwater invertebrates – data from DOC database, tadpole shrimp and kakahi information from GWRC records.

- Fish – data from New Zealand Freshwater Fish database (NIWA 2022), GWRC data, Wilderlab database (Wilderlab 2022).

- Moss – expert information – Jessica Beever *pers comm*, Perrie 2010, Museum of New Zealand Te Papa Tongarewa records

- Marine invertebrate – expert information – Geoff Read *pers comm.*

- Bats – DOC records and recent surveys completed by the Sustainable Wairarapa Bat Group (Carylon 2021, Ryan 2022).

Time scales were also considered, as old records may or may not be of current relevance. The point needs to be made however, that this exercise is about identifying the habitats of Threatened species and if those habitat conditions are still present, then the site remains of importance to the survival of a Threatened species. The approach taken here has been to include old observations but note as ‘old’, those observations made over 50 years ago.

All location data was checked for validity. For example, if a co-ordinate was at a point that was not within or close to a waterbody, then that record was excluded. Location data for a number of sites of some species did not fall in a ‘natural’ waterbody (eg, dabchick records from sewage treatment plants ponds or plant records that fell in dry paddocks). Those observations were excluded from the list of localities. Localities were included however in cases where wetland plants have been recorded but the wetland has not, as yet, been listed on the GWRC natural wetland database (GWRC Scientific Wetland database 2021). For many site locations, it is the entire waterbody that is of relevance, rather than the location of the observation. For example, lamprey spawn in the headwaters of rivers, so the whole river is of relevance to the consideration of habitat as they are diadromous and need to be able to migrate to the sea to complete their life-cycle. Similarly with bird habitat, the whole of the waterbody is of importance.

3.4 Habitat use

In general, the breeding habitat for a Threatened species was regarded as being of the greatest importance. However, in some cases, the use of habitat in the region for non-breeding purposes (eg, food collection, roosting or migration) has been considered a critical part of the life-cycle of the species. Kōtuku / white heron only breed at one site in the South Island but are a Migrant in the Wellington Region (i.e., less than 15 individuals are recorded in the region annually), being regularly recorded using habitat at Wairarapa Moana. Ngutu pare / wrybill meets the criteria of being a regional resident (i.e., more than 15 individuals have been recorded in the region annually, Townsend et al 2007). Ngutu pare breed on the South Island braided rivers but the entire population migrates north to winter in the North Island and individuals are regularly recorded at Lake Wairarapa.

Two bird species that were initially considered to have met the criteria for being nationally Threatened and being freshwater-dependent were tarapirohe / black-fronted tern and tuturiwhatu / northern New Zealand dotterel. Expert advice however was that both tarapirohe and tuturiwhatu are coastal species in the Wellington Region that primarily use marine habitat to feed. Consequently, these species have not been listed as freshwater-dependent. Significant coastal bird sites have been included however for species that do use freshwater habitat in the region as part of their life-cycle (eg, kōtuku / white heron, ngutu pare / wrybill and taranui / Caspian tern). The inclusion of pārera / grey duck was questioned, as the driver of its threat status is hybridisation with exotic mallard ducks. As such, there were concerns as to whether an action plan could make an improvement in the status of the species if it could not prevent inbreeding in the wild. Bird experts have now identified that some pure-bred pārera may be selectively choosing pure-bred partners and that it is considered worthwhile to protect the habitat of these pure-bred birds.

4. Results

4.1 Threatened freshwater-dependent species recorded within the Wellington Region

A total of 30 species were identified as meeting the criteria required by the NPS-FM, including: eleven plant, nine invertebrate, seven bird, two fish and one bat species (Table 5.1).

Table 4.1: Nationally Threatened freshwater-dependent species in the Wellington Region

Species type	Species name	Common name	National threat status
Birds	*Ardea alba modesta*	Kōtuku, white heron	Critical
	Botaurus poiciloptilus	Matuku-hurepo, Australasian bittern	Critical
	Anas superciliosa	Pārera, grey duck	Vulnerable
	Hydroprogne caspia	Taranui, Caspian tern	Vulnerable
	Anarhynchus frontalis	Ngutu pare, wrybill	Increasing
	Anas chlorotis	Pāteke, brown teal	Increasing
	Poliocephalus rufopectus	Weweia, New Zealand dabchick	Increasing
Fish	*Galaxias postvectis*	Kokopu, short-jaw kokopu	Vulnerable
	Geotria australis	Piharau, lamprey	Vulnerable
Plants	*Crassula peduncularis*	Purple stonecrop	Critical
	Juncus holoschoenus var. *holoschoenus*	Rush family	Critical
	Carex cirrhosa	Curly sedge	Endangered
	Centipeda minima subsp. *minima*	Sneezeweed	Endangered
	Gratiola concinna	Plantain family	Endangered
	Mazus novaezeelandiae subsp. *impolitus*	Mazaceae family	Endangered
	Pterostylis micromega	Swamp orchid	Endangered
	Althenia bilocularis	Aquatic herb	Vulnerable
	Amphibromus fluitans	Water brome	Vulnerable
	Juncus pauciflorus	Leafless rush	Vulnerable
Invertebrates	*Omanuperia hollowayae*	Stonefly	Critical
	Potomopyrgus oppidanus	Freshwater snail	Critical
	Cryptobiosella spinosa	Caddisfly	Endangered
	Cryptobiosella furcata	Caddisfly	Endangered
	Hydrochema sp. *W*	Caddisfly	Endangered
	Lepidurus apus viridis	Tadpole shrimp	Endangered
	Echyridella aucklandica	Kākahi, freshwater mussel	Vulnerable
	Xenobiosella motueka	Caddisfly	Vulnerable
	Boccardiella magniovata	Large-egged polychaete	Critical
Bat	*Chalinolobus tuberculatus*	Pekapeka, long-tailed bat	Critical

4.2 Locations and critical habitat requirements of freshwater-dependent species in the Wellington Region

A total of 260 observations were detailed for the Threatened species identified (Table 5.2). Some observations cover a number of sites (eg, bittern habitat includes wetlands and streams within 15km of a breeding site).

Table 4.2: Number of observations per Threatened species type

Species type	Number of observations
Birds	61
Fish	115
Plants	50
Invertebrates	30
Bats	4

Details of the location/observation data and habitat requirements for each species are listed in Appendix A, Table A1. Species and observations that were not selected for inclusion are listed in Appendix B, Tables B1 and B2.

5. Discussion

The main limitation to this analysis was the lack of search effort for some species across the region. While, for example, there are a number of fishing records, there are multiple waterways and the observations have only been made at selected locations. The recent use of environmental DNA sampling is proving to be valuable, so it is likely that fish information will be improved in future. Locating Threatened plants relies on a small pool of specialists, as these species usually require good botanical knowledge to establish their presence. Expertise is also required for determining invertebrate and moss species. While kākahi may be easier to identify than a small caddisfly, determining a particular kākahi species still provides challenges (the shell looks slightly different between species). For birds, GWRC has accumulated data through regional monitoring programmes in the last ten years that is more up-to-date than that found in older databases and eBird is providing a useful resource. Given these limitations, the information provided in this report should be viewed as a point-in-time of current knowledge and more localities of some of the Threatened species listed will be found as the search effort improves.

There are decisions that need to be made about how the relevant waterbody for each species is mapped. As noted by Whatley 2020, effective management of Threatened species habitat requires an integrated approach, rather than considering waterbodies in isolation. For fish in particular, the finding of a species in the headwaters in one part of the catchment indicates that that whole river system is of relevance. It has been suggested that a single record could be scaled to a catchment so that everything downstream is included. There is also the question however as to whether or not the whole catchment of the waterbody should be included. If a species has been recorded in one arm of a river's headwaters, then it could be expected to be able to reach the other arms (unless there are physical barriers). For freshwater invertebrates, the riparian zone around the waterway is important to the survival of the species.

Defining critical habitat requirements is challenging for many species. For example, birds need a food supply which, in turn, is affected by water levels and quality. Detailing the impact each of these factors on the viability of a population is however far from an exact science. Sometimes there is insufficient information to enable the identification of important habitat characteristics. An approach that has been taken by Thorsen 2021a, 2021b is to identify the main factors known to threaten the persistence of species at the sites in broad categories (eg, water quantity or habitat structure). Champion 2021 has identified a number of factors in a similar way for the plants. A similar approach is taken in this report.

6. Recommendations and next steps

The next step in identifying the locations of the habitats of threatened species is to map the geographical co-ordinates provided in the spreadsheet detailed in Appendix A, Table A1. Some wetlands that are not currently listed in the GWRC Scientific Wetland GIS layer need to be delineated. This can be completed in the office using GIS, though ideally a site visit would provide more accuracy. Some of the wetlands are very small, but the NPS-FM does not have a size requirement for wetlands that contain Threatened species.

As series of five workshops were held with other regional councils to assist in obtaining a consistent approach to determining which species are relevant to the requirement of the NPS-FM. Decisions about how to map the habitat of freshwater fish and about data cut-out points (eg, age of the observation) were discussed. There was some divergence about the mapping of fish habitat, but the approach taken by GWRC at this stage is to include the catchment of the waterways where Threatened fish observations have been made. In terms of data cut-off points, there was a general consensus that observations prior to 2000 should only be used where the site has not been revisited (eg, because access has been denied or searches for species are constrained by season or terrain).

Some of the NPS-FM Threatened species locations identified in this report are in sites that are already identified in the Greater Wellington Natural Resource Plan (NRP) schedules (Home » Proposed Natural Resources Plan (gw.govt.nz) (eg, significant bird sites). The scheduled waterbodies that contain nationally Threatened freshwater species are listed in Appendix C, Table C1. Other species locations are not in scheduled sites and are listed in Appendix C, Table C2. Field visits and/or consultation with landowners will be required for those sites.

Acknowledgements

Special thanks are given to Pat Enright for his assistance with the locations of Threatened plants in the region and to Alton Perrie for his assistance with fish, freshwater invertebrates and *Fissidens berteroi*. Tom Drinan (DOC), Jessica Beever (Landcare Research), Geoff Read (NIWA), Bridget Hatton (Te Papa), Cindy Baker (NIWA), Roger Uys (GWRC), Brian Smith (NIWA), Tony Silbery (ex-DOC), Owen Spearpoint (GWRC), Beverley Clarkson (Landcare Research) and Evan Harrison (GWRC) all provided valuable input to this report.

References

Allibone RA and Gray D. 2018. *Critical habitat for Canterbury freshwater fish, koura/kekewai and kakahi.* Report prepared for Canterbury Regional Council.

Birds Online: [Home page | New Zealand Birds Online (nzbirdsonline.org.nz)](nzbirdsonline.org.nz)

Carlyon E. 2021. *Sustainable Wairarapa Incorporated (SWI) Bat Group long-tail bat monitoring*. Unpublished report written on behalf of Sustainable Wairarapa Inc. Bat Group.

Champion P, Elcock S and Moss M. 2021. *Stocktake of nationally threatened freshwater dependent plants*. Unpub. NIWA Report 2021186HN to Department of Conservation.

Clarkson BR, Fitzgerald NB, Champion PD, Forester L and Rance BD. 2021. *New Zealand wetland plant list 2021.* Manaaki Whenua – Landcare Research contract report LC3975 for Hawke's Bay Regional Council.

Crisp P. 2020a. *Conservation status of indigenous vascular plant species in the Wellington region.* Greater Wellington Regional Council Publication No. GW/ESCI-G-20/20 Wellington.

Crisp P. 2020b. *Conservation status of native bird species in the Wellington region.* Greater Wellington Regional Council, Publication No. GW/ESCI-G-20/75, Wellington.

Crisp P, Perrie A, Morar A and Royal C. 2022. *Conservation status of indigenous freshwater fish in the Wellington region*. Greater Wellington Regional Council Publication No. GW/ESCI-T-22/02.

de Lange P, Rolfe J, Champion P, Courtney S, Heenan P, Barkla J, Cameron E, Norton D and Hitchmough R. 2013. Conservation status of New Zealand indigenous vascular plants 2012. *New Zealand Threat Classification Series 3.* 70 p.

Department of Conservation Threat Classification System website 2022: https://www.doc.govt.nz/about-us/science-publications/conservation-publications/nz-threat-classification-system

Dekrout AS, Clarkson BD and Parsons S. 2014. Temporal and spatial distribution and habitat associations of an urban population of New Zealand long-tailed bats (Chalinolobus tuberculatus). *New Zealand Journal of Zoology* 41(4): 285-295.

Dunn NR, Allibone RM, Closs GP, Crow SK, David BO, Goodman JM, Griffiths M, Jack DC, Ling N, Waters JM and Rolfe JJ. 2017. Conservation status of New Zealand freshwater fishes. *New Zealand Threat Classification Series 24*. 11 p.

Freeman D, Schnabel K, Marshall B, Gordon D, Wing S, Tracey D and Hitchmough R 2013. Conservation status of New Zealand marine invertebrates 2014. *New Zealand Threat Classification Series 9.* 20 p

Grainger N, Harding J, Drinan T, Collier K, Smith B, Death R, Makan T and Rolfe J. 2018. Conservation status of New Zealand freshwater invertebrates, 2018. *New Zealand Threat Classification Series 28.* 25 p

Goodman JM. 2002. *The ecology and conservation of shortjaw kokopu (Galaxias postvectis) in Nelson and Marlborough.* MSc Thesis, University of Canterbury, NZ.

Henderson IM. 1983. A contribution to the systematics of New Zealand Philopotamidae (Trichoptera). *New Zealand Journal of Zoology* 10:2, 163-176.

McArthur N. 2020. *A review of the freshwater biostatus of the birds of the Wellington region.* Client report prepared for Greater Wellington Regional Council, Wellington.

McGuinness CA. 2001 *The conservation requirements of New Zealand's nationally threatened invertebrates/ Carl A McGuinnes*s. Wellington, N.Z: Dept. of Conservation, Biodiversity Recovery Unit, 2001

McLellan, I. D. 1991. *Notonemouridae (Insecta: Plecoptera).* Fauna of New Zealand / Ko te Aitanga Pepeke o Aotearoa [no.] 22.

Michel P. 2021. *Amendment to the New Zealand Threat Classification System manual 2008: revised categories 202*1. Department of Conservation, Wellington. 5 p.

National Policy Statement for Freshwater Management 2020, December 2022. https://environment.govt.nz/assets/publications/National-Policy-Statement-for-Freshwater-Management-2020.pdf

NIWA 2022. NIWA Freshwater Fish Database. Retrieved freshwater fish data from https://niwa.co.nz/information-services/nz-freshwater-fish-database

NIWA website. https://niwa.co.nz/our-science/freshwater/tools/fishatlas/species/fish-species

NZPCN website New Zealand Plant Conservation Network (nzpcn.org.nz)

Rockwell G, Littlemore J and Scrimeour J. 2017. Habitat preferences of long-tailed bats (*Chalinolobus tuberculatus*) along forested riparian corridors in the Pikikiariki Ecological Area, Pureora Forest Park. DOC Research and Development Series 349.

Ryan J. 2022. *Sustainable Wairarapa Inc. (SWI) Bat/ Pekapeka survey report 2021-2022*. Unpublished report to funders.

Perrie AC. 2010. The aquatic moss *Fissidens berteroi*: Observations of habitat characteristics from populations in the Wellington region. *Wellington Botanical Society Bulletin* 52, April 2010.

Perrie AC. 2019. *Tadpole shrimp survey Sept 2019: Wairio & Parera Road*. Unpublished report for Greater Wellington Regional Council.

Resource Management Act 1991.
https://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

O'Donnell CFJ. 2000. *Distribution, status and conservation of long-tailed bat (Chalinolobus tuberculatus) communities in Canterbury, New Zealand*. Unpublished Report UOO/38. Environment Canterbury.

O'Donnell CFJ, Borkin KM, Christie J, Davidson-Watts I, Dennis G, Pryde M and Michel P. 2022. *Conservation status of bats in Aotearoa New Zealand, 2022*. Department of Conservation, Wellington.

McDowall RM. 2000: *The Reed Field Guide to New Zealand Freshwater Fish*. Reed Publishing (NZ) Ltd, Auckland

Melchior M, Squires NJ, Clearwater SJ and Collier KJ. 2023. Discovery of a host fish species for the threatened New Zealand freshwater mussel *Echyridellla aucklandica* (Bivalve: Unionida: Hyridae). *New Zealand Journal of Marine and Freshwater Research* 57: 152-159.

Robertson HA, Baird KA, Elliot GP, Hitchmough RA, McArthur NJ, Makan T, Miskelly CM, O'Donnell CJ, Sagar PM, Scofield RP, Taylor GA and Michel P. 2021. Conservation status of birds in Aotearoa New Zealand 2021. *New Zealand Threat Classification Series 36*. Department of Conservation, Wellington. 43 p.

Rolfe JR, Fife AJ, Beever JE, Brownsey PJ and Hitchmough RA. 2016. Conservation status of New Zealand mosses 2014. *New Zealand Threat Classification Series 13.* 12 p

Storey R, Kilroy C, Matheson F, Neale M, Crow S and Whitehead A. 2018. *Scoping indicators for impacts on freshwater biodiversity and ecosystem processes of rivers and streams.* NIWA client report 20118118HN to Ministry for the Environment.

Thorsen M. 2022a. *Mapping threatened and rare freshwater-dependent flora and fauna within the Bay of Plenty region, December 2021*. Ahika Consulting Report for Bay of Plenty Regional Council.

Thorsen M. 2022b. *Mapping threatened and rare freshwater-dependent flora and fauna within the Otago region, April 2022*. Ahika Consulting Report for Otago Regional Council.

Townsend AJ, de Lange PJ, Duffy CAJ, Miskelly C M, Molloy J, Norton DA. 2007. *New Zealand Threat Classification System manual*. Department of Conservation, Wellington. 35p.

Whatley M. 2020. *Identifying the location of freshwater habitats of threatened species in New Zealand: A summary of current tools and resources*. Unpub. Adaptative Environmental Consulting Report to Ministry for the Environment.

Wilderlab. 2022. Retrieved freshwater fish data from https://www.wilderlab.co.nz/

Appendix A

Table A1: NPS-FM Threatened freshwater species observations

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Bird	*Botaurus pociloptilus*	Matuku-hūrepo	Australasian bittern	Nationally Critical	Obligate	Wairarapa Moana (whole wetland complex)	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Eastern Lake Wairarapa), Schedule F2b: Significant habitats for indigenous birds in lakes (Lake Wairarapa), Schedule F2c: Significant habitats for indigenous birds in the coastal marine area (Lake Onoke), Schedule F3: Identified natural wetlands (Boggy Pond/Matthews Lagoon, JK Donald/Tairoa Wetlands, Lake Domain Reserve, Pounui Lagoon, Tauherenikau Delta, Western Alsops Bay Wetlands, Wairongomai River Mouth.		1790011	5431053	eBird, GW/DOC monitoring data	Known breeding site in wetlands around Lake Wairarapa and Lake Onoke. Requires good food supply and clear water to fish, as need to be able to see prey to fish. Food mainly fish, but also spiders, molluscs, worms, freshwater crayfish, frogs and lizards	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Botaurus pociloptilus*	Matuku-hūrepo	Australasian bittern	Nationally Critical	Obligate	All wetlands and streams within 15km of Wairarapa Moana	Schedule F3: Significant Natural Wetlands	Wetlands in Wetlands - Scientific 2021 that aren't in F3, Main Rivers and streams within 15km	1790011	5431053	eBird	Adult birds need a network of wetlands within 15km radius, use cover around lakes and creeks, as well as rank grass along drain edges in paddocks	Birds online	Y	Not sure	Y	Y	na	na	na
Bird	*Botaurus pociloptilus*	Matuku-hūrepo	Australasian bittern	Nationally Critical	Obligate	Waikanae Estuary	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Waikanae River Mouth)		1769459	5472778	eBird, multiple at the estuary	Thought to be a breeding site, as for Wairarapa Moana	Birds online	Y	Not sure	Y	Y	na	na	na
Bird	*Botaurus pociloptilus*	Matuku-hūrepo	Australasian bittern	Nationally Critical	Obligate	All wetlands and streams within 15km of Waikanae Estuary	Schedule F3: Significant Natural Wetlands	Wetlands in Wetlands - Scientific 2021 that aren't in F3, Main Rivers and streams within 15km	1769459	5472778	eBird, Te Harakeke sighting	Food supply - as for Wairarapa Moana	Birds online	Y	Not sure	Y	Y	na	na	na
Bird	*Botaurus pociloptilus*	Matuku-hūrepo	Australasian bittern	Nationally Critical	Obligate	Huritini Swamp	Schedule F3: Significant Natural Wetlands		1782228	5490868	Hurutini (GW wetland monitoring programme - owner observations), Hugh Robertson	Thought to be a breeding site, as for Wairarapa Moana	Birds online	Y	Not sure	Y	Y	na	na	na
Bird	*Botaurus pociloptilus*	Matuku-hūrepo	Australasian bittern	Nationally Critical	Obligate	All wetlands and streams within 15km of Huritini Swamp	Schedule F3: Significant Natural Wetlands	Wetlands in Wetlands - Scientific 2021 that aren't in F3, Main Rivers and streams within 15km	1782228	5490868	eBird South Waikawa Beach dune lake, Ngatotara Lagoon, Lake Wairongomai observations, Waitohu wetlands survey report	Food supply - as for Wairarapa Moana	Birds online	Y	Not sure	Y	Y	na	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
											(GW - John Cheyne)									
Bird	*Botaurus pociloptilus*	Matuku-hūrepo	Australasian bittern	Nationally Critical	Obligate	Pauatahatanui Inlet (foraging habitat)	Schedule F2c: Significant habitats for indigenous birds in the coastal marine area (Te Awarua-o- Porirua Harbour – Pauatahanui Arm, Te Awarua-o-Porirua Harbour – Onepoto Arm)		1758552	5449627	eBird observations	Visit for food	Birds online	Y	Not sure	Y	Y	na	na	na
Bird	*Botaurus pociloptilus*	Matuku-hūrepo	Australasian bittern	Nationally Critical	Obligate	Tuturumuri Swamp C	Schedule F3: Significant Natural Wetlands		1807759	5412064	eBird observation	Visit for food	Birds online	Y	Not sure	Y	Y	na	na	na
Bird	*Botaurus pociloptilus*	Matuku-hūrepo	Australasian bittern	Nationally Critical	Obligate	All wetlands and streams within 15km of Tuturumuri Swamp C	Schedule F3: Significant Natural Wetlands	Wetlands in Wetlands - Scientific 2021 that aren't in F3, Main Rivers and streams within 15km	1807759	5412064	eBird observation, Nikki McArthur	Thought to be a breeding site, as for Wairarapa Moana	Birds online	Y	Not sure	Y	Y	na	na	na
Bird	*Botaurus pociloptilus*	Matuku-hūrepo	Australasian bittern	Nationally Critical	Obligate	Waitohu Stream Mouth (foraging habitat)	Schedule F2c: Significant habitats for indigenous birds in the coastal marine area (Waitohu Stream Mouth)		1780072	5489002	eBird observation, Hugh Robertson	Visit for food	Birds online	Y	Not sure	Y	Y	na	na	na
Bird	*Ardea alba modesta*	Kōtuku	White heron	Nationally Critical - Regional Migrant	Obligate	Wairarapa Moana wetlands	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Eastern Lake Wairarapa), Schedule F2b: Significant habitats for indigenous birds in lakes (Lake Wairarapa), Schedule F3: Identified natural wetlands (Boggy Pond/Matthews Lagoon		1790011	5431053	eBird observation - Boggy Pond and Wairio	Breed outside the region, but visits for food. Feed on small fish, frogs, lizards and invertebrates	Birds Online	Y	Not sure	N	N	na	na	na
Bird	*Ardea alba modesta*	Kōtuku	White heron	Nationally Critical - Regional Migrant	Obligate	Hutt estuary	Schedule F2: Significant habitats for indigenous birds (Te Awa Kairangi/ Hutt River (mouth to 1.3km upstream)		1759110	5433028	eBird observations	Breed outside the region, but visits for food. Feed on small fish, frogs, lizards and invertebrates	Birds Online	Y	Not sure	N	N	na	na	na
Bird	*Anas superciliosa*	Pārera	Grey duck	Nationally vulnerable	Obligate	Wairarapa Moana	Schedule F2b: Significant habitats for indigenous birds in lakes (Lake Wairarapa), Schedule F3: Identified natural wetlands (Boggy Pond/Matthews Lagoon, JK Donald/Tairoa Wetlands, Lake Domain Reserve, Pounui Lagoon		1790011	5431053	eBird observations - only used those of experienced birders where they detailed the distinctive features	While pure grey duck populations are rare, as hydridisation is occuring with mallards, this species is thought to still be present in more remote locations. Nest under cover next to water bodies and eat seeds, aquatic plant species, but also insects, freshwater snails and worms	NZTCS assessment, Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Anas superciliosa*	Pārera	Grey duck	Nationally vulnerable	Obligate	Pahaoa River	Schedule F2c: Significant habitats for indigenous birds in the coastal marine area (Pahaoa Estuary and Pahaoa Scientific Reserve)		1827506	5413735	Nikki McArthur eBird observation	As for Wairarapa Moana	NZTCS assessment, Birds Online	Y	Not sure	Y	Y	na	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Bird	*Anas superciliosa*	Pārera	Grey duck	Nationally vulnerable	Obligate	Burkhart Wetland	Schedule F3: Identified natural wetlands (Burkhart Wetlands)		1848322	5430311	Stuart Nicholson eBird observation	As for Wairarapa Moana	NZTCS assessment, Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Anas superciliosa*	Pārera	Grey duck	Nationally vulnerable	Obligate	Tuturumuri Swamp B	Schedule F3: Identified natural wetlands (Tuturumuri Swamp B)		1807756	5412533	Nikki McArthur eBird observation	As for Wairarapa Moana	NZTCS assessment, Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Anas superciliosa*	Pārera	Grey duck	Nationally vulnerable	Obligate	Tuturumuri Swamp A	Schedule F3: Identified natural wetlands (Tuturumuri Swamp B)		1807762	5412046	Joanna McVeagh eBird observation	As for Wairarapa Moana	NZTCS assessment, Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Anas superciliosa*	Pārera	Grey duck	Nationally vulnerable	Obligate	Te Harakeke Swamp	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Te Harakeke Swamp)		1772387	5476239	Ian Armitage eBird observation	As for Wairarapa Moana	NZTCS assessment, Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Anas superciliosa*	Pārera	Grey duck	Nationally vulnerable	Obligate	Waikanae Estuary	Schedule F2c: Significant habitats for indigenous birds in the coastal marine area (Waikanae River Mouth)		1769459	5472778	Pauline and Ray Priest photo	As for Wairarapa Moana	NZTCS assessment, Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Lake Onoke	Schedule F2c: Significant habitats for indigenous birds in the coastal marine area (Lake Onoke)		1778075	5417073	Wairarapa Birds NZ	Breeds on Onoke spit (only known breeding site in the region). Uses lakes and rivers to feed as well as shallow coastal waters. Feed mostly on small surface-swimming fish such as yellow-eyed mullet, piper and smelt. Also recordings of feeding on crickets and marine worms through probing in soft mud and wading in shallow water.	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Lake Wairarapa	Schedule F2b: Significant habitats for indigenous birds in lakes (Lake Wairarapa)		1790011	5431053	Wairarapa Birds NZ, GW/DOC lake-edge surveys	Have tried nesting on one of the western river deltas feeding into the lake. As for Wairarapa Moana	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Wellington Harbour	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Wellington Harbour (Port Nicholson)-inland waters)		1754073	5422368	eBird observations, GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Wellington Harbour	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Wellington Harbour (Port Nicholson Pencarrow Sewer Outfall to Burdan's Gate)		5419043	1756400	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Makara Estuary	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Makara Estuary)		1743821	5435271	eBird observations, GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Porirua Harbour	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Te Awarua-o-Porirua Harbour - Pauatahanui Arm, Onepoto Arm))		1758552	5449627	eBird observations, GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Waikanae Estuary	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Waikanae River Mouth)		1769459	5472778	eBird observations, GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Waitohu Stream Mouth	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Waitohu Stream Mouth)		1779100	5489385	eBird observations, GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Otaki River Mouth	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Otaki River Mouth)		1775818	5482543	eBird observations, GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Kapiti Island foreshore	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Kapiti Island foreshore)		1757535	5472534	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Paraparaumu foreshore	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Paraparaumu Beach)		5471985	1767075	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	White Rock	Schedule F2c: Habitats for indigenous birds in the coastal marine area (White Rock to Te Kaukau Point)		5395390	1801190	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Tora coast	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Tora Coast)		5397956	1806302	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Onoke Spit Barrier (breeding site)	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Onoke Spit Barrier)		1776540	5416113	GWRC coastal surveys, Forest and Bird	Breeds on Onoke spit (only known breeding site in the region). Uses lakes and rivers to feed as well as shallow coastal waters. Feed mostly on small surface-swimming fish such as yellow-eyed mullet, piper and smelt. Also recordings of feeding on crickets and marine worms through probing in soft mud and wading in shallow water.	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Ngakauau Stream mouth	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Ngakauau Stream mouth)	New change to schedule	1868021	5464302	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Ngawi foreshore north	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Ngawi Foreshore North)	New change to schedule	1785393	5395367	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Uruti Point	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Uruti Point)	New change to schedule	1857271	5442689	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Waimīmiha coastline	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Waimīmiha coastline)	New change to schedule	1863622	5458541	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Whakataki River mouth	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Whakataki River mouth)	New change to schedule	1872013	5470553	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Wairongomai River Mouth (breeding site)	Schedule F3: Identified natural wetlands (Wairongomai River Mouth)		1782386	5430396	Forest and Bird	Possible breeding site, as for Onoke Spit	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Baring Head coastline	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Baring Head/Orua-pouanui coastline)		1756035	5414879	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Hydroprogne caspia*	Taranui	Capsian tern	Nationally vulnerable	Facultative	Baring Head coastline	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Riversdale Beach & Motuwaireka Stream mouth)		1858793	5447413	GWRC coastal surveys	Visit for food	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Anarhynchus frontalis*	Ngutu-pare	Wrybill	Nationally Increasing	Obligate	Lake Wairarapa	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Eastern Lake Wairarapa), Schedule F2b: Significant habitats for indigenous birds in lakes (Lake Wairarapa)		1790011	5431053	GW/DOC lakeshore surveys	Breeds outside region (SI braided rivers), but entire population migrates north to winter in the harbours of the NI. Feed mainly on inter-tidal mudflats. Eat a range of aquatic invertebrates, as well as annelid and polychate worms and small molluscs	Birds Online	Y	Not sure	N	Y	na	na	na
Bird	*Anarhynchus frontalis*	Ngutu-pare	Wrybill	Nationally Increasing	Obligate	Lake Onoke	Schedule F2c: Significant habitats for indigenous birds in the coastal marine area (Lake Onoke)		1778587	5415851	GWRC coastal surveys	As for Lake Wairarapa	Birds Online	Y	Not sure	N	Y	na	na	na
Bird	*Anarhynchus frontalis*	Ngutu-pare	Wrybill	Nationally Increasing	Obligate	Petone foreshore	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Wellington Harbour (Port Nicholson) foreshore)		1754073	5422368	Birds NZ data	As for Lake Wairarapa	Birds Online	Y	Not sure	N	Y	na	na	na
Bird	*Anarhynchus frontalis*	Ngutu-pare	Wrybill	Nationally Increasing	Obligate	Waikanae Estuary	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Waikanae River Mouth)		1769459	5472778	eBird observations	As for Lake Wairarapa	Birds Online	Y	Not sure	N	Y	na	na	na
Bird	*Anarhynchus frontalis*	Ngutu-pare	Wrybill	Nationally Increasing	Obligate	Otaki Estuary	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Otaki River Mouth)		1777495	5485912	eBird observations	As for Lake Wairarapa	Birds Online	Y	Not sure	N	Y	na	na	na
Bird	*Anarhynchus frontalis*	Ngutu-pare	Wrybill	Nationally Increasing	Obligate	Waitohu Stream Mouth	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Waitohu Stream Mouth)		1779100	5489385	eBird observations	As for Lake Wairarapa	Birds Online	Y	Not sure	N	Y	na	na	na
Bird	*Anarhynchus frontalis*	Ngutu-pare	Wrybill	Nationally Increasing	Obligate	Riversdale Beach	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Riversdale Beach & Motuwaireka Stream mouth)		1858793	5447413	eBird observations	As for Lake Wairarapa	Birds Online	Y	Not sure	N	Y	na	na	na
Bird	*Anas chlorotis*	Pāteke	Brown teal	Nationally Increasing	Obligate	Zealandia	na	Wetlands Scientific 2021 (Karori Dam, Karori Reservoir)	1746493	5427069	eBird observations	Only thought to be breeding at sanctuary sites, such as Zelandia and Pukaha. Breed in bases of rushes, grass or fern clumps. Territories contain abundant food, escape cover as well as suitable nesting and brood-rearing habitat. Eat seeds of sedges, clover leaves, caddisfly larvae, beetles, caterpillars, moths and earthworms. In inter-tidal areas, gastropods, bivalves,	Birds Online	Y	Not sure	Y	Y	na	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
												crustacean and polychaete worms								
Bird	*Anas chlorotis*	Pāteke	Brown teal	Nationally Increasing	Obligate	Waikanae Estuary	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Waikanae River Mouth)		1769459	5472778	eBird observations	As for Zealandia	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Poliocephalus rufopectus*	Weweia	NZ dabchick	Nationally Increasing	Obligate	Wairarapa Moana	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Eastern Lake Wairarapa), Schedule F2b: Significant habitats for indigenous birds in lakes (Lake Wairarapa), Schedule F2c: Significant habitats for indigenous birds in the coastal marine area (Lake Onoke), Schedule F3: Identified natural wetlands (Boggy Pond/Matthews Lagoon, JK Donald/Tairoa Wetlands, Lake Domain Reserve, Pounui Lagoon.		1790011	5431053	GW/DOC lakeshore counts, eBird observations	Breeding birds favour shallow waters with dense vegetation on small freshwater lakes and pools, sand-dune lakes and lagoons. Pairs nest on the water, anchoring the nest to aquatic vegetation. Mainly east aquatic invertebrates such as insects and their larvae. Do use small farm dams. Non-breeding birds flock on more open freshwater bodies.	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Poliocephalus rufopectus*	Weweia	NZ dabchick	Nationally Increasing	Obligate	Lake Pounui	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Lake Pounui Wetlands)		1776732	5420875	eBird observations	As for Wairarapa Moana	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Poliocephalus rufopectus*	Weweia	NZ dabchick	Nationally Increasing	Obligate	Queen Elizabeth Park - Kapiti	Schedule F3: Identified natural wetlands (Queen Elizabeth Park Bush and Wetlands)		1788226	5462927	eBird observations	As for Wairarapa Moana	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Poliocephalus rufopectus*	Weweia	NZ dabchick	Nationally Increasing	Obligate	Parangarahu Lakes	Schedule F2b: Significant habitats for indigenous birds in lakes (Parangrahu Lakes and wetlands)		1756055	5419017	eBird observations	As for Wairarapa Moana	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Poliocephalus rufopectus*	Weweia	NZ dabchick	Nationally Increasing	Obligate	Waikanae Estuary	Schedule F2c: Habitats for indigenous birds in the coastal marine area (Waikanae River Mouth)		1769459	5472778	eBird observations	As for Wairarapa Moana	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Poliocephalus rufopectus*	Weweia	NZ dabchick	Nationally Increasing	Obligate	Te Harakeke Swamp	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Te Harakeke Swamp)		1772387	5476239	eBird observations	As for Wairarapa Moana	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Poliocephalus rufopectus*	Weweia	NZ dabchick	Nationally Increasing	Obligate	Te Hapua Wetland A	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Te Hapua Wetland A)		1774926	5479544	KCDC Ecological sites	As for Wairarapa Moana	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Poliocephalus rufopectus*	Weweia	NZ dabchick	Nationally Increasing	Obligate	Lake Kaitawa & Keelings Bush	Schedule F3: Identified natural wetlands (Lake Kaitawa & Keelings Bush)		1783367	5489531	KCDC Ecological sites	As for Wairarapa Moana	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Poliocephalus rufopectus*	Weweia	NZ dabchick	Nationally Increasing	Obligate	Otepua-Paruāuku	Schedule F3: Identified natural wetlands (Otepua-Paruāuku)		1783621	5488045	KCDC Ecological sites	As for Wairarapa Moana	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Poliocephalus rufopectus*	Weweia	NZ dabchick	Nationally Increasing	Obligate	Waimanguru Lagoon (Forest Lake)	Schedule F3: Identified natural wetlands (Waimanguru Lagoon (Forest Lake))		1782813	5488818	KCDC Ecological sites	As for Wairarapa Moana	Birds Online	Y	Not sure	Y	Y	na	na	na
Bird	*Poliocephalus rufopectus*	Weweia	NZ dabchick	Nationally Increasing	Obligate	Waimeha Lagoon, Waikanae	Schedule F3: Identified natural wetlands (Waimeha Lagoon, Waikanae)		1770150	5474052	KCDC Ecological sites	As for Wairarapa Moana	Birds Online	Y	Not sure	Y	Y	na	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Oterei River tributary (MAINRIV ID 3222)	F1: Threatened or At Risk Fish Habitat (Oterei River and all tributaries)		1816173	5409275	Department of Conservation Wellington	Short-jaw kokopu live in small bouldery streams in dense forest, go to sea during the larval stage and return about 19 weeks later as whitebait. (McDowall, 2000). Migration barriers and deforestation biggest impacts. Need good riparian vegetation, pool habitat with boulder and cobble fish cover, fish passage to the sea and flow regime that provides autumn freshes for spawning. Presence of exotic fish impact shortjaw populations (Goodman 2002)	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Oterei River tributary (MAINRIV ID 3222)	F1: Threatened or At Risk Fish Habitat (Oterei River and all tributaries)		1816673	5409074	Department of Conservation Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Opouawe River (Poley Stream)	F1: Threatened or At Risk Fish Habitat (Opouawe River and all tributaries)		1796271	5403580	Massey University	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Whawanui River tributary (MAINRIV ID 3299)	F1: Threatened or At Risk Fish Habitat (Whawanui River and all tributaries)		1795270	5399980	Massey University	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Whawanui River	F1: Threatened or At Risk Fish Habitat (Whawanui River and all tributaries)		1795370	5400480	Massey University	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Waitetuna Stream	F1: Threatened or At Risk Fish Habitat (Waitetuna Stream and all tributaries)		1793768	5391781	Department of Conservation Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Otakaha Stream tributary (MAINRIV ID 3291)	F1: Threatened or At Risk Fish Habitat (Otakaha Stream and all tributaries)		1791370	5399481	Massey University	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Otakaha Stream	F1: Threatened or At Risk Fish Habitat (Otakaha Stream and all tributaries)		1791770	5400081	Massey University	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Otakaha Stream tributary (MAINRIV ID 3301)	F1: Threatened or At Risk Fish Habitat (Otakaha Stream and all tributaries)		1791770	5398681	Massey University	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Pararaki Stream	F1: Threatened or At Risk Fish Habitat (Pararaki Stream and all tributaries)		1791371	5402781	Department of Conservation Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na

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Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Pararaki Stream	F1: Threatened or At Risk Fish Habitat (Pararaki Stream and all tributaries)		1792071	5402981	Department of Conservation Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Pararaki Stream	F1: Threatened or At Risk Fish Habitat (Pararaki Stream and all tributaries)		1794271	5404780	Department of Conservation Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Makotukutuku Stream (Washpool Creek)	F1: Threatened or At Risk Fish Habitat (Makotukutuku Stream and all tributaries)		1790971	5405281	Department of Conservation Nelson Marlborough	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Makotukutuku Stream (Washpool Creek)	F1: Threatened or At Risk Fish Habitat (Makotukutuku Stream and all tributaries)		1791438	5405662	Water Ways Consulting Ltd	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Makotukutuku Stream (Washpool Creek)	F1: Threatened or At Risk Fish Habitat (Makotukutuku Stream and all tributaries)		1791471	5405581	Department of Conservation Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Makotukutuku Stream (Washpool Creek)	F1: Threatened or At Risk Fish Habitat (Makotukutuku Stream and all tributaries)		1792072	5406381	Department of Conservation Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Makotukutuku Stream (Washpool Creek)	F1: Threatened or At Risk Fish Habitat (Makotukutuku Stream and all tributaries)		1792372	5406581	Department of Conservation Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Battery Stream tributary (MAINRIV ID 2911 and 3027)	F1: Threatened or At Risk Fish Habitat (Battery Stream and all tributaries)		1777475	5421484	NIWA	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Mukamukaiti Stream	F1: Threatened or At Risk Fish Habitat (Mukamukaiti Stream and all tributaries)		1765775	5415686	Massey University	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Mukamukaiti Stream	F1: Threatened or At Risk Fish Habitat (Mukamukaiti Stream and all tributaries)		1766075	5415286	NIWA	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Catchpool Stream	F1: Threatened or At Risk Fish Habitat (Wainuiomata River and all tributaries excluding Black Creek)		1759576	5420387	Otago University	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Wainuiomata River	F1: Threatened or At Risk Fish Habitat (Wainuiomata River and all tributaries excluding Black Creek)*		1759731	5422970	Strickland and Quarteman 2001	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Day's Bay	F1: Threatened or At Risk Fish Habitat (Days Bay Stream and all tributaries)		1759777	5428486	Unknown Institution	As for Oterei River and all tributaries	NIWA website,	Y	Y	na	na	Y	y	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
													Allibone and Gray 2018							
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Kaiwharawhara Stream	F1: Threatened or At Risk Fish Habitat (Kaiwharawhara Stream and all catchments)		1748489	5431048	Wellington Regional Council	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Owhiro Stream	F1: Threatened or At Risk Fish Habitat (Owhiro Stream and all tributaries)		1747078	5423088	Private individuals	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Owhiro Stream	F1: Threatened or At Risk Fish Habitat (Owhiro Stream and all tributaries)		1745678	5423289	NIWA	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Duck Creek (MAINRIV ID 1921 and 1781)	F1: Threatened or At Risk Fish Habitat (Duck Creek and all tributaries)		1759300	5444409	Cardno Ltd	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Ration Creek MAINRIV ID 1660, 1666, 1680 and 1686	F1: Threatened or At Risk Fish Habitat (Little Waitangi Stream and all tributaries)		1762389	5449636	Cardno Ltd	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Horokiri Stream	F1: Threatened or At Risk Fish Habitat (Horokiri Stream and all tributaries)		1763454	5452290	Cardno Ltd	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Horokiri Stream	F1: Threatened or At Risk Fish Habitat (Horokiri Stream and all tributaries)		1764080	5454485	Fish and Game Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Horokiri Stream	F1: Threatened or At Risk Fish Habitat (Horokiri Stream and all tributaries)		1764172	5455192	Boffa Miskell Ltd	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Horokiri Stream	F1: Threatened or At Risk Fish Habitat (Horokiri Stream and all tributaries)		1764316	5456134	Boffa Miskell Ltd	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Wainui Stream	F1: Threatened or At Risk Fish Habitat (Wainui Stream and all tributaries)*		1765041	5462277	Wellington Regional Council	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Wainui Stream	F1: Threatened or At Risk Fish Habitat (Wainui Stream and all tributaries)*		1765056	5462186	Wildlands	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Wainui Stream (MAINRIV ID 1167, 1074 and 1031) - Te Puna Stream	F1: Threatened or At Risk Fish Habitat (Wainui Stream and all tributaries)*		1765132	5458968	Boffa Miskell Ltd	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na

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Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Wainui Stream (MAINRIV ID 1167, 1074 and 1031) - Te Puna Stream	F1: Threatened or At Risk Fish Habitat (Wainui Stream and all tributaries)*		1765224	5459349	Boffa Miskell Ltd	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Wharemauku Stream	F1: Threatened or At Risk Fish Habitat (Wharemaku Stream and all tributaries)		1769081	5467885	Department of Conservation Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Maungakotukutuku Stream and Waikanae River	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1770181	5463185	NIWA (Old)	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Waikanae River	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1773682	5472385	NIWA (Old)	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Waikanae River and MAINRIV ID 726	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1779582	5471885	NIWA	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Waikanae River and MAINRIV ID 597	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1779782	5472585	NIWA	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Waikanae River and MAINRIV ID 597	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1779982	5472485	NIWA	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Waikanae River	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1780082	5473785	Massey University	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Mangaone Stream	F1: Threatened or At Risk Fish Habitat (Mangaone Stream and all tributaries)		1782983	5476885	Unknown Institution	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Otaki River and Pukeatua Stream	F1: Threatened or At Risk Fish Habitat (Otaki River and all tributaries)		1786383	5473985	Fish and Game Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Otaki River and Pukehinau Stream	F1: Threatened or At Risk Fish Habitat (Otaki River and all tributaries)		1786683	5476685	Fish and Game Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Waiotauru River and Otaki River	F1: Threatened or At Risk Fish Habitat (Otaki River and all tributaries)		1787783	5472884	Unknown Institution (Old)	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Waitohu Stream and MAINRIV ID 187, 179	F1: Threatened or At Risk Fish Habitat (Waitohu Stream and all tributaries)		1788483	5482785	Massey University	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na

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Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Hutt River headwaters	F1: Threatened or At Risk Fish Habitat (Te Awa Kairangi/Hutt River)*		1786202	5455037	Fish and Game Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Galaxias postvectis*	Kōkopu	Shortjaw kokopu	Nationally Vulnerable	Obligate	Orongorongo River	F1: Threatened or At Risk Fish Habitat (Orongorongo River and all tributaries)*		1772437	5432505	Fish and Game Wellington	As for Oterei River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Y	na	na	Y	y	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waipoua River	F1: Threatened or At Risk Fish Habitat (Waipoua River and all tributaries)		1824966	5462948	Perrie	Migratory fish, spend most of their lives at sea and only move into freshwater to spawn and for their juvenile life stage Lamprey lifecycle takes about 9 years to complete. Threats are migration barriers, loss of habitat, poor water quality and some activities in streams like clearing drains. Predation from some introduced freshwater fish.	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Castlepoint Stream	F1: Threatened or At Risk Fish Habitat (Castlepoint Stream and all tributaries)		1871900	5467471	Wellington Regional Council	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018							
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Whareama River	F1: Threatened or At Risk Fish Habitat (Whareama River and all tributaries)		1857693	5457471	Wellington Regional Council	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Whareama River	F1: Threatened or At Risk Fish Habitat (Whareama River and all tributaries)		1857693	5457471	Department of Conservation Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Ruamahanga River	F1: Threatened or At Risk Fish Habitat (Ruamahanga River and all tributaries above but not including Kopuaranga River)		1788976	5425882	Department of Conservation Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Lake Wairarapa	F1: Threatened or At Risk Fish Habitat (Lake Wairarapa)		1791378	5438682	Unknown Institution (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Burlings Stream	F1: Threatened or At Risk Fish Habitat (Burlings Stream and all tributaries)		1781777	5432283	Unknown Institution (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Smiths Creek	F1: Threatened or At Risk Fish Habitat (Tauherenikau River and all tributaries)		1791481	5452682	Unknown Institution (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Devil Creek	F1: Threatened or At Risk Fish Habitat (Waiohine River up to and including the Mangaterere Stream)		1801982	5457281	Department of Conservation Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na

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Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waiohine River	F1: Threatened or At Risk Fish Habitat (Waiohine River up to and including the Mangaterere Stream)		1801782	5456181	Unknown Institution	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Mangaterere Stream	F1: Threatened or At Risk Fish Habitat (Waiohine River up to and including the Mangaterere Stream)		1809983	5454980	Department of Conservation Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Mangaterere Stream	F1: Threatened or At Risk Fish Habitat (Waiohine River up to and including the Mangaterere River)		1811120	5456863	NIWA	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Mikimiki Stream (MAINRIV ID 484	F1: Threatened or At Risk Fish Habitat (Waipoua River and all tributaries)		1819787	5475482	Unknown Institution (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Kiriwhakapapa Stream (MAINRIV ID 370)	F1: Threatened or At Risk Fish Habitat (Waipoua River and all tributaries)		1818487	5478883	NIWA (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Ruamahanga River	F1: Threatened or At Risk Fish Habitat (Ruamahanga River and all tributaries above but not including Kopuaranga River)*		1819744	5485351	eDNA database - Wilderlab	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Wainuiomata River	F1: Threatened or At Risk Fish Habitat (Wainuiomata River and all tributaries excluding Black Creek)		1757375	5415688	Fish and Game Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Wainuiomata River	F1: Threatened or At Risk Fish Habitat (Wainuiomata River and all tributaries excluding Black Creek)		1766177	5429285	Massey University	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Wainuiomata River	Wainuiomata River and all tributaries excluding Black Creek		1756975	5413988	Unknown Institution (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Catchpool Stream	F1: Threatened or At Risk Fish Habitat (Wainuiomata River and all tributaries excluding Black Creek)		1761376	5420787	NIWA (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Catchpool Stream	F1: Threatened or At Risk Fish Habitat (Wainuiomata River and all tributaries excluding Black Creek)		1761076	5420587	Massey University	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Catchpool Stream	F1: Threatened or At Risk Fish Habitat (Wainuiomata River and all tributaries excluding Black Creek)		1760976	5420587	Fish and Game Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Catchpool Stream	F1: Threatened or At Risk Fish Habitat (Wainuiomata River and all tributaries excluding Black Creek)		1760076	5420087	Department of Conservation Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na

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Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Catchpool Stream	F1: Threatened or At Risk Fish Habitat (Wainuiomata River and all tributaries excluding Black Creek)		1759776	5420187	NIWA	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Butterfly Creek	F1: Threatened or At Risk Fish Habitat (Lake Kohangatera, Gollans Stream and all tributaries)		1758877	5424987	NIWA	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Hutt River	F1: Threatened or At Risk Fish Habitat (Akatarawa River and all tributaries)		1770479	5445285	NIWA	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Hutt River	F1: Threatened or At Risk Fish Habitat (Speedy's Stream and all tributaries)		1761779	5437986	Department of Conservation Northland	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Kaiwharawhara	F1: Threatened or At Risk Fish Habitat (Kaiwharawhara Stream and all catchments)*		1749825	5430845	Perrie	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Hutt River	F1: Threatened or At Risk Fish Habitat (Te Awa Kairangi/Hutt River)		1764479	5440685	Unknown Institution	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Hutt River	F1: Threatened or At Risk Fish Habitat (Te Awa Kairangi/Hutt River)*		1759219	5434469	eDNA database - Wilderlab	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Karori Stream	F1: Threatened or At Risk Fish Habitat (Karori Stream and all tributaries)		1742978	5425889	NIWA	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Makara Stream	F1: Threatened or At Risk Fish Habitat (Makara Stream and all tributaries)		1743579	5431288	NIWA	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Makara Stream	F1: Threatened or At Risk Fish Habitat (Makara Stream and all tributaries)		1743579	5431288	NIWA	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Little Waitangi Stream (MAINRIV ID 1686)	F1: Threatened or At Risk Fish Habitat (Little Waitangi Stream and all tributaries)		1761180	5448786	NIWA (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Duck Creek (MAINRIV ID 1781)	F1: Threatened or At Risk Fish Habitat (Duck Creek and all tributaries)		1759480	5447286	Department of Conservation Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Upper Duck Creek (MAINRIV ID 1921)	F1: Threatened or At Risk Fish Habitat (Duck Creek and all tributaries)		1759271	5445541	Boffa Miskell Ltd	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Upper Duck Creek (MAINRIV ID 1921)	F1: Threatened or At Risk Fish Habitat (Duck Creek and all tributaries)		1759262	5445477	Boffa Miskell Ltd	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Upper Duck Creek (MAINRIV ID 1921)	F1: Threatened or At Risk Fish Habitat (Duck Creek and all tributaries)		1759182	5446074	Boffa Miskell Ltd	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Pauatahanui Stream	F1: Threatened or At Risk Fish Habitat (Pauatahanui Stream and all tributaries)		1761180	5446786	NIWA	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Pauatahanui Stream tributary (MAINRIV ID 1867)	F1: Threatened or At Risk Fish Habitat (Pauatahanui Stream and all tributaries)		1761280	5445886	NIWA	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Pauatahanui Stream	F1: Threatened or At Risk Fish Habitat (Pauatahanui Stream and all tributaries)		1760937	5446898	Boffa Miskell Ltd	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Pauatahanui Stream	F1: Threatened or At Risk Fish Habitat (Pauatahanui Stream and all tributaries)		1760916	5446949	Boffa Miskell Ltd	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Horokiri Stream	F1: Threatened or At Risk Fish Habitat (Horokiri Stream and all tributaries)		1760180	5448986	Unknown Institution (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Horokiri Stream	F1: Threatened or At Risk Fish Habitat (Horokiri Stream and all tributaries)		1761280	5450186	Fish and Game Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Horokiri Stream	F1: Threatened or At Risk Fish Habitat (Horokiri Stream and all tributaries)		1762280	5451085	Fish and Game Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Horokiri Stream tributary (MAINRIV ID 1463)	F1: Threatened or At Risk Fish Habitat (Horokiri Stream and all tributaries)		1762480	5453585	Fish and Game Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Horokiri Stream tributary (MAINRIV ID 3332)	F1: Threatened or At Risk Fish Habitat (Horokiri Stream and all tributaries)		1762881	5456085	Fish and Game Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Horokiri Stream	F1: Threatened or At Risk Fish Habitat (Horokiri Stream and all tributaries)		1763680	5452885	Fish and Game Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Whareroa Stream	F1: Threatened or At Risk Fish Habitat (Whareroa Stream and all tributaries)		1767481	5464185	NIWA (Old)	As for Waipoua River and all tributaries	NIWA website,	Y	Not sure	Y	na	Y	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
													Allibone and Gray 2018							
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waikanae River	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1774482	5471585	Fish and Game Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waikanae River	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1773682	5472285	Fish and Game Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waikanae River	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1780082	5473785	Massey University	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waikanae River - estuary	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1768982	5473285	NIWA (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waikanae River	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1773482	5472085	NIWA (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waikanae River	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1773682	5472385	NIWA (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waikanae River	F1: Threatened or At Risk Fish Habitat (Waikanae River and all tributaries)		1773182	5472085	NIWA (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waikanae River	F1: Threatened or At Risk Fish Habitat (Waikanae River)*		1770157	5472958	eDNA database - Wilderlab	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Mangaone Stream	F1: Threatened or At Risk Fish Habitat (Mangaone Stream and all tributaries)		1779590	5481061	Tonkin and Taylor	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Mangaone Stream	F1: Threatened or At Risk Fish Habitat (Mangaone Stream and all tributaries)		1779536	5481078	Tonkin and Taylor	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Mangaone Stream	F1: Threatened or At Risk Fish Habitat (Mangaone Stream and all tributaries)		1779382	5481115	Tonkin and Taylor	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Mangaone Stream	F1: Threatened or At Risk Fish Habitat (Mangaone Stream and all tributaries)		1778955	5481476	Tonkin and Taylor	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Mangaone Stream	F1: Threatened or At Risk Fish Habitat (Mangaone Stream and all tributaries)		1779511	5481050	Tonkin and Taylor	As for Waipoua River and all tributaries	NIWA website,	Y	Not sure	Y	na	Y	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
													Allibone and Gray 2018							
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waitohu Stream (MAINRIV ID 50) - Mangapouri Stream	F1: Threatened or At Risk Fish Habitat (Waitohu Stream and all tributaries)		1780775	5487200	Royal (old obs)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waitohu Stream	F1: Threatened or At Risk Fish Habitat (Waitohu Stream and all tributaries)		1782883	5486386	Department of Conservation Wellington	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waitohu Stream	F1: Threatened or At Risk Fish Habitat (Waitohu Stream and all tributaries)		1781273	5488166	Wellington Regional Council	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Fish	*Geotria australis*	Piharau	Lamprey	Nationally Vulnerable	Obligate	Waitohu Stream	F1: Threatened or At Risk Fish Habitat (Waitohu Stream and all tributaries)		1779183	5488886	NIWA (Old)	As for Waipoua River and all tributaries	NIWA website, Allibone and Gray 2018	Y	Not sure	Y	na	Y	na	na
Invertebrate	*Hydrochorema sp. W*		Caddisfly	Nationally Endangered	Obligate	Stokes Valley stream tributary	F1: Rivers and lakes with significant indigenous ecosystems (Stokes Valley Stream and all tributaries)		1766278	5437885	NZ Trichoptera database, Jeffrey 2016 - 1 indivdual 29/1/1999	Hydrochema sp are found in stony stream and rivers on bush covered and farmland areas - they eat other stream invertebrates and are highly sensitive to water quality	NIWA website	Y	Y	N	Y	na	na	na
Invertebrate	*Hydrochorema sp. W*		Caddisfly	Nationally Endangered	Obligate	Stokes Valley stream tributary	F1: Rivers and lakes with significant indigenous ecosystems (Stokes Valley Stream and all tributaries)		1766278	5437885	NZ Trichoptera database, Jeffrey 2016 - 2 individuals 29/1/1999	Hydrochema sp are found in stony stream and rivers on bush covered and farmland areas - they eat other stream invertebrates and are highly sensitive to water quality	NIWA website	Y	Y	N	Y	na	na	na
Invertebrate	*Hydrochorema sp. W*		Caddisfly	Nationally Endangered	Obligate	Catchpool Stream tributary, near the ford	F1: Rivers and lakes with significant indigenous ecosystems (Wainuiomata River and all tributaries excluding Black Creek)		1761076	5420586	NZ Trichoptera database, Jeffrey 2016 - 2 individuals 16/12/2022	As for Stokes Valley	NIWA website	Y	Y	N	Y	na	na	na
Invertebrate	*Hydrochorema sp. W*		Caddisfly	Nationally Endangered	Obligate	Windy Point, Turakirae, Mukamukakaiti Stream outlet	F1: Rivers and lakes with significant indigenous ecosystems (Mukamukaiti Stream and all tributaries)		1765974	5415286	NZ Trichoptera database, Jeffrey 2016 - 1 individual 31/12/2003	As for Stokes Valley	NIWA website	Y	Y	N	Y	na	na	na
Invertebrate	*Xenobiosella motueka*		Caddisfly	Nationally Vulnerable	Obligate	Waiotauru River tributary, Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1785982	5470084	NZ Trichoptera database, Jeffrey 2016 - 1 individual 29/11/1997	Type locality is a swiflty flowing river in Tasman Bay (Motueka River). Given that this species is found in the Tararuas, it is probably that high water quality is a critical requirement.	Henderson 1983	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	Waiotauru Valley (River), Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1786882	5471984	NZ Trichoptera database, Jeffrey 2016 -	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes	McGuinness 2001	Y	Y	N	Y	na	na	na

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											1 individual 20/01/1999	150-700m. Assume high water quality required								
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	Waiotauru Valley (River), Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1786882	5471984	NZ Trichoptera database, Jeffrey 2016 - 3 individuals 15/12/1998	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes 150-700m. Assume high water quality required	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	Waiotauru Valley (River), Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1786882	5471984	NZ Trichoptera database, Jeffrey 2016 - 2 individuals 14/02/1998	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes 150-700m. Assume high water quality required	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	Waiotauru Valley (River), Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1786882	5471984	NZ Trichoptera database, Jeffrey 2016 - 1 individual 2/02/1998	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes 150-700m. Assume high water quality required	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	Waiotauru Valley (River), Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1786882	5471984	NZ Trichoptera database, Jeffrey 2016 - 1 individual 2/02/1998	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes 150-700m. Assume high water quality required	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	Waiotauru Valley (River), Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1786882	5471984	NZ Trichoptera database, Jeffrey 2016 - 3 individuals 15/12/1998	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes 150-700m. Assume high water quality required	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	Waiotauru River tributary, Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1785982	5470084	NZ Trichoptera database, Jeffrey 2016 - 1 individual 20/01/1999	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes 150-700m. Assume high water quality required	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	Waiotauru River tributary, Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1785982	5470084	NZ Trichoptera database, Jeffrey 2016 - 1 individual 28/12/1998	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes 150-700m. Assume high water quality required	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	Waiotauru River tributary, Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1785982	5470084	NZ Trichoptera database, Jeffrey 2016 - 1 individual 13/12/1997	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes 150-700m. Assume high water quality required	McGuinness 2001	Y	Y	N	Y	na	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	Waiotauru River tributary, Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1785982	5470084	NZ Trichoptera database, Jeffrey 2016 - 1 individual 29/11/1997	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes 150-700m. Assume high water quality required	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	Waiotauru River tributary, Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1785982	5470084	NZ Trichoptera database, Jeffrey 2016 - 1 individual 29/11/1997	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes 150-700m. Assume high water quality required	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella spinosa*		Caddisfly	Nationally Endangered	Obligate	South Whakanui Track, Rimutakas, Tributary of Turere Stream	F1: Rivers and lakes with significant indigenous ecosystems (Orongorongo River and all tributaries)		1767176	5426685	NZ Trichoptera database, Jeffrey 2016 - 1 individual 16/01/1982	Larvae known only from small, forest streams. Occurs in beech forest and has been collected between altitudes 150-700m. Assume high water quality required	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella furcata*		Caddisfly	Nationally Endangered	Obligate	Te Matawai Hut, Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1802485	5487585	NZ Trichoptera database, Jeffrey 2016 - 3 individuals 17/03/1982	Larvae only known from small, forest streams. Type locality is a very small spring-fed stream in silver beech foest and leatherwood scrub, 920m. All recent records have been from small springfed streams and seepages at lower altitides than the type locality (340 - 920m)	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella furcata*		Caddisfly	Nationally Endangered	Obligate	Te Matawai Hut, Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1802485	5487585	NZ Trichoptera database, Jeffrey 2016 - 1 individual 17/03/1982	Larvae only known from small, forest streams. Type locality is a very small spring-fed stream in silver beech foest and leatherwood scrub, 920m. All recent records have been from small springfed streams and seepages at lower altitides than the type locality (340 - 920m)	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Cryptobiosella furcata*		Caddisfly	Nationally Endangered	Obligate	Te Matawai Hut, Tararua Ranges	F1: Rivers and lakes with significant indigenous ecosystems (Otaki River and all tributaries)		1802485	5487585	NZ Trichoptera database, Jeffrey 2016 - 0 individuals 9/02/1982	Larvae only known from small, forest streams. Type locality is a very small spring-fed stream in silver beech foest and leatherwood scrub, 920m. All recent records have been from small springfed streams and seepages at lower altitides than the type locality (340 - 920m)	McGuinness 2001	Y	Y	N	Y	na	na	na
Invertebrate	*Omanuperla hollowayae*		Stonefly	Nationally Critical	Obligate	Northern Tararuas, Dundas Basin 1100m, headwaters of	F1: Rivers and lakes with significant indigenous ecosystems (Ruamahanga River and all tributaries above but not including Kopuaranga River)		1808156	5489375	Threatened Stonefly database (Stephen Pawson), Jeffry 2016 - 0	All specimens found between 940m and 1300m asl - in the subalpine and alpine zones. Tararua Range is type locality	McLellan 1991	Y	Y	N	Y	na	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
						Ruamahanga River					individuals 26/11/1984									
Invertebrate	*Omanuperla hollowayae*		Stonefly	Nationally Critical	Obligate	Northern Tararuas, Dundas Basin 1150m, headwaters of Ruamahanga River	F1: Rivers and lakes with significant indigenous ecosystems (Ruamahanga River and all tributaries above but not including Kopuaranga River)		1809286	5489385	Threatened Stonefly database (Stephen Pawson), Jeffery 2016 - 0 individuals 26/11/1984	All specimens found between 940m and 1300m asl - in the subalpine and alpine zones. Tararua Range is type locality	McLellan 1991	Y	Y	N	Y	na	na	na
Invertebrate	*Omanuperla hollowayae*		Stonefly	Nationally Critical	Obligate	Rimutaka Ranges Mt Matthews, 940m, headwaters of Orongorongo River	F1: Rivers and lakes with significant indigenous ecosystems (Orongorongo River and all tributaries)		1768675	5420585	Threatened Stonefly database (Stephen Pawson), Jeffery 2016 - 0 individuals 26/11/1986	All specimens found between 940m and 1300m asl - in the subalpine and alpine zones. Tararua Range is type locality	McLellan 1991	Y	Y	N	Y	na	na	na
Invertebrate	*Omanuperla hollowayae*		Stonefly	Nationally Critical	Obligate	Taraua Ranges, Dundas Hut, headwaters of Ruamahanga River	F1: Rivers and lakes with significant indigenous ecosystems (Ruamahanga River and all tributaries above but not including Kopuaranga River)		1808396	5489805	Threatened Stonefly database (Stephen Pawson), Jeffery 2016 - 0 individuals 26/11/1984	All specimens found between 940m and 1300m asl - in the subalpine and alpine zones. Tararua Range is type locality	McLellan 1991	Y	Y	N	Y	na	na	na
Invertebrate	*Lepidurus apus viridis*		Tadpole shrimp	Nationally Endangered	Obligate	Wairio wetland, side of Lake Wairarapa	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Eastern Lake Wairarapa)		1788514	5431046	McEwen , 2019, Wairio fish survey, Perrie, 2020 Sept	Tadpole shrimp appear to be more likely to be found in water bodies that have a high coverage of grasses, aquatic/semi-aquatic and emergent vegetation (>90% cover) compare with more open areas. Usually found in temporary ponds, rather than permanently flowing streams. Eat plant deteritus and small aquatic invertebrates	Perrie 2020, NIWA website	Y	Y	N	Y	na	na	na
Invertebrate	*Echyridella aucklandica*	Kākahi	Mussel	Nationally Vulnerable	Obligate	Lake Domain, Lake Wairarapa	Schedule A2: Lakes with outstanding indigenous ecosystem values (Lake Wairarapa)		1793504	5439899	Echyridella aucklandica spreadsheet (Bruce Marshall), Jeffery 2016 - 0 individuals 11/12/2004	Young kakahi require clean water and a substrate that's not too silty and won't clog their gills. Larvae called glochidia also need to latch onto other fish gills or fins as part of the life cycle. Host species smelt (Retropinna retropinna). Concern about the lack of juveniles.	NIWA website, Melchior et al. 2023	Y	Y	N	Y	na	na	na
Invertebrate	*Echyridella aucklandica*	Kākahi	Mussel	Nationally Vulnerable	Obligate	Lake Domain, Lake Wairarapa,	Schedule A2: Lakes with outstanding indigenous ecosystem values (Lake Wairarapa)		1793504	5439899	Echyridella aucklandica spreadsheet (Bruce Marshall), Jeffery 2016 - 15 individuals 11/12/2004	Young kakahi require clean water and a substrate that's not too silty and won't clog their gills. Larvae called glochidia also need to latch onto other fish gills or fins as part of the life cycle. Concern about the lack of juveniles	NIWA website, Melchior et al. 2023	Y	Y	N	Y	na	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Invertebrate	*Echyridella aucklandica*	Kākahi	Mussel	Nationally Vulnerable	Obligate	Lake Domain, Lake Wairarapa	Schedule A2: Lakes with outstanding indigenous ecosystem values (Lake Wairarapa)		1793502	5439806	Echyridella aucklandica spreadsheet (Bruce Marshall), Jeffery 2016 - 75 individuals 10/02/2007	Young kakahi require clean water and a substrate that's not too silty and won't clog their gills. Larvae called glochidia also need to latch onto other fish gills or fins as part of the life cycle. Concern about the lack of juveniles	NIWA website, Melchior et al. 2023	Y	Y	N	Y	na	na	na
Invertebrate	*Potamopyrgus oppidanus*		Freshwater snail	Nationally Critical	Obligate	Gully streams at Te Ahumairangi Hill in Wadestone, Wellington	Schedule F1: Rivers and lakes with significant indigenous ecosystems (Kaiwharawhara Stream and all tributaries)		1748594	5429605	Tateidae spreadsheet (Bruce Marshall), Jeffrey 2016, 30 individuals, 23/10/1975	Only known from the type locality in the stream at Te Ahumairangi Hill in Wellington. Spring-fed gully streams. Sediment runoff, cleraing of habitat and loss of habitat are threats	Haase 2008 and DOC news release	Y	Y	N	Y	na	na	na
Marine invertebrate	*Boccardiella magniovata*		Large-egged polychaete	Nationally Critical	Obligate, but brackish	0.5km upstream of Hutt estuary	Schedule F1: Rivers and lakes with significant indigenous ecosystems (Te Awa Kairangi/Hutt River)		1759311	5434119	Rod Asher (ex-Cawthron), Geoff Read (NIWA)	Brackish water, no destruction of habitat structure	Geoff Read (NIWA), pers comm 12/10/2022	Y	N	N	Y	na	na	na
presence	*Althenia bilocularis*		Aquatic herb	Nationally Vulnerable	Obligate	Lake Kohangatera	Schedule A2: Lakes with outstanding indigenous ecosystem values (Lake Kohangatera)		1756332	5419085	Enright and Hopkins , de Winton, Taumoepeau, Champion spreadsheet	Usually in shallow fresh water habitat not far from coast, lacustrine and riverine. Coastal development threat	NZPCN, Champion 2021	Y	Y	Y	Y	na	na	na
Plant	*Althenia bilocularis*		Aquatic herb	Nationally Vulnerable	Obligate	Lake Kohangapirpiri	Schedule A2: Lakes with outstanding indigenous ecosystem values (Lake Kohangapirpiri)		1755414	5419643	Wells, de Winton, Champion spreadsheet	Usually in shallow fresh water habitat not far from coast, lacustrine and riverine. Coastal development threat	NZPCN, Champion 2021	Y	Y	Y	Y	na	na	na
Plant	*Althenia bilocularis*		Aquatic herb	Nationally Vulnerable	Obligate	Lake Wairarapa	Schedule A2: Lakes with outstanding indigenous ecosystem values (Lake Wairarapa)		1788190	5435414	Mason (old), NZ virtual Herbarium	Usually in shallow fresh water habitat not far from coast, lacustrine and riverine. Coastal development threat	NZPCN, Champion 2021	Y	Y	Y	Y	na	na	na
Plant	*Althenia bilocularis*		Aquatic herb	Nationally Vulnerable	Obligate	Te Pouaruhe wetland	Schedule F3: Identified natural wetlands (Lake Onoke wetlands)		1776244	5417478	Johnson, NZ Virtual Herbarium	Usually in shallow fresh water habitat not far from coast, lacustrine and riverine. Coastal development threat	NZPCN, Champion 2021	Y	Y	Y	Y	na	na	na
Plant	*Amphibromus fluitans*		Water brome	Nationally Vulnerable	Obligate	Wairio, Lake Wairarapa	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Eastern Lake Wairarapa)		1789210	5431644	Ogle, Silbery, Champion spreadsheet and Regionally threatened plant database	Seasonally dry wetlands or edges of lakes and lagoons. Drainage, grazing (though also benefits), weeds.	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Amphibromus fluitans*		Water brome	Nationally Vulnerable	Obligate	Boggy Pond/Matthews Lagoon	Schedule F3: Identified natural wetlands (Boggy Pond/Matthews Lagoon)		1789712	5430641	Ogle, Silbery, Champion spreadsheet and Regionally threatened plant database	Seasonally dry wetlands or edges of lakes and lagoons. Drainage, grazing (though also benefits), weeds.	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Plant	*Amphibromus fluitans*		Water brome	Nationally Vulnerable	Obligate	JK Donald wetland	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Eastern Lake Wairarapa)		1793262	5436502	Ogle (old), Champion spreadsheet and Regionally threatened plant database	Seasonally dry wetlands or edges of lakes and lagoons. Drainage, grazing (though also benefits), weeds.	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Amphibromus fluitans*		Water brome	Nationally Vulnerable	Obligate	JK Donald wetland	Schedule F3: Identified natural wetlands (JK Donald/Tairoa)		1793828	5436417	Ogle, Silbery, Champion spreadsheet and Regionally threatened plant database	Seasonally dry wetlands or edges of lakes and lagoons. Drainage, grazing (though also benefits), weeds.	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Amphibromus fluitans*		Water brome	Nationally Vulnerable	Obligate	Queen Elizabeth Park Railway wetlands	Schedule F3: Identified natural wetlands (Queen Elizabeth Park Railway Wetlands)		1766343	5462469	Ogle, Regionally threatened plant database	Seasonally dry wetlands or edges of lakes and lagoons. Drainage, grazing (though also benefits), weeds.	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Amphibromus fluitans*		Water brome	Nationally Vulnerable	Obligate	Ica Station wetland	na	New map, Amp flu Ica Station	1857394	5463484	Silbery, Regionally threatened plant database	Seasonally dry wetlands or edges of lakes and lagoons. Drainage, grazing (though also benefits), weeds.	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Carex cirrhosa*		Curly sedge	Nationally Endangered	Facultative wet	Lake Domain, Lake Wairarapa	Schedule A2: Lakes with outstanding indigenous ecosystem values (Lake Wairarapa)		1792626	5440657	Silbery and Enright, Champion spreadsheet	Lake, pond margins, seasonal inundation. Weeds, changes in hydrology	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Y
Plant	*Carex cirrhosa*		Curly sedge	Nationally Endangered	Facultative wet	Lake Pounui	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Lake Pounui Wetlands)		1777339	5420847	Ogle, Champion spreadsheet	Lake, pond margins, seasonal inundation. Weeds, changes in hydrology	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Y
Plant	*Carex cirrhosa*		Curly sedge	Nationally Endangered	Facultative wet	Western Reserve, Lake Wairarapa	Schedule A3: Wetlands with outstanding indigenous biodiversity values (Lake Pounui Wetlands)		1782917	5434442	Burke (old), Leon Perrie spreadsheet	Lake, pond margins, seasonal inundation. Weeds, changes in hydrology	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Y
Plant	*Centipeda minima subsp. minima*		Sneezeweed	Nationally Endangered	Facultative wet	Raumati South Peatlands A	na	Wetlands Scientific 2021 (Raumati South Peatlands A)	1767656	5467212	Ward, iNaturalist	Wet or partially dried out lake, pond and stream margins - intolerant of any competition, so needs to be weed-free	NZPCN	Y	Not sure	Y	Y	na	na	Not sure
Plant	*Centipeda minima subsp. minima*		Sneezeweed	Nationally Endangered	Facultative wet	Boar Creek pond	na	New map, Boar Creek Reserve	1794235	5447907	Enright, iNaturalist	Wet or partially dried out lake, pond and stream margins - intolerant of any competition, so needs to be weed-free	NZPCN	Y	Not sure	Y	Y	na	na	Not sure
Plant	*Crassula peduncularis*		Purple stonecrop	Nationally Critical	Facultative wet	Cape Palliser North Fen 7	na	Wetlands Scientific 2021 (Capr Palliser North Fen 7))	1792277	5391224	Silbery, Regionally threatened plant database	Ephemeral wetlands, lake margins, damp coastal turfs. Affected by weeds, benefits from grazing	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Plant	*Crassula peduncularis*		Purple stonecrop	Nationally Critical	Facultative wet	Palliser Bay	na	New map, Cra ped 1	1792337	5391237	Enright, Regionally threatened plant database	Ephemeral wetlands, lake margins, damp coastal turfs. Affected by weeds, benefits from grazing	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Crassula peduncularis*		Purple stonecrop	Nationally Critical	Facultative wet	Te Awaiti	na	New map, Cra ped 5	1821649	5409306	Silbery, Regionally threatened plant database	Ephemeral wetlands, lake margins, damp coastal turfs. Affected by weeds, benefits from grazing	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Crassula peduncularis*		Purple stonecrop	Nationally Critical	Facultative wet	Turakirae (old)	na	New map, Cra ped 9	1758785	5413246	de Lange, Regionally threatened plant database	Ephemeral wetlands, lake margins, damp coastal turfs. Affected by weeds, benefits from grazing	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Crassula peduncularis*		Purple stonecrop	Nationally Critical	Facultative wet	Orongorongo Station	na	New map, Cra ped 8	1759621	5413228	de Lange, Champion spreadsheet	Ephemeral wetlands, lake margins, damp coastal turfs. Affected by weeds, benefits from grazing	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Crassula peduncularis*		Purple stonecrop	Nationally Critical	Facultative wet	Orongorongo Station	na	New map, Cra ped 10	1758827	5415096	de Lange, Champion spreadsheet	Ephemeral wetlands, lake margins, damp coastal turfs. Affected by weeds, benefits from grazing	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Crassula peduncularis*		Purple stonecrop	Nationally Critical	Facultative wet	Mangatoetoe Stream	na	New map, Cra ped 4	1788149	5392276	Silbery, Regionally threatened plant database	Ephemeral wetlands, lake margins, damp coastal turfs. Affected by weeds, benefits from grazing	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Crassula peduncularis*		Purple stonecrop	Nationally Critical	Facultative wet	Mangatoetoe Stream	na	New map, Cra ped 3	1788060	5392156	Enright, Regionally threatened plant database	Ephemeral wetlands, lake margins, damp coastal turfs. Affected by weeds, benefits from grazing	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Crassula peduncularis*		Purple stonecrop	Nationally Critical	Facultative wet	South of Glenburn Station	na	New map, Cra ped 7	1836702	5419126	Silbery, Regionally threatened plant database	Ephemeral wetlands, lake margins, damp coastal turfs. Affected by weeds, benefits from grazing	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Crassula peduncularis*		Purple stonecrop	Nationally Critical	Facultative wet	North of Honeycomb Rock	na	New map, Cra ped 6	1835612	5418201	Silbery, Regionally threatened plant database	Ephemeral wetlands, lake margins, damp coastal turfs. Affected by weeds, benefits from grazing	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Crassula peduncularis*		Purple stonecrop	Nationally Critical	Facultative wet	North of Oterei River	na	New map, Cra ped 11	1821579	5409125	Enright, Champion spreadsheet	Ephemeral wetlands, lake margins, damp coastal turfs. Affected by weeds, benefits from grazing	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Gratiola concinna*		Gratiola	Nationally Endangered	Facultative wet	Highden QEII covenant	na	New map, Gra con 2	1818308	5476512	Enright and Silbery, Champion spreadsheet and Regionally threatened	Sometimes aquatic at edge of shallow lakes or rivers, muddy hollows in forest. Threatened by habitat modification and wetland drainage, also invasive weeds	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Y?

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
											plant database									
Plant	*Gratiola concinna*		Gratiola	Nationally Endangered	Facultative wet	Next to Highden covenant	na	New map, Gra con 1	1818393	5467410	Enright and Silbery, Champion spreadsheet	Sometimes aquatic at edge of shallow lakes or rivers, muddy hollows in forest. Threatened by habitat modification and wetland drainage, also invasive weeds	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Y?
Plant	*Juncus pauciflorus*		Leafless rush	Nationally Vulnerable	Facultative wet	Mangaroa Swamp	na	Map of Mangaroa Swamp sent to UHCC	1775909	5445220	Healy (Old), Regionally threatened plant database	In damp ground under scrub. Development biggest threat	NZPCN, Champion 2021	Y	Not sure	Not sure	Y	na	na	Y?
Plant	*Juncus holoschoenus var holoschoenus*		Rush	Nationally Critical	Obligate	Pahaoa gorge	na	New map, Jun hol	1823569	5419677	Enright, Landcare Research Systematics Collections Data	Damp ground and hollows in light scrub, pasture, swamp margins, dune swales . Threats are weeds, eutrophication, hare browse	NZPCN, Champion 2021	Y	Y	Y	Y	na	na	Y
Plant	*Mazus novaezeelandiae subsp. impolitus*		Dwarf musk	Nationally Endangered	Facultative wet	Te Kaukau Point Seal Haulout (incorporate), Maz nov imp 2	Schedule F3: Identified natural wetlands (Te Kaukau Point Seal Haulout)		1802730	5395131	Enright and Silbery, Champion spreadsheet	Prefers coastal sites, damp hollows. Very susceptible to disturbance, habitat clearance and modification. Benefits from grazing, but too much trampling has impacts. Weed threat.	NZPCN, Champion 2021	Y	N	Y	Y	na	na	Benefits
Plant	*Mazus novaezeelandiae subsp. impolitus*		Dwarf musk	Nationally Endangered	Facultative wet	Pahaoa wetland (incorporate), Maz nov imp 4	Schedule F3: Identified natural wetlands (Pahaoa)		1827146	5413395	Enright, Champion spreadsheet	Prefers coastal sites, damp hollows. Very susceptible to disturbance, habitat clearance and modification. Benefits from grazing, but too much trampling has impacts. Weed threat.	NZPCN, Champion 2021	Y	N	Y	Y	na	na	Benefits
Plant	*Mazus novaezeelandiae subsp. impolitus*		Dwarf musk	Nationally Endangered	Facultative wet	Wetland up from Pahaoa	na	New map, Maz nov imp 6	1828803	5414180	Enright, Champion spreadsheet	Prefers coastal sites, damp hollows. Very susceptible to disturbance, habitat clearance and modification. Benefits from grazing, but too much trampling has impacts. Weed threat.	NZPCN, Champion 2021	Y	N	Y	Y	na	na	Benefits
Plant	*Mazus novaezeelandiae subsp. impolitus*		Dwarf musk	Nationally Endangered	Facultative wet	Wetland up the road from Awhea	na	New map, Maz nov imp 5	1813353	5403269	Enright, Champion spreadsheet	Prefers coastal sites, damp hollows. Very susceptible to disturbance, habitat clearance and modification. Benefits from grazing, but too much trampling has impacts. Weed threat.	NZPCN, Champion 2021	Y	N	Y	Y	na	na	Benefits

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Plant	*Mazus novaezeelandiae subsp. impolitus*		Dwarf musk	Nationally Endangered	Facultative wet	Along Pahaoa River	na	New map, Maz nov imp 3	1828803	5414180	Enright, Champion spreadsheet	Prefers coastal sites, damp hollows. Very susceptible to disturbance, habitat clearance and modification. Benefits from grazing, but too much trampling has impacts. Weed threat.	NZPCN, Champion 2021	Y	N	Y	Y	na	na	Benefits
Plant	*Mazus novaezeelandiae subsp. impolitus*		Dwarf musk	Nationally Endangered	Facultative wet	South of Pahaoa River Mouth	na	New map, Maz nov imp 7	1827117	5413275	Enright, Champion spreadsheet	Prefers coastal sites, damp hollows. Very susceptible to disturbance, habitat clearance and modification. Benefits from grazing, but too much trampling has impacts. Weed threat.	NZPCN, Champion 2021	Y	N	Y	Y	na	na	Benefits
Plant	*Pterostylis micromega*		Swamp orchid	Nationally Endangered	Obligate	Davies Swamp wetland	Schedule F3: Identified natural wetlands (Davies Swamp Wetland)		1780618	5425716	Silbery, Regionally threatened plant database	Bogs, fens and swamps. Wetland drainage, weeds, benefits from disturbance.	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Pterostylis micromega*		Swamp orchid	Nationally Endangered	Obligate	Papatahi Neville Davies wetland	Schedule F3: Identified natural wetlands (Papatahi Neville Davies)		1780207	5425543	Enright, Regionally threatened plant database	Bogs, fens and swamps. Wetland drainage, weeds, benefits from disturbance.	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Pterostylis micromega*		Swamp orchid	Nationally Endangered	Obligate	Seep on side of Ruamahanga north of Martinborough	na	New map, Pte mic	1808982	5440156	Enright, Regionally threatened plant database	Bogs, fens and swamps. Wetland drainage, weeds, benefits from disturbance.	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Plant	*Pterostylis micromega*		Swamp orchid	Nationally Endangered	Obligate	Mangaroa Swamp	na	Map of Mangaroa Swamp sent to UHCC	1773964	5443719	Enright (old), Regionally threatened plant database	Bogs, fens and swamps. Wetland drainage, weeds, benefits from disturbance.	NZPCN, Champion 2021	Y	Not sure	Y	Y	na	na	Benefits
Moss	*Fissidens berteroi*		Moss	Nationally Vulnerable	Obligate	Lake Wairarapa, Lake Domain Reserve	Schedule A2: Lakes with outstanding indigenous ecosystem values (Lake Wairarapa)		1792786	5440238	Perrie	No water quality requirement as found downstream of the Auckland zoo, water levels important as is habitat structure. Champion lists reduced water levels, eutrophication and weed competition as threats	Jessica Beever pers comm., Perrie report, Champion 2021	Y	Not sure	N	Y	na	na	na
Moss	*Fissidens berteroi*		Moss	Nationally Vulnerable	Obligate	Bridge over Barton's outflow (Lake Wairarapa)	na	New map (Waterway)	1793697	5344114	Perrie	As for Lake Wairarapa	Jessica Beever pers comm., Perrie report , Champion 2021	Y	Not sure	N	Y	na	na	na
Moss	*Fissidens berteroi*		Moss	Nationally Vulnerable	Obligate	Lake Wairarapa western side of lake near DOC reserve	na	New map (Waterway)	1783108	5434581	Perrie	As for Lake Wairarapa	Jessica Beever pers comm., Perrie report, Champion 2021	Y	Not sure	N	Y	na	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Moss	*Fissidens berteroi*		Moss	Nationally Vulnerable	Obligate	Abbotts Creek	na	New map (Waterway)	1792103	5443205	Moss 1982	As for Lake Wairarapa	Jessica Beever pers comm., Perrie report, Champion 2021	Y	Not sure	N	Y	na	na	na
Moss	*Fissidens berteroi*		Moss	Nationally Vulnerable	Obligate	Abbotts Creek	na	New map (Waterway)	1792424	5443230	Brownsey 1984	As for Lake Wairarapa	Jessica Beever pers comm., Perrie report, Champion 2021	Y	Not sure	N	Y	na	na	na
Moss	*Fissidens berteroi*		Moss	Nationally Vulnerable	Obligate	Makoura Stream	na	New map (Waterway)	1823665	5462724	Perrie	As for Lake Wairarapa	Jessica Beever pers comm., Perrie report, Champion 2021	Y	Not sure	N	Y	na	na	na
Moss	*Fissidens berteroi*		Moss	Nationally Vulnerable	Obligate	Makoura Stream	na	New map (Waterway)	1823821	5462277	Perrie	As for Lake Wairarapa	Jessica Beever pers comm., Perrie report, Champion 2021	Y	Not sure	N	Y	na	na	na
Moss	*Fissidens berteroi*		Moss	Nationally Vulnerable	Obligate	Zealandia	na	New map (Waterway)	1746409	5426999	Perrie	As for Lake Wairarapa	Jessica Beever pers comm., Perrie report, Champion 2021	Y	Not sure	N	Y	na	na	na
Moss	*Fissidens berteroi*		Moss	Nationally Vulnerable	Obligate	Kuripuni Stream	na	New map (Waterway)	1822121	5462945	Perrie	As for Lake Wairarapa	Jessica Beever pers comm., Perrie report, Champion 2021	Y	Not sure	N	Y	na	na	na
Moss	*Fissidens berteroi*		Moss	Nationally Vulnerable	Obligate	Kuripuni Stream	na	New map (Waterway)	1822960	5462458	Perrie	As for Lake Wairarapa	Jessica Beever pers comm., Perrie report, Champion 2021	Y	Not sure	N	Y	na	na	na
Bat	*Chalinolobus tuberculatus*	Pekapeka	Long-tailed bat	Nationally Critical	Facultative wet	Lowes Bush roost site	Schedule A3: Wetlands with outstanding biodiversity values (Allen/Lowes Bush)		1818232	5458332	Sustainable Wairarapa Bat Group	Roost trees present in wetland area, require freedom from disturbance and mammalian pest cotrol	O'Donnell 2000	Y	Y	Y	Y	Y	na	na
Bat	*Chalinolobus tuberculatus*	Pekapeka	Long-tailed bat	Nationally Critical	Facultative wet	All wetlands, rivers and streams within 2,000m of Lowes Bush roost site	na	Wetlands in Wetlands - Scientific 2021 that aren't in F3, Main Rivers and streams within 2 km	1818232	5458332	Sustainable Wairarapa Bat Group	Foraging habitat: Freshwater invertebrates from clean wetlands, rivers and streams within 2Km of a roosting site	O'Donnell 2000, Rockwell et al. 2017, Dekrout et al. 2014	Y	Y	Y	Y	Y	na	na

Species type	Species Name	Maori Name	Common Name	Threat Ranking	Freshwater Rating	Waterbody/Site	Schedule F1 name location	Other locations	Easting	Northing	Observation source	Critical requirements	Critical requirements reference	Water level	Water quality	Pests	Habitat disturbance	Connectivity	Riparian habitat at spawning site	Grazing
Bat	*Chalinolobus tuberculatus*	Pekapeka	Long-tailed bat	Nationally Critical	Facultative wet	All wetlands, rivers and streams within 2,000m of Mt Holdsworth roost site	na	Wetlands in Wetlands - Scientific 2021 that aren't in F3, Main Rivers and streams within 2 km	1809165	5470999	Sustainable Wairarapa Bat Group	Foraging habitat: Freshwater invertebrates from clean wetlands, rivers and streams within 2Km of a roosting site	O'Donnell 2000, Rockwell et al. 2017, Dekrout et al. 2014	Y	Y	Y	Y	Y	na	na
Bat	*Chalinolobus tuberculatus*	Pekapeka	Long-tailed bat	Nationally Critical	Facultative wet	All wetlands, rivers and streams within 2,000m of Rewa Bush roost site	na	Wetlands in Wetlands - Scientific 2021 that aren't in F3, Main Rivers and streams within 2 km	1809165	5470999	Sustainable Wairarapa Bat Group	Foraging habitat: Freshwater invertebrates from clean wetlands, rivers and streams within 2Km of a roosting site	O'Donnell 2000, Rockwell et al. 2017, Dekrout et al. 2014	Y	Y	Y	Y	Y	na	na

Appendix B

Table B1: Nationally Threatened species in the Wellington Region not selected for inclusion

Taxonomic name	Maori/Common name	NZTCS publication[1]	National threat ranking	Reason for exclusion
Deinacrida rugosa	Cook Strait giant wētā	Orthoptera 2022	Vulnerable	Terrestrial
Ornithonyssus spinosa	Mite on pekapeka /long-tailed bat	Parasitic mites and ticks (Acari) 2021	Critical	Host not a freshwater species
Alloptes (Sternalloptes) oxylobus	Mite on Tarāpunga/ red-billed gull)	Parasitic mites and ticks (Acari) 2021	Vulnerable	Host not a freshwater species
Guntheria (Derrickiella) apteryxi	Mite on kiwi-nui /North Island brown kiwi	Parasitic mites and ticks (Acari) 2021	Vulnerable	Host not a freshwater species
Ixodes jacksoni	Tick on kawau tikitiki/ spotted shag	Parasitic mites and ticks (Acari) 2021	Vulnerable	Host not a freshwater species
Dermanyssus sp.1 "North Island saddleback"	Mite on Tīeke/ North Island saddleback	Parasitic mites and ticks (Acari) 2021	Vulnerable	Host not a freshwater species
Charadrius obscurus aquilonius	Northern New Zealand dotterel	Birds 2021	Increasing	Coastal species
Chidonias albostriatus	Tarapirohe/ black-fronted tern	Birds 2021	Endangered	Marine/coastal species in region
Egretta sacra sacra	Matuku moana/ reef heron	Birds 2021	Endangered	Coastal species
Eudyamys taitensis	Koekoeā/ long-tailed cuckoo	Birds 2021	Vulnerable	Forest species
Hymenolaimus malacorhynchos	Whio/blue duck	Birds 2021	Vulnerable	Individuals have been seen in the Tararuas, but not breeding
Nestor meridionalis meridionalis	Kākā/ North Island kaka	Birds 2021	Vulnerable	Forest species
Stictocarbo punctatus	Kawau tikitiki/ spotted shag	Birds 2021	Vulnerable	Coastal species
Falco novaeseelandiae ferox	Kārearea/ bush falcon	Birds 2021	Increasing	Forest species
Oligosoma aff. *infrapunctatum* "Southern North Island"	Kupe skink	Reptiles 2021	Critical	Terrestrial
Oligosoma whitakeri	Whitaker's skink	Reptiles 2021	Endangered	Terrestrial
Prasmiola unica	Harvestman	Minor invertebrate groups 2012	Critical	Terrestrial

Taxonomic name	**Common/Maori name**	**NZTCS publication**	**National threat ranking**	**Reason for exclusion**
Cortinarius gemmeus	Agaric mushroom	Non-lichenised agarics, boletes and russuloid fungi	Vulnerable	Terrestrial: Mt Holdsworth
Inocybe amygdalina	Agaric mushroom	Non-lichenised agarics, boletes and russuloid fungi	Vulnerable	Terrestrial Wellington City
Laccaria paraphysata	Agaric mushroom	Non-lichenised agarics, boletes and russuloid fungi	Vulnerable	Terrestrial Muritai
Russula albolutescens	Russulloid mushroom	Non-lichenised agarics, boletes and russuloid fungi	Vulnerable	Terrestrial Fensham
Russula allochroa	Russuloid mushroom	Non-lichenised agarics, boletes and russuloid fungi	Vulnerable	Terrestrial Rimutaka FP, Tararua FP, Mana Island
Russula aucklandica	Russuloid mushroom	Non-lichenised agarics, boletes and russuloid fungi	Vulnerable	Terrestrial Fensham
Russula multicystidiata	Russuloid mushroom	Non-lichenised agarics, boletes and russuloid fungi	Vulnerable	Terrestrial Keith George, Mt Holdsworth
Russula vinaceocuticulata	Russuloid mushroom	Non-lichenised agarics, boletes and russuloid fungi	Vulnerable	Terrestrial Akatarawa Saddle
Dione arcuata	Red seaweed	Macroalgae 2019	Critical	Coastal
Gelidium johnstonii	Red seaweed	Macroalgae 2019	Critical	Coastal
Gigartina dilatata	Red seaweed	Macroalgae 2019	Critical	Coastal
Prasionema heeschiae	Green seaweed	Macroalgae 2019	Critical	Coastal
Gigartina sp. C	Red seaweed	Macroalgae 2019	Critical	Coastal
Prasiola sp. A	Green seaweed	Macroalgae 2019	Critical	Coastal
Prasiola novaezelandiae	Green seaweed	Macroalgae 2019	Endangered	Coastal
Orcinus orca	Orca, killer whale	Marine mammals 2019	Critical	Coastal (visit Wellington Harbour regularly)
Cladia blanchonii	Lichen	Lichens and lichenicolous fungi 2018	Vulnerable	Rocky outcrops or mossy soil
Ramalina pacifa	Lichen	Lichens and lichenicolous fungi 2018	Vulnerable	Coastal

Taxonomic name	Common/Maori name	NZTCS publication	National threat ranking	Reason for exclusion
Carcharodon carcharias	Great white shark	Chondrichthyans (chimaeras, sharks and rays) 2016	Endangered	Deep sea
Cetorhinus maximus	Basking shark	Chondrichthyans (chimaeras, sharks and rays) 2016	Vulnerable	Deep sea
Mystacina tuberculatus rhyacobia	Pekepeka/central lesser short-tailed bat	Bats 2017	Declining	Terrestrial
Orthoclydon pseudostinaria	Looper moth	Lepidoptera (butterflies and moths) 2015	Critical	Terrestrial
Notoreas peronata subsp "Castlepoint"	Pimelea moth	Lepidoptera (butterflies and moths) 2015	Critical	Terrestrial
"Schiffermuelleria" orthophanes	Looper moth	Lepidoptera (butterflies and moths) 2015	Critical	Terrestrial
Didymodon calycinus	Moss	Mosses 2014	Critical	Terrestrial
Porribus pacificus	Bat flea	Fleas 2014	Vulnerable	Terrestrial
Smeagol climoi	Gravel maggot	Marine invertebrates 2013	Critical	Marine
Spio aequalis	Giant spionid worm	Marine invertebrates 2013	Endangered	Marine
Chathamisis bayeri	Bamboo coral	Marine invertebrates 2013	Vulnerable	Deep marine
Paragorgia alisonae	Bubblegum coral	Marine invertebrates 2013	Vulnerable	Deep marine
Atriplex buchananii	Buchanan's orache	Vascular plants 2017	Vulnerable	Coastal, clay
Anogramma leptophylla	Jersey fern	Vascular plants 2017	Vulnerable	Banks
Brachyglottis pentacopa		Vascular plants 2017	Critical	Shrublands
Brachyglottis kirkii var *kirikii*	Kohurangi/ Kirk's daisy	Vascular plants 2017	Vulnerable	Epiphytic
Dactylanthus taylorii	Pua o te rēinga, wood rose	Vascular plants 2017	Vulnerable	Forest
Gastrodia cooperae	Cooper's black orchid	Vascular plants 2017	Critical	Forest
Geranium retrorsum	Turnip-rooted geranium	Vascular plants 2017	Vulnerable	Clay pans and rocky coast
Korthasella salicoriodies	Dwarf mistletoe	Vascular plants 2017	Critical	Forest and shrublands
Kunzea serotina	Makahikātoa/kanuka	Vascular plants 2017	Vulnerable	Montane, subalpine forest
Lepidium oleraceum	Nau/Cook's scurvy grass	Vascular plants 2017	Endangered	Coastal, friable soil

Taxonomic name	Common/Maori name	NZTCS publication	National threat ranking	Reason for exclusion
Leptinella nana[2]	Pygmy button daisy	Vascular plants 2017	Critical	Clifftop grassland
Muehlenbeckia astonii	Shrubby tororaro, mingimingi	Vascular plants 2017	Endangered	Grey scrub
Myosotis brevis		Vascular plants 2017	Vulnerable	Shingle habitat
Olearia gardneri[2]	Deciduous tree daisy	Vascular plants 2017	Endangered	Forests on calcareous siltstones
Pimelea aff. *aridula*		Vascular plants 2017	Endangered	Rocky habitat
Pimelea aff. *villosa*		Vascular plants 2017	Endangered	Sand dunes
Pimelea tomentosa		Vascular plants 2017	Vulnerable	Cliff tops, seral habitats
Pittosporum obcordatum[2]	Heart-leaved kohuhu	Vascular plants 2017	Vulnerable	Forest
Pterostylis irwinii	Greenhood	Vascular plants 2017	Endangered	Montane
Rorippa divaricata[2]	Matangoa, NZ watercress	Vascular plants 2017	Vulnerable	Disturbed ground
Sebaea ovata	Sebaea	Vascular plants 2017	Critical	Regionally extinct
Simplicia felix		Vascular plants 2017	Critical	Forest
Solanum aviculare var. *aviculare*	Poroporo	Vascular plants 2017	Vulnerable	Open shrubland
Urticularia australis	Yellow bladderwort	Vascular plants 2017	Critical	Regionally extinct

1: As published on https://www.doc.govt.nz/about-us/science-publications/conservation-publications/nz-threat-classification-system/

2: Species were identified as freshwater species by Champion 2021, but observation locations in the Wellington Region were not freshwater habitats

Table B2: Threatened freshwater species locations not selected for inclusion

Species	Site	Easting	Northing	Reason for exclusion
Amphibromus fluitans	Back dunes of Queen Elizabeth Park, Ogle 1989	1765488	5463114	No wetlands can be determined nearby
Amphibromus fluitans	Paddock north of Boggy Pond, Ogle 984	1792740	5432885	Paddock with no discernible wetlands
Carex cirrhosa	Paddock to west of Lake Wairarapa, Mason, Druce 1951	1784861	5436701	Paddock with no discernible wetlands
Carex cirrhosa	Forest on western side of Lake Wairarapa, Chinnock	1782650	543701	Forest
Carex cirrhosa	Paddock to west of Lake Wairarapa, Mason 1951	1784849	543612	Paddock
Carex cirrhosa	In Wairio, Braggins 1966	1788515	5431062	Co-ordinates vague
Crassula peduncularis	Paddock, Druce 1962	1789838	5391028	Co-ordinates vague
Crassula peduncularis	Paddock, Druce 1972	1764403	5439377	Paddock with no discernible wetlands
Crassula peduncularis	Pine forest de Lange and Silbery 1990	1835703	5420403	Pine forest – no discernible wetlands
Crassula peduncularis	Eastern Wairarapa Enright 2009	1821580	5409125	Point in the sea
Mazus novaezeelandiae subsp *impolitus*	Eastern Wairarapa, Enright 2010	1826689	5413013	Point in the sea
Mazus novaezeelandiae subsp *impolitus*	Near Eparaima, Heenan	1854674	5443856	Paddock
Juncus holoschoenus var *holoschoenus*	Druce, 1967	1823787	5418937	Now pine forest
Urticularia australis	Suburban area de Lange 1991	1768502	5472266	Was at Waikanae ponds, but gone now
Galaxias postvectis	Underground	170249	5425970	Uncertainty about veracity
Galaxias postvectis	Unnamed stream Sinclair Head	1741378	5421589	1975, uncertainty about veracity
Galaxias postvectis	Waipapa Stream	1744041	5420044	Not captured to ID – short catchment
Galaxias postvectis	Little Waitangi Stream	1762280	5450385	Old - 1963
Geotria australis	Kaiwhata River – WRC 2005	1871900	5467471	Co-ordinates in the sea
Species	**Site**	**Easting**	**Northing**	**Reason for exclusion**
Geotria australis	Horokiri Stream	1762880	5451885	Co-ordinates in a paddock
Geotria australis	Near Waiohine River	1806582	5451080	Co-ordinates in a paddock
Geotria australis	Waikanae	1774482	5471585	Co-ordinates in a paddock
Geotria australis	Waimeha	1769582	5473582	Not a waterbody, Unknown institution

Appendix C

Table C1: NPS-FM threatened species locations in NRP scheduled sites

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
F2c	Pahaoa Estuary and Pahaoa Scientific Reserve	Eastern Wairarapa	Waterbodies and associated vegetation	pārera/grey duck (Bird)	*Anas superciliosa*
F3	Burkhart Wetlands	Eastern Wairarapa	Waterbodies and associated vegetation	pārera/grey duck (Bird)	*Anas superciliosa*
F3	Tuturumuri Swamp C	Eastern Wairarapa	Whole wetland	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F1	Makotukutuku Stream and all tributaries	Eastern Wairarapa	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Pararaki Stream and all tributaries	Eastern Wairarapa	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Otakaha Stream and all tributaries	Eastern Wairarapa	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Waitetuna Stream and all tributaries	Eastern Wairarapa	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Whawanui River and all tributaries	Eastern Wairarapa	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Opouawe River and all tributaries	Eastern Wairarapa	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Oterei River and all tributaries	Eastern Wairarapa	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
F1	Whareama River and all tributaries	Eastern Wairarapa	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Castlepoint Stream and all tributaries	Eastern Wairarapa	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F3	Pahaoa	Eastern Wairarapa	Whole wetland	Endemic herb (Plant)	*Mazus novaezeelandiae* subsp. *impolitus*
F2c	Riversdale Beach and Motuwaireka Stream Mouth	Eastern Wairarapa	Stream mouth	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F2c	Tora Coast	Eastern Wairarapa	Stream mouth	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F2c	White Rock to Te Kaukau Point including White Rock beach and Opouawe River Mouth	Eastern Wairarapa	River mouth	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F3	Te Kaukau Point Seal Haulout	Eastern Wairarapa	Whole wetland	Endemic herb (Plant)	*Mazus novaezeelandiae* subsp. *impolitus*
F3	Queen Elizabeth Park Railway Wetlands	Kāpiti	Whole wetland	water brome (Plant)	*Amphibromus fluitans*
F2c	Otaki River mouth	Kāpiti	River mouth	ngutu-pare/wrybill (Bird)	*Anarhynchus frontalis*
F2c	Waikanae Estuary	Kāpiti	Estuary	ngutu-pare/wrybill (Bird)	*Anarhynchus frontalis*
F2c	Waitohu Stream mouth	Kāpiti	Stream mouth	ngutu-pare/wrybill (Bird)	*Anarhynchus frontalis*
F2c	Waikanae Estuary	Kāpiti	Waterbodies and associated vegetation	pāteke/brown teal (Bird)	*Anas chlorotis*
A3	Te Harakeke Swamp	Kāpiti	Waterbodies and associated vegetation	pārera/grey duck (Bird)	*Anas superciliosa*

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
F2c	Waikanae Estuary	Kāpiti	Waterbodies and associated vegetation	pārera/grey duck (Bird)	*Anas superciliosa*
A3	Waikanae River Mouth	Kāpiti	Whole river mouth area	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F2c	Waikanae Estuary	Kāpiti	Whole estuary	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F2c	Waitohu Stream mouth	Kāpiti	Whole stream mouth area	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F3	Huritini Swamp	Kāpiti	Whole wetland	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F1	Ōtaki River and all tributaries	Kāpiti	Tararua Forest Park, above 840m altitude	caddisfly (Invertebrate)	*Cryptobiosella furcata*
F1	Ōtaki River and all tributaries	Kāpiti	Taraua Forest Park, Waiotauru Valley and River tributary	caddisfly (Invertebrate)	*Cryptobiosella spinosa*
F1	Waitohu Stream and all tributaries	Kāpiti	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Ōtaki River and all tributaries	Kāpiti	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Wainui Stream and all tributaries	Kāpiti	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Mangaone Stream and all tributaries	Kāpiti	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Waikanae River and all tributaries	Kāpiti	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Wharemaukū Stream and all tributaries	Kāpiti	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
F1	Waitohu Stream and all tributaries	Kāpiti	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Mangaone Stream and all tributaries	Kāpiti	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Waikanae River and all tributaries	Kāpiti	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Whareroa Stream and all tributaries	Kāpiti	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F2c	Kāpiti Island foreshore	Kāpiti	Foreshore, shore platforms and reefs	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F2c	Otaki River mouth	Kāpiti	River mouth	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F2c	Waikanae Estuary	Kāpiti	River mouth estuary	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F2c	Waitohu Stream mouth	Kāpiti	Stream mouth estuary	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F2c	Paraparaumu Beach	Kāpiti	River mouth	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
A3	Te Hapua Wetland A	Kāpiti	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
A3	Te Harakeke Swamp	Kāpiti	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F2c	Waikanae Estuary	Kāpiti	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F3	Lake Kaitawa & Keelings Bush	Kāpiti	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F3	Otepua-Paruāuku	Kāpiti	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
F3	Queen Elizabeth Park Bush and Wetlands	Kāpiti	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F3	Waimanguru Lagoon (Forest Lake)	Kāpiti	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F3	Waimeha Lagoon, Waikanae	Kāpiti	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F1	Ōtaki River and all tributaries	Kāpiti	Taraua Forest Park, Waiotauru River tributary	caddisfly (Invertebrate)	*Xenobiosella motueka*
A3	Eastern Lake Wairarapa Wetland	Ruamāhanga	Whole wetland	water brome (Plant)	*Amphibromus fluitans*
F3	Boggy Pond/Matthews Lagoon	Ruamāhanga	Whole wetland	water brome (Plant)	*Amphibromus fluitans*
F3	JK Donald/Tairoa	Ruamāhanga	Whole wetland	water brome (Plant)	*Amphibromus fluitans*
A3	Eastern Lake Wairarapa Wetland	Ruamāhanga	Whole wetland	ngutu-pare/wrybill (Bird)	*Anarhynchus frontalis*
F2b	Lake Wairarapa	Ruamāhanga	Whole waterbody	ngutu-pare/wrybill (Bird)	*Anarhynchus frontalis*
F2c	Lake Onoke	Ruamāhanga	Whole waterbody	ngutu-pare/wrybill (Bird)	*Anarhynchus frontalis*
F2c	Riversdale Beach & Motuwaireka Stream mouth	Ruamāhanga	Stream mouth and beach foreshore	ngutu-pare/wrybill (Bird)	*Anarhynchus frontalis*
F2b	Lake Wairarapa	Ruamāhanga	Waterbodies and associated vegetation	pārera/grey duck (Bird)	*Anas superciliosa*
F3	Boggy Pond/Matthews Lagoon	Ruamāhanga	Waterbodies and associated vegetation	pārera/grey duck (Bird)	*Anas superciliosa*

NRP Schedule	**Waterbody Name**	**Whaitua**	**Location**	**Threatened species name (Māori/Common)**	**Threatened species name (Scientific)**
F3	JK Donald/Tairoa	Ruamāhanga	Waterbodies and associated vegetation	pārera/grey duck (Bird)	*Anas superciliosa*
F3	Lake Domain Reserve	Ruamāhanga	Waterbodies and associated vegetation	pārera/grey duck (Bird)	*Anas superciliosa*
F3	Pounui Lagoon	Ruamāhanga	Waterbodies and associated vegetation	pārera/grey duck (Bird)	*Anas superciliosa*
F3	Tuturumuri Swamp A	Ruamāhanga	Waterbodies and associated vegetation	pārera/grey duck (Bird)	*Anas superciliosa*
F3	Tuturumuri Swamp B	Ruamāhanga	Waterbodies and associated vegetation	pārera/grey duck (Bird)	*Anas superciliosa*
A3	Eastern Lake Wairarapa Wetland	Ruamāhanga	Whole wetland	kōtuku/white heron (Bird)	*Ardea alba modesta*
F2b	Lake Wairarapa	Ruamāhanga	Whole waterbody	kōtuku/white heron (Bird)	*Ardea alba modesta*
F3	Boggy Pond/Matthews Lagoon	Ruamāhanga	Whole wetland	kōtuku/white heron (Bird)	*Ardea alba modesta*
A3	Eastern Lake Wairarapa Wetland	Ruamāhanga	Whole wetland	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F2b	Lake Wairarapa	Ruamāhanga	Whole waterbody	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F2c	Lake Onoke	Ruamāhanga	Whole waterbody	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F3	Boggy Pond/Matthews Lagoon	Ruamāhanga	Whole wetland	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F3	JK Donald/Tairoa	Ruamāhanga	Whole wetland	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F3	Lake Domain Reserve	Ruamāhanga	Whole wetland	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F3	Pounui Lagoon	Ruamāhanga	Whole wetland	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
F3	Tauherenikau Delta	Ruamāhanga	Whole wetland	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F3	Wairongomai River Mouth	Ruamāhanga	Whole wetland	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F3	Western Alsops Bay	Ruamāhanga	Whole wetland	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
A2	Lake Wairarapa	Ruamāhanga	Edge of Lake Domain and at Western Lake Reserve	curly sedge (Plant)	*Carex cirrhosa*
A3	Lake Pounui Wetlands	Ruamāhanga	Whole wetland	curly sedge (Plant)	*Carex cirrhosa*
A3	Allen/Lowes Bush	Ruamāhanga	Whole wetland	Pekapeka/long-tailed bat (Bat)	*Chalinolobus tuberculatus*
A2	Lake Wairarapa	Ruamāhanga	Edge of Lake Domain	kākahi/freshwater mussel (Invertebrate)	*Echyridella aucklandica*
A2	Lake Wairarapa	Ruamāhanga	Edge of Lake Domain	Moss (Plant)	*Fissidens berteroi*
F1	Mukamukaiti Stream and all tributaries	Ruamāhanga	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Battery Stream and all tributaries	Ruamāhanga	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Lake Wairarapa	Ruamāhanga	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Burlings Stream and all tributaries	Ruamāhanga	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Tauherenikau River and all tributaries	Ruamāhanga	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Ruamāhanga River and all tributaries above,	Ruamāhanga	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
	but not including the Kopuaranga River				
F1	Waiohine River and all tributaries up to and including Mangaterere Stream	Ruamāhanga	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Waipoua River and all tributaries	Ruamāhanga	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Mukamukaiti Stream and all tributaries	Ruamāhanga	Mukamukaiti Stream outlet	caddisfly (Invertebrate)	*Hydrochorema* sp. W.
F2b	Lake Wairarapa	Ruamāhanga	Whole waterbody	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F2c	Lake Onoke	Ruamāhanga	Whole waterbody	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F2c	Onoke Spit Barrier	Ruamāhanga	Whole spit	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F3	Wairongomai River Mouth	Ruamāhanga	River mouth and delta	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
A3	Eastern Lake Wairarapa Wetland	Ruamāhanga	Whole wetland	tadpole shrimp (Invertebrate)	*Lepidurus apus viridis*
F1	Ruamāhanga River and all tributaries above, but not including the Kopuaranga River	Ruamāhanga	Tararua Forest Park, above 1040m	stonefly (Invertebrate)	*Omanuperia hollowaye*
A3	Eastern Lake Wairarapa Wetland	Ruamāhanga	Whole wetland	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
A3	Lake Pounui Wetlands	Ruamāhanga	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
F2b	Lake Wairarapa	Ruamāhanga	Waterbody and wetlands	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F2c	Lake Onoke	Ruamāhanga	Waterbody and wetlands	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F3	Boggy Pond/Matthews Lagoon	Ruamāhanga	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F3	JK Donald/Tairoa	Ruamāhanga	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F3	Lake Domain Reserve	Ruamāhanga	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F3	Pounui Lagoon	Ruamāhanga	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F3	Davies Swamp	Ruamāhanga	Whole wetland	swamp orchid (Plant)	*Pterostylis micromega*
F3	Papatahi Neville Davies	Ruamāhanga	Whole wetland	swamp orchid (Plant)	*Pterostylis micromega*
F2c	Te Awarua-o- Porirua Harbour – Onepoto Arm	Te Awarua-o-Porirua	Whole waterbody and wetlands	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F2c	Te Awarua-o- Porirua Harbour – Pauatahanui Arm	Te Awarua-o-Porirua	Whole waterbody and wetlands	matuku-hūrepo/Australasian bittern (Bird)	*Botaurus poiciloptilus*
F1	Horokiri Stream and all tributaries	Te Awarua-o-Porirua	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Little Waitangi Stream and all tributaries	Te Awarua-o-Porirua	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Duck Creek Stream and all tributaries	Te Awarua-o-Porirua	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
F1	Horokiri Stream and all tributaries	Te Awarua-o-Porirua	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Little Waitangi Stream and all tributaries	Te Awarua-o-Porirua	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Pauatahanui Stream and all tributaries	Te Awarua-o-Porirua	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Duck Creek Stream and all tributaries	Te Awarua-o-Porirua	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F2c	Te Awarua-o- Porirua Harbour – Onepoto Arm	Te Awarua-o-Porirua	Harbour - Onepoto Arm	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F2c	Te Awarua-o- Porirua Harbour – Pauatahanui Arm	Te Awarua-o-Porirua	Harbour - Pauatahanui Arm	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
A2	Lake Kohangapiripiri	Te Whanganui-a-Tara	Whole waterbody	Aquatic herb (Plant)	*Althenia bilocularis*
A2	Lake Kohangatera	Te Whanganui-a-Tara	Whole waterbody	Aquatic herb (Plant)	*Althenia bilocularis*
F2c	Wellington Harbour (Port Nicholson) foreshore; western shore of Te Awa Kairangi/Hutt River mouth to Petone Beach rowing club	Te Whanganui-a-Tara	Foreshore and river mouth	ngutu-pare/wrybill (Bird)	*Anarhynchus frontalis*

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
F2	Te Awa Kairangi/Hutt River (mouth to 1.3km upstream)	Te Whanganui-a-Tara	River mouth/estuary	kōtuku/white heron (Bird)	*Ardea alba modesta*
F1	Te Awa Kairangi/Hutt River, and all tributaries above and including the Pākuratahi River	Te Whanganui-a-Tara	Hutt River 0.5km upstream of Hutt estuary	Large-egged polychaete (Invertebrate)	*Boccardiella magniovata*
F1	Orongorongo River and all tributaries	Te Whanganui-a-Tara	Remutaka Forest Park, above 660m altitude	caddisfly (Invertebrate)	*Cryptobiosella spinosa*
F1	Ōwhiro Stream and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Kaiwharawhara Stream and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Te Awa Kairangi/Hutt River, and all tributaries above and including the Pākuratahi River	Te Whanganui-a-Tara	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Days Bay Stream and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Wainuiomata River and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Orongorongo River and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	kōkopu/shortjaw kokopu (Fish)	*Galaxias postvectis*
F1	Makara Stream and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
F1	Karori Stream and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Kaiwharawhara Stream and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Te Awa Kairangi/Hutt River, and all tributaries above and including the Pākuratahi River	Te Whanganui-a-Tara	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Akatarawa River and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Lake Kohangatera, Gollans Stream and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Wainuiomata River and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Speedy's Stream and all tributaries	Te Whanganui-a-Tara	Relevant habitat and fish passage	piharau/lamprey (Fish)	*Geotria australis*
F1	Stokes Valley Stream and all tributaries	Te Whanganui-a-Tara	Stokes Valley Stream, above 120m altitude	caddisfly (Invertebrate)	*Hydrochorema* sp. W.
F1	Wainuiomata River and all tributaries	Te Whanganui-a-Tara	Remutaka Forest Park, Catchpool tributary	caddisfly (Invertebrate)	*Hydrochorema* sp. W.
F2c	Wellington Harbour (Port Nicholson foreshore); Pencarrow	Te Whanganui-a-Tara	Foreshore	taranui/Caspian tern (Bird)	*Hydroprogne caspia*

NRP Schedule	Waterbody Name	Whaitua	Location	Threatened species name (Māori/Common)	Threatened species name (Scientific)
	sewer outfall to Burdan's Gate				
F2c	Baring Head/ Ōrua-pouanui coastline, including the Wainuiomata River Estuary (Baring Head/Ōrua- pouanui, Wainuiomata River mouth and foreshore)	Te Whanganui-a-Tara	Coastline, river mouth and foreshore	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F2c	Makara Estuary	Te Whanganui-a-Tara	Foreshore and estuary	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F2c	Wellington Harbour (Port Nicholson) – inland waters	Te Whanganui-a-Tara	Coastal marine area	taranui/Caspian tern (Bird)	*Hydroprogne caspia*
F1	Orongorongo River and all tributaries	Te Whanganui-a-Tara	Remutaka Forest Park, above 640m	stonefly (Invertebrate)	*Omanuperia hollowayae*
F2b	Parangarahu Lakes, Lake Kohangapiripiri and Lake Kohangatera (including adjacent wetlands)	Te Whanganui-a-Tara	Waterbodies and associated vegetation	weweia/New Zealand dabchick (Bird)	*Poliocephalus rufopectus*
F1	Kaiwharawhara Stream and all tributaries	Te Whanganui-a-Tara	Gully streams on Te Ahumairangi Hill, Wadestown	freshwater snail (Invertebrate)	*Potamopyrgus oppidanus*

Table C2: Identified NPS-FM threatened species locations not in NRP scheduled sites

Maori/common name	Scientific name	Location	Maps	Easting	Northing
Pateke/brown teal	*Anas chlorotis*	Zealandia dam	Karori Dam, Karori Reservoir[1]	1746493	5427069
Water brome	*Amphibromus fluitans*	Ica Station wetland	Amp flu Ica Station[2]	1857394	5463484
Sneezeweed	*Centipeda minima subsp. minima*	Raumati South Peatlands A wetland	Raumati South Peatlands A[1]	1767656	5467212
Sneezeweed	*Centipeda minima subsp. minima*	Boar Creek Reserve	New map	1794235	5447907
Purple stonecrop	*Crassula peduncularis*	Cape Palliser North wetland	Cape Palliser North Fen 7[1]	1792277	5391224
Purple stonecrop	*Crassula peduncularis*	Palliser Bay wetland	Cra ped 1[2]	1792337	5391237
Purple stonecrop	*Crassula peduncularis*	Te Awaiti wetland	Cra ped 5[2]	1821649	5409306
Purple stonecrop	*Crassula peduncularis*	Turakirae wetland	Cra ped 9[2]	1758785	5413246
Purple stonecrop	*Crassula peduncularis*	Orongorongo Station wetland	Cra ped 8[2]	1759621	5413228
Purple stonecrop	*Crassula peduncularis*	Orongorongo Station	Cra ped 10[2]	1758827	5415096
Purple stonecrop	*Crassula peduncularis*	Mangatoetoe Stream	Cra ped 4[2]	1788149	5392276
Maori/common name	**Scientific name**	**Location**	**Maps**	**Easting**	**Northing**
Purple stonecrop	*Crassula peduncularis*	Mangatoetoe Stream	Cra ped 3[2]	1788060	5392156

Purple stonecrop	*Crassula peduncularis*	South of Glenburn Station	Cra ped 7[2]	1836702	5419126
Purple stonecrop	*Crassula peduncularis*	North of Honeycomb Rock	Cra ped 6[2]	1835612	5418201
Purple stonecrop	*Crassula peduncularis*	North of Oterei River	Cra ped 11[2]	1821579	5409125
	Gratiola concinna	Highden QEII covenant wetland	Gra con 2[2]	1818308	5476512
	Gratiola concinna	Next to Highden Covenant	Gra con 1[2]	1818393	5467410
Leafless rush	*Juncus pauciflorus*	Mangaroa Swamp	Mangaroa Swamp map sent to UHCC[3]	1775909	5445220
Dwarf musk	*Juncus holoschoenus var holoschoenus*	Pahaoa gorge	Jun hol[2]	1823569	5419677
Dwarf musk	*Mazus novaezeelandiae* subsp. *impolitus*	Wetland up from Pahaoa	Maz nov imp 6[2]	1828803	5414180
Dwarf musk	*Mazus novaezeelandiae* subsp. *impolitus*	Wetland north of Awhea	Maz nov imp 5[2]	1813353	5403269
Dwarf musk	*Mazus novaezeelandiae* subsp. *impolitus*	Along Pahaoa River	Maz nov imp 3[2]	1828803	5414180
Dwarf musk	*Mazus novaezeelandiae* subsp. *impolitus*	South of Pahaoa River Mouth	Maz nov imp 7[2]	1827117	5413275
Swamp orchid	*Pterostylis micromega*	Ruamahanga north of Martinborough	Pte mic[2]	1808982	5440156
Maori/common name	**Scientific name**	**Location**	**Maps**	**Easting**	**Northing**
Swamp orchid	*Pterostylis micromega*	Mangaroa Swamp	Mangaroa Swamp map	1773964	5443719

			sent to UHCC[3]		
Moss	*Fissidens berteroi*	Bridge over Barton's outflow (Lake Wairarapa)	New waterway map	1793697	5344114
Moss	*Fissidens berteroi*	Western side of lake near DOC reserve	New waterway map	1783108	5434581
Moss	*Fissidens berteroi*	Abbotts Creek	New waterway map	1792103	5443205
Moss	*Fissidens berteroi*	Makoura Stream	New waterway map	1823665	5462724
Moss	*Fissidens berteroi*	Zealandia	New waterway map	1746409	5426999
Moss	*Fissidens berteroi*	Kurupuni Stream	New waterway map	1822960	5462458

1: Wetlands Scientific GIS layer 2021
2: J:\TERRESTRIAL BIODIVERSITY (new)\Conservation planning\Species distributions\Plants\Threatened species
3: J:\TERRESTRIAL BIODIVERSITY (new)\Assessments and advice\Wetland Delineations

Subject:	**Erosion Risk Mapping for Te-Awarua-o-Porirua and Te-Whanganui-a-Tara**

Attention:	Barry Loe
From:	Stu Easton, Tom Nation, James Blyth
Date	11th August 2023
Copies to:	Gerard Willis, Dougall Gordon, Jamie Peryer

1 Introduction

Collaborations have developed spatial erosion risk layers to support Greater Wellington Regional Council's (GWRC) Plan Change 1 (PC1) and implementation of Te-Awarua-o-Porirua and Te-Whanganui-a-Tara Whaitua Implementation Plans (WIPs). The layers are designed to map erosion risk and enable prioritisation of sediment mitigations to achieve target sediment load reductions. This technical memorandum documents the erosion risk layer development methodology and briefly summarises the results.

1.1 Background

Erosion risk mapping, focussed on hillslope erosion (surficial erosion and shallow landslides), was originally carried out by Collaborations to support the GWRC land management team to identify erosion Critical Source Areas (CSAs) in the Takapu and Pouewe part Freshwater Management Units (part-FMUs) (Collaborations, 2023a)[1]. This mapping was then updated and assessed for its relevance and applications to potential PC1 policies (Collaborations, 2023b)[2].

At the request of GWRC, the erosion risk mapping has been expanded to cover all of Te-Awarua-o-Porirua (TAoP) and Te-Whanganui-a-Tara (TWT) Whaitua FMUs and processed to map:

1. The 'highest-risk' land currently in pasture defined as the most erodible 10% by area, and 'high risk' land in pasture defined as the most erodible 30% by area, within each Whaitua.
2. The 'highest-risk' land currently in forestry, defined as the most erodible 10% by area within each Whaitua.

[1] Collaborations, 2023. Sediment Reduction Implementation Plan for Pouewe and Takapu – Deliverable 1. Prepared for Greater Wellington Regional Council. 06 April 2023.
[2] Collaborations, 2023. Erosion Risk Mapping for Plan Change 1 – Takapū and Pouewe Rural Property Analysis. Prepared for Greater Wellington Regional Council. 31 May 2023.

This has necessitated some changes in the erosion risk mapping from the previous two technical memos to meet the project aims, namely:

- Analysis at 5-metre resolution (rather than 1-metre resolution),
- Spatial consideration of rainfall erosivity,
- Fundamental Soil Layer (FSL) information used to fill gaps in S-map coverage, and
- Combination of landslide and surficial erosion risk to produce a single hillslope erosion risk layer.

The erosion risk mapping methodology is described in Section 2. Results are presented in Section 3 and discussed alongside limitations in Section 4. A3 Whaitua erosion risk maps and summary tables are included in the Appendices.

2 Methodology

The erosion risk mapping methodology follows that established for the dSedNet sediment modelling for the Porirua Whaitua (Jacobs, 2019), modified and updated with more recent approaches and datasets to spatially identify erosion risk.

The three primary erosion types identified in the project catchments are surficial erosion, shallow landslides, and streambank erosion. Collectively, shallow landslides and surficial erosion are termed hillslope erosion which is predicted to account for the majority of sediment loading in the two Whaitua and is the focus of the erosion risk maps.

Methods for risk layer development for each erosion type are outlined in the following sub-sections.

2.1 Hillslope erosion risk

Hillslope erosion risk accounts for surficial and shallow landslide risk in a combined layer. This approach has been undertaken to provide a single risk layer that is easier to understand and disseminate than two separate layers. An aggregated hillslope risk layer also provides flexibility of mitigation options for potential treatment, i.e. retirement, pole planting, or sediment bunds will all reduce sediment losses from the mapped risk area to varying degrees. By contrast, consideration of surficial and landslide erosion processes separately necessitates separate consideration of mitigations, e.g. pole planting at typical densities is generally assumed to reduce landslide risk but not surficial erosion rates.

2.1.1 Surficial erosion

A 5-metre resolution Revised Universal Soil Loss Equation (RUSLE) model has been developed spatially (in GIS) to predict surficial erosion vulnerability and loads. The RUSLE (Renard et al. 1997) predicts surficial erosion according to:

$$\boldsymbol{E} = \boldsymbol{R} \times \boldsymbol{K} \times \boldsymbol{LS} \times \boldsymbol{C} \times \boldsymbol{P}$$

Equation 1

Where: $\boldsymbol{E}$ is the soil erosion per unit area (t ha^{-1} year^{-1});
$\boldsymbol{R}$ is the rainfall erosivity (MJ mm ha $^{-1}$ h^{-1} year^{-1});
$\boldsymbol{K}$ is the soil erodibility (t ha h ha^{-1} MJ^{-1} mm^{-1});
$\boldsymbol{LS}$ is the slope length and steepness factor (dimensionless);
$\boldsymbol{C}$ is the cover management factor (dimensionless); and
$\boldsymbol{P}$ is the practice factor (conservation measures) (dimensionless).

The R, K, LS, and C factors have been calculated as spatial grids based on the methodologies in the following subsections. The P factor is related to farm management practices (contouring, terracing etc.) and is assumed to be equal to 1.

2.1.1.1 R factor

We have adopted an R factor based on mean annual rainfall following Dymond at al. (2016). Mean annual rainfall has been taken from the New Zealand Environmental Data Stack spatial mean annual rainfall layer (McCarthy et al., 2021)[3].

2.1.1.2 K factor

Following Dymond (2010), and consistent with the previous dSedNet modelling, the K-factor has been differentiated based on soil texture:

- Sand: 0.05
- Silt: 0.35
- Clay: 0.20
- Loam: 0.25

The K-factor values above have been applied to the Smap spatial layer (2022 update) provided by GWRC. Where Smap did not have coverage the New Zealand Fundamental Soils Layer (FSL) was used. In areas where neither Smap nor the FSL had coverage, loam was assumed. Following Renard et al. (1997), the K factor values above have been converted to SI units (multiplied by 0.1317).

2.1.1.3 LS factor

The LS factor encompasses the slope length (L) and slope steepness (S) factors. We have adopted the spatial approach of Moore & Burch (1986) and Moore & Wilson (1992) which accounts for flow accumulation within the landscape:

$$\boldsymbol{LS} = \left(\frac{\boldsymbol{A_S}}{\mathbf{22.13}}\right)^{\mathbf{0.4}} \times \left(\frac{\sin\boldsymbol{\theta}}{\mathbf{0.0896}}\right)^{\mathbf{1.3}}$$

Equation 2

Where: $\boldsymbol{LS}$ is the combined length and slope factors,

[3] https://datastore.landcareresearch.co.nz/ne/dataset/nzenvds

A_s is the specific catchment area,
θ is the slope angle.

The LS factor has been calculated using a 5-m resolution DEM derived from the Wellington Region LiDAR data[4].

2.1.1.4 C factor

C factor values have been adapted from SedNetNZ, which applies the following (Dymond et al. 2016):

- 0.005 for plantation forest, native forest, and scrub;
- 0.01 for pasture and urban areas;
- 1.0 for bare earth.

The C factor values above have been mapped to the Land Cover Database (LCDB) version 5.0[5] (mapped summer 2018/19).

2.1.2 Landslide erosion

Landslides are thought to be a significant contributor to sediment loading in Te-Awarua-o-Porirua and Te-Whanganui-a-Tara Whaitua, however they are difficult to predict and highly variable (spatially and temporally). Work in New Zealand shows that landslides are generally confined to steep slopes greater than 26 degrees (DeRose 2013; Dymond et al. 2016), and the highest number of landslides per area occur in pastureland (Glade, 1998). It is recognised that geology is an important risk-factor for shallow landslides however project timelines have precluded explicit consideration of underlying rock-type.

We have followed the previous approach used for the Porirua Whaitua dSedNet modelling to define at-risk hillsides as steep land (>26 degrees) without woody vegetation cover, mapped using a 5-m resolution DEM derived from the Wellington region LiDAR information and the LCDB (High- and Low-producing grassland categories).

2.1.3 Hillslope risk aggregation

Hillslope erosion risk has been estimated as an intersection of the developed surficial and landslide erosion risk layers. Risk categories are based on area-quantiles calculated from the modelled surficial erosion loss rates: ‘Highest risk’ is the most erodible 10%, ‘Very high risk’ is the most erodible 20%, and ‘High risk’ is the most erodible 30%. By definition, ‘High risk' includes all ‘Very high risk’ and ‘Highest risk’ land, and ‘Very high risk’ includes all ‘Highest risk’ land.

[4] https://data.linz.govt.nz/layer/53621-wellington-lidar-1m-dem-2013-2014/
[5] https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/

For example, the highest risk pastoral land is calculated as the 10% of pasture area with the highest surficial erosion loss rates, that is also at risk of landslides (on slopes above 26°). Processing to calculate quantiles and map erosion risk has been carried out in ArcGIS Pro[6].

2.1.3.1 Pasture Erosion Risk

Pasture erosion risk has been calculated for each Whaitua within the area defined by the LCDB as "High-producing grassland" and "Low-producing grassland". Risk quantiles were calculated first, then any pixels not at risk of shallow landslides removed.

2.1.3.2 Forestry Erosion Risk

Forestry erosion risk is based on potential erosion risk on land currently in forestry should that land be converted to pasture. Forestry area is derived from the LCDB categorisation of "Exotic Forest" and "Forest – Harvested". The layer does not account for the harvest status or tree-age profile of forestry land, nor does it account for or attempt to model forestry harvest or harvest activities. As for pasture, risk quantiles were calculated first, then any pixels not at risk of shallow landslides removed.

2.2 Streambank erosion

In the Porirua Whaitua dSednet modelling, Streambank erosion rates were calibrated to annual loads as estimated following the methodology in Dymond et al. (2016), largely relying on default values due to a lack of local information. The approach developed in Dymond et al. (2016) has since been updated and refined in Smith & Betts (2021). The published spatial index of streambank erosion susceptibility[7] has been summarised for the project catchments to identify the most erodible stream reaches.

The streambank erosion susceptibility index is based on stream power, channel sinuosity, soil erodibility, valley confinement, and proportional extent of riparian vegetation. The index is linked to the River Environments Classification (REC) version 2.5, with other data inputs estimated from measured relationships in NZ and national scale datasets such as the Fundamental Soils Layer, National 15m DEM, and EcoSat Woody.

We have summarised the streambank erosion susceptibility index within each FMU and part-FMU to rank each REC reach from most to least susceptible.

3 Results

A map series showing the erosion risk layers for each Whaitua is included in Appendix B. Additional outputs have been provided to GWRC separate to this technical memo:

- Summary statistics of pasture and forestry hillslope erosion risk.

[6] ArcGIS Pro Version 3.1.1. ESRI Inc.
[7] https://data.mfe.govt.nz/layer/105771-streambank-erosion-susceptibility-index/

- Map series' summarising pasture and forestry hillslope erosion risk.
- Spatial layers of pasture and forestry hillslope erosion risk.

The following subsections briefly describe and summarise the developed layers.

3.1 Hillslope Erosion risk

3.1.1 Surficial erosion risk

A 5-metre scale raster layer estimating annual surficial erosion rate (t/ha/year) has been produced, which may be visualised and summarised in various ways to identify CSAs at different scales or areas of interest. Figure 1 shows the 'raw' surficial erosion rate raster. In general, topography is the largest contributing factor to high erosion rates. The steep slopes and high rainfall in the Tararua and Remutaka ranges contribute to high predicted erosion rates even with extensive native woody vegetation cover. Elsewhere, high erosion rates are predicted for pastoral land in the Pouewe and Parangarehu part-FMUs.

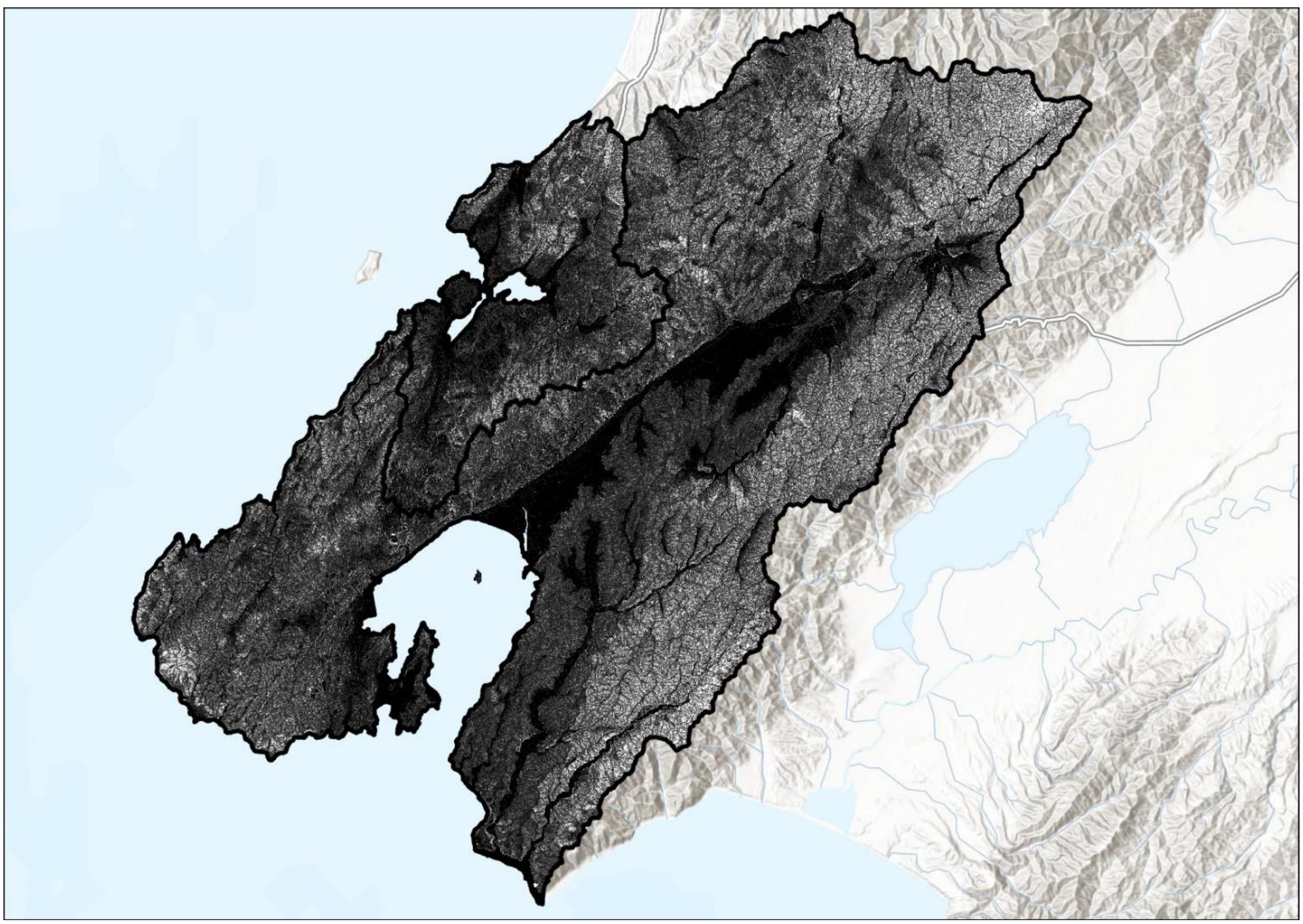


Figure 1 RUSLE modelled surficial erosion layer. Relative surficial erosion rate is visualised from low (black) to high (white).

3.1.2 Landslide erosion risk

As for surficial erosion, a 5-metre scale raster layer of landslide erosion susceptibility has been produced (Figure 2). The landslide erosion risk areas show a high degree of overlap with surficial erosion CSAs across steep pasture land as both methodologies are influenced by slope angle and land cover.

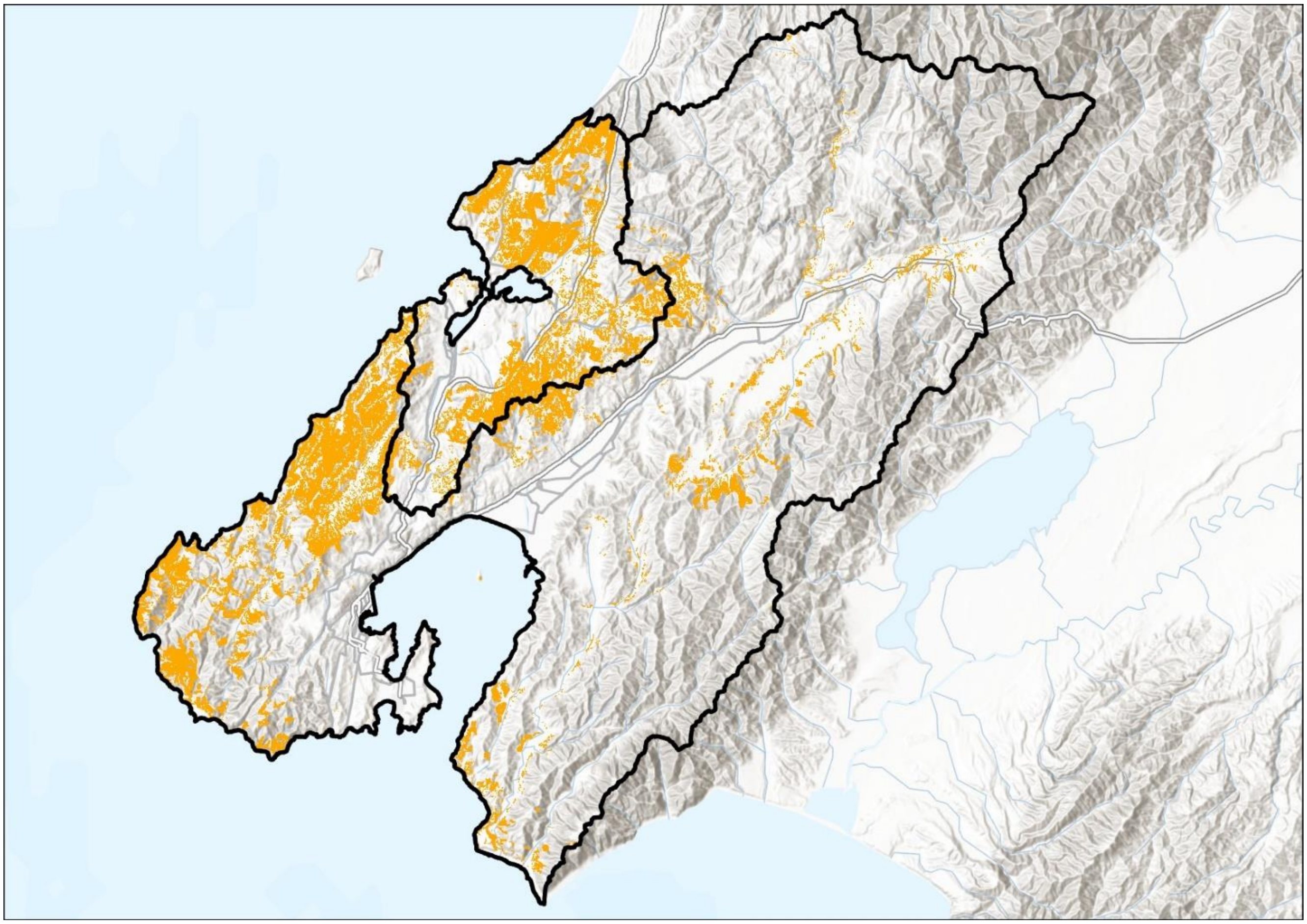


Figure 2 Landslide risk extent in yellow

3.1.3 Combined hillslope erosion risk

The hillslope erosion risk (combined surficial and landslide risk) is mapped in Appendix B. Table 1 and Table 2 summarise the risk areas for Pasture and Forestry for each Whaitua, respectively. Table 3 and Table 4 in Appendix A summarise the risk areas for Pasture and Forestry at the part-FMU scale. The highest risk areas are predicted to be in the Parangarehu (TWT) and Pouewe (TAoP) part-FMUs, which each account for more than half of the mapped hillslope risk area in their respective Whaitua.

In general, high surficial erosion risk and shallow-landslide risk are spatially correlated on pastoral land. However in some places high surficial erosion rates are estimated for pixels that are not deemed to be at risk of land sliding, for example where there is high flow accumulation at the base of gullies. These pixels are precluded from the hillslope erosion risk layer which is why the risk mapping summary tables cover an area slightly smaller than the areal quantile value (e.g. 8% of pasture is in the 'highest' risk category instead of 10%).

Table 1 Hillslope erosion risk - Pasture

Area	Statistic	Te Awarua-o-Porirua	Te Whanganui-a-Tara
FMU	Area (ha)	20,121	116,007
	Area in Pasture	8,562	16,973
High risk - Pasture	Area (ha)	1,771	3,385
	Proportion of Pasture in FMU	21%	20%
Very high risk - Pasture	Area (ha)	1,252	2,468
	Proportion of Pasture in FMU	15%	15%
Highest risk - Pasture	Area (ha)	646	1,325
	Proportion of Pasture in FMU	8%	8%

Table 2 Hillslope erosion risk - Forestry

Area	Statistic	Te Awarua-o-Porirua	Te Whanganui-a-Tara
FMU	Area (ha)	20,121	116,007
	Area in Forestry (ha)	2,733	9,138
Highest risk - Forestry	Area (ha)	220	771
	Proportion of Forestry in FMU	8%	8%

3.2 Streambank erosion risk

Streambank erosion risk was ranked by the erosion susceptibility index and is included in the erosion risk maps in Appendix B. Stream lengths predicted to be the most erodible are generally found in the lower reaches of the largest catchments in each Whaitua (e.g. Hutt River and Porirua stream), likely due to the influence of high flow rates, lack of riparian vegetation, and reduced valley confinement.

4 Discussion and limitations

4.1 Erosion risk layers

4.1.1 Hillslope erosion

The hillslope erosion risk layer is based on the RUSLE modelled surficial erosion rate, intersected with the landslide risk layer. The risk layer accounts for erosion risk factors including land cover, slope steepness, flow accumulation, soil type, and rainfall, and allows for spatial targeting of mitigations at multiple scales (e.g. paddock, property, and catchment). The layer development methodology improves on previous methods by using updated input data such as LiDAR, Smap, and the latest LCDB information. Visual analysis indicates a good agreement with national scale erosion layers (e.g. NZEEM), with improvements in resolution and detail.

The methodology to identify landslide risk is simple in comparison to the multi-factor methods for surficial and streambank erosion due to the lack of local information and general difficulty in predicting landslides. Improvements may be made by accounting for underlying geology in the risk layer, or by mapping active landslides (e.g. through imagery classification methods) to build risk-associations with other factors, such as slope aspect and soil attributes. Due to its simplicity, we expect that the landslide risk layer is relatively conservative, that is it predicts an area larger than if additional risk-factors were included.

Further improvements to the hillslope risk layers may be made by using aerial or satellite imagery to map land cover more precisely, in particular small pockets of vegetation and areas of bare earth not captured in the LCDB. Other limitations of the methodology are the lack of explicit consideration of sediment loading from forestry harvest and harvest activities, or accounting for currently- implemented erosion control measures such as pole planting on erodible pasture.

4.1.2 Streambank erosion

In general, streambank erosion risk is predicted to be highest where flows are highest correlating with the largest catchments within each FMU (Hutt river and Porirua stream) and the lower reaches within each catchment (i.e. higher-order streams). There are several limitations associated with the streambank erosion susceptibility index which should be considered when using the mapped streambank CSAs to target mitigations. In particular, riparian fencing is not accounted for in the index, and the extent of riparian vegetation is based on the EcoSat Woody land use classification[8], which is approximately 20 years old and relatively coarse (15m resolution). Further mapping of current riparian fencing and established riparian vegetation will allow GWRC to preclude some identified high-risk reaches and better target streambank erosion mitigations. Furthermore, the application of the index to lower order streams is uncertain due to a lack of calibration information, resulting in low index values due to lower estimated flow and greater levels of valley confinement. Further limitations of the layer are outlined in Smith & Betts (2021).

4.2 Mitigations

It is expected that PC1 will require sediment mitigations on the identified erosion risk areas. Appropriate mitigation type and extent will vary depending on physical factors such as slope, aspect, site access and pest-control, and non-physical factors such as cost and landowner cooperation. The produced maps are intended to guide general mitigation placement but do not preclude site specific assessment.

For surficial erosion, mitigations may include directly targeting erodible terrain through measures such as land use change or intercepting eroded sediment before reaching waterways through measures such as wetland or bund construction. For landslides, mitigations are generally limited to those that can stabilise slopes (e.g. re-vegetation or pole planting). Streambank erosion mitigations are likely to include fencing and revegetation, with possible bank engineering works. Mitigations targeting hillslope

[8] https://lris.scinfo.org.nz/layer/48183-ecosat-woody-north-island/

erosion such as retirement or re-vegetation will also reduce streambank erosion risk as the establishment of woody vegetation (once mature) will reduce runoff rates. Within the mapped risk areas, site specific assessment is likely to be necessary to inform mitigation choice and placement – for example bund placement on flow paths or pole planting on steeper slopes.

4.3 Limitations

The erosion risk layers are designed to spatially identify erosion risk and enable prioritisation of sediment mitigations to achieve target sediment load reductions. There are several assumptions and limitations associated with the layers:

- The accuracy of the risk layers relies on various information sources and data sets, each with their own sources of error. Any error in those data sets will also be present in the erosion risk layers. For example, the LCDB land use mapping does not identify small pockets of vegetation or open earth that may influence local erosion risk.
- The risk layers are based on surficial erosion rate, intersected with the landslide risk layer. There remain erosion risks outside of the mapped at-risk areas (for example, where surficial erosion rates are high, but not deemed to be at-risk of landslides). The layers do not purport to map all sources of sediment within the project area. The risk area quantiles (i.e. highest risk, very high risk, and high risk) represent relative risk and have been calculated at the FMU scale. They may need to be re-assessed for risk area mapping at part-FMU or sub-catchment scales, particularly when considering implementation at a smaller scale.
- Erosion risk maps do not account for sediment delivery processes such as interception or deposition or assess connectivity to the stream network.
- Earthworks, forestry harvest, or other land-disturbing activities are not considered. Similarly, already-implemented erosion control measures such as established pole planting or sediment retention bunds are not accounted for in the current iteration of the risk layers.
- The mapped risk areas should not be used exclusively as the basis for management and investment decisions. They are intended to identify high erosion risk areas but do not replace the need for site specific field assessment and expert advice.

5 Summary

A spatial layer of hillslope erosion risk was developed and a national streambank erosion risk layer was summarised for Te Whanganui-a-Tara and Te Awarua-o-Porirua Whaitua. The hillslope erosion risk layer accounts for landslide risk and surficial erosion rate calculated using the RUSLE. Data inputs include LiDAR information and a range of national datasets that account for soil type, slope, rainfall and land cover. Analysis of the hillslope erosion risk layer was undertaken for pastoral and exotic forestry land identifying the highest (10^{th} percentile), and high (30^{th} percentile) erosion risk areas within each FMU.

6 References

Collaborations, (2023 a). Sediment Reduction Implementation Plan for Pouewe and Takapu – Deliverable 1. Prepared for Greater Wellington Regional Council. 06 April 2023.

Collaborations, (2023 b). Erosion Risk Mapping for Plan Change 1 – Takapū and Pouewe Rural Property Analysis. Prepared for Greater Wellington Regional Council. 31 May 2023.

De Rose, R. C. (2013). Slope control on the frequency distribution of shallow landslides and associated soil properties, North Island, New Zealand. Earth Surface Processes and Landforms, 38(4), 356-371.

Dymond, J. R., Herzig, A., Basher, L., Betts, H. D., Marden, M., Phillips, C. J., and Roygard, J. (2016). Development of a New Zealand SedNet model for assessment of catchment-wide soil-conservation works. Geomorphology, 257, 85-93.

Dymond, J. R. (2010). Soil erosion in New Zealand is a net sink of CO2. Earth Surface Processes and Landforms, 35(15), 1763-1772.

Glade, T. (1998). Establishing the frequency and magnitude of landslide-triggering rainstorm events in New Zealand. Environmental Geology 35, 160– 174.

Jacobs, (2019). Porirua Whaitua Collaborative Modelling Project Baseline Modelling Technical Report. Project IZ080700. Prepared for Greater Wellington Regional Council.

McCarthy, J. K., Leathwick, J. R., Roudier, P., Barringer, J. R. F., Etherington, T. R., Morgan, F. J., Odgers, N. P., Price, R. H., Wiser, S. K., Richardson, S. J. (2021). New Zealand Environmental Data Stack (NZEnvDS): A standardised collection of environmental spatial layers for biodiversity modelling and site characterisation. New Zealand Journal of Ecology, 45(2): 3440

Moore, I.D. and Burch, G.J., (1986). Physical basis of the length-slope factor in the Universal Soil Loss Equation. Soil Science Society of America Journal, 50(5), pp.1294-1298.

Moore, I.D. and Wilson, J.P., (1992). Length-slope factors for the Revised Universal Soil Loss Equation: Simplified method of estimation. Journal of soil and water conservation, 47(5), pp.423-428.

Renard, K. G., Foster, G. R., Weesies, G. A., McCool, D. K., and Yoder, D. C. (1997). Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation, U.S Government Printing Office, Washington DC, 1997.

Smith, H.,Betts, H. (2021). Memorandum on implementing a national index for susceptibility to streambank erosion. Prepared for: Ministry for the Environment. Contract Report: LC399

Appendix A Hillslope Erosion Risk Tables

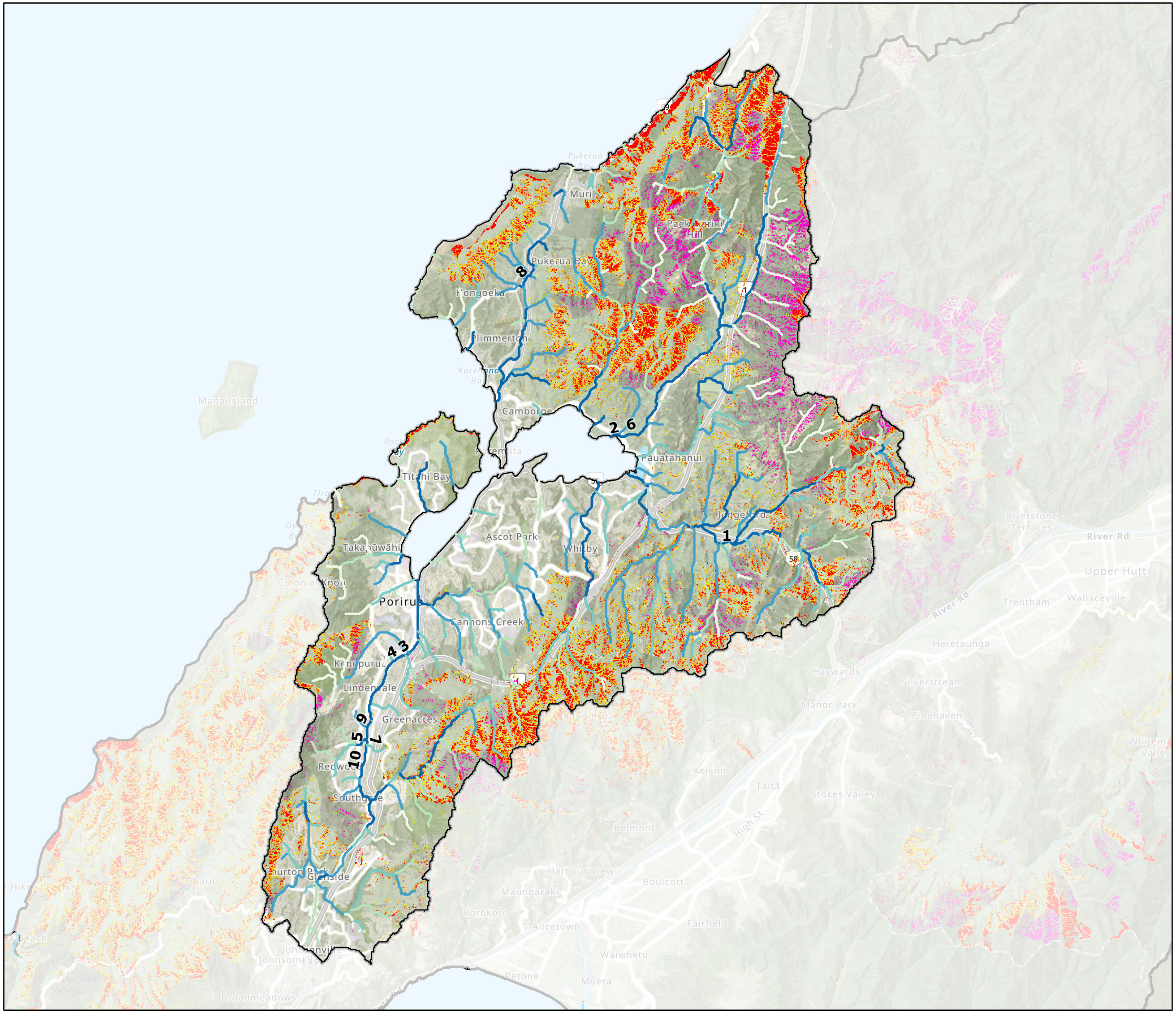
Table 3 Hillslope erosion risk - Te Awarua-o-Porirua

Part-FMU	Area (ha)	Area in Pasture (ha)	High risk (30th) percentile erosion - Pasture			Very high risk (20th) percentile erosion - Pasture			Highest risk (10th) percentile erosion - Pasture			Area in Forestry (ha)	Highest Risk (10th) percentile erosion - Forestry		
			Area (ha)	% of Pasture in part-FMU	% of FMU risk area	Area (ha)	% of Pasture in part-FMU	% of FMU risk area	Area (ha)	% of Pasture in part-FMU	% of FMU risk area		Area (ha)	% of Forestry in part-FMU	% of FMU risk area
Pouewe	6,146	2,922	801	27%	45%	597	20%	48%	337	12%	52%	1,462	156	11%	71%
Taupo	1,138	787	96	12%	5%	56	7%	5%	20	3%	3%	40	0	1%	0%
Duck Creek	1,032	486	160	33%	9%	116	24%	9%	59	12%	9%	104	3	3%	1%
Takapu	5,247	3,050	551	18%	31%	380	12%	30%	188	6%	29%	706	51	7%	23%
Te Rio o Porirua and Rangituhi	6,558	1,316	163	12%	9%	102	8%	8%	42	3%	7%	421	9	2%	4%
Total	**20,121**	**8,562**	**1,771**	**21%**	**100%**	**1,252**	**15%**	**100%**	**646**	**8%**	**100%**	**2,733**	**220**	**8%**	**100%**

Table 4 Hillslope erosion risk - Te Whanganui-a-Tara

Part-FMU	Area (ha)	Area in Pasture (ha)	High risk (30th) percentile erosion - Pasture			Very high risk (20th) percentile erosion - Pasture			Highest risk (10th) percentile erosion - Pasture			Area in Forestry (ha)	Highest Risk (10th) percentile erosion - Forestry		
			Area (ha)	% of Pasture in part-FMU	% of FMU risk area	Area (ha)	% of Pasture in part-FMU	% of FMU risk area	Area (ha)	% of Pasture in part-FMU	% of FMU risk area		Area (ha)	% of Forestry in part-FMU	% of FMU risk area
Kaiwharawhara Stream	1,665	59	20	34%	1%	15	26%	1%	8	14%	1%	70	1	2%	0%
Korokoro Stream	1,668	249	64	26%	2%	46	19%	2%	22	9%	2%	190	8	4%	1%
Makara Estuary	9	1	0	15%	0%	0	8%	0%	0	4%	0%	0	0	0%	0%
Te Awa Kairangi lower mainstem	171	7	0	2%	0%	0	1%	0%	0	0%	0%	0	0	0%	0%
Te Awa Kairangi urban streams	11,895	1,361	220	16%	6%	164	12%	7%	79	6%	6%	1,188	59	5%	8%
Wai Tai (south-western coast)	14	7	1	18%	0%	1	15%	0%	1	10%	0%	0	0	0%	0%
Wainuiomata rural streams	7,076	1,112	82	7%	2%	55	5%	2%	22	2%	2%	375	8	2%	1%
Wainuiomata urban streams	1,533	130	2	1%	0%	1	1%	0%	1	0%	0%	22	0	2%	0%
Wellington urban	10,110	406	132	32%	4%	102	25%	4%	56	14%	4%	390	13	3%	2%
Parangarehu catchment streams and South-west coast rural streams	17,346	8,376	2,387	28%	71%	1,713	20%	69%	911	11%	69%	633	14	2%	2%
Te Awa Kairangi and Wainuiomata small forested, Te Awa Kairangi forested mainstems and Orongorongo	55,986	1,462	241	17%	7%	192	13%	8%	119	8%	9%	4,949	536	11%	70%
Te Awa Kairangi rural streams and rural mainstems	8,533	3,803	235	6%	7%	177	5%	7%	107	3%	8%	1,319	132	10%	17%
Total	**116,007**	**16,973**	**3,385**	**20%**	**100%**	**2,468**	**15%**	**100%**	**1,325**	**8%**	**100%**	**9,138**	**771**	**8%**	**100%**

Appendix B Catchment erosion risk maps (A3 size)



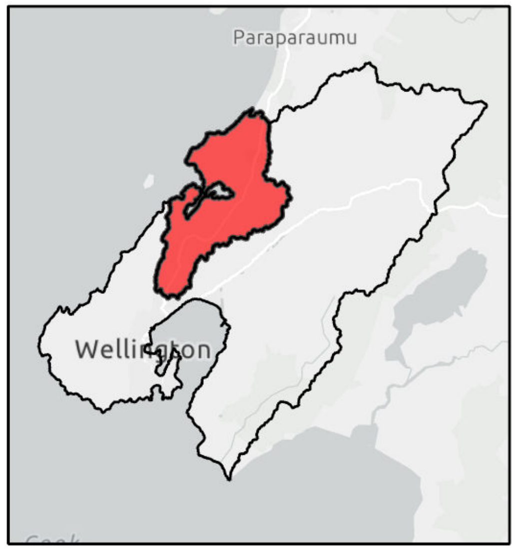
Hillslope erosion risk

- Highest erosion risk - Forestry
- Highest erosion risk - Pasture
- Very High erosion risk - Pasture
- High erosion risk - Pasture

Streambank Erosion Risk quantiles

Top 10 reaches labelled

- Lowest risk
- Low risk
- Medium risk
- High risk
- Highest risk
- FMU Boundary



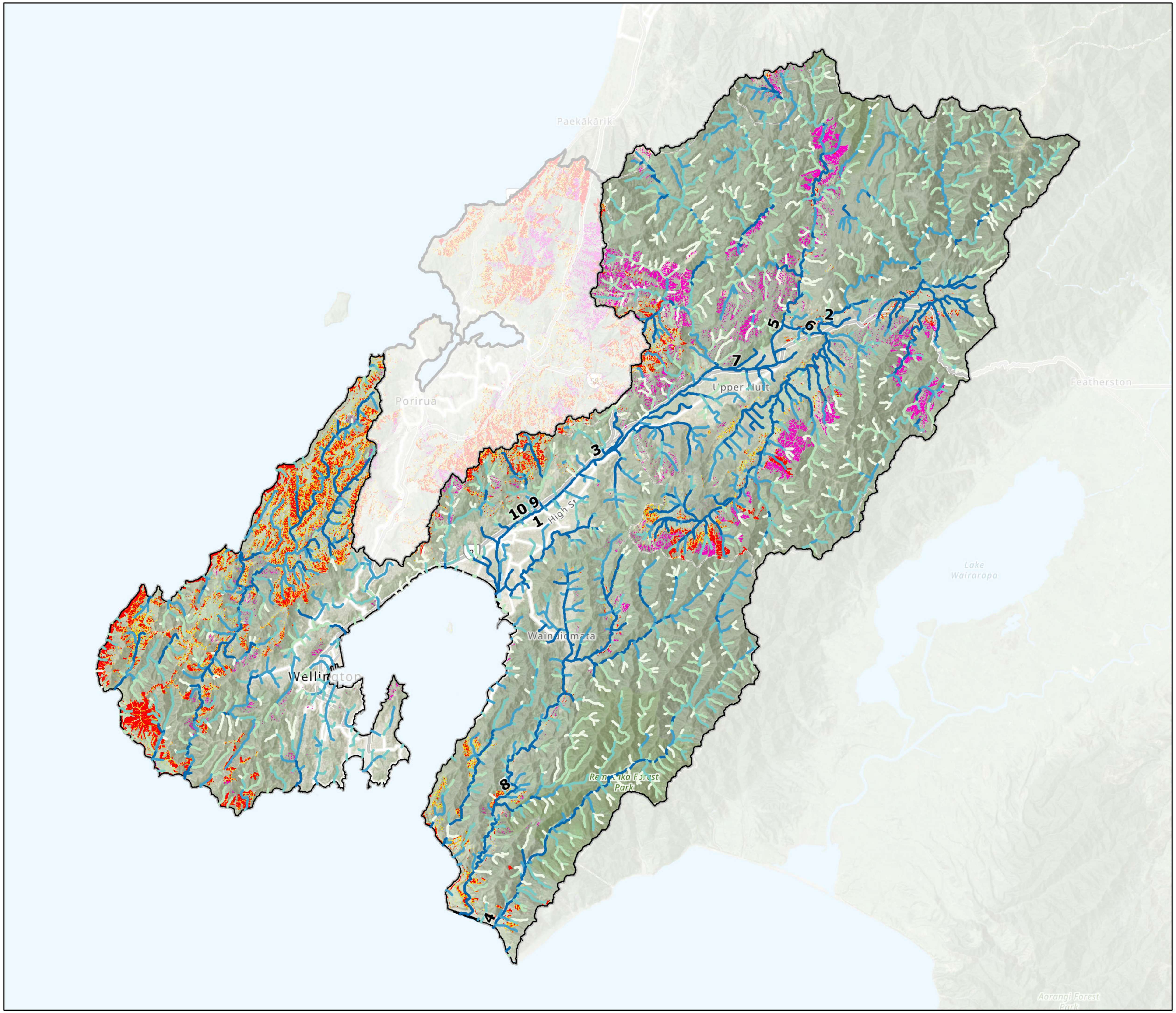
N

0 2,500 5,000 Metres

Erosion Risk Te Awarua-o-Porirua

Project:	Sediment Assessment	Author	SE & TN
Client:	GWRC	Date	August 2023
Ref:	001	Size	A3

Collaborations



Hillslope erosion risk

- Highest erosion risk - Forestry
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- High erosion risk - Pasture

Streambank Erosion Risk quantiles

Top 10 reaches labelled

- Lowest risk
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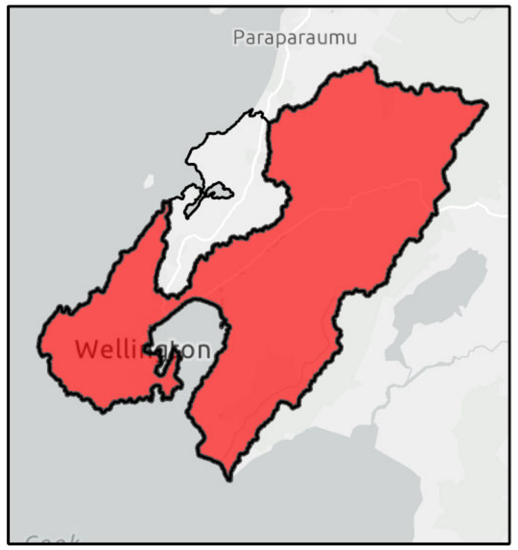
- Highest risk
- FMU Boundary



N

0 5,000 10,000 Metres

Erosion Risk
Te Whanganui-a-Tara

Project:	Sediment Assessment	Author	SE & TN
Client:	GWRC	Date	August 2023
Ref:	002	Size	A3

Collaborations

Memorandum

Date:	18/10/2023
To:	Karen Inglis
From:	Stu Farrant (Morphum)
CC:	Michael Greer
Project Number:	P04004

Subject: Minimum Stormwater Contaminant Treatment Requirement for New Urban Development and Redevelopment – PC1 NRP

Morphum Environmental have been engaged by Greater Wellington Regional Council (GWRC) to support with the drafting of provisions to Plan Change 1 (PC1) of the Natural Resources Plan (NRP). This includes technical works to support the appointed planner (Karen Inglis) and Freshwater scientist (Michael Greer) who have also been engaged to prepare content and supporting technical reports.

The proposed PC1 will require urban development that involves development or redevelopment of impervious surface areas between 1000 m^2 and 3000 m^2 to implement contaminant treatment to mitigate the potential water quality impacts on freshwater receiving environments. Larger (i.e greater than 3000m^2) greenfield/brownfield/roading development redevelopment will also be driven to this treatment requirement through policy direction. We understand that the intent is to require a treatment device(s) that achieve an agreed performance outcome of what is agreed to be a 'minimum treatment device'. This will enable applicants flexibility with what their site specific solution may be but will ensure that an appropriate level of water quality treatment is provided to support long term aspirations for te mana o Te Wai and requirements of the National Policy Statement-Freshwater Management (NPS-FM).

The selection of treatment devices to mitigate urban stormwater need to consider the following;

1. Ability to treat contaminants in both particulate and soluble form.
2. Ability to reliably capture and treat a sufficient volume during rainfall to respond to the highly variable quality of stormwater and the need to treat runoff across a range of small and moderate rainfall events.
3. Ability to reliably capture contaminants and prevent the incidence of remobilisation during large events.
4. Ability to be easily maintained over a realistic lifespan by contractors without specialist equipment.

We understand that the focus of the GWRC PC1 is the treatment of Zinc and Copper to align with the requirements of the NPS-FM but it is important to note that other urban contaminants such as sediments, hydrocarbons, nutrients, microplastics, other metals and other emerging contaminants need to be mitigated to protect freshwater ecosystems. Additionally, biophysical metrics such as temperature, dissolved oxygen, pH and modified hydrology need to be considered where discharge connects to existing or piped waterways.

Typically, it is agreed that to provide robust mitigation, stormwater devices need to capture and treat at least 85% of the mean annual runoff volume. This is achieved through capturing all rainfall events up to the 3 month average return interval (ARI) which is approximated for design purposes as 1/3 of the 2 year ARI event rainfall runoff. This reflects the highly variable nature of urban stormwater and the need to preferentially treat the entire volume of the frequent rainfall events which are known to mobilise accumulated contaminants on urban surfaces. This is the basis of design guidance across New Zealand including the Wellington Water, *Water Sensitive Design for Stormwater: Technical Device Design Guideline (2019).* The Wellington guidelines were developed based on continuous simulation modelling with 10 years of 5 minute timestep rainfall data for three representative rainfall gauges across the Wellington metropolitan area (did not include gauges from Kapiti or Wairarapa).

This technical approach determines that online devices such as swales and open water ponds do not provide reliable long-term performance and many proprietary devices that capture only coarse sediments or separate floatable oils are not capable of providing the level of protection required for freshwater ecosystems. It is noted that the use of other strategies which capture and divert rainfall to either reuse or evapotranspiration such as Green Roofs and Rainwater Reuse Tanks (where plumbed into constant internal demands) are very effective at managing roof areas and support other important outcomes such as hydrologic controls to mimic more natural catchment hydrology. The use of either of these methods to manage roof areas can therefore readily reduce the 'effective imperviousness' and therefore significantly reduce the requirements for other stormwater treatment devices. Therefore, in the instance that a development includes rainwater collection and internal non potable reuse (i.e. for toilet flushing and cold water laundry) the stormwater device would only need to be sized for non roof impervious areas.

Selection of treatment strategies for developments needs to consider the scale of development and the overall urban design integration. For large scale greenfield developments this will typically result in more complex strategies which may contain multiple devices in series (treatment train) and a mix of large scale consolidated devices (such as constructed wetlands) and small lot scale measures (such as rainwater reuse). For more intensive infill and brownfield development the solutions are often more simplistic with stormwater managed through a smaller number of consolidated devices which are integrated with landscaping.

It is considered that the optimal stormwater treatment device for the smaller scale urban development (and to provide a benchmark for a minimum contaminant treatment performance across other larger scale developments/redevelopment) captured by PC1 which could be easily used as a measure of compliance with the requirements of PC1 is a **bioretention device** (often referred to as a raingarden) which can receive flows from impervious surfaces up to around 2 ha. Bioretention is easily integrated into most sites and is spatially efficient with the ability to be elevated above surrounding surfaces and integrated with other hard landscape elements such as retaining structures and paths. Further bioretention is well suited to be integrated with the upgrade of existing roads given the limited footprint and the ability to be designed around other underground services. The following provides a summary of key metrics;

- Sized with a filter media area of 2% of the contributing impervious catchment.
- Designed with specific filter media layers and event detention (ponding) on surface in accordance with guidelines.
- Can capture and treat in excess of 85% of mean annual stormwater volume for all climate zones across Wellington region.
- Suited to variable micro-climates through selection of locally appropriate plant species.
- Easily designed and constructed to bypass flows in excess of 3 moth ARI events to protect from resuspension of captured contaminants.
- Able to be maintained, remediated and managed over long term.

Based on the design and construction of a bioretention in accordance with local design guidelines it is estimated that removal performance of the following can be achieved (as per WWL Technical design Guidelines);

- Total Zinc 90%
- Total Copper 90%
- Total Suspended Solids 90%
- Total Nitrogen 40%
- Total Phosphorous 60%

Based on the practicalities of constructing functional bioretention device it is suggested that a minimum contributing catchment area of 50 m^2 is required to sustain a minimum 1 m^2 bioretention.

The removal of contaminants (particularly nutrients) is limited by the inability to remove 100 % of contaminants (due to residual background concentrations) as well as the small amount of contaminants in infrequent bypass events. It is considered that any desire to increase contaminant removal through increasing the treatment footprint is not efficient or practical.

With regards to the current proposed wording for PC1 the following wording is recommended for Policy P1.

> Policy P1: Minimise new and reduce existing adverse effects of stormwater discharges from new urban subdivision, development or redevelopment through contaminant treatment devices or systems.
>
> The adverse effects of the discharge of **stormwater** from new urban subdivision, development or **redevelopment** ~~where the discharge will enter water~~ shall be minimised by implementing:
>
> (a) On-site or communal stormwater treatment systems or devices that are designed to:
>
> (i) Receive at least 85% of the mean annual stormwater generated from all effective impervious surfaces of the site (approximated as treating up to the 1/3 50% AEP rainfall event); and
>
> (ii) Achieve load reduction factors for copper and zinc equal to or greater than those defined for Bioretention/Raingardens
>
> or
>
> ~~(b) Source control techniques that result in copper and zinc load reductions equal to or greater than what would be achieved through on-site or communal stormwater treatment systems or devices designed in accordance with (a):~~
>
> *Note: Stormwater treatment systems and devices and source control techniques can be used in combination to achieve the copper and zinc load reductions required by (a). Copper and Zinc are used as proxies for suite of urban contaminants with stormwater treatment required for all impervious surfaces. Effective impervious refers to surfaces which do not have any other form of stormwater management such as rainwater collection and reuse of green roofs.*

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Assessment of alignment between the regulatory provisions and target attribute states in proposed Plan Change 1 to the Natural Resources Plan – Whaitua Te Whanganui-a-Tara

Report No. 2023-008

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Prepared for: Greater Wellington
Report No. 2023-008
Date: 04/10/2023

Quality Assurance (Report Status: Final)			
Role	**Responsibility**	**Date**	**Signature**
Prepared by Approved for issue by	Michael Greer	04/10/2023	
Structure and content reviewed by	Duncan Gray	11/07/2023	

RECOMMENDED CITATION: Greer, M.J.C. 2023. Assessment of alignment between the regulatory provisions and target attribute states in proposed Plan Change 1 to the Natural Resources Plan – Whaitua Te Whanganui-a-Tara. Torlesse Environmental Report No. 2023-008. Christchurch, New Zealand.

Glossary

Term	Meaning
2A type attributes	Attributes that are treated in the same way as the compulsory attributes in Appendix 2A of the NPS-FM 2020 in PC1 (i.e., are directly linked to the provisions)
2B type attributes	Attributes that are treated in the same way as the compulsory attributes in Appendix 2B of the NPS-FM 2020 in PC1 (i.e., are not directly linked to the provisions)
Action planning	Developing and implementing an action plan in accordance with the NPS-FM 2020
BSP	Biophysical Science Programme (for Whaitua Te Whanganui-a-Tara)
CFU	Colony Forming Unit
CLM	Contaminant Load Model
CLUES	Catchment Land Use for Environmental Sustainability
CMP	Collaborative Modelling Programme
Cu	Copper
DFS	Deposited fine sediment
DIN	Dissolved inorganic nitrogen
DRP	Dissolved reactive Phosphorus
Earthworks	means the alteration or disturbance of land, including by moving, removing, placing, blading, cutting, contouring, filling or excavation of earth (or any matter constituting the land including soil, clay, sand and rock) (PC1 definition).
E. coli	*Escherichia coli*
EQR	Ecological Quality Rating (for macroalgae)
ERTP	Erosion risk treatment plan – A plan prepared in compliance with Schedule 36 (PC1 definition)
FEP	Farm Environment Plan prepared in accordance with Schedule Z of the operative NRP and Schedule 36 of PC1
GW	Greater Wellington
High erosion risk land	Land with high erosion risk in Te Awarua-o-Porirua Whaitua shown on Map 90 or in Whaitua Te Whanganui-a-Tara shown on Map 93 (based on PC1 definition)
Highest erosion risk land	Land with highest erosion risk in Te Awarua-o-Porirua Whaitua shown on Map 90, 91 and 92 or in Whaitua Te Whanganui-a-Tara shown on Map 93, 94 and 94 (based on PC1 definition)
Livestock	Farm animals
Low slope land	means land identified as low slope land in https://www.mfe.govt.nz/fresh-water/freshwater-acts-and-regulations/stock-exclusion (Stock Exclusion Regulations definition).
LUC	Land Use Capability (class)
NH_4-N	Ammoniacal – nitrogen
NRP	Natural Resources Plan (for the Wellington Region)
NPS-FM	National Policy Statement for Freshwater Management
NO_3-N	Nitrate – nitrogen
Part-FMU	Part Freshwater Management Unit
PC1	Proposed Plan Change 1 to the NRP
The proposed provisions	The regulatory provisions of PC1
REC	River Environment Classification
SFS	Suspended Fine Sediment (as measured by visual clarity)
Soil conservation treatment	Includes: • Revegetation of highest or high erosion risk land; • Planting of poplar or willow poles on grazing land; • Construction of sediment detention structures; and • Wetland construction and restoration. (Based on PC1 definition (Schedule 36 – Table D1))
The Stock Exclusion Regulations	Resource Management (Stock Exclusion) Regulations 2020
TAoP	Te Awarua-o-Porirua
TAS	Target attribute state
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
Whaitua	Whaitua is the Māori word for catchment or space. The Wellington Region is divided into five whaitua, which will eventually each have a Whaitua Committee responsible for them
WTWT	Whaitua Te Whanganui-a-Tara
Zn	Zinc

Executive summary

Plan Change 1 (PC1) to the Natural Resources Plan (NRP) for the Wellington Region will implement the National Policy Statement for Freshwater Management (NPS-FM) 2020 for Whaitua Te Whanganui-a-Tara (WTWT). This involves setting objectives, policies, rules and other methods to manage activities such as urban development, earthworks, stormwater, wastewater and rural land use. Accordingly, PC1 will:

- Define Target Attribute States (TASs) for the compulsory attributes in Appendix 2 of the NPS-FM 2020;
- Set equivalent coastal water quality and ecology objectives ('coastal objectives'); and
- Establish provisions that will contribute to those TASs and coastal objectives being met.

This process is especially important for those compulsory attributes in Appendix 2A of the NPS-FM 2020; as these require limits (input controls, output controls, or land use controls) be set as rules in regional plans to contribute to the achievement of their target states.

In this report, the extent to which the proposed regulatory provisions of PC1 will achieve the TASs and coastal objectives for WTWT is assessed using the scenario testing outputs of the Te Whanganui-a-Tara Biophysical Science Programme (BSP) which informed their selection by the WTWT Committee . The scenarios tested through the BSP were:

- Business as usual (BAU) – Represented the regulatory and management approach at the time;
- Improved – Included a range of actions with the potential to minimise the impact of urban and rural land uses such as stormwater treatment, wastewater network upgrades, riparian planting, space planting and retirement; and
- Water Sensitive – Included much the same actions as Improved, but with an increase in their extent and efficacy.

Results suggest that the proposed provisions of PC1 require outcomes and actions that are likely to achieve most (~85%) of the WTWT TASs and coastal objectives. However, there are still a number that are unlikely to be met through the proposed provisions alone (see Table I). In most cases, the 'gap' between the outcome of the proposed provisions and the TAS/coastal objective can be filled through non-regulatory actions like those assumed under the BSP Water Sensitive scenario; e.g.:

- Planting 10 metre riparian buffers on all second order streams on pastoral land less than 15 degrees; and
- Retiring all high erosion risk land and highest erosion risk land (as defined in PC1).

Nonetheless, some TASs may not be met unless action planning includes greater non-regulatory actions than those described above, or land use is changed (Table I).

Table I: Description of the TASs and coastal objectives that will not be met through the proposed provisions alone. The non-regulatory actions that could potentially fill these 'gaps' are also identified from the BSP scenario assumptions.

Part Freshwater Management Unit	Attribute	Possible non-regulatory actions to fill the 'gap' between the proposed provisions and TAS/objective based on the BSP scenario assumptions
Wainuiomata rural streams	Periphyton biomass	Planting of five metre riparian buffers on all second order and above streams on pastoral land less than 10 degrees. *Note: The actions described above are likely only necessary to offset the effects of climate change at 2090. This attribute should be maintained by the proposed provisions at 2040.*
Korokoro Stream		
Wainuiomata rural streams	Suspended fine sediment	• Planting of 10 metre riparian buffers on all second order and above streams on pastoral land less than 15 degrees • Retirement of all high risk erosion land.
Parangārehu catchment streams and South-west coast rural streams	Dissolved reactive phosphorus	
Wainuiomata rural streams		
Parangārehu catchment streams and South-west coast rural streams	*E. coli*	
Te Awa Kairangi rural streams and mainstems		
Te Whanganui-a-Tara (Harbour and estuaries)	Enterococci	
Mākara Estuary	Muddiness (% area >50% mud)	
	Muddiness (% of sample)	
	Sedimentation rate	
Te Awa Kairangi rural streams and mainstems	Macroinvertebrates	
Wainuiomata rural streams		
Te Awa Kairangi lower mainstem	Suspended fine sediment	• Planting of 10 metre riparian buffers on all second order and above streams on pastoral land less than 15 degrees • Retirement of all high risk erosion land; and • Additional mitigations not considered in BSP scenarios or land-use change.
Small forested and forested mainstems	Dissolved reactive phosphorus	
Kaiwharawhara Stream		• Additional urban mitigations not considered in the BSP scenarios.
Waiwhetū Stream		
Wellington urban	*E. coli*	
Wainuiomata urban streams		
	Ammonia	
Te Awa Kairangi rural streams and mainstems	Periphyton biomass	• Planting of 10 metre riparian buffers on all second order and above streams on pastoral land less than 15 degrees; • Retirement of all high risk erosion land; and • Additional mitigations not considered in the BSP scenarios or land-use change.
Te Awa Kairangi lower mainstem		
	Fish community health	
Kaiwharawhara Stream	Macroinvertebrates	
Te Awa Kairangi lower mainstem		
Small forested and forested mainstems	Fish community health	Unlikely to be achieved by the proposed provisions or non-regulatory actions (i.e., outside of GW's control).
Te Awa Kairangi rural streams and mainstems	F-IBI	
Te Awa Kairangi urban streams		

Contents

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1 Introduction

1.1 Background

Plan Change 1 (PC1) to the Natural Resources Plan (NRP) for the Wellington Region will implement the National Policy Statement for Freshwater Management (NPS-FM) 2020 for Whaitua Te Whanganui-a-Tara (WTWT) and the Te Awarua-o-Porirua (TAoP) Whaitua. This involves setting objectives, policies, rules and other methods to manage activities such as urban development, earthworks, stormwater, wastewater and rural land use. Accordingly, PC1 will:

- Define target attribute states ('TASs') for the compulsory attributes in Appendix 2 of the NPS-FM 2020;
- Set equivalent coastal water quality and ecology objectives ('coastal objectives'); and
- Establish provisions that will contribute to the achievement of those TASs and coastal objectives.

This process is especially important for those compulsory attributes in Appendix 2A of the NPS-FM 2020; as these require limits (input controls, output controls, or land use controls) be set as rules in regional plans to contribute to the achievement of their target states.(as opposed to those in Appendix 2B, which can be achieved through action planning[1] alone).

The proposed TASs and coastal objectives for WTWT are set out in Table 1 to Table 3. These are based on those published by WTWT Committee ('the Committee) in their Whaitua Implementation Programme (WIP). However, refinements have been made based on the recommendations of a technical advisory group (Greer *et al.*, 2023). For each river and lake attribute, the tables include a baseline and target state for each part Freshwater Management Unit (part-FMU) (Table 2, and Table 3). The differences between those states provide an indication of the magnitude of the improvement required by the TASs and, for rivers, have been used to define default TASs that prescribe the direction of change required for each attribute across each part-FMU[2] (Table 3).

The development of Table 1 to Table 3, and how they should be interpreted, is documented in Greer *et al.* (2023). However, most of the relevant detail can also be found in the glossary of this report and the footnotes to the tables. The attribute state frameworks behind the river and lakes TASs in Table 2 and Table 3 are provided in Appendix A.

[1] I.e., developing and implementing an action plan in accordance with the NPS-FM 2020.

[2] Where baseline state is unknown, this direction of change is based on the difference in the assumed baseline in the WIP and the TAS.

1.2 Target attribute states and coastal objectives

Table 1: Coastal objectives for WTWT.

<table>
<tr><th>Parameter</th><th>Unit</th><th>Statistic</th><th>Te Whanganui-a-Tara (Harbour and estuaries)</th><th>Mākara Estuary</th><th>Wainuiomata Estuary</th><th>Wai Tai</th></tr>
<tr><td>Benthic marine invertebrate diversity</td><td colspan="2">Subjective - State of ecosystem health and level of disturbance</td><td rowspan="8">Maintain or improve</td><td rowspan="5">Maintain or improve</td><td colspan="2" rowspan="9">Maintain or improve</td></tr>
<tr><td>Macroalgae</td><td>EQR</td><td rowspan="2">Latest score</td></tr>
<tr><td>Phytoplankton</td><td>mg chl-a/ m^3</td></tr>
<tr><td>Copper in sediment</td><td>mg/kg</td><td rowspan="2">Mean of latest round of replicate samples</td></tr>
<tr><td>Zinc in sediment</td><td>mg/kg</td></tr>
<tr><td rowspan="2">Muddiness</td><td>% >50% mud</td><td rowspan="3">Latest score</td><td>≤5</td></tr>
<tr><td>% of sample</td><td><10</td></tr>
<tr><td>Sedimentation rate</td><td>Current:Natural</td><td>≤2:1</td></tr>
<tr><td>Enterococci</td><td>cfu/100 mL</td><td>95th %ile</td><td>≤200</td><td>Maintain or improve</td></tr>
</table>

Table 2: Lakes TASs for WTWT.

Parameter	Unit	Statistic	Timeframe	Lake Kōhangatera Baseline Numeric	Lake Kōhangatera Baseline State	Lake Kōhangatera TAS[1] Numeric	Lake Kōhangatera TAS[1] State	Lake Kōhangapiripiri Baseline Numeric	Lake Kōhangapiripiri Baseline State	Lake Kōhangapiripiri TAS[1] Numeric	Lake Kōhangapiripiri TAS[1] State	Other lakes default TAS[1]
Phytoplankton[2]	**mg chl-a/m^3**	Median	By 2040	5.0	C	≤2	A	1.5	A	M	A	M
		Maximum		35		≤10		6.0				
Total nitrogen[2]	**mg/m^3**	Median		480	B	M	B	660	C	≤500	B	
Total phosphorus[2]	**mg/m^3**	Median		40	C	≤20	B	43	C	≤20	B	
Ammonia (toxicity)[2]	**mg/L**	Median		0.005	A	M	A	0.003	A	M	A	
		95th %ile		0.024				0.005				
***E. coli*[2]**	**/100mL**	Median		125	A		A	23	A		A	
		%>260/100mL		174				0				
		%>540/100mL		0				0				
		95th %ile		350				186				
Cyanobacteria (planktonic)[2]	**Total biovolume mm^3/L**	80th %ile		0.248	A		A	0.008	A		A	
Submerged plants (natives)	**Native Condition Index (% of max)**	Latest		81.4	A		A	35.7	C	≥75	A	
Submerged plants (invasive species)	**Invasive Impact Index (% of max)**	Latest		15.6	B		B	61.5	C	≤25	B	
Lake-bottom dissolved oxygen[3]	**mg/L**	Annual minimum		Insufficient data		≥7.5	A	Insufficient data		≥7.5	A	

[1] M = Maintain; I = Improve. Maintenance, improvement or deterioration in the state of an attribute will be assessed through:

- Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and
- Taking the impact of climate and human activity into account.

[2] Baseline state based on limited data collected over a period that is inconsistent with the monitoring requirements and baseline period defined in the NPS-FM 2020.

[3] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or be maintained at a better state.

Table 3: Rivers TASs for WTWT

				Te Awa Kairangi, Ōrongorongo and Wainuiomata																			
				Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems					Te Awa Kairangi lower mainstem					Te Awa Kairangi rural streams and rural mainstems					Te Awa Kairangi urban streams				
				Whakatikei R. @ Riverstone				Part-FMU default TAS[1]	Hutt R. @ Boulcott				Part-FMU default TAS[1]	Mangaroa R. @ Te Marua				Part-FMU default TAS[1]	Hulls Ck adj. Reynolds Bach Dr.				Part-FMU default TAS[1]
				Baseline		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]			Baseline[2]		TAS[1]		
Parameter	Unit	Statistic	Timeframe	Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State	
Periphyton biomass[2]	mg chl-a/m^2	92nd %ile	By 2040	Insufficient data		≤50	A	M	284	D	≤120	B	I	220	D	≤120	B	I	Insufficient data		≤200	C	M
Ammonia (toxicity)	mg/L	Median		0.002	A	M	A		0.002	A	M	A	M	0.002	A	M	A	M	0.008	A	M	A	
		95th %ile		0.004					0.003					0.01					0.012				
Nitrate (toxicity)	mg/L	Median		0.1	A		A		0.2	A		A		0.4	A		A		0.2	A		A	
		95th %ile		0.3					0.3					0.6					0.4				
Suspended fine sediment	Black disc (m)	Median		4	A		A		2.4	C	≥2.95	A	I	1.5	D	≥2.22	C	I	1.2	A		A	
E. coli	/100mL	Median		22	A		A		58	D	≤58	C		170	D	≤130	B		1,100	E	≤130	C	I
		%>260/100mL		5					18		≤18			35		≤30			100		≤34		
		%>540/100mL		3					8		≤8			18		≤10			79		≤20		
		95th %ile		290					1,250		≤1,200			2,450		≤1,000			13,000		≤1,200		
Fish	Fish-IBI	Latest		Insufficient data		≥34	A		Insufficient data		≥34	A	M	Insufficient data		≥34	A		Insufficient data		≥34	A	
Fish community health (abundance, structure and composition)		Expert assessment[3]				N/A[3]	A	I			N/A[3]	B	I			N/A[3]	B				N/A[3]	C	M
Macroinvertebrates (1 of 2)	MCI	Median		129.6	B	≥130	A		109.1	C	110	B		118.3	C	≥118.3	B				≥90	C	
	QMCI	Median		7.0		≥7			5.5		5.5			5.7		≥5.7					≥4.5		
Macroinvertebrates (2 of 2)	ASPM	Median		0.56	B	≥0.6	A		0.4	B	M	B	M	0.5	B	M	B	M			≥0.3	C	
Deposited fine sediment[2]	%cover	Median		25	C	≤13	A		5	A		A		0	A		A		11	B	M	B	
Dissolved oxygen	mg/L	1-day minimum		Insufficient data		≥7.5	A	M	Insufficient data		≥7.5	A		Insufficient data		≥7.5	A		Insufficient data		≥7.5	A	
		7-day mean minimum				≥8.0					≥8.0					≥8.0					≥8.0		
Dissolved inorganic nitrogen[4]	mg/L	Median		0.15		M			0.2		M			0.44		M			0.24		M		
Dissolved reactive phosphorus[4]	mg/L	Median		0.008		≤0.006		I	0.004					0.010		≤0.006		I	0.018				
		95th%ile		0.011		≤0.011			0.008					0.015		≤0.015			0.027				
Dissolved copper	µg/L	Median		Insufficient data		≤1	A	M	0.3	A	M	A		Insufficient data		≤1	A	M	1.9	C	≤1.4	B	I
		95th %ile				≤1.4			0.6							≤1.4			3.6		≤1.8		
Dissolved zinc	µg/L	Median				≤2.4	A		0.5	A		A				≤2.4	A		8.0	C	≤8	B	
		95th %ile				≤8			1.9							≤8			19.2		≤15		
Ecosystem metabolism[5]	g O_2 m^{-2} d^{-1}	N/A[5]		M																			

				Te Awa Kairangi, Ōrongorongo and Wainuiomata															South-west coast, Mākara and Ōhariu catchment and Parangārehu Lakes				
				Waiwhetū Stream					Wainuiomata urban streams					Wainuiomata rural streams					Parangārehu catchment streams and South-west coast rural streams				
				Waiwhetū S. @ Whites Line East				Part-FMU default TAS[1]	Black Ck @ Rowe Parade				Part-FMU default TAS[1]	Wainuiomata River D/S of White Br.				Part-FMU default TAS[1]	Mākara S. @ Kennels				Part-FMU default TAS[1]
				Baseline		TAS[1]			Baseline[2]		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]		
Parameter	**Unit**	**Statistic**	**Timeframe**	**Numeric**	**State**	**Numeric**	**State**		**Numeric**	**State**	**Numeric**	**State**		**Numeric**	**State**	**Numeric**	**State**		**Numeric**	**State**	**Numeric**	**State**	
Periphyton biomass[2]	**mg chl-a/m^2**	92nd %ile		Insufficient data		≤200	C	M	Insufficient data		≤200	C	M	324	D	≤200	C	I	Insufficient data		≤200	C	M
Ammonia (toxicity)	**mg/L**	Median		0.027	B	≤0.02	A	I	0.025	B	≤0.03	A	I	0.004	A	M	A	I	0.005	A	M	A	
		95th %ile		0.076		≤0.05			0.066		≤0.05			0.025					0.023				
Nitrate (toxicity)	**mg/L**	Median		0.5	A	M	A	M	0.4	A	M	A	M	0.2	A		A		0.4	A		A	
		95th %ile		0.9					0.7					0.4					1.2				
Suspended fine sediment	**Black disc(m)**	Median		1.1	A		A		1.3	D	≥2.22	C	I	2.1	D	≥2.22	C	I	1.6	D	≥2.22	C	I
E. coli	**/100mL**	Median		495	E	≤130	C	I	1250	E	≤130	C		100	B	≤100	A		375	E	≤260	D	
		%>260/100mL		73		≤34			86		≤34			18		≤18			62		≤50		
		%>540/100mL		42		≤20			71		≤20			7		≤5			32		≤30		
		95th %ile		5,800		≤1200			4,360		≤1200			1,000		≤540			6,500		≤3,850		
Fish	**Fish-IBI**	Latest		Insufficient data		≥34	A	M	Insufficient data		≥34	A	M	Insufficient data		≥34	A	M	Insufficient data		≥34	A	M
Fish community health (abundance, structure and composition)		Expert assessment[3]				N/A[3]	C	I			N/A[3]	C	I			N/A[3]	B	I			N/A[3]	C	
Macroinvertebrates (1 of 2)	**MCI**	Median	By 2040	55.4	D	≥90	C				≥90	C		109.5	C	≥110	B		107.3	C	M	C	
	QMCI	Median		2.2		≥4.5					≥4.5			4.9		≥5.5			5.1				
Macroinvertebrates (2 of 2)	**ASPM**	Median		0.1	D	≥0.3	C				≥0.3	C		0.4	B	≥0.6	A		0.4	B		B	
Deposited fine sediment[2]	**%cover**	Median		30	D	≤29	C		11	A	M	A	M	20	C	≤13	A		85	D	≤27	C	I
Dissolved oxygen	**mg/L**	1-day minimum		Insufficient data		≥7.5	A		Insufficient data		≥7.5	A		Insufficient data		≥7.5	A	M	Insufficient data		≥7.5	A	M
		7-day mean minimum				≥8.0					≥8.0					≥8.0					≥8.0		
Dissolved inorganic nitrogen[4]	**mg/L**	Median		0.56		M		M	0.5		M			0.17		M			0.42		M		
Dissolved reactive phosphorus[4]	**mg/L**	Median		0.024		≤0.018		I	0.021		≤0.018		I	0.011		≤0.01		I	0.027		≤0.018		I
		95th%ile		0.049		≤0.049			0.035		≤0.035			0.023		≤0.023			0.064		≤0.054		
Dissolved copper	**µg/L**	Median		1.0	C	≤1	A		1.0	C	M	C	M	Insufficient data		≤1	A	M	Insufficient data		≤1	A	M
		95th %ile		4.0		≤1.4			2.0							≤1.4					≤1.4		
Dissolved zinc	**µg/L**	Median		18.3	D	≤8	B		11.2	D	≤11.2	C	I			≤2.4	A				≤2.4	A	
		95th %ile		51.5		≤15			71.2		≤42					≤8					≤8		
Ecosystem metabolism	**$g\ O_2\ m^{-2}\ d^{-1}$**	N/A[5]		M																			

				Korokoro catchment					Wellington urban catchment										Island rivers TAS[1]
				Korokoro Stream					Kaiwharawhara Stream					Wellington urban					
				Korokoro S. @ Cornish St. Br.				Part-FMU default TAS[1]	Kaiwharawhara S. @ Ngaio Gorge				Part-FMU default TAS[1]	Karori S. @ Mākara Peak				Part-FMU default TAS[1]	
				Baseline		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]			
Parameter	Unit	Statistic	Timeframe	Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State		
Periphyton biomass[2]	mg chl-a/m[2]	92nd %ile	By 2040	Insufficient data		≤120	B	M	191	D	≤200	C	I	Insufficient data		≤200	C	M	M
Ammonia (toxicity)	mg/L	Median				≤0.03	A		0.004	A	M	A	M	0.009	A	M	A		
		95th %ile				≤0.05			0.031					0.026					
Nitrate (toxicity)	mg/L	Median				≥1	A		1.1	B		B		1.3	B		B		
		95th %ile				≥1.5			1.5					1.6					
Suspended fine sediment	Black disc (m)	Median				≥2.95	A		3.2	A		A		3.2	A		A		
E. coli	/100mL	Median				≤130	B	I	530	E	≤130	C	I	1400	E	≤130	C	I	
		%>260/100mL				≤30			73		≤34			97		≤34			
		%>540/100mL				≤10			50		≤20			83		≤20			
		95th %ile				≤1,000			5,150		≤1,200			4,550		≤1,200			
Fish	Fish-IBI	Latest				≥34	A	M	Insufficient data		≥34	A	M	Insufficient data		≥34	A	M	
Fish community health (abundance, structure and composition)	Expert assessment[3]					N/A[3]	C	I			N/A[3]	C	I			N/A[3]	C	I	
Macroinvertebrates (1 of 2)	MCI	Median				≥130	A		81.9	D	≥92.4	C		91.8	D	≥91.8	C		
	QMCI	Median				≥6.5			2.8		≥4.5			3.1		≥4.5			
Macroinvertebrates (2 of 2)	ASPM	Median				≥0.6	A		0.25	D	≥0.3	C	I	0.29	D	≥0.3	C		
Deposited fine sediment[2]	%cover	Median				≤13	A	M	20	C	≤13	A		25	C	≤19	B		
Dissolved oxygen	mg/L	1-day minimum				≥7.5	A		Insufficient data		≥7.5	A	M	Insufficient data		≥7.5	A	M	
		7-day mean minimum				≥8.0					≥8.0					≥8.0			
Dissolved inorganic nitrogen[4]	mg/L	Median				≤0.26			1.14		M			1.29		M			
Dissolved reactive phosphorus[4]	mg/L	Median				≤0.006		I	0.037		≤0.018		I	0.035					
		95th%ile				≤0.021			0.064		≤0.054			0.062					
Dissolved copper	µg/L	Median				≤1	A	M	1.3	C	≤1.3	B		1.3	D	≤1.3	C	I	
		95th %ile				≤1.4			2.8		≤1.8			5.9		≤4.3			
Dissolved zinc	µg/L	Median				≤2.4	A		6.1	B	≤2.4	A		16.2	D	≤16.2	C		
		95th %ile				≤8			12.8		≤8			43.0		≤42			
Ecosystem metabolism	$g\ O_2\ m^{-2}\ d^{-1}$	N/A[5]		M															

[1] M = Maintain; I = Improve. Maintenance, improvement or deterioration in the state of an attribute will be assessed through:
- Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and
- Taking the impact of climate and human activity into account.

[2] Baseline state based on limited data.
[3] The A, B, C and D states to be assigned on the basis of fish community health reflecting an excellent, good, fair and poor state of aquatic ecosystem health respectively.
[4] Median concentration targets reflect the nutrient outcomes required by Clause 3.13 of the NPS-FM 2020
[5] Further monitoring needed to define baseline state and develop attribute state framework.

1.3 Introduction to the Te Whanganui-a-Tara Biophysical Science Programme

1.3.1 Biophysical Science Programme framework

The decisions made by the Committee in the WIP were informed by the outputs of three expert panels that were convened for the Te Whanganui-a-Tara Biophysical Science Programme (BSP). These panels inputted into one another and covered river flows and allocation, freshwater quality and ecology, and coastal water quality and ecology.

The purpose of these panels was to test the effects of the following scenarios on various biophysical attributes (the full assumptions of each scenario are provided in Appendix B):

- Business as usual (BAU) – Represented the regulatory and management approach at the time;
- Improved – Included a range of actions with the potential to minimise the impact of urban and rural land uses, such as stormwater treatment, wastewater network upgrades, riparian planting, space planting and retirement; and
- Water Sensitive – Included much the same actions as Improved, but with an increase in their extent and efficacy.

1.3.2 Scenario testing

1.3.2.1 Purpose

The purpose of scenario testing was to inform the Committee about the direction and magnitude of effects of different actions on specific attributes, so they could ultimately:

- Make informed decisions regarding TASs and coastal objectives; and
- Understand the actions required to achieve those TASs and objectives, and their 'cost and benefit'.

The BSP scenarios were not presented to the Committee as potential solutions whose assumptions could be carried over directly into the WIP and NRP. Rather, they were intended to highlight the effects of various actions so that the TASs, coastal objectives and recommendations in the WIP could be tailored to reflect the values of the community.

1.3.2.2 Relevant expert panel outputs

The impacts of the BSP scenarios on freshwater quality and ecology attributes were tested by a Freshwater Quality and Ecology Expert Panel (hereafter referred to as 'the Freshwater Panel'). That panel utilised environmental data from a range of sources, including:

- A proxy catchment assessment based on the extensive, well calibrated and validated Source modelling results for the TAoP Whaitua (Easton *et al.*, 2019b, 2019a). This provided an estimate of how water quality may change in certain catchments under the different scenarios based on the modelled results for similar characteristics in the TAoP Whaitua (Blyth, 2020).
- Whaitua specific baseline:

  - Contaminant yields generated by the urban Contaminant Load Model (CLM) (Easton and Hopkinson, 2020); and
  - Sediment loads generated using the Source dSedNet plugin for Source (Easton and Cetin, 2020).
- A detailed assessment of the current state and drivers of water quality and ecology in WTWT (Greer and Ausseil, 2018).

The methodology employed by the Freshwater Panel and their outputs are documented in Greer *et al.* (2022). They were also summarised for the Committee in a standalone executive summary.

Coastal ecology, sediment quality, deposition and texture under the BSP scenarios were assessed by a Coastal Expert Panel ('the Coastal Panel') whose assessments were informed by the inputs and outputs of the Freshwater Panel. Their assessments are published in Melidonis *et al.* (2020).

Note: The impacts of the scenarios on lakes were not tested as part of BSP.

1.4 Report objectives

The purpose of this report is to assess the extent to which the proposed regulatory provisions of PC1[3] ('the proposed provisions') will achieve the TASs and coastal objectives for WTWT (Table 1 to Table 3) using the expert panel outputs described in Section 1.3.2.2. This is necessary as the impacts of the proposed provisions were not explicitly tested through the BSP.

1.5 Scope and limitations of this assessment

- This assessment does not cover the full range of topics that GW will need to produce expert evidence on during the PC1 Freshwater Planning Process. Rather it is intended to inform the PC1 S32 report, and, in tandem with Greer *et al.*, (2023), transparently document the technical work that has been completed since the TWT WIP was published. Consequently, detailed introductions to the freshwater and coastal environments in WTWT, the NPS-FM 2020 and the NRP are not provided.
- While this report summarises the relevant publicly available scientific information produced by the BSP, it cannot describe the extent to which that information guided the Committee in their selection of the TASs and coastal objectives in the WIP. Consequently, that a TAS or coastal objective is assessed as being unachievable is not justification for changing it, as the extent to which achievability factored into the Committees' decisions is unknown.
- While this assessment relies heavily on the results of scenario testing conducted by the Freshwater and Coastal Panels, it is not one of their outputs. Rather it should be treated as the peer reviewed opinion of one expert.
- A comparable report has been prepared for TAoP Whaitua by Greer (2023). The similarities between the scenarios tested for that Whaitua and WTWT means that large parts of that report are replicated here.

[3] https://www.gw.govt.nz/your-region/plans-policies-and-bylaws/updating-our-regional-policy-statement-and-natural-resources-plan/natural-resources-plan-2023-changes/

2 Methods

2.1 Scale of assessment

The impact of the proposed provisions on each of the attributes listed in Table 1 to Table 3 (except ecosystem metabolism) was assessed for each of the spatial areas set out in the headers of those tables (hereafter collectively referred to as 'part-FMUs'). This resulted in 215 TASs and coastal objectives being assessed across the 17 part-FMUs listed below and mapped in Figure 1:

- Rivers:
    - Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems (hereafter abbreviated to 'Small forested and forested mainstems');
    - Te Awa Kairangi lower mainstem
    - Te Awa Kairangi rural streams and rural mainstems (hereafter abbreviated to 'Te Awa Kairangi rural streams and mainstems');
    - Te Awa Kairangi urban streams;
    - Waiwhetū Stream;
    - Wainuiomata urban streams;
    - Wainuiomata rural streams;
    - Parangārehu catchment streams and South-west coast rural streams;
    - Korokoro Stream;
    - Kaiwharawhara Stream; and
    - Wellington urban.
- Lakes:
    - Lake Kōhangatera; and
    - Lake Kōhangapiripiri.
- Coastal:
    - Te Whanganui-a-Tara (Harbour and estuaries);
    - Mākara Estuary;
    - Wainuiomata Estuary; and
    - Wai Tai.

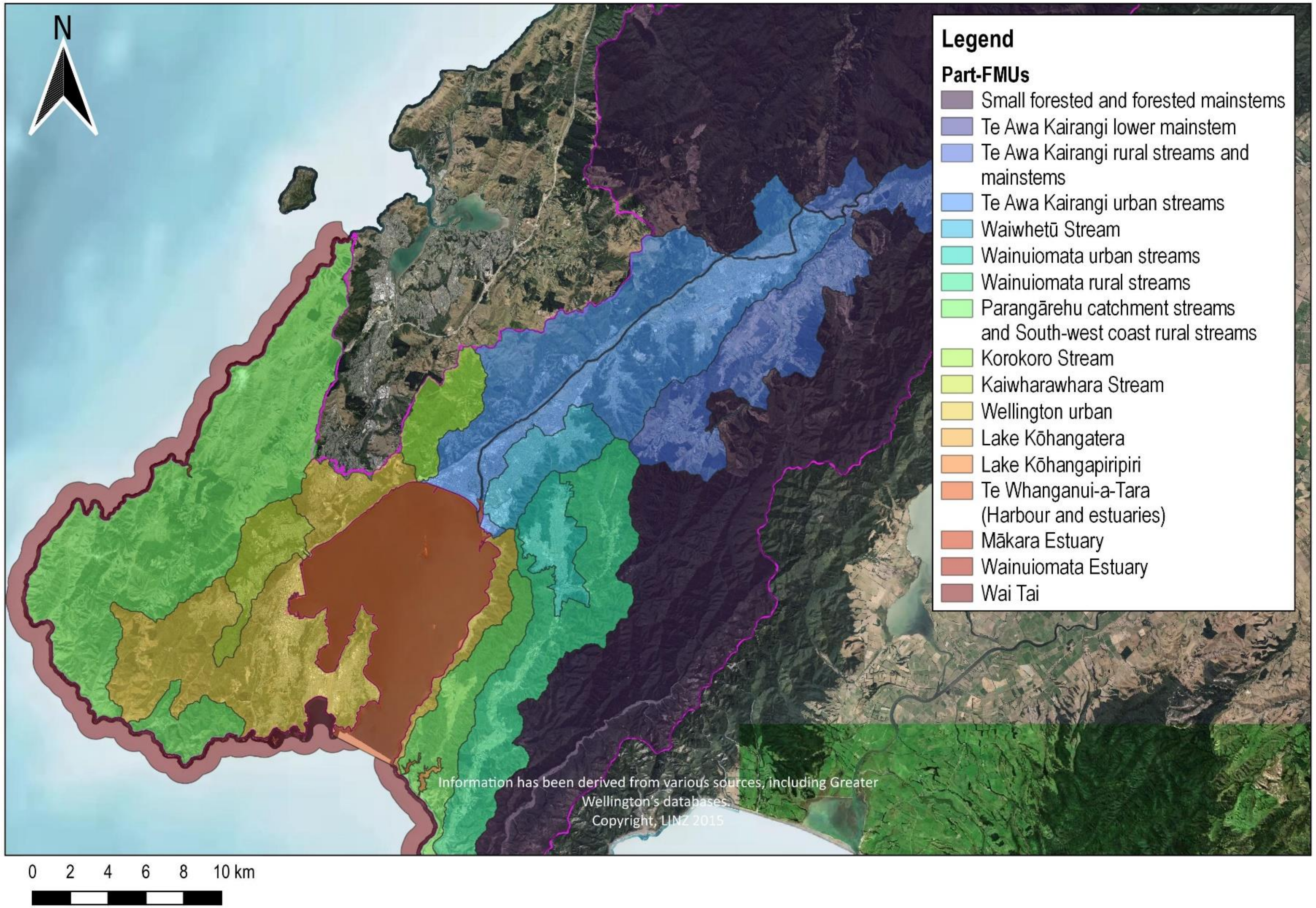

Figure 1: Map of WTWT part-FMUs

2.2 Assessment method for 2A type attributes

The NPS-FM 2020 requires that the proposed provisions contribute to the achievement of the target states for attributes in Appendix 2A of that document and the nutrient outcomes required clause 3.13. Consequently, these attributes require a more detailed assessment methodology than the other attributes in Table 1 to Table 3. The proposed provisions are also directly linked to the TASs or coastal objectives for the following attributes:

- TASs for dissolved copper (Cu);
- TASs for dissolved zinc (Zn); and
- Coastal enterococci objectives.

Thus, for this assessment they are treated the same way as the NPS-FM 2020 Appendix 2A compulsory attributes (hereafter collectively referred to as '2A type attributes'). A full list of the 2A type attributes assessed in this report is provided in Table 4.

Table 4: 2A type attributes and attribute groups.

Attribute Group	2A type attributes
Sediment	• Rivers – Suspended fine sediment (SFS)
Faecal indicator bacteria	• Rivers – *E. coli* • Coast – Enterococci
Nitrogen	• Rivers – Nitrate (NO_3-N) • Rivers – Ammonia (NH_4-N) • Rivers – Dissolved inorganic nitrogen (DIN) (nutrient outcome)
Phosphorus	• Rivers – Dissolved reactive phosphorus (DRP) (nutrient outcome).
Metals	• Rivers – Dissolved copper (Cu) • Rivers – Dissolved zinc (Zn)
Rivers – Periphyton	

Note: The NPS-FM 2020 Appendix 2A attributes for lakes cannot be assessed in the same way as the 2A type attributes in Table 4 as applicable scenario testing results are not available. More detail is provided in Section 2.3.

2.2.1 Scenario assignment

To date, the biophysical effects of the proposed provisions have not been explicitly assessed. Consequently, the BSP scenario testing outputs represent the best available information that can be used to assess the extent to which the proposed provisions will contribute to achievement of the 2A type TASs and coastal objectives in Table 1 and Table 3.

No single BSP scenario aligns perfectly with all the proposed provisions. Thus, for each activity managed by the proposed provisions an assessment has been made of where the relevant provisions sit in relation to the assumptions of the scenarios. This was based on:

- Where the proposed provisions require regulated parties to undertake specific actions (e.g., the installation of a specific treatment device in new urban developments), how similar those actions are to those assumed under the BSP scenarios; or
- Where the proposed provisions require regulated partied to achieve a certain outcome (e.g., a specific percentage reduction in contaminant loads) how similar those outcomes are to those assessed under the BSP scenarios.

The BSP scenario which most closely match the proposed provisions was 'assigned' to each of the following activities:

- Livestock exclusion;
- Riparian management;
- Retirement;
- Space planting (of trees);
- Earthworks;
- Stormwater management;
- Wastewater management;
- Land-use change (other than retirement); and
- Practice change (for the activities not listed above).

This activity based assessment was then used to assign a BSP scenario to each of the attribute groups set out in Table 4. The distribution of rural and urban land-cover differs significantly between the part-FMUs listed in Section 2.1. Accordingly, so too does the relative importance of different activities on water quality and ecology. To account for this, most attributes had different scenarios assigned for:

- Urban part-FMUs (i.e., those almost entirely in urban land-cover):
    - Te Awa Kairangi urban streams;
    - Waiwhetū Stream;
    - Wainuiomata urban streams;
    - Kaiwharawhara Stream; and
    - Wellington urban.

  ; and
- Rural and mixed-rural part-FMUs (i.e., those not classified as 'urban').

The scenario assignment process and outputs are described in full in Section 3. In short it was based on expert opinion and involved:

- Identifying the relevant scenario assumptions for each activity;
- Considering the actual and potential actions and outcomes required for each activity by the proposed provisions;
- Identifying the BSP scenario whose assumptions most closely matched the requirements of the proposed provisions for each activity using the template set out below in Table 5;
- Identifying which activities, and therefore, BSP scenarios, are most relevant to each of the attribute groups in Table 4;

- Providing a detailed description of how the proposed provisions and the assumptions of the assigned scenario align for each activity and attribute group based on the scenario testing outputs, monitoring results and the wider literature; and
- Describing the key differences between the proposed provisions and the assigned scenario for each activity and attribute group.

Table 5: Example of the scenario alignment outputs for individual activities (in this case retirement).

BAU	Improved	Water Sensitive
No retirement.	• Retirement of LUC class 7e and 8e land with grassland land cover. Assumed this land reverts to native cover. • Approximate area retired = 3,733 ha.	• As for Improved but with additional retirement of LUC class 6e land with grassland land cover. • Approximate area retired = 27,985 ha.
BAU	**Improved**	**Water Sensitive**
	↑	
	Provisions	
	• WH.R27(b) and Schedule 36(B)&(E) require retirement of all highest erosion risk land on farms >20 ha by 2040 (50% by 2023). • Approximate area retired = 3,734 ha.	

2.2.2 Identification and approach for 'maintain' 2A type TASs and coastal objectives

The 2A type TASs and coastal objectives that require an attribute be maintained were identified where:

- The baseline state for an attribute meets the TAS (Table 3);
- The baseline state is unknown, but the part-FMU default TAS requires the attribute be maintained (Table 3);
- The coastal narrative objective simply requires the attribute "*Maintain or improve*" (Table 1); or
- The baseline state does not meet the TAS, but current state and trend analysis (as reported in GW (2022)) indicates that the TAS is currently met and that this is likely to continue (i.e., improving trends are likely (>66% probability)). This applies to:
  - Ammonia (toxicity) – Waiwhetū Stream part-FMU; and
  - Periphyton biomass (trend analysis results not available):
    - Kaiwharawhara Stream part-FMU; and
    - Wainuiomata rural streams part-FMU.

For these 'maintain' 2A type TASs and coastal objectives, consideration was given to the Freshwater and Coastal Panel's assessment of the assigned BSP scenario (Greer *et al.*, 2022; Melidonis *et al.*, 2020), and whether the proposed provisions allow for degradation from the baseline state. For each attribute group (see Table 4), the results of these assessments were documented in a short narrative and summarised in the format of Table 6.

Table 6: Example of the summary tables produced for maintain 2A type attributes.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions likely to achieve TAS?
				BAU	Improved	Water Sensitive	
Part-FMU 1	Site 1	Attribute 1	A	Maintain	Maintain	Maintain	✓
Part-FMU 2	Site 2			Degrade	Maintain	Improve	
Part-FMU 3	Site 3			Degrade	Maintain	Improve	
Part-FMU 1	Site 1	Attribute 2	A	Degrade	Improve	Improve	
Part-FMU 2	Site 2			Degrade	Maintain	Improve	
Part-FMU 3	Site 3			Degrade	Improve	Improve	

↑
Provisions

2.2.3 Identification of approach for 'improve' 2A type TASs and coastal objectives

The TASs and coastal objectives that require an improvement in a 2A type attribute were identified where:

- The baseline and current state (as reported in GW (2022)) of an attribute in a part-FMU does not meet the TAS (Table 3);
- The baseline state is unknown, but the part-FMU default TAS requires the attribute be improved (Table 3); or
- A numeric coastal objective has been set for the attribute in a part-FMU (Table 1).

The primary consideration given to these 'improve' 2A type TASs and coastal objectives was whether their achievement was predicted by the Freshwater and Coastal Panels under the assigned scenario. If not, consideration was given to the likely 'gap' that would need to be filled by action planning. For each attribute group (see Table 4), these assessments were documented in a short narrative and summarised in the format of Table 7. For the sediment attribute group, the results of national-scale modelling were considered alongside the Freshwater Panel outputs. Thus, two summary tables were produced (more detail below).

Note: These assessments do not make categorical conclusions about whether a specific TAS will be met by the proposed provisions. Rather results are given in terms of the likely outcomes of the proposed provisions and degree of consistency with the BSP scenarios predicted to achieve the TAS.

Table 7: Example of the summary tables produced for 'improve' 2A type TASs and coastal objectives.

					Scenario results			Provisions likely to achieve TAS?
Part-FMU	**Site**	**Attribute**	**Baseline state**	**TAS**	**BAU**	**Improved**	**Water Sensitive**	
Part-FMU 1	Site 1	Attribute 1	C	A	C	C	C	×
Part-FMU 2	Site 2		D	C	D	C	C	✓
Part-FMU 3	Site 3			C	D	D	C	×
Part-FMU 1	Site 1	Attribute 2	D	C	D	D	C	
Part-FMU 2	Site 2			C	D	D	C	
Part-FMU 3	Site 3			C	D	D	C	

↑
Provisions

The Freshwater Panel's assessments for suspended fine sediment (SFS) factored in the impacts of climate change (at 2090) on increased winter flood frequency (Greer *et al.*, 2022). In most rural part-FMUs this resulted in the benefits of the BSP scenario assumptions on visual clarity being partially or fully offset by an increase in event sediment loads caused by factors outside of GW's control (Greer *et al.*, 2022). In order to better understand the impacts of the different BSP scenarios on SFS without climate change, the results of erosion modelling by Neverman *et al.* (2019) were paired with site specific sediment clarity relationships documented in Greer *et al.* (2023) to generate SFS predictions for the following part-FMUs under each scenario:

- Te Awa Kairangi lower mainstem;
- Te Awa Kairangi rural streams and rural mainstems; and
- Parangārehu catchment streams and South-west coast rural streams.

This approach is considered appropriate as the modelling by Neverman *et al.* (2019):

- Tested the effects of a range of rural mitigations on sediment loads that are broadly consistent with the relevant assumptions of the BSP scenarios; and
- Did not consider the potential impacts of climate change on sediment loads.

The alignment between the mitigations tested by Neverman *et al.* (2019) and the assumptions of the BSP scenarios is described in Table 8.

Table 8: Alignment between the rural erosion mitigations tested by by Neverman *et al.* (2019) and the relevant assumptions of BSP scenarios assessed by the Freshwater Panel. The sediment load reduction factors for the BSP scenarios were drawn directly from assumptions of the scenarios (where applicable – Appendix B), or the commonly used performance values cited in Phillips *et al.* (2020).

<table>
<tr><th rowspan="2">BSP scenario</th><th colspan="2">Relevant mitigations modelled by Neverman et al. (2019)</th><th colspan="2">Relevant BSP scenario assumptions</th></tr>
<tr><th>Actions</th><th>Indicative load reduction factor</th><th>Actions</th><th>Indicative load reduction factor</th></tr>
<tr><td>BAU</td><td colspan="2">Riparian exclusion on all ‘major streams’</td><td>80% (stream bank erosion)</td><td>50%
(Phillips et al., 2020)</td></tr>
<tr><td rowspan="3">Improved</td><td>Riparian exclusion on all ‘major streams’</td><td>80% (stream bank erosion)</td><td>BAU + livestock exclusion with 5m of riparian planting on all REC order ≥2 streams catchment slope <15°</td><td>80% (stream bank erosion)</td></tr>
<tr><td rowspan="2">Whole Farm Plans on all LUC class 6e, 71 and 8e land</td><td rowspan="2">70%</td><td>Space planting of class 6e land</td><td>70%</td></tr>
<tr><td>Retirement of class 7e and 8e land</td><td>90%
(Phillips et al., 2020)</td></tr>
<tr><td rowspan="2">Water Sensitive</td><td>Riparian exclusion on all ‘major streams’</td><td>80% (stream bank erosion)</td><td>BAU + livestock exclusion with 10m of riparian planting on all REC order ≥2 streams catchment slope <15°</td><td>80% (stream bank erosion)</td></tr>
<tr><td>Retirement of class 6e, 7e and 8e land</td><td>90%</td><td>Retirement of class 6e, 7e and 8e land</td><td>90%
(Phillips et al., 2020)</td></tr>
</table>

2.3 Assessment method for 2B type attributes

2.3.1 Identification of ‘maintain’ and ‘improve’ 2B type TASs and coastal objectives

Whether the TASs and coastal objectives in Table 1 to Table 3 require the maintenance or improvement of the 2B type attributes listed in Table 9 was determined through the approach described in Sections 2.2.2 and 2.2.3. Through this process, the following ‘maintain’ TASs were identified as requiring an improvement from the reported baseline state that has already been achieved (GW, 2022):

- Small forested and forested mainstems:
  - Deposited fine sediment;
  - Macroinvertebrates (1 of 2); and
  - Macroinvertebrates (2 of 2).
- Kaiwharawhara Stream:
  - Deposited fine sediment (DFS); and
  - Macroinvertebrates (2 of 2).
- Wellington urban streams – Macroinvertebrates (2 of 2);
- Wainuiomata rural streams – Deposited fine sediment; and
- Lake Kōhangapiripiri:
  - Submerged plants (natives); and
  - Submerged plants (invasive species).

Table 9: 2B type attributes.

Environment	Attribute
Rivers[1]	• Deposited fine sediment (DFS) • Macroinvertebrate Community Index score and Quantitative Macroinvertebrate Community Index score (Q/MCI) • Macroinvertebrate Average Score Per Metric (ASPM) • Fish Index of Biotic Integrity (F-IBI) • Fish community health • Dissolved oxygen
Lakes	• Phytoplankton • Total nitrogen (TN) • Total phosphorus (TP) • NH_4-N • *E. coli* • Cyanobacteria (planktonic) • Submerged plants (natives) • Submerged plants (invasive species) • Lake-bottom dissolved oxygen
Coastal water	• Benthic marine invertebrate diversity • Macroalgal Ecological Quality Rating (EQR) • Phytoplankton • Cu in sediment • Zn in sediment • Muddiness (% area >50% mud) • Muddiness (% of sample) • Sedimentation rate

[1] There are no data available for ecosystem metabolism and no attribute state framework. Furthermore, this attribute was not considered in the BSP. Consequently, this attribute is not considered in this report.

2.3.2 River TASs and coastal objectives

There is no NPS-FM 2020 requirement for the proposed provisions to contribute to the achievement of the target states or coastal objectives for the attributes in Table 1 and Table 3 that are not listed in Appendix 2A of the NPS-FM or Section 2.2 (hereafter referred to collectively as '2B type attributes'). Consequently, the assessment process for these attributes was not as detailed or structured as that described above for 2A type attributes.

For each 2B type TAS and coastal objectives in Table 1 to Table 3 a narrative assessment was made of:

- The most applicable BSP scenario (based on expert opinion and the results of the scenario assignment process described in Sections 2.2 and 3); and
- The likely outcome of the proposed provisions based on the Freshwater and Coastal Panel outputs for the most applicable scenario.

Where the outputs of the Freshwater and Coastal Panels allowed, the assessments described above were also summarised in tables like those produced for 2A type attributes (see Table 6 and Table 7).

This approach provided a general indication of whether the proposed provisions are likely to result in the achievement of most 2B type river TASs and coastal objectives. However, there is a high level of uncertainty around the assessments made for DFS. Since it was not assessed by the Freshwater Panel due to uncertainties around the response of this attribute to the BSP scenario assumptions (Greer *et al.*, 2022 – Addendum 1).

2.3.3 Lake TASs

It was not possible to conduct a detailed assessment of the impacts of the proposed provisions on the lake attributes in Table 2, as the effects of the BSP scenarios on the Parangārehu Lakes and their upstream river catchments were not assessed by the Freshwater Panel. Consequently, they were also treated as 2B type attributes in this report, despite many being listed in Appendix 2A of the NPS-FM 2020. Furthermore, the assessment of these lake attributes is generally limited to determining whether the proposed provisions are consistent with at least the maintenance of the lake attributes and, therefore, not in direct conflict with the achievement of the relevant TASs.

2.4 Assumptions

- It was not possible to determine which types of livestock are present on a given farm or part of a farm. Thus, it was assumed that livestock exclusion will occur on all rivers where the proposed provisions require the exclusion of beef cattle. This may have resulted in the extent of livestock exclusion under the proposed provisions being overestimated in areas where sheep are the only type of livestock present.
- It was assumed that it will generally not be possible to obtain resource consent for the non-complying activities in the proposed provisions. Similarly, based on the policies of the operative NRP and PC1 it was assumed that it will be difficult to obtain resource consent allowing:
  - Livestock access to waterways as a discretionary activity; or

    - The use of land for farming activities without a Farm Environment Plan (FEP) and associated erosion risk treatment plan (ERTP) as a discretionary activity (only applies in some urban part-FMUs; non-complying activity elsewhere).
- Full maps of the location and extent of high risk erosion prone land and highest risk erosion prone land were not produced in time to be considered in this assessment. Thus, the assumed area and location of this land was based off the interim mapping conducted for the Pouewe and Takapū part-FMUs in the TAoP Whaitua.
- It is not possible to predict where individual types of soil conservation treatment will be applied in the future. Thus, for the purposes this assessment it was simply assumed that space planting of poplar and willow poles will be the primary treatment method applied on high erosion risk land. Space planting was chosen over the other treatment methods allowed for under the proposed provisions (Schedule 36 – Table D1) because:
    - It was the only one tested through the BSP scenario testing process other than revegetation;
    - The sediment load reduction factors cited for space planting in Phillips *et al.* (2020) and assumed in the BSP scenario testing (Easton *et al.*, 2019b) (70%) reflect:
        - The mid-point of the range cited in Phillips *et al.* (2020) for the different soil conservation treatment types allowed for under the proposed provisions (50% to 90%); and
        - The cited *assumed* performance of erosion control methods in a well-implemented farm plan in Dymond *et al.* (2010).
- It was assumed that the proposed provisions have been fully implemented and complied with, and that the resulting effects on the environment have been fully realised.

3 Scenario assignment for 2A type attributes

3.1 Alignment between the proposed provisions and BSP scenarios by activity

3.1.1 Retirement

The erosion risk treatment plans (ERTPs) stipulated by clause (b) of Rule WH.R27 of PC1 require:

- Woody vegetation capable of reaching canopy cover of ≥80% in ten years to be established on 50% of the highest erosion risk land on farms greater than 20 hectares (ha) by 2033 (Schedule 36 (E)(1)); and
- The remaining 50% of highest erosion risk land on farms greater than 20 ha to be revegetated by 2040[4] (Schedule 36 (B)).

The result of this revegetation is the affected land will effectively be retired from farming. The location and extent of the highest risk erosion land in WTWT had not been fully mapped at the time of writing. However, interim mapping of the Pouewe and Takapū part-FMUs in the TAoP Whaitua by Collaborations (Taylor Collaborations Ltd), suggests that there is a good alignment between highest risk erosion land and the Land Use Capability (LUC) class 7e and 8e land[5] Thus, the proposed provisions will likely require 3,734 ha of retirement[6], which is the same as was assumed under the BSP Improved scenario (Table 10).

Note: It is possible that some landowners will apply for resource consent to farm without an ERTP. However, it is unlikely it will be granted unless the application includes erosion control methods that are at least as effective as the ERTP requirements of PC1, given:

- *Farming without an ERTP is a non-complying activity in all rural and mixed rural part-FMUs[7].*
- *The significant (>20%) load reductions required to meet the SFS TASs for the following part-FMUs:*
    - *Te Awa Kairangi rural streams and mainstems;*
    - *Te Awa Kairangi lower mainstem;*
    - *Wainuiomata urban streams; and*
    - *Parangārehu catchment streams and south-west coast rural streams.*

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[4] The proposed provisions do not require highest erosion land to be revegetated where it is not practicable and alternative erosion control treatment is applied over the balance of the property that result in the same level of soil loss avoidance. However, given that revegetation is by far the most effective erosion control treatment, and that, by definition, highest erosion risk land has the highest soil losses, it is unlikely that this exemption will reduce the amount of retirement required by 2040.

[5] Area of highest risk erosion land in the Pouewe and Takapū part FMUs 10% greater than area of LUC class 7e and 8e land (Stuart Easton *pers. comm.*)

[6] Calculated through geospatial analysis of the LUC system (all class 7e and 8e land) and the Land Cover Database version 5.0.

[7] Condition (a) of Rule WH.R30 cannot be met as the no single rural or mixed rural part-FMU meets all TASs for DIN, DRP and visual clarity.

- The wording of Policy WH.P23 which aims to *"[r]educe discharges of sediment from farming activities on high and highest erosion risk land by [] **requiring** that farm environment plans prepared for farms with highest erosion risk land (pasture) and/or high erosion risk land (pasture) include an erosion risk treatment plan".*

Table 10: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the BSP scenario assumptions on retirement.

BAU	Improved	Water Sensitive
No retirement.	• Retirement of LUC class 7e and 8e land with grassland land cover. Assumed this land reverts to native cover. • Approximate area retired = 3,734 ha.	• As for Improved but with additional retirement of LUC class 6e land with grassland land cover. • Approximate area retired = 27,985 ha.
BAU	**Improved**	**Water Sensitive**
	↑	
	Provisions	
	• WH.R27(b) and Schedule 36(B)&(E) require retirement of all highest erosion risk land on farms >20 ha by 2040 (50% by 2023). • Approximate area retired = 3,734 ha.	

3.1.2 Space planting (of trees)

The ERTPs stipulated by clause (b) of Rule WH.R27 require high erosion risk land on farms greater than 20 ha to have "*appropriate soil conservation treatment*" to "*provide effective erosion control*" (Schedule 36(E)(3)(c)). Space planting of poplar and willow poles is effective at controlling erosion on slopes and in gullies (Phillips *et al.*, 2020). Thus, it can be assumed that there will be few instances where its application will not be required on high erosion risk land[8].

Based on interim mapping of the Pouewe and Takapū part-FMUs in the TAoP whaitua, there is a good alignment between high risk erosion land and the LUC class 6e land[9]. Thus, the proposed provisions will likely require space planting across 3,337 ha of high erosion risk land[10], which is the same as assumed under the BSP Improved scenario (Table 11).

Note: It is possible that some landowners will apply for resource consent to farm without an. However, it is unlikely it will be granted (see Section 3.1.1).

[8] See Section 2.4 for reasoning behind the assumption that space planting will be the primary soil conservation treatment type applied to high erosion risk land.

[9] Area of high risk erosion land in the Pouewe and Takapū part-FMUs 6% greater than area of LUC class 6e land (Stuart Easton *pers. comm.*)

[10] Calculated through geospatial analysis of the LUC system and the LCDB.

Table 11: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the BSP scenario assumptions on space planting.

BAU	Improved	Water Sensitive
No additional space planting assumed.	• Space/pole planting of LUC class 6e land with grassland land cover. • Approximate area treated = 3,337 ha.	No additional space planting assumed as LUC class 6e land with grassland land cover is assumed to be retired under this scenario.
BAU	**Improved**	**Water Sensitive**

↑

Provisions
• Rule WH.R27(b) and Schedule 36 (E)(3)(c) require appropriate soil conservation treatment (assumed to be space planting) of all high erosion risk land on farms >20 ha. • Approximate area treated = 3,337 ha.

3.1.3 Livestock exclusion

The Resource Management (Stock Exclusion) Regulations 2020 (the 'Stock Exclusion Regulations') require livestock exclusion from wide (greater than one metre (m)) rivers on all low slope land by 01/07/2025. This equates to approximately 86 kilometres (km) of the River Environment Classification[11] network length in WTWT. Furthermore, the permitted activity conditions in Rule R98((b),(c)[12]) of the NRP means that livestock access to an additional 45 km of Category 2 surface water bodies will be a discretionary activity on that date (Rule R99).

It cannot be said with any certainty how much livestock exclusion the existing NRP provisions will result in. However, many land-owners will choose to farm under the permitted activity rule and will exclude livestock from all rivers on low slope land. Furthermore, it is unlikely that those who choose to apply for resource consent for livestock access will obtain it for all rivers on their property given:

- The Farm Environment Plan (FEP) requirements of the operative NRP and PC1;and
- The need to reduce sediment and *E. coli* losses across the WTWT to meet the TASs and coastal objectives.

The proposed provisions of PC1 that drive livestock exclusion beyond what is already required by the Stock Exclusion Regulations and the NRP are rules WH.R28, WH.R29 and WH.R27:

- Rule WH.R29 makes livestock access to rivers in the Mangaroa River and Mākara Stream catchments a discretionary activity except where a small stream riparian programme has been developed in accordance with Schedule 36(F) (Rule WH.R28(b)). This affects 10 km

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[11] The REC (v2.5) is a database of catchment spatial attributes, summarised for every segment in New Zealand's network of rivers

[12] With the exception of the Mangaroa Catchment almost all WTWT rivers in the lowland areas shown on Map 45 of the operative NRP are listed in Schedule F1 of the NRP and are, therefore, category 2 surface water bodies.

and 65 km of the REC network in the Mangaroa River and Mākara Stream catchments respectively as well as an additional unknown length of unmapped river.
- The retirement required by the proposed provisions (WH.R27(b) and Schedule 36(B)&(E); see Section 3.1.1) will likely result in livestock being excluded from rivers in impacted areas. Geospatial analysis of the REC and LUC system suggest that this could impact approximately 30 km[13] of the REC network in WTWT.

In combination, the proposed provisions, the current NRP provisions and the Stock Exclusion Regulations provide some level of control over livestock access across at least 237 km of the rivers in WTWT (Figure 2b). On 86 km livestock access will be not allowed by the Stock Exclusion Regulations, on 121 km it will be a discretionary activity, and on the remaining 30 km it will be a non-complying activity (consequence of proposed provisions relating to farming on highest erosion risk land (see Section 3.1.1).

The total extent of stock exclusion required under the proposed provisions far exceeds that assumed under the BSP Water Sensitive scenario (197 km[14] (Figure 2a and Table 12)). However, 32% (76 km) is expected to occur in just the Mākara Stream Catchment, which makes up just 7% of the Whaitua and 44% of the Parangārehu catchment streams and South-west coast rural streams part-FMU (Figure 2). Consequently, for the vast majority of WTWT the proposed stock exclusion stock exclusion provisions are generally consistent with the assumptions of the BSP Water Sensitive scenario (predicted stock exclusion outside of Mākara Stream Catchment = 160 km and 145 km under the proposed provisions and the Water Sensitive scenario respectively (Table 12).

[13] Represents the total length of REC network within pastoral areas of LUC class 7e and 8e land.

[14] Calculated through geospatial analysis of the REC, the LUC system and the New Zealand Land Cover Database.

Table 12: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the BSP scenario assumptions on livestock exclusion.

BAU	Improved	Water Sensitive
• No livestock access to Category 1 or 2 waterbodies. • No additional livestock exclusion except because of urban development or retirement required by existing resource consents. • Approximate length of livestock exclusion = 91 km (excluding Mākara Stream Catchment).	• Livestock exclusion undertaken on all REC order 2 or greater streams with catchment slope less than 15 degrees. • All streams within retired areas receive livestock exclusion. • Approximate length of livestock exclusion = 143 km (excluding Mākara Stream Catchment).	• Same as Improved but with greater impact from retirement. • Approximate length of livestock exclusion outside of the Mākara Stream Catchment = 145 km (excluding Mākara Stream Catchment).
BAU	Improved	Water Sensitive
		↑
		Provisions
		Approximate length of livestock exclusion required by proposed provisions and existing regulations outside of the Mākara Stream Catchment = 160 km (excluding Mākara Stream Catchment) **Proposed provisions** • The ERTPs required under Rule WH.R27(b) should result in the exclusion of livestock in rivers running through highest erosion risk land on farms >20 ha. Applies to 22 km of REC network. • Rule WH.R28 requires livestock exclusion on all rivers in the Mangaroa River Catchment unless resource consent is obtained (Rule WH.R29) or a small stream riparian programme is developed (Rule WH.R28(b) and Schedule 36(F)). Applies to 9 km of REC network. **Existing regulations** • Under the Stock Exclusion Regulations, livestock exclusion is required on all rivers greater than one metre wide on low slope land. Applies to 85 km of REC network. • Rule R98(b)&(c) of the NRP requires livestock exclusion on all Category 2 surface water bodies unless resource consent is obtained (Rule R99). Applies to 45 km of REC network.

Notes:

- *In the Mākara Stream Catchment the proposed stock exclusion provisions go beyond the assumptions of the BSP Water Sensitive Scenario; and*
- *The length of river covered by the proposed provisions, the current NRP provisions and the Stock Exclusion Regulations have been calculated using the REC network which does not detect smaller streams. Consequently, the cited length of rivers impacted by these documents will have been underestimated. This is also true for the cited length of river impacted by retirement under the scenarios.*

3.1.4 Riparian management

The future riparian management required by regulation (including the proposed provisions) in WTWT is most consistent with that assumed under the BSP BAU scenario (Table 13).

The proposed provisions do not explicitly require riparian planting of streams. However, the Stock Exclusion Regulations require livestock exclusion with a three-metre setback on wide rivers on all low slope land by 01/07/2025. This equates to approximately 86 km of REC network length. While planting of these setbacks is not required, it can be assumed that some form of vegetation will establish in them over time, even if it is just grass and scrub. Furthermore, the ERTPs stipulated by the proposed provisions (Rule WH.R27(b) and Schedule 36(B)&(E)) require that woody vegetation be established on on all highest erosion risk land on farms greater than 20 ha by 2040, which equates to 30 km[13] of the REC network in WTWT receiving riparian planting.

In combination, the proposed provisions and the Stock Exclusion Regulations could require some form of riparian management along 116 km of the REC network in WTWT. While this is greater than that assumed under the BSP BAU scenario (no additional riparian planting), it falls short of the 165 km assumed under the Improved scenario[2] (Figure 3). Furthermore, the required riparian management (simple three metre setback) on the 86 km of river covered by the Stock Exclusion Regulations will likely:

- be far less effective at shading out periphyton (unlikely to result in the establishment of tall trees); and
- strip less sediment and *E. coli* from run-off (~10% (Semadenis-Davies *et al.*, 2020)),

than the five metre planted riparian margins (minimum) assumed under that scenario.

Table 13: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the BSP scenario assumptions on riparian management.

BAU	Improved	Water Sensitive
No additional riparian planting.	• Five metres of riparian planting undertaken on all REC order 2 or greater streams with catchment slope less than 15 degrees. • All streams within retired areas receive riparian planting • Approximate length of new riparian planting = 164 km.	• Same as improved but with 10 metres of riparian plating and greater impact from retirement. • Approximate length of riparian planting = 196 km.
BAU	Improved	Water Sensitive

↑

Provisions
Approximate length of riparian management required by proposed provisions = 116 km **<u>Proposed provisions</u>** • The ERTPs required under Rule WH.R27(b) requires riparian planting of rivers running through highest erosion risk land on farms >20 ha. Applies to 30 km of REC network. **<u>Existing regulations</u>** • Under the Stock Exclusion Regulations livestock exclusion with a three-metre setback is required on all rivers greater than one metre wide on low slope land. Applies to 86 km of REC network.

Notes:

- *The length of river covered by the proposed provisions and the Stock Exclusion Regulations have been calculated using the REC network which does not detect smaller streams. Consequently, the cited length of rivers impacted by these documents will have been underestimated. This is also true for the cited length of river impacted by retirement under the BSP scenarios.*

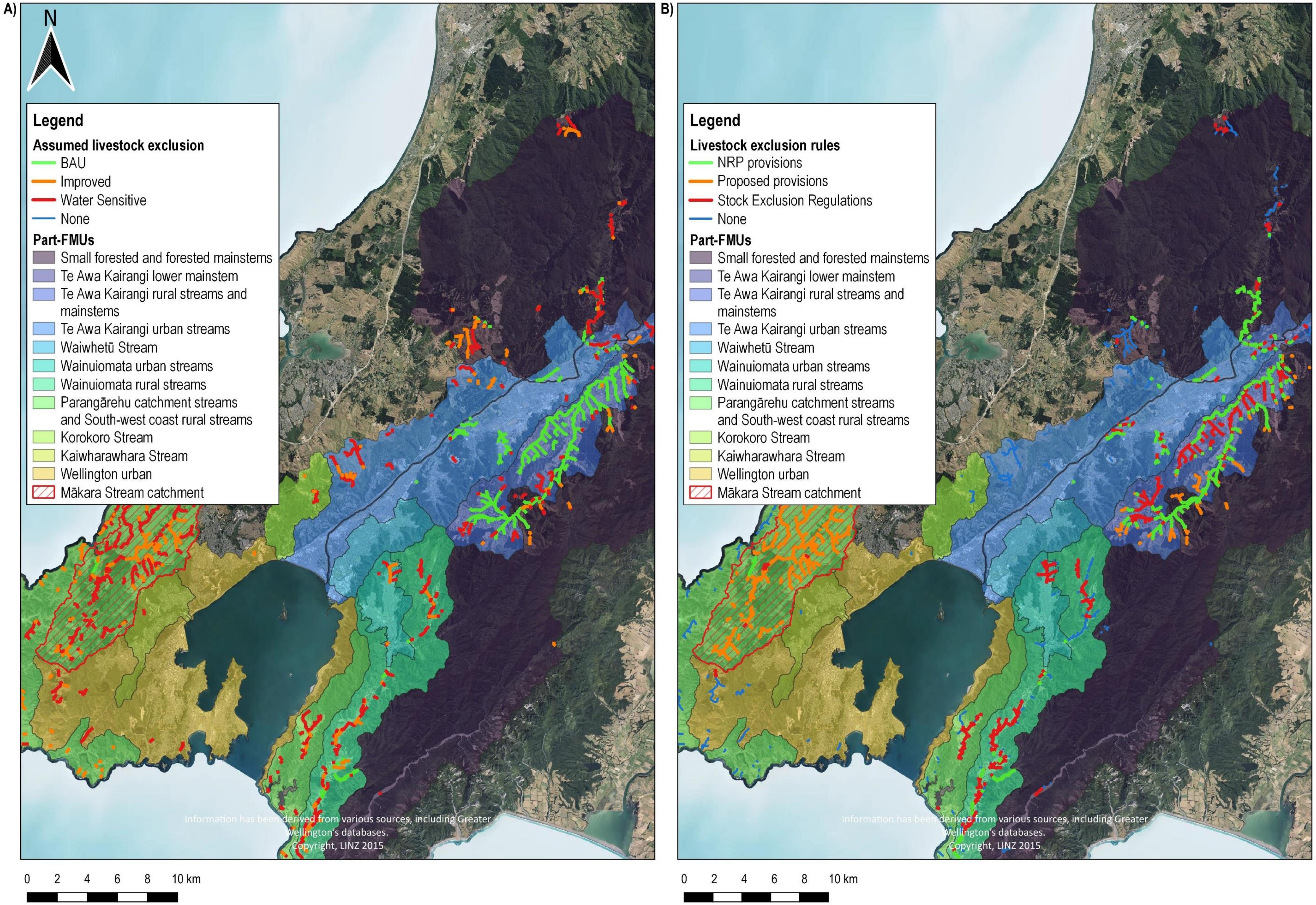

Figure 2: Livestock exclusion assumed under the different BSP scenarios (A) and the proposed provisions (B). The BSP scenarios are additive (i.e., exclusion under the BSP BAU scenario is also assumed under Improved and Water Sensitive).The Mākara Stream Catchment boundary is shown in red.

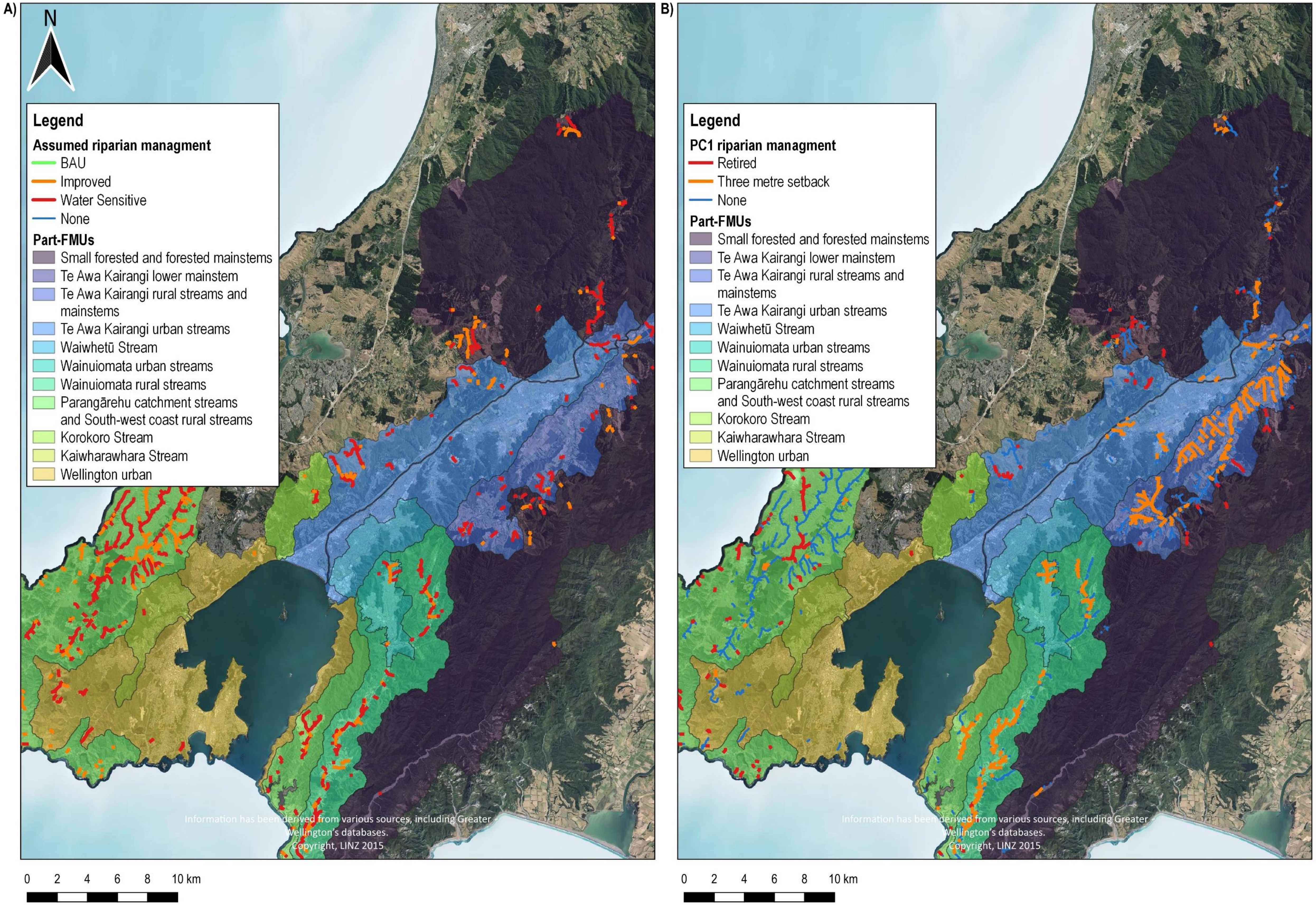

Figure 3: Riparian management assumed under the different BSP scenarios (A) and the proposed provisions (B). The BSP scenarios are additive (i.e., riparian management under the BSP BAU scenario is also assumed under Improved and Water Sensitive).

3.1.5 Earthworks

Policy WH.P29 combined with the conditions of Rule WH.R23 and the matters of discretion in Rule WH.R24 should ensure that the *Erosion and Sediment Control Guide for Land Disturbing Activities in the Wellington Region* (the 'erosion and sediment control guidelines') (Leersnyder *et al.*, 2021) is followed across all earthworks sites. The erosion and sediment control guidelines combined with the total suspended solids (TSS) standards in Policy WH.P30 should also ensure the widespread use of chemically treated sediment retention ponds at sites between 0.3 ha and 5 ha (due to the challenges of meeting the TSS standard without flocculation (ARC, 2004)). It can also be assumed that the activity status of Rule WH.R25 (non-complying) will make it difficult to obtain resource consent to conduct earthworks operations that are contrary to the erosion and sediment control guidelines and the TSS standards in Policy WH.P30.

All the BSP scenarios assumed compliance with the erosion and sediment control guidelines and the widespread use of well-managed chemically treated sediment retention ponds (to reduce sediment loads from earthworks sites by 90%). Consequently, the proposed earthworks provisions are consistent with the BSP Water Sensitive Scenario (Table 14).

Table 14: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the BSP scenario assumptions on earthworks.

BAU	Improved	Water Sensitive
• Construction sediment control practices across 100% of of construction areas. • Assumes GW Erosion and Sediment Control guidelines are followed and the widespread use of well-managed chemically treated sediment retention ponds.		
BAU	Improved	Water Sensitive
		↑
		Provisions
		• Policy WH.P29, Rule WH.R23 and Rule WH.R24 require that the erosion and sediment control guidelines are followed across all earthworks sites covered by those rules. • Policy WH.P30 should ensure the widespread use of chemically treated sediment retention ponds at sites between 0.3 ha and 5 ha.

3.1.6 Stormwater management

The stormwater management required by the proposed provisions goes beyond that assumed under the BSP Water Sensitive scenario (Table 15).

Table 15: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the BSP scenario assumptions on stormwater management.

BAU	Improved	Water Sensitive

No storm water capture or treatment.	• Installation of rainwater tanks on 50% of new greenfield and infill dwellings and 10% of existing residential dwellings (relevant to sediment).
	• In greenfield and infill development, the treatment of:
	  ○ 40% of roads with bioretention; and
	  ○ 100% of paved and rooved surfaces with wetlands.
	• In existing urban areas, the treatment of 50% runoff from major roads and paved commercial and industrial areas with media filters.
		• Installation of rainwater tanks on 100% of new greenfield and infill dwellings and 50% of existing residential dwellings.
		• In greenfield and infill development, the treatment of:
		  ○ 50% of paved surface in new greenfield dwellings and 25% of infill dwellings with permeable paving;
		  ○ 90% of roads with bioretention; and
		  ○ 100% of paved and rooved surfaces with wetlands.
		• In existing urban areas, the treatment of:
		  ○ 100% runoff from major roads with wetlands
		  ○ 100% runoff from paved industrial areas with media filters
		  ○ 100% runoff from paved commercial areas with bioretention.

BAU	Improved	Water Sensitive
		↑
		Provisions
		• Most new infill and urban developments carried out under Rule WH.R5, Rule WH.R6 and Rule WH.R7 (<0.3 ha of new impervious surface) required to provide hydrological controls. • New infill and urban developments carried out under Rule Rule WH.R6 and Rule WH.R7 generally required to treat stormwater with the equivalent of a bioretention device. • Some infill and urban developments >0.3 ha carried out under Rule WH.R11 required to provide treatment and hydrological controls through consent conditions (Policy WH.P10 and Policy WH.P14). • Stormwater network operators required by Rule WH.R9 and Schedule 31 to reduce contaminant loads from existing urban areas to meet the relevant TASs for Cu and Zn (not achieved under the BSP Water Sensitive scenario).

3.1.6.1 New urban development as defined in PC1

Under the proposed provisions almost all new small (less than 0.3 ha of new impervious surface) infill and urban developments carried out as a permitted (Rule WH.R5 - <0.1 ha of new impervious surface) or controlled activity (Rule WH.R6 and Rule WH.R7- 0.1 to 0.3 ha of new impervious surface) will be required to provide hydrological controls (most likely to be in the form of rainwater tanks). Furthermore, all new infill and urban developments carried out as a controlled activity will be required to treat stormwater with a device that achieves copper (Cu), and zinc (Zn) load reduction factors equivalent to that of a bioretention device (commonly known as a 'raingarden'). While not an absolute requirement of the proposed provisions, the wording of Policy WH.P10 and Policy WH.P14 means it is also likely that most infill and urban developments greater than 0.3 ha carried out as a discretionary activity (Rule WH.R11) will be required by consent conditions to provide a similar level of contaminant treatment and hydrological control to what is required by Rule WH.R6.

The stormwater treatment assumed under the BSP scenarios are the same as what was assumed for the equivalent TAoP Collaborative Modelling Project (CMP) scenarios. Easton *et al.* (2019b), who documented the freshwater scenario modelling conducted for the CMP, assumed the contaminant load reduction factors for rain gardens set out in Table 16, and noted that these were "*derived from the International Stormwater Best Management Practices (BMP) database and agreed on within the TAoP (Modelling Leadership Group (MLG)*". These load reduction factors are broadly consistent with what was assumed to be achieved through the treatment chains for new developments under the BSP Improved and Water Sensitive scenarios (Table 16). Thus, in terms of stormwater contaminant losses from new urban developments it can be concluded that proposed provisions are consistent with the assumptions of those scenarios.

Table 16: Load reduction factors for raingardens compared to the treatment chain load reduction factors assumed for new urban developments under the BSP Improved and Water Sensitive scenarios (rain garden values from Easton *et al.*, (2019b) , scenario values from assumptions (Appendix B)).

Contaminant	Raingarden load reduction factors (same as required by proposed provisions)	Treatment chain load reduction factor – Improved	Treatment chain load reduction factor – Water Sensitive
Sediment	90%	80%	75% - 90%
E. coli	90%	90%	90%
TN	40%	40%	40% - 60%
TP	60%	50%	40% - 60%
Cu	80%	70%	50% - 80%
Zn	80%	70%	50% - 80%

The hydrological control requirements for new urban developments with greater than 0.3 ha of new impervious surface area in the proposed provisions are more stringent than the assumptions of the BSP Improved scenario (50% of new dwelling have rain tanks installed). However, they are more lenient than assumed under the Water Sensitive scenario (100% of new dwellings have rain tanks installed) as they do not apply to infill developments with less than 0.1 ha of new impervious surface area. Consequently, the proposed provisions should be at least as effective as the assumptions of the BSP Improved scenario at mitigating the impacts of new urban development on bank erosion (which contributes to sediment loads).

3.1.6.2 Existing discharges from stormwater networks

Rule WH.R9 and Schedule 31 ((1)(c)-(e), and (2)(b)) of the proposed provisions require stormwater network operators to reduce their Cu and Zn loads over time to meet the relevant TASs. The Freshwater Panel outputs in Greer *et al.* (2022) indicates that some of these TASs may not met be met even with the implementation of the BSP Water Sensitive scenario assumptions. Accordingly, the proposed provisions are likely to result in all stormwater contaminant loads from existing urban area being reduced by as much as would occur under that scenario.

Notes: Stormwater treatment does not only remove Cu and Zn; it also treats the other contaminants assessed in this report (see Table 16 for the comparative impacts of stormwater treatment on different contaminants).

3.1.7 Discharges from wastewater networks

The proposed provisions go beyond the wastewater management assumptions of BSP Water Sensitive scenario (Table 17).

Rule WH.R14 of the proposed provisions require that for a wastewater network discharge to coastal and/or freshwater to be a restricted discretionary activity (rather than non-complying) network operators must include a strategy within their resource consent applications to progressively reduce and remove wastewater network catchment discharges (in accordance with Schedule 32) including:

"the reduction of Escherichia coli or enterococci is commensurate with what is required in the receiving environment to meet the target attribute state in Table 8.2 or coastal water objective in Table 8.1 for the relevant part FMU or coastal water management unit"

The Freshwater Panel outputs suggest that some of the *E. coli* TASs for urban catchments are not expected to be met under the BSP Water Sensitive scenario. Consequently, it can be expected that to achieve the *E. coli* and enterococci reductions required by Rule WH.R14, network operators may have to reduce wastewater discharge volumes (and associated contaminant loads) by at least as much as was assumed under that scenario.

Table 17: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the BSP scenario assumptions on wastewater management.

BAU	Improved	Water Sensitive
New urban development does not increase the frequency or volume of wastewater overflows of dry-weather wastewater discharges through cross-connections.	• All cross connections repaired. • Wastewater overflows reduced from 12 per year on average to four.	As for Improved but wastewater overflows reduced to two per year.
BAU	Improved	Water Sensitive
		↑
		Provisions
		Networks operators to wastewater discharge volumes and loads to meet *E. coli* TASs and enterococci objectives (Rule WH.R14).

3.1.8 Land-use change not associated with retirement.

3.1.8.1 Urban development or rural land

All three BSP scenarios assumed greenfield, infill and rural residential development would occur within council identified development zones to accommodate population projections to 2043. While the provisions cannot ensure the land-use change assumed in the BSP scenarios goes ahead, the proposed urban development provisions prohibit new unplanned urban development (Rule WH.R13). Consequently, they are broadly consistent with the BSP Water Sensitive scenario assumptions (Table 18).

3.1.8.2 Change of rural land uses

The BSP scenarios all assumed that rural land use would not change from the baseline period except for conversion to urban development. The proposed provisions are consistent with this assumption (Table 18), in that any change to a higher intensity land use will generally be a non-complying activity (Rule WH.R32), as Condition (d) of Rule WH.R31 is not met in any rural or mixed rural part-FMU[15]. Furthermore, the FEPs required by Rule WH.R27(a) will further ensure land use intensity does not increase by requiring the avoidance of an increase in the "*risk of loss of nitrogen, phosphorus, sediment or E.coli to water*" (Schedule Z(B)(2) of the operative NRP).

Note: The proposed provisions also require that highest erosion risk land currently used for plantation forestry must no longer be used for this once existing trees are harvested. However, this is not considered in this assessment as the implications on land-cover and sediment losses are unclear.

[15] No single rural or mixed rural part-FMU meets all TASs for DIN, DRP and visual clarity and only the Small forested and forested mainstems part-FMU currently meets the TASs for *E. coli*.

Table 18: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the BSP scenario assumptions on land-use change not associated with retirement.

BAU	Improved	Water Sensitive
• Greenfield, infill and rural residential development assumed to occur within council identified development zones to accommodate population projections to 2043. • No change in rural and land use except where it relates to urban development.		
BAU	Improved	Water Sensitive
		↑
		Provisions
		• Rule WH.RU9 prohibits unplanned urban development. • Change to a higher intensity rural land-use is a non-complying activity (Rule WH.R31(d) and Rule WH.R32).

3.1.9 Practice change other than livestock exclusion, riparian planting and space planting

The proposed provisions require that land use practices improve beyond that assumed under the BSP Water Sensitive scenario (Table 19).

None of BSP scenarios assumed changes in land use practice except the livestock exclusion, riparian planting, space planting and sediment control (earthworks) described above in Sections 3.1.2 to 3.1.5 above. However, the proposed provisions require some level of good management practice for:

- Vegetation Clearance on land with high erosion risk (Rule WH.R17 to Rule WH.R19);
- Plantation Forestry (Rule WH.R20 to Rule WH.R22);and
- Farming activities on 20ha or more of land (Rule WH.R27).

The impact this will have on contaminant losses cannot be quantified, but it is likely negligible compared to the required retirement, livestock exclusion and space planting.

Table 19: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the BSP scenario assumptions on practice change not associated with livestock exclusion, riparian planting and space planting.

BAU	Improved	Water Sensitive
Assumes no change in practice other than livestock exclusion, riparian planting, space planting and sediment control (earthworks).		
BAU	Improved	Water Sensitive
		↑
		Provisions
		Require some level of good management practices for: • Vegetation Clearance on land with high erosion risk (Rule WH.R17 - Rule WH.R19); • Plantation Forestry (Rule WH.R20 - Rule WH.R22); and • Farming activities on 20ha or more of land (Rule WH.R27).

3.2 Alignment between the proposed provisions and BSP scenarios by attribute group

3.2.1 Sediment

3.2.1.1 Rural and mixed-rural part-FMUs

In rural and mixed rural part-FMUs the proposed provisions relevant to the sediment attribute group are most consistent with the assumptions of the BSP Improved scenario in that they require a similar or greater level of:

- Retirement;
- Space planting of high erosion risk land;
- Livestock exclusion; and
- Land use change (excluding retirement).

However, in some part-FMUs they may still result in slightly lower sediment load reductions than were predicted under that scenario as the required riparian management is less extensive than that assumed under Improved (30%) and, on low slope land, may be 25% less effective at reducing sediment loads (based on the load reduction factors presented for three and five metre setbacks in Semadenis-Davies *et al.*, (2020)).

3.2.1.2 Urban part-FMUs

The proposed provisions require sediment loads in stormwater (including from earthworks sites) and wastewater be reduced to the same extent assumed under BSP Water Sensitive scenario (see Sections 3.1.5, 3.1.6 and 3.1.7). Thus, in purely urban catchments the proposed provisions should achieve the same outcomes for this attribute group as predicted under that scenario.

3.2.2 Faecal indicator bacteria

3.2.2.1 Rural and mixed-rural part-FMUs

In rural and mixed rural catchments, the proposed provisions are likely to impact the faecal indicator bacteria attribute group in a manner most consistent with the predicted outcomes of the BSP Improved scenario, as they require a similar level of retirement and a slightly greater level of stock exclusion. However, as for sediment they may still result in slightly lower *E. coli* reductions than predicted under Improved as the required riparian management is likely to be less effective at stripping microbial contaminants than assumed under that scenario [16].

3.2.2.2 Urban part-FMUs

As stated in Section 3.1.7, the proposed provisions require urban sources of faecal indicator bacteria to be reduced to the same extent assumed under BSP Water Sensitive scenario. Consequently, in purely urban catchments the proposed provisions should achieve the same outcomes for *E. coli* and enterococci as predicted under that scenario (Greer *et al.*, 2022).

3.2.3 Nitrogen

3.2.3.1 Rural and mixed rural catchments

In rural and mixed rural catchments, the proposed provisions are most consistent with the nitrogen management assumptions of the BSP Improved scenario. The reasons for this are the same as those provided for faecal indicator bacteria in Section 3.2.2.1.

3.2.3.2 Urban catchments

The proposed provisions require nitrogen loads in stormwater and wastewater be reduced to the same extent assumed under the BSP Water Sensitive scenario (see Sections 3.1.6 and 3.1.7).

3.2.4 Phosphorus

3.2.4.1 Rural and mixed rural catchments

For the same reasons as provided for sediment (Section 3.2.1.1) the proposed provisions relevant to the phosphorus attribute group are most consistent with the assumptions of the BSP Improved scenario.

3.2.4.2 Urban catchments

The proposed provisions require phosphorous loads in stormwater and wastewater be reduced to the same extent assumed under the BSP Water Sensitive scenario (see Sections 3.1.6 and 3.1.7).

[16] Potentially 15% for rivers on low slope and (Semadenis-Davies *et al.*, 2020).

3.2.5 Metals

The stormwater management required by the proposed provisions goes beyond that assumed under the BSP Water Sensitive scenario (see Section 3.1.6). Accordingly, they are likely to result in reductions in Cu and Zn concentrations equal to or greater than those predicted under that scenario.

Note: Only the stormwater management provisions are relevant to this attribute group.

3.2.6 Periphyton

3.2.6.1 Rural and mixed-rural catchments

Based on the Freshwater Panel's scenario assessments(Greer *et al.*, 2022), shade was considered a key driver of the predicted changes in this attribute under the different BSP scenarios. On that basis the proposed provisions' impact on periphyton growth is likely to be most similar to what was projected under that the BAU scenario, given the riparian management (i.e., shading) they require is most consistent with what was assumed under that scenario (see Section 3.1.4).

3.2.6.2 Urban catchments

The proposed provisions require that nitrogen and phosphorus loads in stormwater and wastewater be reduced by at least the amount assumed under the BSP Water Sensitive scenario. In urban areas the riparian management required by the provisions (i.e., none) is also consistent with the Water Sensitive scenario. Thus, in urban part-FMUs the proposed provisions are likely to achieve the periphyton outcomes predicted under that scenario.

3.2.7 Summary

Table 20 summarises the likely impact of the proposed provisions on each attribute group compared to the assumptions of the BSP scenarios.

Table 20: Summary of where the likely impacts of the proposed provisions on each attribute group sit in relation to the BSP scenarios.

Attribute group	Most applicable scenario	Indication of where provisions sit in relation to scenarios: BAU	Improved	Water Sensitive
Sediment (rural and mixed-rural part-FMUs)	Improved		↑ Provisions	
Sediment (urban part-FMUs)	Water Sensitive			↑ Provisions
Faecal indicator bacteria (rural and mixed-rural part-FMUs)	Improved		↑ Provisions	
Faecal indicator bacteria (urban part-FMUs)	Water Sensitive			↑ Provisions
Nitrogen (rural and mixed-rural part-FMUs)	Improved		↑ Provisions	
Nitrogen (urban part-FMUs)	Water Sensitive			↑ Provisions
Phosphorus (rural and mixed-rural part-FMUs)	Improved		↑ Provisions	
Phosphorus (urban part-FMUs)	Water Sensitive			↑ Provisions
Metals	Water Sensitive			↑ Provisions
Periphyton (rural and mixed rural part-FMUs)	Improved	↑ Provisions (between BAU and Improved)		
Periphyton (urban part-FMUs)	Water Sensitive			↑ Provisions

4 Results

4.1 Assessment of whether the proposed provisions are likely to achieve the TASs and coastal objectives for 2A type attributes

4.1.1 Maintain TASs and coastal objectives

4.1.1.1 Sediment and phosphorus attribute groups

Depending on the part-FMU, the proposed provisions that manage sediment and phosphorus losses are most consistent with either the BSP Improved scenario (rural and mixed-rural part-FMUs) or the Water Sensitive scenario (urban part-FMUs). The Freshwater Panel predicted suspended fine sediment (SFS (measured through visual clarity)) and dissolved reactive phosphorus (DRP) concentrations would at least be maintained in all part-FMUs under both those scenarios; despite background loads increasing due to to climate change (Greer *et al.*, 2022) (Table 21 and Table 22). Thus, the proposed provisions are likely sufficient to ensure the maintenance of these attributes in those part-FMUs where the TASs require this.

Table 21: The predicted direction of change in SFS under the different BSP scenarios in the part-FMUs where the TASs require the maintenance of this attribute (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Baseline state and TAS</th><th colspan="3">Scenario results</th><th rowspan="2">Provisions likely to achieve TAS?</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td>Small forested and forested mainstems</td><td>Whakatikei R. @ Riverstone</td><td rowspan="6">SFS</td><td rowspan="6">A</td><td>Maintain</td><td rowspan="3">Maintain</td><td>Maintain</td><td rowspan="6">✓</td></tr>
<tr><td>Te Awa Kairangi urban streams</td><td>Hulls Ck adj. Reynolds Bach Dr.</td><td rowspan="5">Degrade</td><td rowspan="5">Improve</td></tr>
<tr><td>Waiwhetū Stream</td><td>Waiwhetu S. @ Whites Line East</td></tr>
<tr><td>Korokoro Stream</td><td>Korokoro S. @ Cornish St. Br.[1]</td><td>Improve</td></tr>
<tr><td>Kaiwharawhara Stream</td><td>Kaiwharawhara S. @ Ngaio Gorge</td><td>Maintain</td></tr>
<tr><td>Wellington urban</td><td>Karori S. @ Mākara Peak[2]</td><td>Improve</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>↑ Provisions (rural part-FMUs)</td><td>↑ Provisions (urban part-FMUs)</td><td></td></tr>
</table>

[1] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.
[2] Assessed as B in Greer *et al.* (2022).

Table 22: The predicted direction of change in DRP concentrations under the different BSP scenarios in the part-FMUs where the TASs require the maintenance of this attribute (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions likely to achieve TAS?
				BAU	Improved	Water Sensitive	
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	DRP (Median mg/L)	0.004	Maintain	Improve	Improve	✓
Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.		0.018				
Wellington urban	Karori S. @ Mākara Peak		0.035				
Small forested and forested mainstems	Whakatikei R. @ Riverstone	DRP (95th %ile mg/L)	0.011	Maintain	Maintain	Maintain	
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott		0.008		Improve	Improve	
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua		0.015	Improve			
Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.		0.027	Maintain			
Waiwhetū Stream	Waiwhetu S. @ Whites Line East		0.049				
Wainuiomata urban streams	Black Ck @ Rowe Parade		0.035				
Wainuiomata rural streams	Wainuiomata River D/S of White Br.		0.017				
Wellington urban	Karori S. @ Mākara Peak		0.062				
					↑ **Provisions (rural part-FMUs)**	↑ **Provisions (urban part-FMUs)**	

4.1.1.2 Faecal indicator bacteria attribute group

For faecal indicator bacteria, the proposed provisions are most consistent with the BSP Improved scenario (Section 3.2.2) in rural and mixed-rural part-FMUs. Based on the Freshwater and Coastal Panels' assessment of this scenario (Greer *et al.*, 2022; Melidonis *et al.*, 2020), it is likely that the proposed provisions will ensure that *E. coli* and enterococci concentrations are maintained in those part-FMUs where this is required by the TASs and coastal objectives (Table 23).

4.1.1.3 Nitrogen attribute group

In rural and mixed-rural part-FMUs, the proposed provisions that manage nitrogen losses are most consistent with assumptions of the BSP Improved scenario, while in urban areas they align better with the Water Sensitive scenario. The Freshwater Panel's assessment of both of those scenarios (Greer *et al.*, 2022), indicates that the proposed provisions are likely to achieve those TASs that require dissolved inorganic nitrogen (DIN), nitrate-nitrogen (NO_3-N) and ammoniacal nitrogen (NH_4-N) concentrations to be maintained (Table 24 and Table 25).

Table 23: The predicted direction of change in *E. coli* (rivers) and enterococci (coast) concentrations under the different BSP scenarios in the part-FMUs where the TASs/coastal objectives require the maintenance of these attributes (based on the outputs of the Freshwater and Coastal Panels (Greer *et al.*, 2022; Melidonis *et al.*, 2020)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs/coastal objectives.

Part-FMU	Site	Attribute	Baseline state and TAS/ objective	Scenario results: BAU	Scenario results: Improved	Scenario results: Water Sensitive	Provisions likely to achieve TAS/ objective?
Small forested and forested mainstems	Whakatikei R. @ Riverstone	*E. coli*	A[1]	Maintain	Maintain	Maintain	✓
Mākara Estuary		Enterococci (95th %ile /100mL)	Maintain or improve	Maintain	Improve	Improve	
Wainuiomata Estuary							
Wai Tai							
					↑ Provisions		

[1] Assessed as B in Greer *et al.* (2022).

Table 24: The predicted direction of change in DIN, NO_3-N, and NH_4-N concentrations under the different BSP scenarios in the urban part-FMUs where the TASs require the maintenance of these attributes (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results: BAU	Scenario results: Improved	Scenario results: Water Sensitive	Provisions likely to achieve TAS?
Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.	NH_4-N	A	Maintain	Improve	Improve	✓
Waiwhetū Stream	Waiwhetu S. @ Whites Line East		A[1]				
Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge		B				
Wellington urban	Karori S. @ Mākara Peak		A				
Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.	NO_3-N	A	Maintain	Improve	Improve	
Waiwhetū Stream	Waiwhetu S. @ Whites Line East						
Wainuiomata urban streams	Black Ck @ Rowe Parade						
Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge		B				
Wellington urban	Karori S. @ Mākara Peak						
Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.	DIN (median mg/L)	0.24	Maintain	Improve	Improve	
Waiwhetū Stream	Waiwhetu S. @ Whites Line East		0.56				
Wainuiomata urban streams	Black Ck @ Rowe Parade		0.5				
Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge		1.14				
Wellington urban	Karori S. @ Mākara Peak		1.29				

↑ Provisions

[1] Baseline state is B. However, current state is A and trend analysis indicates it will remain so (GW, 2022).

Table 25: The predicted direction of change in DIN, NO_3-N, and NH_4-N concentrations under the different BSP scenarios in the rural and mixed-rural part-FMUs where the TASs require the maintenance of these attributes (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions likely to achieve TAS?
				BAU	Improved	Water Sensitive	
Small forested and forested mainstems	Whakatikei R. @ Riverstone	NH_4-N	A	Maintain	Maintain	Maintain	✓
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott				Improve	Improve	
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua				Maintain	Maintain	
Wainuiomata rural streams	Wainuiomata River D/S of White Br.				Improve	Improve	
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels				Maintain	Maintain	
Korokoro Stream	Korokoro S. @ Cornish St. Br.		A[1]				
Small forested and forested mainstems	Whakatikei R. @ Riverstone	NO_3-N	A	Maintain	Maintain	Maintain	
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott				Improve	Improve	
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua						
Wainuiomata rural streams	Wainuiomata River D/S of White Br.						
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels						
Korokoro Stream	Korokoro S. @ Cornish St. Br.		A[1]				
Small forested and forested mainstems	Whakatikei R. @ Riverstone	DIN (median mg/L)	0.15	Maintain	Maintain	Maintain	
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott		0.2		Improve	Improve	
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua		0.44				
Wainuiomata rural streams	Wainuiomata River D/S of White Br.		0.17				
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels		0.42				
Korokoro Stream	Korokoro S. @ Cornish St. Br.		≤0.263[1]				

↑ **Provisions**

[1] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.

4.1.1.4 Metals attribute group

The proposed provisions require that the TASs for Cu and Zn in Table 3 be met through the actions of stormwater network operators (via loads; see Section 3.1.6). Consequently, for the purposes of this assessment it is assumed that the proposed provisions are sufficient to ensure the achievement of those TASs (Table 26).

Table 26: The predicted direction of change in Zn and Cu concentrations under the different BSP scenarios in the part-FMUs where the TASs require the maintenance of these attributes (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions likely to achieve TAS?
				BAU	Improved	Water Sensitive	
Small forested and forested mainstems	Whakatikei R. @ Riverstone	Cu	A[1]	Maintain	Maintain	Maintain	✓
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott		A[2]	Degrade	Improve	Improve	
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua		A[1]	Maintain	Maintain	Maintain	
Wainuiomata urban streams	Black Ck @ Rowe Parade		C	Degrade			
Wainuiomata rural streams	Wainuiomata River D/S of White Br.		A[1]				
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels			Maintain			
Korokoro Stream	Korokoro S. @ Cornish St. Br.						
Small forested and forested mainstems	Whakatikei R. @ Riverstone	Zn	A[1]	Maintain	Maintain	Maintain	
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott		A	Degrade	Improve	Improve	
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua		A[1]	Maintain	Maintain	Maintain	
Wainuiomata rural streams	Wainuiomata River D/S of White Br.			Degrade	Improve	Improve	
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels			Maintain	Maintain	Maintain	
Korokoro Stream	Korokoro S. @ Cornish St. Br.						

↑
Provisions

[1] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.
[2] Assessed as B in Greer *et al.* (2022).

4.1.1.5 Periphyton

The Freshwater Panel's assessment of the BSP BAU and Water Sensitive scenarios suggests that the proposed provisions are likely sufficient to ensure the maintenance of periphyton biomass in all but two of the part-FMUs where this is required by the TASs (Table 27 and Table 28).

Furthermore, while the Freshwater Panel did predict that this attribute would degrade in the Wainuiomata rural streams and Korokoro Stream part-FMUs under the assigned BSP scenario (BAU), this is because they accounted for the impacts of climate change at 2090 on summer low flows (Greer *et al.*, 2022). There is no reason to expect that the proposed provisions themselves will cause a degradation in periphyton biomass in these part-FMUs; rather they are just unlikely to mitigate the adverse effects of climate change.

Table 27: The predicted direction of change in periphyton biomass under the different BSP scenarios in the urban part-FMUs where the TASs require the maintenance of this attribute (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Baseline state and TAS</th><th colspan="3">Scenario results</th><th rowspan="2">Provisions likely to achieve TAS?</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td>Te Awa Kairangi urban streams</td><td>Hulls Ck adj. Reynolds Bach Dr.</td><td rowspan="5">Periphyton biomass</td><td rowspan="3">C[1]</td><td rowspan="3">Degrade</td><td rowspan="3">Maintain</td><td rowspan="5">Improve</td><td rowspan="5">✓</td></tr>
<tr><td>Waiwhetū Stream</td><td>Waiwhetu S. @ Whites Line East</td></tr>
<tr><td>Wainuiomata urban streams</td><td>Black Ck @ Rowe Parade</td></tr>
<tr><td>Kaiwharawhara Stream</td><td>Kaiwharawhara S. @ Ngaio Gorge</td><td>C[2]</td><td rowspan="2">Maintain</td><td rowspan="2">Maintain</td></tr>
<tr><td>Wellington urban</td><td>Karori S. @ Mākara Peak</td><td>C[1]</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>↑
Provisions</td><td></td></tr>
</table>

[1] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.
[2] Baseline state is D. However, current state is C (GW, 2022).

Table 28: The predicted direction of change in periphyton biomass under the different BSP scenarios in the rural and mixed-rural part-FMUs where the TASs require the maintenance of this attribute (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions likely to achieve TAS?
				BAU	Improved	Water Sensitive	
Small forested and forested mainstems	Whakatikei R. @ Riverstone	Periphyton biomass	A[1]	Maintain	Maintain	Maintain	✓
Wainuiomata rural streams	Wainuiomata River D/S of White Br.		C[2]	Degrade		Improve	×
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels		C[1]	Maintain	Improve		✓
Korokoro Stream	Korokoro S. @ Cornish St. Br.			Degrade			×

↑ Provisions

[1] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.
[2] Baseline state is D. However, current state is C (GW, 2022).

4.1.2 Improve TASs and coastal objectives

4.1.2.1 Sediment attribute group

In combination[17], the Freshwater Panel's BSP Improved and Water Sensitive scenario assessments and the national scale erosion modelling by Neverman *et al.* (2019) suggest that the proposed provisions may achieve all but two of the TASs that require an improvement in SFS (Greer *et al.*, 2022) (Table 29 and Table 30). The part-FMUs where this is not the case are:

- Te Awa Kairangi lower mainstem; and
- Wainuiomata rural streams.

Based on the Freshwater Panel outputs, the achievement of those TASs will require the implementation of the proposed provisions and additional non-regulatory actions that are at least as effective at reducing rural sediment losses as those assumed under that BSP Water Sensitive scenario (Table 29); i.e.:

- Planting 10-m riparian buffers on all second order and above streams on low slope (<15°) pastoral land; and
- Retiring all high erosion risk land.

[17] I.e., TAS predicted to be met under assigned scenario based on outputs of either Neverman *et al.* (2019) or Greer *et al.* (2022).

Table 29: Predicted SFS attribute states under the different BSP scenarios in the part-FMUs where the TASs require an improvement in this attribute (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Baseline state</th><th rowspan="2">TAS</th><th colspan="3">Scenario results</th><th rowspan="2">Provisions likely to achieve TAS?</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td>Te Awa Kairangi lower mainstem</td><td>Hutt R. @ Boulcott</td><td rowspan="5">SFS</td><td>C[1]</td><td>A</td><td>C</td><td rowspan="2">C</td><td rowspan="5">C</td><td>×</td></tr>
<tr><td>Te Awa Kairangi rural streams and mainstems</td><td>Mangaroa R. @ Te Marua</td><td>D</td><td rowspan="4">C</td><td rowspan="4">D</td><td rowspan="2">✓</td></tr>
<tr><td>Wainuiomata urban streams</td><td>Black Ck @ Rowe Parade</td><td>D[2]</td><td rowspan="3">D</td></tr>
<tr><td>Wainuiomata rural streams</td><td>Wainuiomata River D/S of White Br.</td><td rowspan="2">D</td><td rowspan="2">×</td></tr>
<tr><td>Parangārehu catchment streams and South-west coast rural streams</td><td>Mākara S. @ Kennels</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>↑ Provisions (rural part-FMUs)</td><td>↑ Provisions (urban part-FMUs)</td><td></td></tr>
</table>

[1] Assessed as B in Greer *et al.* (2022); the states presented for WSP scenarios are based on the baseline state in Table 3 and the Freshwater Panels 'change' assessments.
[2] Not assessed in Greer *et al.* (2022); the states presented for WSP scenarios are based on the baseline state in Table 3 and the Freshwater Panels 'change' assessments.

Table 30: Predicted SFS attribute states (and sediment load reductions) and under the different BSP scenarios in the rural and mixed-rural part-FMUs where the TASs require an improvement in this attribute (based on modelled sediment loads in Neverman *et al.* (2019) and the site specific sediment clarity relationships set out in Greer *et al.* (2023)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Baseline state</th><th rowspan="2">TAS</th><th colspan="3">Scenario results</th><th rowspan="2">Provisions likely to achieve TAS?</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td>Te Awa Kairangi lower mainstem</td><td>Hutt R. @ Boulcott</td><td rowspan="3">SFS</td><td>C[1]</td><td>A</td><td>C (-7%)</td><td>C (-8%)</td><td>B (-8.3%)</td><td rowspan="2">×</td></tr>
<tr><td>Te Awa Kairangi rural streams and mainstems</td><td>Mangaroa R. @ Te Marua</td><td>D</td><td>C</td><td>D (-5%)</td><td>D (-34%)</td><td>C (-43%)</td></tr>
<tr><td>Parangārehu catchment streams and South-west coast rural streams</td><td>Mākara S. @ Kennels</td><td>D</td><td>C</td><td>D (-3%)</td><td>C (-53%)</td><td>A (-55%)</td><td>✓</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>↑ Provisions</td><td></td><td></td></tr>
</table>

[1] Assessed as B in Greer *et al.* (2022); the states presented for WSP scenarios are based on the baseline state in Table 3 and the Freshwater Panels 'change' assessments.

4.1.2.2 Faecal indicator bacteria attribute group

The Freshwater Panels' assessment of the BSP Improved (rural and mixed rural part-FMUs) and Water Sensitive scenario (urban part-FMUs) suggest the proposed provisions are likely to achieve all of the *E. coli* TASs that require an improvement except in the following part-FMUs: (Table 31 and Table 32) (Greer *et al.*, 2022):

- Rural and mixed rural part-FMUs:
  - Te Awa Kairangi rural streams and mainstems; and
  - Parangārehu catchment streams and South-west coast rural streams.
- Urban part-FMUs:
  - Wainuiomata urban streams; and
  - Wellington urban.

In contrast, the outputs Coastal Panels' assessment indicate that the proposed provisions are unlikely to result in the achievement of the only coastal objective that requires an improvement in enterococci (Table 31) (Melidonis *et al.*, 2020).

In rural and mixed rural part-FMUs all *E. coli* TASs and enterococci coastal objectives were predicted to be met under the BSP Water Sensitive scenario. This suggests that in areas where the proposed provisions are unlikely to result in their achievement (Table 31), additional non-regulatory actions like those assumed under that scenario may be required; i.e.:

- Planting 10-m riparian buffers on all second order and above streams on low slope (<15°) pastoral land; and
- Retiring all high erosion risk land.

Note: The information produced by the BSP does not allow for the identification of specific non-regulatory actions that could result in the achievement of the E. coli TASs for the Wainuiomata urban streams; and Wellington urban part-FMUs.

Table 31: Predicted *E. coli* attribute states (rivers) and enterococci concentrations (coast) under the different BSP scenarios in the rural and mixed-rural part-FMUs where the TASs or coastal objectives require an improvement in these attributes (based on the outputs of the freshwater and Coastal Panels (Greer *et al.*, 2022; Melidonis *et al.*, 2020)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs/coastal objectives.

Part-FMU	Site	Attribute	Baseline state	TAS/ objective	Scenario results			Provisions likely to achieve TAS/ objective?
					BAU	Improved	Water Sensitive	
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott		D	C	D	C	B	✓
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua		D	B	D	C	B	×
Wainuiomata rural streams	Wainuiomata River D/S of White Br.		B[1]	A	B	A	A	✓
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	*E. coli*	E	D	E	E	D	×
Korokoro Stream	Korokoro S. @ Cornish St. Br.		N/A[2]	B	Maintain	Improve (within attribute state)	Improve (one attribute state)	?
Te Whanganui-a-Tara (Harbour and estuaries)		Enterococci (95th %ile /100mL)	>200	≤200	>200	>200	≤200	×

↑
Provisions

[1] Assessed as D in Greer *et al.* (2022); the states presented for WSP scenarios are based on the baseline state in Table 3 and the Freshwater Panels 'change' assessments.
[2] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.

Table 32: Predicted *E. coli* attribute states under the different BSP scenarios in the urban part-FMUs where the TASs require an improvement in this attribute (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results			Provisions likely to achieve TAS?
					BAU	Improved	Water Sensitive	
Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.		E[1]			C	C	✓
Waiwhetū Stream	Waiwhetu S. @ Whites Line East		E					
Wainuiomata urban streams	Black Ck @ Rowe Parade	*E. coli*	E[1]	C	E	D	D	×
Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge		E			C	C	✓
Wellington urban	Karori S. @ Mākara Peak					D	D	×

↑
Provisions

[1] Not assessed in Greer *et al.* (2022); the states presented for WSP scenarios are based on the baseline state in Table 3 and the Freshwater Panels 'change' assessments.

4.1.2.3 Nitrogen attribute group

The Freshwater Panel's assessment of the BSP Water Sensitive Scenario suggests that the proposed provisions are unlikely to achieve the reductions in NH_4-N concentrations required by the TAS for the Wainuiomata urban streams part-FMU (Table 33) (Greer *et al.*, 2022). Unfortunately, it is not possible to identify specific non-regulatory actions that could achieve this TAS using information produced by the BSP.

Table 33: Predicted NH_4-N attribute states under the different BSP scenarios in the part-FMUs where the TASs require an improvement in this attribute (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results			Provisions likely to achieve TAS?
					BAU	Improved	Water Sensitive	
Wainuiomata urban streams	Black Ck @ Rowe Parade	NH_4-N	B	A	B	B	B	×
							↑ Provisions	

4.1.2.4 Phosphorus attribute group

It is unlikely that the proposed provisions will achieve most of the TASs that require an improvement in DRP given the Freshwater Panel's assessment of the BSP Improved and Water Sensitive scenarios (Table 34 and Table 35) (Greer *et al.*, 2022). Furthermore, in most part-FMUs it is likely that these TASs will not be achieved without non-regulatory actions that are more effective at reducing phosphorus losses than those assumed under the BSP Water Sensitive scenario (Table 34 and Table 35); i.e.:

- Planting 10-m riparian buffers on all second order and above streams on low slope (<15°) pastoral land; and
- Retiring all high erosion risk land.

Table 34: Predicted DRP concentrations under the different BSP scenarios in the rural and mixed-rural part-FMUs where the TASs require an improvement in this attribute (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). Ranges are given in this table as the Freshwater Panel considered change in NPS-FM 2020 attribute state rather than mass concentration. The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results			Provisions likely to achieve TAS?
					BAU	Improved	Water Sensitive	
Small forested and forested mainstems	Whakatikei R. @ Riverstone	DRP (Median mg/L)	0.008	≤0.006	0.008	0.008	0.008	×
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua		0.01	≤0.006	0.006 – 0.01	≤0.006	≤0.006	✓
Wainuiomata rural streams	Wainuiomata River D/S of White Br.		0.011	≤0.01	0.011	0.01 – 0.011	≤0.01	×
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels		0.027	≤0.018	>0.027	0.018 – 0.027	≤0.018	
Korokoro Stream	Korokoro S. @ Cornish St. Br.		N/A[1]	≤0.006	Maintain	Improve	Improve	?
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	DRP (95th %ile mg/L)	0.064	≤0.054	>0.064	0.054 – 0.064	≤0.054	×
Korokoro Stream	Korokoro S. @ Cornish St. Br.		N/A[1]	≤0.021	Maintain	Improve	Improve	?

↑
Provisions

[1] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.

Table 35: Predicted DRP concentrations under the different BSP scenarios in the urban part-FMUs where the TASs require an improvement in this attribute (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). Ranges are given in this table as the Freshwater Panel considered change in NPS-FM 2020 attribute state rather than mass concentration. The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results			Provisions likely to achieve TAS?
					BAU	Improved	Water Sensitive	
Waiwhetū Stream	Waiwhetu S. @ Whites Line East	DRP (Median mg/L)	0.024	≤0.018	0.024	0.018 – 0.024	0.018 – 0.024	×
Wainuiomata urban streams	Black Ck @ Rowe Parade		0.021	≤0.018	0.021	0.018 – 0.021	≤0.018	✓
Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge		0.037	≤0.018	0.037	0.018 – 0.037	0.018 – 0.037	×
		DRP (95th %ile mg/L)	0.064	≤0.054	0.064	0.054 – 0.064	0.054 – 0.064	

↑
Provisions

4.1.2.5 Metals attribute group

The proposed provisions require that the Cu and Zn TASs in Table 3 be met through the actions of stormwater network operators (see Section 3.1.6). Consequently, it is simply assumed that the provisions are sufficient to ensure that these TASs are achieved, even in those part-FMUs where the Freshwater Panel's outputs suggests this will require actions beyond the assumptions of the BSP Water Sensitive Scenario (i.e., Te Awa Kairangi urban streams, Waiwhetū Stream, Kaiwharawhara Stream, Wellington urban) (Table 36).

Table 36: Predicted Cu and Zn attribute states under the different BSP scenarios in the part-FMUs where the TASs require an improvement in these attributes (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Baseline state</th><th rowspan="2">TAS</th><th colspan="3">Scenario results</th><th rowspan="2">Provisions likely to achieve TAS?</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td>Te Awa Kairangi urban streams</td><td>Hulls Ck adj. Reynolds Bach Dr.</td><td rowspan="4">Cu</td><td>C[1]</td><td>B</td><td>C</td><td>C</td><td>A</td><td rowspan="9">✓</td></tr>
<tr><td>Waiwhetū Stream</td><td>Waiwhetu S. @ Whites Line East</td><td rowspan="2">C</td><td>A</td><td rowspan="3">D</td><td>D</td><td>B</td></tr>
<tr><td>Kaiwharawhara Stream</td><td>Kaiwharawhara S. @ Ngaio Gorge</td><td>B</td><td>C</td><td>C</td></tr>
<tr><td>Wellington urban</td><td>Karori S. @ Mākara Peak</td><td>D</td><td>C</td><td>D</td><td>D</td></tr>
<tr><td>Te Awa Kairangi urban streams</td><td>Hulls Ck adj. Reynolds Bach Dr.</td><td rowspan="5">Zn</td><td>C[1]</td><td>B</td><td>C</td><td>B</td><td>A</td></tr>
<tr><td>Waiwhetū Stream</td><td>Waiwhetu S. @ Whites Line East</td><td>D</td><td>B</td><td rowspan="4">D</td><td>C</td><td>B</td></tr>
<tr><td>Wainuiomata urban streams</td><td>Black Ck @ Rowe Parade</td><td>D[1]</td><td>C</td><td>B</td><td>A</td></tr>
<tr><td>Kaiwharawhara Stream</td><td>Kaiwharawhara S. @ Ngaio Gorge</td><td>B</td><td>A</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>Wellington urban</td><td>Karori S. @ Mākara Peak</td><td>D</td><td>C</td></tr>
</table>

↑
Provisions

[1] Not assessed in Greer *et al.* (2022); the states presented for WSP scenarios are based on the baseline state in Table 3 and the Freshwater Panels 'change' assessments.

4.1.2.6 Periphyton

The Freshwater Panel outputs indicate that the proposed provisions are unlikely to improve periphyton biomass in the Te Awa Kairangi rural streams and mainstems part-FMU or the Te Awa Kairangi lower mainstem part-FMU to the extent required by the relevant TASs (Table 37). Furthermore, it is unlikely that that those TASs will be met without additional non-regulatory actions that go beyond those assumed under the BSP Water Sensitive scenario (Table 37).

Table 37: Predicted periphyton biomass attribute states under the different BSP scenarios in the part-FMUs where the TASs require an improvement in this attribute (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results			Provisions likely to achieve TAS?
					BAU	Improved	Water Sensitive	
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	Periphyton biomass	D[1]	B	D	D	D	×
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua						C	
					↑ Provisions			

[1] Assessed as C in Greer *et al.* (2022); the states presented for WSP scenarios are based on the baseline state in Table 3 and the Freshwater Panels 'change' assessments.

4.2 Assessment of whether the proposed provisions are likely to achieve the TASs and coastal objectives for 2B type attributes

4.2.1 Maintain TASs and coastal objectives

4.2.1.1 Deposited sediment

Based on the Freshwater Panel's assessment of the BSP Improved and Water Sensitive scenarios, the proposed provisions are expected to reduce sediment loads in all part-FMUs and, consequently, should not increase deposited fine sediment (DFS) in those part-FMUs where the TASs require this attribute be maintained (Table 38). Similarly, the Coastal Panel's assessment of the BSP Improved scenario suggests that the proposed provisions should be sufficient to achieve the maintenance of the 'muddiness' and 'sedimentation rate' attributes where this is required by the coastal objectives (Melidonis *et al.*, 2020) (Table 38).

Table 38: The predicted direction of change in DFS (rivers), muddiness (coast) and sedimentation rate (coast) under the different BSP scenarios in the part-FMUs where the TASs and coastal objectives require the maintenance of these attributes (based on the outputs of the freshwater and Coastal Panels (Greer *et al.*, 2022; Melidonis *et al.*, 2020)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they consistent with the achievement of the TASs/coastal objectives.

Part-FMU	Site	Attribute	Baseline state and TAS/ objective	Scenario results: BAU	Scenario results: Improved	Scenario results: Water Sensitive	Provisions consistent with the TAS/ objective?
Small forested and forested mainstems	Whakatikei R. @ Riverstone	DFS	A[1]	Maintain	Maintain	Maintain	✓
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott		A		Improve	Improve	
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua			Improve			
Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.		B	Degrade	Maintain		
Wainuiomata urban streams	Black Ck @ Rowe Parade		A		Improve		
Wainuiomata rural streams	Wainuiomata River D/S of White Br.		A[1]				
Korokoro Stream	Korokoro S. @ Cornish St. Br.		A[2]				
Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge		A[1]		Maintain		
Te Whanganui-a-Tara (Harbour and estuaries)		Muddiness (% area >50% mud and % of sample)	Maintain or improve	Degrade	Maintain	Improve	
Wainuiomata Estuary					Improve		
Wai Tai					Maintain	Maintain	
Te Whanganui-a-Tara (Harbour and estuaries)		Sedimentation rate (C:N)	Maintain or improve	Degrade	Maintain	Improve	
Wainuiomata Estuary					Improve		
Wai Tai					Maintain	Maintain	
					↑ Provisions (rural part-FMUs)	↑ Provisions (urban part-FMUs)	

[1] Baseline state is C. However, current state is A (GW, 2022).
[2] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained

4.2.1.2 Faecal indicator bacteria in lakes

The Freshwater Panel outputs indicate that *E. coli* inputs to lakes from rivers in rural and mixed-rural part-FMUs would not increase under the assumptions of the BSP Improved scenario (Greer *et al.*, 2022). Consequently, it can be assumed that the proposed provisions will be sufficient to meet the *E. coli* TASs for Lake Kōhangatera and Lake Kōhangapiripiri (Table 39).

Table 39: The predicted direction of change in *E. coli* concentrations (lakes) under the different BSP scenarios in the part-FMUs where the TASs require the maintenance of this attribute (based on the Freshwater Panel's outputs for rivers in rural and mixed-rural part-FMUs (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions likely to achieve TAS?
				BAU	Improved	Water Sensitive	
Lake Kōhangatera		*E. coli*	A	Maintain[1]	Improve[1]	Improve[1]	✓
Lake Kōhangapiripiri							
					↑ Provisions		

[1] Based on the freshwater panel results for rural rivers.

4.2.1.3 Nitrogen in lakes

Nitrogen concentrations in lakes are driven by internal cycling and external inputs (Schallenberg, 2019). Thus, in the absence of relevant modelling results, the only conclusion that can be drawn from the Freshwater Panel's assessment of the most relevant BSP scenario (Improved), is that the proposed provisions are unlikely to increase external (i.e., from rivers) nitrogen loads to Lake Kōhangatera and Lake Kōhangapiripiri. Hence, they also are unlikely to <u>cause</u> an in increase in total nitrogen (TN) or NH_4-N concentrations that would prevent these attributes being maintained (Table 40). However, as the internal nutrient cycling processes of these lakes are not fully understood, more detailed analysis would be needed to confirm that concentrations of these attributes will not increase for other reasons.

Table 40: The assumed direction of change in TN and NH_4-N concentrations (lakes) under the different BSP scenarios in the part-FMUs where the TASs require the maintenance of these attributes (based on the Freshwater Panel's outputs for nitrogen attributes in rivers in rural and mixed-rural part-FMUs (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they consistent with the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions consistent with the TAS?
				BAU	Improved	Water Sensitive	
Lake Kōhangatera		NH_4-N	A	Maintain[1]	Maintain[1]	Maintain[1]	✓
Lake Kōhangapiripiri							
Lake Kōhangatera		TN	B	Maintain[1]	Maintain[1]	Maintain[1]	
					↑ Provisions		

[1] Based on the freshwater panel results for rural rivers.

4.2.1.4 Metals in coastal environments

The proposed provisions require that stormwater network operators achieve the rivers Cu and Zn TASs through actions that may have to go beyond those assumed under the BSP Water Sensitive Scenario (see Section 3.1.6 and Table 36). Based on this and the outputs of the Coastal Panel, it is likely that the proposed provisions will result in sediment Cu and Zn concentrations at least being maintained where this is required by the coastal objectives (Table 41).

Table 41: The predicted direction of change in sediment Cu and Zn concentrations (coast) under the different BSP scenarios in the part-FMUs where the coastal objectives require the maintenance of these attributes (based on the outputs of Coastal Panel (Melidonis *et al.*, 2020)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the coastal objectives.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Objective</th><th colspan="3">Scenario results</th><th rowspan="2">Provisions likely to achieve objective?</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td colspan="2">Te Whanganui-a-Tara (Harbour and estuaries)</td><td rowspan="4">Sediment Cu</td><td rowspan="4">Maintain or improve</td><td rowspan="4">Degrade</td><td rowspan="4">Maintain</td><td rowspan="2">Improve</td><td rowspan="8">✓</td></tr>
<tr><td colspan="2">Mākara Estuary</td></tr>
<tr><td colspan="2">Wainuiomata Estuary</td><td>Maintain</td></tr>
<tr><td colspan="2">Wai Tai</td><td>Improve</td></tr>
<tr><td colspan="2">Te Whanganui-a-Tara (Harbour and estuaries)</td><td rowspan="4">Sediment Zn</td><td rowspan="4">Maintain or improve</td><td rowspan="4">Degrade</td><td rowspan="4">Maintain</td><td rowspan="2">Improve</td></tr>
<tr><td colspan="2">Mākara Estuary</td></tr>
<tr><td colspan="2">Wainuiomata Estuary</td><td>Maintain</td></tr>
<tr><td colspan="2">Wai Tai</td><td>Improve</td></tr>
</table>

↑ Provisions

4.2.1.5 Dissolved oxygen

Dissolved oxygen (DO) was not explicitly assessed by the Freshwater Panel (Greer *et al.*, 2022). However, given that primary production is major driver of DO (He *et al.*, 2011) it can be assumed that in rivers, the direction, but not the magnitude, of change in this attribute under the proposed provisions will not be dissimilar to that predicted for periphyton under the BSP scenarios assigned to that attribute (rural and mixed rural part-FMUs = BAU; urban part-FMUs = Water Sensitive). On that basis it is likely that the proposed provisions will maintain DO in all part-FMUs where that is required by the TASs (Table 42).

It is not possible to assign a BSP scenario to the proposed provisions for DO in lakes, as none of the Freshwater Panel outputs for rivers are directly transferable. Nevertheless, as the proposed provisions do not allow for an increase in external nutrient inputs that would increase primary productivity (Sections 4.2.1.3 and 4.2.2.2 (below)), it is unlikely that they will degrade DO in Lake Kōhangatera and Lake Kōhangapiripiri.

Table 42: The predicted direction of change in DO concentrations under the different BSP scenarios in the part-FMUs where the TASs require the maintenance of this attribute (based on the periphyton outputs of the Freshwater Panel (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Baseline state and TAS</th><th colspan="3">Scenario results</th><th rowspan="2">Provisions likely to achieve TAS?</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td>Small forested and forested mainstems</td><td>Whakatikei R. @ Riverstone</td><td rowspan="10">DO</td><td rowspan="10">A[1]</td><td>Maintain</td><td rowspan="2">Maintain</td><td rowspan="2">Maintain</td><td rowspan="10">✓</td></tr>
<tr><td>Te Awa Kairangi lower mainstem</td><td>Hutt R. @ Boulcott</td><td rowspan="5">Degrade</td></tr>
<tr><td>Te Awa Kairangi rural streams and mainstems</td><td>Mangaroa R. @ Te Marua</td><td>Improve</td><td rowspan="8">Improve</td></tr>
<tr><td>Te Awa Kairangi urban streams</td><td>Hulls Ck adj. Reynolds Bach Dr.</td><td rowspan="3">Maintain</td></tr>
<tr><td>Wainuiomata urban streams</td><td>Black Ck @ Rowe Parade</td></tr>
<tr><td>Wainuiomata rural streams</td><td>Wainuiomata River D/S of White Br.</td></tr>
<tr><td>Parangārehu catchment streams and South-west coast rural streams</td><td>Mākara S. @ Kennels</td><td>Maintain</td><td>Improve</td></tr>
<tr><td>Korokoro Stream</td><td>Korokoro S. @ Cornish St. Br.</td><td>Degrade</td><td>Improve</td></tr>
<tr><td>Kaiwharawhara Stream</td><td>Kaiwharawhara S. @ Ngaio Gorge</td><td rowspan="2">Maintain</td><td rowspan="2">Maintain</td></tr>
<tr><td>Wellington urban</td><td>Karori S. @ Mākara Peak</td></tr>
</table>

↑ **Provisions (rural part-FMUs)**

↑ **Provisions (urban part-FMUs)**

[1] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.

4.2.1.6 Plants in lakes and coastal environments

Melidonis *et al.* (2020) notes that in coastal environments macroalgae and phytoplankton respond to sediment and nutrient inputs. This means that the proposed provisions would be expected to achieve a similar outcome for those attributes as the BSP Improved scenario (the most applicable BSP scenario for the sediment, phosphorus and nitrogen attribute groups in rural and mixed-rural part-FMUs). On that basis, they are likely sufficient to meet the coastal objectives that require the maintenance of these attributes (Table 43).

As with DO, it is not possible to assign a BSP scenario to the proposed provisions for submerged plants or phytoplankton in lakes. However, as the proposed provisions do not allow for an increase in external nutrient inputs (Sections 4.2.1.3 and 4.2.2.2 (below)), they should not degrade these attributes where the TASs require they be maintained (Lake Kōhangatera = phytoplankton and submerged plants; Lake Kōhangapiripiri = submerged plants[18]). However, how these attributes will respond in the future to other factors, such as internal nutrient cycling or invasive plant species, is uncertain.

[18] The baseline state for both submerged plants attributes is C (Table 2) and does not meet the TASs. However, current state meets the relevant TASs (Greer *et al.*, 2023).

Table 43: The predicted direction of change in macroalgae and phytoplankton in the part-FMUs where coastal objectives require the maintenance of these attributes (based on the outputs of the Coastal Panel (Melidonis *et al.*, 2020)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the coastal objectives.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Objective</th><th colspan="3">Scenario results</th><th rowspan="2">Provisions likely to achieve objective?</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td colspan="2">Te Whanganui-a-Tara (Harbour and estuaries)</td><td rowspan="4">Macroalgae</td><td rowspan="4">Maintain or improve</td><td rowspan="2">Maintain</td><td rowspan="4">Maintain</td><td>Maintain</td><td rowspan="8">✓</td></tr>
<tr><td colspan="2">Mākara Estuary</td><td>Improve</td></tr>
<tr><td colspan="2">Wainuiomata Estuary</td><td>Degrade</td><td rowspan="2">Maintain</td></tr>
<tr><td colspan="2">Wai Tai</td><td>Maintain</td></tr>
<tr><td colspan="2">Te Whanganui-a-Tara (Harbour and estuaries)</td><td rowspan="4">Phytoplankton</td><td rowspan="4">Maintain or improve</td><td rowspan="2">Maintain</td><td rowspan="4">Maintain</td><td>Maintain</td></tr>
<tr><td colspan="2">Mākara Estuary</td><td>Improve</td></tr>
<tr><td colspan="2">Wainuiomata Estuary</td><td>Degrade</td><td rowspan="2">Maintain</td></tr>
<tr><td colspan="2">Wai Tai</td><td>Maintain</td></tr>
<tr><td colspan="2"></td><td></td><td></td><td></td><td>↑
Provisions</td><td></td><td></td></tr>
</table>

4.2.1.7 Fish and macroinvertebrates

The impacts of the proposed provisions on fish and macroinvertebrate communities in rural and mixed rural part-FMUs are likely to be most consistent with those predicted under BSP Improved scenario given they are expected to achieve similar or better outcomes for sediment (cited as an important stressor in the Freshwater and Coastal Panels' outputs (Greer *et al.*, 2022; Melidonis *et al.*, 2020)). However, in purely urban part-FMUs the proposed provisions will likely have a similar impact as the BSP Water Sensitive, which is the assigned scenario for sediment, metals, nitrogen, phosphorus and periphyton in those part-FMUs (Section 3.2).

Based on the Freshwater and Coastal Panels' assessment of the BSP Improved and Water Sensitive scenarios, it is likely that the proposed provisions will achieve those TASs and coastal objectives that require the maintenance of the following fish and macroinvertebrate attributes (Table 44 and Table 45) (Greer *et al.*, 2022; Melidonis *et al.*, 2020):

- Fish index of biotic integrity (F-IBI) (rivers);
- Fish community health[19] (rivers);
- Macroinvertebrate community index score and quantitative macroinvertebrate community index score Q/MCI (rivers); and
- Benthic marine invertebrate diversity (coast).

[19] Based on the Freshwater Panel's assessments for 'Ecosystem health'.

Table 44: The predicted direction of change in F-IBI and fish community health under the different BSP scenarios in the part-FMUs where the TASs require the maintenance of these attributes (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The results presented for fish community health are based on the Freshwater Panel's assessment for 'Ecosystem health'. The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results: BAU	Scenario results: Improved	Scenario results: Water Sensitive	Provisions likely to achieve TAS?
Small forested and forested mainstems	Whakatikei R. @ Riverstone	F-IBI	N/A[1]	Maintain	Maintain	Maintain	✓
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott						
Waiwhetū Stream	Waiwhetu S. @ Whites Line East						
Wainuiomata urban streams	Black Ck @ Rowe Parade						
Wainuiomata rural streams	Wainuiomata River D/S of White Br.						
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels						
Korokoro Stream	Korokoro S.						
Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge						
Wellington urban	Karori S. @ Mākara Peak						
Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.	Fish community health	N/A[1]	Degrade	Improve	Improve	
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels						
					↑ Provisions (rural part-FMUs)	↑ Provisions (urban part-FMUs)	

[1] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.

Table 45: The predicted direction of change in Q/MCI (rivers), ASPM (rivers) and Benthic marine invertebrate diversity (coast) under the different BSP scenarios in the part-FMUs where the TASs and coastal objectives require the maintenance of these attributes (based on the outputs of the Freshwater and Coastal Panels (Greer *et al.*, 2022; Melidonis *et al.*, 2020)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs/coastal objectives.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Baseline state and TAS/ objective</th><th colspan="3">Scenario results</th><th rowspan="2">Provisions likely to achieve TAS/ objective?</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td>Small forested and forested mainstems</td><td>Whakatikei R. @ Riverstone</td><td rowspan="3">Q/MCI</td><td>A[1]</td><td>Maintain</td><td>Maintain</td><td>Maintain</td><td rowspan="14">✓</td></tr>
<tr><td>Te Awa Kairangi urban streams</td><td>Hulls Ck adj. Reynolds Bach Dr.</td><td>N/A[2]</td><td rowspan="2">Degrade</td><td rowspan="2">Improve</td><td rowspan="2">Improve</td></tr>
<tr><td>Parangārehu catchment streams and South-west coast rural streams</td><td>Mākara S. @ Kennels</td><td>C</td></tr>
<tr><td>Small forested and forested mainstems</td><td>Whakatikei R. @ Riverstone</td><td rowspan="7">ASPM</td><td>A[1]</td><td>Maintain</td><td rowspan="2">Maintain</td><td rowspan="2">Maintain</td></tr>
<tr><td>Te Awa Kairangi lower mainstem</td><td>Hutt R. @ Boulcott</td><td rowspan="2">B</td><td>Degrade</td></tr>
<tr><td>Te Awa Kairangi rural streams and mainstems</td><td>Mangaroa R. @ Te Marua</td><td>Maintain</td><td rowspan="5">Improve</td><td rowspan="5">Improve</td></tr>
<tr><td>Te Awa Kairangi urban streams</td><td>Hulls Ck adj. Reynolds Bach Dr.</td><td>N/A[2]</td><td rowspan="4">Degrade</td></tr>
<tr><td>Parangārehu catchment streams and South-west coast rural streams</td><td>Mākara S. @ Kennels</td><td>B</td></tr>
<tr><td>Kaiwharawhara Stream</td><td>Kaiwharawhara S. @ Ngaio Gorge</td><td rowspan="2">C[3]</td></tr>
<tr><td>Wellington urban</td><td>Karori S. @ Mākara Peak</td></tr>
<tr><td colspan="2">Te Whanganui-a-Tara (Harbour and estuaries)</td><td rowspan="4">Benthic marine invertebrate diversity</td><td rowspan="4">Maintain or improve</td><td rowspan="2">Maintain</td><td>Maintain</td><td>Maintain</td></tr>
<tr><td colspan="2">Mākara Estuary</td><td>Improve</td><td rowspan="2">Improve</td></tr>
<tr><td colspan="2">Wainuiomata Estuary</td><td>Degrade</td><td rowspan="2">Maintain</td></tr>
<tr><td colspan="2">Wai Tai</td><td>Maintain</td><td>Maintain</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>↑ Provisions (rural part-FMUs)</td><td>↑ Provisions (urban part-FMUs)</td><td></td></tr>
</table>

[1] Baseline state is B. However, current state is A and trend analysis indicates it will remain so (GW, 2022).
[2] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.
[3] Baseline state is D. However, current state is C and trend analysis indicates it will remain so (GW, 2022)..

4.2.2 Improve TASs and coastal objectives

4.2.2.1 Sediment

Based on the Freshwater Panels assessment for the BSP Improved and Water Sensitive scenarios, the proposed provisions will likely reduce sediment loads throughout WTWT, and this may contribute to an improvement in DFS in those part-FMUs where the TASs require this (Table 46). However, as the Freshwater Panel did not explicitly assess DFS it not possible to determine whether the proposed provisions will be sufficient to ensure the achievement of these TASs on their own.

The Coastal Panel's assessments for the BSP Improved scenario suggest that, on their own, the proposed provisions may not be sufficient to improve muddiness and sediment rate in the Mākara Estuary to the extent required by the coastal objectives (Table 46). Accordingly, additional non-regulatory actions may be needed such as those assumed under the BSP Water Sensitive scenario, e.g.:

- Planting 10-m riparian buffers on all second order and above streams on low slope (<15°) pastoral land; and
- Retiring all high erosion risk land.

Note: As the Freshwater Panel outputs fed into the Coastal Panel process, the impacts of climate change on sediment loads is factored into the muddiness and sediment rate assessments. National scale erosion modelling by Neverman et al. (2019) suggests that in the absence of any climate change impacts the assumptions of the Improved Scenario, and therefore the proposed provisions, may result in much greater sediment load reductions (55%) than were considered by the Coastal Panel (Table 30).

Table 46: The predicted direction of change in DFS (rivers) and the predicted state of muddiness (coast) and sedimentation rate (coast) under the different BSP scenarios in the part-FMUs where the TASs and coastal objectives require an improvement in these attributes (based on the outputs of the Freshwater and Coastal Panels (Greer *et al.*, 2022; Melidonis *et al.*, 2020)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are consistent with the achievement of the TASs/coastal objectives.

Part-FMU	Site	Attribute	Baseline state	TAS/ objective	Scenario results			Provisions consistent with TAS/ objective?
					BAU	Improved	Water Sensitive	
Waiwhetū Stream	Waiwhetu S. @ Whites Line East	DFS	D	C	Degrade	Maintain	Improve	✓
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels					Improve		
Wellington urban	Karori S. @ Mākara Peak		C	B				
Mākara Estuary		Muddiness (% area >50% mud)	5 – 15	≤5	>15	5 – 15	≤5	×
		Muddiness (% of sample)	10 – 25	<10	> 25	10 – 25	<10	
		Sedimentation rate (C:N)	2– 5	≤2	>5	2– 5	≤2	
						↑ Provisions (rural part-FMUs)	↑ Provisions (urban part-FMUs)	

4.2.2.2 Nutrients, phytoplankton and cyanobacteria (lakes)

The Freshwater Panel's assessment of the BSP Improved scenarios indicates that proposed provisions are unlikely to increase external (i.e., from rivers) nitrogen or phosphorus loads to Lake Kōhangatera and Lake Kōhangapiripiri and, consequently, should not cause an increase in TN or total phosphorus (TP) concentrations where the TASs require an improvement in these attributes (Table 47). Similarly, by not allowing for an increase in external nutrient inputs, the proposed provisions are unlikely to directly degrade phytoplankton or cyanobacteria concentrations where the TASs require they be improved (Lake Kōhangatera = phytoplankton and cyanobacteria; Lake Kōhangapiripiri = cyanobacteria). Nonetheless, it is not possible to confirm that the proposed provisions will result in an improvement in any of these attributes due to uncertainties around baseline state and internal nutrient cycling.

Note: It is not possible to assign a BSP scenario to the proposed provisions for phytoplankton and cyanobacteria in lakes.

Table 47: The assumed direction of change in TN and TP concentrations under the different BSP scenarios in the part-FMUs where the TASs require the improvement of these attributes (based on the Freshwater Panel's outputs for rivers in rural and mixed-rural part-FMUs (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are consistent with the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results			Provisions consistent with TAS?
					BAU	Improved	Water Sensitive	
Lake Kōhangatera		TP	C	B	Degrade[1]	Maintain[1]	Maintain[1]	✓
Lake Kōhangapiripiri								
		TN	C	B	Maintain[1]	Maintain[1]	Maintain[1]	
						↑ Provisions		

[1] Based on the freshwater panel results for rural rivers.

4.2.2.3 Dissolved oxygen

The Waiwhetū Stream is only part-FMU where the default TAS requires an improvement in DO. However, as a macrophyte dominated system, DO is driven by those plants rather than periphyton Consequently, it is not possible to use the Freshwater Panel's periphyton assessments to determine whether the provisions will improve DO in this part-FMU.

4.2.2.4 Fish and macroinvertebrates

Based on the Freshwater Panel's assessment of the BSP Improved and Water Sensitive scenarios (Greer *et al.*, 2022), the proposed provisions:

- Are unlikely to achieve or contribute to the improvements in the F-IBI required by the TASs (Table 48);
- Will likely contribute to the achievement of the TASs that require an improvement in fish community health (Table 48), except in:
  - The Small forested and forested mainstems part-FMU; and
  - The Te Awa Kairangi lower mainstem part-FMU.
- Are unlikely to achieve those Q/MCI and ASPM TASs that require an improvement except in (Table 49):
  - The Waiwhetū Stream part-FMU; and
  - The Wellington urban part-FMU.

The Freshwater Panel's outputs indicate that additional non-regulatory actions like those assumed under the BSP Water Sensitive Scenario may achieve some of the macroinvertebrate and fish community health TASs that will not be met through the proposed provisions; i.e.:

- Planting 10-m riparian buffers on all second order and above streams on low slope (<15°) pastoral land; and
- Retiring all high erosion risk land.

However, it is possible that even with those mitigations the following macroinvertebrate TASs may not be met (Table 49):

  - Te Awa Kairangi lower mainstem (Q/MCI); and
  - Kaiwharawhara Stream (ASPM).

Furthermore, improving the F-IBI requires the introduction of one or more species which, based on the Freshwater Panel's outputs, is unlikely to be achieved by GW unless remediable fish passage barriers are present (i.e., not a single action assumed under the BSP scenarios was predicted to improve this attribute in any part-FMU). Similarly, the fish community health TAS for the 'Small forested and forested mainstems' part-FMU is unlikely to be met through the actions of GW given this area is in reference condition (i.e., natural state).

Table 48: The predicted direction of change in F-IBI and fish community health under the different BSP scenarios in the part-FMUs where the TASs require an improvement in this attribute (based on the Freshwater Panel's 'Ecosystem health' assessments (Greer *et al.*, 2022)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are consistent with the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results			Provisions consistent with TAS?
					BAU	Improved	Water Sensitive	
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua	F-IBI	N/A[1]	A	Maintain	Maintain	Maintain	×
Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.							
Small forested and forested mainstems	Whakatikei R. @ Riverstone	Fish community health	N/A[1]	A	Maintain	Maintain	Maintain	
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott			B	Degrade			
Te Awa Kairangi rural streams and mainstems	Mangaroa R. @ Te Marua				Maintain	Improve	Improve	✓
Waiwhetū Stream	Waiwhetu S. @ Whites Line East			C	Degrade			
Wainuiomata urban streams	Black Ck @ Rowe Parade							
Wainuiomata rural streams	Wainuiomata River D/S of White Br.			B				
Korokoro Stream	Korokoro S. @ Cornish St. Br.			A				
Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge			C				
Wellington urban	Karori S. @ Mākara Peak							

↑ Provisions (rural part-FMUs) ↑ Provisions (urban part-FMUs)

[1] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.

Table 49: The predicted state of Q/MCI (rivers) and ASPM under the different BSP scenarios in the part-FMUs where the TASs require an improvement in these attributes (based on the outputs of the Freshwater Panel (Greer *et al.*, 2022)). The results presented for fish community health are based on the Freshwater Panel's assessment for 'Ecosystem health'. The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are consistent with the achievement of the TASs.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Baseline state</th><th rowspan="2">TAS</th><th colspan="3">Scenario results</th><th rowspan="2">Assigned scenario consistent with TAS</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td>Te Awa Kairangi lower mainstem</td><td>Hutt R. @ Boulcott</td><td rowspan="8">Q/MCI</td><td rowspan="2">C</td><td rowspan="2">B</td><td rowspan="2">C</td><td rowspan="2">C</td><td>C</td><td rowspan="2">×</td></tr>
<tr><td>Te Awa Kairangi rural streams and mainstems</td><td>Mangaroa R. @ Te Marua</td><td>A</td></tr>
<tr><td>Waiwhetū Stream</td><td>Waiwhetu S. @ Whites Line East</td><td>D[1]</td><td>C</td><td>D</td><td>D</td><td>C</td><td>✓</td></tr>
<tr><td>Wainuiomata urban streams</td><td>Black Ck @ Rowe Parade</td><td>N/A[2]</td><td>C</td><td>Degrade</td><td>Improve</td><td>Improve</td><td>?</td></tr>
<tr><td>Wainuiomata rural streams</td><td>Wainuiomata River D/S of White Br.</td><td>C</td><td>B</td><td>C</td><td>C</td><td>B</td><td>×</td></tr>
<tr><td>Korokoro Stream</td><td>Korokoro S. @ Cornish St. Br.</td><td>N/A[2]</td><td>A</td><td>Degrade</td><td>Improve</td><td>Improve</td><td>?</td></tr>
<tr><td>Kaiwharawhara Stream</td><td>Kaiwharawhara S. @ Ngaio Gorge</td><td rowspan="2">D[1]</td><td rowspan="2">C</td><td rowspan="2">D</td><td rowspan="2">D</td><td>D</td><td>×</td></tr>
<tr><td>Wellington urban</td><td>Karori S. @ Mākara Peak</td><td>C</td><td rowspan="2">✓</td></tr>
<tr><td>Waiwhetū Stream</td><td>Waiwhetu S. @ Whites Line East</td><td rowspan="4">ASPM</td><td>D</td><td rowspan="2">C</td><td>D</td><td>D</td><td>C</td></tr>
<tr><td>Wainuiomata urban streams</td><td>Black Ck @ Rowe Parade</td><td>N/A[2]</td><td>Degrade</td><td>Improve</td><td>Improve</td><td>?</td></tr>
<tr><td>Wainuiomata rural streams</td><td>Wainuiomata River D/S of White Br.</td><td>B</td><td rowspan="2">A</td><td>B</td><td>B</td><td>A</td><td>×</td></tr>
<tr><td>Korokoro Stream</td><td>Korokoro S. @ Cornish St. Br.</td><td>N/A[2]</td><td>Degrade</td><td>Improve</td><td>Improve</td><td>?</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>↑
Provisions (rural part-FMUs)</td><td>↑
Provisions (urban part-FMUs)</td><td></td></tr>
</table>

[1] Assessed as B in Greer *et al.* (2022); the states presented for WSP scenarios are based on the baseline state in Table 3 and the Freshwater Panels 'change' assessments.
[2] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or maintained.

5 Conclusions

The results of this assessment suggest that the proposed provisions of PC1 require outcomes and actions that are likely to achieve most (~85%) of the WTWT TASs and coastal objectives. However, there are a number that are unlikely to be met through the proposed provisions alone. In most cases it is likely that the 'gap' between the consequences of the proposed provisions and these TASs and coastal objectives can be filled through non-regulatory actions like those assumed under the BSP Water Sensitive scenario; e.g.:

- Planting 10-m riparian buffers on all second order and above streams on low slope (<15°) pastoral land; and
- Retiring all high erosion risk land.

Nonetheless, some TASs may not be met unless action planning includes even greater non-regulatory actions than those described above, or land use is changed.

The TASs and coastal objectives that have been identified as inconsistent with the proposed provisions are set out below in Table 50.

Table 50: Description of the TASs and coastal objectives that will not be met through the proposed provisions alone. The non-regulatory actions that could potentially fill these 'gaps' are also identified from the BSP scenario assumptions.

<table>
<tr><th>Part-FMU</th><th>Attribute</th><th>Attribute type</th><th>Possible non-regulatory actions to plug 'gap' between provisions and TAS/objective</th></tr>
<tr><td>Wainuiomata rural streams</td><td rowspan="2">Periphyton biomass</td><td rowspan="8">2A</td><td rowspan="2">Planting of five metre riparian buffers on all second order and above streams on pastoral land less than 10 degrees.

Note: This is likely only necessary to offset the effects of climate change at 2090. This attribute should be maintained by the proposed provisions at 2040.</td></tr>
<tr><td>Korokoro Stream</td></tr>
<tr><td>Wainuiomata rural streams</td><td>SFS</td><td rowspan="12">• Planting of 10 metre riparian buffers on all second order and above streams on pastoral land less than 15 degrees; and
• Retirement of all high risk erosion land</td></tr>
<tr><td>Parangārehu catchment streams and South-west coast rural streams</td><td rowspan="2">DRP</td></tr>
<tr><td>Wainuiomata rural streams</td></tr>
<tr><td>Parangārehu catchment streams and South-west coast rural streams</td><td rowspan="2">E. coli</td></tr>
<tr><td>Te Awa Kairangi rural streams and mainstems</td></tr>
<tr><td>Te Whanganui-a-Tara (Harbour and estuaries)</td><td>Enterococci</td></tr>
<tr><td rowspan="3">Mākara Estuary</td><td>Muddiness (% area >50% mud)</td><td rowspan="6">2B</td></tr>
<tr><td>Muddiness (% of sample)</td></tr>
<tr><td>Sedimentation rate</td></tr>
<tr><td>Te Awa Kairangi rural streams and mainstems</td><td rowspan="2">Q/MCI</td></tr>
<tr><td rowspan="2">Wainuiomata rural streams</td></tr>
<tr><td>ASPM</td></tr>
<tr><td>Te Awa Kairangi lower mainstem</td><td>SFS</td><td rowspan="9">2A</td><td rowspan="2">• Planting of 10 metre riparian buffers on all second order and above streams on pastoral land less than 15 degrees;
• Retirement of all high risk erosion land; and
• Additional mitigations not considered in BSP scenarios or land-use change.</td></tr>
<tr><td>Small forested and forested mainstems</td><td rowspan="3">DRP</td></tr>
<tr><td>Kaiwharawhara Stream</td><td rowspan="5">• Additional urban mitigations not considered in BSP scenarios.</td></tr>
<tr><td>Waiwhetū Stream</td></tr>
<tr><td>Wellington urban</td><td rowspan="2">E. coli</td></tr>
<tr><td rowspan="2">Wainuiomata urban streams</td></tr>
<tr><td>NH_4-N</td></tr>
<tr><td>Te Awa Kairangi rural streams and mainstems</td><td rowspan="2">Periphyton biomass</td><td rowspan="5">• Planting of 10 metre riparian buffers on all second order and above streams on pastoral land less than 15 degrees;
• Retirement of all high risk erosion land; and
• Additional mitigations not considered in BSP scenarios or land-use change.</td></tr>
<tr><td rowspan="2">Te Awa Kairangi lower mainstem</td></tr>
<tr><td>Fish community health</td><td rowspan="6">2B</td></tr>
<tr><td>Kaiwharawhara Stream</td><td rowspan="2">Q/MCI</td></tr>
<tr><td>Te Awa Kairangi lower mainstem</td></tr>
<tr><td>Small forested and forested mainstems</td><td>Fish community health</td><td rowspan="3">Unlikely to be achieved through action planning (i.e., outside of GW's control).</td></tr>
<tr><td>Te Awa Kairangi rural streams and mainstems</td><td rowspan="2">F-IBI</td></tr>
<tr><td>Te Awa Kairangi urban streams</td></tr>
</table>

6 References

Auckland Regional Council (ARC), 2004. The Use of Flocculants and Coagulants to Aid the Settlement of Suspended Sediment in Earthworks Runoff : Trials, Methodology and Design (Technical Publication No. No. 227). Auckland Regional Council, Auckland, New Zealand.

Blyth, J., 2020. Whaitua Te Whanganui-a-Tara Expert Panel Proxy Modelling Catchment Assessment (Greater Wellington Regional Council Publication No. GW/ESCI-T-19/123). Greater Wellington Regional Council, Wellington, New Zealand.

Dymond, J.R., Betts, H.D., Schierlitz, C.S., 2010. An erosion model for evaluating regional land-use scenarios. Environ. Model. Softw. 25, 289–298.

Easton, S., Cetin, L., 2020. dSedNet model development and results (Jacobs Memorandum No. IZ130500). Jacobs New Zealand Ltd, Wellington, New Zealand.

Easton, S., Hopkinson, O., 2020. Contaminant Load Model development (Jacobs Memorandum No. IZ130500). Jacobs New Zealand Ltd, Wellington, New Zealand.

Easton, S., Shrestha, M., Cetin, L., Blyth, J., Sands, M., 2019a. Porirua Whaitua Collaborative Modelling Project. Baseline Modelling Technical Report (Jacobs Report No. IZ080700). Jacobs New Zealand Ltd, Wellington, New Zealand.

Easton, S., Shrestha, M., Cetin, L., Sands, M., 2019b. Porirua Whaitua Collaborative Modelling Project. Scenario Modelling Technical Report (Jacobs Report No. IZ080700). Jacobs New Zealand Ltd, Wellington, New Zealand.

Greater Wellington (GW), 2022. 2021/22 River water quality and ecology monitoring (Greater Wellington Publication). Greater Wellington, Wellington, New Zealand.

Greer, M.J.C., 2023. Assessment of alignment between the regulatory provisions and target attribute states in proposed Plan Change 1 to the Natural Resources Plan – Te Awarua-o-Porirua Whaitua (Torlesse Environmental Report No. 2023–007). Torlesse Environmental Ltd, Christchurch, New Zealand.

Greer, M.J.C., Ausseil, O., 2018. Whaitua Te Whanganui-a-Tara: River and stream water quality and ecology (Technical report prepared by Aquanet Consulting Limited for Greater Wellington Regional Council). Aquanet Consulting Ltd., Wellington, New Zealand.

Greer, M.J.C., Ausseil, O., Clapcott, J.E., Farrant, S., Heath, M.W., Norton, N., 2022. Whaitua Te Whanganui-a-Tara water quality and ecology scenario assessment (Aquanet Report). Aquanet Consulting Limited, Wellington, New Zealand.

Greer, M.J.C., Blyth, J., Easton, S., Gadd, J., King, B., Nation, T., Oliver, M., Perrie, A., 2023. Technical assessments undertaken to inform the target attribute state framework of proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region (Torlesse Environmental Report No. 2023–006). Torlesse Environmental Ltd, Christchurch, New Zealand.

He, J., Chu, A., Ryan, M.C., Valeo, C., Zaitlin, B., 2011. Abiotic influences on dissolved oxygen in a riverine environment. Ecol. Eng. 37, 1804–1814.

Leersnyder, H., Parsonson, M., Bunting, K., Stewart, C., 2021. Erosion and sediment control guide for land disturbing activities in the Wellington Region (Greater Wellington Publication). Greater Wellington, Wellington, New Zealand.

Melidonis, M., Oliver, M., Stevens, L., Conwell, C., 2020. Whaitua Te-Whanganui-a-Tara Coastal Assessment Report (Greater Wellington Publication No. GW/ESCI-T-21/16). Greater Wellington, Wellington, New Zealand.

Neverman, A.J., Djanibekov, U., Soliman, T., Walsh, P., Speikermann, R., Basher, L., 2019. Impact testing of a proposed suspended sediment attribute: identifying erosion and sediment control mitigations to meet proposed sediment attribute bottom lines and the costs and benefits of those mitigations (Contract Report No. LC3574).

Phillips, C.J., Basher, L., Spiekermann, R., 2020. Biophysical performance of erosion and sediment control techniques in New Zealand: a review (Contract Report No. LC3761). Manaaki Whenua – Landcare Research.

Schallenberg, M., 2019. Determining reference conditions for New Zealand lakes. Sci. Conserv. 334, 1–46.

Semadenis-Davies, A., Haddadchi, A., Booker, D.J., 2020. Modelling the impacts of the Draft Stock Exclusion Section 360 Regulations on river water quality: E. coli and Sediment (NIWA Client Report No. 2020052AK). NIWA, Auckland, New Zealand.

Appendices

Appendix A – Attribute state tables

Table 1: Attribute states for dissolved copper (toxicity) developed by GW.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved Copper (Toxicity)**		
Attribute Unit	µg DCu/L (micrograms of dissolved Copper per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95th percentile**	
A	≤1	≤1.4	99% species protection level: No observed effect on any species tested
B	>1 and ≤1.4	>1.4 and ≤1.8	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
C	>1.4 and ≤2.5	>1.8 and ≤4.3	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
D	>2.5	>4.3	Starts approaching acute impact level (i.e., risk of death) for sensitive species

Table 2: Attribute states for dissolved zinc (toxicity) developed by GW.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved Zinc (Toxicity)**		
Attribute Unit	µg DZn/L (micrograms of dissolved Zinc per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95th percentile**	
A	≤2.4	≤8	99% species protection level: No observed effect on any species tested
B	>2.4 and ≤8	>8 and ≤15	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
C	>8 and ≤31	>15 and ≤42	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
D	>31	>42	Starts approaching acute impact level (i.e., risk of death) for sensitive species

Values for this metal should be expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a standard hardness for ANZG 2018 guidelines of 30 mg CaCO3/L. Criteria values for other hardness may be calculated as per the equation presented in the ANZG 2018 guidelines.

Table 3: Attribute states for ammonia (toxicity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Ammonia (Toxicity)**		
Attribute Unit	mg NH_4-N/L (milligrams ammoniacal-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	**Annual 95th percentile**	
A	≤0.03	≤0.05	99% species protection level. No observed effect on any species.
B	>0.03 and ≤0.24	>0.05 and ≤0.40	95% species protection level. Starts impacting occasionally on the 5% most sensitive species.
National Bottom Line	**0.24**	**0.4**	
C	>0.24 and ≤1.30	>0.40 and ≤2.020	80% species protection level. Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).
D	>1.30	>2.20	Starts approaching acute impact level (i.e., risk of death) for sensitive species.

Numeric attribute state is based on pH 8 and temperature of 20°C. Compliance with the numeric attribute states should be undertaken after pH adjustment.

Table 4: Attribute states for Nitrate (toxicity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Nitrate (Toxicity)**		
Attribute Unit	mg NO_3-N/L (milligrams nitrate-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	**Annual 95th Percentile**	
A	≤1.0	≤1.5	High conservation value system. Unlikely to be effects even on sensitive species.
B	>1.0 and ≤2.4	>1.5 and ≤3.5	Some growth effect on up to 5% of species.
National Bottom Line	**2.4**	**3.5**	
C	>2.4 and ≤6.9	>3.5 and ≤9.8	Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.
D	>6.9	>9.8	Impacts on growth of multiple species, and starts approaching acute impact level (i.e., risk of death) for sensitive species at higher concentrations (> 20 mg/l).

Note: This attribute measures the toxic effect of nitrate, not the trophic state. Where other attributes measure trophic state, for example periphyton, freshwater objectives, limits and/or methods for those attributes will be more stringent.

Table 5: Attribute states for suspended fine sediment (visual clarity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health				
Freshwater Body Type	Rivers				
Attribute	**Suspended fine sediment**				
Attribute Unit	Visual clarity (metres)				
Attribute State	**Numeric Attribute state by suspended sediment class**				**Narrative Attribute State**
	Median				
	1	**2**	**3**	**4**	
A	≥1.78	≥0.93	≥2.95	≥1.38	Minimal impact of suspended sediment on instream biota. Ecological communities are similar to those observed in natural reference conditions.
B	<1.78 and ≥1.55	<0.93 and ≥0.76	<2.95 and ≥2.57	<1.38 and ≥1.17	Low to moderate impact of suspended sediment on instream biota. Abundance of sensitive fish species may be reduced.
C	<1.55 and >1.34	<0.76 and >0.61	<2.57 and >2.22	<1.17 and >0.98	Moderate to high impact of suspended sediment on instream biota. Sensitive fish species may be lost
National Bottom Line	**1.34**	**0.61**	**2.22**	**0.98**	
D	<1.34	<0.61	<2.22	<0.98	High impact of suspended sediment on instream biota. Ecological communities are significantly altered, and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.

Based on a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years.

Councils may monitor turbidity and convert the measures to visual clarity.

See Appendix 2C Tables 23 and 26 for the definition of suspended sediment classes and their composition.

The following are examples of naturally occurring processes relevant for suspended sediment:

- naturally highly coloured brown-water streams
- glacial flour affected streams and rivers
- selected lake-fed REC classes (particularly warm climate classes) where low visual clarity may reflect autochthonous phytoplankton production

Table 6: Attribute states for *E. coli* taken from Appendix 2A of the NPS-FM 2020.

Value	Human health for recreation				
Freshwater Body Type	Lakes and rivers				
Attribute	***E. coli***				
Attribute Unit	*E. coli* / 100ml (number of *E. coli* per hundred millilitres)				
Attribute State	**Numeric Attribute State**				**Narrative Attribute State**
	% exceedances over 540 cfu/100ml	**% exceedances over 260 cfu/100ml**	**Median concentration (cfu/100ml)**	**95th percentile of *E. coli* /100ml**	**Description of risk of *Campylobacter* infection (based on *E. coli* indicator)**
A (blue)	<5%	<20%	<130	<540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 1% .
B (green)	5-10%	20-30%	<130	<1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 2%.
C (yellow)	10-20%	20-34%	<130	<1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 3% *.
D (orange)	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is >50 in 1000 (>5% risk). The predicted average infection risk is >3%.
E (red)	>30%	>50%	>260	>1200	For more than 30% of the time the estimated risk is >50 in 1000 (>5% risk). The predicted average infection risk is >7%.

Based on a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years.

Table 7: Attribute states for periphyton (trophic state) taken from Appendix 2A of the NPS-FM 2020.

<table>
<tr><td>Value</td><td colspan="3">Ecosystem health</td></tr>
<tr><td>Freshwater Body Type</td><td colspan="3">Rivers</td></tr>
<tr><td>Attribute</td><td colspan="3">Periphyton (Trophic state)</td></tr>
<tr><td>Attribute Unit</td><td colspan="3">mg chl-a/m^2 (milligrams chlorophyll-a per square metre)</td></tr>
<tr><td>Attribute State</td><td>Numeric Attribute State (Default Class)</td><td>Numeric Attribute State (Productive Class[1])</td><td>Narrative Attribute State</td></tr>
<tr><td></td><td>Exceeded no more than 8% of samples[2]</td><td>Exceeded no more than 17% of samples[2]</td><td></td></tr>
<tr><td>A</td><td>≤50</td><td>≤50</td><td>Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat</td></tr>
<tr><td>B</td><td>>50 and ≤120</td><td>>50 and ≤120</td><td>Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat</td></tr>
<tr><td>C</td><td>>120 and ≤200</td><td>>120 and ≤200</td><td rowspan="2">Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat</td></tr>
<tr><td>National Bottom Line</td><td>200</td><td>200</td></tr>
<tr><td>D</td><td>>200</td><td>>200</td><td>Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat</td></tr>
</table>

At low risk sites monitoring may be conducted using visual estimates of periphyton cover. Should monitoring based on visual cover estimates indicate that a site is approaching the relevant periphyton abundance threshold, monitoring should then be upgraded to include measurement of chlorophyll-a.

Classes are streams and rivers defined according to types in the River Environment Classification (REC). The Productive periphyton class is defined by the combination of REC "Dry" Climate categories (that is, Warm-Dry (WD) and Cool-Dry (CD)) and REC Geology categories that have naturally high levels of nutrient enrichment due to their catchment geology (that is, Soft-Sedimentary (SS), Volcanic Acidic (VA) and Volcanic Basic (VB)). Therefore, the productive category is defined by the following REC defined types: WD/SS, WD/VB, WD/VA, CD/SS, CD/VB, CD/VA. The Default class includes all REC types not in the Productive class.

Based on a monthly monitoring regime. The minimum record length for grading a site based on periphyton (chlorophyll-a) is 3 years.

Table 8: Attribute states for the Fish index of Biotic Integrity taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	**Fish (rivers)**	
Attribute Unit	Fish Index of Biotic Integrity (F-IBI)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
A	≥34	High integrity of fish community. Habitat and migratory access have minimal degradation.
B	<34 and ≥28	Moderate integrity of fish community. Habitat and/or migratory access are reduced and show some signs of stress.
C	<28 and ≥18	Low integrity of fish community. Habitat and/or migratory access is considerably impairing and stressing the community
D	<18	Severe loss of fish community integrity. There is substantial loss of habitat and/or migratory access, causing a high level of stress on the community.

Sampling is to occur at least annually between December and April (inclusive) following the protocols for at least one of the backpack electrofishing method, spotlighting method, or trapping method in Joy M, David B, and Lake M. 2013. New Zealand Freshwater Fish Sampling Protocols (Part 1): Wadeable rivers and streams. Massey University: Palmerston North, New Zealand. (See clause 1.8)

The F-IBI score is to be calculated using the general method defined by Joy, MK, and Death RG. 2004. Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. Environmental Management, 34(3), 415-428 (see clause 1.8).

Table 9: Attribute states for the Macroinvertebrate Community Index score and Quantitative Macroinvertebrate Community Index score taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Macroinvertebrates (1 of 2)**		
Attribute Unit	Macroinvertebrate Community Index (MCI) score and Quantitative Macroinvertebrate Community Index (QMCI) score		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	QMCI	**MCI**	
A	≥6.5	≥130	Macroinvertebrate community, indicative of pristine conditions with almost no organic pollution or nutrient enrichment
B	≥5.5 and <6.5	≥110 and <130	Macroinvertebrate community indicative of mild organic pollution or nutrient enrichment. Largely composed of taxa sensitive to organic pollution/nutrient enrichment.
C	≥4.5 and <5.5	≥90 and <110	Macroinvertebrate community indicative of moderate organic pollution or nutrient enrichment. There is a mix of taxa sensitive and insensitive to organic pollution/nutrient enrichment.
National Bottom Line	**4.5**	**90**	
D	<4.5	<90	Macroinvertebrate community indicative of severe organic pollution or nutrient enrichment. Communities are largely composed of taxa insensitive to inorganic pollution/nutrient enrichment.

MCI and QMCI scores to be determined using annual samples taken between 1 November and 30 April with either fixed counts with at least 200 individuals, or full counts, and with current state calculated as the five-year median score. All sites for which the deposited sediment attribute does not apply, whether because they are in river environment classes shown in Table 25 in Appendix 2C or because they require alternate habitat monitoring under clause 3.25 are to use soft sediment sensitivity scores and taxonomic resolution as defined in table A1.1 in Clapcott *et al.* 2017 Macroinvertebrate metrics for the National Policy Statement for Freshwater Management. Cawthron Institute: Nelson, New Zealand (see clause 1.8).

MCI and QMCI to be assessed using the method defined in Stark JD, and Maxted, JR. 2007 A user guide for the Macroinvertebrate Community Index. Cawthron Institute: Nelson, New Zealand (See Clause 1.8), except for sites for which the deposited sediment attribute does not apply, which require use of the soft-sediment sensitivity scores and taxonomic resolution defined in table A1.1 in Clapcott *et al.* 2017 Macroinvertebrate metrics for the National Policy Statement for Freshwater Management. Cawthron Institute: Nelson, New Zealand (see clause 1.8).

Table 10: Attribute states for the Macroinvertebrate Average Score Per Metric taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	**Macroinvertebrates (2 of 2)**	
Attribute Unit	Macroinvertebrate Average Score Per Metric (ASPM)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
A	≥0.6	Macroinvertebrate communities have high ecological integrity, similar to that expected in reference conditions.
B	<0.6 and ≥0.4	Macroinvertebrate communities have mild-to-moderate loss of ecological integrity.
C	<0.4 and ≥0.3	Macroinvertebrate communities have moderate-to severe loss of ecological integrity.
National Bottom Line	**0.3**	
D	<0.3	Macroinvertebrate communities have severe loss of ecological integrity.

Sampling is to occur at least annually between December and April (inclusive) following the protocols for at least one of the backpack electrofishing method, spotlighting method, or trapping method in Joy M, David B, and Lake M. 2013. New Zealand Freshwater Fish Sampling Protocols (Part 1): Wadeable rivers and streams. Massey University: Palmerston North, New Zealand. (see clause 1.8)

The F-IBI score is to be calculated using the general method defined by Joy, MK, and Death RG. 2004. Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. Environmental Management, 34(3), 415-428. (see clause 1.8)

Table 11: Attribute states for dissolved reactive phosphorus taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved reactive phosphorus**		
Attribute Unit	mg DRP/L (milligrams dissolved inorganic nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95th percentile**	
A	≤0.006	≤0.021	Ecological communities and ecosystem processes are similar to those of natural reference conditions. No adverse effects attributable to DRP enrichment are expected.
B	>0.006 and ≤0.010	>0.021 and ≤0.030	Ecological communities are slightly impacted by minor DRP elevation above natural reference conditions. If other conditions also favour eutrophication, sensitive ecosystems may experience additional algal and plant growth, loss of sensitive macroinvertebrate taxa, and higher respiration and decay rates.
C	>0.010 and ≤0.018	>0.030 and ≤0.054	Ecological communities are impacted by moderate DRP elevation above natural reference conditions, but sensitive species are not experiencing nitrate toxicity. If other conditions also favour eutrophication, DRP enrichment may cause increased algal and plant growth, loss of sensitive macroinvertebrate & fish taxa, and high rates of respiration and decay.
D	>0.018	>0.054	Ecological communities impacted by substantial DRP elevation above natural reference conditions. In combination with other conditions favouring eutrophication, DIN enrichment drives excessive primary production and significant changes in macroinvertebrate and fish communities, as taxa sensitive to hypoxia are lost

Numeric attribute state must be derived from the rolling median of monthly monitoring over five years.

Table 12: Attribute states for dissolved oxygen taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved oxygen**		
Attribute Unit	mg/L (milligrams per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	7-day mean minimum	**1-day minimum**	
A	≥8.0	≥7.5	No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near pristine) sites.
B	≥7.0 and <8.0	≥5.0 and <7.5	Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.
C	≥5.0 and <7.0	≥4.0 and <5.0	Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.
National Bottom Line	**5.0**	**4.0**	
D	<5.0	<4.0	Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.

The 7-day mean minimum is the mean value of 7 consecutive daily minimum values.

The 1-day minimum is the lowest daily minimum across the summer period (1 November to 30 April).

Table 13: Attribute states for phytoplankton (trophic state) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Lakes		
Attribute	**Phytoplankton (Trophic state)**		
Attribute Unit	mg chl-a/m^3 (milligrams chlorophyll-a per cubic metre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual median	**Annual maximum**	
A	≤2	≤10	Lake ecological communities are healthy and resilient, similar to natural reference conditions
B	>2 and ≤5	>10 and ≤25	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.
C	>5 and ≤12	>25 and ≤60	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes.
National Bottom Line	**12**	**60**	
D	>12	>60	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

For lakes and lagoons that are intermittently open to the sea, monitoring data should be analysed separately for closed periods and open periods.

Table 14: Attribute states for total nitrogen (trophic state) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Lakes		
Attribute	**Total nitrogen (Trophic state)**		
Attribute Unit	mg/m³ (milligrams per cubic metre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual median	**Annual median**	
	Seasonally stratified and brackish	Polymictic	
A	≤160	≤300	Lake ecological communities are healthy and resilient, similar to natural reference conditions
B	>160 and ≤350	>300 and ≤500	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.
C	>350 and ≤750	>500 and ≤800	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions
National Bottom Line	**750**	**800**	
D	>750	>800	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

For lakes and lagoons that are intermittently open to the sea, monitoring data should be analysed separately for closed periods and open periods.

Table 15: Attribute states for total phosphorus (trophic state) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Total phosphorus (Trophic state)**	
Attribute Unit	mg/m^3 (milligrams per cubic metre)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	Annual median	
A	≤10	Lake ecological communities are healthy and resilient, similar to natural reference conditions
B	>10 and ≤20	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.
C	>20 and ≤50	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions
National Bottom Line	**50**	
D	>50	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

Table 16: Attribute states for cyanobacteria (planktonic) taken from Appendix 2A of the NPS-FM 2020.

Value	Human contact		
Freshwater Body Type	Lakes and lake fed rivers		
Attribute	**Cyanobacteria (planktonic)**		
Attribute Unit	Biovolume mm^3/L (cubic millimetres per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	80th percentile	**80th percentile**	
	biovolume equivalent for the combined total of all cyanobacteria	biovolume equivalent of potentially toxic cyanobacteria	
A	≤0.5	≤0.5	Risk exposure from cyanobacteria is no different to that in natural conditions (from any contact with freshwater).
B	>0.5 and ≤1.0	>0.5 and ≤1.0	Low risk of health effects from exposure to cyanobacteria (from any contact with freshwater).
C	>1.0 and ≤10	>1 and ≤1.8	Moderate risk of health effects from exposure to cyanobacteria (from any contact with freshwater).
National Bottom Line	**10**	**1.8**	
D	>10	>1.8	High health risks (for example, respiratory, irritation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with freshwater).

The 80th percentile must be determined using a minimum of 12 samples collected over 3 years. Thirty samples collected over 3 years is recommended.

Table 17: Attribute states for submerged plants (natives) taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Submerged plants (natives)**	
Attribute Unit	Lake Submerged Plant (Native Condition Index)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	(% of maximum potential score)	
A	>75%	Excellent ecological condition. Native submerged plant communities are almost completely intact.
B	>50 and ≤75%	High ecological condition. Native submerged plant communities are largely intact.
C	≥20 and ≤50%	Moderate ecological condition. Native submerged plant communities are moderately impacted.
National Bottom Line	**20%**	
D	<20%	Poor ecological condition. Native submerged plant communities are largely degraded or absent.

Monitoring to be conducted, and numeric attribute state to be determined, following the method described in Clayton J, and Edwards T. 2006. LakeSPI: A method for monitoring ecological condition in New Zealand lakes. User Manual Version 2. National Institute of Water & Atmospheric Research: Hamilton, New Zealand. (see clause 1.8)

Lakes in a devegetated state receive scores of 0.

Table 18: Attribute states for submerged plants (invasive species) taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Submerged plants (invasive species)**	
Attribute Unit	Lake Submerged Plant (Invasive Impact Index))	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	(% of maximum potential score)	
A	0%	No invasive plants present in the lake. Native plant communities remain intact.
B	>1 and ≤25%	Invasive plants having only a minor impact on native vegetation. Invasive plants will be patchy in nature co-existing with native vegetation. Often major weed species not present or in early stages of invasion.
C	>25 and ≤90%	Invasive plants having a moderate to high impact on native vegetation. Native plant communities likely displaced by invasive weed beds particularly in the 2 – 8 m depth range.
National Bottom Line	**90%**	
D	>90%	Tall dense weed beds exclude native vegetation and dominate entire depth range of plant growth. The species concerned are likely hornwort and Egeria.

Monitoring to be conducted, and numeric attribute state to be determined, following the method described in Clayton J, and Edwards T. 2006. LakeSPI: A method for monitoring ecological condition in New Zealand lakes. User Manual Version 2. National Institute of Water & Atmospheric Research: Hamilton, New Zealand. (see clause 1.8).

Table 19: Attribute states for lake-bottom dissolved oxygen taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Lake-bottom dissolved oxygen**	
Attribute Unit	mg/L (milligrams per litre)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	Measured or estimated annual minimum	
A	≥7.5	No risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.
B	≥2.0 and <7.5	Minimal risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments
C	≥0.5 and <2.0	Risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.
National Bottom Line	**0.5**	
D	<0.5%	Likelihood from lake-bottom dissolved oxygen of biogeochemical conditions resulting in nutrient release from sediments..

To be measured less than 1 metre above sediment surface at the deepest part of the lake using either continuous monitoring sensors or discrete dissolved oxygen profiles.

Appendix B – Detailed BSP scenario assumptions

BAU scenario

- No storm water capture or treatment.
- Numbers of additional dwellings are from the overall supply of realisable residential capacity from the Wellington City Council, Hutt City Council and Upper Hutt City Council housing and business development capacity assessments. These projections aim to represent the realisable new dwellings to accommodate residential population growth over the 30 years from 2017-2047.
- The resulting areas for development are calculated based on an assumed density of 15 additional dwellings/ha for standalone and 7.5 additional dwellings/ha (ha) for terraced housing (giving a total density of 20 dwellings/ha).
- Assumed new development form for dwellings within existing residential zones is 43% urban grassland and parks, 15% roads, 17% paved, 25% roofs. For greenfield development zones it is 36% urban grassland and parks, 20% roads, 14% paved, 30% roofs.
- Standalone houses and greenfield development replace forest and pasture, while terrace style housing replaces urban grass and parks and residential impervious cover.
- The wastewater network condition does not change, and additional dwellings and population do not increase the wastewater overflows.
- Livestock exclusion in all REC streams in identified 'Category 1 or 2' areas of the Natural Resources Plan (NRP).

Improved scenario

- Numbers of additional dwellings, development form and land cover replacement for are the same as for BAU.
- A mixture of site and catchment scale stormwater retention devices fitted to catch and treat runoff from impervious surfaces of residential developments. These treatment trains result in the following (approximate) reductions in contaminate yields and flow from impervious surfaces:
    - Suspended sediment, 80%
    - Total and dissolved zinc, 70%
    - Total and dissolved copper, 70%
    - Total nitrogen, 40%
    - Total phosphorus, 50%
    - *E. coli*, 90%
    - Total flow, 6%
- Rain tanks retrofitted to 10% existing residential roofs to reduce total flow from these by 1%.
- 50% of runoff from commercial and industrial paved surfaces and major roads receives media filter treatment. These result in the following weighted (approximate) reductions for these surfaces:
    - Suspended sediment, 40%.
    - Total and dissolved zinc and copper, 25%.
    - Total nitrogen and phosphorus, 20%.
    - *E. coli*, 40%.
- 50% of commercial and industrial roofs and existing residential roofs are replaced/treated with low zinc yielding materials.
- Sediment control applied to all construction sites, with a 90% effectiveness for removal of generated sediment, metals, and nutrients.

- Wastewater network condition is significantly improved to remove dry weather leaks and remove overflows in all but the four largest rainfalls each year.
- Livestock exclusion is undertaken on all REC order 2 or greater streams with grassland land cover and catchment slope less than 10 degrees. All areas of exclusion receive five meters of riparian planting. These result in weighted reduction factors for runoff from pastoral lands of:
  - Total and dissolved phosphorus, 50%;
  - *E. coli*, 44%; and
  - Streambank erosion component of suspended sediment, 80%.
- Space/pole planting of Land Use Capability (LUC) class 6e land with grassland land cover. Poles assumed to have reached maturity and act to reduce hillslope erosion sediment yields and particulate phosphorus yields by 70%.
- Retirement of LUC class 7e and 8e land with existing grassland land cover. Assumed this land reverts to native cover and adopts the relevant contaminant and flow generation characteristics. Streams within these areas are assumed to receive livestock exclusion through the retirement.

Water Sensitive scenario

- Numbers of additional dwellings and land cover replacement for are the same as for BAU. However, the development form changes to have less paved surfaces and greater urban grassland and parks.
- A mixture of site and catchment scale stormwater retention devices are fitted to catch and treat runoff from greater areas of impervious surfaces of residential developments than under Improved. Load reduction factors are largely the same as in the Improved scenario, but greater use and size of rain tanks reduces total flow by around 37% and shift the frequency of 'channel forming flows and cumulative frequency distribution towards a pre-development state.
- Rain tanks retrofitted to 50% existing residential roofs reduce total flow from these by 30%.
- 100% of runoff from commercial and industrial paved surfaces and major roads receives different types of runoff treatment. These result in the following weighted (approximate) reductions for these surfaces:
  - Suspended sediment, 75-90%;
  - Total and dissolved zinc and copper, 50-80%;
  - Total nitrogen and phosphorus, 40-60%; and
  - *E. coli*, 90%.
- 100% of commercial and industrial roofs and existing residential roofs are replaced/treated with low zinc yielding materials.
- The wastewater network condition is significantly improved to remove dry weather leaks remove overflows in all but the two largest rainfalls each year.
- As for Improved livestock exclusion is undertaken on all REC order 2 or greater streams with grassland land cover and catchment slope less than 15 degrees. However, all areas of exclusion receive 10 meters of riparian planting following the GW planting guidance.
- Retirement of LUC classes 6e, 7e and 8e land with existing grassland land cover.

Assumed riparian management under the different scenarios

- Under BAU stock exclusion entails a simple one metre fencing setback with no riparian planting;

- Under Improved a five-metre setback is assumed with riparian planting carried in accordance with existing guidance documents from Greater Wellington[20] (see Figure 1 for the type of riparian planting assumed); and
- Under Water Sensitive a 10-metre setback with riparian planting is assumed (Figure 1).

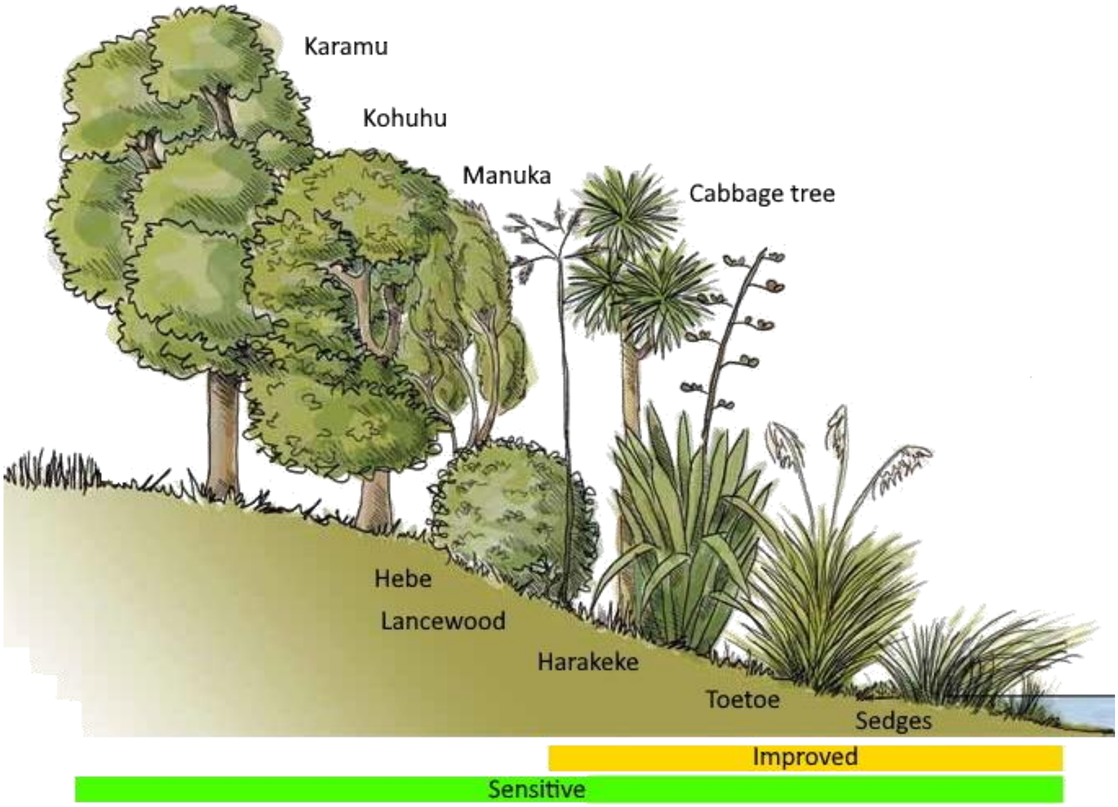

Figure 1: Assumed level of riparian planting under the Improved and Water Sensitive scenarios.

[20] Greater Wellington Regional Council, 2009: Mind the Stream – A guide to looking after streams in the Wellington Region. Wellington. http://www.gw.govt.nz/assets/council-publications/Mind%20the%20stream%20booklet%20Full.pdf

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Assessment of alignment between the regulatory provisions and target attribute states in proposed Plan Change 1 to the Natural Resources Plan – Te Awarua-o-Porirua Whaitua

Report No. 2023-007

TORLESSE ENVIRONMENTAL LTD

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Prepared for: Greater Wellington
Report No. 2023-007
Date: 04/10/2023

Quality Assurance (Report Status: Final)			
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Approved for issue by:			
Reviewed by	Duncan Gray	11/07/2023	

RECOMMENDED CITATION: Greer, M.J.C. 2023. Assessment of alignment between the regulatory provisions and target attribute states in proposed Plan Change 1 to the Natural Resources Plan – Te Awarua-o-Porirua Whaitua. Prepared for Greater Wellington. Torlesse Environmental Report No. 2023-007. Torlesse Environmental Limited, Christchurch, New Zealand.

Glossary

Term	Meaning
2A type attributes	Attributes that are treated in the same way as the compulsory attributes in Appendix 2A of the NPS-FM 2020 in PC1
2B type attributes	Attributes that are treated in the same way as the compulsory attributes in Appendix 2B of the NPS-FM 2020 in PC1
Action planning	Developing and implementing an action plan in accordance with the NPS-FM 2020
BSP	Biophysical Science Programme (for Whaitua Te Whanganui-a-Tara)
CFU	Colony Forming Unit
CLM	Contaminant Load Model
CLUES	Catchment Land Use for Environmental Sustainability
CMP	Collaborative Modelling Programme
Cu	Copper
DFS	Deposited fine sediment
DIN	Dissolved inorganic nitrogen
DRP	Dissolved reactive Phosphorus
Earthworks	means the alteration or disturbance of land, including by moving, removing, placing, blading, cutting, contouring, filling or excavation of earth (or any matter constituting the land including soil, clay, sand and rock) (PC1 definition).
E. coli	*Escherichia coli*
EQR	Ecological Quality Rating (for macroalgae)
ERTP	Erosion risk treatment plan – A plan prepared in compliance with Schedule 36 (PC1 definition)
FEP	Farm Environment Plan prepared in accordance with Schedule Z of the operative NRP and Schedule 36 of PC1
GW	Greater Wellington
High erosion risk land	Land with high erosion risk in Te Awarua-o-Porirua Whaitua shown on Map 90 or in Whaitua Te Whanganui-a-Tara shown on Map 93 (based on PC1 definition)
Highest erosion risk land	Land with highest erosion risk in Te Awarua-o-Porirua Whaitua shown on Map 90, 91 and 92 or in Whaitua Te Whanganui-a-Tara shown on Map 93, 94 and 94 (based on PC1 definition)
Livestock	Farm animals
Low slope land	means land identified as low slope land in https://www.mfe.govt.nz/fresh-water/freshwater-acts-and-regulations/stock-exclusion (Stock Exclusion Regulations definition).
LUC	Land Use Capability (class)
MLG	Modelling Lead Group
NH_4-N	Ammoniacal – nitrogen
NRP	Natural Resources Plan for the Wellington Region
NPS-FM	National Policy Statement for Freshwater Management
NO_3-N	Nitrate – nitrogen
Part-FMU	Part Freshwater Management Unit
PC1	Proposed Plan Change 1 to the NRP
The proposed provisions	The regulatory provisions of PC1
REC	River Environment Classification
SFS	Suspended Fine Sediment (as measured by visual clarity)
Soil conservation treatment	Includes: • Revegetation of highest or high erosion risk land; • Planting of poplar or willow poles on grazing land; • Construction of sediment detention structures; and • Wetland construction and restoration. (based on PC1 definition (Schedule 36 – Table D1))
Stock Exclusion Regulations	Resource Management (Stock Exclusion) Regulations 2020
TAoP	Te Awarua-o-Porirua
TAS	Target attribute state
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
Whaitua	Whaitua is the Māori word for catchment or space. The Wellington Region is divided into five whaitua, which will eventually each have a Whaitua Committee responsible for them
WTWT	Whaitua Te Whanganui-a-Tara
Zn	Zinc

Executive summary

Proposed Plan Change 1 (PC1) to the Natural Resources Plan (NRP) for the Wellington Region will implement the National Policy Statement for Freshwater Management (NPS-FM) 2020 for Te Awarua-o-Porirua (TAoP) Whaitua. This involves setting objectives, policies, rules and other methods to manage activities such as urban development, earthworks, stormwater, wastewater and rural land use. Accordingly, PC1 will:

- Define Target Attribute States (TASs) for the compulsory attributes in Appendix 2 of the NPS-FM 2020;
- Set equivalent coastal water quality and ecology objectives ('coastal objectives'); and
- Establish provisions that will contribute to those TASs and coastal objectives being met.

This process is especially important for those compulsory attributes in Appendix 2A of the NPS-FM 2020; as these require limits (input controls, output controls, or land use controls) be set as rules in regional plans to contribute to the achievement of their target states.

In this report, the extent to which the proposed regulatory provisions of PC1 will achieve the TASs and coastal objectives for TAoP Whaitua is assessed using the scenario testing outputs of the Collaborative Modelling Project (CMP), which informed their selection by the TAoP Whaitua Committee. The scenarios tested through the CMP were:

- Business as usual (BAU) – Represented the regulatory and management approach at the time;
- Improved – Included a range of actions with the potential to minimise the impact of urban and rural land uses such as stormwater treatment, wastewater network upgrades, riparian planting, space planting and retirement; and
- Water Sensitive – Included much the same actions as Improved, but with an increase in their extent and efficacy.

Results suggest that the proposed regulatory provisions of PC1 require outcomes and actions that are likely to achieve most (~90%) of the TAoP TASs and coastal objectives. However, there are several that are unlikely to be met through the proposed provisions alone (see Table I).

In most cases, the 'gap' between the outcome of the proposed provisions and the TAS/coastal objective can be filled through non-regulatory actions like those assumed under the middle of the road CMP (Improved) scenario (e.g., planting five metre riparian buffers on all second order streams on low slope pastoral land)/ Nonetheless, a small number of TAS and coastal objectives may not be met unless unless action planning includes even greater non-regulatory actions, such as as the retirement of all high erosion risk land (as defined in PC1) or even mitigations that go beyond the assumptions of the most aspirational (Water Sensitive) CMP scenario (Table I).

Table I: Description of the TASs and coastal objectives that will not be met through the proposed provisions alone. The non-regulatory actions that could potentially fill these 'gaps' are also identified from the CMP scenario assumptions.

<table>
<tr><th>Part-FMU</th><th>Attribute</th><th>Possible non-regulatory actions to fill the 'gap' between the proposed provisions and TAS/objective based on the CMP scenario assumptions</th></tr>
<tr><td>Pouewe</td><td>Periphyton biomass</td><td>Planting of riparian buffers on all second order and above streams on low slope pastoral land.</td></tr>
<tr><td rowspan="2">Taupō</td><td>Nitrate</td><td rowspan="4">• Planting of riparian buffers on all second order and above streams on low slope pastoral land; and
• Retirement of all high erosion risk land.</td></tr>
<tr><td rowspan="5">E. coli</td></tr>
<tr><td>Pouewe</td></tr>
<tr><td>Takapū</td></tr>
<tr><td>Wai-o-hata</td><td rowspan="4">• Everything above; and
• Additional mitigations not considered in CMP scenarios or land-use change.</td></tr>
<tr><td>Te Rio o Porirua and Rangituhi</td></tr>
<tr><td>Onepoto Arm</td><td rowspan="2">Enterococci</td></tr>
<tr><td>Pāuatahanui Inlet</td></tr>
</table>

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1.1 Background

Plan Change 1 (PC1) to the Natural Resources Plan (NRP) for the Wellington Region will implement the National Policy Statement for Freshwater Management (NPS-FM) 2020 for Te Awarua-o-Porirua (TAoP) Whaitua and Whaitua Te Whanganui-a-Tara (WTWT). This involves setting objectives, policies, rules and other methods to manage activities such as urban development, earthworks, stormwater, wastewater and rural land use. Accordingly, PC1 will:

- Define target attribute states ('TASs') for the compulsory attributes in Appendix 2 of the NPS-FM 2020;
- Set equivalent coastal water quality and ecology objectives ('coastal objectives'); and
- Establish provisions that will contribute to the achievement of those TASs and coastal objectives.

This process is especially important for those compulsory attributes in Appendix 2A of the NPS-FM 2020; as these require limits (input controls, output controls, or land use controls) be set as rules in regional plans to contribute to the achievement of their target states.(as opposed to those in Appendix 2B, which can be achieved through action planning[1] alone).

The proposed TASs and coastal objectives for TAoP Whaitua are set out in Table 1 and Table 2. These are based on those published by TAoP Whaitua Committee ('the Committee) in their Whaitua Implementation Programme (WIP). However, minor refinements have been made based on the recommendations of a technical advisory panel (Greer *et al.*, 2023). For each river attribute the tables include a baseline and target state for each part Freshwater Management Unit (part-FMU) (Table 2). The differences between those states provide an indication of the magnitude of the improvement required by the TASs and have been used to define default TASs that prescribe the direction of change required for each attribute across each part-FMU[2] (Table 2).

The development of Table 1 and Table 2, and how they should be interpreted, is documented in Greer *et al.* (2023). However, most of the relevant detail can also be found in the glossary of this report and the footnotes to the tables. The attribute state frameworks behind the river TASs in Table 2 are provided in Appendix A.

[1] I.e., developing and implementing an action plan in accordance with the NPS-FM 2020.

[2] Where baseline state is unknown, this direction of change is based on the difference in the assumed baseline in the WIP and the TAS.

1.2 Target Attribute States and coastal objectives

Table 1: Coastal objectives for the TAoP Whaitua. Note that the sediment and metal load reduction targets are not objectives in themselves, rather they are the proxies for the sedimentation rate and sediment metal objectives used in this assessment.

			Onepoto Arm		Pāuatahanui Inlet		Coast
Parameter	**Unit**	**Statistic**	**Intertidal**	**Subtidal**	**Intertidal**	**Subtidal**	
Enterococci	**cfu/100 mL**	95th %ile	≤500		≤200		≤200
Macroalgae	**EQR**	Latest score	Maintain or improve				Maintain or improve
Copper in sediment	**mg/kg**	Mean of latest round of replicate samples					
Zinc in sediment	**mg/kg**						
Muddiness	**% >50% mud**	Latest score					
	% of sample						
Sedimentation rate	**mm/year**	5-year mean	1		2		
Sediment load reduction	***% Δ in annual average loads (from the baseline period)***		*40%*				
Copper load reduction			*15% to be achieved through regulation*[1]				
Zinc load reduction			*40%*				

[1] In total a 40% reduction in copper load is required, with 25% to be achieved through action planning. For the purposes of this report, the copper load reduction target is considered to be a 15% reduction as that is the desired outcome of the proposed provisions.

Table 2: Rivers TASs for TAoP Whaitua

				Taupō					Pouewe					Wai-o-hata					Takapū				
				Taupō S. @ Plimmerton Domain				Part-FMU default TAS[1]	Horokiri S. @ Snodgrass				Part-FMU default TAS[1]	Duck Ck @ Tradewinds Dr. Br.				Part-FMU default TAS[1]	Pāuatahanui S. @ Elmwood Br.				Part-FMU default TAS[1]
				Baseline		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]		
Parameter	**Unit**	**Statistic**	**Timeframe**	**Numeric**	**State**	**Numeric**	**State**		**Numeric**	**State**	**Numeric**	**State**		**Numeric**	**State**	**Numeric**	**State**		**Numeric**	**State**	**Numeric**	**State**	
Periphyton biomass	**mg chl-a/m²**	92nd %ile	By 2040	N/A[2]				M	436[3]	D	≤120	B	I	Insufficient data		≤120	B	I	Insufficient data		≤120	B	I
Ammonia (toxicity)	**mg/L**	Median		0.011	B[4]	≤0.03	A	I	0.002	A	M	A	M	0.013	A[4]	M	A	M	0.005	A	M	A	M
		95th %ile		0.051		≤0.05			0.013					0.044					0.018				
Nitrate (toxicity)	**mg/L**	Median		0.4	B[4]	≤1	A		0.6	A		A		0.5	B[4]	≤1	A	I	0.3	A		A	
		95th %ile		2.1		≤1.5			1.1					1.6		≤1.5			0.8				
Suspended fine sediment	**Black disc (m)**	Median		1.2	A[4]	≥0.93	A	M	2.3	C		C		1.2	A[4]	≥0.93	A	M	1.8	D	≥2.22	C	I
E. coli	**/100mL**	Median		735	E[4]	≤130	B	I	370	E	≤130	B	I	703	E[4]	≤130	C	I	275	E	≤130	C	
		%>260/100mL		96		≤30			63		≤30			92		≤20			55		≤20		
		%>540/100mL		62		≤10			32		≤10			59		≤34			18		≤34		
		95th %ile		5,299		≤1,000			4,950		≤1,000			4,783		≤1,200			6,050		≤1,200		
Fish	**Fish-IBI**	Latest		Insufficient data		M		M	Insufficient data		M		M	Insufficient data		M		M	Insufficient data		M		M
Fish community health (abundance, structure and composition)		Expert assessment[5]				N/A[5]	B	I			N/A[5]	A	I			N/A[5]	B	I			N/A[5]	B	I
Macroinvertebrates (1 of 2)	**MCI**	Median				≥100	B		115.0	B	≥130	A				≥100	B		101.2	D	≥105	B	
	QMCI	Median				≥5			6.0		≥6.5					≥5			3.8		≥5.25		
Macroinvertebrates (2 of 2)	**ASPM**	Median				≥0.4	B		0.5	B	M	B	M			≥0.4	B		0.4	C	≥0.40	C	M
Deposited fine sediment[3]	**%cover**	Median		N/A[6]					10	A		A				M		M	60	D	≤27	C	I
Dissolved oxygen	**mg/L**	1-day minimum		Insufficient data		M		M	Insufficient data		M								Insufficient data		M		M
		7-day mean minimum																					
Dissolved inorganic nitrogen[7]	**mg/L**	Median		0.41[4]		≤1.03		I	0.64					0.48[4]					0.33				
Dissolved reactive phosphorus[7]	**mg/L**	Median		0.017[4]		M		M	0.011					0.018[4]		M			0.014				
		95th%ile		0.047[4]					0.026					0.05[4]					0.022				
Dissolved copper	**µg/L**	Median		0.61	D[4]	≤1	B	I	0.03	A[4]	M	A		0.47	C[4]	≤1	A	I	0.06	A[4]	M	A	
		95th %ile		4.69		≤1.8			0.12					2.93		≤1.4			0.27				
Dissolved zinc	**µg/L**	Median		3.91	C[4]	≤2.4	A		0.07	A[4]		A		1.96	B[4]	≤2.4	A		0.11	A[4]		A	
		95th %ile		32.25		≤8			0.23					13.04		≤8			0.48				
Ecosystem metabolism	**g O_2 m^{-2} d^{-1}**	N/A[8]		M																			

Parameter	Unit	Statistic	Timeframe	Te Rio o Porirua and Rangituhi					Island rivers TAS[1]
				Porirua S. @ Milk Depot				Part-FMU default TAS[1]	
				Baseline		TAS[1]			
				Numeric	State	Numeric	State		
Periphyton biomass	**mg chl-a/m²**	92nd %ile	By 2040	Insufficient data		≤120	B	I	M
Ammonia (toxicity)	**mg/L**	Median		0.006	A	M	A	M	
		95th %ile		0.034					
Nitrate (toxicity)	**mg/L**	Median		0.9	B	≤0.9	A	I	
		95th %ile		1.6		≤1.5			
Suspended fine sediment	**Black disc (m)**	Median		1.7	A	M	A	M	
E. coli	**/100mL**	Median		1400	E	≤130	C	I	
		%>260/100mL		95		≤20			
		%>540/100mL		83		≤34			
		95th %ile		6950		≤1200			
Fish	**Fish-IBI**	Latest		Insufficient data		M		M	
Fish community health (abundance, structure and composition)		Expert assessment[5]				N/A[5]	C	I	
Macroinvertebrates (1 of 2)	**MCI**	Median		87.0	D	≥90	C		
	QMCI	Median		4.3		≥4.5			
Macroinvertebrates (2 of 2)	**ASPM**	Median		0.3	D	≥0.3	C		
Deposited fine sediment[3]	**%cover**	Median		20	C	M	C	M	
Dissolved oxygen	**mg/L**	1-day minimum		Insufficient data		M			
		7-day mean minimum							
Dissolved inorganic nitrogen[7]	**mg/L**	Median		0.92					
Dissolved reactive phosphorus[7]	**mg/L**	Median		0.018					
		95th%ile		0.034					
Dissolved copper	**µg/L**	Median		1.1	C	M	C		
		95th %ile		2.6					
Dissolved zinc	**µg/L**	Median		7.5	D	≤7.5	C	I	
		95th %ile		58		≤42			
Ecosystem metabolism	**g O_2 m^{-2} d^{-1}**	N/A[8]		M[8]					

[1] M = Maintain; I = Improve. Maintenance, improvement or deterioration in the state of an attribute will be assessed through:
- Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and
- Taking the impact of climate and human activity into account.

[2] All rivers in part-FMU naturally soft bottomed and unlikely to support periphyton growth (River Environment Classification group = WW/L/SS).
[3] Baseline state based on limited data.
[4] Baseline state based on eWater Source model results. Further monitoring needed to confirm whether the attribute meets the TAS.
[5] The A, B, C and D states to be assigned on the basis of fish community health reflecting an excellent, good, fair and poor state of aquatic ecosystem health respectively.
[6] All rivers in part-FMU naturally soft bottomed (River Environment Classification group = WW/L/SS).
[7] Median concentration targets reflect the nutrient outcomes required by Clause 3.13 of the NPS-FM 2020
[8] Further monitoring needed to define baseline state and develop attribute state framework.

1.3 Introduction to the TAoP Collaborative Modelling Project

1.3.1 Collaborative Modelling Project framework

The decisions made by the TAoP Committee in the WIP were informed by the outputs of a Collaborative Modelling Project (CMP). The CMP was designed and led by an expert panel known as the Modelling Leadership Group (MLG) whose purpose was to develop a broad multidisciplinary modelling framework (Figure 1) that:

- Covered the effect of urban and rural land and water resource use on water quantity and quality, in freshwater, harbour and coastal waters; and
- Encompassed environmental, social, cultural and economic aspects.

Ultimately a set of multiple interacting and stand-alone models were required to deliver this coverage. The purpose of those models was to test the effects of the following scenarios on various biophysical attributes (the full assumptions of each scenario are provided in Appendix B):

- Business as usual (BAU) – Represented the regulatory and management approach at the time;
- Improved – Included a range of actions with the potential to minimise the impact of urban and rural land uses, such as stormwater treatment, wastewater network upgrades, riparian planting, space planting and retirement; and
- Water Sensitive – Included much the same actions as Improved, but with an increase in their extent and efficacy.

1.3.2 Scenario testing

1.3.2.1 Purpose

The purpose of scenario testing was to inform the Committee about the direction and magnitude of effects of different actions on specific attributes so they could ultimately:

- Make informed decisions regarding TASs and coastal objectives; and
- Understand the actions required to achieve those TASs and objectives, and their 'cost and benefit'.

The CMP scenarios were not presented to the Committee as potential solutions whose assumptions could be carried over directly into the WIP and NRP. Rather, they were intended to highlight the effects of various actions so that the TASs, coastal objectives and recommendations in the WIP could be tailored to reflect the values of the community.

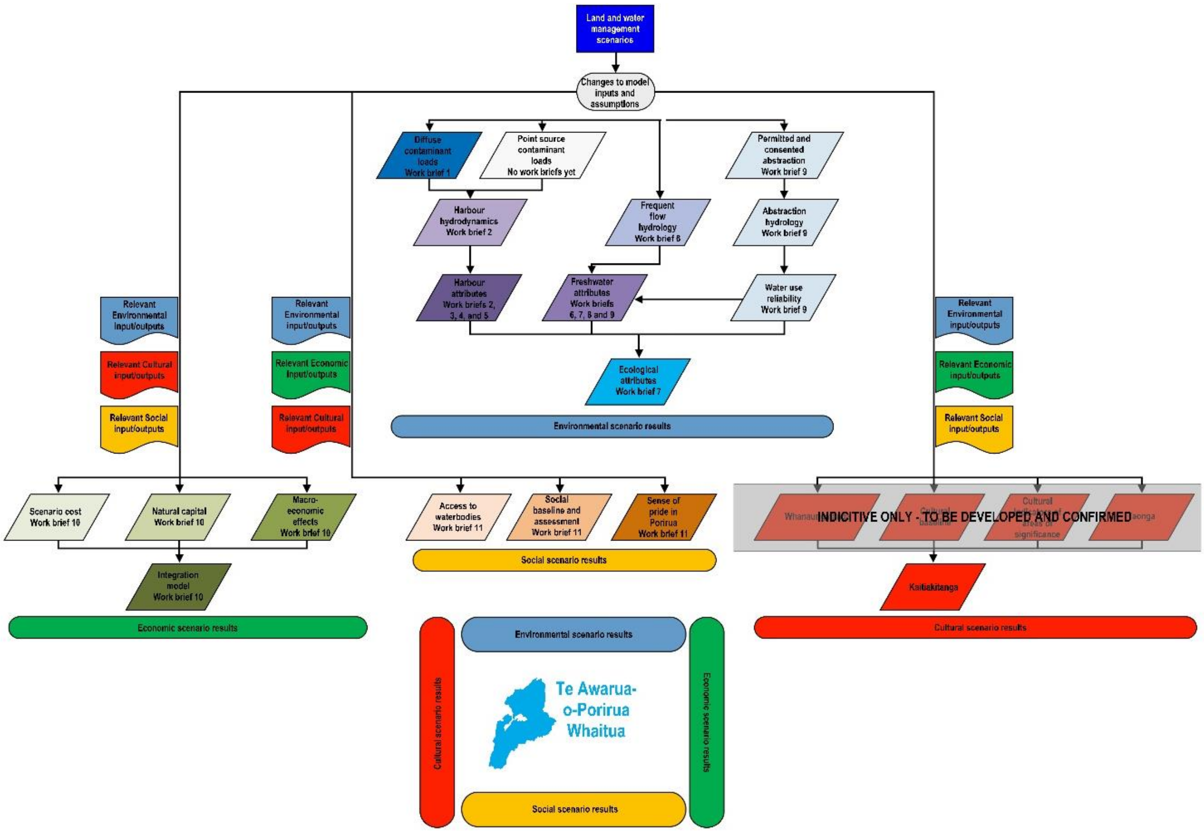

Figure 1: Diagram of the TAoP CMP framework provided to the Committee

1.3.2.2 Relevant models and outputs

The impacts of the CMP scenarios on freshwater quality and contaminant loads into Te Awarua-Porirua Harbour were tested with an integrated catchment model developed by Jacobs (Jacobs New Zealand Ltd) using the eWater Source (Source) modelling framework (Easton *et al.*, 2019a). That model utilised environmental data from a range of sources, including Whaitua specific contaminant yields generated by the following models:

- The Catchment Land Use for Environmental Stability (CLUES) model (Semadenis-Davies and Kachhara, 2017); and
- The urban Contaminant Load Model (CLM) (Moores *et al.*, 2017).

The Source modelling results are documented in Easton *et al.*, (2019b) and were summarised by GW officers for the Committee in:

- A spreadsheet[3];
- A memorandum drafted in April 2018 (Miller and King, 2018a); and

[3] https://www.gw.govt.nz/assets/Documents/2022/05/RESULTS-TAoPW-Information-for-Objective-Setting-freshwater-scenario-modelling-19-April-2018-1.pdf

- A presentation[4] during a Committee meeting on the 19th of April 2018.

The state of sediment quality, deposition and texture, and water quality in Te Awarua-Porirua Harbour under the CMP scenarios were modelled by DHI (DHI Water and Environment Limited) using a suite of hydrodynamic, wave, sediment transport and contaminant dispersion models. The Source modelling was a major input to those models; providing the estimated contaminant loads and flows to the harbour under the different CMP scenarios. The results of the harbour modelling are presented in Oldman (2019) and were further summarised by GW in:

- A spreadsheet[5];
- A memorandum drafted in April 2018 (Miller and King, 2018b); and
- A summary technical report (Miller and King, 2018c).

Note: The CMP Improved scenario was not tested by Oldman (2019).

The impacts of the CMP scenarios on freshwater and coastal ecological attributes were assessed through expert opinion. Background information on this process, and who was involved, is limited. However, based on the outputs, it is clear that results of the freshwater and coastal modelling were considered. The results of the freshwater and harbour expert assessments were provided to the Committee as spreadsheets[6,7] and were summarised by GW officers in presentations[8,9], reports and memoranda (Miller and King, 2018b, 2018d, 2018c).

1.4 Report objectives

The purpose of this report is to assess the extent to which the proposed regulatory provisions of PC1[10] ('the proposed provisions') will achieve the TASs and coastal objectives for TAoP Whaitua in PC1 (Table 1 and Table 2) using the CMP outputs described above in Section 1.3.2.2. This is necessary as the impacts of the proposed provisions were not explicitly tested through the CMP.

[4] https://www.gw.govt.nz/assets/Documents/2022/05/Scenario-modelling-of-state-of-fresh-water-in-Te-Awarua-o-Porirua.pdf
[5] https://www.gw.govt.nz/assets/Documents/2022/05/Harbour-Summary-Table-current-state-and-scenario-projections-31-05-18.pdf
[6] https://www.gw.govt.nz/assets/Documents/2022/05/Ecological-assessment-summary-sheets.pdf
[7] https://www.gw.govt.nz/assets/Documents/2022/05/Harbour-Summary-Table-current-state-and-scenario-projections-31-05-18.pdf
[8] https://www.gw.govt.nz/assets/Documents/2022/05/PRESENTATION-Scenario-assessment-of-ecological-attributes-in-Te-Awarua-o-Porirua-10May18.pdf
[9] https://www.gw.govt.nz/assets/Documents/2022/05/Ecological-Attributes-for-Te-Awarua-o-Porirua-Harbour-2.pdf
[10] https://www.gw.govt.nz/your-region/plans-policies-and-bylaws/updating-our-regional-policy-statement-and-natural-resources-plan/natural-resources-plan-2023-changes/

1.5 Scope and limitations of this assessment

- This assessment does not cover the full range of topics that GW will need to produce expert evidence on during the PC1 Freshwater Planning Process. Rather it is intended to inform the PC1 S32 report, and, in tandem with Greer *et al.*, (2023), transparently document the technical work that has been completed since the TAoP WIP was published. Consequently, detailed introductions to the freshwater and coastal environments in TAoP Whaitua, the NPS-FM 2020 and the NRP are not provided.
- Torlesse (Torlesse Environmental Limited) was not involved in the TAoP CMP process. Thus, is unable to confirm the extent to which its outputs contributed to the Committee decisions on the TASs and coastal objectives in the WIP. Consequently, that a TAS or coastal objective is assessed as being unachievable is not justification for changing it, as 'achievability' may, or may not, have factored into their selection.
- While this assessment relies heavily on the results of scenario testing conducted for the CMP, it is not an output of the project. Rather it should be treated as the peer reviewed opinion of one expert.
- A comparable report has been prepared for WTWT by Greer (2023). The similarities between the scenarios tested for that Whaitua and TAoP means that large parts of that report are replicated here.

2 Methods

2.1 Scale of assessment

The impact of the proposed provisions on each of the attributes listed in Table 1 and Table 2 (except ecosystem metabolism) was assessed for each of the spatial areas (except the 'Coast' (Table 1)) set out in the headers of those tables (hereafter collectively referred to as 'part-FMUs'). This resulted in 89 TASs and coastal objectives being assessed across the 7 part-FMUs listed below and mapped in Figure 2:

- Rivers:
  - Taupō;
  - Pouewe;
  - Wai-o-hata
  - Takapū; and
  - Te Rio o Porirua and Rangituhi.
- Coastal:
  - Te Awarua-o-Porirua Harbour – Onepoto Arm; and
  - Te Awarua-o-Porirua Harbour – Pāuatahanui Inlet.

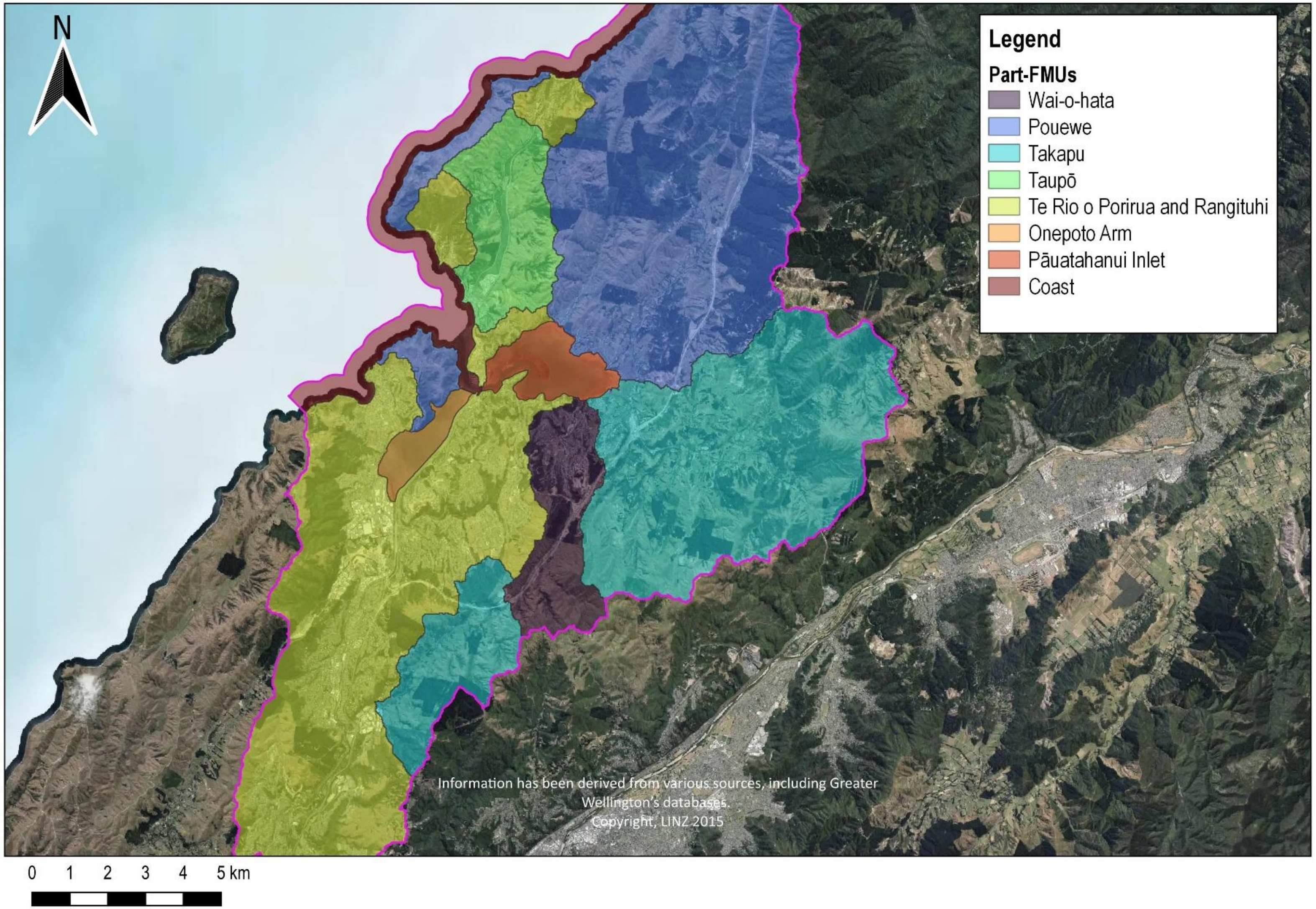

Figure 2: Map of TAoP part-FMUs

2.2 Assessment method for 2A type attributes

The NPS-FM 2020 requires that the proposed provisions contribute to the achievement of the target states for attributes in Appendix 2A of that document and the nutrient outcomes required by clause 3.13. Consequently, these attributes require a more detailed assessment methodology than the other attributes in Table 1 and Table 2. The proposed provisions are also directly linked to the TASs or coastal objectives for the following attributes:

- Dissolved copper (Cu) TASs;
- Dissolved zinc (Zn) TASs;
- Cu load reduction targets for Te Awarua-o-Porirua Harbour;
- Zn load reduction targets for Te Awarua-o-Porirua Harbour;
- Sediment load reduction targets for Te Awarua-o-Porirua Harbour; and
- Enterococci coastal objectives for Te Awarua-o-Porirua Harbour.

Thus, for this assessment they are treated the same way as the NPS-FM 2020 Appendix 2A compulsory attributes (hereafter collectively referred to as '2A type attributes'). A full list of the 2A type attributes assessed in this report is provided in Table 3.

Table 3: 2A type attributes and attribute groups.

Attribute Group	Attributes
Sediment	• Rivers – Suspended fine sediment (SFS) • Harbour – Sediment load reduction target[1]
Faecal indicator bacteria	• Rivers – *E. coli* • Harbour – Enterococci
Nitrogen	• Rivers – Nitrate (NO_3-N) • Rivers – Ammonia (NH_4-N) • Rivers – Dissolved inorganic nitrogen (DIN) (nutrient outcome)
Phosphorus	• Rivers – Dissolved reactive phosphorus (DRP) (nutrient outcome).
Metals	• Cu o River – Dissolved Cu o Harbour – Cu load reduction target[1] • Zn o River – Dissolved Zn o Harbour – Zn load reduction target[1]
Rivers – Periphyton	

[1] These sediment and metal load reductions are used as proxies for the Te Awarua-o-Porirua Harbour sedimentation rate and sediment Cu and Zn concentration coastal objectives in Table 1. For sediment and Zn they are expected to achieve the relevant coastal objectives. However, for Cu an additional 25% reduction in loads may be required. Consequently, the draft provisions being assessed as meeting the Cu load reduction targets does not necessarily mean they will achieve the sediment concentration objective.

2.2.1 Scenario assignment

To date the biophysical effects of the proposed provisions have not been explicitly modelled. Consequently, the CMP scenario testing outputs represent the best available information that can be used to assess the extent to which the proposed provisions will contribute to achievement of the 2A type TASs and coastal objectives in Table 1 and Table 2.

No single CMP scenario aligns perfectly with all the proposed provisions. Thus, for each activity managed by PC1 an assessment has been made of where the relevant proposed provisions sit in relation to the assumptions of the scenarios. This was based on:

- Where the proposed provisions require regulated parties to undertake specific actions (e.g., the installation of a specific treatment device in new urban developments), how similar those actions are to those assumed under the CMP scenarios; or
- Where the proposed provisions require regulated partied to achieve a certain outcome (e.g., a specific percentage reduction in contaminant loads) how similar those outcomes are to those assessed under the CMP scenarios.

The CMP scenario which most closely match the proposed provisions was 'assigned' to each of the following activities:

- Livestock exclusion;
- Riparian management;
- Retirement;
- Space planting (of trees);
- Earthworks;
- Stormwater management;
- Wastewater management;
- Land-use change (other than retirement); and
- Practice change (for the activities not listed above).

This activity-based assessment was then used to assign a CMP scenario to each of the attribute groups set out in Table 3:

The scenario assignment process and outputs are described in full in Section 3. In short it was based on expert opinion and involved:

- Identifying the relevant scenario assumptions for each activity;
- Considering the actual and potential actions and outcomes required for each activity by the proposed provisions;
- Identifying the CMP scenario whose assumptions most closely matched the requirements of the proposed provisions for each activity using the template set out below in Table 4;
- Identifying which activities, and therefore, CMP scenarios, are most relevant to each of the attribute groups in Table 3;

- Providing a narrative description of how the proposed provisions and the assumptions of the assigned scenario align for each activity and attribute group based on the scenario testing outputs, monitoring results and the wider literature; and
- Describing the key differences between the proposed provisions and the assigned scenario for each activity and attribute group.

Table 4: Example of the scenario alignment outputs for individual activities (in this case retirement).

BAU	Improved	Water Sensitive
275 ha in the headwaters of the Kenepuru Stream and Duck Creek retired as an offset for the Transmission Gully motorway project.	• As for BAU but with additional retirement of LUC class 7e and 8e land with grassland land cover. Assumed this land reverts to native cover. • Approximate area retired = 1,994 ha.	• As for Improved but with additional retirement of LUC class 6e land with grassland land cover. • Approximate area retired = 4,416 ha.
BAU	**Improved**	**Water Sensitive**
	↑	

Provisions
• Encompasses BAU retirement which are required by existing resource consents. • Rule P.R26(b) and Schedule 36(B)&(E) require retirement of all highest erosion risk land on farms >20 ha by 2040 (50% by 2023). • Approximate area retired = 1,895ha.

2.2.2 Identification and approach for 'maintain' 2A type TASs and coastal objectives

The 2A type TASs and coastal objectives that require an attribute be maintained were identified where:

- The baseline state for an attribute meets the TAS (Table 2);
- The baseline state is unknown, but the part-FMU default TAS requires the attribute be maintained (Table 2);
- The coastal narrative objective simply requires the attribute "*Maintain or improve*" (Table 1); or
- The baseline state does not meet the TAS, but current state and trend analysis (as reported in GW (2022)) indicates that the TAS is currently met and that this is likely to continue (i.e., improving trends are likely (>66% probability)). This applies to the Nitrate (toxicity) TAS for the Te Rio o Porirua and Rangituhi part-FMU.

For these 'maintain' 2A type TASs and coastal objectives, consideration was given to the modelled or assessed impacts of the CMP scenario assigned to the relevant attribute group, and whether the proposed provisions allow for degradation from the baseline state. For each attribute group (see Table 3), the results of these assessments were documented in a short narrative and summarised in the format of Table 5.

Table 5: Example of the summary tables produced for 'maintain' 2A type TASs and coastal objectives.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Assigned scenario consistent with TAS
				BAU	Improved	Water Sensitive	
Part-FMU 1	Site 1	Attribute 1	A	Maintain	Maintain	Maintain	✓
Part-FMU 2	Site 2			Degrade	Maintain	Improve	
Part-FMU 3	Site 3			Degrade	Maintain	Improve	
Part-FMU 1	Site 1	Attribute 2	A	Degrade	Improve	Improve	
Part-FMU 2	Site 2			Degrade	Maintain	Improve	
Part-FMU 3	Site 3			Degrade	Improve	Improve	

↑ Provisions

The relevant scenario results for each attribute group were drawn from:

- Sediment:
  - Modelled loads = Easton *et al.* (2019b);
  - Visual clarity = Site specific sediment clarity relationships set out in Greer *et al.* (2023)).
- Nutrients = Easton *et al.* (2019b); and
- Metals = Easton *et al.* (2019b).

2.2.3 Identification and approach for 'improve' 2A type TASs and coastal objectives

The TASs and coastal objectives that require an improvement in a 2A type attribute were identified where:

- The baseline and current state (as reported in GW (2022)) of an attribute in a part-FMU does not meet the TAS (Table 2);
- The baseline state is unknown, but the part-FMU default TAS requires the attribute be improved (Table 2); or
- A numeric coastal objective has been set for the attribute in a part-FMU (Table 1).

The primary consideration given to these 'improve' 2A type TASs and coastal objectives was whether their achievement was modelled or predicted under the assigned CMP scenario. If not, consideration was given to the likely 'gap' that would need to be filled by action planning. For each attribute group (see Table 3), these assessments were documented in a short narrative and summarised in the format of Table 6.

Assessment of the proposed provisions against the 'improve TASs and coastal objectives for 2A type attributes relied on the CMP outputs listed below:

- Sediment:
  - Modelled loads = Easton *et al.* (2019b); and
  - Visual clarity = Site specific sediment clarity relationships set out in Greer *et al.* (2023)).

- Nutrients = Easton *et al.* (2019b);
- Metals = Easton *et al.* (2019b);
- Faecal indicator bacteria = Easton *et al.* (2019) (freshwater) and Oldman (2019) (harbour); and
- Periphyton = The expert assessments for ecological attributes provided on the GW website[6].

Note: These assessments do not make categorical conclusions about whether a specific TAS will be met by the proposed provisions. Rather results are given in terms of the likely outcomes of the proposed provisions and degree of consistency with the CMP scenarios predicted to achieve the TAS.

Table 6: Example of the summary tables produced for 'improve' 2A type TASs and coastal objectives.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results			Provisions likely to achieve TAS?
					BAU	Improved	Water Sensitive	
Part-FMU 1	Site 1	Attribute 1	C	A	C	C	C	×
Part-FMU 2	Site 2		D	C	D	C	C	✓
Part-FMU 3	Site 3			C	D	D	C	×
Part-FMU 1	Site 1	Attribute 2	D	C	D	D	C	
Part-FMU 2	Site 2			C	D	D	C	
Part-FMU 3	Site 3			C	D	D	C	

↑ Provisions

2.3 Assessment method for 2B type attributes

Whether the TASs and coastal objectives in Table 1 to Table 2 require the maintenance or improvement of 2B type attributes was determined through the approach described in Sections 2.2.2 and 2.2.3. Through this process, the Macroinvertebrates (2 of 2) TAS for the Te Rio o Porirua and Rangituhi part-FMU was identified as requiring an improvement from the reported baseline state that has already been achieved (GW, 2022).

There is no NPS-FM 2020 requirement for the proposed regulatory provisions to contribute to the achievement of the target states or coastal objectives for the attributes in Table 1 and Table 2 that are not listed in Appendix 2A of the NPS-FM or Section 2.2 (hereafter referred to collectively as '2B type attributes'). Consequently, the assessment process for these attributes was not as detailed or structured as that described above for 2A type attributes.

For each of the 2B type attributes listed in Table 7 a simple narrative assessment was made of:

- The most applicable CMP scenario (based on expert opinion and the results of the scenario assignment described in Sections 2.2.1 and 3); and
- The likely outcome of the proposed provisions in each part-FMU based on the modelled or predicted outcome of the most applicable scenario.

Where the CMP outputs allowed, the assessments described above were also summarised in tables like those produced for 2A type attributes (see Table 5 and Table 6).

For the TASs and coastal objectives that require the maintenance of a 2B type attribute, this approach provided a general indication of whether the proposed provisions will result in their achievement.

Unlike for the 2A type attributes, the CMP outputs cannot be used to determine whether the proposed provisions will achieve those TASs and coastal objectives that require an improvement in 2B type attributes. This is because in the CMP these attributes were either:

- Not assessed;
- Considered using a different attribute state framework; or
- Assessed from a baseline state that is no longer relevant.

Consequently, the assessment of these 'improve' 2B type TASs and coastal objectives was generally limited to determining whether the proposed provisions are likely to result in an improvement in the state of the attribute and, therefore, contribute to the achievement of the TAS or coastal objective.

Relevant CMP scenario testing results were drawn from:

- Sediment = Easton *et al.* (2019b); and
- All other attributes = The ecological assessment summary sheets provided on the GW website[6,7].

Table 7: 2B type attributes.

Environment	Attribute
Rivers	• Deposited fine sediment (DFS) • Macroinvertebrate Community Index score and Quantitative Macroinvertebrate Community Index score (Q/MCI) • Macroinvertebrate Average Score Per Metric (ASPM) • Fish Index of Biotic Integrity (F-IBI) • Fish community health • Dissolved oxygen
Te Awarua-o-Porirua Harbour	• Muddiness (% area >50% mud) • Muddiness (% of sample) • Macroalgal Ecological Quality Rating (EQR)

[1] There are no data available for ecosystem metabolism and no attribute state framework. Furthermore, this attribute was not considered in the CMP. Consequently, this attribute is not considered in this report.

2.4 Assumptions

- It was not possible to determine which types of livestock are present on a given farm or part of a farm. Thus, it was assumed that livestock exclusion will occur on all rivers where the proposed provisions require the exclusion of beef cattle. This may have resulted in the extent of livestock exclusion under the proposed provisions being overestimated in areas where sheep are the only type of livestock present.
- It was assumed that it will generally not be possible to obtain resource consent for the non-complying activities in the proposed provisions. Similarly, based on the policies of the

operative NRP and PC1 it was assumed that it will be difficult to obtain resource consent allowing:

    - Livestock access to waterways as a discretionary activity; or
    - The use of land for farming activities without a Farm Environment Plan (FEP) and associated erosion risk treatment plan (ERTP) as a discretionary activity (only non-complying in the Takapū part-FMU).

- Full maps of the location and extent of high risk erosion prone land and highest risk erosion prone land were not produced in time to be considered in this assessment. Thus, the assumed area and location of this land was based off the extrapolation of interim mapping conducted for the Pouewe and Takapū part-FMUs.
- It is not possible to predict where individual types of soil conservation treatment will be applied in the future. Thus, for the purposes this assessment it was simply assumed that space planting of poplar and willow poles will be the primary treatment method applied on high erosion risk land. Space planting was chosen over the other treatment methods allowed for under the proposed provisions (Schedule 36 – Table D1) because:
    - It was the only one tested through the CMP scenario testing process other than revegetation;
    - The sediment load reduction factors cited for space planting in Phillips *et al.* (2020) and used in the CMP scenario modelling (Easton *et al.*, 2019b) (70%) reflect:
        - The mid-point of the range cited in Phillips *et al.* (2020) for the different soil conservation treatment types allowed for under the proposed provisions (50% to 90%); and
        - The cited *assumed* performance of erosion control methods in a well-implemented farm plan in Dymond *et al.* (2010).
- It was assumed that the proposed provisions have been fully implemented and complied with, and that the resulting effects on the environment have been fully realised.

3 Scenario assignment for 2A type attributes

3.1 Alignment between the proposed provisions and CMP scenarios by activity

3.1.1 Retirement

The ERTPs stipulated by clause (b) of Rule P.R26 of PC1 require:

- Woody vegetation capable of reaching canopy cover of ≥80% in ten years to be established on 50% of the highest erosion risk land on farms greater than 20 hectares (ha) by 2033 (Schedule 36 (E)(1)); and
- The remaining 50% of highest erosion risk land on farms greater than 20 ha to be revegetated by 2040[11] (Schedule 36 (B)).

The result of this revegetation is the affected land will effectively be retired from farming. Interim mapping of the highest erosion risk land in the Pouewe and Takapū part-FMUs indicates that this could result in approximately 1,620 ha of new retirement in the TAoP Whaitua, with an additional 275 ha required by existing resource consents (based on the assumptions of the CMP BAU scenario) (1,895 ha total retirement). This is most consistent with what was assumed under the CMP Improved scenario (1,994 ha) (Table 8).

Note: It is possible that some landowners will apply for resource consent to farm without an ERTP (non-complying activity in Takapū part-FMU[12]; discretionary elsewhere). However, it is unlikely it will be granted unless the application includes erosion control methods that are at least as effective as the ERTP requirements of PC1, given:

- *The significant load reductions required to meet the sedimentation coastal objectives for the harbour and the SFS TAS for the Takapū part-FMU; and*
- *The wording of Policy P.P22 which aims to "[r]educe discharges of sediment from farming activities on high and highest erosion risk land by [] **requiring** that farm environment plans prepared for farms with highest erosion risk land (pasture) and/or high erosion risk land (pasture) include an erosion risk treatment plan".*

[11] The proposed provisions do not require highest erosion land to be revegetated where it is not practicable and alternative erosion control treatment can be applied over the balance of the property that results in the same level of soil loss avoidance. However, given that revegetation is by far the most effective erosion control treatment, and that, by definition, highest erosion risk land has the highest soil losses, it is unlikely that this exemption will significantly reduce the amount of retirement required by 2040.

[12] Condition (a) of Rule P.R27 cannot be met.

Table 8: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the CMP scenario assumptions on retirement.

BAU	Improved	Water Sensitive
275 ha in the headwaters of the Kenepuru Stream and Duck Creek retired as an offset for the Transmission Gully motorway project.	• As for BAU but with additional retirement of LUC class 7e and 8e land with grassland land cover. Assumed this land reverts to native cover. • Approximate area retired = 1,994 ha.	• As for Improved but with additional retirement of LUC class 6e land with grassland land cover. • Approximate area retired = 4,416 ha.
BAU	**Improved**	**Water Sensitive**
	↑	

Provisions
• Encompasses BAU retirement which are required by existing resource consents. • Rule P.R26(b) and Schedule 36(B)&(E) require retirement of all highest erosion risk land on farms >20 ha by 2040 (50% by 2023). • Approximate area retired = 1,895ha.

3.1.2 Space planting (of trees)

The ERTPs stipulated by clause (b) of Rule P.R26 require high erosion risk land on farms greater than 20 ha to have "*appropriate soil conservation treatment*" to "*provide effective erosion control*" (Schedule 36(E)(3)(c)). Space planting of poplar and willow poles is effective at controlling erosion on slopes and in gullies (Phillips *et al.*, 2020). Thus, it can be assumed that there will be few instances where its application will not be required on high erosion risk land[13]. Consequently, the proposed provisions will likely require space planting across 2,428 ha of high erosion risk land[14]. This is consistent with what was assumed under the CMP Improved scenario (2,422 ha) (Table 9).

Note: It is possible that some landowners will apply for resource consent to farm without an. However, it is unlikely it will be granted (see Section 3.1.1).

[13] See Section 2.4 for reasoning behind the assumption that space planting will be the primary soil conservation treatment type applied to high erosion risk land.

[14] Based on interim mapping of the high erosion risk land in the Pouewe and Takapū part-FMUs.

Table 9: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the CMP scenario assumptions on space planting.

BAU	Improved	Water Sensitive
No additional space planting assumed.	• Space/pole planting of LUC class 6e land with grassland land cover. • Approximate area treated = 2,422 ha.	No additional space planting assumed as LUC class 6e land with grassland land cover is assumed to be retired under this scenario.
BAU	Improved	Water Sensitive
	↑	
	Provisions	
	• Rule P.R26(b) and Schedule 36 (E)(3)(c) require appropriate soil conservation treatment (assumed to be space planting) on all high erosion risk land on farms >20 ha. • Approximate area treated = 2,428 ha.	

3.1.3 Livestock exclusion

In combination, the proposed provisions and the Resource Management (Stock Exclusion) Regulations 2020 (the 'Stock Exclusion Regulations') provide some level of control over livestock access across at least 45 km of the River Environment Classification[15] network in the TAoP Whaitua. This is 45% less than assumed under the CMP Improved scenario (85 km[16] of the REC network (Easton *et al.*, 2019b)), and is, therefore, most consistent with BAU (Figure 3a) (Table 10).

The specifics of the livestock exclusion required by the proposed provisions and the Stock Exclusion Regulations are as follows:

- The Stock Exclusion Regulations require livestock exclusion from wide (greater than one metre (m)) rivers on all low slope land by 01/07/2025. This equates to approximately 31 kilometres (km) of the REC network length in the Whaitua; and
- The proposed provisions of PC1 are likely to result in livestock exclusion from an additional 14 km[17] of the REC network in areas retired under ERTPs ((WH.R27(b) and Schedule 36(B)&(E); see Section 3.1.1)

[15] The REC (v2.5) is a database of catchment spatial attributes, summarised for every segment in New Zealand's network of rivers.

[16] This is more than the figure cited in Easton *et al.* (2019b) as it includes existing stock exclusion.

[17] Represents the total length of REC network within LUC class 7e and 8e land with grassland land cover (proxy for highest erosion risk land). There is a high level of uncertainty in this figure as rivers are not evenly distributed through the landscape. Thus, while class LUC class 7e and 8e land may cover a similar amount of area to highest erosion risk land (interim mapping conducted for the Pouewe and Takapū part-FMUs), if it is distributed differently across the landscape, the length of river flowing through it may be significantly different.

Table 10: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the CMP scenario assumptions on livestock exclusion.

BAU	Improved	Water Sensitive
• No additional livestock exclusion except as a result of urban development or retirement required by existing resource consents. • Approximate length of livestock exclusion = 12.5 km.	• Livestock exclusion undertaken on all REC order 2 or greater streams with catchment slope less than 15 degrees. • All streams within retired areas receive livestock exclusion. • Approximate length of livestock exclusion = 85 km.	• Same as Improved but with greater impact from retirement. • Approximate length of livestock exclusion = 102 km.
BAU	**Improved**	**Water Sensitive**

↑

Provisions
Approximate length of livestock exclusion required by proposed provisions and existing regulations = 45 km. **Proposed provisions** • The ERTPs required under Rule P.R26(b) should result in the exclusion of livestock in rivers running through highest erosion risk land on farms >20 ha. Applies to 14 km of REC network. **Existing regulations** • Under the Stock Exclusion Regulations, livestock exclusion is required on all rivers greater than one metre wide on low slope land. Applies to ≥31 km of REC network.

Notes:

- *The length of river covered by the proposed provisions and the Stock Exclusion Regulations have been calculated using the REC network which does not detect smaller streams. Consequently, the cited length of rivers impacted by these documents will have been underestimated. This is also true for the cited length of river impacted by retirement under the CMP scenarios.*
- *Easton et al. (2019b) calculated that livestock exclusion has already occurred on 22 km of rivers in TAoP Whaitua (mostly on rivers covered by the Stock Exclusion Regulations). Furthermore, while not required by the proposed provisions, livestock exclusion may occur in as much as 12.5 km of river simply because of urban development (as assumed under the CMP BAU scenario) and retirement required by existing resource consents.*

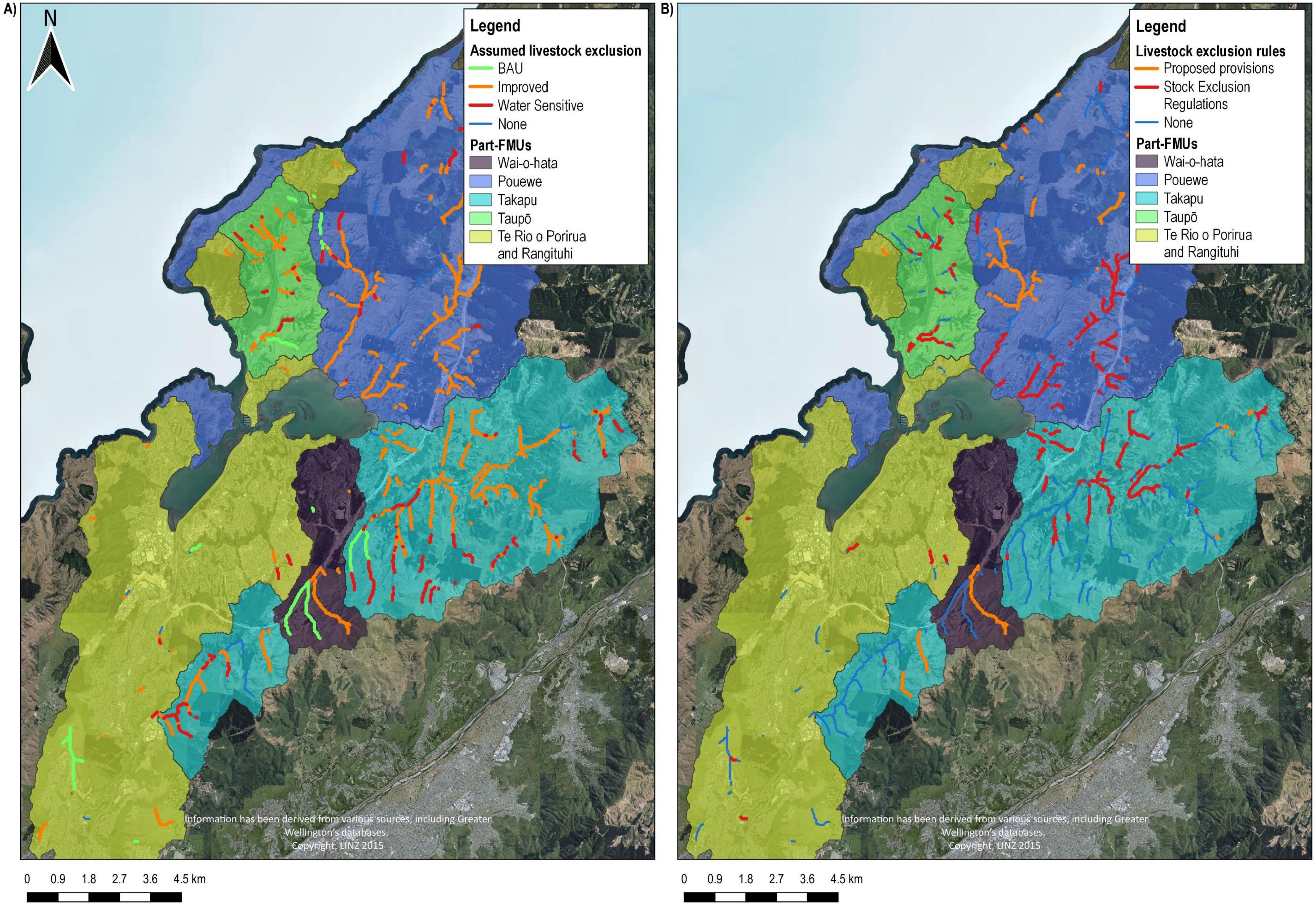

Figure 3: Livestock exclusion assumed under the different CMP scenarios (A) and the proposed provisions (B). The CMP scenarios are additive (i.e., exclusion under the CMP BAU scenario is also assumed under Improved and Water Sensitive).

3.1.4 Riparian management

The future riparian management required by regulation (including the proposed provisions) in TAoP Whaitua is most consistent with that assumed under the CMP BAU scenario (Table 11).

The proposed provisions do not explicitly require riparian planting of streams. However, the Stock Exclusion Regulations require livestock exclusion with a three-metre setback on wide rivers on all low slope land by 01/07/2025. This equates to approximately 31 km of REC network length. While planting of these setbacks is not required, it can be assumed that some form of vegetation will establish in them over time, even if it is just grass and scrub. Furthermore, the ERTPs stipulated by the proposed provisions (Rule P.R26(b) and Schedule 36(B)&(E)) require that woody vegetation be established on all highest erosion risk land on farms greater than 20 ha by 2040, which equates to 14 km[17] of the REC network in the TAoP Whaitua.

In combination, the proposed provisions and the Stock Exclusion Regulations could require some form of riparian management along 45 km of the REC network in the TAoP Whaitua. An additional four kilometres is also required by the conditions of existing resource consents (49 km total). While this is greater than that assumed under the CMP BAU scenario (3.8 km), it falls well short of the 76 km assumed under the Improved scenario (Figure 4). Furthermore, the required riparian management on most rivers under the Stock Exclusion Regulations (three metre setback) will likely be less effective at sediment and *E. coli* removal than that assumed under the Improved scenario (~10% (Semadenis-Davies *et al.*, 2020)).

Notes:

- *The length of river covered by the proposed provisions and the Stock Exclusion Regulations have been calculated using the REC network which does not detect smaller streams. Consequently, the length of impacted rivers will have been underestimated. This is also true for the cited length of river impacted by retirement under the CMP scenarios.*
- *Easton et al.* (2019b) *calculated that riparian planting has already occurred in 22 km of river in TAoP Whaitua (mostly on rivers covered by the Stock Exclusion Regulations). Furthermore, riparian planting will likely occur on an additional 3.8 km of river because of retirement required by existing resource consents.*

Table 11: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the CMP scenario assumptions on riparian management.

BAU	Improved	Water Sensitive
• No additional riparian planting except that resulting from retirement required by existing resource consent conditions. • Approximate length of riparian planting = 3.8 km.	• Five metres of riparian planting undertaken on all REC order 2 or greater streams with catchment slope less than 15 degrees. • All streams within retired areas receive riparian planting • Approximate length of new riparian planting = 76 km.	• Same as improved but with greater impact from retirement. • Approximate length of riparian planting = 94 km.
BAU	Improved	Water Sensitive

↑

Provisions
Approximate length of riparian management required by proposed provisions/consents = 49 km. **Proposed provisions** • The ERTPs required under Rule P.R26(b) require riparian planting of rivers running through highest erosion risk land on farms >20 ha. Applies to 14 km of REC network. **Existing regulations** • Under the Stock Exclusion Regulations livestock exclusion with a three-metre setback is required on all rivers greater than one metre wide on low slope land. Applies to ~31 km of REC network.

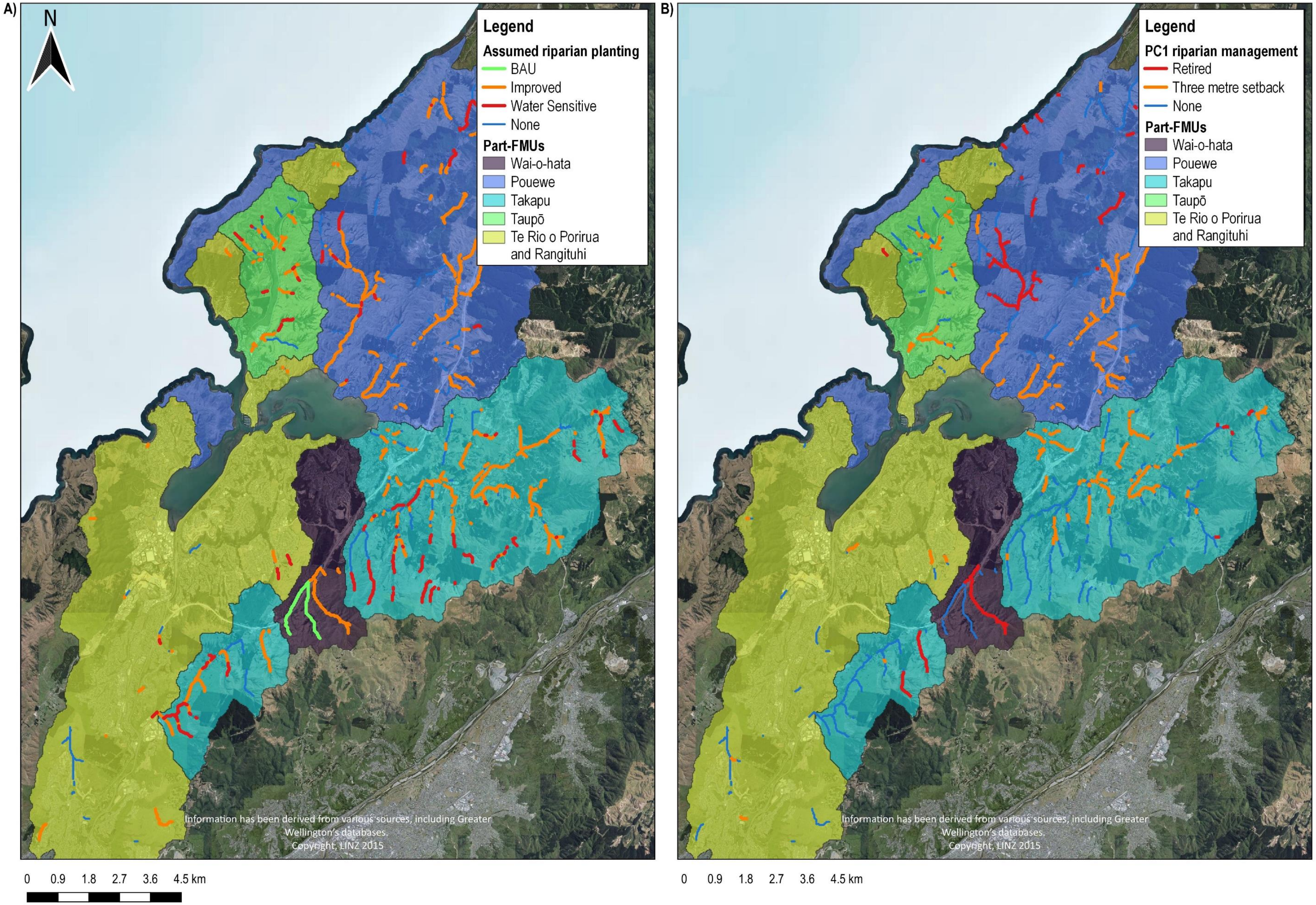

Figure 4: Riparian management assumed under the different CMP scenarios (A) and the proposed provisions (B). The CMP scenarios are additive (i.e., riparian management under the CMP BAU scenario is also assumed under Improved and Water Sensitive).

3.1.5 Earthworks

Policy P.P27 combined with the conditions of Rule P.R22 and the matters of discretion in Rule P.R23 should ensure that the *Erosion and Sediment Control Guide for Land Disturbing Activities in the Wellington Region* (the 'erosion and sediment control guidelines') (Leersnyder *et al.*, 2021) is followed across all earthworks sites. The erosion and sediment control guidelines combined with the total suspended solids (TSS) standards in Policy P.P28 should also ensure the widespread use of chemically treated sediment retention ponds at sites between 0.3 ha and 5 ha (due to the challenges of meeting the TSS standard without flocculation (ARC, 2004)). It can also be assumed that the activity status of Rule P.R24 (non-complying) will make it difficult to obtain resource consent to conduct earthworks operations that are contrary to the erosion and sediment control guidelines and the TSS standards in Policy P.P28.

All the CMP scenarios assumed compliance with the erosion and sediment control guidelines and the widespread use of well-managed chemically treated sediment retention ponds (to reduce sediment loads from earthworks sites by 90%). Consequently, the proposed earthworks provisions are consistent with the CMP Water Sensitive Scenario[18] (Table 12).

Table 12: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the CMP scenario assumptions on earthworks.

BAU	Improved	Water Sensitive
• Construction sediment control practices across 100% of construction areas. • Assumes GW Erosion and Sediment Control guidelines are followed and the widespread use of well-managed chemically treated sediment retention ponds		

BAU	Improved	Water Sensitive
		↑
		Provisions
		• Policy P.P27, Rule P.R22 and Rule P.R23 require that the erosion and sediment control guidelines are followed across all earthworks sites covered by those rules. • Policy P.P28 should ensure the widespread use of chemically treated sediment retention ponds at sites between 0.3 ha and 5 ha.

[18] Note: While Easton *et al.* (2019) assumed the CMP scenario assumptions would result in the removal of 90% of the sediment load generated by earthworks sites, there is uncertainty around the exact treatment performance of various erosion and sediment control practices. For example, Phillips *et al.*, (2020) cites studies where treated pond performance ranges between 68% and 99% and provides a general figure of 70%. However, it is outside the scope of this assessment to critically review the Easton *et al.*'s (2019) model inputs.

3.1.6 Stormwater management

The stormwater management required by the proposed provisions goes beyond that assumed under the CMP Water Sensitive scenario (Table 13).

Table 13: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the CMP scenario assumptions on stormwater management.

BAU	Improved	Water Sensitive

No storm water capture or treatment.	• Installation of rainwater tanks on 50% of new greenfield and infill dwellings and 10% of existing residential dwellings (relevant to sediment).
	• In greenfield and infill development, the treatment of:
	  ○ 40% of roads with bioretention; and
	  ○ 100% of paved and rooved surfaces with wetlands.
	• In existing urban areas, the treatment of 50% runoff from major roads and paved commercial and industrial areas with media filters.
		• Installation of rainwater tanks on 100% of new greenfield and infill dwellings and 50% of existing residential dwellings
		• In greenfield and infill development, the treatment of:
		  ○ 50% of paved surface in new greenfield dwellings and 25% of infill dwellings with permeable paving;
		  ○ 90% of roads with bioretention; and
		  ○ 100% of paved and rooved surfaces with wetlands.
		• In existing urban areas, the treatment of:
		  ○ 100% runoff from major roads with wetlands
		  ○ 100% runoff from paved industrial areas with media filters
		  ○ 100% runoff from paved commercial areas with bioretention.

BAU	Improved	Water Sensitive
		↑

Provisions
• Most new infill and urban developments carried out under Rule P.R5, Rule P.R6 and Rule P.R7 (<0.3 ha of new impervious surface) required to provide hydrological controls • New infill and urban developments carried out under Rule P.R6 and Rule P.R7 generally required to treat stormwater with the equivalent of a bioretention device. • Some infill and urban developments >0.3 ha carried out under Rule P.R10 required to provide treatment and hydrological controls through consent conditions (Policy P.P10 and Policy P.P13). • Stormwater network operators required by Rule P.R8 and Schedule 31 to reduce contaminant loads from existing urban areas to meet the relevant TASs and coastal objectives for Cu and Zn (not achieved under the CMP Water Sensitive scenario).

3.1.6.1 New urban development as defined in PC1

Under the proposed provisions almost all new small (less than 0.3 ha of new impervious surface) infill and urban developments carried out as a permitted (Rule P.R5 - <0.1 ha of new impervious surface) or controlled activity (Rule P.R6 and Rule P.R7- 0.1 to 0.3 ha of new impervious surface) will be required to provide hydrological controls (most likely to be in the form of rainwater tanks). Furthermore, all new infill and urban developments carried out as a controlled activity will be required to treat stormwater with a device that achieves copper (Cu) and zinc (Zn) load reduction factors equivalent to that of a bioretention device (commonly known as a 'raingarden'). While not an absolute requirement of the proposed provisions, the wording of Policy P.P10 and Policy P.P13 means it is also likely that most infill and urban developments greater than 0.3 ha carried out as a discretionary activity (Rule P.R10) will be required by consent conditions to provide a similar level of contaminant treatment and hydrological control to that required by Rule P.R6.

Easton *et al.* (2019b) assumed raingardens achieved the contaminant load reduction factors set out in Table 14, and notes that these were "*derived from the International Stormwater Best Management Practices (BMP) database and agreed on within the TAoP MLG*". These load reduction factors are broadly consistent with that achieved through the treatment chain assumed for new developments under the CMP Water Sensitive scenario (Table 14). Thus, in terms of stormwater contaminant losses from new urban developments it can be concluded that proposed provisions are consistent with the assumptions of that scenario.

Table 14: Load reduction factors for raingardens compared to the treatment chain load reduction factors assumed for new urban developments under the CMP Improved and Water Sensitive scenarios (all values from *Easton et al.*, (2019b))

Contaminant	Raingarden load reduction factors (same as required by proposed provisions)	Treatment chain load reduction factor – Improved	Treatment chain load reduction factor – Water Sensitive
Sediment	90%	80% - 84%	75% - 89%
E. coli	90%	90%	45% - 90%
Total Nitrogen	40%	40%	40%
Total phosphorus	60%	50% - 54%	48% - 59%
Copper	80%	70% - 74%	55% - 79%
Zinc	80%	70% - 74%	55% - 79%

The hydrological control requirements for new urban developments with greater than 0.3 ha of new impervious surface area in the proposed provisions are more stringent than the assumptions of the CMP Improved scenario (50% of new dwelling have rain tanks installed). However, the proposed provisions are more lenient than that assumed under the Water Sensitive scenario (100% of new dwellings have rain tanks installed) as they do not apply to infill developments with less than 0.1 ha of new impervious surface area. Consequently, the proposed provisions should be at least as effective as the assumptions of the CMP Improved scenarios at mitigating the impacts of new urban development on bank erosion (which contributes to sediment loads).

3.1.6.2 Existing discharges from stormwater networks

Rule P.R8 and Schedule 31 ((1)(c)-(e), and (2)(b)) of the proposed provisions requires stormwater network operators to reduce their Cu and Zn loads over time to meet the relevant TASs and harbour load reduction targets (Zn = 40%; Cu = 15% (an additional 25% required through action planning)). As some of these TASs and targets were predicted not to be met under the CMP Water Sensitive scenario (Easton *et al.*, 2019b) it is likely the proposed provisions will require actions beyond those assumed under that scenario (Table 15).

Note: Stormwater treatment does not only remove Cu and Zn; it also treats the other contaminants assessed in this report (see Table 14 for the comparative impacts of stormwater treatment on different contaminants).

3.1.7 Discharges from wastewater networks

The proposed provisions go beyond the wastewater management assumptions of CMP Water Sensitive scenario (Table 15).

Table 15: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the CMP scenario assumptions on wastewater management

BAU	Improved	Water Sensitive
New urban development does not increase the frequency or volume of wastewater overflows or dry-weather wastewater discharges through cross-connections.	• All cross connections repaired resulting in a 77% reduction in *E. coli* yields where they currently occur. • Wastewater overflows reduced from 12 per year on average to four (66% reduction in load).	As for Improved but wastewater overflows reduced to two per year (83% reduction in load).
BAU	**Improved**	**Water Sensitive**
		↑
		Provisions
		Networks operators to reduce wastewater discharge volumes and loads by up to 92% (commensurate with that required to meet *E. coli* TASs and enterococci objectives (Rule P.R13).

Rule P.R13 of the proposed provisions require that for a wastewater network discharge to coastal and/or freshwater to be a restricted discretionary activity (rather than non-complying) network operators must include a strategy within their resource consent applications to progressively reduce and remove wastewater network catchment discharges (in accordance with Schedule 32) including:

"the reduction of Escherichia coli or enterococci is commensurate with what is required in the receiving environment to meet the target attribute state in Table 9.2 or coastal water objective in Table 9.1 for the relevant part FMU or coastal water management unit"

The proportional reductions in *E. coli* load needed to achieve the TASs range between 59% (Takapū) and 92% (Te Rio o Porirua and Rangituhi) depending on the part-FMU (Table 16).

Under the CMP Water Sensitive scenario:

- The repair of all cross connections between the wastewater and stormwater network was only assumed to achieve a 77% (maximum) reduction in dry weather wastewater discharge *E. coli* loads (based on yields listed in Easton *et al.* (2019b)); and
- Overflow loads were assumed to be reduced by 83% (12 overflows per year on average reduced to two).

Consequently, it can be expected that to achieve the *E. coli* and enterococci load reductions required by Rule P.R13, network operators may have to reduce wastewater discharge volumes (and associated contaminant loads) by even more than that assumed under the CMP Water Sensitive Scenario.

Table 16: Estimated *E. coli* load reduction required to meet the *E. coli* TAS in each part-FMU (based on the relationships between *E. coli* loads and concentrations under the different CMP scenarios (Easton *et al.*, 2019b)).

Part-FMU	Calculated % reduction for TAS
Pouewe	-67%
Te Rio o Porirua and Rangituhi	-92%
Wai-o-hata	-83%
Takapū	-59%
Taupō*	-88%

3.1.8 Land-use change not associated with retirement.

3.1.8.1 Urban development or rural land

All three CMP scenarios assumed greenfield, infill and rural residential development would occur within council identified development zones to accommodate population projections to 2043. While the provisions cannot ensure the land-use change assumed in the CMP scenarios goes ahead, the proposed urban development provisions prohibit new unplanned urban development (Rule P.R12). Consequently, they are broadly consistent with the CMP Water Sensitive scenario assumptions (Table 17).

3.1.8.2 Change of rural land uses

The CMP scenarios assumed that rural land use would not change from the baseline period except for conversion to urban development. The proposed provisions are consistent with this assumption (Table 17), in that any change to a higher intensity land use will generally be a non-complying activity (Rule P.R29) as the *E. coli* component of Rule P.R28 (Condition (e)) is unlikely to be met over the life of the plan (more detail provided in Section 4.1.2.2). Furthermore, the FEPs required by Rule P.R26(a) will further ensure land use intensity does not increase, by requiring the avoidance of an increase in the "*risk of loss of nitrogen, phosphorus, sediment or E.coli to water*" (Schedule Z(B)(2) of the operative NRP).

Table 17: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the CMP scenario assumptions on land-use change not associated with retirement.

BAU	Improved	Water Sensitive
• Greenfield, infill and rural residential development assumed to occur within council identified development zones to accommodate population projections to 2043. • No change in rural and land use except where it relates to urban development.		
BAU	Improved	Water Sensitive
		↑
		Provisions
		• Rule P.R12 prohibits unplanned urban development • Change to a higher intensity rural land-use is a non-complying activity (Rule P.R28(e) and Rule P.R29).

Note: The proposed provisions also require that highest erosion risk land currently used for plantation forestry must no longer be used for this once existing trees are harvested. However, this is not considered in this assessment as the implications on land-cover and sediment losses are unclear.

3.1.9 Practice change other than livestock exclusion, riparian planting and space planting

The proposed provisions require that land use practices improve beyond that assumed under the CMP Water Sensitive scenario (Table 18).

None of CMP scenarios assumed changes in land use practice except the livestock exclusion, riparian planting, space planting and sediment control (earthworks) described above in Sections 3.1.1 to 3.1.5 above. However, the proposed provisions require some level of good management practices for:

- Vegetation Clearance on land with high erosion risk (Rule P.R16 to Rule P.R18);
- Plantation Forestry (Rule P.R19 to Rule P.R21); and
- Farming activities on 20ha or more of land (Rule P.R26).

The impact this will have on contaminant losses cannot be quantified, but it is likely negligible compared to the required retirement, livestock exclusion and space planting.

Table 18: Summary assessment of where the proposed provisions sit (denoted by the ↑) in relation to the CMP scenario assumptions on practice change not associated with livestock exclusion, riparian planting and space planting.

BAU	Improved	Water Sensitive
Assumes no change in practice other than **livestock** exclusion, riparian planting, space planting and sediment control (earthworks)		
BAU	Improved	Water Sensitive
		↑
		Provisions Require some level of good management practices for: • Vegetation clearance on land with high erosion risk (Rule P.R16 - Rule P.R18); • Plantation Forestry (Rule P.R19 – Rule P.R21); and • Farming activities on 20ha or more of land (Rule P.R26).

3.2 Alignment between the proposed provisions and CMP scenarios by attribute group

3.2.1 Sediment

For the sediment attribute group, the proposed provisions are most consistent with what has been assumed under the CMP Improved scenario in that they require a similar or higher level of:

- Retirement;
- Sediment control on earthworks sites;
- Stormwater management; and
- Space planting of high erosion risk land;
- Land use change (excluding retirement).

However, they are still likely to result in slightly lower sediment load reductions than were modelled under that scenario as:

- The proposed provisions require 5% less retirement than the CMP Improved scenario. However, based on the treatment efficiencies cited in Phillips *et al.*, (2020)[19] this is likely to only result in 2% lower sediment load reductions[20] (Table 19); and
- The stock exclusion and riparian management required by the proposed provisions is less extensive than that assumed under the CMP Improved scenario (44%) and, on low slope land, may also be 25% less effective at reducing sediment loads (based on the load reduction factors presented for three and five metre setbacks in Semadenis-Davies *et al.*, (2020)).

[19] Treatment performance (% reduction from baseline erosion) of afforestation = 90% for landslide, gully and earthflow erosions compared to 70% for space planting.

[20] There is very high degree of uncertainty around this figure.

Table 19: Potential differences in sediment load reduction under the proposed provisions and the CMP Improved scenario based on the cited treatment performances for afforestation and space planting in Phillips *et al.*, (2020).

Sediment treatment	Treatment performance (gully, earthflow & landslide erosion)	Improved		Provisions	
		Area (ha)	Equivalent area with 100% treatment (ha)	Area (ha)	Equivalent area with 100% treatment (ha)
None	0	15,819	0	16,722	0
Space planting	0.7	2,422	1,695	2,428	1,699
Retirement	0.9	1,994	1,795	1,895	1,704
Total equivalent area with 100% treatment	**3,490**			**3,404**	
Difference between provisions and Improved scenario	**-2%**				

3.2.2 Faecal indicator bacteria

The proposed provisions are likely to impact the faecal indicator bacteria attribute group in a manner most consistent with the modelled outcomes of the CMP Improved scenario as:

- They require a similar level of retirement, and Easton *et al.* (2019b) noted that this was the main driver of the modelled improvements in *E. coli* in rural areas under that scenario;
- They require urban sources of faecal indicator bacteria to be reduced by more than that assumed under the CMP Water Sensitive scenario (see Sections 3.1.6 and 3.1.7). However, this is unlikely to result in the *E. coli* reductions beyond what was modelled under the Improved scenario given the relative contribution of rural sources (modelled instream *E. coli* concentrations generally in the E state upstream of urban influences (Easton *et al.*, 2019b)).

However, it must be noted that the proposed provisions do require significantly less extensive (44%) and effective[21] stock exclusion and riparian planting than assumed under the Improved scenario.

3.2.3 Nitrogen

The proposed provisions are most consistent with the nitrogen management assumptions of the CMP Improved scenario. The reasons for this are the same as those provided for faecal indicator bacteria in Section 3.2.2.

3.2.4 Phosphorus

For the same reasons as provided for sediment (Section 3.2.1) the proposed provisions relevant to the phosphorus attribute group are most consistent with the assumptions of the CMP Improved scenario.

[21] Potentially 15% for rivers on low slope and (Semadenis-Davies *et al.*, 2020).

3.2.5 Metals

The stormwater management required by the proposed provisions goes beyond that assumed under the CMP Water Sensitive scenario (see Section 3.1.6). Accordingly, they are likely to result in reductions in Cu and Zn concentrations equal to or greater than those modelled under that scenario.

Note: Only the stormwater management provisions are relevant to this attribute group.

3.2.6 Periphyton

Periphyton growth is driven by flow, shade and nutrient concentrations. However, based on the expert assessment for ecological attributes[6], shade was considered the primary driver of the predicted changes in this attribute under the different CMP scenarios. On that basis the proposed provisions' impact on periphyton growth is likely to be most similar to what was projected under that the BAU scenario, given the required riparian management (i.e., shading) is most consistent with the assumptions of that scenario (see Section 3.1.4).

Note: While the proposed provisions are most consistent with the assumptions of the CMP BAU scenario, they do require significantly more nutrient mitigations than assumed under that scenario (see Sections 3.2.3 and 3.2.4.).

3.2.7 Summary

Table 20 summarises the likely impact of the proposed provisions on each attribute group compared to the assumptions of the CMP scenarios.

Table 20: Summary of where the likely impacts of the proposed provisions on each attribute group sit in relation to the CMP scenarios.

Attribute group	Most applicable scenario	Indication of where provisions sit in relation to scenarios
Sediment	Improved	BAU — Improved — Water Sensitive ↑ Provisions (at Improved)
Faecal indicator bacteria	Improved	BAU — Improved — Water Sensitive ↑ Provisions (just below Improved)
Nitrogen	Improved	BAU — Improved — Water Sensitive ↑ Provisions (just below Improved)
Phosphorus	Improved	BAU — Improved — Water Sensitive ↑ Provisions (just below Improved)
Metals	Water Sensitive	BAU — Improved — Water Sensitive ↑ Provisions (at Water Sensitive)
Periphyton	BAU	BAU — Improved — Water Sensitive ↑ Provisions (between BAU and Improved, near BAU)

4 Results

4.1 Assessment of whether the proposed provisions are likely to achieve the TASs and coastal objectives for 2A type attributes

4.1.1 Maintain TASs and coastal objectives

4.1.1.1 Sediment and phosphorus attribute groups

The proposed provisions that manage sediment and phosphorus losses, are most consistent with the assumptions of the CMP Improved scenario (albeit with 45% and 35% less stock exclusion and riparian planting respectively). That scenario was modelled to result in significant reductions in sediment/phosphorus loads and improvements in suspended fine sediment (SFS; as measured by visual clarity) in all part-FMUs (Easton *et al.*, 2019b; Greer *et al.*, 2023). While the proposed provisions might not result in the same level of improvement, they will likely ensure that SFS and dissolved reactive phosphorus (DRP) concentrations are maintained in those part-FMUs where the TASs require this (Table 21 and Table 22).

Table 21: The modelled direction of change in SFS under the different CMP scenarios in the part-FMUs where the TASs require the maintenance of this attribute (based on modelled sediment loads in Easton *et al.*, (2019b). and the site specific sediment clarity relationships set out in Greer *et al.* (2023)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions likely to achieve TAS?
				BAU	Improved	Water Sensitive	
Taupō	Taupō S. @ Plimmerton Domain	SFS	A	Degrade	Improve	Improve	✓
Pouewe	Horokiri S. @ Snodgrass		C	Improve			
Wai-o-hata	Duck Ck		A				
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot			Degrade			
					↑ Provisions		

Table 22: The modelled direction of change in DRP concentrations under the different CMP scenarios in the part-FMUs where the TASs require the maintenance of this attribute (Easton *et al.*, 2019b). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions likely to achieve TAS?
				BAU	Improved	Water Sensitive	
Taupō	Taupō S. @ Plimmerton Domain	DRP (median mg/L)	0.017	Improve	Improve	Improve	✓
Pouewe	Horokiri S. @ Snodgrass		0.011				
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.		0.018				
Takapū	Pāuatahanui S. @ Elmwood Br.		0.014				
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot		0.018				
Taupō	Taupō S. @ Plimmerton Domain	DRP (95th %ile mg/L)	0.047	Improve	Improve	Improve	
Pouewe	Horokiri S. @ Snodgrass		0.026				
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.		0.050				
Takapū	Pāuatahanui S. @ Elmwood Br.		0.022				
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot		0.034				
					↑ Provisions		

4.1.1.2 Nitrogen attribute group

Under the assigned CMP scenario (Improved), modelled dissolved inorganic nitrogen (DIN), nitrate-nitrogen (NO_3-N) and ammoniacal-nitrogen (NH_4-N) concentrations were improved in all part-FMUs where the TASs require they be maintained (Table 23) (Easton *et al.*, 2019b). Consequently, the proposed provisions will likely result in the achievement of these TASs.

Table 23: The modelled direction of change in DIN, NO_3-N, and NH_4-N concentrations under the different CMP scenarios in the part-FMUs where the TASs require the maintenance of these attributes (Easton *et al.*, 2019b). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions likely to achieve TAS?
				BAU	Improved	Water Sensitive	
Taupō	Taupō S. @ Plimmerton Domain	DIN (median mg/L)	0.41	Improve	Improve	Improve	✓
Pouewe	Horokiri S. @ Snodgrass		0.64				
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.		0.48				
Takapū	Pāuatahanui S. @ Elmwood Br.		0.33				
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot		0.92				
Pouewe	Horokiri S. @ Snodgrass	NH_4-N	A	Improve	Improve	Improve	
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.						
Takapū	Pāuatahanui S. @ Elmwood Br.						
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot						
Pouewe	Horokiri S. @ Snodgrass	NO_3-N	A	Improve	Improve	Improve	
Takapū	Pāuatahanui S. @ Elmwood Br.						
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot		A[1]				

↑
Provisions

[1] Baseline state is B. However, current state is A and trend analysis indicates it will remain so (GW, 2022).

4.1.1.3 Metals attribute group

The proposed provisions require that the Cu and Zn TASs be met through the actions of stormwater network operators (see Section 3.1.6). Consequently, for the purposes of this assessment it is assumed that they are sufficient to ensure the achievement of these TASs (Table 24).

Table 24: The modelled direction of change in dissolved Zn and Cn concentrations under the different CMP scenarios in the part-FMUs where the TASs require the maintenance of these attributes (Easton *et al.*, 2019b). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions likely to achieve TAS?
				BAU	Improved	Water Sensitive	
Pouewe	Horokiri S. @ Snodgrass	Cu	A	Degrade	Degrade	Degrade	✓
Takapū	Pāuatahanui S. @ Elmwood Br.		A				
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot		C		Maintain		
Pouewe	Horokiri S. @ Snodgrass	Zn	A	Degrade	Degrade	Degrade	
Takapū	Pāuatahanui S. @ Elmwood Br.						

↑
Provisions

4.1.2 Improve TASs and coastal objectives

4.1.2.1 Sediment attribute group

The CMP modelling outputs for the Improved scenario suggest that the proposed provisions may achieve all of the sediment TASs and coastal objectives that require an improvement from baseline state (Easton *et al.*, 2019b; Greer *et al.*, 2023) (Table 25).

It must be noted, however, that the proposed provisions require less stock exclusion and riparian management than assumed under the CMP Improved scenario and may result in slightly smaller sediment load reductions.

Table 25: Modelled SFS attribute states (rivers) and sediment load reductions (coast) under the different CMP scenarios in the rural and mixed-rural part-FMUs where the TASs or coastal objectives require an improvement in these attributes (based on modelled sediment loads in Easton *et al.*, (2019b) and the site specific sediment clarity relationships set out in Greer *et al.* (2023)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs/coastal objectives.

Part-FMU	Site	Attribute	Baseline state	TAS/ objective	Scenario results			Provisions likely to achieve TAS/ objective?
					BAU	Improved	Water Sensitive	
Takapū	Pāuatahanui S. @ Elmwood Br.	SFS	D	C	D	C	C	✓
Onepoto Arm		Sediment load Δ	5,200 t/yr.	-40%	-11%	-46%	-49%	
Pāuatahanui Inlet			8,000 t/yr.		-1%	-40%	-46%	

↑
Provisions

4.1.2.2 Faecal indicator bacteria attribute group

E. coli and enterococci modelling by Easton *et al.*(2019b) and Oldman (2019) for the CMP Improved scenario indicates that the proposed provisions are unlikely to be sufficient to achieve any of the relevant TASs and coastal objectives (Table 26).

That many of the *E. coli* TASs and enterococci coastal objectives were not predicted to be met under the CMP Water Sensitive scenario suggests that their achievement may require the implementation of non-regulatory actions beyond those assumed under that scenario (Table 26); i.e:

- Excluding stock and planting all second order and above streams on low slope pastural land; and
- Retiring all high erosion risk land.

Table 26: Modelled *E. coli* attribute states (rivers) and enterococci concentrations (coast) under the different CMP scenarios in the rural and mixed-rural part-FMUs where the TASs or coastal objectives require an improvement in these attributes (Easton *et al.*, 2019b; Oldman, 2019). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs/coastal objectives.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results: BAU	Scenario results: Improved	Scenario results: Water Sensitive	Provisions likely to achieve TAS/ objective?
Taupō	Taupō S. @ Plimmerton Domain	*E. coli*	E[1]	B	E	D	C	×
Pouewe	Horokiri S. @ Snodgrass		E	B	D	C	B	
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.			C	E	D	D	
Takapū	Pāuatahanui S. @ Elmwood Br.				D		C	
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot				E	E	D	
Onepoto Arm		Enterococci (95th %ile /100mL)	>500	≤500	>500	N/A	>500	
Pāuatahanui Inlet				≤200			>200 - ≤500	

↑
Provisions

[1] Modelled as D in Easton *et al.*, (2019b).

4.1.2.3 Nitrogen attribute group

Modelling by Easton *et al.* (2019b) suggests that the assumptions of the CMP Improved scenario and, therefore, the proposed provisions are likely sufficient to achieve almost all of the TASs for the nitrogen attribute group that represent an improvement from baseline state. The exception is the NO_3-N TAS for the Taupō part-FMU (Table 27). That TAS was only modelled as being met under the Water Sensitive scenario (Table 27). Thus, it may not be achieved without additional non-regulatory actions equivalent to those assumed under that scenario; i.e.:

- Excluding stock and planting all second order and above streams on low slope pastural land; and
- Retiring all high erosion risk land.

Table 27: Modelled NH_4-N and NO_3-N attribute states under the different CMP scenarios in the part-FMUs where the TASs require an improvement in these attributes (Easton *et al.*, 2019b). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Baseline state</th><th rowspan="2">TAS</th><th colspan="3">Scenario results</th><th rowspan="2">Provisions likely to achieve TAS?</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td rowspan="2">Taupō</td><td rowspan="2">Taupō S. @ Plimmerton Domain</td><td>NH_4-N</td><td>B</td><td>A</td><td>A</td><td>A</td><td>A</td><td>✓</td></tr>
<tr><td rowspan="2">NO_3-N</td><td rowspan="2">B</td><td rowspan="2">A</td><td>B</td><td>B</td><td rowspan="2">A</td><td>×</td></tr>
<tr><td>Wai-o-hata</td><td>Duck Ck @ Tradewinds Dr. Br.</td><td>A</td><td>A</td><td>✓</td></tr>
</table>

↑ Provisions

4.1.2.4 Phosphorus attribute group

None of the TASs for DRP require an improvement in this attribute.

4.1.2.5 Metals attribute group

The proposed provisions require that the Cu and Zn TASs in Table 2 be met through the actions of stormwater network operators (via loads; see Section 3.1.6). Consequently, it is simply assumed that the provisions are sufficient to ensure that these TASs are achieved, even in those part-FMUs where the modelling by Easton *et al.* (2019b) suggests it will require actions beyond the assumptions of the CMP Water Sensitive Scenario (Table 28).

Table 28: Modelled Cu and Zn attribute states (rivers) and load reductions (coast) under the different CMP scenarios in the part-FMUs where the TASs or coastal objectives require an improvement in these attributes (Easton *et al.*, 2019b). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are likely to result in the achievement of the TASs/coastal objectives.

Part-FMU	Site	Attribute	Baseline state	TAS/ objective	Scenario results			Provisions likely to achieve TAS/ objective?
					BAU	Improved	Water Sensitive	
Taupō	Taupō S. @ Plimmerton Domain	Cu	D	B	C	C	C	✓
Wai-o-hata	Duck Ck		C	A				
Onepoto Arm		Cu load Δ	240 kg/yr.	-15%	+6%	-7%	-20%	
Pāuatahanui Inlet			70 kg/yr.		+33%	+9%	-18%	
Taupō	Taupō S. @ Plimmerton Domain	Zn	C	A	C	B	A	
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.		B		B			
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot		D[1]	C	C	C	C	
Onepoto Arm		Zn load Δ	2,650 kg/yr.	-40%	+1%	-30%	-60%	
Pāuatahanui Inlet			580 kg/yr.		+17%	-14%	-46%	

↑ **Provisions**

[1] Modelled as C in Easton *et al.*, (2019b).

4.1.2.6 Periphyton

The expert assessment for ecological attributes[6] indicate that assumptions of the CMP scenario most consistent with the proposed provisions (BAU) are unlikely to achieve the periphyton TASs in the part-FMUs where improvements in this attribute are required (Table 29). This is, however, not unexpected as (non-regulatory) riparian planting is the primary mechanism by which GW intends to reduce periphyton biomass[22]. It is also uncertain whether the TASs for the Wai-o-hata, Takapū, Te Rio o Porirua and Rangituhi part-FMUs actually require an improvement in this attribute as relevant biomass data do not exist.

[22] This is accounted for in the nutrient outcomes set out in Greer *et al.* (2023) and is possible (i.e., there is currently limited shading) at TAS sites in the Pouewe, Wai-o-hata, Takapū, Te Rio o Porirua and Rangituhi part-FMUs (based on a shading assessment conducted by GW).

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Table 29: Predicted periphyton biomass attribute states under the different CMP scenarios in the part-FMUs where the TASs require an improvement in this attribute (based on the expert assessment for ecological attributes[6]). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

<table>
<tr><th rowspan="2">Part-FMU</th><th rowspan="2">Site</th><th rowspan="2">Attribute</th><th rowspan="2">Baseline state</th><th rowspan="2">TAS</th><th colspan="3">Scenario results</th><th rowspan="2">Provisions likely to achieve TAS?</th></tr>
<tr><th>BAU</th><th>Improved</th><th>Water Sensitive</th></tr>
<tr><td>Pouewe</td><td>Horokiri S. @ Snodgrass</td><td rowspan="4">Periphyton biomass</td><td>D[1]</td><td rowspan="4">B</td><td rowspan="3">C</td><td>B</td><td>B</td><td>×</td></tr>
<tr><td>Wai-o-hata</td><td>Duck Ck @ Tradewinds Dr. Br.</td><td rowspan="3">N/A[2]</td><td>C</td><td>C</td><td rowspan="3">?</td></tr>
<tr><td>Takapū</td><td>Pāuatahanui S. @ Elmwood Br.</td><td rowspan="2">B</td><td rowspan="2">B</td></tr>
<tr><td>Te Rio o Porirua and Rangituhi</td><td>Porirua S. @ Milk Depot</td><td>B</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>↑
Provisions</td><td></td><td></td><td></td></tr>
</table>

[1] Baseline state based on limited data.
[2] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or be maintained at a better state.

4.2 Assessment of the proposed provisions against the TASs and coastal objectives for 2B type attributes

4.2.1 Maintain TAS and coastal objectives

4.2.1.1 Deposited sediment

Based on the modelling outputs for the CMP Improved Scenario ((Easton *et al.*, 2019b)), the proposed provisions are expected to reduce sediment loads in all part-FMUs and, consequently, should not increase deposited fine sediment (DFS) in those part-FMUs where the TASs require this attribute be maintained (Table 30). Similarly, the provisions should be sufficient to achieve the maintenance of coastal objectives for 'muddiness' (Table 30), given that this was the predicted result of the BAU scenario (Miller and King, 2018c; Oldman, 2019).

Table 30: The predicted direction of change in DFS and muddiness under the different CMP scenarios in the part-FMUs where the TASs or coastal objectives require the maintenance of these attributes. The direction of change in DFS under the scenarios mirrors the predicted change in modelled sediment loads in Easton *et al.*, (2019b). Muddiness results are drawn from Miller and King (2018c) (% area >50% mud) and Oldman (2019) (% of sample). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for these attributes and whether they are consistent with the achievement of the TASs/coastal objectives.

Part-FMU	Site	Attribute	Baseline state and TAS/objective	Scenarios results			Provisions consistent with TAS/ objective?
				BAU	Improved	Water Sensitive	
Pouewe	Horokiri S. @ Snodgrass	DFS	A	Improve	Improve	Improve	✓
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.		N/A[1]	Improve			
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot		C	Degrade			
Onepoto Arm	Intertidal	Muddiness (% area >50% mud)	Maintain or improve	Maintain	Maintain	Maintain	
Pāuatahanui Inlet					Improve	Improve	
Onepoto Arm		Muddiness (% of sample)		Improve	Not modelled	Improve	
Pāuatahanui Inlet				Maintain			
					↑ Provisions		

[1] Baseline state unknown. TAS is simply to maintain.

4.2.1.2 Macroalgae

Miller and King (2018c) note that the coastal macroalgae ecological quality rating (EQR) attribute is a proxy for nutrient enrichment. On that basis, it is likely that the proposed provisions will, at a minimum, achieve the coastal objectives that require the maintenance of this attribute given that was the predicted outcome of CMP scenario assigned to the nitrogen and phosphorus attribute groups (Improved – see Sections 3.2.3 and 3.2.4) (Table 31).

Table 31: The predicted direction of change in EQR under the different CMP scenarios in the part-FMUs where the coastal objectives require the maintenance of this attribute (Miller and King (2018c)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the coastal objectives.

Part-FMU	Site	Attribute	Baseline state and objective	Scenarios result			Provisions likely to achieve objective?
				BAU	Improved	Water Sensitive	
Onepoto Arm	Intertidal	EQR	Maintain or improve	Maintain	Maintain	Improve	✓
Pāuatahanui Inlet	Intertidal						
					↑ Provisions		

4.2.1.3 Dissolved oxygen

Dissolved oxygen (DO) was not explicitly assessed in the expert assessment for ecological attributes[6]. However, given that primary production is major driver of DO in streams (He *et al.*, 2011) it can be assumed that the direction, but not the magnitude, of change in this attribute under the proposed provisions will not be dissimilar to that predicted for periphyton under the CMP BAU scenario (see Section 3.2.6). On that basis it is likely that they will maintain DO in all part-FMUs where that is required by the TASs (Table 32).

Table 32: The predicted direction of change in DO concentrations under the different CMP scenarios in the part-FMUs where the TASs require the maintenance of this attribute (based on the periphyton assessments in the expert assessment for ecological attributes[6]). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results			Provisions likely to achieve TAS?
				BAU	Improved	Water Sensitive	
Taupō	Taupō S. @ Plimmerton Domain	DO	N/A[1]	Maintain	Maintain	Maintain	✓
Pouewe	Horokiri S. @ Snodgrass						
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.						
Takapū	Pāuatahanui S. @ Elmwood Br.						
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot						
				↑ Provisions			

[1] Baseline state unknown. TAS is simply to maintain.

4.2.1.4 Fish and macroinvertebrates

The impacts of the proposed provisions on fish and macroinvertebrate communities are likely to be most consistent with those predicted under CMP Improved scenario given they are expected to achieve similar or better outcomes for the sediment and metal attribute groups (both oft cited as important stressors in the expert assessment for ecological attributes[6]). However, it must be noted that the proposed provisions may not result in as large an improvement as predicted under the Improved scenario given they do not require as much stock exclusion and riparian planting (see Sections 3.1.3 and 3.1.4).

A change in the fish index of biotic integrity (F-IBI) requires the introduction or extirpation of one or more species. Accordingly, it is unlikely that the state of the F-IBI attribute would change in response to the assumptions of any of the CMP scenarios (Table 33). While this is not supported by any TAoP CMP outputs (as F-IBI was not assessed), it is consistent with the results of the WTWT Biophysical Science Programme (BSP) scenario testing process (Greer *et al.*, 2022). Consequently, the proposed provisions are likely to result in the achievement of the F-IBI TASs for all part-FMUs . Furthermore, the expert assessment for ecological attributes[6] indicates that the proposed provisions will likely achieve those TASs that require the maintenance of the macroinvertebrate average score per metric (ASPM) (Table 34).

Table 33: The likely direction of change in F-IBI under the different CMP scenarios in the part-FMUs where the TASs require the maintenance of this attribute. This attribute was not tested as part of the CMP scenario modelling, and the results below are based on expert opinion supported by the results of the WTWT scenario testing process. The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results: BAU	Scenario results: Improved	Scenario results: Water Sensitive	Provisions likely to achieve TAS?
Taupō	Taupō S. @ Plimmerton Domain	F-IBI	N/A[1]	Maintain			✓
Pouewe	Horokiri S. @ Snodgrass						
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.						
Takapū	Pāuatahanui S. @ Elmwood Br.						
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot						
					↑ Provisions		

[1] Baseline state unknown. TAS is simply to maintain.

Table 34: The predicted direction of change in ASPM under the different CMP scenarios in the part-FMUs where the TASs require the maintenance of this attribute (based on the MCI assessments in the expert assessment for ecological attributes[6]). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are likely to result in the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state and TAS	Scenario results: BAU	Scenario results: Improved	Scenario results: Water Sensitive	Provisions likely to achieve TAS?
Pouewe	Horokiri S. @ Snodgrass	ASPM	A	Improve	Improve	Improve	✓
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot		C[1]	Maintain			
					↑ Provisions		

[1] Baseline state is D. However, current state is C and trend analysis for Q/MCI indicates it will remain so (GW, 2022).

4.2.2 Improve TASs and coastal objectives

4.2.2.1 Deposited sediment

Based on the modelling by Easton *et al.*, (2019b), the proposed provisions will likely reduce sediment loads throughout TAoP Whaitua, and this may contribute to the improvement in DFS required by the TASs for the Takapū part-FMU (Table 35). However, as DFS was not assessed as part of the CMP it not possible to determine whether the proposed provisions will be sufficient to ensure the achievement of this TASs on their own.

Table 35: The predicted direction of change in DFS under the different CMP scenarios in the part-FMUs where the TASs require an improvement in this attribute (based on modelled sediment loads in Easton *et al.*, (2019b)). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are consistent with the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results: BAU	Scenario results: Improved	Scenario results: Water Sensitive	Provisions consistent with TAS?
Takapū	Pāuatahanui S. @ Elmwood Br.	DFS	D	C	Degrade	Improve	Improve	✓
						↑ Provisions		

4.2.2.2 Fish and macroinvertebrates

Based on the CMP Improved scenario results provided in the expert assessment for ecological attributes[6] the proposed provisions will likely contribute to the achievement of the fish community health, Q/MCI[23] and ASPM TASs in all part-FMUs where those attributes are required to improve, except in the Wai-o-hata part-FMU were they may only maintain fish community health (Table 36 and Table 37)

Table 36: The predicted direction of change in fish community health under the different CMP scenarios in the part-FMUs where the TASs require an improvement in this attribute (based on the expert assessment for ecological attributes[6]). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are consistent with the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results: BAU	Scenario results: Improved	Scenario results: Water Sensitive	Provisions consistent with TAS?
Taupō	Taupō S. @ Plimmerton Domain	Fish community health	N/A[1]	B	Maintain	Improve	Improve	✓
Pouewe	Horokiri S. @ Snodgrass			A				
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.			B		Maintain		×
Takapū	Pāuatahanui S. @ Elmwood Br.					Improve	Improve	✓
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot			C				
						↑ Provisions		

[1] Baseline state unknown. Assumed that the TAS represents an improvement based on part-FMU default TAS.

[23] Macroinvertebrate community index score and quantitative macroinvertebrate community index score.

Table 37: The predicted direction of change in Q/MCI and ASPM under the different CMP scenarios in the part-FMUs where the TASs require an improvement in these attributes (based on the expert assessment for ecological attributes[6]). The bottom row and right hand column provide an indication of where the proposed provisions sit in relation to the scenarios for this attribute and whether they are consistent with the achievement of the TASs.

Part-FMU	Site	Attribute	Baseline state	TAS	Scenario results: BAU	Scenario results: Improved	Scenario results: Water Sensitive	Provisions consistent with TAS?
Taupō	Taupō S. @ Plimmerton Domain	Q/MCI	N/A[1]	B	Maintain	Improve	Improve	✓
Pouewe	Horokiri S. @ Snodgrass	Q/MCI	B	A	Improve	Improve	Improve	✓
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.	Q/MCI	N/A[1]	B	Maintain	Improve	Improve	✓
Takapū	Pāuatahanui S. @ Elmwood Br.	Q/MCI	D	B	Maintain	Improve	Improve	✓
Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot	Q/MCI	D	C	Maintain	Improve	Improve	✓
Taupō	Taupō S. @ Plimmerton Domain	ASPM	N/A[1]	B	Maintain	Improve	Improve	✓
Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.	ASPM	N/A[1]	B	Maintain	Improve	Improve	✓

↑ Provisions (between BAU and Improved)

[1] Baseline state unknown. Assumed that the TAS represents an improvement based on part-FMU default TAS.

5 Conclusions

The results of this assessment suggest that the proposed provisions of PC1 require outcomes and actions that are likely to achieve most (~90%) of the TAoP TASs and coastal objectives. However, there are several that are unlikely to be met through the proposed provisions alone. In most cases, the 'gap' between the outcome of the proposed provisions and the TAS/coastal objective can be filled through non-regulatory actions like those assumed under the middle of the road CMP (Improved) scenario (e.g., excluding stock and planting five metre riparian buffers on all second order streams on low slope pastoral land).

Nonetheless, a small number of TAS and coastal objectives may not be met unless action planning includes greater non-regulatory actions than those described above, such as as the retirement of all high erosion risk land (as defined in PC1) or even mitigations that go beyond the assumptions of the most aspirational (Water Sensitive) CMP scenario (Table 38).

Table 38: Description of the TAS and coastal objectives that will either not be met through the provisions alone (2A type attributes) or require an improvement where the proposed provisions are not expected to result in one (2B type attributes). The non-regulatory actions that could potentially fill these 'gaps' are also identified from the CMP scenario assumptions.

<table>
<tr><th>Part-FMU</th><th>Attribute</th><th>Attribute type</th><th>Possible non-regulatory actions to plug 'gap' between provisions and TAS/objective</th></tr>
<tr><td>Pouewe</td><td>Periphyton biomass</td><td rowspan="9"></td><td>Planting of riparian buffers on all second order and above streams on low slope pastoral land.</td></tr>
<tr><td rowspan="2">Taupō</td><td>NO_3-N</td><td rowspan="4">• Planting of riparian buffers on all second order and above streams on low slope pastoral land.; and
• Retirement of all high erosion risk land.</td></tr>
<tr><td rowspan="5">E. coli</td></tr>
<tr><td>Pouewe</td></tr>
<tr><td>Takapū</td></tr>
<tr><td>Wai-o-hata</td><td rowspan="4">• Everything above; and
• Additional mitigations not considered in CMP scenarios or land-use change.</td></tr>
<tr><td>Te Rio o Porirua and Rangituhi</td></tr>
<tr><td>Onepoto Arm</td><td rowspan="2">Enterococci</td></tr>
<tr><td>Pāuatahanui Inlet</td></tr>
<tr><td>Wai-o-hata</td><td>Fish community health</td><td>2B</td><td>• Planting of riparian buffers on all second order and above streams on low slope pastoral land
• Retirement of all high erosion risk land and highest erosion risk land.</td></tr>
</table>

6 References

Auckland Regional Council (ARC), 2004. The Use of Flocculants and Coagulants to Aid the Settlement of Suspended Sediment in Earthworks Runoff : Trials, Methodology and Design (Technical Publication No. No. 227). Auckland Regional Council, Auckland, New Zealand.

Dymond, J.R., Betts, H.D., Schierlitz, C.S., 2010. An erosion model for evaluating regional land-use scenarios. Environ. Model. Softw. 25, 289–298.

Easton, S., Shrestha, M., Cetin, L., Blyth, J., Sands, M., 2019a. Porirua Whaitua Collaborative Modelling Project. Baseline Modelling Technical Report (Jacobs Report No. IZ080700). Jacobs New Zealand Ltd, Wellington, New Zealand.

Easton, S., Shrestha, M., Cetin, L., Sands, M., 2019b. Porirua Whaitua Collaborative Modelling Project. Scenario Modelling Technical Report (Jacobs Report No. IZ080700). Jacobs New Zealand Ltd, Wellington, New Zealand.

Greater Wellington (GW), 2022. 2021/22 River water quality and ecology monitoring (Greater Wellington Publication). Greater Wellington, Wellington, New Zealand.

Greer, M.J.C., 2023. Assessment of alignment between the regulatory provisions and target attribute states in proposed Plan Change 1 to the Natural Resources Plan – Whaitua Te Whanganui-a-Tara (Torlesse Environmental Report No. 2023–008). Torlesse Environmental Ltd, Christchurch, New Zealand.

Greer, M.J.C., Ausseil, O., Clapcott, J.E., Farrant, S., Heath, M.W., Norton, N., 2022. Whaitua Te Whanganui-a-Tara water quality and ecology scenario assessment (Aquanet Report). Aquanet Consulting Limited, Wellington, New Zealand.

Greer, M.J.C., Blyth, J., Easton, S., Gadd, J., King, B., Nation, T., Oliver, M., Perrie, A., 2023. Technical assessments undertaken to inform the target attribute state framework of proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region (Torlesse Environmental Report No. 2023–006). Torlesse Environmental Ltd, Christchurch, New Zealand.

He, J., Chu, A., Ryan, M.C., Valeo, C., Zaitlin, B., 2011. Abiotic influences on dissolved oxygen in a riverine environment. Ecol. Eng. 37, 1804–1814.

Leersnyder, H., Parsonson, M., Bunting, K., Stewart, C., 2021. Erosion and sediment control guide for land disturbing activities in the Wellington Region (Greater Wellington Publication). Greater Wellington, Wellington, New Zealand.

Miller, S., King, B., 2018a. Key messages from scenario modelling results for E. coli and toxicity attributes (Technical Memorandum). Greater Wellington Regional Council, Wellington, New Zealand.

Miller, S., King, B., 2018b. Key messages for harbour attributes using expert assessment (Technical Memorandum). Greater Wellington Regional Council, Wellington, New Zealand.

Miller, S., King, B., 2018c. Technical Report associated with Te Awarua-o-Porirua Harbour Modelling Results and further quantitative information (Greater Wellington Regional Council Publication). Wellington, New Zealand.

Miller, S., King, B., 2018d. Key messages from scenario assessments for periphyton, macroinvertebrates and native fish (Technical Memorandum). Greater Wellington Regional Council, Wellington, New Zealand.

Moores, J., Easton, S., Gadd, J., Sands, M., 2017. Te Awarua-o-Porirua Collaborative Modelling Project: Customisation of urban contaminant load model and estimation of contaminant loads from sources excluded from the core models (NIWA Client Report No. 2017050AK). NIWA, Auckland, New Zealand.

Oldman, J., 2019. Porirua Harbour - Modelling for Whaitua Collaborative Modelling Group (DHI Report No. Report 44800943/01). DHI, Auckland, New Zealand.

Phillips, C.J., Basher, L., Spiekermann, R., 2020. Biophysical performance of erosion and sediment control techniques in New Zealand: a review (Contract Report No. LC3761). Manaaki Whenua – Landcare Research.

Semadenis-Davies, A., Haddadchi, A., Booker, D.J., 2020. Modelling the impacts of the Draft Stock Exclusion Section 360 Regulations on river water quality: E. coli and Sediment (NIWA Client Report No. 2020052AK). NIWA, Auckland, New Zealand.

Semadenis-Davies, A., Kachhara, A., 2017. Te Awarua-o-Porirua (TAoP) Collaborative Modelling Project: CLUES modelling of rural contaminants (NIWA Client Report No. 2017189AK). NIWA, Auckland, New Zealand.

Appendices

Appendix A – Attribute state tables

Table 1: Attribute states for dissolved copper (toxicity) developed by GW.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved Copper (Toxicity)**		
Attribute Unit	µg DCu/L (micrograms of dissolved Copper per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95th percentile**	
A	≤1	≤1.4	99% species protection level: No observed effect on any species tested
B	>1 and ≤1.4	>1.4 and ≤1.8	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
C	>1.4 and ≤2.5	>1.8 and ≤4.3	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
D	>2.5	>4.3	Starts approaching acute impact level (i.e., risk of death) for sensitive species

Table 2: Attribute states for dissolved zinc (toxicity) developed by GW.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved Zinc (Toxicity)**		
Attribute Unit	µg DZn/L (micrograms of dissolved Zinc per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95th percentile**	
A	≤2.4	≤8	99% species protection level: No observed effect on any species tested
B	>2.4 and ≤8	>8 and ≤15	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
C	>8 and ≤31	>15 and ≤42	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
D	>31	>42	Starts approaching acute impact level (i.e., risk of death) for sensitive species

Values for this metal should be expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a standard hardness for ANZG 2018 guidelines of 30 mg CaCO3/L. Criteria values for other hardness may be calculated as per the equation presented in the ANZG 2018 guidelines.

Table 3: Attribute states for ammonia (toxicity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Ammonia (Toxicity)**		
Attribute Unit	mg NH_4-N/L (milligrams ammoniacal-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	**Annual 95th percentile**	
A	≤0.03	≤0.05	99% species protection level. No observed effect on any species.
B	>0.03 and ≤0.24	>0.05 and ≤0.40	95% species protection level. Starts impacting occasionally on the 5% most sensitive species.
National Bottom Line	**0.24**	**0.4**	
C	>0.24 and ≤1.30	>0.40 and ≤2.020	80% species protection level. Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).
D	>1.30	>2.20	Starts approaching acute impact level (i.e., risk of death) for sensitive species.

Numeric attribute state is based on pH 8 and temperature of 20°C. Compliance with the numeric attribute states should be undertaken after pH adjustment.

Table 4: Attribute states for nitrate (toxicity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Nitrate (Toxicity)**		
Attribute Unit	mg NO_3-N/L (milligrams nitrate-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	**Annual 95th Percentile**	
A	≤1.0	≤1.5	High conservation value system. Unlikely to be effects even on sensitive species.
B	>1.0 and ≤2.4	>1.5 and ≤3.5	Some growth effect on up to 5% of species.
National Bottom Line	**2.4**	**3.5**	
C	>2.4 and ≤6.9	>3.5 and ≤9.8	Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.
D	>6.9	>9.8	Impacts on growth of multiple species, and starts approaching acute impact level (i.e., risk of death) for sensitive species at higher concentrations (> 20 mg/l).

Note: This attribute measures the toxic effect of nitrate, not the trophic state. Where other attributes measure trophic state, for example periphyton, freshwater objectives, limits and/or methods for those attributes will be more stringent.

Table 5: Attribute states for suspended fine sediment (visual clarity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health				
Freshwater Body Type	Rivers				
Attribute	**Suspended fine sediment**				
Attribute Unit	Visual clarity (metres)				
Attribute State	**Numeric Attribute state by suspended sediment class**				**Narrative Attribute State**
	Median				
	1	**2**	**3**	**4**	
A	≥1.78	≥0.93	≥2.95	≥1.38	Minimal impact of suspended sediment on instream biota. Ecological communities are similar to those observed in natural reference conditions.
B	<1.78 and ≥1.55	<0.93 and ≥0.76	<2.95 and ≥2.57	<1.38 and ≥1.17	Low to moderate impact of suspended sediment on instream biota. Abundance of sensitive fish species may be reduced.
C	<1.55 and >1.34	<0.76 and >0.61	<2.57 and >2.22	<1.17 and >0.98	Moderate to high impact of suspended sediment on instream biota. Sensitive fish species may be lost
National Bottom Line	**1.34**	**0.61**	**2.22**	**0.98**	
D	<1.34	<0.61	<2.22	<0.98	High impact of suspended sediment on instream biota. Ecological communities are significantly altered, and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.

Based on a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years.

Councils may monitor turbidity and convert the measures to visual clarity.

See Appendix 2C Tables 23 and 26 for the definition of suspended sediment classes and their composition.

The following are examples of naturally occurring processes relevant for suspended sediment:

- naturally highly coloured brown-water streams
- glacial flour affected streams and rivers
- selected lake-fed REC classes (particularly warm climate classes) where low visual clarity may reflect autochthonous phytoplankton production

Table 6: Attribute states for *E. coli* taken from Appendix 2A of the NPS-FM 2020.

Value	Human health for recreation				
Freshwater Body Type	Lakes and rivers				
Attribute	***E. coli***				
Attribute Unit	*E. coli* / 100ml (number of *E. coli* per hundred millilitres)				
Attribute State	**Numeric Attribute State**				**Narrative Attribute State**
	% exceedances over 540 cfu/100ml	**% exceedances over 260 cfu/100ml**	**Median concentration (cfu/100ml)**	**95th percentile of *E. coli* /100ml**	**Description of risk of *Campylobacter* infection (based on *E. coli* indicator)**
A (blue)	<5%	<20%	<130	<540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 1% .
B (green)	5-10%	20-30%	<130	<1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 2%.
C (yellow)	10-20%	20-34%	<130	<1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 3% *.
D (orange)	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is >50 in 1000 (>5% risk). The predicted average infection risk is >3%.
E (red)	>30%	>50%	>260	>1200	For more than 30% of the time the estimated risk is >50 in 1000 (>5% risk). The predicted average infection risk is >7%.

Based on a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years.

Table 7: Attribute states for periphyton (trophic state) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Periphyton (Trophic state)**		
Attribute Unit	mg chl-a/m^2 (milligrams chlorophyll-a per square metre)		
Attribute State	**Numeric Attribute State (Default Class)**	**Numeric Attribute State (Productive Class[1])**	**Narrative Attribute State**
	Exceeded no more than 8% of samples[2]	**Exceeded no more than 17% of samples[2]**	
A	≤50	≤50	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat
B	>50 and ≤120	>50 and ≤120	Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat
C	>120 and ≤200	>120 and ≤200	Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat
National Bottom Line	**200**	**200**	
D	>200	>200	Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat

At low risk sites monitoring may be conducted using visual estimates of periphyton cover. Should monitoring based on visual cover estimates indicate that a site is approaching the relevant periphyton abundance threshold, monitoring should then be upgraded to include measurement of chlorophyll-a.

Classes are streams and rivers defined according to types in the River Environment Classification (REC). The Productive periphyton class is defined by the combination of REC "Dry" Climate categories (that is, Warm-Dry (WD) and Cool-Dry (CD)) and REC Geology categories that have naturally high levels of nutrient enrichment due to their catchment geology (that is, Soft-Sedimentary (SS), Volcanic Acidic (VA) and Volcanic Basic (VB)). Therefore, the productive category is defined by the following REC defined types: WD/SS, WD/VB, WD/VA, CD/SS, CD/VB, CD/VA. The Default class includes all REC types not in the Productive class.

Based on a monthly monitoring regime. The minimum record length for grading a site based on periphyton (chlorophyll-a) is 3 years.

Table 8: Attribute states for the Fish index of Biotic Integrity taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	**Fish (rivers)**	
Attribute Unit	Fish Index of Biotic Integrity (F-IBI)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
A	≥34	High integrity of fish community. Habitat and migratory access have minimal degradation.
B	<34 and ≥28	Moderate integrity of fish community. Habitat and/or migratory access are reduced and show some signs of stress.
C	<28 and ≥18	Low integrity of fish community. Habitat and/or migratory access is considerably impairing and stressing the community
D	<18	Severe loss of fish community integrity. There is substantial loss of habitat and/or migratory access, causing a high level of stress on the community.

Sampling is to occur at least annually between December and April (inclusive) following the protocols for at least one of the backpack electrofishing method, spotlighting method, or trapping method in Joy M, David B, and Lake M. 2013. New Zealand Freshwater Fish Sampling Protocols (Part 1): Wadeable rivers and streams. Massey University: Palmerston North, New Zealand. (See clause 1.8)

The F-IBI score is to be calculated using the general method defined by Joy, MK, and Death RG. 2004. Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. Environmental Management, 34(3), 415-428 (see clause 1.8).

Table 9: Attribute states for the Macroinvertebrate Community Index score and Quantitative Macroinvertebrate Community Index score taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Macroinvertebrates (1 of 2)**		
Attribute Unit	Macroinvertebrate Community Index (MCI) score and Quantitative Macroinvertebrate Community Index (QMCI) score		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	QMCI	**MCI**	
A	≥6.5	≥130	Macroinvertebrate community, indicative of pristine conditions with almost no organic pollution or nutrient enrichment
B	≥5.5 and <6.5	≥110 and <130	Macroinvertebrate community indicative of mild organic pollution or nutrient enrichment. Largely composed of taxa sensitive to organic pollution/nutrient enrichment.
C	≥4.5 and <5.5	≥90 and <110	Macroinvertebrate community indicative of moderate organic pollution or nutrient enrichment. There is a mix of taxa sensitive and insensitive to organic pollution/nutrient enrichment.
National Bottom Line	**4.5**	**90**	
D	<4.5	<90	Macroinvertebrate community indicative of severe organic pollution or nutrient enrichment. Communities are largely composed of taxa insensitive to inorganic pollution/nutrient enrichment.

MCI and QMCI scores to be determined using annual samples taken between 1 November and 30 April with either fixed counts with at least 200 individuals, or full counts, and with current state calculated as the five-year median score. All sites for which the deposited sediment attribute does not apply, whether because they are in river environment classes shown in Table 25 in Appendix 2C or because they require alternate habitat monitoring under clause 3.25 are to use soft sediment sensitivity scores and taxonomic resolution as defined in table A1.1 in Clapcott *et al.* 2017 Macroinvertebrate metrics for the National Policy Statement for Freshwater Management. Cawthron Institute: Nelson, New Zealand (see clause 1.8).

MCI and QMCI to be assessed using the method defined in Stark JD, and Maxted, JR. 2007 A user guide for the Macroinvertebrate Community Index. Cawthron Institute: Nelson, New Zealand (See Clause 1.8), except for sites for which the deposited sediment attribute does not apply, which require use of the soft-sediment sensitivity scores and taxonomic resolution defined in table A1.1 in Clapcott *et al.* 2017 Macroinvertebrate metrics for the National Policy Statement for Freshwater Management. Cawthron Institute: Nelson, New Zealand (see clause 1.8).

Table 10: Attribute states for the Macroinvertebrate Average Score Per Metric taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	**Macroinvertebrates (2 of 2)**	
Attribute Unit	Macroinvertebrate Average Score Per Metric (ASPM)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
A	≥0.6	Macroinvertebrate communities have high ecological integrity, similar to that expected in reference conditions.
B	<0.6 and ≥0.4	Macroinvertebrate communities have mild-to-moderate loss of ecological integrity.
C	<0.4 and ≥0.3	Macroinvertebrate communities have moderate-to severe loss of ecological integrity.
National Bottom Line	**0.3**	
D	<0.3	Macroinvertebrate communities have severe loss of ecological integrity.

Sampling is to occur at least annually between December and April (inclusive) following the protocols for at least one of the backpack electrofishing method, spotlighting method, or trapping method in Joy M, David B, and Lake M. 2013. New Zealand Freshwater Fish Sampling Protocols (Part 1): Wadeable rivers and streams. Massey University: Palmerston North, New Zealand. (see clause 1.8)

The F-IBI score is to be calculated using the general method defined by Joy, MK, and Death RG. 2004. Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. Environmental Management, 34(3), 415-428. (see clause 1.8)

Table 11: Attribute states for dissolved reactive phosphorus taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved reactive phosphorus**		
Attribute Unit	mg DRP/L (milligrams dissolved inorganic nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95th percentile**	
A	≤0.006	≤0.021	Ecological communities and ecosystem processes are similar to those of natural reference conditions. No adverse effects attributable to DRP enrichment are expected.
B	>0.006 and ≤0.010	>0.021 and ≤0.030	Ecological communities are slightly impacted by minor DRP elevation above natural reference conditions. If other conditions also favour eutrophication, sensitive ecosystems may experience additional algal and plant growth, loss of sensitive macroinvertebrate taxa, and higher respiration and decay rates.
C	>0.010 and ≤0.018	>0.030 and ≤0.054	Ecological communities are impacted by moderate DRP elevation above natural reference conditions, but sensitive species are not experiencing nitrate toxicity. If other conditions also favour eutrophication, DRP enrichment may cause increased algal and plant growth, loss of sensitive macroinvertebrate & fish taxa, and high rates of respiration and decay.
D	>0.018	>0.054	Ecological communities impacted by substantial DRP elevation above natural reference conditions. In combination with other conditions favouring eutrophication, DIN enrichment drives excessive primary production and significant changes in macroinvertebrate and fish communities, as taxa sensitive to hypoxia are lost

Numeric attribute state must be derived from the rolling median of monthly monitoring over five years.

Table 12: Attribute states for dissolved oxygen taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved oxygen**		
Attribute Unit	mg/L (milligrams per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	7-day mean minimum	**1-day minimum**	
A	≥8.0	≥7.5	No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near pristine) sites.
B	≥7.0 and <8.0	≥5.0 and <7.5	Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.
C	≥5.0 and <7.0	≥4.0 and <5.0	Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.
National Bottom Line	**5.0**	**4.0**	
D	<5.0	<4.0	Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.

The 7-day mean minimum is the mean value of 7 consecutive daily minimum values.

The 1-day minimum is the lowest daily minimum across the summer period (1 November to 30 April).

Appendix B – Detailed CMP scenario assumptions

BAU scenario

- No storm water capture or treatment.
- Greenfield, infill and rural residential development is located within Wellington City and Porirua City councils identified development zones. The number of additional dwellings represents what would be required to accommodate residential population growth to 2043 with current development practice (i.e., density and development form) .
- Assumed new development form for new dwellings:
  - Within existing residential zones:
    - Wellington City = 43% urban grassland and parks, 15% roads, 17% paved, 25% roofs.
    - Porirua City = 51% urban grassland and parks, 19% paved, 29% roofs (road area modelled).
  - In greenfield development zones = 36% urban grassland and parks, 20% roads, 14% paved, 30% roofs.
- Standalone houses and greenfield development replace forest and pasture covers, while terrace style housing replaces urban grass and parks and residential impervious covers.
- 275 hectares in the headwaters of the Kenepuru Stream and Duck Creek retired as an offset for the Transmission Gully motorway project (applies to all scenarios).
- Transmission Gully and Petone to Grenada are operational (applies to all scenarios).
- Sediment control applied to all construction sites, with a 90% effectiveness for removal of generated sediment, metals (dissolved and particulate zinc and copper), and nutrients (nitrogen and phosphorus and sub-species).
- Wastewater network condition does not change, and additional dwellings and population does not increase the wastewater overflows.

Improved scenario

- Numbers of additional dwellings the same as under BAU but for greenfield and infill sites there is an increased proportion of urban greenspace, and a corresponding decrease in impervious surfaces. Greenfield development zones = 37% urban grassland and parks, 20% roads, 12% paved, 30% roofs
- Rain tanks fitted to 50% of new greenfield and infill dwellings to reduce total flow from these by 4.7% and 1.9% respectively.
- A mixture of site and catchment scale stormwater retention devices fitted to catch and treat runoff from impervious surfaces of residential developments. These treatment trains result in the following (approximate) reductions in contaminate yields and flow from impervious surfaces:
  - Suspended sediment, 80%
  - Total and dissolved zinc, 70%
  - Total and dissolved copper, 70%
  - Total nitrogen, 40%
  - Total phosphorus, 50%
  - *E. coli*, 90%
  - Total flow, 6% (includes benefits of rain tanks).
- Rain tanks retrofitted to 10% existing residential roofs to reduce total flow from these by 1%.

- 50% of runoff from existing commercial and industrial paved surfaces and major roads receives media filter treatment. These result in the following weighted (approximate) reductions for these surfaces:
  - Suspended sediment, 40%.
  - Total and dissolved zinc and copper, 25%.
  - Total nitrogen and phosphorus, 20%.
  - *E. coli*, 40%.
- 50% of commercial and industrial roofs and existing residential roofs are replaced/treated with low zinc yielding materials.
- Sediment control applied to all construction sites, with a 90% effectiveness for removal of generated sediment, metals, and nutrients.
- Wastewater network condition is significantly improved to remove dry weather leaks and remove overflows in all but the four largest rainfalls each year.
- Livestock exclusion is undertaken on all REC order 2 or greater streams with grassland land cover and catchment slope less than 15 degrees. All areas of exclusion receive five meters of riparian planting. These result in weighted reduction factors for runoff from pastoral lands of:
  - Total and dissolved phosphorus, 50%;
  - *E. coli*, 44%; and
  - Streambank erosion component of suspended sediment, 80%.
- Space/pole planting of Land Use Capability (LUC) class 6e land with grassland land cover. Poles assumed to have reached maturity and act to reduce hillslope erosion sediment yields and particulate phosphorus yields by 70%.
- Retirement of LUC class 7e and 8e land with grassland land cover. Assumed this land reverts to native cover and adopts the relevant contaminant and flow generation characteristics. Streams within these areas are assumed to receive livestock exclusion through the retirement.

Water Sensitive scenario

- Numbers of additional dwellings and land cover replacement for are the same as for BAU. However, the development form changes to have less paved surfaces and greater urban grassland and parks.
  - Greenfield development zones = 54% urban grassland and parks, 20% roads, 6% paved, 20% roofs.
  - Within existing residential zones:
    - Wellington City = 48% urban grassland and parks, 15% roads, 11% paved, 25% roofs.
    - Porirua City = 57% urban grassland and parks, 13% paved, 29% roofs (road area modelled).
- Rain tanks fitted to 100% of new greenfield and infill dwellings to reduce total flow from these by 25.2 % and 22.3% respectively.
- A mixture of site and catchment scale stormwater retention devices are fitted to catch and treat runoff from greater areas of impervious surfaces of residential developments than under Improved. Load reduction factors are largely the same as in the Improved scenario, but greater use and size of rain tanks reduces total flow by around 37% and shift the frequency of 'channel forming flows and cumulative frequency distribution towards a pre-development state.
- Rain tanks retrofitted to 50% existing residential roofs reduce total flow from these by 30%.
- 100% of runoff from commercial and industrial paved surfaces and major roads receives different types of runoff treatment. These result in the following weighted (approximate) reductions for these surfaces:

    - Suspended sediment, 75-90%;
    - Total and dissolved zinc and copper, 50-80%;
    - Total nitrogen and phosphorus, 40-60%; and
    - *E. coli*, 90%.
- 100% of existing commercial and industrial roofs and existing residential roofs are replaced/treated with low zinc yielding materials.
- Sediment control is applied to all construction sites, with a 90% effectiveness for removal of generated sediment, metals, and nutrients.
- The wastewater network condition is significantly improved to remove dry weather leaks remove overflows in all but the two largest rainfalls each year.
- As for Improved, livestock exclusion and riparian planting (five meters) is undertaken on all REC order 2 or greater streams with grassland land cover and catchment slope less than 15 degrees.
- Retirement of LUC classes 6e, 7e and 8e land with grassland land cover.

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Technical assessments undertaken to inform the target attribute state framework of proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region

Report No. 2023-006

TORLESSE ENVIRONMENTAL LTD

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Prepared for: Greater Wellington
Report No. 2023-006
Date: 10/10/2023

Quality Assurance (Report Status: Final)			
Role	**Responsibility**	**Date**	**Signature**
Prepared by Approved for issue by:	Michael Greer	10/10/2023	[signature]
Reviewed by	Duncan Gray	26/09/2023	[signature]

RECOMMENDED CITATION: Greer, M.J.C., Blyth, J., Eason, S., Gadd, J., King, B., Nation, T., Oliver, M., Perrie, A. 2023. Technical assessments undertaken to inform the target attribute state framework of proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region. Torlesse Environmental Limited, Christchurch, New Zealand.

Glossary

Term	Meaning
BSP	Biophysical Science Programme (for Whaitua Te Whanganui-a-Tara)
CFU	Colony Forming Unit
CMP	Collaborative Modelling Programme
Cu	Copper
DFS	Deposited fine sediment
DGV	Default Guideline Value from the Australian and New Zealand guidelines for fresh and marine water quality
DIN	Dissolved inorganic nitrogen
DRP	Dissolved reactive Phosphorus
E. coli	*Escherichia coli*
EQR	Ecological Quality Rating (for macroalgae)
GW	Greater Wellington
LakeSPI	Lake Submerged Plant Indicators
NH_4-N	Ammoniacal – nitrogen
NRP	Natural Resources Plan (for the Wellington Region)
NPS-FM	National Policy Statement for Freshwater Management
NO_3-N	Nitrate – nitrogen
NOF	The National Objectives Framework
NOs	Nutrient outcomes (as defined in Clause 3.13 of the NPS-FM 2020)
Part-FMU	Part Freshwater Management Unit
PC1	Plan Change 1 (to the Natural Resources Plan)
REC	River Environment Classification
SFS	Suspended Fine Sediment (as measured by visual clarity)
TAG	Technical Advisory Group
TAoP	Te Awarua-o-Porirua
TAS	Target attribute state
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
Whaitua	Whaitua is the Māori word for catchment or space. The Wellington Region is divided into five whaitua, which will eventually each have a Whaitua Committee responsible for them.
WMU	Water Management Unit (used in TAoP WIP)
WTWT	Whaitua Te Whanganui-a-Tara
WIP	Whaitua Implementation Programme
Zn	Zinc

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Appendices

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1 Introduction

1.1 Background and report objectives

Plan Change 1 (PC1) to the Natural Resources Plan (NRP) for the Wellington Region will implement the National Policy Statement for Freshwater Management (NPS-FM) 2020 for Te Awarua-o-Porirua (TAoP) Whaitua and Whaitua Te Whanganui-a-Tara (WTWT). This involves setting objectives, policies, rules and other methods to manage activities such as urban development, earthworks, stormwater, wastewater and rural land use. Accordingly, PC1 will:

- Define Target Attribute States ('TASs') for the compulsory attributes in Appendix 2 of the NPS-FM 2020;
- Set equivalent coastal water quality and ecology objectives ('coastal objectives'); and
- Establish provisions that will contribute to the achievement of those TASs and coastal objectives.

The TASs and coastal objectives in PC1 will be based on those published by WTWT and TAoP Whaitua Committees ('the Committees) in their Whaitua Implementation Programmes ('WIPs'). However, a Technical Advisory Group[1] ('TAG') and other experts commissioned by Greater Wellington (GW) to provide specific pieces of advice have recommended that the WIP approach be refined prior to being adopted in PC1 to ensure robustness and consistency with current national policy. The purpose of this report is to document the technical assessments that informed those recommended refinements to ensure transparency in the PC1 TAS and coastal objective setting process (as required by Clause 3.6 of the NPS-FM 2020).

1.2 Structure of report

This report collates the technical memoranda provided to GW by internal and external technical experts during the PC1 TAS development process. In Part 1 the purpose and conclusions of each of these memoranda are:

- Summarised; and
- Incorporated into a set of recommended TASs and coastal objective tables for WTWT and TAoP Whaitua.

The bodies of each of these memoranda are then reproduced in Part 2 (Section 3 to Section 13) and their supplementary material provided in Appendix A to J.

Note – In general, only those minor formatting and editorial changes necessary to ensure consistency in appearance and terminology have been made to the memoranda in Part 2. However, the lead author of this report (Dr Michael Greer) has made new additions to some memoranda to account for relevant technical advice or policy changes that has arisen after their publication. These additions have been made at the end of the relevant memorandum in new, clearly labelled, sub-sections.

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1 Membership = Mr Ned Norton (Land Water People Ltd), Mr James Blyth (Taylor Collaborations Ltd), Mr Brent King (GW) and Dr Michael Greer (Torlesse Environmental Ltd).

1.3 Scope and limitations

- The specific matters covered in this report are:
  - The part Freshwater Management Units (part-FMUs) and sites for which TASs and coastal objectives should be set;
  - How baseline states, TASs and nutrient outcomes should be set to ensure consistency with both the *intent* of the WIPs and the requirements of the NPS-FM 2020;
  - The sediment load reductions needed to meet the suspended fine sediment (SFS; as measured by visual clarity) TASs and the coastal objectives for sedimentation rate (TAoP only);
  - The need for a conservative approach to managing heavy metal losses in the TAoP whaitua; and
  - The alignment between existing water quality standards/objectives in the NRP and the TASs.
- This report does not cover the full range of topics that GW will need to produce expert evidence on during the PC1 hearing process. Rather it is intended to inform the PC1 S32 report, and, in tandem with Greer (2023a, 2023b), transparently document the technical work that has been completed since the WTWT and TAoP WIPs were published. Consequently, detailed introductions to the freshwater and coastal environments in TAoP and WTWT, the NPS-FM 2020 and the NRP are not provided.
- The recommendations made in this report were made by technical experts based on the best available information. However, whether they are adopted in PC1 is ultimately a policy decision to be made by GW.

Part 1 – Synthesis of technical work conducted during the development of PC1

At the beginning of the PC1 development process Aquanet Consulting Ltd (now Traverse Environmental Ltd) conducted a detailed review of the TAoP and WTWT WIPs and associated technical reports. This review identified a number of issues with the approach to setting the WIP targets and objectives that need to be addressed in order to ensure that PC1's TASs and coastal objectives are robust, defensible and measurable. Each of these identified issues, and how they have been addressed, are summarised in Section 2.1 to Section 2.9.

2 Summary of technical issues identified with WIP approach and the recommended approach for resolving them

2.1 Issue 1: The TAoP and WTWT WIPs do not set TASs at the site scale as required by the NPS-FM 2020 (full detail in Section 3)

The WTWT and TAoP WIPs split those whaitua into different 'management zones'[2] and set TASs that apply across the entirety of those management zones (i.e., all rivers must meet the TAS). In contrast, the NPS-FM 2020 requires regional councils to "*identify the site or sites to which the TASs target attribute state applies*". To address this difference in approach, GW commissioned Collaborations (Taylor Collaborations Ltd) to define a TASs site list based on the existing monitoring network that captures the variability between the WIP TASs without imposing arduous and redundant monitoring restrictions on GW (i.e., by requiring monitoring at multiple sites with similar current states, catchment characteristics and future mitigations).

The TASs site list developed by Collaborations was then used to further refine the management zones in the WIPs into part-FMUs for inclusion in PC1. The philosophy behind this refinement process was:

- Each part-FMU ideally has a single TAS site;
- The management units recommended in the WIPs are an appropriate starting point for selecting part-FMUs; and
- The list of TAS sites recommended by Collaborations provides an appropriate indication of where TASs need to be set to detect the impact of practice change on water quality and ecology across the TAoP Whaitua and WTWT. As such, overlaying that list of sites with the management units in the WIPs is an appropriate method of identifying where those management units need to be refined.

The recommended PC1 part-FMU and TAS site framework developed through this process is set out in Table 1.

[2] Referred to as Water Management Units (WMUs) in the TAoP WIP and Sub-catchment areas in the WTWT WIP.

Table 1: Recommended part-FMUs and TASs sites for TAoP Whaitua and WTWT.

Whaitua	Catchment	Recommended part-FMUs	Recommended TAS site
TWT	Te Awa Kairangi, Ōrongorongo and Wainuiomata	Te Awa Kairangi and Wainuiomata small forested, Te Awa Kairangi forested mainstems and Ōrongorongo	Whakatikei R. @ Riverstone
		Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott
		Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua
		Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.
		Waiwhetū Stream	Waiwhetū S. @ Whites Line E.
		Wainuiomata urban streams	Black Ck @ Rowe Parade end
		Wainuiomata rural streams	Wainuiomata R. DS of White Br.
	South-west coast, Mākara and Ōhariu catchment and Parangārehu Lakes	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels
	Korokoro catchment	Korokoro Stream	Korokoro S.@ Cornish St. Br.
	Wellington urban catchment	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge
		Wellington urban	Karori S. @ Mākara Peak
TOaP		Taupō	Taupō S. @ Plimmerton Domain
		Pouewe	Horokiri S. @ Snodgrass
		Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.
		Takapū	Pāuatahanui S. @ Elmwood Br.
		Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot

2.2 Issue 2: The TAoP WIP does not include TASs for the compulsory attributes introduced in the NPS-FM 2020 and the WTWT targets for many of those attributes were set based on limited data (full detail in Section 4)

The 2020 version of the NPS-FM introduced several attributes that were either not monitored by GW until recently and/or were not included in the TAoP or WTWT WIPs. The NPS-FM 2020 does not allow local authorities to "*delay making decisions solely because of uncertainty about the quality or quantity of the information available*". Thus, it is not an option to simply ignore these attributes in PC1. Instead, the following approach is recommended for setting baseline states and TASs (reviewed and agreed to by the TAG):

- General approach for river attributes considered in the WIPs (WTWT and TAoP):
    - Do not set baseline states where monitoring and modelling data are demonstrably inadequate to do so, instead simply acknowledge that there are "*insufficient data*";
    - Adopt all WIP TASs where except where they:
        - Do not meet the relevant NPS-FM National Bottom Line (NBL); or
        - Are below the baseline state,

      in which case set the TAS at the better of the NBL or baseline state.

      Note – The decision to include all TASs set out in the WIPs regardless of whether they are informed by monitoring or modelling data was made late in the PC1 development process. Thus, it is not captured in Torlesse's recommendations to the TAG in Section 4.

  - Include a new Fish Community Health attribute without baseline states and TASs set at the same band as those for Macroinvertebrate Community Index and Quantitative Macroinvertebrate Community Index (Q/MCI); and
  - Do not define baseline state for ecosystem metabolism and set a narrative TAS that ensures the attribute is at least maintained.
- Approach for river attributes not considered in the TAoP WIP:
  - Suspended fine sediment (SFS):
    - Set baseline states from:
      - Monitoring data; or
      - The results of the sediment concentration modelling conducted as part of the TAoP Collaborative Modelling Project (CMP) (Easton *et al.*, 2019b) and the regional sediment-clarity relationships developed by Collaborations (see Sections 2.6 and 9 below); and
    - Set TASs at the better of baseline state or the NBL.

      Note – The decision to use modelling data from the TAoP CMP as 'the best available' source of baseline data when monitoring data are not available was made late in the PC1 development process. Thus, it is not captured in Torlesse's recommendations to the TAG in Section 4.

  - Deposited fine sediment (DFS):
    - Set baseline states based on monitoring data where available; and
    - Set TASs at the better of baseline state or NBL.
  - Macroinvertebrate average score per metric (ASPM):
    - Set baseline states based on monitoring data where available; and
    - Set TASs at same level as Q/MCI.
  - Fish Index of Biotic Integrity (F-IBI) and dissolved oxygen (DO):
    - Do not set baseline states given lack of monitoring data; and
      Set a narrative TAS that ensures the attribute is at least maintained.

      Note – This differs from the recommended approached accepted by the TAG as the monitoring data required to set baseline states has not been collected.

  - Dissolved reactive phosphorus (DRP):
    - Set baseline state based on monitoring data or the results of the water quality modelling conducted as part of the TAoP CMP (Easton *et al.*, 2019b); and
    - Set TASs for the 95th percentile concentration at the baseline state and set a separate TAS for the median concentrations that reflects recommended nutrient outcomes (NOs) developed in accordance with Clause 3.13 of the NPS-FM 2020 and the associated national guidance (see Section 2.4).
- General approach for lake attributes in WTWT:
  - For attributes with existing monitoring data:

- Set baseline states based on all available data regardless of whether they meet the requirements of the NPS-FM 2020 and/or were collected outside of the NPS-FM 2020 prescribed baseline period.
- Adopt all WIP TAS where available except where they are below the baseline state, in which case set the TAS at the better of the NBL or baseline state.

  Notes:
  - *The decision to include all TASs set out in the WIPs regardless of whether they are informed by monitoring or modelling data was made late in the PC1 development process. Thus, it is not captured in Section 4 or Section 7; similarly.*
  - *The decision to set baseline states for lakes off limited data collected outside of the NPS-FM 2020 prescribed baseline period was made after the memorandum reproduced in Section 7 was published. This approach was considered justified as the alternative was to have a lakes TAS table in PC1 without any baseline states other than for submerged plants (natives and invasive species).*

- Lake bottom dissolved oxygen:
  - Do not set baseline states given lack of monitoring data; and
  - Set TASs in accordance with the WTWT WIP.
- Submerged plants (natives and invasive species):
  - Set baseline state based on results of Lake Submerged Plant Indicators (LakeSPI) 2016 surveys; and
  - Set TASs in accordance with the WTWT WIP except where that would allow a degradation from baseline state.

2.3 Issue 3: The WIPs do not explicitly set TASs for the habitat component of the NPS-FM 2020 compulsory value of ecosystem health (full detail in Section 5)

The NPS-FM 2020 identifies habitat as one of the five biophysical components of ecosystem health and notes that it is necessary for regional councils to manage and treat it as a value. Neither the WTWT nor TAoP WIPs includes specific habitat attribute TASs. To determine whether this is an issue that GW needs to address in PC1, Torlesse reviewed the relevant literature to identify whether:

- The existing compulsory attributes in the NPS-FM 2020 manage habitat;
- There are multi-metric habitat attributes that targets could be set for habitat; and
- There are individual habitat attributes that targets could be set for habitat.

Upon receiving that review the TAG agreed that it was not necessary to set specific TASs for habitat in PC1 as:

- Meeting the targets for existing compulsory attributes will:
  - Manage some key components of habitat; and
  - Require habitat be managed to achieve ecological outcomes.

- The existing multimeric habitat metrics are generally not fit for this purpose; and
- A lack of relevant guideline values means that attribute state thresholds cannot be defined for most of the individual habitat metrics that are not currently included in Appendix 2 of the NPS-FM 2020.

2.4 Issue 4: The WIPs do not set nutrient outcomes in accordance with clause 3.13 of the NPS-FM 2020 (full detail in Section 6)

The NPS-FM 2020 requires regional councils to:

- Set appropriate instream concentrations and exceedance criteria, or instream loads, for nitrogen and phosphorus (nutrient outcomes (NOs)).
- Identify limits on resource use that will achieve any NOs.

Unfortunately:

- The NOs in the TAoP WIP were developed prior to the release of the NPS-FM 2020 and are no longer relevant; and
- The WTWT WIP is silent on NOs.

Consequently, it was necessary for GW to define the NOs in PC1 in isolation from the WIPs. To that end, Torlesse used the available national guidance from MfE (2022a, 2022b) to identify median dissolved inorganic nitrogen (DIN) and DRP concentrations that can be used as NOs for the TAoP Whaitua and WTWT (see Table 2). Specifically, these median concentrations were identified by:

1. Selecting periphyton biomass thresholds (based on the WIP TASs) and under-protection risk thresholds (based on the guidance in MfE (2022b));
2. Obtaining NOs from updated versions of the tables in Snelder *et al.*'s (2022)[3];
3. Assessing confidence in the NOs through the approach specified in MfE (2022b); and
4. Applying the NOs or one of the following alternative criteria (where appropriate; see footnotes to Table 2 for further detail):
    a. The baseline concentration where lower than the NOs;
    b. The WIP target states for nitrate (NO_3-N) toxicity or DRP where lower than the NOs;
    c. The saturation concentrations for periphyton where lower than the NOs; and
    d. The relevant reference concentration from McDowall *et al.* (2013) where the identified NOs = 0.

[3] These updates were made in response to validation exercises conducted for several regions revealing the original NC are generally too permissive (see Section 6 and Appendix F).

Table 2: Recommended NOs for TAS sites in WTWT and TAoP Whaitua. Selected from the updates to the Snelder *et al.* (2022) (under-protection risk = 50%) except where alternative criteria are more appropriate (see footnotes).

Whaitua	Part-FMU	Site	Shaded	DIN (mg/L)	DRP (mg/L)
TAoP	Taupō	Taupō S. @ Plimmerton Domain	Y	1.03[a]	0.018[a]
	Pouewe	Horokiri S. @ Snodgrass		0.64[b]	0.014[b]
	Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.		~0.48[b]	0.025
	Takapū	Pāuatahanui S. @ Elmwood Br.		0.33[b]	0.012[b]
	Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot		0.92[b]	0.018[b]
TWT	Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone		0.15[c]	0.006[d]
	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	N	0.20[b]	0.004[b]
	Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	Y	0.44[b]	0.006[e]
	Te Awa Kairangi urban streams	Hulls C. adj. Reynolds Bach Dr.		0.24[b]	0.018[b]
	Waiwhetū Stream	Waiwhetū S. @ Whites Line E.		0.56[b]	0.018[e]
	Wainuiomata urban streams	Black C. @ Rowe Parade end		0.5[b]	0.018[e]
	Wainuiomata rural streams	Wainuiomata R. DS White Br.		0.17[b]	0.011[e]
	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels		0.42[b]	0.018[e]
	Korokoro Stream	Korokoro Stream @ Cornish St. Br.		0.26	0.006[e]
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge		1.03[b]	0.018[e]
	Wellington urban	Karori S. @ Mākara Peak		1.29[b]	0.035[e]

[a] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (River Environment Classification group = WW/L/SS). Sum of NO_3-N and NH_4-N TAS applied as alternative DIN criteria (improvement likely required for both attributes). NPS-FM 2020 attribute state C thresholds applied as alternative DRP thresholds (reflects modelled baseline state).

[b] Snelder *et al.* (2022) nutrient outcome > than current concentrations. Baseline concentrations applied as alternative criteria.

[c] Site in reference condition and nutrient outcome represents an improvement which is unlikely to be possible. Baseline concentrations applied as alternative criteria.

[d] Snelder *et al.* (2022) nutrient outcome = 0. The lesser of McDowall *et al.* (2013) 80th %ile trigger, baseline state or WIP TAS applied as alternative criteria.

[e] Snelder *et al.* (2022) nutrient outcome > than the DRP TAS. TAS applied as alternative criteria.

2.5 Issue 5: The WTWT WIP baseline states for the Parangārehu Lakes are not supported by monitoring data (full detail in Section 7)

The baseline states for lake attributes in the WTWT WIP were based on the best available data at the time and expert opinion (Heath, 2022; Schallenberg, 2019). However, the paucity of lake water quality data at that time means they can only be considered estimates, rather than accurate state assessments. To establish more precise estimates of baseline state, Mr Alton Perrie (Senior Environmental Scientist – GW) analysed all of the available lake monitoring data for the NPS-FM 2020 2A and 2B attributes currently monitored in Lake Kōhangatera and Lake Kōhangapiripiri (all but lake bottom dissolved oxygen). It is recommended that the resulting baselines are incorporated in the TAS tables in PC1 (see Table 7 below).

2.6 Issue 6: The scale of sediment load reductions required to meet the visual clarity TASs are unclear (full detail in Section 9)

The NPS-FM 2020 SFS attribute uses visual clarity rather than a direct measure of suspended sediment concentration. Consequently, the difference between the baseline state and TASs for this attribute does not provide a clear indication of the degree by which sediment losses must be reduced, since the relationship between visual clarity and sediment concentration/load is not linear. To address this issue Collaborations developed site and regional specific relationships between visual clarity and total suspended solid (TSS) concentrations. These relationships were then used to calculate the sediment load reductions required to meet the recommended PC1 SFS TASs through the methods described in Neverman *et al.* (2021) and Hicks *et al.* (2019) (see Table 3).

Table 3: Estimated sediment load reductions required to achieve the SFS TASs for TAoP Whaitua and WTWT. Baseline clarity medians below the target are in bold. *Note – baseline states and load reduction targets have been updated from those originally provided by Collaborations to account for the February 2023 amendments to the NPS-FM 2020 definition of baseline state (i.e., baseline state = median visual clarity on the 7th of September 2017).*

Part-FMU	Target Attribute Site	Baseline clarity median (m)	Clarity target (m)	Baseline dSedNet mean annual TSS load (t/year)	TSS load reduction required to meet clarity target
WTWT TAS					
Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone	4	4	3,189	0%
Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	**1.5**	**2.22**	**10,965**	**-51%**
Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.	1.2	1.2	181	0%
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	**2.4**	**2.95**	**102,303**	**-24%**
Waiwhetū Stream	Waiwhetū S. @ Whites Line E.	1.1	1.1	228	0%
Wainuiomata urban streams	Black C. @ Rowe Parade end	**1.3**	**2.22**	**382**	**-50%**
Wainuiomata rural streams	Wainuiomata R. DS White Br.	**2.1**	**2.22**	**12,243**	**-7%**
Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	3.2	3.2	290	0%
Wellington urban	Karori S. @ Mākara Peak	3.2	3.2	2,159	0%
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	**1.6**	**2.22**	**4,437**	**-34%**
TAoP TAS					
Pouewe	Horokiri Stream @ Snodgrass	2.3	2.3	764	0%
Takapū	Pāuatahanui S. @ Elmwood Bridge	**1.8**	**2.22**	**2311**	**-24%**
Te Riu o Porirua	Porirua S. @ Milk Depot	1.7	1.7	1705	0%
Taupō	Taupō S. @ Plimmerton Domain	1.2	1.2	15	0%
Wai-o-hata	Duck Ck at @ Tradewinds Dr. Br.	1.2	1.2	526	0%

2.7 Issue 7: The link between the TAoP WIP coastal objectives and load reduction targets for sediment and metal attributes are not supported by sufficiently robust technical analysis (full detail in Section 11 to Section 13)

The TAoP WIP assumes that:

- A 40% reduction in sediment loads to the Onepoto Arm and Pāuatahanui Inlet (the main arms of Te Awarua-o-Porirua harbour) is needed to achieve the WIP coastal objectives for sedimentation rate. **However**;
- That 40% sediment load reduction will result in a commensurate increase in sediment copper (Cu) and zinc (Zn) concentrations in the the Onepoto Arm and Pāuatahanui Inlet due to a loss of dilution. **Thus**;
- A 40% reduction in total Cu and Zn loads to the Onepoto Arm and Pāuatahanui Inlet is also needed to maintain sediment metal concentrations and achieve the relevant WIP coastal objectives.

Due to size of the sediment and metal load reductions proposed in the WIP, the review by Aquanet Consulting identified that further scrutiny of the assumptions above was needed prior to PC1 being notified. This has since been provided by:

- Mr Brent King (Team Leader, Evaluation and Insights – GW) – Relationship between sediment load reductions and harbour sedimentation rate (Section 11);
- Dr Jennifer Gadd (Aquatic Chemist – NIWA) – Relationships between sediment load reductions, metal load reductions and sediment metal concentrations (Section 13); and
- Dr Megan Oliver (Principal Advisor Knowledge – GW) – The need to take a precautionary approach to maintaining sediment metal concentrations in TAoP harbour (Section 12).

Based on the advice provided by the experts listed above, there is now adequate evidence to support the inclusion of the WIP coastal objectives for sedimentation rate and sediment Cu and Zn concentrations in PC1, as well as the associated loads reduction targets.

2.8 Additional minor recommendations and conclusions made through PC1 TAG process

- For those attributes with multiple assessment statistics (e.g., median and 95th percentile concentrations) and multiple potential baseline periods (dissolved Cu and Zn in rivers only) it is recommended that baseline state be calculated from the baseline period with the lowest average concentration of the attribute;
- Many of the TASs in the WTWT and TAoP WIPs have been set to maintain the baseline state. It is clear from the NPS-FM 2020 definition of **degrading** that when setting TASs maintain does not mean 'within an attribute state. Thus, 'maintain' TASs need to capture the baseline state in some way, rather than simply denoting an attribute state. This could be addressed by incorporating a "maintain or improve" narrative into the relevant TASs that then cross-reference a footnote to the effect of:

  "Maintenance, improvement or deterioration in the state of an attribute will be assessed through:

  - *Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and*

- *Taking the impact of climate and human activity into account."*

- The enterococci attribute state framework used in both the TAoP and WTWT WIPs is not appropriate for use in PC1 as the different assessment statistics are in direct conflict with one another (e.g., the attribute state B thresholds require the 95th percentile concentration to be lower than the 90th percentile concentration). It is recommended that only the "*95th percentile*" statistic be used as that is the one which has been drawn from MfE/MoH (2003); and
- The WTWT and TAoP WIP TASs are not well aligned with the exiting numeric water quality and ecology objectives/ standards in the NRP. However, that in itself is not justification for not adopting them in PC1.

2.9 Recommended TASs and coastal objectives based on additional technical work conducted during PC1 development.

Table 4 to Table 8 set out TASs and coastal objectives tables for WTWT and TAoP Whaitua that account for all of the technical recommendations set out in this report. The differences between the baseline states and TASs in those tables provide an indication of the environmental change required by the TASs and, have been used to define default TASs that prescribe the direction of change required for each attribute across each part-FMU[4] (Table 5 and Table 8). The attribute state frameworks behind the river and lakes TASs are provided in Appendix A.

Table 4: Recommended coastal objectives for the TAoP Whaitua.

			Onepoto Arm		Pāuatahanui Inlet		Coast
Parameter	**Unit**	**Statistic**	**Intertidal**	**Subtidal**	**Intertidal**	**Subtidal**	
Enterococci	**cfu/100 mL**	95th %ile	≤500		≤200		≤200
Macroalgae	**EQR**	Latest score	Maintain or improve				Maintain or improve
Copper in sediment	**mg/kg**	Mean of latest round of replicate samples					
Zinc in sediment	**mg/kg**						
Muddiness	**% >50% mud**	Latest score					
	% of sample						
Sedimentation rate	**mm/year**	5-year mean	1		2		

[4] Where baseline state is unknown, this direction of change is based on the difference in the assumed baseline in the WIP and the TAS.

Table 5: Recommended river TASs for TAoP Whaitua.

				Taupō					Pouewe					Wai-o-hata					Takapū				
				Taupō S. @ Plimmerton Domain				Part FMU default TAS[1]	Horokiri S. @ Snodgrass				Part FMU default TAS[1]	Duck Ck @ Tradewinds Dr. Br.				Part FMU default TAS[1]	Pāuatahanui S. @ Elmwood Br.				Part FMU default TAS[1]
				Baseline		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]		
Parameter	Unit	Statistic	Timeframe	Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State	
Periphyton biomass	mg chl-a/m^2	92nd %ile	By 2040	N/A[2]				M	436[3]	D	≤120	B	I	Insufficient data		≤120	B	I	Insufficient data		≤120	B	I
Ammonia (toxicity)	mg/L	Median		0.011	B[4]	≤0.03	A	I	0.002	A	M	A	M	0.013	A[4]	M	A	M	0.005	A	M	A	M
		95th %ile		0.051		≤0.05			0.013					0.044					0.018				
Nitrate (toxicity)	mg/L	Median		0.4	B[4]	≤1	A		0.6	A		A		0.5	B[4]	≤1	A	I	0.3	A		A	
		95th %ile		2.1		≤1.5			1.1					1.6		≤1.5			0.8				
Suspended fine sediment	Black disc (m)	Median		1.2	A[4]	≥0.93	A	M	2.3	C		C		1.2	A[4]	≥0.93	A	M	1.8	D	≥2.22	C	I
E. coli	/100mL	Median		735	E[4]	≤130	B	I	370	E	≤130	B	I	703	E[4]	≤130	C	I	275	E	≤130	C	
		%>260/100mL		96		≤30			63		≤30			92		≤20			55		≤20		
		%>540/100mL		62		≤10			32		≤10			59		≤34			18		≤34		
		95th %ile		5,299		≤1,000			4,950		≤1,000			4,783		≤1,200			6,050		≤1,200		
Fish	Fish-IBI	Latest		Insufficient data		M		M	Insufficient data		M		M	Insufficient data		M		M	Insufficient data		M		M
Fish community health (abundance, structure and composition)		Expert assessment[5]				N/A[5]	B	I			N/A[5]	A	I			N/A[5]	B	I			N/A[5]	B	I
Macroinvertebrates (1 of 2)	MCI	Median				≥100	B		115.0	B	≥130	A				≥100	B		101.2	D	≥105	B	
	QMCI	Median				≥5			6.0		≥6.5					≥5			3.8		≥5.25		
Macroinvertebrates (2 of 2)	ASPM	Median				≥0.4	B		0.5	B	M	B	M			≥0.4	B		0.4	C	≥0.40	C	M
Deposited fine sediment[3]	%cover	Median		N/A[6]					10	A		A				M		M	60	D	≤27	C	I
Dissolved oxygen	mg/L	1-day minimum		Insufficient data		M		M	Insufficient data		M								Insufficient data		M		M
		7-day mean minimum																					
Dissolved inorganic nitrogen[7]	mg/L	Median		0.41[4]		≤1.03		I	0.64					0.48[4]					0.33				
Dissolved reactive phosphorus[7]	mg/L	Median		0.017[4]		M		M	0.011					0.018[4]		M			0.014				
		95th%ile		0.047[4]					0.026					0.05[4]					0.022				
Dissolved copper	µg/L	Median		0.61	D[4]	≤1	B	I	0.03	A[4]	M	A		0.47	C[4]	≤1	A	I	0.06	A[4]	M	A	
		95th %ile		4.69		≤1.8			0.12					2.93		≤1.4			0.27				
Dissolved zinc	µg/L	Median		3.91	C[4]	≤2.4	A		0.07	A[4]		A		1.96	B[4]	≤2.4	A		0.11	A[4]		A	
		95th %ile		32.25		≤8			0.23					13.04		≤8			0.48				
Ecosystem metabolism	g O_2 m^{-2} d^{-1}	N/A[8]		M																			

Parameter	Unit	Statistic	Timeframe	Te Rio o Porirua and Rangituhi: Porirua S. @ Milk Depot – Baseline Numeric	Baseline State	TAS[1] Numeric	TAS[1] State	Part FMU default TAS[1]	Island rivers TAS[1]
Periphyton biomass	mg chl-a/m²	92nd %ile	By 2040	Insufficient data		≤120	B	I	M
Ammonia (toxicity)	mg/L	Median		0.006	A	M	A	M	
		95th %ile		0.034					
Nitrate (toxicity)	mg/L	Median		0.9	B	≤0.9	A	I	
		95th %ile		1.6		≤1.5			
Suspended fine sediment	Black disc (m)	Median		1.7	A	M	A	M	
E. coli	/100mL	Median		1400	E	≤130	C	I	
		%>260/100mL		95		≤20			
		%>540/100mL		83		≤34			
		95th %ile		6950		≤1200			
Fish	Fish-IBI	Latest		Insufficient data		M		M	
Fish community health (abundance, structure and composition)		Expert assessment[5]				N/A[5]	C	I	
Macroinvertebrates (1 of 2)	MCI	Median		87.0	D	≥90	C		
	QMCI	Median		4.3		≥4.5			
Macroinvertebrates (2 of 2)	ASPM	Median		0.3	D	≥0.3	C		
Deposited fine sediment[3]	%cover	Median		20	C	M	C	M	
Dissolved oxygen	mg/L	1-day minimum		Insufficient data		M			
		7-day mean minimum							
Dissolved inorganic nitrogen[7]	mg/L	Median		0.92					
Dissolved reactive phosphorus[7]	mg/L	Median		0.018					
		95th%ile		0.034					
Dissolved copper	µg/L	Median		1.1	C	M	C		
		95th %ile		2.6					
Dissolved zinc	µg/L	Median		7.5	D	≤7.5	C	I	
		95th %ile		58		≤42			
Ecosystem metabolism	$g\ O_2\ m^{-2}\ d^{-1}$	N/A[8]		M[8]					

[1] M = Maintain; I = Improve. Maintenance, improvement or deterioration in the state of an attribute will be assessed through:

- Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and
- Taking the impact of climate and human activity into account.

[2] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (River Environment Classification group = WW/L/SS).
[3] Baseline state based on limited data.
[4] Baseline state based on eWater Source model results. Further monitoring needed to confirm whether the attribute meets the TAS.
[5] The A, B, C and D states to be assigned on the basis of fish community health reflecting an excellent, good, fair and poor state of aquatic ecosystem health respectively.
[6] All rivers in part FMU naturally soft bottomed (River Environment Classification group = WW/L/SS).
[7] Median concentration targets reflect the nutrient outcomes required by Clause 3.13 of the NPS-FM 2020
[8] Further monitoring needed to define baseline state and develop attribute state framework.

Table 6: Recommended coastal objectives for WTWT.

<table>
<tr><th>Parameter</th><th>Unit</th><th>Statistic</th><th>Te Whanganui-a-Tara (Harbour and estuaries)</th><th>Mākara Estuary</th><th>Wainuiomata Estuary</th><th>Wai Tai</th></tr>
<tr><td>Benthic marine invertebrate diversity</td><td colspan="2">Subjective - State of ecosystem health and level of disturbance</td><td rowspan="8">Maintain or improve</td><td rowspan="5">Maintain or improve</td><td colspan="2" rowspan="9">Maintain or improve</td></tr>
<tr><td>Macroalgae</td><td>EQR</td><td rowspan="2">Latest score</td></tr>
<tr><td>Phytoplankton</td><td>mg chl-a/ m^3</td></tr>
<tr><td>Copper in sediment</td><td>mg/kg</td><td rowspan="2">Mean of latest round of replicate samples</td></tr>
<tr><td>Zinc in sediment</td><td>mg/kg</td></tr>
<tr><td rowspan="2">Muddiness</td><td>% >50% mud</td><td rowspan="3">Latest score</td><td>≤5</td></tr>
<tr><td>% of sample</td><td><10</td></tr>
<tr><td>Sedimentation rate</td><td>Current:Natural</td><td>≤2:1</td></tr>
<tr><td>Enterococci</td><td>cfu/100 mL</td><td>95th %ile</td><td>≤200</td><td>Maintain or improve</td></tr>
</table>

Table 7: Recommended lake TASs for WTWT.

				Lake Kōhangatera				Lake Kōhangapiripiri				Other lakes default TAS[1]
				Baseline		TAS[1]		Baseline		TAS[1]		
Parameter	**Unit**	**Statistic**	**Timeframe**	**Numeric**	**State**	**Numeric**	**State**	**Numeric**	**State**	**Numeric**	**State**	
Phytoplankton[2]	**mg chl-a/m^3**	Median	By 2040	5.0	C	≤2	A	1.5	A	M	A	M
		Maximum		35		≤10		6.0				
Total nitrogen[2]	**mg/m^3**	Median		480	B	M	B	660	C	≤500	B	
Total phosphorus[2]	**mg/m^3**	Median		40	C	≤20	B	43	C	≤20	B	
Ammonia (toxicity)[2]	**mg/L**	Median		0.005	A	M	A	0.003	A	M	A	
		95th %ile		0.024				0.005				
E. coli[2]	**/100mL**	Median		125	A		A	23	A		A	
		%>260/100mL		174				0				
		%>540/100mL		0				0				
		95th %ile		350				186				
Cyanobacteria (planktonic)[2]	**Total biovolume mm^3/L**	80th %ile		0.248	A		A	0.008	A		A	
Submerged plants (natives)	**Native Condition Index (% of max)**	Latest		81.4	A		A	35.7	C	≥75	A	
Submerged plants (invasive species)	**Invasive Impact Index (% of max)**	Latest		15.6	B		B	61.5	C	≤25	B	
Lake-bottom dissolved oxygen[3]	**mg/L**	Annual minimum		Insufficient data		≥7.5	A	Insufficient data		≥7.5	A	

[1] M = Maintain; I = Improve. Maintenance, improvement or deterioration in the state of an attribute will be assessed through:

- Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and
- Taking the impact of climate and human activity into account.

[2] Baseline state based on limited data collected over a period that is inconsistent with the monitoring requirements and baseline period defined in the NPS-FM 2020.

[3] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or be maintained at a better state.

Table 8: Recommended river TASs for WTWT.

<table>
<tr><td colspan="4" rowspan="4"></td><td colspan="20">Te Awa Kairangi, Ōrongorongo and Wainuiomata</td></tr>
<tr><td colspan="5">Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems</td><td colspan="5">Te Awa Kairangi lower mainstem</td><td colspan="5">Te Awa Kairangi rural streams and rural mainstems</td><td colspan="5">Te Awa Kairangi urban streams</td></tr>
<tr><td colspan="4">Whakatikei R. @ Riverstone</td><td rowspan="3">Part FMU default TAS[1]</td><td colspan="4">Hutt R. @ Boulcott</td><td rowspan="3">Part FMU default TAS[1]</td><td colspan="4">Mangaroa R. @ Te Marua</td><td rowspan="3">Part FMU default TAS[1]</td><td colspan="4">Hulls Ck adj. Reynolds Bach Dr.</td><td rowspan="3">Part FMU default TAS[1]</td></tr>
<tr><td colspan="2">Baseline</td><td colspan="2">TAS[1]</td><td colspan="2">Baseline</td><td colspan="2">TAS[1]</td><td colspan="2">Baseline</td><td colspan="2">TAS[1]</td><td colspan="2">Baseline[2]</td><td colspan="2">TAS[1]</td></tr>
<tr><td>Parameter</td><td>Unit</td><td>Statistic</td><td>Timeframe</td><td>Numeric</td><td>State</td><td>Numeric</td><td>State</td><td>Numeric</td><td>State</td><td>Numeric</td><td>State</td><td>Numeric</td><td>State</td><td>Numeric</td><td>State</td><td>Numeric</td><td>State</td><td>Numeric</td><td>State</td></tr>
<tr><td>Periphyton biomass[2]</td><td>$mg\ chl\text{-}a/m^2$</td><td>92nd %ile</td><td rowspan="26">By 2040</td><td colspan="2">Insufficient data</td><td>≤50</td><td>A</td><td rowspan="11">M</td><td>284</td><td>D</td><td>≤120</td><td>B</td><td>I</td><td>220</td><td>D</td><td>≤120</td><td>B</td><td>I</td><td colspan="2">Insufficient data</td><td>≤200</td><td>C</td><td rowspan="6">M</td></tr>
<tr><td rowspan="2">Ammonia (toxicity)</td><td rowspan="2">mg/L</td><td>Median</td><td>0.002</td><td rowspan="2">A</td><td rowspan="9">M</td><td rowspan="2">A</td><td>0.002</td><td rowspan="2">A</td><td rowspan="4">M</td><td rowspan="2">A</td><td rowspan="4">M</td><td>0.002</td><td rowspan="2">A</td><td rowspan="4">M</td><td rowspan="2">A</td><td rowspan="4">M</td><td>0.008</td><td rowspan="2">A</td><td rowspan="5">M</td><td rowspan="2">A</td></tr>
<tr><td>95th %ile</td><td>0.004</td><td>0.003</td><td>0.01</td><td>0.012</td></tr>
<tr><td rowspan="2">Nitrate (toxicity)</td><td rowspan="2">mg/L</td><td>Median</td><td>0.1</td><td rowspan="2">A</td><td rowspan="2">A</td><td>0.2</td><td rowspan="2">A</td><td rowspan="2">A</td><td>0.4</td><td rowspan="2">A</td><td rowspan="2">A</td><td>0.2</td><td rowspan="2">A</td><td rowspan="2">A</td></tr>
<tr><td>95th %ile</td><td>0.3</td><td>0.3</td><td>0.6</td><td>0.4</td></tr>
<tr><td>Suspended fine sediment</td><td>Black disc (m)</td><td>Median</td><td>4</td><td>A</td><td>A</td><td>2.4</td><td>C</td><td>≥2.95</td><td>A</td><td rowspan="5">I</td><td>1.5</td><td>D</td><td>≥2.22</td><td>C</td><td rowspan="9">I</td><td>1.2</td><td>A</td><td>A</td></tr>
<tr><td rowspan="4">E. coli</td><td rowspan="4">/100mL</td><td>Median</td><td>22</td><td rowspan="4">A</td><td rowspan="4">A</td><td>58</td><td rowspan="4">D</td><td>≤58</td><td rowspan="4">C</td><td>170</td><td rowspan="4">D</td><td>≤130</td><td rowspan="4">B</td><td>1,100</td><td rowspan="4">E</td><td>≤130</td><td rowspan="4">C</td><td rowspan="5">I</td></tr>
<tr><td>%>260/100mL</td><td>5</td><td>18</td><td>≤18</td><td>35</td><td>≤30</td><td>100</td><td>≤34</td></tr>
<tr><td>%>540/100mL</td><td>3</td><td>8</td><td>≤8</td><td>18</td><td>≤10</td><td>79</td><td>≤20</td></tr>
<tr><td>95th %ile</td><td>290</td><td>1,250</td><td>≤1,200</td><td>2,450</td><td>≤1,000</td><td>13,000</td><td>≤1,200</td></tr>
<tr><td>Fish</td><td>Fish-IBI</td><td>Latest</td><td colspan="2" rowspan="2">Insufficient data</td><td>≥34</td><td>A</td><td colspan="2" rowspan="2">Insufficient data</td><td>≥34</td><td>A</td><td>M</td><td colspan="2" rowspan="2">Insufficient data</td><td>≥34</td><td>A</td><td colspan="2" rowspan="5">Insufficient data</td><td>≥34</td><td>A</td></tr>
<tr><td colspan="2">Fish community health (abundance, structure and composition)</td><td>Expert assessment[3]</td><td>N/A[3]</td><td>A</td><td rowspan="5">I</td><td>N/A[3]</td><td>B</td><td rowspan="3">I</td><td>N/A[3]</td><td>B</td><td>N/A[3]</td><td>C</td><td rowspan="10">M</td></tr>
<tr><td rowspan="2">Macroinvertebrates (1 of 2)</td><td>MCI</td><td>Median</td><td>129.6</td><td rowspan="2">B</td><td>≥130</td><td rowspan="2">A</td><td>109.1</td><td rowspan="2">C</td><td>110</td><td rowspan="2">B</td><td>118.3</td><td rowspan="2">C</td><td>≥118.3</td><td rowspan="2">B</td><td>≥90</td><td rowspan="2">C</td></tr>
<tr><td>QMCI</td><td>Median</td><td>7.0</td><td>≥7</td><td>5.5</td><td>5.5</td><td>5.7</td><td>≥5.7</td><td>≥4.5</td></tr>
<tr><td>Macroinvertebrates (2 of 2)</td><td>ASPM</td><td>Median</td><td>0.56</td><td>B</td><td>≥0.6</td><td>A</td><td>0.4</td><td>B</td><td rowspan="2">M</td><td>B</td><td rowspan="11">M</td><td>0.5</td><td>B</td><td rowspan="2">M</td><td>B</td><td rowspan="5">M</td><td>≥0.3</td><td>C</td></tr>
<tr><td>Deposited fine sediment[2]</td><td>%cover</td><td>Median</td><td>25</td><td>C</td><td>≤13</td><td>A</td><td>5</td><td>A</td><td>A</td><td>0</td><td>A</td><td>A</td><td>11</td><td>B</td><td>M</td><td>B</td></tr>
<tr><td rowspan="2">Dissolved oxygen</td><td rowspan="2">mg/L</td><td>1-day minimum</td><td colspan="2" rowspan="2">Insufficient data</td><td>≥7.5</td><td rowspan="2">A</td><td rowspan="3">M</td><td colspan="2" rowspan="2">Insufficient data</td><td>≥7.5</td><td rowspan="2">A</td><td colspan="2" rowspan="2">Insufficient data</td><td>≥7.5</td><td rowspan="2">A</td><td colspan="2" rowspan="2">Insufficient data</td><td>≥7.5</td><td rowspan="2">A</td></tr>
<tr><td>7-day mean minimum</td><td>≥8.0</td><td>≥8.0</td><td>≥8.0</td><td>≥8.0</td></tr>
<tr><td>Dissolved inorganic nitrogen[4]</td><td>mg/L</td><td>Median</td><td colspan="2">0.15</td><td colspan="2">M</td><td colspan="2">0.2</td><td colspan="2" rowspan="3">M</td><td colspan="2">0.44</td><td colspan="2">M</td><td colspan="2">0.24</td><td colspan="2" rowspan="3">M</td></tr>
<tr><td rowspan="2">Dissolved reactive phosphorus[4]</td><td rowspan="2">mg/L</td><td>Median</td><td colspan="2">0.008</td><td colspan="2">≤0.006</td><td rowspan="2">I</td><td colspan="2">0.004</td><td colspan="2">0.010</td><td colspan="2">≤0.006</td><td rowspan="2">I</td><td colspan="2">0.018</td></tr>
<tr><td>95th%ile</td><td colspan="2">0.011</td><td colspan="2">≤0.011</td><td colspan="2">0.008</td><td colspan="2">0.015</td><td colspan="2">≤0.015</td><td colspan="2">0.027</td></tr>
<tr><td rowspan="2">Dissolved copper</td><td rowspan="2">µg/L</td><td>Median</td><td colspan="2" rowspan="4">Insufficient data</td><td>≤1</td><td rowspan="2">A</td><td rowspan="4">M</td><td>0.3</td><td rowspan="2">A</td><td rowspan="4">M</td><td rowspan="2">A</td><td colspan="2" rowspan="4">Insufficient data</td><td>≤1</td><td rowspan="2">A</td><td rowspan="4">M</td><td>1.9</td><td rowspan="2">C</td><td>≤1.4</td><td rowspan="2">B</td><td rowspan="4">I</td></tr>
<tr><td>95th %ile</td><td>≤1.4</td><td>0.6</td><td>≤1.4</td><td>3.6</td><td>≤1.8</td></tr>
<tr><td rowspan="2">Dissolved zinc</td><td rowspan="2">µg/L</td><td>Median</td><td>≤2.4</td><td rowspan="2">A</td><td>0.5</td><td rowspan="2">A</td><td rowspan="2">A</td><td>≤2.4</td><td rowspan="2">A</td><td>8.0</td><td rowspan="2">C</td><td>≤8</td><td rowspan="2">B</td></tr>
<tr><td>95th %ile</td><td>≤8</td><td>1.9</td><td>≤8</td><td>19.2</td><td>≤15</td></tr>
<tr><td>Ecosystem metabolism[5]</td><td>$g\ O_2\ m^{-2}\ d^{-1}$</td><td>N/A[5]</td><td colspan="20">M</td></tr>
</table>

Parameter	Unit	Statistic	Timeframe	Te Awa Kairangi, Ōrongorongo and Wainuiomata															South-west coast, Mākara and Ōhariu catchment and Parangārehu Lakes				
				Waiwhetū Stream					Wainuiomata urban streams					Wainuiomata rural streams					Parangārehu catchment streams and South-west coast rural streams				
				Waiwhetū S. @ Whites Line East				Part FMU default TAS[1]	Black Ck @ Rowe Parade				Part FMU default TAS[1]	Wainuiomata River D/S of White Br.				Part FMU default TAS[1]	Mākara S. @ Kennels				Part FMU default TAS[1]
				Baseline		TAS[1]			Baseline[2]		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]		
Parameter	Unit	Statistic	Timeframe	Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State	
Periphyton biomass[2]	mg chl-a/m[2]	92nd %ile		Insufficient data		≤200	C	M	Insufficient data		≤200	C	M	324	D	≤200	C	I	Insufficient data		≤200	C	M
Ammonia (toxicity)	mg/L	Median		0.027	B	≤0.02	A	I	0.025	B	≤0.03	A	I	0.004	A	M	A	M	0.005	A	M	A	
		95th %ile		0.076		≤0.05			0.066		≤0.05			0.025					0.023				
Nitrate (toxicity)	mg/L	Median		0.5	A	M	A	M	0.4	A	M	A	M	0.2	A		A		0.4	A		A	
		95th %ile		0.9					0.7					0.4					1.2				
Suspended fine sediment	Black disc(m)	Median		1.1	A		A		1.3	D	≥2.22	C	I	2.1	D	≥2.22	C	I	1.6	D	≥2.22	C	I
E. coli	/100mL	Median		495	E	≤130	C	I	1250	E	≤130	C		100	B	≤100	A		375	E	≤260	D	
		%>260/100mL		73		≤34			86		≤34			18		≤18			62		≤50		
		%>540/100mL		42		≤20			71		≤20			7		≤5			32		≤30		
		95th %ile		5,800		≤1200			4,360		≤1200			1,000		≤540			6,500		≤3,850		
Fish	Fish-IBI	Latest		Insufficient data		≥34	A	M	Insufficient data		≥34	A	M	Insufficient data		≥34	A	M	Insufficient data		≥34	A	M
Fish community health (abundance, structure and composition)		Expert assessment[3]				N/A[3]	C	I			N/A[3]	C	I			N/A[3]	B	I			N/A[3]	C	
Macroinvertebrates (1 of 2)	MCI	Median	By 2040	55.4	D	≥90	C				≥90	C		109.5	C	≥110	B		107.3	C	M	C	
	QMCI	Median		2.2		≥4.5					≥4.5			4.9		≥5.5			5.1				
Macroinvertebrates (2 of 2)	ASPM	Median		0.1	D	≥0.3	C				≥0.3	C		0.4	B	≥0.6	A		0.4	B		B	
Deposited fine sediment[2]	%cover	Median		30	D	≤29	C		11	A	M	A	M	20	C	≤13	A		85	D	≤27	C	I
Dissolved oxygen	mg/L	1-day minimum		Insufficient data		≥7.5	A		Insufficient data		≥7.5	A		Insufficient data		≥7.5	A	M	Insufficient data		≥7.5	A	M
		7-day mean minimum				≥8.0					≥8.0					≥8.0					≥8.0		
Dissolved inorganic nitrogen[4]	mg/L	Median		0.56		M		M	0.5		M			0.17		M			0.42		M		
Dissolved reactive phosphorus[4]	mg/L	Median		0.024		≤0.018		I	0.021		≤0.018		I	0.011		≤0.01		I	0.027		≤0.018		I
		95th%ile		0.049		≤0.049			0.035		≤0.035			0.023		≤0.023			0.064		≤0.054		
Dissolved copper	µg/L	Median		1.0	C	≤1	A		1.0	C	M	C	M	Insufficient data		≤1	A	M	Insufficient data		≤1	A	M
		95th %ile		4.0		≤1.4			2.0							≤1.4					≤1.4		
Dissolved zinc	µg/L	Median		18.3	D	≤8	B		11.2	D	≤11.2	C	I			≤2.4	A				≤2.4	A	
		95th %ile		51.5		≤15			71.2		≤42					≤8					≤8		
Ecosystem metabolism	g O_2 m^{-2} d^{-1}	N/A[5]		M																			

				Korokoro catchment					Wellington urban catchment										Island rivers TAS[1]
				Korokoro Stream					Kaiwharawhara Stream					Wellington urban					
				Korokoro S. @ Cornish St. Br.				Part FMU default TAS[1]	Kaiwharawhara S. @ Ngaio Gorge				Part FMU default TAS[1]	Karori S. @ Mākara Peak				Part FMU default TAS[1]	
				Baseline		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]			
Parameter	Unit	Statistic	Timeframe	Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State		
Periphyton biomass[2]	mg chl-a/m^2	92nd %ile	By 2040	Insufficient data		≤120	B	M	191	D	≤200	C	I	Insufficient data		≤200	C	M	M
Ammonia (toxicity)	mg/L	Median				≤0.03	A		0.004	A	M	A	M	0.009	A	M	A		
		95th %ile				≤0.05			0.031					0.026					
Nitrate (toxicity)	mg/L	Median				≥1	A		1.1	B		B		1.3	B		B		
		95th %ile				≥1.5			1.5					1.6					
Suspended fine sediment	Black disc (m)	Median				≥2.95	A		3.2	A		A		3.2	A		A		
E. coli	/100mL	Median				≤130	B	I	530	E	≤130	C	I	1400	E	≤130	C	I	
		%>260/100mL				≤30			73		≤34			97		≤34			
		%>540/100mL				≤10			50		≤20			83		≤20			
		95th %ile				≤1,000			5,150		≤1,200			4,550		≤1,200			
Fish	Fish-IBI	Latest				≥34	A	M	Insufficient data		≥34	A	M	Insufficient data		≥34	A	M	
Fish community health (abundance, structure and composition)	Expert assessment[3]					N/A[3]	C	I			N/A[3]	C	I			N/A[3]	C	I	
Macroinvertebrates (1 of 2)	MCI	Median				≥130	A		81.9	D	≥92.4	C		91.8	D	≥91.8	C		
	QMCI	Median				≥6.5			2.8		≥4.5			3.1		≥4.5			
Macroinvertebrates (2 of 2)	ASPM	Median				≥0.6	A		0.25	D	≥0.3	C	I	0.29	D	≥0.3	C		
Deposited fine sediment[2]	%cover	Median				≤13	A	M	20	C	≤13	A		25	C	≤19	B		
Dissolved oxygen	mg/L	1-day minimum				≥7.5	A		Insufficient data		≥7.5	A	M	Insufficient data		≥7.5	A	M	
		7-day mean minimum				≥8.0					≥8.0					≥8.0			
Dissolved inorganic nitrogen[4]	mg/L	Median				≤0.26			1.14		M			1.29		M			
Dissolved reactive phosphorus[4]	mg/L	Median				≤0.006		I	0.037		≤0.018		I	0.035					
		95th%ile				≤0.021			0.064		≤0.054			0.062					
Dissolved copper	µg/L	Median				≤1	A	M	1.3	C	≤1.3	B		1.3	D	≤1.3	C	I	
		95th %ile				≤1.4			2.8		≤1.8			5.9		≤4.3			
Dissolved zinc	µg/L	Median				≤2.4	A		6.1	B	≤2.4	A		16.2	D	≤16.2	C		
		95th %ile				≤8			12.8		≤8			43.0		≤42			
Ecosystem metabolism	g O_2 m^{-2} d^{-1}	N/A[5]		M															

[1] M = Maintain; I = Improve. Maintenance, improvement or deterioration in the state of an attribute will be assessed through:

- Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and
- Taking the impact of climate and human activity into account.

[2] Baseline state based on limited data.

[3] The A, B, C and D states to be assigned on the basis of fish community health reflecting an excellent, good, fair and poor state of aquatic ecosystem health respectively.

[4] Median concentration targets reflect the nutrient outcomes required by Clause 3.13 of the NPS-FM 2020

[5] Further monitoring needed to define baseline state and develop attribute state framework.

Part 2 – Reproduction of technical memoranda produced during the development of PC1

3 Recommended part-FMUs and TAS sites for Te Awarua-o-Porirua Whaitua and Whaitua te Whanganui-a-Tara

First published: 17/02/2022

To: Plan Change 1 Policy and Technical Team
Greater Wellington

The purpose of this memorandum is to document the part-FMU and TAS site selection, refinement and delineation that Torlesse and Collaborations have completed to date for TAoP Whaitua and WTWT.

Note: The part-FMUs and TASs sites presented in this memorandum are the authors technical recommendations, not GW Policy.

3.1 TAS site selection

A full methodology of how TAS sites were selected is provided in the Collaborations memorandum attached as Appendix B. Briefly, the processes involved:

1. Refining a set of 29 sub-catchments provided by GW to better account for their hydrological and land-use characteristics.
2. Identifying sub-catchments with similar:
   a. Current water quality (at the time);
   b. WIP TASs; and
   c. Catchment characteristics.
3. Over laying GW's monitoring network over the sub-catchments to:
   a. Identify the sub-catchments where additional sites are needed;
   b. Identify the sub-catchments where sites need to be moved to better detect land-use effects and the results of changing practice;
   c. Identify the most appropriate monitoring site for setting TASs in sub-catchments with multiple existing monitoring sites; and
   d. Identify the sub-catchments where a monitoring site is not necessary as progress towards TASs can be assessed based on monitoring data collected from a similar 'proxy' catchment (see Step 2 above).

The final recommended list of TAS sites (see Table 11) is largely consistent with the recommendations made by Collaborations (Appendix B). However, GW have separately determined that monitoring is not possible in the Takapūwahia or Gollans streams. Thus, those sites have been excluded.

<u>*Notes:*</u>

- *The Collaborations memorandum (Appendix B) refers to sub-FMUs rather than sub-catchments and makes recommendations on what these should be. That piece of work was* *produced some time ago and represents a first cut at turning the WIP management units (TAoP management units = WMUs; WTWT = Catchment × Sub-catchment area) into part-FMUs. As such, there are conflicts between the part-FMUs presented in the body of this memorandum and the sub-FMUs in Appendix B. The list set out in Table 11 represents the latest technical thinking, and Appendix B demonstrates how part-FMUs have evolved through time.*

- *Collaborations recommends a range of additional modelling sites. These are relevant for accounting and plan implementation monitoring, but not for the setting of TASs. As such they are not considered here.*

3.2 Part-FMU selection

3.2.1 Approach

The recommended part-FMUs in this memorandum have been developed based on the following technical assumptions:

- Each part-FMU ideally has a single TAS site;
- The management units recommended in the TAoP and WTWT WIPs (see Table 9) are an appropriate starting point for selecting part-FMUs (TAoP management units = WMUs; WTWT = Catchment × Sub-catchment area); and
- The list of TAS sites recommended by Collaborations provides an appropriate indication of where TASs need to be set to detect the impact of practice change on water quality and ecology across the TAoP Whaitua and WTWT[5]. As such, overlaying that list of sites with the management units in the WIPs is an appropriate method of identifying where those management units need to be refined.

The process of refining the WIP management units into part-FMUs was straight forward. Management units without TAS sites were merged with the management unit containing the relevant proxy catchment identified in the Collaborations memorandum. WIP management units with multiple TAS sites were then assessed to determine whether there was justification for splitting them based on land-use (i.e., would the same actions be needed to meet the target attribute state at each site). Table 9, Table 10, Table 11 respectively:

- Describe the original management units in the TAoP and WTWT WIPs;
- Outline the changes that have been made to them to develop the final recommended list of part-FMUs; and
- List the final recommended part-FMUs and the TAS site for each one.

[5] Note this site list does not reflect a representative monitoring network, and it will not be possible to define 'state' in all rivers across these whaitua based on the data collected at those sites. It is expected that plan effectiveness monitoring will extend beyond the TAS sites.

The original WIP management units and amended recommended part-FMUs are mapped in Appendix C (TAoP) and D (WTWT).

3.2.2 Split WIP management units

- Two WIP management units were identified as having more than one TAS site:
    - WTWT = Te Awa Kairangi forested mainstems (Hutt River at Te Marua Intake and Whakatikei River at Riverstone).
    - TAoP = Takapū (Pāuatahanui Stream at Elmwood Bridge and Duck Creek at Tradewinds Drive Bridge).
- For the Te Awa Kairangi forested mainstems it was decided that **the Hutt River at Te Marua Intake site should be removed** instead of splitting the management unit as:
    - The WIP TASs at the two sites and land-use practices required to achieve them (i.e., maintain their predominately forested upstream catchments) are sufficiently similar that there is limited benefit in splitting the WIP management unit into separate two part-FMUs;
    - The upstream catchment of the Hutt River at Te Marua Intake site is almost entirely within the native forests of the Kaitoke Regional Park, Pākuratahi Forest Regional Park and the Hutt Water Collection Area. (86%). Thus, water quality and ecology at this site is unlikely to be meaningfully impacted by upstream practice change and
    - GW science staff have indicated they would like the flexibility to cease monitoring at the Hutt River at Te Marua Intake site given its limited value for plan effectiveness monitoring and its close proximity to the NIWA monitoring site at Kaitoke .

      Note: This differs from the recommendation made in the original version of this memorandum provided to GW, which was to keep both sites in the same management unit.

- For the Takapū WMU in the TAoP WIP it was decided that the **Duck Creek catchment should have its own part-FMU** (Wai-o-hata in Table 10 and Table 11), as:
    - The Collaborations memorandum does not suggest that the two sites in the WIP WMU are suitable proxies for each other, meaning both need to be retained; and
    - Land-use in the Duck Creek catchment is significantly different than the rest of the WMU. Specifically, the Collaborations memorandum notes *"*[t]*he WIP included this catchment within Takapū* [management unit]*, though the catchment is unique with high proportions of pasture, exotic forest and residential land-uses that was not represented by any other* [management units]".

3.2.3 Merged WIP management units

- Based on the proxy catchment recommendations in the Collaborations memorandum (Appendix B) two catchments in the WTWT WIP were merged (Te Awa Kairangi catchment and Ōrongorongo and Wainuiomata catchment), and within those catchments, six sub-catchment groups were reduced to two part-FMUs (Table 10 and Table 11).
- In addition, two WMUs in the TAoP WIP were merged (Rangituhi and Te Rio o Porirua) to account for the fact that monitoring is not possible in one of them (Rangituhi) (Table 10 and Table 11). The South-west coast, Mākara and Ōhariu catchment and Parangārehu Lakes Catchments in the WTWT WIP were also merged for the same reason, resulting in all rivers in those Catchments being merged into a single part-FMU (Table 10 and Table 11).

  Note: The decision to merge these management units was made after the Collaborations memorandum was published and is based on monitoring feasibility. It was not a recommendation of the authors of that memorandum.

Table 9: Original management units set out in the TAoP and WTWT WIPs.

Whaitua	WIP Catchment (WTWT only)	WIP Sub-catchment area (WTWT) or WMU (TAoP)
WTWT	Te Awa Kairangi catchment	Te Awa Kairangi small forested
		Te Awa Kairangi forested mainstems
		Te Awa Kairangi lower mainstem
		Te Awa Kairangi rural mainstems
		Te Awa Kairangi rural streams
		Te Awa Kairangi urban streams
		Waiwhetū Stream
	Ōrongorongo and Wainuiomata catchment	Ōrongorongo
		Wainuiomata small forested
		Wainuiomata urban streams
		Wainuiomata rural streams
	South-west coast, Mākara and Ōhariu catchment	South-west coast rural streams
	Korokoro catchment	Korokoro Stream
	Wellington urban catchment	Kaiwharawhara Stream
		Wellington urban
	Parangārehu Lakes catchment	Parangārehu catchment streams
TOaP		Taupō
		Pouewe
		Rangituhi
		Takapū
		Te Rio o Porirua

Table 10: The WIP management units that were merged or split to create the final recommended part-FMUs.

Merge/split	Whaitua	WIP Catchment (WTWT only)	WIP Sub-catchment area (WTWT) or WMU (TAoP)
Merge	WTWT	• Te Awa Kairangi catchment • Ōrongorongo and Wainuiomata catchment	• Te Awa Kairangi small forested • Te Awa Kairangi forested mainstems • Wainuiomata small forested • Ōrongorongo
			• Te Awa Kairangi rural mainstems • Te Awa Kairangi rural streams
		• South-west coast, Mākara and Ōhariu catchment • Parangārehu Lakes catchment	• South-west coast rural streams • Parangārehu catchment streams
	TAoP		• Rangituhi • Te Rio o Porirua
Split			• Takapū • Wai-o-hata (new)

Table 11: Final recommended part-FMUs for TAoP Whaitua and WTWT and the recommended TAS site for each one.

Whaitua	WIP Catchment (WTWT only)	Recommended part-FMUs	Recommended TAS site
WTWT	Te Awa Kairangi, Ōrongorongo and Wainuiomata	Te Awa Kairangi and Wainuiomata small forested, Te Awa Kairangi forested mainstems and Ōrongorongo	Whakatikei R. @ Riverstone
		Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott
		Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua
		Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.
		Waiwhetū Stream	Waiwhetū S. @ Whites Line E.
		Wainuiomata urban streams	Black Ck @ Rowe Parade end
		Wainuiomata rural streams	Wainuiomata R. DS of White Br.
	South-west coast, Mākara and Ōhariu catchment and Parangārehu Lakes	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels
	Korokoro catchment	Korokoro Stream	Korokoro S.@ Cornish St. Br.
	Wellington urban catchment	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge
		Wellington urban	Karori S. @ Mākara Peak
TOaP		Taupō	Taupō S. @ Plimmerton Domain
		Pouewe	Horokiri S. @ Snodgrass
		Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.
		Takapū	Pāuatahanui S. @ Elmwood Br.
		Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot

One potential issue arising from merging multiple WIP management units into a single part-FMU is that the TAS set at the site may not fully capture the direction or magnitude of change signalled by the WIP TASs for the 'lost' management units. Table 12 sets out a summary of the WIP TAS improvements lost by the merging process set out in Section 3.2.3. In most cases the issues raised in Table 12 are inconsequential, as there is a high level of uncertainty in the baseline states for most of the lost WIP management units anyway (and, therefore, a high level of uncertainty in the level of improvement needed to meet the TASs). The exception being the aspirational TASs set for the Rangituhi management unit in the TAoP WIP not being captured by those set for the TAS site in the Te Rio o Porirua management unit.

Table 12: Identification of where the level of improvement indicated by the WIP TASs are different from those required when the WIP management units are merged into the part-FMUs in Table 11.

WIP	WIP management unit	Merged into	Attribute	Difference between TAS:		Notes
				When the part-FMUs inTable 11 are adopted	In the WIPs	
TWT	Te Awa Kairangi rural streams	Te Awa Kairangi rural streams and rural mainstems	ASPM	Requires maintenance	Requires a one attribute state improvement	WIP baseline attribute state for lost management unit not supported by measured data
TWT	Parangārehu catchment streams	Parangārehu catchment streams and South-west coast rural streams	Periphyton	Requires maintenance	Requires a one attribute state improvement	
TWT	Parangārehu catchment streams	Parangārehu catchment streams and South-west coast rural streams	*E. coli*	Requires a one-attribute state improvement	Requires a two-attribute state improvement	
TWT	Parangārehu catchment streams	Parangārehu catchment streams and South-west coast rural streams	Macroinvertebrates (MCI/QMCI)	Requires maintenance	Requires a one-attribute state improvement	
TAoP	Rangituhi	Te Rio o Porirua and Rangituhi	Periphyton	Requires a one-attribute state improvement	Requires maintenance	
TAoP	Rangituhi	Te Rio o Porirua and Rangituhi	Ammonia (NH_4-N)	Requires a one-attribute state improvement	Requires maintenance	
TAoP	Rangituhi	Te Rio o Porirua and Rangituhi	NO_3-N	Requires a one-attribute state improvement	Requires maintenance	
TAoP	Rangituhi	Te Rio o Porirua and Rangituhi	*E. coli*	Requires a two-attribute state improvement	Requires a four-attribute state improvement	
TAoP	Rangituhi	Te Rio o Porirua and Rangituhi	Macroinvertebrates (MCI/QMCI)	Requires a one attribute state improvement	Requires a two-attribute state improvement	
TAoP	Rangituhi	Te Rio o Porirua and Rangituhi	Cu	Requires a one-attribute state improvement	Requires a three-attribute state improvement	
TAoP	Rangituhi	Te Rio o Porirua and Rangituhi	Zn	Requires a one-attribute state improvement	Requires a three-attribute state improvement	

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4 Recommended approach to dealing with new attributes and values introduced in the NPS-FM 2020

First published: 13/07/2022

To: Plan Change 1 Policy and Technical Team
Greater Wellington

The NPS-FM 2020 introduced several new attributes that are not currently monitored and/or were not considered in the WIPs produced before August 2020. Table 13 provides:

- A review of the existing data available for each attribute;
- An analysis of what can be achieved by way of monitoring for the 2023 and 2024 plan changes;
- An assessment of whether the new attributes are managed by the existing TASs;
- Torlesse's recommended approach for setting targets for new attributes; and
- The PC1 TAG's recommended approach for setting targets for new attributes (discussed in meetings held on the 02/05/2022 and the 16/05/2022).

Note: Since this memorandum was first published GW have made the decision to include all TASs set out in the WIPs regardless of whether they are informed by monitoring or modelling data. Consequently, any recommendation in Table 13 to not set a numeric TASs where one has been included in the WIP should be disregarded.

Table 13: Recommended approach for dealing with new attributes introduced in the NPS-FM 2020.

Attribute	Existing data	Achievable outcome by 2023 PC		Achievable outcome by 2024 PC		Justification for management through other TAS, limits etc. (is there a need for TAS)	Recommended approach	PC1 Technical Teams recommended approach

Suspended fine sediment (rivers)	Long-term monthly record at existing RSoE monitoring sites.	Outcome:	• Full baseline and TASs for existing sites.
			• No baseline for new sites (could use general TSS to clarity relationships and dSedNet results but limited value if monitoring is planned – see sediment memo) .
				Outcome:	Interim baseline for new sites (not robust enough to set a specific TASs above the baseline (i.e., 'improve' rather than A/B/C).	There is no technical justification to rely on other attributes to manage this attribute as:
						• This is a 2A attribute requiring limits on resource use.
						• Sediment loads, targets etc., have not been developed to reflect an unintended consequence of rural and urban mitigations. Sediment management is an important issue on its own.
						• Baseline states can easily be calculated for existing sites and reasonably robust interim baselines can be calculated for new sites from the normal routine monitoring GW conduct (if ESci can establish sites).
						• TASs have been set in the WTWT WIP and can be calculated from sediment load reductions in TAoP WIP.
							• Existing sites – Establish baseline from monitoring data (already done) and
							  ○ Set TASs in TAoP at current (i.e., de-couple from sediment load reductions).
							  ○ Set TASs in WTWT in accordance with WIP.
							• New sites:
							  ○ Do not set baselines or TASs in PC1 or only include narrative 'maintain' TASs without a baseline.
							  ○ Establish sites by July 2022 and conduct two years of routine clarity monitoring.
							  ○ Calculate interim baseline from resulting data.
							  ○ Include baseline in 2024 plan change and set narrative TASs (i.e., 'maintain'/'improve').
								Adopt recommended approach with changes
								• Existing sites.
								  ○ Set baselines from monitoring data
								  ○ Set TASs in TAoP at current (i.e., de-couple from sediment load reductions).
								  ○ Set TASs in WTWT in accordance with WIP.
								• New sites
								  ○ Do not set baselines in PC1 and only include narrative 'maintain or improve' TASs without a baseline.
								
								Additional tech work
								• Existing sites:
								  ○ For TAoP calculate future visual clarity states that are consistent with load reductions using the approach set out in sediment memo. Use national approach bolstered with site specific TSS-visual clarity co-efficient – James or Hayden to do. Still need to have this prepared.
								  ○ Calculate load reductions needed to achieve WTWT TASs using methods described in Section 9 and consider achievability based on available information (EP assessments and existing modelling).
								• New sites:
								  ○ If ESci have capacity establish sites by July 2022 and conduct two years of routine clarity monitoring
								  ○ Calculate interim baseline from resulting data.
								  ○ Include baseline in 2024 plan change and set narrative TASs (i.e., 'maintain'/'improve').

		Effort:	Negligible – already monitored	Effort:	No additional effort beyond establishing new sites as visual clarity is part of GW's Environmental Science (ESci) department's routine monitoring protocols (whether establishing new sites is achievable will require discussions with ESci).			
		Start:	N/A	Start:	July 2022 at the latest to ensure two years of data at new sites			
Submerged plants (natives) and Submerged plants (invasive species) (lakes)	Surveys (LakeSPI may not be calculable for all) conducted in 2022 for: • Lake Wairongamai (Kapiti). • Lake Waitawa (Kapiti). • Lake Nganoke (Ruamāhanga). • Waikanae lagoons (Kapiti). • Wairarapa lagoons (Barton's, Boggy's,	Outcome:	• Up-to-date baseline and TASs for sites surveyed in 2022 (see left); • Slightly out of date baseline and TASs for Lake Kōhangatera and Lake Kōhangapiripiri – just outside the three-year monitoring frequency period; or • Updated baseline and TASs for Lake Kōhangatera and Lake Kōhangapiripiri – Marginal benefit as we are within the three-year monitoring period now and will only be just out at notification.	Outcome:	• Up to date baseline and TASs for sites surveyed in 2022 (see left); • Updated baseline and TASs for Lake Kōhangatera and Lake Kōhangapiripiri – This may well be needed if this attribute is not included in the plan until the 2024 PC as data for these lakes will be five years old at this point.	There is no technical justification to rely on other TAS to manage this attribute as: • This is the only attribute measured for most lakes (i.e., we know the most about this attribute). • There is an abundance of monitoring data, unlikely that any additional work needed if TASs for Lake Kōhangatera and Lake Kōhangapiripiri are set in PC1.	• Include baselines and TAS for WTWT and TAoP in PC1 based on 2019 survey results. • Set baselines and TASs for Kapiti, Ruamāhanga and Eastern Hills in 2024 PC based on 2022 surveys. • Do not monitor any new sites as a lot of lakes have now been surveyed.	Adopt recommended approach. However, check with ESci regarding future monitoring plans.
		Effort:	Minimal effort if Lake Kōhangatera and Lake Kōhangapiripiri re-surveyed (not recommended) – contracted to NIWA, costs likely to be >10K.	Effort:	Minimal effort if Lake Kōhangatera and Lake Kōhangapiripiri re-surveyed (recommended at this point) – contracted to NIWA, costs likely to be >10K.			

Attribute	Existing data	Achievable outcome by 2023 PC		Achievable outcome by 2024 PC		Justification for management through other TAS, limits etc. (is there a need for TAS)	Recommended approach	PC1 Technical Teams recommended approach
	Matthew's etc.) (Ruamāhanga). • Lake Rototawai (Ruamāhanga). • Pounui Lagoon (Ruamāhanga). • Lake Pounui (Ruamāhanga). Now outdated surveys conducted in 2019 for: • Lake Kōhangatera (TWT). • Lake Kōhangapiripiri (TWT). Assumed LakeSPI not applicable to Wairarapa and Onoke due to depth and trophic status – confirmed with Mary de Winton.	Start:	If Lake Kōhangatera and Lake Kōhangapiripiri are re-surveyed this will need to be contracted ASAP – conducted summer of 2022/2023.	Start:	If Lake Kōhangatera and Lake Kōhangapiripiri are re-surveyed this will need to be contracted by mid-2023 – conducted summer of 2023/2024.			
Fish (rivers)	Little to no data for any existing or new sites.	Outcome:	• Conduct fish surveys at all existing and new sites in WTWT and TAoP where IBI needs to be set. • Postpone fishing of areas to be covered by 2024 PC until summer 2023/2024 due to effort required to fish every site in the region in one year.	Outcome:	Conduct fish surveys at all existing and new sites in in areas covered by 2024 PC where IBI needs to be set.	• Very little justification for leaving out of PC and relying on management via environmental flows and the water quality, plant and macroinvertebrate attributes. • These factors all exert a significant influence over the health of fish populations. • However, as the IBI is a presence absence metric it is not particularly sensitive to changes in these attributes, even when they create a shift in abundance or composition. • Changes are likely to be the result of large-scale habitat change, the removal of fish passage barriers or broader population level processes that may be impacted by factors working across a range of spatial scales.	• Conduct fish surveys at all relevant existing and new sites in WTWT and TAoP in 2022/2023 and include baseline states and TASs in PC1. • Conduct fish surveys at all relevant existing and new sites in the rest of the region in 2023/2024 and include baseline states and TASs in PC1 . • See Section 4.1 for options for setting TASs for this attribute,	Confirm data availability with ESci and pursue recommended approach to fill any gaps. • Conduct fish surveys at all relevant existing and new sites in WTWT and TAoP in 2022/2023 and include baseline states and TASs in PC1. • Conduct fish surveys at all relevant existing and new sites in the rest of the region in 2023/2024 and include baseline states and TASs in PC1. General approach for TASs: • Await national IBI calculator, upon arrival calculate national IBI for sites. • Set IBI TASs at current attribute state with maintain or improve narrative. • Adopt fish narrative approach set out in memo below with following modifications: The abundance, structure and composition of fish communities are maintained or improved and are reflective of a/n excellent/good/fair/poor state of aquatic ecosystem health. • Set to be consistent with WIP MCI TASs in WTWT. • Set to be consistent the WIP narrative fish TASs in TAoP.
		Effort:	Very high – Potentially three monitoring officers for 0.5 to 1 day per site (60 person days).	Effort:	Very high – Potentially three monitoring officers for 0.5 to 1 day per site (~60 person days).			
		Start:	• Scoped and planned July 2022. • Commenced in December 2022.	Start:	• Scoped and planned July 2023. • Commenced in December 2023.			

Attribute	Existing data	Achievable outcome by 2023 PC		Achievable outcome by 2024 PC		Justification for management through other TAS, limits etc. (is there a need for TAS)	Recommended approach	PC1 Technical Teams recommended approach

Macroinvertebrates (1 of 2) and Macroinvertebrates (2 of 2) (rivers)	Long-term monthly record at existing RSoE monitoring sites.	Outcome:	• Full baseline and TASs for existing sites.
			• No baseline for new sites.
				Outcome:	Interim baseline for new sites (not robust enough to set a specific TAS above the baseline (i.e., 'improve' rather than A/B/C).	There is very little technical justification for relying on other TAS to manage this attribute as:
						• Baseline states can easily be calculated for existing sites and interim baselines can be calculated for new sites from the normal routine monitoring GW conduct (if ESci can establish sites).
						• Ultimately the water quality and periphyton attributes should be managed to achieve these invertebrate outcomes. Thus, it is important to set a TAS for macroinvertebrates to match the level at which the other TASs have been set (now and into the future).
							• Existing sites – Establish baseline from monitoring data (already done) and set TASs in PC1.
							• New sites:
							  ○ Do not set baselines or TASs in PC1 or only include narrative 'maintain' TASs without a baseline.
							  ○ Establish monitoring sites by July 2022 and conduct two years of macroinvertebrate monitoring.
							  ○ Calculate interim baseline from resulting data.
							  ○ Include baseline in 2024 PC and set narrative TASs ('maintain'/'improve').
								• Adopt recommended approach. Waiting for ESci to confirm capacity for new sites.

		Effort:	Negligible – Already monitored	Effort:	No additional effort beyond establishing new sites as invertebrate monitoring is part of ESci's routine monitoring protocols (whether establishing new sites is achievable will require discussions with ESci).			
		Start:	N/A	Start:	July 2022 at the latest to get two years of data at new sites.			

Deposited fine sediment (rivers)	Long-term monthly record at existing RSoE monitoring sites.	Outcome:	• Full baseline and TASs for existing sites.
			• No baseline for new sites .
				Outcome:	• Interim baseline for new sites (not robust enough to set a specific TAS above the baseline (i.e., 'improve' rather than A/B/C).	• There is some technical justification for relying on other TASs to manage this attribute as:
						  ○ Overall sediment input will be controlled by the visual clarity attribute and associated limits.
						  ○ Action planning for the macroinvertebrate attribute states will require some management of deposited fine sediment in many places.
						  ○ There is significant uncertainty around how changes in sediment load will affect deposited fine sediment cover and over what timeframe. Thus, the achievability of any TAS set above the baseline will be uncertain.
						• Nevertheless, assuming that ESci can establish the required additional sites, there will be baseline data available and sufficient information on the direction of change in sediment load to set a narrative 'maintain' or 'improve' TAS.
							• Existing sites – Establish baseline from monitoring data (already done) and
							  ○ Set TASs in TAoP at current.
							  ○ Set TASs in WTWT in accordance with WIP.
							• New sites:
							  ○ Do not set baselines or TASs in PC1 or only include narrative 'maintain' TASs without a baseline.
							  ○ Establish monitoring sites by July 2022 and conduct two years of sediment cover monitoring.
							  ○ Calculate interim baseline from resulting data.
							  ○ Include baseline in 2024 PC and set narrative TASs ('maintain'/'improve').
								• Adopt recommended approach. Waiting for ESci to confirm capacity for new sites.

		Effort:	Negligible – already monitored just not reported.	Effort:	No additional effort beyond establishing new sites as deposited sediment monitoring is part of ESci's routine monitoring protocols (whether establishing new sites is achievable will require discussions with ESci).			
		Start:	N/A.	Start:	July 2022 at the latest to get two years of data at new sites.			

Dissolved oxygen (rivers)	Limited data for a small number of sites in the Kapiti, Eastern Hills and Ruamāhanga Whaitua.	Outcome:	• Full baseline for sites in WTWT and TAoP.
			• No baseline for sites in other Whaitua.
				Outcome:	Full baseline for other sites	• There is a moderate technical justification for relying on other TAS/provisions to manage this attribute as:
						  ○ Factors that drive DO should be controlled via the periphyton attribute, environmental flows and wastewater rules (2a attribute applies which requires limits).
						  ○ In large parts of the region DO is unlikely to be a significant problem due to climate, hydrology and topography.
						  ○ Where DO is a problem (mainly low gradient streams) it will need to be managed (via action plans) to meet the macroinvertebrate TASs (i.e., not including it in the PC will not mean it will be ignored).
							• Conduct DO monitoring at relevant existing and new sites in WTWT and TAoP in 2022/2023 and include baseline states and TASs in PC1.
							• Conduct DO monitoring at relevant existing and new sites in the rest of the region in 2023/2024 and include baseline states and TASs in 2024 PC.
							• As this attribute can generally be managed through other TASs and plan provisions there is a strong justification for only monitoring and setting TASs for sites identified as high risk. Conducting widespread DO monitoring at all sites would be costly and time consuming and may be of less value than focusing monitoring efforts on new sites or other attributes such as F-IBI.
								• Adopt recommended approach pending ESci confirming capacity for additional monitoring stream and sites.

		Effort:	Moderate. • Would require the purchase/rental of >10 D-Opto probes. • Additional time (during monitoring run) would need to be spent at each site to install probe. • Each site would likely need to be revisited outside of routine monthly sampling for retrieval. • Data would need to be cleaned and processed.	Effort:	Moderate. • Would require the purchase/rental of >10 D-Opto probes. • Additional time (during monitoring run) would need to be spent at each site to install probe. • Each site would likely need to be revisited outside of routine monthly sampling for retrieval. • Data would need to be cleaned and processed.			
		Start:	Summer 2022	Start:	Summer 2023			

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Attribute	Existing data	Achievable outcome by 2023 PC		Achievable outcome by 2024 PC		Justification for management through other TAS, limits etc. (is there a need for TAS)	Recommended approach	PC1 Technical Teams recommended approach
Lake bottom dissolved oxygen (lakes)	No data to my knowledge	Outcome:	Unlikely to be able to assign a baseline or TASs to any lakes.	Outcome:	Short baseline data series for all lakes likely to be identified in the NRP.	There is a strong justification for relying on other TAS/provisions to manage this attribute as it is designed to control nutrient release from bed sediments. Thus, there is a large amount of cross over with the nutrient attributes (one controls the process, the others controls the outcome).	• Do not attempt to define a baseline state at 2024 PC and only set TAS at 'maintain' and the bottom-line. • Monitoring this attribute requires significant work and targeted management may only be necessary in the future if external nutrient load control proves unsuccessful at achieving nutrient and/or phytoplankton TASs. • This needs to be discussed with a lake expert and will need to have a strong policy justification.	• Adopt recommended approach with some caveats: ○ Policy to determine whether inclusion needed in PC1 for Parangārehu Lakes (avoid re-visiting WTWT and TAoP chapters in 2024). ○ ESci would like to revisit possibility of monitoring. If his team have capacity, we can change. ○ Approach lake expert to review justification about attribute redundancy .
		Effort:	N/A.	Effort:	Very large – Would require a new monthly lake monitoring programme (new sites even in Wairarapa and Onoke) or installation of a number of fixed monitoring stations.			
		Start:	N/A.	Start:	July 2022 to get two years of data.			
Mid-hypolimnetic dissolved oxygen (seasonally stratifying lakes)	No data to my knowledge.	Outcome:	Unlikely to be able to assign a baseline or TASs to any lakes.	Outcome:	Short baseline data series for all seasonally stratified lakes likely to be identified in the NRP.	There may be some technical justification for relying on other TAS/provisions to manage this attribute as I assume hypolimnion oxygen will be driven by primary production (managed by LakeSPI and phytoplankton attributes). However, this should be checked with a lake expert.	• Check with a lake expert regarding whether this attribute is already managed by LakeSPI and phytoplankton attribute. If it is do not attempt to define a baseline state at 2024 PC and only set TAS at 'maintain' or the bottom-line. • If the lake expert things this attribute is not sufficiently managed by the LakeSPI, and phytoplankton attributes then progress with plan to establish new monitoring programme for seasonally stratified lakes likely to be identified in the NRP.	• Adopt recommended approach with some caveats: ○ Policy to determine whether inclusion needed in PC1 for Parangārehu Lakes (avoid re-visiting WTWT and TAoP chapters in 2024). ○ ESci would like to revisit possibility of monitoring. If this team have capacity, we can change. • Approach lake expert to review justification about attribute redundancy.
		Effort:	N/A.	Effort:	Very large – Would require a new monthly lake monitoring programme or installation of a number of fixed monitoring stations.			
		Start:	N/A.	Start:	July 2022 to get two years of data.			
Dissolved reactive phosphorus	Long-term monthly record at existing RSoE monitoring sites	Outcome:	• Full baseline and TASs for existing sites. • No measured baseline for new sites (could use modelled results for TAoP sites).	Outcome:	Interim baseline for new sites (not robust enough to set a specific TAS above the baseline (i.e., 'improve' rather than A/B/C).	There is limited technical justification to rely on other TAS to manage this attribute as: • Baseline states can easily be calculated for existing sites and interim baselines can be calculated for new sites from the normal routine monitoring GW conduct (if ESci can establish sites). • Nutrient exceedance criteria need to be set for this attribute regardless of where TASs are included in the NRP.	• Existing sites – Establish baseline from monitoring data (already done) and set TASs. • New sites: ○ Do not set baselines or TASs in PC1 or only include narrative 'maintain' TASs without a baseline. ○ Establish monitoring sites by July 2022 and conduct two years of routine monitoring. ○ Calculate interim baseline from resulting data. ○ Include baseline in 2024 PC and set narrative TASs ('maintain'/'improve').	• Adopt recommended approach pending ESci confirming capacity for additional sites.
		Effort:	Negligible – already monitored.	Effort:	No additional effort beyond establishing new sites as DRP is part of ESci's routine monitoring protocols (whether establishing new sites is achievable will require discussions with ESci).			
		Start:	N/A	Start:	July 2022 at the latest to get two years of data at new sites			
Ecosystem metabolism (both gross primary production and ecosystem respiration) (rivers)	None.	Outcome:	• Full baseline for sites in WTWT and TAoP • No baseline for sites in other Whaitua.	Outcome:	Full baseline for other sites.	• There is a strong technical justification for relying on other TAS/provisions to manage this attribute as: ○ Factors that drive ecosystem metabolism should be partially managed via nutrient exceedance criteria, the periphyton and DO attributes, and wastewater rules. ○ There are no attribute state thresholds in the NPS-FM.	• Calculate for DO sites in WTWT and TAoP in 2022/2023 and include baseline (as measured value) and TASs (narrative 'maintain') in PC1. • Calculate for DO sites in the rest of the region in 2023/2024 and include baseline (as measured value) and TASs (narrative 'maintain') in 2024 PC. • There seems to be a strong justification for only monitoring and setting TASs for sites identified as high risk for DO. Conducting widespread monitoring at all sites would be costly and reasonably time consuming and may be of less value than focusing monitoring efforts on new sites or other attributes such as F-IBI.	• Adopt recommended approach pending ESci confirming capacity for additional monitoring stream and sites
		Effort:	Same as DO.	Effort:	Same as DO.			
		Start:	Summer 2022.	Start:	Summer 2023.			

4.1 Potential methods for setting TASs for fish

The NPS-FM 2020 includes the F-IBI as a compulsory attribute in Appendix 2B. However, there are several technical issues that makes setting site specific TASs for fish difficult at the current time, especially ones that are consistent with the NPS-FM 2020 attribute states. These issues and potential options for addressing them are set out in Section 4.1.1 to 4.1.5 below.

4.1.1 Issues with NPS-FM 2020 F-IBI attribute and the F-IBI in general

4.1.1.1 Lack of clarity regarding how the NPS-FM 2020 attribute state thresholds have been selected

The *Science Technical Freshwater Science and Technical Advisory Group (STAG) Report to the Minister for the Environment* (STAG, 2019), which originally proposed the NPS-FM 2020 fish attribute, contains no information on how the attribute state thresholds for F-IBI were determined, as such their relevance to the Wellington Region is unclear. Compared to most other regions, the average F-IBI in Wellington is high (40 – 50 (MfE, 2019)). As such the applicability of the attribute state framework that sets the most stringent threshold at 35 is questionable. It also means that the fish attribute state framework in the TAoP WIP is unlikely to align well with the NPS-FM 2020 attribute states.

The STAG themselves noted these issues with their proposed attribute state framework:

- *"Some members note that we do not understand the scale of natural variation, how to take this into account and question whether some degree of region-specific modification may be required"* (STAG, 2019)*; and*
- *"Some members register concerns regarding the proposal to introduce Fish IBI into the NOF as an attribute, owing to [] the need for more detailed and independent evaluation of the methodology and rationale used to derive the proposed numeric attribute states for the fish IBI"* (STAG, 2020).

4.1.1.2 Lack of clarity regarding how the F-IBI used in the NPS-FM is supposed to be calculated

Several national F-IBI score calculations exist, including:

- Joy and Death (2004); and
- MfE (2019).

However, their relevance to the NPS-FM 2020 attribute states is unclear. While the attribute state table itself notes "*the F-IBI score is to be calculated using the general method defined by Joy, MK, and Death RG. 2004*", this is not overly helpful due to the ambiguity introduced by the word "general". Furthermore, while the STAG suggests the attribute states should be assessed using Joy and Death (2004) (with Salmonids excluded) they also note that the "*Fish IBI would need to be standardised in a national model" and that this "may change the results gained from current programmes*".

What makes this noteworthy is that it suggests that the NPS-FM 2020 attribute states may have been determined based on F-IBI scores that were calculated in a manner that is different from how regional councils will ultimately be expected to benchmark their data against the attribute state thresholds. It must be noted, however, that this may be the case regardless, as salmonids appear to have been excluded from the F-IBI when the STAG were considering the attribute state thresholds, but the NPS-FM makes no reference to this method.

The MfE website suggests that a National F-IBI calculator is being developed and will be available in mid-2022. Hopefully at that point it will become clear whether the NPS-FM 2020 IBI attribute states are appropriate for use in the Wellington Region, or whether some degree of modification will be needed.

Note: This memorandum was first published prior to the release of the national F-IBI calculator on the MfE website.

4.1.1.3 Lack of baseline data

To my knowledge the TAS sites identified in Nation and Blyth (2022) have not been fished using the Joy *et al.* (2013) methods (as stipulated in the NPS-FM 2020). As such, it is not possible to calculate a baseline F-IBI state for these sites (noting that how F-IBI should be calculated is still unclear). Furthermore, attempting to assign a baseline state from data collected from a nearby proxy site would be inappropriate.

The F-IBI at a site is influenced by factors such as general habitat characteristics of the fished reach, specifically, the occurrence of pools and riffles, and the presence of fish passage barriers. Thus, one would need to be confident that a proposed proxy site was similar to the TAS site in this regard before using it to assign a baseline state. Even then, there would be significant uncertainty around the resulting assessments. An example is provided below in Figure 1. From that aerial photograph the differences in habitat in a 150-metre fishing reach in the Wainuiomata River at the Manuka Track monitoring site and the closest fished site downstream are clearly visible. The lack of riffles and pools at the later site means that F-IBI could be significantly different from at the upstream monitoring site despite how close they are.

Another complication is the lack of directly transferable proxy data. While MfE (2019) provides a F-IBI score for all sites fished between 1998 and 2018, the F-IBI has been calculated differently to that prescribed by the NPS-FM 2020. We are also unable to conduct our own benchmarking against the NPS-FM 2020 attribute states using data from the New Zealand Freshwater Fish Database (NZFFD) due to the lack of certainty around the NPS-FM 2020 F-IBI calculation methodology

4.1.1.4 The F-IBI is unlikely to adequately capture the Committees' desires for improvement in fish community health

The F-IBI is a presence absence metric that responds strongly to only one component of fish community health, diversity; for the F-IBI to change at a site, a species must be introduced or extirpated.

Certain actions, such as removing fish passage barriers and naturalising modified waterways, can improve F-IBI at a site by allowing the recolonisation of previously inaccessible or uninhabited reaches. However, while managing discharges, controlling works on the bed and conducting restoration works can improve the structure and composition of the resident fish community, the impact on diversity is likely to be limited in many cases. The migratory nature of many native fish species facilitates the constant colonisation of most rivers and streams, even where they provide poor habitat and have degraded water quality. Thus, the F-IBI at a site may not respond to changes in water quality and habitat despite the abundance and health of certain resident species improving (i.e., all species that the river can support were already there prior to implementing the mitigations just in a poorer state).

It must also be noted that in some rivers and streams a low F-IBI score may not be a symptom of land-use, discharges or water takes. Rather they may be the result of a wider species conservation issues or the presence of an invasive species, both of which are hard to manage through a regional plan and may be covered by legislation other than the Resource Management Act ('the RMA').

Figure 1: Aerial photograph demonstrating the differences in pool and riffle habitat in 150 metre fishing reaches (blue lines) in the Wainuiomata River at the Manuka Track monitoring site (top) and the closest fished site downstream (bottom).

4.1.1.5 The F-IBI does not cover key components of fish community health.

The F-IBI responds to changes in diversity, it is not sensitive to other important aspects of fish community health such as abundance, structure and composition. While harder to quantify, these factors are more likely to respond to regulation and mitigation actions than diversity. For example, removing a fish passage barrier constructed in the last ten years might not change the diversity of a fish community dominated by long-lived migratory species. However, it might result in additional recruitment and, consequently, affect abundance and size class distribution. Such improvements would not be detectable from the F-IBI.

4.1.2 Options for using existing regional information for setting TASs for fish

4.1.2.1 General issues of using the Wellington F-IBI

A Wellington specific F-IBI has been developed by Joy and Henderson (2004) and is used in Objective O19 of the operative NRP. However, using the regional F-IBI to set or benchmark TASs has some technical and policy pitfalls:

- The Wellington F-IBI framework is the better part of 20 years old. Thus, it is not informed by the latest fishing data (minor issue);
- As mentioned in Section 4.1.1.1 , on average F-IBI scores are higher Wellington rivers than in many other regions. As such the Wellington specific thresholds do not align with those in the NPS-FM 2020 (see Table 14 below);
- There are also other potential reasons why the NPS-FM 2020 and Wellington attribute state thresholds do not align:
    - The NPS-FM 2020 adopts a four-band attribute state framework, while the Wellington system originally adopted a seven-band approach. These seven bands were then reduced to four through the NRP appeals process by merging the two top categories into the A band and the three bottom categories into the D band. It is unclear what the thresholds would have been, or how they would have differed from the NPS-FM 2020, if Joy and Henderson (2004) had originally created a four band framework comparable to that in the NPS-FM 2020; and
    - The national F-IBI calculator may simply generate lower values than the regional IBI calculator from the same fish data. As such it is possible that when Wellington fish data are analysed using an appropriate national F-IBI calculator the NPS-FM 2020 attribute state thresholds will prove to be accurate descriptors of the state of fish communities in the region. However, it must be noted that initial analysis conducted by GW suggests that this is unlikely to be the case, and that the national F-IBI calculator may generate higher values than the regional version (Figure 2).
- It is unclear whether the lack of alignment between the NPS-FM 2020 attribute state thresholds and the Wellington specific thresholds poses a significant problem should the latter be used to set target TASs as they are more stringent than the national version. However, it is apparent that benchmarking against any F-IBI thresholds should be done using the F-IBI calculator that informed the development of said thresholds. Thus, if the Wellington F-IBI thresholds are adopted in the NRP then benchmarking should be conducted using just the Wellington F-IBI calculator. As such, the primary risk of using the Wellington F-IBI thresholds comes from the potential for future central government directions stipulating a specific national F-IBI calculator that regional councils are to use when reporting.
- Should the regional F-IBI be used to set TASs, there would still be a lack of data for some TAS sites.

Table 14: Comparison of the NPS-FM 2020 and Wellington F-IBI thresholds.

Attribute band	NPS-FM 2020 threshold	Wellington thresholds used in NRP
A	≥34	≥48
B	<34 and ≥28	<48 and ≥38
C	<28 and ≥18	<38 and ≥30
D	<18	<30

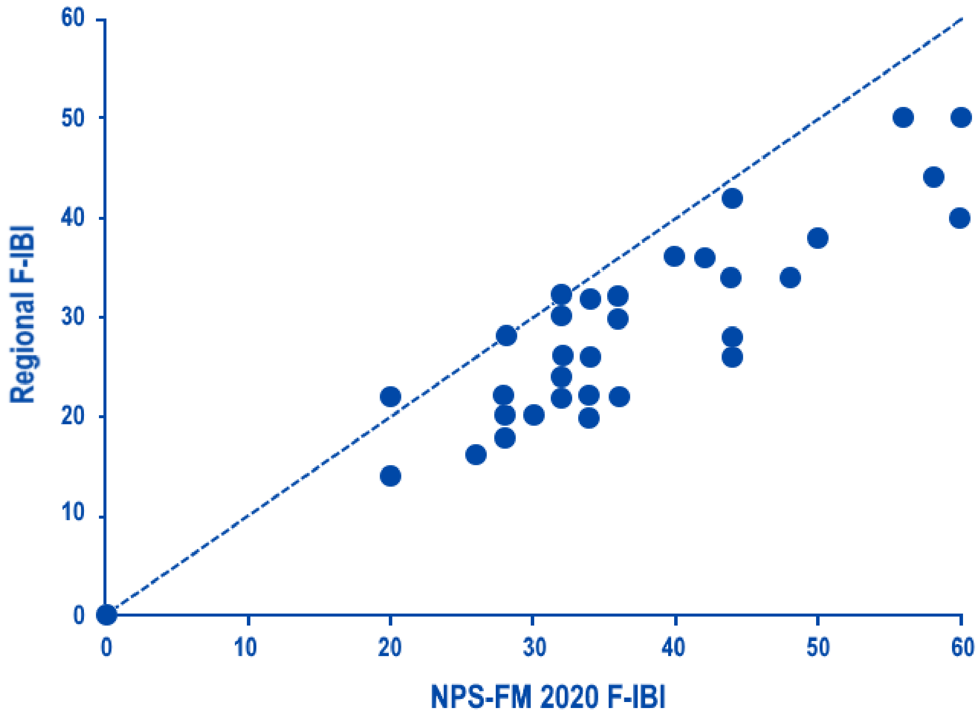

Figure 2: Comparisons of Wellington F-IBI vs draft National F-IBI scores calculated from the same data.

4.1.2.2 Option to use the F-IBI scores in Objective O19 of the NRP as TASs

One option for using the regional F-IBI in the absence of baseline state data for the TAS sites is to adopt the NRP O19 F-IBI thresholds. In additional to the general short comings of adopting the regional F-IBI (see above) the main issue with adopting such an approach is that it is designed to achieve a blanket 'good' level of ecosystem health (i.e., B state) in most rivers and an 'excellent' level of ecosystem health (A state) in Class 1 rivers and rivers with high macroinvertebrate community health. As such they do not factor in any variability in current state between sites (should it exist), or what is achievable based on the target states of related attributes.

4.1.2.3 Option to use the regional F-IBI thresholds and regional calculator to assign relevant TASs for sites

While there are technical issues with the regional F-IBI in terms of its age and how the attribute state thresholds have been calculated, there are benefits in adopting this approach as it could potentially bypass the issues with the National F-IBI framework described above in Sections 4.1.1.1 and 4.1.1.2 in that:

- We know how the F-IBI thresholds have been developed;
- We have a way to calculate the F-IBI and benchmark it against the thresholds; and
- We know that the F-IBI thresholds are relevant to the Wellington Region.

However, as mentioned in Section 4.1.2.1 , the primary risk of adopting such an approach is that central government may, in the future, require F-IBI to be assessed using a national metric which is unlikely to correspond well to the Wellington F-IBI thresholds. This could result in a reporting headache in which F-IBI changes due to shifts in calculation method rather than an actual change in fish community health.

4.1.2.4 Option to use the NPS-FM 2020 F-IBI thresholds and the regional F-IBI calculator to assign TASs

As previously mentioned, this approach is unlikely to work. It is clear from the attribute state thresholds and work conducted by GW that there is a risk that the regional and national F-IBIs do not align well. Accordingly, mixing and matching metrics and thresholds is not appropriate.

4.1.3 Recommended approach for setting F-IBI attribute states

4.1.3.1 Options for TAoP

1. Define current state using the selected F-IBI (Wellington or national) and set the TASs based on the desired improvements signalled in the WIP (see Table 15 for example). This is unlikely to be appropriate as the WIP uses a narrative approach for fish with attribute states that do not align with the Wellington or national F-IBI thresholds. The WIP narrative attributes encompass a range population characteristics which may be more sensitive to regulation and mitigation than the F-IBI. As such, the potential for improvements in this subjective attribute may be far greater than for F-IBI.
2. Define current state using the selected F-IBI (Wellington or national) and set the TASs at current. This is a defensible approach and reflects the uncertainty around GW's ability to have a material impact on fish presence-absence in many waterways. It can also be supported by the WTWT Biophysical Science Programme (BSP) Freshwater Quality and Ecology Expert Panel (hereafter referred to as 'the Freshwater Panel') outputs.
3. Define current state using the selected F-IBI (Wellington or national) and undertake an expert panel assessment of the regulatory actions recommended in the WIP to assess their likely effect on F-IBI. Based on the Freshwater Panel outputs (Greer *et al.*, 2022). this will likely show that current state is the most appropriate TAS. Limited benefit over Option 2 (Greer *et al.*, 2022).

4.1.3.2 Options for WTWT

1. Define current state using the selected F-IBI (Wellington or national) and set TASs based on the desired improvements signalled in the WIP. This is unlikely to be defensible as the WIP

TASs in many areas represent an improvement which is in direct conflict with the Freshwater Panel outputs.

2. Define current state using the selected F-IBI (Wellington or national) and set the TASs at current at all time steps. This is a defensible approach and reflects the uncertainty around GW's ability to have a material impact on fish presence-absence in many water ways. It can also be supported by the WTWT BSP Freshwater Panel outputs (Greer *et al.*, 2022).

4.1.4 Incorporating a narrative attribute to account for other aspects of fish health

As stated in Section 4.1.1.5 the F-IBI only responds to changes in diversity, it is not sensitive to other important aspects of fish community health such as abundance, structure and composition. As such, adopting a narrative attribute approach that captures these components of fish community health in addition to implementing an F-IBI attribute state would best capture the intent of the TAoP WIP. However, I do not consider that the narrative attribute states in that WIP are appropriate as, despite being relatable to the lay person:

- They do not define the specific components of fish community health to be measured;
- The terminology used is inconsistent between attribute states. I.e.:
    - A = Typical of undisturbed;
    - B = Low stress;
    - C = Moderate stress; and
    - D = Large changes.
- Some of the key assessment categories referenced are likely to remain difficult to benchmark against for the foreseeable future:
    - When assessing against the A state it is unclear how one would define what is typical of the reference condition for that stream type. While there are (poor performing) presence-absence models, we are a long way off being able to define reference state abundance, composition or structure for a given stream: and
    - When assessing against the B and C attribute states it is difficult to determine what a low or moderate level of stress would be in the absence of specific stress index (which is not forthcoming).

Instead, it is my opinion that adapting the O19 narrative fish objectives into a four-band framework would be more appropriate for the following reasons:

- The O19 narrative fish objective was conferenced on, mediated, and agreed to during the NRP appeals;
- The excellent-good-fair-poor scale set out in Table 15 is widely used when setting environmental guidelines and corresponds well to A-B-C-D attribute state framework in the NPS-FM 2020. Thus, while the various components of the recommended narrative cannot currently be benchmarked against the prescribed level of ecosystem health, the wording allows for the adoption of any future relevant community health indices provided they are graded in the four-category scale that has become ubiquitous in ecosystem health metrics; and

- While it is not possible to benchmark the various components of the narrative against the prescribed level of ecosystem health, they are all currently measurable. Thus, any direction of change can be assessed and reported on. This is a key difference between this framework and the narrative attribute states in the TAoP WIP.

In terms of selecting the level at which the narrative TASs is set, there is two defensible options:

- Set it to reflect the Q/MCI objective (preferred), which should in turn reflect the likely outcome of meeting the water quality, habitat and periphyton attribute states (in the absence of any fish passage issues); or If the F-IBI attribute states are set to maintain current state due to the uncertainty around GW's ability to effect change in this metric, then the narrative attribute state could be set at the same level. However, this could well be questioned because managing water quality, periphyton and habitat to achieve an improving Q/MCI TASs would be expected to translate into an improvement in fish community structure and composition regardless of whether new species move into the site or not.

Table 15: Potential fish community health narrative attribute.

Value	Ecosystem health (Aquatic life)
Freshwater body type	Rivers
Attribute unit	N/A
Attribute band	Attribute description
A	The abundance, structure and composition of fish communities are reflective of an excellent state of aquatic ecosystem health
B	The abundance, structure and composition of fish communities are reflective of a good state of aquatic ecosystem health
C	The abundance, structure and composition of fish communities are reflective of a fair state of aquatic ecosystem health
D	The abundance, structure and composition of fish communities are reflective of a poor state of aquatic ecosystem health

4.1.5 Final summary of possible approaches to setting TASs for fish

1. Select which F-IBI to use based on the risks:
    a. Wellington F-IBI – We already know how the F-IBI thresholds have been developed, we have a way to calculate the F-IBI and benchmark it against the thresholds and we know that the F-IBI thresholds are relevant to the Wellington Region. The major risk is that if we adopt it and central government direction requires benchmarking using a national F-IBI these would not align with the Wellington thresholds.
    b. National F-IBI (preferred) – In theory there is a low risk of a national F-IBI being required that does not align with the NPS-FM 2020 attribute (although there is some uncertainty around this now). However, there are some questions around the applicability of the F- IBI thresholds to the Wellington Region and this will remain the case until the national F-IBI calculator is released (in the next few months).
2. Define current state using the selected F-IBI (preferably national) and set the TASs at current. This is a defensible approach and reflects the uncertainty around GW's ability to

have a material impact on presence-absence in many water ways. It can be supported by the WTWT BSP Freshwater Panel outputs (Greer *et al.*, 2022).

3. Adapt the O19 narrative fish attribute into a four-band framework and set the TASs to reflect the Q/MCI TASs (preferred), which should in turn reflect the likely outcome of meeting the water quality, habitat and periphyton attribute states.

Notes:

- *The recommended approach above was discussed in the PC1 TAG meetings held on the 02/05/2022 and the 16/05/2022. The TAG agreed that the approach was reasonable (Table 13):*
- *For WTWT, GW have not accepted the TAGS recommendation to set F-IBI TASs at baseline state and have instead adopted the WIP TASs (added by Michael Greer September 2023).*

4.1.6 Additional note on sites

The TAG discussed what flexibility there is around F-IBI TAS sites, given that the water quality sites may not be fit for this purpose. They considered that for the F-IBI TASs a site be a reach between two points or even a stream. One way to implement this in the plan change process could be through a footnote to the relevant table (see Table 16 for a rough example).

Table 16: Example for incorporating date flexibility for fish into a TAS table.

	NH_4-N toxicity		NO_3-N toxicity		F IBI[2]	
Site[1]	Baseline state	TAS	Baseline state	TAS	Baseline state	TAS
River @ location	B	A	A	A	Unknown	Maintain or improve
River @ location	B	A	A	A	Unknown	Maintain or improve
River @ location	B	A	A	A	Unknown	Maintain or improve

[1] Applies to all attributes except F-IBI, which may be assessed at different sites on the rivers identified in this column.
[2] The Regional Council will:
(i) Identify the representative sites at which progress towards the F-IBI TASs will be monitored on the main stems of the rivers listed in Table XX; and
(ii) Keep a record of the locations of representative monitoring sites in an action plan developed in accordance with Method MXX.

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5 Habitat attribute review

First published: 13/07/2022

To: Plan Change 1 Policy and Technical Team
Greater Wellington

The NPS-FM 2020 identifies habitat as one of the five biophysical components of aquatic ecosystem health. Accordingly, the NPS-FM 2020 notes that it is necessary to manage habitat (Appendix 1A(1) and (3)) and treat it as a value (3.9(1)). That raises the following questions:

- Do the existing compulsory attributes already manage habitat?
- Are there multi-metric habitat attributes that targets could be set for?
- Are there individual habitat attributes that targets could be set for?

5.1 Relevance of existing attributes to habitat management

How the existing compulsory attributes relate to the management of habitat are set out below in Table 17.

Table 17: How the existing NPS-FM 2020 attributes relate to habitat.

Attribute	How it provides for habitat
Deposited sediment	Deposited sediment cover is a key component of aquatic habitat quality. Setting TASs for this attribute ensures that deposited cover does not degrade habitat quality and that the bed is composed of substrates that provide a diversity of habitats (including those in the hyporheic zone)
Fish	The health and functioning of fish communities is heavily impacted by the diversity, quality, and quantity of habitat available. Thus, meeting the fish TASs will require that habitat is managed.
Macroinvertebrates	EPT taxa have a significant influence over all macroinvertebrate indices for which TAS must be set. This is by historical design as they are the most sensitive taxa to organic pollution (which the MCI was developed for). However, these taxa also favour undisturbed, structurally complex habitat such as gravely-cobbly riffles clear of filamentous algae/macrophytes. As such, achieving the macroinvertebrate TASs will require some protection or enhancement of benthic habitat
Periphyton	Nuisance blooms of periphyton smother benthic habitat used by invertebrates and fish. As such, managing periphyton to the biomass TASs will influence benthic habitat quality and quantity.

5.2 Applicability of existing multimeric indicators

A description and an assessment of the strength and weaknesses of the existing multimeric indicators that could be used to set TASs for habitat are provided in Table 18.

5.3 Potential individual habitat attributes that targets could be set for

There are many habitat metrics that GW could measure, set a baseline state for, and assign a ‘maintain or improve’ type TAS for (specifically, all the individual components of the Rapid Habitat Score (RHS), Rabid Habitat Pressure Score (RHPS), Stream ecological valuation (SEV) and Habitat Quality Index (HQI). However, to my knowledge, of these attributes only macrophyte volume has a (somewhat) defensible effects-based guideline value that can be relied upon. The guideline, which is from Matheson *et al.* (2012) is 50% volume/CAV and is already included in O19 of the NRP.

5.4 Recommended approach to managing habitat

In my opinion setting specific TASs for habitat in PC1 is not necessary as:

- Meeting the targets for existing compulsory attributes will:
  - Manage some specific components of habitat; and
  - Require habitat generally to be managed to achieve ecological outcomes.
- The existing multimeric habitat metrics are generally not fit for this purpose and a lack of relevant guideline values means that attribute state thresholds cannot be defined for most of the individual habitat metrics that are not currently included in Appendix 2 of the NPS-FM 2020.

Note: The recommended approach above was discussed in the PC1 TAG meeting on the 13/06/2022. The TAG agreed that the approach was reasonable.

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Table 18: Potential multimeric habitat indices that could be used as TASs in PC1.

Attribute	Source	Description	Specific attributes considered	Existing grading system?	Pros	Cons
RHS	Clapcott (2015)	• Provides a 'habitat quality score' for a river reach which indicates general stream habitat condition for the physical aspect, such as the structure of the stream banks or the nature of the stream bed. • Developed to help with national standardisation of stream habitat assessment. • Involves scoring 10 attributes on a scale of 1 – 10 and taking the sum. Observed score can be compared to the average score from reference site(s) to provide a HQS % assessment	• Deposited sediment • Invertebrate habitat diversity • Invertebrate habitat abundance • Fish habitat diversity • Fish habitat abundance • Hydraulic heterogeneity • Bank erosion • Bank vegetation • Riparian width • Riparian shade	Yes, from Clapcott *et al.* (2020) A = >75 B = >50 - ≤ 75 C = >25 - ≤ 50 D = ≤ 25	• Established and widely used. • Monitored by GW (i.e., there is existing data and no extra monitoring burden). • Fast and cheap to do, new sites could be scored quickly. • Has existing national grading system that has previously been used in national reporting.	• Generally, only supposed to apply to hard-bottomed wadable streams and is poor at accounting for natural variability in deposited sediment cover. Clapcott *et al.* (2020) recommends scoring deposited sediment as a deviation from reference state but does not provide an updated scoring system to do this. • Applicability of national guidelines to Wellington untested. • Scoring system somewhat subjective.
RHPS	Holmes *et al.* (2020)	• Complements the RHS, but where the RHS measures the state of habitat, the RHPS assesses the degree of habitat modification and potential pressures such as instream or bank engineering. As such, it provides an indication of the whether a site is at risk of degradation rather than a measure of how degraded that site is. • Involves scoring 12 river pressure attributes on a scale of 1 – 10 and taking the sum.	• Nuisance benthic algae • Nuisance aquatic macrophytes • Instream structures (structures below the base flow waterline) • Instream disturbance • Discharges and drains • Introduced riparian plants occurring at nuisance levels • Bank modification • Livestock riparian disturbance • Human riparian disturbance • Occurrence of rubbish in the stream and riparian area • Surrounding land use and flood plain modification • Flood plain constraints	No	• Provides an indication of future risk from activities by the plan change (i.e., may be more directly impacted by provisions than RHS which is more impacted by factors outside of human control). • Is similar to the RHS in terms of monitoring effort.	• Is still in draft (untested). • Attribute state thresholds have not been developed. • Scoring system somewhat subjective. • Current state is unknown.
SEV Fish spawning habitat and Habitat for aquatic fauna function scores	Storey *et al.* (2011)	• Developed to assess physical habitat quality in Auckland's urban streams but now used extensively in Wellington for consenting purposes. • Combines measurements and visual assessment of 29 variables, to calculate a scores for 14 ecological functions including fish spawning habitat and habitat for aquatic fauna.	Too long to list	No	• There is a lot of data for the Wellington Region. • The SEV is a well-established and generally accepted measure of stream health.	• Not currently monitored by GW. • Using the individual habitat function scores of the SEV is not standard procedure. • No existing attribute state thresholds (exist for individual variables but are inconsistent and given different weightings). • Intensive to monitor compared to the RHS.
HQI	Death *et al* (n.d.).	The HQI provides an assessment of the relative change in selected geomorphic characteristics and habitat quality from reference condition (or some other pre-defined time-step. It is calculated by determining the ratio between a river's current geomorphological characteristics and the appropriate historical condition.	• Sinuosity • Active channel • Bank full channel • Permitted Floodplain • Braiding Index • Pools • Thalweg length	No	• Can be done as a desktop exercise • Provides an indication of large-scale habitat changes caused by activities such as river engineering • Was developed for Wellington	• Only considers geomorphology. Thus, does not capture key components of aquatic habitat such as cover. • Attribute state thresholds have not been developed. • May not be possible to measure for all sites, especially where those with a canopy or where there is dearth of historical aerial photographs. • Generally, captures the effects of one or two activities (urban channel modification and flood protection).

6 Recommended nutrient outcomes for sites in PC1 based on national guidance

First published: 28/03/2023

To: Plan Change 1 Policy and Technical Team
Greater Wellington Regional Council

6.1 Introduction

The NPS-FM 2020 (amended February 2023) requires regional councils to:

- Set appropriate instream concentrations and exceedance criteria, or instream loads, for nitrogen and phosphorus (nutrient outcomes (NOs)).
- Identify limits on resource use that will achieve any nutrient outcomes.

On that basis NOs effectively act as NPS-FM 2020 Appendix 2A attributes. However, unlike Appendix 2A attributes, the NPS-FM 2020 does not define a state framework from which NOs can be selected. Instead, Clause 3.13 requires regional councils to define their own NOs in accordance with the following:

- To achieve a target attribute state for any nutrient attribute, and any attribute affected by nutrients, every regional council must, at a minimum, set appropriate instream concentrations and exceedance criteria, or instream loads, for nitrogen and phosphorus (examples of attributes affected by nutrients include periphyton, dissolved oxygen, submerged plants, fish, macroinvertebrates, and ecosystem metabolism).
- Where there are nutrient-sensitive downstream receiving environments, the instream concentrations and exceedance criteria, or the instream loads, for nitrogen and phosphorus for the upstream contributing water bodies must be set so as to achieve the environmental outcomes sought for the nutrient-sensitive downstream receiving environments.
- In setting instream concentrations and exceedance criteria, or instream loads, for nitrogen and phosphorus under this clause, the regional council must determine the most appropriate form(s) of nitrogen and phosphorus to be managed for the receiving environment.

This memorandum provides recommendations on how to set NOs for TAoP Whaitua and WTWT in accordance with Clause 3.13 of the NPS-FM 2020 based on the best available national guidance (all guidance released post the 2023 amendments to the NPS-FM 2020).

6.2 Available guidance

6.2.1 Framework

The most comprehensive national guidance on how regional councils should develop NOs comes from MfE (2022a). This document is focused on how regional councils should set instream concentrations thresholds (ICTs) as NOs. To do that, it first describes the relationship between the nutrients and the various attributes in Appendix 2 of the NPS-FM 2020 (Figure 3). It then sets out a framework for navigating the difficult decisions regional councils will face when setting NOs based on the PrOACT framework for smart decision-making:

1. **P**roblem: Define the decision problem carefully so the right problem will be solved. Section 1 of this guidance presents the problem to be solved.
2. **O**bjectives: Clearly define and differentiate fundamental and means objectives (aims in this case) that must be met to solve the problem.
3. **A**lternatives: As far as practicable, present the full range of alternative strategies for meeting the fundamental aims. This is critical as it frames the entire approach to solving the problem, ensuring the choices available to decision-makers are preserved.
4. **C**onsequences: Describe how well the alternative strategies enable the fundamental aims to be met.
5. **T**rade-offs: Balance the pros and cons of the alternative strategies that can be chosen to meet the fundamental aims.

As part of that framework, the MfE (2022a) guidance defines the Fundamental Aims and Means Aims of ICTs, against which various NOs development strategies can be assessed. These are presented below and in Figure 3:

- **Fundamental Aim (FA) 1** is to establish a set of ICTs that protects the target states of all nutrient-affected attributes within regions.
- **Fundamental Aim (FA) 2** is to minimise the cost to councils of setting ICTs for nutrient-affected attributes.
- FA1 means aims
    - **Means Aims (MA) 1–8** are to define dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) ICTs that allow councils to meet the target states for each of the following attributes:
    - Chl a (MA1)
    - MCI (MA2)
    - QMCI (MA3)
    - ASPM (MA4)
    - F-IBI (MA5)
    - DO (MA6)
    - GPP (MA7)
    - ER (MA8).
- FA2 means aims
    - **Means Aim 9** is to minimise the number of attribute-specific ICTs required by councils.
    - **Means Aim 10** is to minimise unnecessary data analyses employed to derive ICTs.
    - **Means Aim 11** is to minimise the duplication of effort.
    - **Means Aim 12** is to minimise unnecessary collection of data.

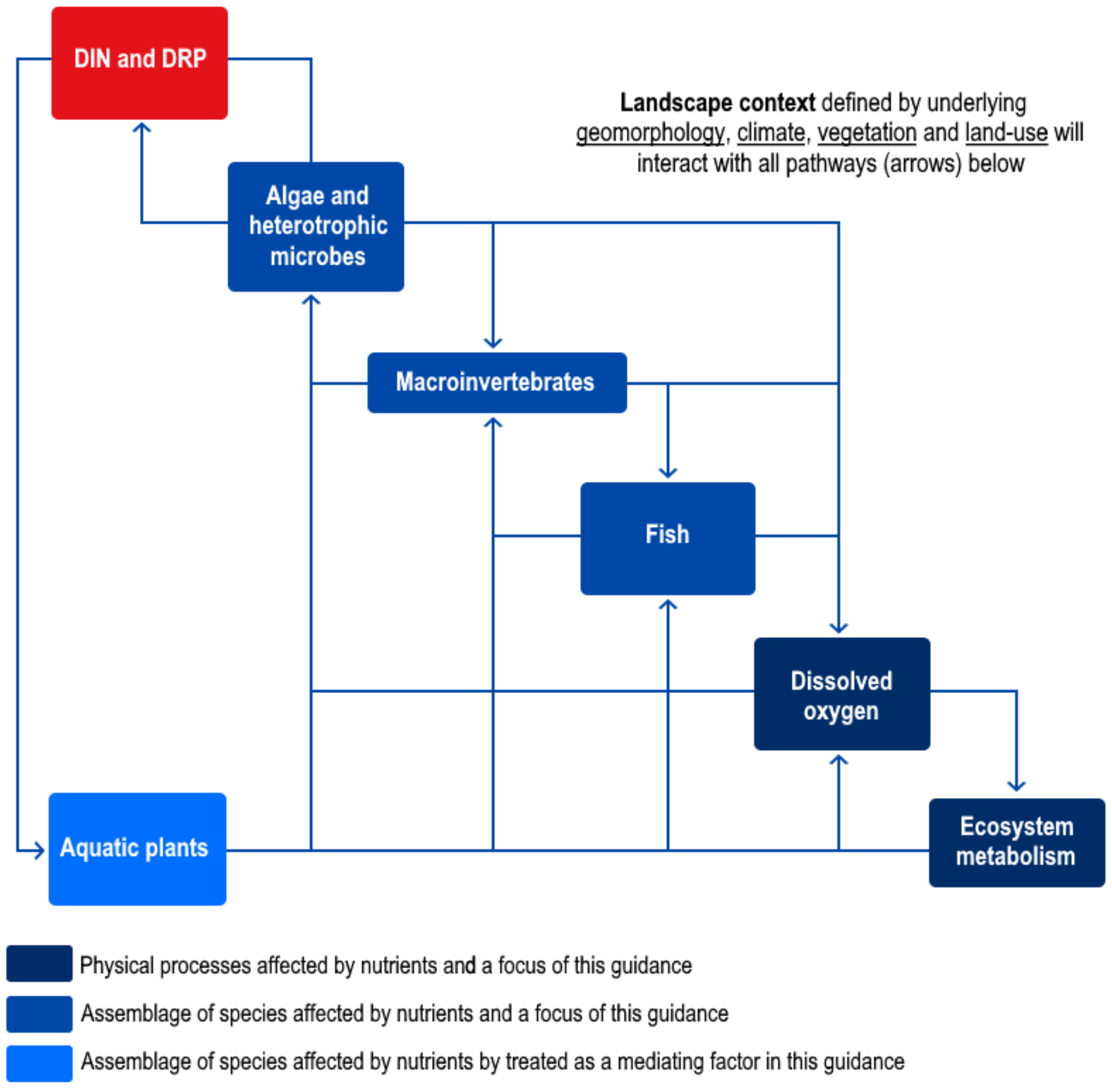

Figure 3: Simple conceptual model summarising the primary links between nutrients and the constituents of river ecosystems. Re-created from MfE (2022a) (Figure 2-1).

6.2.2 Possible strategies for developing nutrient outcomes

MfE (2022a) propose four possible strategies that regional councils could use to set NOs. These are set out in Table 19. How each of these strategies achieve the various Fundamental Aims and Means Aims identified in MfE (2022a) are set out in Figure 4.

Table 19: Description of the four strategies proposed in MfE (2022a) for setting NOs.

Strategy	Summary
Strategy 1: Use ICTs that have already been developed for a nutrient-affected attribute	Implementing Strategy 1 involves obtaining peer-reviewed, published ICTs from New Zealand technical reports and papers, ideally for all nutrient-affected attributes. However, ICTs references only exist for: • Periphyton (Ton Snelder *et al.*, 2022) • Macroinvertebrates (Canning *et al.*, 2021)
Strategy 2: Model ICTs for the most sensitive attribute	The objective of Strategy 2 is to generate, for each type of river, a single set of six ICTs for an attribute determined to be most sensitive to nutrient enrichment.
Strategy 3: Model ICTs of a subset of attributes for which sufficient data exist	• The objective of Strategy 3 is to generate, for each type of river, a set of ICTs for attributes for which there are sufficient available data. • The key differences between Strategies 2 and 3 are the determinants of attributes selected for ICTs modelling. In Strategy 2, the aim is to model ICTs for attributes that are likely the most nutrient-sensitive attributes within each type of river and for which we have sufficient data. In Strategy 3, the main determinant is data availability, resulting in a selection of attributes that are not necessarily the most nutrient sensitive within river types
Strategy 4: Implement monitoring to obtain data to refine ICTs for a subset of attributes	• The objective of Strategy 4 is to evaluate whether collecting more data to refine ICTs of an attribute justifies the data collection cost and, if it does, design and implement monitoring to obtain that data. • After exploring Strategies 2 and 3, it may be concluded that (a) ICTs are required for particular attributes; and (b) there is insufficient data — nationally, regionally or both — to model ICTs for those attributes. In that case, there is an option of designing an adaptive monitoring programme to collect the data required to develop and/or refine ICTs for a specific attribute over time • This is not necessarily a strategy for setting ICTs. But rather a method for determining whether there is justification for improving or broadening the scope of ICTs set under Strategy 2 or 3

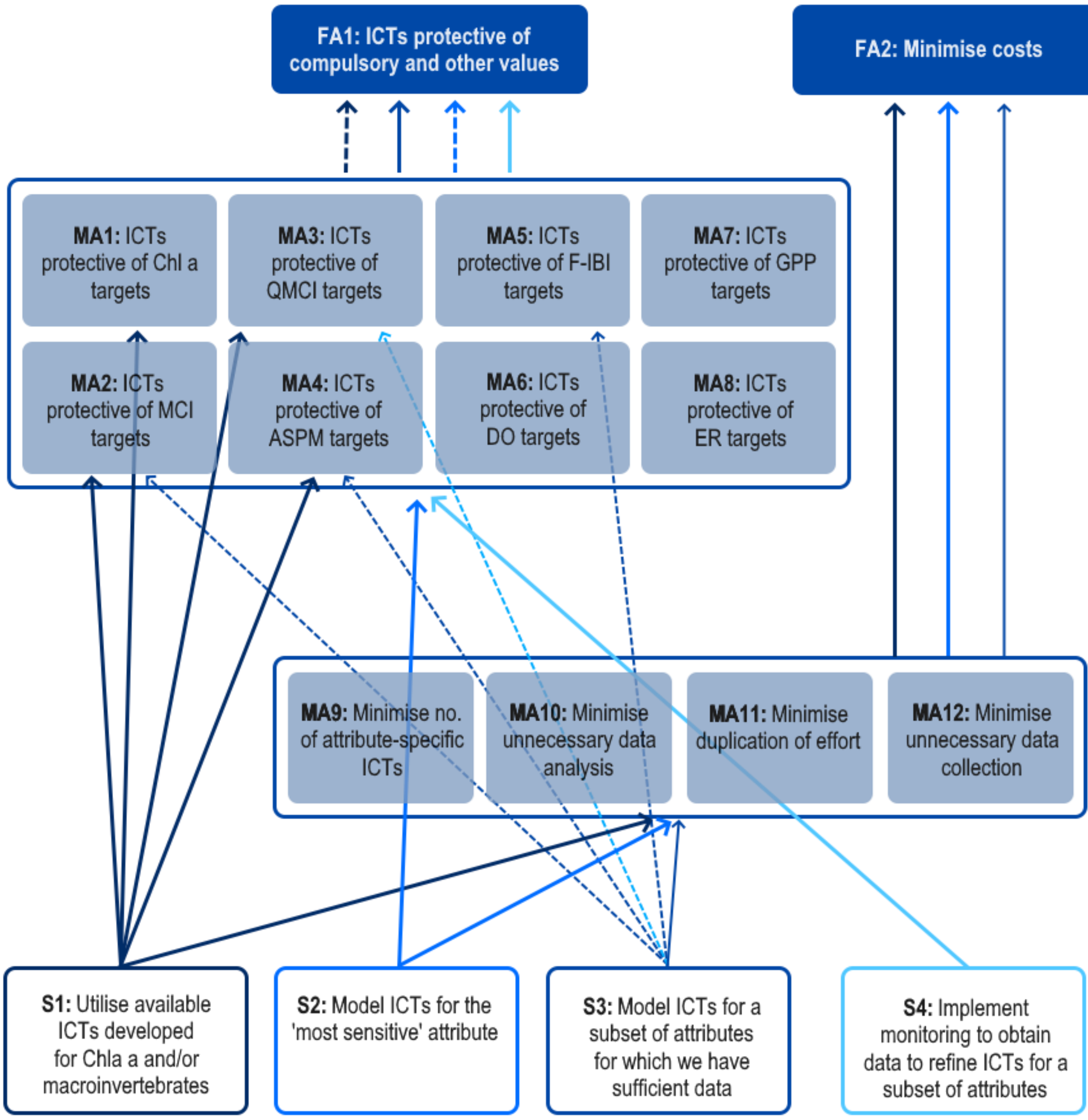

Figure 4: Aims network linking four strategies for obtaining ICTs (strategies 1 to 4 (Table 19) to means aims (MA) and fundamental aims (FA). Heavy solid lines = strongly facilitates aim; light solid line = weakly facilitates aim; dashed line = extent to which aim has been met unknown. Re-created from MfE (2022a) (Figure 3-6).

6.3 Identification of suitable strategy for adoption in PC1

An assessment of which of the four strategies for setting NOs in MfE (2022a) are feasible before PC1 is notified is set out in Table 20. Importantly, this is not an assessment of which strategy should be used in the long-term. Rather it simply denotes which can be used to set NOs in the limited timeframe available.

Of the four strategies set out in MfE (2022a), only Strategy 1 is likely to yield useable NOs before PC1 is notified (Table 20) as Strategies 2, 3 and 4[6] all require modelling which:

- Ideally should be based on as yet unavailable national scale modelling; and
- Cannot be conducted in the absence of this national scale modelling, as regional scale modelling does not exist and cannot be conducted in time for PC1 notification.

As such, it is recommended that GW pursue strategy 1 for PC1, but begin actively working towards defining how long-term NOs will be developed for future plan changes. This is consistent with guidance in MfE (2022a) which notes that "*[i]f councils have not yet developed their own ICTs using sound approaches (see Strategy 2), then we recommend implementing Strategy 1 in the short term, for inclusion in regional plans. Strategy 1 is not, however, a long-term solution, given the uncertainties about how its implementation will meet FA1*".

Table 20: Assessment of whether the four strategies for setting nutrient ICTs in MfE (2022a) are feasible before PC1 is notified.

Strategy	Feasible before PC1 notification	Notes
Strategy 1: Use ICTs that have already been developed for a nutrient-affected attribute	**Yes**	Published New Zealand ICTs are available for periphyton and Macroinvertebrates. Accordingly, this strategy can be used to set nutrient ICTs in PC1 at minimal cost.
Strategy 2: Model ICTs for the most sensitive attribute	**No**	• Implementing this strategy involves a significant amount of modelling to link the response of all nutrient sensitive attributes to nitrogen and phosphorus concentrations. • MfE (2022a) recommends that this modelling should be done at a national level. • While MfE (2022a) note that while there is nothing precluding regional councils from conducting their own modelling where sufficient data are available, it would be inefficient. • GW are unlikely to be able to conduct the required modelling to implement this strategy in time to include the resulting ICTs in PC1
Strategy 3: Model ICTs of a subset of attributes for which sufficient data exist	**No**	• While less arduous than Strategy 2, implementing this strategy still involves a significant amount of modelling. • MfE (2022a) recommends that this modelling should be done at a national level. • GW are unlikely to be able to conduct the required modelling to implement this strategy in time to include the resulting ICTs in PC1
Strategy 4: Implement monitoring to obtain data to refine ICTs for a subset of attributes	**Not applicable**	This strategy involves assessing whether there is value in collecting additional data to improve ICTs developed under Strategy 2 or 3. Neither of which are currently feasible.

[6] Ultimately requires ICTs to be set in accordance with Strategy 2 or 3

6.4 Implementation of Strategy 1

Implementing Strategy 1 in MfE (2022a) is straightforward process that involves selecting already published NOs from New Zealand technical reports and papers. Accordingly; key tasks include:

1. Selecting which published set of NOs are most relevant to the areas covered by PC1. Two sets of ICTs currently exist:
   a. Periphyton (Ton Snelder *et al.*, 2022); and
   b. Macroinvertebrates (Canning *et al.*, 2021).
2. Identifying the specific numeric NOs from the source selected under Step 1 that correspond to the PC1 target attribute states (TASs) for the relevant nutrient sensitive attribute.

6.4.1 Selecting the relevant set of nutrient outcomes from the literature

6.4.1.1 Options

6.4.1.1.1 Snelder et al. (2022)

The Snelder *et al.* (2022) NOs are set in relation to the NPS-FM 2020 periphyton biomass attribute state thresholds. They were developed by using ordinary least-squares regression to fit models that explained the relationship between periphyton and environmental factors, including nutrient concentrations, hydrology, and physical habitat at regional council monitoring sites. NOs were then obtained by inverting the fitted models to find the concentrations associated with periphyton attribute state thresholds.

Due to model uncertainty, a single nutrient criterion cannot ensure that a target level of periphyton biomass is not exceeded. Instead, there is a probability distribution that describes the risk of under-protection at a specific river location. Accordingly, the NOs derived in Snelder *et al.* (2022) are presented in lookup table format that provide for choice in the level of under-protection risk that might be acceptable. These lookup tables are provided for:

– DIN, DRP, total nitrogen (TN) and total phosphorus (TP), under;
 └──► Shaded and unshaded conditions, across;
  └──► Twenty-one River Environmental Classification[7] (REC) source-of-flow classes, and
  └──► Six levels of risk ranging from 5% to 50% for;
   └──► Each of the NPS-FM 2020 periphyton biomass A/B, B/C and C/D attribute state thresholds (756 NOs to select from for each nutrient attribute).

The objective of the NOs is to maintain periphyton biomass at or below the nominated thresholds at a proportion of sites that is the complement of the under-protection risk.

6.4.1.1.2 Canning et al. (2021)

Canning *et al.* (2021) uses the 'minimisation of mismatch' between nutrients and biology approach, described by the '*European Union's 'Best practice for establishing nutrient concentrations to support good ecological status*' guidelines' to define a single NOs for each of DIN and DRP that relate to the NPS-FM 2020 national bottom lines for macroinvertebrates (Q/MCI and ASPM). Those NOs are based on measured macroinvertebrate and measured and modelled nutrient data from regional council monitoring

[7] The REC is a database of catchment spatial attributes, summarised for every segment in New Zealand's network of rivers.

sites and reflect the DIN and DRP thresholds that maximise the probability of a site meeting those thresholds and passing the NPS-FM 2020 Q/MCI and ASPM bottom lines, while minimising the passing of the ecological targets and failing on the nutrient threshold (or vice-versa)

6.4.1.2 Recommended option - Snelder et al. (2022)

MfE (2022a) does not recommend which set of NOs regional councils should use when implementing Strategy 1. However, it does note a number of weaknesses in the NOs developed by Canning *et al.* (2021) that make them less appealing than those presented in Snelder *et al.* (2022); Specifically;

- Canning *et al.* (2021) only provides NOs that relate to the bottom line for the nutrient sensitive attributes they are designed to protect, whereas Snelder *et al.* (2022) includes NOs that relate to each periphyton biomass attribute state;
- Canning *et al.'s* (2021) modelling approach does not account for the mediating effects of landscape context or other anthropogenic stressors on nutrient-macroinvertebrate relationships. In contrast Snelder *et al.* (2022) accounted for the mediating effects of several factors including:
    - Climatological and topographical variables as defined in the REC;
    - Hydrological variables;
    - Shaded versus unshaded streams; and
    - Deposited fine sediment.
- MfE (2022a) notes that while a "*single set of* [NOs] *for all of New Zealand may be seen as advantageous and/or practical by some, in that it is easy to implement. Others may view this as being being unrealistic and a biased*"; and
- No guidance is available to help regional councils implement the NOs developed by Canning *et al.* (2021). In contrast, MfE (2022b) provides detailed guidance on how councils should set NOs using the lookup tables developed by Snelder *et al.* (2022).

Furthermore, setting NOs aimed at directly achieving specific macroinvertebrate endpoints, as in Canning *et al.* (2021), fails to recognise that while elevated nutrients and degraded macroinvertebrate community health often co-occur, this is because both are driven by an increase in intensive land-use (which affects a range of environmental factors), and that any causative link between the two is generally indirect and complex. As such, setting blanket NOs based on such correlative relationships will not necessarily achieve the desired objective in terms of macroinvertebrate community health.

The limitations of the recommended NOs in Canning *et al.* (2021), and the general issues with setting NOs for macroinvertebrate health, mean that Snelder *et al.* (2022) currently represents the best available option when implementing Strategy 1 from MfE (2022a). It is worth noting, however, that the minimisation of mismatch approach used by Canning *et al.* (2021) should be considered as an option for exploring NOs for some nutrient sensitive attributes if and when GW develop more refined thresholds in accordance with Strategies 2 through 4 in MfE (2022a).

6.5 Implementation of Snelder *et al.* (2022) as published (superseded, see Section 6.6)

6.5.1 Introduction to guidance

Guidance on the interpretation and use of Snelder *et al.*'s (2022) look-up tables of in-stream nutrient concentrations and exceedance criteria is provided in MfE (2022b). That document outlines the following steps to be taken when selecting NOs from the Snelder *et al.* (2022) lookup tables:

1. Select an appropriate periphyton biomass threshold.
2. Select under-protection risk for a site.
3. Obtain NOs from the tables.
4. Assess confidence in the NOs.
5. Apply the NOs or alternative criteria. The five situations where alternative criteria should apply are:
    a. Where baseline concentrations are lower than the NOs, in which case use those;
    b. Where the look up table value = 0, in which case explore possible alternatives such as reference values from McDowall *et al.* (2013); and
    c. Where there are sensitive downstream receiving environments that require nutrient concentrations or loads that imply the identified criterion is too high.
    d. Where the identified criteria are higher than levels to achieve other TASs at the site (e.g., for NO_3-N toxicity).
    e. Where the look up table value is > than saturation point, in which case reduce to at least saturation point when the periphyton TAS represents an improvement.

6.5.2 Step 1a – Select periphyton biomass thresholds

The TASs for periphyton biomass that are being considered for inclusion in PC1 have been extracted from the WTWT and TAoP WIPs (Table 21).

Table 21: REC source of flow categories and periphyton TAS for sites in WTWT and TAoP Whaitua.

Whaitua	Part-FMU	Site	REC source of flow category	Periphyton Target Attribute State
TAoP	Taupō	Taupō S. @ Plimmerton Domain	WD/L	B
	Pouewe	Horokiri S. @ Snodgrass	CW/L	
	Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.	WW/L	
	Takapū	Pāuatahanui S. @ Elmwood Br.	CW/L	
	Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot	WW/L	
TWT	Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Hutt R. @ Te Marua Intake	CX/H	A
		Whakatikei R. @ Riverstone	CW/L	
	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	CW/L	B
	Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	CW/L	
	Te Awa Kairangi urban streams	Hulls C. adj. Reynolds Bach Dr.	WW/L	C
	Waiwhetū Stream	Waiwhetū S. @ Whites Line E.	WW/L	
	Wainuiomata urban streams	Black C. @ Rowe Parade end	CW/L	
	Wainuiomata rural streams	Wainuiomata R. DS White Br.	CW/L	
	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	CW/L	
	Korokoro Stream	Korokoro S.@ Cornish St. Br.	CW/L	B
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	CW/L	C
	Wellington urban	Karori S. @ Mākara Peak	CW/L	

6.5.3 Step 1b – Select under-protection risk thresholds

MfE (2022b) notes that

> "*Precise guidance on selecting the under-protection risk cannot be given, however councils should provide the demonstrable process that sets out how and why they made their under-protection risk decision. In broad terms, the risk a council adopts should be linked to the environmental outcomes it requires, and the values of the resources it is managing, with lower under-protection risk being adopted in places with higher value and vice versa*".

Here the method for selecting the recommended under-protection risk for TAoP Whaitua and WTWT was simply to identify the level at which the corresponding unshaded[8] NOs:

- Require reductions in DIN and DRP concentrations in those rivers where the periphyton biomass TAS represents an improvement; but
- Do not require such large reductions in nutrient concentrations as to be unachievable.

The results of this analysis are presented in Table 22 and Table 23, which show the 15% under protection risk is the best available option for implementing the Snelder *et al.*'s (2022) look-up tables as:

- At the 20% under-protection risk the unshaded NOs only require reductions in DIN or DRP concentrations in one of these sites; Porirua Stream at Milk Depot (Table 22).;

[8] Unshaded values were used in this step as they provide an indication of the applicability of the under-protection risk in the absence of the co-variate effect of shade.

- At the 15% under-protection risk >10% reductions in DIN and DRP concentrations are required in four of those same five sites (Table 22); and
- However, at the 10% under-protection level the required reductions in DIN and DRP are so large that final concentrations would need to approximate reference condition (Table 23).

Table 22: Required reductions in DIN and DRP concentrations to meet the unshaded Snelder *et al.* (2022) NOs at under-protection levels between 10% and 20%. Data are only provided for those sites where an improvement in periphyton biomass is required, and long-term nutrient data are available.

Site	% reduction					
	10% under-protection		15% under-protection		20% under-protection	
	DIN	DRP	DIN	DRP	DIN	DRP
Horokiri S. @ Snodgrass	88%	70%	59%	20%	0%	0%
Pāuatahanui S. @ Elmwood Bridge	80%	75%	32%	33%	0%	0%
Porirua S. @ Milk Depot	96%	90%	87%	80%	66%	50%
Hutt R. @ Boulcott	71%	40%	2%	0%	0%	0%
Mangaroa R. @ Te Marua	86%	67%	53%	11%	0%	0%

Table 23: The unshaded Snelder *et al.* (2022) NOs at 10% and 15% under-protection risk for those sites where an improvement in periphyton biomass is required and long-term nutrient data are available. Baseline states for reference (undisturbed) sites are provided for comparative purposes.

Site name	DIN concentration (mg/L)		DRP concentration (mg/L)	
	At 10%	At 15%	At 10%	At 15%
Horokiri S. @ Snodgrass	0.058	0.196	0.003	0.008
Pāuatahanui S. @ Elmwood Bridge	0.054	0.196	0.003	0.008
Porirua S. @ Milk Depot	0.034	0.12	0.002	0.004
Hutt R. @ Boulcott	0.058	0.196	0.003	0.008
Mangaroa R. @ Te Marua	0.058	0.196	0.003	0.008
Reference sites				
Whakatikei R. @ Riverstone	0.120		0.008	
Hutt R. @ Te Marua Intake Site	0.065		0.004	
Wainuiomata R. @ Manuka Track	0.054		0.011	

6.5.4 Step 2 – Obtain nutrient outcomes from tables

It is my understanding GW will utilise riparian planting to help control periphyton growth as part of their action planning process. Accordingly, NOs with a 15% under-protection risk have been selected for sites in WTWT and TAoP on the assumption that they will be shaded in the future. The exception being the Hutt River at Boulcott, which is far too wide for riparian planting to be an effective method of controlling periphyton (predicted width at median flow for all other rivers ≤ 15 metres (Booker, 2010)). The resulting NOs are set out in Table 24.

Table 24: Snelder *et al.* (2022) NOs for TAS for sites in WTWT and TAoP Whaitua. Under-protection risk = 15%.

<table>
<tr><th>Whaitua</th><th>Part-FMU</th><th>Site</th><th>REC source of flow category</th><th>Periphyton Target Attribute State</th><th>Shaded</th><th>DIN (mg/L)</th><th>DRP (mg/L)</th></tr>
<tr><td rowspan="5">TAoP</td><td>Taupō</td><td>Taupō S. @ Plimmerton Domain</td><td>WD/L</td><td>Maintain</td><td rowspan="6">Y</td><td colspan="2">N/A[a]</td></tr>
<tr><td>Pouewe</td><td>Horokiri S. @ Snodgrass</td><td>CW/L</td><td rowspan="4">B</td><td>1.085</td><td>0.025</td></tr>
<tr><td>Wai-o-hata</td><td>Duck Ck @ Tradewinds Dr. Br.</td><td>WW/L</td><td>0.866</td><td>0.015</td></tr>
<tr><td>Takapū</td><td>Pāuatahanui S. @ Elmwood Br.</td><td>CW/L</td><td>1.085</td><td>0.025</td></tr>
<tr><td>Te Rio o Porirua and Rangituhi</td><td>Porirua S. @ Milk Depot</td><td>WW/L</td><td>0.866</td><td>0.015</td></tr>
<tr><td rowspan="11">WTWT</td><td>Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems</td><td>Whakatikei R. @ Riverstone</td><td>CW/L</td><td>A</td><td>0.004</td><td>0</td></tr>
<tr><td>Te Awa Kairangi lower mainstem</td><td>Hutt R. @ Boulcott</td><td>CW/L</td><td rowspan="2">B</td><td>N</td><td>0.196</td><td>0.008</td></tr>
<tr><td>Te Awa Kairangi rural streams and rural mainstems</td><td>Mangaroa R. @ Te Marua</td><td>CW/L</td><td rowspan="9">Y</td><td>1.085</td><td>0.025</td></tr>
<tr><td>Te Awa Kairangi urban streams</td><td>Hulls C. adj. Reynolds Bach Dr.</td><td>WW/L</td><td rowspan="5">C</td><td>3.336</td><td>0.131</td></tr>
<tr><td>Waiwhetū Stream</td><td>Waiwhetū S. @ Whites Line E.</td><td>WW/L</td><td>3.336</td><td>0.131</td></tr>
<tr><td>Wainuiomata urban streams</td><td>Black C. @ Rowe Parade end</td><td>CW/L</td><td>3.335</td><td>0.152</td></tr>
<tr><td>Wainuiomata rural streams</td><td>Wainuiomata R. DS White Br.</td><td>CW/L</td><td>3.335</td><td>0.152</td></tr>
<tr><td>Parangārehu catchment streams and South-west coast rural streams</td><td>Mākara S. @ Kennels</td><td>CW/L</td><td>3.335</td><td>0.152</td></tr>
<tr><td>Korokoro Stream</td><td>Korokoro S.@ Cornish St. Br.</td><td>CW/L</td><td>B</td><td>1.085</td><td>0.025</td></tr>
<tr><td>Kaiwharawhara Stream</td><td>Kaiwharawhara S. @ Ngaio Gorge</td><td>CW/L</td><td rowspan="2">C</td><td>3.335</td><td>0.152</td></tr>
<tr><td>Wellington urban</td><td>Karori S. @ Mākara Peak</td><td>CW/L</td><td>3.335</td><td>0.152</td></tr>
</table>

[a] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (River Environment Classification group = WW/L/SS).

6.5.5 Step 3 – Assess confidence in the nutrient outcomes

MfE (2022b) sets out a methodology by which NOs selected from the look-up tables Snelder *et al.* (2022) can be validated. The objective of this validation exercise is to use monitoring data to assess whether the NOs are reasonably consistent with local observations of the relationships between periphyton abundance and nutrient concentrations.

Dr Ton Snelder has conducted the validation exercise described in MfE (2022b) using periphyton and nutrient data collected from across the Wellington Region. This analysis is provided in Appendix E to this report. Dr Snelder concluded that "[t]*he validation of the criteria of Snelder et al. (2022) for the Wellington region, based on 16 monitoring sites, indicates that the criteria are too permissive (i.e., biomass thresholds will be exceeded at more sites than expected given the selected under-protection risk even when nutrient criteria are complied with)*". On that basis, he noted that a "*reasonable conclusion is that **the criteria are the best available and are appropriate to use**, but that they are uncertain*.

6.5.6 Step 4 – Application of the nutrient outcomes or alternative criteria

The final step in implementing the MfE (2022b) guidance on setting NOs based on the Snelder *et al.*'s (2022) look-up tables is to determine where alternative criteria are the most appropriate option. The specific situations where this is the case are:

1. Where current concentrations are lower than the lookup table value, in which case use those;
2. Where the look up table value equals zero, in which case explore possible alternatives such as reference values from McDowall *et al.* (2013); and
3. Where there are sensitive downstream receiving environments that require nutrient concentrations or loads that imply the identified criterion is too high.
4. Where the identified NOs are higher than levels to achieve other attribute states at the site (e.g., the NO_3-N toxicity or DRP target attributes).
5. Where the lookup table value is greater than the saturation point (1 mg/L for DIN; 0.025 mg/L for DRP), in which case reduce to at least saturation point when the periphyton TAS represents an improvement.

Table 25 provides an update to Table 24, with alternative criteria applied to address the issues outlined above.

Table 25: NOs for TAS for sites in WTWT and TAoP Whaitua. Selected from the Snelder *et al.*'s (2022) lookup tables (under-protection risk = 15%) except where alternative criteria are more appropriate (see footnotes).

Whaitua	Part-FMU	Site	REC source of flow category	Periphyton Target Attribute State	Shaded	DIN (mg/L)	DRP (mg/L)
TAoP	Taupō	Taupō S. @ Plimmerton Domain	WD/L	Maintain	Y	~0.41[b]	~0.017[b]
	Pouewe	Horokiri S. @ Snodgrass	CW/L	B		0.64[b]	0.011[b]
	Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.	WW/L			~0.48[b]	0.015
	Takapū	Pāuatahanui S. @ Elmwood Br.	CW/L			0.33[b]	0.014[b]
	Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot	WW/L			0.866	0.015
WTWT	Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone	CW/L	A		0.015[c]	0.006[d]
	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	CW/L	B	N	0.196	0.004[b]
	Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	CW/L		Y	0.44[b]	0.006[e]
	Te Awa Kairangi urban streams	Hulls C. adj. Reynolds Bach Dr.	WW/L	C		0.24[b]	0.018[b]
	Waiwhetū Stream	Waiwhetū S. @ Whites Line E.	WW/L			0.56[b]	0.018[e]
	Wainuiomata urban streams	Black C. @ Rowe Parade end	CW/L			0.5[b]	0.018[e]
	Wainuiomata rural streams	Wainuiomata R. DS White Br.	CW/L			0.17[b]	0.011[e]
	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	CW/L			0.42[b]	0.018[e]
	Korokoro Stream	Korokoro S.@ Cornish St. Br.	CW/L	B		1.03[f]	0.006[e]
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	CW/L	C		1.03[b]	0.018[e]
	Wellington urban	Karori S. @ Mākara Peak	CW/L			1.29[b]	0.031[e]

[a] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (River Environment Classification group = WW/L/SS). Modelled baseline state applied as alternative criteria.
[b] Snelder *et al.* (2022) nutrient outcome > than current concentrations. Current concentrations applied as alternative criteria.
[c] Site in reference conditions and NOs represents and improvement which is unlikely to be possible.
[d] Snelder *et al.* (2022) nutrient outcome = 0. The lesser of McDowall *et al.* (2013) 80th %ile trigger, current state or WIP TAS applied as alternative criteria.
[e] Snelder *et al.* (2022) nutrient outcome > than the dissolved reactive phosphorus TAS. TAS applied as alternative criteria.
[f] Snelder *et al.* (2022) nutrient outcome > than TAS for NH_4-N and NO_3-N toxicity. Sum of NH_4-N and NH_4-N TAS applied as alternative criteria.

6.6 Implementation of updates to Snelder *et al.* (2022) nutrient outcomes (supersedes Section 6.5)

6.6.1 Background to updates

Since conducting the validation exercise described in Section 6.5.5, Dr Snelder has revised the NOs set out in Snelder *et al.* (2022). These revisions were made in response to validation exercises conducted for several regions revealing the original NOs are generally too permissive.

The process by which Dr Snelder developed the updated NOs are explained in detail in Appendix F. Briefly, the same general methodology was followed as in Snelder *et al.* (2022) except generalised linear models were used instead of ordinary least squares models. The resulting NOs are more stringent than those produced by Snelder *et al.* (2022), and generally consistent with GW monitoring data. As such, they represent the best available option for implementing Strategy 1 in MfE (2022a) (Dr Snelder agrees; *pers. comm.* 22/03/2023).

It is important to note that several parties, including GW, are pushing for a national level update to Snelder *et al.* (2022) to address the issues identified by Dr Snelder in Appendix F. If this update includes an expansion of the input data set to capture monitoring conducted since 2019 it may produce slightly different NOs from those set out in Appendix F.

6.6.2 Step 1a – Select periphyton biomass thresholds

The TASs for periphyton biomass that are being considered for inclusion in PC1 are set out in Table 21.

6.6.3 Step 1b – Select under-protection risk thresholds

Re-running the process described in 6.5.3 using the updated NOs in Appendix F suggests that adopting an under protection risk of 50% is the best available option for ensuring achievable reductions in nutrient concentrations at those sites where the TASs requires an improvement in periphyton biomass (Table 26 and Table 27).

Table 26: Required reductions in DIN and DRP concentrations to meet the unshaded updated Snelder *et al.* (2022) NOs at under-protection levels between 25% and 50%. Data are only provided for those sites where an improvement in periphyton biomass is required, and long-term measured nutrient data are available.

Site	% reduction					
	25% under-protection		30% under-protection		50% under-protection	
	DIN	DRP	DIN	DRP	DIN	DRP
Horokiri S. @ Snodgrass	95%	91%	92%	82%	59%	0%
Pāuatahanui S. @ Elmwood Bridge	90%	93%	84%	86%	19%	21%
Porirua S. @ Milk Depot	97%	94%	95%	89%	75%	56%
Hutt R. @ Boulcott	84%	75%	74%	50%	0%	0%
Mangaroa R. @ Te Marua	93%	90%	88%	80%	40%	0%

Table 27: Unshaded updated Snelder *et al.* (2022) NOs at 30% and 50% under-protection risk for those sites where an improvement in periphyton biomass is required and long-term nutrient data are available. Baseline states for reference (undisturbed) sites are provided for comparative purposes.

Site name	DIN concentration (mg/L)		DRP concentration (mg/L)	
	At 30%	At 50%	At 30%	At 50%
Horokiri S. @ Snodgrass	0.051	0.263	0.002	0.011
Pāuatahanui S. @ Elmwood Bridge	0.051	0.263	0.002	0.011
Porirua S. @ Milk Depot	0.046	0.231	0.002	0.008
Hutt R. @ Boulcott	0.051	0.263	0.002	0.011
Mangaroa R. @ Te Marua	0.051	0.263	0.002	0.011
Reference sites				
Whakatikei R. @ Riverstone	0.120		0.008	
Hutt R. @ Te Marua Intake Site	0.065		0.004	
Wainuiomata R. @ Manuka Track	0.054		0.011	

6.6.4 Step 2 – Obtain nutrient outcomes from tables

Table 28 provides an update to Table 24 based on the update to the Snelder *et al.* (2022) NOs set out in Appendix F.

Table 28: Updated NOs for TAS for sites in WTWT and TAoP Whaitua. Under-protection risk = 50%.

Whaitua	Part-FMU	Site	REC source of flow category	Periphyton Target Attribute State	Shaded	DIN (mg/L)	DRP (mg/L)
	Taupō	Taupō S. @ Plimmerton Domain	WD/L	Maintain		N/A[a]	
	Pouewe	Horokiri S. @ Snodgrass	CW/L			1.33	0.034
TAoP	Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.	WW/L			1.23	0.025
	Takapū	Pāuatahanui S. @ Elmwood Br.	CW/L	B		1.33	0.034
	Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot	WW/L		Y	1.23	0.025
	Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone	CW/L	A		0.008	0.000
	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	CW/L	B	N	0.26	0.011
	Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	CW/L			1.33	0.034
	Te Awa Kairangi urban streams	Hulls C. adj. Reynolds Bach Dr.	WW/L			3.03	0.147
TWT	Waiwhetū Stream	Waiwhetū S. @ Whites Line E.	WW/L			3.03	0.147
	Wainuiomata urban streams	Black C. @ Rowe Parade end	CW/L	C		3.30	0.163
	Wainuiomata rural streams	Wainuiomata R. DS White Br.	CW/L		Y	3.30	0.163
	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	CW/L			3.30	0.163
	Korokoro Stream	Korokoro S.@ Cornish St. Br.	CW/L	B		0.26	0.011
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	CW/L	C		3.30	0.163
	Wellington urban	Karori S. @ Mākara Peak	CW/L			3.30	0.163

[a] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (River Environment Classification group = WW/L/SS).

6.6.5 Step 3 – Assess confidence in the nutrient outcomes

As stated in Section 6.6.1 Dr Snelder has conducted the validation exercise described in MfE (2022b) for the updated NOs set out in Appendix F (results of validation can also be found there). He concluded that:

> *"For most of the levels of under protection risk, the confidence bound includes the associated level of under-protection risk". This indicates that the new criteria are consistent with the monitoring data within the inherent uncertainty in both the observations of [periphyton biomass] and the uncertainty in the criteria themselves."*

6.6.6 Step 4 – Application of the nutrient outcomes or alternative criteria

Table 29 provides an update to Table 25, with alternative criteria applied where appropriate (see Section 6.5.6). This represents the recommended NOs for inclusion in PC1.

Table 29: NOs for TAS for sites in WTWT and TAoP Whaitua. Selected from the updates to the Snelder *et al.* (2022) (Appendix F) (under-protection risk = 50%) except where alternative criteria are more appropriate (see footnotes).

Whaitua	Part-FMU	Site	REC source of flow category	Periphyton Target Attribute State	Shaded	DIN (mg/L)	DRP (mg/L)
TAoP	Taupō	Taupō S. @ Plimmerton Domain	WD/L	B	Y	~0.41	~0.017[a]
	Pouewe	Horokiri S. @ Snodgrass	CW/L			0.64[b]	0.011[b]
	Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.	WW/L			~0.48[b]	~0.018[b]
	Takapū	Pāuatahanui S. @ Elmwood Br.	CW/L			0.33[b]	0.014[b]
	Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot	WW/L			0.92[b]	0.018[b]
TWT	Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone	CW/L	A		0.15[c]	0.006[d]
	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	CW/L	B	N	0.20[b]	0.004[b]
	Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	CW/L		Y	0.44[b]	0.006[e]
	Te Awa Kairangi urban streams	Hulls C. adj. Reynolds Bach Dr.	WW/L	C		0.24[b]	0.018[b]
	Waiwhetū Stream	Waiwhetū S. @ Whites Line E.	WW/L			0.56[b]	0.018[e]
	Wainuiomata urban streams	Black C. @ Rowe Parade end	CW/L			0.5[b]	0.018[e]
	Wainuiomata rural streams	Wainuiomata R. DS White Br.	CW/L			0.17[b]	0.01[e]
	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	CW/L			0.42[b]	0.018[e]
	Korokoro Stream	Korokoro S.@ Cornish St. Br.	CW/L	B		0.26	0.006[e]
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	CW/L	C		1.14[b]	0.018[e]
	Wellington urban	Karori S. @ Mākara Peak	CW/L			1.29[b]	0.035[e]

[a] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (REC = WW/L/SS). Modelled baseline state applied as alternative criteria.
[b] Snelder *et al.* (2022) nutrient outcome > than baseline concentrations. Baseline concentrations applied as alternative criteria.
[c] Site in reference conditions and nutrient outcome represents an improvement which is unlikely to be possible. Baseline concentrations applied as alternative criteria.
[d] Snelder *et al.* (2022) nutrient outcome = 0. The lesser of McDowall *et al.* (2013) 80th %ile trigger, baseline state or WIP TAS applied as alternative criteria.
[e] Snelder *et al.* (2022) nutrient outcome > than the dissolved reactive phosphorus WIP TAS. WIP TAS applied as alternative criteria.

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7 Assessment of the current state of the Parangārehu Lakes

To: Michael Greer and Rachel Pawson

From: Alton Perrie

First published: 28/07/2023

7.1 Introduction

The purpose of this memorandum is to:

1. Provide an overview of previous assessments of the current state of the Parangārehu Lakes (Lake Kōhangapiripiri and Lake Kōhangatera);
2. Update the assessment of the current state of the Parangārehu Lakes using data collected during 2022/23;
3. Make recommendations on current baseline states of selected NPS-FM 2020 attributes to be included in PC1 to the NRP for the Wellington Region; and,
4. Provide commentary on the improvements (indicated by TASs) desired in the WTWT WIP.

Previous assessments of the current state of the Parangārehu lakes undertaken by Schallenberg (2019) and during the WIP process (documented in Heath (2022)) used the best available data and expert opinion to assess the current state of these lakes. However, these assessments highlighted the paucity of water quality data available, and the current states presented can only be considered estimates rather than accurate state assessments established by a robust monitoring programme. Heath (2022) placed only low to moderate confidence in any current state assessments made for the NPS-FM 2020 water quality attributes presented in the WIP. However, assessments of the current state of aquatic plant NPS-FM 2020 attributes in the WIP are considered robust as both lakes have been assessed on several occasions following appropriate methods.

Given the limited water quality data available, assessments against NPS-FM 2020 water quality attribute thresholds presented in this memo used all of the data available (i.e., states are not calculated from monthly measurements spanning a one-year period). Given this lack of data, it is also important to acknowledge that the water quality reporting requirements of the NPS-FM 2020 could not be adhered to. The data used in this memorandum are provided in Table 30.

Table 30: Available water quality data for the Parangārehu Lakes that was used in this memorandum. Values below the detection limit have been halved. - indicates not sampled/no result on this date.

Date	Chlorophyll *a* (mg/m^3)	TN (mg/L)	TP (mg/L)	pH	NH_4-N (mg/L)	*E. coli* (cfu/100 mL)	Cyanobacteria biovolume (mm^3/L)
Lake Kōhangapiripiri							
Mar. 2011	1.5	0.72	0.026	7.1	0.005	-	-
Mar. 2013	1.5	0.53	0.034	7.3	0.005	-	-
Feb. 2016	1.5	0.73	0.086	7.8	0.086	-	-
April 2018	1.5	0.51	0.021	7.4	0.0025	-	-
April 2019	5	0.7	0.05	7.6	0.0025	-	-
July 2022	1.5	0.8	0.046	7.2	0.061	50	0
Sep. 2022	1.5	0.5	0.025	7.4	0.007	10	0.0001
Nov. 2022	1.5	0.46	0.04	7.5	0.0025	23	2
Feb. 2023	1.5	0.62	0.051	7.5	0.008	10	0.001
Mar. 2023	6	0.73	0.098	7.5	0.034	220	0.008
June 2023	-	-	-	-	-	-	0.0006
Lake Kōhangatera							
Mar. 2011	1.5	0.49	0.025	8	0.005	-	-
Mar. 2013	1.5	0.41	0.05	7.5	0.005	-	-
Feb. 2016	5	0.53	0.034	9.2	0.0025	-	-
April 2018	1.5	1.23	0.096	7	0.025	-	-
April 2019	35	0.48	0.04	8.3	0.01	-	-
July 2022	1.5	0.74	0.052	7.1	0.011	400	0
Sep. 2022	6	0.33	0.039	7.3	0.007	50	0.04
Nov. 2022	17	0.41	0.058	7.5	0.006	11	0.0003[1] 20[1]
Feb. 2023	4	0.55	0.071	7.2	0.007	200	0.01
Mar. 2023	8	0.4	0.039	7.2	0.067	200	0.3
June 2023	6	0.45	0.04	7.3	0.008	30	0.0007

[1] Two samples were collected for analysis of cyanobacteria biovolume on this sampling occasion given the visual evidence of a phytoplankton bloom in the southern part of the lake.

7.2 Current state

7.2.1 Water quality attributes

Water quality data are inherently variable month to month and can exhibit strong seasonal patterns, hence monthly data collected over 2-5 years is typically recommended to establish the state of lake water quality (Burns *et al.*, 2000; McBride, 2016). While the NPS-FM 2020 does require annual statistics for some lake attributes, McBride (2016) indicates that these statistics would be far more robust if calculated annually but based on a five-year rolling approach (i.e., a median statistic is generated annually using the last five years of data; see McBride (2016) for more details). Water quality data assessed in Schallenberg (2019) and Heath (2022) were also typically collected during summer or autumn months when other field work was being undertaken (i.e., aquatic plant assessments) and are therefore not representative of seasonal variability.

In August 2022, GW commenced a bi-monthly water quality sampling programme to help better understand the current state of water quality in the Parangārehu lakes. This more recently collected water quality data, along with historically available data are discussed further below in the context of setting current attribute states for key lake water quality attributes in the NPS-FM 2020.

Due to the paucity of data available prior to 2017, it is considered that, for water quality attributes, the current attribute states presented in the memorandum represent the best available estimates of 'baseline state' (i.e., the state as 7 September 2017) despite being calculated from data collected more recently than allowed for by the NPS-FM 2020.

7.2.1.1 Nutrient attributes for phytoplankton growth

Schallenberg (2019) and Heath (2022) estimated the TN[9] states of Lakes Kōhangapiripiri and Kōhangatera to be "C" and "B" respectively. Median concentrations calculated based on all available data (incl. more recently collected data) are 0.660 and 0.480 mg/L which confirms the placement of the lakes in these bands (Table 30, Table 31). However, it is worth noting that the median concentration for Lake Kōhangatera is very close to the NPS-FM 2020 threshold between "B" and "C" bands (0.500 mg/L). Furthermore, there is a high level of variability in the data collected to date (Figure 5).

Both lakes were estimated to be in a "C" state for TP (Heath, 2022; Schallenberg, 2019). Calculation of median TP concentrations using all available data again confirms the placement of the lakes in this NPS-FM band, but as with TN, there is considerable variation in this limited dataset (Figure 5) and median values place these lakes near the "C"/"D" threshold of 0.050 mg/L (Table 31).

Overall, the low number of data points available to make these current state assessments and the variability in the data collected to date, make the confidence in current state assessments very low.

Table 31: Summary of state estimates for Lakes Kōhangapiripiri and Kōhangatera from Schallenberg (2019) and the WIP (Heath, 2022) for key lake water quality attributes in the NPS-FM 2020. Median and maximum (where applicable) concentrations and their associated NPS-FM state and WIP TASs are also presented.

Lake	Schallenberg (2019)	WIP	Median to date	Max. to date	TAS
Phytoplankton					
Kōhangapiripiri	"A/B"	"A"	1.5 mg/m³ "A"	6 mg/m³ "A"	"A"
Kōhangatera	"A/B"	"A"	5.0 mg/m³ "B"	35 mg/m³ "C"	"A"
TN					
Kōhangapiripiri	"C"	"C"	0.660 mg/L "C"	NA	"B"
Kōhangatera	"B"	"B"	0.480 mg/L "B"		"B"
TP					
Kōhangapiripiri	"C"	"C"	0.043 mg/L "C"	NA	"B"
Kōhangatera	"C"	"C"	0.040 mg/L "C"		"B"

Previously, Perrie and Milne (2012) speculated that given the low level of modification within the catchments of both lakes, the elevated concentrations of nutrients recorded may represent natural conditions associated with the natural dissolved organic matter in the lakes (i.e., while concentrations of TN are indicative of a super trophic state in Lake Kōhangatera this nitrogen is largely present in an organic form and not bioavailable). However, there is little information in the scientific lake literature to support this speculation and further monitoring and investigation would be required to establish whether this is the case or not.

[9] Following Schallenberg (2019), the polymictic total nitrogen NPS-FM 2020 thresholds were used in the assessment here.

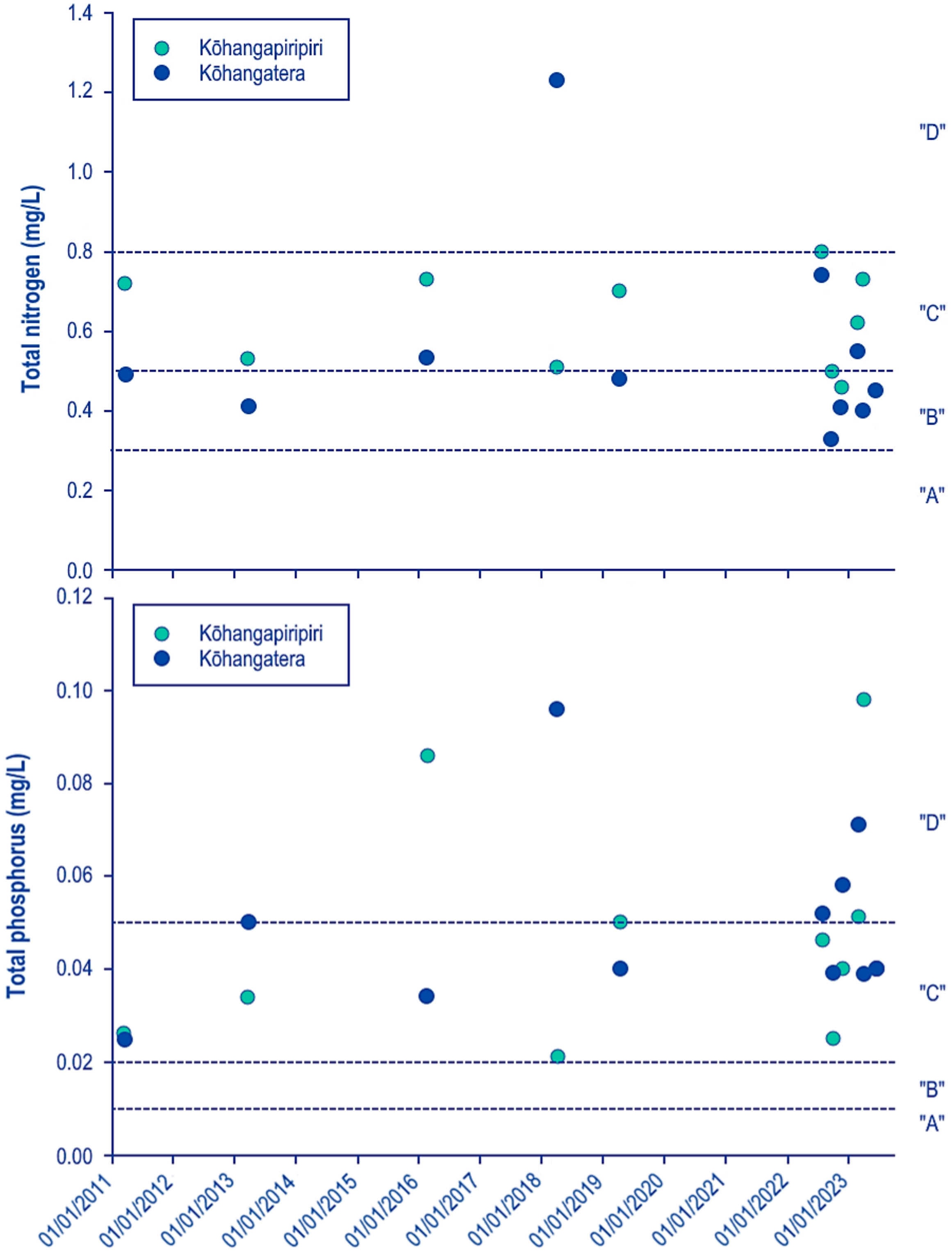

Figure 5: Available TN (top) and TP (bottom) concentration data for the Parangārehu Lakes (as of June 2023). Horozontal dashed lines indicate the various NPS-FM 2020 bands with band grades indicated on the right y-axis.

7.2.1.2 Phytoplankton and cyanobacteria attributes

Schallenberg (2019) placed both lakes in "A"/"B" states and Heath (2022) placed both lakes in the "A" state for the phytoplankton (trophic state) attribute. Additional data has recorded higher maximum chlorophyll *a* concentrations in Lake Kōhangatera (Figure 6) which would place this lake in a "C" state. The additional data collected from Lake Kōhangapiripiri still currently places this lake in the "A" state. Algal blooms have also previously been reported for these lakes (Gibbs, 2002) and a palaeoecological reconstruction for Lake Kōhangapiripiri indicates a significant increase in algal biomass post European settlement (https://lakes380.com/lakes/Kōhangapiripiri/).

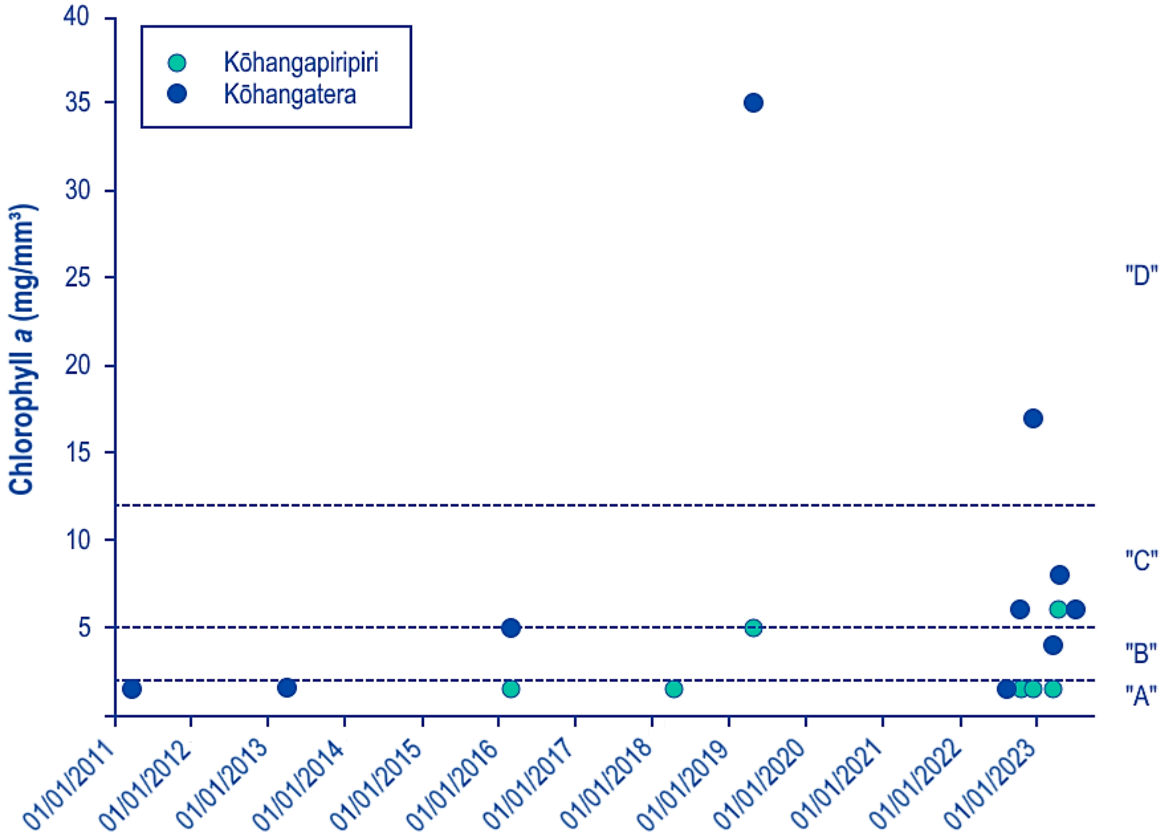

Figure 6: Available chlorophyll a concentration data for the Parangārehu Lakes (as of June 2023). Horizontal dashed lines indicate the various NPS-FM 2020 bands (median) with band grades indicated on the right y-axis.

Since July 2022, cyanobacteria biovolume data has been collected from these lakes for first time. While biovolume data are typically low, in November 2022 both lakes recorded high to extremely high cyanobacteria biovolumes (20 and 2 mm^3/L in Kōhangatera and Kōhangapiripiri, respectively; Figure 7). Based on data collected to date (see Table 30), the 80th percentile required by the NPS 2020 to assess the cyanobacteria attribute are 0.248 mm^3/L in Lake Kōhangatera and 0.008 mm^3/L in Lake

Kōhangapiripiri. This would place both lakes in the “A” band[10] for the cyanobacteria (planktonic) which aligns with the “A” band stated in the WIP (Heath, 2022).

Figure 7: Cyanobacterial scum (*Dolichospermum lemmermannii*) observed around the southern edge of Lake Kōhangatera (November 2022).

7.2.1.3 Ammonia toxicity

Schallenberg (2019) did not attempt to characterise a baseline state for NH_4-N toxicity in either lake. Heath (2022) estimated the baseline state for NH_4-N toxicity to be in the “A” band in the WIP for both lakes. Comparison of median pH-adjusted NH_4-N nitrogen concentrations calculated from all available data with thresholds in the NPS-FM 2020 would place both lakes in the “A” band (Median = 0.003 and 0.005 mg/L in Lakes Kōhangapiripiri and Kōhangatera, respectively). Similarly, 95th percentile pH-adjusted NH_4-N l concentrations would also place both lakes in the “A” band (95th percentile = 0.005 and 0.024 mg/L in Lakes Kōhangapiripiri and Kōhangatera, respectively).

[10] While currently placed in the “A” band, it’s again important to highlight the data paucity for this attribute as the NPS-FM 2020 requires that the 80th percentile needs to be calculated from a minimum of 12 results collected over three years. Therefore, there is high uncertainty with this current state assessment. Regardless of the NPS-FM 2020 cyanobacteria band thresholds and statistical assessment, it is worth being aware that the currently recorded maximum concentrations in both lakes are above or well above the 1.8 mm^3/L action (red mode) of the New Zealand guidelines for cyanobacteria in recreational fresh waters (MfE/MoH, 2009).

7.2.1.4 *E. coli*

Heath (2022) considered there to be insufficient data to attempt to estimate a current *E. coli* state and Schallenberg (2019) did not attempt to assess a baseline *E. coli* attribute state. Five *E. coli* results are available for Lakes Kōhangapiripiri and six for Lake Kōhangatera that were collected during the 2022/23 year (Table 30). While restricted to just a few data points, *E. coli* results are typically low with maximum concentrations of 200 and 400 CFU/100mL recorded in Lake Kōhangapiripiri and Kōhangatera, respectively (median = 23 and 125 CFU/100mL, respectively). Comparisons of these data with thresholds in the NPS-FM 2020 would place both lakes in the "A" band for the various *E. coli* attribute thresholds (Table 32).

Table 32: Summary of *E. coli* statistics compared against NPS-FM 2020 thresholds.

Lake	Statistic	Numeric (% or CFU/100mL)
Lake Kōhangapiripiri	Median (CFU/100mL)	23
	95th %ile (CFU/100mL)	186
	% over 260	0
	% over 540	0
Lake Kōhangatera	Median (CFU/100mL)	125
	95th %ile (CFU/100mL)	350
	% over 260	17
	% over 540	0

7.2.2 Aquatic plant attributes

Assessments of the current state and baseline states (at 7 September 2017) of the two submerged plant attributes (native and invasive species) in the NPS-FM 2020 that are presented in the WIP are considered robust because assessments have been undertaken following appropriate methodology (Heath, 2022). However, it is still important to acknowledge that a level of band/state jumping is still evident between different assessments undertaken several years apart (Table 33). For example, when including the most recent surveys (February 2023), scores for native condition in Lake Kōhangapiripiri have ranged from a "C" state (2016) through to a "A" state (2023) (Table 33).

Table 33: Summary of native condition and invasive impact scores for submerged vegetation in Lakes Kōhangapiripiri and Kōhangatera. NPS-FM states, based on these scores, are presented in parentheses. Current states, baseline states and TASs for these attributes are also presented. Native condition and invasive impact scores are sourced from de Winton (2020) and de Winton (in prep).

Year	Lake Kōhangapiripiri		Lake Kōhangatera	
	Native condition	Invasive impact	Native condition	Invasive impact
2004	70.0 ("B")	38.5 ("C")	70.0 ("B")	23.0 ("B")
2011	72.9 ("B")	37.8 ("C")	82.9 ("A")	5.2 ("B")
2013	Not assessed	Not assessed	83.0 ("A")	8.1 ("B")
2016 (Baseline state)	35.7 ("C")	61.5 ("C")	81.4 ("A")	15.6 ("B")
2019	64.3 ("B")	48.1 ("C")	74.3 ("B")	9.6 ("B")
2023 (Current state)	81.4 ("A")	7.4 ("B")	78.6 ("A")	5.9 ("B")
WIP current states	"B"	"C"	"B"	"B"
WIP TAS	"A"	"B"	"A"	"B"

7.3 Recommendations on current/baseline states for NPS-FM 2020 lake attributes to be included in PC1

Based on a meeting held on 28/06/2023 attended by Dr Michael Greer (Principal Scientist/Director, Torlesse Environmental Ltd), Ms Rachel Pawson (Senior Policy Advisor, GW) and myself, it was agreed that all available data (including data collected during 2022/23) should be used to inform the baseline state of the water quality attributes to be included in PC1. This decision was made given the lack of data available prior to this point that was used to determine the current state estimates during the WIP process. Table 34 summarises the recommended current/baseline states to be included in the upcoming Plan Change. It should still be noted though that even with the inclusion of more recently collected data to determine these current states, these data still fall well short of the data requirements in the NPS-FM 2020 and those recommended by Burns *et al.* (2000) for understanding lake water quality. Hence, there is still low confidence in the accuracy of these current state assessments. The collection of additional water quality data from these two lakes needs to be a priority for GW moving forward. No changes are recommended to the baseline states presented in the WIP for NPS-FM aquatic plant attribute states.

Table 34: Recommended current (water quality attributes) and baseline (submerged plant attribute) states for selected NPS-FM water quality attributes to be included in PC1. An * indicate where these differ from the baseline states presented in the WIP.

Attribute	Lake Kōhangapiripiri	Lake Kōhangatera
TN	"C"	"B"
TP	"C"	"C"
Chlorophyll *a*	"A"	"C"*
Cyanobacteria	"A"	"A"
NH_4-N (toxicity)	"A"	"A"
E. coli	"A"	"A"
Submerged plants (natives)	"C"*	"A"*
Submerged plants (invasive species)	"C"	"B"

7.4 Improvements required by the WIP

7.4.1 Water quality attributes

Compared to their current state estimates (in Schallenberg (2019) and Heath (2022); see Table 31), the WIP requires reductions in nutrients in both lakes. Concentrations of TP are required to reduce to shift both lakes from their estimated "C" states up into "B" states and concentrations of TN are required to reduce in Lake Kōhangapiripiri to shift it from an estimated "C" state to a "B" state. Lake Kōhangatera is currently estimated as being in "B" state for TN and the WIP does not require an improvement from this state. However, without robust water quality data to understand the current nutrient concentrations in each lake, it is difficult to establish the actual size of nutrient reductions required to make these improvements.

Despite the current inability to establish accurate estimates of the nutrient state for these lakes, data available since the WIP assessments indicate that phytoplankton and cyanobacteria attributes may be in a poorer to much poorer state than originally estimated. Thus, understanding the current nutrient state and the influence of nutrients on the state of phytoplankton and cyanobacteria in these lakes should be a high priority to better enable protection of their outstanding values. Anthropogenic sources of nutrients that drive proliferation of phytoplankton, cyanobacteria and benthic algal blooms all have the potential to impact on the high aquatic plant values that both lakes are known for (i.e., they are scheduled as Outstanding Waterbodies in the Proposed Natural Resources Plan).

Notwithstanding the limitations in the current lake data, there is enough general understanding in lake management that reducing external anthropogenic nutrient inputs into these lakes will be beneficial to protecting their existing high values (MfE and Stats NZ, 2023). Unfortunately, though, based on the current data it is not possible to determine the extent to which anthropogenic nutrient loads must reduce to meet the WIP nutrient and phytoplankton TASs because:

- It is not possible to ***accurately*** determine the baseline state of these attributes from the available data (i.e., the level of in-lake improvement needed to meet the TAS is uncertain); and
- Relationships between external nutrient loads, in-lake nutrient concentrations and phytoplankton and cyanobacteria biomass have not been established.

As such, it is my opinion that based on the lack of robust data, the most defensible method of setting TAS for nutrients and phytoplankton may be to acknowledge in the Plan that an accurate baseline cannot be established but that there is a clear desire for these attributes to improve by 2040. This may best be captured in PC1 by a narrative 'improve' target. This approach would need to:

1. Be coupled with the implementation of a robust monitoring programme to fill current knowledge gaps (including current state and a lake nutrient budget); and
2. Ensure that processes are in place to minimise external nutrient load inputs in the catchments of both lakes.

7.4.2 Aquatic plant attributes

Based on the assessments in Schallenberg (2019) and Heath (2022), the WIP requires improvements in the submerged plants (natives) attribute in both lakes from the “B” band up into the “A” band. For the submerged plants (invasive), the WIP requires Lake Kōhangapiripiri to shift it from the “C” band to a “B” band. The WIP baseline for submerged plants (invasive) in Lake Kōhangatera is the “B” band and the WIP does not require an improvement from this band.

Based on the February 2023 surveys of aquatic plants that occurred post the setting of the WIPs TAS for aquatic plant attributes, both lakes are currently meeting their TAS (see Table 33). This indicates that these TAS are achievable for both lakes, although note the variability in these states in previous years.

In my opinion, maintaining these TAS post 2023 will require:

1. regular monitoring of the current presence of invasive weeds and their impact;
2. undertaking control of these invasive weeds as required (note this currently occurs in Lake Kōhangatera);
3. ensuring no new invasive weeds are introduced into these lakes;
4. ensuring no new non-native fishes are introduced into these lakes that may directly or in-directly (via water quality degradation pathways) impact native aquatic plants;
5. regular monitoring of the native aquatic plant communities to better understand their variability and their drivers (both natural and anthropogenic); and,
6. ensuring water quality is maintained to support healthy native aquatic plant communities.

7.4.3 Additional note based on decisions made after publication (Author: Michael Greer)

Since this memorandum was published GW have made the decision to:

- Include all TASs set out in the WIPs regardless of whether they are informed by monitoring or modelling data that meets the requirements of the NPS-FM 2020; and
- Set baseline states for lakes off limited data collected outside of the NPS-FM 2020 prescribed baseline period (Presented in Sections 7.2 and 7.3). This approach was considered justified as the alternative was to have a lakes TAS table in PC1 without any baseline states other than for submerged plants (natives and invasive species).

Consequently, the recommendations made in Section 7.4.1 have not been adopted in Table 7.

8 Recommended approach for setting 'maintain' TASs in PC1

First published: 13/07/2022

To: Plan Change 1 Policy and Technical Team
Greater Wellington Regional Council

Many of the TASs in the WTWT and TAoP WIPs represent a maintain state. It is clear from the NPS-FM 2020 definition of **degrading**, that when setting TAS maintain does not mean 'within an attribute state. Thus, 'maintain' TASs need to capture the baseline state in some way, rather than simply denoting an attribute state. One option for doing this is to set hard numeric objectives that reflect the baseline state. However, this would likely result in sites fluctuating between meeting and not meeting that TAS due to natural temporal variability in water quality and freshwater ecosystems. An alternative recommended approach that relies on using trend analysis or statistical comparisons between monitoring periods is set out below in Table 35.

Table 35: Possible method for presenting 'maintain' TASs without specifying numbers.

Site	Assessment statistic	Baseline state			Short term target		Long term target	
		Baseline period	By statistic	Numeric State	Numeric State	Concentration	State	Conc.
Site 1	Median	2012-2017	1.5 mg/L (B)	B	B	Maintain at baseline state or improve*	A	1 mg/L
	95th percentile		2.2 mg/L (B)					1.5 mg/L
Site 2	Median	2012-2017	B	C	C	Maintain at baseline state or improve*	A	1 mg/L
	95th percentile		3.6 mg/L (B)					1.5 mg/L
Site 3	Median	2012-2017	C	D	C	Maintain at baseline state or improve*	A	1 mg/L
	95th percentile		D			6.9 mg/L		1.5 mg/L

*At sites where monitoring is continuous (conducted at a regular interval over the period for assessment) maintenance and/or improvement at the baseline state shall be determined through benchmarking against the TAS thresholds and trend analysis. An attribute will not be considered to be maintained within an attribute state:

- If trend analysis indicates a deteriorating trend is more likely than not since the baseline period[11]:
- The trend is inconsistent with what would be expected based on climate cycles over the period for assessment;
- There is evidence of a human activity contributing to the trend.

At sites where monitoring is intermittent (conducted in blocks over the period for assessment) maintenance and/or improvement shall be determined using an appropriate statistical analysis such as the Kruskal-Wallis test. Water quality will not be considered to be maintain or improved if:

- Such an analysis detects statistically significant (if measured via a p-value) or meaningful (if measured via an effect size) degradation between monitoring blocks (including the baseline period).
- Changes in water quality is inconsistent with what would be expected based on climate cycles over the period for assessment;
- There is evidence of a human activity contributing to changes in water quality.

Note: The recommended approach above was discussed in the PC1 TAG meetings held on the 02/05/2022 and the 16/05/2022. The TAG agreed that the approach was reasonable.

[11] The NPS-FM stipulates that degrading means that "*a deteriorating trend is more likely than not*". Thus, in Table 35 the trend categories that constitutes 'maintain or improve' has been determined from that definition. However, there may be some benefit in selecting site-specific trend categories for maintenance based on the value and condition of the stream.

8.1 Amendments made when drafting PC1 provisions (Author: Michael Greer)

During the development of PC1 it became clear that the footnote to Table 35 would take up too much space in the NRP. Accordingly, the wording was simplified to

"Maintenance, improvement or deterioration in the state of an attribute will be assessed through:

- *Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and*
- *Taking the impact of climate and human activity into account."*

Prepared by:

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9 Sediment load reductions to meet suspended fine sediment TASs

Subject:	**Plan Change 1 Sediment – Clarity relationship assessment**
Attention:	Rachel Pawson, Michael Greer, Alastair Smaill
From:	Stuart Easton, James Blyth
First published:	22 August 2023
Copies to:	Brent King

9.1 Introduction

This memo assesses suspended sediment and visual clarity (clarity) relationships for existing State of Environment (SOE) monitored TAS across WTWT and TAoP Whaitua. Analysis varied for both Whaitua:

9.1.1 Te Whanganui-a-Tara Whaitua

- Suspended sediment load reductions were estimated based on requirements to meet visual clarity targets set in the WIP.
    - Calculation of suspended sediment load reductions was necessary as only a baseline sediment model was built for this Whaitua, and clarity targets set by the Whaitua Committee were not linked directly to modelled scenarios with specified load reductions (but clarity targets were however guided by Expert Panel predictions of clarity attribute state improvements during mitigation scenarios that relied heavily on Porirua Whaitua water quality modelling).

9.1.2 Te Awarua-o-Porirua Whaitua

- Suspended sediment load reductions were estimated based on requirements to meet visual clarity targets set in WIP (as for WTWT).
    - As the NPS-FM 2020 identified clarity as an attribute in the National Objectives Framework (NOF) after the TAoP Whaitua was completed, clarity targets were set by GW more recently for three sites only.
- Clarity improvements were predicted, based on three previously modelled sediment load reduction scenarios.

Provided data are summarised in Section 9.2, analysis methodology is included in Section 9.3 and results are provided in Section 9.4. A brief limitations discussion is given in Section 9.5.

9.1.3 Scope of Works

Currently GW are exploring the use of sediment loads as part of the management framework for meeting the visual clarity target attribute states for TAoP and WTWT. Thus, it is important that the link between these two factors is understood when drafting the S32 technical report. Furthermore, visual clarity was not a compulsory attribute when the TAoP WIP was being developed and was not considered in the modelling for that Whaitua process. Linking sediment loads and visual clarity will help fill this gap and enable changes in visual clarity to be estimated under the scenarios already tested for the TAoP Whaitua. This will further GW's understanding of the benefits of certain non-regulatory management actions when drafting action plans.

9.2 Data

Data provided by GW comprised:

1. Suspended Sediment Concentration (SSC), Total Suspended Solids (TSS), and Clarity measurements from 2011 – 2021 for 23 SOE sites.
2. Paired Autosampler-derived SSC and Turbidity measurements for 3 sites: Horokiri Stream at Snodgrass, Pāuatahanui Stream at Gorge, and Porirua Stream at Town Centre.
3. Sediment load estimates from dSedNet modelling in TAoP Whaitua and WTWT. Scenario load reductions were available for TAoP Whaitua only.
4. Baseline and target TAS clarity medians and attribute states set by GW (*pers. comm.* Michael Greer October 2022).

9.2.1 Monitoring data

Analysed monitoring data were limited to the most recent 5 years (2016–2021 inclusive) to ensure consistency with current land use and climate patterns. To improve the relationship between clarity and suspended sediment, reported SSC and TSS values less than the detection limit were removed. Table 36 summarises the selected data. Due to the greater number of samples available, TSS was preferred to SSC to achieve a robust relationship with clarity measurements.

SSC is the preferable measurement to use for clarity relationships given it involves complete analysis of a sample container, while TSS involves analysing only a sub-sample. However, GW's monitoring record has a greater number of paired TSS and clarity measurements (see Table 36). Both TSS and SSC samples from SOE sites have collected limited numbers of event-based flows, where higher concentrations of suspended sediment occur. Subsequently, the greater number of TSS samples is predominantly at sediment concentrations below 200 mg/L, with a handful of samples between 200 and 500 mg/L (see Figure 8). It is expected the TSS and SSC relationship in Figure 8 would decrease if more event-based flows were captured. For this analysis, it was considered acceptable to use TSS to establish relationships with clarity, as both measurements were often collected concurrently during SOE monitoring rounds. Figure 8 plots all paired SSC:TSS samples and shows a strong correlation.

Table 36: Monitoring site data summary (2016-2021).

Monitoring Site	TAS?	Whaitua	Clarity Count	SSC Count (above detection)	TSS count (above detection)
Taupo Stream at Plimmerton Domain	Yes	TAoP	16	1	11
Horokiri Stream at Snodgrass	Yes	TAoP	58	145	28
Pāuatahanui Stream at Elmwood Bridge	Yes	TAoP	58	8	32
Porirua Stream at Milk Depot	Yes	TAoP	58	8	30
Whakatikei River at Riverstone	Yes	TWT	57	1	10
Hutt River at Te Marua Intake Site	Yes	TWT	58	2	8
Mangaroa River at Te Marua	Yes	TWT	57	5	20
Hulls Creek adjacent Reynolds Bach Drive	Yes	TWT	16	5	14
Hutt River at Boulcott	Yes	TWT	58	12	29
Waiwhetū Stream at Whites Line East	Yes	TWT	54	3	11
Black Creek at Rowe Parade end	Yes	TWT	17	4	16
Wainuiomata River Dnstr of White Bridge	Yes	TWT	58	2	9
Kaiwharawhara Stream at Ngaio Gorge	Yes	TWT	58	3	5
Karori Stream at Mākara Peak Mountain Bike Park	Yes	TWT	58	1	4
Mākara Stream at Kennels	Yes	TWT	58	13	55
Porirua Stream at Glenside Overhead Cables	No	TAoP	40	8	15
Akatarawa River at Hutt Confluence	No	TWT	58	1	9
Hutt River Opposite Manor Park Golf Club	No	TWT	58	10	27
Owhiro Stream at Mouth	No	TWT	17	6	15
Pākuratahi River 50m Below Farm Creek	No	TWT	57	4	12
Stokes Valley Stream at Eastern Hutt Road	No	TWT	17	4	12
Wainuiomata River at Manuka Track	No	TWT	58	0	1
Ōrongorongo River at Ōrongorongo Station	No	TWT	0	0	0

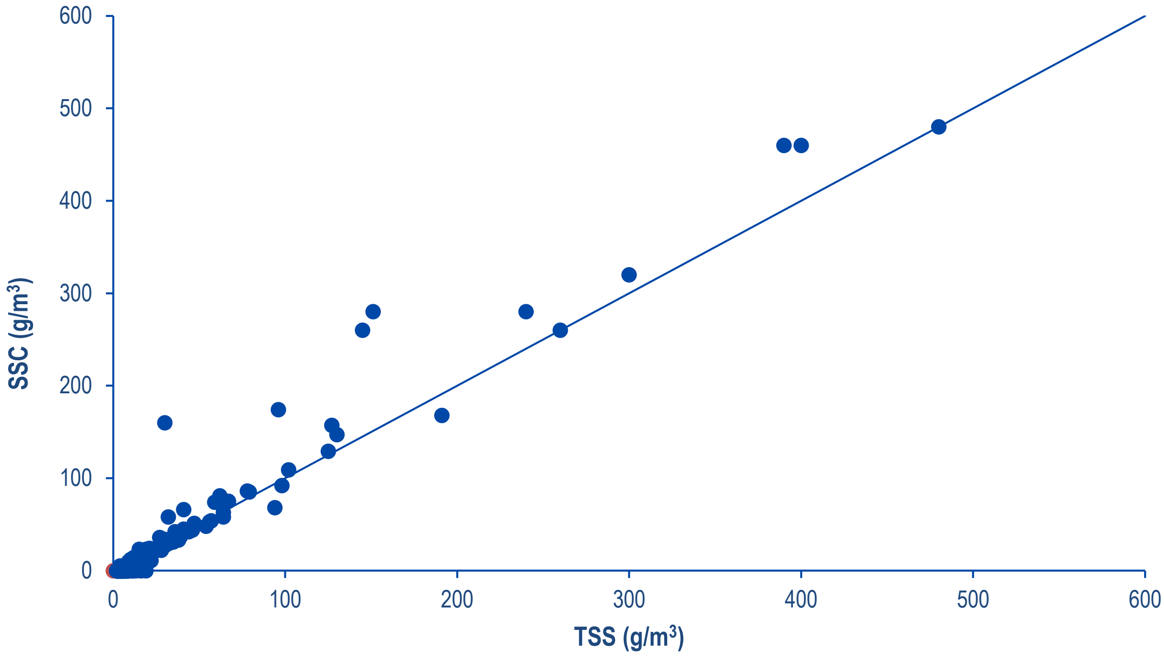

Figure 8: Paired SSC and TSS samples for all sites (n=106). 1:1 line plotted in blue.

9.2.2 Baseline Clarity and Targets

Baseline and target visual clarity medians and associated attribute states from the NPS-FM 2020 as provided by GW are shown in Table 37

Table 37: Baseline visual clarity and targets. Baseline medians below the target are in bold.

Site	Whaitua	Baseline median	Baseline attribute state	Target median	Target attribute state
Akatarawa River at Hutt Confluence	TWT	4.8	A	≥4.8	A
Hutt River at Te Marua Intake Site		4.6	A	≥4.6	A
Whakatikei River at Riverstone		4	A	≥4	A
Hutt River at Boulcott		**2.8**	B	≥2.95	A
Hutt River Opposite Manor Park Golf Club		3	A	≥3	A
Mangaroa River at Te Marua		**1.6**	D	≥2.22	C
Pākuratahi River 50m Below Farm Creek		4.5	A	≥4.5	A
Hulls Creek adjacent Reynolds Bach Drive		1.2	A	≥1.2	A
Waiwhetū Stream at Whites Line East		1.4	A	≥1.4	A
Ōrongorongo River at Ōrongorongo Station		≥2.95	A	≥[a]	A
Wainuiomata River at Manuka Track		3.9	A	≥3.9	A
Black Creek at Rowe Parade end		1.3	D	≥2.22	C
Wainuiomata River Dnstr of White Bridge		2.2	D	≥2.2	C
Mākara Stream at Kennels		**1.6**	D	≥2.22	C
Korokoro Stream		≥2.95	A	≥[a]	A
Kaiwharawhara Stream at Ngaio Gorge		3.6	A	≥3.6	A
Karori Stream at Mākara Peak Mountain Bike Park		3.2	A	≥3.2	A
Owhiro Stream at Mouth		**1.8**	D	≥2.22	C
Horokiri Stream at Snodgrass	TAoP	2.8	B	≥2.8	B
Pāuatahanui Stream at Elmwood Bridge		**2**	D	≥2.22	C
Porirua Stream at Milk Depot		2.4	A	≥2.4	A

[a] Maintain or improve

9.2.3 Autosampler data

Three autosamplers have collected SSC and turbidity measurements in the Porirua Whaitua since 2012; Horokiri Stream at Snodgrass, Pāuatahanui Stream at Gorge, and Porirua Stream at Town Centre. Of the sites, only Horokiri has clarity measurements that align with the turbidity and SSC samples:

- Horokiri Stream at Snodgrass clarity - turbidity relationship is poor ($r^2 = 0.45$, n = 63).
- Horokiri Stream at Snodgrass clarity - SSC relationship is strong ($r^2=0.97$), although there are only 6 paired samples above the SSC detection limit.

Due to the lack of matching clarity data, the autosampler information has been precluded from the remainder of the analysis.

9.2.4 Sediment load estimates

Baseline sediment loads were taken from previously modelled dSedNet results (Easton *et al.*, 2019b; Easton and Cetin, 2020). While monitoring locations generally align with the dSedNet reporting points, discrepancies are present; e.g., the Karori stream monitoring site is mid-way along a dSedNet sub-catchment, resulting in a likely overestimate of sediment load due to the increased contributing catchment area in the model. Furthermore, the reporting periods from which annual average loads are derived do not align between TAoP sites (2005-2014), WTWT sites (1992-2018), and the selected clarity monitoring period used in this analysis (2016-2021). Further limitations are outlined in the referenced reports. Reported sediment loads should therefore be viewed as estimates only.

9.3 Methodology

For WTWT sites and three TAoP sites with available data (Horokiri Stream at Snodgrass, Pāuatahanui Stream at Elmwood Bridge, and Porirua Stream at Milk Depot), the proportional change in sediment load required to meet visual clarity targets was estimated using the approach in Hicks *et al.* (2019) (also reported in Neverman *et al.* (2021)):

$$PR_v = 1 - (V_o/V_b)^{1/\alpha}$$

Equation 1

PR_v = minimum proportional reduction in load required to achieve the objective
V_o = target median visual clarity
V_b = baseline median visual clarity
α = co-efficient used in power law relationship between SSC and clarity, note TSS has been preferred in this analysis (see Section 9.2).

For each TAS with monitoring data, site specific TSS – visual clarity coefficients were calculated (see Section 9.4.1). Where r^2 values were less than 0.5, the regional coefficient of -0.782 was adopted (Figure 9), which is comparable to the national average of -0.76 reported in Hicks *et al.* (2019).

Baseline and target median visual clarity values were provided by GW (Table 37).

For TAoP sites, an inverse approach has also been applied to estimate the visual clarity reductions achieved under each of the three sediment load reduction scenarios modelled for the Porirua Whaitua: Business as Usual (BAU), Improved, and Water Sensitive (WS):

$$V_o = (1 - PR_v)^{\alpha} \times V_b$$

Equation 2

V_o = median visual clarity achieved under the scenario
PR_v = proportional reduction in load under the scenario
α = Co-efficient used in power law relationship between TSS and visual clarity.
V_b = median visual clarity calculated from the monitoring data (Section 9.2)

9.4 Results

9.4.1 Clarity : TSS relationship

Paired clarity and TSS samples were plotted for all data points (Figure 9), for each TAS site (Appendix G), and for all sites within each of the two Whaitua (Appendix H). The regional[12] clarity:TSS relationship is described by the equation ($r^2 = 0.62$):

$$Clarity = 4.11\, TSS^{-0.782}$$

Equation 3

In general, there was a robust relationship between the two variables which were expectedly negatively correlated. TAS site r^2 values were above 0.5 for all sites except Taupo Stream at Plimmerton Domain (n=11) and Waiwhetū Stream at Whites Line East (n=11). For these two sites, the analysis in Sections 9.4.2 and 9.4.3 used the regional exponent from Equation 3 (-0.782). For all other sites, the site-specific exponent was used. Inter-site exponent standard deviation = 0.1.

Data limitations are evident in paired samples at TSS concentrations below 10 mg/L. This is where there can be a high variability in field clarity measurements, yet the corresponding TSS concentrations exhibit low variability. The relationship strengthens when TSS exceeds 10 mg/L, indicating suspended sediment has a greater 'control' on clarity measurements, likely as flow increases following rainfall. It could be expected that the relationship would be improved with greater data availability or increased TSS reporting precision.

[12] Regional refers to this plan change's monitoring sites (i.e. TAoP and TWT Whaituas only, not all of Wellington regional).

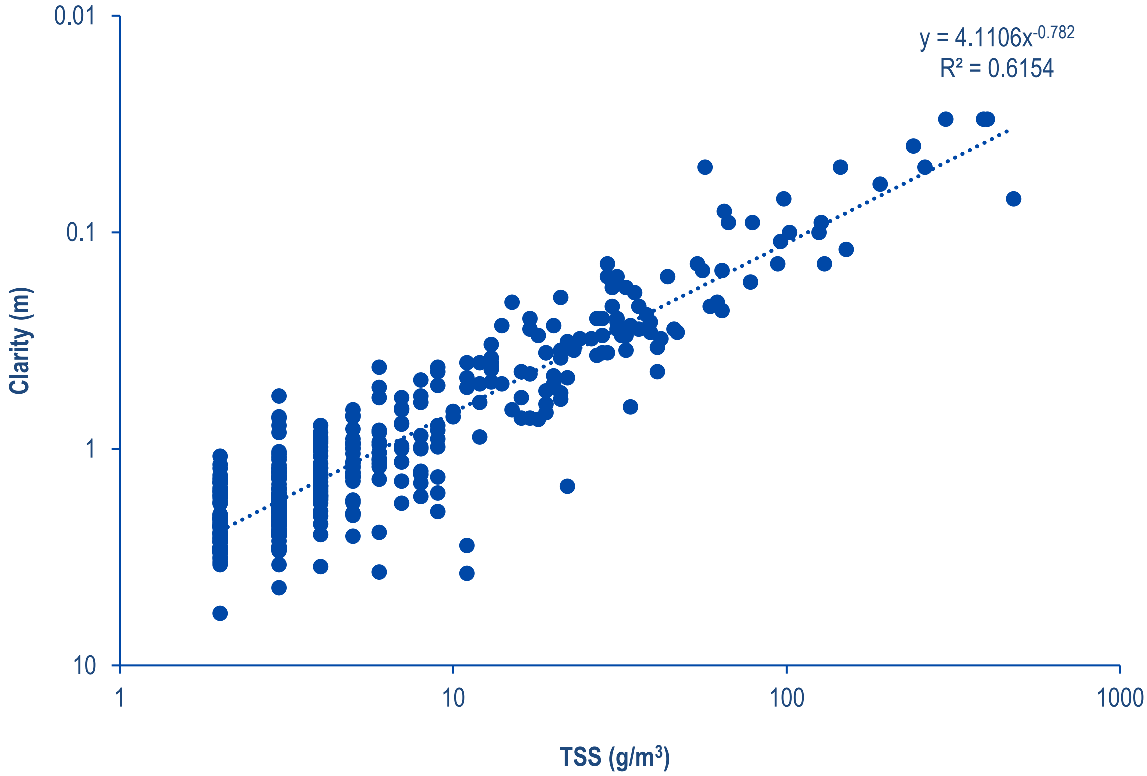

Figure 9: Paired Clarity measurements and TSS samples for all sites (n=373). Log10 scale.

9.4.2 Annual sediment load reductions

The estimated load reduction required to achieve clarity targets for monitored TAS as calculated by Equation 1 are presented in Table 38.

Significant (>10%) reductions in sediment load are required for four of the five sites that do not currently meet the clarity targets, in particular the Black Creek at Rowe Parade site. The remaining site, Hutt River at Boulcott, requires a 7% reduction in sediment load to achieve the 2.95 m clarity target.

Table 38 is extended in Appendix I to show the range of load reductions calculated with the regional exponent and inter-site standard deviation. For four of five sites that do not currently meet the clarity targets, the range in load reduction is relatively small (≤ 5%). For Mangaroa River at Te Marua, the reduction calculated with the regional exponent (-31% to -38%, ± 1. std. dev.) is significantly less than that calculated with the site-specific exponent (-45%) due to the relatively small clarity improvements observed in response to increased sediment load (TSS) for this site (see Appendix H).

Table 38: Estimated load reduction required to achieve clarity targets for monitored TAS. Current clarity medians below the target are in bold (Superseded – see Table 40).

Target Attribute Site	Part-FMU	Monitoring Site	Baseline clarity median (m)	Clarity target (m)	Baseline dSedNet mean annual load (t/year)	Load reduction required to meet clarity target
Te Whanganui-a-Tara TAS						
Whakatikei River	Whakatikei	Whakatikei River at Riverstone	4	4	3,189	0%
Mangaroa River	Mangaroa	Mangaroa River at Te Marua	**1.6**	**2.22**	**10,965**	**-45%**
Hulls Creek	Te Awa Kairangi Urban Streams	Hulls Creek adjacent Reynolds Bach Drive	1.2	1.2	181	0%
Te Awa Kairangi Downstream	Te Awa Kairangi mainstem	Hutt River at Boulcott	**2.8**	**2.95**	**102,303**	**-7%**
Waiwhetū Stream	Waiwhetū	Waiwhetū Stream at Whites Line East	1.4	1.4	228	0%
Wainuiomata River Upstream	Wainuiomata Urban Streams	Black Creek at Rowe Parade end	**1.3**	**2.22**	**382**	**-50%**
Wainuiomata River Downstream	Wainuiomata Rural Streams	Wainuiomata River Downstream of White Bridge	2.2	2.2	12,243	0%
Kaiwharawhara Stream	Kaiwharawhara	Kaiwharawhara Stream at Ngaio Gorge	3.6	3.6	290	0%
Karori Stream Upstream	Wellington Urban	Karori Stream at Mākara Peak Mountain Bike Park	3.2	3.2	2,159	0%
Mākara Stream	South-west coast rural streams	Mākara Stream at Kennels	**1.6**	**2.22**	**4,437**	**-34%**
Te Awarua-o-Porirua TAS						
Horokiri Stream	Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	2.8	2.8	764	0%
Pāuatahanui Stream	Takapū	Pāuatahanui Stream at Elmwood Bridge	**2**	**2.22**	**2311**	**-13%**
Porirua Stream	Te Riu o Porirua	Porirua Stream at Milk Depot	2.4	2.4	1705	0%

9.4.3 Porirua scenario clarity change

Estimated clarity achieved under modelled load reduction scenarios for monitored Porirua Whaitua TAS (as estimated by Equation 2) are presented in Table 39. The results indicate that under the Improved and WS scenarios, significant improvements in clarity are predicted for all monitored sites. The Taupo and Porirua Stream sites are predicted remain in the 'A' NOF band in all scenarios. Horokiri stream is predicted to improve from the 'B' band to the 'A' band in the Improved and WS scenarios. Pāuatahanui Stream at Elmwood bridge is predicted to be in the 'B' band the WS and Improved scenarios and above the target clarity, however, would remain below the national bottom line under the BAU scenario.

Table 39: Estimated clarity (m) and NOF band achieved under modelled sediment load reduction scenarios for monitored TAoP TAS.

Target Attribute Site	Part-FMU	Monitoring Site	Baseline clarity		BAU scenario clarity		Improved scenario clarity		WS scenario clarity	
			Median (m)	NOF band	Median (m)	NOF band	Median (m)	NOF band	Median (m)	NOF band
Taupo Stream	Plimmerton and Pukerua Bay	Taupo Stream at Plimmerton Domain	1.64 [a]	A	1.66	A	2.45	A	2.80	A
Horokiri Stream	Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	2.8	B	2.84	B	5.32	A	5.39	A
Pāuatahanui Stream	Takapū	Pāuatahanui Stream at Elmwood Bridge	**2**	**D**	**1.94**	**D**	2.59	B	2.83	B
Porirua Stream	Te Riu o Porirua	Porirua Stream at Milk Depot	2.40	A	2.31	A	2.57	A	2.58	A

[a] Median calculated from the monitoring data (2016-21) as Taupo Stream median and target clarity values were not set for the WIP (Section 9.2).

9.5 Limitations

The approach undertaken in this memo uses best available information and follows methods established in the literature, however limitations that are difficult to quantify are inherent in the data and methods. In particular, the use of median clarity and modelled average annual loads as key inputs fail to account for temporal aspects of erosion and sedimentation; for example, sediment mitigation measures that reduce high-flow loads (e.g., gullying or land sliding processes) may not be apparent in clarity measurements during mid- or low flows. Hence, it is unlikely that clarity values of upwards of 5 metres as predicted for the Horokiri Stream under the Improved and WS scenarios (Table 39) will be achieved in reality, even if the modelled ~50% reduction in sediment load occurs.

9.6 Update in response to February 2023 amendments to the NPS-FM 2020 (Author: Michael Greer)

The February 2023 amendments to the NPS-FM 2020 changed the definition of baseline state meaning some of the sediment load reductions listed in Table 38 are no longer relevant. Accordingly, an update is provided in Table 40 that accounts for these amendments (i.e., baseline state = median visual clarity on 07/09/2017). The Taupō and Wai-o-hata part-FMUs have also been added to Table 40 with baseline states calculated from:

- The results of sediment modelling (median TSS concentration) conducted as part of the TAoP CMP (Easton *et al.*, 2019b); and
- The regional TSS-visual clarity relationship set out in Equation 3.

Table 40: Updated estimated load reductions required to achieve clarity targets for monitored TAS. Baseline clarity medians below the target are in bold. Changes made from Table 38 are denoted in red.

Target Attribute Site	Part-FMU	Monitoring Site	Baseline clarity median (m)	Clarity target (m)	Baseline dSedNet mean annual load (t/year)	Load reduction required to meet clarity target
Te Whanganui-a-Tara TAS						
Whakatikei River	Whakatikei	Whakatikei River at Riverstone	4	4	3,189	0%
Mangaroa River	Mangaroa	Mangaroa River at Te Marua	**1.5**	**2.22**	**10,965**	**-51%**
Hulls Creek	Te Awa Kairangi Urban Streams	Hulls Creek adjacent Reynolds Bach Drive	1.2	1.2	181	0%
Te Awa Kairangi Downstream	Te Awa Kairangi mainstem	Hutt River at Boulcott	**2.4**	**2.95**	**102,303**	**-24%**
Waiwhetū Stream	Waiwhetū	Waiwhetū Stream at Whites Line East	1.1	1.1	228	0%
Wainuiomata River Upstream	Wainuiomata Urban Streams	Black Creek at Rowe Parade end	**1.3**	**2.22**	**382**	**-50%**
Wainuiomata River Downstream	Wainuiomata Rural Streams	Wainuiomata River Downstream of White Bridge	**2.1**	**2.22**	**12,243**	**-7%**
Kaiwharawhara Stream	Kaiwharawhara	Kaiwharawhara Stream at Ngaio Gorge	3.2	3.2	290	0%
Karori Stream Upstream	Wellington Urban	Karori Stream at Mākara Peak Mountain Bike Park	3.2	3.2	2,159	0%
Mākara Stream	South-west coast rural streams	Mākara Stream at Kennels	**1.6**	**2.22**	**4,437**	**-34%**
Te Awarua-o-Porirua TAS						
Horokiri Stream	Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	2.3	2.3	764	0%
Pāuatahanui Stream	Takapū	Pāuatahanui Stream at Elmwood Bridge	**1.8**	**2.22**	**2311**	**-24%**
Porirua Stream	Te Riu o Porirua	Porirua Stream at Milk Depot	1.7	1.7	1705	0%
Taupō Stream	Taupō	Taupō Stream at Plimmerton Domain	1.2	1.2	15	0%
Duck Creek	Wai-o-hata	Duck Creek at at Tradewinds Drive Bridge	1.2	1.2	526	0%

First published: 13/07/2022

To: Plan Change 1 Policy and Technical Team
Greater Wellington Regional Council

10 Alignment between existing numeric standards in the operative NRP and the WIP TASs

The purpose of this memorandum is to assess whether the TASs in the TAoP and WTWT WIP are consistent with existing numeric standards in the objectives, policies and rules of the operative NRP. This assessment has been conducted to inform the Plan Change 1 Policy and Team about where the WIP TASs sit in relation to existing NRP provisions. There is no requirement for the PC1 TASs to be consistent with the operative NRP. Thus, the findings presented here should not be treated as an assessment of the appropriateness of the WIP TASs.

10.1 Alignment between the NRP O18 and O19 objectives and WIP TASs

Objective O18 (relates to contact recreation and Māori customary use) and O19 (relates to biodiversity, aquatic ecosystem health and mahinga kai) of the NRP sets out general water quality and ecology objectives for all rivers in the Wellington Region. In doing so, they include numeric outcomes for the NPS-FM 2020 compulsory attributes identified in Table 41. Furthermore, the Cu and Zn TASs set in the TOaP and WTWT WIPs are covered by the O19 toxicant objective for rivers.

Table 41: Description of NPS-FM 2020 compulsory attributes with numeric objectives set in Objectives O18 and O19 of the NRP.

Attribute	NRP objective	Freshwater body type	Notes on NRP objectives
Cyanobacteria (planktonic)	O18	Lakes	Only applies to significant contact recreation freshwater bodies and sites with significant mana whenua values
E. coli		Rivers and lakes	Assessment statistics different from those in the NPS-FM 2020
Suspended fine sediment		Rivers	• Listed as water clarity • Only applies to significant contact recreation freshwater bodies and sites with significant mana whenua values
Deposited fine sediment			Only applies to significant contact recreation freshwater bodies and sites with significant mana whenua values
Periphyton (trophic state)	O19		Corresponds to periphyton biomass objective rather than the periphyton cover objective.
Macroinvertebrates (1 of 2)			MCI/QMCI
Fish			Corresponds to the Index of Biotic Integrity column
NO_3-N toxicity			Included in toxicants
NH_4-N toxicity			
Phytoplankton (trophic state)		Lakes	N/A
Total nitrogen (trophic state)			
TP (trophic state)			
Submerged plants (natives)			
Submerged plants (invasive species)			
Lake-bottom dissolved oxygen			
Mid-hypolimnetic dissolved oxygen			

Inconsistencies (i.e., where the TAS is less protective than the NRP objectives) between the O18 and O19 numeric objectives and the TOaP and WTWT WIP TASs are set out in Table 42. All other TASs are consistent with (i.e., equally, or more protective than) the NRP objectives. This analysis is based on the following assumptions:

- The O18 *E. coli a*ttributes are equivalent to the NPS-FM 2020 E states as:
  - The statistical, flow and seasonal restrictions on the *E. coli* objective in Table 3.1 of Objective O18 of the NRP means that concentrations can exceed 540 CFU/100mL ~40 % of the time (NPS-FM 2020 E state threshold = 30%); and
  - The objective for median *E. coli* concentrations Table 3.2 of Objective O18 of the NRP is roughly four times higher than the NPS-FM 2020 E state threshold for that statistic.
- The NPS-FM 2020 attribute states take priority over regionalised thresholds for MCI and Fish IBI; and
- The NRP river-classes and the NPS-FM 2020 sediment classes for sites in the different TAoP Whaitua and WTWT part-FMUs are consistent with those set out in Table 44.

Table 42: Inconsistencies (TAS less protective than the NRP objective) between the numeric objectives in O18 and O19 of the NRP and the TAoP Whaitua and WTWT WIP TASs. Parenthesised numbers denote the number of attribute state differences between the NRP objective and the WIP TAS. The NPS-FM 2020 attribute states have been used for macroinvertebrates and fish.

Whaitua	Part-FMU	Site	Attributes (and no# of attribute states between TAS and NRP objective)
TAoP Whaitua	Te Rio o Porirua	Porirua S. @ Glenside	NH_4-N (1), Cu (1), Zn (1)
	Te Rio o Porirua	Porirua S. @ Milk Depot	
WTWT	Wellington urban	Karori S. @ Mākara Peak	Cu (1), Periphyton (1)
		Owhiro S. @ Mouth	
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	Periphyton (1)
	South-west coast rural streams	Mākara S. @ Kennels	
	Waiwhetū Stream	Waiwhetū S. @ Whites Line East	
	Te Awa Kairangi rural mainstems	Mangaroa R. @ Te Marua	
	Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.	Periphyton (1)
		Stokes Valley S. @ Eastern Hutt Rd	
	Te Awa Kairangi rural streams	Pākuratahi Catchment	Periphyton (1), macroinvertebrates (1)
	Wainuiomata urban streams	Black Creek @ Rowe Parade	
	Wainuiomata rural streams	Wainuiomata R. D/S of White Br.	Periphyton (1)
	Parangārehu Lakes	Lake Kōhangatera	Invasive submerged plants (1), total nitrogen (1), TP (1)
		Lake Kōhangapiripiri	

10.2 Alignment between the operative NRP permitted activity rule standards and the WIP TAS and NPS-FM 2020 attributes

The permitted activity rules in the NRP includes receiving environment water quality standards for some of the attributes for which targets have been set in the TAoP and WTWT WIPs. These standards are described in the context of the NPS-FM 2020/WIP attribute states in Table 43.

Table 43: Description of NRP permitted activity receiving environment water quality standards for attributes with TASs in the TAoP and WTWT WIPs.

NRP Rule	Attribute	Receiving environment standard
Rule R91	NH_4-N toxicity	B state in all rivers
	NO_3-N toxicity	A state in all rivers
	Cu toxicity	A state in significant rivers and river class 1
		B state in all other rivers
	Zn toxicity	A state in significant rivers and river class 1
		B state in all other rivers
Rule R55	NH_4-N toxicity	B state in all rivers
	NO_3-N toxicity	A state in all rivers
	Cu toxicity	B state in all rivers
	Zn toxicity	
Rule R59	*E. coli*	E state in all rivers
	Dissolved oxygen	C state in all rivers

Table 44: Locations, NRP river classes, NPS-FM 2020 sediment classes and significance (in relation to Objectives O18 and O19 of the NRP) of sites in different TAoP Whaitua and WTWT part-FMUs.

Whaitua	Part-FMU	Site	Easting	Northing	NRP river class	SFS class	DFS class	Sig. O18	Sig. O19
TAoP	Pouewe	Horokiri S. @ Snodgrass	1761804	5450652	2	3	4	N	N
TAoP	Rangituhi	N/A			2	2	1	N	N
TAoP	Takapū	Pāuatahanui S. @ Elmwood Bridge	1761097	5446783	2	3	4	Y	N
TAoP	Taupō	Taupō S. @ Plimmerton Domain	1756919	5450368	6	2	0	Y	N
TAoP	Te Rio o Porirua	Porirua S. @ Glenside	1753290	5438364	2	3	4	Y	N
TAoP	Te Rio o Porirua	Porirua S. @ Milk Depot	1754366	5443031	2	2	2	Y	N
TWT	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	1749069	5431077	2	3	4	Y	N
TWT	Korokoro Stream	N/A			2	3	4	Y	N
TWT	Ōrongorongo	Ōrongorongo R. @ Ōrongorongo Station	1758930	5413094	1	3	4	Y	Y
TWT	South-west coast rural streams	Mākara S. @ Kennels	1743530	5433635	2	3	4	N	N
TWT	Te Awa Kairangi forested mainstems	Akatarawa R. @ Hutt Confluence	1776183	5449184	1	3	4	Y	Y
TWT	Te Awa Kairangi forested mainstems	Hutt R. @ Te Marua Intake Site	1780071	5450158	1	3	4	Y	Y
TWT	Te Awa Kairangi forested mainstems	Pākuratahi R. 50m Below Farm Ck	1784607	5451677	1	3	4	Y	Y
TWT	Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone	1772256	5446748	4	3	4	N	N
TWT	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	1761038	5437628	4	3	4	Y	N
TWT	Te Awa Kairangi lower mainstem	Hutt R. Opposite Manor Park	1766679	5442285	4	3	4	Y	N
TWT	Te Awa Kairangi rural mainstems	Mangaroa R. @ Te Marua	1778726	5448590	1	3	4	N	N
TWT	Te Awa Kairangi rural streams - Mangaroa Lower	N/A			6	3	4	N	N
TWT	Te Awa Kairangi rural streams - Mangaroa Upper				3	3	4	N	N
TWT	Te Awa Kairangi rural streams - Pākuratahi				1	3	4	N	Y
TWT	Te Awa Kairangi small forested				1	3	4	N	Y
TWT	Te Awa Kairangi urban streams	Hulls Ck adjacent Reynolds Bach Dr.	1767288	5442588	2	2	2	N	N
TWT	Te Awa Kairangi urban streams	Stokes Valley S. @ Eastern Hutt Rd	1766285	5441567	2	3	4	N	N
TWT	Wainuiomata rural streams	Wainuiomata R. D/S of White Br.	1757315	5415739	4	3	4	Y	N
TWT	Wainuiomata small forested	Wainuiomata R. @ Manuka Track	1768301	5430792	1	3	4	Y	Y
TWT	Wainuiomata urban streams	Black Ck @ Rowe Parade end	1763349	5429187	3	3	4	N	N
TWT	Waiwhetū Stream	Waiwhetū S. @ Whites Line East	1760977	5434510	6	2	2	N	N
TWT	Wellington urban	Karori S. @ Mākara Peak	1744222	5427016	2	3	4	N	N
TWT	Wellington urban	Owhiro S. @ Mouth	1747228	5421631	2	3	4	N	N

Table 45 sets out where the NRP permitted activity receiving environment water quality standards are inconsistent (i.e., less protective) with the TOaP and WTWT WIP TASs. All other permitted activity standards are consistent with (i.e., equally, or more protective than) the WIP TAS. This analysis is based on the following assumptions:

- The *E. coli* receiving environment standard in Rule R57 of the NRP references Table 3.1 of the NRP. Thus, it is equivalent to the NPS-FM 2020 E state for the reasons set out in Section 10.1;
- The NRP Schedule V 95% species protection threshold for NO_3-N equates to the NPS-FM 2020 A attribute state;
- The NRP Schedule V 95% species protection threshold for NH_4-N equates to the NPS-FM 2020 B attribute state; and
- The NRP river-classes for sites in the different TAoP and WTWT part-FMUS are consistent with those set out in Table 44.

Table 45: NRP permitted activity standards that are inconsistent with the TAoP and WTWT WIP TASs. Parenthesised numbers denote the number of attribute state differences between the NRP permitted activity standards and the WIP TAS.

Permitted activity rule	Attribute	Part-FMU
Rule R91	NH_4-N	Everywhere (1) except: • Kaiwharawhara Stream • Te Rio o Porirua • Wellington urban
	Cu	Everywhere (1) except: • Taupō • Te Awa Kairangi rural mainstems • Te Awa Kairangi small forested • Kaiwharawhara Stream • Wainuiomata small forested • Wainuiomata urban streams • Ōrongorongo
	Zn	Everywhere (1) except: • Te Rio o Porirua • Te Awa Kairangi rural mainstems • Waiwhetū Stream • Ōrongorongo
Rule R82	NH_4-N	Everywhere (1) except: • Te Rio o Porirua • Wellington urban • Kaiwharawhara Stream
	Cu	Everywhere (1) except: • Taupō • Te Rio o Porirua • Kaiwharawhara Stream • Wellington urban • Wainuiomata urban streams
	Zn	Everywhere (1) except: • Te Rio o Porirua • Waiwhetū Stream
Rule R57	*E. coli*	Everywhere (1+)
	Dissolved oxygen	Everywhere in WTWT (2)

11 Review of the sediment load reduction required to achieve sedimentation rate targets in Te Awarua-o-Porirua

To: Rachel Pawson, Environmental Policy

From: Brent King, Team Leader, Science Integration

First published: 2nd December 2022

Reviewed by: John Oldman (see Appendix J)

11.1 Purpose

This memo provides further information on the derivation of the sediment loads and load reduction 'targets' given in TAoP WIP. It provides recommended changes to the way the current load is expressed and further justification for the reduction targets.

11.2 Derivation of the limits and load reductions

Sediment load reduction targets were expressed in TAoP WIP (Table 46). These were designed to reflect the reductions necessary to achieve the sedimentation rate objectives in TAoP (Table 46).

Table 46: Total sediment load limits and targets to be achieved by 2040 in TAoP Whaitua (adapted from TAoP WIP).

Metric	Pāuatahanui	Onepoto
Sedimentation rate objective (2040)	Net average sedimentation rate is less than 2mm/year in Pāuatahanui Inlet (rolling average over the most recent 5 years of data)	Net average sedimentation rate is less than 1mm/year in Onepoto Arm (rolling average over the most recent 5 years of data)
Current total sediment load Annual average (tonnes/yr)	5,200	2,800
Sediment limit Annual average (tonnes/yr)	5,200	2,800
Sediment target % reduction from limit	40	40

The harbour modelling illustrated that reductions in sediment load would be required to reach the sedimentation rate objectives from estimated current sedimentation rates of 4.7mm/year for Pāuatahanui Inlet and 4.1mm/year for Onepoto Arm (Oldman, 2019). The modelling, however, did not directly estimate the amount of load reduction required to achieve the specific objectives set for each WMU.

The load reductions required were instead found in two ways (GWRC, 2019).

For Pāuatahanui, this was:

- Harbour modelling indicating that a sediment reduction of around 45% is estimated to result in a sedimentation rate of around 2mm/yr

- The bulk of sediment reductions in catchments draining to the Pāuatahanui Inlet are estimated to come through the mitigations associated with the modelled 'improved' scenario. This produced a load reduction of around 40%.
- While additional sediment reductions were made in the modelled 'Water Sensitive' scenario, the additional cost for these was significant.

For Onepoto, this was

- Harbour modelling indicating that a sediment reduction in Onepoto source loads of between 15 and 58% estimated to result in a sedimentation rate of between 2.5 and 0.3mm/yr
- Simple linear interpolation between these points suggests a load reduction of 40-45% may approximate to a sedimentation rate of around 1mm/yr
- The bulk of sediment reductions in catchments draining to the Onepoto Arm are estimated to come through the mitigations associated with the modelled 'improved' scenario with small additional reductions in the modelled 'Water Sensitive' scenario. The 'improved' scenario produced a load reduction of around 45%.

In both cases, the 'limit' from which the reduction target is expressed was the annual average sediment load from the 2005-14 period.

11.3 Reviews of the limits and load reductions

Brydon Hughes of Land Water People (LWP) provided review comments on the logic and basis used to establish water quality objectives, limits and targets in the TAoP WIP (Hughes, 2019) (Comments on the derivation of harbour sedimentation rate objectives, limits and load reductions noted:

- Harbour sedimentation modelling limited to a single 'representative' year (2010) while catchment model included multi-year variability
- While heavily reliant on interpolation of model results, the overall approach utilised to develop sediment loads and targets follows a logical process which appropriately recognises limitations of the available data
- Due to model uncertainties, greater emphasis in terms of policy development should be placed on the sediment load percentage reduction target rather than the absolute sediment load estimate. Future modelling may update or change calculated sediment load estimates creating potential issues meeting absolute numerical load limits. However, the numeric percentage reduction target will ensure progress toward achieving nominated water quality objectives

Further review (Greer, 2022) noted that further justification is needed for using a linear relationship based on just two points to set a sediment load target that could have significant impacts on land-use. It also noted it is not appropriate to link just the 2010 annual sediment load with the sedimentation rate from the harbour model, as those average sedimentation rates consider annual sedimentation in 2010 **and** sedimentation in events in 2004, 2005, 2006 and 2013.

11.4 Sedimentation rates and sediment input variability

Sediment plate data collected annually from 2008, with more extensive coverage from 2013 (Stevens and Forrest, 2020) illustrated a generally positive (i.e., depositing) sedimentation rate across this period, with very high spatial and temporal variability in annual deposition or erosion rates (Figure 10). Bathymetric surveys carried out in 2009, 2014 and 2019 similarly illustrate a generally positive deposition rate across the longer period, though rates were around 0mm/yr between 2009 and 2014, and around 10mm/yr between 2014 and 2019 (Waller, 2019) (Figure 11).

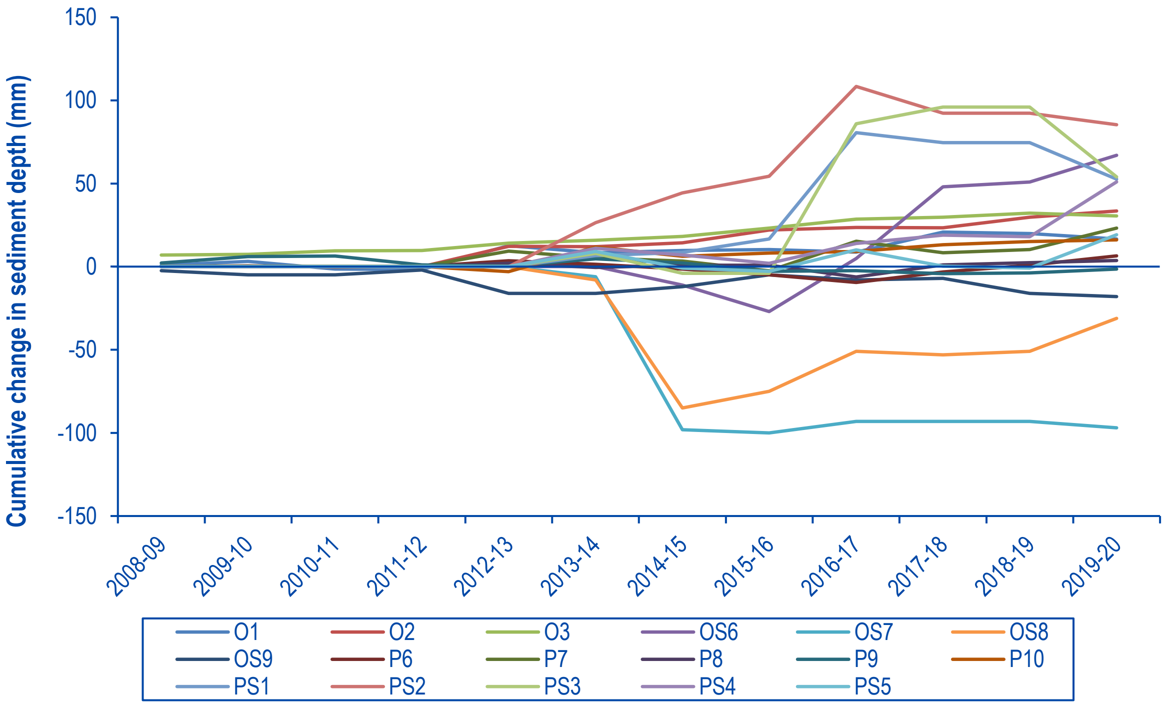

Figure 10: Cumulative change in sediment level over sediment plates in TAoP (adapted from Stevens and Forrest (2020)).

This variability demonstrates the importance of developing the harbour model over a range of events. TAoP catchment water quality modelling used the period 2005-14 as a representative range of climatic conditions (Easton *et al.*, 2019a). The ten-year running average of freshwater inflows for the period 2005-2014 is close to the long-term average value from 1975-2016, and there is sequence of higher than average inflows followed by lower than average inflows throughout the period 2005-2014 (Oldman, 2019).

Sediment input loads are also highly variable, and the sediment load delivered to Te Awarua-o-Porirua through the 2005-14 period appears to be relatively low, at ~8,000 tonnes/year, compared with a long-term average of ~12,800 tonnes/year (Figure 12).

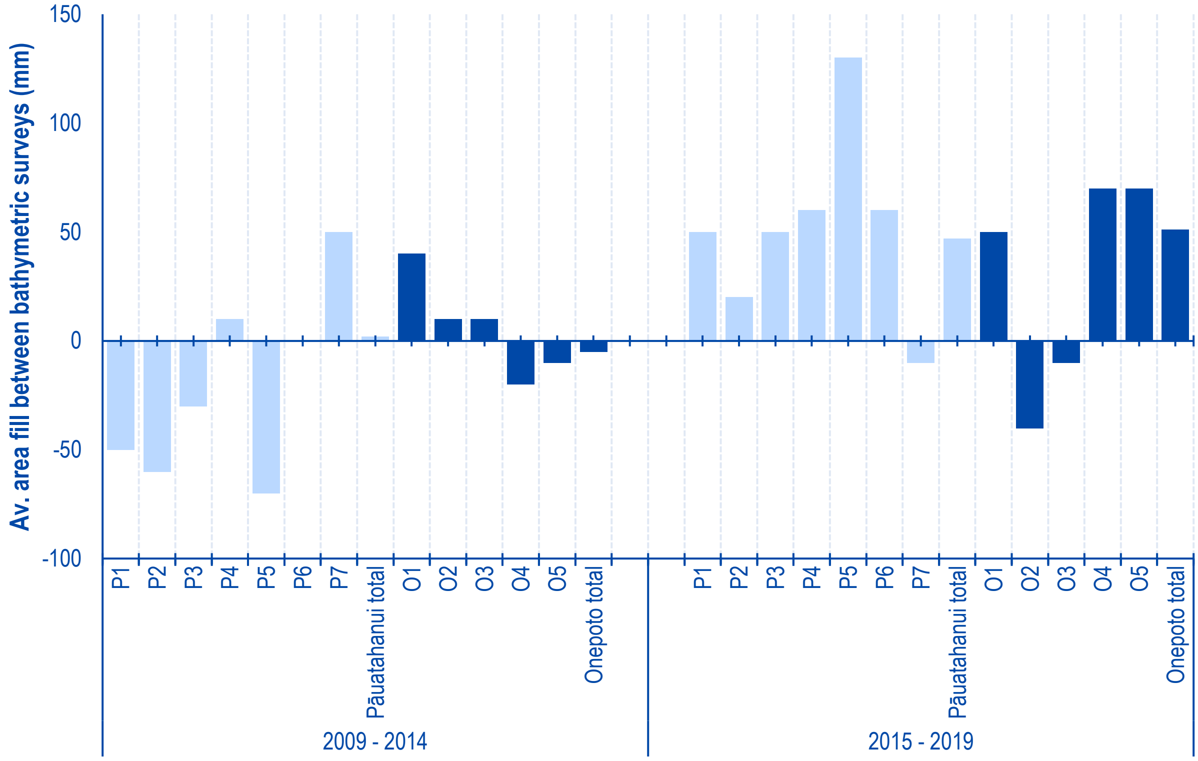

Figure 11 - Average area fill between bathymetric surveys (adapted from Waller (2019)).

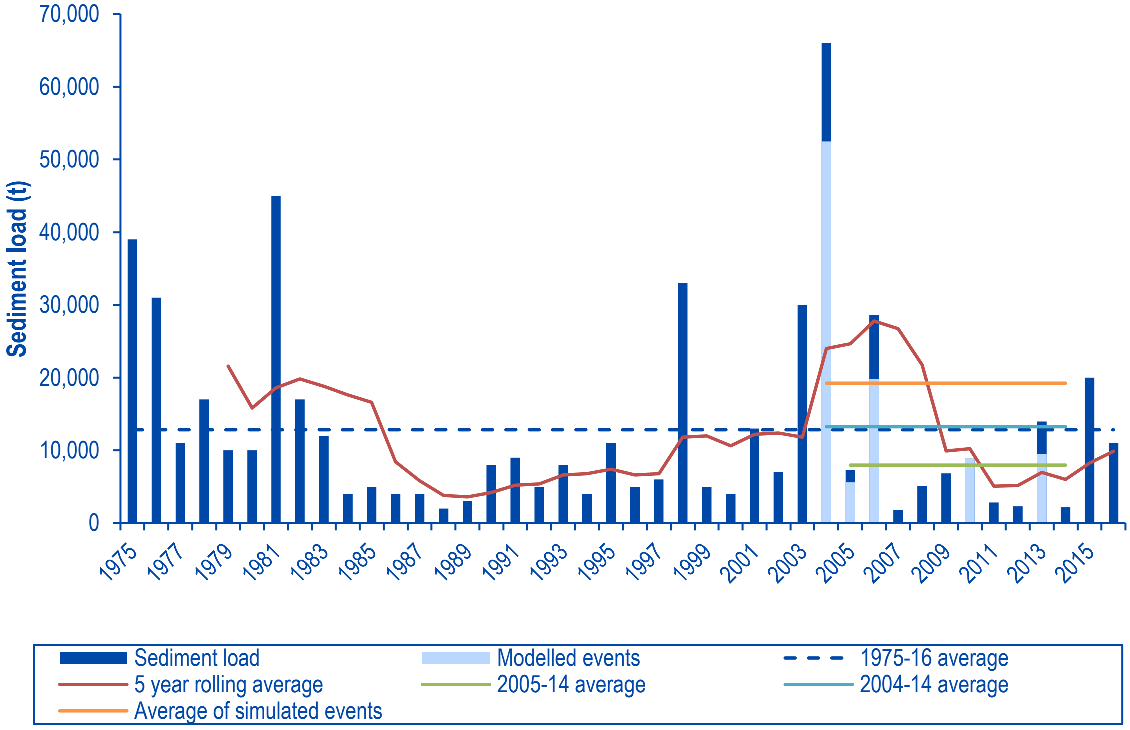

Figure 12: Estimated annual sediment loads to TAoP (adapted from Oldman, (2019)).

To make the harbour model more representative of the longer-term sediment load, harbour modelling was carried out using sediment load inputs of one whole year (2010) and several storm events in 2004, 05, 06 and 13. The sediment load data demonstrated that the majority (70-80%) of the year's sediment was delivered during individual events. Incorporating the 2004 event brought the average of the simulated events to ~19,200. The average annual sediment for the 2004-14 period was ~13,200.

Simulating the events illustrated the effect that they can have on sediment deposition, which wasn't well reflected in the simulation of one year. The 2010 year simulation represented the 2005-14 'average' conditions well, but it could be considered a relatively low input year in the historical context. This suggests that using the annual average sediment load from the 2005-14 period might be underestimating the sediment inputs that are associated with the current sedimentation rates of TAoP. This, therefore, may be unsuitable as a 'limit' from which to express sediment reductions.

Revision of sediment load reduction requirements

The catchment and harbour modelling illustrated how the sedimentation rate could be expected to change following changes in sediment inputs with alternative catchment management, such as earthworks controls, livestock exclusion and stabilising erosion prone land. As for the baseline, the scenario modelling was also run over one whole year and a series of events, and reporting described how the average sedimentation depth changed across all these model runs (Table 47). These results indicate how the sedimentation rate could respond if the sediment input were at that given level (Figure 13).

Table 47: TAoP sedimentation scenario results[1].

Simulation	Duration	Baseline			BAU			Water Sensitive		
		Annual load (t)	Event load (t)	Sed depth (mm)	Annual load (t)	Event load (t))	Sed depth (mm)	Annual load (t)	Event load (t)	Sed depth (mm)
Onepoto										
2004	31	29,000	23,200	14.30	18,100	14,500	8.64	4,400	3,500	1.57
2005	32	1,700	900	0.09	1,800	1,000	0.07	1,200	600	-0.16
2006	47	9,800	7,400	3.93	7,300	5,000	2.41	3,700	2,200	0.57
2010	364	3,300	3,300	0.97	2,800	2,800	0.58	1,400	1,400	-0.31
2013	61	4,800	2,900	1.19	4,200	2,200	0.69	2,300	900	-0.11
Average		9,700	7,540	4.06	4,025	5,100	2.48	2,150	1,720	0.31
Pāuatahanui										
2004	31	36,600	29,300	11.55		26,900	10.75		10,600	4.43
2005	32	5,600	4,700	1.99	5,700	4,800	1.97	3,400	2,800	1.10
2006	47	18,800	12,400	4.82	18,200	11,800	4.58	7,900	4,900	1.93
2010	364	5,500	5,500	2.40	5,400	5,400	2.34	3,000	3,000	1.38
2013	61	9,200	6,600	2.51	9,000	6,300	2.36	5,000	2,900	0.98
Average		15,100	11,700	4.66	14,400	11,000	4.40	6,500	4,800	1.96

[1] Further information from modelling in Oldman (2019) provided by John Oldman via email (13/11/2021)

Most events are modelled for a period of between 30-60 days and incorporate around 70-80% of the annual sediment load (Table 47). As such, these may not account for sediment input, redistribution and export occurring over the remainder of the year. Redistribution of sediments may result in small changes in deposition patterns and rates at sub-estuary level, however, the effects on basin wide deposition rates are expected to be relatively small. Accounting for these processes across the remainder of the year may result in relatively small changes for some plotted points moving left and up on Figure 13.

Figure 13 illustrates that the sediment input that corresponds to the target sedimentation rate in Pāuatahanui appears to be around 5,000 tonnes/yr for 2mm/yr, and around 3,000 tonnes/yr for 1mm /yr for Onepoto. However, the uncertainty noted could mean that the sediment inputs could be larger for a corresponding sedimentation rate.

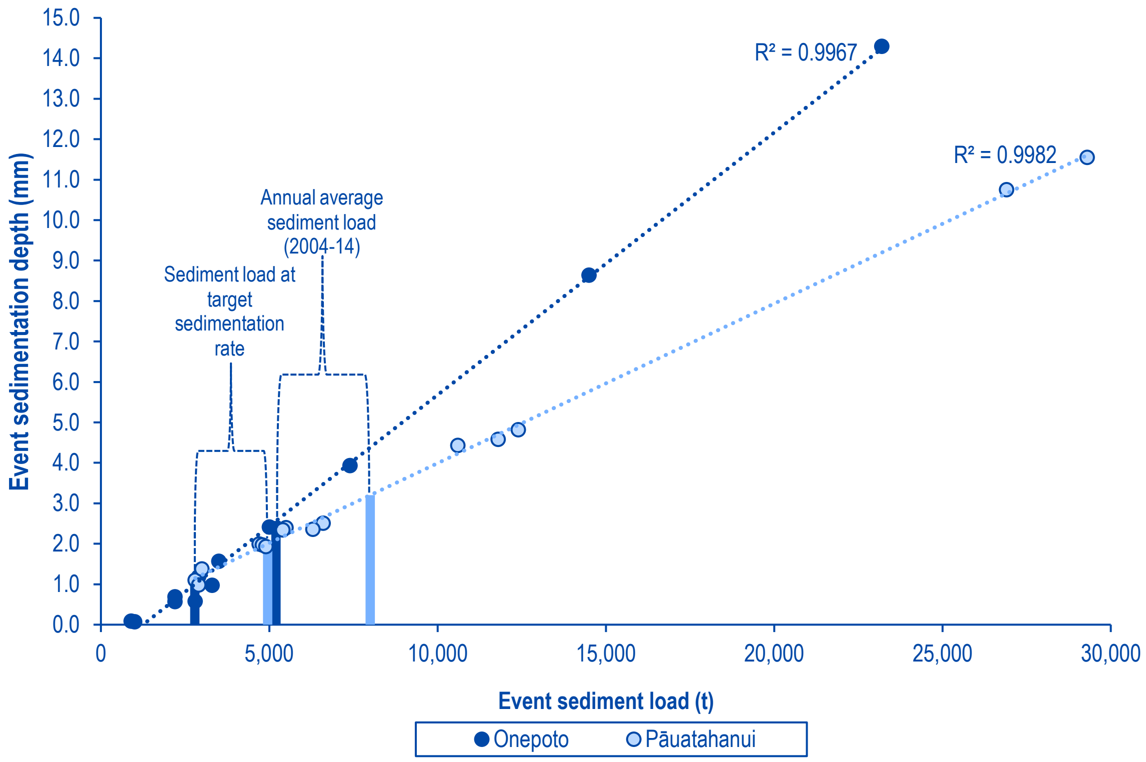

Figure 13: Simulated sedimentation events in TAoP.

These loads appear to nearly match the average inputs estimated for the 2005-14 period (Table 48). This period also coincided with lower sedimentation rates observed through the sediment plate monitoring (Figure 10) and the 2009-14 period of bathymetric surveys (Figure 11). This suggests that maintaining average sediment input rates at around the 2005-14 levels may be required to reach the sedimentation rate targets. This arguably suggests that the sedimentation rate targets could be achieved with very little further intervention beyond what is already planned for.

However, the 2015-14 sediment inputs are much lower than the long-term average (Figure 12 and Table 48) and the rolling average of sediment input is returning toward the longer-term levels. The more recent sediment plate (Figure 10) and bathymetric survey data (Figure 11) also suggest sedimentation rates have been higher in the more recent years (i.e., from 2014 onwards). Therefore, it may not be reasonable to assume that we could maintain sediment input at such levels by doing little more than already planned actions.

Table 48: Estimated sediment loads.

Metric	Onepoto			Pāuatahanui		
	Baseline	BAU	Water Sensitive	Baseline	BAU	Water Sensitive
Average sediment load for simulated events (t)	7,500	5,100	1,700	11,700	11,000	4,800
Average sediment load for simulated years (t/yr)	9,700	6,800	2,600	15,100	14,400	6,500
Average sediment load for 2004–14 (t/yr)	5,200	3,900	1,700	8,000	7,700	3,800
Average sediment load for 2005-14 (t)	2,800	2,500	1,400	5,200	5,100	2,800

As such, it may be more appropriate to express the reference point for reductions using the longer-term annual loads, which is well represented by the annual load for 2004-14. This period includes years with both larger events and lower input, which is reflective of the longer-term average and is likely more representative of the sediment inputs the harbour typically experiences.

Conclusion and Recommendations

Using the 2005-14 period sediment load averages to express the current sediment load and load limit in the WIP may not have been appropriate. These levels reflect a lower level of sediment input than the historical levels. Instead, the current sediment load should be expressed using the longer-term average annual load.

The modelled relationship between sediment load and sedimentation rate suggests that the sediment loads required to achieve the sedimentation rate targets in TAoP may be similar to those estimated through the 2005-14 period (around 5,000 and 3,000 tonnes per year in each arm). This is approximately a 40% reduction from the long-term average, which is well represented by the 2004-14 annual average load (Figure 13 and Table 48). This illustrates a need to reduce sediment inputs to TAoP to meet the sedimentation rate targets, which are unlikely to be achieved with the interventions that are already planned for.

There is uncertainty around the sediment load that is expected to achieve the target, and greater emphasis should be placed on the sediment load percentage reduction.

This sediment input baseline and load reduction targets in the WIP should be revised using the figures given in Table 49.

Table 49: Revised sediment load estimates and reduction targets for TAoP.

Metric	Pāuatahanui	Onepoto
Sedimentation rate objective (2040)	Net average sedimentation rate is less than 2mm/year in Pāuatahanui Inlet (rolling average over the most recent 5 years of data)	Net average sedimentation rate is less than 1mm/year in Onepoto Arm (rolling average over the most recent 5 years of data)
Long-term average annual load (2004-14) (t/yr)	8,000	5,200
Sediment limit Annual average (t/yr)	8,000	5,200
Sediment target % reduction from limit	40%	40%

Brent King

12 Technical memo to support coastal attribute implementation for TAoP and WTWT

To: Rachel Pawson, Environmental Policy

Copied to: Megan Melidonis, Evan Harrison

From: Megan Oliver, Senior Environmental Scientist

First published: 10th March 2023

12.1 Enterococci

The enterococci attribute state framework used in both the TAoP and WTWT WIPs is not appropriate for use in PC1.

The 95th percentile statistics and the narrative attribute states are in line with the Guideline values for microbiological quality of marine recreational waters in the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE/MoH 2003). However, the percent exceedance over 500 per 100mL assessment statistic is not supported by a quantitative microbial risk assessment (QMRA).

The specific percentage exceedance frequency adopted in the WIP is also in direct conflict with the 95th percentile thresholds for attribute state B, C and D. For example, at the C/D threshold the 95th percentile threshold allows for 500 per 100 mL to be exceeded five percent of the time, while the precent exceedance threshold allows the same threshold to be exceeded 20% of the time. It appears that this metric was adopted to provide some level of consistency with the NPS-FM E. coli attribute. However, it must be noted that:

- The *E. coli* NPS-FM thresholds are supported by a QMRA; and
- The percentage of exceedance statistics in the NPS-FM E. coli attribute do not contradict the 95th percentile thresholds.

It is recommended that the "*Percentage of exceedances over 500 enterococci per 100 ml*" statistic is deleted from the WIP enterococci attribute and ignored in any estimates of baseline state.

12.2 Sediment metals

12.2.1 Effects of metals

Metals, such as Cu and Zn, are normal constituents of marine and estuarine environments. In healthy environments, these trace metals occur in small but measurable amounts within animals and plant tissue, where they are a necessary part of nutrition and physiology. Metal concentrations in urban areas, however, typically exceed healthy concentrations, entering marine and coastal areas via industrial waste, and the wastewater and stormwater networks.

12.2.2 State and source of metals in Porirua Harbour

There have been several studies investigating the sources, concentrations and impacts of metals in Porirua Harbour (see Hooper (2002) for summary) but frequent, routine monitoring of metals in harbour sediments didn't begin until 2004. Results from almost two decades of monitoring indicate that concentrations of metals such as Zn and Cu do not currently exceed Australian and New Zealand guidelines for fresh and marine water quality (ANZG) (2018) Default Guideline Values (DGV) in sediments at representative sites and are generally very low. However, the concentrations of Zn almost doubled in the intertidal sediments of the inner Onepoto Arm (Figure 14) between the 2015 and 2020 sampling periods, and this represents a change of attribute bands and a declining state.

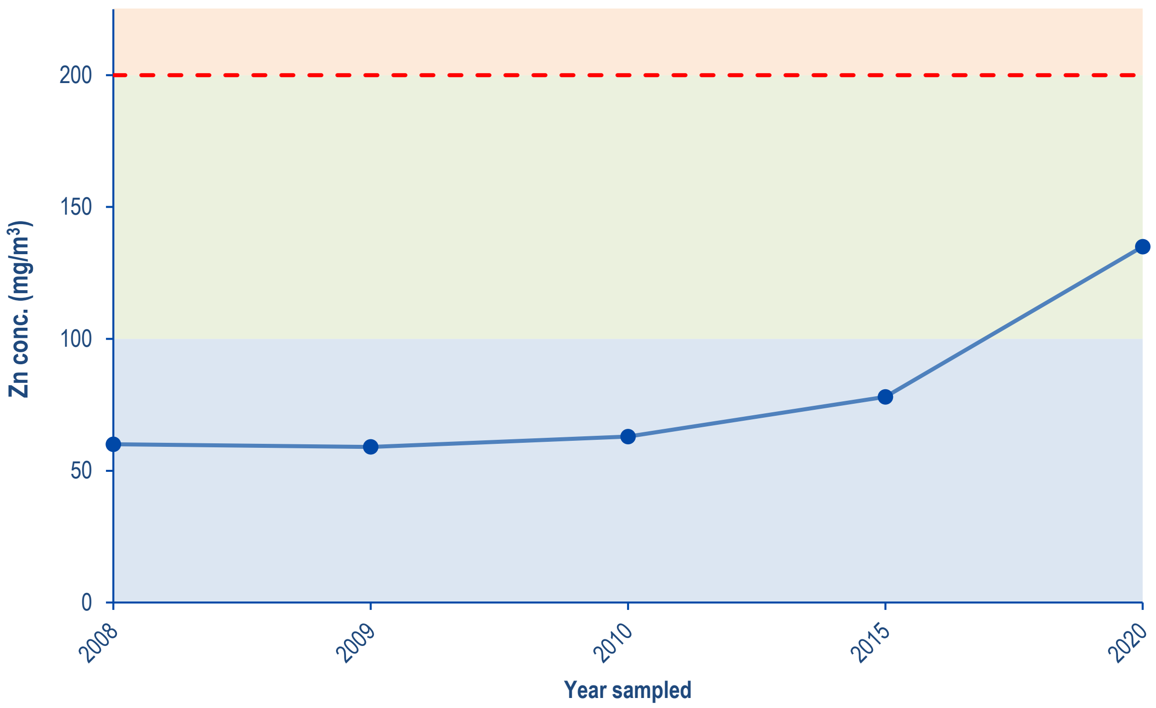

Figure 14: Concentrations of Zn in the intertidal sediments of the inner Onepoto Arm, Porirua Harbour. Blue shaded area represents the A band, green shading the B band, and orange shading the C band. The red dashed line on the boundary between B and C bands depicts the national Default Guideline Value for Zn concentrations in sediment.

The intertidal areas of Porirua Harbour are still relatively healthy, with sandy sediments, low concentrations of stormwater contaminants, and reasonable biodiversity values. Any increase in sediment metal concentrations should, therefore, be avoided to reduce likelihood of these areas being degraded by unforeseen toxicity effects. The objective state of 'maintain' should be interpreted as no significant decline within the band.

The subtidal areas of both arms are muddy, poorly oxygenated, have lower biodiversity values, and higher concentrations of contaminants, compared with the intertidal areas. While these areas are unlikely to show improvements over the timeframes of the NRP due to legacy contamination issues, it is important that the target attribute state not allow for any further degradation or increase in contaminant concentrations such as has been occurring in these low energy, depositional environments for multiple decades.

Studies targeting sediment in highly impact areas, such as near stormwater outfalls in the inner Onepoto Arm, indicate there are locally elevated hotspots where Cu and Zn (Figure 15) concentrations approach or exceed DGVs and are expected to be having negative ecological impacts (C band for Zn) (Sorensen and Milne, 2009). Furthermore, core samples from deeper sediments at these inner harbour sites indicate that contamination is present to some depth (Figure 15). Repeat monitoring of these impacted sites in the inner Onepoto Arm is planned for early 2024.

It is appropriate, therefore that Zn and Cu have been adopted throughout the TAoP and WTWT WIPs as attributes and proxies for a suite of other urban contaminants (e.g., mercury, cadmium, lead, hydrocarbons) and should be monitored as part of an ongoing programme of whaitua plan implementation.

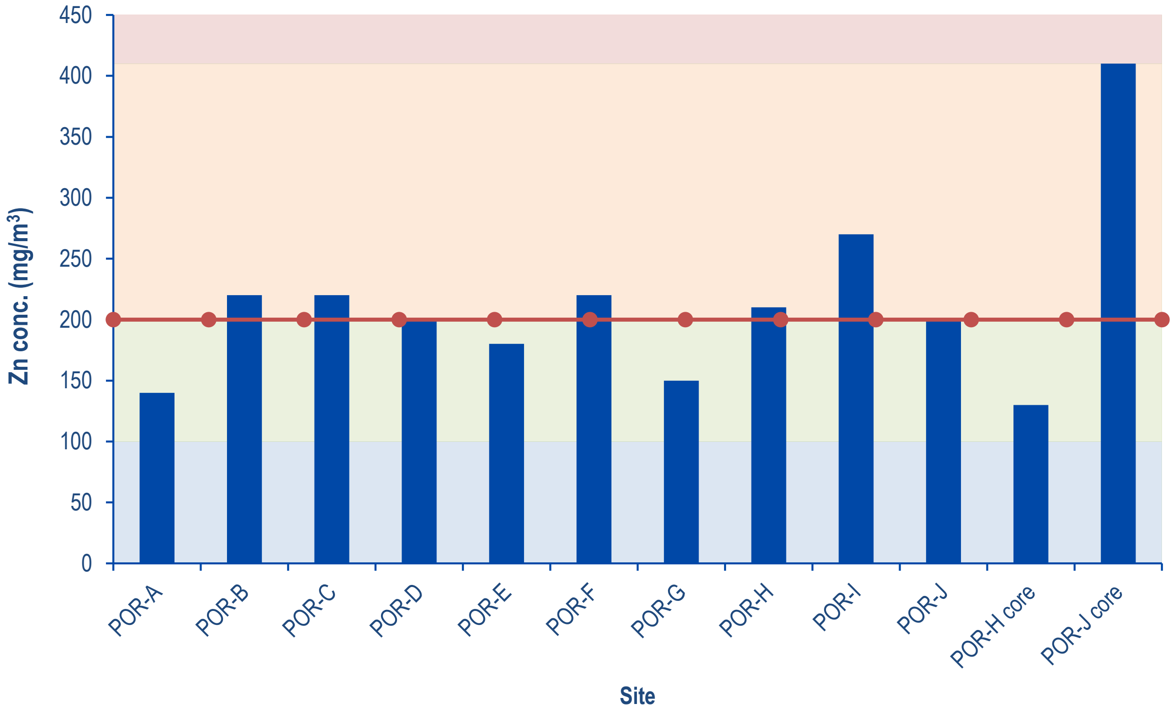

Figure 15: Concentrations of Zn in the intertidal sediments of sites targeted for investigation and known to be impacted by stormwater in the inner Onepoto Arm, Porirua Harbour. Grey shaded area represents the A band for this attribute, green shading the B band, orange shading the C band, and red shading for the D band. The red dashed line on the boundary between B and C bands depicts the national Default Guideline Value for sediment quality. Adapted from Sorenson and Milne (2009).

12.2.3 Justification for precautionary 'maintain' approach

There is a high level of uncertainty about the effects of metals on marine organisms across the full range of concentrations, and the antagonistic and synergistic effects of various sediment quality parameters. This makes it very difficult to predict how a degradation in sediment Cu or Zn attribute state would impact the ecology of the Porirua Harbour. However, research emerging from the Sustainable Seas National Science Challenge indicates that the cumulative impacts of high catchment sediment, nutrient and metal inputs to low energy environments such as estuaries have the potential to cause catastrophic changes in ecosystem health and functioning at concentrations lower than DGV. Furthermore, the DGVs were developed using sediment and invertebrate data from a North American data set and as such, have not been validated for New Zealand infauna, and should be applied with caution.

Cu and Zn toxicity to estuarine animals varies widely and can be more toxic to fish and invertebrates than the DGVs suggest. These toxic effects manifest themselves through impaired larval development, reproduction and slowed growth rates. It is appropriate, therefore, that a precautionary 'maintain' approach is taken to setting target attribute states; not doing so risks further, and potentially significant, environmental degradation. Due to the risk of adverse effects occurring below and between DGVs (see above), what constitutes 'maintenance' in the context of sediment metal target attribute states should reflect what is required by the NPS-FM 2020 for freshwater attributes (i.e., no degrading trends, even within an attribute state).

12.3 Monitoring attributes at sites within Porirua Harbour

Assessing impact, be that improvement or decline, in the marine environment, is difficult because of the scales over which pollutants disperse. For example, sediment entering a harbour or estuary from a number of rivers can distribute widely due to rain, wind and tides throughout a coastal zone, making it difficult to trace or attribute the sediment to a source. Monitoring changes, or tracking progress towards meeting environmental outcomes must, therefore, be set in areas of the coast that accumulate the attribute of interest, and are relatively stable over time, so you can return to it and reliably measure decline or improvement in state. When thinking about where sediment and pollutants accumulate in Porirua Harbour, we generally divide the harbour into the intertidal and subtidal zones of each of the two arms.

For monitoring data to be of sufficient resolution to benchmark against a 'maintain objective, annual or biennial monitoring of intertidal sites at three to four sites in each arm is required. We already monitor two intertidal sites in each arm at regular intervals as part of our State of the Environment Monitoring programme, and have done so since 2007, so we have a good record against which to compare future results. Two to three additional sites could be added to the intertidal areas of each arm to represent other sub-estuary areas, as well as periodic sampling of the contaminant hotspots discussed in Section 12.2.212.3.3.

As for intertidal sites, tracking progress towards target states as set by the WIP, will require semi-regular (three to four-yearly) monitoring of at least two representative subtidal sites in each arm. These need to be sites that are not scoured out by rainfall events or prone to erosion that would alter the sediment grain size profile and limit repeated analyses of sediment health. Fortunately, we already have five sites (two in Onepoto and three in Pāuatahanui) that we monitor regularly as part of our State of the Environment programme, and these would be suitable for evaluating progress towards attribute targets.

12.3.1 Adoption of four band approach from WTWT for other attributes

At the time the TAoP WIP was prepared we adopted an assessment framework, benchmarked to the ANZG (2018) sediment quality guidelines[13], for Cu and Zn in sediment and simplified the five-scale framework to four bands for the WIP, which effectively grouped concentrations of Cu or Zn greater than the guideline values (GV-Low) into the D, or Poor band; they were previously separated into D and E. This was the assessment framework developed by Salt Ecology Ltd and widely used at that time for reporting on estuarine health.

More recent reporting has taken a different approach to creating a four-class scale and groups the previous A and B bands (values less than 0.5 of the GV-Low) into a single Very Good or A band and separated out values that are between GV Low -GV High (C Band, or Fair) and greater than GV-High (D band or Poor). These risk classifications were reviewed based on Hewitt *et al.* (2009) and updated to be more consistent with the National Objectives Framework structure for freshwater; an approach many other Regional Councils were using in their limit setting programmes, including the Whaitua programme.

The revised bands are a better reflection the overall ecological state. That is, if metals are <50% of the GV then conditions are very good, and the likelihood of adverse impacts are very low. If metals are approaching the GV-Low value, then likelihood of adverse impacts are low, and condition is deemed Good. Conditions are 'fair' when adverse effects are 'possible' (greater than GV-Low), and 'poor' when adverse effects are 'probable' (greater than GV-High).

The implications of this change are the A and B targets will be adjusted to A, and C targets will be adjusted to B. This is relevant for the Zn concentrations in the intertidal and subtidal sediments of the Onepoto Arm and the Cu concentrations of the subtidal Onepoto Arm. These are all 'maintain within a band' targets, but the widening of the A band does pose the risk of not maintaining baseline if targets are set based on the state thresholds for this attribute. Therefore, it is essential to define the baseline states in a numerical way and use that numeric to track progress towards the objective target. If, for example, monitoring shows a statistically significant increase in say, Zn concentrations, this should be considered an unacceptable decline in attribute state, irrespective of whether there is a change of band.

12.3.2 Revised baseline state assessment

As noted in the previous section, where possible, a numeric value should be calculated for each attribute to establish a baseline numeric state against which changes from that state, and progress towards the objective states, can be measured. State of the environment monitoring data can be used to calculate a baseline figure for Cu and Zn in the intertidal and subtidal areas of each estuary arm. We propose this figure be the mean concentration of the three replicates at each of the nine sites (four intertidal, five subtidal) measured during the 2015 sediment surveys (Table 50). We cannot nominate a site-specific numeric for the macroalgae attribute however, as the metric was developed to be an estuary-wide measure and cannot be scaled down to site level without losing rigour in the metric.

[13] The Guideline Value-High (GV-high) [formerly ANZECC (2000) Interim Sediment Quality Guideline high (ISQG-high)] can be interpreted as reflecting the potential for 'probable' ecological effects. The Default Guideline Value (DGV) [formerly ANZECC (2000) Interim Sediment Quality Guideline low (ISQG-low)] and can be interpreted as reflecting the potential for 'possible' ecological effects.

Subsequent assessments of state and progress towards targets should use the mean of replicate samples taken for each site in the most recent survey. Table 51 provides current state concentrations for Zn and Cu at all nine sites from the 2020 surveys and compares current values with the 2015 baseline values. The inner harbour sites in the Onepoto Arm show an increase in Zn and Cu concentrations in intertidal sediments; this is the area of both harbour arms for which the most stringent limits should be set. This represents a decline within a band.

Table 50: Baseline (2015) numeric values for Zn and Cu coastal water quality objectives.

			Onepoto Arm				Pāuatahanui Arm				
			Intertidal		Subtidal		Intertidal		Subtidal		
		Site	A	B	1	2	A	B	1	2	3
Total Zn in sediment		Baseline state (mg/m³)	38	77.7	179	138.7	37.3	20.2	73	62.7	62
	Coastal Objective	Objective state	A	A	B	B	A	A	A	A	A
		Objective concentration (mg/m³)	<100	<100	100-<200	100-<200	<100	<100	<100	<100	<100
		Objectives to be met by	M	M	M	M	M	M	M	M	M
Total Cu in sediment		Baseline state (mg/m³)	4.2	3.9	20.5	18.2	4.8	2.0	11.0	9.5	8.0
	Coastal Objective	Objective state	A	A	A	A	A	A	A	A	A
		Objective concentration (mg/m³)	<32.5	<32.5	<32.5	<32.5	<32.5	<32.5	<32.5	<32.5	<32.5
		Objectives to be met by	M	M	M	M	M	M	M	M	M

Table 51: Current (2020) state numeric values (mg/m³) for Zn and Cu coastal water quality objectives. Red text denotes a decline in state from baseline.

		Onepoto Arm				Pāuatahanui Arm				
		Intertidal		Subtidal		Intertidal		Subtidal		
	Site	A	B	1	2	A	B	1	2	3
Total Zn in sediment	Baseline state	38	77.7	179	138.7	37.3	20.2	73	62.7	62
	Current state	46.3	135.7	196	149	41.7	31	76.7	77.7	68.7
Total Cu in sediment	Baseline state	4.2	3.9	20.5	18.2	4.8	2.0	11.0	9.5	8.0
	Current state	4.5	7.5	20.7	18.2	4.8	3.8	10.4	11.5	7.9

12.3.3 Expert opinion of ecological importance of sedimentation rates vs sediment metals

The WIP proposes reducing sediment inputs by ~40% to achieve an average areal sedimentation rate of 2 mm per year. There is also a concurrent requirement to reduce catchment metal loads by 40%. Most of this sediment reduction is, however, targeted at rural areas (retirement of land, riparian planting), where metals, which are generated in urban settings, are not an issue. Therefore, a 40% reduction in sediment load won't result in a concurrent reduction in metal loading to the harbour. Indeed, the reduction in 'clean' sediment entering from rural areas may concentrate the sediment metal concentrations and accelerate a decline in this attribute.

Given the most recent monitoring results indicate an increasing concentration of Zn and Cu in the sediments of the Onepoto Arm, a reduction in metal loads entering from the urban areas is needed to maintain the objective state via a range of proposed mitigation options.

12.4 Conclusion

The known effects of metal toxicity in coastal invertebrates and sediments, combined with the limitations of the default sediment guidelines, the measured decline in attribute state for Zn (and Cu to a lesser degree) in the inner Onepoto arm, and recorded hotspots of contamination, require application of the precautionary approach and implementation of a range of mitigation options to stem the input of sediment metals to this sensitive receiving environment.

13 Metal reductions to achieve metal-sediment targets

From:	**Jennifer Gadd**
To:	Michael Greer. Torlesse Environmental Ltd Brent King, Rachel Pawson, Greater Wellington
First published:	14th April 2023

13.1 Introduction and scope

The TAoP WIP targets a reduction in sediment loads of 40% to reduce sediment accumulation and the muddiness of the Porirua Harbour. The WIP also recommends a 40% reduction in Cu and Zn loads (commensurate with the reduction in sediment) to ensure that metal concentrations in harbour bed sediments do not increase.

GW asked for technical advice around the validity of that assumption – that a 40% reduction in metals is also required.

13.2 Sources of metals and sediment in the Porirua catchment

The current sources of sediment and metals to each arm of the Porirua Harbour were modelled by Jacobs (see Easton *et al.,* (2019a, 2019b)).

For the Onepoto Arm, the majority of the sediment and metal loads (Table 52) are delivered via the Porirua River. This source makes up approximately 2/3 of the total sediment and metal loads (66-69%).

For Pāuatahanui Inlet (Table 52), most sediment (69%) is delivered via the Pāuatahanui River. However, a large proportion of the metals is sourced from the urban Duck Creek catchment, and in future scenarios via Pāuatahanui Stream, Horokiri and Motukaraka Creeks.

The key sources of the sediment and metals are not 100% clear in the modelling reports. Presumably the key sources of metals are urban sources, as suggested by those catchments with higher proportions of urban land use having higher metal loads. In future scenarios, Transmission Gully also contributes metals to the Pāuatahanui Arm.

Given that the sediment load reduction scenarios are based on reduction in rural sediment sources (reducing hillslope, landslide and stream bank erosion) I've assumed that these are the key sources of sediment. Though these sediments would contain some attached metals, these are expected to be low compared to the urban sources.

Table 52: Sediment and metal loads delivered annually to each harbour arm. Note this table was produced before the memorandum reproduced in Section 11 was drafted; hence the disparity with Table 49.

Harbour arm (WMU)	Sediment	Cu	Zn
Onepoto Arm	2,800 tonnes/yr	240 kg	2,650 kg
Pāuatahanui Inlet	5,200 tonnes/yr	70 kg	580 kg

13.3 Processes by which catchment delivered metals end up in bed sediment

Both Cu and Zn are found in a mixture of dissolved and particulate forms in stormwater and in streams. Within these freshwater systems, metals may adsorb to sediments (changing from dissolved to particulate) or desorb from the sediments (changing from particulate to dissolved), depending on their concentration, the amount of sediment and water chemistry such as pH. These suspended sediments may continue to be transported downstream or may settle in depositional locations within the streams – either temporarily or permanently.

Similarly, the metals delivered to the harbour will be found as a mixture of dissolved and particulate forms. The behaviour of metals in estuaries is complex and not all metals act the same – depending on their form and their chemical properties.

Metals that are attached to fine particles, or have high affinity for those particles, can be removed (from the water column) as small particles that are held apart by electrostatic repulsive forces flocculate into larger particles when the freshwater mixes with saline water. Some metals (those truly dissolved) behave conservatively and are simply diluted (Mosley and Liss, 2019). Metals delivered to the estuary as colloids (i.e., bound to dissolved organic matter) can disassociate at low salinities and therefore more metals are found in dissolved form.

Cu and Zn tend to show variable behaviour – as reviewed by Mosley and Liss (2019) some studies have suggested that they behave conservatively, and other studies have suggested removal or addition. It is likely that the particulate forms of Cu and Zn will accumulate in the bed sediment as the particles flocculate and these settle in depositional areas of the harbour. These newly deposited sediments will mix with the existing sediments through bioturbation as well as physical processes.

Dissolved Cu and Zn tend to be associated with colloids and this form is likely to dissociate at low salinities, but then be readsorbed (either to dissolved organic matter or inorganic particles) as pH increases towards mid to high salinities. This is predicted to be affected by sediment characteristics, such as cation exchange capacity and the amount of organic material present. Through these processes, dissolved metals are expected to be reduced to very low concentrations within fully saline waters.

In the Porirua Harbour example, as Cu and Zn will be transported in both dissolved and particulate form, all of these processes are relevant. It can be expected that the particulate forms flocculate, settle and mix with existing bed sediments. Dissolved forms can be expected to also become attached to particles within the harbour – whether those particles are also delivered via stormwater and streams or from different sources. More sediment delivered to the harbour provides more binding sites for the metals and more ability for them to adsorb to the sediment. The more sediment, the greater the binding capacity overall, but also the metal concentrations within a given volume of sediment can be expected to be lower.

Therefore, with lower sediment loads delivered, it makes sense that would be a higher concentration of metals bound to a given volume of sediment (assuming the adsorption capacity is not reached, which seems unlikely given the high concentrations of sediment relative to metals).

13.4 Modelling of metal-sediment concentrations

Oldman's (2019) modelling of sediment transport, deposition and metal accumulation is based on a mass-balance approach for the metals. The metals and sediments delivered from each catchment (in mg/L, as modelled by Easton *et al.* (2019a, 2019b)) are used to calculate metal-sediment concentrations (in mg/kg) used in the sediment modelling. These sediments delivered are uniformly mixed with the surface layer of the existing bed sediments.

Oldman (2019) lists three assumptions in their modelling approach:

- That there was no loss of seabed metals to the dissolved phase
- All the metal load was particulate; and
- Current observed metal concentrations in the harbour do not represent equilibrium conditions.

This is described by Oldman (2019) as worst-case, but assumption 1 also seems consistent with literature that suggests metal loss depends on stream alkalinity and dissolved carbon dioxide content; and that metals may be removed at low salinity (where a pH low can occur) but be readsorbed at higher salinity.

The inputs are the total Cu and Zn loads delivered from the catchments as calculated by Easton *et al.* (2019a, 2019b), which includes both dissolved and particulate forms. Treating all as particulate metals is consistent with the theory that dissolved metals will bind to sediment within the estuary, thus becoming particulate.

The third assumption presumably means there is additional capacity for metal adsorption in the sediments.

13.5 Proposed changes in sediment and metal loads

The load reduction targets are set out in the TAoP WIP and shown in Table 53. This sets out that the metal targets are based on ensuring the current Cu and Zn concentrations in the harbour sediments do not increase when the sediment loads are decreased by 40%.

Table 53: Targeted load reductions for sediment, Cu and Zn as set out in the WIP.

Harbour arm (WMU)	Sediment	Cu	Zn
Onepoto Arm	40% (1,120/2,800 kg)	40% (40% x 240 kg = 96 kg)	40% (40% x 2,650 kg = 1,060 kg)
Pāuatahanui Inlet	40% (2,080/5,200 kg)	40% (40% x 70 kg = 28 kg)	40% (40% x 580 kg = 232 kg)

The required reduction in sediment loads in the Pāuatahanui Inlet is expected to be achieved through reduction in stream bank erosion (largely in the Pāuatahanui River), land slide erosion in the catchment and some areas of reduced hill slope erosion. Only 3% of the sediment load to the Pāuatahanui Inlet is expected to come from non-rural areas – the Duck Creek catchment, with mixed urban/rural land use (M. Greer, pers. comm).

The reduction in sediment loads in the Onepoto Arm is expected to be achieved through a combination of rural (66%) and mixed urban/rural (34%) loads. The methods to achieve the planned load reduction are not specified.

Zn load reductions are expected to be achieved through additional treatment systems in existing urban areas, focussing on major roads and commercial/industrial areas; replacement of high Zn-yielding roofs and treatment of all impervious surfaces in new urban developments. Some of these methods will also reduce Cu loads.

13.5.1 Do metals loads need to be reduced by 40%?

The assumption stated in the WIP is that because sediment loads are targeted for a 40% reduction, metal loads must also be reduced by 40% to retain the same concentrations in the harbour sediments.

This assumption is consistent with our understanding of how metals are retained in harbour sediments.

However, the 40% metal reduction may be achieved to some extent through the targeted reduction in sediments, because sediments are themselves sourced of metals. This depends on the sources of metals and sediment within each of the harbour arms.

13.5.2 Pāuatahanui Inlet

The modelling indicates that the major sources of sediment to the Pāuatahanui Inlet are derived from rural sources. These would not be expected to be associated with high metal concentrations (at least to the extent of increasing concentrations within the harbour). Conversely the modelling suggests at least 50% of the metal loads are derived from urban sources (based on 40% of total loads coming from Duck Creek and Browns Bay alone). The Pāuatahanui Stream is also a major contributor of metals – at around 30-40% of the total loads to the Pāuatahanui Inlet. This catchment has only a low proportion (3-4%) of urban land use and roading but given that the modelled metals concentrations from urban land uses are at least 40x higher than that of rural land uses, it is likely that most metals delivered via this source are from urban land use.

Given the likely dominance of urban sources of metals, a reduction in the rural sediment loads (via stock exclusion, retirement, space planting etc) of 40% would not reduce the total metal loads to the Pāuatahanui Inlet by 40%. If the 50% of the metals are from urban, and 50% from rural sources (i.e., attached to the sediment), there would be a maximum of 20% reduction in metals through the sediment reductions. However, based on the information available, it is likely that the metals delivered from rural sources is much lower than 50% and therefore the reduction in metals from sediment mitigation would be much less than 20%.

13.5.3 Onepoto Arm

The modelling indicates that the major sources of sediment to the Onepoto Arm are derived from both rural (66%) and mixed rural-urban (34%) sources. Sediment reductions are from a combination of retirement/space planting and urban development. While the sources (in terms of land use) of metals are not clearly quantified, it is highly likely that urban land use dominates the loads to the Onepoto Arm.

Again, the rural sources of sediment would not be expected to be associated with high loads of metals and so reductions in sediment loads due to retirement and space planting are not expected to greatly reduce the metal loads. On the other hand, sediment load reductions due to treating greenfield developments and/or retrofitting existing urban areas would reduce metals. It is not possible to quantify the effect of this on total reduction in metal loads to the Onepoto Arm with the available data.

If it was assumed that around 25% of the planned sediment reductions (totalling 40% overall load) were from urban land use, then the maximum metal reduction would also be 25%, or 10% of the overall load. Therefore another 30% reduction must be achieved elsewhere to meet the 40% target. Note that it is also likely that a 25% reduction in sediment in urban areas would not equal a 25% reduction in metals. Typically, 40-60% of metals in stormwater are in the dissolved form and dissolved metals are not as readily removed as the particulate form. Therefore, it is likely that the required additional treatment must remove more than 30% of the total loads to the Onepoto Arm.

13.6 Summary

The assumption that a 40% reduction in sediment loads to the Porirua Harbour requires a 40% reduction in metal loads to the harbour to ensure metal concentrations do not increase is consistent with literature around metal deposition processes in estuaries. Although the required information is not available to quantify the reduction in metals with the planned mitigations, it is clear that the mitigations to sediment loads will not achieve a 40% reduction in metal loads to either harbour arm. Therefore, additional mitigations that target metals are required, and these may need to target around 30% or more of total metal loads to each arm.

14 References

Australian and New Zealand Governments and Australian state and territory governments (ANZG), 2018. Australian and New Zealand guidelines for fresh and marine water quality. Governments and Australian state and territory governments, Canberra, Australia.

Booker, D.J., 2010. Predicting wetted width in any river at any discharge. Earth Surface Processes and Landforms 35, 828–841. https://doi.org/10.1002/esp.1981

Burns, N., Bryers, G., Bowman, E., 2000. Protocols for monitoring trophic levels of New Zealand lakes and reservoirs (Lakes Consulting report). Lakes Consulting, Pauanui, New Zealand.

Canning, A.D., Joy, M.K., Death, R.G., 2021. Nutrient criteria to achieve New Zealand's riverine macroinvertebrate targets. PeerJ 9, e11556.

Clapcott, J.E., 2015. National rapid habitat assessment protocol development for streams and rivers (Cawthron Report No. 2649). Cawthron Institute, Nelson, New Zealand.

Clapcott, J.E., Casanovas, P., Doehring, K., 2020. Indicators of freshwater quality based on deposited sediment and rapid habitat assessment (Cawthron Report No. 3402). Cawthron Institute, Nelson, New Zealand.

de Winton, M., 2020. LakeSPI surveys of the Parangarahu Lakes and aquatic weed delimitation in Lake Kōhangatera (Client Report No. 2020005HN). NIWA, Hamilton, New Zealand.

de Winton, M., in prep. LakeSPI surveys of the Parangarahu Lakes (Client Report). NIWA, Hamilton, New Zealand.

Death, R.G., Fuller, I., Death, A., n.d. A technique to assess river habitat change – The missing dimension for water resource management. Unpublished.

Easton, S., Cetin, L., 2020. dSedNet model development and results (Jacobs Memorandum No. IZ130500). Jacobs New Zealand Ltd, Wellington, New Zealand.

Easton, S., Shrestha, M., Cetin, L., Blyth, J., Sands, M., 2019a. Porirua Whaitua Collaborative Modelling Project. Baseline Modelling Technical Report (Jacobs Report No. IZ080700). Jacobs New Zealand Ltd, Wellington, New Zealand.

Easton, S., Shrestha, M., Cetin, L., Sands, M., 2019b. Porirua Whaitua Collaborative Modelling Project. Scenario Modelling Technical Report (Jacobs Report No. IZ080700). Jacobs New Zealand Ltd, Wellington, New Zealand.

Gibbs, G.W., 2002. Pencarrow Lakes. Conservation values and management. Department of Conservation, Wellington, New Zealand.

Greater Wellington Regional Council (GWRC), 2019. Assessments of the current state and derivation of numeric objectives and limits for Te Awarua-o-Porirua Whaitua Implementation Programme (WIP) (GWRC Technical Memorandum). Greater Wellington Regional Council.

Greer, M.J.C., 2023a. Assessment of alignment between the regulatory provisions and target attribute states in proposed Plan Change 1 to the Natural Resources Plan – Te Awarua-o-Porirua Whaitua (Torlesse Environmental Report No. 2023– 007). Torlesse Environmental Ltd, Christchurch, New Zealand.

Greer, M.J.C., 2023b. Assessment of alignment between the regulatory provisions and target attribute states in proposed Plan Change 1 to the Natural Resources Plan – Whaitua Te Whanganui-a-Tara (Torlesse Environmental Report No. 2023– 008). Torlesse Environmental Ltd, Christchurch, New Zealand.

Greer, M.J.C., 2022. Technical review of TASs for PC1 to the NRP (Unpublished Aquanet technical memorandum). Aquanet Consulting Ltd., Christchurch, New Zealand.

Greer, M.J.C., Ausseil, O., Clapcott, J.E., Farrant, S., Heath, M.W., Norton, N., 2022. Whaitua Te Whanganui-a-Tara water quality and ecology scenario assessment (Aquanet Report). Aquanet Consulting Limited, Wellington, New Zealand.

Heath, M.W., 2022. Parangarahu lakes current state assessment for Whaitua Te Whanganui-a-Tara (Aquanet technical memorandum). Aquanet Consulting Ltd., Wellington, New Zealand.
Hewitt, J.E., Anderson, M.J., Hickey, C.W., Kelly, S., Thrush, S.F., 2009. Enhancing the Ecological Significance of Sediment Contamination Guidelines through Integration with Community Analysis. Environ. Sci. Technol. 43, 2118–2123. https://doi.org/10.1021/es802175k
Hicks, M., Haddadchi, A., Whitehead, A.L., Shankar, U., 2019. Sediment load reductions to meet suspended and deposited sediment thresholds (NIWA Client Report No. 2019100CH). NIWA, Christchurch, New Zealand.
Holmes, R., Clapcott, J.E., Haidekker, S., Hicks, A.S., Pingram, M., Hodson, R., Death, A., Fuller, I., Harding, J.S., Neale, M.W., Valois, A., Franklin, P.A., 2020. National rapid river pressures assessment protocol for streams and rivers (Cawthron Report No. 3543). Cawthron Institute, Nelson, New Zealand.
Hooper, K.L., 2002. The impact of stormwater discharges on freshwater, marine water and marine sediments and the implications for environmental management of the Pauatahanui Inlet, Porirua, New Zealand. (Masters of Applied Science). Massey University, Palmerston North, New Zealand.
Hughes, B., 2019. Review of objectives and limits for the Te-Awarua-o-Porirua Whaitua Implementation Programme (LWP memorandum No. GW01382016- 011). Land Water People, Christchurch, New Zealand.
Joy, M., David, B.O., Lake, M.D., 2013. New Zealand freshwater fish sampling protocols: Part 1. Wadeable river & streams: Field guide. Ecology Group, Institute of Natural Resources, Massey University.
Joy, M.K., Death, R.G., 2004. Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. Environmental Management 34, 415–428. https://doi.org/10.1007/s00267-004-0083-0
Joy, M.K., Henderson, I., 2004. A fish Index of Biotic Integrity (IBI) for the Wellington Region: Introduction and user-guide for use with the Wellington_Fish_IBI software (Institute of Natural Resources Report). Centre for Freshwater Ecosystem Modeling and Management, Massey University, Palmerston North, New Zealand.
Matheson, F., Quinn, J., Hickey, C., 2012. Review of the New Zealand instream plant and nutrient guidelines and development of an extended decision making framework: Phases 1 and 2 final report (Client Report No. HAM2012- 081). NIWA, Hamilton, New Zealand.
McBride, G.B., 2016. National Objectives Framework: Statistical considerations for design and assessment (NIWA Client Report No. HAM16022). NIWA, Hamilton, New Zealand.
McDowell, R.W., Snelder, T.H., Cox, N., Booker, D.J., Wilcock, R.J., 2013. Establishment of reference or baseline conditions of chemical indicators in New Zealand streams and rivers relative to present conditions. Mar. Freshwater Res. 64, 387–400.
Ministry for the Environment, 2019. Fish Index of Biotic Integrity in New Zealand rivers 1999–2018. Ministry for the Environment, Wellington, New Zealand.
Ministry for the Environment and Ministry of Health (MfE/MoH), 2009. New Zealand guidelines for managing cyanobacteria in recreational fresh waters – Interim guidelines. Ministry for the Environment, Wellington, New Zealand.
Ministry for the Environment and Ministry of Health (MfE/MoH), 2003. Microbiological water quality guidelines for marine and freshwater recreational areas. Ministry for the Environment, Wellington, New Zealand.
Ministry for the Environment (MfE), 2022a. Setting instream nutrient concentration thresholds for nutrient-affected attributes in rivers: Guidance on implementing Clause 3.13 of the NPS-FM (No. MFE 1662). Ministry for the Environment, Wellington, New Zealand.

Ministry for the Environment (MfE), 2022b. Guidance on look-up tables for setting nutrient targets for periphyton: second edition. (No. MFE 1644). Ministry for the Environment, Wellington, New Zealand.
Ministry for the Environment (MfE), Stats NZ, 2023. Our freshwater 2023. (No. ME 1748), New Zealand's Environmental Reporting Series. Ministry for the Environment and Stats NZ.
Mosley, L.M., Liss, P.S., 2019. Particle aggregation, pH changes and metal behaviour during estuarine mixing: review and integration. Marine and Freshwater Research 71, 300–310.
Nation, T., Blyth, J., 2022. Spatial assessments of target attribute and monitoring sites, and consideration of Freshwater Management Units for 2022 plan change (Collaborations Technical Memorandum). Collaborations, Wellington, New Zealand.
Neverman, A.J., Smith, H., Herzig, A., Basher, L., 2021. Modelling baseline suspended sediment loads and load reductions required to achieve Draft Freshwater Objectives for Southland (Contract Report prepared for Environment Southland. No. LC3749). Manaaki Whenua – Landcare Research, Palmerston North, New Zealand.
Oldman, J., 2019. Porirua Harbour - Modelling for Whaitua Collaborative Modelling Group (DHI Report No. Report 44800943/01). DHI, Auckland, New Zealand.
Perrie, A., Milne, J.R., 2012. Lake water quality and ecology in the Wellington region : State and trends (Greater Wellington Publication No. GW/EMI-T-12/139). Greater Wellington Regional Council, Wellington, New Zealand.
Schallenberg, M., 2019. Ecological assessment of the Parangarahu Lakes (Hydrosphere Research Report). Hydrosphere Research Ltd., Dunedin, New Zealand.
Science and Technical Advisory Group (STAG), 2020. Freshwater Science and Technical Advisory Group: Supplementary report to the Minister for the Environment. Wellington, New Zealand.
Science and Technical Advisory Group (STAG), 2019. Freshwater Science and Technical Advisory Group: Report to the Minister for the Environment (No. CR 372). Wellington, New Zealand.
Snelder, T., Kilroy, C., Booker, D.J., 2022. Derivation of nutrient criteria for periphyton biomass objectives: Using regional council monitoring data. LWP Limited, Christchurch, New Zealand.
Sorensen, P.G., Milne, J.R., 2009. Porirua Harbour targeted intertidal sediment quality assessment (Greater Wellington Publication No. No. GW/EMI-T-09-136). Greater Wellington Regional Council, Wellington, New Zealand.
Stevens, L., Forrest, B., 2020. Te Awarua-o-Porirua Harbour Sediment Plate Monitoring 2019/2020 (Salt Ecology Report No. 038). Salt Ecology, Nelson, New Zealand.
Storey, R.G., Neale, M.W., Rowe, D.K., Collier, K.J., Hatton, C., Joy, M.K., Maxted, J.R., Moore, R., Parkyn, S.M., Phillips, N., Quinn, J.M., 2011. Stream Ecological Valuation (SEV): A method for assessing the ecological functions of Auckland streams (Auckland Council Technical Report No. 2011/009). Auckland Council, Auckland, New Zealand.
Waller, B., 2019. Porirua Harbour bathymetric survey 2019: Report of survey (DML memorandum No. 1902). Discovery Marine Ltd, Auckland, New Zealand.

Appendices

Appendix A – Attribute state tables

Table A1: Attribute states for dissolved copper (toxicity) developed by GW.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved Copper (Toxicity)**		
Attribute Unit	µg DCu/L (micrograms of dissolved Copper per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95th percentile**	
A	≤1	≤1.4	99% species protection level: No observed effect on any species tested
B	>1 and ≤1.4	>1.4 and ≤1.8	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
C	>1.4 and ≤2.5	>1.8 and ≤4.3	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
D	>2.5	>4.3	Starts approaching acute impact level (i.e., risk of death) for sensitive species

Table A2: Attribute states for dissolved zinc (toxicity) developed by GW.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved Zinc (Toxicity)**		
Attribute Unit	µg DZn/L (micrograms of dissolved Zinc per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95th percentile**	
A	≤2.4	≤8	99% species protection level: No observed effect on any species tested
B	>2.4 and ≤8	>8 and ≤15	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
C	>8 and ≤31	>15 and ≤42	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
D	>31	>42	Starts approaching acute impact level (i.e., risk of death) for sensitive species

Values for this metal should be expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a standard hardness for ANZG 2018 guidelines of 30 mg CaCO3/L. Criteria values for other hardness may be calculated as per the equation presented in the ANZG 2018 guidelines.

Table A3: Attribute states for ammonia (toxicity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Ammonia (Toxicity)**		
Attribute Unit	mg NH_4-N/L (milligrams ammoniacal-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	**Annual 95th percentile**	
A	≤0.03	≤0.05	99% species protection level. No observed effect on any species.
B	>0.03 and ≤0.24	>0.05 and ≤0.40	95% species protection level. Starts impacting occasionally on the 5% most sensitive species.
National Bottom Line	**0.24**	**0.4**	
C	>0.24 and ≤1.30	>0.40 and ≤2.020	80% species protection level. Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).
D	>1.30	>2.20	Starts approaching acute impact level (i.e., risk of death) for sensitive species.

Numeric attribute state is based on pH 8 and temperature of 20°C. Compliance with the numeric attribute states should be undertaken after pH adjustment.

Table A4: Attribute states for nitrate (toxicity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Nitrate (Toxicity)**		
Attribute Unit	mg NO_3-N/L (milligrams nitrate-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	**Annual 95th Percentile**	
A	≤1.0	≤1.5	High conservation value system. Unlikely to be effects even on sensitive species.
B	>1.0 and ≤2.4	>1.5 and ≤3.5	Some growth effect on up to 5% of species.
National Bottom Line	**2.4**	**3.5**	
C	>2.4 and ≤6.9	>3.5 and ≤9.8	Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.
D	>6.9	>9.8	Impacts on growth of multiple species, and starts approaching acute impact level (i.e., risk of death) for sensitive species at higher concentrations (> 20 mg/l).

Note: This attribute measures the toxic effect of nitrate, not the trophic state. Where other attributes measure trophic state, for example periphyton, freshwater objectives, limits and/or methods for those attributes will be more stringent.

Table A5: Attribute states for suspended fine sediment (visual clarity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health				
Freshwater Body Type	Rivers				
Attribute	**Suspended fine sediment**				
Attribute Unit	Visual clarity (metres)				
Attribute State	**Numeric Attribute state by suspended sediment class**				**Narrative Attribute State**
	Median				
	1	**2**	**3**	**4**	
A	≥1.78	≥0.93	≥2.95	≥1.38	Minimal impact of suspended sediment on instream biota. Ecological communities are similar to those observed in natural reference conditions.
B	<1.78 and ≥1.55	<0.93 and ≥0.76	<2.95 and ≥2.57	<1.38 and ≥1.17	Low to moderate impact of suspended sediment on instream biota. Abundance of sensitive fish species may be reduced.
C	<1.55 and >1.34	<0.76 and >0.61	<2.57 and >2.22	<1.17 and >0.98	Moderate to high impact of suspended sediment on instream biota. Sensitive fish species may be lost
National Bottom Line	**1.34**	**0.61**	**2.22**	**0.98**	
D	<1.34	<0.61	<2.22	<0.98	High impact of suspended sediment on instream biota. Ecological communities are significantly altered, and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.

Based on a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years.

Councils may monitor turbidity and convert the measures to visual clarity.

See Appendix 2C Tables 23 and 26 for the definition of suspended sediment classes and their composition.

The following are examples of naturally occurring processes relevant for suspended sediment:

- naturally highly coloured brown-water streams
- glacial flour affected streams and rivers
- selected lake-fed REC classes (particularly warm climate classes) where low visual clarity may reflect autochthonous phytoplankton production

Table A6: Attribute states for *E. coli* taken from Appendix 2A of the NPS-FM 2020.

Value	Human health for recreation				
Freshwater Body Type	Lakes and rivers				
Attribute	***E. coli***				
Attribute Unit	*E. coli* / 100ml (number of *E. coli* per hundred millilitres)				
Attribute State	**Numeric Attribute State**				**Narrative Attribute State**
	% exceedances over 540 cfu/100ml	**% exceedances over 260 cfu/100ml**	**Median concentration (cfu/100ml)**	**95th percentile of *E. coli* /100ml**	**Description of risk of *Campylobacter* infection (based on *E. coli* indicator)**
A (blue)	<5%	<20%	<130	<540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 1% .
B (green)	5-10%	20-30%	<130	<1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 2%.
C (yellow)	10-20%	20-34%	<130	<1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 3% *.
D (orange)	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is >50 in 1000 (>5% risk). The predicted average infection risk is >3%.
E (red)	>30%	>50%	>260	>1200	For more than 30% of the time the estimated risk is >50 in 1000 (>5% risk). The predicted average infection risk is >7%.

Based on a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years.

Table A7: Attribute states for periphyton (trophic state) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Periphyton (Trophic state)**		
Attribute Unit	mg chl-a/m² (milligrams chlorophyll-a per square metre)		
Attribute State	**Numeric Attribute State (Default Class)**	**Numeric Attribute State (Productive Class[1])**	**Narrative Attribute State**
	Exceeded no more than 8% of samples[2]	**Exceeded no more than 17% of samples[2]**	
A	≤50	≤50	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat
B	>50 and ≤120	>50 and ≤120	Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat
C	>120 and ≤200	>120 and ≤200	Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat
National Bottom Line	**200**	**200**	
D	>200	>200	Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat

At low risk sites monitoring may be conducted using visual estimates of periphyton cover. Should monitoring based on visual cover estimates indicate that a site is approaching the relevant periphyton abundance threshold, monitoring should then be upgraded to include measurement of chlorophyll-a.

Classes are streams and rivers defined according to types in the River Environment Classification (REC). The Productive periphyton class is defined by the combination of REC "Dry" Climate categories (that is, Warm-Dry (WD) and Cool-Dry (CD)) and REC Geology categories that have naturally high levels of nutrient enrichment due to their catchment geology (that is, Soft-Sedimentary (SS), Volcanic Acidic (VA) and Volcanic Basic (VB)). Therefore, the productive category is defined by the following REC defined types: WD/SS, WD/VB, WD/VA, CD/SS, CD/VB, CD/VA. The Default class includes all REC types not in the Productive class.

Based on a monthly monitoring regime. The minimum record length for grading a site based on periphyton (chlorophyll-a) is 3 years.

Table A8: Attribute states for the Fish index of Biotic Integrity taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	**Fish (rivers)**	
Attribute Unit	Fish Index of Biotic Integrity (F-IBI)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
A	≥34	High integrity of fish community. Habitat and migratory access have minimal degradation.
B	<34 and ≥28	Moderate integrity of fish community. Habitat and/or migratory access are reduced and show some signs of stress.
C	<28 and ≥18	Low integrity of fish community. Habitat and/or migratory access is considerably impairing and stressing the community
D	<18	Severe loss of fish community integrity. There is substantial loss of habitat and/or migratory access, causing a high level of stress on the community.

Sampling is to occur at least annually between December and April (inclusive) following the protocols for at least one of the backpack electrofishing method, spotlighting method, or trapping method in Joy M, David B, and Lake M. 2013. New Zealand Freshwater Fish Sampling Protocols (Part 1): Wadeable rivers and streams. Massey University: Palmerston North, New Zealand. (See clause 1.8)

The F-IBI score is to be calculated using the general method defined by Joy, MK, and Death RG. 2004. Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. Environmental Management, 34(3), 415-428 (see clause 1.8).

Table A9: Attribute states for the Macroinvertebrate Community Index score and Quantitative Macroinvertebrate Community Index score taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Macroinvertebrates (1 of 2)**		
Attribute Unit	Macroinvertebrate Community Index (MCI) score and Quantitative Macroinvertebrate Community Index (QMCI) score		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	QMCI	**MCI**	
A	≥6.5	≥130	Macroinvertebrate community, indicative of pristine conditions with almost no organic pollution or nutrient enrichment
B	≥5.5 and <6.5	≥110 and <130	Macroinvertebrate community indicative of mild organic pollution or nutrient enrichment. Largely composed of taxa sensitive to organic pollution/nutrient enrichment.
C	≥4.5 and <5.5	≥90 and <110	Macroinvertebrate community indicative of moderate organic pollution or nutrient enrichment. There is a mix of taxa sensitive and insensitive to organic pollution/nutrient enrichment.
National Bottom Line	**4.5**	**90**	
D	<4.5	<90	Macroinvertebrate community indicative of severe organic pollution or nutrient enrichment. Communities are largely composed of taxa insensitive to inorganic pollution/nutrient enrichment.

MCI and QMCI scores to be determined using annual samples taken between 1 November and 30 April with either fixed counts with at least 200 individuals, or full counts, and with current state calculated as the five-year median score. All sites for which the deposited sediment attribute does not apply, whether because they are in river environment classes shown in Table 25 in Appendix 2C or because they require alternate habitat monitoring under clause 3.25 are to use soft sediment sensitivity scores and taxonomic resolution as defined in table A1.1 in Clapcott *et al.* 2017 Macroinvertebrate metrics for the National Policy Statement for Freshwater Management. Cawthron Institute: Nelson, New Zealand (see clause 1.8).

MCI and QMCI to be assessed using the method defined in Stark JD, and Maxted, JR. 2007 A user guide for the Macroinvertebrate Community Index. Cawthron Institute: Nelson, New Zealand (See Clause 1.8), except for sites for which the deposited sediment attribute does not apply, which require use of the soft-sediment sensitivity scores and taxonomic resolution defined in table A1.1 in Clapcott *et al.* 2017 Macroinvertebrate metrics for the National Policy Statement for Freshwater Management. Cawthron Institute: Nelson, New Zealand (see clause 1.8).

Table A10: Attribute states for the Macroinvertebrate Average Score Per Metric taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	**Macroinvertebrates (2 of 2)**	
Attribute Unit	Macroinvertebrate Average Score Per Metric (ASPM)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
A	≥0.6	Macroinvertebrate communities have high ecological integrity, similar to that expected in reference conditions.
B	<0.6 and ≥0.4	Macroinvertebrate communities have mild-to-moderate loss of ecological integrity.
C	<0.4 and ≥0.3	Macroinvertebrate communities have moderate-to severe loss of ecological integrity.
National Bottom Line	**0.3**	
D	<0.3	Macroinvertebrate communities have severe loss of ecological integrity.

Sampling is to occur at least annually between December and April (inclusive) following the protocols for at least one of the backpack electrofishing method, spotlighting method, or trapping method in Joy M, David B, and Lake M. 2013. New Zealand Freshwater Fish Sampling Protocols (Part 1): Wadeable rivers and streams. Massey University: Palmerston North, New Zealand. (see clause 1.8)

The F-IBI score is to be calculated using the general method defined by Joy, MK, and Death RG. 2004. Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. Environmental Management, 34(3), 415-428. (see clause 1.8)

Table A11: Attribute states for dissolved reactive phosphorus taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved reactive phosphorus**		
Attribute Unit	mg DRP/L (milligrams dissolved inorganic nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95th percentile**	
A	≤0.006	≤0.021	Ecological communities and ecosystem processes are similar to those of natural reference conditions. No adverse effects attributable to DRP enrichment are expected.
B	>0.006 and ≤0.010	>0.021 and ≤0.030	Ecological communities are slightly impacted by minor DRP elevation above natural reference conditions. If other conditions also favour eutrophication, sensitive ecosystems may experience additional algal and plant growth, loss of sensitive macroinvertebrate taxa, and higher respiration and decay rates.
C	>0.010 and ≤0.018	>0.030 and ≤0.054	Ecological communities are impacted by moderate DRP elevation above natural reference conditions, but sensitive species are not experiencing nitrate toxicity. If other conditions also favour eutrophication, DRP enrichment may cause increased algal and plant growth, loss of sensitive macroinvertebrate & fish taxa, and high rates of respiration and decay.
D	>0.018	>0.054	Ecological communities impacted by substantial DRP elevation above natural reference conditions. In combination with other conditions favouring eutrophication, DIN enrichment drives excessive primary production and significant changes in macroinvertebrate and fish communities, as taxa sensitive to hypoxia are lost

Numeric attribute state must be derived from the rolling median of monthly monitoring over five years.

Table A12: Attribute states for dissolved oxygen taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved oxygen**		
Attribute Unit	mg/L (milligrams per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	7-day mean minimum	**1-day minimum**	
A	≥8.0	≥7.5	No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near pristine) sites.
B	≥7.0 and <8.0	≥5.0 and <7.5	Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.
C	≥5.0 and <7.0	≥4.0 and <5.0	Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.
National Bottom Line	**5.0**	**4.0**	
D	<5.0	<4.0	Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.

The 7-day mean minimum is the mean value of 7 consecutive daily minimum values.

The 1-day minimum is the lowest daily minimum across the summer period (1 November to 30 April).

Table A13: Attribute states for phytoplankton (trophic state) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Lakes		
Attribute	**Phytoplankton (Trophic state)**		
Attribute Unit	mg chl-a/m^3 (milligrams chlorophyll-a per cubic metre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual median	**Annual maximum**	
A	≤2	≤10	Lake ecological communities are healthy and resilient, similar to natural reference conditions
B	>2 and ≤5	>10 and ≤25	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.
C	>5 and ≤12	>25 and ≤60	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes.
National Bottom Line	**12**	**60**	
D	>12	>60	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

For lakes and lagoons that are intermittently open to the sea, monitoring data should be analysed separately for closed periods and open periods.

Table A14: Attribute states for total nitrogen (trophic state) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Lakes		
Attribute	**Total nitrogen (Trophic state)**		
Attribute Unit	mg/m^3 (milligrams per cubic metre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual median	**Annual median**	
	Seasonally stratified and brackish	Polymictic	
A	≤160	≤300	Lake ecological communities are healthy and resilient, similar to natural reference conditions
B	>160 and ≤350	>300 and ≤500	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.
C	>350 and ≤750	>500 and ≤800	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions
National Bottom Line	**750**	**800**	
D	>750	>800	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

For lakes and lagoons that are intermittently open to the sea, monitoring data should be analysed separately for closed periods and open periods.

Table A15: Attribute states for total phosphorus (trophic state) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Total phosphorus (Trophic state)**	
Attribute Unit	mg/m^3 (milligrams per cubic metre)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	Annual median	
A	≤10	Lake ecological communities are healthy and resilient, similar to natural reference conditions
B	>10 and ≤20	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.
C	>20 and ≤50	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions
National Bottom Line	**50**	
D	>50	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

Table A16: Attribute states for cyanobacteria (planktonic) taken from Appendix 2A of the NPS-FM 2020.

Value	Human contact		
Freshwater Body Type	Lakes and lake fed rivers		
Attribute	**Cyanobacteria (planktonic)**		
Attribute Unit	Biovolume mm^3/L (cubic millimetres per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	80th percentile	**80th percentile**	
	biovolume equivalent for the combined total of all cyanobacteria	biovolume equivalent of potentially toxic cyanobacteria	
A	≤0.5	≤0.5	Risk exposure from cyanobacteria is no different to that in natural conditions (from any contact with freshwater).
B	>0.5 and ≤1.0	>0.5 and ≤1.0	Low risk of health effects from exposure to cyanobacteria (from any contact with freshwater).
C	>1.0 and ≤10	>1 and ≤1.8	Moderate risk of health effects from exposure to cyanobacteria (from any contact with freshwater).
National Bottom Line	**10**	**1.8**	
D	>10	>1.8	High health risks (for example, respiratory, irritation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with freshwater).

The 80th percentile must be determined using a minimum of 12 samples collected over 3 years. Thirty samples collected over 3 years is recommended.

Table A17: Attribute states for submerged plants (natives) taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Submerged plants (natives)**	
Attribute Unit	Lake Submerged Plant (Native Condition Index)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	(% of maximum potential score)	
A	>75%	Excellent ecological condition. Native submerged plant communities are almost completely intact.
B	>50 and ≤75%	High ecological condition. Native submerged plant communities are largely intact.
C	≥20 and ≤50%	Moderate ecological condition. Native submerged plant communities are moderately impacted.
National Bottom Line	**20%**	
D	<20%	Poor ecological condition. Native submerged plant communities are largely degraded or absent.

Monitoring to be conducted, and numeric attribute state to be determined, following the method described in Clayton J, and Edwards T. 2006. LakeSPI: A method for monitoring ecological condition in New Zealand lakes. User Manual Version 2. National Institute of Water & Atmospheric Research: Hamilton, New Zealand. (see clause 1.8)

Lakes in a devegetated state receive scores of 0.

Table A18: Attribute states for submerged plants (invasive species) taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Submerged plants (invasive species)**	
Attribute Unit	Lake Submerged Plant (Invasive Impact Index))	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	(% of maximum potential score)	
A	0%	No invasive plants present in the lake. Native plant communities remain intact.
B	>1 and ≤25%	Invasive plants having only a minor impact on native vegetation. Invasive plants will be patchy in nature co-existing with native vegetation. Often major weed species not present or in early stages of invasion.
C	>25 and ≤90%	Invasive plants having a moderate to high impact on native vegetation. Native plant communities likely displaced by invasive weed beds particularly in the 2 – 8 m depth range.
National Bottom Line	**90%**	
D	>90%	Tall dense weed beds exclude native vegetation and dominate entire depth range of plant growth. The species concerned are likely hornwort and Egeria.

Monitoring to be conducted, and numeric attribute state to be determined, following the method described in Clayton J, and Edwards T. 2006. LakeSPI: A method for monitoring ecological condition in New Zealand lakes. User Manual Version 2. National Institute of Water & Atmospheric Research: Hamilton, New Zealand. (see clause 1.8).

Table A19: Attribute states for lake-bottom dissolved oxygen taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Lake-bottom dissolved oxygen**	
Attribute Unit	mg/L (milligrams per litre)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	Measured or estimated annual minimum	
A	≥7.5	No risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.
B	≥2.0 and <7.5	Minimal risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments
C	≥0.5 and <2.0	Risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.
National Bottom Line	**0.5**	
D	<0.5%	Likelihood from lake-bottom dissolved oxygen of biogeochemical conditions resulting in nutrient release from sediments..

To be measured less than 1 metre above sediment surface at the deepest part of the lake using either continuous monitoring sensors or discrete dissolved oxygen profiles.

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Appendix B – Collaborations memorandum (Section 3)

Subject: **Spatial assessments of target attribute and monitoring sites, and consideration of Freshwater Management Units for 2022 plan change**

Attention: Greater Wellington Regional Council (GWRC)

From: Tom Nation, James Blyth

Date 27 March 2022

Copies to: Brent King, Rachel Pawson, Alastair Smaill, Michael Greer, Ned Norton, Amanda Valois, Evan Harrison

1 Introduction

The purpose of this memo is to document an approach for identifying and recommending sites to assign target attribute states (locations where water quality targets defined by Whaitua Committees will be applied) to support for the upcoming plan change, which specifically covers two Whaitua extents; te Awarua-o-Porirua and te Whanganui-a-Tara. The assessment presented in this memo covers:

- Consideration of the suitability of existing river long-term monitoring sites for the purpose of assigning target attribute states
- Consideration of redundant existing long-term monitoring sites for this purpose
- Consideration of potential redistribution of existing long-term monitoring sites to better suit this purpose
- While the primary objective of this work focussed on sites to express target attribute states, this ultimately fed into consideration of alternative sub-FMUs aligned to the recommended sites for targets[14].

Visions of the various Whaitua Implementation Plans (WIP's) were also incorporated throughout the tasks above.

The premise of this work is based on implementing the targets from the WIP's, freshwater accounting and requirements of the National Policy Statement for Freshwater Management (NPS-FM, Ministry for the Environment 2020). The use, non-use and suggestions about moving monitoring sites may not align with other GWRC interests or scientific requirements, and monitoring programme changes can be considered at a later date.

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[14] Sub-FMUs are essentially smaller management zones within the Whaitua that may be a single hydrological catchment or a collection of smaller catchments with similar landuses. The terminology can be re-defined at the plan change. Freshwater accounting is required at the FMU scale, not at a sub-FMU or sub-catchment.

2 Mātauranga-a-iwi monitoring and cultural sites

When defining target attribute sites and subsequent locations for water quality monitoring, ideally there would be an overlap between western science and mātauranga-a-iwi monitoring for aspects such as mahinga kai. Te Kāhui Taiao expressed over 26 sites with cultural significance within Te Whanganui-a-Tara Whaitua alone. Some of these sites already align with sub FMU boundaries and existing water quality monitoring locations, however a number have no or limited 'western' science data available.

The NPS-FM requires every local authority to actively involve tangata whenua in freshwater management, including developing and implementing mātauranga māori and other monitoring. This process is in development at GWRC, with new teams being built. In addition, there hasn't been an exercise by mana whenua to determine where the most suitable monitoring sites could be across both these Whaitua, aligning with GWRC's budget and resources. Following discussions with Vanessa Tipoki, it seems that the most logical approach is for mana whenua to lead this work in a separate project. While the outcomes of such work may not align with the target attribute and proposed monitoring sites (or FMU/sub FMU boundaries) from the current process, this could be corrected at a later date.

3 Spatial assessments

Spatial assessments were conducted at the sub-FMU scale and upstream of existing water quality monitoring sites. GWRC provided a spatial layer that consisted of ~29 sub-FMUs with corresponding 'accounting points'. Following a review of the sub-FMUs, it was identified that they did not always follow hydrological catchment boundaries or may have been agglomerated from a collection of similar landuses, despite being in different spatial areas. Revisions of these sub-FMUs was undertaken (see Section 6), which involved partitioning some so they aligned with hydrological catchment boundaries (mountains to sea approach). The purpose was to provide a range of comparable outputs at either a sub-FMU level, or where appropriate, a hydrological catchment (such as upstream of a monitoring point) which could help guide decisions on:

- Where target attribute sites could be set
- If there was sufficient monitoring within a sub-FMU at/near a target attribute site to help report on water quality state and trends

The spatial assessments included:

- Determining catchment area of a sub-FMU and draining to a monitoring site
- Assessing landuse areas of each sub-FMU and draining to a monitoring site for exotic forest, exotic vegetation (i.e., gorse), native forest, pastoral, urban residential, urban commercial, urban industrial, water and other (everything else).
    - For the monitoring sites, generally the three dominant landuses from each site were used for additional groupings in Table B1. In some cases, a similar proportion of landuses was indicated with a hyphen (i.e., native + exotic forest/exotic veg).

- Assessment of NZEEM[15] annual average sediment loads (t/year) of that sub-FMU and monitoring point.
    - NZEEM sediment loads is a suitable way to combine a number of parameters into one output to help for faster catchment comparisons. NZEEM includes assessments of slope, rainfall, land cover and geology.
- Defining which local territorial authority (TA) preside over each sub-FMU and monitoring point
    - While they are GWRC monitoring sites, many of the landuse or practice changes to improve water quality will be driven by TA's and Wellington Water (funded by TA's). Subsequently, some TA's may implement the regional policy statement in different ways and paces than others. Having targets and monitoring in similar catchments and different TA's could allow GWRC to apply different strategies and track differences in catchment changes for TAs.
- Comparing monitoring sites from other spatial sources in LAWA, such as NIWA's River Water Quality Network.
- Considering sites of cultural significance around both Whaitua as presented in the WIP's and Te Mahere Wai.

4 Target attribute sites

4.1 Method

We recommend discontinuing the use of the terminology 'accounting points' which is not used in the NPS-FM or guidelines to freshwater accounting (Ministry for the Environment 2015). Accounting is completed at the FMU scale, but not always to specific sites within an FMU (for example, nutrient loads may be calculated off all landuses within an FMU, but not always to a specific point, such as a target attribute site, unless it's a catchment/sub-FMU of interest).

The current approach for defining target attribute sites has focussed on:

- Using the revised sub-FMUs and GWRC's existing 'accounting points' and comparing their landuse and areas to monitoring sites.
- Identifying culturally significant sub-FMUs and waterbodies which will likely have Mātauranga Māori monitoring at some point in time and therefore could also have a suitable target attribute site and/or water quality monitoring site. Some of these sites have been identified in Table B2 and Section 5.3.
- Reviewing Te Mahere Wai, Te Awarua-o-Porirua and Te Whanganui-a-Tara WIP's to ensure alignment of sub-FMU/catchments with the "FMUs or WMU's" in these documents that were developed over many years by community representatives. Target attribute states were often set at the FMU scale in these reports, and this has been used to guide where a target attribute site could be located in a stream, lake or river in this document.

[15] New Zealand Empirical Erosion Model (NZeem®) was developed by Landcare Research. The primary contact is John Dymond. This is freely available as a raster layer in GIS.

The assessment steps were:

- Identify the monitoring sites in a sub-FMU
- Check how well the monitoring site matches the characteristics (e.g., area, land use, NZEEM, TA jurisdiction etc) of the sub-FMU it falls within
    - If not well matched, consider if a target attribute state could be set at the sub-FMU outlet (i.e., where it discharges into a harbour) rather than at an upstream existing monitoring site.
    - Further consideration is needed by GWRC as to how targets might be set in such catchments. See Waiwhetū Stream example below.
- Check for consistency in the water quality current state and the target attribute state set by Whaitua Committees (in various WIP's) across different sub-FMUs and monitoring sites within those. Alignment in both current and target water quality state can indicate target attribute sites may not be necessary at multiple locations, as this could be suitably represented by a single sub-FMU or target attribute site.
    - Where alignment was identified, selection of the appropriate existing site to use was based on a principle of using the site with the poorer water quality than the others. This approach is conservative in that it expresses the greater need for improvement, the strongest basis for justifying alternative management and we would expect this site to show the same or greater level of improvement as we track progress over time.
    - The sites not recommended for use are noted as 'target set by proxy from [site]'.
- Identify sub-FMUs without a suitable existing monitoring site to set targets at.
    - In some cases, these could be readily monitored, perhaps by repurposing some of the sites not used for setting targets.
    - Some of these might not be well suited to monitoring in the short-term, and modelling may be the best way to understand their conditions for target setting and tracking progress.

In addition, further spatial assessments were conducted where a target attribute state could be set at the sub-FMU *outlet* (i.e., where it discharges into a harbour) rather than at an upstream existing monitoring site.

An example of this would be Waiwhetū Stream, where water quality monitoring is conducted ~ halfway up the stream, but there is significant industrial land downstream that is underrepresented by the existing monitoring/target attribute site (see Figure B1). Subsequently, you could not assume that monitoring results at the existing upstream site (which is primarily residential) would reflect changes in water quality across the entire stream, given industrial and commercial land will respond to Water Sensitive Urban Design (WSUD) requirements differently. These situations may have resulted in *two* target attribute sites within a single sub-FMU, one at the existing monitoring site, and the other at the outlet. Most of the outlet sites are unsuitable for monitoring (based on discussions with GWRC Environmental Science staff) and have therefore been identified as 'modelling'[16] sites.

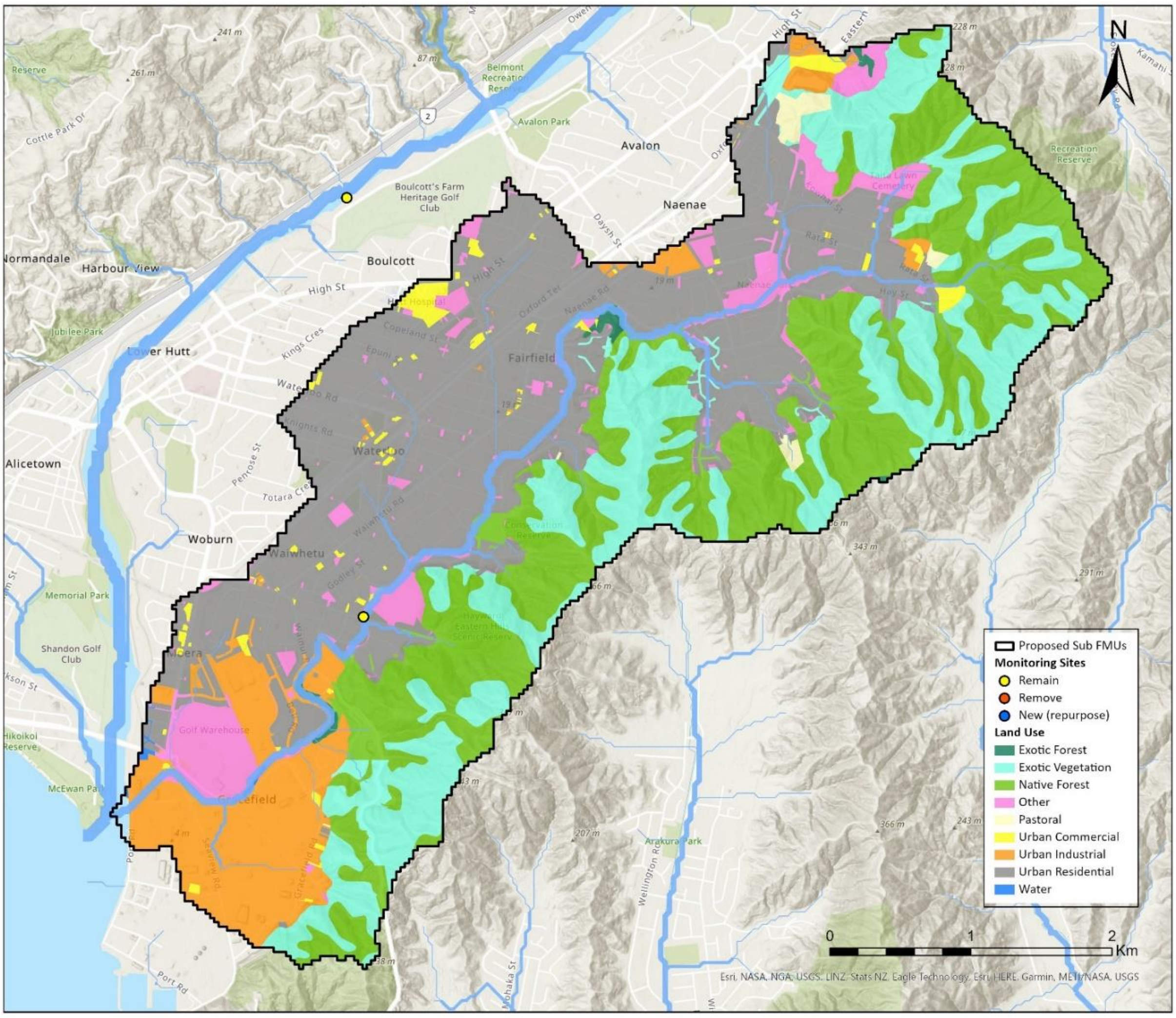


Figure B1 - Waiwhetū Stream - sub-FMU land use & monitoring site

A modelling target attribute site was applied for Eastbourne sub-FMU. This sub-FMUs has short and steep small urban streams with native headwaters that could not be proxied from other locations, and routine SOE water quality monitoring may not capture adequate samples for long term analysis, nor reflect the hydrology that drives contaminants in these areas. This may also be the case for Takapūwahia Stream in the Rangituhi sub-FMU (which has been proposed as a new monitoring site). It is likely that these sites could be better suited for event based monitoring of stormwater runoff, to see how changes in peak concentrations are reduced over time. However, Collaborations understand GWRC are not resourced for long term monitoring in such a manner, as it would require the use of autosamplers or staff on call to sample during wet weather.

[16] Modelling in this situation refers to any method that isn't monitoring that would attempt to predict the concentrations or load for a sub-FMU/catchment at the outlet, which could include excel based calculations through to daily water quality modelling (if available).

See **Appendix B1** for a map of the proposed target attribute sites and **Appendix B2** for a summary of the sub-FMUs landuse, NZEEM loads and current/target water quality states. The current water quality state and targets for each sub-FMU was derived from the two WIP's. Appendix B was used in conjunction with Table B2. Landuse statistics for monitoring sites and sub-FMUs are presented in **Appendix B3** and **Appendix B4.**

4.2 Target attribute sites

Table B1 lists the proposed target attribute sites, aligning with the approach described in Section 3 and 4. Naming conventions can be modified during the plan change.

Table B1. Suggested target attribute sites including sub-FMU, monitoring (light green), modelling (blue) or proxy (dark green) representation.

Target Attribute Site	Sub-FMU	Monitoring Site	Targets set/assessed by proxy or modelling	TA
Taupo Stream	Plimmerton and Pukerua Bay	Taupo Stream at Plimmerton Domain	-	PCC
Horokiri Stream	Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	-	PCC
Horokiri Stream Outlet	Pouewe (Battle Hill)	-	Modelling	PCC
Pāuatahanui Stream	Takapū	Pāuatahanui Stream at Elmwood Bridge	-	PCC
Pāuatahanui Stream Outlet	Takapū	-	Modelling	PCC
Duck Creek	Duck Creek	Duck Creek*	-	PCC
Porirua Stream	Te Riu o Porirua	Porirua Stream at Milk Depot	-	PCC
Porirua Stream Outlet	Te Riu o Porirua	-	Modelling	PCC
Takapūwahia Stream	Rangituhi	Takapūwahia Stream*	-	PCC
Titahi Bay	Titahi Bay	-	Proxy (Te Riu o Porirua)	PCC
Whakatikei River	Whakatikei	Whakatikei River at Riverstone	-	UHCC
Akatarawa River	Akatarawa	-	Proxy (from Whakatikei)	UHCC
Te Awa Kairangi Upstream	Kaitoke	Hutt River at Te Marua Intake Site	-	UHCC
Pākuratahi River	Pākuratahi	-	Proxy (from Mangaroa)	UHCC
Mangaroa River	Mangaroa	Mangaroa River at Te Marua	-	UHCC

Target Attribute Site	Sub-FMU	Monitoring Site	Targets set/assessed by proxy or modelling	TA
Hulls Creek	Te Awa Kairangi Urban Streams	Hulls Creek adjacent Reynolds Bach Drive	-	UHCC
Te Awa Kairangi Downstream	Te Awa Kairangi mainstem	Hutt River at Boulcott	-	HCC
Te Awa Kairangi Outlet	Te Awa Kairangi mainstem	-	Modelling	HCC
Korokoro Stream	Korokoro	Korokoro Stream*	-	HCC/WCC
Waiwhetū Stream	Waiwhetū	Waiwhetū at Whites Line East	-	HCC
Waiwhetū Stream Outlet	Waiwhetū	-	Modelling	HCC
Wainuiomata River Upstream	Wainuiomata Urban Streams	Black Creek at Rowe Parade end	-	HCC
Wainuiomata River Downstream	Wainuiomata Rural Streams	Wainuiomata River Downstream of White Bridge	-	HCC
Ōrongorongo River	Ōrongorongo	-	Proxy from Whakatikei	HCC
Gollans Stream	Parangārahu catchment streams	Gollans Stream above Lake Kōhangatera*	-	HCC
Eastbourne Streams	Eastbourne	-	Modelling	HCC
Kaiwharawhara Stream	Kaiwharawhara	Kaiwharawhara Stream at Ngaio Gorge	-	WCC
Karori Stream Upstream	Wellington Urban	Karori Stream at Mākara Peak Mountain Bike Park	-	WCC
Karori Stream Outlet	Wellington Urban	-	Modelling	WCC
Owhiro Stream	Wellington Urban	-	Proxy from Kaiwharawhara or Karori Stream	WCC
Mākara Stream	South-west coast rural streams	Mākara Stream at Kennels	-	WCC

* Indicates a re-purposed (new) monitoring site. See Section 5.3.

5 Using existing water quality monitoring sites for assigning target states

This section presents a list of water quality monitoring sites. GWRC provided a spatial layer showing 23 long term freshwater quality monitoring sites within the two Whaitua. A spatial assessment was conducted on monitoring sites following the approach outlined in Section 3.

Table B2 presents a summary of the assessments of each monitoring site. The dominant landuse and catchment landuse/NZEEM stats were used to define groupings. Their sediment loads were then averaged to produce a 'group average' sediment load. This information was used to assess what sites to keep or remove for each group. The water quality current state was derived from the most recent water quality assessments as output from Hayden (Salt Ecology), and may differ slightly to the current state presented for the sub-FMUs (from the WIP's) in **Appendix B2**.

In total, **eight** existing monitoring sites are not recommended to be used to assign and track target attribute states, and an additional **four** sites are suggested to be introduced for this purpose. **Fifteen** existing sites are suggested to be used, including using some recent sites (i.e., Black Creek) that have short data records and were installed for the purposes of providing data for Wellington Waters stage 1 global stormwater consent. This results in 19 sites being used to assign target attribute sites, compared with around 23 existing long-term monitoring sites.

This assessment does not consider the other purposes for which any sites might have been established, such as monitoring reference conditions or hazardous or contaminated sites. Consideration of moving monitoring sites to catchment outlets has been undertaken through discussions with GWRC environmental monitoring and science teams, resulting in all sites remaining at their current location.

Table B2. Water quality monitoring sites landuse, NZEEM loads and current/target state summary.

									WIP NOF current state (C) and targets (T) for five selected attributes											
									E.coli		N		Zn		Cu		Periphyton		MCI	
Catchment name	**Monitoring Point**	**Total Area (ha)**	**Dominant Landuse***	**NZEEM t/ha/yr**	**Grouped average (t/ha/yr)**	**TA**	**Monitoring comment**	**Use for target setting**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**
Mangaroa	Mangaroa River at Te Marua	10,356	Native + Pastoral + Exotic Forest	3.3	3.3	UHCC		Yes	D	B	A	A	-	A	-	A	C*	B	D	B
Pākuratahi	Pākuratahi River 50m Below Farm Creek	8,034	Native + Pastoral/Exotic Veg	2.8	2.8	UHCC		No	D	B	A	A	-	A	-	A	-	B	A	B
Kaiwharawhara Stream	Kaiwharawhara Stream at Ngaio Gorge	1,562	Native + Urban Res + Exotic Veg	1.4		WCC	Culturally important site	Yes	E	C	B	B	C	A	D	B	C	C	D	C
Wellington Urban	Owhiro Stream at Mouth*	957	Exotic Veg + Native + Urban Res	1.7	1.2	WCC	Also monitored by WWL since 2019. Part of Wellington Water stormwater consent monitoring. Kaiwharawhara can be used as proxy.	No	E*	C	B*	B	B*	A	C*	C	-	C	D*	C
Te Awa Kairangi urban streams	Stokes Valley Stream at Eastern Hutt Road*	1,128	Native + Urban Res + Exotic Veg	0.6		HCC	Waiwhetū Stream can be used to proxy plan progress. Part of Wellington Water stormwater consent monitoring.	No	E*	C	A*	A	D*	A	C*	A	-	C	-	C
Te Riu o Porirua (Porirua Stream)	Porirua Stream at Glenside overhead cables	1,504	Mixed (Pastoral + Urban Res)	1.7	1.7	PCC	Same catchment as Milk Depot, upstream (smaller)	No	E	C	B	A	C	C	B	C	-	B	D	C
Te Riu o Porirua (Porirua Stream)	Porirua Stream at Milk Depot	3,906	Mixed (Pastoral + Urban Res)	1.8		PCC	Same catchment of Glenside, downstream	Yes	E	C	B	A	D	C	D	C	-	B	D	C
Kaitoke	Hutt River at Te Marua Intake Site	18,971	Native + Pastoral/Exotic Veg	2.8		UHCC	NIWA NRWQN site Hutt River at Kaitoke monitored ~ 4.5 km upstream	Yes	A	A	A	A	-	A	-	A	-	A	A	A
Wainuiomata small forested	Wainuiomata River at Manuka Track	2,700	Native	2.0	2.5	HCC	Likely monitored by WWL and reference site.	Remove	A	A	A	A	-	A	-	A	-	A	A	A
Ōrongorongo	Ōrongorongo River at Station	9,597	Native + Exotic Veg	2.6		HCC	Similar landuse to Kaitoke, naturally high DRP.	Remove	B	A	A	A	-	A	-	A	-	A	C	A
Akatarawa	Akatarawa River at Hutt Confluence	11,644	Native + Exotic Forest	1.9	1.8	UHCC	~4.3 km downstream of Te Marua Intake Site. Proxy from Whakatikei due to similar landuse	Remove	B	A	A	A	-	A	-	A	-	A	A	A
Whakatikei	Whakatikei River at Riverstone	8,073	Native + Exotic Forest	1.8		UHCC	~26% exotic forest, similar to Akatarawa. Useful to monitor polices and WIP recs on forestry.	Yes	A	A	A	A	-	A	-	A	-	A	B	A
Te Awa Kairangi lower mainstem	Hutt River at Boulcott	60,547	Native + Exotic Forest/Pastoral	2.2	2.3	HCC	NIWA NRWQN site Hutt River at Boulcott was considered as a replacement but is no longer monitored. Tidal effects downstream mean the outlet cannot be monitored, this being the most suitable lower reach site.	Yes	D	C	A	A	A	A	A	A	C*	B	C	B

									WIP NOF current state (C) and targets (T) for five selected attributes											
									E.coli		N		Zn		Cu		Periphyton		MCI	
Catchment name	**Monitoring Point**	**Total Area (ha)**	**Dominant Landuse***	**NZEEM t/ha/yr**	**Grouped average (t/ha/yr)**	**TA**	**Monitoring comment**	**Use for target setting**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**
Te Awa Kairangi lower mainstem	Hutt River Opposite Manor Park Golf Club	55,865	Native + Exotic Forest/Pastoral	2.3		HCC	Mid-Point TAK monitoring site along boundary of two TA's (UHCC/HCC)	Remove	D	C	A	A	A	A	A	A	-	B	B	B
Wainuiomata rural streams	Wainuiomata River Downstream of White Bridge	13,160	Native + Exotic Veg + Pastoral	1.6	1.6	HCC		Yes	D	C	A	A	B*	A	A*	A	D*	C	C	B
Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	2,885	Pastoral + Exotic Forest	4.6	4.6	PCC	Main harbour site - High levels exotic forest + sed yield. Pasture increases downstream	Yes	E	B	A	A	-	A	-	A	C	B	B	A
South-west coast rural streams	Mākara Stream at Kennels	7,204	Pastoral + Exotic Veg	3.1	3.1	WCC	Important rural site + exotic forest in different TA.	Yes	E	D	A	A	-	A	-	A	-	C	C	C
Takapū	Pāuatahanui Stream at Elmwood Bridge	3,930	Pastoral + Native/Exotic Forest	2.3	2.3	PCC	Main harbour site. 50 ha residential and Transmission Gulley downstream of monitoring point (but small relative to catchment size).	Yes	E	C	A	A	-	A	-	A	-	B	C	B
Plimmerton & Pukerua Bay	Taupo Stream at Plimmerton Domain*	1,142	Pastoral + Native	2.2	2.2	PCC	D/S of Plimmerton Farms Development, useful for regulation. Culturally significant site. Part of Wellington Water stormwater consent monitoring. Continue once stage 1 stormwater consent completed	Yes	E*	B	A*	A	A*	A	B*	B	-	B	-	B
Te Awa Kairangi urban streams	Hulls Creek adjacent Reynolds Bach Drive*	1,360	Urban (mixed) + Native/Exotic Forest	0.8	0.7	UHCC	Monitored for Silverstream Landfill? 16% commercial. Part of Wellington Water stormwater consent monitoring. Continue once stage 1 stormwater consent completed. Falls into different TA and useful to compare to Waiwhetū (HCC) and Kaiwharawhara (WCC).	Yes	E*	C	A*	A	C*	A	C*	A	-	C	-	C
Waiwhetū Stream	Waiwhetū at Whites Line East	1,346	Urban + Native/Exotic Veg	0.7		HCC	Culturally important site, large industrial area below existing monitoring site that isn't captured in WQ data	Yes	E	C	A	A	D	B	D	A	-	C	D	C
Wainuiomata urban streams	Black Creek at Rowe Parade end*	1,460	Urban + Native + Exotic Veg	0.8	0.8	HCC	Part of Wellington Water stormwater consent monitoring. Continue once stage 1 stormwater consent completed.	Yes	E*	C	A*	A	C*	A	C*	B	-	C	-	D
Karori Stream	Karori Stream at Mākara Peak Mountain Bike Park	689	Urban + Native	0.8		WCC	Similar stats to Wainui Urban Streams. Can compare TA responses to WIP/plan.	Yes	E	C	B	B	D	A	D	C	-	C	C	C

* Indicates "manual" monitoring site with short water quality record. Added by GWRC and paid for by Wellington Water to expand knowledge for Stage 1 of global stormwater consent.

As outlined in Section 4, 're-purposing' of monitoring sites by either moving them within a sub-FMU or creating an entirely new site was considered when setting target attribute sites. Assessing water quality state and trends within the next 5 - 10 years at target attribute sites would most likely be through observed monitoring data, unless GWRC begin development (and updates) of water quality models. Some important considerations for GWRC that haven't been factored into this assessment include:

- A full cost benefit assessment of monitoring versus modelling. The cost of building whaitua specific water quality and flow models calibrated to a set 'baseline' time period, and used to predict water quality for accounting purposes should be compared against the costs of maintaining existing and new monitoring sites, as well as incorporating Mātauranga Māori monitoring practices (and resourcing).
    - Setting of target attribute sites and undertaking freshwater accounting at an FMU requires some level of monitoring, modelling or suitable proxies. Currently this assessment has focussed heavily on using monitoring data when a detailed water quality model with targeted monitoring may be cheaper. This is more relevant when considering monitoring requirements across the entire region.
- The additional monitoring requirements may mean a substantial cost and resource increase for GWRC, which could negate the '*re-purposed'* sites and rely increasingly on proxy monitoring catchments or models.
- Locations of current monitoring sites have been chosen carefully by GWRC, however in some situations, they are upstream of tidal influences and do not capture large landuse changes that occur downstream. Examples of this include Waiwhetū Stream, Hutt River at Boulcott and Horokiri at Snodgrass. This may mean freshwater accounting would be challenging without the use of a model or additional 'paired monitoring'.
- What coastal water quality monitoring GWRC will undertake for representing the 'receiving environment', and if target attribute sites are expressed in coastal locations, how you would assess changes in concentrations and loads (i.e., harbours, southwest coast). Is this going to be driven by summing of loads from major sub-FMUs that feed into appropriate receiving water bodies? If so, this would need suitable monitoring or modelling across all sub-FMUs.

5.1 Monitoring sites not used for setting target attribute states

The eight existing sites that were not used and the reasoning, are described briefly below:

1. **Porirua Stream at Glenside overhead cables** – mid catchment monitoring site, similar proportions of landuse exist at the downstream site (Porirua Stream at Milk Depot). Expect the same relative level of change in water quality across the catchment as a result of the plan change and RPS update.
2. **Pākuratahi River 50m Below Farm Creek** – upper Te Awa Kairangi catchment monitoring site. While it has different landuse proportions to Mangaroa (i.e., Pākuratahi has a lot more native forest), the target water quality states set by the Whaitua Committee would be the same as Mangaroa (defined as 'Te Awa Kairangi Rural Streams'). Mangaroa has poorer water quality and would continue to be monitored, and therefore could proxy for Pākuratahi. In addition, the downstream site 'Hutt River

at Te Marua' would remain and provide an indication of water quality trends from headwaters of Te Awa Kairangi prior to the confluence with Mangaroa.

3. **Wainuiomata River at Manuka Track –** little change in water quality is expected in the native catchments. In addition, this catchment is used for water supply by Wellington Water, so will have ongoing monitoring for drinking water standards and annual reporting. No proxy catchment is proposed however Whakatikei could be used if necessary, given the current and target attributes are all 'A state' for both sub-FMUs.
4. **Hutt River Opposite Manor Park Golf Club** – whilst this is an important site for the midstream reaches of Te Awa Kairangi/Hutt River between two TA boundaries, the downstream Boulcott monitoring site can provide sufficient representation of targets set for Te Awa Kairangi and water quality state and trends, allowing this site to be repurposed elsewhere.
5. **Ōrongorongo River at Ōrongorongo Station –** limited development is likely to occur in this catchment, which is primarily native. Re-purposing monitoring to catchments with no data, or are culturally significant (i.e., Korokoro, Parangārahu Lakes) would likely serve the community better. Setting of a target attribute site at this location could be proxied from Whakatikei, which has similar landuse proportions but would represent poorer water quality (due to forestry impacts) (see Section 4). Whakatikei and Ōrongorongo also have the same target attributes from the WIP, being an 'A state'.
6. **Akatarawa River at Hutt Confluence** – nearby Whakatikei River has similar catchment size and proportions of exotic forest and pasture, with similar water quality trends. While Whakatikei has a slightly greater proportion of exotic forest to total catchment area (than Akatarawa), impacts from RPS and NRP polices on forestry harvest and best practice would be echoed across both catchments. Setting of a target attribute site at this location could be proxied from Whakatikei, with both sub-FMUs having the same targets.
7. **Owhiro Stream at Mouth** – monitoring of this site is currently short term, as part of data collection to support Wellington Water's stage 1 global stormwater consent. Monitoring at this site could eventually be discontinued, and the setting of target attribute states can be proxied from Kaiwharawhara and Karori Streams which have a similar landuse and would be subject to the same development rules within the WCC TA boundary. Both proxy sites have similar or poorer water quality than Owhiro (see Table B2).
8. **Stokes Valley Stream at Eastern Hutt Road** – A short term record exists for this site as it is monitored to support Wellington Water's stage 1 global stormwater consent. Monitoring at this site could eventually be discontinued, as the Waiwhetū Stream and Black Creek within HCC TA boundary will continue to be monitored, and have similar catchment areas, landuse and NZEEM yields which are suitable to be used as a proxy for setting target attribute states. Hulls Creek adjacent Reynolds Bach Drive would instead be monitored to ensure an urban stream from UHCC can be compared against WCC and HCC in relation to water quality improvement.

See **Appendix B1** for a map of the monitoring sites that are to remain, be removed and be 're-purposed'.

5.2 Consideration of moving sites to lower points of the sub-FMU

A review of the landuse statistics for current monitoring sites at Mākara Stream at Kennels, Wainuiomata River Downstream of White Bridge and Kaiwharawhara Stream at Ngaio Gorge against their outlet landuse statistics showed little change in landuse proportions. Subsequently, the existing site remained suitable for setting target attribute states, assuming that flow and nutrient inputs would be relative downstream (i.e., concentrations should be similar). In addition, Mākara Stream at Kennels is upstream of the Mākara Estuary, allowing quantification of loads into the estuary.

Three additional sites were also considered to be moved, however following discussions with GWRC monitoring and science teams, these sites were kept at their existing locations and an additional target attribute site was suggested to be established downstream. They are:

Hutt River at Te Marua Intake Site - a NIWA NRWQN site exists in the headwaters of Te Awa Kairangi, ~4.5 km upstream which could be a suitable proxy. Moving the site downstream to the confluence with Mangaroa River was considered, which would ensure two of the larger headwater tributaries of Te Awa Kairangi are measured before they are impacted from downstream urban populations. However, this ~2.5 km move was considered unnecessary given the established record at this monitoring site and small landuse change over that reach.

Waiwhetū at Whites Line East - there is a significant increase in industrial land downstream of the existing monitoring site (~160 ha increase, changing proportions from 3% to 10% of total catchment area). Monitoring upstream would be unlikely to reflect the changes in water quality off industrial land, which may have different WSUD practices implemented than residential. Historical monitoring was ~0.9 km downstream, however this old site was decommissioned in 2011 due to tidal influences on water quality, with the current monitoring site representing the point above the tidal zone (Perrie and Conwell, 2011). Because of this, we recommend nominating target attribute states at an additional point at the outlet of Waiwhetū Stream to help establish the management of the landuse in the lower reaches. However, due to the tidal influence, information about this point may need to be estimated using modelling rather than monitoring.

Horokiri Stream at Snodgrass – this catchment has large sediment contributions to Pāuatahanui inlet. This would be driven by exotic forestry and pasture landuses. Between the outlet of the catchment and the upstream monitoring point, pasture increases by over 330 ha (~28%). Additional nutrients and lowland farming practices would likely mean the upstream monitoring site would underestimate the nutrient and sediment losses from these lower landuses. Historically, a monitoring site known as Horokiri Stream at Ongly was located ~ 1.1 km downstream, but this was decommissioned in early 2000's and moved to the current site due to the presence of a flow monitoring station at this location and continuous monitoring of other water quality parameters (i.e., temperature and dissolved oxygen) (Warr, 2002). Because of this, we recommend nominating target attribute states at an additional point at the outlet of Horokiri Stream to help establish the management of the landuse in the lower reaches. However, due to the tidal influence, information about this point may need to be estimated using modelling rather than monitoring.

5.3 Re-purposed (new) sites

A list of the suggested four new sites for setting target attribute states and potentially establishing monitoring sites is described below.

1. **Korokoro Stream** – this site was identified in both WIP's as an important sub-FMU or FMU (Te Mahere Wai) and is culturally significant. In addition, its landuse is relatively unique to other catchments meaning setting targets by proxy in another catchment would not be suitable.
2. **Parangārahu Lakes** – a culturally and biologically significant site and also the only two lakes within both Whaitua. Ongoing monitoring could be conducted in the primary tributary draining to Lake Kōhangatera, as this lake has a larger catchment than Lake Kōhangapiripiri (and should better reflect changing landuse practices). Re-purposing the monitoring site from Ōrongorongo River at Ōrongorongo Station.
3. **Duck Creek (Whitby)** – The WIP included this catchment within Takapū sub-FMU, though the catchment is unique with high proportions of pasture, exotic forest and residential landuses that was not represented by any other sub-FMUs. We recommend delineating a separate sub-FMU for this area and setting targets and monitoring at a new site.
4. **Rangituhi Catchment** – Currently not monitored. The stream is in close proximity to Takapūwahia and Hongoeka marae and was identified as a WMU in Te Awarua-o-Porirua WIP with more ambitious target attribute states assigned (than surrounding sub-FMUs such as Porirua Stream). Assigning targets and a monitoring site at this location should allow overlap with Matauranga Maori monitoring while also providing water quality data from a small mixed urban/forest catchment that could be applied elsewhere (for example, Te Awa Kairangi urban streams has a similar landuse proportion and NZEEM loads to Rangituhi). Suitability of monitoring this stream has not been considered (i.e., whether there is sufficient baseflow for SOE monitoring etc).

5.4 Modelling sites

As described in Section 4.1, Section 5.2 and Table B1, there are a number of suggested sites of which target attribute states are recommended to be applied, typically downstream of another target attribute (and monitoring site) within the same sub-FMU. Many of these sites are at the outlet of a catchment, such as the mouth of Te Awa Kairangi or Waiwhetū Stream, with the exception being the small urban streams in Eastbourne which are not suitably represented by potential proxy sites. The suggestion for modelling at these sites to predict water quality changes is based on their locations being relatively poor for water quality monitoring, due to tidal influences or hydrological drivers (i.e., short and steep streams). A suitable approach will need to be determined in how to model or predict water quality at these locations, using either existing models or establishing new methods.

6 FMUs

Background on FMUs and sub-FMUs

Regarding the spatial scale of an FMU, the following points relevant to this memo should be considered:

- The NPS-FM (2020) requires freshwater accounting[17] at each FMU, at a minimum of every five years (for detailed reporting on state, trends etc).
    - Should plan change outline a large number of FMUs, then GWRC would be required to report on this, and naturally this could lead to detailed assessments of each FMU. Scale is important, as by limiting the number of FMUs, this helps balance uncertainty in data (which could be misleading at too finer a scale) while also ensuring management and reporting obligations are simpler and potentially can be summarised easier.
- Within an FMU, sub-FMUs (or catchments) can be defined for locations such as where landuse changes significantly, a hydrological boundary is present or a catchment that may hold cultural significance. GWRC has proposed ~29 to start with.
- NPS-FM has a ki uta ki tai approach (mountains to sea) and consider the interconnectedness between freshwater catchments and landuse draining from headwaters, through rivers/streams/lakes and aquifers and discharging to the coast.
- Setting of target attribute states can occur at a site, or multiple sites within an FMU, but must have regard to environmental outcomes, connection between water bodies and to receiving environments.
- The mountains to sea approach was a consistent theme across all WIP's, specifically mentioned in Te Mahere Wai o Te Kāhui Taiao and Whaitua te Whanganui-a-Tara WIP.

In its simplest form, an FMU could be set at the highest level; the existing Whaitua boundary. This would mean GWRC have five FMUs for the entire region and when undertaking accounting, assess water quality and quantity and write a single report for each of the Whaitua at designated time intervals. However, the previous Whaitua programmes have interchangeably used the terminology FMUs (or WMU's in the case of Porirua) to define their preferred spatial boundaries for the management of catchments, following the NPS-FM. A lot of thought went into these 'FMUs', which needs to be considered by GWRC through the plan change process.

Moving to a single FMU for each Whaitua may frustrate previous committee members and mana whenua partners, while having numerous FMUs (aligning with the various WIP's) would result in increased reporting and assessments requirements (even if a single report is still

[17] "Freshwater quality accounting system" means a system that, for each freshwater management unit, records, aggregates and keeps regularly updated, information on the measured, modelled or estimated: a) loads and/or concentrations of relevant contaminants; b) sources of relevant contaminants; c) amount of each contaminant attributable to each source; and d) where limits have been set, proportion of the limit that is being used.

produced for each Whaitua boundary, you would have to specifically assess each FMU). The reason consideration of FMUs is relevant, is that this feeds into the number of target attribute sites that need to be defined and also the amount of monitoring (and modelling) that GWRC will need to conduct to assess the change over time.

An example could be a single FMU for all of Wellington Urban Streams. Accounting of the contaminants, loads, concentrations and flows could occur for the entire FMU, with optional specific mention of certain catchments/sub-FMUs such as Kaiwharawhara, which hold cultural significance to mana whenua. Alternatively, if GWRC broke this into three smaller FMUs, splitting out Karori Stream, Wellington Urban Streams and Kaiwharawhara Stream, then a commensurate level of detail for accounting and reporting on the many statistics would be required for each of these FMUs, increasing the effort required. If a regional water quality model isn't available, then it's likely that monitoring data would fill the gap to inform changes in water quality, subsequently requiring you to have a monitoring site at each FMU (aligning with your target attribute sites), or a suitable proxy catchment.

Delineated sub-FMUs

The maps in **Appendix B1** show a revised version of sub-FMUs that expanded on previous data sets provided by GWRC. While some are hydrologically correct, delineated by catchment boundaries, others still follow the original sub-FMU boundary which was presumably grouped by landuse. An example would be Mākara Stream, where the sub-FMU includes all streams draining to the southwest coast, or Horokiri Stream that has many small catchment which drain towards Pukerua Bay.

Further revisions could separate this out into hydrologically distinct catchments, but for the purpose of this exercise these have been appropriate to compare landuses, and where necessary (to inform target attribute sites and monitoring points), an 'outlet' assessment was conducted to reflect the streams actual hydrological catchment at the coast (rather than using the sub-FMU).

Some of the steps involved in the sub-FMU modifications are detailed below (for reference purposes only).

STEP 1

- Deleted the coastal sub-FMUs (retained the lake and Estuary FMUs)
- Disaggregated the merged sub-FMUs in Porirua and the Wellington Urban sub-FMU
- Further split the Wellington Urban sub-FMU to separate Karori Stream
- Fixed the two hydrological issues in Porirua (boundary alignments)

STEP 2

- Merged 2 Sub-FMUs around Titahi Bay, keeping Rangituhi separate
- Merged the 6 sub-FMUs around Plimmerton and Pukerua Bay
- Spilt out the Te Awa Kairangi small forested sub-FMU into 4 sub-FMUs
- Results in 31 sub-FMUs including the harbour and estuary sub-FMUs (25 if only considering freshwater stream and river catchments)

7 References

Ministry for the Environment. 2015. A Guide to Freshwater Accounting under the National Policy

Statement for Freshwater Management 2014. Wellington: Ministry for the Environment.

Ministry for the Environment. 2020. National Policy Statement for Freshwater Management 2020.

Perrie, A., & Conwell, C. 2011. Annual freshwater quality monitoring report for the Wellington region, 2011/12. Greater Wellington Regional Council. Environmental Science Department.

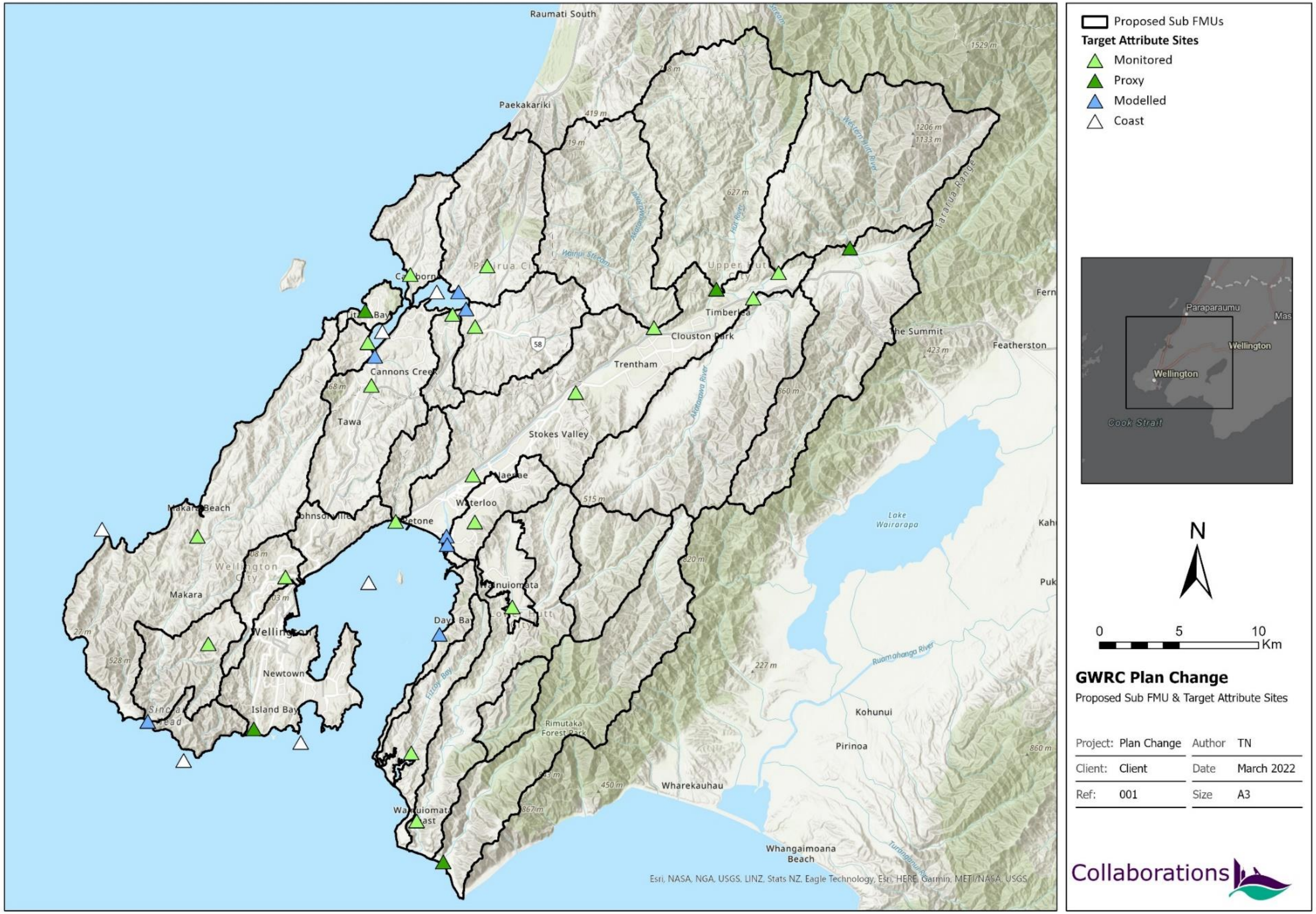
Te Awarua-o-Porirua Whaitua Committee. 2019. Te Awarua-o-Porirua Whaitua Implementation Programme.

Te Kāhui Taiao. 2021. Te Mahere Wai o Te Kāhui Taiao. Prepared for Greater Wellington Te Pane Matua Taiao.

Whaitua Te Whanganui-a-Tara Committee. 2021. Te Whaitua te Whanganui-a-Tara Implementation Programme.

Warr, S. 2002. Rivers State of the Environment Monitoring Review.

Appendix B1 - Target attribute and monitoring sites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Target Attribute Sites
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Modelled
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5
10
Km
GWRC Plan Change
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Project: Plan Change
Author TN
Client: Client
Date March 2022
Ref: 001
Size A3
Collaborations
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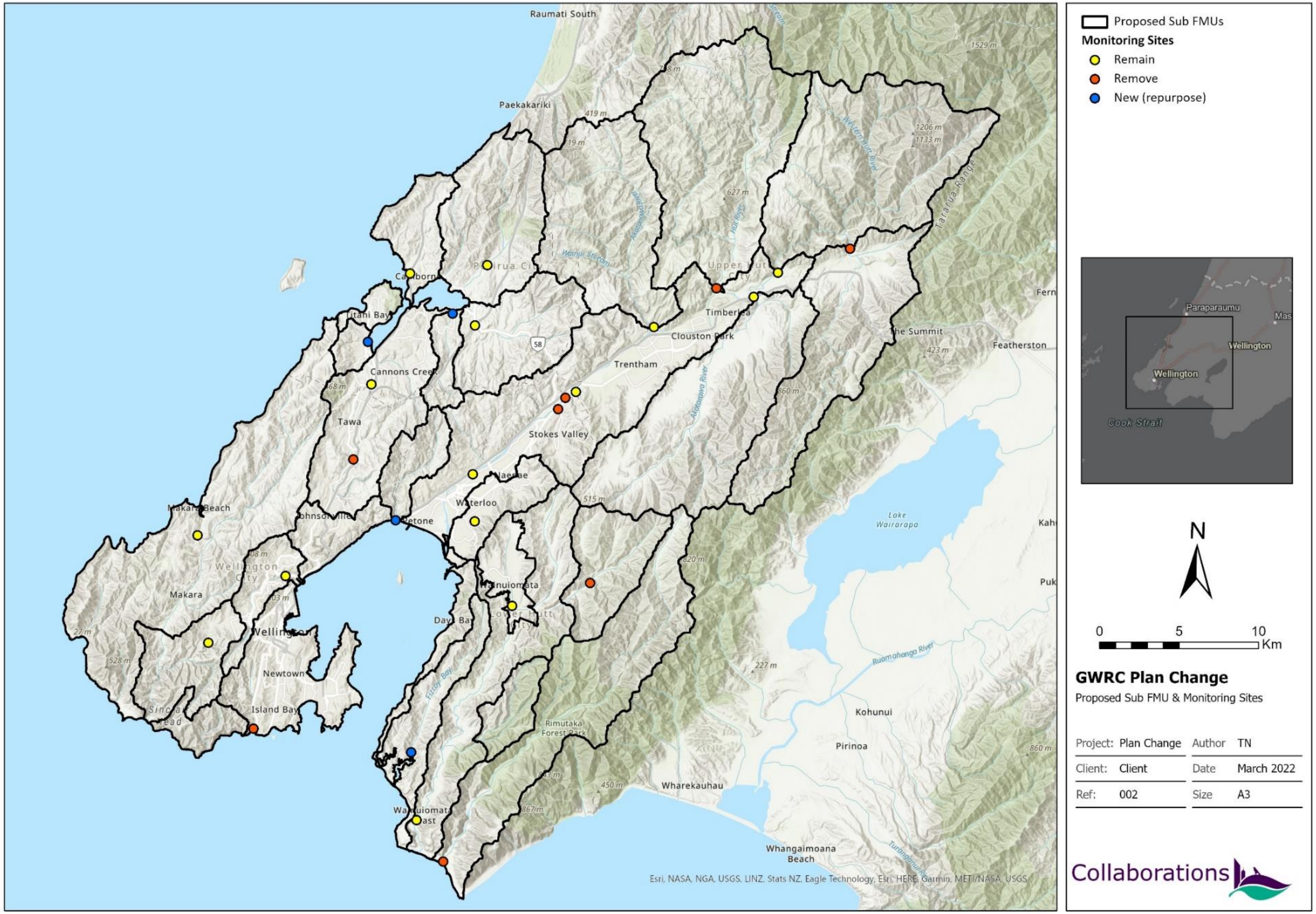
Paekakariki
Upper Hutt
Timberlea
Clouston Park
Trentham
Cannons Creek
Tawa
Stokes Valley
Featherston
Makara Beach
Waterloo
Petone
Makara
Wellington
Newtown
Island Bay
Day's Bay
Wainuiomata
Lake Wairarapa
Kohunui
Pirinoa
Wharekauhau
Whangaimoana Beach
Rimutaka Forest Park
Tararua Range
Ruamahanga River
Paraparaumu
Cook Strait
Esri, NASA, NGA, USGS, LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS


Proposed Sub FMUs
Monitoring Sites
Remain
Remove
New (repurpose)
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0
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10
Km
GWRC Plan Change
Proposed Sub FMU & Monitoring Sites
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Author TN
Client: Client
Date March 2022
Ref: 002
Size A3
Collaborations
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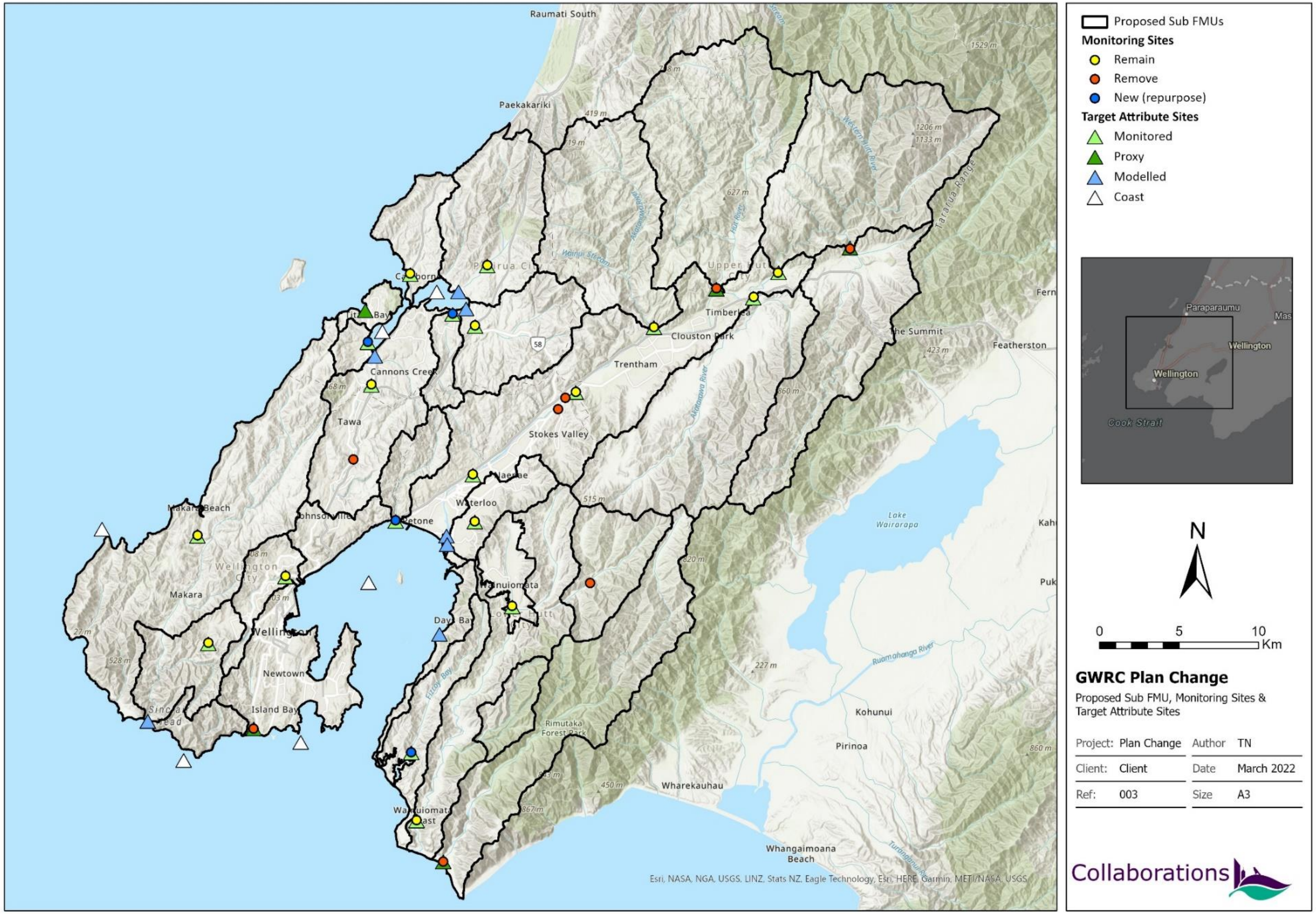
Paekakariki
Tawa
Trentham
Stokes Valley
Clouston Park
Waterloo
Makara
Newtown
Island Bay
Featherston
Kohunui
Pirinoa
Wharekauhau
Whangaimoana Beach
Lake Wairarapa
Cook Strait
Esri, NASA, NGA, USGS, LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS


Proposed Sub FMUs
Monitoring Sites
Remain
Remove
New (repurpose)
Target Attribute Sites
Monitored
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0
5
10
Km
GWRC Plan Change
Proposed Sub FMU, Monitoring Sites & Target Attribute Sites
Project: Plan Change
Author TN
Client: Client
Date March 2022
Ref: 003
Size A3
Collaborations
Esri, NASA, NGA, USGS, LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS

Appendix B2 – Sub-FMU water quality

Main sub-catchment	Total Area (ha)	Dominant Landuse*	NZEEM t/ha/yr	Group Avg. (t/ha/yr)	Comment	WIP NOF current state (C) and Targets (T) for five selected attributes											
						E.coli		N		Zn		Cu		Periphyton		MCI	
						C	T	C	T	C	T	C	T	C	T	C	T
Karori Stream	3,103	Exotic Veg + Native + Urban Res	2.54			E	C	B	B	B	A	D	C	C	C	C	C
Wainuiomata small forested	4,924	Native	2.01	2.46	While split into two groupings (native versus native + exotic forest), all these sub-FMUs have the same current + future states. Could all be represented by a single monitoring and target site.	A	A	A	A	A	A	A	A	A	A	A	A
Kaitoke	10,938	Native	2.80			A	A	A	A	A	A	A	A	A	A	A	A
Ōrongorongo	9,579	Native + Exotic Veg	2.56			A	A	A	A	A	A	A	A	A	A	A	A
Akatarawa	11,651	Native + Exotic Forest	1.86	1.81		A	A	A	A	A	A	A	A	A	A	A	A
Whakatikei	8,077	Native + Exotic Forest	1.76		More pasture + forest as a proportion than Akatarawa	A	A	A	A	A	A	A	A	A	A	A	A
Parangārahu catchment streams	2,786	Native + Exotic Veg + Pastoral	1.10	1.29		E	C	A	A	A	A	A	A	C	B	C	B
Wainuiomata rural streams	7,116	Native + Exotic Veg + Pastoral	1.48			D	C	A	A	A	A	A	A	C	C	C	B
Eastbourne	1,011	Native + Exotic Veg + Urban Res	1.48			E	C	B	B	B	A	D	C	C	C	C	C
Korokoro Stream	1,673	Native + Pastoral + Exotic Forest/Veg	2.23			C	B	A	A	A	A	A	A	B	B	B	A
Mangaroa	10,371	Native + Pastoral + Exotic Forest	3.27			D	B	A	A	A	A	A	A	C	B	C	B
Pākuratahi	8,048	Native + Pastoral/Exotic Veg	2.83			D	B	A	A	A	A	A	A	C	B	C	B
Kaiwharawhara Stream	1,687	Native + Urban Res + Exotic Veg	1.28			E	C	B	B	B	A	C	B	C	C	C	C
Te Awa Kairangi urban streams	13,541	Native + Urban Res + Exotic Forest	0.94	0.80	Similar proportions, Rangituhi could proxy for Te Awa Kairangi Urban Streams	E	C	A	A	B	A	B	A	C	C	C	C
Rangituhi	649	Native + Urban Res + Pastoral	0.71			E	A	A	A	D	A	D	A	A	A	C	A
Wainuiomata urban streams	1,557	Urban Res + Native + Exotic Veg	0.77			E	C	A	A	B	A	B	B	C	C	D	D
Pouewe (Battle Hill)	5,640	Pastoral + Exotic Forest + Native	3.94		Similar to Southwest Coast Streams, except high % of exotic forest - not grouped for that reason	E	B	A	A	A	A	A	A	C	B	C/B	A
South-west coast rural streams	14,596	Pastoral + Exotic Veg	3.74		Could potentially be proxied off Pouewe	E	D	A	A	A	A	A	A	C	C	C	C
Takapū	4,252	Pastoral + Native + Exotic Forest	2.22			E	C	A	A	A	A	A	A	C	B	C/B	B
Plimmerton & Pukerua Bay	2,140	Pastoral + Native + Urban Res	2.26	2.41	Could be proxied off Duck Creek	E	B	A	A	C	A	D	B	C	B	C	B
Duck Creek	1,061	Pastoral + Urban Res + Exotic Forest	2.56		Similar to Plimmerton, except higher % of exotic forest. Current state probably incorrect as originally lumped with Takapū WMU (primarily pastural). I.e., likely similar to Plimmerton	E	C	A	A	A	A	A	A	C	B	C/B	B
Waiwhetū Stream	1,960	Urban Res + Native + Exotic Veg	0.63	0.67		E	C	A	A	D	B	C	A	C	C	D	C
Wellington Urban	6,242	Urban Res + Native + Exotic Veg	0.72			E	C	B	B	B	A	D	C	C	C	C	C
Te Rio o Porirua (Porirua Stream)	6,098	Urban Res + Pastoral	1.59	1.44		E	C	B	A	D	C	D	C	C/B	B	C	C
Titahi Bay	658	Urban Res + Pastoral + Other	1.29		Slightly different landuses but could be proxied off Porirua. Same target states.	E	C	B	A	D	C	D	C	C/B	B	C	C

Appendix B3 – Monitoring sites landuse statistics (from upstream catchment)

Monitoring Point	Landuse	Area (ha)	Percent	Total (ha)
Akatarawa River at Hutt Confluence	Exotic Forest	2007.3	17%	11650.8
	Exotic Vegetation	75.1	1%	
	Native Forest	9158.7	79%	
	Other	3.7	0%	
	Pastoral	383.5	3%	
	Urban Commercial	6.1	0%	
	Urban Residential	13.9	0%	
	Water	2.5	0%	
Black Creek at Rowe Parade end	Exotic Forest	11.8	1%	1484.5
	Exotic Vegetation	197.2	13%	
	Native Forest	550.9	37%	
	Other	112.0	8%	
	Pastoral	137.8	9%	
	Urban Commercial	28.2	2%	
	Urban Industrial	16.9	1%	
	Urban Residential	429.8	29%	
Horokiri Stream at Snodgrass	Exotic Forest	871.4	30%	2884.8
	Exotic Vegetation	447.6	16%	
	Native Forest	392.4	14%	
	Other	0.0	0%	
	Pastoral	1173.4	41%	
Hulls Creek adjacent Reynolds Bach Drive	Exotic Forest	326.9	22%	1517.8
	Exotic Vegetation	90.4	6%	
	Native Forest	469.5	31%	
	Other	110.6	7%	
	Pastoral	18.0	1%	
	Urban Commercial	243.5	16%	
	Urban Industrial	4.6	0%	
	Urban Residential	254.2	17%	
	Water	0.1	0%	
Hutt River at Boulcott	Exotic Forest	7575.9	12%	61020.8
	Exotic Vegetation	2381.8	4%	
	Native Forest	40288.0	66%	
	Other	1163.9	2%	

Monitoring Point	Landuse	Area (ha)	Percent	Total (ha)
	Pastoral	6412.4	11%	
	Urban Commercial	574.5	1%	
	Urban Industrial	156.8	0%	
	Urban Residential	2240.7	4%	
	Water	226.9	0%	
Hutt River at Te Marua Intake Site	Exotic Forest	681.9	4%	18985.7
	Exotic Vegetation	1045.4	6%	
	Native Forest	16311.3	86%	
	Other	27.2	0%	
	Pastoral	918.9	5%	
	Urban Residential	0.5	0%	
	Water	0.5	0%	
Hutt River Opposite Manor Park Golf Club	Exotic Forest	7485.5	13%	56285.4
	Exotic Vegetation	2008.3	4%	
	Native Forest	38186.1	68%	
	Other	827.1	1%	
	Pastoral	5551.7	10%	
	Urban Commercial	526.3	1%	
	Urban Industrial	79.1	0%	
	Urban Residential	1449.6	3%	
	Water	171.8	0%	
Kaiwharawhara Stream at Ngaio Gorge	Exotic Forest	87.8	6%	1581.7
	Exotic Vegetation	281.7	18%	
	Native Forest	552.8	35%	
	Other	51.7	3%	
	Pastoral	49.9	3%	
	Urban Commercial	25.0	2%	
	Urban Industrial	4.8	0%	
	Urban Residential	524.3	33%	
	Water	3.7	0%	
Karori Stream at Mākara Peak Mountain Bike Park	Exotic Forest	11.3	2%	695.5
	Exotic Vegetation	28.6	4%	
	Native Forest	287.7	41%	
	Other	29.5	4%	
	Pastoral	15.1	2%	
	Urban Commercial	6.8	1%	
	Urban Industrial	0.6	0%	
	Urban Residential	315.9	45%	

Monitoring Point	Landuse	Area (ha)	Percent	Total (ha)
Mākara Stream at Kennels	Exotic Forest	556.9	8%	7203.2
	Exotic Vegetation	1434.9	20%	
	Native Forest	496.4	7%	
	Other	95.1	1%	
	Pastoral	4610.3	64%	
	Urban Commercial	2.9	0%	
	Urban Industrial	0.0	0%	
	Urban Residential	5.6	0%	
	Water	1.2	0%	
Mangaroa River at Te Marua	Exotic Forest	1649.1	16%	10370.5
	Exotic Vegetation	399.4	4%	
	Native Forest	5050.3	49%	
	Other	24.3	0%	
	Pastoral	3178.0	31%	
	Urban Commercial	0.9	0%	
	Urban Industrial	8.7	0%	
	Urban Residential	59.0	1%	
	Water	0.7	0%	
Ōrongorongo River at Station	Exotic Forest	20.8	0%	9578.6
	Exotic Vegetation	1288.8	13%	
	Native Forest	7722.2	81%	
	Other	326.0	3%	
	Pastoral	220.9	2%	
Owhiro Stream at Mouth	Exotic Forest	30.2	3%	965.2
	Exotic Vegetation	441.4	46%	
	Native Forest	249.4	26%	
	Other	85.1	9%	
	Pastoral	2.8	0%	
	Urban Commercial	3.9	0%	
	Urban Industrial	7.3	1%	
	Urban Residential	145.2	15%	
Pākuratahi River 50m Below Farm Creek	Exotic Forest	646.0	8%	8047.9
	Exotic Vegetation	852.5	11%	
	Native Forest	5613.6	70%	
	Other	26.0	0%	
	Pastoral	909.4	11%	
	Urban Residential	0.5	0%	
Pāuatahanui Stream at Elmwood Bridge	Exotic Forest	606.8	15%	3942.9

Monitoring Point	Landuse	Area (ha)	Percent	Total (ha)
	Exotic Vegetation	148.3	4%	
	Native Forest	832.0	21%	
	Other	54.5	1%	
	Pastoral	2297.8	58%	
	Urban Commercial	1.9	0%	
	Urban Industrial	0.9	0%	
	Urban Residential	0.6	0%	
Porirua Stream at Glenside overhead cables	Exotic Forest	66.5	4%	1579.0
	Exotic Vegetation	160.2	10%	
	Native Forest	183.9	12%	
	Other	163.3	10%	
	Pastoral	537.6	34%	
	Urban Commercial	14.7	1%	
	Urban Industrial	19.4	1%	
	Urban Residential	433.5	27%	
Porirua Stream at Milk Depot	Exotic Forest	450.2	11%	4026.2
	Exotic Vegetation	363.4	9%	
	Native Forest	526.9	13%	
	Other	302.0	8%	
	Pastoral	1240.7	31%	
	Urban Commercial	136.3	3%	
	Urban Industrial	101.8	3%	
	Urban Residential	905.0	22%	
Stokes Valley Stream at Eastern Hutt Road	Exotic Forest	9.0	1%	1137.2
	Exotic Vegetation	107.7	9%	
	Native Forest	681.6	60%	
	Other	20.1	2%	
	Pastoral	15.0	1%	
	Urban Commercial	14.8	1%	
	Urban Industrial	2.7	0%	
	Urban Residential	285.5	25%	
	Water	0.8	0%	
Taupo Stream at Plimmerton Domain	Exotic Forest	36.1	3%	1147.8
	Exotic Vegetation	25.5	2%	
	Native Forest	164.5	14%	
	Other	13.1	1%	
	Pastoral	822.8	72%	
	Urban Commercial	13.3	1%	

Monitoring Point	Landuse	Area (ha)	Percent	Total (ha)
	Urban Industrial	6.6	1%	
	Urban Residential	65.7	6%	
Wainuiomata River at Manuka Track	Exotic Forest	2.6	0%	2699.5
	Native Forest	2690.5	100%	
	Pastoral	6.4	0%	
Wainuiomata River Downstream of White Bridge	Exotic Forest	368.3	3%	13221.7
	Exotic Vegetation	2375.2	18%	
	Native Forest	8549.4	65%	
	Other	230.6	2%	
	Pastoral	1110.5	8%	
	Urban Commercial	30.6	0%	
	Urban Industrial	18.7	0%	
	Urban Residential	537.1	4%	
	Water	1.2	0%	
Waiwhetū at Whites Line East	Exotic Forest	5.6	0%	1388.1
	Exotic Vegetation	283.1	20%	
	Native Forest	356.6	26%	
	Other	86.6	6%	
	Pastoral	12.1	1%	
	Urban Commercial	41.9	3%	
	Urban Industrial	19.1	1%	
	Urban Residential	583.0	42%	
Whakatikei River at Riverstone	Exotic Forest	1960.2	24%	8073.3
	Exotic Vegetation	169.0	2%	
	Native Forest	5398.3	67%	
	Other	7.1	0%	
	Pastoral	522.3	6%	
	Urban Residential	15.4	0%	
	Water	1.1	0%	

Appendix B4 – sub-FMU landuse statistics

Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
Akatarawa	Exotic Forest	2007.2	17%	11650.7
	Exotic Vegetation	75.1	1%	
	Native Forest	9158.7	79%	
	Other	3.7	0%	
	Pastoral	383.5	3%	
	Urban Commercial	6.1	0%	
	Urban Residential	13.9	0%	
	Water	2.5	0%	
Duck Creek	Exotic Forest	137.9	13%	1061.2
	Exotic Vegetation	54.8	5%	
	Native Forest	76.5	7%	
	Other	87.5	8%	
	Pastoral	532.1	50%	
	Urban Commercial	10.9	1%	
	Urban Industrial	1.7	0%	
	Urban Residential	157.5	15%	
	Water	2.2	0%	
Eastbourne	Exotic Forest	8.6	1%	1010.7
	Exotic Vegetation	205.7	20%	
	Native Forest	605.0	60%	
	Other	27.4	3%	
	Pastoral	29.8	3%	
	Urban Commercial	5.2	1%	
	Urban Industrial	0.7	0%	
	Urban Residential	128.2	13%	
Kaitoke	Exotic Forest	36.0	0%	10937.8
	Exotic Vegetation	192.9	2%	
	Native Forest	10697.8	98%	
	Other	1.2	0%	
	Pastoral	9.5	0%	
	Water	0.5	0%	
Kaiwharawhara Estuary	Native Forest	0.4	71%	0.6
	Other	0.1	15%	
	Urban Commercial	0.1	14%	
Kaiwharawhara Stream	Exotic Forest	89.1	5%	1687.4
	Exotic Vegetation	281.7	17%	

Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
	Native Forest	596.9	35%	
	Other	56.5	3%	
	Pastoral	49.9	3%	
	Urban Commercial	31.5	2%	
	Urban Industrial	10.3	1%	
	Urban Residential	567.7	34%	
	Water	3.7	0%	
Karori Stream	Exotic Forest	123.5	4%	3103.3
	Exotic Vegetation	1591.4	51%	
	Native Forest	674.1	22%	
	Other	41.7	1%	
	Pastoral	347.1	11%	
	Urban Commercial	6.9	0%	
	Urban Industrial	0.6	0%	
	Urban Residential	318.0	10%	
Korokoro Estuary	Native Forest	0.0	1%	0.2
	Other	0.1	93%	
	Urban Residential	0.0	7%	
Korokoro Stream	Exotic Forest	197.2	12%	1672.7
	Exotic Vegetation	193.8	12%	
	Native Forest	905.5	54%	
	Other	14.7	1%	
	Pastoral	300.1	18%	
	Urban Commercial	3.2	0%	
	Urban Industrial	12.0	1%	
	Urban Residential	46.2	3%	
Lake Kōhangapiripiri	Exotic Vegetation	0.7	3%	22.4
	Native Forest	9.7	43%	
	Other	1.2	5%	
	Water	10.8	48%	
Lake Kōhangatera	Exotic Vegetation	3.1	5%	67.2
	Native Forest	45.8	68%	
	Other	0.7	1%	
	Water	17.6	26%	
Mākara Estuary	Exotic Vegetation	0.0	1%	9.3
	Native Forest	3.9	41%	
	Other	0.2	3%	
	Pastoral	1.2	13%	

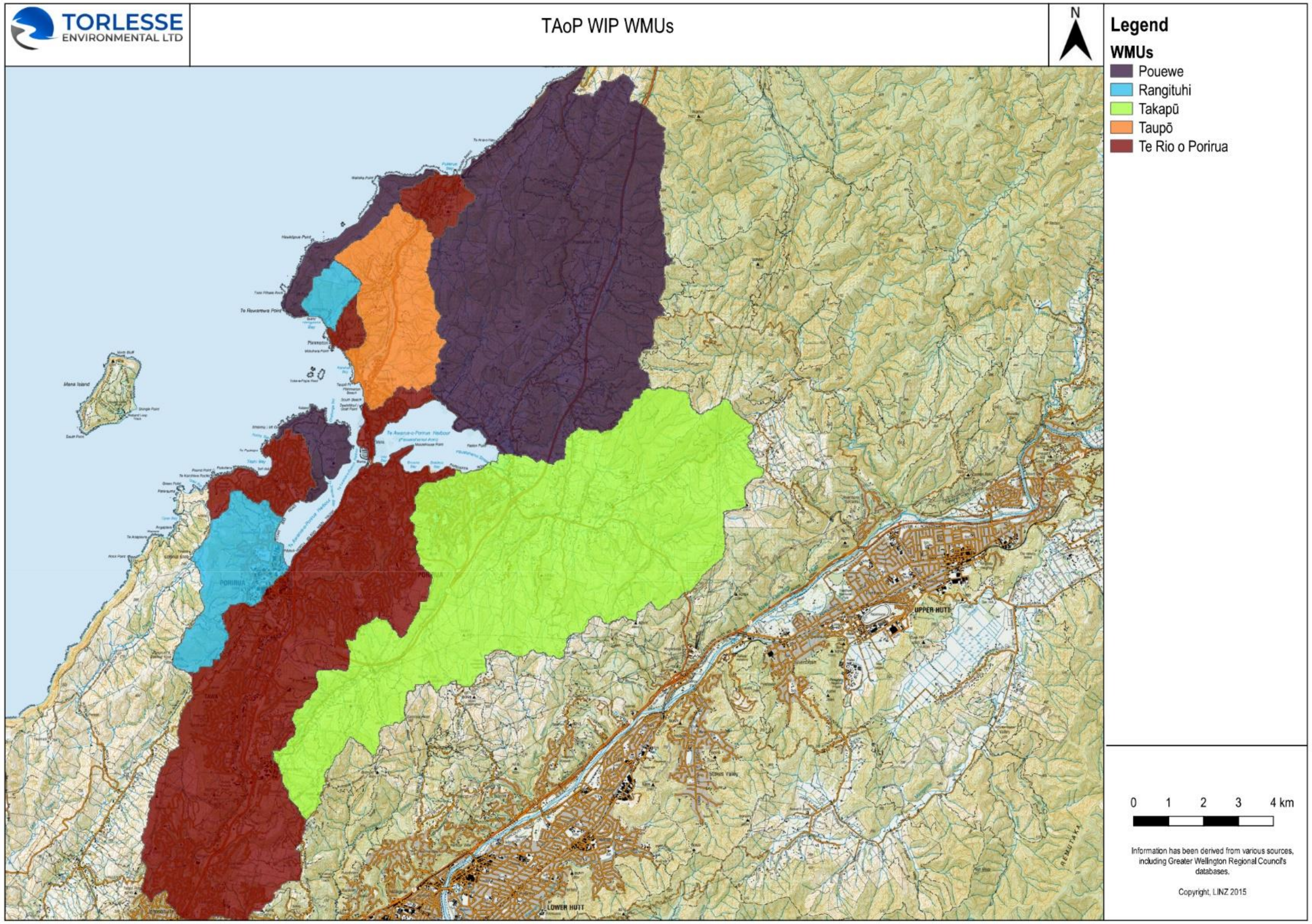
Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
	Urban Residential	0.2	2%	
	Water	3.8	40%	
Mangaroa	Exotic Forest	1649.1	16%	10370.5
	Exotic Vegetation	399.3	4%	
	Native Forest	5050.4	49%	
	Other	24.3	0%	
	Pastoral	3178.0	31%	
	Urban Commercial	0.9	0%	
	Urban Industrial	8.7	0%	
	Urban Residential	59.0	1%	
	Water	0.8	0%	
Ōrongorongo	Exotic Forest	20.8	0%	9578.6
	Exotic Vegetation	1288.8	13%	
	Native Forest	7722.2	81%	
	Other	326.0	3%	
	Pastoral	220.9	2%	
Pākuratahi	Exotic Forest	646.0	8%	8048.0
	Exotic Vegetation	852.5	11%	
	Native Forest	5613.6	70%	
	Other	26.0	0%	
	Pastoral	909.4	11%	
	Urban Residential	0.5	0%	
Parangārahu catchment streams	Exotic Forest	2.1	0%	2785.7
	Exotic Vegetation	1058.3	38%	
	Native Forest	1205.6	43%	
	Other	48.1	2%	
	Pastoral	471.8	17%	
Plimmerton & Pukerua Bay	Exotic Forest	41.4	2%	2139.6
	Exotic Vegetation	242.7	11%	
	Native Forest	351.6	16%	
	Other	87.8	4%	
	Pastoral	1136.0	53%	
	Urban Commercial	28.4	1%	
	Urban Industrial	6.7	0%	
	Urban Residential	244.9	11%	
	Water	0.1	0%	
Pouewe (Battle Hill)	Exotic Forest	1503.4	27%	5639.6
	Exotic Vegetation	585.6	10%	

Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
	Native Forest	753.9	13%	
	Other	25.0	0%	
	Pastoral	2766.9	49%	
	Urban Residential	3.8	0%	
	Water	1.0	0%	
Rangituhi	Exotic Forest	5.1	1%	648.8
	Exotic Vegetation	63.6	10%	
	Native Forest	255.8	39%	
	Other	22.9	4%	
	Pastoral	87.2	13%	
	Urban Commercial	58.1	9%	
	Urban Industrial	35.5	5%	
	Urban Residential	120.6	19%	
South-west coast rural streams	Exotic Forest	630.6	4%	14596.3
	Exotic Vegetation	5373.7	37%	
	Native Forest	825.7	6%	
	Other	167.7	1%	
	Pastoral	7579.9	52%	
	Urban Commercial	3.1	0%	
	Urban Industrial	0.1	0%	
	Urban Residential	8.3	0%	
	Water	7.1	0%	
Takapū	Exotic Forest	612.6	14%	4251.9
	Exotic Vegetation	181.9	4%	
	Native Forest	870.3	20%	
	Other	87.3	2%	
	Pastoral	2439.4	57%	
	Urban Commercial	5.0	0%	
	Urban Industrial	1.9	0%	
	Urban Residential	53.1	1%	
	Water	0.4	0%	
Te Awa Kairangi Estuary	Native Forest	2.8	34%	8.4
	Other	0.1	2%	
	Urban Commercial	0.0	0%	
	Urban Industrial	0.1	1%	
	Water	5.3	63%	
Te Awa Kairangi urban streams	Exotic Forest	1280.8	9%	13541.3
	Exotic Vegetation	701.5	5%	

Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
	Native Forest	4712.3	35%	
	Other	1299.3	10%	
	Pastoral	1437.9	11%	
	Urban Commercial	695.0	5%	
	Urban Industrial	287.5	2%	
	Urban Residential	2822.8	21%	
	Water	304.4	2%	
Te Rio o Porirua (Porirua Stream)	Exotic Forest	518.2	8%	6098.3
	Exotic Vegetation	594.3	10%	
	Native Forest	697.5	11%	
	Other	602.3	10%	
	Pastoral	1594.5	26%	
	Urban Commercial	256.2	4%	
	Urban Industrial	111.1	2%	
	Urban Residential	1724.2	28%	
	Water	0.0	0%	
Titahi Bay	Exotic Forest	7.7	1%	657.5
	Exotic Vegetation	104.9	16%	
	Native Forest	36.1	5%	
	Other	117.9	18%	
	Pastoral	130.5	20%	
	Urban Commercial	7.7	1%	
	Urban Industrial	26.3	4%	
	Urban Residential	225.5	34%	
	Water	0.9	0%	
Wainuiomata rural streams	Exotic Forest	351.1	5%	7115.5
	Exotic Vegetation	2163.8	30%	
	Native Forest	3348.0	47%	
	Other	125.2	2%	
	Pastoral	1107.3	16%	
	Urban Commercial	0.1	0%	
	Urban Industrial	0.0	0%	
	Urban Residential	9.7	0%	
	Water	10.2	0%	
Wainuiomata small forested	Exotic Forest	5.6	0%	4923.6
	Exotic Vegetation	172.5	4%	
	Native Forest	4728.9	96%	
	Pastoral	16.6	0%	

Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
Wainuiomata urban streams	Exotic Forest	11.6	1%	1557.0
	Exotic Vegetation	220.9	14%	
	Native Forest	474.3	30%	
	Other	130.6	8%	
	Pastoral	142.8	9%	
	Urban Commercial	30.5	2%	
	Urban Industrial	18.7	1%	
	Urban Residential	527.5	34%	
	Water	0.1	0%	
Waiwhetū Stream	Exotic Forest	8.9	0%	1959.6
	Exotic Vegetation	376.3	19%	
	Native Forest	473.3	24%	
	Other	135.3	7%	
	Pastoral	12.2	1%	
	Urban Commercial	54.8	3%	
	Urban Industrial	188.1	10%	
	Urban Residential	709.0	36%	
	Water	1.8	0%	
Wellington Urban	Exotic Forest	311.3	5%	6241.9
	Exotic Vegetation	646.4	10%	
	Native Forest	1365.2	22%	
	Other	614.0	10%	
	Pastoral	59.8	1%	
	Urban Commercial	435.3	7%	
	Urban Industrial	340.1	5%	
	Urban Residential	2469.8	40%	
Whakatikei	Exotic Forest	1960.2	24%	8077.1
	Exotic Vegetation	169.0	2%	
	Native Forest	5401.0	67%	
	Other	7.1	0%	
	Pastoral	522.6	6%	
	Urban Residential	15.4	0%	
	Water	1.7	0%	

Appendix C – TAoP Whaitua part-FMU refinement process maps (Section 3)



TORLESSE ENVIRONMENTAL LTD
TAoP WIP WMUs
N
Legend
WMUs
Pouewe
Rangituhi
Takapū
Taupō
Te Rio o Porirua
UPPER HUTT
LOWER HUTT
0 1 2 3 4 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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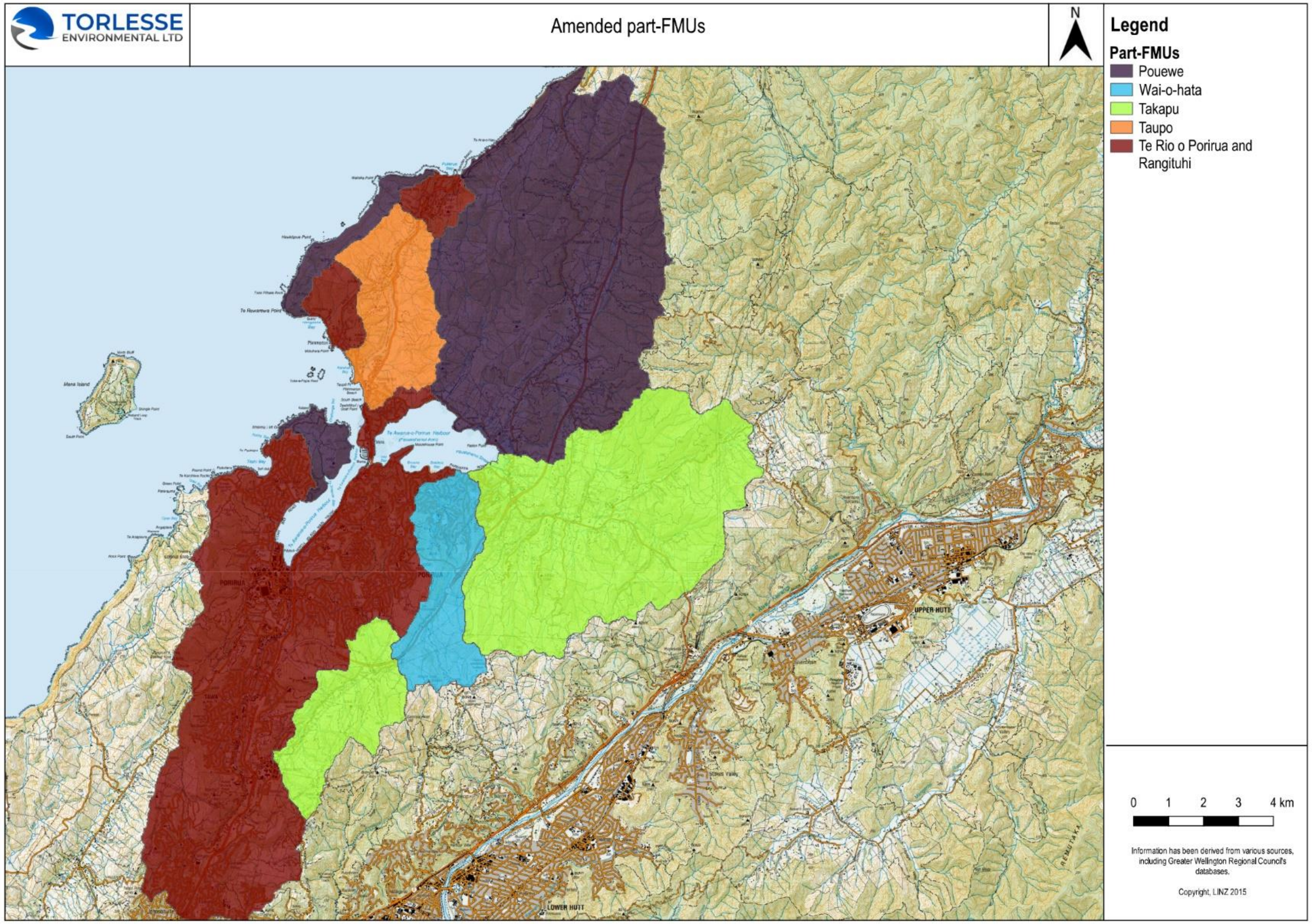

TORLESSE
ENVIRONMENTAL LTD
Amended part-FMUs
N
Legend
Part-FMUs
Pouewe
Wai-o-hata
Takapu
Taupo
Te Rio o Porirua and Rangituhi
UPPER HUTT
LOWER HUTT
0 1 2 3 4 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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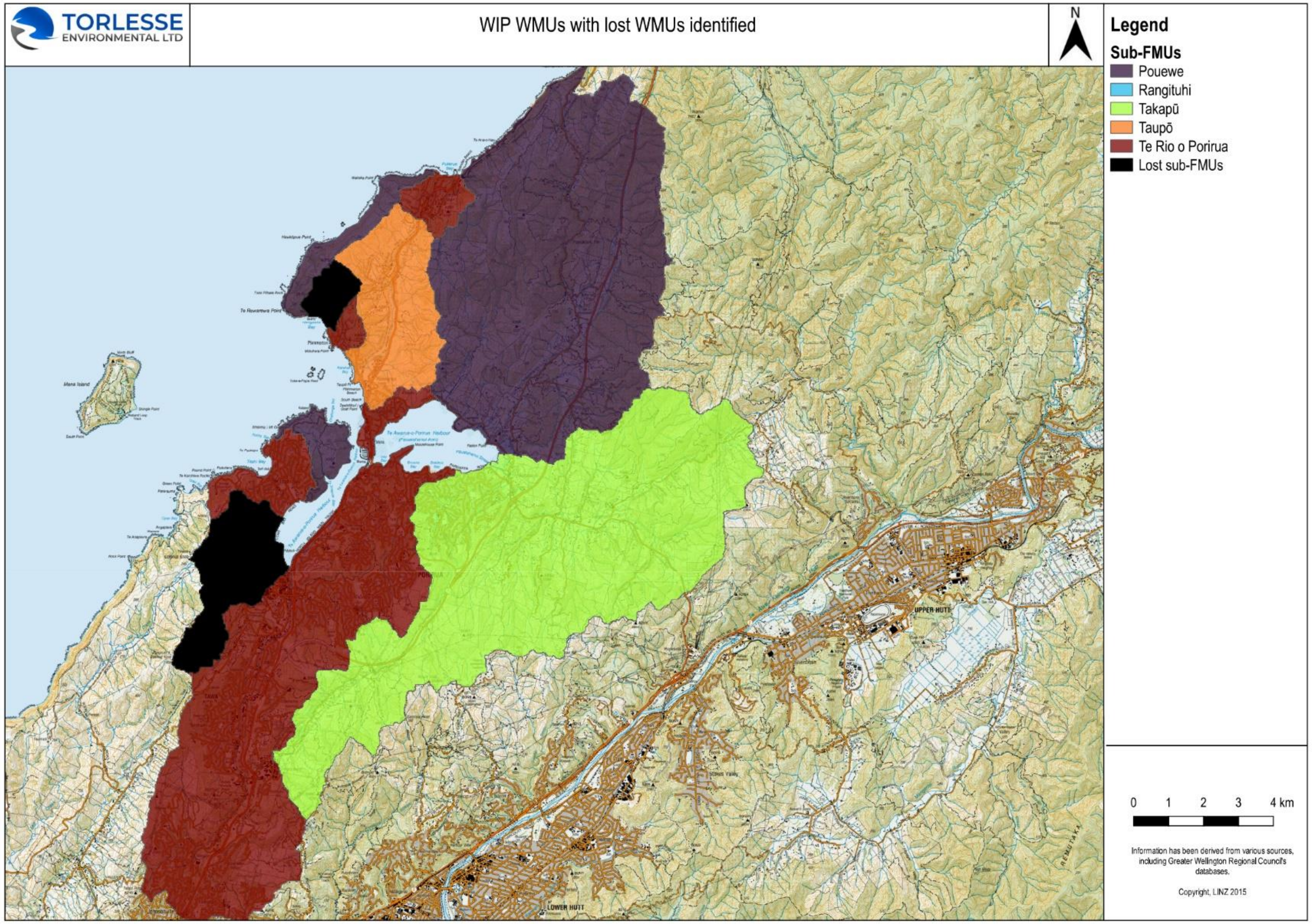
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ENVIRONMENTAL LTD
WIP WMUs with lost WMUs identified
N
Legend
Sub-FMUs
Pouewe
Rangituhi
Takapū
Taupō
Te Rio o Porirua
Lost sub-FMUs
UPPER HUTT
LOWER HUTT
0 1 2 3 4 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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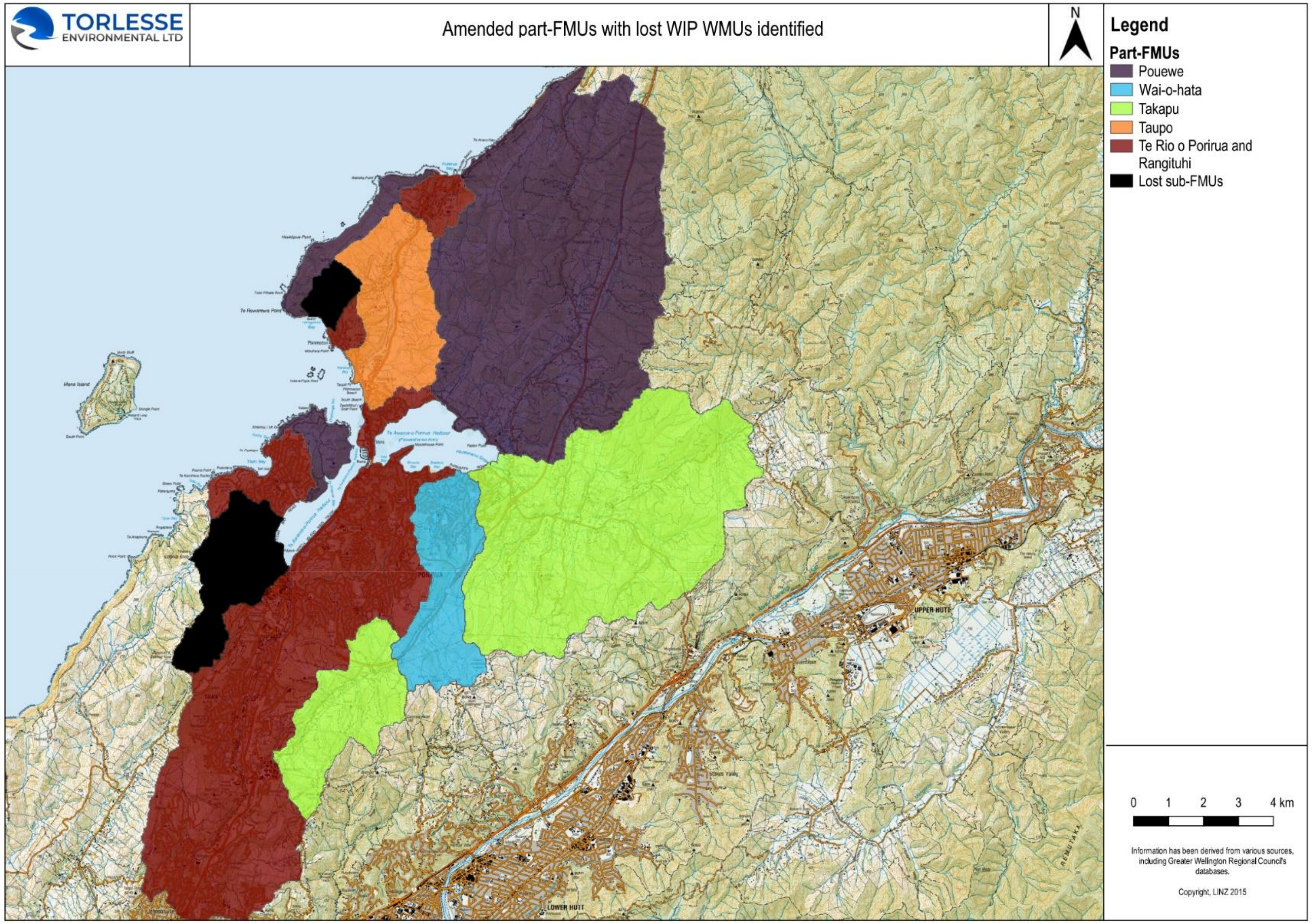
TORLESSE ENVIRONMENTAL LTD
Amended part-FMUs with lost WIP WMUs identified
N
Legend
Part-FMUs
Pouewe
Wai-o-hata
Takapu
Taupo
Te Rio o Porirua and Rangituhi
Lost sub-FMUs
UPPER HUTT
LOWER HUTT
0 1 2 3 4 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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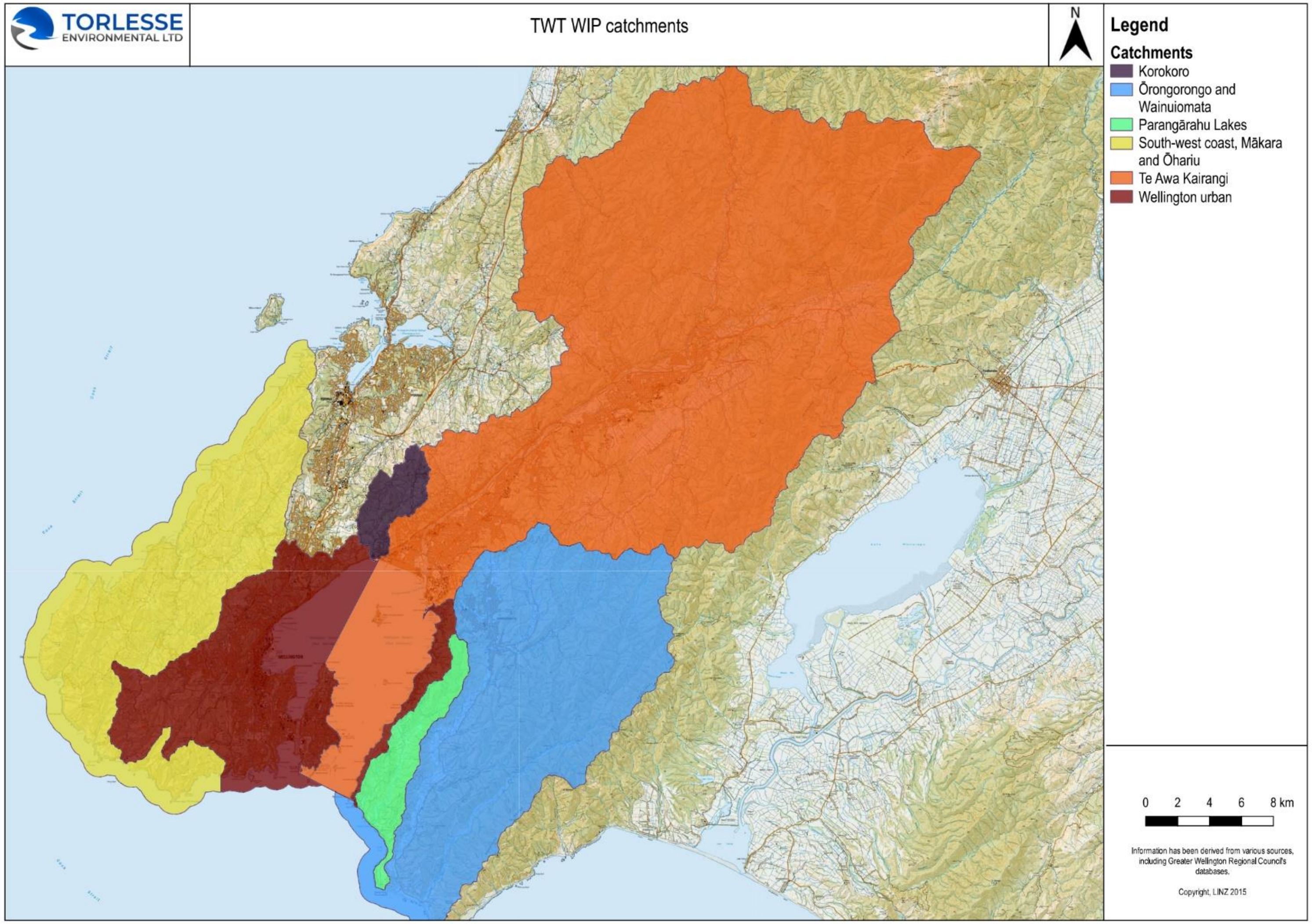
Appendix D – WTWT part-FMU refinement process maps (Section 3)


TORLESSE ENVIRONMENTAL LTD
TWT WIP catchments
N
Legend
Catchments
Korokoro
Ōrongorongo and Wainuiomata
Parangārahu Lakes
South-west coast, Mākara and Ōhariu
Te Awa Kairangi
Wellington urban
0 2 4 6 8 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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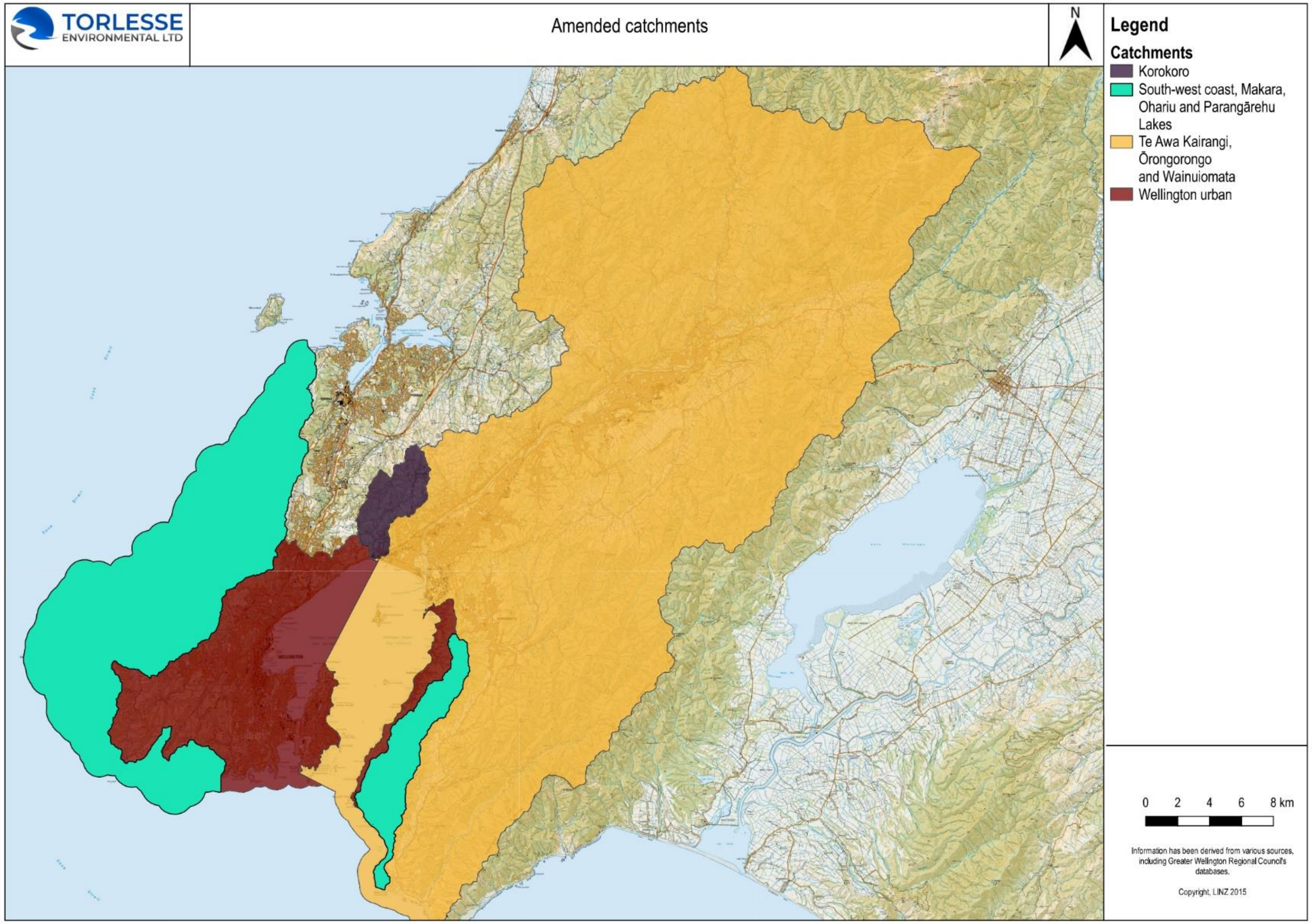
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N
Legend
Catchments
Korokoro
South-west coast, Makara, Ohariu and Parangārehu Lakes
Te Awa Kairangi, Ōrongorongo and Wainuiomata
Wellington urban
0 2 4 6 8 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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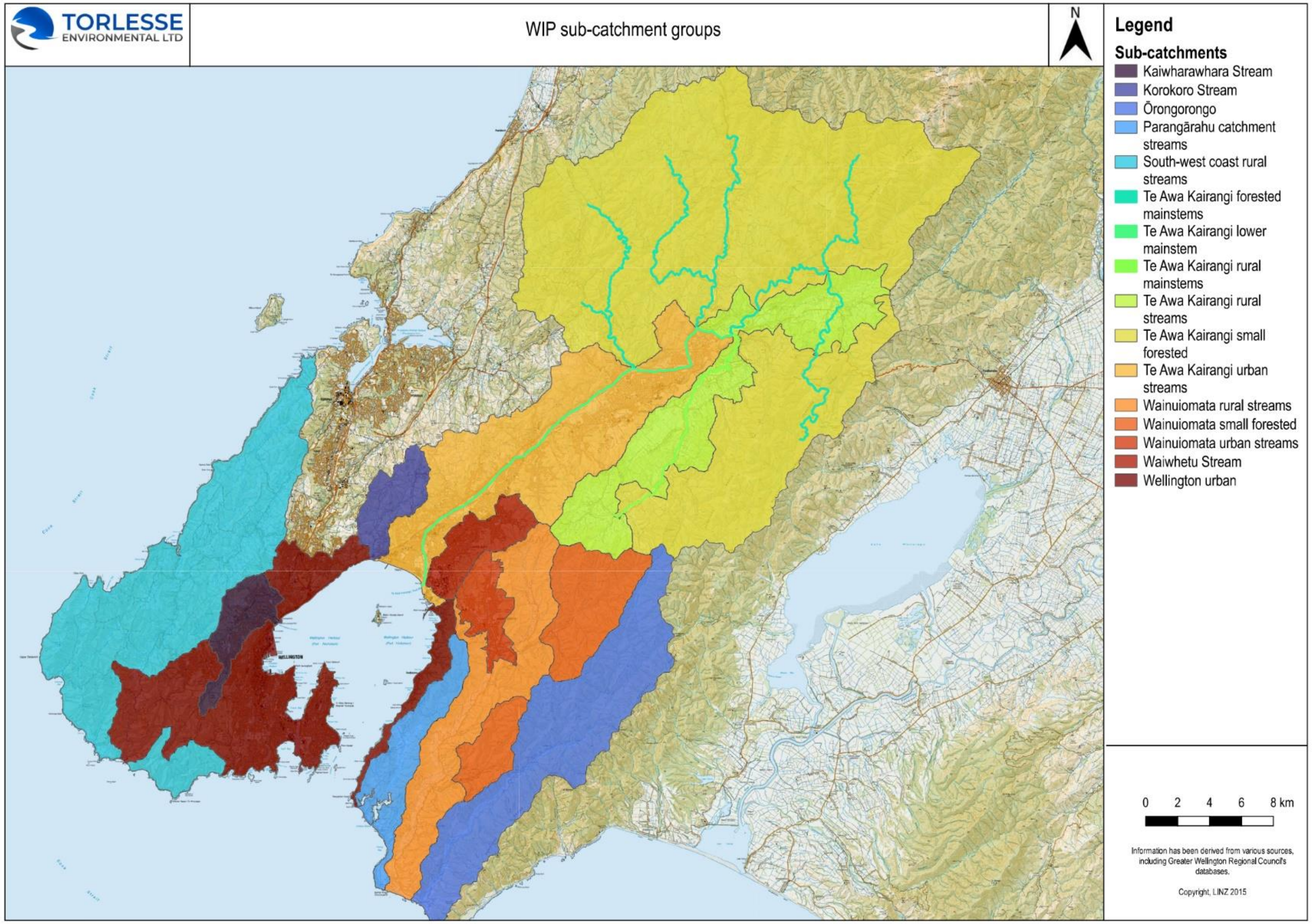
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WIP sub-catchment groups
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Legend
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Korokoro Stream
Ōrongorongo
Parangārahu catchment streams
South-west coast rural streams
Te Awa Kairangi forested mainstems
Te Awa Kairangi lower mainstem
Te Awa Kairangi rural mainstems
Te Awa Kairangi rural streams
Te Awa Kairangi small forested
Te Awa Kairangi urban streams
Wainuiomata rural streams
Wainuiomata small forested
Wainuiomata urban streams
Waiwhetu Stream
Wellington urban
0 2 4 6 8 km
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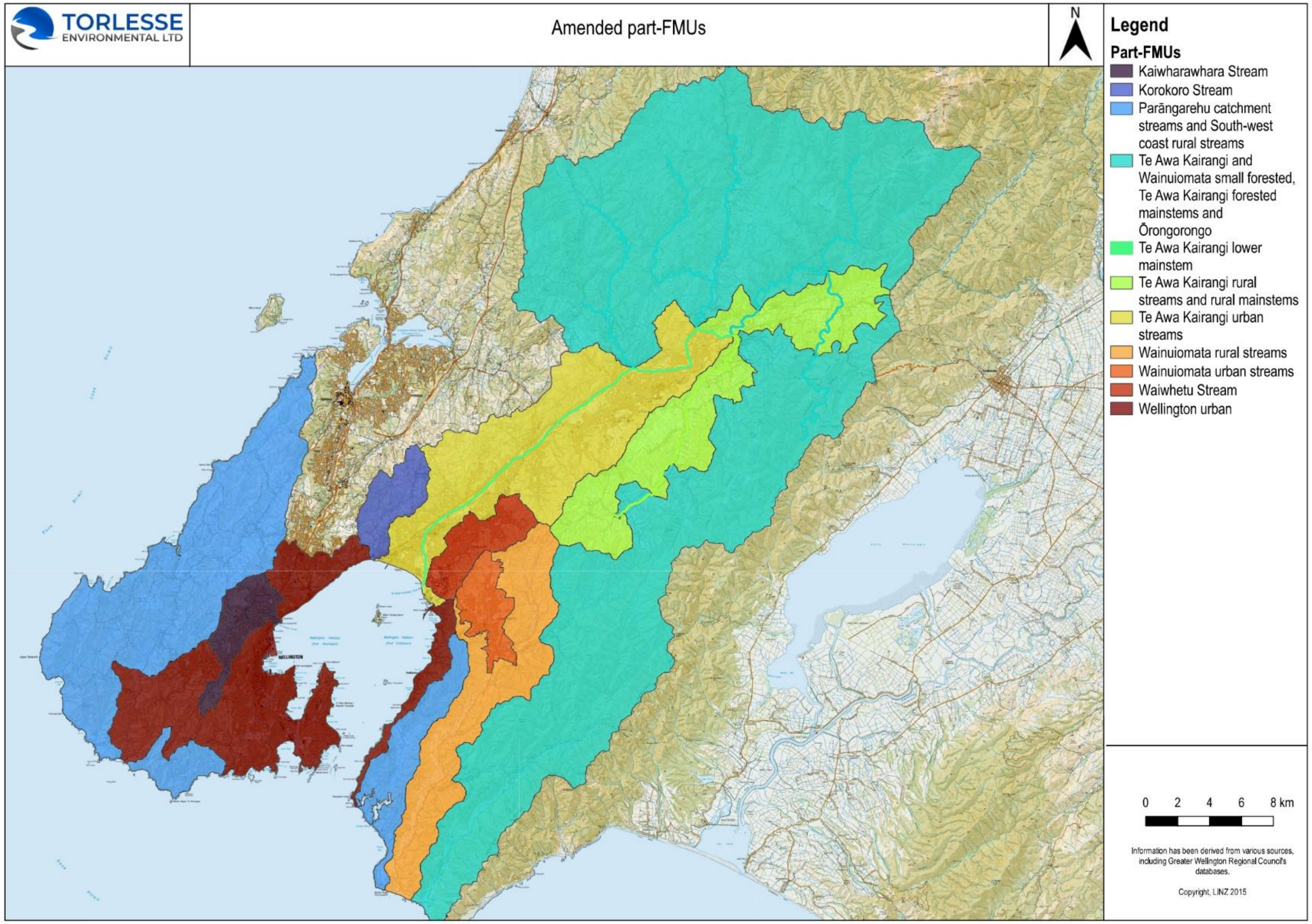
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Te Awa Kairangi lower mainstem
Te Awa Kairangi rural streams and rural mainstems
Te Awa Kairangi urban streams
Wainuiomata rural streams
Wainuiomata urban streams
Waiwhetu Stream
Wellington urban
0 2 4 6 8 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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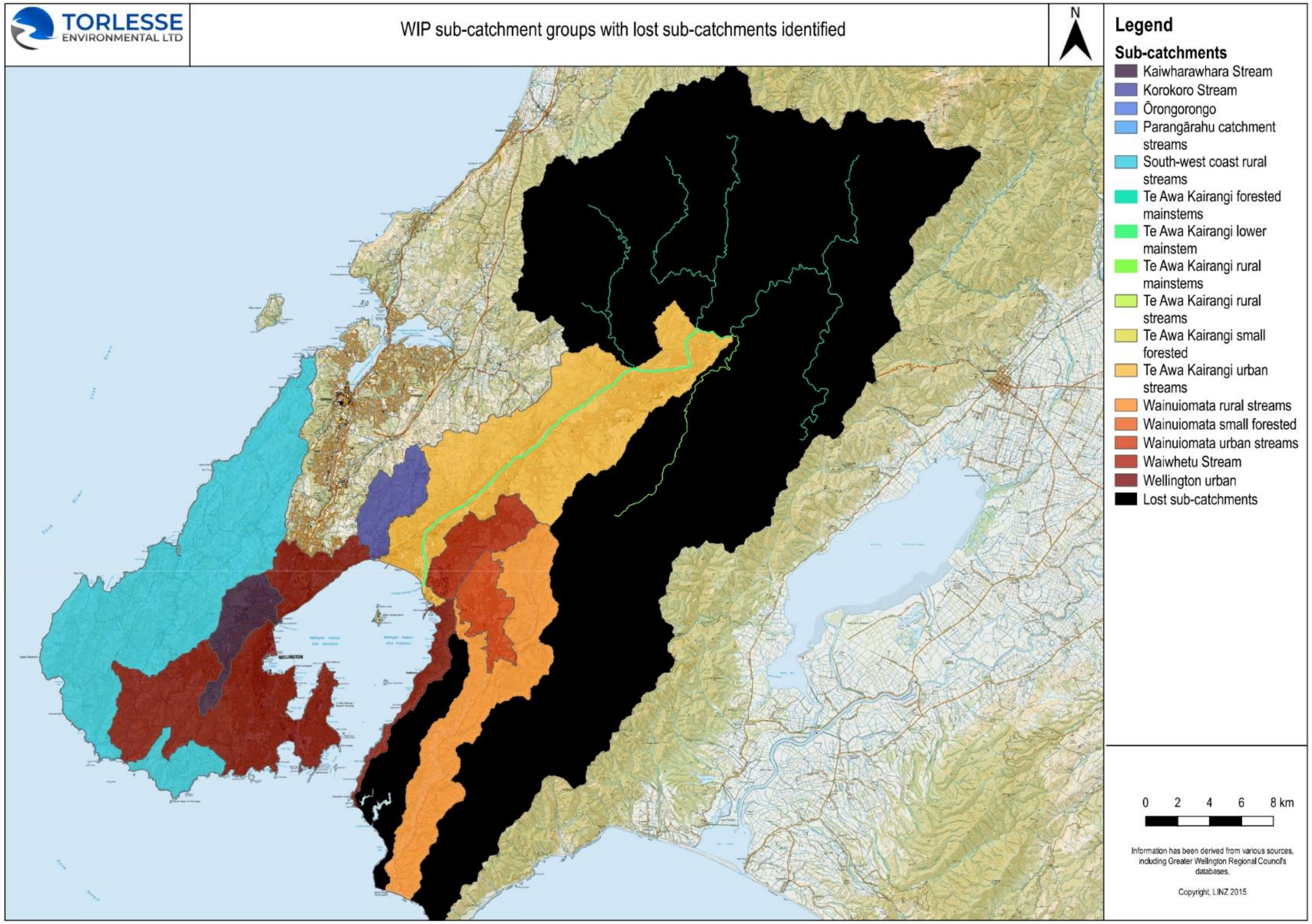
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WIP sub-catchment groups with lost sub-catchments identified
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Legend
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Ōrongorongo
Parangārahu catchment streams
South-west coast rural streams
Te Awa Kairangi forested mainstems
Te Awa Kairangi lower mainstem
Te Awa Kairangi rural mainstems
Te Awa Kairangi rural streams
Te Awa Kairangi small forested
Te Awa Kairangi urban streams
Wainuiomata rural streams
Wainuiomata small forested
Wainuiomata urban streams
Waiwhetu Stream
Wellington urban
Lost sub-catchments
0 2 4 6 8 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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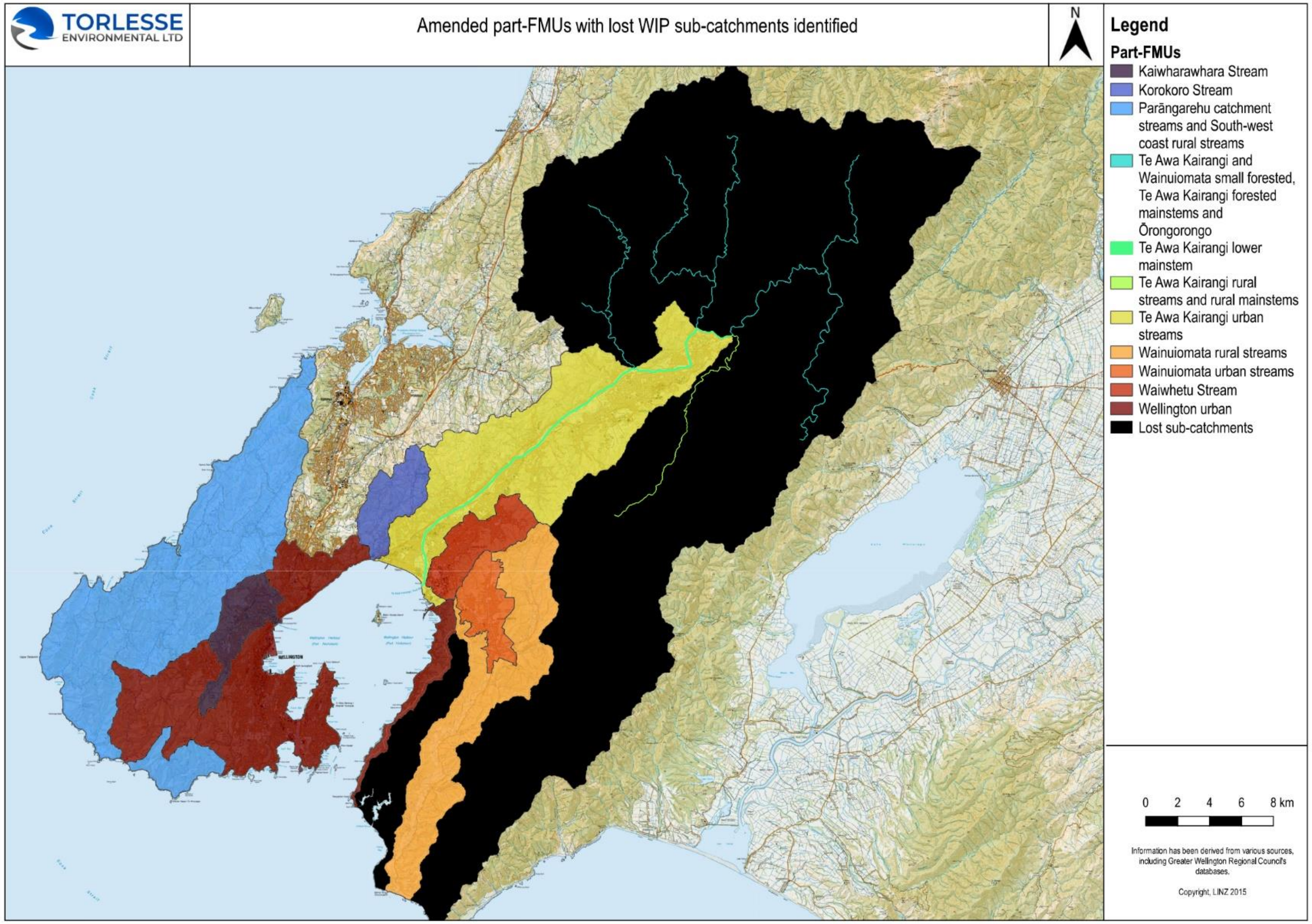
TORLESSE
ENVIRONMENTAL LTD
Amended part-FMUs with lost WIP sub-catchments identified
N
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Part-FMUs
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Korokoro Stream
Parāngarehu catchment streams and South-west coast rural streams
Te Awa Kairangi and Wainuiomata small forested, Te Awa Kairangi forested mainstems and Ōrongorongo
Te Awa Kairangi lower mainstem
Te Awa Kairangi rural streams and rural mainstems
Te Awa Kairangi urban streams
Wainuiomata rural streams
Wainuiomata urban streams
Waiwhetu Stream
Wellington urban
Lost sub-catchments
0 2 4 6 8 km
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Appendix E – Validation of nutrient criteria to achieve periphyton target attribute states in the Greater Wellington Region (Section 6)

Memorandum: Validation of nutrient criteria to achieve periphyton target attribute states in the Greater Wellington Region

Author: Ton Snelder LWP Ltd

Date: 14 November 2022

Introduction

The NPS-FM 2020 requires that regional councils set instream concentrations and exceedance criteria for nutrients to achieve target attribute states for periphyton biomass. The NPS-FM periphyton attribute is defined as the algal component of periphyton as chlorophyll *a*, mg m^{-2}. Exceedances of specified biomass thresholds are allowed in no more than one in 12 samples (based on monthly monitoring), which is the 92^{nd} percentile of the distribution of monthly periphyton biomass observations. The NPS-FM specifies that the 92^{nd} percentile is assessed from monthly observations made over at least three years. Thresholds of 50, 120 and 200 mg m^{-2} define the upper boundaries of the NPS-FM A, B and C bands, which indicate a scale of potential target attribute states from very high to minimum acceptable levels of environmental protection.

To assist councils, the Ministry for the Environment (MFE) commissioned the development of nutrient criteria to achieve a range of target attribute states based on modelling that was informed by a national dataset of 251 sites located across New Zealand (T Snelder *et al.*, 2022). Snelder *et al.* (2022) provide nutrient criteria in a series of look-up tables that apply to all hard-bottomed (i.e., cobble- or gravel-bed) streams and rivers, which are classified into one of 21 River Environment Classification (REC) Source-of-flow classes. Criteria were derived to apply to both shaded and unshaded sites.

An important feature of the criteria provided by Snelder *et al.* (2022) is the inclusion of under-protection risk. The under-protection risk concept arises due to the uncertainty associated with the statistical models underlying the nutrient criteria in the look-up tables. The models predict the periphyton biomass given the nutrient concentration, but they are uncertain at the level of individual sites. The models are more reliably used to predict the proportion of sites that exceed a given periphyton biomass. The criteria therefore require the user to choose both the target periphyton biomass (i.e., target attribute state) and the acceptable proportion of sites that can exceed this level of biomass. The proportion of sites that can exceed the target periphyton biomass is referred to as the under-protection risk because it is the probability that a randomly chosen site will exceed the target biomass despite having nutrient concentrations equal to, or lower than, the criterion for that site.

The derived criteria are intended to provide default values that can be used in the absence of other more appropriate criteria (e.g., potentially from locally derived observations and modelling). Guidance provided by MFE (2022) suggests that use of the look-up tables to define criteria, for example within a region, should be accompanied by a verification that considers whether the nutrient criteria are reasonably consistent with local observations of relationships between periphyton abundance and nutrient concentrations. There are limited ways to assess confidence in the criteria. However, where a monitoring network for periphyton and nutrients exists within a region, a validation analysis can be performed with the following seven steps:

Obtain the median concentration of each nutrient and 92nd percentile biomass from the observations at each monitoring site.

Obtain the REC source-of-flow class and shade status for each site.

For a fixed nutrient and level of under-protection risk, obtain the criteria for the A, B and C bands for each site based on the site's REC source-of-flow class and shade status.

For each nutrient and site, interpolate the biomass from the criteria by:

a) treating the biomass thresholds (upper limits) for A, B and C bands of 50, 120 and 200 mg m^{-2} as the variable Y and nutrient criteria from the look-up tables for each band as the variable X

b) interpolating the biomass from the above Y values for the value of X defined by the observed site nutrient concentration

c) treating the interpolated biomass as a prediction.

Calculate, over all sites, the proportion of observed values that exceed the above predicted values.

Repeat this process for each nutrient and level of under-protection risk.

Assess whether the nutrient criteria are consistent with the observations by comparing the proportion of sites for which observations exceed the predictions with the levels of under-protection risk.

MFE (2022) suggests that reasonable agreement between the observed proportion of sites and level of under-protection risk can be interpreted as evidence that the nutrient criteria are valid for the sites represented by the monitoring network. MFE (2022) notes that perfect agreement should not be expected and that divergence between the proportion of observations that exceed the predictions, and the under-protection risk can be expected to decrease as the sample size increases. This memo reports on a verification analysis that was performed using periphyton and nutrient data collected by Greater Wellington Region Council (GWRC).

Data

For 16 sites located across the region (Figure E1), GWRC provided monthly observations of concentrations of four forms of nutrient: total nitrogen (TN), nitrate-nitrogen (NO3N), total phosphorus (TP) and dissolved reactive phosphorus (DRP). In addition, there were monthly observations of periphyton biomass as chlorophyll-a (CHLA). The majority of the 16 sites (11) belonged to the CW/L REC Source-of-flow class (Figure E1). The number of observations of CHLA at these sites varied between 40 and 62.

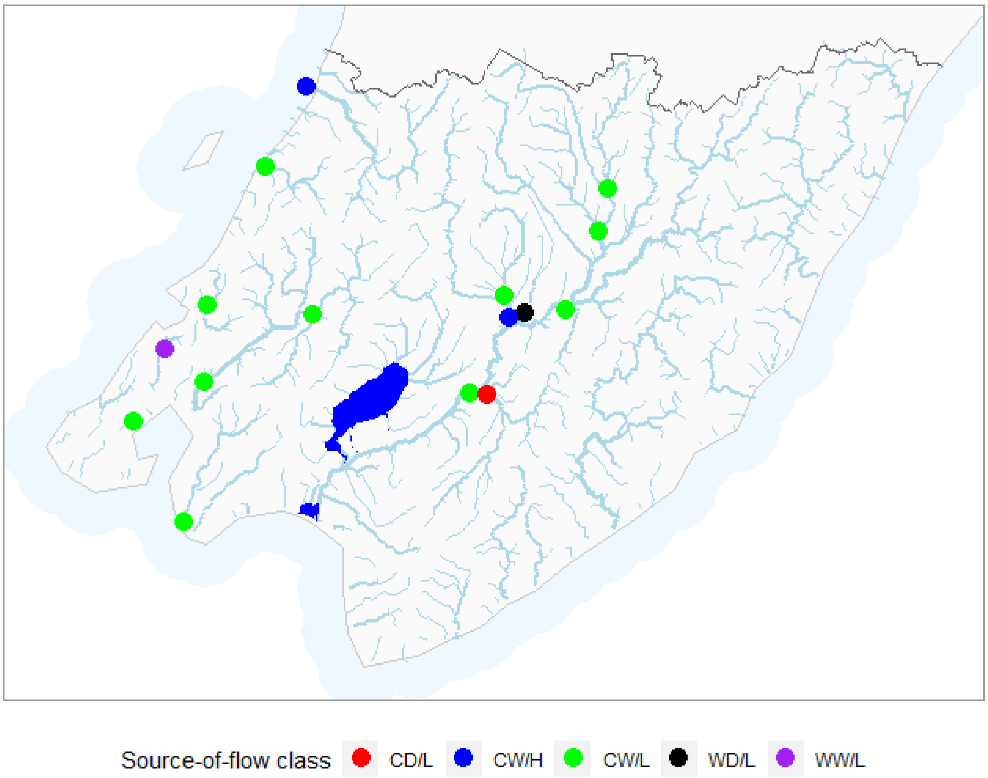

Figure E1. Location of the 16 periphyton monitoring sites in the Wellington region. Sites are colour coded by their Source-of-flow class.

The median values of TN, NO3N, TP and DRP and the mean and 92nd percentile of CHLA (CHLA92) were calculated for each site from the dataset. The standard error of estimate of the mean of CHLA was calculated and the precision of the estimated CHLA92 at each site was calculated based on the method of Wilson (1927) as recommended by Brown *et al.* (2001) and was expressed as the 95% confidence interval.

Validation analysis

The monthly CHLA observations at each site were mainly low values with occasional high values. CHLA92 exceeded 200 mg m^{-2} at three sites (Figure E2).

The distributions at each site approximately followed the theoretical exponential distribution (Figure E2). See Snelder *et al.* (2022) Section 5.1 for an explanation of the exponential distribution and how CHLA92 is estimated from the mean of the observed values based on the exponential distribution.

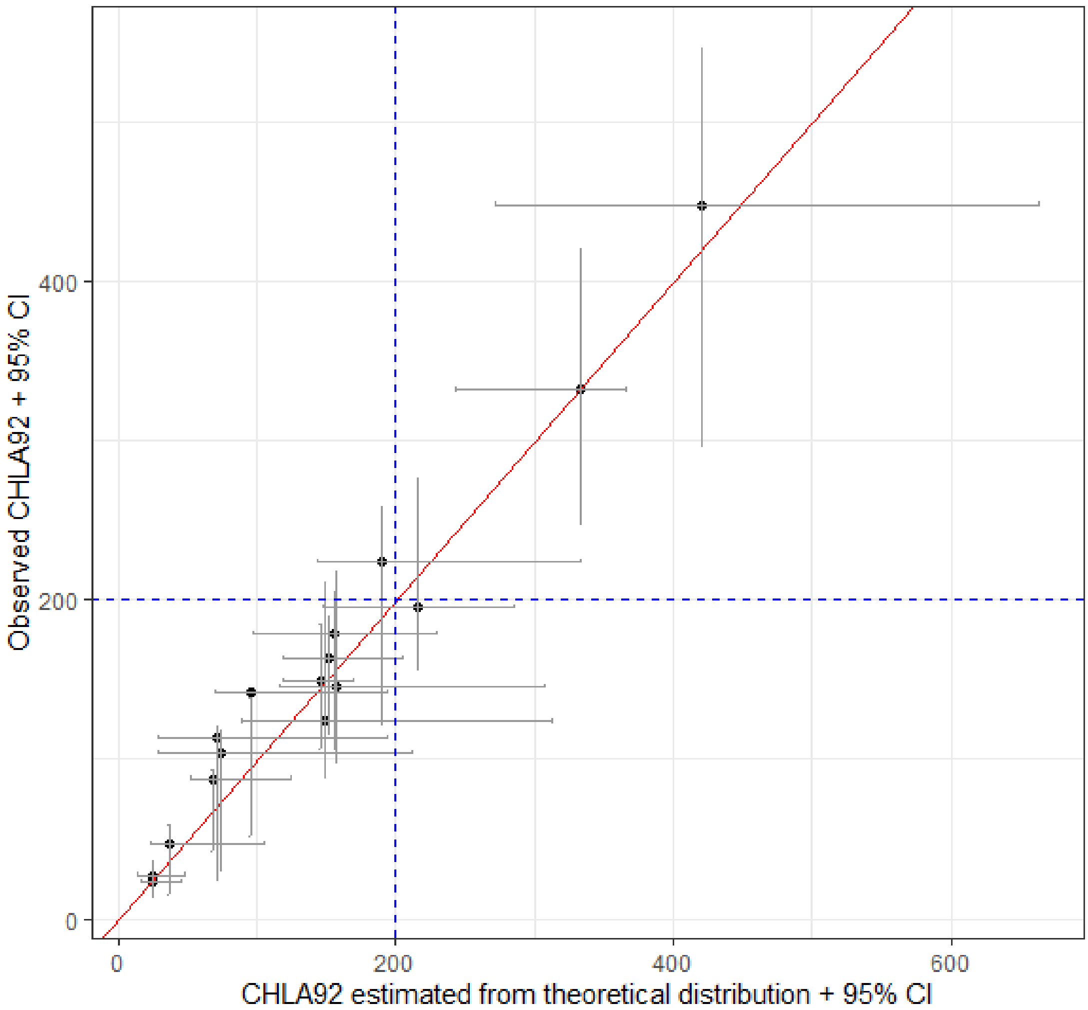

Figure E2. Relationship between observed CHLA92 for each site and the same value calculated from the mean of the observed values based on the theoretical (exponential) distribution. The error bars indicate the 95% confidence interval for both sets of estimates of CHLA92. The red dashed line is one to one. The blue dashed lines indicate CHLA92 values of 200 mg m^{-2}.

Predicted values of CHLA92 were derived for each site by interpolation of the nutrient criteria look-up tables (i.e., the observed median nutrient concentration at each site was used to evaluate CHLA92 from the look-up tables – see step 4 of validation procedure described above). The observed and predicted values of CHLA92 at the 16 sites in the Wellington region based on the four nutrient forms are shown as scatter plots in Figure E3. Theoretically, 5%, 10%, 15%, 20%, 30% and 50% of the sites should have observed biomass that exceeds the predicted biomass when the predictions are made based on the corresponding levels of under-protection risk (i.e., should lie above the red lines on Figure E3).

The data shown in Figure E3 indicate that the proportions of sites for which observed CHLA92 exceeds predicted CHLA92 increases systematically as the under-protection risk increases for all four nutrient forms. However, Table E1 indicates that the proportion of sites for which observed CHLA92 exceeds the predicted is higher than expected according to the level of under-protection risk for all four nutrient forms and for all levels of under protection risk. This indicates that the criteria are too permissive (i.e., the criteria concentrations are too high).

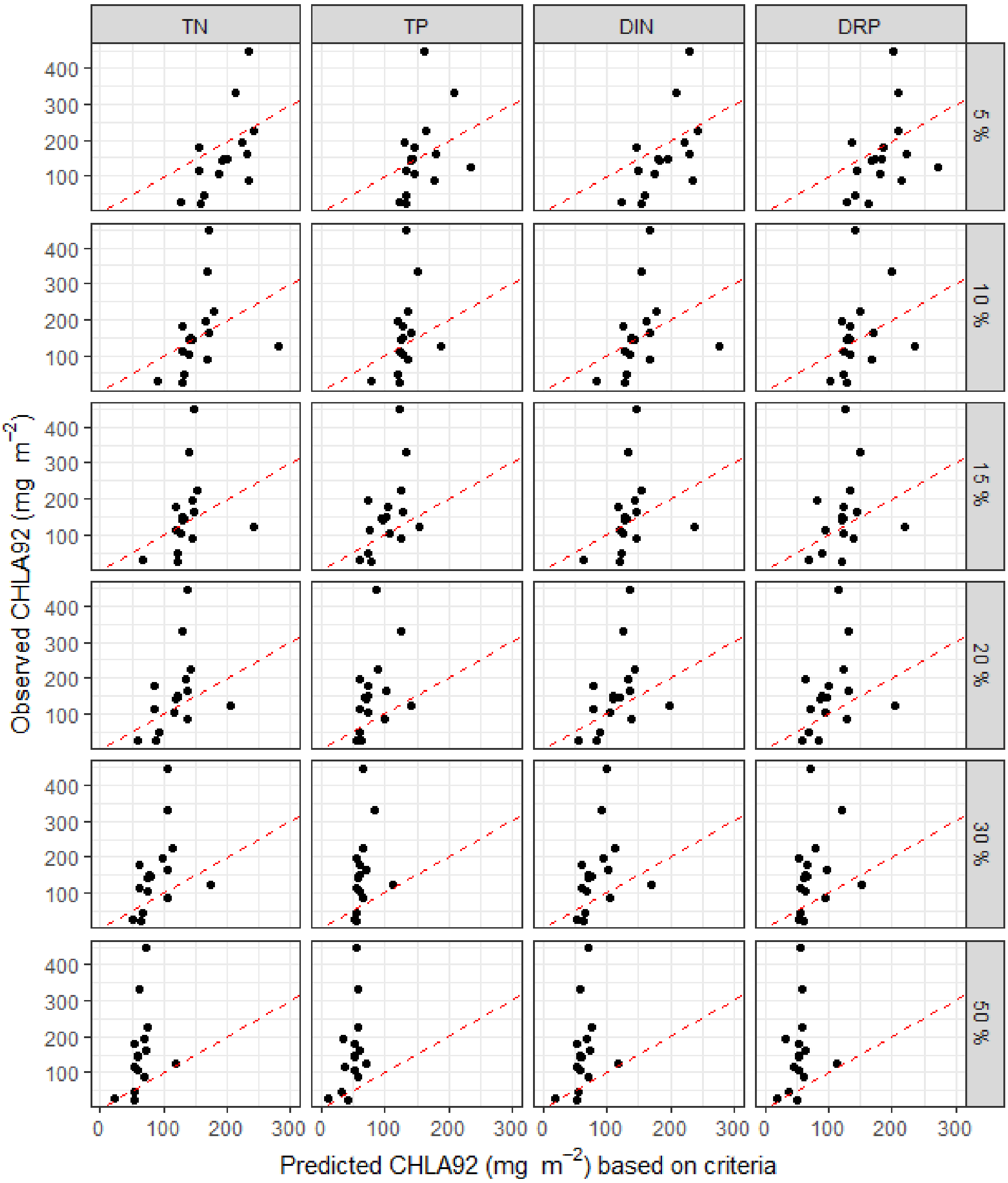

Figure E3. The observed and predicted values of CHLA92 at the 16 sites in the Wellington region where predicted values are derived from the nutrient criteria for under-protection risks of 5, 10,15, 20, 30 and 50%. Panel labels indicate the under-protection risks and the nutrient form (TN, DIN, TP and DRP). The dashed red diagonal (one to one) line represents agreement between the predictions and observations. The points lying below the red line indicate sites for which the observed biomass was less than that predicted by the targets and vice versa.

Table E1. Proportion of sites (%) for which observed biomass exceeds that predicted for the four levels of under-protection risk.

Under protection risk (%)	Nutrient form			
	TN	DIN	TP	DRP
5	19	19	50	25
10	50	50	56	50
15	56	56	62	62
20	62	69	69	69
30	69	69	81	69
50	88	88	94	94

Uncertainty of validation analysis

Because the observed values of CHLA92 are imprecise (i.e., are estimates of the population value calculated from the monthly samples), the above analysis is uncertain. A second analysis was undertaken to estimate the uncertainty of the first analysis. The second analysis repeated the first analysis but used a Monte Carlo simulation to generate 1000 “realisations” of the observed CHLA92 observations. For each site, a random error was added to the observed mean CHLA and then this “perturbed” mean was used to estimate CHLA92 based on theoretical empirical distribution (see Figure E2). The random error was derived by drawing from a normal distribution with a standard deviation equal to the standard error of the observed mean CHLA.

Figure E4 summarises the results of the Monte-Carlo procedure and shows the proportion of “exceeding” sites and the 95% confidence interval for each level of under-protection risk. In Figure E4, for all levels of under protection risk and all nutrient forms, the lower confidence limit is greater than the associated level of under-protection risk (indicated by horizontal lines). For example, for TN and the 15% under-protection risk, the 95% CI for the proportion of “exceeding” sites extends between 32% and 60% with a best estimate of 40%. This confirms the results of the first validation analysis and means that, globally, we are confident that the observations are inconsistent with the criteria (i.e., the criteria are too permissive, which means the criteria concentrations are too high).

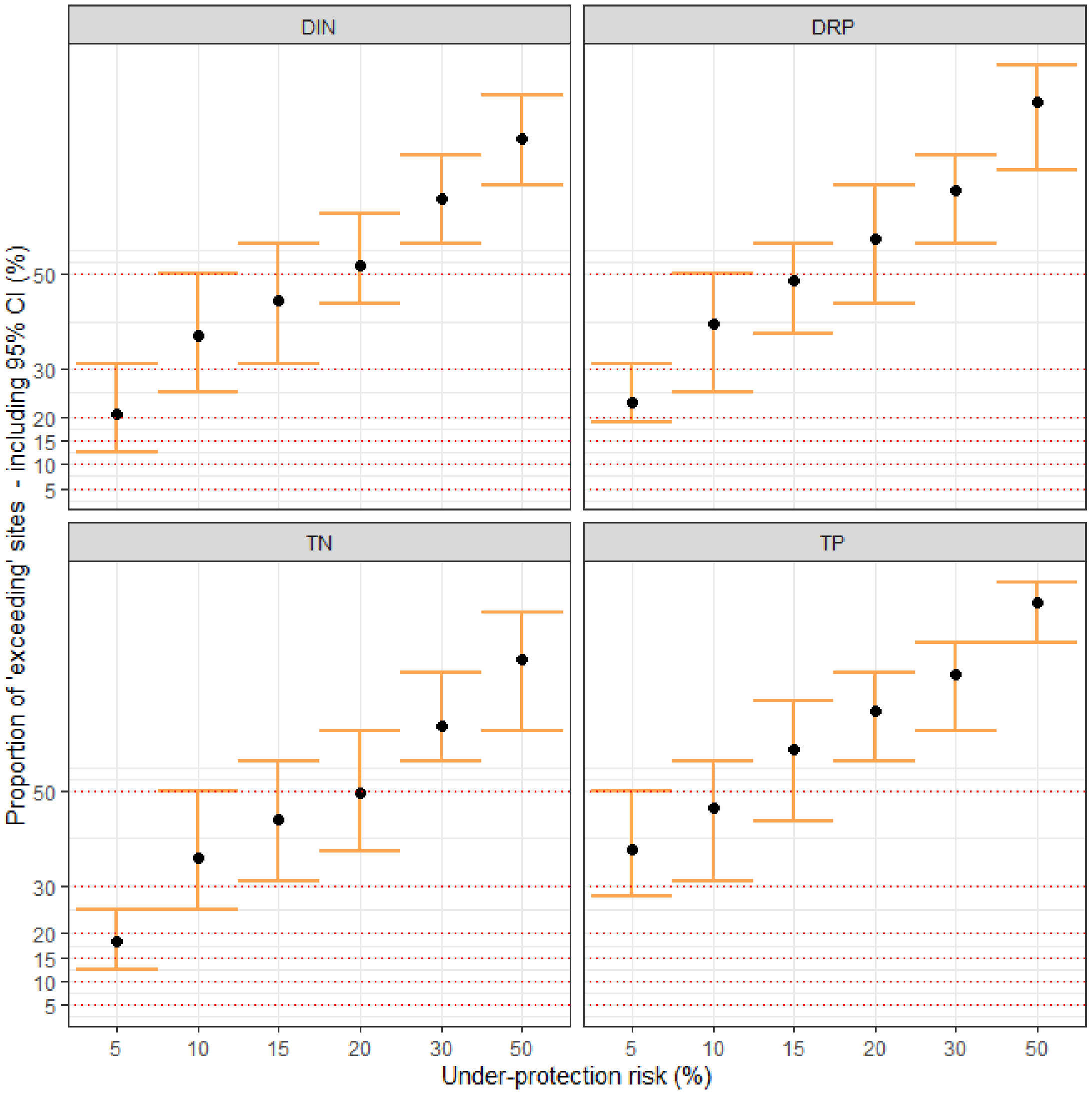

Figure E4. Proportion of "exceeding" sites (i.e., sites that are under-protected) for each level of under-protection risk (x-axis). The error bars indicate the 95% confidence interval of the observed "exceeding" sites, which was generated from a Monte Carlo analysis.

Comparison of site data with the models underlying the criteria

The observed CHLA92 was compared with predictions made using the models underlying the criteria, which are fully described by Snelder *et al.* (2022). There are four linear regression models each including one of the four nutrient forms as a predictor. Each model also includes several other predictors describing the hydrological regime, electrical conductivity, turbidity and shade at each site. The predictor values for all 16 GWRC sites are available from the dataset described by Snelder *et al.* (2022) and together with the observed nutrient concentrations were used to predict CHLA92 at each site.

Predictions of CHLA92 for the 16 GWRC sites generally under-estimated[18] the observed values (Figure E5). This is indicated by most points being above the red

[18] Note that under-estimation means the model is positively biased (Moriasi *et al.*, 2015).

dashed one-to-one lines in Figure E5. The average discrepancy between the observations and predictions was similar across all four nutrient forms and ranged from 38% to 47% (relative to the observed values).

Under-estimation by the model is consistent with the criteria being too permissive. This is most easily understood by considering a site at which the observed CHLA92 is just equal to a threshold (e.g., 200 mg m^{-2}, which defines the upper limit of the C band).

- The model will tend to under-estimate CHLA92 based on the observed nutrient concentration and will predict that the CHLA92 threshold has not been reached.
- The nutrient criterion derived from the model for a threshold of 200 mg m^{-2} will be higher than the observed nutrient concentration and therefore this will be too permissive because the (observed) CHLA92 threshold has been reached.

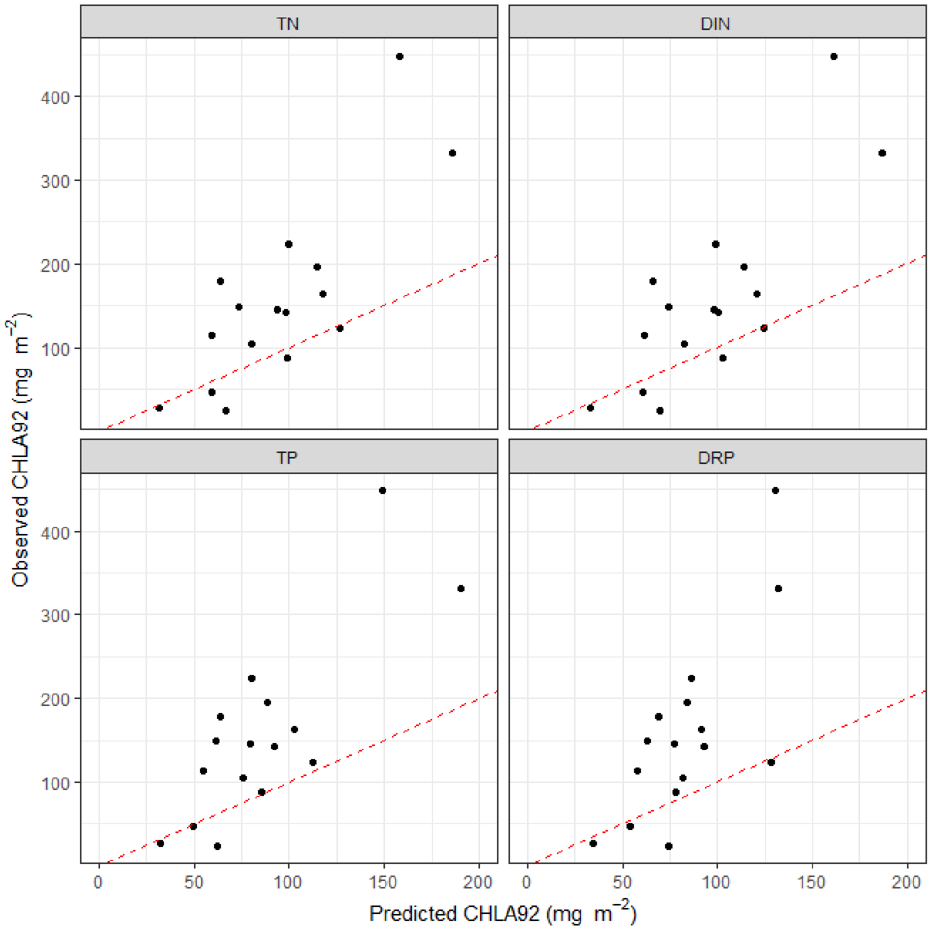

Figure E5. Predicted versus observed CHLA92 at each of the 16 sites. The dashed red diagonal (one to one) line represents agreement between the predictions and observations.

There are three potential contributing factors to the under-estimation of CHLA92 at most of the 16 GWRC site. First, the sampling sites in the Wellington region may be atypical compared to the 256 national sites that were used to fit the models underlying the criteria. Evidence that this may be the case is that the dataset used by Snelder *et al.* (2022) to derive the nutrient criteria had 20 sites (out of 251; i.e., 8%) with CHLA92 > 200 mg m^{-2}. However, of the 16 sites used in this validation study, three had CHLA92

> 200 mg m^{-2} (i.e., 19%) suggesting that high-biomass sites were over-represented. The risk the validation dataset is poorly representative increases as the sample size used to validate the criteria decreases. In addition, the small size of the sample (16 sites) could cause a validation result (i.e., that the criteria are too permissive) that is specific to this sample.

A second reason could be that the 16 sampled sites are representative of the region's rivers but the 256 sites that were used to derive the criteria were not. In other words, the biomass – nutrient relationship in rivers in the Wellington region differs appreciably from that represented by the 256 national sites. This risk increases as the sample size used to validate the criteria decreases, and the sample size of only 16 sites in this study is likely to be inadequate for inferring that that biomass – nutrient relationship in Wellington region's rivers differ from the modelled relationship.

Third, the models underlying the criteria were unable to explain "high" values of CHLA92 (Snelder *et al.* 2022) and this means that model predictions tended to under-estimate the observations). The models used by Snelder *et al.* (2022) to derive the nutrient criteria do not produce CHLA92 predictions appreciably greater than 200 mg m^{-2} at nutrient concentrations that are within the overall observed range. However, there were sites with CHLA92 > 200 mg m^{-2} in the data Snelder *et al.* (2022) used to derive the models. This indicates that sites with biomass greater than 200 mg m^{-2} were associated with factors that were not represented by the models[19]. The combination of the inability to predict CHLA92 > 200 mg m^{-2} and some observations in the dataset that exceeded this value led to the tendency for the model predictions to under-estimate the observations, which is referred to as positive bias (Moriasi *et al.*, 2015).

Snelder *et al.* (2022) corrected for retransformation bias[20] when deriving the criteria. However, there was no attempt to compensate for the positive bias of the underlying models. Therefore, as a further step in this validation exercise, the criteria were re-derived with an explicit correction for positive bias of the models and the validation for GWRC sites was repeated with the bias-corrected criteria[21]. The details and results are set out in the Appendix E1 to this memo. Although accounting for the bias did reduce the extent to which the validation indicates the criteria were too permissive, the

[19] Snelder *et al.*. (2022) concluded that there are unknown factors that cause high biomass at some sites. High biomass sites were not generally associated with high nutrient concentrations which suggests that some factor or combination of factors produces high biomass, and that nutrient control is a necessary but not sufficient requirement for achieving biomass targets at these sites. The work was unable to determine what these factors are.

[20] A non-linear transformation of the response variable (e.g., fourth root transformation of CHLA92 in the models defined by Snelder *et al.*. 2022) is required to satisfy the assumption of normality for linear regression models. However, it introduces a bias when predictions made using this model are retransformed to the original units (e.g., by raising to the power of four in the models defined by Snelder *et al.*. 2022). A factor must be applied to correct for retransformation bias; Snelder *et al.*. (2022) used the method of Duan (1983).

[21] It is not entirely clear that correcting for the bias in this global manner (i.e., by adding an amount equal to the mean difference between observations and predictions) and then using the corrected predictions to generate criteria is appropriate. In this study, this approach was applied, but it did not appreciably improve the validation.

improvement was modest, and the validation still indicated that the bias-corrected criteria are too permissive.

Conclusions

The validation of the criteria of Snelder *et al.* (2022) for the Wellington region, based on 16 monitoring sites, indicates that the criteria are too permissive (i.e., biomass thresholds will be exceeded at more sites than expected given the selected under-protection risk even when nutrient criteria are complied with).

Snelder *et al.* (2022) derived the criteria from the best available dataset and based on models that were consistent with the conceptual understanding of nutrient – periphyton biomass relationships. The models and associated criteria account for variation in factors such as hydrological regime, electrical conductivity, turbidity and shade that mediate nutrient – periphyton biomass relationships. There is no reason to expect that the models and criteria are not reasonably applicable to rivers in the Wellington region. It is noted that the correlation between the model predictions and observations shown in Figure E5 indicate that the models correctly represent the direction of the relationships between biomass and the various explanatory variables that are included in the models.

Conceptually the procedure outlined in the MFE guidance is an appropriate way to validate the criteria, however, the results are influenced by biases that can arise for three reasons. First, the 16 monitoring sites may be atypical compared to the 256 national sites that were used to derive the criteria. There is no statistical approach that can confirm that the validation result obtained by this study is influenced by this type of bias other than by increasing the number of validation sites. Second, the sampled sites may be representative of the region's rivers but the 256 sites that were used to derive the criteria were not. Again, there is no statistical approach that that can confirm that the validation result obtained by this study is influenced by this type of bias other than by increasing the number of validation sites.

The third potential cause of bias is that the criteria themselves are derived from biased models. In this study, repeating the validation procedure using criteria re-derived with an explicit correction of the model predictions for this bias made only a modest reduction in the extent to which the validation indicated the criteria were too permissive. At this point, the options for improving the approach to defining the criteria have been exhausted.

A reasonable conclusion is that the criteria are the best available and are appropriate to use, but that they are uncertain. In addition, the best available evidence is the criteria are too permissive. These two points need to be considered if the criteria are to be used to set instream nutrient concentration requirements. For example, ideally any regulation would include the ability to update the instream nutrient concentration requirements in the future should the criteria be revised.

An alternative conclusion is that different criteria should be used or derived, perhaps based on a region-specific analysis. The problem with this is that it is unlikely that more certain criteria can be derived given the small number of regional sites for which there is data.

References

Booker, D.J., 2010. Predicting wetted width in any river at any discharge. Earth Surf. Process. Landf. 35, 828–841. https://doi.org/10.1002/esp.1981
Booker, D.J., Snelder, T.H., Greenwood, M.J., Crow, S.K., 2015. Relationships between invertebrate communities and both hydrological regime and other environmental factors across New Zealand's rivers. Ecohydrology 8, 13–32. https://doi.org/10.1002/eco.1481
Brown, L.D., Cai, T.T., DasGupta, A., 2001. Interval estimation for a binomial proportion. Stat. Sci. 16, 101–133.
Canning, A.D., Joy, M.K., Death, R.G., 2021. Nutrient criteria to achieve New Zealand's riverine macroinvertebrate targets. PeerJ 9, e11556.
Clapcott, J.E., Goodwin, E., 2014. Technical report of Macroinvertebrate Community Index predictions for the Wellington Region (Cawthron Report No. 2503). Cawthron Institute, Nelson, New Zealand.
Clapcott, J.E., Goodwin, E., Snelder, T.H., 2013. Predictive models of benthic macroinvertebrate metrics (Cawthron Report No. 2301). Cawthron Institute, Nelson, New Zealand.
Clapcott, J.E., Wagenhoff, A., Neale, M.W., Storey, R.G., Smith, B.J., Death, R.G., Harding, J.S., Matthaei, C.D., Quinn, J., Collier, K.J., Atalah, J., Goodwin, E., Rabel, H., Mackman, J., Young, R.G., 2017. Macroinvertebrate metrics for the National Policy Statement for Freshwater Management (Cawthron Report No. 3073). Cawthron Institute, Nelson, New Zealand.
Clapcott, J.E., Young, R.G., Harding, J.S., Matthaei, C.D., Quinn, J.M., Death, R.G., 2011. Sediment assessment methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values. Cawthron Institute, Nelson, New Zealand.
Collier, K.J., 1995. Environmental factors affecting the taxonomic composition of aquatic macroinvertebrate communities in lowland waterways of Northland, New Zealand. N. Z. J. Mar. Freshw. Res. 29, 453–465.
Collier, K.J., Smith, B.J., 2000. Interactions of Adult Stoneflies (Plecoptera) with Riparian Zones I. Effects of Air Temperature and Humidity on Longevity. Aquat. Insects 22, 275–284. https://doi.org/10.1076/0165-0424(200010)22:4;1-Y;FT275
Duan, N., 1983. Smearing estimate: a nonparametric retransformation method. J. Am. Stat. Assoc. 78, 605–610.
Larned, S.T., Snelder, T.H., Unwin, M., 2017. Water Quality in New Zealand Rivers: Modelled water quality state (NIWA Client Report No. CHC2016- 070). NIWA, Christchurch, New Zealand.
Matheson, F., Quinn, J., Unwin, M., 2016. Review of the New Zealand instream plant and nutrient guidelines and development of an extended decision making framework: Phase 3 (Client Report No. HAM2015- 064). NIWA, Hamilton, New Zealand.
Matthaei, C.D., Piggott, J.J., Townsend, C.R., 2010. Multiple stressors in agricultural streams: interactions among sediment addition, nutrient enrichment and water abstraction. J. Appl. Ecol. 47, 639–649.
McDowell, R.W., Snelder, T.H., Cox, N., Booker, D.J., Wilcock, R.J., 2013. Establishment of reference or baseline conditions of chemical indicators in New Zealand streams and rivers relative to present conditions. Mar. Freshw. Res. 64, 387–400.
MFE, 2022. Guidance on look-up tables for setting nutrient targets for periphyton: second edition (No. ME 1644). Ministry for the Environment., Wellington, New Zealand.
Ministry for the Environment (MfE), 2022a. Setting instream nutrient concentration thresholds for nutrient-affected attributes in rivers: Guidance on implementing Clause 3.13 of the NPS-FM (No. MFE 1662). Ministry for the Environment, Wellington, New Zealand.

Ministry for the Environment (MfE), 2022b. Guidance on look-up tables for setting nutrient targets for periphyton: second edition. (No. MFE 1644). Ministry for the Environment, Wellington, New Zealand.
Moriasi, D.N., Gitau, M.W., Pai, N., Daggupati, P., 2015. Hydrologic and water quality models: Performance measures and evaluation criteria. Trans. ASABE 58, 1763–1785.
Niyogi, D.K., Koren, M., Arbuckle, C.J., Townsend, C.R., 2007. Longitudinal changes in biota along four New Zealand streams: Declines and improvements in stream health related to land use. N. Z. J. Mar. Freshw. Res. 41, 63–75. https://doi.org/10.1080/00288330709509896
Piggott, J.J., Lange, K., Townsend, C.R., Matthaei, C.D., 2012. Multiple stressors in agricultural streams: A mesocosm study of interactions among raised water temperature, sediment addition and nutrient enrichment. PLoS ONE 7, 1–14.
Quinn, J.M., Smith, B.J., Burrell, G.P., Parkyn, S.M., 2000. Leaf litter characteristics affect colonisation by stream invertebrates and growth of Olinga feredayi (*Trichoptera: Conoesucidae*). N. Z. J. Mar. Freshw. Res. 34, 273–287.
Quinn, J.M., Steele, G.L., Hickey, C.W., Vickers, M.L., 1994. Upper thermal tolerances of twelve New Zealand stream invertebrate species. N. Z. J. Mar. Freshw. Res. 28, 391–397.
Snelder, T, Kilroy, C., Booker, D., 2022. Derivation of Nutrient Criteria for Periphyton Biomass Objectives. Using regional council monitoring data (LWP Client Report No. 2021–13). LWP and NIWA Ltd, Christchurch, New Zealand.
Snelder, Ton, Kilroy, C., Booker, D.J., 2022. Derivation of nutrient criteria for periphyton biomass objectives: Using regional council monitoring data. LWP Limited, Christchurch, New Zealand.
Stark, J.D., Maxted, J.R., 2007. A user guide for the macroinvertebrate community index (Cawthron Report No. No.1166). Cawthron Institute, Nelson, New Zealand.
Unwin, M., Larned, S.T., 2013. Statistical models, indicators and trend analyses for reporting national-scale river water quality (NEMAR Phase 3) (Client Report No. CHC2013- 033). NIWA, Christchurch, New Zealand.
Wagenhoff, A., Townsend, C.R., Phillips, N., Matthaei, C.D., 2011. Subsidy-stress and multiple-stressor effects along gradients of deposited fine sediment and dissolved nutrients in a regional set of streams and rivers. Freshw. Biol. 56, 1916–1936.
Wilson, E., 1927. Calculating a confidence interval of a proportion. J Am Stat Assoc 22, 209–212.

Appendix E1: Explicit inclusion of bias in derivation of the criteria

The regression models used by Snelder *et al.* (2022) to derive the nutrient criteria were positively biased (i.e., under-estimated biomass). Although Snelder *et al.* (2022) corrected for retransformation bias when deriving the criteria, the remaining small positive bias was not corrected. Because the results of this study indicated that the criteria were too permissive and that this was associated with positive model bias, the criteria were re-derived with an explicit correction for positive bias.

The first step was to calculate the model bias as the mean of the difference between the observed minus the predicted values. This was performed after back-transforming the predictions to the original units by raising the model predictions to the power of four (because the observations were fourth-root transformed in the model). The bias for each model is shown in Table E2.

Table E2. Bias (in original units of CHLA92 mg m^{-2}) for the model used by Snelder et al. (2022) to derive the nutrient criteria. The bias for predictions made for the GWRC sites using the models of Snelder et al. (2022) are shown. Note that the predictions and observations for the GWRC sites are shown in Figure E5.

Nutrient	**Bias (Snelder *et al.* 2022)**	**Bias GWRC sites (this study)**
TN	13	61
DIN	14	59
TP	14	70
DRP	16	73

The second step was to rederive the criteria as described by Snelder *et al.* (2022) with one modification. Rather than adding the retransformation correction factor (CF) to the predictions (see Equation 3 Snelder *et al.* 2022), the bias values shown in Table E2 were added to the back-transformed model predictions. The derivation process was then as described by Snelder *et al.* (2022). A comparison of the criteria produced by both derivation procedures is shown in Figure E7. As expected, the bias corrected criteria are slightly more stringent (i.e., lower concentrations).

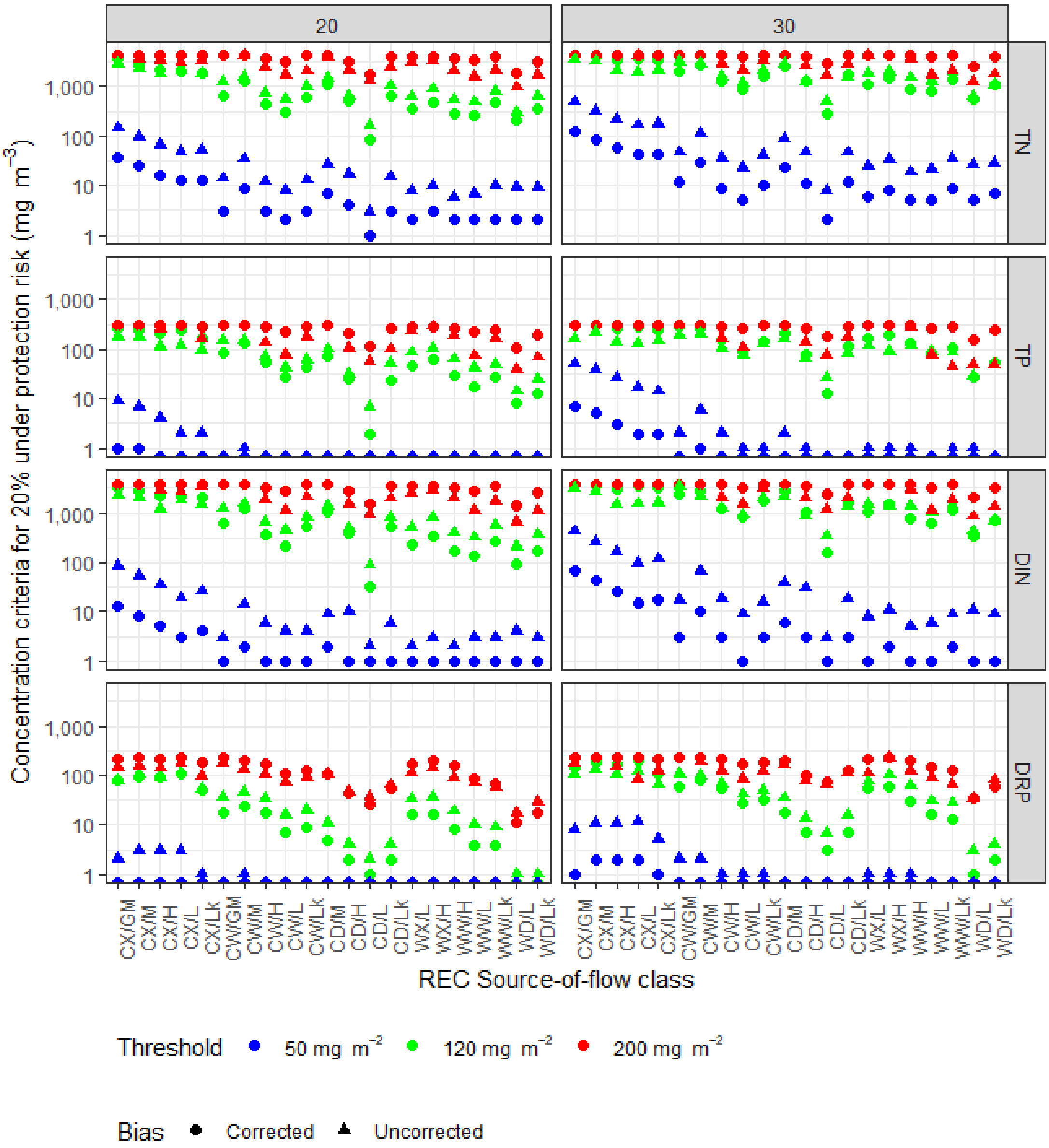

Figure E7. Nutrient criteria for REC Source-of-flow classes and 20% and 30% under protection risk.For each nutrient, the maximum possible value for a criterion is the maximum observed nutrient concentration (i.e., 4,500, 3,800, 300 and 230 mg m^{-3} for TN, DIN, TP and DRP, respectively). Note that the y-axes are log transformed and therefore accentuate the differences between corrected and uncorrected values for the lower thresholds compared to the higher thresholds.

The next step was to re-apply the validation procedures described above using the bias-corrected criteria. The results are shown in Table E3 and Figure E8 below.

The results based on the corrected criteria indicate they are too permissive. For example, Table E3 indicates that the proportion of sites for which observed CHLA92 exceeds the predicted is higher than expected according to the level of under-protection risk for all four nutrient forms and for all levels of under protection risk. However, comparison of the results based on the bias-corrected criteria with the original (uncorrected) criteria (shown in Table E1 and Figure E3) indicate a small reduction in the extent to which the bias-corrected criteria are too permissive. The reduction is relatively small, and the overall conclusion remains that the criteria are too permissive.

Table E3. Proportion of GWRC sites (%) for which observed biomass exceeds that predicted for the four levels of under-protection risk for validation based on the bias-corrected criteria. Results are comparable to Table E1.

Under protection risk (%)	**Nutrient form**			
	TN	**DIN**	**TP**	**DRP**
5	19	19	31	25
10	31	38	56	50
15	56	56	56	56
20	56	56	69	62
30	69	69	75	69
50	75	75	81	75

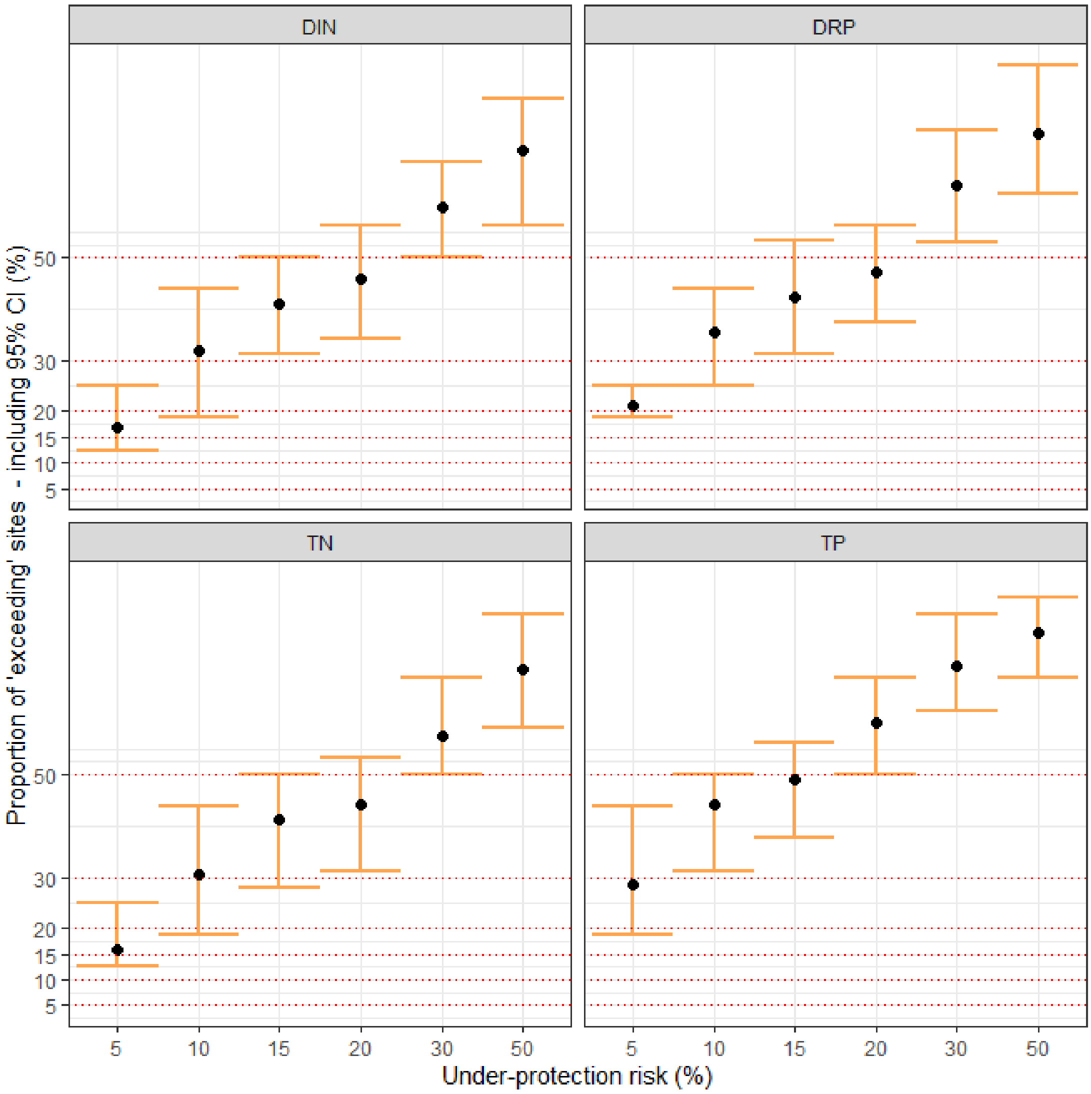

Figure E8. Proportion of "exceeding" sites (i.e., sites that are under-protected) for each level of under-protection risk (x-axis) for validation based on the bias-corrected criteria. The error bars indicate the 95% confidence interval of the observed "exceeding" sites, which was generated from a Monte Carlo analysis. These results are comparable to Figure E4.

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Appendix F – Update of nutrient criteria to achieve periphyton target attribute states in the Greater Wellington Region (Section 6)

Test of periphyton nutrient criteria based on GLM models and assuming gamma distribution for Wellington Region

Version 1, 22 March 2023

Ton Snelder, LWP Ltd

The study by Snelder *et al.* (2022) fitted OLS models to chlorophyll observations at a national dataset comprising 251 monitoring sites (summarized as the 92nd percentile of the observations and referred to hereafter as Chla92) using several predictors that include nutrient concentrations (typically summarized as median values of the observations of dissolved inorganic nitrogen (DIN), dissolved reactive phosphorus (DRP), total nitrogen (TN) and total phosphorus (TP)) and other environmental observations at the sites including substrate composition, shade and hydrological indices. These fitted models were subsequently used to defined criteria for DIN, DRP, TN and TP to achieve fixed Chla92 values (50, 120 and 200 mg m^{-2}).

A validation of the criteria for the Wellington Region based on 16 sites concluded that derived criteria were too permissive. Without getting into a lot of detail, the reason for this is that the model is unable to predict the highest site values of Chla92 (values >> 200 mg m^{-2}).

When the OLS models were fitted, the site values of Chla92 were forth root transformed to approximate normality. Despite the transformation to normality, the high Chla92 values were not well described by the normal distribution (Figure F1). In effect the tail of the actual distribution is fatter than represented by the normal distribution. In addition, the normal distribution does not reflect the zero lower-bound of the Chla92 values (Figure F1). These violations of statistical assumptions probably don't have an appreciable effect on estimates of the central tendency (conditional mean) but will have a relatively greater influence on predictions associated with the edges of the data distribution such as the predicted 70th, 80th and 90th percentile values. This is important to the criteria because these predicted percentile values are used to derive the criteria for 30%, 20% and 10% under protection risk (UPR); respectively. The OLS model will under-predict these values and this leads to defining criteria that are too permissive.

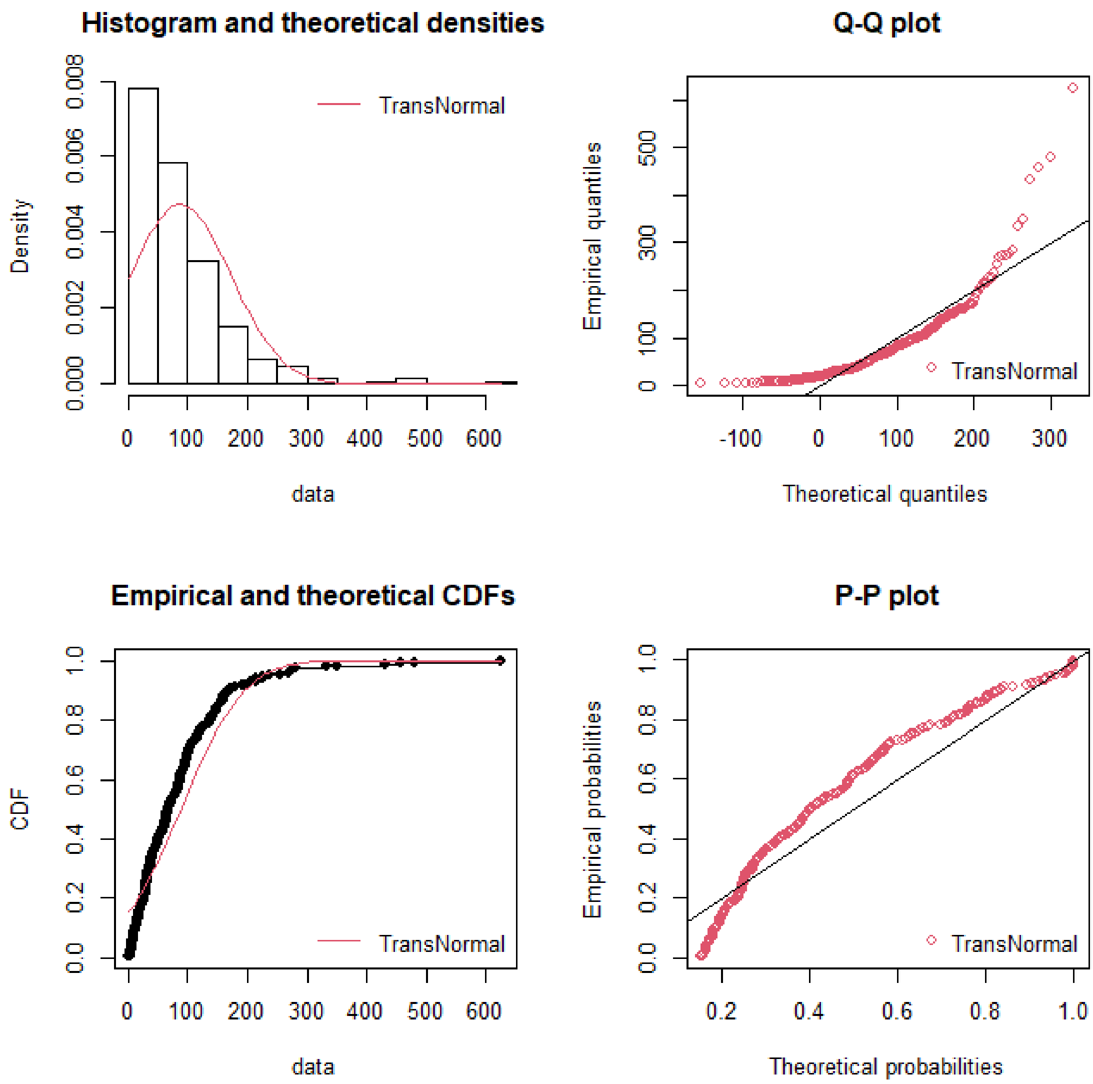

Figure F1. Normal distribution fitted to the fourth root transformed Chla92 values at 251 monitoring sites.

The gamma distribution more accurately represents the actual distribution of the Chla92 values (Figure F2). The gamma distribution is zero-bounded and allows for a fatter tail than the normal distribution. The better fit of the gamma distribution indicates that modelling Chla92 using the same methods as the Snelder *et al.* (2022), but based on a generalized linear model (GLM) may achieve better results.

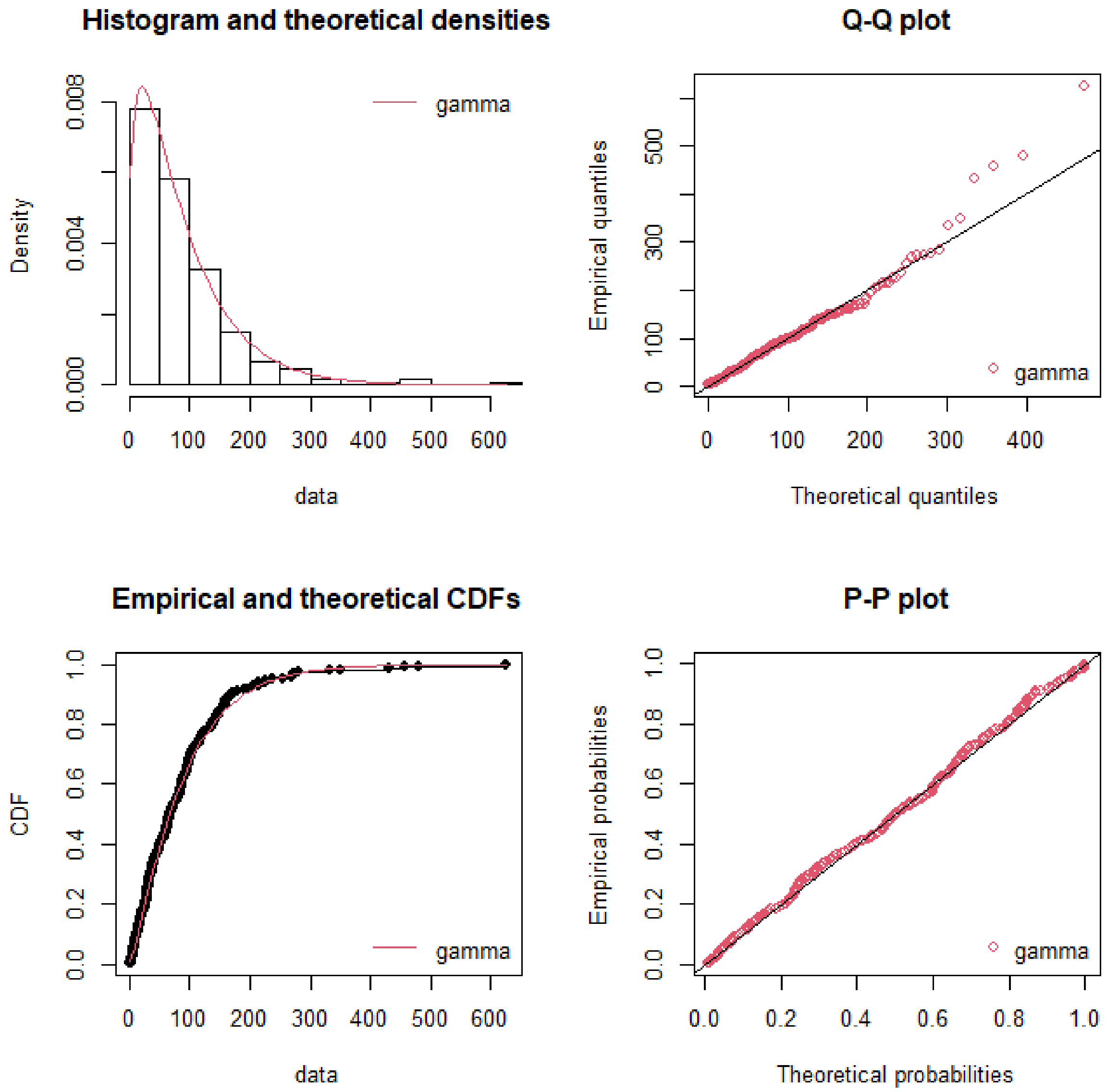

Figure F2. Gamma distribution fitted to the Chla92 values.

GLM models were fitted using the same procedures as Snelder *et al.* (2022). A very similar set of fitted models to Snelder *et al.* (2022) was obtained – see Table F1.

Table F1. Fitted coefficients for GLM regression models pertaining to each nutrient variable.

Nutrient	Intercept.	log10.Nutrient.	Temp95	FRE3	Shade	EC	Turb	Reversals	sdQ	FineSed	nNeg
TN	3.42	0.46	0.04	-0.03	-0.2	0	-0.06	-0.01	1.57	NA	NA
DIN	3.56	0.34	0.04	-0.03	-0.22	0	-0.06	-0.01	1.72	NA	NA
TP	10.07	0.54	0.05	-0.04	-0.16	NA	-0.05	-0.02	3.37	-0.01	-0.02
DRP	11.38	0.39	0.05	-0.03	-0.15	NA	NA	-0.02	3.27	-0.01	-0.03

The four GLM models were able to represent the values of Chal92 in excess of 300 mg m^{-2} (Figure F3), whereas the OLS models derived by Snelder *et al.* (2022) were not (see Figure 17 of Snelder *et al.* 2022). Note however that the mean (indicated in Figure F3 by the lower line of points is indicating a biomass ceiling at a Chla92 value less than 200 mg m^{-2}. This is consistent with the findings of a "biomass ceiling" and a "saturating concentration" by Snelder *et al.* (2022). At this stage, it does not appear that the GLM models would change those conclusions but further work on this is desirable.

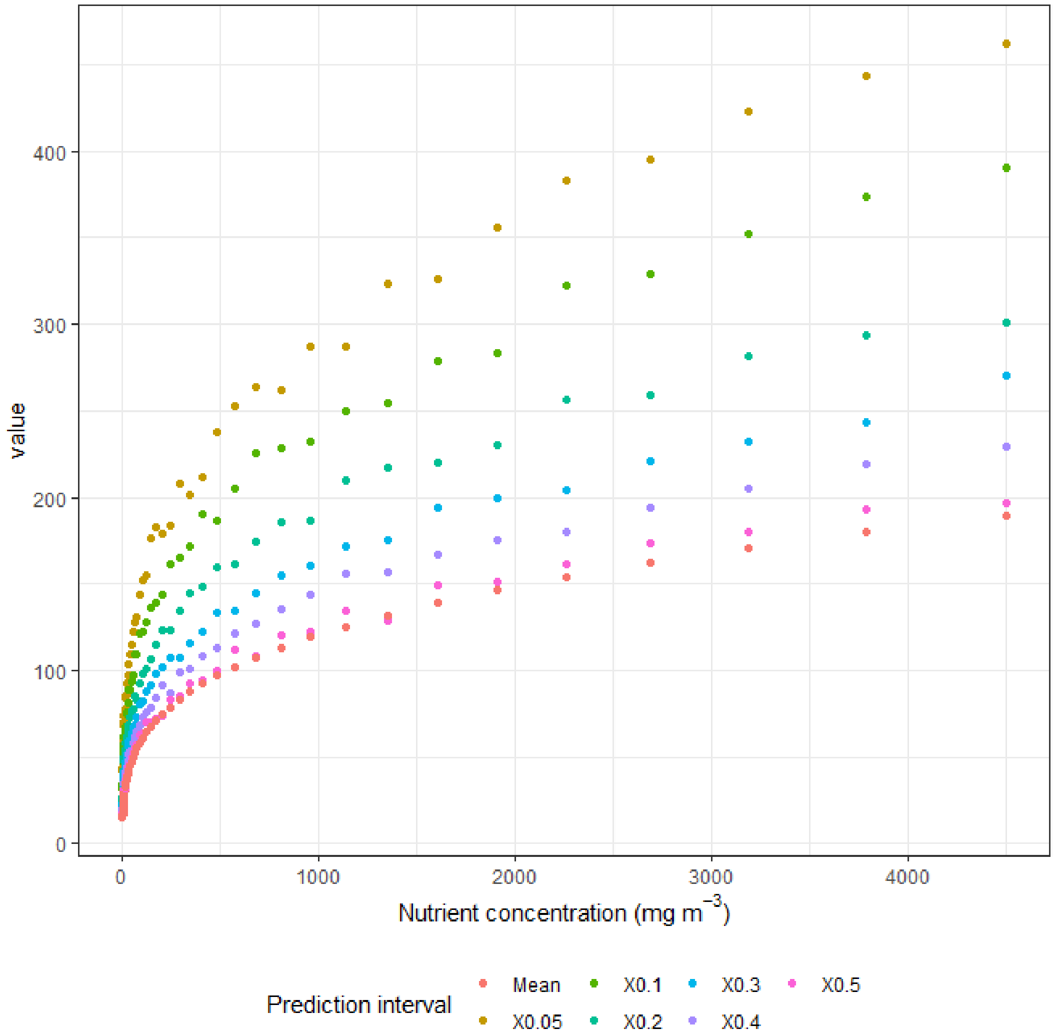

Figure F3. Predictions of Chla92 for the 95%, 90%, 20%, 30%, 40% and 50% prediction intervals over a range of TN concentrations made using the GLM based on gamma distribution. The curves represent the prediction intervals for varying TN concentration at a site that has mean values for all predictors fitted in the GLM model.

The four GLM models were used to derive nutrient criteria in approximately the same manner as Snelder *et al.* (2022). There are some additional details that are omitted here about the derivation of prediction intervals from the GLM models – which are not as for OLS models, but the principles are the same. Note that the criteria presented here are based on the method deployed by Snelder *et al.* (2022) with two modifications. First, the criteria were derived from a sub-sample of 500 randomly selected segments of stream order > 3 in each REC class. This was because the derivation of prediction intervals from the GLM models is numerically intensive and this approach made the processing time more tractable. Tests indicate that 500 random segments produces the same results as would the all segments in each REC class. Second, the criteria for each REC class were derived as the geometric mean (not the ordinary mean) of the individual nutrient concentrations derived for each segment (for more details see Section 4.71 of Snelder *et al.* 2022). The geometric mean was calculated as the exponentiated mean of the log of the individual nutrient concentrations. The exponentiated standard deviation of the log of the individual nutrient concentrations was also obtained as a measure of the within-class variability. The measure of the within-class variability was used in the validation procedure to account for within-class variation in the criteria. It is desirable to account for this variation in the validation because it is based on a small sample of specific sites but the method produces a mean criteria for an entire REC class. The "best" estimate of the criteria for a specific site is the criteria produced for the specific segment that the site is located on. Using the mean for that segment's class means there is some uncertainty in the criteria that are used; because the best criteria will be different to the mean. The measure of the within-class variability can be incorporated in a Monte Carlo analysis so that the validation accounts for this uncertainty.

The criteria derived using the GLM models were generally less permissive (i.e., lower concentrations) than those derived by (T Snelder *et al.*, 2022). This is consistent with the GLM models being better able to represent the high Chla92 values.

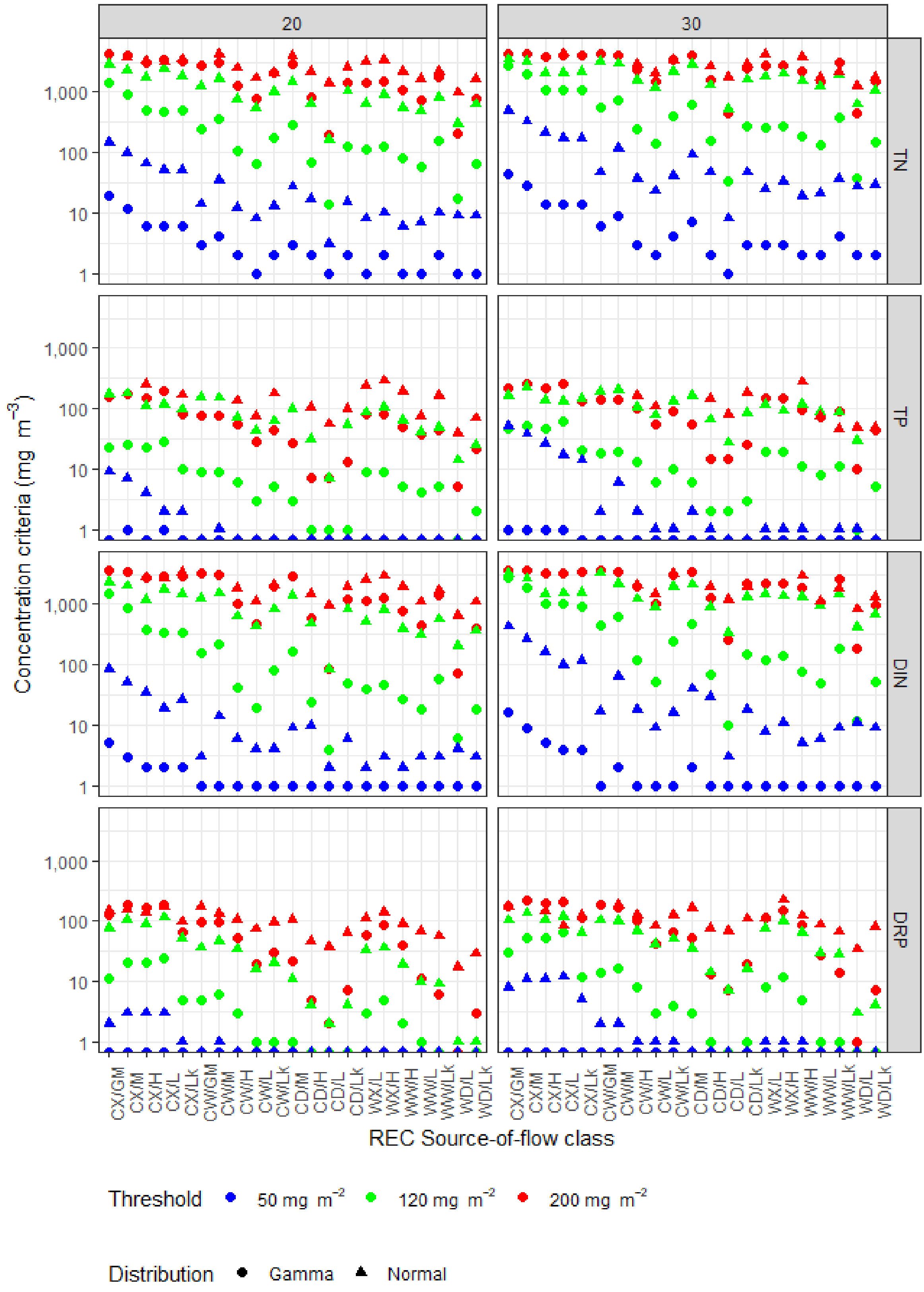

Figure F4. Comparison of nutrient criteria derived based on the normal distribution (OLS models) and gamma distribution (GLM models) for unshaded sites and the 20% and 30% UPR and for three Chla92 thresholds.

The criteria derived using the GLM (gamma distribution) were validated using dataset pertaining to 19 sites in the Wellington Region. The GLM results presented below can be compared with results based on the OLS models provided in a memo from Ton Snelder to GWRC dated 14 November 2022.

Predicted values of CHLA92 were derived for each site by interpolation of the GLM-based nutrient criteria look-up tables (i.e., the observed median nutrient concentration at each site was used to evaluate CHLA92 from the look-up tables – see step 4 of validation procedure described by a memo from GWRC dated 14 November 2022). The observed and predicted values of CHLA92 at the 19 sites in the region based on the four nutrient forms (TN, DIN, TP and DRP) are shown as scatter plots in Figure F5. Theoretically, 5%, 10%, 15%, 20%, 25%, 30% and 50% of the sites should have observed biomass that exceeds the predicted biomass when the predictions are made based on the corresponding levels of under-protection risk (i.e., should lie above the red lines on Figure F5).

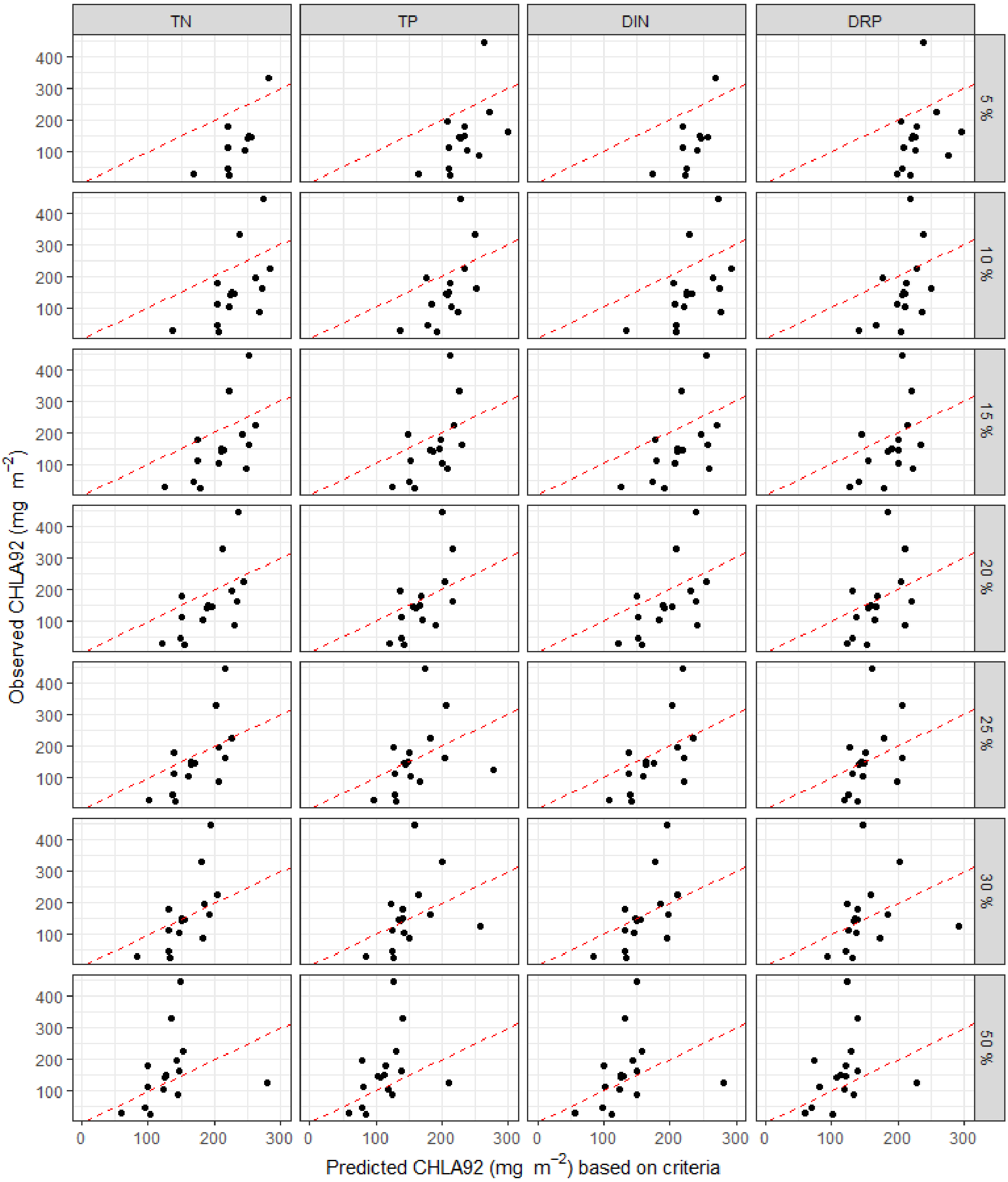

Figure 5. The observed and predicted values of CHLA92 at the 19 sites in the Wellington region where predicted values are derived from the nutrient criteria for under-protection risks of 5, 10,15, 20, 25%, 30% and 50%. Panel labels indicate the under-protection risks and the nutrient form (TN and TP). The dashed red diagonal (one to one) line represents agreement between the predictions and observations. The points lying below the red line indicate sites for which the observed biomass was less than that predicted by the targets and vice versa. Note that the GLM-based criteria include the 25% UPR.

The data shown in Figure F5 indicate that the proportions of sites for which observed CHLA92 exceeds predicted CHLA92 increases systematically as the under-protection risk increases for all four nutrient forms. Table F2 indicates that the proportion of sites for which observed CHLA92 exceeds the predicted is close to the expected for the 15%, 20%, 30% and 50% levels of under-protection risk for TN and TP and is slightly higher than expected for the 5% and 10% levels. The column headed "discrepancy" is the difference (for each nutrient) in the UPR and the observed proportion of sites exceeding the threshold. These validation results are considerably better than those for the OLS models (Table F3) reported in the memo from Ton Snelder to ORC dated 22 Feb 2023.

Table F2. Validation results for GLM-based criteria. Proportion of sites (%) for which observed biomass exceeds that predicted for the six levels of under-protection risk and two forms of nutrient (TN and TP). The discrepancy is the difference between the UPR and the observed proportion of sites exceeding the threshold (%). Note that the GLM-based criteria include the 25% UPR.

Under protection risk (%)	Proportion exceeding (%)				Discrepancy (%)			
	TN	TP	DIN	DRP	TN	TP	DIN	DRP
5	12	12	12	12	-7	-7	-7	-7
10	12	19	12	19	-2	-9	-2	-9
15	19	25	19	25	-4	-10	-4	-10
20	19	31	19	31	1	-11	1	-11
25	19	44	19	44	6	-19	6	-19
30	31	50	38	50	-1	-20	-8	-20
50	62	62	62	62	-12	-12	-12	-12

Table F3. Validation results for OLS-based criteria reported in memo from Ton Snelder to GWRC dated 14 November 2022. Proportion of sites (%) for which observed biomass exceeds that predicted for the six levels of under-protection risk and two forms of nutrient (TN and TP). The discrepancy is the difference between the UPR and the observed proportion of sites exceeding the threshold (%).

Under protection risk (%)	Proportion exceeding (%)				Discrepancy (%)			
	TN	TP	DIN	DRP	TN	TP	DIN	DRP
5	19	50	19	25	-14	-45	-14	-20
10	50	56	50	50	-40	-46	-40	-40
15	56	62	56	62	-41	-47	-41	-47
20	62	69	69	69	-42	-49	-49	-49
30	69	81	69	69	-39	-51	-39	-39
50	88	94	88	94	-38	-44	-38	-44

The above analysis is uncertain for two reasons. First, the observed values of CHLA92 are imprecise (i.e., are estimates of the population value calculated from the monthly samples). Second, there is within-class variability in the “best” estimate of the criteria for each site. This within-class variability is quantified by the measure of within-class variability in the criteria explained above. Therefore, a second analysis was undertaken to estimate the uncertainty of the first analysis. The second analysis repeated the first analysis but used a Monte Carlo simulation to generate 1000 “realisations” of the observed and predicted CHLA92 for each site. For each site, a random error was added to the observed mean CHLA and then this “perturbed” mean was used to produce a realisation of the observed CHLA92 based on theoretical empirical distribution (see Figure F2 of the memo from Ton Snelder to ORC dated 22 Feb 2023). The random error was derived by drawing from a normal distribution with a standard deviation equal to the standard error of the observed mean CHLA. In addition, for each site, a random error was added to the criteria and then this “perturbed” criteria was used to produce a realisation of the predicted CHLA92.

Figure F6 summarises the results of the Monte-Carlo procedure and shows the proportion of “exceeding” sites and the 95% confidence interval for each level of under-protection risk. In Figure F6, for most of the levels of under protection risk, the confidence bound includes the associated level of under-protection risk (indicated by horizontal lines). This indicates that the new criteria are consistent with the monitoring data within the inherent uncertainty in both the observations of CHLA92 and the uncertainty in the criteria themselves. At the least, this analysis allows us to understand why the validations have consistently indicated that the criteria derived by (T Snelder *et al.*, 2022) are too permissive.

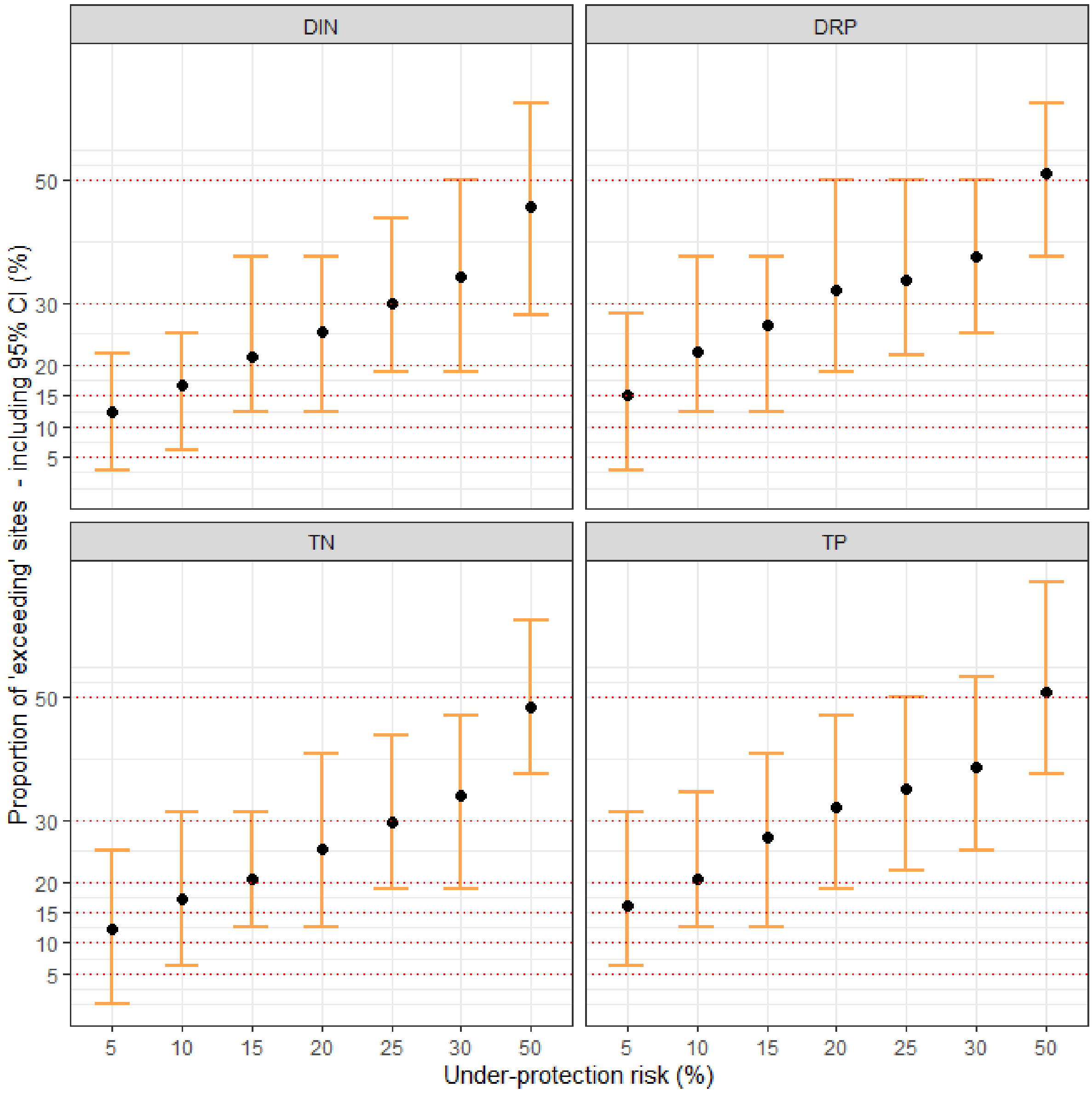

Figure F6. Proportion of "exceeding" sites (i.e., sites that are under-protected) for each level of under-protection risk (x-axis) and the two nutrients. The error bars indicate the 95% confidence interval of the observed "exceeding" sites, which was generated from a Monte Carlo analysis.

Appendix G – Site-specific TSS : Clarity plots (Section 9)

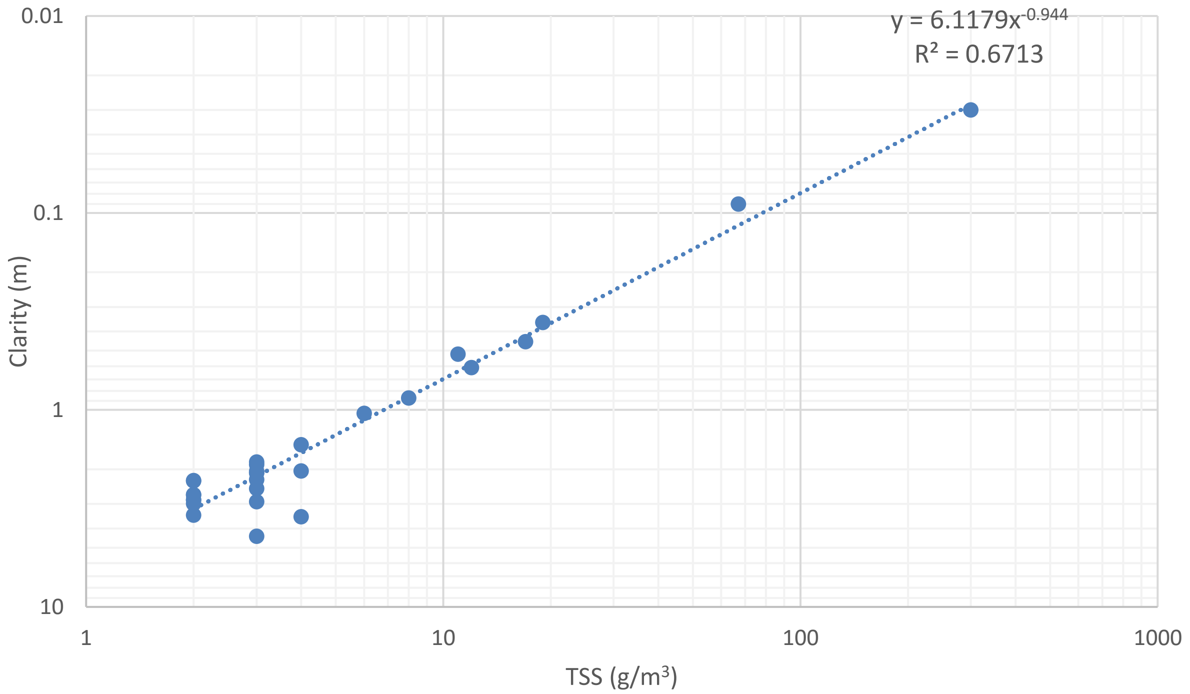

Figure G1 Horokiri at Snodgrass TSS - Clarity relationship

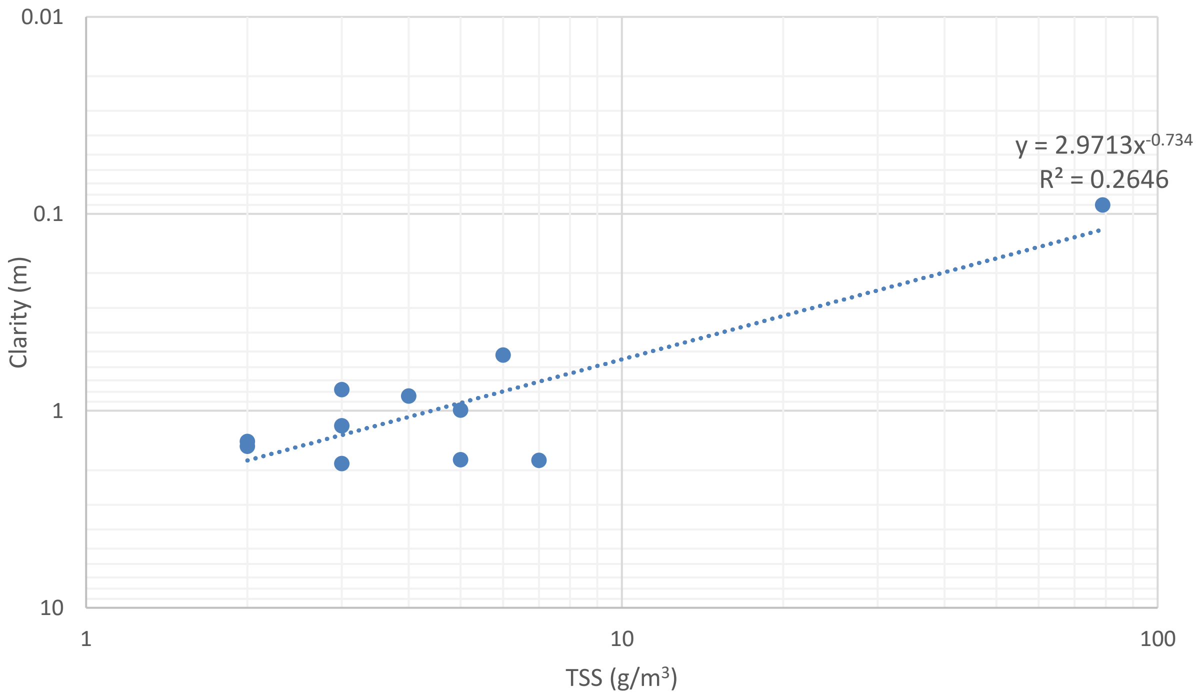

Figure G2 Taupo Stream at Plimmerton Domain TSS - Clarity relationship

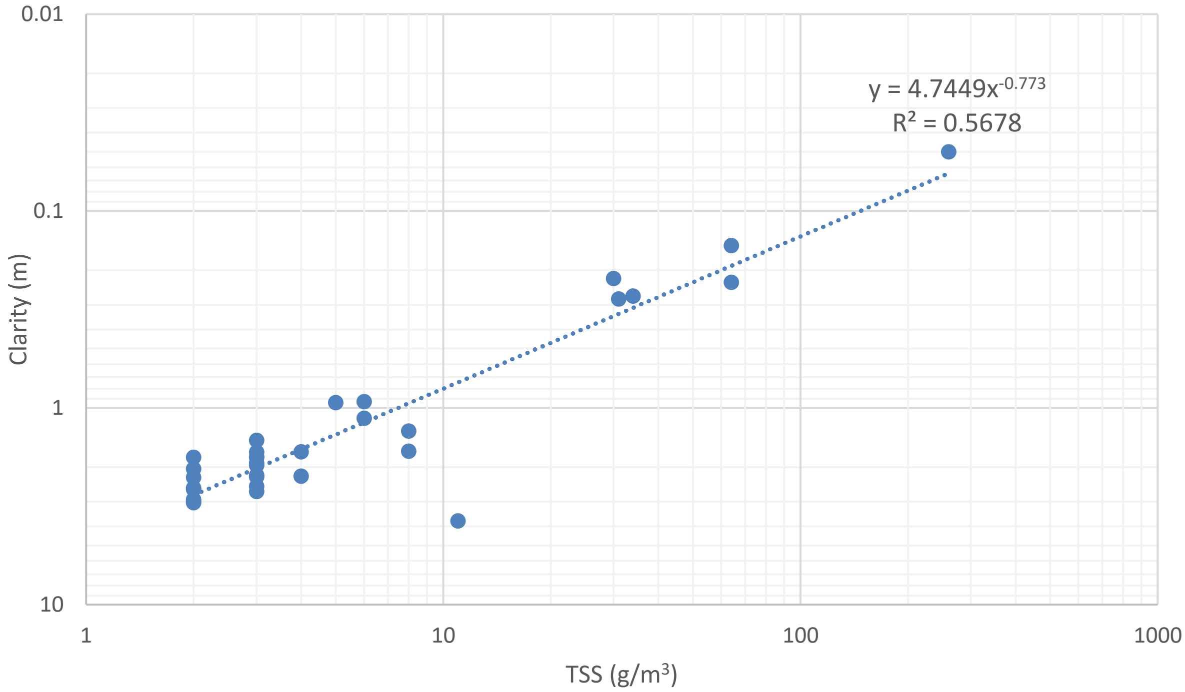

Figure G3 Pāuatahanui Stream at Elmwood Bridge TSS - Clarity relationship

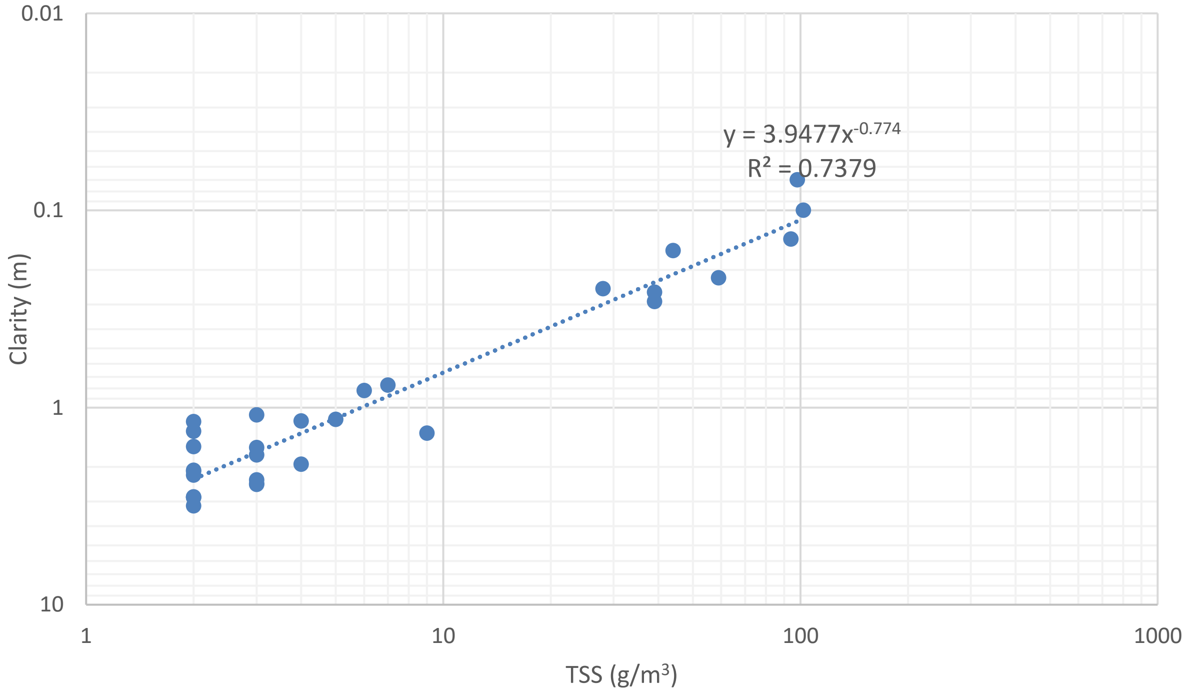

Figure G4 Porirua Stream at Milk Depot TSS - Clarity relationship

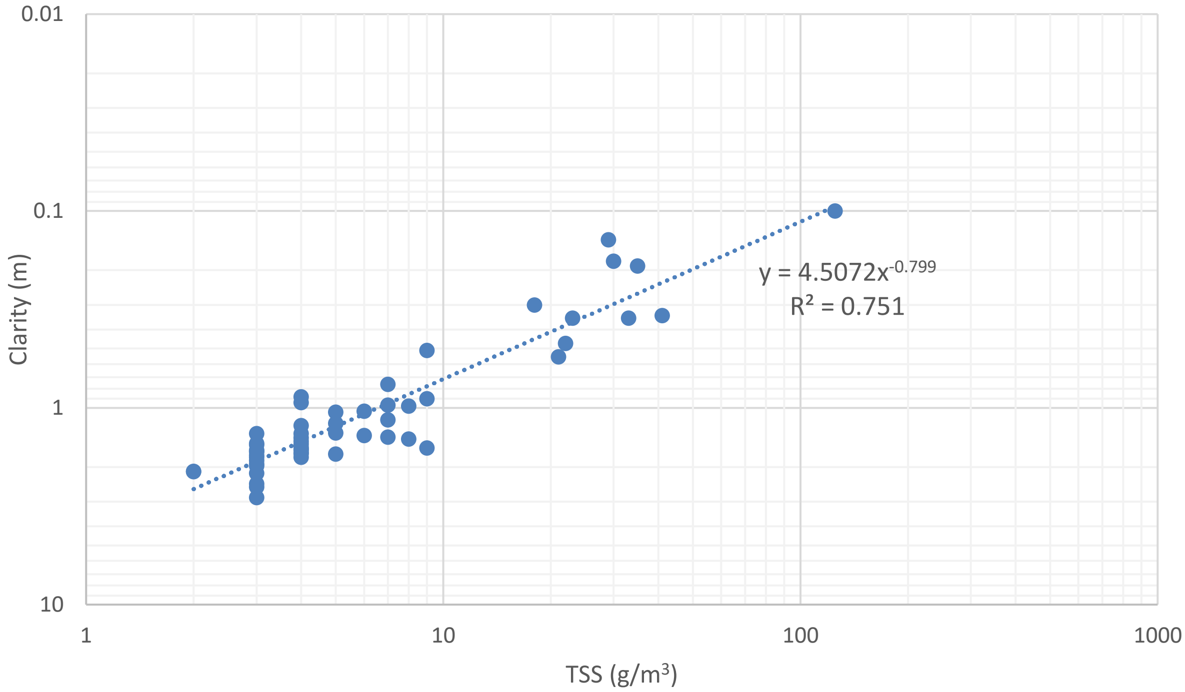

Figure G5 Mākara Stream at Kennels TSS - Clarity relationship

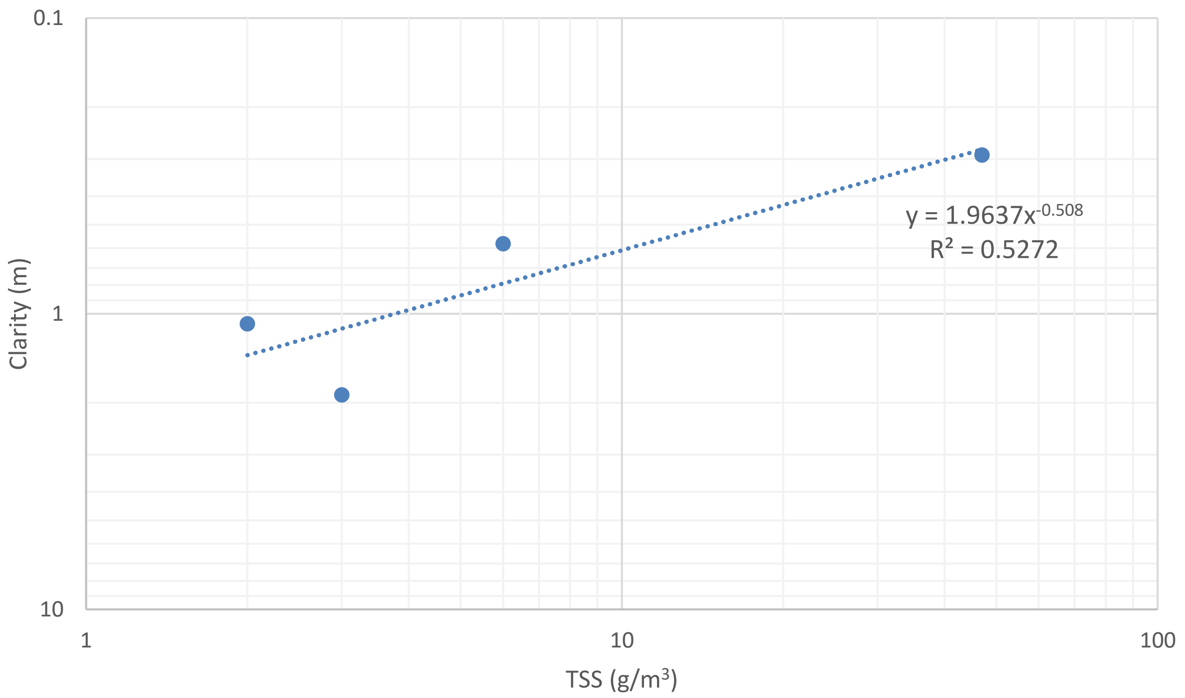

Figure G6 Karori Stream at Mākara Peak Mountain Bike Park TSS - Clarity relationship

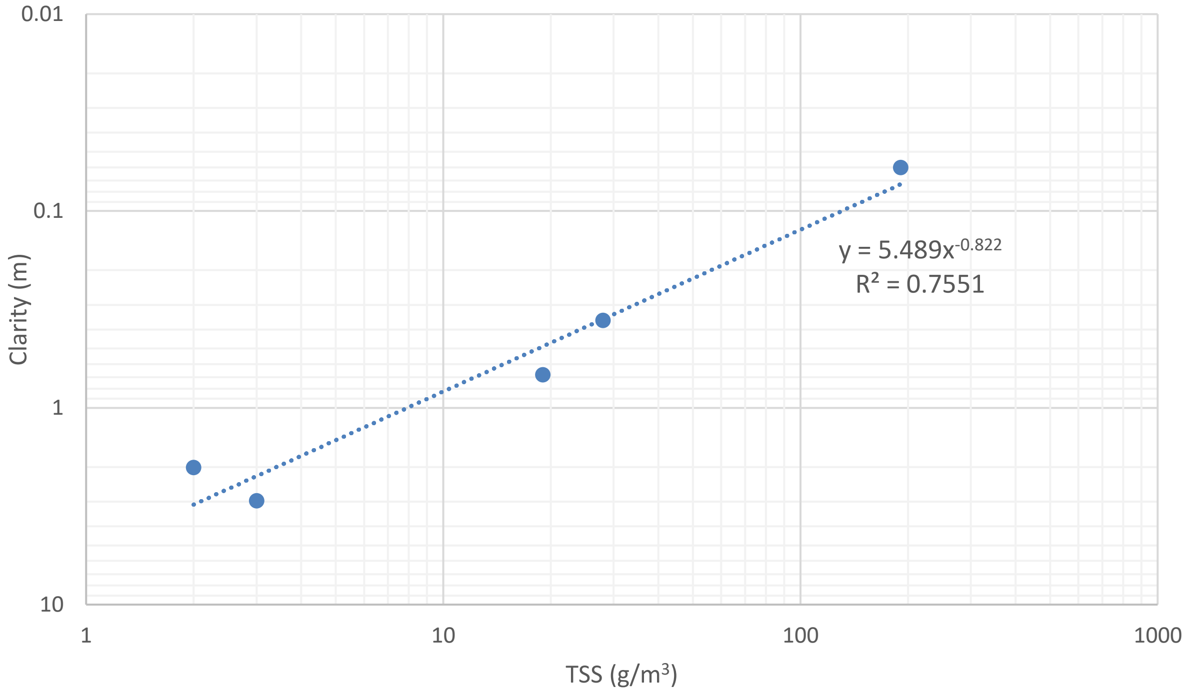

Figure G7 Kaiwharawhara Stream at Ngaio Gorge TSS - Clarity relationship

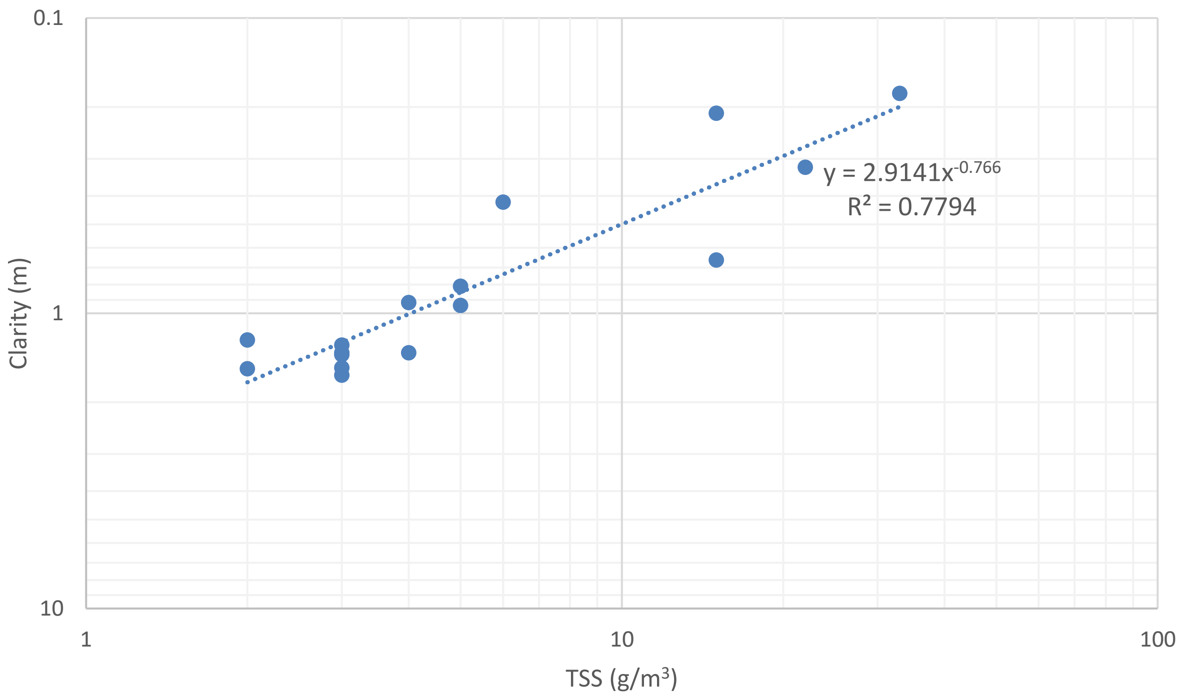

Figure G8 Black Creek at Rowe Parade end TSS - Clarity relationship

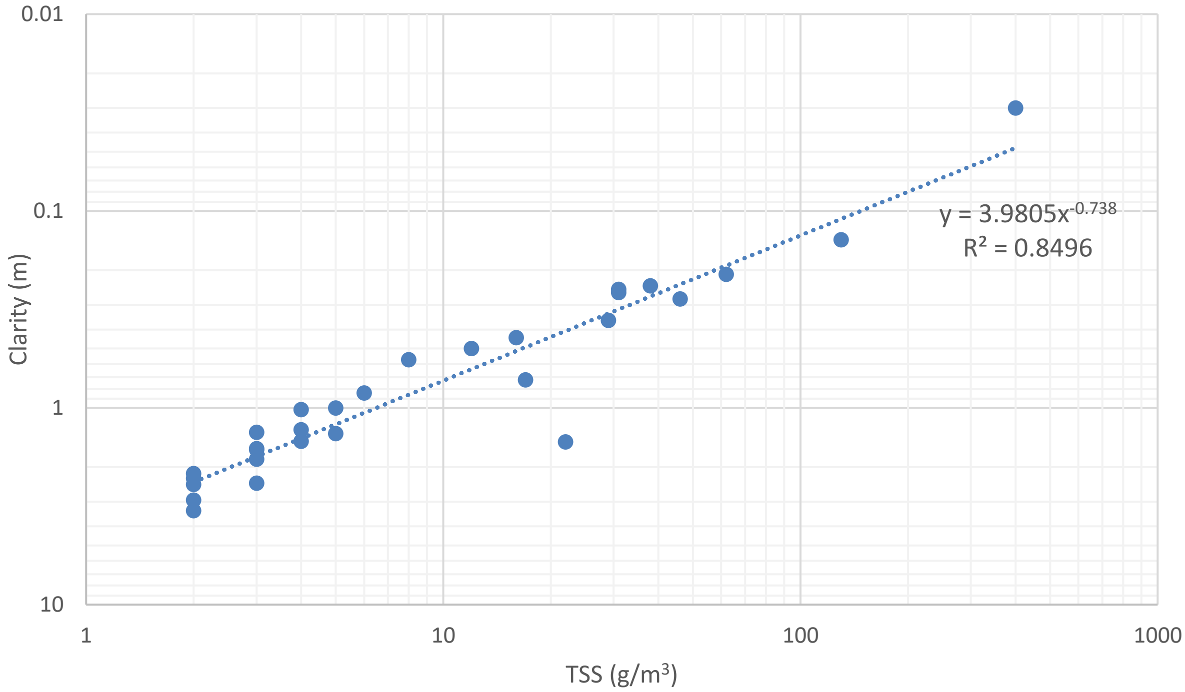

Figure G9 Hutt River at Boulcott TSS - Clarity relationship

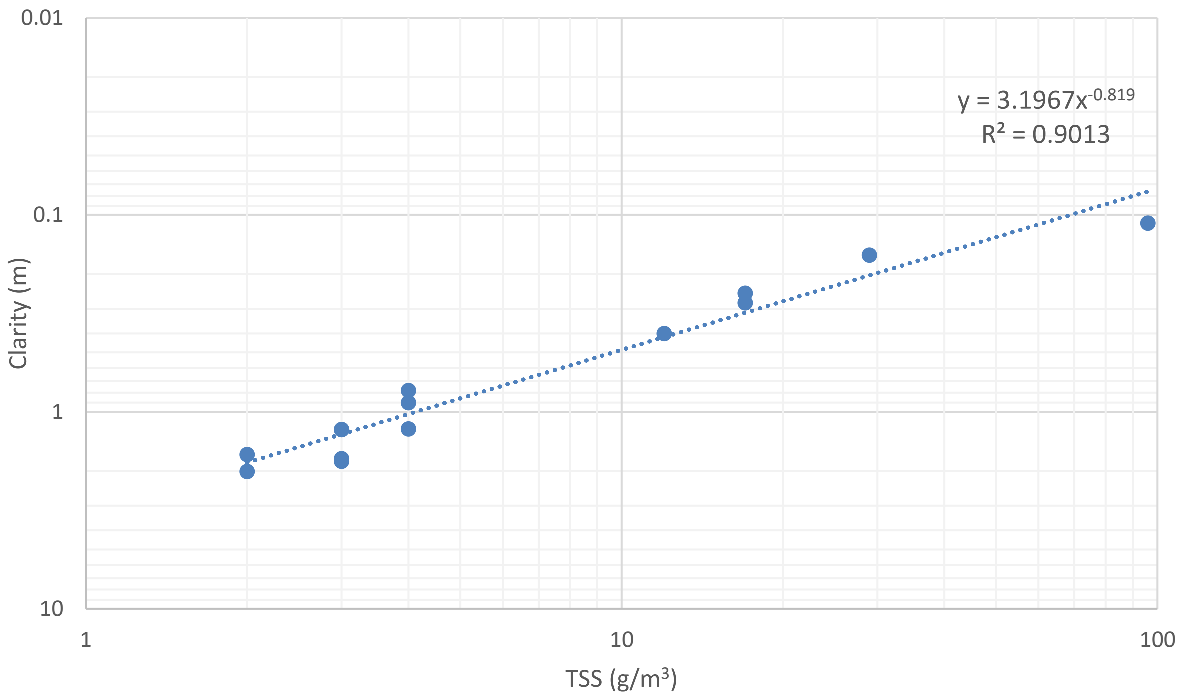

Figure G10 Hulls Creek adjacent Reynolds Bach Drive TSS - Clarity relationship

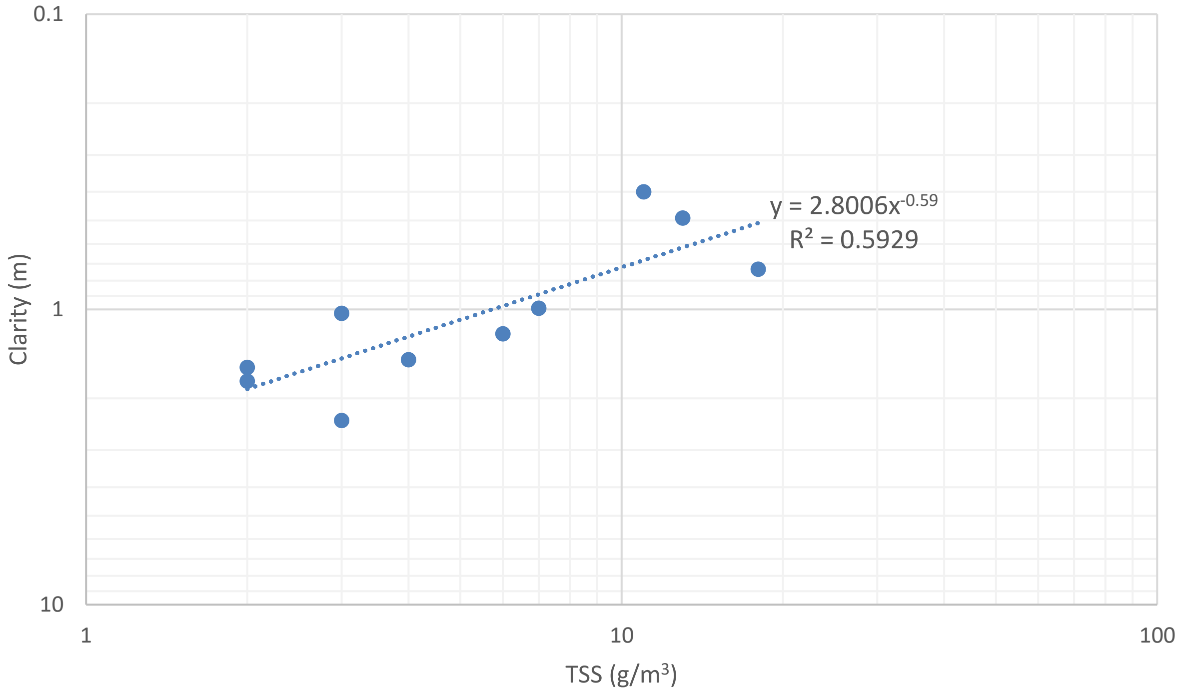

Figure G11 Whakatikei River at Riverstone TSS - Clarity relationship

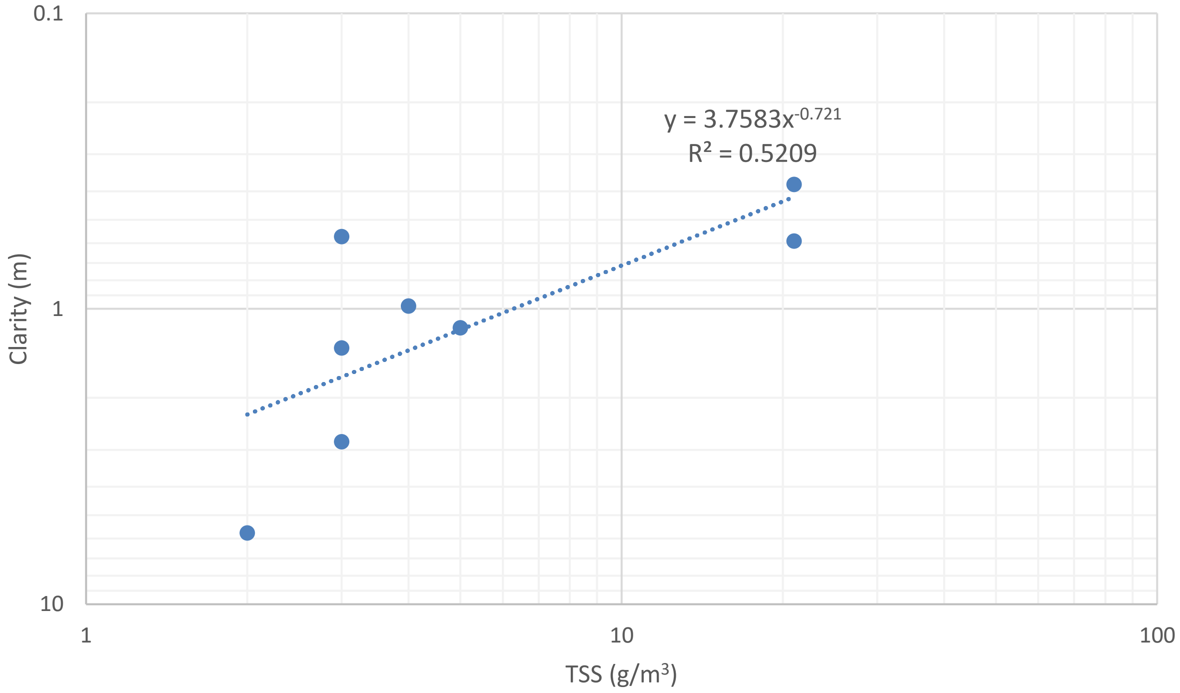

Figure G12 Hutt River at Te Marua Intake Site TSS - Clarity relationship

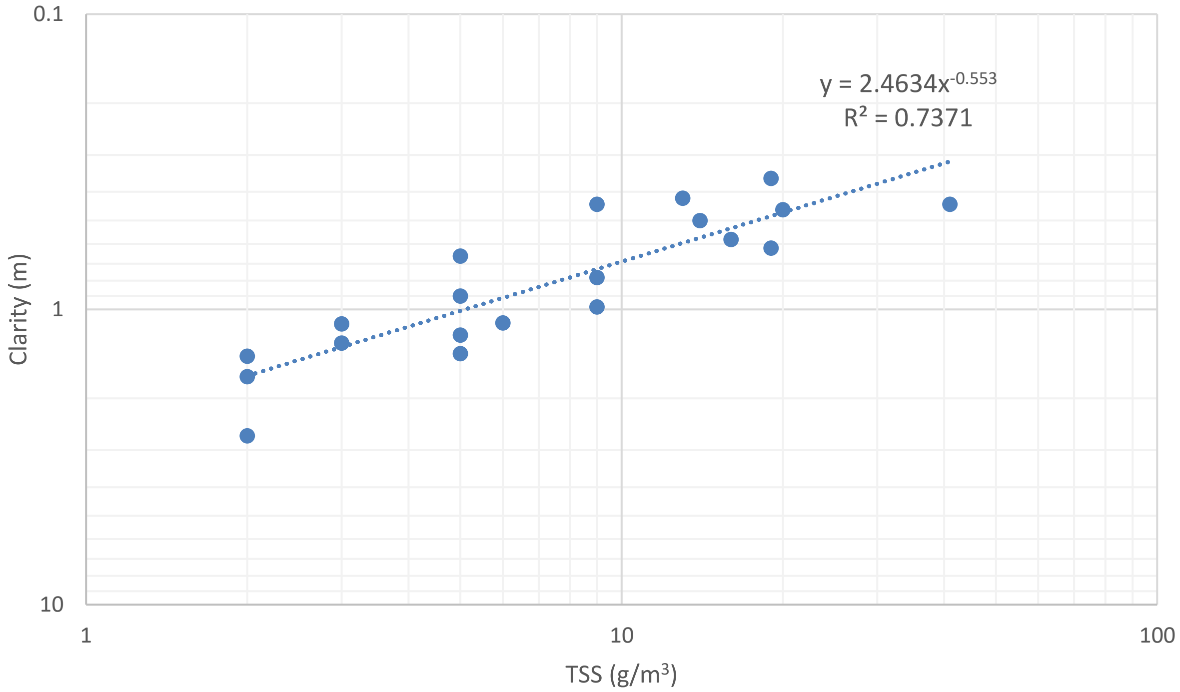

Figure G13 Mangaroa River at Te Marua TSS - Clarity relationship

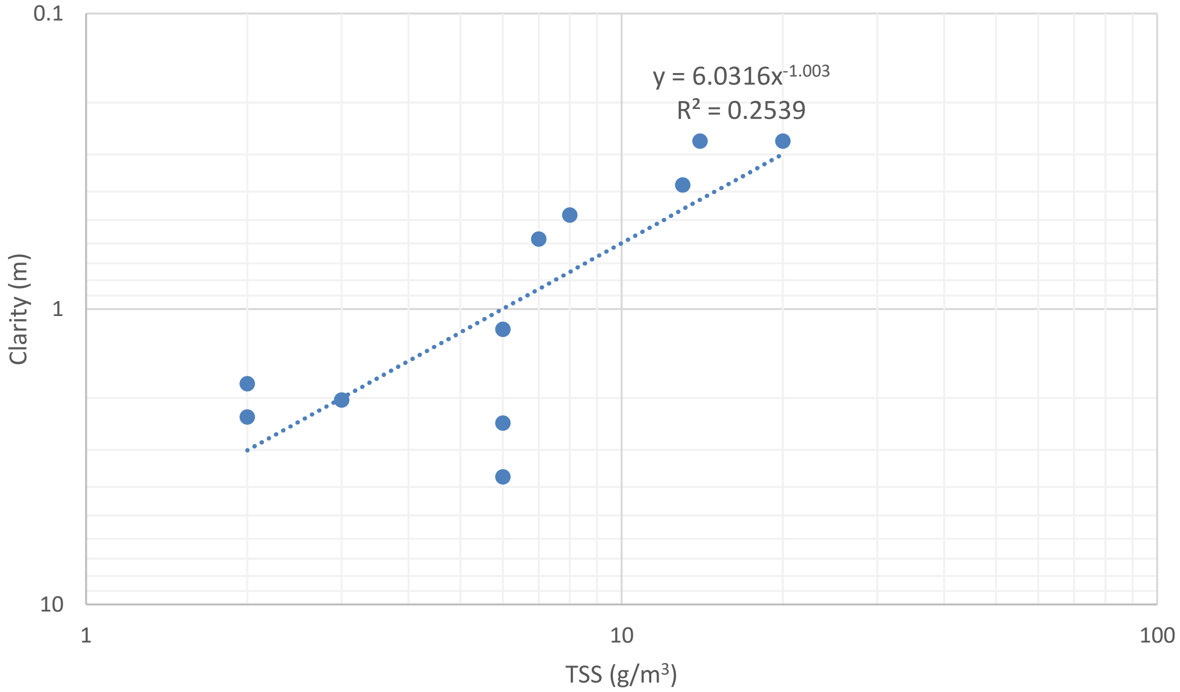

Figure G14 Waiwhetū Stream at Whites Line East TSS - Clarity relationship

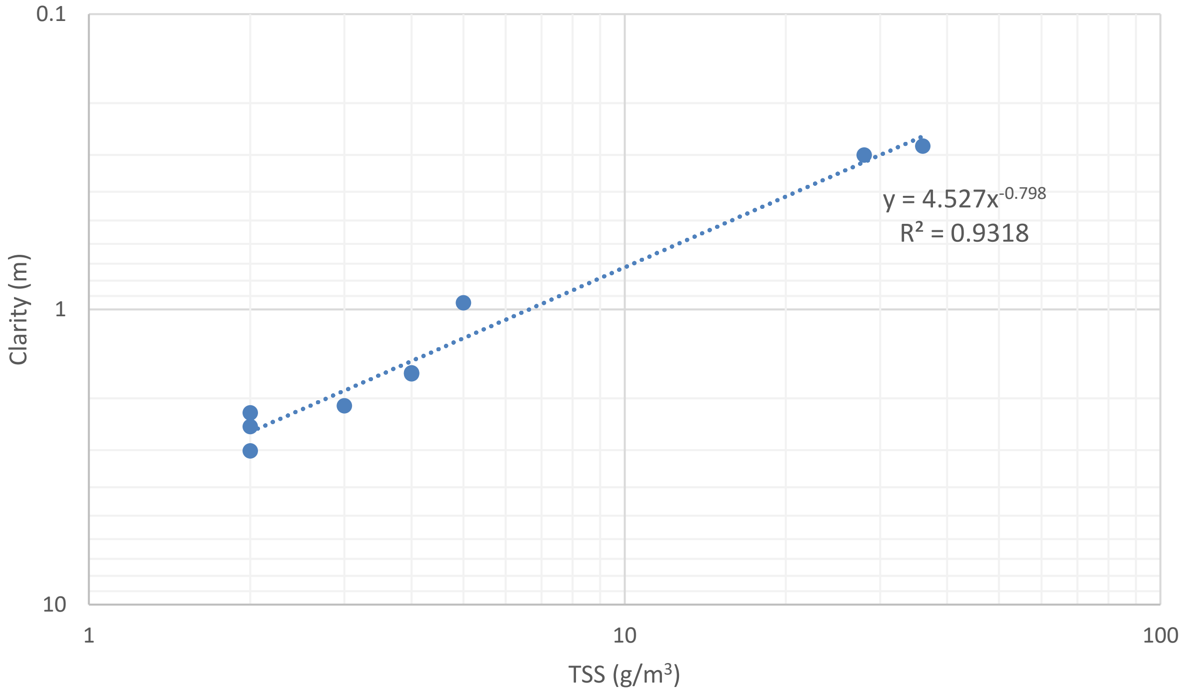

Figure G15 Wainuiomata River Dnstr of White Bridge TSS - Clarity relationship

Appendix H – Regional TSS : Clarity plots (Section 9)

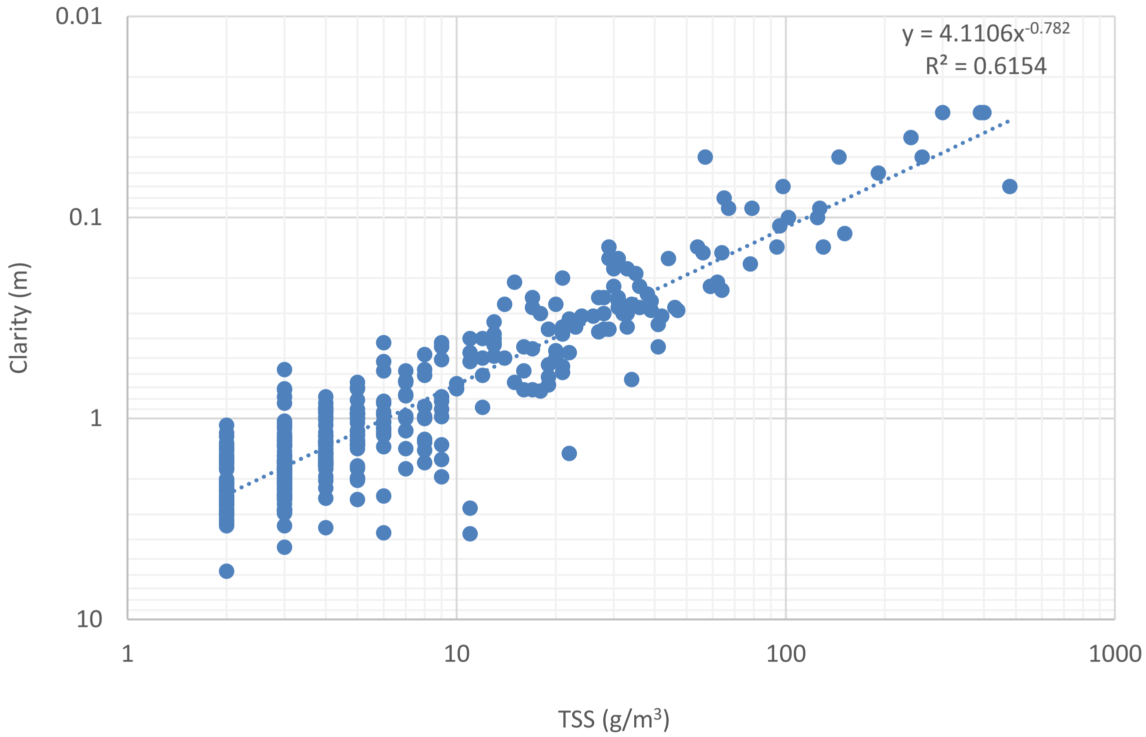

Figure H1 Paired Clarity measurements and TSS samples for all sites (n=373). Log10 scale.

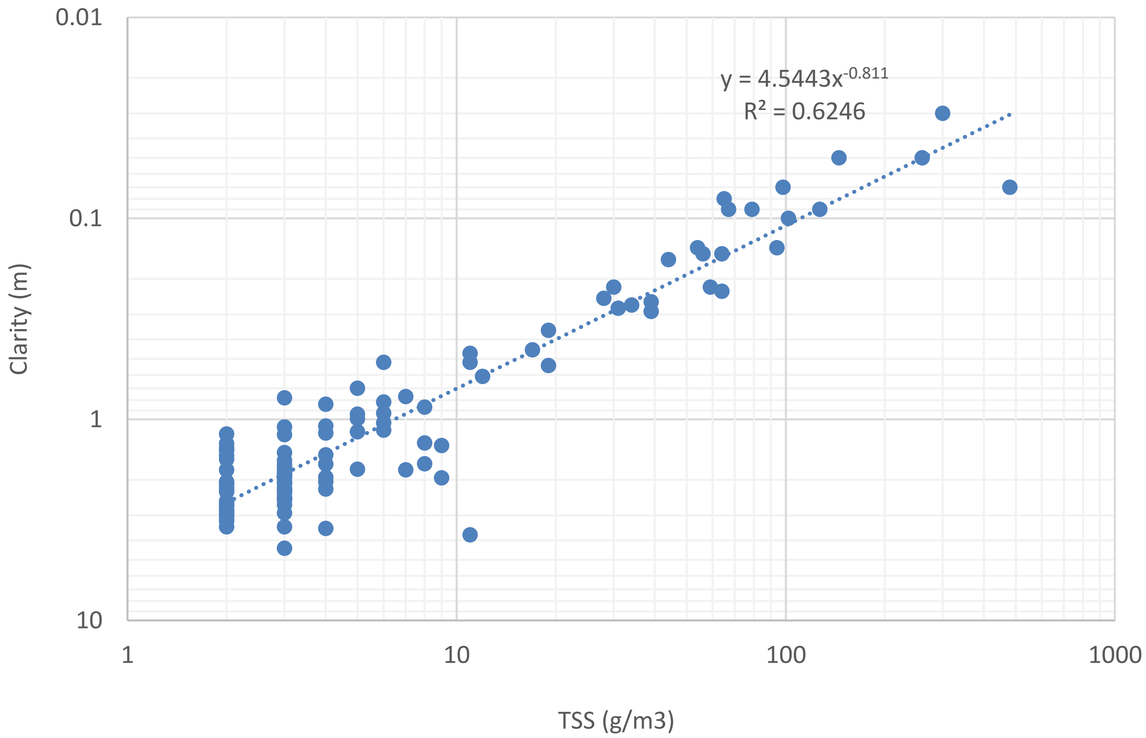

Figure H2 Paired Clarity measurements and TSS samples for all Te Awarua-o-Porirua sites (n=116). Log10 scale.

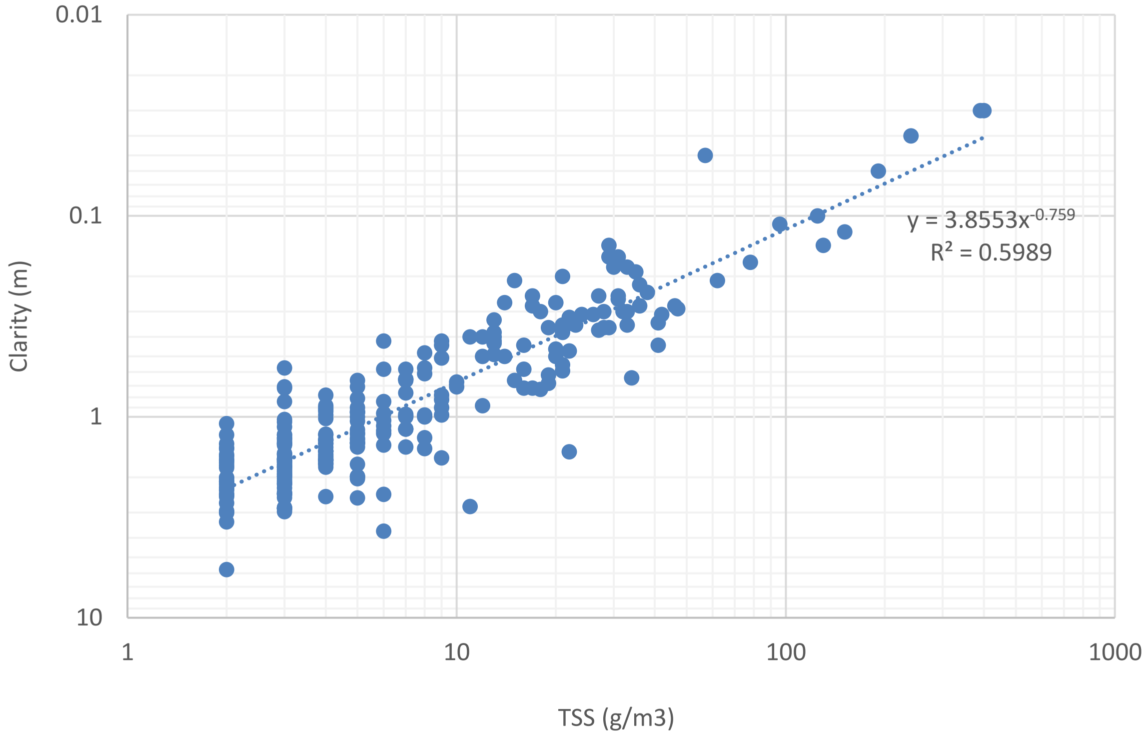

Figure H3 Paired Clarity measurements and TSS samples for all Te Whanganui-a-Tara sites (n=257). Log10 scale.

Appendix I – Sediment load reduction range (Section 9)

Table I1. Estimated load reduction required to achieve clarity targets and ranges for monitored TAS. Current clarity medians below the target are in bold.

Target Attribute Site (TAS)	Sub-FMU	Monitoring Site	Baseline clarity median (m)	Clarity target (m)	Baseline dSedNet mean annual load (t/year)	Load reduction required to meet clarity target (site-specific exponent)	Site Exponent	R^2	Load reduction (regional exponent)	Load reduction range	
										+1 Std. Dev.	-1 Std. Dev.
Te Whanganui-a-Tara TAS											
Whakatikei River	Whakatikei	Whakatikei River at Riverstone	4	4	3,189	0%	-0.59	0.59	0%	0%	0%
Akatarawa River	Akatarawa	Akatarawa River at Hutt Confluence	4.8	4.8	8,147	0%	-0.74	0.56	0%	0%	0%
Te Awa Kairangi Upstream	Kaitoke	Hutt River at Te Marua Intake Site	4.6	4.6	70,950	0%	-0.72	0.52	0%	0%	0%
Pākuratahi River	Pākuratahi	Pākuratahi River 50m Below Farm Creek	4.5	4.5	10,896	0%	-0.82	0.52	0%	0%	0%
Mangaroa River	Mangaroa	Mangaroa River at Te Marua	**1.6**	**2.22**	**10,965**	**-45%**	**-0.55**	**0.74**	**-34%**	**-38%**	**-31%**
Hulls Creek	Te Awa Kairangi Urban Streams	Hulls Creek adjacent Reynolds Bach Drive	1.2	1.2	181	0%	-0.82	0.90	0%	0%	0%
Te Awa Kairangi Downstream	Te Awa Kairangi mainstem	Hutt River at Boulcott	**2.8**	**2.95**	**102,303**	**-7%**	**-0.74**	**0.85**	**-6%**	**-7%**	**-6%**
Waiwhetū Stream	Waiwhetū	Waiwhetū Stream at Whites Line East	1.4	1.4	228	0%	-1.00	0.25	0%	0%	0%
Wainuiomata River Upstream	Wainuiomata Urban Streams	Black Creek at Rowe Parade end	**1.3**	**2.22**	**382**	**-50%**	**-0.77**	**0.78**	**-50%**	**-55%**	**-45%**
Wainuiomata River Downstream	Wainuiomata Rural Streams	Wainuiomata River Downstream of White Bridge	2.2	2.2	12,243	0%	-0.80	0.93	0%	0%	0%
Kaiwharawhara Stream	Kaiwharawhara	Kaiwharawhara Stream at Ngaio Gorge	3.6	3.6	290	0%	-0.82	0.75	0%	0%	0%
Karori Stream Upstream	Wellington Urban	Karori Stream at Mākara Peak Mountain Bike Park	3.2	3.2	2,159	0%	-0.51	0.53	0%	0%	0%

Target Attribute Site (TAS)	Sub-FMU	Monitoring Site	Baseline clarity median (m)	Clarity target (m)	Baseline dSedNet mean annual load (t/year)	Load reduction required to meet clarity target (site-specific exponent)	Site Exponent	R^2	Load reduction (regional exponent)	Load reduction range	
										+1 Std. Dev.	-1 Std. Dev.
Mākara Stream	South-west coast rural streams	Mākara Stream at Kennels	**1.6**	**2.22**	**4,437**	**-34%**	**-0.80**	**0.75**	**-34%**	**-38%**	**-31%**
Te Awarua-o-Porirua TAS											
Horokiri Stream	Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	2.8	2.8	764	0%	-0.94	0.67	0%	0%	0%
Pāuatahanui Stream	Takapū	Pāuatahanui Stream at Elmwood Bridge	**2**	**2.22**	**2311**	**-13%**	**-0.77**	**0.57**	**-12%**	**-14%**	**-11%**
Porirua Stream	Te Riu o Porirua	Porirua Stream at Milk Depot	2.4	2.4	124	0%	-0.77	0.74	0%	0%	0%

Appendix J – Peer review of sediment load target setting process for TAoP (Section 11)

Greater Wellington Regional Council
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Ref:	Init:	Date:
44801481/01	JWO	1st December 2021

1) Concerning – Review of Whaitua Sediment Model Outputs

Dear Brent

I have reviewed your memo relating to the derivation of sediment loads in relation to sedimentation rate reduction targets that were set out in the Te Awarua-o-Porirua Whaitua Implementation Plan[22].

Your memo uses a combination of sediment plate data, harbour wide survey data, outputs from the sediment modelling we undertook for the Whaitua in 2019 and the temporal variability of sediment loads entering the harbour to derive an appropriate baseline sediment load for consideration of sediment load reduction targets for the Whaitua Implementation Plan.

As we discussed in DHI (2019), the majority of sediments are delivered during individual storm events which is why we chose to model a range of individual storm events in addition to the annual 2010 simulation. The purpose of the annual simulation was to quantify the subsequent movement of sediments between storm events and allow a more direct comparison of model result with both the survey and sediment plate data (both of which provide estimates of annual sedimentation rates). That modelling showed that the primary pattern of deposition is established during storm events with only relatively minor changes to sedimentation patterns and rates between storms.

The ten year period from 2005-2014 was used for the Whaitua catchment modelling because it was deemed to be representative of the climatic conditions within the Porirua catchment.

The 2010 annual simulation that we carried out provided representative estimates of 'average' sedimentation rates for the period 2005-2014 primarily because the sediment load delivered in 2010

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22 Te Awarua-o-Porirua Whaitua Committee, 2019. Te Awarua-o-Porirua Whaitua Implementation Programme

(8839 tonnes/yr) was very similar to the average sediment load delivered between 2005-2014 (7971 tonnes/yr).

However, in the context of longer term historic loads delivered to the harbour (and as we discussed in DHI, 2019), 2010 could be considered a relatively low sediment load year. This is primarily why we opted to include the simulation of the 2004 storm event (which delivered over five times the average sediment load delivered between 2005-2014).

As you conclude in your memo, using the period 2004-2014 to define a baseline sediment load is therefore more appropriate when considering the sediment load reduction targets for the Whaitua Implementation Plan since the mean load over this period is more representative of the historical sediment loads delivered to the harbour.

Your methodology for estimating the sediment loads required to meet the Whaitua Implementation Plan target sedimentation rates uses the same approach that we have adopted for Catchment Receiving Environment Scenario Tool that we have developed for both Auckland Council and the Bay of Plenty Regional Council. That is, we take results from a number of representative model simulations (which can be event based or annual simulations) and manipulate the underlying data to determine the what-if outcomes of sediment load reductions without the need for rerunning the underlying sediment transport model.

I am not sure that the event based estimates of basin wide sedimentation rates (as opposed to the true annual estimates from an annual model run) will overstate the longer-term sedimentation rate (paragraph 1, pg. 6 of your memo). The subsequent reworking of sediments and the relatively small input of sediments between storm events will result in relatively small changes in deposition patterns and rates at a subestuary level, but I believe that basin wide deposition rates will be primarily driven by the event based deposition. Importantly however, your conclusion that not accounting for sediment dynamics and inputs outside the period of the storm events would result in relatively small changes in the sediment load/deposition relationship (from your Figure 4 repeated below) is correct. I'm happy to discuss this further and assist you with rewording this paragraph if required.

The only editorial comment I have is that the caption on Figure 2 should refer to "adapted from DML, 2019".

Thanks for the opportunity to review this work.

Best regards
John Oldman
Principal Coastal Scientist

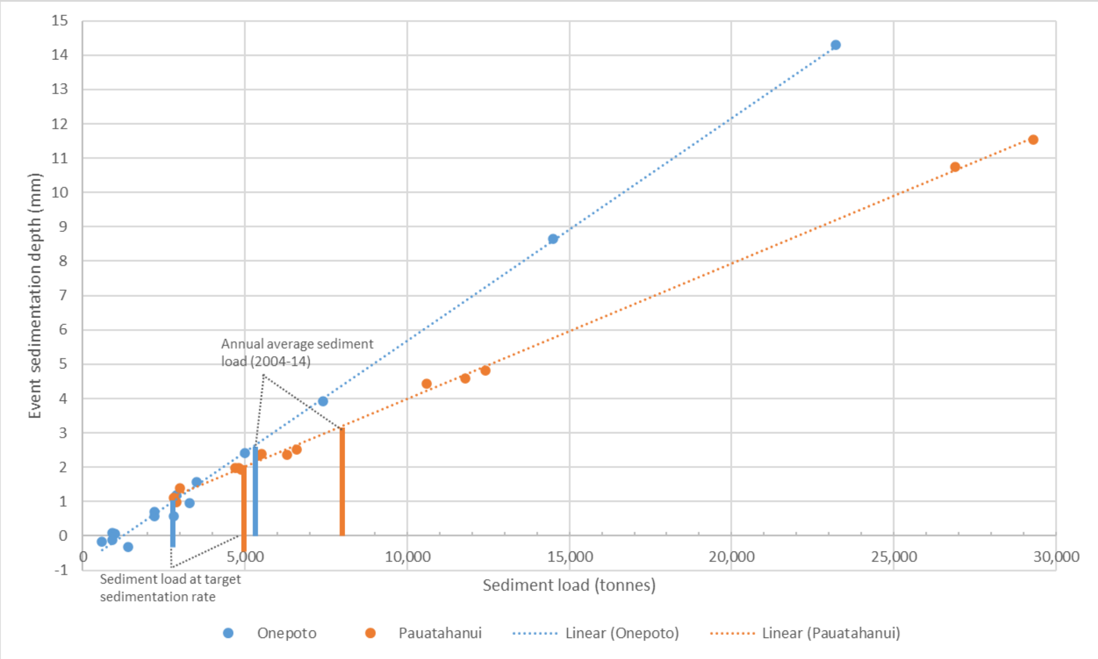

Figure 4 - Simulated sedimentation events in Te Awarua-o-Porirua

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Wastewater improvement affordability

Implications of implementation timeframes for affordability

Greater Wellington Regional Council

3 May 2023

→ **The Power of Commitment**

Project name	GWRC Water improvements affordability						
Document title	Wastewater improvement affordability | Implications of implementation timeframes for affordability						
Project number	12584753						
File name	GWRC Timeframe Affordability Report						
Status Code	Revision	Author	Reviewer		Approved for issue		
			Name	Signature	Name	Signature	Date
S3	DRAFT	David Norman Ellen Donaldson	David Walker		David Walker		
S4	FINAL	David Norman Ellen Donaldson	David Walker		David Walker		3 May 2023

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Contents

1. Executive Summary

The National Policy Statement for Freshwater Management 2020 (NPS-FM) requires that water quality targets are set for *E.coli* one band above the current state. *E.coli* is one of the key contaminants in wastewater.

Greater Wellington Regional Council (GWRC) has previously consulted with the community and mana whenua on the values and desired outcomes for water quality. These engagements, known as Whaitua processes, set target attribute states for *E.coli* and a timeframe for achievement.

The question now turns to *affordability* of the target attribute states. While the report also quantifies some of the benefits of the proposed improvements and funding tools that may be applied to pay for the improvements, the focus is affordability. Consequently, the report sets out different ways of measuring the affordability of the proposed changes against estimates of the costs to improve the wastewater network to reduce *E.coli* levels in water bodies across two whaitua – Whaitua Te Whanganui-a-Tara and Te Awarua-o-Porirua Whaitua.

It is important to note that in addition to the costs discussed here, there will be significant additional spending required to achieve the desired stormwater outcomes. In some cases this will more than double the costs of water improvements covered in this report.

The key points from this report are:

- ***The estimated cost of achieving the E.coli target states is $344-419 million for Te Awarua-o-Porirua and $2.50-3.10 billion for Te Whanganui-a-Tara*** in cashflow terms expressed in today's dollars, and subject to the assumptions and caveats set out in this report.
- ***There are seemingly no easy fixes or "quick wins" that may allow the majority of the E.coli improvements to occur quickly at low cost***. Water specialists we spoke to identified the condition and capacity of the bulk network; and cross-connections where private property owners have their wastewater connected into the stormwater network as the two biggest problems. The former is expensive to fix, while the latter is particularly difficult to identify and therefore time-consuming and also expensive.
- ***Implementing the wastewater improvements within the ambitious 20-year timeframe will increase costs for ratepayers significantly***. While the final mechanism for funding the wastewater improvements has not been decided, if the costs were seen as an add-on to existing rates bills, property rates would need to rise by a sustained 12% to 37% to accommodate the wastewater improvements over a 20-year timeframe, depending on the Council area and whether a low or high estimate of costs is adopted.
- If wastewater improvements were to be funded by general or targeted rates, or through water charges by a new water entity, in all council areas, based on the cost estimates in this report, total rates or equivalent burden would remain below the 5% of household income threshold recommended by the Shand Inquiry.[1] However, given the likelihood that cost estimates in this report are at the lower end of the true cost of achieving the target states for *E.coli*, given this study does not consider costs associated with achieving other target attributes, and given the large rates increases already required in many council jurisdictions to deal with other costs, the 20-year implementation timeframe taken with these other factors ***may result in rates and water charges breaching the 5% threshold***.
- ***Benefits of the proposed reduction in E.coli levels are significant***. Public benefits include use values; non-use values; the cultural value to mana whenua of cleaner water due to less *E.coli* contamination; and reducing reputational damage from the region's wastewater challenges, which may already be affecting visitation and spending in the region. International studies suggest that improving *E.coli* levels by two-thirds to three-quarters (as proposed) could add large private benefits in the form of higher property values to properties located within 500 metres of a cleaner water body.
- ***Most of the costs of the wastewater improvements are likely to be funded by ratepayers more broadly*** although new development will need to make a significant contribution. This fact limits the number of appropriate tools. Most of the costs will likely need to be funded via targeted or general rates, water charges if under the four-entity model, and/or direct investment by central government.

[1] Shand, D et al. (2007). *Funding Local Government: Report of the Local Government Rates Inquiry*.

2. Introduction and purpose of the report

The National Policy Statement for Freshwater Management 2020 (NPS-FM) requires that water quality targets are set for *E.coli* one band above the current state. *E.coli* is one of the key contaminants in wastewater to be managed.

Greater Wellington Regional Council (GWRC) has previously consulted with the community and mana whenua on the values and desired outcomes for water quality. These engagements, known as Whaitua processes, set target attribute states for *E.coli* and a timeframe for achievement.

Previous work has been done on the aggregate costs of infrastructure to enable the proposed improvements across the two Whaitua of Te Awarua-o-Porirua (Porirua plus a few northern suburbs of Wellington City) and Te Whanganui-a-Tara (Upper Hutt, Hutt City and most of Wellington City). That work did not focus on ***where*** the cost would fall or the ***affordability*** of the upgrades that would be required to meet the targets.

GWRC engaged GHD to consider the following questions:

1. What is the total cost, broken down for each whaitua, territorial authority (City or District Council jurisdiction) and household within each whaitua to achieve the *E.coli* target attribute state across different timeframes?
2. What is the affordability impact of different levels of improvement and different timeframes of implementation?
3. Can the benefits of the improvements be economically quantified or proxied to demonstrate more clearly the benefits to decision-makers and residents?
4. Are there elements of the improvements that can be implemented earlier on that achieve a greater share of the benefits at a lower cost ("quick wins")?
5. How might these costs be funded? i.e. who should bear the costs directly, and what tools could be applied to collect the revenue needed for the improvements?[2]

2.1 Scope of the work: wastewater

It is important to note that this report is focused on *E.coli* and therefore on wastewater improvements, which would form the bulk of the improvements that would improve *E.coli* levels. Improvements to the stormwater network, which could also have some benefits for *E.coli* levels, are not within the scope of this work.

As a consequence, the work at hand should be seen as part of a suite of improvements (and not necessarily even the most costly improvements) required to overcome the other water challenges of quantity passing through the stormwater system in severe rain events, or quality of water as it relates to chemicals and sediments that can enter the stormwater system.

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[2] As highlighted earlier, while this report provides estimates of costs and some benefits, it is not a cost-benefit analysis. Its primary focus is on the affordability of the proposed wastewater improvements, and therefore uses comparisons of costings in today's unescalated and undiscounted dollars against today's household incomes and rates bills.

3. Costs of the improvements

Two previous studies[3],[4] for GWRC have examined the potential costs of stormwater and wastewater improvements. Each of these studies provided lower and upper estimates of the costs of improving the wastewater network. We undertook a process of updating the original figures to today's dollars and estimating the costs in aggregate for the two whaitua, and the implication for the cost per household. In summary:

- The studies demonstrated that the cost of wastewater improvements is high although this may be less than half the costs involved in the combined stormwater and wastewater improvements in some areas.
- Headline cost estimates for improving the wastewater network alone, and thus reducing *E.coli* levels in water bodies, is $344-419 million for Te Awarua-o-Porirua and $2.50-3.10 billion for Te Whanganui-a-Tara in unescalated, undiscounted terms.
- Dividing these costs by the number of households in each whaitua today suggests a per-existing-household cost of between $10,350 and $22,900 in undiscounted, unescalated terms.
- A number of caveats and assumptions accompany these estimates and should be kept in mind when interpreting the results.

3.1 Reconciling the original cost estimates

We did not re-interrogate the cost data in the original reports for accuracy. However, we did work with the report authors to understand some of the technical details behind their figures so as to present the total cost of the scenarios in each report in common units of measurement (2022 dollars). This required reconciliation between approaches based on the real discount rates used, assumed lifecycle of the assets, and checking with the authors on assumptions about ongoing maintenance. Report authors were at pains to point out that the initial estimates they used were headline figures based on the interventions developed by a wider team. For wastewater, there is an information deficit with regard to how much maintenance and renewal costs are likely to be. It is possible that maintenance costs are under-estimated.

Having removed all discounting, we updated the costs in each report to December 2022 dollars so that the costs closely resemble current values of a dollar. It is important to note the updated dollar values do not reflect cost escalation or change of scope within the construction and maintenance costs, but simply general inflation.

We also cross-checked these estimates with Wellington Water data to ensure that the figures we used are of the right magnitude, although not identical.

3.2 Headline cost estimates

Low and high estimates are provided in the original cost estimation reports for each whaitua and constituent council area.[5]

The resultant, nominal (in today's dollars, undiscounted) costs of stormwater and wastewater improvements by whaitua are consequently estimated as:

- Te Awarua-o-Porirua: $344-419 million
- Te Whanganui-a-tara: $2.50-3.10 billion.

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[3]Blyth, J. M. 2020. Whaitua te Whanganui-a-Tara - An overview of the Wellington City, Hutt Valley and Wainuiomata Wastewater and Stormwater networks and considerations of scenarios that were assessed to improve water quality**.** Prepared for Greater Wellington Regional Council Whaitua Committee.

[4] Ira, S J T. 2018. The Cost Aggregation Model and Indicative Life Cycle Cost Estimates for Various Intervention Scenarios for the Te Awarua-o-Porirua Whaitua Collaborative Modelling Project. Report prepared for Greater Wellington Regional Council as part of the Te Awarua-o-Porirua Collaborative Modelling Project.

[5] It is important to note that the assumed actions undertaken to improve wastewater in this report align with those in the original two reports by Blyth and Ira. Any more stringent or rapid changes proposed by GWRC would lead to higher or more pressing costs, while any reduced programme of improvements would lead to lower estimates of costs.

3.2.1 Caveats in interpreting these results

Presenting these figures as a simple cost/person or cost/household is not particularly insightful for at least two reasons. First, a discussion of who will pay and what funding tool will be used is highly material. For instance, if it was decided that the entire infrastructure costs should be covered by growth or new development (an extreme end of the spectrum), the direct cost to the existing ratepayer would be zero. At the other extreme, if the full costs of this approach were funded equally by ratepayers, the cost would be very high. Second, there are a number of reasons to conclude that the costs given here may be significantly lower than the true cost of achieving the outcomes covered in the original reports. These reasons include:

- While the reports both covered stormwater and wastewater improvements, the focus of the current work is on wastewater improvements because of the focus on improving *E.coli* levels. ***Only the work previously completed on wastewater is therefore covered in the figures in this report***.[6] The full costs of achieving all the water improvement outcomes (both wastewater and stormwater related) will therefore be significantly higher than reported here, and in some cases more than double.
- Current projections for growth in the number of households in the whaitua are significantly higher than the projections originally used in the modelling. The implications for the estimates below are that these are likely to ***low estimates*** as more households will create more demand for wastewater capacity.
- Wastewater maintenance costs are notoriously hard to estimate, as highlighted above. Some estimates of these maintenance costs have been included for Te Awarua-o-Porirua, but the report author believes the true cost may be higher. ***No estimate of maintenance costs has been included in the Te Whanganui-a-Tara figures***.
- ***Cross connections***, which occur when private wastewater connections are made into the stormwater network rather than the wastewater network, are a cost estimated here, but there is in fact ***little certainty about how big this problem is***, and the costs would be borne by each individual property where this is shown to be a problem. Unfortunately, detecting which properties have this incorrect connection is difficult and expensive.

Keeping these caveats in mind, a sense of scale of the huge changes required can nevertheless be seen dividing the estimated cost of the improvements in each whaitua by the current estimated number of households of each whaitua:

- Te Awarua-o-Porirua: $10,350-$12,600 per household
- Te Whanganui-a-Tara: $18,500-$22,900 per household.

3.3 Cost implications by implementation timeframe

The original Whaitua Implementation Programmes (WIPs) call for an improvement implementation period of around 20 years. But questions remain over what impact a slower or more rapid implementation period may have on the annual costs and therefore affordability of the proposed changes. We therefore consider the following:

- The ***total cost*** at the whaitua and council level of the low and high cost estimates, by implementation timeframe of 10 to 40 years (with 20 years assumed to be the base case for implementation timeframe for the WIPs).
- The ***cost per household*** at the whaitua and council level of the low and high cost estimates, by implementation timeframe of 10 to 40 years.

Crucial to interpreting these figures is to bear in mind that:

- All figures are expressed in nominal (cashflow) terms, not in discounted terms.
- No cost escalation or inflation is included.

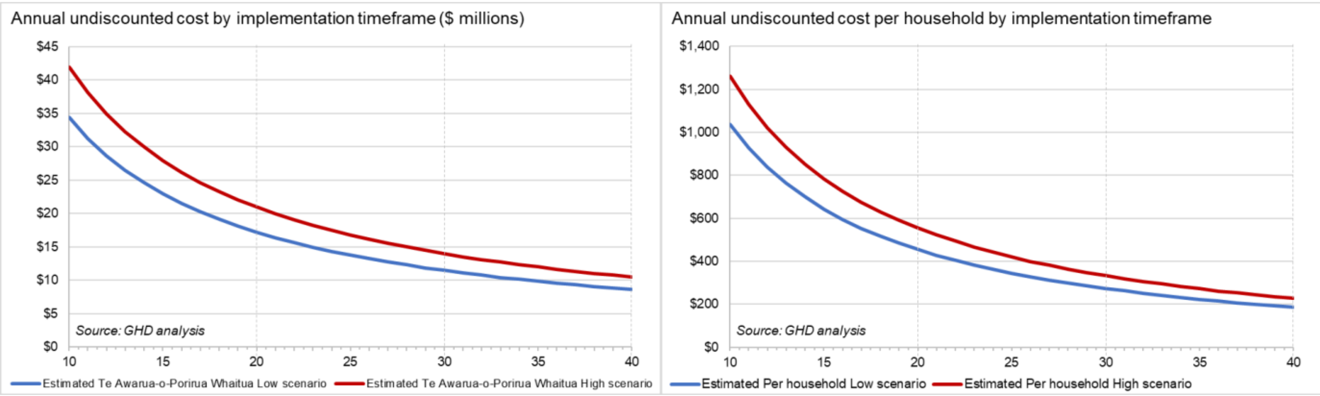
[6] The wastewater improvements outlined in the reports by Blyth and Ira include the following assumed interventions: inspection and repair of laterals to remove significant ground infiltration and wastewater leakage; fixing and removing cross connections (although these costs are uncertain and unlikely fully included); increased capacity of network and treatment plant capacity reducing wastewater overflows (that limits overflows to two per site per year); wastewater network renewals; upgrades to rising mains stream crossings and in contributing catchments to convey residual overflows.

- Estimates of cost per household are to provide a sense of scale of total impact on a community. How the improvements will be funded has not yet been finalised. As suggested previously, a funding approach that places all these costs on growth, for instance, would have very different outcomes on the typical ratepayer, but may have other effects too such as suppressing housing delivery (a point discussed later in this report).
- The cost per year, whether total cost for the whaitua, council or household within a whaitua or council area, should be interpreted as the cost per year for each year of the implementation timeframe. e.g. if a ***10***-year implementation timeframe is used, and the estimated cost for a scenario is ***$2,000*** per household, that implies that the cost to achieve the outcomes is the equivalent of each household paying ***$2,000 a year for 10 years***.

3.3.1 Te Awarua-o-Porirua Whaitua

At the 20-year implementation timeframe, the annual cost without discounting or cost escalation is $16.9-20.6 million. At a 10-year implementation timeframe, the cost per year would be $34.4-41.9 million. At the other end of the spectrum, a 40-year implementation timeframe would cost $8.6-$10.5 million a year in undiscounted, unescalated terms. These numbers are represented in Figure 1.

Figure 1 Total and household cost per year by number of years of implementation, Te Awarua-o-Porirua Whaitua



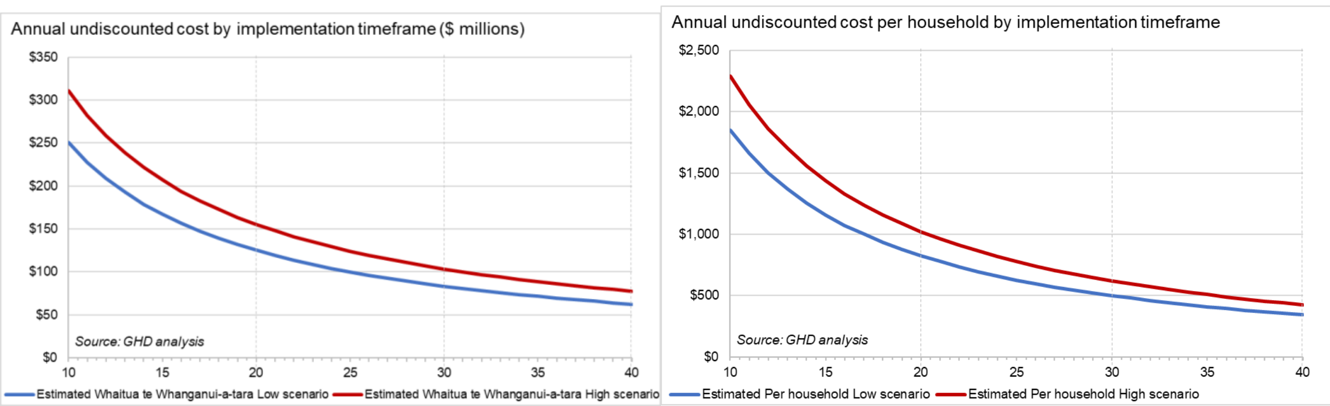
From a household perspective, the cost of reducing *E.coli* in waterbodies for the Te Awarua-o-Porirua Whaitua is estimated at $1,035-$1,260 a year for 10 years, to $185-$225 a year for 40 years at the other end of the spectrum.

3.3.2 Whaitua Te Whanganui-a-Tara

The bulk of the anticipated wastewater improvements are in Whaitua Te Whanganui-a-Tara. Consequently, the costs in this whaitua are significantly higher in aggregate and per household than in Te Awarua-o-Porirua Whaitua.

At the 20-year implementation timeframe, the annual cost without discounting or cost escalation is $125-155 million. At a 10-year implementation timeframe, the cost per year would be $250-310 million. At the other end of the spectrum, a 40-year implementation timeframe would cost $63-78 million a year for 40 years in undiscounted, unescalated terms. These numbers are represented in Figure 2.

Figure 2 Total and household cost per year by number of years of implementation, Whaitua Te Whanganui-a-Tara

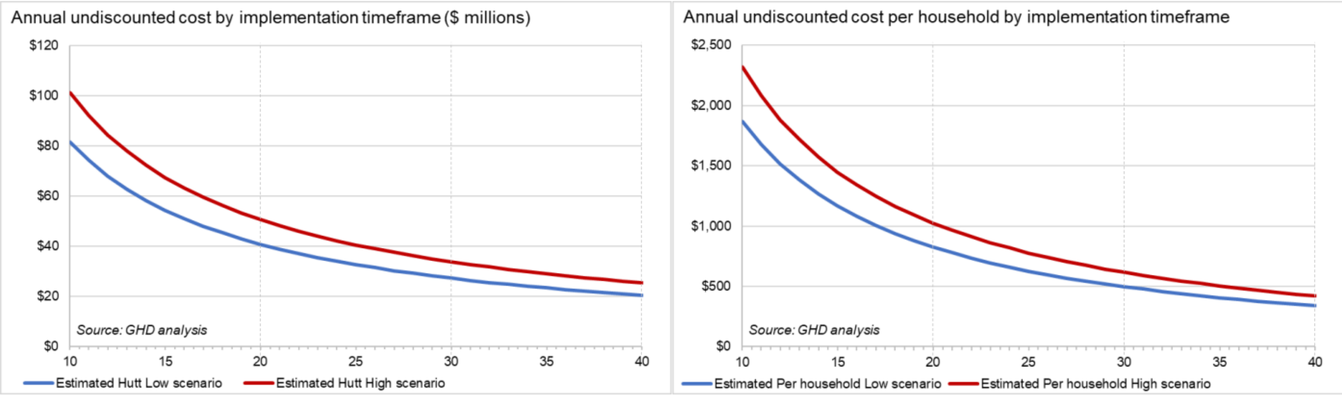


From a household perspective, the cost of reducing *E.coli* in waterbodies for the Whaitua Te Whanganui-a-Tara is estimated at $1,850-$2,290 a year for 10 years, to $345-$425 a year for 40 years at the other end of the spectrum.

3.3.3 Hutt City

At the 20-year implementation timeframe, the annual cost without discounting or cost escalation is $41-51 million. At a 10-year implementation timeframe, the cost per year would be $81-101 million. At the other end of the spectrum, a 40-year implementation timeframe would cost $20-25 million a year in undiscounted, unescalated terms. These numbers are represented in Figure 3.

Figure 3 Total and household cost per year by number of years of implementation, Hutt City

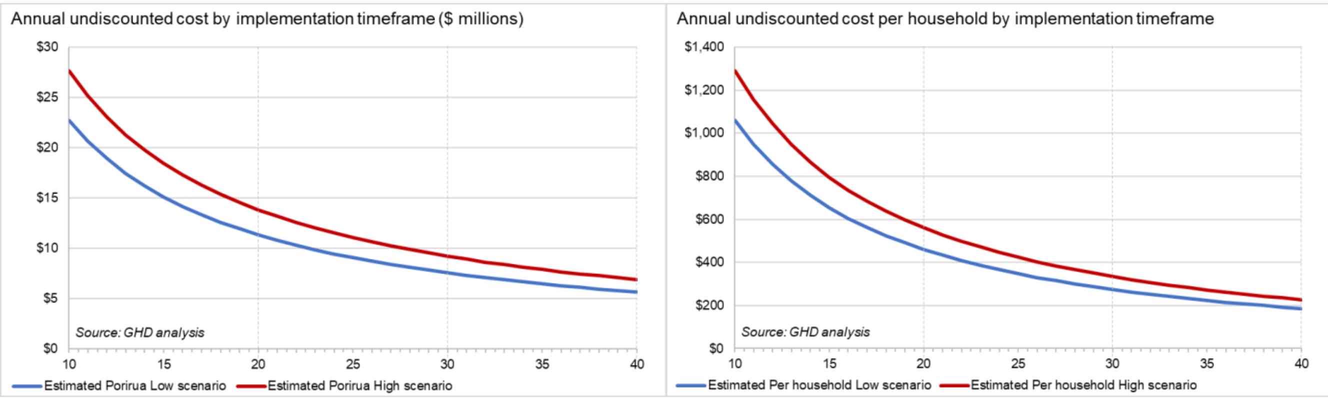


From a household perspective, the cost of reducing *E.coli* in water for Hutt City is estimated at $1,870-$2,320 a year for 10 years, to $340-$420 a year for 40 years at the other end of the spectrum.

3.3.4 Porirua City

At the 20-year implementation timeframe, the annual cost without discounting or cost escalation is $11.1-13.6 million. At a 10-year implementation timeframe, the cost per year would be $22.3-27.3 million. At the other end of the spectrum, a 40-year implementation timeframe would cost $5.6-6.8 million a year in undiscounted, unescalated terms. These numbers are represented in Figure 4.

Figure 4 Total and household cost per year by number of years of implementation, Porirua City

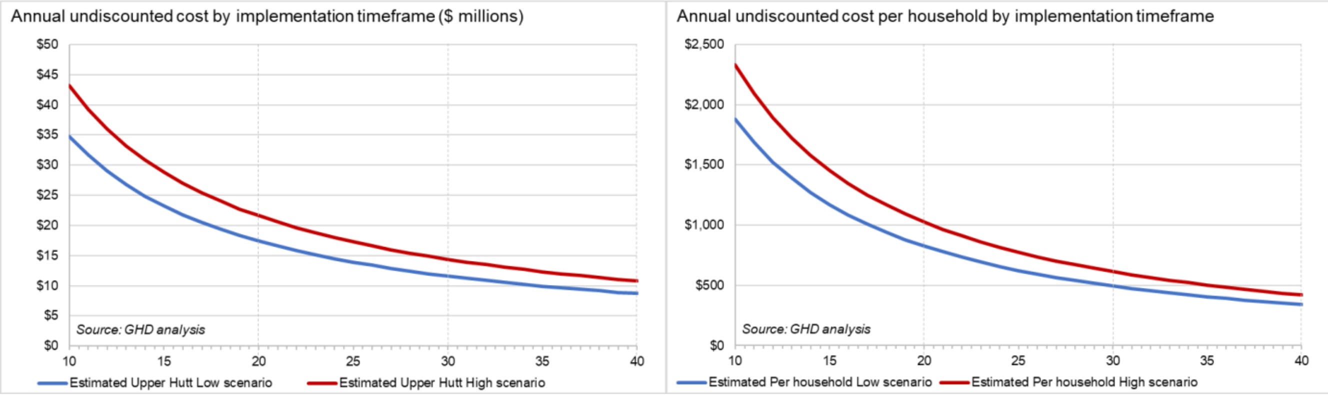


From a household perspective, the cost of reducing *E.coli* in water for Porirua is estimated to cost from $1,060-$1,290 a year for 10 years, to $185-$225 a year for 40 years at the other end of the spectrum.

3.3.5 Upper Hutt City

At the 20-year implementation timeframe, the annual cost without discounting or cost escalation is $17.4-21.6 million. At a 10-year implementation timeframe, the cost per year would be $35-43 million. At the other end of the spectrum, a 40-year implementation timeframe would cost $8.7-10.8 million a year in undiscounted, unescalated terms. These numbers are represented in Figure 5.

Figure 5 Total and household cost per year by number of years of implementation, Upper Hutt

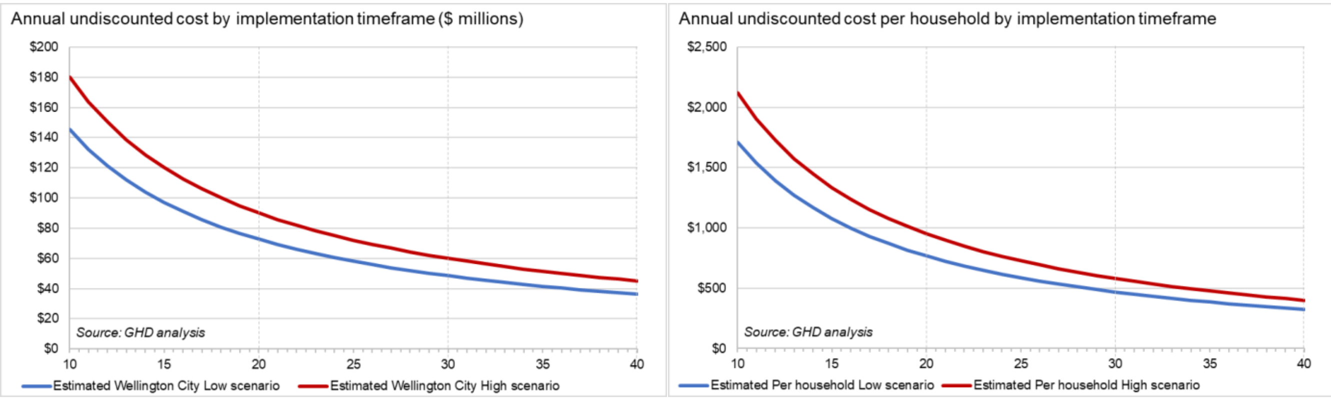


From a household perspective, the cost of reducing *E.coli* in water for Upper Hutt is estimated to cost from $1,880-$2,335 a year for 10 years, to $340-$420 a year for 40 years at the other end of the spectrum.

3.3.6 Wellington City

At the 20-year implementation timeframe, the annual cost without discounting or cost escalation, is $73-90 million. At a 10-year implementation timeframe, the cost per year would be $146-180 million. At the other end of the spectrum, a 40-year implementation timeframe would cost $36-45 million a year in undiscounted, unescalated terms. These numbers are represented in Figure 6.

Figure 6 Total and household cost per year by number of years of implementation, Wellington City



From a household perspective, the cost of reducing *E.coli* in water for Wellington City is estimated to cost from $1,710-$2,120 a year for 10 years, to $325-$400 a year for 40 years at the other end of the spectrum.

4. Potential for quick gains

Having considered the large cost of improvements, the question arises as to whether there are opportunities for elements of the wastewater improvement programme that could be delivered quickly and with significant gains to water quality at relatively low cost.

Scale of the problem

There are an estimated 1,000 wastewater overflow points across the four councils. Some overflows into streams happen on an almost monthly basis. While a desirable end goal may be no overflows, according to water specialists spoken to, this is likely unachievable given the cost associated with that level of service.

However, with climate change large-scale wet weather events will likely become more common and leakage into pipes from rising sea water levels will become a greater challenge, meaning there will be a need to better manage water flows. This likely outcome presents both an argument for improving water management and an opportunity to improve climate resilience at the same time as improving water quality.

The biggest challenges in the system

Discussions with stakeholders confirmed that the two most challenging components of the wastewater challenge across the two whaitua are:

- Limited capacity of the existing bulk wastewater network to deal with:
    - population growth
    - wet weather overflows, as a result of the wastewater and stormwater systems being combined
- Cross connections, whereby private wastewater connections have been incorrectly made into the stormwater network.

There are other challenges with regard to leaking pipes that result in wastewater leaking into the environment and stormwater entering the wastewater system, leading to further capacity constraints when there is heavy rain.

Solutions will be costly and take time

Unfortunately, both these major wastewater challenges are expensive and difficult to fix. Upgrading the existing network to better cope with population growth and heavy rain events will cost billions of dollars and form the bulk of the costs covered in this study.

Cross connections occur on private land and are hard to isolate and therefore fix. While these costs accrue to the private land owners, a fix-order can only be issued when the problem is known to exist, and finding where faults exist is a challenge. Pilot projects have been undertaken to identify cross connections with mixed levels of success in actually reducing wastewater contamination of water.

Although there are no quick fixes, we would anticipate that as part of the programme investigation, an assessment of the severity of overflows would be undertaken. This would at least provide a prioritisation opportunity to fix the most pressing issues.

5. Affordability of the improvements

There are a number of ways affordability of the proposed improvements can be considered. We consider three primary approaches and comment on the implications of a fourth factor.

- Estimated equivalent percentage increase in property rates bill by timeframe of implementation
- Cost per household as a share of household income by timeframe of implementation
- Equivalent total rates implication as a share of household income
- Proportion of population aged under 15 or over 65.

In summary:

- Were the costs to be covered by traditional general rates or targeted rate mechanisms, the impact across council areas would vary from ***an equivalent of a 12% step-change in rates*** (i.e. rates rise by 12% and remain 12% higher than they would otherwise in subsequent years) ***to a 37% step change in rates*** assuming a 20-year implementation period.
- As a ***share of household income***, the additional cost given the other assumptions in this report would fall ***between 0.3% and 0.8%*** of current household incomes assuming a 20-year implementation period.
- Adding the current rates burden to the existing rates burden on the different council areas suggests a ***rates burden on ratepayers of between 3.6% and 4.8% of 2022 household incomes*** at a 10-year implementation period just to meet the *E.coli* requirements. This is below the 5% maximum rates burden threshold recommended by the Shand Inquiry into local government funding.[7]
- However, given the likelihood that cost estimates in this report are lower than the true cost of achieving the target states for *E.coli*, given this study does not consider costs associated with achieving other target attributes, and given the large rates increases already required in many council jurisdictions to deal with other costs, the 20-year implementation timeframe taken with these other factors ***may result in rates and water charges breaching the 5% threshold***.
- Of the four council areas, ***Upper Hutt and Porirua*** have the largest proportion of residents aged under 15 or over 65. Consequently, higher incomes in these areas are more concentrated within a smaller share of households, and ***at the margins there may be more households that struggle to afford significant increases*** in costs for wastewater improvements.

5.1 Estimated equivalent percentage rates increase

As this report has explicitly highlighted, the final mechanism for funding the improvements in infrastructure have not yet been finalised. It seems unlikely that all these costs will be charged to general rates, for instance. Some may be funded by central government or other mechanisms. However, as a simple way to consider the affordability impact of the costs of the improvements on the community more broadly, the costs can be presented as the equivalent of a certain percentage increase in rates per household to provide a sense of scale of affordability at a community level.

There are several assumptions to be considered here.

- We do not discount or inflate dollar values but use cashflow dollars.
- Related to the previous point, we do not allow for any other growth in rates spending. Equivalent percentage rates increases are the increase on rates paid in the June 2022 rates year.
- We assume none of the infrastructure costs are debt-funded. It is unlikely that all this infrastructure would be cash-funded, but adding in assumptions about interest rates, borrowing terms, and construction timeframe versus debt timeframe adds further complexity that will not materially change the outcomes presented here.

[7] Shand, D et al. (2007). *Funding Local Government: Report of the Local Government Rates Inquiry*.

The best way to interpret the data here is that the infrastructure is funded year-by-year as the revenue is gathered.

- We assume the population grows in line with the GWRC regional and council-level population projections.[8]
- We divide all current rates (residential and commercial) across households in the relevant council area. This is because although some rates are charged on businesses rather than households, ultimately people own businesses and therefore these costs are borne by people who are predominantly local residents. We note this assumption may hold less well for Wellington City, which has a high proportion of commercial buildings occupied by government rather than private businesses.
- We assume future rates are split across councils in the approximate proportions that today's local and regional council rates are spread.
- We assume the costs of improving water quality with regard to *E.coli* levels are spread across council areas in line with the current spread of council rates at the city and regional level. It is important to note that the relevant councils may decide on a different cost distribution from what is presented here.
- We divide the implied increase in cost per whaitua or council area to achieve the wastewater outcomes by the total rates collected in each whaitua and council area in the year to June 2022 to indicate what percentage increase in rates (costs borne by the community) would be necessary to support the wastewater infrastructure upgrades over different time horizons.

Results at a whaitua level are displayed in Figure 7. The bulk of the costs associated with improvements are expected to be in the Whaitua Te Whanganui-a-Tara. As a result, in the extreme case of these costs being covered entirely by general rates, in this whaitua rates would need to rise by up to 50% at implementation (and remain at that higher level throughout the implementation period) if the changes were implemented over a 10-year timeframe. Over a longer 40-year timeframe, rates would need to rise by up to a sustained 13% to cover the costs of improvements in undiscounted, unescalated terms.

Figure 7 Equivalent percentage rates increase by implementation timeframe, by whaitua

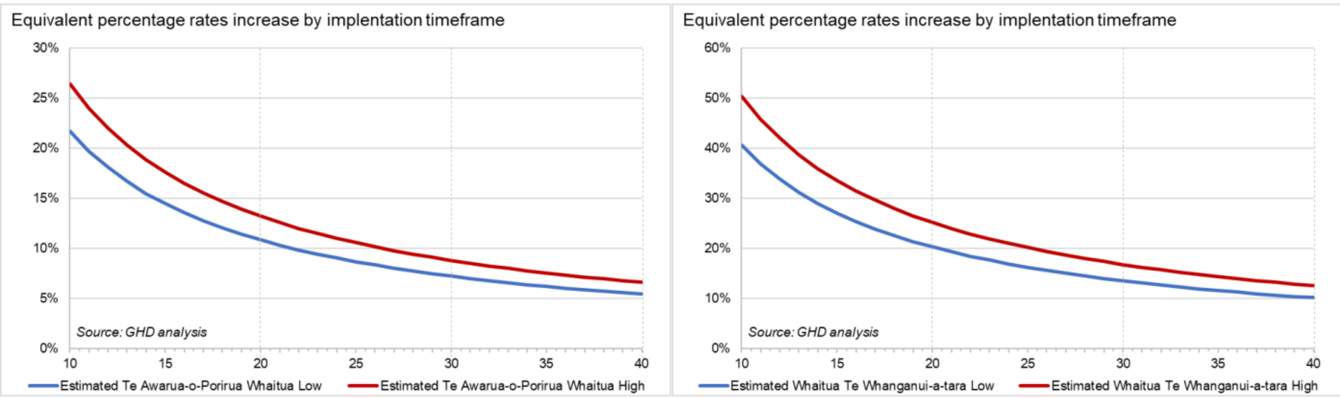


Figure 8 and Figure 9 show the effect on rates if that mechanism was chosen for covering the costs of improvements targeting *E.coli* levels. Implementing the proposed wastewater improvements in Hutt City over the current targeted 20-year implementation timeframe would impose a cost on residents equivalent to a 25-31% rates increase in Hutt City, a 12-14% increase in Porirua, a 29-37% increase in Upper Hutt, and a 16-20% increase in Wellington City. Shorter implementation timeframes would have much larger impacts on equivalent rates burden. If the changes were implemented over 10 years, the impacts would be 49-61% for Hutt City, 24-29% for Porirua, 59-73% for Upper Hutt, and 32-40% for Wellington City in undiscounted, unescalated terms. Over longer timeframes, the burden becomes more manageable, at an estimated 12-15% one-off and maintained rates rise for Hutt City, 6-7% for Porirua, 15-18% for Upper Hutt and 8-10% for Wellington over 40 years.

[8] GWRC. *Household and population forecasts*, completed by Sense Partners. Retrieved from http://demographics.sensepartners.nz/ on 10 March 2023.

Figure 8 Equivalent percentage rates increase by implementation timeframe, Hutt City and Porirua

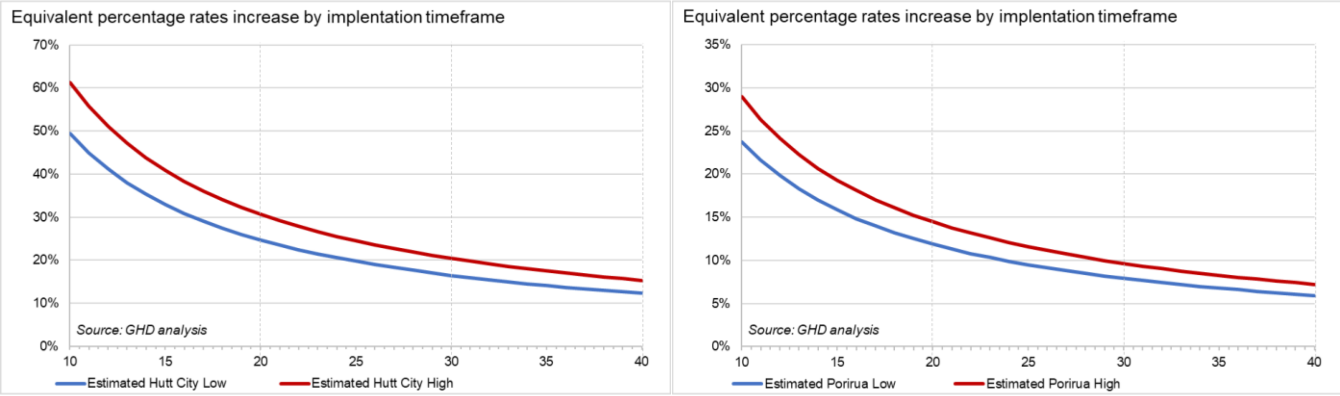
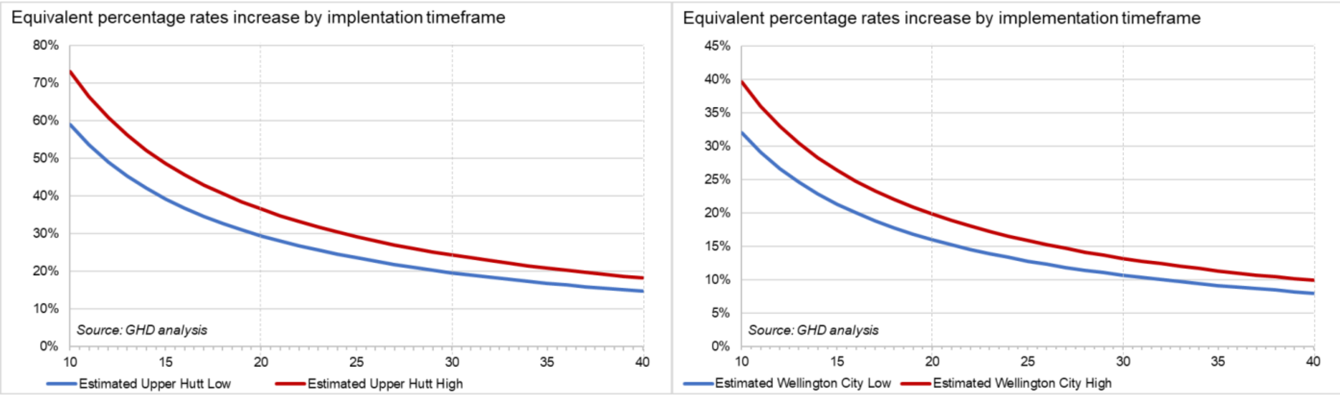


Figure 9 Equivalent percentage rates increase by implementation timeframe, Upper Hutt and Wellington City



5.2 Equivalent cost relative to household incomes

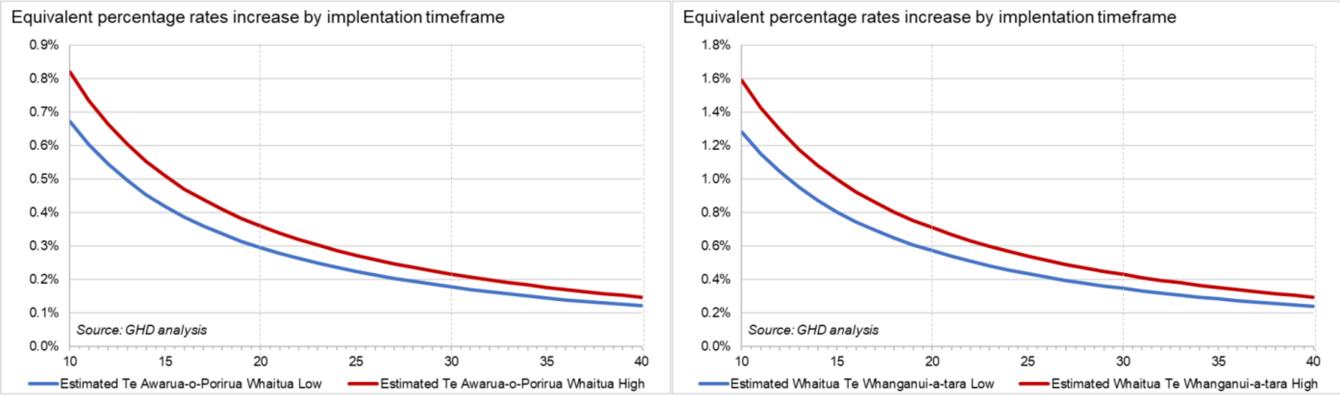
Another way to consider the affordability of the costs to improve water quality is to estimate the equivalent annual cost per household (bearing in mind previous comments that not all these costs will be covered directly by general rates) as a share of today's household income.

We use household incomes today again for the sake of simplicity, and in acknowledging that, while somewhat transitory, New Zealand is in an environment where inflation is growing faster than wages. This means trying to allow for growth in real wages (stripping out inflation) may imply having to assume real wages fall over the next two to three years.

Statistics New Zealand census data provides household incomes as of 2018 by council area. This data was used, along with the estimate of the number of households in each whaitua in 2018, to estimate household incomes by whaitua for 2018. Data from Infometrics provided estimates of household incomes for constituent councils for 2022. Using these growth rates, we were again able to estimate household incomes by whaitua for 2022.

Dividing the estimated per-year spend required for each whaitua and council area by household income in 2022 for each implementation timeframe provides an estimate of the additional share of household incomes that would be required for the wastewater improvements. The results are shown in Figure 10 for the two whaitua and in Figure 11 and Figure 12 for the four constituent council areas.

Figure 10 Equivalent share of household income required by implementation timeframe, by whaitua



Because of the higher share of costs to improve water quality in the Whaitua Te Whanganui-a-Tara, a larger share of household income will be required to apply to improving wastewater infrastructure with regard to *E.coli* than in the Te Awarua-o-Porirua Whaitua. At the target 20-year timeframe, an equivalent of 0.3-0.4% of 2022 household income would need to be committed to *E.coli* focused projects in Te Awarua-o-Porirua Whaitua each year for 20 years, compared with 0.6-0.7% for Whaitua Te Whanganui-a-Tara, in undiscounted, unescalated terms. At a 10-year timeframe, these proportions double, while they halve over a 40-year timeframe.

Figure 11 Equivalent share of household income required by implementation timeframe, Hutt City and Porirua

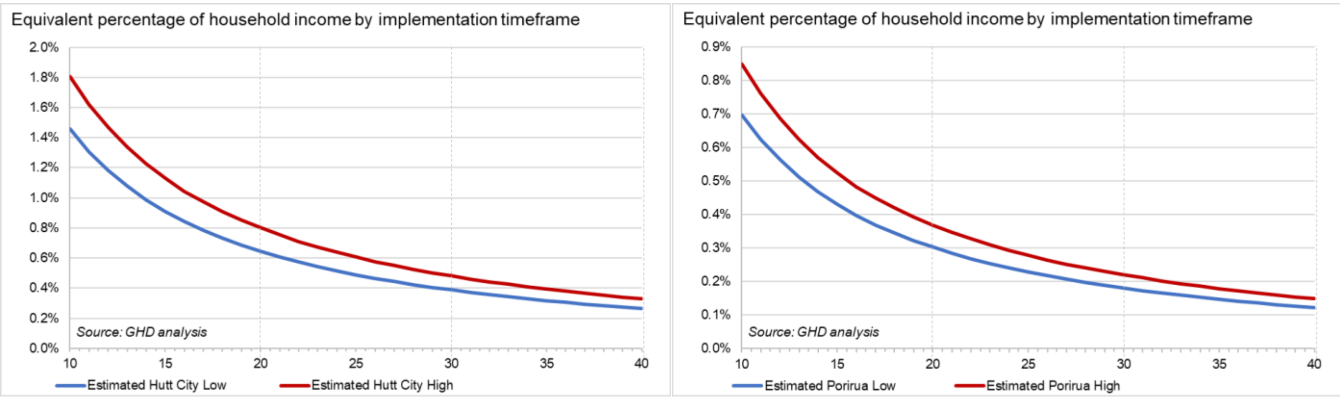
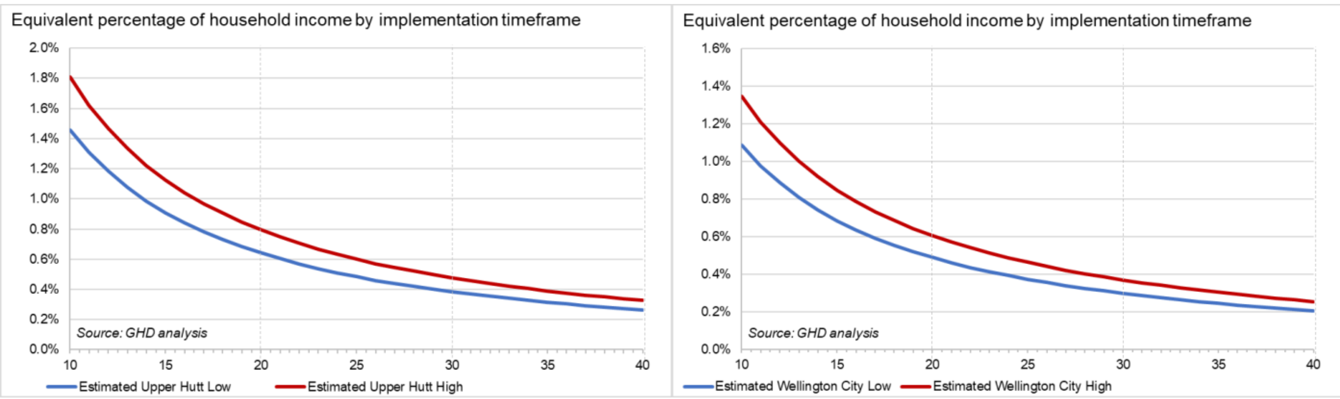


Figure 12 Equivalent share of household income required by implementation timeframe, Upper Hutt and Wellington City



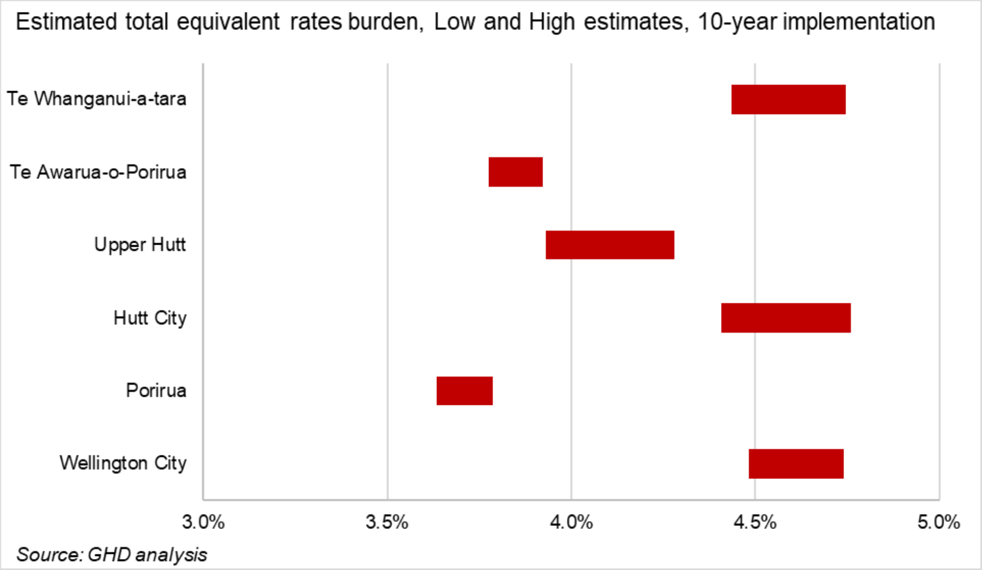
Of the four council areas, assuming that the costs are shared across councils within the whaitua roughly in line with current rates shares, the biggest impacts are in Upper Hutt and Hutt City, where up to 1.8% of annual household incomes in 2022 would be consumed by actions to reduce *E.coli* levels. Over a 20-year implementation timeframe, the equivalent shares of household income required would be the equivalent of 0.6-0.8% in Hutt City, 0.3-0.4% in Porirua, 0.6-0.8% in Upper Hutt, and 0.5-0.6% in Wellington City.

5.2.1 Overall impacts on affordability

The Shand Inquiry recommended that property rates should not account for more than 5% of a household's income at the upper end of charges.[9] Having evaluated the equivalent impact of the investment needed to reduce *E.coli* levels in terms of rates and in terms of household incomes, those two components are now brought together with current rates bills. This allows us to estimate the total burden of current rates levels and potential costs to improve wastewater outcomes as a share of household incomes.

There are caveats to this analysis. Councils are facing steep rates rises already as borrowing costs have risen and as they seek to overcome infrastructure shortfalls across various infrastructure classes. Some of the costs of improving wastewater outcomes will, on the other hand, be captured in those planned investment budgets. Consequently, the figures presented here should only be considered as indicative. In none of the scenarios, council areas or whaitua, does the sum of current rates bills plus the equivalent implied increase in rates for funding wastewater improvements breach the 5% threshold, as demonstrated in Figure 13.

Figure 13 Equivalent total rates burden assuming 10-year implementation period



Across a 10-year implementation period, acknowledging the assumptions set out throughout this report, the total equivalent rates burden (notwithstanding not all the costs may be paid in rates) could see costs to households reach 4.8% in Hutt City. At longer implementation timeframes, the total equivalent rates burden would be lower.

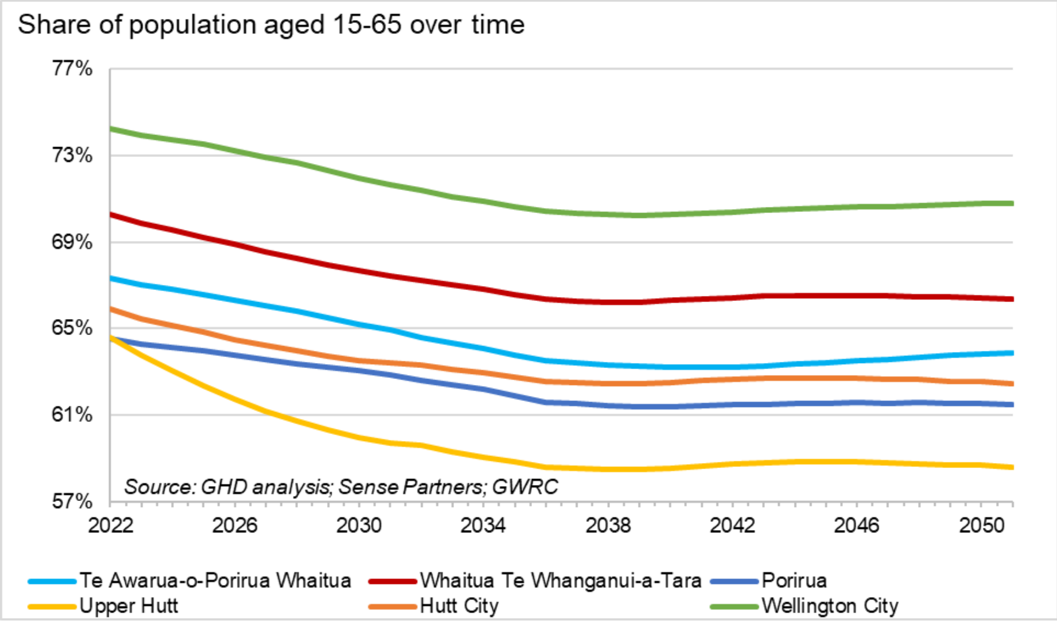
5.3 Local population demographics

People under the age of 15 and over the age of 65 are far less likely to be earning an income than those aged 20-65. While median household incomes provide a good idea of the burden of an increase in costs, they do not provide an indication of households with residents at either end of the age spectrum, where affordability can be more of a challenge.

GWRC population projections provide an insight into the current and potential future mix of age groups across the four constituent council areas. Figure 14 shows changes in the share of the population in each whaitua and council area that are working age over the next 30 years.

[9] Shand, D et al. (2007). *Funding Local Government: Report of the Local Government Rates Inquiry*.

Figure 14 Estimated share of population of working age by whaitua and council area, 2022 to 2052



Wellington City has by far the highest share of people of working age. This is a function of its role as a university city that attracts young people, and the large role government and government support industries play in the region.

At the other end of the spectrum, Upper Hutt has an unusually large share of over-65s for the region, while Porirua has a large proportion of young people and children. This means larger proportions of households in these two council areas are likely to find the impact of a large increase in costs to cover water infrastructure upgrades harder to afford than would be the case in Wellington City for instance.

6. Benefits of the improvements

This section quantifies the public use and non-use value benefits of lower *E.coli* levels in water bodies due to wastewater improvements. It further discusses the cultural value of improved water quality and provides a proxy for the private benefit that improved water quality can have on property values. These benefits are summarised in Figure 15.

Figure 15 Summary table of benefits identified of wastewater improvements

Benefit	Quantified, proxied or described value
Value of cleaner water for users of water bodies	$159-235 million over 50 years
Value of cleaner water for non-users of water bodies	$229-337 million over 50 years
Cultural value of cleaner water	Unquantified
Potential impact on tourism spending from better environmental reputation	$700 million over 50 years
Private property value increase from proximity to cleaner water bodies	$24-34,500 per property in proximity

In summary:

- ***Use values*** are estimated at $159-235 million in undiscounted, unescalated terms over the next 50 years ***($212 million at a 20-year implementation*** timeframe).
- ***Non-use values*** are estimated at $229-337 million in undiscounted, unescalated terms over the next 50 years ***($305 million at a 20-year implementation*** timeframe).
- The ***cultural value*** to mana whenua of cleaner water due to less *E.coli* contamination is hard to quantify and has not been quantified in this report, but is likely to be considerable given traditional ties to water and land.
- The state of water quality in Wellington is sufficiently poor that it ***affects the region's reputation*** as a part of the "100% pure New Zealand" brand. If even 1% of tourists who would otherwise visit the region do not materialise because of a poor *E.coli* reputation, that would be around $700 million in costs over the next 50 years (undiscounted and without allowing for growth in tourism numbers nationally).
- Target states for water bodies in the two whaitua suggest reduction in *E.coli* levels of two-thirds to three-quarters across the whaitua. International studies suggest this could add ***private benefits of between $24,000 and $34,500 in value per property*** located within 500 metres of a cleaner water body.

6.1 Public benefits of better wastewater outcomes

There are a number of public benefits that result from a reduction of *E.coli* levels due to better wastewater management. These are the main reasons to implement the changes. However, they are often hard to meaningfully quantify in dollar terms because they are what economics calls "non market traded" values. The cultural value people derive from knowing the waterways their families have traditionally been connected to are cleaner than they were, for instance, is hard to express in dollars. That does not make these benefits any less real; it just makes them more intangible. The genuine benefits set out in this section should always be held in mind when considered against the (typically financial) costs of implementing the changes.

6.1.1 Use values from improved water quality

Use values of cleaner water include:

- use of water for fishing or food gathering
- use of water for cultural practices
- recreational use of water for swimming and other water-based activities.

Waterways have value as ***food sources***. People derive value from access to clean water bodies for drinking and food purposes (fishing, gathering and the like). Māori in particular value water for its *mahinga kai* (value of food resources and their ecosystems) and for *kai moana* (food from the sea).

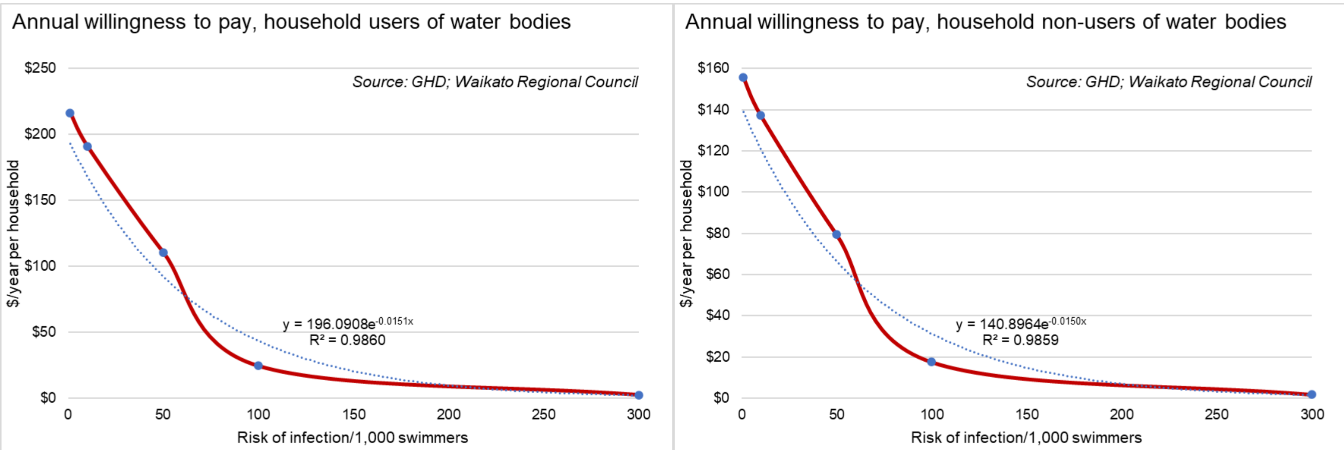
Secondly, improved access to cleaner water is likely to improve the ***recreational value*** of rivers, lakes and the coast. Being able to use water recreationally supports a healthier lifestyle.

Putting a dollar value on these values is hard. Work done by Auckland Council demonstrated how many Council amenities provide value to those who use them as well as to those who do not.[10] One pertinent example for the work at hand is what the Auckland Council work demonstrated about the use value of parks. Those who use Council parks derived significant value from them – around $376.50 per household per year in today's dollars. They derive this value from parks based on the way they can use parks. Other amenities that provide some of the same uses as rivers, lakes and beaches that were covered by the Auckland Council study include swimming pools ($290 of value a year for user households) and sports parks ($147 of value a year for user households). These figures provide an indication of the recreational value of amenities that have some overlap with water bodies. They do not account for the financial value to those who use them for gathering food, for instance. Nor is it likely these figures capture the cultural value of a clean waterway (dealt with separately in this report).

But a study in the Waikato Region provides possibly the most useful estimates of the use (and non-use) values for differing levels of risk of infection from water bodies.[11] The study estimated the willingness to pay that people have for different (lower) levels of risk of infection, updating figures from an earlier 2014 report.[12] The original study found that 31% of people had used a river, stream, lake or wetland in the Waikato (i.e. users) and 69% were non-users. It then used revealed and stated preference analysis to estimate the willingness to pay that users and non-users had from different levels of risk of infection.

Figure 16 shows the results of the study, updated to 2022 dollars, for users and non-users of the water bodies. We have also shown the approximate modelled pattern of the curves that allow us to estimate the value people derive from movement between any two points on the curve. It demonstrates, for instance, that as the risk of infection falls from 300 per 1,000 swimmers to 100 per 1,000, willingness to pay rises about $23 for users (from $2 to $25). As risk of infection falls even lower, the value to people rises far more sharply. As risk of infection falls from 100 to 10 per 1,000 swimmers, the value rises by a further $167 per household.

Figure 16 Willingness to pay for lower risks of infection



GWRC has set current and targeted freshwater attribute states for *E.coli* for both whaitua.[13] Combining this Wellington level of risk by water body grading with the curves in Figure 16 allows us to estimate what an

[10] Auckland Council. (2020). *Use and non-use values of Auckland Council amenities*. Retrieved 13 March, 2023, from https://knowledgeauckland.org.nz/media/1892/use-and-non-use-values-of-auckland-council-amenities-july-2020-nexus-et-al.pdf
[11] Ministry for the Environment (2020). Essential Freshwater Package: Benefits Analysis. Retrieved 15 March 2023, from https://environment.govt.nz/assets/Publications/Files/essential-freshwater-package-benefits-analysis.pdf
[12] Waikato Regional Council (2014). *Non-market values for fresh water in the Waikato region: a combined revealed and stated preference approach*. Retrieved 15 March 2023, from TR201417.pdf (waikatoregion.govt.nz)
[13] Current state and desired target attributes states for *E.coli* provided by GWRC as outlined in Te Whaitua te Whanganui-a-Tara Implementation Programme (gw.govt.nz) and Te-Awarua-o-Porirua-Whatiua-Implementation-Programme.pdf (gw.govt.nz).

improvement in water bodies from, say, Grade D to Grade C would mean in value per using and non-using household.

Te Awarua-o-Porirua whaitua

The five target attribute state sites within water bodies in the Te Awarua-o-Porirua whaitua had particularly high levels of *E.coli*, contibuting to a simple average risk of infection of 110 per 1,000 people in the current state. The proposed improvements would dramatically reduce the risk of infection across water bodies to around 26/1,000. Figure 16 shows that as we move from the higher risk to lower risk, the difference in willingness to pay between these two levels of risk of infection is around $95 per ***using*** household per year.

Whaitua te Whanganui-a-tara

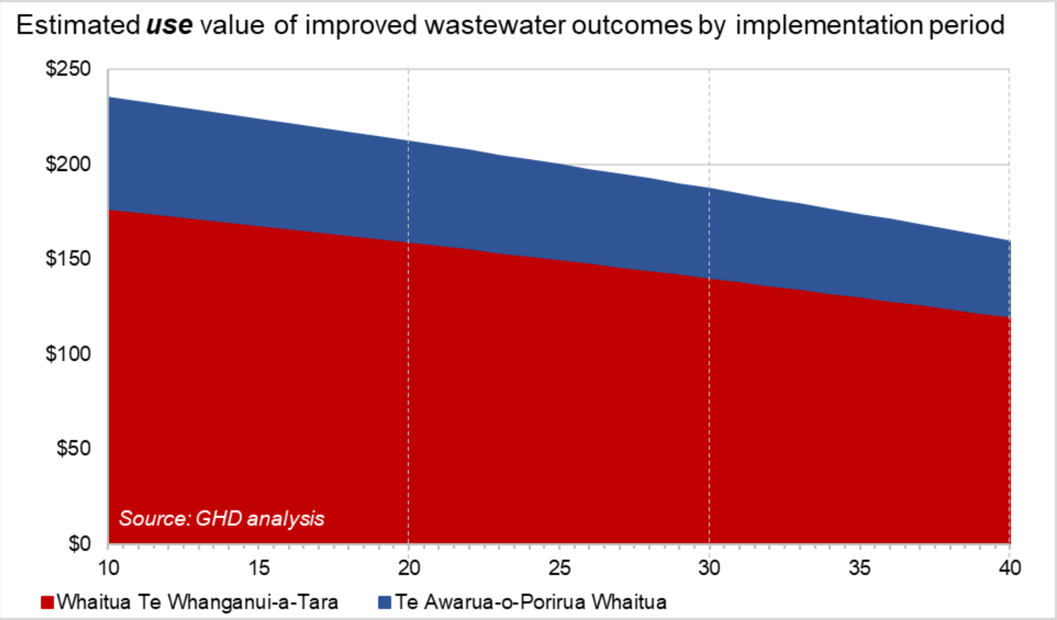
The 12 target attribute states within water bodies in the Whaitua Te Whanganui-a-Tara also had high levels of *E.coli*, contibuting to a simple average risk of infection of 77 per 1,000 people in the current state. The proposed improvements would dramatically reduce the risk of infection across water bodies to around 25/1,000. Figure 16 shows that as we move from the higher risk to lower risk, the difference in willingness to pay between these two levels of risk of infection is around $73 per ***using*** household per year.

Estimate use value by implementation period by whaitua

Multiplying these values by the number of ***user*** households (rounded down to 30%) assumed to be in each whaitua over the next 50 years provides a basic estimate of the value of use benefits in ***undiscounted*** terms so as to match the cost stream, which is measured in today's dollars undiscounted.

We are able to modify this value based on the assumed implementation timeframe. For instance, if we assume the benefits are implemented over a 10-year timeframe, they are higher than if the timeframe taken is longer because in any given year the share of the remediation work completed is lower when a longer implementation timeframe is adopted. We present the benefits based on implementation timeframes in Figure 17.

Figure 17 Estimated use value of wastewater improvements by years to full implementation



Because of its much smaller number of households, Te Awarua-o-Porirua receives about a third of the benefit that Whaitua te Whanganui-a-Tara is estimated to receive even though its benefit per household because of the greater improvement in water quality is higher. Total use value benefits to households over a 20-year period by improving water quality by reducing *E.coli* risk are around $212 million in undiscounted terms. Over a 40-year implementation timeframe this drops to $159 million in undiscounted terms.

6.1.2 Greater cultural value of knowing water is cleaner

Te Mana o te Wai is part of the National Policy Statement for Freshwater Management and describes the vital importance of water. The presence of *E.coli* is a significant issue for mana whenua, and is the cause of cultural distress. According to Māori beliefs, the presence of wastewater in waterbodies impacts significantly on the mauri of the waterbodies. Further, it creates an unacceptable health risk associated with various cultural practices, including collecting and eating mahinga kai. The inability of mana whenua to undertake their traditional cultural practices results in a loss of cultural identity and intergenerational knowledge. Improving the wastewater network, and thus removing the presence of *E.coli* in water bodies will bring significant benefits from a cultural perspective that are hard to quantify. Healthy waterways are important for cultural practices such as exercising *ahikaroa* and *kaitiakitanga*.[14]

Clean water is an integral part of life satisfaction and happiness, as clean water plays an important role across many cultural traditions.[15] *Kaitiakitanga* (guardianship and protection) is the traditional Māori concept focussed on the protection and conservation of the environment. Māori consider water to be the source or foundation of all life.

The improvement of water bodies may have financial and social implications. Water bodies within the whaitua were rich for kaimoana and related resources, pipi, pupu, kina, paua, mussels, oysters and other species of fish and seafood that sustained the people.[16] Having clean, safe, sustainable water ways for all reduces peoples need to travel to alternative swimming/food sources, or to purchase food that can be collected instead. This will also reduce the health risks, particularly those who, despite health warnings, choose to swim and collect food in the water polluted harbours and streams.

Investing in wastewater improvements works towards restoring the mauri of waterways. The reduction of human waste prevents the contamination of water, and the subsequent spiritual and cultural loss to the community. Improving the quality of water, through minimising the presence of human waste, works to restore the mana whenua relationship with their *takiwā* (traditional region), restoring the ability for cultural practices and the transmission of intergenerational knowledge.[17]

Improving water quality can also improve people's sense of place. Through improving the quality of water, this can enhance people's connection and sense of responsibility for sustaining and caring for the wellbeing of local waterways and estuary.

6.1.3 Non-use values from improved water quality

Non-use value of cleaner water include:

- Option value
- Bequest value
- Visual or sensory amenity value.

Access to cleaner water has an ***option value***. This well-documented economic concept refers to the benefit conferred upon people by having the option to use the water, even if they do not use it.[18] Even those who are non-users of the waterways enjoy the benefit of knowing that it is there for use, and that it is clean.

Bequest value refers to the value people derive from knowing their children or grandchildren will also get to benefit from the same amenities, such as clean waterways.

Finally, cleaner water can have ***amenity value*** that is enjoyed by non-users. For instance, it can look cleaner, smell cleaner and give them enjoyment even though they do not use it.

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[14] Ministry for the Environment — Manatū Mō Te Taiao (2021). *Sources and impacts of freshwater pollution*. Retrieved 16 March, 2023, from Sources and impacts of freshwater pollution | Ministry for the Environment

[15] United Nations Educational, Scientific and Cultural Organisation. (2022). *UN World Water Development Report 2021: Cultural values of water*. Retrieved 16 March, 2023, from Cultural values of water | 2021 World Water Development Report (unesco.org)

[16] Ngati Toa Rangatira (2012) *Deed of Settlement of Historical Claims*. Retrieved on 16 March, 2023, from Ngāti Toa Rangatira Deed of Settlement 7 Dec 2012 (www.govt.nz)

[17] Te Kāhui Taiao (2021). *Te Mahere Wai, a Mana Whenua Whaitua Implementation Programme*. Retrieved 16 March, 2023, from te_mahere_wai_20211028_v32_DIGI_FINAL.pdf (gw.govt.nz)

[18] Science Direct. (1999-2021). *Option Value*. Retrieved January 12, 2022, from https://www.sciencedirect.com/topics/social-sciences/option-value

Again, the Auckland Council works provides some figures that set a range for the potential value of cleaner waterways for non-users. Even those who ***do not use*** Council parks derived significant value from them – around $185.50 per household per year in today's dollars. They derive this value from parks based on the visual amenity parks provide, and the option to use them if they so wish. Other amenities that provide some of the same uses as rivers, lakes and beaches that were covered by the Auckland Council study include swimming pools ($153 of value a year for ***non***-user households) and sports parks ($123 of value a year for ***non***-user households).

But again, the Waikato Regional Council work provides good estimates specifically for the non-use of water bodies. The curve for willingness to pay by non-users has already been introduced in Figure 16. Again as one shifts from a risk of infection of 300 per 1,000 swimmers to 100 per 1,000, the willingness to pay (in 2022 dollars) rises about $16 per household per year. As water quality improves from a risk of 100 to a risk of 10 per 1,000 swimmers, the change in non-user value rises by $120.

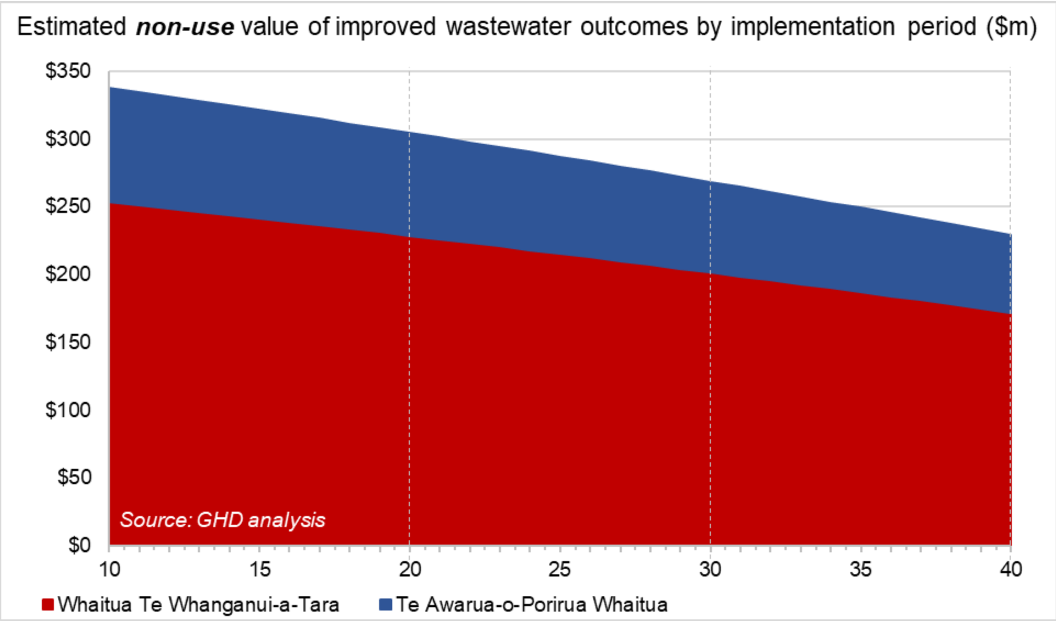
Estimate non-use value by implementation period by whaitua

Multiplying these values by the number of ***non***-user households (rounded to 70%) assumed to be in each whaitua over the next 50 years provides a basic estimate of the value of use benefits in ***undiscounted*** terms so as to match the cost stream, which is measured in today's dollars undiscounted.

We are able to modify this value based on the assumed implementation timeframe. For instance, if we assume the benefits are implemented over a 10-year timeframe, they are higher than if the timeframe taken is longer because in any given year the share of the remediation work completed is lower when a longer implementation timeframe is adopted. We present the benefits based on implementation timeframes in Figure 18.

The total benefit to non-users is actually greater than to users simply because more households are assumed to be non-users (70%) and because the difference in value derived by users and non-users is not that great). The total value derived by non-users over a 20-year implementation timeframe is estimated at around $305 million in undiscounted terms in total, compared with $229 million in total over a 40-year timeframe, as Figure 18 demonstrates.

Figure 18 Estimated non-use value of wastewater improvements by years to full implementation



6.1.4 Reputational value of improved water quality

New Zealand is known internationally for its "100% pure New Zealand" branding. Water quality challenges around the country put this image at risk. According to Infometrics, annual tourism GDP (gross domestic product) in New

Zealand was around $15 billion pre-COVID, or $41 million a day.[19] With borders now open, we can expect tourism to return to these sorts of levels over the next couple of years.

Within the total, the Wellington Region accounted for around 10% of total tourism GDP pre-COVID, or $1.4 billion a year. If even a small share of this tourism spending is at risk due to ongoing and growing wastewater management challenges, the impact on Wellington tourism GDP and employment could be significant. For instance, if just 1% of Wellington's pre-COVID visitors were to choose not to visit because of a growing reputation for wastewater challenges and poor water quality, the cost to the region would be over $14 million a year. Over a 50-year timeframe, this impact would be $700 million.

6.2 Private benefit to property owners

Living near water bodies that are not as prone to contamination by *E.coli* as they used to be improves the amenity of those water bodies (because of their greater useability) and therefore the value of properties nearby. This is a private benefit that accrues to property owners near water bodies that benefit from reduced *E.coli* levels. A meta-analysis conducted by the US Environmental Protection Agency demonstrated that there are statistically significant benefits from reduced *E.coli* levels for properties near water bodies.[20] For properties within 500 metres of a water body, a 1% reduction in *E.coli* levels is associated with a 0.05% increase in property value. In the two whaitua, where the targeted reduction in *E.coli* levels is between 67% and 76%, this implies a gain in property values of between 3.5% and 4.0% for properties near to water bodies.

It is beyond the scope of this work to estimate the number of properties within 500 metres of each water body, or the value of properties within each of those catchments. But median property values for Wellington City, Porirua, Upper Hutt and Hutt City range between $685,000 and $950,000.[21] At these proposed water quality improvements levels and these median house prices, properties within 500 metres of benefitting water bodies could see ***property values rise by between $24,000 and $34,500 per benefitting property*** within the various catchments.

[19] Infometrics. Retrieved on 13 March, 2023, from https://ecoprofile.infometrics.co.nz/Wellington%2bRegion/Tourism/TourismGdp
[20] U.S. Environmental Protection Agency National Center for Environmental Economics. (2019). *Property values and water quality: A nationwide meta-analysis and the implications for benefit transfer*. Retrieved on 22 March, 2023 from https://www.epa.gov/environmental-economics/property-values-and-water-quality-nationwide-meta-analysis-and-implications Retrieved on 22 March 2023 **from** https://www.epa.gov/environmental-economics/property-values-and-water-quality-nationwide-meta-analysis-and-implications
[21] REINZ. (2023). *REINZ Monthly Property Report - February 2023*. Retrieved on 22 March, 2023, from https://www.reinz.co.nz/libraryviewer?ResourceID=513 Retrieved on 22 March 2023 from https://www.reinz.co.nz/libraryviewer?ResourceID=513

7. The funding toolkit

Given the significant costs associated with improving water quality set out in the previous chapters of this report, considering who should pay and what tools are available is fundamentally important from an equity, transparency or affordability perspective. This chapter sets out some basic principles of project prioritisation and funding, before evaluating the range of funding tools available in some detail. In summary:

- Infrastructure needs to be of the right type, delivered to the right place, paid for by the right people at the right price announced at the right time using the right funding mechanism if it is to be effective.
- There are numerous funding mechanisms or tools available, ranging from general rates and targeted rates to tools targeting new development such as development contributions or infrastructure growth charges, through to ad-hoc tools such as developer agreements to deliver infrastructure or central government investments when projects meet certain criteria.
- Not all funding tools are equally good, nor appropriate for wastewater investment. There are at least 10 considerations in choosing an appropriate funding tool, including whether use of a tool unlocks further borrowing capacity or enjoys public acceptance and transparency.
- Under central government's current plan to manage water through four entities, the tools available are likely to be more limited, and the bulk of costs will be borne by water customers, who are by and large the same people as ratepayers.

7.1 The six principles of prioritisation and funding

To make good investment choices, and to enjoy widespread support, it is crucial to deliver the right infrastructure to the right place, paid for by the right people at the right price, announced at the right time using the right funding mechanism.

7.1.1 The right infrastructure

> ***"…deliver the*** **right infrastructure** ***to the*** **right place** ***paid for by the*** **right people** ***at the*** **right price** ***announced at the*** **right time** ***using the*** **right funding mechanism*****."***

"***Should we be building this infrastructure at all?***" is the first question to ask. This report has already discussed the challenges of prioritising projects that have maximum benefit, given the cost involved.

Not every project that can be delivered, even if it meets one or more objectives, is a good project to deliver because of the inevitable trade-offs required with a limited budget. In an ideal world with unlimited resources and time, one would undertake a comprehensive cost-benefit analysis of each project's quantified benefits and costs. But in the real world, while large projects should still be subject to that very detailed level of scrutiny, time and resource constraints mean smaller projects cannot practically be subjected to the same level of testing. But the key is to have a good idea of whether the benefits of the project (in meeting objectives) outweigh the costs.

7.1.2 The right place

Infrastructure and, consequently, infrastructure charges should ***incentivise development and water quality improvement in places that achieve the desired objectives***. The natural way this happens is through accurate pricing (discussed further below). If it is cheaper to improve water quality in a certain area, for instance, then that should be reflected in the costs of development there.

7.1.3 The right people

In thinking about who pays for something, economics starts with the position that those who benefit from something most (in this case, infrastructure) should be the ones who pay the bulk of the cost. Following this rule reduces the risk of bad investment decisions where some areas receive investment at huge subsidy from others, creating artificially low development costs that do not get accounted for in local land prices. It is important to acknowledge that determining who benefits and by how much is sometimes a challenge, so often this is a best estimate rather than a calculation with certainty.

Occasionally, it may also be appropriate to depart somewhat from this principle on equity grounds (e.g. where the cost of water quality improvement in one location is so high that it cannot be borne only by the residents of that discrete location). However, this should be the exception, not the norm. In summary, areas that benefit most should contribute most to the cost of those improvements.

7.1.4 The right price

This discussion has already touched on the importance of charging the right price for infrastructure provision in general or water quality improvements more specifically. When the true cost of infrastructure is not charged, it incentivises undesirable behaviours. This exacerbates not only the funding shortfall that infrastructure agencies often struggle with through the under-collection of the true cost of those infrastructure projects but can also mean poorer outcomes.

A further point that must be made on pricing is that charging a higher, more accurate price for infrastructure or expecting development to keep to a better standard on water quality does not push house prices up. It pushes land prices down.

If infrastructure providers signal that development will need to pay its own way for water quality, land prices will fall to reflect that fact, rather than house prices rising."

The Auckland experience and the international literature both demonstrate this. Work completed by the Chief Economist Unit at Auckland Council suggested that, at the time of the work, land purchasers outside Auckland's Rural Urban Boundary were overpaying for land on the assumption that the general ratepayer would continue to greatly subsidise infrastructure in those areas. In other words, land prices reflect the price developers believe they will have to pay for infrastructure. If infrastructure providers signal that better infrastructure is needed to better manage water quality on (re)development sites, own way, land will fall to reflect that fact, rather than house prices rising.[22]

The international evidence on this trend for costs to pass up the chain rather than down to house prices is also instructive. In almost all cases, the vast majority of costs passed up to land values.[23]

7.1.5 The right timing

The signal that those who benefit from improvements will primarily need to pay for it is a vital message to communicate. Infrastructure plans should not be announced before it is clear how those improvements are proposed to be funded. This avoids the risk that properties continue to trade hands without the information needed for buyers to make informed decisions about what the infrastructure costs for improving water quality in that location may be. Announcing intentions about how new infrastructure will be in advance ensures that property sales do not occur at true market prices.

Right timing also refers to when the infrastructure is built. Infrastructure should be built at a time that ensures timely uptake of the new capacity that justifies the investment.

7.1.6 The right funding mechanism

The funding tool or mechanism is the actual legal instrument and process that accesses the money to undertake the infrastructure improvements. Funding tools that can be charged by local governments can range from general rates charged on all residents of an area, to targeted rates for a specific use in a specific location, to development contributions (DCs), financial contributions, infrastructure growth charges, targeted levies with central government or even ad-hoc agreements with specific developers for them to directly deliver certain infrastructure components.

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[22] See Shane Martin and David Norman, *An evidence based approach: Does the Rural Urban Boundary impose a price premium on land inside it?* 2020. https://www.aucklandcouncil.govt.nz/about-auckland-council/business-in-auckland/Reports/does-the-rub-impose-a-price-premium-on-land-inside-it-20-Feb-2020.pdf

[23] See Harshal Chitale, *Unshackling growth Growth paying for itself*. 2018. https://www.aucklandcouncil.govt.nz/about-auckland-council/business-in-auckland/docsoccasionalpapers/unshackling-growth%20-%20April%202018.pdf

Other tools that do not yet have a legal basis are also being discussed, such as value capture (VC) mechanisms. There are several criteria against which to evaluate funding tools, as will be discussed later in this report.

7.2 The commonly used funding tools

There are several tools already available to local government for funding infrastructure, and an additional tool is currently being proposed. We would note that other ad-hoc grants and funding channels are at times accessible (such as shovel-ready projects in the wake of the COVID-19 lockdowns). These are not dealt with here because their structure and use varies on a case-by-case basis. Nevertheless, there are arguments for using these ad-hoc tools where the costs to be locally borne would otherwise be prohibitively large, a point we return to later.

- **General rates** are the largest single source of income for local governments. These are charged on residential and business properties and include both a fixed (general uniform) rate and a component based on property value. The variable component can be based on the property's capital value (land plus improvement value) or on land values. In cases where specific infrastructure charges do not cover the full cost of that infrastructure, general rates (all ratepayers) pick up the tab, which can be a misalignment with the economic principles set out above, specifically that those who benefit should pay.
- **Targeted rates** are collected by local councils for a specific purpose and in a specific geography, for example to fund the construction of the Wellington Regional Stadium in 1999. Some councils charge a rate targeted to a specific purpose but not geography, but this is effectively a general rate charged as a flat charge per rateable property or as a function of rateable value.
- **DCs** are most commonly used by local governments to ensure new development contributes toward new infrastructure to facilitate that growth. DCs are generally charged at subdivision resource consent, at building consent for an additional dwelling on a site or, in rare instances, at service connection.
- **Infrastructure growth charges** (IGCs) are functionally similar to DCs but are contractual charges at the time a property first connects to the network. Like DCs, they are designed to ensure that the cost of new infrastructure is allocated to those who will benefit from the assets or require the addition of new assets to service demand. Conceptually, IGCs could be applied to any network but connection to a water network is a more practical scenario for using an IGC than for roading infrastructure, for instance.
- **Financial contributions** can be charged under the Resource Management Act provisions rather than the Local Government Act provisions used for most other funding tools introduced here. The purpose of financial contributions, which can be in the form of money and/or land, is to address the environmental effects of development. They can be used to fund similar assets as DCs, but DCs and financial contributions cannot both be charged on the same asset.
- **Developer agreements** are voluntary agreements between developers and a council agency. They allow for the direct provision of infrastructure or land by the developer. The developer agreement can in these instances replace other funding tools that would otherwise have been applied, such as DCs.
- **Targeted levies** are functionally equivalent to targeted rates in how they are administered. The big difference is that they allow access to third-party funding (the Crown in the current form of the law) via the new Infrastructure Funding and Financing Act of 2020. Subject to legislative change, it may be possible, at some point in future, to use targeted levies to provide access to non-government third parties.
- **Value capture tax tools** (not yet legal in New Zealand) seek to capture, for government, some of the private value gains that accrue to property owners in particular locations, as a function of government investment there. They are based on the economic principle of "beneficiary pays"; those who benefit from investment in a specific location should be the ones who primarily pay for it. As such, they make good economic sense, but as described above, can be very hard to accurately measure and enforce.

7.3 Choosing the right funding tool

There are at least 10 considerations in choosing the right funding tool. This section sets out these considerations with some practical examples of tools that meet them well or that do not.

7.3.1 Is this tool easy to administer and enforce?

Any tool that is hard to calculate or where the infrastructure provider has no ability to enforce collection is weak. For instance, the processes to establish property values (land and improvements) are well documented and have been similar for many years. This makes the use of general or targeted rates on capital value or land value easy to administer. They are also easily enforceable. This paper has already touched on the ability to estimate VC impacts at the other end of the scale. In the middle are any more ad-hoc tools such as targeted levies or developer agreements, where the tool is relatively new (in the case of a targeted levy) or where court action may lead to unexpected outcomes.

Best tools in the toolbox: DCs, general rates, and targeted rates

7.3.2 Can this funding tool be borrowed against?

This is one of the great weaknesses of DCs. DCs require councils to forecast what the development community is going to do, which is hard both in times of rapid house price growth and in times of decline as is currently being experienced. This means the revenue stream from DCs is uncertain and is not counted as a stable revenue stream against which to borrow by credit ratings agencies. General and targeted rates, on the other hand, are practically guaranteed revenues, underpinned by the property against which they are issued.

"…the revenue stream from DCs is uncertain... General and targeted rates, on the other hand, are practically guaranteed revenues…"

Best tools in the toolbox: General rates, and targeted rates

7.3.3 Does this funding tool create certainty of timing?

Closely tied to the previous point, any tool involving guesswork (even if informed by data) about when the revenue will be generated and therefore when it can be borrowed against or spent on infrastructure, creates uncertainty. If one is relying on an uncertain revenue source like DCs, it also means one cannot have the confidence to start building a piece of infrastructure because if the development market hits a downturn, one's revenue stream to pay for the infrastructure becomes highly uncertain.

Best tools in the toolbox: General rates, targeted rates, and targeted levies

7.3.4 Does this tool incentivise development?

To make sure that a piece of new infrastructure does not sit under-utilised if development materialises more slowly than anticipated, a funding tool that encourages more rapid development is needed. Tools like DCs, which are triggered when a developer begins development, disincentivise development because the longer development is delayed, the longer until payment is required. Tools like targeted rates, which are charged regardless of whether development slows or accelerates, nudges development along because the landowner at any given time contributes whether they are developing or not. Developers are, albeit to a limited extent, incentivised to develop.

One other major incentivising element to funding tools is available through the economically-sound application of general or targeted rates. While general rates are not always a good way to fund new infrastructure, if they are used, basing them on land values rather than capital values is more likely to incentivise efficient use of land. The advantages of a land value-based ratings system are covered in depth in a paper by Auckland's Chief Economist Unit.[24] In summary, capital value-based taxes penalise people for developing land efficiently. Land value-based taxes incentivise people to use land efficiently. Both approaches are legal in New Zealand.

Best tools in the toolbox: Value capture, targeted rates, and targeted levies

[24] See David Norman and Shane Martin, *Landing on the right ratings base for Auckland*. 2020. https://www.aucklandcouncil.govt.nz/about-auckland-council/business-in-auckland/docsoccasionalpapers/landing-on-the-right-ratings-base-for-auckland.pdf

7.3.5 Can this funding tool be hypothecated?

Local governments are challenged by a period of huge cost escalation, necessary infrastructure investment and insatiable demands for service improvements from the public. These realities are triggering bigger rates rises to avoid infrastructure failure. Charging extra to fund a specific piece of infrastructure, using a tool that can be ring-fenced for that purpose, can be more palatable to residents. Targeted rates, targeted levies and DCs can all be used in this way, providing transparency as to what the funding goes toward.

Best tools in the toolbox: Value capture, DCs, IGCs (if they could be applied to the transport network), developer agreements, targeted rates and targeted levies

7.3.6 Is this tool publicly acceptable?

In general, if a tool can be shown to primarily charge those who directly benefit from new infrastructure, it is likely to enjoy greater support. However, this is an area misunderstood, particularly by existing residents and ratepayers. Often, infrastructure investment results in improved or maintained property values (either because of improved amenity like a new bus route, or reduced risk because of water quality or flood protection work), but landowners do not always make the connection between the rise in their property value and infrastructure that enables this through, for instance, better transport or three waters provision.

Further, options such as rates postponements already exist for those who are asked to contribute a fair share to the cost of infrastructure that guards their property value, but who do not have the regular income to afford to pay for this. Under these policies, rates can be deferred until the property is sold and the windfall gain in value attributable to infrastructure can be realised.

Nevertheless, public acceptability of a tool can be a challenge. Some tools that show that development is broadly paying for itself are likely to be more acceptable, especially for greenfield growth where few people live at present.

Best tools in the toolbox: Value capture, DCs, IGCs (if applicable), financial contributions, developer agreements, targeted rates, and targeted levies

7.3.7 Does this tool unlock third-party spending?

This paper has already introduced some forms of third-party funding – primarily targeted levies in conjunction with central government, or voluntary developer agreements. The value of third-party funding comes only if this contribution to delivering infrastructure can be kept off the infrastructure agency's balance sheet.

There is scope to widen the list of agencies that may be able to provide this third-party funding, including NZ Green Investment Finance for example. This will increase the choice of financing partners available to local governments where the tool is already being applied.

Best tools in the toolbox: Developer agreements, and targeted levies

7.3.8 Is this tool inter-generationally fair?

In net present value terms, there should be no difference between a one-off accurately estimated DC charged to a developer (and included in house prices) and a 30-year targeted rate or levy imposed on a property instead. They should pay for the same infrastructure at the same approximate cost. However, the latter rate/levy mechanism is arguably considerably more transparent and logical to the non-technical observer of a contribution toward infrastructure costs because it is paid annually by the occupier of the property at any given time. This means the incidence of the levy or rate falls on the developer while they own the land, and on the home or business owner when they occupy the land. This creates a sense of intergenerational fairness that may favour targeted rates and levies over DCs for instance.

Best tools in the toolbox: Value capture, targeted rates, and targeted levies

7.3.9 Can this tool be used to build a kitty in advance of building?

A further consideration is whether a tool can be charged in advance of starting to build the infrastructure. This allows debt-heavy infrastructure agencies to build up a kitty to help pay for the infrastructure down the track. In the case of targeted rates, there is the added bonus of allowing councils to borrow against those collected funds to leverage up available funds to build infrastructure sooner.

Best tools in the toolbox: Value capture, DCs, IGCs (if applicable), financial contributions, general rates, targeted rates, and targeted levies

7.3.10 Is a legislative change needed to use this tool?

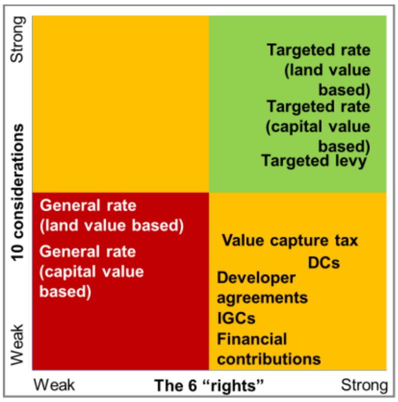
Except for value capture taxes, all these tools already exist in New Zealand law, so legally they can be applied although there may be limitations on the types of activities that can be funded by specific tools. Any time new legislation is introduced, it is a lengthy process that creates risk of perverse outcomes. That is not a reason to avoid new tools or legislation but does encourage one to consider the usefulness of existing tools before leaping after new ones.

Best tools in the toolbox: All tools other than value capture

7.4 Evaluating funding tools against the considerations

This paper has considered the need to deliver the right infrastructure to the right place paid for by the right people at the right price announced at the right time using the right funding mechanism. It has further examined 10 considerations in choosing the right funding mechanism or tool. This section provides a summary of where the different tools sit in their performance against the six "rights" and the 10 considerations.

Figure 19 Performance of different funding tools against the six "rights" and the 10 considerations



Considerations in choosing a funding tool in the transport growth context	Value Capture	DCs	IGCs	Financial contributions	Developer agreements	General Rates, Capital Value	General Rates, Land Value	Targeted Rates, Capital Value	Targeted Rates, Land Value	Targeted Levy (IFF)
Easy to administer / enforce?		✓				✓	✓	✓	✓	✓
Can be borrowed against?						✓	✓	✓	✓	
Creates certainty of timing?						✓	✓	✓	✓	✓
Incentives development?	✓							✓	✓	✓
Can be hypothecated?	✓	✓	✓	✓	✓			✓	✓	✓
Is publicly acceptable/ beneficiaries pay?	✓	✓	✓	✓	✓			✓	✓	✓
Can access 3rd party funding?					✓					✓
Is intergenerationally fair?	✓							✓	✓	✓
Can be charged in advance?	✓	✓	✓	✓		✓	✓	✓	✓	✓
Doesn't require legislative change?		✓	✓	✓	✓	✓	✓	✓	✓	✓

Targeted rates (levied by a council) and targeted levies agreed with central government (as being applied in Milldale in Auckland) are the tools that do best across both these ways of evaluating tools. General rates of various forms are among the weakest ways to fund infrastructure for several reasons.

7.4.1 When the funds would be received

It is vitally important to understand ***when*** funds would be received for infrastructure delivery. Any change in the tools used that means there would likely be a delay in accessing funding for infrastructure compared with the status quo would be a step backwards in terms of delivery.

Most tools can be implemented to collect money in advance of delivering the infrastructure to build a pool of funding to apply (consideration nine). However, to get a fuller picture of which tools are best for receiving the funds earlier and therefore getting infrastructure delivered faster, this question should be viewed along with whether:

- the tool provides leverage in terms of the ability to borrow against
- the tool provides certainty of timing of receiving funding
- the tool incentivises more rapid development
- the tool can be used to access third party funding.

Combining these considerations, Figure 20 shows the spectrum of how quickly different tools unlock a pool of money that can be accessed for infrastructure delivery if that infrastructure needs to be centrally delivered. It also takes into account the other points made above about incentivising development or accessing third party funding.

Figure 20 Certainty, speed and scale of accessing more funding

Of any of the common tools, targeted rates and levies provide the most rapid access to the funding stream while incentivising faster development.

7.5 Application of tools to wastewater challenges

As discussed previously, cross connections on private property, when identified, are remediated at the cost of the property owner, not by ratepayers more broadly.

Our focus here is therefore primarily the range of tools applicable to the wastewater capacity challenge. For stormwater, where water sensitive design is proposed, for instance, a different set of tools may be appropriate.

7.5.1 Inappropriate tools

Two of the tools discussed in this report are inappropriate for funding the wastewater improvements needed to reduce *E.coli* levels: ***value capture*** mechanisms and ***financial contributions (FCs)***.

Value capture is inappropriate primarily because it is not currently an available tool even though some of the benefits of wastewater improvements will benefit private land owners. This will also make it hard to identify how land values have been affected directly by improved water quality in specific locations.

FCs are used to offset additional environmental impacts from new development. As most of the costs for improving wastewater are due to existing development, not new development, FCs are unlikely to be able to be used to recoup much of the cost anyway, but will also be inappropriate when the costs of improved infrastructure would far more simply be covered by some of the other mechanisms described below.

7.5.2 Tools to apply to growth areas

Some of the costs associated with wastewater improvements will be the consequence of growth. As this report has highlighted, the original modelling accounted for some growth in households in the two whaitua. GWRC’s current projections suggest even more dramatic growth in households over the next 50 years.

It is therefore appropriate that growth shoulder a significant portion of the cost of improving wastewater outcomes. The exact share would need to be established through a thorough analysis of who benefits from the improvements, i.e. how much of the benefit of improved wastewater outcomes accrue to existing residents versus those being added through growth.

Tools that can be used to ensure that growth bears an appropriate share of the cost of reducing *E.coli* levels include:

- Targeted rates
- DCs
- IGCs
- Targeted levies.

All these tools have functionally the same intent, which is to collect funds from growth to pay its share of the cost of infrastructure. One advantage of targeted rates is that they can be applied to both growth (so that new development pays its share) and to existing development where a service improvement (better wastewater services) occurs.

A further tool that could be adopted is ad-hoc ***developer agreements***, where rather than providing a share of the funding, a developer agrees to deliver a new piece of infrastructure, an improvement or upgrade that allows their growth to be accommodated by the network.

7.5.3 Tools to apply more broadly

All the tools mentioned under the previous heading will only meet some of the cost of the wastewater improvements – the share that can be shown to be attributable to accommodating growth. The rest will have to be funded by:

- more traditional tools
- ad-hoc central government tools
- in the case of cross-connection remediation, ***owners of individual properties will pay***.

The two most traditional tools likely to be used are ***general rates*** or ***targeted rates***, with general rates carrying most of the load at present in Wellington. As discussed previously, general rates are charged across all ratepayers typically based on land or land plus improvement value. Targeted rates are charged for a specific purpose in a specific location.

The latter tool tends to be politically more acceptable because it is targeted to a specific use, which gives the public confidence that it will not be spent on other uses. Some councils, most notably Auckland Council, have introduced “targeted rates” that are targeted by use, but not by geography. In the case of the two whaitua it may be possible to introduce different rates in different areas based on the level of improvement in water quality enabled by the interventions. The greater the clarity ratepayers have between what they are paying for and improvements in their communities, the less opposition there is likely to be.

7.5.4 The impact of a separate water entity

At the time of writing it remains government policy to establish four new water entities for managing three waters. In the event that this occurs, the challenge of wastewater network funding will pass to the new entities. While they will be able to use the mechanisms of ***IGCs*** to cover the costs of infrastructure for the connection of new development to the network, the other growth funding tools are unlikely to be available.

Similarly, in the case of the bulk of the wastewater improvements required, funding tools will be limited. As an entity that is to broadly fund itself, operating on a commercial model, Entity C (of which Wellington Region is a part) would need to source the funding for wastewater improvements primarily from its customers. This means ***charging for the improvements through water charges reflected on customers’ water bills***. Water customers are the same people as ratepayers by and large, so while the entity charging would be different, the same significant costs discussed in this report would be imposed.

In some cases, there may be an argument that the scale of the improvements may be too large to place upon local water customers alone. In this case ***central government may provide ad-hoc funding assistance*** for projects. This shifts the costs from water customers or ratepayers to taxpayers, who are also by and large the same people although the burden may be shifted outside of the geographic area that benefits. Wellington Region, however, with one of the highest average household incomes in the country, is more likely to be a net subsidiser of other parts of the country rather than a net beneficiary of ad-hoc taxpayer funding.

Subject to the final revenue raising policies of the emerging Entity C, there might an opportunity to spread some of the costs across the wider entity area beyond the Wellington region given a premise of the reforms is to spread costs across greater areas. However, this policy has not yet been developed or adopted so cannot be relied upon at this stage.

8. Limitations

This report has been prepared by GHD for Greater Wellington Regional Council and may only be used and relied on by Greater Wellington Regional Council for the purpose agreed between GHD and Greater Wellington Regional Council as set out this report.

GHD otherwise disclaims responsibility to any person other than Greater Wellington Regional Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

8.1 Assumptions

This report has relied on documents produced for Greater Wellington Regional Council as well as rates and other data sourced from constituent councils. Where possible, we have interrogated this data to better understand its sources and implications, but this has not always been possible. Costs presented in the original reports are indicative life cycle cost estimates based on the available information at the time of publishing. We have not verified the accuracy of the cost data and have used this information inflated to 2022 dollar values ghd.com

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GHD Advisory

Environmental effects offsets: Estimating financial contributions FINAL

Greater Wellington Regional Council

24 August 2023

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Printed date	24/08/2023 1:33:00 pm
Last saved date	24 August 2023
File name	Environmental effects offsets: Estimating financial contributions FINAL
Author	David Norman, Logan Peck
Project manager	David Norman
Client name	Greater Wellington Regional Council
Project name	AOG Consultancy Panel - Greater Wellington Regional Council
Document title	Environmental effects offsets: Estimating financial contributions FINAL
Revision version	Rev A
Project number	12584753

Document status

Status Code	Revision	Author	Reviewer		Approved for issue		
			Name	Signature	Name	Signature	Date
Final	A	David Norman, Logan Peck	David Walker	*D. Walker*	Mary O'Callahan	*M. O'Callahan*	24 August 2023

1. Executive summary

This Executive Summary and the remainder of the report should be read in conjunction with the scope and limitations set out in the Introduction.

The National Policy Statement on Freshwater Management (NPS FM) requires water quality to be maintained or improved. Likely greenfield development in the Te Awarua-o-Porirua and Te Whanganui-a-Tara whaitua catchments will come with an unavoidable increase in stormwater contaminants entering receiving freshwater and coastal environments, even with best practice contaminant treatment systems in place. Greater Wellington Regional Council (GWRC) proposes a compensatory offset in the form of a financial contribution (FC) be collected from greenfield development to cover the ***residual contaminants*** (specifically zinc and copper in this instance) that cannot be practically covered by best practice contaminant treatment systems onsite. These FCs would be used to construct or upgrade a stormwater treatment system to serve the same sub-catchment.

GWRC commissioned GHD to investigate the likely extent of greenfield development over the next 30-50 years in the Te Awarua-o-Porirua and Te Whanganui-a-Tara whaitua, to work with GWRC to understand the contaminant implications of that development, to estimate the scale and cost of an appropriate intervention to offset the contaminants, to estimate the likely scale of financial contribution required to cover this cost, and to comment on the economic implications of the FC on development activity.

Almost 12,000 new ***dwellings*** are expected to be added to greenfield areas across the two whaitua over the next 50 years, with 6,450 in Te-Awarua-o-Porirua and 5,470 in Te Whanganui-a-Tara. These dwellings will be a mix of stand-alone homes and townhouses. Between them, they are expected to generate around 606 hectares of roading, hardstand and roof cover. An estimated 88 hectares of roof, roading and hardstand cover is expected to be built out in ***non-residential*** greenfield areas over around 30 years, all of it in Te Awarua-o-Porirua.

It was estimated that, while the bulk of zinc and copper contaminants would be dealt with within greenfield developments, approximately 6.2 hectares of wetland type infrastructure would be needed to offset the residual contaminants not dealt with onsite. Around 1.7 hectares would be needed in Te Whanganui-a-Tara and a further 4.6 hectares in Te Awarua-o-Porirua (where all the non-residential greenfield land is expected to be developed).

Wetlands are expensive to construct, at an estimated cost of around $4 million per hectare, implying a total cost across the two whaitua of around $25 million at today's costs.

FCs were calculated using an interest rate assumption of 6.15% to fund the interventions, while an average annual cost escalation of 5% was assumed, and a delivery timeframe for the wetlands of 2037-2039. FCs were calculated on the basis of Equivalent Household Units (EHUs), with dwellings with a roof site coverage of less than $55m^2$ assumed to be 0.6 of an EHU. Non-residential FCs were estimated at a rate per $100m^2$ of hardstand or roofing cover. The consequent FCs are set out below.

Residential FCs per EHU	**$ excl GST**
Whaitua te Whanganui-a-Tara	$ 4,240
Te Awarua-o-Porirua Whaitua	$ 4,599
Non-residential FC per 100m2 hardstand or roofing	**$ excl GST**
Te Awarua-o-Porirua Whaitua	$ 858

By not requiring development to pay to offset its impacts on the environment, development is incentivised to happen in a way that is not cognisant of those impacts. This ignores the economic principle of user (or polluter) pays. Evidence from New Zealand and abroad shows that accurately charging to offset these negative impacts will push raw land prices down, not property prices up. The scale of the FCs is small relative to the overall price of delivering a dwelling into the market. Nevertheless, there may be an impact on those developers who have paid a price for land that does not reflect the cost of mitigating their environmental impacts. At the margins, the policy will make some developments infeasible.

Developers who have overpaid may resell, hold onto the land until land prices rise again, or rework their proposed development. Regardless, this situation does not justify ignoring these residual contaminants; perpetuating the current state because some developers have overpaid or because of cyclical weakness in the housing market will only exacerbate the environmental challenge.

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2. Introduction

Purpose

Greenfield development comes with an unavoidable increase in stormwater contaminants entering receiving freshwater and coastal environments, even with best practice contaminant treatment systems in place. This increase in contaminants conflicts with the NPS FM requirement to maintain or improve water quality.

To provide “headroom” in the sub-catchment/part FMU, it is proposed that a compensatory offset in the form of an FC will be collected by GWRC to cover the ***residual contaminants*** that cannot be practically covered by best practice contaminant treatment systems onsite. This will be transferred to the relevant water services entity to construct or upgrade a stormwater treatment system to serve existing urban development within the same sub-catchment/part FMU, such that the offset occurs in the same catchment as the greenfield development.

The FC will be collected from all greenfield developments requiring a regional stormwater consent (i.e. any development creating more than 1000m^2 impervious area) within the sub-catchment/part FMU.

The purpose of this work is therefore to:

1. Estimate the total FCs to be collected if all current undeveloped urban and future urban zone is developed (split by whaitua).

2. Estimate the costs to a greenfield development for the FC offset.

3. Understand any other economic implication of the FC policy.

Information prepared by others to inform this report

- Estimating the contaminant impact from greenfield development (estimated by Stu Farrant of Morphum Environmental)
- Developing raw cost estimates for infrastructure upgrades (also provided by Stu Farrant of Morphum Environmental)
- Estimating the appropriate longer-term interest rate assumption (provided by GWRC)
- Determining the appropriate delivery period for the wetlands.

Scope and limitations

This report has been prepared by GHD for Greater Wellington Regional Council and may only be used and relied on by Greater Wellington Regional Council for the purpose agreed between GHD and Greater Wellington Regional Council.

GHD otherwise disclaims responsibility to any person other than Greater Wellington Regional Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD. GHD disclaims liability arising from any of the assumptions or information prepared by others being incorrect.

3. Estimating greenfield development

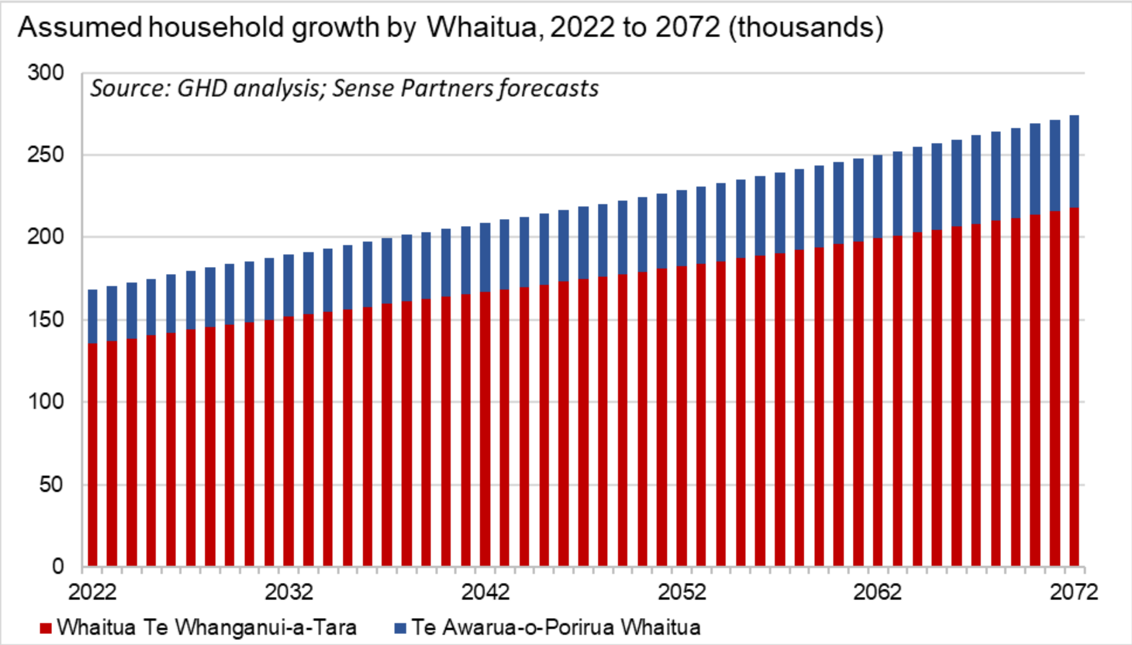
The first step to calculating financial contributions that would be needed, is to estimate the amount of greenfield development that may be expected to occur over the next several decades.

Total growth in households by whaitua to 2072

As of 2022, Te Awarua-o-Porirua Whaitua is estimated to have around 33,200 households, and Whaitua Te Whanganui-a-Tara around 135,400 households. While the relationship between dwellings and households is not one to one, it provides a good estimate of the number of dwellings. Some dwellings include more than one household, while some dwellings are empty. Households therefore provide a fair proxy of the total number of households likely to be delivered.

Earlier work has identified the expected total growth in households in the two whaitua over the next 50 years. This growth is set out in Figure 1.

Figure 1 Expected growth in households across the whaitua



The number of households in Te Whanganui-a-Tara is expected to increase by about 82,000 over the next 50 years, and by about 23,000 in Te Awarua-o-Porirua. While there are plans for intensification across the region’s urban council areas, some of this growth will be accommodated by greenfield development, which is the focus of this work.

Where greenfield residential growth is expected

GWRC was able to identify a number of greenfield areas that are already live-zoned, future urban zoned, or are potential additional areas for future development. On advice from GWRC, the analysis of potential greenfield development is limited to live zoned and expected future urban zoned areas rather than the less likely development areas. Should these less likely areas be advanced in future, the model can be re-run to incorporate the impact of adding in these areas on the scale of offset intervention needed and therefore cost.

Figure 2 Anticipated greenfield residential areas with build-out periods

GF Area name	Total Dwellings to be added	Start Year	End Year	Remarks
Porirua NGA (Already Planned)	2000	2022	2042	Part one of the Porirua NGA development - see part two below
Porirua NGA (New)	1500	2024	2053	
Kingsley Heights	250	2032	2037	
GF St Patricks	600	2029	2039	
GF Gabites	220	2025	2035	No longer includes Maymorn
GF Gillespies Block	1000	2034	2043	
Judgeford	450	2030	2041	No longer includes Upper WE Growth Corridor
Lincolnshire Farm	2000	2025	2061	
Upper Stebbings	500	2041	2055	
Wainuiomata North	1500	2053	2072	
Upper Hutt Southern Growth Area	1500	2053	2060	
GF Canon Point	400	2029	2041	
TOTAL	**11,920**			

Consequently, an estimated 6,450 new dwellings are assumed to be added to Te-Awarua-o-Porirua in greenfield areas by 2061, when the last area included as likely is expected to be built out. These 6,450 dwellings constitute about 37% of all dwellings expected to be added in the whaitua by 2061.

In Te Whanganui-a-Tara, an estimated 5,470 additional dwellings are expected to be added in greenfield areas out to 2072. These dwellings would constitute just 11% of dwellings expected to be added to the whaitua in that period, demonstrating the strong focus on intensification in existing brownfield areas.

Greenfield dwellings by typology

Smaller homes are likely to have a smaller residual contaminant role because of smaller roof surfaces, smaller impervious driveway surfaces and so on. Consequently, it is useful to understand the mix of housing typologies likely to be delivered. This also acts as a good cross-check on the credibility of the housing development numbers.

In terms of housing typology, we anticipate that the greenfield housing will be a mix of stand-alone homes and more dense housing. Given it is likely that individual developments would include a mix of typologies, but to provide some idea of the likely overall mix of housing, we undertook the following steps:

1. Sourced from GWRC or estimated the number of hectares of each development area.
2. Divided the estimate of the size of each development area by the expected number of dwellings for a gross m^2/dwelling measure.
3. Divided each development's gross m^2/dwelling measure by two to account for the fact that typically around 50% of a residential development's space is consumed by land required for roads, parks, floodplains and streams that are not built over, to yield a net m^2/dwelling measure.
4. Assumed a development with a net m^2/dwelling measure less than or equal to 300 m^2 would be predominantly townhouse type development, with developments with net m^2/dwelling measures greater than 300 m^2 assumed to be predominantly stand-alone homes.

This approach produced the estimates of townhouses and stand-alone homes in greenfield areas by whaitua in Figure 3.

Figure 3 Estimated greenfield dwellings to be added by typology

Dwellings	Townhouse	Stand-alone	TOTAL
Whaitua te Whanganui-a-Tara	2,100	3,370	5,470
Te Awarua-o-Porirua Whaitua	-	6,450	6,450
	2,100	**9,820**	**11,920**

Estimating the number of townhouses separately from the number of stand-alone homes allows us to consider the typically smaller impact of townhouses because of their smaller roof and other impervious surface cover. The number of dwellings can be converted into Equivalent Household Units (EHUs), variously called Household Unit Equivalents (HUEs) or Household Equivalent Units (HEUs) by different councils across New Zealand. This allows GWRC the flexibility to acknowledge that the impact of more compact dwellings is likely to be less per dwelling, so that smaller, more compact homes are not disadvantaged by having to contribute the same as larger homes across bigger footprints that produced more contaminants.

From dwellings to residential EHUs

We estimate that one townhouse has an impact that is 60% that of a stand-alone dwelling, or 40% less than a stand-alone dwelling. This is borne out by recent construction data. Townhouses in the four urban councils across Wellington region tend to be about 40% smaller than stand-alone homes (an average of 98m^2 compared with 169 m^2 for stand-alone homes). They are likely to have a smaller footprint and less impervious surface coverage than a stand-alone home. Because they are smaller, they tend to have fewer occupants and therefore contribute less to the need for roading and other infrastructure that may cause run-off.

Figure 4 Estimated greenfield EHUs by typology

EHUs	Townhouse	Stand-alone	TOTAL
Whaitua Te Whanganui-a-Tara	1,260	3,370	4,630
Te Awarua-o-Porirua Whaitua	-	6,450	6,450
	1,260	**9,820**	**11,080**

Consequently, the implied number of residential EHUs is 11,080 in total, and in each of the two whaitua is:

- Te Awarua-o-Porirua: 6,450 (with growth overwhelmingly expected to be in stand-alone homes)
- Te Whanganui-a-Tara: 4,630 (where a significant amount of townhouse type development is expected).

Residential impervious surfaces

When the goal is to consider how residential and non-residential greenfield development affects residual contaminants, with a view to offsetting these contaminants, we need to think of dwellings in terms of their impervious surfaces. Assuming approximately 25% of land in greenfield areas is consumed for roading and pathways (a rule of thumb adopted elsewhere in the country)[1], yields the following mix of land use for primarily residential purposes.

Figure 5 Estimated impervious surfaces in greenfield residential areas

Residential growth (hectares)	Roofcover	Roading + Hardstand	Permeable surfaces	TOTAL
Whaitua Te Whanganui-a-Tara	46.6	138.6	283.7	**468.9**
Te Awarua-o-Porirua Whaitua	66.1	354.4	878.5	**1,299.0**
TOTAL	**112.6**	**493.0**	**1,162.2**	**1,767.9**

Across the two whaitua, an estimated 113 hectares of a land will receive roof cover, while a further 493 hectares of land will be required for roading and hard-stand areas (including driveways, pavements and impervious patios).

[1] See for instance the *Warkworth Structure Plan* of June 2019, which provides detailed estimates of the role of different elements of development in residential and non-residential areas. Warkworth was chosen because of its relatively low density and thus similarity to proposed greenfield development in the two whaitua, and due to its detailed level of analysis with regard to land use by zoning type.

When considering appropriate interventions, it is the residual contaminants from these surface types that will need to be offset.

Where greenfield non-residential growth is expected

The best available data from GWRC on likely non-residential development suggests the following pattern of non-residential development by whaitua.

Figure 6 Anticipated greenfield non-residential areas with build-out periods

GF Area name	Total Hectares	Start Year	End Year
Judgeford Flats	93	2025	2034
Lincolnshire Farm 1	10	2025	2034
Lincolnshire Farm 2	35	2035	2054
TOTAL	**138**		

All these areas fall within the Te Awarua-o-Porirua whaitua, with some development expected to begin in the 2024/25 financial year and some from the 2034/35 financial year.

Non-residential impervious surfaces

For non-residential areas, it was assumed that 55% of gross land area was available for development (again in line with other parts of the country), and 70% site cover on developable land. We assumed 60% of that site cover was roofing and 40% was carparking or other hard-stand uses.

Figure 7 Estimated impervious surfaces in non-residential areas by whaitua

Non-residential growth (hectares)	Roofcover	Roading + Hardstand	Permeable surfaces	TOTAL
Whaitua te Whanganui-a-Tara	-	-	-	**-**
Te Awarua-o-Porirua Whaitua	31.9	55.8	50.4	**138.0**
TOTAL	**31.9**	**55.8**	**50.4**	**138.0**

An estimated 32 hectares of total roof cover are expected to be needed within Te Awarua-o-Porirua, along with a further 56 hectares of hard-stand and roading.

4. Appropriate offsetting interventions and costs

With input from Morphum Environmental (see Appendix), it was possible to estimate the potential impact of expected greenfield development on residual contaminants. The assumption is that the bulk of contaminants from run-off would be dealt with onsite within greenfield developments (around 85%), but that ***residual*** contaminants would be offset by a centralised intervention in each whaitua. An appropriate way of offsetting residual contaminants not managed on-site is through centralised wetlands.

The likely size of wetland needed to offset the expected level of residual contaminants by full build-out is shown in Figure 8.

Figure 8 Estimated wetland area required to offset residual contaminants

	Offsetting wetland required for residual contaminants (hectares)		
Development type	**Whaitua te Whanganui-a-Tara**	**Te Awarua-o-Porirua Whaitua**	**TOTAL**
Residential	**1.7**	**3.8**	**5.5**
Non-residential	**0.0**	**0.8**	**0.8**
TOTAL	**1.7**	**4.6**	**6.2**

It is estimated that residential development in Te Whanganui-a-Tara would require around 1.7 hectares of wetlands to offset these residual contaminants. Te Awarua-o-Porirua would require 3.8 hectares. With new non-residential greenfield development only anticipated in Te Awarua-o-Porirua, an estimated 0.8 hectares are estimated to be required to offset residual contaminants there. The total impact is estimated at around 1.7 hectares for Te Whanganui-a-Tara and 4.6 hectares for Te Awarua-o-Porirua.

Costing these interventions

Wetlands are likely to use low-lying land where it would be more difficult to build anyway. This means that the land is likely to be significantly less expensive than prime building land, as its best alternative use may be relatively low productivity rural uses. While there is variation in the pricing for wetlands, a general pattern emerges that allows an estimation of the likely cost for establishing a wetland based on size.

Morphum Environmental provided an estimate of the cost per hectare for developing wetlands, which is included in the Appendix report. The largest component of the cost is from bulk earthworks, while topsoils, planting and other costs make up the rest of the typical cost of around $4 million per hectare.

This implies an offset cost per whaitua as follows:

- Te Awarua-o-Porirua: $18.3 million including the allowance for both residential and non-residential greenfield development
- Te Whanganui-a-Tara: $6.7 million for its expected greenfield residential development.

5. Implied financial contribution

For each whaitua, we have calculated an estimated FC:

- per residential EHU
- per 100m^2 of non-residential roofing or hardstand cover.

Further assumptions are:

- A 6.15% interest rate[2]
- There is a 5% cost escalation per year to allow for cost increases until construction of the wetlands[3]
- The wetlands in both whaitua are constructed from 2037 to 2039, an assumption agreed with GWRC
- All works are debt-funded, such that any FCs that are collected before construction of the offset intervention reduce overall council debt thus saving interest costs on other debts
- The expected delivery timeframes for each greenfield area as provided by GWRC determines when FCs are collected.

Residential FCs

Based on the assumptions about interest rates and the expected period of delivery of new dwellings across the two whaitua, the estimated cost per EHU is set out in Figure 9.

Figure 9 Estimated FC per residential EHU

Residential FCs per EHU	$ excl GST
Whaitua te Whanganui-a-Tara	$ 4,240
Te Awarua-o-Porirua Whaitua	$ 4,599

The estimated FC per EHU is $4,240 to $4,599 depending on the whaitua. We recommend that ***this FC be charged on new dwellings with an anticipated footprint (site coverage) of more than 55m^2***, excluding any hardstand (i.e. dwellings likely to be more than 100m^2 in total floor area, but double storeyed). While the modelling has assumed hardstand areas on these properties (patios, driveways and so on) for the purpose of estimating contaminant load, often information on patio surface areas and the like is not provided in building consent applications, which is why a dwelling site coverage estimate is used instead.

Dwellings with ***a site coverage of the dwelling of less than or equal to 55m^2*** cover at construction would be ***charged at 0.6 of these FC rates*** in line with development contributions policies used in New Zealand where smaller properties that place less demand on the network (or in this case produce fewer contaminants) pay less. This equates to $2,544 in Te Whanganui-a-Tara and $2,759 in Te Awarua-o-Porirua.

Non-residential FCs

Non-residential FCs are for Te Awarua-o-Porirua only as at this point no non-residential development is expected in greenfield areas in Te Whanganui-a-Tara. Should future changes require development of greenfield business land in Te Whanganui-a-Tara, we recommend a similar starting point for FCs based on roofing or hardstand cover. The assumption is that the impact of roofing on one hand, and roading and hardstand on the other is similar, and therefore the FC for 100 m^2 of cover of is the same regardless of whether the impermeable cover is roofing or hardstand.

[2] This is GWRC's latest indicative fixed term borrowing rate for a 2037 time-horizon, the date at which wetland construction is assumed to begin.
[3] We would note that construction cost increases have been significantly higher than 5% in recent years, even before COVID-19, but this estimate is based on a longer-term average view of construction cost escalation that makes some allowance for the higher cost growth environment today, but also for a potential lower cost growth in future across the period until construction is completed.

We would note that unlike residential development, larger scale industrial and business developments tend to have a lot more detail on their intended hardstand areas as well as building footprint at the consent stage, which is why a more direct FC per 100 m^2 of hardstand or roofing can be used for non-residential development.

Estimates for non-residential development FCs by coverage type are shown in Figure 10.

Figure 10 Estimated FC per 100m2 of non-residential development by coverage type

Non-residential FC per 100m2 hardstand or roofing	$ excl GST
Te Awarua-o-Porirua Whaitua	$ 858

The estimated FC per $100m^2$ of hardstand or roofing is $858.

Comparing residential and non-residential FCs

Non-residential FCs appear to be significantly lower than for residential FCs. There are at least four reasons for this.

1. The density of development expected across most of the ***residential*** greenfield areas is particularly low, such that only around 9% of these greenfield areas would consist of roofing or on-site hardstand areas. Roading required to access these properties creates a large impervious surface (assumed to be 25% of the total surface area of the greenfield areas), the cost of which needs to be shared across the relatively small footprint of houses enabled by that development.

   In contrast, business and industrial (***non-residential***) land is expected to be more intensively developed, with a roofing and on-site hardstand coverage of around 38% compared to 9% for residential development. This 38% of land needs to contribute toward the roading run-off impacts it creates but using the same 25% roading assumption for non-residential greenfield areas, the cost of additional roading impacts borne by the non-residential areas works out lower because of the more intensive level of development. That said, the sheer scale of industrial developments (where buildings could have roof coverage of up to $10{,}000m^2$ each for instance) means that overall, the FCs per hectare of land developed in non-residential areas will be higher.
2. The assumed timeframes over which residential development is delivered is longer, meaning further interest costs need to be borne to pay for the share of FCs attributable to residential development.
3. Taken with reason (2) above, most of the non-residential development is expected to be in the next decade, in advance of the wetland being developed. As a result, a large proportion of the FCs for non-residential contaminants are collected in advance of the cost of constructing the wetland. Because these earlier revenue streams can be used in the interim to offset GWRC interest costs, the overall cost to be borne by non-residential development diminishes.
4. One full EHU of residential development assumes around $150m^2$ of roof and hardstand per residential dwelling, compared with the $100m^2$ unit of payment for non-residential FCs.

Crucially, if assumptions on the intensity of development in residential greenfield areas change, it would be worth reviewing the FCs calculations as a more intensive development pattern could lead to significantly lower FCs per EHU even though the total wetland area required to service this higher intensity of development could rise.

6. Implications of proposed financial contributions

The basic economic principle of user pays states that when consumers of a good or service pay the full cost of what they consume, society allocates its limited resources most appropriately.

This somewhat complicated explanation simply means that when an inaccurate price is charged for something (either too much or too little), perverse outcomes occur. For example, by not requiring development to fully pay for its own demands on the stormwater network or to offset its impacts on the environment, we incentivise development to happen in a way that is not cognisant of those impacts. By not capturing the ***negative externalities*** of that development (impacts on water quality beyond the footprint of the development), poorer development outcomes are encouraged. This is poor resource allocation because by not pricing accurately, we send the wrong signals to the market about the societal impacts of development choices.

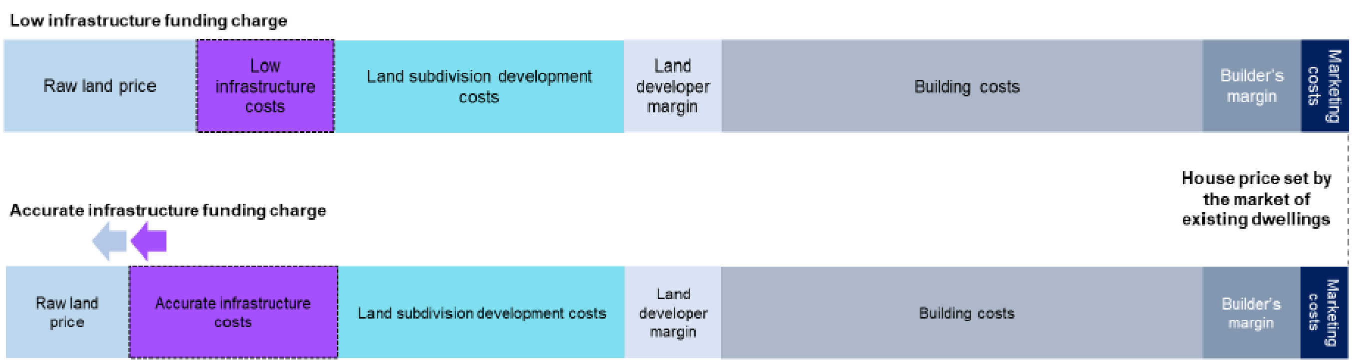
Offsetting negative externalities does not raise property prices

It is a commonly held but inaccurate belief that charging more accurately for infrastructure (including infrastructure such as wetlands to offset negative externalities) will raise property prices.

The inaccuracy of this view is demonstrated both by theory and by case studies. We begin by considering the theory. When a new dwelling is built, it enters a market of, in the case of the two whaitua, tens of thousands of existing homes. New homes delivered into this market have to compete on price with these tens of thousands of homes, and especially with other recently constructed homes. As a consequence, developers are what economics calls “price-takers”. No individual developer sets the price of a home. If they charge too much, people will simply buy somewhere else.

In determining development feasibility, therefore, the developer has to consider the price at which the developed homes will sell at the end of the project; a price set by the market. The developer then works backwards to ensure they make a profit and cover all the other inputs required to go from empty or under-used land to a new completed development. This process requires the developer to calculate infrastructure costs (including development contributions, any requirement for extra on-site infrastructure, or FCs). What is left after covering profit and all the inputs, is a residual value the developer can pay for the undeveloped or under-developed “raw land”. This process of working out the feasibility of the project is demonstrated in the top bar in Figure 11.

Figure 11 How development pricing changes when infrastructure costs rise



If the cost of meeting the infrastructure and offset requirements (e.g. through FCs) of the land rises, as shown in the second bar in Figure 11, the developer will be very limited in their ability to pass on those costs. Instead, developers will have to pay less for “raw land” if the development is to maximise its commercial viability. All things being equal, property prices are unaffected and raw land prices fall.

The empirical evidence from overseas and in New Zealand supports this theoretical description. The international evidence on this trend for infrastructure costs to pass up the chain to land prices rather than down to house prices is instructive. Work done in Auckland Council's Chief Economist Unit summarising the findings of international studies shows that in almost all cases, the vast majority of costs were passed up the chain.[4]

In New Zealand, the Auckland experience is invaluable in demonstrating that the true costs of infrastructure are internalised rather than passed on into higher house prices. In its independent role, the Chief Economist Unit at Auckland Council evaluated whether that city's Rural Urban Boundary (RUB) constrained access to developable land and thus artificially inflated land prices inside the boundary, a common accusation against growth boundaries.[5]

A key finding of this study of over 30,000 property sales was that once the true cost of infrastructure is factored into land values, it appears that land prices outside the RUB were inflated. This is likely because of speculation on land purchases just outside the boundary, where developers believe that at some point in future, development will be allowed with an ongoing subsidy from the general ratepayer. In other words, developers are offering a price for raw land based on what they think they will have to pay for infrastructure. If a clear signal is sent that development will need to pay more for infrastructure (including on-site stormwater management), raw land prices will fall, rather than house prices rising.

The implication for the whaitua is that as the need to offset contaminant impacts through infrastructure such as wetlands is signalled, raw land prices will adjust to reflect the true cost of infrastructure to service new developments.

Developers who have overpaid for land

The scale of the FCs (at estimated costs up to $4,599 in this analysis) is small relative to the overall price of delivering a dwelling into the market. June median residential property prices in Porirua were $840,000, and in Wellington City they were $881,000.[6]

Nevertheless, the introduction of the requirement to offset residual contaminants through off-site infrastructure funded by FCs will have an impact on those developers who have paid a price for land that does not reflect the cost of mitigating their environmental impacts. At the margins, the policy will make some developments infeasible, especially in the current market of falling land values.

Developers who have overpaid, and where development was sufficiently marginal that this additional cost renders the project infeasible, will have to make a choice. They may:

- Resell the land (potentially at a lower price than they paid if they bought the land since prices began to fall in early 2022) to someone who will be able to make the development work with full knowledge of the need to pay FCs to offset residual contaminant loads.
- Hold onto the land until land prices rise again across the region such that the development becomes feasible again.
- Rework their proposed development perhaps to allow for a greater number of smaller dwellings that pay less in FCs per unit.

In the case of developers finding development infeasible, this will mean a slowdown in development while the market adjusts to the more accurate costs of ensuring negative externalities are covered by development. It is also worth noting that the impact of proposed FCs would be tiny compared to the wider impact of falling land prices due to higher interest rates seen across New Zealand, which is the primary driver of changes in developer activity.

Regardless of the potential impact of the FCs on rendering some development infeasible at this point, this fact does not justify ignoring these residual contaminants being offset; perpetuating the current state because some developers have overpaid or because of cyclical weakness in the housing market will only exacerbate the environmental challenge. There will always be some developers who overpay for land and struggle to make the development commercially viable.

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[4] See Harshal Chitale, *Unshackling growth Growth paying for itself*. 2018. https://www.aucklandcouncil.govt.nz/about-auckland-council/business-in-auckland/docsoccasionalpapers/unshackling-growth%20-%20April%202018.pdf

[5] See Shane Martin and David Norman, *An evidence based approach: Does the Rural Urban Boundary impose a price premium on land inside it?* 2020. https://www.aucklandcouncil.govt.nz/about-auckland-council/business-in-auckland/Reports/does-the-rub-impose-a-price-premium-on-land-inside-it-20-Feb-2020.pdf

[6] See REINZ, *Monthly Property Report*, 13 July 2023. https://www.reinz.co.nz/libraryviewer?ResourceID=580

7. Appendix

See the attached memorandum from Morphum Environmental setting out the approach to estimating the offset requirements and the estimated cost per hectare of wetland.

MORPHUM environmental

Memorandum

Date:	5/10/2023
To:	David Norman (GHD)
From:	Stu Farrant (Morphum)
CC:	Mary O'Callahan (GHD); Karen Ingliss (4Sight)

Subject: Water quality offsetting basis of recommendations

This memo provides high level context around the basis of calculations to inform the proposed financial offsetting for residual contaminants from urban development. The scale of offset treatment required for residual contaminant loads is based on a number of assumptions and generalisations (to reflect the variability between different land developments) but is considered to provide a fair and reasonable average area required to provide additional water quality treatment.

Development assumptions (in terms of total development area and imperviousness) are based on the summary data provided by GHD. This was separated for the Te Whanganui a Tara and Te Awarua o Porirua Whaitua catchments. These are included in Table 1 below.

Table 1; Assumed future development areas (provided by GHD)

Residential growth (hectares)	Roof cover	Roading + Hardstand	Permeable surfaces	TOTAL
Whaitua Te Whanganui-a-Tara	46.6	138.6	283.7	**468.9**
Te Awarua-o-Porirua Whaitua	66.1	354.4	878.5	**1,299.0**
TOTAL	**112.6**	**493**	**1,162.20**	**1,767.9**
Share of total	**6%**	**28%**	**66%**	**100%**

The following steps summarise the sizing methodology used to calculate proposed offset treatment areas;

1. Development treatment of SW is assumed to be provided via a constructed wetland. It is noted that whilst in reality there is an expectation that a range of water sensitive design measures including wetlands and bioretention could be used, for the purposes of these calculations a single device type was assumed. It is also noted that constructed wetlands require approximately twice the footprint of a bioretention but have a CAPEX and OPEX cost of less than half that of bioretention meaning that the use of the constructed wetlands as a

proxy is considered reasonable given that land values are not currently factored in the calculations.

2. Wetland sizing is based on the required treatment footprint relative to the contributing impervious area only to reflect the intent to only treat urban landcover (roofs, roads and hardstand) with unpaved areas assumed to be a mix of gardens or undeveloped vegetation. Table 16 of the Wellington Water Sensitive Design Technical Guidelines (2019) was used to estimate a required wetland size of 5.1% of the contributing impervious catchment. This figure is for a 95% impervious catchment and is therefore slightly conservative when applied against the full (100%) impervious landcover. This sizing relationship was developed for the guidelines based on continuous simulation modelling which used real historical local rainfall (including for Whenua Tapu and Kelburn) rain gauges at 5 minute timesteps with treatment devices sized to pass 85-90% of the mean annual stormwater volume through the respective treatment devices. This is known to ensure that the full water quality volume and flowrate are treated.
3. Treatment effectiveness is based on performance reported in Table 4 in the Wellington Guidelines which was based on industry standards documented in other guidelines including the NZTA Highways design guidelines. Table 4 provides removal effectiveness (in terms of load reduction for metals) of 90% for bioretention and 80% for wetlands. To allow for flexibility with how water quality may be provided within future development, a removal effectiveness of 85% load reduction was applied (i.e. average of performance for wetlands and bioretention). This therefore results in 15% residual loads which are considered impractical to remove through upsizing devices or other measures due to diminishing returns and the reality that some load remains in large rainfall events which bypass devices.
4. Offset financial contributions are therefore based on the residual 15% contaminant load and applying the same sizing ratio as above. Table 2 provides a summary of the calculated residual treatment areas separated for roofs and Roads/Hardstand. It is considered that the combination of 'best practice' measures (in accordance with Wellington Water Sensitive Design Guidelines) included in the developments and the residual treatment areas in Table 2 would be equivalent to 100% load reduction for metals (and other urban contaminants).

Table 2; Calculated offset wetland sizes

Te Whanganui a Tara Residential	**Roof**	**Road/Hardstand**
Required best practice wetland area (ha)	2.38	7.07
Required offset wetland for residual load (ha)	0.42	1.25
Te Awarua o Porirua Residential	**Roof**	**Road/Hardstand**
Required best practice wetland area (ha)	3.37	18.07
Required offset wetland for residual load (ha)	0.59	3.19

5. The cost of stormwater management devices can vary significantly depending on site specific considerations. In particular, aspects such as contaminated soil, retaining or complex pipe works can increase costs and therefore need to be understood in early business case planning. Costs have also been identified as being particularly high in New Zealand (and in particular Wellington) compared to other comparable markets (such as Australia) which may be reflective on the lack of track record in the local contracting market. There are also a range of ancillary costs related to co-benefits such as landscape amenity, pathway connections and

structures which are not directly related to the treatment of stormwater quality but clearly recognised to provide benefits.

For the purpose of estimating the costs which are reasonable to include in offset contribution, the assumption of wetlands without significant complexity and excluding ancillary works unrelated to water treatment is applied. Based on this, an estimate of $4M/ha is suggested. This correlates with a number of recent constructed wetland projects when costs associated with non water quality aspects are removed. This cost estimate aligns with the following contributing cost components for key works;

- $300,000 Lump Sum cost for hydraulic structures (inlets, outlet and weirs etc) and bypass works
- $200,000 Lump Sum cost for enabling works and contractor overheads

• Bulk Earthworks (Based on average 1.5 m depth)	$225/m2
• Topsoils/ base prep	$50/m2
• Wetland lining (based on GCL)	$25/m2
• Planting (procurement and planting)	$50/m2

OPEX costs have not been considered at this stage.

Stu Farrant

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GHD Advisory

ghd.com

→ The Power of Commitment

Memorandum

October 4, 2023

To	Alastair Smaill, **Alastair.Smaill@gw.govt.nz** Karen Inglis, **Karen.Inglis@4sight.co.nz**		
From	David Norman, Chief Economist GHD **David.Norman@ghd.com**	**Project No.**	12622514
Project Name	AOG Consultancy Panel – GWRC – Financial Contributions Estimation		
Subject	Defining EHUs and estimating FCs for stand-alone roading projects		

Scope and limitations

This memorandum has been prepared by GHD for Greater Wellington Regional Council and may only be used and relied on by Greater Wellington Regional Council for the purpose agreed between GHD and Greater Wellington Regional Council.

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Introduction

Greater Wellington Regional Council has requested further information on two points:

- A definition of an Equivalent Household Unit (EHU)
- A financial contribution (FC) estimate for stand-alone roading projects not linked to greenfield development.

This brief memorandum deals with these two points.

Definition of an EHU

An EHU is an Equivalent Household Unit. An EHU is the basis for assessing the residual environmental impact (measured for copper and zinc contaminants in this instance) of the development of an average-sized residential unit for the purposes of calculating FCs. Each average-sized new residential unit is deemed to create one unit of impact (one EHU).

Because non-residential developments also impact contaminant levels, but can vary dramatically in size, every 100m2 of roofing or roading/hardstand area is deemed to create one unit of impact, rather than using the EHU unit of measure used for residential development.

FCs are calculated based on the number of EHUs expected to be delivered in greenfield areas in the two whaitua. Non-residential FCs are calculated based on the amount of roofing and roading/hardstand expected in non-residential development areas.

FC estimate for stand-alone roading projects

Unlike roading that is developed to access new residential or non-residential development, where the impact of that roading is included in estimates of the FCs for the residential or non-residential development, the contaminant impacts of, for example, new highway lanes, need to be estimated differently.

Morphum Environmental estimate that 85% of contaminant run-off from these roads would be dealt with on-site. This is the same assumption as used for residential and non-residential development in the earlier work. Using the relationship between zinc and copper contaminant run-off and the required size of wetlands from the initial work, the estimated FC is ***\$360 per 100m^2*** of roading / hardstand when that roading is not in direct support of new greenfield development.

Greater Wellington
Te Pane Matua Taiao

MEMO

TO	Environmental Policy
COPIED TO	Megan Melidonis, Senior Environmental Scientist
FROM	Megan Oliver, Senior Environmental Scientist
DATE	16 January 2023

FOR YOUR ACTION

Coastal sites and habitats with significant indigenous biodiversity values in the Wellington region: Technical memo to support updates to Schedules F4 and F5 in the 2023 Plan Change

This memo summarises the key supporting information from which the marine sites and habitats of significance in the Wellington region were selected for inclusion in updated Schedules F4 (Sites of significant indigenous biodiversity values in the coastal marine area) and F5 (Habitats with significant indigenous biodiversity values in the coastal marine area) of the Natural Resources Plan (GWRC 2022).

Background

Schedules F4 and F5 list estuaries, coastal and offshore marine sites and habitats in the Wellington region with significant indigenous biodiversity values. The criteria against which these sites and habitats of significance have been assessed are listed in Policy 23 of the Regional Policy Statement for the Wellington region (Appendix 1; RPS, GWRC 2013). These criteria have been developed to identify indigenous ecosystems and habitats with significant indigenous biodiversity values. Sites and habitats are considered significant if they meet one or more of the Policy 23 criteria. These criteria align closely with NZ Coastal Policy Statement Policy 11 for protecting indigenous biological diversity in the coastal environment.

The sites and habitats listed in Schedules F4 and F5 are drawn directly from several reports and a recent dive campaign:

- a report prepared by the Department of Conservation (DOC) listing the locations and values (social and ecological) for all the estuaries in the Wellington Hawke's Bay Conservancy (Todd et al. 2016);
- two NIWA reports commissioned by GWRC listing coastal and marine sites and habitats of significance in the Wellington region (MacDiarmid et al. 2012; Nelson et al. 2021);
- a report by Victoria University of Wellington (Bell et al. 2022) describing animal-dominated reef communities on the Kapiti Coast; and
- a sampling campaign in March 2022 by scientific divers at the Department of Conservation and NIWA taxonomists to collect and identify a black coral colony at Kapiti Island.

Estuaries in the Wellington region

Information for estuaries relevant to the Policy 23 criteria is taken from Todd et al. (2016). This report collates for the first time, all of the available information for estuaries throughout the Wellington Hawke's Bay conservancy, including ecological, historical, cultural and recreational values. This represents a significant body of work and it is from this report that the 35 estuarine sites located within the Wellington region were selected for Schedule F4. The key studies on which the report is based and from which the fulfilment of Policy 23 criteria could be assessed were a freshwater fish survey (Allibone et al. 2010) and three region-wide broad scale habitat mapping surveys documenting the distribution of estuaries throughout the Wellington region (Robertson & Stevens 2007a, b, c). The freshwater fish study may appear anomalous but it is important because most of New Zealand's freshwater fish are migratory and require unimpeded passage between freshwater and the sea, via estuaries, in order to complete their life cycle.

Information taken from these reports for assessment against Policy 23 criteria is specific to the aquatic flora and fauna of estuaries and does not include birds; sites for birds in the coastal marine area are considered in Schedule F2c.

Coastal and offshore marine sites and habitats of significance in the Wellington region

In 2011 GWRC engaged NIWA to identify coastal and marine areas of significant biodiversity value in the Wellington region that fulfill the Policy 23 criteria (MacDiarmid et al. 2012). Seven sites and five habitats of significant marine biodiversity were identified within the region. These sites ranged from shallow Porirua Harbour to the methane seeps lying in 1,100 m of water in the southeast corner of the region.

In 2021 NIWA was commissioned to update this report and an additional seven sites and one habitat were included in the schedules (Nelson et al, 2021). These new sites included the recently mapped and sampled nearshore red algae meadows and horse mussel beds in Evans Bay, as well as two offshore seamounts at the outer extremes of the territorial sea.

These sites and habitats are deemed significant for the indigenous ecosystems and biodiversity they support, and all are impacted to some degree by human activities. Information for some sites, such as the Opouawe Bank methane seeps is plentiful, but for other sites, such as the sponge gardens and horse mussel beds, the information is more variable. Accordingly, sites that have well defined locations have been included in Schedule F4 and those sites and habitats for which there is little or no spatial information (eg, kelp and black coral colonies) have been included in Schedule F5.

Further information about the sources of data and the process by which sites and habitats of significance were finalised are contained within the report (Nelson et al, 2021).

Additional sites and habitats

Schedule F4 also includes two marine reserves, two wildlife reserves, one scientific and one scenic reserve and a wildlife refuge. The NZCPS 2010 requires the protection of indigenous biodiversity in the coastal environment, including areas set aside for full or partial protection under other legislation [Policy 11a(vi)].

Schedule F5 also includes seal haul-outs, inanga spawning habitat, saltmarsh and seagrass habitats. Seal haul outs were identified as significant during the development of the Regional Policy Statement. Inanga spawning habitat, saltmarsh and seagrass habitats span the freshwater/marine boundary and are included in Schedule F5 to ensure these significant habitats are protected in both the coastal marine area and riverine environments. The ecosystem functions and values of these habitats are well documented though their full spatial extent is still to be determined.

Black coral colonies were added to both schedules following the collection of samples from the northern end of Kapiti Island in 2022. There was anecdotal evidence of colonies in the area but it wasn't until 2022 when the Guardians of Kapiti Marine Reserve provided video evidence that formal sampling by Department of Conservation scientific divers and identification by coral taxonomists was carried out. This revealed a single large colony outside the boundaries of the marine reserve which is vulnerable to anchoring and fishing activities. Local divers have found other colonies in the area but these have not yet been mapped. Black coral colonies are therefore included in schedule F4 where we have a known location, and schedule F5 as a recognized significant habitat. Note we have withheld the precise location of the Kapiti Island colony for the interim, pending conversations with the community.

Finally, marine ecologists from Victoria University of Wellington were engaged by GWRC in a programme of work in 2021/22 and 2022/23 to progressively map animal-dominated reef habitats in Wellington Harbour and on the south-west coast of the region. This work located and described the biodiversity values of a range of reefs, primarily sponge gardens. These gardens, which generally occur below the depth at which light can penetrate (e.g., >30m depth), provide important ecological functions and support high biodiversity of fish and invertebrate species. This work is ongoing and will also identify and describe shallow water (<30m depth) animal-dominated communities to be added to these schedules at a later date.

Information gaps

There is currently insufficient information about the extent and diversity of the Wellington region's marine environment to prepare a definitive list of significant marine sites and habitats. For many sites, we know their general location, but not their full spatial extent (eg, Kapiti Island rhodolith beds, or black coral colonies). For some habitats, we have robust scientific information about their ecosystem values but not their location (eg, kelp forests). Therefore, Schedules F4 and F5 should be considered 'working tables' to be updated in time as new information becomes available.

References

Allibone R, David B, Hitchmough R, Jellyman D, Ling N, Ravenscroft P, Waters J. 2010. *Conservation status of New Zealand freshwater fish 2009*. New Zealand Journal of Marine and Freshwater Research, 44 (4): 271–287.

Bell J J, Harris B, Rogers A, Micaroni V. 2022. *A preliminary exploration of the rocky mesophotic communities of the Wellington Region*. A report prepared for Greater Wellington Regional Council and Department of Conservation by Victoria University of Wellington. Link to report

GWRC. 2013. *Regional Policy Statement for the Wellington region.* Greater Wellington Regional Council Publication No. GW/EP-G-13/21, Wellington.

GWRC. 2022. Proposed *Natural Resources Plan for the Wellington region – Te Tikanga Taiao o Te Upoko o Te Ikaa a Maui* – Final Appeals Version. Greater Wellington Regional Council, Publication No. GW/EP-G-14/87, Wellington.

MacDiarmid A, Nelson W, Gordon D, Bowden D, Mountjoy J and Lamarche G. 2012. *Sites of significance for indigenous marine biodiversity in the Wellington region.* Report prepared for Greater Wellington Regional Council by NIWA. Link to report

Nelson W A, Bowden D, D'Archino R, MacDiarmid A, Mountjoy J, Peart R, Rowden A, Watson S. 2021. *Sites of significance for indigenous marine biodiversity in the Wellington Region – 2021 update*. NIWA Client Report 2020351WN Link to report

NZCPS. 2010. *New Zealand Coastal Policy Statement.* Department of Conservation, Wellington.

Robertson B and Stevens L. 2007a. *Kapiti, Southwest, South Coasts and Wellington Harbour: Risk assessment and monitoring recommendations.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management.

Robertson B and Stevens L. 2007b. *Lake Onoke 2007: Vulnerability assessment and monitoring recommendations.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management.

Robertson B and Stevens L. 2007c. *Wairarapa Coastal Habitats: Mapping, risk assessment and monitoring.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management.

Todd, M., Kettles, H., Graeme, C., Sawyer, J., McEwan, A., Adams, L. 2016. *Estuarine systems in the lower North Island/Te Ika-a-Māui: ranking of significance, current status and future management options*. Department of Conservation, Wellington, New Zealand: 400. Estuarine systems in the lower North Island/Te Ika-a-Māui (doc.govt.nz)

Appendix 1 – Greater Wellington Regional Policy Statement: Policy 23 criteria

Policy 23: Identifying indigenous ecosystems and habitats with significant indigenous biodiversity values – district and regional plans

District and regional plans shall identify and evaluate indigenous ecosystems and habitats with significant indigenous biodiversity values; these ecosystems and habitats will be considered significant if they meet one or more of the following criteria:

(a) Representativeness: the ecosystems or habitats that are typical and characteristic examples of the full range of the original or current natural diversity of ecosystem and habitat types in a district or in the region, and:

- (i) are no longer commonplace (less than about 30% remaining); or
- (ii) are poorly represented in existing protected areas (less than about 20% legally protected).

(b) Rarity: the ecosystem or habitat has biological or physical features that are scarce or threatened in a local, regional or national context. This can include individual species, rare and distinctive biological communities and physical features that are unusual or rare.

(c) Diversity: the ecosystem or habitat has a natural diversity of ecological units, ecosystems, species and physical features within an area.

(d) Ecological context of an area: the ecosystem or habitat:

- (i) enhances connectivity or otherwise buffers representative, rare or diverse indigenous ecosystems and habitats; or
- (ii) provides seasonal or core habitat for protected or threatened indigenous species.

(e) Tangata whenua values: the ecosystem or habitat contains characteristics of special spiritual, historical or cultural significance to tangata whenua, identified in accordance with tikanga Māori.

Plan Change 1
Te Awarua o Porirua whaitua

Water quantity and allocation technical report

Mike Thompson

Knowledge and Insights – Water

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GW/KI-T-23/19

October 2023

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Report reviewed by:	M Harkness	Senior Analyst - Knowledge & Insights Data	
Report approved for release by:	A Brown	Team Leader – Knowledge & Insights Water	**Date**: 13th October 2023

The report may be cited as:

Thompson M. 2023. *Plan Change 1 – Te Awarua o Porirua; Water quantity and allocation technical report. Prepared by Greater Wellington Regional Council to support Section 32 assessment for Plan Change 1. GWRC Report No. GW/KI-T-23/19*

Executive summary

Water takes, either consented or unconsented/permitted, are not currently considered to be contributing in a major way to the deterioration, and ongoing decline, of water quality and ecosystem health in Te Awarua o Porirua. Nor is there evidence in the available stream flow records to date of deteriorating trends in low flows. Demand for water, and abstractive pressure from takes, is relatively low.

However, the absence of obvious and widespread impacts does not mean localised effects are not problematic at times, nor that current NRP allocation provisions adequately manage for risks associated with future pressures relating to changing patterns in land and water use and a warming climate.

This report describes the reasoning and technical justifications for the whaitua allocation recommendations and subsequent amendments being proposed. In summary, it is considered that sound technical arguments exist for most whaitua recommendations and, where the arguments are less compelling, the following changes are suggested:

- The recommended allocation limit be amended from 30% of MALF to a more precautionary setting of 20% of MALF (either as a default or equivalent numerical flow value). This is intended to align the provision more appropriately with direction from the 2020 NPS-FM and te Mana o te Wai and is considered a more technically defensible position based on the best currently available expert advice regarding default limits. In combination with the whaitua recommendation for a minimum flow equating to 90% of MALF and the removal of the permitted activity rule, it is considered that the amended allocation limit will help reduce risks of ecosystem health (and dependent values) being adversely impacted in a significant way;

- The recommendation for minimum flows to apply to all permitted activity water uses be amended to apply just to those in the three catchments with well maintained flow management sites that have real time data available on the GWRC website. This is because no practical mechanism exists in un-gauged catchments to either apply a minimum flow or for water users to monitor for compliance;

- The recommendation to require water meters on all permitted activity takes be removed and periodic catchment land and water use surveys be adopted instead as a way of gathering permitted activity information. The administrative, cost and data burden of this requirement is unlikely to be be justified by the quality of information it yields.

There should be no consequences for existing consent holders from any of the whaitua recommendations that are different to those expected when the consents are renewed under the NRP.

Contents

1. Background and context

1.1 Report purpose

The purpose of this report is to provide technical support to the Section 32 (cost and benefit) planning assessment for Natural Resource Plan change proposals associated with Whaitua Te Awarua-o-Porirua. The report is focused on proposals relating to the allocation of water via resource consent and permitted activity rules and the anticipated effects of these proposals.

1.2 General catchment characteristics

Te Awarua-o-Porirua whaitua comprises a series of small stream catchments that primarily discharge directly to the Pauatahanui Inlet or Onepoto Arm of the harbour[1]. Streams rise in the surrounding hill country and have relatively steep and short channels and, therefore, do not support large natural base flows.

The three largest catchments by area are those of the Porirua, Pauatahanui and Horokiri streams (Figure 1). Porirua Stream lies within a highly urbanised catchment, while the other two are predominantly a mix of rural and lifestyle block land use.

Stream morphologies are generally characterised as sinous single thread channels with riffle-run-pool sequences and some gravel banking. There is no known significant groundwater resource in this whaitua although localised pockets of groundwater are present in the re-worked gravels along the stream valley floors.

[1] Some minor gully streams discharge directly to the open ocean, on either side of the Porirua Harbour mouth

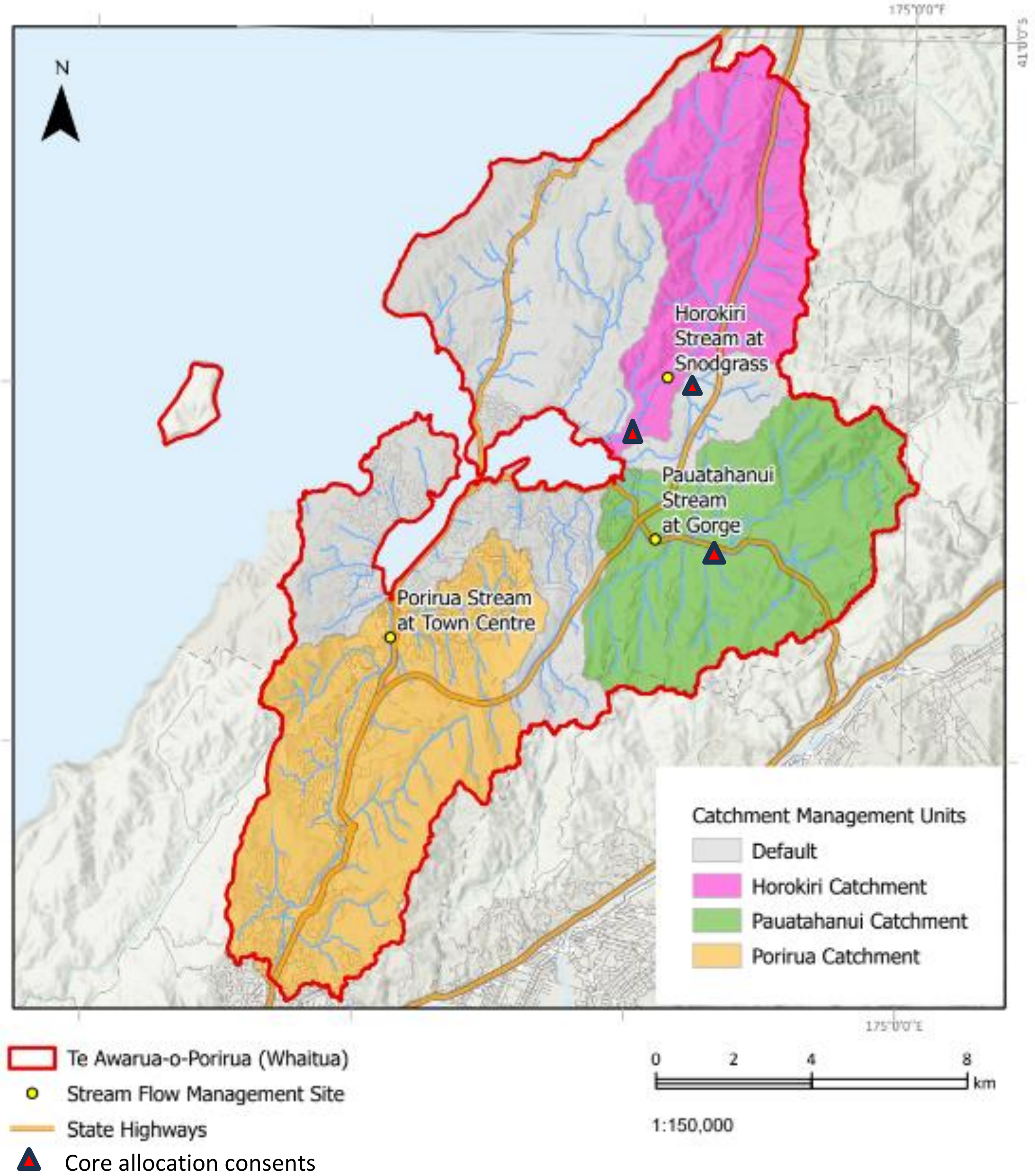

Figure 1: Te Awarua-o-Porirua water allocation catchment allocation units, core allocation consents and stream flow management sites (for applying minimum flows)

1.3 Stream flow regimes

Each of these three catchments mentioned above has a GWRC stream flow recorder site (Figure 1). Of the other stream catchments in the whaitua, only the Taupō Stream has a flow recorder. Flow statistics from the recorder sites are provided in Table 1.

Table 1: Median and mean annual low flow (MALF) flow statistics for the existing continuous flow recorder sites. MALF statistics are commonly used in GWRC and around the country as the primary flow index for referencing allocation regimes. MALF values here are reproduced from Keenan (2018a and b) and naturalised where appropriate for surface abstractions (i.e. converted to an estimate of natural MALF that would occur in the absence of upstream abstractions). Median flow statistics are calculated from the GWRC archive.

	Data record	Summer Median[1] (L/sec)	Natural 7D MALF (L/sec)	Natural 7D MALF (m^3/day)
Porirua Stream at Town Centre	1968-2022	255	142	12,270
Pauatahanui Stream at Gorge	1975-2022	220	112	9,675
Horokiri Stream at Snograss (Mouth)	2002-2022	190	91	7,860
Taupō Stream at Flax Swamp[2]	1979-2022	25	10	865

[1] For the six months between November and April inclusive. Can be interpreted as natural as any abstraction occurring would have been very minor in comparison.

[2] This site has a problematic history (the weir is prone to drowning) and is currently not maintained to a standard that would make it suitable to include in the regional plan as a management site.

Beyond the data collected at flow recorder sites and some sporadic flow gauging at other locations, stream flow hydrology information is sparse. Little is known about longitudinal patterns of flow, gains and losses associated with shallow groundwater exchange, or the potential for natural bed drying in severe summers (noting that there are no measurements or observations of zero flow in the GWRC archives).

With respect to changes in flow regime over time, Figure 2 shows the variation in annual minimum flows since 1990 for the Porirua, Pauatahanui and Horokiri streams. Inter-annual variability is relatively high throughout, especially for the Porirua Stream, but there do not appear to be any systematic changes or notable trends across the records to date. The tendency towards lower flow minima that has been observed in Wairarapa rivers in recent years is not so apparent in these Porirua Harbour streams.

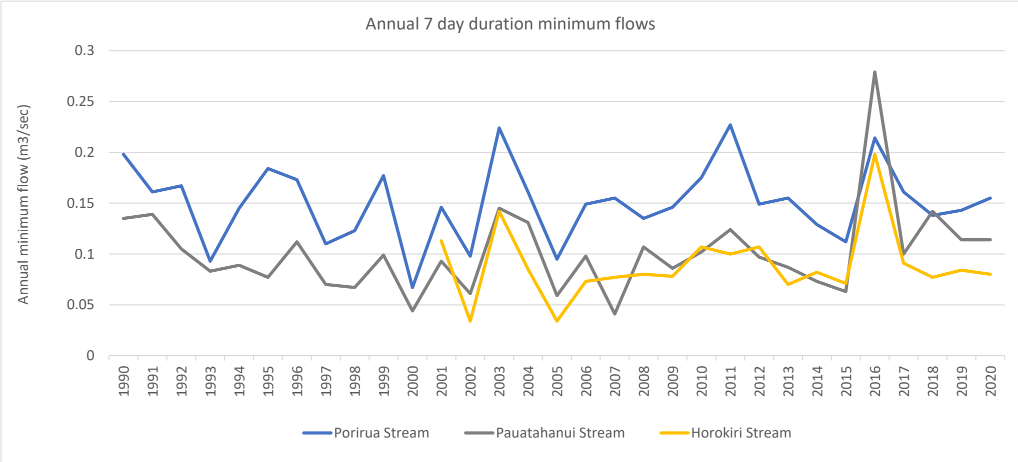

Figure 2: Annual minimum 7 day duration low flows for the Porirua, Pauatahanui and Horokiri streams since 1990

1.4 Demand for water

1.4.1 Consented water takes

There is currently a relatively low demand for water in Te Awarua-o-Porirua Whaitua compared to other parts of the region such as the Ruamāhanga and the Kāpiti Coast. There are only three existing consents for core allocation (Figure 1, Table 2) and none for supplementary, or high flow, allocation. All consented water takes are directly from streams. One consent (Judgeford Golf Club) is for a water take from the main stem of the Pauatahanui Stream and one (Leacroft Nurseries) is from the main stem of the Horokiri Stream. The other one (for Gareth Morgan Golf Ltd) is from a catchment – the Ration Stream – that does not have currently have a GWRC flow recorder. There are no consented takes from the Porirua Stream catchment. There are currently no consented groundwater takes and only a small handful have been issued in the past.

Table 2: Consented water takes (core allocation) and cumulative proportion of MALF

Consent holder	Catchment	Maximum instant Rate (L/sec)	Maximum daily volume (m^3/day)
Judgeford Golf Club	Pauatahanui Stream	12.2	130
	As % of catchment MALF	*11%*	2%
Leacroft Nurseries Ltd	Horokiri Stream	1.8	103
	As % of catchment MALF	*2%*	*1%*
Gareth Morgan Golf Ltd	Ration Stream	0.9	40
	As % of catchment MALF	*15%*[1]	*11%*

[1] This is the estimated percentage of MALF at the point of take as the catchment mouth MALF is not known

For the purposes of managing consented water takes (allocation and minimum flow limits), all catchments within Te Awarua-o-Porirua are currently governed by default surface water policies and rules in the Natural Resources Plan rather than catchment-specific numerical limits. There is no known significant groundwater resource in this whaitua and no groundwater allocation limits expressed in the NRP. Likewise, there are no recognised lakes (or takes from lakes).

The technical basis for the current allocation regime is discussed in Section 2.

1.4.2 Unconsented and permitted water takes

In addition to consented core allocation, water can also be abstracted under Section 14(3)(b) of the RMA for reasonable stock drinking and domestic needs as well as under Rule R152 of the NRP as a permitted activity.

Unconsented and permitted takes are not required to be notified to GWRC, nor do they need to be metered. This means accurately identifying volumes of unconsented water use in Te Awarua-o-Porirua is not possible. However, desktop modelling based on assumptions that are informed by land use type, parcel size, proximity to water sources and stock numbers can provide a good indication of at least the stock and domestic use components. This was done for primary catchments of Te Awarua-o-Porirua by Beca (2017). Results are reproduced in Table 3 for the four catchments with flow statistics presented in Table 3.

The Beca (2017) modelling suggests combined stock and domestic water use ranges between about 0.5 and 2 L/sec (as a daily average) in the selected catchments while as a proportion of catchment MALF, it is likely around one or two percent for the three larger catchments and around six percent of MALF in the Taupō Stream catchment.

Table 3: Modelled unconsented stock and domestic use (S14(3)b RMA) in four representative catchments of Te Awarua-o-Porirua. Figures are presented for each catchment as average litres per second and as percentage of MALF. Maximum potential permitted activity use under the NRP Rukle 152 allowances is also provided in the righthand column. Source Beca (2017).

Catchment	**Modelled likely use (average L/sec and as % of MALF)**			**Maximum permitted activity use[1] (average L/sec and % of MALF)**
	Domestic use	**Stock use**	**Combined Domestic and Stock use**	
Porirua Stream	0.24	0.50	0.75	39.47
As % of MALF	*0%*	*0%*	*1%*	*28%*
Pauatahanui Stream	0.40	1.50	1.90	47.57
As % of MALF	*0%*	*1%*	*2%*	*42%*
Horokiri Stream	0.28	0.74	1.02	30.32
As % of MALF	*0%*	*1%*	*1%*	*33%*
Taupo Stream	0.06	0.56	0.62	8.22
As % of MALF	*1%*	*6%*	*6%*	*82%*

[1] Based on the NRP maximum allowances of 2.5 L/sec and 20 m^3/day (or 10 m^3/d for properties smaller than 20 hectares)

While current use under the NRP permitted activity rule is unknown, postal surveys by GWRC of rural land owners around the Wellington and Kāpiti districts in 2020[2] offer some insights that are perhaps at least also broadly indicative of behaviour in Te Awarua-o-Porirua. In Te Whanganui a Tara, only four percent of approximately 140 survey respondents stated that they took surface or groundwater for a use that was neither stock or domestic. On the Kāpiti Coast, it was about 10 percent of approximately 875 survey respondents. Although neither of these survey results provide an estimate of volumes taken, they both indicate permitted activity use is only occuring on a small minority of rural properties. Furthermore, it is likely that permitted activity use in Te Awarua-o-Porirua whaitua is more similar in profile to Te Whanganui a Tara than Kāpiti Coast, given the relatively widespread abundance of groundwater in the latter.

[2] Findings summarised in GWRC (2020) and Blythe (2022)

If the maximum potential permitty activity allowances in Rule 152 of the NRP were to be fully taken up throughout the whaitua (righthand colum in Table 3), unconsented water use would become much more significant and more dominant than consented takes as an abstractive pressure; ranging between about 30 and 80 percent of MALF in the selected catchments.

1.5 Stream water quality and ecology

Water quality and ecological indicators are routinely measured by GWRC in the Horokiri, Pauatahanui and Porirua stream catchments.

The primary water quality concern relates to bacterial (pathogenic) pollution throughout the streams and receiving water bodies of the whaitua. This contamination primarily relates to runoff from the highly urbanised environment. Nitrate levels are generally relatively low although elevated phosphorus concentrations, related to mobilisation from soil during erosion events are of concern. Continuous records of water temperature or dissolved oxygen are not routinely collected although manual measurements are not indicative of persistent or widespread problems. The relatively steep gradient, short catchments will generally ensure water remains well oxygenated.

Macroinvertebrate health (MCI) is moderately impaired throughout the whaitua. With respect to the role of the flow regime, it is thought that increased flows and more frequent bed-disturbing flows (due to modified catchment surfaces, especially in the urban areas) are more of a factor than excessive low flows. Periphyton can be a problem with nuisance blooms thought to be related to elevated phosphorus and lack of stream shading.

With respect to habitat quality, the WIP (2017) concludes:

> *Stream habitats have been heavily modified in the Whaitua. In urban habitat has been cleared and streams modified (e.g. piped, straightened) for urban development and transport links. This has reduced spawning habitat, created barriers to fish passage and reduced physical diversity of streambank and stream-bed habitat. In rural areas, the forest and vegetation that once grew beside streams has been largely removed for pastoral farming.*

Fish monitoring is not undertaken routinely in this catchment so conclusions about abundance, condition and any patterns of change over time cannot be reached. However, the WIP (2017) states:

> *Many streams in the Whaitua have excellent diversity of fish species, including at-risk species such as giant kokopu, inanga, longfin eel and redfin bully. However, native freshwater fish populations are also under stress or in decline. Many of the factors that affect MCI also apply to native fish, along with obstructed passage from the sea (including piped sections and physical barriers) throughout the catchment.*

National Objective Framework (NOF) attributes and current state, as presented to Te Awarua-o-Porirua whaitua committee in 2018, are summarised in Appendix 1.

Overall, there is little evidence or suggestion (e.g.in the WIP) that low flows or current levels of abstraction are an important factor where degradation of water quality or ecology has been observed. Nevertheless, the potential for abstraction to aggravate low flows and reduce the quality and amount of aquatic habitat exists.

2. Current NRP allocation regime – technical reasoning

By and large, no catchment-specific investigations or analyses were undertaken when developing limits for Te Awarua-o-Porirua in the Natural Resources Plan (NRP). Instead, reliance was placed on more general technical guidance, 'rules of thumb' and expert judgement about levels of risk to water bodies. This approach was considered appropriate at the time for several reasons:

- Demand for resource consent to take water in this whaitua is low, and, therefore, risk of adverse impacts is also low;
- Information on instream values and hydrology was relatively sparse;
- The upcoming whaitua process was the better mechanism for contemplating catchment specific limits (rather than the NRP).

The following is a slightly fuller explanation of the NRP allocation limits and technical reasoning. The purpose is to provide context to the next sections of the report that set out changes to these limits recommended by the whaitua committee and/or proposed based on subsequent assessments.

2.1 Core allocation and minimum flow limits for surface water

2.1.1 Policies

Core allocation describes the amount of water available to consent above the minimum flow, which is the flow at which all consented surface water abstraction must cease (with some exceptions – e.g. human health needs).

There are currently no numerical limits listed in the NRP for any of the catchments in Te Awarua-o-Porirua. Both minimum flow and surface water core allocation limits are covered by a general policy framework (Table 4).

Table 4: NRP policies for minimum flow and allocation limits in Te Awarua-o-Porirua

Type of limit	NRP policy	Limit[1]
Minimum flow	P.P1	90% of MALF
Core allocation limit	P121	30% of MALF[2]

[1] MALF is defined in the NRP as the **natural mean annual low flow** with a seven day duration

[2] There are no streams/rivers with a mean flow greater than 5 m3/sec in Te Awarua-o-Porirua so the second default allocation limit in the NRP for these larger systems is not relevant (and not listed here)

In addition to the limits above, Policy P119 was introduced to the NRP during the appeals process in 2020 and requires that consented water takes are reduced as stream flows decline towards the minimum flow.

2.1.2 Reasoning

The default minimum flow and core allocation limits that currently apply in Te Awarua-o-Porirua (and in some other parts of the Wellington region) were based on technical guidance supporting the proposed National Environmental Standard (pNES) for ecological flows and water levels (Ministry for the Environment 2008). The pNES guidance in turn is based on a body of New Zealand research (summarised in Beca, 2008) that has characterised the general risks associated with exceeding certain allocation thresholds. While the pNES was never brought into legislation, at the time the NRP provisions were being drafted the pNES default criteria were widely considered appropriate to apply in situations where bespoke catchment limits had not been defined and demand for water was relatively low.

Mean annual low flow (MALF) is known to be an ecologically relevant flow statistic and is commonly used around the country as a key reference index for setting both minimum flows and allocation limits. More specifically, as stream flows fall (or are drawn) to, and below, MALF, risks of adverse impacts to aquatic species increase. Loss of physical instream habitat is often the most obvious consequence of low flows but other more subtle stressors also become more prominent, such as changes to thermal and oxygen profiles. Extended duration of low flows may also promote nuisance algae growth. In adopting the pNES recommendation of a '90/30'[3] for default limits, the rationale was that this combination of limits would prevent excessive alteration of natural flows around MALF and could therefore be considered generally precautionary in favour of stream ecosystem health and instream values.

2.2 Supplementary allocation limits

Above median flow, more water becomes available to allocate (in addition to core allocation). This is defined in the NRP as 'supplementary allocation' and is governed by P124, with reference to Schedule U, which was introduced to the NRP during appeals in 2020.

Two streams in Te Awarua-o-Porirua are listed in Schedule U, the Pauatahanui and Horokiri streams, and both fall into the smaller stream category whereby the maximum supplementary allocation available above median flow is 10 percent (of natural stream flow at the point of abstraction). It is very likely that all other streams in Te Awarua-o-Porirua would also fall into the same small stream category when the methods of Schedule U are applied.

2.2.1 Reasoning

For the NRP, a panel of freshwater experts was assembled by GWRC to provide advice on supplementary allocation criteria. There was a consensus of opinion in that group that the data and knowledge with which to derive ecologically-explicit supplementary flow thresholds is relatively limited. However, they were able to agree on some key guiding principles: (1) that median flow is ecologically-relevant (often viewed as providing an approximation of typical

[3] Shorthand used from here on, meaning (in this case) a minimum flow of 90 percent of MALF and an allocation limit of 30 percent of MALF

habitat conditions, and therefore river/stream carrying capacity & productivity, during flow recessions – see Hay and Kitson 2013), and (2) that preserving flushing flows (and hence a fundamental part of the natural flow regime) is important, especially for ensuring that periphyton accrual is not encouraged by abstraction.

From these principles it was considered that supplementary allocation should only be available above median flow (i.e. so that there is no further reduction of flows in the range between MALF and median) and that the frequency of flushing flows (defined as three times median or higher) should not be altered.

No particular advice was provided by the expert panel on the size of the supplementary allocation volume that could be made available above median flow. In the absence of any firm technical advice, GWRC opted for equity between users and the river and the NRP was therefore originally notified with a 1:1 flow sharing regime above median. During NRP submission process this policy was adapted to make a distinction between rivers and streams. For streams, the allocation cap was reduced from a 50 percent flow share to a maximum of 10 percent of the flow above median. The choice of 10 percent was not based on any specific GWRC analysis but was put forward as a more precautionary alternative by a submitter (NZ Fish and Game Council). During NRP appeals, Schedule U was developed to provide more certainty to consenting officers and applicants about how supplementary allocation volumes should be calculated, but also ensure that the cumulative effect of multiple supplementary takes on the same river or stream are appropriately accounted for.

2.3 Groundwater allocation limits

There are currently no groundwater management zones identified in the NRP for Te Awarua-o-Porirua and therefore no groundwater allocation limits listed. Applications for consent to take groundwater are treated as discretionary activities under P.R1 and assessed on their own merits. To date, only a small handful of groundwater consents have been issued (these were temporary consents from the Pauatahanui Stream valley for dust suppression during the Transmission Gully roading project; all groundwater consents have now expired).

2.3.1 Reasoning

The absence of meaningful groundwater resources or demand for groundwater in Te Awarua-o-Porirua means that any applications can be assessed and managed on a case by case basis without risk of significant adverse effects (either local or cumulative). The same technical principles and criteria that are applied in other parts of the region[4] (where limits and groundwater categories A/B/C exist) can be applied in Te Awarua-o-Porirua. That is, the level of hydraulic connectivity to surface water streams should be determined and, if

[4] Conjunctive frameworks for managing surface and groundwater in the Ruamāhanga Valley, Kāpiti Coast and Hutt Valley, summarised in Table 4.1 of the NRP: *Classifying and managing groundwater and surface water connectivity*

appropriate, a portion of the allocation volume is counted against the surface water core allocation limit and there may also be some low flow restrictions applied in accordance with the minimum flow for the relevant stream. Likewise, the groundwater storage available to support any takes can be determined with reference (primarily) to aquifer recharge, as has been done in other parts of the region where groundwater limits are defined.

2.4 Unconsented and permitted activity water takes

In addition to consented core allocation, water can also be abstracted under Section 14(3)(b) of the RMA for reasonable stock drinking and domestic needs as well as under Rule R152 of the NRP as a permitted activity

Table 5: Permitted activity allowances under Rule R152

Property size	**Rate**	**Volume** per day
Greater than 20 hectares	2.5 L/sec	20 m^3
Less than 20 hectares	2.5 L/sec	10 m^3

2.4.1 Reasoning

The choice of limits and thresholds for the NRP permitted activity rule was not informed by any particular technical arguments.

3. Allocation regime – whaitua committee recommendations

Te Awarua-o-Porirua Whaitua Committee focused on two aspects of the allocation regime where they perceived the highest risks to lie; core allocation of surface water (consented) from streams and permitted activity takes. Their recommendations for changes to the NRP policies and rules are summarised in this section, with particular regard to the technical arguments informing their decisions.

Technical advice and material provided to the committee and notes from committee workshop meetings are provided in the reference section of this report.

The committee did not comment on groundwater or supplementary allocation or recommend any changes to the NRP approach for either.

3.1 Core allocation and minimum flow limits for surface water

3.1.1 Whaitua recommendations

The committee opted to retain the NRP default limits for minimum flow (90 percent of MALF) and core allocation (30 percent of MALF) for consented takes. However, for the sake of clarity and certainty, they wished to see these limits expressed as numbers (L/sec) rather than proportions of MALF, where the hydrological information exists to support this translation. The whaitua recommendations are compared to the NRP provisions in Table 6.

Table 6: Recommended minimum flows and surface water core allocation

Catchment [Flow management site]	Minimum flow		Core allocation	
	NRP	Whaitua	NRP	Whaitua
Porirua Stream [Town Centre]	90%MALF	128 L/sec	30%MALF	60 L/sec
Pauatahanui Stream [Gorge]	90%MALF	101 L/sec	30%MALF	34 L/sec
Horokiri Stream [Snodgrass]	90%MALF	82 L/sec	30%MALF	27 L/sec
Elsewhere	90%MALF	90%MALF	30%MALF	30%MALF

In addition to the numerical limits for the three catchments in Table 6, the committee also sought amendments (WIP Recommendation 68) to the NRP rule and policy framework to ensure that water takes from any tributaries of the main stem streams do not (collectively) exceed more than 30 percent of MALF of that tributary; i.e. to guard against the total allocation amount for each of the three catchments in Table 6 being taken from tributaries that cannot support it.

3.1.2 Reasoning

The committee were provided with a summary of the rationale for the NRP default limits (as described in Section 3 of this report) and also some more specific flow-habitat modelling for stream catchments of Te Awarua-o-Porirua. Based on the outputs of this modelling, the NRP default limits (90/30) were characterised to the committee as providing:

- "Good" habitat protection for fish species (i.e. retaining >90 percent of habitat available at MALF for a range of species;
- Modest reliability of supply for water users, comparable with other parts of the region.

There was a particular focus on tuna (eel) as a taonga species. Advice from NIWA (Dr Don Jellyman) was that minimum flows in the range 90-110 percent of MALF would likely avoid creating any population density stress on the tuna but that minimum flows as low as 50 percent of MALF would likely create such a stress.

While there seems to have been a good degree of comfort around the choice of 90 percent of MALF for the minimum flow, some disquiet was expressed by members of the committee about whether a default allocation limit of 30 percent of MALF was sufficiently precautionary[5]. There were also questions about whether mahinga kai values would be sufficiently protected and whether climate change was adequately factored in. The whaitua technical team were asked to consider some alternative minimum flow and allocation limit settings and present these back to the committee. This occurred at a workshop in October 2017[6] and the key decision making tool from that workshop is shown in Figure 3.

Value	Attribute	Effect	Alternative minimum flow and allocation amounts compared to 90+30							
			100+20	90+20	100+25	90+25	100+30	90+30	100+40	90+40
Ecosystem health and mahinga kai	Habitat protection	Intensity of 'human induced' stress	Better	Same	Better	Same	Better	Good protection	Better	Same
		Additional days of stress at or below minimum flow	Better	Better	Better	Slightly better	Same		Worse	Worse
Economic use of water	Supply reliability	Time with full access to allocation amount	Same	Better	Slightly worse	Slightly better	Worse	Moderate reliability	Worse	Worse
		Time on total restrictions	Worse	Same	Worse	Same	Worse		Worse	Same
	Availability of water for economic use	Amount of water that can be taken from a stream	Less ←							→ More

Figure 3: Likely effects of alternative minimum flow and allocation limits compared to NRP 90/30 approach for the Pauatahanui Stream. Table presented to whaitua committee in October 2017 workshop[7].

[5] REPORT TAoPW Committee Workshop 14 September 2017 V.1 (gw.govt.nz)
[6] Final-WORKSHOP-REPORT-Te-Awarua-o-Porirua-Whaitua-Committee-26.10.2017.pdf (gw.govt.nz)
[7] Water-allocation-alternative-levels-of-minimum-flow-and-allocation-limit.pdf (gw.govt.nz)

In comparing options in Figure 3, the technical team's advice to the committee was[6]:

- There is little marginal difference between the options presented;
- All options in their different combinations (100 or 90 percent of MALF minimum flow, and 30, 25 and 20 percent of MALF allocation amount) provide well for all values;
- Using a higher minimum flow and/or lower allocation limit is slightly more precautionary and would provide slightly higher levels of habitat protection. This comes with the trade-off of less water available for use and slightly more time on total restrictions.

Subsequent to this information and advice being provided there remained an element of discomfort among the committee about whether the 90/30 setting was sufficiently conservative and whether it adequately took account of stream health in a more 'holistic' sense. Workshop minutes from November 2017[8] include the statement that "*there was a challenge* [to the committee] as to wh*y we couldn't be more conservative with the flow management tool. What harm would it do to choose 100%+20 percent? Members noted that iwi members may favour this approach*".

Ultimately, the committee endorsed the NRP 90/30 limits, albeit with the recommendation to translate into numerical limits in the Porirua, Pauatahanui and Horokiri catchments (using the hydrological data records available for these catchments).

The hydrological analysis undertaken to determine the minimum flow and allocation numbers presented in Table 6 is described in Keenan (2018). For clarity, it is noted that the allocation limit for the Porirua Stream of 60 L/sec equates to 30 percent of estimated natural MALF at the bottom of the catchment, including the Kenepuru Stream, rather than 30 percent of MALF at the 'Town Centre' flow recorder site (which would equate to 43 L/sec).

Keenan (2018) makes mention of two other catchments, Kakaho Stream and Duck Creek (see Figure 1), and suggests that further hydrological study would be needed to determine MALF and then translate this to numerical limits. In the meantime, and in the absence of any consented water takes, the 90/30 defaults should apply.

[8] REPORT-Te-Awarua-o-Porirua-Whaitua-Workshop-23-November-2017_2.pdf (gw.govt.nz)

3.2 Unconsented and permitted activity water takes

3.2.1 Whaitua recommendations

The committee opted to effectively remove the permitted activity rule in the NRP so that resource consent is required for anything other than 'incidental' uses (or that is not authorised under the RMA S14(3)b rule for stock and reasonable domestic use).

Table 7: Recommended changes to permitted activity maximum rates and volumes (Recommendations 69 and 70 of the WIP)

	NRP	**Whaitua** recommendation (for incidental use)
Rate	2.5 L/sec	2.5 L/sec
Volume per day	10 m^3 – 20 m^3 (1)	5 m^3
Volume per month	300 m^3 – 600 m^3 (2)	10 m^3
Minimum flow applies?	No	Yes

[1] In the NRP, allowance (10 or 20 m^3) depends on property size; no such distinction in the whaitua recommendation

[2] No monthly allowance is specified in the NRP so range here based on extrapolation of maximum daily volumes and property size

The committee also recommended that water must not be taken under the permitted activity rule "*when the affected waterway is below minimum flow*" and that "*users must keep records of the amount taken*".

Recommendation 73 was that "*Greater Wellington collects better information on water take and use volumes, including for takes under 14(3)(b) of the RMA, in order to provide for more accurate and transparent accounting of water use, better management of the Whaitua's waterways, and to ensure the requirements of the NPSFM are met*".

3.2.2 Reasoning

In line with technical and policy advice from the whaitua project team[9], the committee reasoning for changes to the NRP permitted take rule incorporated the following themes[10]:

- There is a great deal of uncertainty about the amount of water currently taken under the permitted activity rule as these takes are not metered and no hard data are collected;

- Modelling (summarised in Table 3 of this report) shows that, while current uptake may be quite low and present only a low risk of adverse stream impacts, the potential for significantly more use and greater impact is much higher. Climate change combined with perhaps significant changes in landuse (e.g. more viticulture) could see demand significantly increase;

[9] REPORT water allocation in Te Awarua-o-Porirua whaitua - August 2017 (gw.govt.nz)
[10] Final-WORKSHOP-REPORT-Te-Awarua-o-Porirua-Whaitua-Committee-26.10.2017.pdf (gw.govt.nz)

- Removing most of the allowance would incentivise people to move to other options such as rain tanks rather than exert further pressure on streams;

Overall, the need to be precautionary and “*add more margins*” was appealing to the committee, as was removing the uncertainty around the amount of permitted takes used and having some control over the potentially larger takes from the streams via the resource consent process.

The application of minimum flows to permitted takes appears to be based on the general principle that restrictions should apply equally for all uses of water (consented and permitted) that are not for essential human health or stock welfare purposes. The requirement for metering and for GWRC to collect better information on unconsented and permitted use was considered necessary by the committee to improve water take accounting and management of total allocation.

The practicalities and costs associated with applying minimum flows and metering regulations were recognised in broad terms by the committee but not explored in any detail.

4. Proposed amendments to the whaitua recommendations

Subsequent to the delivery of Te Awarua-o-Porirua Whaitua Implementation Programme (WIP) report in 2018, the amended National Policy Statement for Freshwater Management (NPS-FM 2020) was gazetted. An important amendment was the strengthened concept of te Mana o te Wai and associated hierarchy of obligations that requires greater weight and more explicit privilege to be given to the health or rivers and streams when setting limits.

While assembling technical material for the current Section 32 planning assessment, the opportunity has been taken to review the whaitua allocation limit recommendations in light of the NPS-FM/te Mana o te Wai and more contemporary thinking about acceptable stream health risks. This has led to some proposals for changes that are described in the following section.

Some of the practical and cost issues associated with the whaitua recommendations for permitted activity water takes have also been more fully considered and some amendments are suggested.

4.1 Core allocation and minimum flow limits for surface water

4.1.1 Recommended amendments to the whaitua limits

It is recommended that a more precautionary approach to allocation is adopted and that the default limit is reduced from 30 percent MALF to 20 percent MALF. This change should apply when translating the ratio to numbers in the three listed catchments (Porirua, Pauatahanui and Horokiri streams) as well as for the proportional default for all other catchments (including tributaries of the main stems in the three listed catchments). The proposed changes are shown in red in Table 8.

No changes to the whaitua recommendations for minimum flow limits are proposed.

Table 8: Whaitua recommended minimum flows and surface water core allocation from Table 6 with proposed amendments (strikethrough and red text)

Catchment [Flow management site]	Minimum flow		Core allocation	
	NRP	Whaitua	NRP	Whaitua
Porirua Stream [Town Centre]	90%MALF	128 L/sec	30%MALF	~~60 L/sec~~ 40 L/sec
Pauatahanui Stream [Gorge]	90%MALF	101 L/sec	30%MALF	~~34 L/sec~~ 22 L/sec
Horokiri Stream [Snodgrass]	90%MALF	82 L/sec	30%MALF	~~27 L/sec~~ 18 L/sec
Elsewhere	90%MALF	90%MALF	30%MALF	~~30%MALF~~ 20%MALF

4.1.2 Reasoning

Recent expert advice from freshwater ecologists in New Zealand, including from the Cawthron Institute and NIWA[11], has been that an allocation limit of 30 percent MALF is not especially precautionary for streams. The advice is based on a modified risk assessment framework that has drawn upon elements of the technical work underpinning the 2008 pNES (Beca 2008), internationally recognised presumptive standards for flow regime protection (Richter et al 2012) and the principles and direction of the 2020 NPS-FM and te Mana o te Wai. The risk assessment framework and rationale is summarised in Table 9.

Default minimum flow and allocation limits being developed for the Kāpiti Coast whaitua committee to consider are currently being developed with the same approach in mind.

[11] For example, Hayes et al 2021, Shearer and Hayes 2021

Table 9: Shearer and Hayes (2021) proposed default minimum flow and primary allocation limits for the Kāpiti Coast whaitua, expressed as % of naturalised 7-day mean annual low flow (MALF), for maintenance of flows that present a low risk of more than minor effects on ecosystem health and wellbeing of streams / rivers, including their instream habitat, life-supporting capacity, mahinga kai and fisheries amenity. Adapted from Hayes et al. (2021).

Limit	Surface water body with mean flow ≤ 5 m³/s	Surface water body with mean flow > 5 m³/s	Abstraction from permanently flowing reaches of intermittent streams	
			Containing threatened indigenous species; or Significant spawning and juvenile rearing habitat for regionally or nationally important salmonid fisheries downstream	Not containing threatened indigenous species; or significant salmonid spawning and juvenile rearing habitat
Minimum / residual flow	90% of naturalised 7-day MALF	80% of naturalised 7-day MALF	90% of naturalised 7-day MALF	80% of naturalised 7-day MALF
Allocation rate	20% of naturalised 7-day MALF	30% of naturalised 7-day MALF	20% of naturalised 7-day MALF; or > 15% of instantaneous flow at point of take if naturalised MALF estimates are zero or are unavailable	25% of naturalised 7-day MALF; or > 20% of instantaneous flow at point of take if naturalised MALF estimates are zero or unavailable

A project team workshop was held at GWRC on 24 May 2023 to consider the updated advice, with input before and afterwards from Dr Robin Holmes from Cawthron. It was agreed that the more conservative allocation limit (20 percent MALF) is more technically defensible for catchments where there is little or no hydrological information and/or there is a poor understanding of stream values.

Discussion then turned to whether the same reasoning should apply in the three Te Awarua-o-Porirua catchments for which more information is available; the Porirua, Pauatahanui and Horokiri streams.

It was felt that if the same committee process been undertaken more recently under the stronger and more environmentally conservative direction of the NPSFM 2020 and te Mana o te Wai, it is possible, or likely even, that the discussion of ecosystem health risks may have been framed in a more precautionary way. For example, the starting reference point in Figure 3 might have been the 90/20 setting (being now regarded as more suitably precautionary) rather than the PNRP status quo of 90/30. Had this different starting point been taken, the committee may well have opted for 90/20, especially considering the hesitancy and disquiet expressed by some on the committee about the 30 percent of MALF allocation limit.

It was agreed therefore that a more defensible position for these three catchments would be to also reduce the allocation limit to a number that equates to 20 percent of MALF in each case (as presented in Table 8).

With respect to the default minimum flow, 90 percent of MALF is still considered ecologically conservative (notwithstanding exceptional circumstances) and, following the logic of the risk assessment framework in Table 9, no change to the whaitua recommendation is therefore considered necessary.

4.2 Unconsented and permitted activity water takes

4.2.1 Proposed amendments to the whaitua recommendations

The only amendments proposed relate to permitted activity use. It is proposed that minimum flows only apply to permitted activity water takes in the three catchments with listed numerical allocation limits and/or flow recorders; these are the Porirua, Pauatahanui and Horokiri streams. Proposed amendments are shown in Table 10.

The other proposed amendment is that rather than require metering and record keeping on all permitted activity takes, weight is placed instead on the recommendation for GWRC to collect better information on these takes.

Table 10: Whaitua recommended changes to permitted activity maximum rates and volumes (from Table 7) with proposed amendments (strikethrough and red text)

	NRP	**Whaitua recommendation (for incidental use)**
Rate	2.5 L/sec	2.5 L/sec
Volume per day	10 m^3 – 20 m^3 (1)	5 m^3
Volume per month	300 m^3 – 600 m^3 (2)	10 m^3
Minimum flow applies?	No	Yes – in the Porirua, Pauatahanui and Horokiri catchments No – everywhere else (default limits and no flow recorder site)

[1] In the NRP, allowance (10 or 20 m^3) depends on property size; no such distinction in the whaitua recommendation

[2] No monthly allowance is specified in the NRP so range here based on extrapolation of maximum daily volumes and property size

4.2.2 Reasoning

(a) Application of minimum flows

While the equity principle of applying minimum flows to all permitted activity takes is reasonable, in practice this will be problematic in catchments that do not have a real time flow measurement site (i.e. those catchments in which the default 90 percent of MALF minimum flow applies). It would require GWRC to determine a surrogate minimum flow from a catchment with a recorder site and this can only be done in a robust way if there is at least a good record of spot gauging measurements in the default limit catchment (which is not the case for most of the catchments in Te Awarua-o-Porirua whaitua).

In short, there is neither the current mechanism to apply a minimum flow in default catchments, nor sufficient hydrological data to robustly derive a surrogate trigger flow. The risk to stream health of not applying a minimum flow in catchments with default limits is likely low. Table 3 in this report (and the background technical report that informed it[12]) estimate from modelling that current permitted uses are likely to account for less than 10 percent of natural low stream flows in the smaller default limit catchments. This order of proportional stream flow reduction, even at the lowest flows and in the smallest streams that are most vulnerable to abstraction, is unlikely to be measurable or to excessively aggravate ecosystem stress already occurring.

Furthermore, with the exception of a single minor consented take on Ration Stream (Table 2) , there are no consented water takes in any of the other catchments with default limits. This further mitigates the risk associated with not applying minimum flows to permitted activity take, as does the significantly reduced volumes available to permitted takes under the new proposals.

Not applying minimum flows to permitted activity takes in the default limit catchments perhaps raises a fairness question in relation to how permitted takes are to be treated in the other catchments (i.e. where a minimum flow will apply). However, the technical argument is stronger in these other catchments, not just because the practical means by which to apply the minimum flows already exists (i.e. real time flow recorder sites) but also because the stream health risks are higher due to the combined pressure of consented and permitted takes (especially in the Pauatahanui Stream catchment).

If, and when, new applications for water take consents in catchments with default limits are received, this would require GWRC to re-assess total allocation pressures and whether numerical limits and real-time monitoring is justified. Through this process, it may be that minimum flows are introduced to more catchments and their associated permitted activity water takes in the future.

[12] REPORT-Modelling-Permitted-Surface-Water-Use-in-Te-Awarua-o-Porirua-Whaitua-23-May-2017.pdf (gw.govt.nz)

(b) Metering of permitted activity takes

A policy requiring metering of all permitted water takes is likely to generate an administrative, data, and cost burden (to both GWRC and water users) that is out of proportion with the potential benefit gained from the information.

Metering data would only be useful for informing policy or community decisions if a large majority of permitted take users installed and maintained meters in accordance with industry standards and regularly submitted quality-assured data. The likelihood of this *not* happening is high for several reasons:

- The costs for meter installation and ongoing calibration and maintenance are relatively high and likely to be a disincentive for many water users to fully comply (see discussion in Section 5);

- Without regulatory oversight of the scale of use, the completeness of any datasets at a catchment scale would be unknown (i.e. if GWRC does not have to be informed about where permitted activity takes are occurring, it cannot assess compliance with metering and reporting);

- Receiving, auditing and archiving consent holder metering data is already a significant challenge for GWRC. If all permitted take metering data were required to be submitted[13], this could expand the incoming data sets by a very significant, but ultimately unknown, amount. Furthermore, experience with consent holder data to date suggests that the smaller takes (often associated with land uses with lower capital investments and returns) have the poorest data quality and need the most 'grooming'.

On balance, it is considered that the outcome sought by requiring meters –that of improved catchment accounting and whaitua stream management – will unlikely be achieved in a substantive way, and the burden would likely be unjustifiably large.

In the experience of GWRC staff[14], periodic land and water use surveys are more likely to yield better information (i.e. more granular and issue-focused) for less cost and burden. Such surveys can be targeted at catchments with greater water use pressure and/or at higher risk. The surveys can identify users and their land use (including consented takes who had changed their land use) and can make some reasonably accurate estimates or measurements of individual take volumes based on the configuration of pump scheme and nature of consumption. Quality assurance of the collected data is better controlled and overall resourcing is likely to be more manageable than for implementing a widespread metering system.

Land and water use surveys in a given catchment could be scheduled, for example, every 10 years to coincide with common catchment expiry dates of

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[13] Noting that a metering policy in Te Awarua o Porirua would likely set a precendent for being adopted region-wide

[14] For example, postal surveys cariied out by GWRC in 2020 in the Te Whanganui a Tara and Kāpiti Coast whaitua, and summer surveys conducted in the mid 2000s in the Wairarapa as part of the groundwater modelling project

consents. Such surveys would require a long term GWRC commitment, although it is noted that they would align with the Recommendation 73 for GWRC to collect better information on unconsented and permitted activity takes.

5. Implications for water users

This section considers the potential for recommendations by the whaitua (Section 3) and suggested amendments (Section 4) to impact existing consented and permitted activity water takes.

5.1 Implications for consent holders

Table 11 shows that current consented abstraction is, cumulatively, less than 20 percent of MALF in each of the three stream catchments with consents in operation (Pauatahanui, Horokiri and Ration streams) and less than the amended numerical limits (Table 8) for the Pauatahanui and Horokiri streams. This means that none of the existing four consent holders in Te Awarua-o-Porirua will be subject to any reductions in allocation as a result of the proposed allocation limit amendments.

Table 11: Catchments with consented water takes. Green shading indicates limit has not been exceeded

Catchment	Total consented allocation (Instant Rate L/sec)	Proportion of MALF	Proportion of limit
Pauatahanui Stream	12.2	11%	61%
Horokiri Stream	1.8	2%	10%
Ration Stream	0.9	15%[1]	N/A[2]

[1] This is the estimated percentage of MALF at the point of take as the catchment mouth MALF is not known

[2] Default limit (20 percent of MALF) applies in this catchment as there is insufficient hydrological data to calculate a numerical catchment limit.

Table 12 summarises the low flow restriction conditions that are currently attached to each of the three resource consents and whether these conditions align with the NRP and whaitua recommendations for minimum flow. For two consents there is complete alignment and so there is no implication for either from the whaitua recommendations. The other consent (Leacroft Nurseries) currently has a discretionary condition that requires cease take only at the direction of GWRC and the minimum flow of 70 L/sec is slightly lower than the whaitua recommendation (82 L/sec). However, since the whaitua limit is simply a translation of the existing NRP limit of 90 percent of MALF[15], the consent holder would be required to migrate to the higher minimum flow (without discretion) at next renewal under the NRP anyway (i.e. there is no new consequence from the whaitua recommendation).

[15] The current minimum flow of 70 L/sec on the Leacroft Nurseries consent was calculated using a value of MALF that has since been updated with more recent flow data

Table 12: Consented water takes, current low flow restriction conditions and alignment with the NRP rules and whaitua recommendations

Consent holder	Current low flow condition	Alignment with NRP minimum flow?	Alignment with whaitua minimum flow?
Judgeford Golf Club	Cease take when Pauatahanui Stream at Gorge falls below 101 L/sec	Yes	Yes
Leacroft Nurseries Ltd	Upon request of GWRC, take is to cease when flow in the Horokiri Stream at Snodgrass falls below 70 L/sec	Almost	Almost
Pauatahanui Golf Club	Cease take when flow in the Ration Stream at point of take falls below 5 L/sec	Yes	Yes

Overall, the recommendations by the whaitua, and subsequent proposed amendments, should have no impact on existing consent holders in Te Awarua-o-Porirua.

5.2 Implications for permitted activity water users

No information is available to quantify the number of users who will be affected by the replacement of the NRP permitted activity allowances with the much lower incidental use rates and volumes, nor specifically how they might be impacted. The recent postal survey work in neighbouring whaitua (described in Section 1.3.2) suggests relatively low numbers of rural properties would potentially be affected. Furthermore, since consentable allocation is available throughout the whaitua (there are no fully allocated catchments under the whaitua recommendations), the impact for those that need the higher volumes should be limited to the costs associated with gaining and maintaining a consent.

The cost of installing and maintaining meters was investigated to inform the section 32 evaluation. Information on these costs was sought from suppliers. Costs will vary based on the works required to modify existing infrastructure and the type of meter installed. Estimated installation costs, including supply of the meter and changes to headworks ranged from $1,300 - $10,000, while estimated maintenance costs (periodic verification of the meter) ranged from $800 - $2,000.

6. Summary

Water takes, either consented or unconsented/permitted, are not currently considered to be contributing in a major way to the deterioration, and ongoing decline, of water quality and ecosystem health in Te Awarua-o-Porirua (noted in Section 1). Nor is there evidence in the available stream flow records to date of deteriorating trends in low flows. Demand for water, and abstractive pressure from takes, is relatively low.

However, the absence of obvious and widespread impacts does not mean localised effects are not problematic at times, nor that current NRP allocation provisions adequately manage for risks associated with future pressures relating to changing patterns in land and water use and a warming climate.

This report has described the reasoning and technical justifications for the whaitua allocation recommendations and subsequent amendments being proposed. In summary, it is considered that sound technical arguments exist for most whaitua recommendations and, where the arguments are less compelling, the following changes are suggested:

- The recommended allocation limit be amended from 30 percent of MALF to a more precautionary setting of 20 percent of MALF (either as a default or equivalent numerical flow value). This is intended to align the provision more appropriately with direction from the 2020 NPS-FM and te Mana o te Wai and is considered a more technically defensible position based on the best currently available expert advice regarding default limits. In combination with the whaitua recommendation for a minimum flow equating to 90 percent of MALF and the removal of the permitted activity rule, it is considered that the amended allocation limit will help reduce risks of ecosystem health (and dependent values) being adversely impacted in a significant way;

- The recommendation for minimum flows to apply to all permitted activity water uses be amended to apply just to those in the three catchments with well maintained flow management sites that have real time data available on the GWRC website. This is because no practical mechanism exists in un-gauged catchments to either apply a minimum flow or for water users to monitor for compliance;

- The recommendation to require water meters on all permitted activity takes be removed and periodic catchment land and water use surveys be adopted instead as a way of gathering permitted activity information. The administrative, cost and data burden of this requirement is unlikely to be be justified by the quality of information it yields.

There should be no consequences for existing consent holders from any of the whaitua recommendations that are different to those expected when the consents are renewed under the NRP.

References

Beca 2008. *Draft guidelines for the selection of methods to determine ecological flows and water levels.* Report prepared by Beca Infrastructure Ltd for the Ministry for the Environment. Ministry for the Environment, Wellington, New Zealand.

Beca 2017. *Modelling permitted surface water use in the Porirua whaitua catchment*. Prepared for Greater Wellington Regional Council by Beca. Report 7772556 // NZ1-13886709-22 0.22

Hay J and Kitson J 2013. *Flow harvesting: A review of policy and potential effects*. Prepared for Environment Southland. Cawthron Report No. 2408. 41 p. plus appendix.

Hayes J, Booker D, Singh S, Franklin P 2021. *Default minimum flow and allocation limits for Otago.* Cawthron Advice Letter 2157 to Otago Regional Council, dated 17 September 2021. 19 p.

Keenan L 2018a. *Porirua whaitua - Minimum flow and core allocation recommendations*. Memo prepared for Greater Wellington Regional Council by Jacobs.

Keenan L 2018b. *Mean annual low flow statistics* for *Porirua whaitua.* Memo prepared for Greater Wellington Regional Council by Jacobs.

Ministry for the Environment (MfE) 2020. *National policy statement for freshwater management 2020.* Published by Ministry for the Environment. 70 p.

Ministry for the Environment (MfE) 2008. *Proposed national environmental standard on ecological flows and water levels: discussion document.* Publication number: ME 868. 61 p.

Richter BD, Davis MM, Apse C, Konrad C 2012. *A presumptive standard for environmental flow protection*. River Research and Applications 28: 1312- 1321.

Shearer K and Hayes J 2021. *Environmental flows and allocation investigations for small streams in the Greater Wellington region.* Prepared for Greater Wellington Regional Council. Cawthron Report No. 3674. 66 p. plus appendices.

Allocation material provided to whaitua committee

- REPORT water allocation in Te Awarua-o-Porirua whaitua - August 2017 (gw.govt.nz)
- PRESENTATION 2 water allocation 23.08.2017 [Read-Only] (gw.govt.nz)
- Tuna habitat needs (gw.govt.nz)
- Water-allocation-alternative-levels-of-minimum-flow-and-allocation-limit.pdf (gw.govt.nz)

Whaitua committee meeting and workshop minutes (allocation topic)

- TAoPW-Committee-Workshop-Record-27th-and-28th-October-2018.pdf (gw.govt.nz)
- REPORT-Te-Awarua-o-Porirua-Whaitua-Workshop-23-November-2017_2.pdf (gw.govt.nz)
- Final-WORKSHOP-REPORT-Te-Awarua-o-Porirua-Whaitua-Committee-26.10.2017.pdf (gw.govt.nz)
- REPORT TAoPW Committee Workshop 14 September 2017 V.1 (gw.govt.nz)
- REPORT Te Awarua-o-Porirua Whaitua Committee Workshop 24.08.17 (gw.govt.nz)
- Notes from meeting with Ned Norton and Don Jellyman

Appendix 1. Water quality and ecological NOF attributes and objectives for Te Awarua-o-Porirua

Source: (reproduced from the WIP).

	WMU name	Taupō	Rangituhi	Pouewe	Takapū	Te Riu o Porirua
E. coli	CURRENT STATE	E	E	E	E	E
	OBJECTIVE	B	A	B	C	C
	TIMEFRAME*	2040	2040	2040	2040	2040
Ammonia	CURRENT STATE	A	A	A	A	C
	OBJECTIVE	A	A	A	A	A/C[17]
	TIMEFRAME*	M	M	M	M	M
Nitrate	CURRENT STATE	A	A	A	A	B
	OBJECTIVE	A	A	A	A	A
	TIMEFRAME*	M	M	M	M	2040
Dissolved Zinc	CURRENT STATE	C	D	A	A	D
	OBJECTIVE	A	A	A	A	C
	TIMEFRAME*	2040	2040	M	M	2040
Dissolved Copper	CURRENT STATE	D	D	A	A	D
	OBJECTIVE	B	A	A	A	C
	TIMEFRAME*	2040	2040	M	M	2040
Periphyton	CURRENT STATE	C	A	C	C	C/B[18]
	OBJECTIVE	B	A	B	B	B
	TIMEFRAME*	2040	M	2040	2040	2040
MCI	CURRENT STATE	C	C	C/B[19]	C/B[20]	C
	OBJECTIVE	B	A	A	B	C
	TIMEFRAME*	2040	2040	2040	2040	M
Native fish	CURRENT STATE	C	C	B/A	B	C/B
	OBJECTIVE	B	A	A	A	B
	TIMEFRAME*	2040	2040	2040	2040	2040