Technical Memorandum
Draft Baseline State for *Escherichia coli* and Cyanobacteria (Planktonic) in Taranaki Rivers and Lakes

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Purpose

The purpose of this memorandum is to provide an assessment of the baseline state of *Escherichia coli (E. coli)* in streams, rivers and lakes, and cyanobacteria (planktonic) in lakes and lake-fed rivers, as a measure of suitability for human contact, as required by the National Policy Statement for Freshwater Management 2020 (NPS-FM).

Draft baseline states for both of the *E. coli* attributes, along with the cyanobacteria attribute included in the NPS-FM are presented: *E. coli* monitored in rivers and lakes with year-round sampling (NPS-FM, Appendix 2A); *E. coli* monitored at primary contact sites (swim spots) during the summer bathing season (NPS-FM, Appendix 2B); and cyanobacteria (planktonic) monitored in lakes and lake fed rivers (NPS-FM, Appendix 2A).

Overview of *Escherichia coli* and cyanobacteria (planktonic)

Escherichia coli (*E. coli*) is an indicator organism for faecal contamination in freshwaters (i.e. rivers and lakes). On its own, *E. coli* doesn't necessarily present a human health hazard. However, it is indicative of the presence of other harmful disease-causing bacteria, viruses and protozoa that cannot be detected so easily. When *E. coli* numbers exceed guideline levels, this signals an unacceptable level of risk to human health.

Livestock are often the main contributor of faecal bacteria in rural areas, whereas large flocks of birds (including gulls, ducks and pūkeko) have contributed to water quality issues in some urban areas near the coast. Occasionally, sources of human wastewater have also been detected in urban waterways, often associated with aged or faulty infrastructure.

Planktonic cyanobacteria (commonly known as blue-green algae) are photosynthetic prokaryote organisms that inhabit all natural waters. Cyanobacteria cells can multiply and form planktonic "blooms" under certain conditions. These can be seen as bright green or blue-green globules in the water column or as surface scums that can accumulate at lake edges. Many species of cyanobacteria are capable of producing toxins knows as cyanotoxins. These natural toxins can pose a threat to people via contact during recreational activities or by accidental ingestion.

There are a number of physical, chemical and biological factors that influence planktonic cyanobacteria growth. Nutrients (nitrogen and phosphorous) discharging into lakes from their catchments are particularly influential in the development of algal blooms.

Escherichia coli, cyanobacteria and the National Objectives Framework

The NPS-FM sets out requirements for councils and communities to maintain or improve freshwater (where it is degraded). It includes a National Objectives Framework (NOF) that specifies nationally applicable standards for particular freshwater parameters (referred to as 'attributes').

Human contact is a compulsory value and the NOF contains two attributes for assessing *E. coli* in streams, rivers and lakes, along with one attribute for assessing cyanobacteria in lakes and lake fed rivers. Other factors that may affect the suitability of a river or lake for human contact include water clarity, deposited sediment, plant growth (from macrophytes to periphyton and phytoplankton), other pathogens and toxicants, and litter. A number of these issues are related to other attributes included in the NOF, and are the subject of separate technical memoranda.

The difference between the two *E. coli* attributes relates to the locations and timing of the monitoring. The first *E. coli* attribute (NPS-FM, Appendix 2A), aims to provide a regional assessment of *E. coli* throughout all rivers and lakes (irrespective of primary contact use, or time of the year). The second *E. coli* attribute (NPS-FM, Appendix 2B), applies only at sites where primary contact (i.e. swimming) is known to occur, and only during the summer bathing season (normally 1 November to 31 March).

Escherichia coli at regional sites

This regional measure of *E. coli* is based on the year round collection of water samples on a monthly basis irrespective of weather or flow conditions. Within this attribute table there are four distinct statistical assessment criteria, each with an associated set of attribute bands (or grades) and descriptions (Table 1). These bands indicate the level to which the *E. coli* attribute is being achieved, ranging from band A (indicative of low *E. coli* numbers, representing a low human health risk) to band E (indicative of high *E. coli* numbers, representing a high human health risk). All four criteria must be assessed, with the overall attribute assessment being based on the lowest scoring criteria.

Percentage of exceedances over 540/100 mL

E. coli are measured in terms of their concentration within 100 ml of water. When *E. coli* reaches a concentration of 540/100 ml it represents the 'Action mode' threshold for recreational water quality monitoring. When this figure is exceeded, freshwaters a considered unsuitable for swimming due to an unacceptable risk to human health. This attribute criteria is graded based on the proportion of sampling results that exceed this value.

Percentage of exceedances over 260/100 mL

If *E. coli* exceeds 260/100 ml (but does not exceed 540/100 mL) it represents the 'Alert mode' threshold for recreational water quality monitoring. When this figure is exceeded, freshwaters are still considered suitable for swimming, but caution is advised due to an elevated risk to human health. This attribute criteria is graded based on the proportion of sampling results that exceed this value.

Median concentration

The median *E. coli* concentration represents the mid-point of *E. coli* levels within the distribution of sample results.

95th percentile

The 95th percentile is a measure of the top range of *E. coli* levels that may occur within the distribution of sample results.

Table 1: NOF attribute – E. coli (NPS-FM, Appendix 2A). Source: MfE 2020.

Value	Human contact			
Freshwater body type	Lakes and rivers			
Attribute unit	*E. coli*/100 mL (number of *E. coli* per hundred millilitres)			
Attribute band and description	**Numeric attribute state**			
Description of risk of *Campylobacter* infection (based on *E. coli* indicator)	% exceedances over 540/100 mL	% exceedances over 260/100 mL	Median concentration /100 mL	95th percentile of *E. coli*/100 mL
A (Blue) For at least half the time, the estimated risk is <1 in 1,000 (0.1% risk). The predicted average infection risk is1%.	<5%	<20%	≤130	≤540
B (Green) For at least half the time, the estimated risk is <1 in 1,000 (0.1% risk). The predicted average infection risk is 2%.	5-10%	20-30%	≤130	≤1000
C (Yellow) For at least half the time, the estimated risk is <1 in 1,000 (0.1% risk). The predicted average infection riskis 3%.	10-20%	20-34%	≤130	≤1200
D (Orange) 20-30% of the time the estimated risk is ≥50 in 1,000 (>5% risk). The predicted average infection riskis >3%.	20-30%	>34%	>130	>1200
E (Red) For more than 30% of the time the estimated risk is ≥50 in 1,000(>5% risk). The predicted average infection riskis >7%.	>30%	>50%	>260	>1200
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 five years. Attribute band must be determined by satisfying all four numeric attribute states (i.e., all four columns in any one row) or, if that is not possible, according to the worst numeric attribute state. The predicted average infection risk is the overall average infection to swimmers based on a random exposure on a random day, ignoring any possibility of not swimming during high flows or when a surveillance advisory is in place (assuming that the *E. coli* concentration follows a lognormal distribution). Actual risk will generally be less if a person does not swim during high flows.				

Escherichia coli (primary contact sites)

The primary contact assessment is based on *E. coli* data from water samples collected on a weekly basis during the bathing season (normally 1 November to 31 March), irrespective of weather or flow conditions. The attribute is assessed against one statistical criteria, the 95th percentile of *E. coli* data recorded at a given site, with an associated set of attribute bands and descriptions (A through D). These bands ranges from band A (indicative of low *E. coli* numbers, representing a low human health risk) to band D (indicative of high *E. coli* numbers, representing a high human health risk).

The 95th percentile bands in this attribute are much lower (more stringent) than the 95th percentile bands for the regional *E. coli* measure; which reflects the higher level of risk that faecal contaminants pose to human health at sites where there is more primary contact (swimming and recreation) and therefore more risk exposure.

Further explanation of the attribute and its associated grading system is provided in Table 2.

Table 2: NOF attribute – E. coli at primary contact sites (NPS-FM, Appendix 2B). Source: MfE 2020.

Value (and component)	Human contact
Freshwater body type	Primary contact sites in lakes and rivers (during the bathing season)
Attribute unit	95th percentile of *E. coli*/100 mL (number of *E. coli* per hundred millilitres)
Attribute band and description	**Numeric attribute states**
Excellent Estimated risk of Campylobacter infection has a < 0.1% occurrence, 95% of the time.	≤ 130
Good Estimated risk of Campylobacter infection has a 0.1 – 1.0% occurrence, 95% of the time.	> 130 and ≤ 260
Fair Estimated risk of Campylobacter infection has a 1 – 5% occurrence, 95% of the time	> 260 and ≤ 540
National bottom line	**540**
Poor Estimated risk of Campylobacter infection has a > 5% occurrence, at least 5% of the time.	> 540
The narrative attribute state description assumes "% of time" equals "% of samples".	

Cyanobacteria (planktonic)

The cyanobacteria attribute sets out numeric attribute states that represent different levels of risk to people as a result of coming into contact with cyanobacteria. This attribute includes a national bottom line of 1.8 mm^3/L biovolume equivalent of potentially toxic cyanobacteria or 10 mm^3/L total biovolume equivalent of all cyanobacteria. At levels exceeding these values, health risks are considered high and include possible respiratory, irritation and allergy symptoms.

Further explanation of the attribute and its associated grading system is provided in Table 3.

Table 3: NOF attribute - Cyanobacteria. Source: MfE 2020.

Value (and component)	Human contact
Freshwater body type	Lakes and lake-fed rivers
Attribute unit	Biovolume mm3/L (cubic millimetres per litre)
Attribute band and description	**Numeric attribute states**
	80th percentile
A Risk exposure from cyanobacteria is no different to that in natural conditions (from any contact with freshwater).	≤0.5 mm3/L biovolume equivalent for the combined total of all cyanobacteria
B Low risk of health effects from exposure to cyanobacteria (from any contact with freshwater).	>0.5 and ≤1.0 mm3/L biovolume equivalent for the combined total of all cyanobacteria
C Moderate risk of health effects from exposure to cyanobacteria (from any contact with freshwater).	>1.0 and ≤1.8 mm3/L biovolume equivalent of potentially toxic cyanobacteria OR >1.0 and ≤10 mm3/L total biovolume of all cyanobacteria
National bottom line	**1.8 mm3/L biovolume equivalent of potentially toxic cyanobacteria** **OR** **10 mm3/L total biovolume of all cyanobacteria**
D High health risks (for example, respiratory, irritation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with freshwater).	>1.8 mm3/L biovolume equivalent of potentially toxic cyanobacteria OR >10 mm3/L total biovolume of all cyanobacteria
The 80th percentile must be determined using a minimum of 12 samples collected over 3 years. Thirty samples collected over 3 years is recommended.	

National target for primary contact (swimmability)

In addition to these attributes, the NPS-FM includes a national target for primary contact (NPS-FM, Appendix 3). The national target is to increase proportions of specified rivers and lakes that are suitable for primary contact, i.e. those in bands A, B and C to 80% by 2023, and 90% no later than 2040. This represents an improvement from a baseline of 71% in 2017. A further target has been set to improve water quality across all categories, meaning that target attribute states must be set above their current baseline state[1].

Categories are based on water quality in terms of the two human contact attributes *E. coli* and cyanobacteria (planktonic) included in Appendix 2A of the NPS-FM. The categories do not include the 95th percentile of *E. coli*/100 mL numeric attribute state if there is insufficient monitoring to establish the 95th percentile. For lakes, further granularity is provided by splitting band D into two categories (orange and red), with red having more than 3.0 mm^3/L biovolume of cyanobacteria (planktonic) using the 80th percentile.

These targets only apply to rivers and streams that are suitably large enough for swimming (i.e. all waterways that are stream order four or greater, and excluding all waterways that are stream order three or less, based on the River Environment Classification[2]). Similarly, for lakes, these targets only apply to lakes with a perimeter of 1.5 km or greater. For lakes, the lowest category for either attribute applies.

The national targets represent combined improvements for all regions, set out below in Figure 1 and require 80% of applicable rivers, streams and lakes to be graded at band C or above, by 2030, and 90% by 2040. TRC

[1] NPS-FM Clause 3.11 (3)
[2] https://niwa.co.nz/freshwater/management-tools/river-environment-classification-0

also set regional swimmability targets in 2018, in accordance with requirements set out under the previous version of the NPS-FM (2017). The regional targets were for:

- 50-55% of rivers of fourth order or larger to be in the blue, green or yellow category in terms of *E. coli* by 2030.
- 97% of lakes with a perimeter of 1.5 km or more to be in the blue, green or yellow category in terms of *E. coli* by 2030.

Monitoring data and available information has improved since the initial targets were identified, and as such these regional targets will be able to be revised as Council sets target attribute states in relation to human contact attributes. Spatial water quality models have been utilized to assess current baseline state in relation to these swimmability targets, and to also predict future state under a range of scenarios. Land Water People (LWP) Ltd have developed a spatial water quality model for the TRC in order to support the baseline and target setting processes (Fraser, 2022). NIWA have also been contracted by the TRC to develop the Catchment Land Use for Environmental Sustainability (CLUES) model for testing a range of land use mitigation scenarios in order to understand the impact on instream *E. coli* concentrations in relation to these targets (Semadeni-Davies et al. 2023).

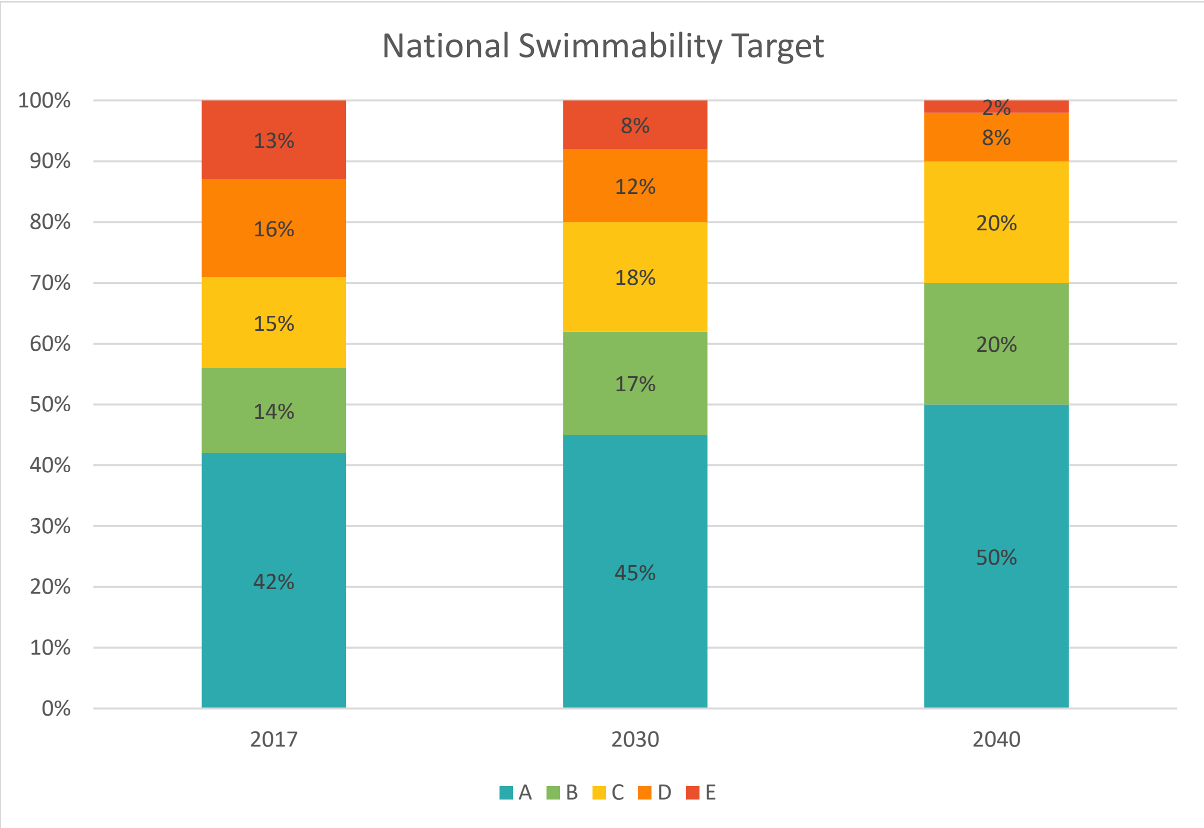

Figure 1: National swimmability targets for 2030 (80% achieving band A, B and C) and 2040 (90% achieving band A, B and C), compared to 2017 baseline. Source: MfE 2020.

Escherichia coli and cyanobacteria monitoring in the Taranaki region

Escherichia coli at regional sites

The Taranaki Regional Council (TRC) has routinely monitored *E. coli* concentrations in a number of the region's rivers and streams, since 1995. Field measurements are taken and water samples collected for laboratory analysis at specified locations around Taranaki, on a monthly basis. Over the years, new sites have been added to the programme, with a total of 16 state of environment (SoE) water quality sites currently monitored. At three of these sites, sampling has previously been undertaken by NIWA as part of a national monitoring programme, although these sites are currently transitioning over to the TRC's monitoring programme. Additionally, *E. coli* data is collected at six periphyton monitoring sites. In total, suitable data is available from 22 monitoring sites to assess the state of *E. coli* concentrations in Taranaki rivers and streams, as required under the NOF.

Recent analysis of sites with sufficient data records have found that the majority of monitoring sites are not meeting national swimmability standards (13 out of 15 sites (TRC, 2022). Furthermore, trends in *E. coli* concentrations show that the majority of sites have degraded over time. This increase in *E. coli* has occurred at six of ten sites over the long term (entire data record) and at nine of 13 sites over the short term (most recent 10 years). Improving trends were shown at a smaller proportion of sites (two out of 10 sites in the long term, and two out of 13 sites in the short term), while indeterminate trends were seen at the remaining sites.

Broadly speaking, sites in the upper river catchments show better results compared to the sites in the middle and lower catchments. This is common in catchments throughout New Zealand, and generally reflects the increasing cumulative impacts of intensive agriculture, urban stormwater and wastewater discharges as water makes its way downstream through the catchment.

Monthly sampling of *E. coli* in Taranaki lakes only commenced at the beginning of 2023, following the establishment of a regional state of environment lakes monitoring programme. This monitoring programme involves the collection of water samples from a range of depths, at the deepest point in the lake, with the use of kayaks. Sampling methodology is based on the National Environmental Monitoring Standards (NEMS) Water Quality Guidelines (Part 3 of 4)[3]. Only the surface water samples are analysed for *E. coli*. Depending on the lake, there are currently between three to five months of sampling results available to inform this baseline assessment.

Given that this is an extremely limited dataset, alternative data sources have also been considered, where available. Lake Rotokare and Lake Herengawe are both monitored during the summer swim season (November to March), as part of the 'Can I Swim Here?' (CISH) recreational water quality programme. This programme involves the collection of weekly surface samples from the shoreline (further detail is provided in the next section). In contrast to the regional SoE programme, where samples are collected from the middle of the lake, and are representative of pelagic water quality, results from the CISH programme have shown that shoreline waters can be subjected to localised impacts on water quality due to proximity to contaminant sources (i.e. waterfowl and overland run-off), and the resuspension of sediment and associated faecal bacteria.

***Escherichia coli* at primary contact sites**

The Council has routinely monitored *E. coli* concentrations at a number of the region's most popular swim spots during the summer period for over 20 years. Prior to the November 2021, this monitoring was only carried out during fine weather and low flow conditions, in order to improve the programme's ability to detect trends in the data and assess long term improvement or degradation in water quality. However, since November 2021, sampling has occurred on a weekly basis regardless of weather conditions. This change brought the monitoring programme into line with the requirements of the NPS-FM and provides the community with greater awareness of suitability for swimming and recreating during a range of weather conditions.

Under the current programme, now referred to as "Can I Swim Here? (CISH)", field measurements are taken and water samples collected for laboratory analysis, once a week between 1 November and 31 March each

[3] https://www.nems.org.nz/documents/water-quality-part-3-lakes/

year at 40 popular primary contact sites, including a range of beaches, rivers and lakes around Taranaki. There are 23 freshwater sites (i.e. rivers and lakes) included in the current CISH programme.

The monitoring results highlight the impact that rainfall has on recreational water quality. *Escherichia coli* concentrations can be significantly elevated at primary contact sites for up to three days following heavy rainfall. This is owing to the runoff of faecal contaminants from land, and resuspension of *E. coli* in the stream bed sediments as river flows increase. Although the monitoring data clearly shows the influence that rainfall has on recreational water quality, elevated *E. coli* concentrations are still common at a number primary contact sites even during fine weather based on the results of the previous monitoring regime. These results point to sources of direct contamination in both rural and urban environments (e.g. potential stock access to waterways, agricultural and industrial point source discharges, aging wastewater infrastructure, and localised impacts of waterfowl).

Cyanobacteria in lakes

Presently, TRC monitors cyanobacteria at eleven lakes across the region. Planktonic cyanobacteria have been monitored at four lakes (Lake Ratapiko, Lake Opunake, Lake Rotomanu and Lake Rotokare) since the 2006-2007 monitoring period as part of the "Can I Swim Here? (CISH)" programme. Recently, the number of lakes surveyed in relation to this programme has increased to seven to include Lake Nganana, Lake Herengawe and Lake Rotorangi. Fortnightly sampling is carried out annually between November and April, with sample collection based on *The New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters* (MfE and MoH, 2009). These samples are collected from shoreline locations that generally correspond to primary contact locations (swim spots). As with *E. coli* monitoring at primary contact sites, the purpose of this monitoring programme is primarily to inform the public of potential health risks at popular swimming sites over the summer bathing season.

Six lakes are surveyed monthly in relation to the regional lakes monitoring programme, which was initiated in May 2023. Sampling of these lakes is based on the National Environmental Monitoring Standards (NEMS) Water Quality Guidelines (Part 3 of 4), and involves the collection of a depth integrated sample within the photic zone, the uppermost layer of a body of water that receives sunlight where phytoplankton perform photosynthesis. The photic zone is home to the majority of aquatic life due to the activity (primary production) of the phytoplankton. All samples are processed in-house using methods outlined in Procedure 051 "Processing and analysing planktonic cyanobacteria." In contrast to the CISH programme, these samples are collected at the deepest point in the lake, with the use of kayaks. Unlike the CISH programme, the purpose of this monitoring programme is to characterise water quality state and trends, including planktonic cyanobacteria, at a subset of regionally representative lakes (irrespective of recreational use), all year round.

Table 4 below, details the current lakes that are surveyed for cyanobacteria in the Taranaki Region, and the corresponding monitoring programmes. In summary, the number of lakes surveyed per Freshwater Management Unit (FMU) include three sites in the Volcanic Ringplain, two sites in each of the Southern Hill Country, Coastal Terraces and Waitara FMUs, and one site in each of the Pātea and Northern Hill Country FMUs. Lake Rotokare and Lake Herengawe are monitored as part of both the CISH and regional SoE programmes; which means there are two designated sampling sites (at deepest point and at the shoreline) at each of these lakes.

Table 4: Lakes sampled by the TRC for cyanobacteria analysis

Freshwater Management Unit	Lake name	Monitoring programmes	Sampling frequency
Southern Hill Country	Lake Rotokare	Lakes SoE	Monthly, year round
		CISH	Fortnightly, Nov - April

Freshwater Management Unit	Lake name	Monitoring programmes	Sampling frequency
	Lake Waikare	Lakes SoE	Monthly, year round
Coastal Terraces	Lake Herengawe	Lakes SoE	Monthly, year round
		CISH	Fortnightly, Nov - April
	Lake Kaikura	Lakes SoE	Monthly, year round
Volcanic Ringplain	Barrett Lagoon	Lakes SoE	Monthly, year round
	Lake Opunake	CISH	Fortnightly, Nov - April
	Lake Rotomanu	CISH	Fortnightly, Nov - April
Waitara	Lake Ratapiko	CISH	Fortnightly, Nov - April
	Lake Ngangana	CISH	Fortnightly, Nov - April
Northern Hill Country	Lake Rotokawau	Lakes SoE	Monthly, year round
Pātea	Lake Rotorangi	CISH	Fortnightly, Nov - April

Baseline state for *Escherichia coli* and cyanobacteria

The NPS-FM requires all regional councils to identify the baseline states of all attributes described in Appendix 2A and 2B of the NPS-FM within each FMU. When compared against national bottom lines and the relevant objectives for an FMU, baselines provide the reference point from which councils must either maintain or improve an attribute, which in turn will contribute toward achieving freshwater objectives for each compulsory and non-compulsory value. Waterbodies must not be allowed to degrade, or remain below an identified baseline state unless that state is determined to be naturally occurring. For attributes associated with the 'Human Contact' value, including *E. coli* and cyanobacteria, the target attribute state must be set above the baseline state of that attribute, unless the baseline state is already within the A band of the applicable NOF attribute table.

Under Clause 1.4 of the NPS-FM, the baseline state, in relation to an attribute, is the best state out of the following:

a) the state of the attribute on the date it is first identified by a regional council under Clause 3.10(1)(b) or (c);

b) the state of the attribute on the date on which a regional council set a freshwater objective for the attribute under the National Policy Statement for Freshwater Management 2014 (as amended in 2017);

c) the state of the attribute on 7 September 2017.

The TRC has not previously set freshwater objectives under the NPS-FM 2014 (amended 2017) for either *E. coli* attribute or cyanobacteria, so the state of these attributes under 1.4 (b) could not be calculated, and was excluded from identification of baseline states. Therefore, the best state out of Clause 1.4 (a) and (c) were used to identify the baseline states for these attributes.

Under Clause 1.6 of the NPS-FM, local authorities must use the best information available at the time (and if practicable, using complete and robust data) to give effect to the NPS-FM. In the absence of complete and robust data, the best information available should be use which may include modelling, partial data, and local knowledge, and preferably use sources that provide the greatest level of certainty (or take all practicable steps necessary to reduce uncertainty).

Under the NPS-FM, *E. coli* and cyanobacteria are associated with the 'Human Contact' value, which is a compulsory value within the NOF (NPS-FM, Appendix 1A). Furthermore, the regional *E. coli* and cyanobacteria attributes both require limits on resource use to be set in order to maintain or improve the suitability of rivers and lakes for swimming and other primary contact activities (NPS-FM, Appendix 2A). The primary contact *E. coli* attribute is one that requires an action plan, where sites fail to achieve the national bottom line or show degradation (NPS-FM, Appendix 2B). Therefore, it is necessary for baseline states to be identified by TRC for the Taranaki region to ensure that target attribute states are set at a level above the baseline state, and (at a minimum) achieve the national bottom line[4].

The remainder of this memorandum documents the methodology carried out by TRC to identify draft baseline states for *E. coli* and cyanobacteria.

Criteria for identifying site-based baseline states for *Escherichia coli* and cyanobacteria

Draft baseline states for *E. coli* and cyanobacteria have been identified for individual monitoring sites. These site-specific baseline states correspond to the NOF attribute bands set out in Appendices 2A and 2B of the NPS-FM, and have been identified using data from the SoE and CISH monitoring programmes discussed previously. Representativeness of these sites and attribute bands within each FMU are critically discussed later in this memo.

Escherichia coli at regional sites (rivers and lakes)

The NPS-FM requires *E. coli* attribute grades for rivers and lakes to be determined using monthly samples, collected year round irrespective of weather and flow conditions. Grades should be calculated using a minimum of 60 samples, collected over a maximum of five years. For river sites, the data from 16 of the 22 monitoring sites meets these requirements however, the data from the remaining six sites does not. The six sites are those included in the TRC's periphyton monitoring programme, where samples have been collected intermittently over a number of years, but have only been collected on a regular basis over the last 12 months. Given the dataset is smaller for these sites, there is a higher level of uncertainty in their attribute grading assessments. However, it is recommended that incomplete/partial data (NPS-FM, Clause 1.6) be included in the identification of site-specific baseline states, as the monitoring for these sites will continue on a long-term basis. In the future these sites will have data which will be considered complete and scientifically robust in assessing progress toward target attribute states.

For lakes, none of the six regional SoE lakes have data which meet these requirements, due to the limited data record available. Monitoring results from TRC's 'Can I Swim Here?' recreational water quality programme have been used to supplement these baseline assessments at Lake Herengawe and Lake Rotokare (where both monitoring programmes occur). As with the river sites with short data records, it is recommended that incomplete/partial data (NPS-FM, Clause 1.6) be included in the identification of site-specific baseline states, as the monitoring for these sites will also be continued on a long-term basis.

Escherichia coli at primary contact sites

Because the CISH programme only commenced in its current form in November 2021, for most sites data are only available from two bathing seasons to inform the assessment presented here. There are some exceptions to this which are explained below:

- Monitoring only began at the Waiwhakaiho River "Meeting of the Waters" and Lake Herengawe sites in November 2022, therefore only one bathing season of data is available for these sites.
- The Waingongoro River "Presbyterian Camp" monitoring site was shifted to "Taumata Park" in November 2022, therefore there is only one bathing season worth of data available for each of these

[4] See NPS-FM clauses 3.31, 3.32, and 3.33 for exceptions to this.

sites. However, these sites are so close that is was deemed appropriate to assess these two data sets as one (the Taumata Park sampling location is only 600 metres downstream of the Presbyterian Camp).

- Lake Opunake is fed by a diversion from the nearby Waiaua River near the coast. It is an artificially created hydro-generation storage lake, historically used for both recreation and electricity production. This lake has been excluded from this assessment due to localised issues with the associated hydroelectricity generation scheme which have impacted lake water levels and quality. Because these issues are unique to Lake Opunake, and are not representative of recreational water quality regionally, it was decided to exclude this site.

In summary, a total of 22 primary contact sites have been included in this baseline assessment. Although there has been less than five bathing seasons under the current CISH programme, the data is considered the best available information, in accordance with Clause 1.6 of the NPS-FM. It was decided not to incorporate monitoring data from previous bathing seasons under the old monitoring regime, as data were biased towards fine weather, low flow conditions and high tide (at river mouth sites).

Cyanobacteria in lakes

Planktonic cyanobacteria was initially monitored as part of the summer recreational water quality programme by measuring cell counts. In 2014, this methodology was replaced with a biovolume calculation (as is now prescribed in the NPS-FM). As such, only data from 2014 onward can be used to assess baseline state.

The NPS-FM suggests that the 80th percentile be determined using a minimum of twelve samples collected over three years. However, thirty samples collected over three years is recommended. Using this recommendation, only four out of eleven lakes currently monitored have adequate data to measure baseline states. These include Lakes Rotokare, Opunake, Ratapiko and Rotomanu. As discussed above, Lake Opunake has been excluded from this assessment due to localised issues which have impacted lake water levels and water quality.

Given the dataset is shorter than recommended for seven sites, there is a higher level of uncertainty in their attribute grading assessments. However, it is recommended that incomplete/partial data (NPS-FM, Clause 1.6) be included in the identification of site-specific baseline states, as the monitoring for these sites will continue on a long-term basis. In the future these sites will have data which will be considered complete and scientifically robust in assessing progress toward target attribute states.

Modelling estimates have also been considered to support this baseline assessment by supplementing the limited monitoring data. In 2016, MfE commissioned a report to estimate the state of freshwaters in New Zealand from a human health perspective (Snelder et al. 2016). Monitored water quality variables were combined with catchment and land-use data to estimate water quality for all lakes in New Zealand, which was subsequently used to make predictions of cyanobacterial biovolumes for all lakes. The spatial water quality attribute models were rated to have satisfactory to good performance according to Snelder et al. (2016). The most accurate model for cyanobacterial biovolume included Chlorophyll-*a*, Total phosphorous and Secchi disc depth and had an R^2 of 0.64 (Snelder et al. 2016). However, a recent evaluation of lake water quality modelling for Taranaki suggests that this model may be underperforming, and that the number of lakes failing the national bottom line may be higher than current estimates (Schallenberg et al, 2023).

Baseline state attribute grades have been assigned for each monitoring site. At Lake Rotokare and Lake Herengawe, which both have two distinct sites that are sampled as part of separate monitoring programmes, separate attribute grades have been assigned for each monitoring site.

Site-based baseline states

Escherichia coli at regional sites (rivers)

An assessment of *E. coli* data from 22 monitored river sites is summarised below in Table 5 and Figure 2, with further detail provided in Appendix 1. Monitoring data have been assessed against the *E. coli* criteria in Appendix 2A of the NOF attribute framework, which is intended for sites that are monitored on a monthly basis, all year round. As such, the sites included in this assessment have been monitored for general state of environment water quality purposes, and in most cases are not sites that are used for primary contact recreation.

Table 5: Distribution of site-based baseline states identified for overall E. coli concentrations in rivers including all NOF criteria.

Attribute criteria	Total no. sites	Attribute grade				
		A	B	C	D	E
% >540	22	2	0	2	9	9
% >260	22	3	1	0	7	11
Median	22	4	N/A	N/A	7	11
Q95	22	2	1	0	19	N/A
Overall grade	22	2	0	1	7	12

The assessment shows that only three out of the 22 monitoring sites meet the minimum standard (band C; based on the national swimmability target), while the remaining 19 sites fall within band D (7 sites), or band E (12 sites). The two sites that achieve band A were Pātea River at Barclay Road Bridge (upper catchment, near Te Papa-Kura-o-Taranaki), and the Hangatahua (Stony) River at Mangatete Bridge (a catchment with special land use protection status). The Punehu Stream at Wiremu Road (upper catchment, near Te Papa-Kura-o-Taranaki), was the one site with an overall grade within band C. The proportion of sites graded within bands D and E is nearly the same across all of the four attribute criteria, ranging from 18 of 22 to 19 of 22 sites. Therefore, it's not just the upper range of *E. coli* counts (typically associated with storm flows) or 95th percentile criteria that reduce the overall grades at most sites. Rather, the overall distribution of the *E. coli* results have contributed to band D or E grades at most sites, specifically owing to the high proportion of results exceeding 540 and 260 cfu/100 ml, as well as the high median counts.

Escherichia coli at regional sites (lakes)

An assessment of *E. coli* data from six lake sites is summarised below in Table 6 and Figure 3, with further detail provided in Appendix 1. Monitoring data have been assessed against the *E. coli* criteria in Appendix 2A of the NOF attribute framework, which is intended for sites that are monitored on a monthly basis, all year round. As such, the sites included in this assessment have been monitored for general state of environment water quality purposes, and for four out six lakes, frequent primary contact recreation is not known to occur.

Table 6: Distribution of site-based baseline states identified for overall E. coli concentrations in lakes including all NOF criteria.

Attribute criteria	Total no. sites	Attribute grade				
		A	B	C	D	E
% >540	-	N/A	N/A	N/A	N/A	N/A
% >260	-	N/A	N/A	N/A	N/A	N/A
Median	6	6	0	0	0	0
Q95	-	N/A	N/A	N/A	N/A	N/A
Overall grade	6	1	5	0	0	0

The overall assessment has graded five out of six lakes within band B, and one within band A, therefore all monitored lakes meet the minimum required standard. It should be noted that this assessment was based on an extremely limited data record, and therefore it was only possible to assess baseline state through the median statistical criteria and maximum results. Where possible, this assessment was supplemented with available data from shoreline sampling, as well as professional judgement. In the case of Lake Herengawe, consistently low *E. coli* concentrations from CISH shoreline samples provided support for keeping the lake within the A band for the overall grading. At Lake Rotokare, occasionally high *E. coli* concentrations from CISH shoreline samples indicated that the overall grading should be downgraded to band B. In the absence of any additional supporting data, overall grades for the remaining four lakes were downgraded from the band A to band B, due to the inherent uncertainty in the limited data.

Escherichia coli at primary contact sites

An assessment of *E. coli* data from 22 monitored primary contact sites is summarised below in Table 7 and Figure 4, with further detail provided in Appendix 1.

Table 7: Distribution of site-based baseline states identified for E. coli concentrations at primary contact sites.

Attribute criteria	Total no. sites	Attribute grade			
		A	B	C	D
Overall grade	22	2	0	0	20

The results show that 20 out of the 22 primary contact sites were within band D for this *E. coli* attribute, and failed to achieve the national bottom line. The 95th percentile for one of these sites was just above the D band threshold (Lake Rotomanu), while it was less than double the threshold at another site (Lake Nganana). The 95th percentiles were within five times the D band threshold at Lake Rotokare, Pātea River at the mouth, Waiwhakaiho River at Meeting of the Waters, and Urenui River at the mouth. Lake Rotorangi and Lake Herengawe were the only two sites graded within the A band, and the only two sites graded higher than the D band.

With the exception of Lake Ratapiko, the lake sites were all among the lowest 95th percentile results, which likely reflects the effect of dilution and contaminant assimilation in these larger water bodies, as well as the reduced faecal inputs from surrounding native bush in some cases. Similarly, Pātea and Urenui River mouths both experience significant dilution and mixing with incoming seawater at high tide, although this effect is not realised when samples are collected at low tide. Ten of the 22 sites included in this assessment are riverine sites located near the coast, at the bottom of their respective catchment. The cumulative impacts of agricultural run-off, industrial discharges and in some cases, nearby colonies of gulls and ducks, all contribute to elevated *E. coli* concentrations at these sites. Notably high 95th percentiles were also seen at a number of mid-catchment river sites, indicating that these cumulative impacts on water quality are realised well before water is reaching the bottom of the catchment.

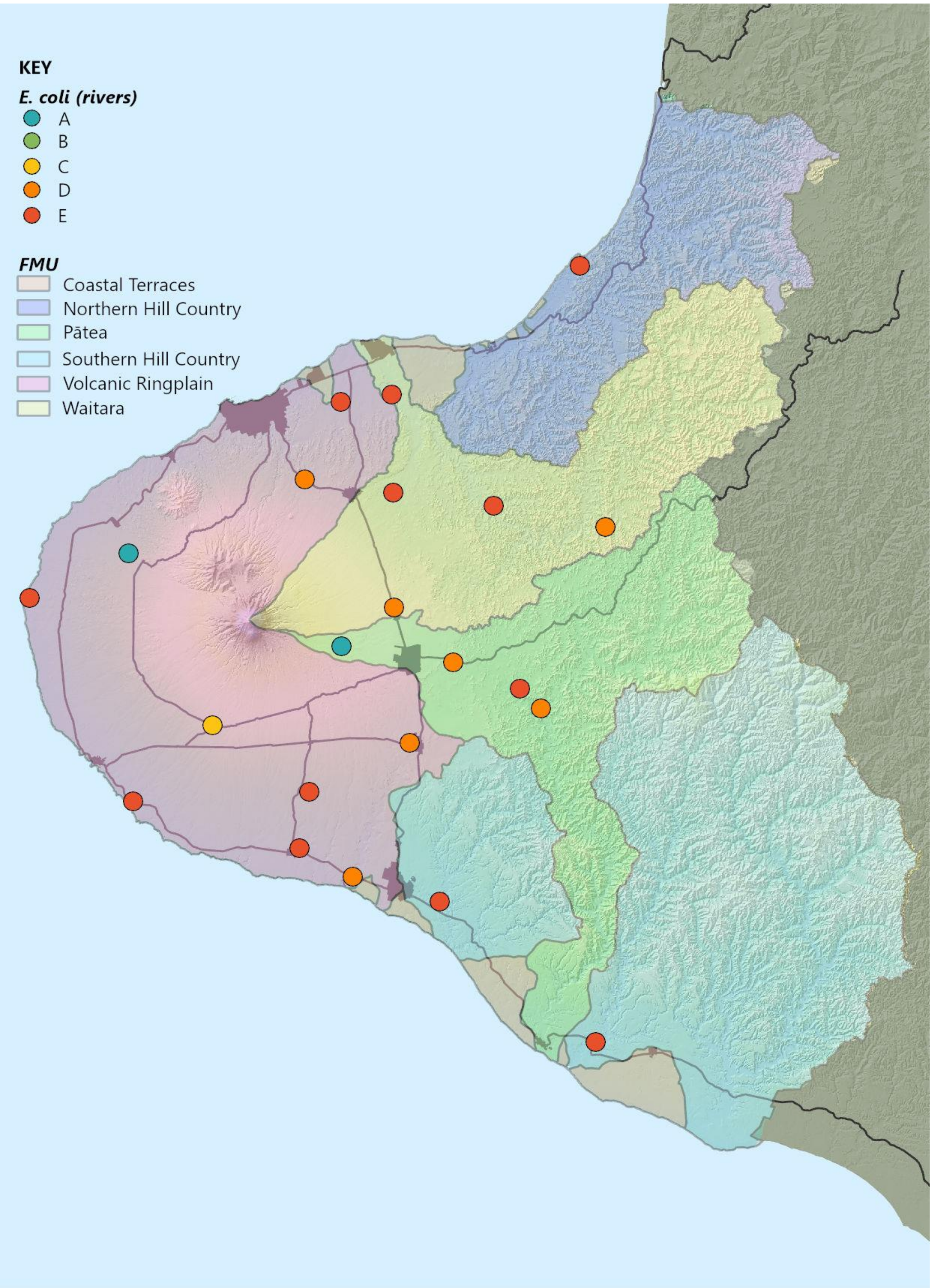

Figure 2: Site-based baseline states identified for E. coli concentrations in rivers across the Taranaki region.

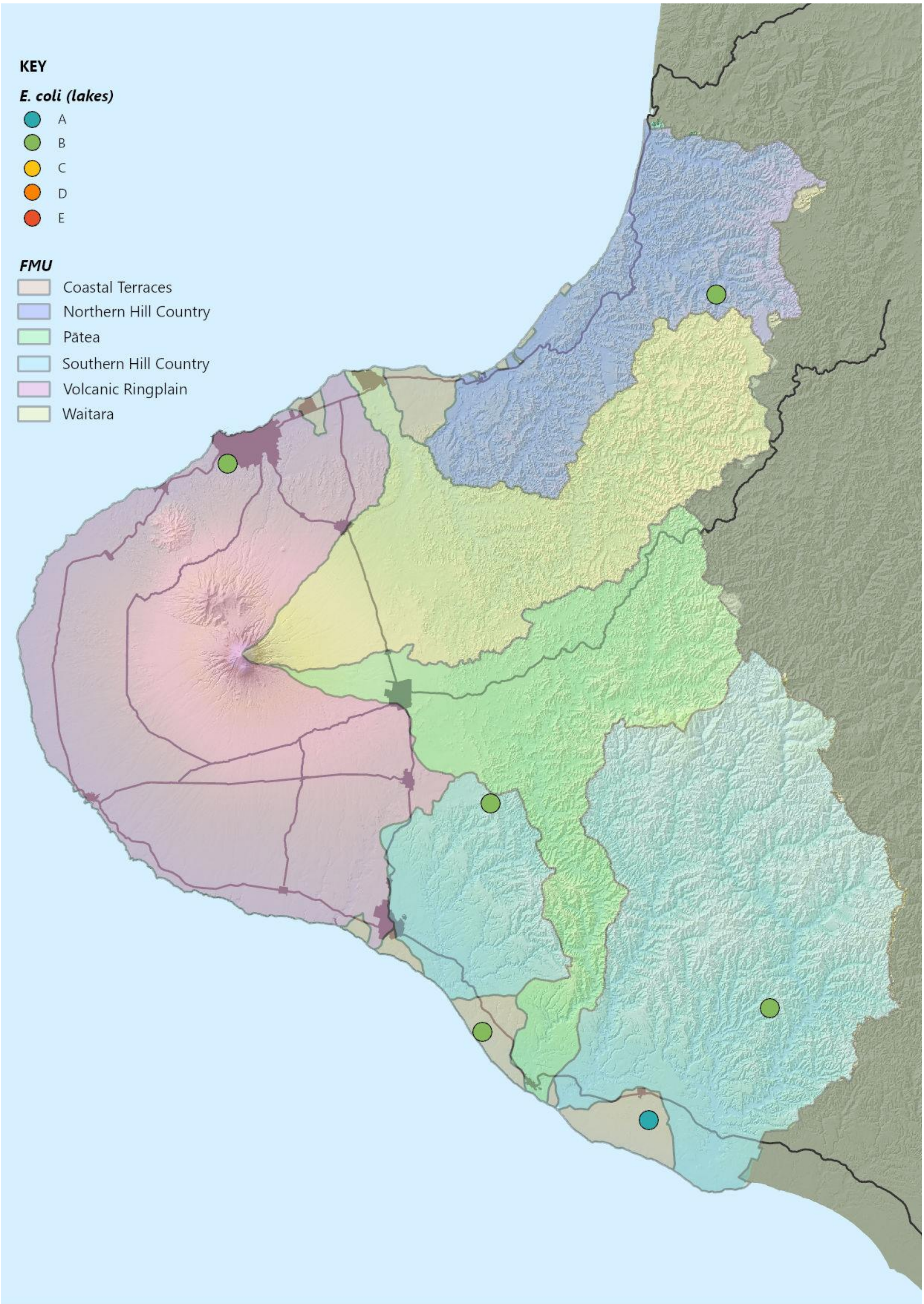

Figure 3: Site-based baseline states identified for E. coli concentrations in lakes across the Taranaki region

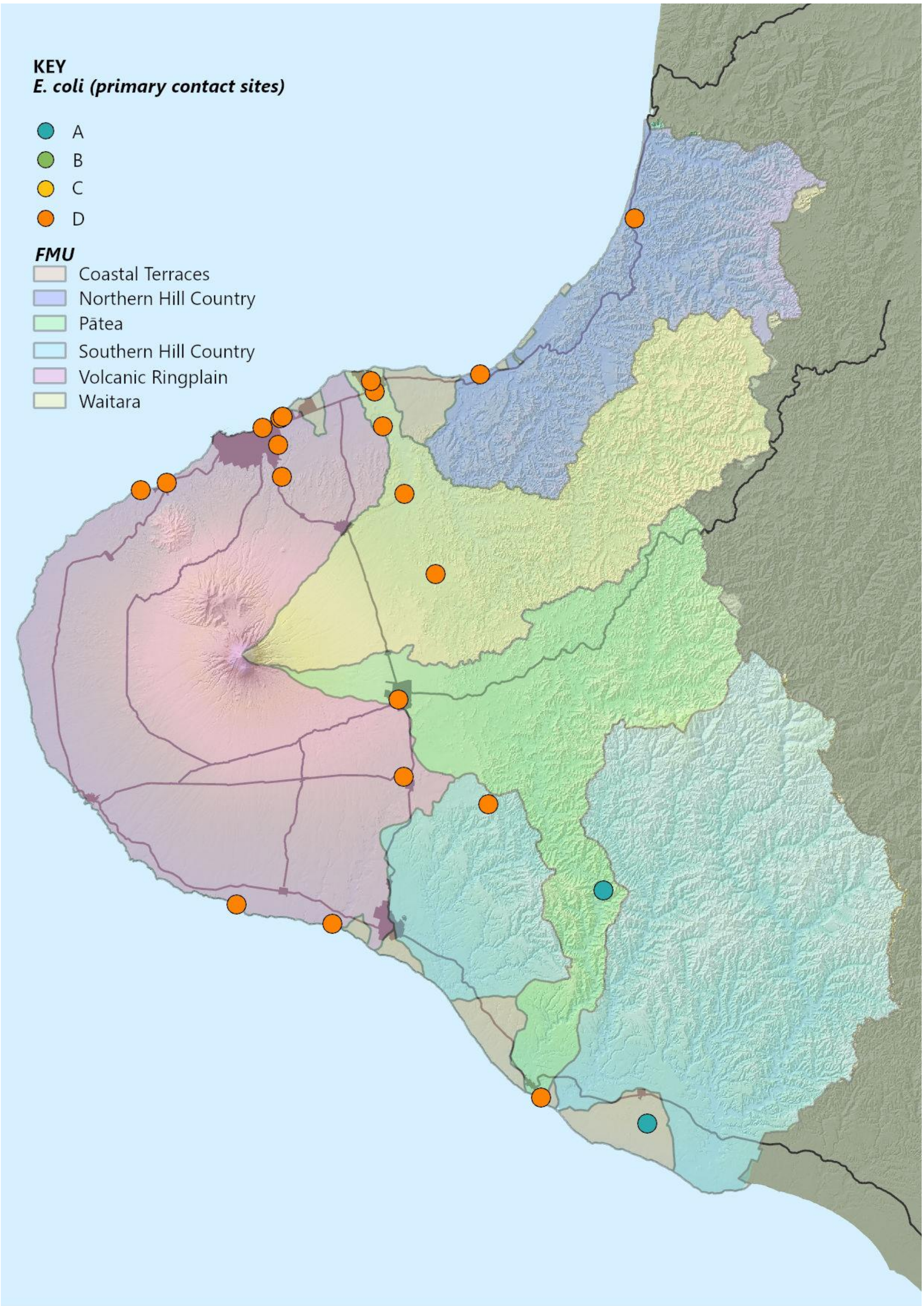

Figure 4: Site-based baseline states identified for E. coli concentrations at primary contact sites (rivers and lakes) across the Taranaki region

Cyanobacteria in lakes

A summary of cyanobacteria biovolume data held by the TRC, together with a baseline assessment is presented in Table 8 and Figure 5 below, with further detail provided in Appendix 1.

Table 8: Distribution of site-based baseline states identified for cyanobacteria biovolumes in lakes across the Taranaki region (number of lakes shown in brackets).

Attribute criteria	No. sites (No. lakes)	Attribute grade			
		A	B	C	D
Overall grade	12 (10)	6 (6)	3 (2)	0	3 (2)

The overall assessment has graded six out of 12 lake sites within band A, three sites within band B and three sites in band D (which is below the national bottom line). It should be noted that the amount of data available to make this assessment was highly variable between sites. Where available data were limited, modelled estimates were used to supplement the sample results.

Lake Rotokare and Lake Rotomanu both recorded an 80th percentile value >1.8 mm^3/L; which is below the national bottom line. Lake Rotokare is a natural landslide dammed lake situated in a 230 hectare scenic reserve within the Tangahoe catchment. It is the largest lake habitat within a predator proof fence and has significant ecological value. Lake Rotomanu is an artificial lake, and a popular recreational spot for boating, jet skiing and kayaking. It is replenished from the nearby Waiwhakaiho River. Both lakes have relatively long term monitoring records associated with the summer recreational water quality programme (now referred to as CISH), and therefore there is a reasonable level of confidence that the grade accurately reflects the state of these lakes. At Lake Rotokare, the same baseline attribute state has been assigned to the mid-lake (at deepest point) sampling site as it has been for the shoreline sampling site.

The remaining lakes monitored in the CISH programme were graded either band A or B; Lake Ratapiko (A), Lake Rotorangi (A), Lake Nganana (A) and Lake Herengawe at deepest point and at the shoreline (both B). The remaining four lakes had extremely limited data (i.e. n = 2 - 3), and therefore the modelled estimates were relied upon. These estimates graded the lakes between the A and B bands; Lake Kaikura (A), Lake Waikare (A), Barrett Lagoon (A) and Lake Rotokawau (B). However, these estimates should be considered a preliminary assessment, given the model performance is low.

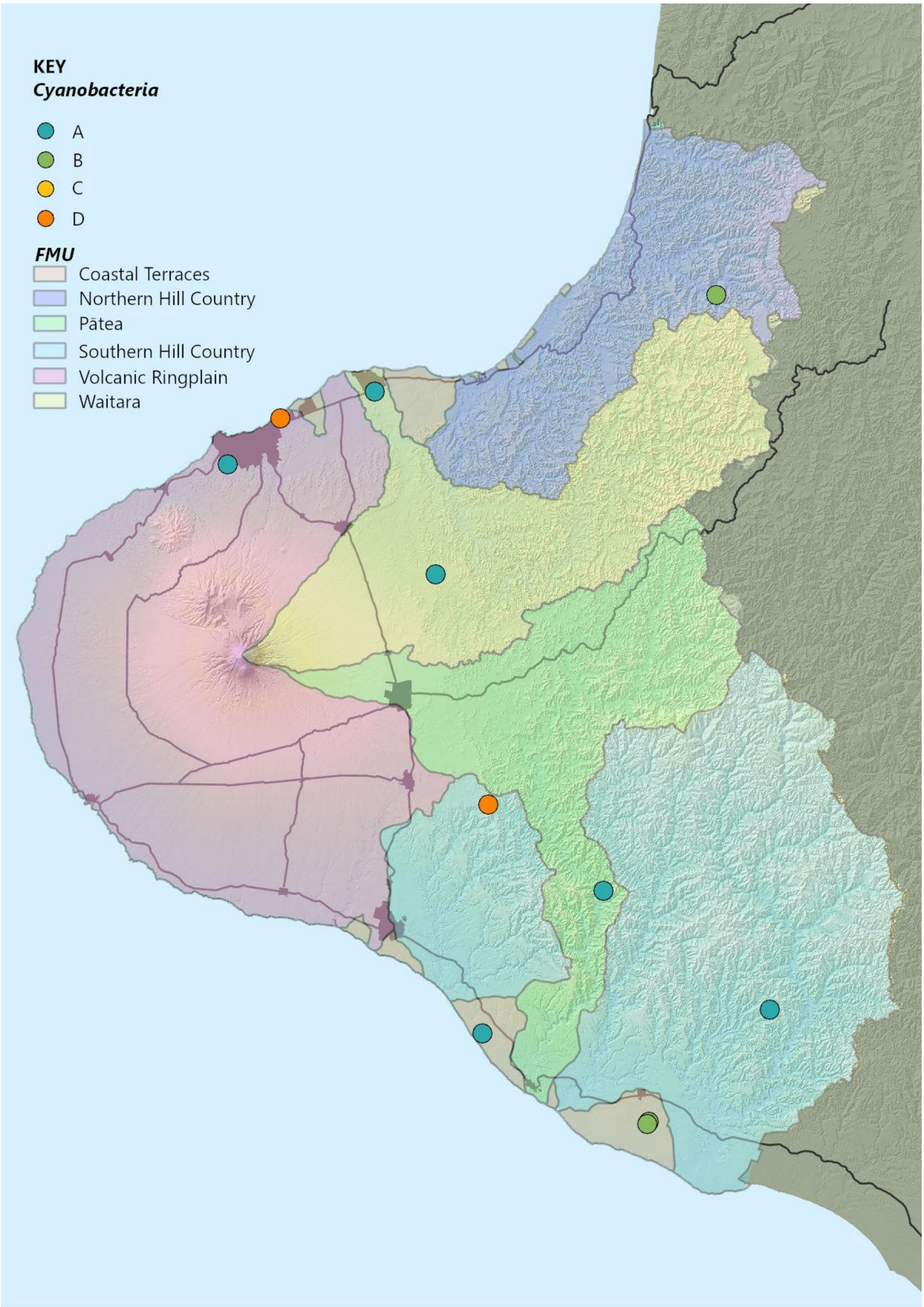

Figure 5: Site-based baseline states identified for cyanobacteria biovolumes in lakes across the Taranaki region.

Baseline period and temporal state variability

Escherichia coli at regional sites

This baseline assessment has been carried out using data that demonstrates the best state of the baseline periods defined in the NPS-FM. It should be noted that the TRC did not set freshwater objectives for this *E. coli* attribute, and therefore sub-clause 1.4(b) is not applicable. A summary of the baseline periods selected for each of 22 river monitoring sites is provided below:

- At 15 sites, the best state was identified in the earliest five years of available data in accordance with sub-clause 1.4(a). Of those sites;
  - Seven had short datasets, and lacked five years of data prior to September 2017. Therefore, sub-clause 1.4(c) was not applicable, and sub-clause 1.4(a) was the only option for selecting a baseline;
  - Eight had long datasets, which meant it was necessary to review the data and select the best state out of the stipulated time periods (i.e. sub-clause 1.4(a) and sub-clause 1.4(c)). At these sites, the best state was identified with the earliest five years of data (sub-clause 1.4(a)).
- The remaining seven sites showed the best state in the five years of data to September 2017 (sub-clause 1.4(c)), though the long term data sets at these sites meant it was necessary to also assess the first five years of data before making this decision.

For the six lake monitoring sites, data records were limited, with regular monitoring only commencing at the start of 2023. Therefore, baselines have been identified at all lakes using the earliest available data (sub-clause 1.4(a)), with there being no data to consider prior September 2017 for sub-clause 1.4(c). As with rivers, the TRC did not set freshwater objectives for this *E. coli* attribute, and therefore sub-clause 1.4(b) is not applicable. Details of these baseline data ranges are included in Appendix 1.

While it is a requirement of the NPS-FM to select the 'best' state when assessing baselines, it is important to understand how representative that baseline is in terms of the variability of the data at a given site. In the case of *E. coli*, as it is prescribed in Appendix 2A of the NOF, the record length for grading a site should be five years (60 data points).

Where there is a long term data record (as is the case for many of the river sites), an assessment is necessary to determine if the selected five-year period is broadly representative of the overall dataset (and therefore meaningful), or whether the natural temporal variability in the data is such that the attribute grading is continuously shifting and therefore the selected baseline is, in a sense, arbitrary. An evaluation of the rolling five-year state shows that temporal variability in attribute grades is common, but the magnitude of change is generally limited (Figure 6).

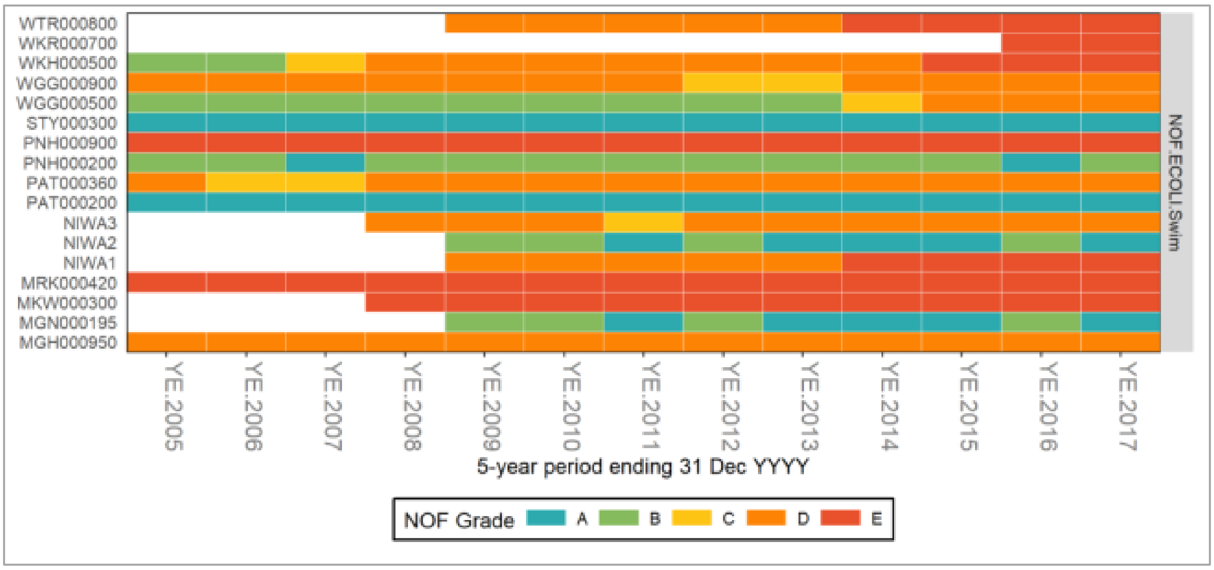

Figure 6: Rolling 5-year state for overall E. coli grade. Source: Fraser, 2022.

Although most sites do show changes in attribute grades over the entire data set, these shifts mostly occur up and down between two consecutive grades (e.g. from B to C and back to B), which is not unexpected given that the numeric values that inform the grading can often sit close to the boundary between two grades. At two sites, more than two grades were recorded over the entire data range. However, these changes only occurred in one-direction (i.e. degrading from band B to band C to D) and as such, likely reflected meaningful long-term environmental change, rather than short-term natural variability. Overall, the 5-year baseline periods that have been selected for this baseline assessment appear to be appropriate, and are not undermined by temporal variability in the data-sets.

The same consideration must be given towards the identification of the baselines state for lakes. However, there is no long-term data record to assess temporal variability against, and therefore professional judgement must be exercised. Given the limited available data, the baselines that have been identified for these lakes must be considered preliminary, and are associated with a higher level of uncertainty. This increased uncertainty was factored in to the baseline grades by correcting the initial grading that was assigned for most lakes, to allow for occasional elevated *E. coli* levels, which are more than likely to be encountered as more samples are collected with time.

At Lake Herengawe and Lake Rotokare, 'Can I Swim Here?' shoreline data was also available to support baseline identification. At Lake Herengawe, the additional samples indicated that *E. coli* numbers remain relatively low, even at the shoreline; therefore the decision was made to leave the grade unadjusted (band A). At Lake Rotokare, the additional samples indicated that *E. coli* numbers are occasionally elevated in shoreline waters; therefore the decision was made to adjust the grade by shifting it from band A to band B.

Escherichia coli at primary contact sites

Given the limited data set available to inform this baseline assessment, it was not possible to select any other baseline period other than the two summer bathing seasons since 1 November 2021. This baseline period is in accordance with sub-clause 1.4(a); the data at which the baseline is first identified. Sub-clauses 1.4(b) and 1.4(c) are not applicable.

While it is a requirement of the NPS-FM to select the 'best' state when assessing baselines, in this instance, the baseline period is the only option available. However, it is important to understand how representative this baseline is in terms of the variability of the data at a given site. *E. coli*, by its nature, can be highly variable in aquatic environments, and given that there was only data available from two summer bathing seasons, this assessment is biased towards that period, and the prevailing environmental conditions during that time.

There was considerable rainfall during the two summer bathing periods that have informed this baseline assessment. Rainfall is an important process for transporting faecal contaminants into lakes, rivers and streams, through the mobilisation and run-off of contaminants from land. Rainfall also leads to increased river flows, with the increased flow and turbulence acting to re-suspend faecal contaminants from river bed sediment reservoirs. *Escherichia coli* numbers in rivers and lakes often spike considerably, during or soon after heavy rainfall, because of these reasons. These spikes in *E. coli* generally inflate the 95th percentile within datasets for primary contact sites.

During the 2021-2022 bathing season, the results from 13 of 22 routine sampling surveys were potentially affected by rainfall. Again, in the 2022-2023 bathing season the results from 16 of 22 routine sampling surveys were potentially affected by rainfall. Appendix 2 provides a summary of rainfall and river flow data from the 2021-2022, and 2022-2023 bathing seasons, relative to the 2010-2020 period. Based on this summary, the overall number of rain events (24 hour periods which recorded 5 mm or more of rainfall) during the last two bathing seasons were higher than the average for the preceding ten years. Therefore, this baseline assessment reflects wetter than usual summer bathing seasons, and as a result, higher than average *E. coli* numbers (particularly at the higher end of the recorded range, which is affected by storm flows and influences the 95th percentile statistic).

However, it is important to note that rainfall is only a process by which faecal contaminants on land can be mobilised and transported into aquatic environments. *Escherichia coli* and other pathogens can still be directly discharged into lakes, rivers and streams via the access of stock and other animals into waterways, and point source discharges. The TRC's previous recreational water quality monitoring programme was able to effectively categorise *E. coli* numbers at primary contact sites under fine weather conditions, due to the associated fine weather sampling protocols (Taranaki Regional Council, 2020; 2020a; 2022).

Monitoring data have been used to calculate 95th percentiles in order to provide a comparison of *E. coli* numbers without the influence of recent rainfall, in order to help quantify the impact of wet weather sampling occasions on the overall baseline grading. Table 9 includes the 95th percentiles from monitoring sites where data was collected over the five summer bathing periods from November 2016 to March 2021, compared to those same sites sampled as part of CISH since November 2021.

Table 9: NOF grade comparison with fine weather and all weather monitoring data.

Site	November 2016 – March 2021 (fine weather and high tide)		November 2021 – March 2023 (all weather and tides)	
	Q95	NOF Band	Q95	NOF Band
Lake Rotokare	172	B	1,562	D
Patea River at King Edward Park	841	D	8,160	D
Patea River at river mouth	114	A	1,478	D
Kaupokonui Stream at river mouth	650	D	7,848	D
Lake Rotomanu	727	D	554	D
Oakura River at river mouth	832	D	7,651	D
Te Henui Stream at river mouth	5,590	D	10,179	D
Timaru Stream at river mouth	891	D	6,797	D
Waingongoro River at Presbyterian camp	839	D	5,414	D
Waingongoro River at river mouth	614	D	6,256	D
Waiwhakaiho River at Merrilands Domain	614	D	6,405	D
Waiwhakaiho River at river mouth	4,880	D	5,703	D

Site	November 2016 – March 2021 (fine weather and high tide)		November 2021 – March 2023 (all weather and tides)	
	Q95	NOF Band	Q95	NOF Band
Lake Ratapiko	140	B	7,075	D
Manganui River at Everett Park	339	C	15,570	D
Waitara River at Town Wharf	1,311	D	9,548	D
Urenui River at river mouth	130	A	4,182	D

This comparison shows that under the previous fine weather, high tide sampling regime, an additional five sites would have been graded band C or better. Four of the sites included two lakes and two tidal river mouths, which are likely to have the best water quality under fine conditions owing to significant dilution. Manganui River at Everett Park was graded band C based on fine weather data, despite recording the highest 95th percentile based on the all-weather data. This site is located in an agricultural catchment and is also downstream of a wastewater treatment plant which can discharge during heavy rain, highlighting the impact that these faecal contaminant sources after rainfall. There are, however, 11 out of 16 sites in this comparison that still fail to achieve the national bottom line during fine weather conditions, albeit by a much smaller margin in many cases.

Although this comparison highlights the clear impact that rainfall has on *E. coli* numbers at primary contact sites, it also demonstrates that rainfall is only one factor that influences *E. coli* numbers, and that the majority of sites would still be failing to meet the required standard if this assessment was carried out exclusively with fine weather sampling data.

Cyanobacteria in lakes

Data records are variable across the ten lakes that have data available to determine cyanobacteria baseline state. The longest data records exist for the three original CISH sites (Lake Rotomanu, Lake Ratapiko and Lake Rotokare), where cyanobacteria biovolume monitoring commenced between October and November 2014. The next longest data records exist for lakes that have subsequently been added to the CISH programme, where routine monitoring commenced in January 2020 (Lake Nganana), and November 2022 (Lake Rotorangi and Lake Herengawe). For the remaining four lakes that are exclusively monitored as part of the regional SoE programme, monitoring records only commenced in early 2023.

Therefore, baselines have been identified at all lakes using the earliest available data (in accordance with sub-clause 1.4(a) in the NPS-FM). In the case of Lake Rotomanu, Lake Ratapiko and Lake Rotokare, the earliest available data coincidentally overlaps with the three year period prior September 2017 (sub-clause 1.4(c)). The TRC did not set freshwater objectives for this cyanobacteria attribute, and therefore sub-clause 1.4(b) is not applicable. Details of these baseline data ranges are included in Appendix 1.

While it is a requirement of the NPS-FM to select the 'best' state when assessing baselines, it is important to understand how representative that baseline is in terms of the variability of the data at a given site. At sites where monitoring has taken place for less than the three baseline period required by the NPS-FM, it is not possible to assess long term temporal variability in the data record. As such, less confidence can be assigned to the baseline grades, as it is not possible to say how representative the baseline period is of 'typical' state. However, it is possible to assess temporal variability of cyanobacteria volumes at Lake Rotomanu, Lake Rotokare, and Lake Ratapiko given that there are seven years' worth of data at these sites.

An evaluation of rolling 3-year state shows that the attribute grades recorded at Lake Rotokare and Lake Rotomanu have displayed some variability, but Lake Ratapiko has remained stable (Table 10). The 80th percentiles for cyanobacteria biovolumes at Lake Rotokare have largely remained in the D band over the duration of the monitoring period, though there does appear to have been an overall reduction in biovolumes in recent years. Attribute grades shifted into the C band between 2021 and 2022, but have since reverted back into the D band. Overall, the D band attribute state appears to provide an appropriate representation of cyanobacteria biovolumes in this lake. At Lake Rotomanu, cyanobacteria biovolumes were within the D band between 2017 and 2020, shifting to the B band in 2021 and then into the A band in 2022. The 80th percentiles recorded for the three years up to 2022 and 2023 have been particularly low, relative to previous years. At this site, the D band baseline state (identified using the first three years of data), is not reflective of current state. Cyanobacteria biovolumes have remained low at Lake Ratapiko throughout the duration of the monitoring period. The A band state that was identified for this site provides an accurate reflection of the overall data record.

Table 10: Three year rolling attribute grade assessment for Lake Rotokare, Lake Rotomanu, and Lake Ratapiko.

FMU	Parameter	2014-17	2015-18	2016-19	2017-20	2018-21	2019-22	2020-23
Lake Rotokare	n	29	27	26	26	28	31	41
	80th percentile	13.88	7.73	11.88	8.04	1.53	1.32	3.82
	NOF band	D	D	D	D	C	C	D
Lake Rotomanu	n	23	27	30	32	31	31	33
	80th percentile	2.77	3.32	3.32	3.32	0.96	0.05	0.09
	NOF band	D	D	D	D	B	A	A
Lake Ratapiko	n	21	22	26	28	30	29	31
	80th percentile	0.00	0.00	0.01	0.00	0.00	0.00	0.00
	NOF band	A	A	A	A	A	A	A

Freshwater Management Unit (FMU) coverage and representativeness

Escherichia coli at regional sites

Monitoring data provides a direct measurement of water quality parameters, and therefore it is the preferred method for assessing environmental state due to its accuracy and certainty. However, attempting to evaluate state at the FMU or region-wide scale using site based monitoring data introduces site selection biases. This can result in under- or over-representation of rivers with certain characteristics.

All available monitoring data were used to inform this *E. coli* baseline assessment. However, there are currently no river monitoring sites within the Coastal Terrace FMU, and coverage of rivers in the Northern and Southern Hill Country FMUs is very limited. See Table 11 for a summary of the *E. coli* monitoring baseline assessment for rivers categorised by FMU.

A number of key river environment classifications are also under represented in the monitoring data. In particular, there are no monitoring sites with indigenous forest as the dominant land cover in the Northern Hill Country, Waitara or Southern Hill Country; FMUs where that land cover is the dominant class for a significant portion of total stream length (approximately 65%, 24% and 43%, respectively). Accordingly, pastoral land cover was proportionately over-represented in those same FMUs. The likely impact of this misrepresentation is to bias the assessment in those FMUs towards a more degraded state.

Conversely, although urban areas make up a relatively small proportion of the region, they can potentially have a disproportionately high impact on water quality, due to stormwater discharges, wastewater overflows and other issues associated with aging or faulty wastewater infrastructure (including septic tanks). However, there was no suitable monitoring data from urban areas that could be included in this assessment. See

Appendix 3 for an assessment of the monitoring network's representativeness of key River Environment Classification[5] categories.

Table 11: Summary of E. coli baseline assessment by FMU (year round, monthly monitoring).

FMU	Total no. sites	Overall attribute grade				
		A	B	C	D	E
Southern Hill Country	2	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (100.0%)
Coastal Terraces	0	N/A	N/A	N/A	N/A	N/A
Pātea	4	1 (25.0%)	0 (0.0%)	0 (0.0%)	2 (50.0%)	1 (25.0%)
Volcanic Ringplain	10	1 (10.0%)	0 (0.0%)	1 (10.0%)	3 (30.0%)	5 (50.0%)
Waitara	5	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (40.0%)	3 (60.0%)
Northern Hill Country	1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (100.0%)
Total	22	2 (9.1%)	0 (0%)	1 (4.6%)	7 (31.8%)	12 (54.5%)

The TRC is currently undertaking a review of its state of environment water quality monitoring network to address these shortcomings, and improve regional representativeness. However, there are significant financial and resourcing constraints associated with monitoring, and although network representativeness can be optimised, there are limitations to the coverage that can be feasibly achieved with conventional monitoring.

With regards to lakes, FMU coverage and representativeness must be considered differently. This is because lakes are not evenly distributed throughout the region, and therefore the number of lakes in each FMU is not proportionate to overall area. The TRC's regional state of the environment lakes monitoring programme was informed by a review of all lakes throughout the region, which identified 17 potential candidate lakes for inclusion. The following criteria were used to exclude lakes as suitable candidates for monitoring:

- Natural and unmodified. Artificial lakes were excluded on the basis that these lakes are less likely to be considered representative of the natural environment.
- Open water area ≥ 1 ha. Although there are many smaller lakes in the region, in most cases these are not particularly deep and may more reasonably be classed as wetlands.
- Suitable boat access to allow monitoring. Boat access is necessary as boats are required to enable sample collection from the deepest point of the lake.

Of these 17 lakes, eight were located in the Coastal Terrace (CT) FMU, five were located in the Southern Hill Country (SHC), three in the Volcanic Ringplain (VRP) and one in the Northern Hill Country (NHC). No suitable lakes were identified in the Waitara or Pātea FMUs. The final six lakes included in the monitoring programme were Lake Rotokawau (NHC), Barrett Lagoon (VRP), Lake Rotokare and Lake Waikare (SHC), and Lake Herengawe and Lake Kaikura (CT). The final set of lakes included in the SoE programme, which have been used to inform this baseline setting process, are considered to be suitably representative of each applicable FMU within the Taranaki region.

Escherichia coli at **primary contact sites**

Clause 3.8 of the NPS-FM requires regional councils to identify primary contact sites (if present), within each FMU. The TRC has intermittently carried out community surveys to gather information on the recreational use of the coast, rivers and lakes in the region. This information has been used to identify and reassess the popularity of primary contact sites over the years, and to help guide the selection of monitoring sites to ensure the most popular sites are included in the summer recreational water quality programme. The most

[5] River Environment Classification System, National Institute of Water and Atmospheric Research, Version 1.

recent survey was carried out during the 2019 – 2020 summer bathing season (TRC, 2021). Previous surveys have been carried out in 2007 (TRC, 2008), and 1984 (TCC, 1984).

The results of the latest survey found that the majority of the most popular sites used for primary contact recreation were already being monitored as part of the TRC's summer recreational water quality monitoring programme. Five additional sites, including two coastal beaches, two rivers (Waiwhakaiho River at Meeting of the Waters and Tongaporutu River at the mouth) and one lake (Lake Rotorangi at the Pātea Dam), were added to the programme after the survey results found that they were among the most the popular sites and warranted regular monitoring.

As with any community-based survey, the value of the findings is limited to the level of engagement and responses received. Therefore, the TRC acknowledges that the results of this survey are unlikely to provide an exhaustive list of potential primary contact sites across the region. However, the survey findings suggest that the most popular sites across the region have been identified and are now being monitored. The TRC will continue to repeat these surveys, and review the recreational water quality monitoring network intermittently into the future.

A summary of *E. coli* grades at primary contact sites is presented below, categorised by FMU (Table 12). However, unlike other NOF attributes, the representativeness of these monitoring sites is limited by the extent and location of primary contact sites that exist within each FMU. For this reason, FMU based monitoring site representativeness is a less pertinent consideration than it is for other NOF attributes. Table 12 highlights that the majority of the region's most popular freshwater primary contact sites are located within the Volcanic Ringplain FMU (ten sites), followed by Waitara (five sites), Pātea (three sites), Northern Hill Country (two sites), Southern Hill Country and Coastal Terraces (one site each). The higher number of popular primary contact sites in the Volcanic Ringplain and Waitara FMUs is partly explained by the fact that the urban centres located within these FMUs are among the region's most populous (New Plymouth, Hāwera and Waitara). It should also be noted that the results of the most recent recreational use survey generally found that the most popular swimming sites overall were a subset of coastal beaches throughout the region. These beaches have not been considered in this assessment, as this NOF attribute specifically pertains to freshwater primary contact sites.

Table 12: Summary of E. coli baseline assessment (at primary contact sites) by FMU.

FMU	Total no. sites	Overall attribute grade			
		A	B	C	D
Southern Hill Country	1	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (100.0%)
Coastal Terraces	1	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Pātea	3	1 (33.3%)	0 (0.0%)	0 (0.0%)	2 (66.7%)
Volcanic Ringplain	10	0 (0.0%)	0 (0.0%)	0 (0.0%)	10 (100.0%)
Waitara	5	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (100.0%)
Northern Hill Country	2	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (100.0%)
Total	22	2 (9.1%)	0 (0.0%)	0 (0.0%)	20 (90.9%)

Cyanobacteria in lakes

The lakes that are monitored for cyanobacteria have been selected for the purposes of both SoE and CISH monitoring.

The final set of lakes included in the SoE programme, which have been used to inform this baseline setting process, are considered to be suitably representative of each applicable FMU within the Taranaki region (see the previous discussion of FMU coverage and representativeness regarding *E. coli* and lakes, for further background).

With regards to lakes monitored as part of the CISH programme, a recent survey found that the majority of the most popular sites used for primary contact recreation are being monitored as part of the programme (see the previous discussion of FMU coverage and representativeness regarding *E. coli* and primary contact sites, for further background).

Taken together, the sites that are monitored as part of each programme, ensure that there is at least one site monitored for planktonic cyanobacteria in each FMU (Table 13).

Table 13: Summary of cyanobacteria (planktonic) baseline assessment by FMU.

FMU	No. sites (No. lakes)	Overall attribute grade			
		A	B	C	D
Southern Hill Country	3 (2)	1 (33.3%)	0 (0.0%)	0 (0.0%)	2 (66.6%)
Coastal Terraces	3 (2)	1 (33.3%)	2 (66.6%)	0 (0.0%)	0 (0.0%)
Pātea	1 (1)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Volcanic Ringplain	2 (2)	1 (50.0%)	0 (0.0%)	0 (0.0%)	1 (50.0%)
Waitara	2 (2)	2 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Northern Hill Country	1 (1)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)
Total	12 (10)	6 (50.0%)	3 (25.0%)	0 (0.0%)	3 (25.0%)

FMU-based baseline states

Escherichia coli (rivers)

Spatial modelling is a useful tool that can be used to help 'fill the gaps' between monitoring sites, and make predictions of water quality based on the catchment characteristics and land use.

Land Water People (LWP) Ltd developed a spatial water quality model for the TRC in order to support the baseline and target setting processes. The spatial model uses a digital drainage network of the Taranaki region describing a wide range of descriptors of the individual network segments and their upstream catchment characteristics. The six catchment characteristics included in the model were geography and topography, climate, hydrology, geology, land cover and stocking density data.

The model incorporates long-term water quality data from monitored sites in the Taranaki, Manawatū-Whanganui, and Waikato regions to estimate river water quality state for the Taranaki region and provide large-scale water quality assessments that are more representative of the true patterns of water quality than assessments based on aggregated data from individual monitoring sites (Fraser, 2022). LWP note that there is considerable uncertainty associated with the modelled water quality predictions at the scale of an individual river segment. However, the modelled data adequately reflects broad scale patterns in water quality.

The modelling output is summarised by FMU in Table 14, and presented spatially in Appendix 4. The results indicate that a significant proportion of total stream reach within each FMU falls within the D and E bands, deemed to be generally unsuitable for primary contact. The FMUs with the highest proportion of stream reach in bands D and E are the Coastal Terraces (97%) and Volcanic Ringplain (83.1%). Pātea and Waitara rank in the middle of the six FMUs, with total proportions of stream reach in the D and E band totalling 67% and 74%, respectively. The Southern Hill Country and Northern Hill Country have the lowest proportions of stream reach in bands D and E, with 41% and 48%, respectively. The fact that these FMUs have the highest predicted proportions of stream reach suitable for swimming, likely reflects the higher proportion of indigenous forest land cover, and lower proportion of intensive agriculture land use relative to the other FMUs (see Appendix 3 for more details on FMU land cover). The visual depiction of these results in Appendix 4 shows that there is a clear pattern of degradation in water quality with distance downstream in each FMU. The one exception to this observation is in the Coastal Terraces, where the model estimates consistently elevated *E. coli* levels across the catchments in this FMU. This likely reflects that there is little variability in land cover, which is dominated by agricultural pasture. There is also no indigenous forest at the top of these catchments, which is a prominent feature of every other FMU (see Appendix 3 and Appendix 4). In the remaining FMUs, the pattern of degradation generally reflects the increasing cumulative impacts of intensive agriculture, urban stormwater and wastewater discharges as water makes its way downstream through these catchments.

As stated earlier, caution is advised when interpreting absolute values or percentages based on spatial water quality models (such as those listed below in Table 14), due to the uncertainty associated with the estimates. However, it should be reiterated that these models are suitable for demonstrating broad scale patterns, and highlighting relative differences between areas of good water quality compared with areas of poor water quality (as shown in Appendix 4). Furthermore, models can become useful tools for scenario testing. TRC has commissioned NIWA to develop the CLUES model in order to test a range of *E. coli* source mitigations and land use scenarios, to understand relative improvements in water quality that we might expect to see. This model is currently still under development but is intended to support the target attribute setting process once complete.

Table 14: FMU-based baseline state (percent total stream reach), summarised by FMU and entire Taranaki region.

FMU	Overall attribute grade				
	A	B	C	D	E
Southern Hill Country	12.3%	35.8%	10.8%	14.0%	27.0%
Coastal Terraces	0.2%	2.2%	0.6%	6.3%	90.7%
Pātea	8.2%	19.2%	5.6%	24.7%	42.3%
Volcanic Ringplain	8.3%	6.8%	1.7%	9.9%	73.2%
Waitara	4.4%	15.2%	5.8%	30.2%	44.4%
Northern Hill Country	0.1%	14.9%	38.4%	34.2%	12.5%
Taranaki region	7.6%	17.9%	8.8%	18.5%	47.2%

Cyanobacteria in lakes

Cyanobacteria biovolume 80th percentiles have been estimated for all lakes in the Taranaki region included in the Freshwater Ecosystems (FENZ) geo-database[6]. A summary of the model is provided in the 'Criteria for identifying site-based baseline states' section of this memorandum, or see Snelder et al. (2016) for further details. It should be noted that FENZ is not a comprehensive database, and as such it was necessary to verify these lakes by cross checking recent aerial photography prior to presenting this data here (Schellenburg et al. 2023). This process identified 19 misclassified lakes that were subsequently removed from the analysis. The cross checking process also identified a number of additional lakes that were not registered on the FENZ database. Including these additional lakes in the analysis was not possible at the time this memorandum was prepared, but it is something that should be pursued in the future.

The model estimates that approximately 92% of lakes in the Taranaki region are likely graded within bands A, B or C for cyanobacteria biovolumes (Table 15). Only 8% of lakes were estimated to fall within band D;

[6] https://www.doc.govt.nz/our-work/freshwater-ecosystems-of-new-zealand/

below the national bottom line. When broken down by FMU, the distribution of lakes across the four grades remains similar, with the majority of lakes graded in band C or higher.

Caution is advised when interpreting absolute values or percentages based on spatial water quality models such as these, due to the uncertainty associated with the estimates. As outlined earlier in the report, a recent evaluation of lake water quality modelling for Taranaki suggests that this model may be underperforming, and that the number of lakes failing the national bottom line may be higher than current estimates (Schallenberg et al., 2023). However, models such as these remain useful for demonstrating broad-scale patterns in water quality that we might expect to see based on physical lake attributes, and characteristics of the surrounding catchments.

Table 15: The number and percentage of lakes in the Taranaki region in each attribute band for Cyanobacteria, based on Snelder et al. (2016).

FMU	Overall attribute grade				Total
	A	B	C	D	
Southern Hill Country	18	11	3	2	34
Coastal Terraces	3	10	1	0	14
Pātea	0	1	0	0	1
Volcanic Ringplain	1	8	3	2	14
Waitara	2	0	0	1	3
Northern Hill Country	0	1	0	0	1
Taranaki region	24 (35.8%)	31 (46.3%)	7 (10.5%)	5 (7.5%)	67 (100.0%)

Baseline state for national primary contact targets

Spatial water quality models have also been used to identify baseline state in relation to the national targets for primary contact, or swimmability. A national model was developed to assess the baseline state of swimmable streams and lakes across the country (MfE, 2018). The assessment focused on rivers and streams fourth order or higher, and lakes with a perimeter greater than 1,500 metres. This section compares the national model estimates with those from the more recent regional spatial water quality model (Fraser, 2022), and also summarises the relevant lake monitoring data.

Focusing on rivers that are fourth order or greater, the national model estimates approximately 61% of river length in Taranaki sits within the D or E band for *E. coli*, meaning those waterways are generally unsuitable for swimming (MfE, 2018; Table 16). However, the regional model estimates the proportion of river length unsuitable for swimming to be higher again, at approximately 74% (Fraser, 2022; Table 16); a difference of 13%. When comparing the model outputs for each grade, the biggest differences are seen in bands C and E, with the regional model predictions 20% lower and 14% higher than the national model predictions, respectively. These differences are likely due to a number of reasons. First, the national model was calibrated using water quality data from across the country (including Taranaki), whereas the Taranaki model was calibrated using water quality data specifically from Taranaki and similar neighboring regions. For this reason, the latter model should provide a closer representation of the actual state of *E. coli* in Taranaki waterways. Second, it is likely that the different outputs were influenced by the different time periods that data were drawn from for the respective calibration processes. However, it is also important to recognize the levels of uncertainty that are associated with each of these models, as described in the previous section. Caution must be exercised when referencing absolute values from these outputs.

As previously discussed, regional councils and unitary authorities were directed to set regional targets to contribute to the overall national targets. MfE suggested a target for Taranaki to improve swimmability from 39% of rivers in 2017 to 67% by 2030, while maintaining the baseline swimmability of 97% of lakes. The additional proportion of rivers that would need to become swimmable to meet this target by 2030 is 28% using the national model baseline assessment, or 41% using the regional model baseline assessment.

Table 16: Comparison of regional and national E. coli spatial model baseline predictions for national swimmability targets.

		Overall attribute grade				
		A	B	C	D	E
Baseline state – model estimates						
Fraser, 2022	Percent total stream reach (≥4th order)	5.9%	13.5%	6.9%	43.1%	30.6%
	Total (swimmable / unswimmable)	26.3%			73.7%	
MfE, 2018	Percent total stream reach (≥4th order)	5.6%	6.9%	26.9%	43.9%	16.8%
	Total (swimmable / unswimmable)	39.4%			60.7%	
Regional targets (2030)						
MfE, 2018		67.4%			22.6%	
TRC, 2018		50-55%			45-50%	

The TRC set a target to improve swimmability from 39% of rivers in 2017 to 50-55% by 2030, while maintaining the baseline swimmability of 97% of lakes (TRC, 2018). The additional proportion of rivers that would need to become swimmable to meet this target by 2030 is 11-16% using the national model baseline assessment, or 24-29% using the regional model baseline assessment. Consideration should be given to revising these regional targets as Council sets target attribute states in relation to human contact attributes, given the additional monitoring data and updated spatial modelling information that is now available. The CLUES model that is under development will be used to make predictions of *E. coli* concentrations in response to a range of possible *E. coli* mitigation scenarios to inform the target setting process (Semadeni-Davies et al. 2023).

There are 17 lakes with a perimeter greater than 1,500 metres; the qualifying criteria for applying the swimmability targets. These lakes include two lakes monitored as part of the regional SoE programme, three lakes that are monitored as part of the CISH programme, and two lakes that are monitored for both purposes. Overall, seven out of 17 lakes with a perimeter greater than 1,500 metres are monitored by the TRC for both *E. coli* and cyanobacteria. Table 17 sets out a summary of *E. coli* and cyanobacteria attribute grades for all 17 lakes, including the cyanobacteria modelling estimates for lakes which are not currently monitored. Further detail is provided in Appendix 5.

Table 17: Swimmability grades for Taranaki lakes with a perimeter greater than 1,500 metres.

	Total	Overall attribute grade				
		A	B	C	D	E
E. coli **(regional sites)**	4	1	3	0	0	0
E. coli **(primary contact sites)**	5	2	0	0	3	0
E. coli **(lowest overall out of regional and primary contact sites)**	7	2	2	0	3	0
Cyanobacteria (measured and modelled; Snelder et al. 2016)	17	8	5	1	2	1
Lowest overall grade (where both ***E. coli*** **and cyanobacteria grades are available)**	7	1	3	0	2	1

Based on the lowest overall *E. coli* grades from the regional SoE and CISH programmes, four out of seven lakes (57%) fall within the A to C (swimmable) range, while the remaining three lakes (43%) fall within the D band (unswimmable). Based on an overall grade from measured and modelled data, 14 out of 17 lakes (82%) sit within the A to C (swimmable) range for cyanobacteria and the remaining three lakes (18%) fall within the

D band (unswimmable). Where information is available for both *E. coli* and cyanobacteria, four out of seven lakes fall within the A to C (swimmable) range (57%), while the remaining three lakes fall within the D band (unswimmable) (43%). These grades provide an updated, regional baseline of lake swimmability in relation to the national primary contact targets. As with the *E. coli* swimmability targets for rivers, consideration should be given to revising the lake swimmability targets as Council sets target attribute states in relation to human contact attributes, given the additional monitoring data and updated spatial modelling information that is now available.

Recommendations

Draft baseline states have been calculated for both monitoring sites (rivers and lakes) and the overall stream network, to provide the best known state for the *E. coli* attribute as an indicator of suitability of rivers and lakes for human contact across each FMU. Draft baseline states have also been calculated for monitoring sites to provide the best known state for the cyanobacteria attribute as another indicator of suitability of lakes for human contact across each FMU.

For *E. coli* in rivers, consideration should be given towards setting target states for monitoring sites and at broader spatial scales (e.g. at catchment or FMU scale) given the available spatial modelling information. This approach recognises that environmental outcomes are intended to be achieved for all waterbodies rather than only at a select few monitoring sites. At this point in time it is not recommended to follow the same approach for *E. coli* or cyanobacteria in lakes. Rather, target state for lakes should be set for monitored lakes only, while the monitoring record remains limited, and associated modelling requires further validation.

When setting target states for attributes associated with the human contact freshwater value, including *E. coli* and cyanobacteria, the target attribute state must be set above the baseline state, unless the baseline state is already within band A of the corresponding NOF attribute table. Previous targets set in relation to the national swimmability targets should also be reviewed with best available information.

To support the target setting process, possible actions and mitigations that are available to promote the maintenance and improvement of freshwater in relation to *E. coli* and cyanobacteria must be identified and assessed. This work is currently underway, with NIWA developing the CLUES model to assess the impact of two existing mitigation options on *E. coli* loads in rivers and streams. The existing mitigations that are already being modelled include the completion of riparian fencing and planting throughout the region, and redirecting all dairy effluent discharges from water to land. Further actions and mitigations should be identified and assessed in order to understand what can be achieved when considering target state, based on the widest range of potential tools available.

Additional river monitoring sites will need to be established in order to achieve monitoring coverage in all FMUs, and appropriate representativeness across the region. Monitoring coverage of lakes and primary contact sites however, is considered to be sufficient.

Finally, consideration should be given to other potential attributes that could be used to assess progress towards, and achievement of, environmental outcomes that are set for the human contact freshwater value, in addition to *E. coli* and cyanobacteria.

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Appendix 1(a) - *E. coli* baseline state assessment (regional sites; rivers)

Site code	FMU	Baseline defn.	Data range start	Data range end	n	% >540	% >260	median	95th	NOF band				Overall NOF band
										% >540	% >260	median	Q95	
WMR000100	NHC	1.4(a)	15/08/2017	17/01/2023	23	39.1	69.6	488.0	3642.5	E	E	E	D	E
PAT000200	PAT	1.4(c)	10/10/2012	9/13/2017	60	3.3	8.3	24.0	400.0	A	A	A	A	A
PAT000360	PAT	1.4(c)	10/10/2012	9/13/2017	60	26.7	43.3	205.0	4400.0	D	D	D	D	D
MGH000950	PAT	1.4(c)	10/10/2012	9/13/2017	60	28.3	38.3	210.0	2050.0	D	D	D	D	D
MKR000495	PAT	1.4(a)	14/11/2018	21/02/2023	10	40.0	70.0	385.0	N/A	E	E	E	N/A	E
WNR000450	SHC	1.4(a)	7/09/2015	5/14/2020	60	30.0	56.7	310.0	3100.0	D	E	E	D	E
TWH000435	SHC	1.4(a)	19/10/2017	9/02/2023	21	33.3	90.5	387.0	10205.0	E	E	E	D	E
MRK000420	VRP	1.4(a)	1/14/1998	12/11/2002	60	70.0	91.7	670.0	20500.0	E	E	E	D	E
PNH000900	VRP	1.4(a)	8/14/2002	8/08/2007	60	28.3	56.7	310.0	5300.0	D	E	E	D	E
PNH000200	VRP	1.4(c)	10/10/2012	9/13/2017	60	11.7	18.3	84.5	965.0	C	A	A	B	C
STY000300	VRP	1.4(a)	1/14/1998	12/11/2002	60	1.7	1.7	7.0	83.0	A	A	A	A	A
WGG000500	VRP	1.4(c)	10/10/2012	9/13/2017	60	23.3	45.0	230.0	3800.0	D	D	D	D	D
WGG000900	VRP	1.4(c)	11/14/2012	9/13/2017	60	23.3	38.3	220.0	3150.0	D	D	D	D	D
WKR000700	VRP	1.4(a)	6/13/2011	6/01/2016	60	73.3	93.3	745.0	4850.0	E	E	E	D	E
WKH000500	VRP	1.4(a)	1/14/1998	11/13/2002	60	28.3	35.0	190.0	5000.0	D	D	D	D	D
KPA000950	VRP	1.4(a)	9/07/2015	8/02/2023	29	31.0	58.6	320.0	2133.0	E	E	E	D	E
WKR000500	VRP	1.4(a)	7/04/2016	7/02/2023	20	85.0	90.0	1400.0	3850.0	E	E	E	D	E
MKW000300	WTR	1.4(a)	7/09/2003	6/11/2008	60	28.3	53.3	285.0	3100.0	D	E	E	D	E
MGN000195	WTR	1.4(c)	9/18/2012	8/29/2017	60	11.7	20.0	73.3	1986.2	C	B	A	D	D
WTR000800	WTR	1.4(a)	2/22/2005	1/19/2010	60	35.0	45.0	184.2	2258.6	E	D	D	D	E
WTR000540	WTR	1.4(a)	9/15/2016	9/09/2021	60	38.3	55.0	325.0	8050.0	E	E	E	D	E
MTA000068	WTR	1.4(a)	18/07/2017	21/02/2023	23	26.1	39.1	190.0	2161.5	D	D	D	D	D

NB: Yellow rows denote sites with partial/incomplete data

Appendix 1(b) - *E. coli* baseline state assessment (regional sites; lakes)

Site name	Site code	FMU	Baseline defn.	Data range end	n	% >540	% >260	median	95th	Max	Overall NOF band
Barrett Lagoon at deepest point	LBR00S100	VRP	1.4(a)	4/07/2023	5	-	-	50 (A)	-	200	B
Lake Kaikura at deepest point	LKK00S500	CT	1.4(a)	6/07/2023	4	-	-	24 (A)	-	230	B
Lake Rotokawau at deepest point	LRW00S500	NHC	1.4(a)	3/07/2023	4	-	-	30 (A)	-	50	B
Lake Waikare at deepest point	LWK00S100	SHC	1.4(a)	5/07/2023	3	-	-	<10 (A)	-	10	B
Lake Herengawe at deepest point	LHN00S100	CT	1.4(a)	7/07/2023	3	-	-	13 (A)	-	14	A
Lake Herengawe (CISH – shoreline data)	LHN000005	CT	-	28/03/2023	24	0	0	20 (A)	77 (A)	98	
Lake Rotokare at deepest point	LRK00S500	SHC	1.4(a)	6/07/2023	5	-	-	6 (A)	-	13	B
Lake Rotokare (CISH – shoreline data)	LRK000003	SHC	-	28/03/2023	44	7	25	75 (A)	1,562 (D)	2,720	

NB: grey rows highlight supporting data sources

Appendix 1(c) - *E. coli* baseline state assessment (primary contact sites)

Site name	Site code	FMU	Baseline defn.	Data range end	n	Q95	Overall NOF band
Lake Rotokare	LRK000003	SHC	1.4(a)	28/03/2023	44	1,562	D
Lake Herengawe	LHN000005	CT	1.4(a)	28/03/2023	22	77	A
Lake Rotorangi	LRT000470	PAT	1.4(a)	28/03/2023	27	67	A
Patea River at King Edward Park	PAT000297	PAT	1.4(a)	28/03/2023	44	8,160	D
Patea River at mouth	PAT000995	PAT	1.4(a)	28/03/2023	45	1,478	D
Kaupokonui Stream at mouth	KPK000995	VRP	1.4(a)	28/03/2023	45	7,848	D
Lake Rotomanu	LRM000002	VRP	1.4(a)	28/03/2023	43	554	D
Oakura River at mouth	OKR000497	VRP	1.4(a)	28/03/2023	44	7,651	D
Te Henui Stream at mouth	THN000499	VRP	1.4(a)	28/03/2023	43	10,179	D
Timaru Stream at mouth	TMR000497	VRP	1.4(a)	28/03/2023	44	6,797	D
Waingongoro at Taumata Park	WGG000494	VRP	1.4(a)	28/03/2023	22	4,786	D
Waingongoro River at Presbyterian camp	WGG000492	VRP	-	29/03/2022	22	5,414	-
Waingongoro River at mouth	WGG000995	VRP	1.4(a)	28/03/2023	43	6,256	D
Waiwhakaiho River at Meeting of the Waters	WKH000673	VRP	1.4(a)	28/03/2023	22	2,696	D
Waiwhakaiho River at Merrilands Domain	WKH000800	VRP	1.4(a)	28/03/2023	44	6,405	D
Waiwhakaiho River at mouth	WKH000950	VRP	1.4(a)	28/03/2023	43	5,703	D
Lake Ngangana	WTR000911	WTR	1.4(a)	28/03/2023	45	950	D
Lake Ratapiko	LRP000050	WTR	1.4(a)	28/03/2023	43	7,075	D
Manganui River at Everett Park	MGN000435	WTR	1.4(a)	28/03/2023	45	15,570	D
Waitara River at Bertrand Road	WTR000800	WTR	1.4(a)	28/03/2023	44	11,348	D
Waitara River at Town Wharf	WTR000922	WTR	1.4(a)	28/03/2023	41	9,548	D
Tongaporutu at boat ramp	TPT000991	NHC	1.4(a)	28/03/2023	44	3,270	D
Urenui River at mouth	URN000480	NHC	1.4(a)	28/03/2023	43	4,182	D

NB: WGG000492 (shown in grey) is presented here to support the baseline identification of WGG000494.

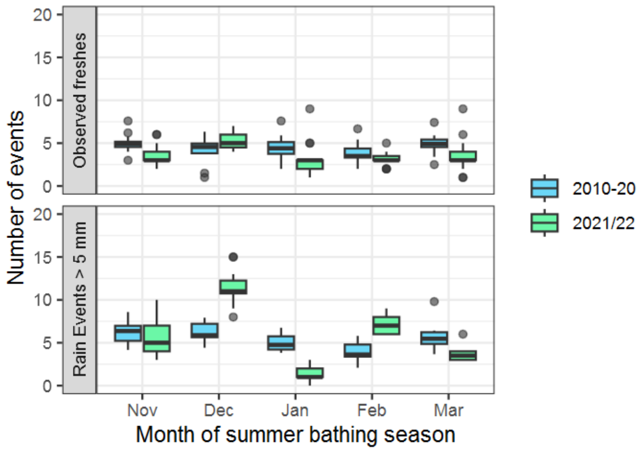
Appendix 1(d) - Cyanobacteria biovolume baseline state assessment

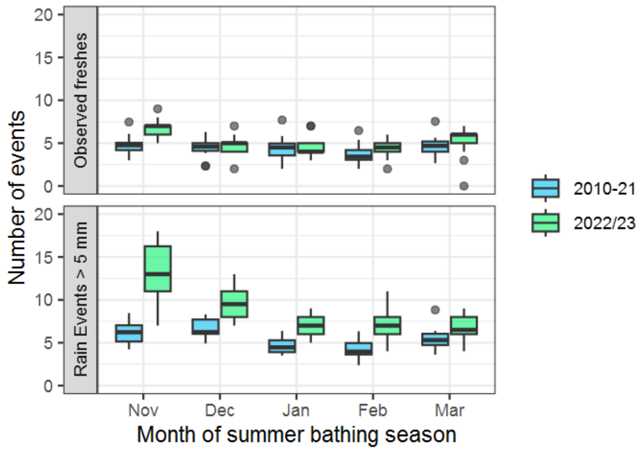
Site name	Site code	FMU	Measured data							Modelled data (Snelder et al. 2016)		Overall NOF band
			Sampling start date	80^{th} percentile (earliest available data – 3 years)	n	Data range (full data set)	n	Baseline defn.	NOF band	80^{th} percentile	NOF band	
Lake Kaikura at deepest point	LKK00E500	CT	05/04/2023	Data deficient	2	0.003 – 0.111 mm^3/L	2	1.4(a)	-	0.41 mm^3/L	A	A
Lake Rotokawau at deepest point	LRW00E500	NHC	23/02/2023	Data deficient	2	0.00 mm^3/L	2	1.4(a)	-	0.82 mm^3/L	B	B
Barrett Lagoon at deepest point	LBR00E100	VRP	26/10/2022	Data deficient	3	0.00 mm^3/L	3	1.4(a)	-	0.48 mm^3/L	A	A
Lake Waikare at deepest point	LWK00E100	SHC	16/03/2023	Data deficient	2	0.00 – 0.068 mm^3/L	2	1.4(a)	-	0.21 mm^3/L	A	A
Lake Rotokare at deepest point	LRK00E500	SHC	01/12/2022	Data deficient	2	0.00 – 1.64 mm^3/L	2	1.4(a)	-	0.58 mm^3/L	B	D
Lake Rotokare at boat ramp	LRK000003	SHC	10/10/2014	13.88 mm^3/L	29	0.00 - 43.32 mm^3/L	97	1.4(a)	D			D
Lake Herengawe at deepest point	LHN00E100	CT	20/04/2023	Data deficient	1	0.40 mm^3/L	1	1.4(a)	-	0.76 mm^3/L	B	B
Lake Herengawe at Rotary Reserve boat ramp	LHN000005	CT	01/11/2022	0.24 mm^3/L	11	0.00 - 0.41 mm^3/L	11	1.4(a)	A			B
Lake Rotomanu at western shoreline	LRM000002	VRP	18/11/2014	2.77 mm^3/L	23	0.00 – 9.84 mm^3/L	88	1.4(a)	D	0.90 mm^3/L	B	D
Lake Rotorangi at Patea Dam pontoon	LRT000470	PAT	01/11/2022	0.13 mm^3/L	9	0.001 - 0.22 mm^3/L	9	1.4(a)	A	0.74 mm^3/L	B	A
Lake Ratapiko at boat ramp	LRP000050	WTR	18/11/2014	0.00 mm^3/L	21	0.00 – 1.66 mm^3/L	80	1.4(a)	A	0.44 mm^3/L	A	A
Lake Ngangana at northern shoreline	WTR000911	WTR	9/01/2020	0.23 mm^3/L	29	0.00 – 16.51 mm^3/L	31	1.4(a)	A	-	-	A

NB: Grey rows highlight sites monitored in the Can I Swim Here? (CISH) programme; White rows highlight sites monitored in the regional State of the Environment lakes programme

Appendix 2 – Rainfall and river flows for *E. coli* (primary contact) baseline period

Event metric	Month	2010-20				2021-22				2022-23			
		Mean	Median	Q25	Q75	Mean	Median	Q25	Q75	Mean	Median	Q25	Q75
Observed freshes (number of sites = 15)	Nov	4.97	4.92	4.55	5.17	3.47	3.00	3.00	4.00	6.67	7.00	6.00	7.00
	Dec	4.24	4.56	3.82	4.96	5.13	5.00	4.50	6.00	4.60	5.00	4.00	5.00
	Jan	4.50	4.40	3.75	5.12	3.13	3.00	2.00	3.00	4.47	4.00	4.00	5.00
	Feb	3.91	3.50	3.32	4.38	3.13	3.00	3.00	3.50	4.38	4.50	4.00	5.00
	Mar	4.88	4.92	4.54	5.42	3.53	3.00	3.00	4.00	5.12	6.00	5.00	6.00
Rain Events > 5 mm (number of sites = 16)	Nov	6.19	6.37	5.22	6.98	5.62	5.00	4.00	7.00	13.38	13.00	11.00	16.25
	Dec	6.14	5.88	5.65	7.21	11.50	11.00	10.75	12.25	9.62	9.50	8.00	11.00
	Jan	4.97	4.75	4.21	5.75	1.31	1.00	1.00	2.00	6.88	7.00	6.00	8.00
	Feb	3.95	3.62	3.39	4.79	7.06	7.00	6.00	8.00	7.06	7.00	6.00	8.00
	Mar	5.62	5.47	4.86	6.22	3.62	3.50	3.00	4.00	6.62	6.50	6.00	8.00





Observed number of freshes (river flow peaks above a running baseline) and rain events greater than 5 mm (24 hour periods from midnight to midnight where there is 5 mm or more of rainfall recorded.

Observations from 15 associated river flow recording sites and 16 associated rainfall monitoring sites are summarized and presented here in the table and box plots.

Appendix 3 – Assessment of river monitoring site representativeness

FMU		CX	CW	WX	WW	WD
Southern Hill Country	Proportion REC	0.7%	**54.5%**	0.0%	31.3%	**13.5%**
	Proportion sites	0.0%	**0.0%**	0.0%	100.0%	**0.0%**
Pātea	Proportion REC	5.9%	65.7%	0.0%	24.0%	**4.4%**
	Proportion sites	25.0%	25.0%	0.0%	50.0%	**0.0%**
Coastal Terraces	Proportion REC	0.0%	0.0%	0.0%	37.33%	62.67%
	Proportion sites	0.0%	0.0%	0.0%	**0.0%**	**0.0%**
Volcanic Ringplain	Proportion REC	34.3%	12.5%	**6.9%**	42.5%	3.7%
	Proportion sites	40.0%	30.0%	**0.0%**	30.0%	0.0%
Waitara	Proportion REC	28.6%	19.2%	10.2%	42.0%	0.0%
	Proportion sites	40.0%	20.0%	20.0%	20.0%	0.0%
Northern Hill Country	Proportion REC	**7.0%**	1.5%	0.0%	91.5%	0.0%
	Proportion sites	**0.0%**	0.0%	0.0%	100.0%	0.0%

Climate REC categories (CX = cool extremely wet; CW = cool wet; WX = warm extremely wet; WW = warm wet; WD = warm dry)

FMU		Hill	Low Elevation	Mountain
Southern Hill Country	Proportion REC	**15.6%**	84.4%	0.0%
	Proportion sites	**0.0%**	100.0%	0.0%
Pātea	Proportion REC	7.3%	92.7%	0.0%
	Proportion sites	25.0%	75.0%	0.0%
Coastal Terraces	Proportion REC	0.00%	100.00%	0.00%
	Proportion sites	0.00%	**0.0%**	0.00%
Volcanic Ringplain	Proportion REC	26.7%	69.8%	**3.5%**
	Proportion sites	40.0%	60.0%	**0.0%**
Waitara	Proportion REC	15.6%	82.3%	2.1%
	Proportion sites	40.0%	60.0%	0.0%
Northern Hill Country	Proportion REC	1.8%	98.2%	0.0%
	Proportion sites	0.0%	100.0%	0.0%

Source of flow REC categories (hill, low elevation, mountain)

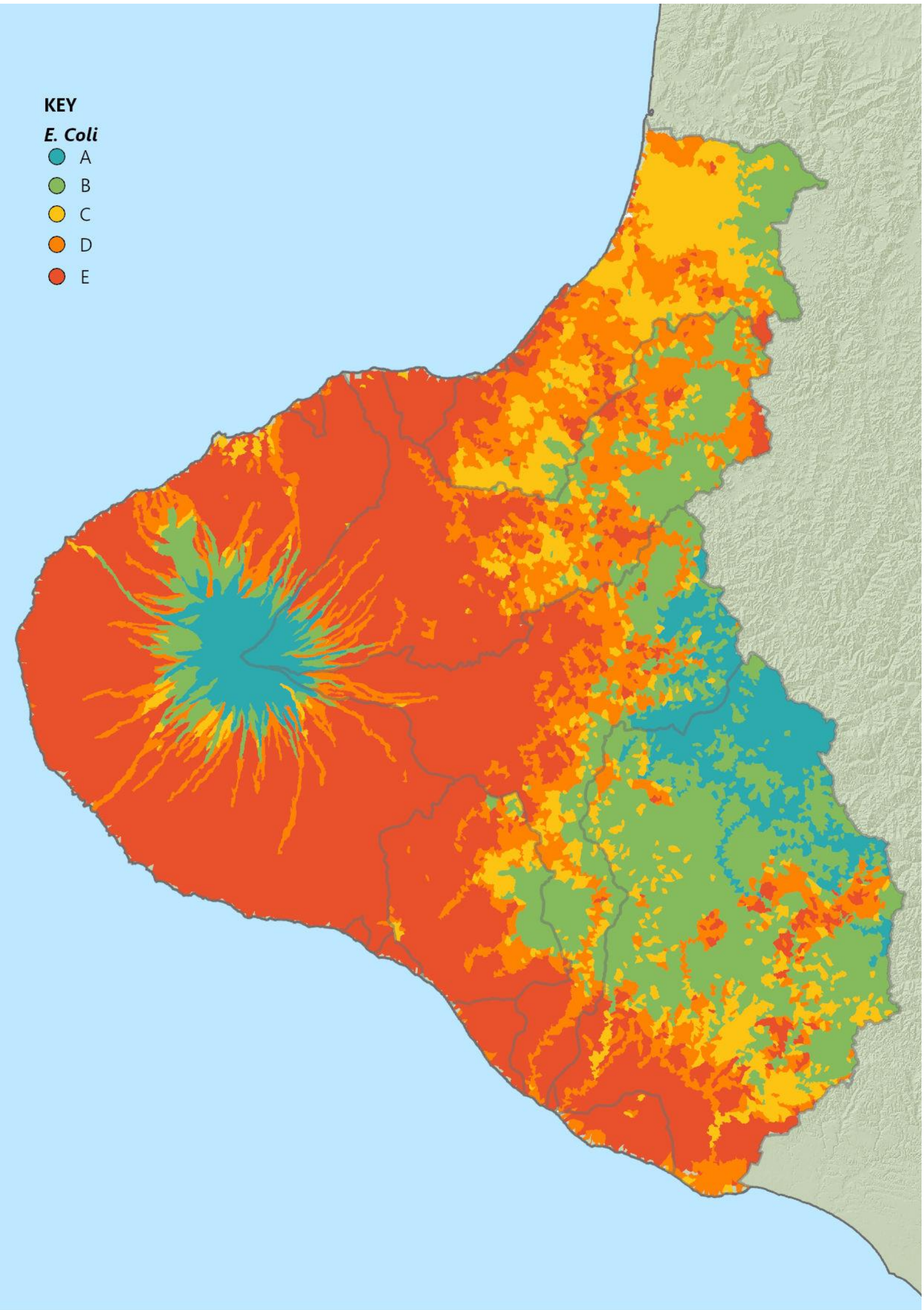
FMU		Al	M	SS	VA
Southern Hill Country	Proportion REC	1.4%	0.4%	82.9%	15.3%
	Proportion sites	0.0%	0.0%	50.0%	50.0%
Pātea	Proportion REC	0.9%	1.1%	67.6%	30.4%
	Proportion sites	0.0%	0.0%	50.0%	50.0%
Coastal Terraces	Proportion REC	29.31%	0.00%	0.00%	70.69%
	Proportion sites	**0.0%**	0.0%	0.0%	**0.0%**
Volcanic Ringplain	Proportion REC	1.0%	0.6%	0.1%	98.3%
	Proportion sites	0.0%	0.0%	0.0%	100.0%
Waitara	Proportion REC	1.2%	0.2%	51.5%	47.1%
	Proportion sites	0.0%	0.0%	60.0%	40.0%
Northern Hill Country	Proportion REC	0.0%	0.0%	91.6%	**8.4%**
	Proportion sites	0.0%	0.0%	100.0%	**0.0%**

Geology REC categories (Al = alluvium; M = miscellaneous; SS = soft sedimentary; VA = volcanic acidic)

FMU		B	EF	IF	P	S	U
Southern Hill Country	Proportion REC	0.0%	0.5%	**43.4%**	45.6%	**10.0%**	**0.5%**
	Proportion sites	0.0%	0.0%	**0.0%**	100.0%	**0.0%**	**0.0%**
Pātea	Proportion REC	0.0%	2.6%	19.3%	67.3%	**9.5%**	**1.4%**
	Proportion sites	0.0%	0.0%	25.0%	75.0%	**0.0%**	**0.0%**
Coastal Terraces	Proportion REC	0.0%	0.0%	0.0%	92.9%	0.0%	7.1%
	Proportion sites	0.0%	0.0%	0.0%	**0.0%**	0.0%	**0.0%**
Volcanic Ringplain	Proportion REC	1.6%	0.0%	13.8%	80.6%	2.5%	**1.6%**
	Proportion sites	0.0%	0.0%	10.0%	80.0%	10.0%	**0.0%**
Waitara	Proportion REC	0.6%	0.4%	**24.4%**	72.5%	1.5%	**0.5%**
	Proportion sites	0.0%	0.0%	**0.0%**	100.0%	0.0%	**0.0%**
Northern Hill Country	Proportion REC	0.0%	0.1%	**64.9%**	33.3%	1.8%	0.0%
	Proportion sites	0.0%	0.0%	**0.0%**	100.0%	0.0%	0.0%

Land cover REC categories (B = bare ground; EF = exotic forest; IF = indigenous forest; P = pasture; S = scrub; U = urban)

Appendix 4 – Taranaki spatial water quality baseline assessment



Regional baseline assessment of E. coli attribute grade for each stream segment expanded to the contributing watershed (5-year period to December 2017) (Fraser, 2022)

Appendix 5 – *E. coli* and cyanobacteria baseline state for Taranaki lakes with a perimeter greater than 1,500 m

FMU	FENZ Lake ID	Name	Latitude	Longitude	Perimeter (m)	*E. coli* (primary contact)	*E. coli* (regional)	Cyanobacteria (measured and modelled)	Overall swimmability (lowest grade)
Pātea	LID 7506	Lake Rotorangi	-39.507804	174.52435	112,417	A		A	A
Waitara	LID 16392	Lake Ratapiko	-39.205697	174.3318	10,100	D		A	D
Volcanic Ringplain	LID 20880	Lake Mangamahoe	-39.123232	174.124826	6,034			B	n/a
Southern Hill Country	LID 16131	Lake Moumahaki	-39.689089	174.669516	4,015			A	n/a
Southern Hill Country	LID 7512	Lake Rotokare	-39.4515	174.411021	3,204	D	B	E	E
Coastal Terraces	LID 15902	Lake Herengawe	-39.79213	174.641667	3,105	A	A	B	B
Southern Hill Country	LID 15907	Lake Waiau	-39.794631	174.680267	3,015			B	n/a
Southern Hill Country	LID 16214	Moumahaki Lakes	-39.689089	174.669516	2,874			A	n/a
Southern Hill Country	LID 16224	Lake Mangawhio	-39.651845	174.793037	2,606			A	n/a
Southern Hill Country	LID 15926	Lake Waikato	-39.830011	174.785533	2,389			B	n/a
Waitara	LID 20969	Lake Cowley	-39.012049	174.235131	2,273			D	n/a
Coastal Terraces	LID 15795	Lake Kaikura	-39.699255	174.405836	2,056		B	A	B
Coastal Terraces	LID 15904	Lake Oturi	-39.779539	174.620808	2,003			A	n/a
Coastal Terraces	LID 15840	Nowell's Lakes West	-39.61685	174.28567	1,839			B	n/a
Southern Hill Country	LID 16222	Lake Waikare	-39.669009	174.80577	1,698		B	A	B
Coastal Terraces	LID 15842	Nowell's Lakes East	-39.617639	174.290887	1,620			C	n/a
Volcanic Ringplain	LID 20904	Lake Rotomanu	-39.040588	174.114741	1,469	D		D	D

NB: Lake Rotomanu has been included here given its perimeter is very close to 1,500 metres, and it is an important lake for recreational use.
n/a: Both *E. coli* and cyanobacteria grades must be available to assess overall swimmability.