MARLBOROUGH
DISTRICT COUNCIL

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State of the Environment
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Executive Summary

River health has become a focal point in recent years due to new legislation, such as the National Policy Statement for Freshwater Management (NPS-FM), and National Environmental Standards introduced in 2020. Healthy waterways are crucial for the social, cultural, and economic well-being of our community. Continuous, long-term monitoring of water quality is essential for effective freshwater resource management. It allows council to assess the effectiveness of plan rules and concentrate improvement efforts where water quality is currently compromised.

To evaluate the health of Marlborough's rivers and streams, council monitors various physical and chemical parameters monthly at 34 sites across the region. Additionally, macroinvertebrates are assessed annually at 49 sites.

This report provides a summary and discussion of several key parameters using data collected over the past five years (2018-2022).

Nitrogen concentrations are highest in spring-fed streams and catchments with substantial pastoral land cover in high-rainfall areas. Elevated nitrogen levels primarily result from leaching of nitrogen from fertilizers and animal waste.

Some waterways naturally exhibit elevated phosphorus concentrations, particularly in the Marlborough Sounds. However, excessively high levels are attributed to direct inputs into rivers, mainly in the form of sediment.

Turbidity is most pronounced in catchments with sedimentary (mudstone) geology, notably in the Awatere River. Elevated turbidity levels in the Awatere River are associated with increased heavy metal concentrations. Catchments dominated by native vegetation and groundwater-fed streams tend to have the clearest water.

E. coli concentrations in waterways increase with the proportion of pastoral land use within a catchment, especially in regions with high rainfall.

Water temperatures, dissolved oxygen concentrations, and pH values generally fall within acceptable ranges. An exception are low oxygen levels in the Tuamarina River, partly due to natural processes within the extensive Para Swamp.

Macroinvertebrate scores are generally higher in waterways located in areas with higher rainfall.

Where applicable, the report also present NPS-FM attribute states. A comparison of NPS-FM states between Marlborough and the rest of New Zealand indicates that Marlborough generally enjoys good river health (refer to *Figure 1*).

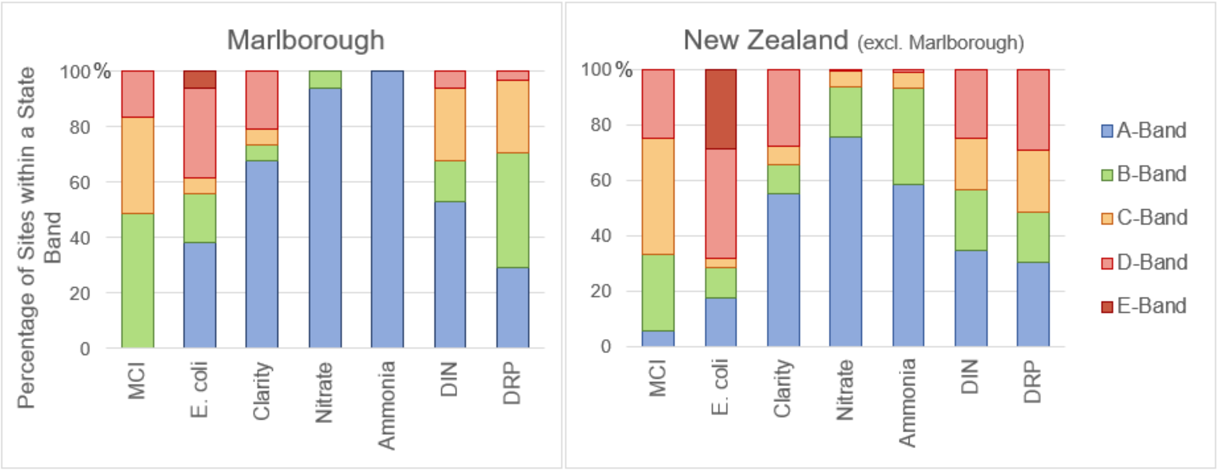

Figure 1: The percentage of sites within the NPS-FM state bands for the Marlborough region (left) and the rest of New Zealand (right).

To assess changes over time, trend analysis was carried out for data over the last 5, 10, and 14 years. The NPS-FM mandates action from councils for attributes (NPS-FM parameters) displaying deteriorating trends. To ensure that reported trends reflect actual changes attributable to human activity, rather than weather-related phenomena, a more sophisticated adjustment for flow and rainfall was conducted.

The analysis revealed increasing trends in nitrogen concentrations for Linkwater Stream and Mill Creek but decreasing trends for Doctors Creek and the Blenheim Springs. Over the past five years, decreasing trends in the Rai catchment and the Kaituna River were observed.

Changes in Dissolved Reactive Phosphorus concentrations were relatively minor across all monitored sites, but significant decreases in Total Phosphorus were identified for Linkwater Stream, the Tuamarina River, and Awatere River over the last five years.

E. coli concentrations improved in numerous rivers and streams, including the Kaituna River, Cullen Creek, Doctors Creek, and the Taylor River. Linkwater Stream experienced the most significant increase in E. coli levels.

Regarding turbidity, clear improvements were noted in Linkwater Stream, Tuamarina River, and the Mid Waihopai Rivers. In the Awatere River, trend analysis indicates decreasing turbidity in the mid reaches but increasing turbidity in the lower part of the river.

The report also presents a Water Quality Index (WQI) for the monitored rivers and streams. The index calculation employs NPS-FM limits where available or limits developed for the NPS-FM but not currently listed as attributes. The WQI simplifies comparisons of water quality across various waterways and serves as a valuable tool for identifying degraded waterways and prioritising improvement actions.

Catchment Care and other projects aim to improve the health of degraded waterways.

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1. Introduction

1.1. Purpose

Healthy rivers and streams are vital to a thriving region. In addition to providing essential ecosystem functions, rivers supply water for agricultural, viticultural, and industrial purposes. Yet, for most people, their primary connection to waterways is through recreational activities such as swimming, fishing, and boating.

The Marlborough District Council undertakes monitoring of surface water quality in the region's streams and rivers as part of its obligations under the Resource Management Act (RMA) of 1991. The monitored waterways encompass a wide range of catchment types and land uses, spanning from pristine native bush catchments to predominantly urbanized areas. Monitoring typically occurs as close to the bottom of each catchment as possible, allowing for the assessment of cumulative effects resulting from human activities within the catchment.

The primary objective of this report is to present information on river water quality in a format accessible to a non-technical audience. The ultimate goal is to engage a diverse range of interested parties in discussions regarding surface water quality and the effectiveness of policies and rules.

The report provides information on the current state of water quality based on physical, chemical and ecological parameters. It explores the reasons for the observed states and discusses changes observed over the years.

The 2020 National Policy Statement for Freshwater Management has established limits for several parameters to assess river health. Councils are mandated to report on waterbody conditions based on these limits on an annual basis. This report fulfils parts of this requirement.

1.2. The Region

The three largest rivers in the Marlborough region are the Te Hoiere/Pelorus River in the North-West, the Wairau River, and the Awatere River in the South. The Wairau River has the largest catchment spanning the region from the mountains of the St Arnaud Ranges in the West to the Pacific Ocean in the East and culminating in the largest cumulative flow of all the rivers in Marlborough.

Positioned on the eastern side of the South Island, Marlborough experiences a diverse rainfall pattern due to the rain shadow effect of the Southern Alps (*Figure 2*). The greatest amount of rainfall (more than 2.5 meters a year) falls on the North bank of the Wairau River and in the Te Hoiere/Pelorus catchment. In stark contrast, the East Coast regions and the lower river plains of the Awatere River catchment receive less than 800 mm of total annual rainfall, rendering them some of the driest places in New Zealand. Consequently, despite the Awatere River catchment being roughly twice the size of Te Hoiere/Pelorus, the mean flow in the Awatere River pales in comparison during late summer when the eastern parts of some of the rivers in the South may dry up completely.

Historically, poor water quality in rivers and streams was primarily linked to point source discharges, such as effluent or industrial waste piped directly into waterways. Over the past few decades, significant strides have been made in reducing the impact of such point sources. Today, diffuse sources, like runoff from land and land-use activities, have become the primary contributors to water quality issues in most rivers and streams. Nevertheless, a few point sources, primarily related to stormwater systems, persist, particularly in residential areas.

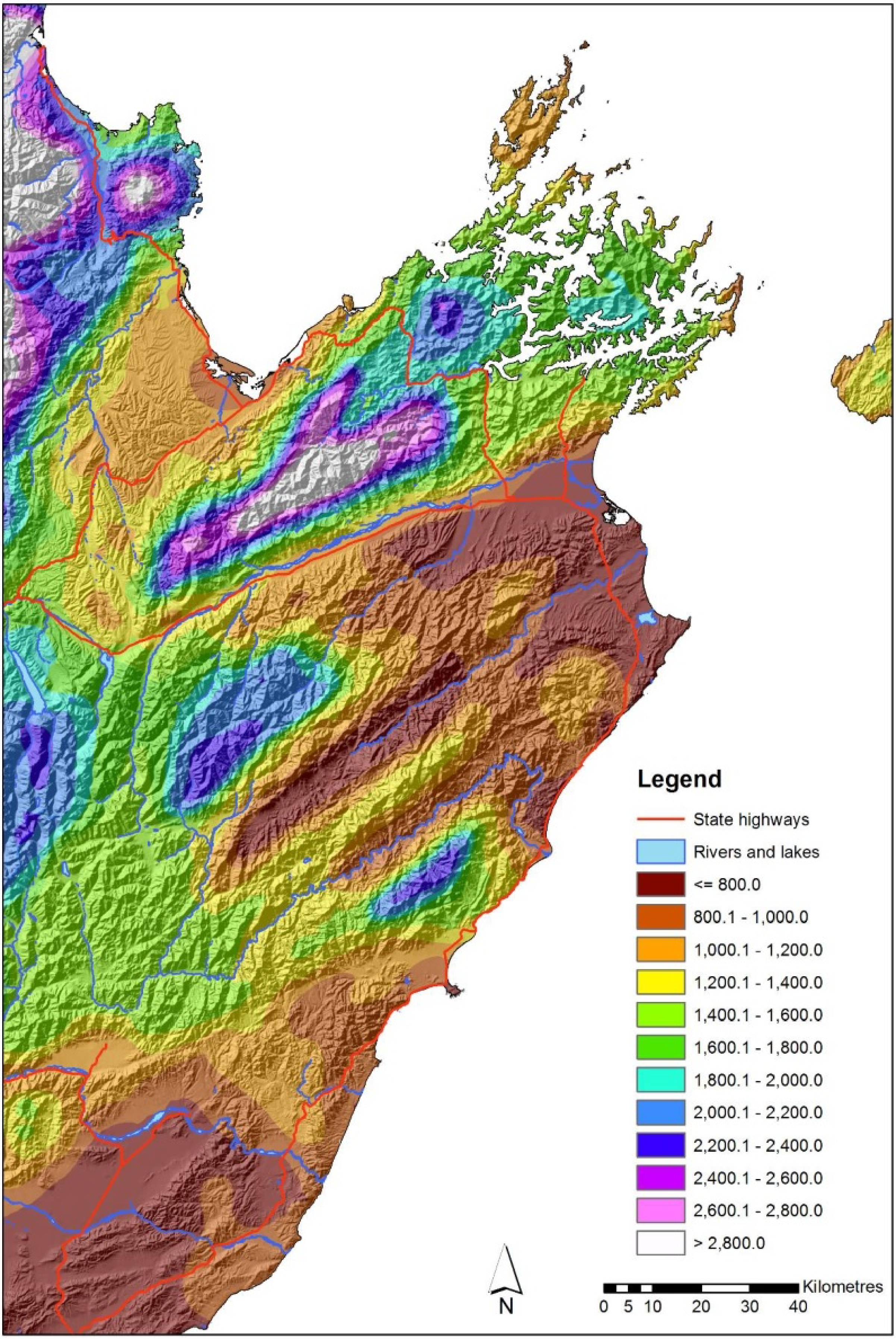

Figure 2: Median Annual Total Rainfall in Marlborough [35].

One of the most significant factors influencing water quality is the alteration of natural land cover. Prior to human settlement, New Zealand was predominantly cloaked in forests. Since human arrival, extensive deforestation has occurred, transforming most of our waterways from pristine to altered states. *Figure 4* illustrates the current land cover of the Marlborough region. The North and West areas retain substantial native vegetation, especially at higher elevations, covering over 40% of the region. Native forests, shrubs, and tussocks still thrive. However, the river plains have been cleared of native vegetation and now serve agricultural or viticultural purposes. Almost 30% of the region has been converted into pasture, primarily for sheep and beef farming, although dairy farming has also gained a foothold, notably in the Rai and Te Hoiere/Pelorus River flats, Tuamarina, Kaituna, and Linkwater areas. Production forests, mainly consisting of Pinus radiata, dominate lower hill regions of Wairau River tributaries, the Rai/TeHoiere area, and parts of the Marlborough Sounds.

Marlborough is most celebrated for its viticulture, with vineyards predominantly found on the Wairau Plain and the lower Awatere River. In recent years, the area growing vines has further increased, with some vineyard development moving further up river valleys (*Figure 3*) and into other areas of the region.

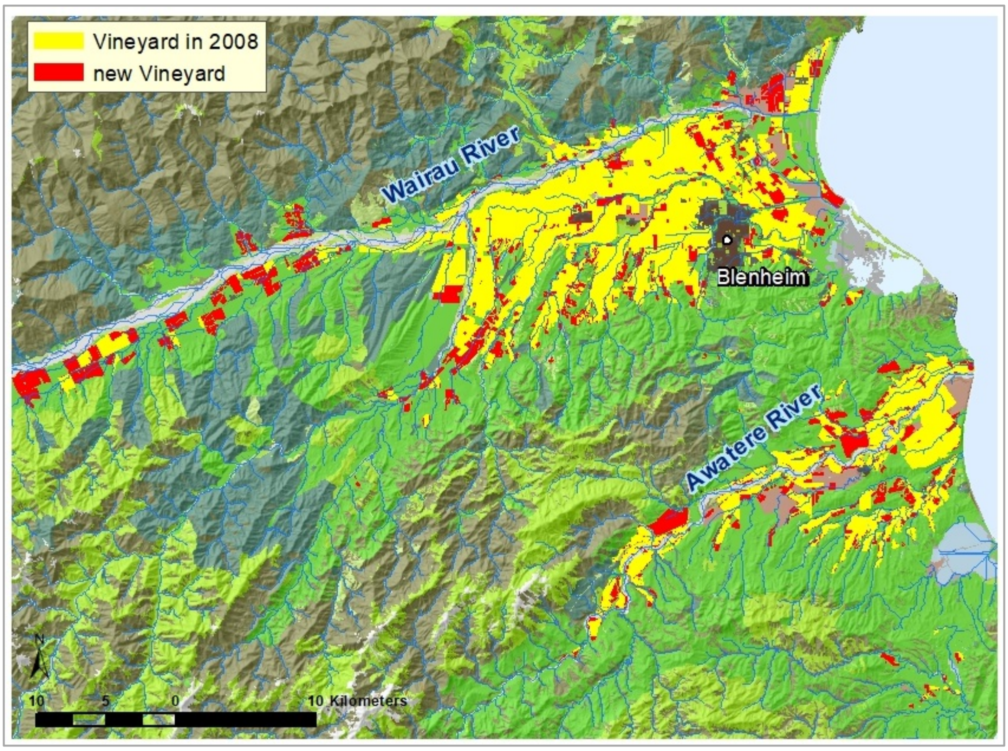

Figure 3: Extend and expansion of vineyards between 2008 and 2022.

2. Methodology

2.1. Sampling and sample analysis

Monthly water quality sampling and field measurements are conducted at 34 sites throughout the region. One of these sites is integrated into the national monitoring network, with NIWA (National Institute of Water and Atmospheric Research) responsible for collecting and analysing water quality samples. NIWA generously shares sampling data for this site via their internet portal. For the remaining 33 sites, our dedicated Marlborough District Council staff collects water samples, which are then dispatched to an independent, accredited laboratory, Hill Laboratories, for analysis.

Water temperature and dissolved oxygen levels are directly measured in the field using YSI handheld meters. We conduct our sampling consistently, regardless of weather conditions, typically during the same week each month.

Macroinvertebrates are sampled annually at 49 sites during the summer months. Council utilises the Kicknet method (C1 [33]) for sampling, focusing on riffle areas whenever feasible. Subsequently, Stark Environmental Ltd performs the analysis providing individual counts up to 200. *Figure 4* provides an overview of the locations of our monthly and annual monitoring sites.

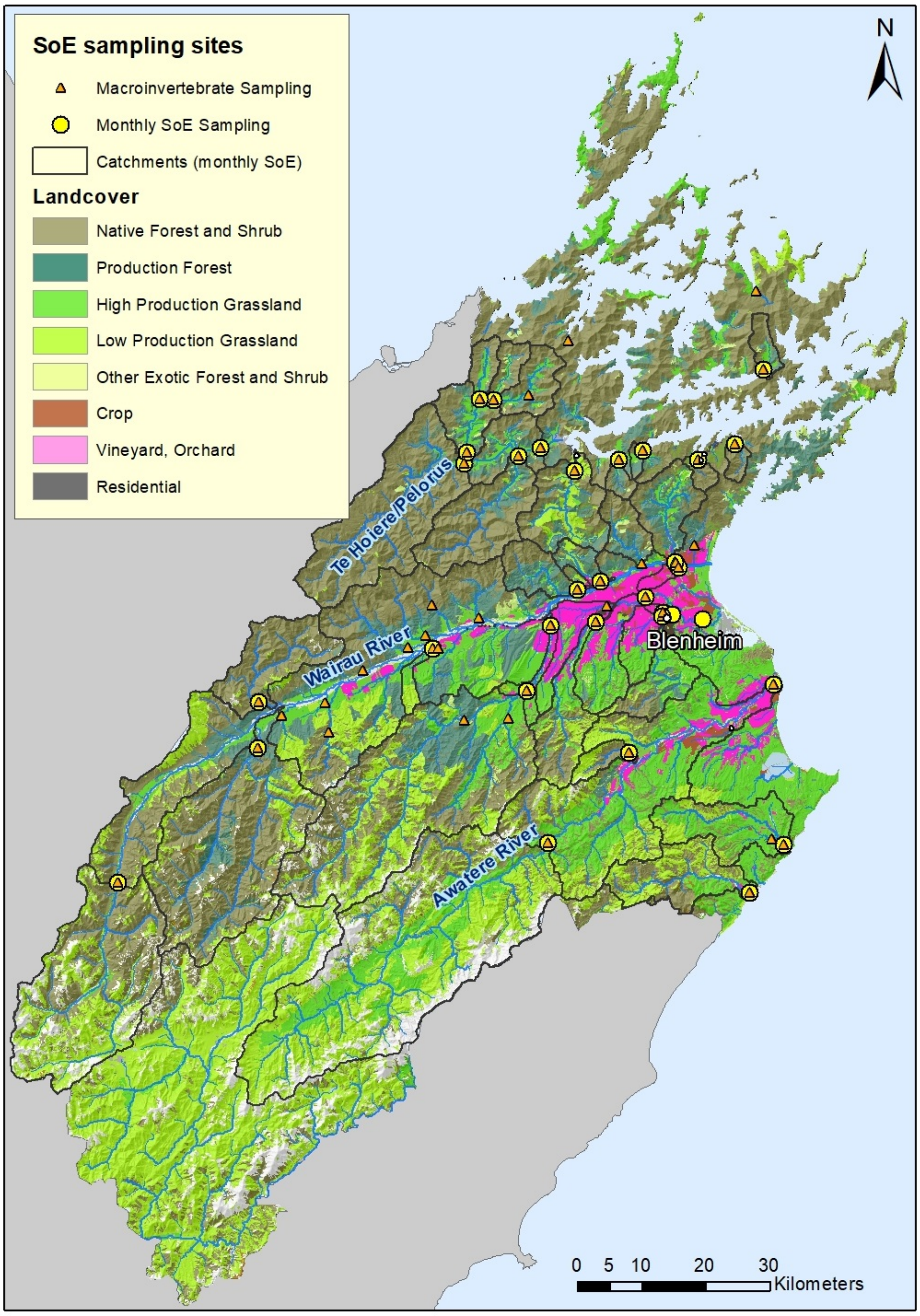

Figure 4: Location of annual Macroinvertebrate sites and monthly sampling sites for physical/chemical parameters. Also shown are the associated catchments of the monthly monitoring sites and Landuse.

2.2. Trend Analysis

There are various techniques available for assessing trends, but non-parametric tests are the most suitable for analysing water quality data because they do not assume a specific data distribution. Water quality data often exhibit varying degrees of skewness, mainly due to values below the detection limit, making it challenging to fit a distribution curve. Additionally, seasonal variations in some parameters must be considered. A commonly used test is the Seasonal Mann-Kendell test, which yields two primary outcomes: the magnitude of the trend (the Sens Slope, presented here as 'annual change') and a p-value indicating the probability of the trend occurring by chance.

In addition to the p-value, the "Level of Confidence" (C) was calculated [6, 32]. In this report, trends with C-values corresponding to "Highly likely" or "Very likely" trends are reported. To produce statistically meaningful results, a minimum of five years of monthly sampling data (60+ data points) is required [31], and the number of 'seasons' should be set to 12 (one for each month) [1].

For many parameters, increased flow can either result in dilution or increased values due to runoff from land. In some waterways, particularly larger rivers, local rainfall runoff can have a more significant impact on water quality at a monitoring site than what is accounted for by increased flow alone. To obtain meaningful trends that reflect changes resulting from management actions rather than weather events, it is essential to adjust for these weather-related variations. This has become particularly important with the National Policy Statement for Freshwater Management now requiring councils to take action upon detection of degrading trends.

Various methods can be employed to adjust data for rainfall or flow. The most commonly used methods are the Generalised Additive Model (GAM) and Locally Weighted Scatterplot Smoothing (LOESS). After visually assessing the fit of both methods to the data for selected sites and parameters (using R), it was decided to use GAM with three degrees of freedom for covariate adjustments.

Trend analysis was conducted using the NIWA ‘Timetrends’ software, with several different covariates for each site. These covariates included:

1. Flow rate at nearby sites
    a. Actual flow during sampling
    b. Daily flow rate
2. Rainfall data from nearby stations
    a. Total rainfall 12 hours, 24 hours, and 48 hours prior to sampling
    b. Daily rainfall totals

The final trend was determined by choosing the trend result for which the covariate provided the greatest explanatory power. Exceptions were made for very rare cases in which the direction or magnitude of the trend significantly differed from those for other covariates, indicating an unsuitable fit. If the covariate adjustment explained less than 10% of the data's variation, the unadjusted trend was used.

Trends were calculated over three different periods: 5 years (2018-2022), 10 years (2013-2022), and 14 years (2008-2022). Trends were not analysed for spot measurements of water temperature and dissolved oxygen because these parameters exhibit significant changes throughout the day. While measurements are generally taken at approximately the same time of the day, changes in the sampling regime over the years could lead to misleading trend results.

Trend analysis for pH values showed a similar increase for all time periods at almost all monitoring sites. This points to a significant change in pH values as a result of (unnotified) changes in the measurement method by the laboratory, rather than actual changes in water quality. This needs to be further investigated and trend results for pH are therefore not included in this report.

2.3. National Policy Statement (NPS-FM)

A new National Policy Statement for Freshwater Management (NPS-FM) came into force on 3 September 2020. It includes a number of policies and objectives for the management of rivers, lakes and wetlands. Concerning the reporting of river water quality, the most critical components of the NPS-FM are referred to as 'attributes.' These are parameters for the assessment of ecosystem health and recreational values for rivers and lakes. The NPS-FM provides limits for 22 attributes, which define bands ranging from A to D/E. The A-band signifies healthy ecosystems, while states falling into the D and E-bands are generally designated as "below the national bottom line." Unless attributed to natural sources, states below the national bottom line are deemed unacceptable.

The majority of attributes define limits based on multiple statistics, with variations from one attribute to another. The most common statistics employed are Median and 95th Percentile concentrations. Attributes also differ in terms of the number of data points and the time periods over which the attribute's state is determined. In this report, attribute data and the associated NPS-FM states are typically presented for the most recent five years to ensure consistency across various parameters.

Thirteen out of the 22 attributes serve as measures to gauge the health of rivers and streams.

Table 1 provides an overview of the current monitoring status for these attributes. Eight of the NPS-FM attributes exclusively apply to the monitoring of lakes. Information on lake health will be presented in a separate report.

Table 1: The attributes within the 2020 NPS-FM that relate to river health and their current monitoring status within the Marlborough Region.

	NPS-FM Table	Attribute	Currently monitored	Comments
Appendix 2A	2	Periphyton	Yes	At selected sites
	5	Ammonia	Yes	At all SoE sites
	6	Nitrate	Yes	At all SoE sites
	7	Dissolved Oxygen below point sources	Consents	
	8	Suspended fine sediment	Yes	At all SoE sites, as turbidity
	9	E. coli	Yes	At all SoE sites
	13	Fish	No	Planned for summer 2023/24
	14	Macroinvertebrates (MCI)	Yes	At all hard-bottomed sites
Appendix 2B	15	Macroinvertebrates (ASPM)	Yes	At all hard-bottomed sites
	16	Deposited fine sediment	Yes	At selected sites, but currently insufficient data for reporting
	17	Dissolved Oxygen (continuous)	Yes	At selected sites, but currently insufficient data for reporting
	20	Dissolved Reactive Phosphorus	Yes	At all SoE sites
	21	Ecosystem metabolism	Yes	At selected sites, but currently insufficient data for reporting
	22	E. coli swimming sites	Yes	Results reported in separate report

3. Parameter Results and Discussion

The subsequent sections present the results for individual parameters monitored as part of the State of the Environment (SoE) program. Simplified Box and Whisker plots are used to effectively convey the distribution of data for multiple sites within a single graph. *Figure 5* illustrates the creation of Box and Whisker Plots and offers examples showcasing common data distributions.

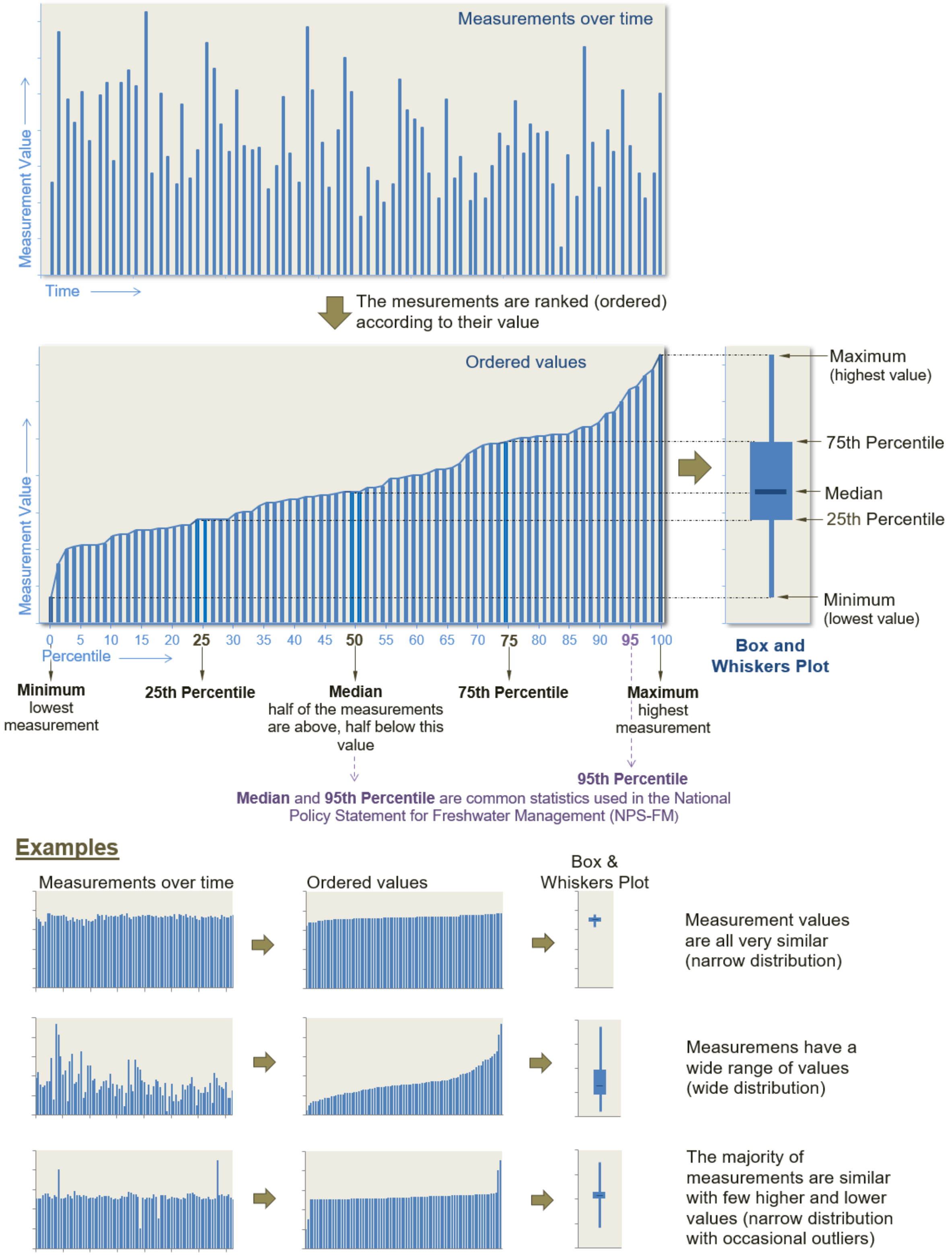

Figure 5: Creation of Box and Whiskers Plots and examples of different data distributions.

The graphs provide a comprehensive summary of data collected during the most recent five-year period (2018-2022). Where national data was available the graphs include a distribution summary for regional and national data.

The sections also present and discuss NPS-FM states for parameters featuring attribute limits. For most parameters, the results of trend analyses are discussed, except for those parameters displaying distinct daily patterns, such as Water Temperature and Dissolved Oxygen. The measurements for these parameters rely on the specific time of day when sampling occurred.

To provide national context, data from the most recent LAWA website update was incorporated. Please note that since this report was composed before the official website update, data from the review process had to be used. Consequently, there may be minor variations between the official LAWA data summary and the information presented here.

3.1. Nitrogen

3.1.1. Dissolved Inorganic Nitrogen (DIN)

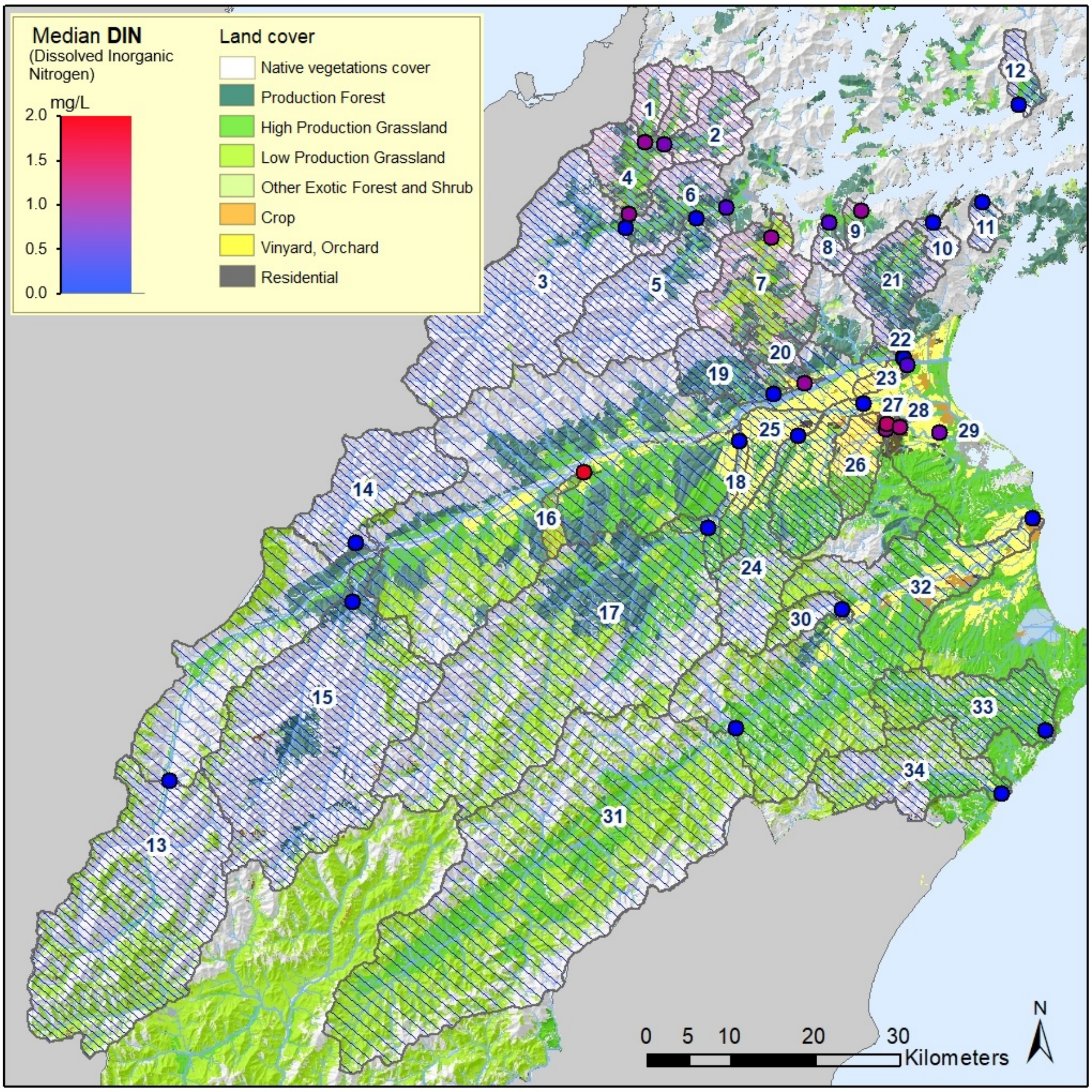

Figure 6: Median DIN concentrations in monitored catchments.

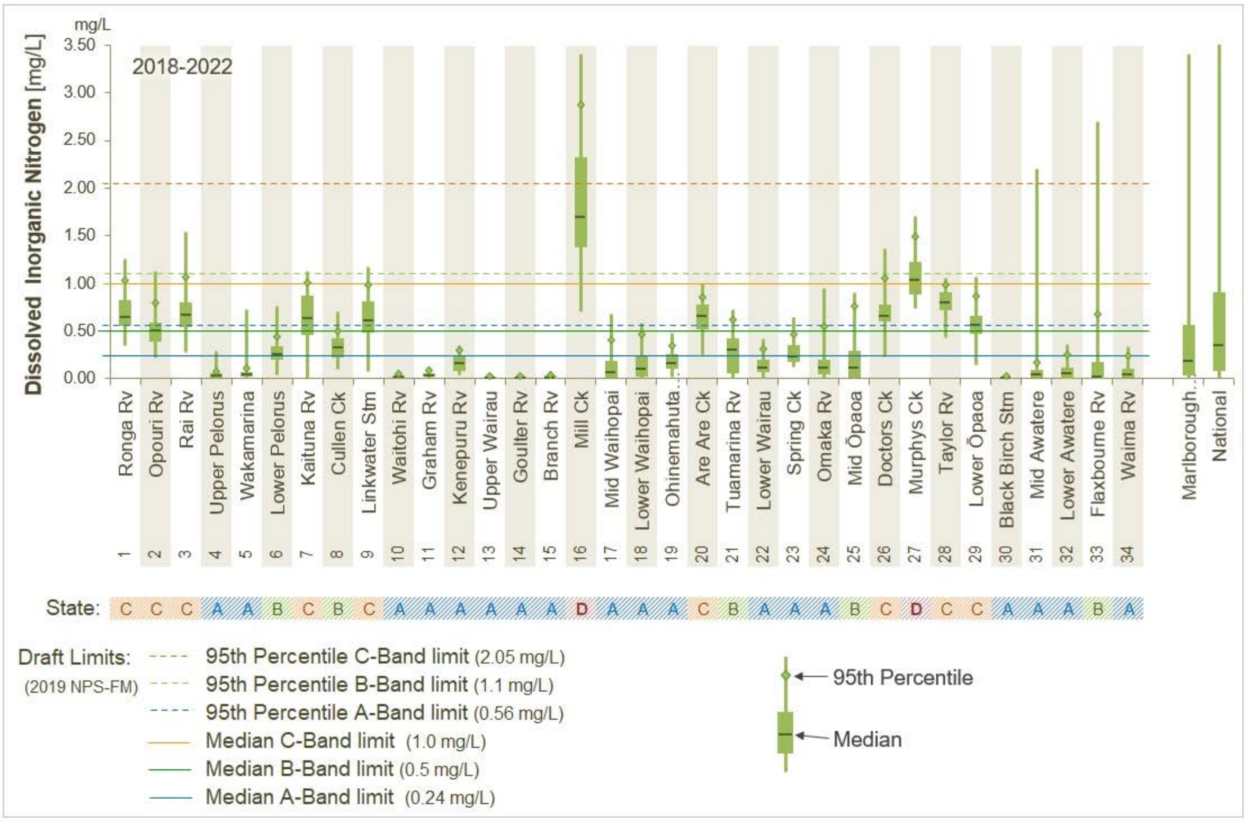

Figure 7: Dissolved Inorganic Nitrogen (DIN) concentrations in the monitored waterways. The site numbers correspond to the associated catchments in Figure 6. Also shown are draft limits from the 2019 NPS-FM draft and states based on these limits.

Dissolved Inorganic Nitrogen (DIN) constitutes the soluble nitrogen content within the water column, readily available for uptake by algae thriving on the river and stream beds.

Elevated DIN concentrations can trigger excessive algae growth, posing detrimental impacts on both aquatic ecosystems and the visual appeal of water bodies. The extent of algae proliferation on riverbeds undergoes direct monitoring at selected locations within the region, with the results discussed later in this report (see Section 3.7.2). Direct assessment of algae mass demands substantial staff resources, limiting its application to a small number of monitoring sites. In contrast, monitoring dissolved nutrient concentrations, such as DIN, is a cost-effective approach that enables us to gauge the potential for algae growth throughout the region.

The Map in *Figure 6* and associated *Figure 7* show the DIN concentrations measured at the 34 State of the Environment monitoring sites.

Naturally, DIN concentrations are very low. This can be seen for rivers with a high percentage of native vegetation cover within their catchment such as the Goulter River, Branch River and Black Birch Stream.

Mill Creek, a groundwater-fed spring located west of the Wairau Valley township, stands out with the highest DIN concentration. Higher DIN concentrations are also found in an area of springs within the Blenheim area, and include Murphys Creek, Doctors Creek and the Taylor River. Other waterways with elevated DIN concentrations are found in catchments with significant areas of pasture and higher rainfall, such as the Rai, Ronga and Kaituna River as well as Cullen Creek and Linkwater Stream.

Nitrogen is comparatively mobile within the environment, meaning that that it does not bind well to soil or other particles. Consequently, it can be easily transported by water through the soil and within the groundwater zone (aquifer). The primary route for nitrogen entering waterways is through leaching from applied fertilizers or animal excreta, including droppings and urine. Rainfall and irrigation events can carry nitrogen beyond the reach of plant root zones, rendering it unavailable for uptake by pasture grasses or other vegetation. Subsequently, this nitrogen is transported into subsurface flows and groundwater, eventually resurfacing in streams and rivers. This phenomenon explains why DIN concentrations tend to be comparatively high in water bodies where groundwater constitutes a significant portion of the flow, as is the case with springs.

Figure 8 shows DIN concentrations at the monitored sites in relation to the percentage of pasture within the catchment. The sites are categorised based on their location within areas in relation to differing rainfall amounts, with higher rainfall in the northern part of the region and comparatively lower rainfall in the southern areas of Marlborough. High rainfall sites exhibit a clear correlation, with DIN concentrations increasing as pasture cover increases. However, this relationship is not present in drier parts of the region. In these catchments, most of the pasture is not subjected to irrigation, and coupled with limited rainfall, instances of nitrogen leaching beyond the root zone are relatively infrequent. Nevertheless, extensive grazing practices in these regions often lead to waterways lacking protective fencing, making them susceptible to direct nutrient inputs from animal excreta, resulting in occasional spikes in DIN levels, as seen in the Flaxbourne River and the Mid Awatere (see *Figure 7*).

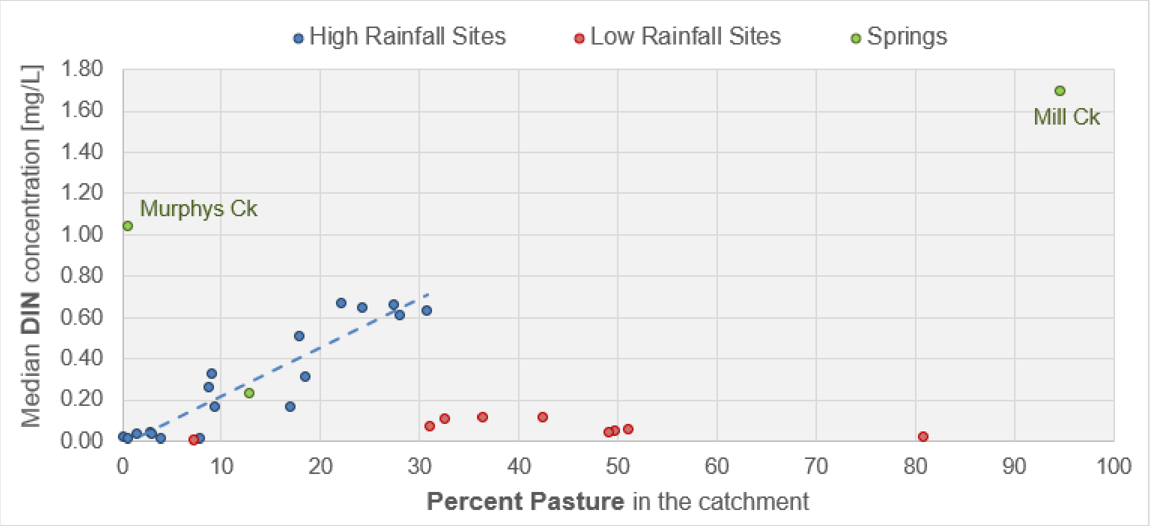

Figure 8: Relationship between DIN concentrations and percentage pasture in the catchment.

Murphys Creek is a comparatively short waterway located in Blenheim. It is an urban spring with no pasture in its surface catchment, but very high DIN concentrations. Almost all of its flow is comprised of Wairau Aquifer water, which carries nitrogen leached from areas within the large Wairau catchment into Murphys Creek.

In the 2019 NPS-FM Draft, attribute limits for DIN were proposed, though they were ultimately not included in the final release. Nevertheless, these limits are still valuable for contextualising DIN concentrations. The majority of sites are within the A and B Draft NPS-FM bands, while the higher concentrations in two of the spring-fed streams put them into the D band (*Figure 7*).

When comparing DIN states in Marlborough to the rest of New Zealand, a noteworthy observation is that a larger percentage of sites in Marlborough are in a better state.

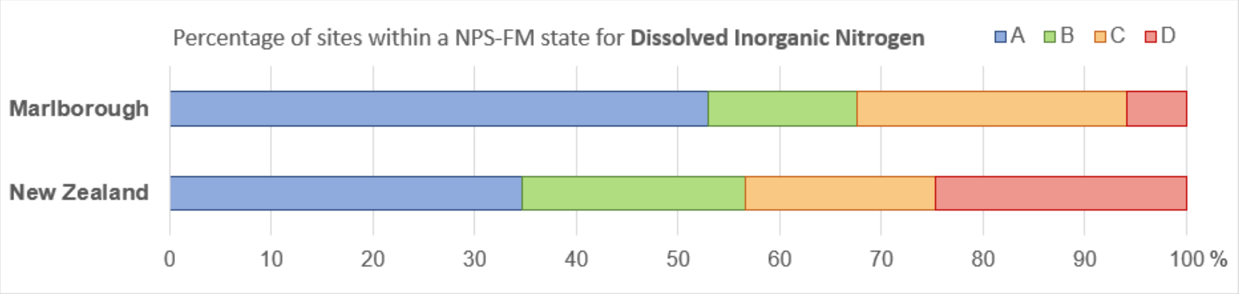

Figure 9: *Percentage of sites within the DIN Draft NPS-FM states in Marlborough and nationally (Marlborough excluded).*

Figure 10 illustrates changes in DIN concentrations over the past 14, 10, and 5 years. Monitoring sites along the Ronga, Opouri, and Rai Rivers exhibit noticeable decreases in DIN concentrations over the last five years. However, in the case of the Opouri and Rai, the 14-year trends reveal a slight increase, indicating that despite recent improvements, DIN concentrations remain slightly higher compared to levels measured 14 years ago. Conversely, DIN concentrations in the Kaituna River have shown consistent decreases, particularly over the past 5-10 years.

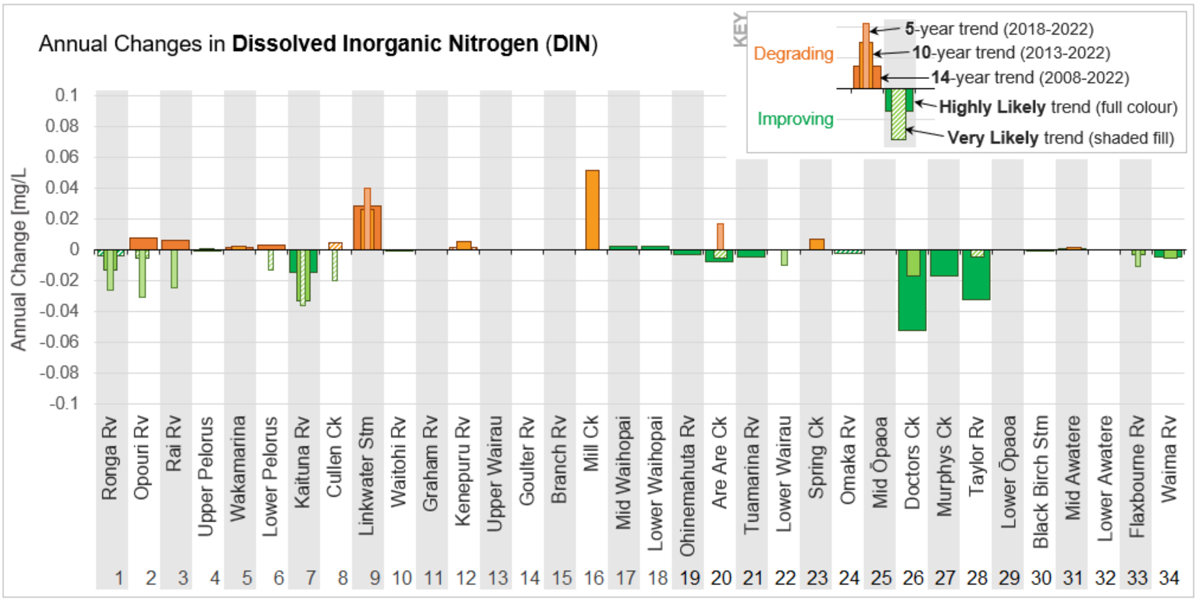

Figure 10: *Annual changes in DIN concentrations over the past 5, 10 and 14 years.*

In contrast, DIN concentrations in Linkwater Stream are on the rise, showing increases for all three time periods assessed.

A significant trend emerges in Mill Creek, where DIN concentrations have notably increased over the past 10 years. Potential factors contributing to this increase may include nitrogen leaching during the initial establishment of vineyards in upstream areas near the monitoring site.

DIN concentrations in the Blenheim springs have been decreasing over the past 14 years, with most of this change occurring more than 10 years ago. These springs are supplied by water from the Wairau Aquifer, and changes within the broader Wairau catchment are the primary drivers. These changes are likely closely linked to the extensive conversion of pasture into vineyards. Established vineyards tend to leach significantly less nitrogen compared to pasture.

In most rivers, DIN concentrations exhibit a seasonal pattern, with higher concentrations during colder months. This pattern is evident in *Figure 11*, depicting DIN concentrations in the lower Wairau River over the past five years. The higher DIN concentrations in the winter months are attributed to reduced plant growth and subsequent lower nitrogen uptake by land and aquatic plants. Additionally, the generally wetter winter conditions increase the likelihood of nitrogen leaching from the land surface into subsurface flows.

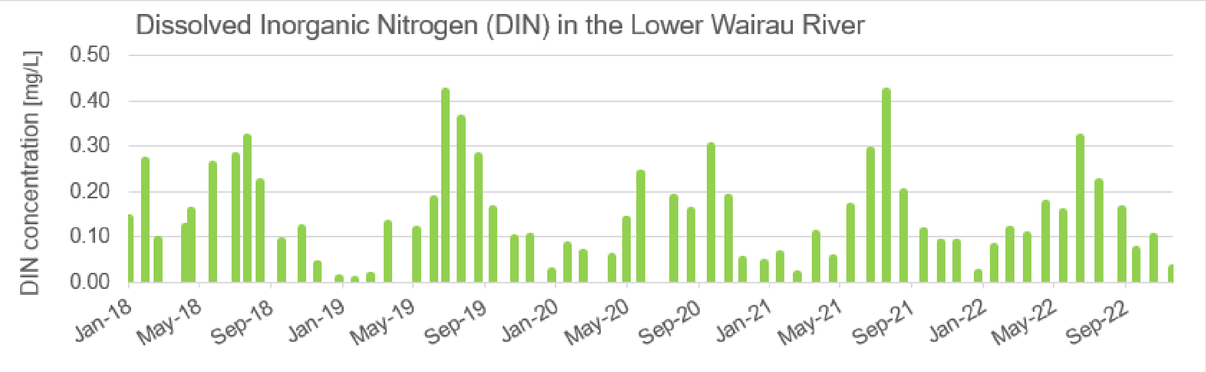

Figure 11: Individual measurements of DIN in the Lower Wairau River showing a distinct seasonality.

3.1.2. Ammonia and Nitrate Nitrogen

Dissolved Inorganic Nitrogen comprises Nitrate, Nitrite, and Ammoniacal nitrogen. During the decomposition of organic matter, such as deceased plant and animal material, nitrogen is released in the form of Ammoniacal Nitrogen. In the presence of oxygen, Ammoniacal Nitrogen rapidly is rapidly converted into Nitrate Nitrogen through the transient Nitrite Nitrogen.

Nitrate Nitrogen and Ammoniacal Nitrogen, when present in concentrations higher than those supporting algae growth, can pose direct toxicity risks to aquatic organisms. Consequently, the NPS-FM establishes limits for these two nitrogen forms to assess the health of waterways.

At all of Marlborough's SoE monitoring sites, almost all DIN exists in the form of Nitrate Nitrogen, with Ammoniacal Nitrogen levels mostly falling below detection limits. Notable Ammoniacal Nitrogen concentrations are primarily observed within the lower Taylor River, flowing through Blenheim, the largest urban area in Marlborough. However, these concentrations remain well within the NPS-FM limits, meaning that all SoE monitoring sites are within the A-Band for Ammoniacal (Ammonia) Nitrogen.

Figure 12 shows that Nitrate Nitrogen concentrations for the SoE monitoring sites closely resembling the graph in *Figure 7* for DIN concentrations. Elevated nitrogen concentrations in the two spring-fed streams, Mill Creek and Murphys Creek, place them in the B-Band of the NPS-FM. Conversely, all other sites remain within the A-Band for the Nitrate attribute. Unlike many other river health attributes, the NPS-FM necessitates the calculation of Nitrate (and Ammonia) using data from a one-year period rather than five years of monitoring. However, Nitrate (and Ammonia) states for monitoring sites within the Marlborough region remain consistent for both timeframes.

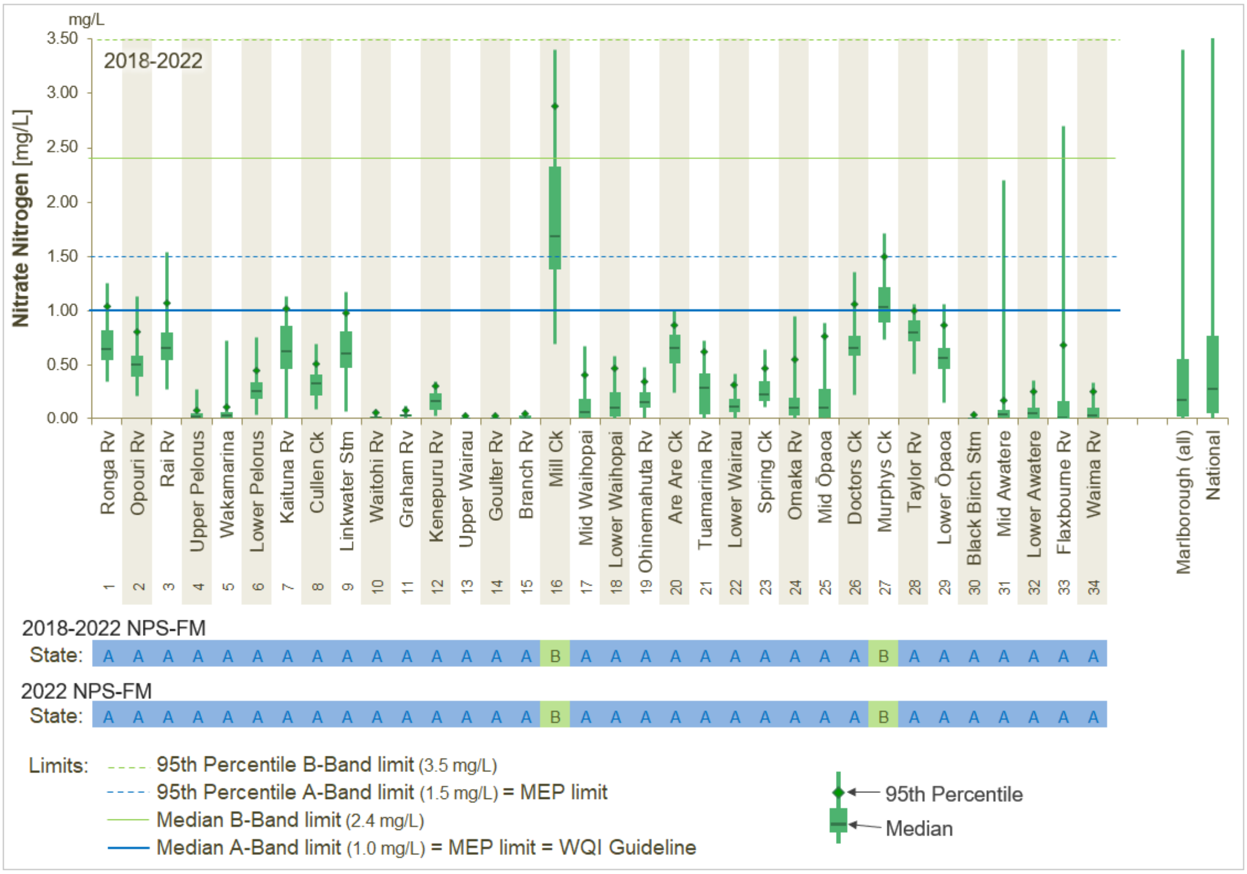

Figure 12: Nitrate-Nitrogen concentrations at the SoE monitoring sites. Also shown are the NPS-FM states based on the last 5 years as well as for 2022 alone.

When comparing Marlborough rivers to those in the rest of New Zealand, it is apparent that a larger proportion of sites in this region fall within the A-Band (*Figure 13*).

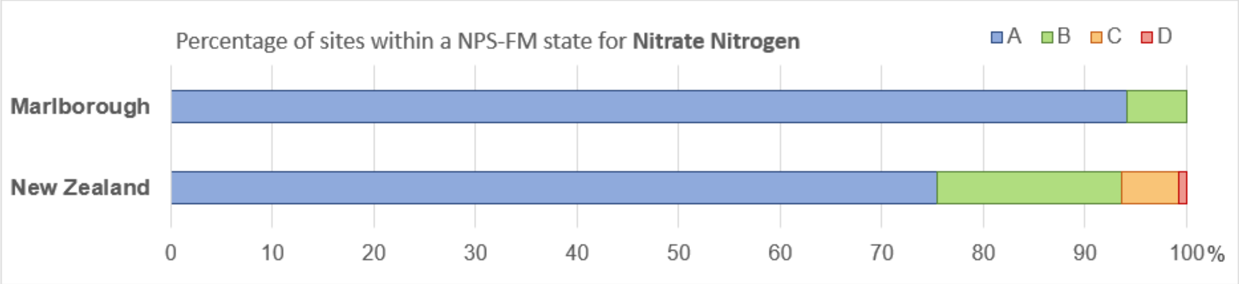

Figure 13: Percentage of sites within the Nitrate NPS-FM states in Marlborough and nationally (Marlborough excluded).

Not surprisingly, the results of the trend analysis reveal that changes over time in Nitrate concentrations closely parallel those in DIN concentrations. One notable exception is a decrease in Nitrate concentration over the last 14 years in the lower Ōpaoa.

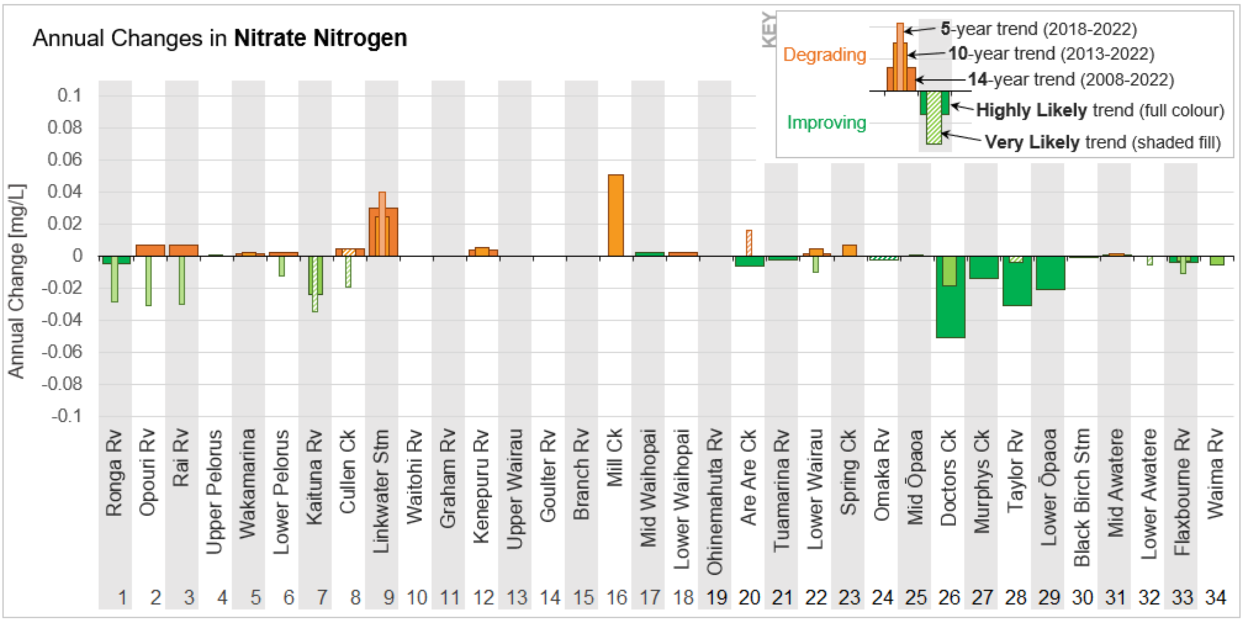

Figure 14: Annual changes in DIN concentrations over the past 5, 10 and 14 years.

3.1.3. Total Nitrogen

Total Nitrogen was introduced into the analysis of SoE samples in 2017, providing us with over five years of data for this parameter. Nitrogen in aquatic environments exists in dissolved forms, as discussed in previous sections, but it can also be bound within particulates. Particulate forms of nitrogen are typically found within algae, microscopic organisms, or bound to other organic materials, such as animal excreta or components of leaf litter.

Monitoring of total nitrogen is crucial for assessing nitrogen loads entering receiving environments, including estuaries.

In *Figure 15*, the upper graph presents the Total Nitrogen concentrations at the SoE sites, while the lower graph illustrates the median proportion of dissolved and particulate nitrogen contributing to the total nitrogen concentration.

The pattern of Total Nitrogen concentrations across the SoE monitoring sites closely resembles that of Dissolved Nitrogen (DIN). However, the distinction between spring-fed streams and pasture-dominated waterways is not as pronounced. This is primarily due to the relatively low proportion of particulate nitrogen in spring-fed streams. Soils and subsoil substrates effectively filter out particles from the water, resulting in groundwater containing virtually no particulates. Additionally, in rivers and streams with comparatively low nitrogen concentrations, particulate nitrogen constitutes a significantly larger portion of the total nitrogen. This implies that the primary source of total nitrogen in these cases is direct inputs into waterways, such as leaf litter or the decomposition of plant and animal matter. Conversely, in streams and rivers with generally higher nitrogen concentrations, the main nitrogen source is leaching, as indicated by the greater proportion of dissolved nitrogen.

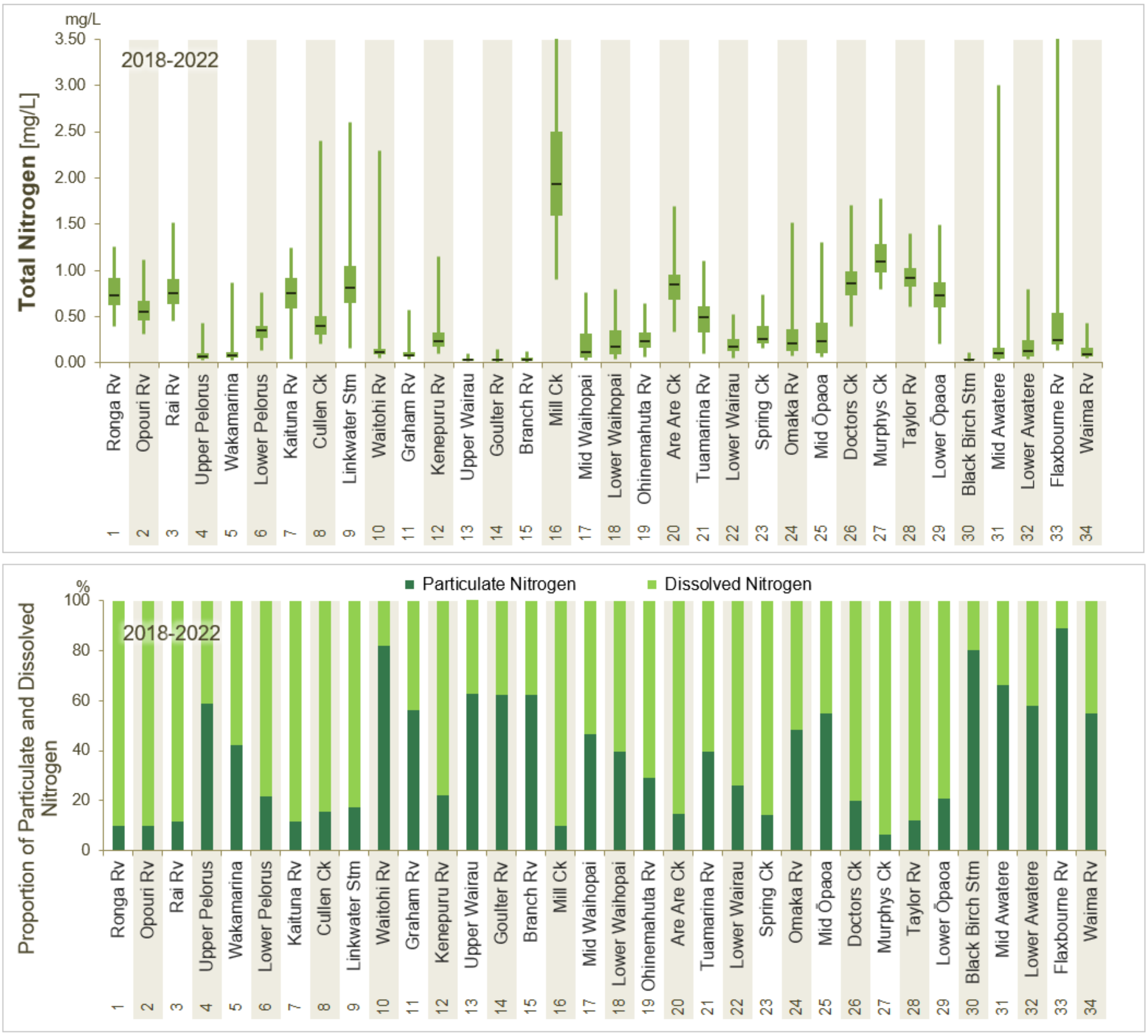

Figure 15: Total Nitrogen concentrations at the SoE monitoring sites (top graph) and proportions of dissolved and particulate nitrogen that make up total nitrogen (bottom graph).

As total nitrogen was added to the analysis relatively recently, trend analysis for this parameter can only be carried out to assess changes over the past five years. The analysis has revealed relatively few changes, showing significant trends for six sites only. These are the Opouri, Rai and Lower Te Hoiere/Pelorus Rivers as well as Linkwater Stream and the Flaxbourne River. Trends at these sites align with those observed for DIN, such as increases in Linkwater Stream and decreases in the Opouri and Rai Rivers. In the case of Are Are Creek, the increase in total nitrogen is notably higher than that for dissolved nitrogen, suggesting additional direct inputs of nitrogen into the stream.

3.2. Phosphorus

3.2.1. Dissolved Reactive Phosphorus

Similar to nitrogen, phosphorus is a vital nutrient for plants, and elevated concentrations in water bodies can trigger excessive growth of algae or aquatic weeds on streambeds. Dissolved Reactive Phosphorus (DRP) represents the form of phosphorus most readily absorbed by aquatic plants.

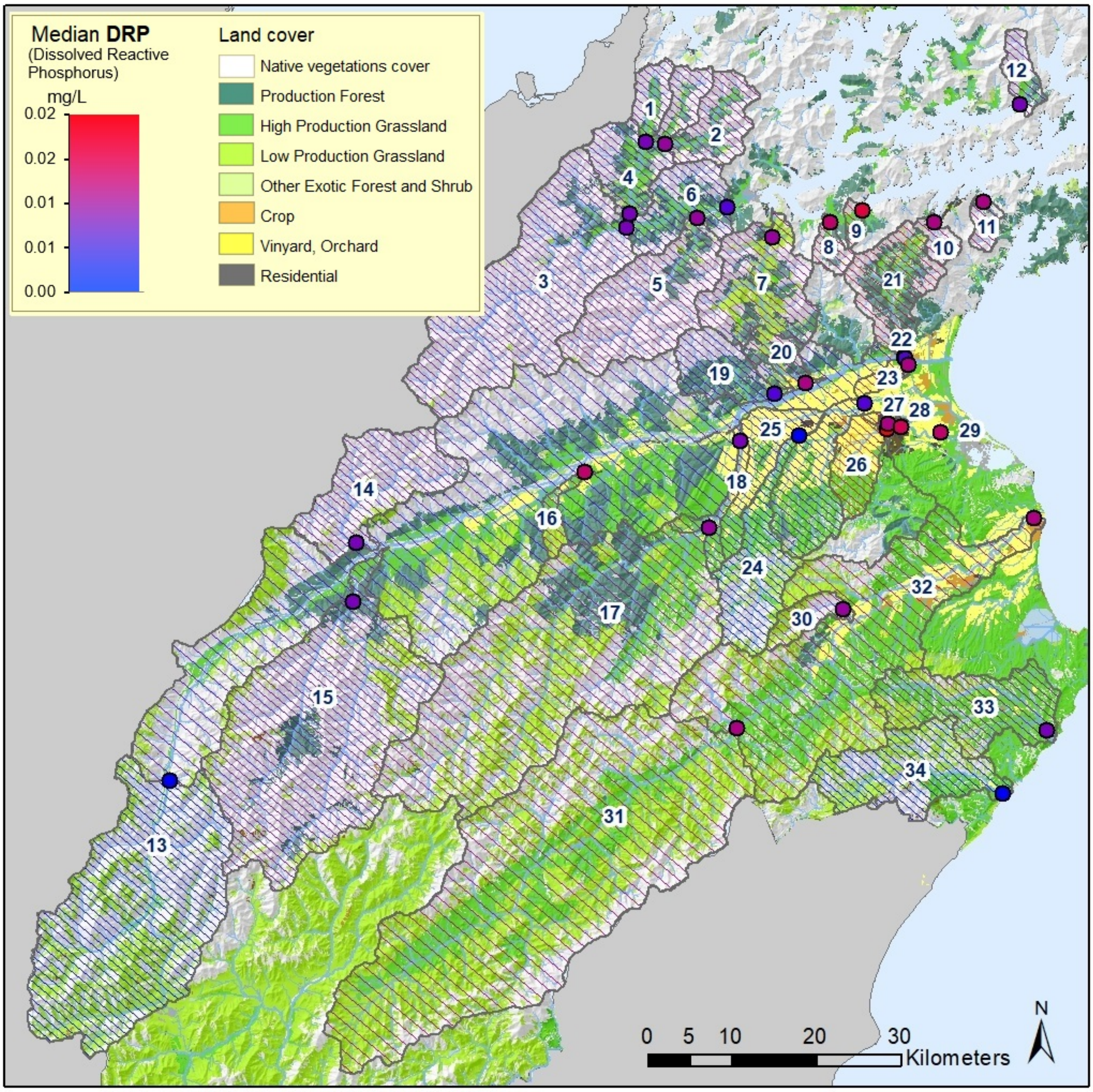

Figure 16: Median Dissolved Reactive Phosphorus (DRP) concentrations at the SoE sites and associated catchment. Wider shading of the catchments indicates that sites represent comparatively large catchments. The catchment numbers correspond to those associated with the names of the waterways in Figure 17.

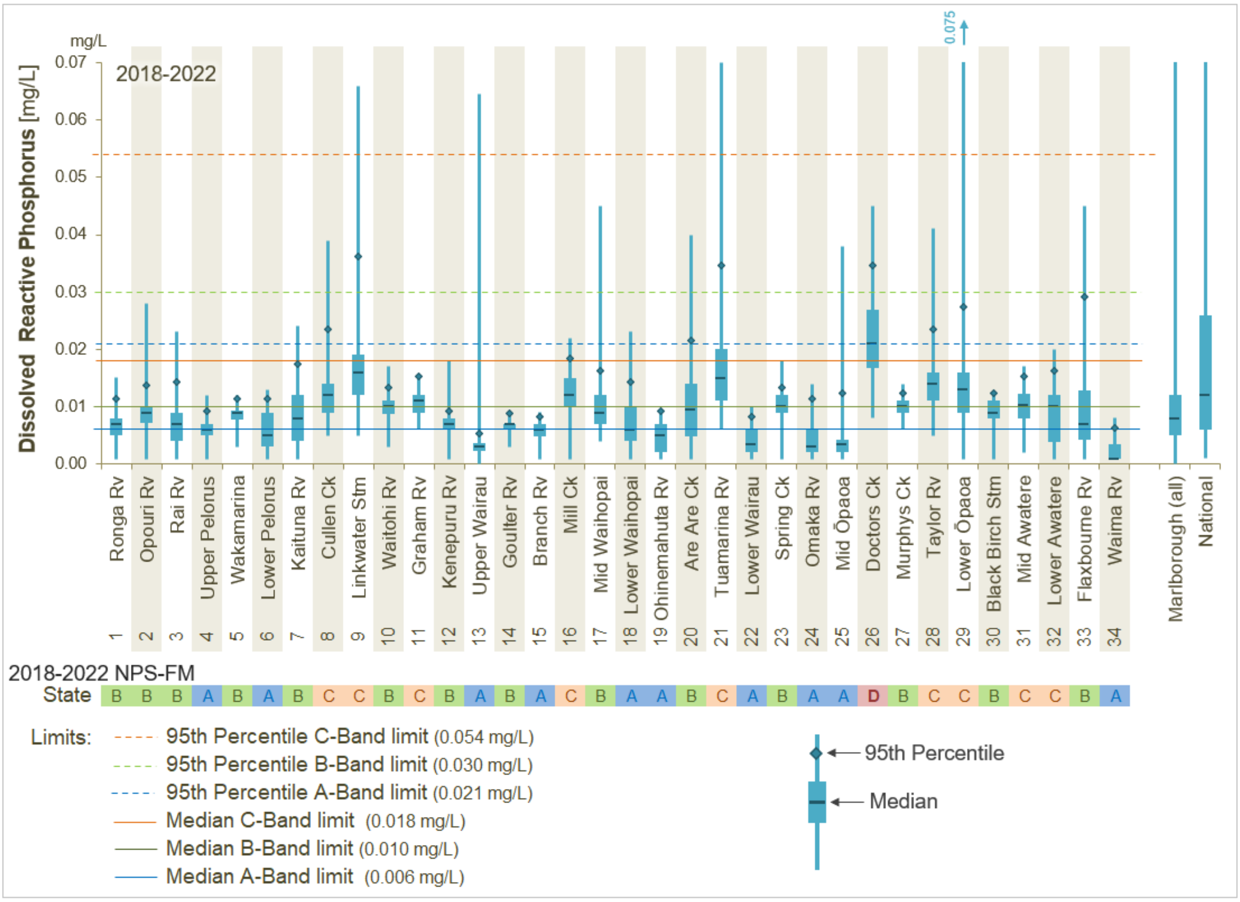

Figure 17: Dissolved Reactive Phosphorus (DRP) concentrations in the monitored waterways. Also shown are the NPS-FM limits and states based on these limits.

Figure 17 presents the DRP concentration data over the past five years for individual SoE monitoring sites, along with their corresponding NPS-FM states based on that data. DRP concentrations can naturally be elevated due to phosphorus-rich geological features within the catchment. For instance, the Goulter River falls into the B-band of the NPS-FM despite having a catchment primarily covered by native vegetation (98%). Another noteworthy observation is the relatively narrow range of DRP concentrations in the Goulter River, shared by other waterways with substantial native vegetation in their catchments, such as the Branch River and the Upper Wairau River. The only exception is a single high-value sample taken during a flood event in the Upper Wairau River.

Similarly, Murphys Creek exhibits a relatively limited range of DRP concentrations. However, in this case, the slightly elevated phosphorus levels result from leaching inputs originating from the broader Wairau catchment, which then resurface in the Blenheim Springs.

Although Doctors Creek also receives a large proportion of its flow from groundwater, DRP concentrations are significantly more variable indicating substantial phosphorus inputs from the surface catchment. Unlike nitrogen, phosphorus effectively binds to soil and sediment, making it generally associated with sediment inputs. This was confirmed in a 2015 Catchment study focused on Doctors Creek [16]. Subsequently, extensive plantings along the creek's banks have been initiated as part of the Taylor River Improvement Project to reduce sediment inputs from erosion. However, it will take some time before the full benefits of these plantings manifest in improved phosphorus and sediment concentrations.

Mill Creek is another example of a predominantly groundwater-fed stream which receives phosphorus leached from upstream areas outside of its surface catchment and additional surface input from within the catchment.

Another waterway with notably high DRP concentrations is the Tuamarina River. A comprehensive water quality study conducted in the catchment of this waterway has revealed that the Para Swamp is releasing phosphorus into the Tuamarina River [18]. The Para Swamp is the largest remaining natural wetland on the Wairau Plain. This wetland contains remnants of invasive willows as a result of large-scale spraying operations aimed at wetland restoration. These remnants could potentially serve as an additional source of phosphorus. However, a potentially more significant contributor is the years of pastoral farming upstream of the wetland, saturating wetland soils with phosphorus. While improved farming practices have led to reduced phosphorus concentrations as the river enters the wetland, the legacy of higher phosphorus concentrations within the wetland now results in increased DRP concentrations as the river flows through. Estimating the time it will take for wetland saturation to reverse is a complex task due to numerous influencing factors and insufficient available information.

Although DRP concentrations tend to be elevated in catchments with a substantial proportion of pastoral land cover, Linkwater Stream and Cullen Creek exhibit somewhat higher concentrations. A contributing factor to this are the naturally higher background levels of DRP. Catchment studies conducted in the Waitohi River [19] and Linkwater area [20] have revealed some of the highest DRP concentrations originating from native bush catchments within the region. This finding points to phosphorus-rich geological features in these parts of the Marlborough Sounds, which also explain the comparatively elevated DRP levels in the Graham River.

Comparing DRP concentrations with those for the rest of New Zealand (displayed on the right side of *Figure 17* and in *Figure 18*) highlights that concentrations observed within Marlborough's waterways generally fall within the lower end of the spectrum.

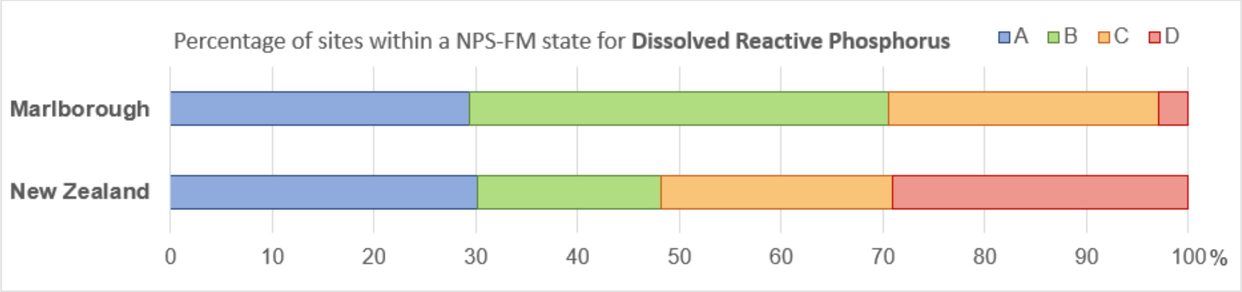

Figure 18: Percentage of sites within the DRP NPS-FM states in Marlborough and nationally (Marlborough excluded).

Due to a significant change in the data stemming from a shift in laboratory providers, trend analysis for DRP concentrations was only feasible for the past ten and five years.

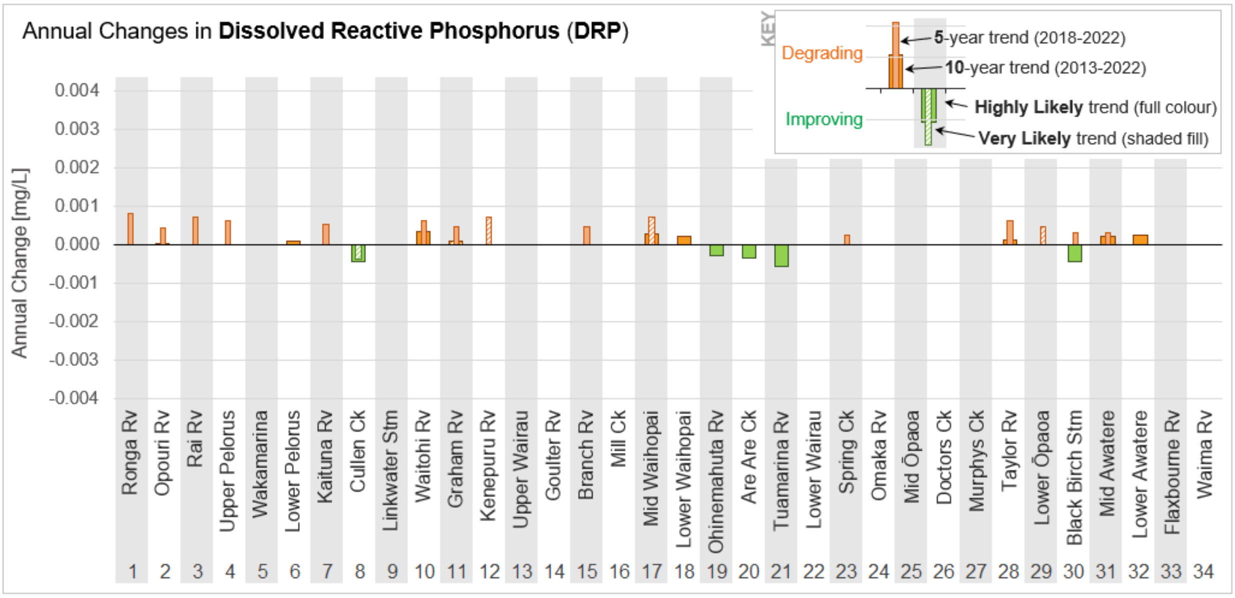

Figure 19: Annual changes in DRP concentrations over the last 5 and 10 years.

The trend analysis indicates increases in several rivers and streams, especially over the past five years. Waterways with increasing DRP concentrations include those in the Rai catchment, the Kenepuru River, the mid Waihopai, and the Taylor River (*Figure 19*). Conversely, decreasing trends were predominantly observed over the past ten years in the Tuamarina River, Cullen Creek, Are Are Creek, and Black Birch Stream.

3.2.2. Total Phosphorus

The analysis of samples for Total Phosphorus was introduced concurrently with the analysis for Total Nitrogen. Both parameters provide valuable insights into assessing the potential effects of nutrient loads on depositional environments, including the lower reaches of large rivers as well as estuaries, and coastal wetlands.

In contrast to nitrogen, there are notable distinctions in the concentration profiles between Dissolved Reactive Phosphorus (DRP) and Total Phosphorus. The maximum concentrations of total phosphorus are significantly higher than mean concentrations when compared to the range of DRP concentrations. These elevated concentrations are typically associated with higher flows and the concurrent input of sediment. This highlights the greater significance of direct inputs into streams as sources of phosphorus compared to the more pronounced influence of leaching for nitrogen. Therefore, it is not surprising that the river with the generally most turbid water, the Awatere River (as will be discussed in Section 3.3), also exhibits the highest Total Phosphorus concentrations.

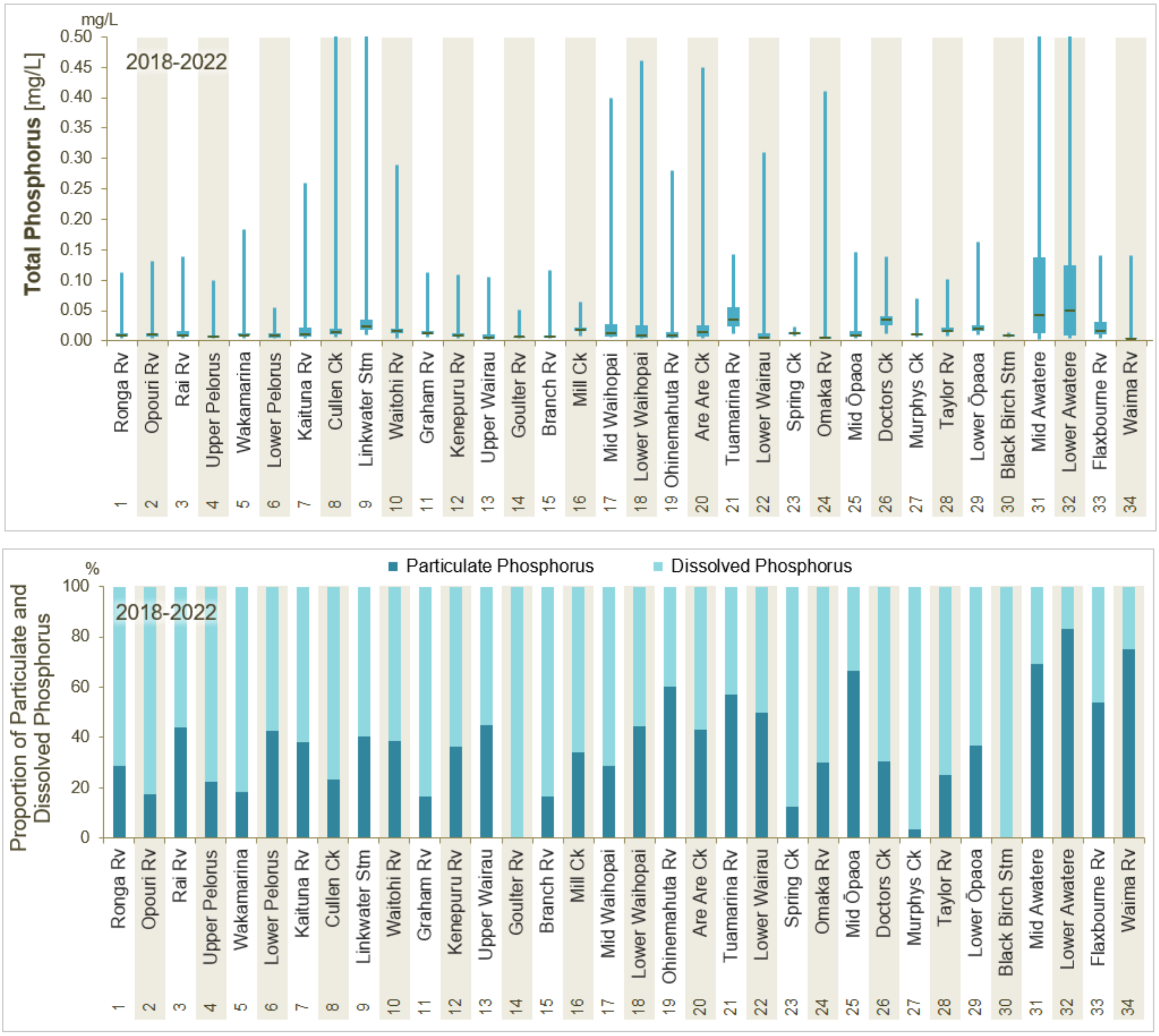

Figure 20: Total Phosphorus concentrations at the SoE monitoring sites (top), and proportions of dissolved and particulate phosphorus (bottom graph).

The Awatere River, along with the other two waterways in the driest part of the region, the Flaxbourne and Waima Rivers, all demonstrate a high proportion of particulate phosphorus in the composition of their total phosphorus concentration. This underscores the relatively minor role of leaching as a phosphorus source for these waterways.

Conversely, spring-fed streams, particularly Murphys Creek and Spring Creek, as well as waterways with predominantly native vegetation cover, exhibit comparatively low total phosphorus concentrations, primarily composed of the dissolved form of phosphorus.

As with total nitrogen, trend analysis could only be conducted over the recent five years.

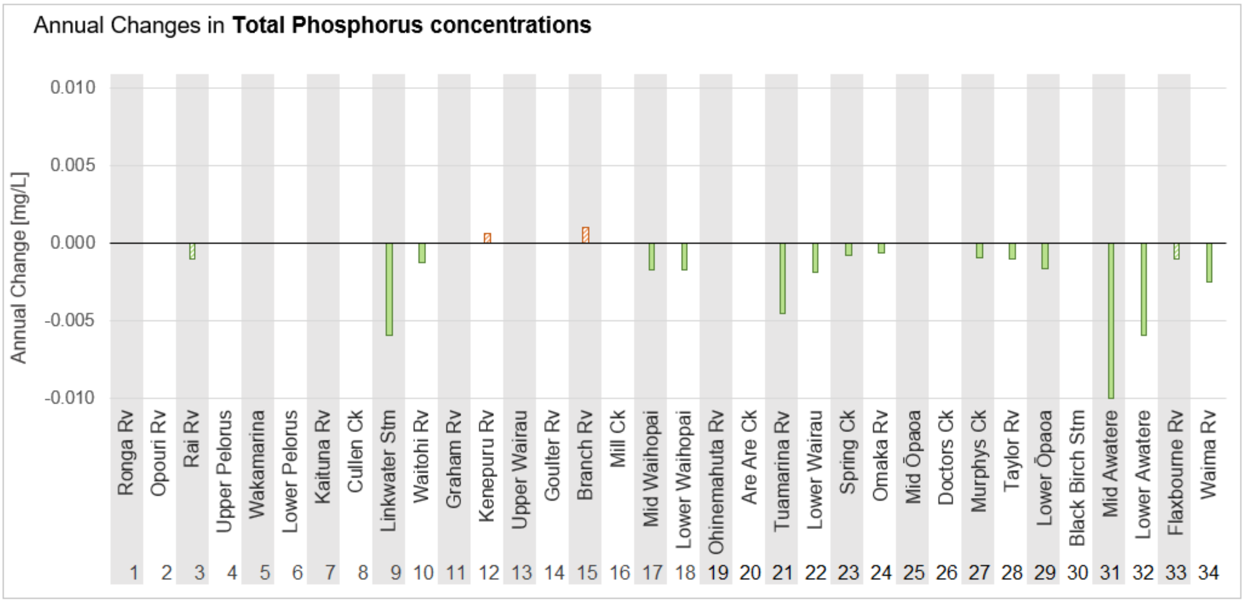

Figure 21: Annual changes in Total Phosphorus concentrations over the last 5 years.

The results of the trend analysis for total phosphorus concentrations differ significantly from the trends observed for DRP. Total Phosphorus trends mainly indicate reductions in concentrations, often of considerable magnitude, particularly for Linkwater Stream, Tuamarina River, and the Awatere River. This suggests substantial reductions in direct inputs of phosphorus into these waterways, potentially stemming from erosion control measures and improved land management practices.

3.3. Turbidity

Turbidity serves as a surrogate measure for the amount of sediment suspended within the water column. Sediment can have detrimental effects on sensitive downstream environments, such as estuaries, leading to the smothering of benthic habitats like seagrass and shellfish beds. Additionally, sediment contributes to low oxygen levels within estuary beds and alters nutrient dynamics due to nutrient binding within the sediment. Similar adverse effects can also occur in the depositional zones of rivers, such as the lower Wairau River.

Figure 23 and the associated Map in *Figure 22* display the turbidity levels at the Sites of Environmental (SoE) monitoring sites. Note that the graph in *Figure 23* represents turbidity values on a logarithmic scale, which is better suited for displaying data for which peaks are significantly larger than median levels. The median turbidity at most sites falls within the range of 0.5 to 1.5 Nephelometric Turbidity Units (NTU), while maxima reach values from 35 up to 800 NTU.

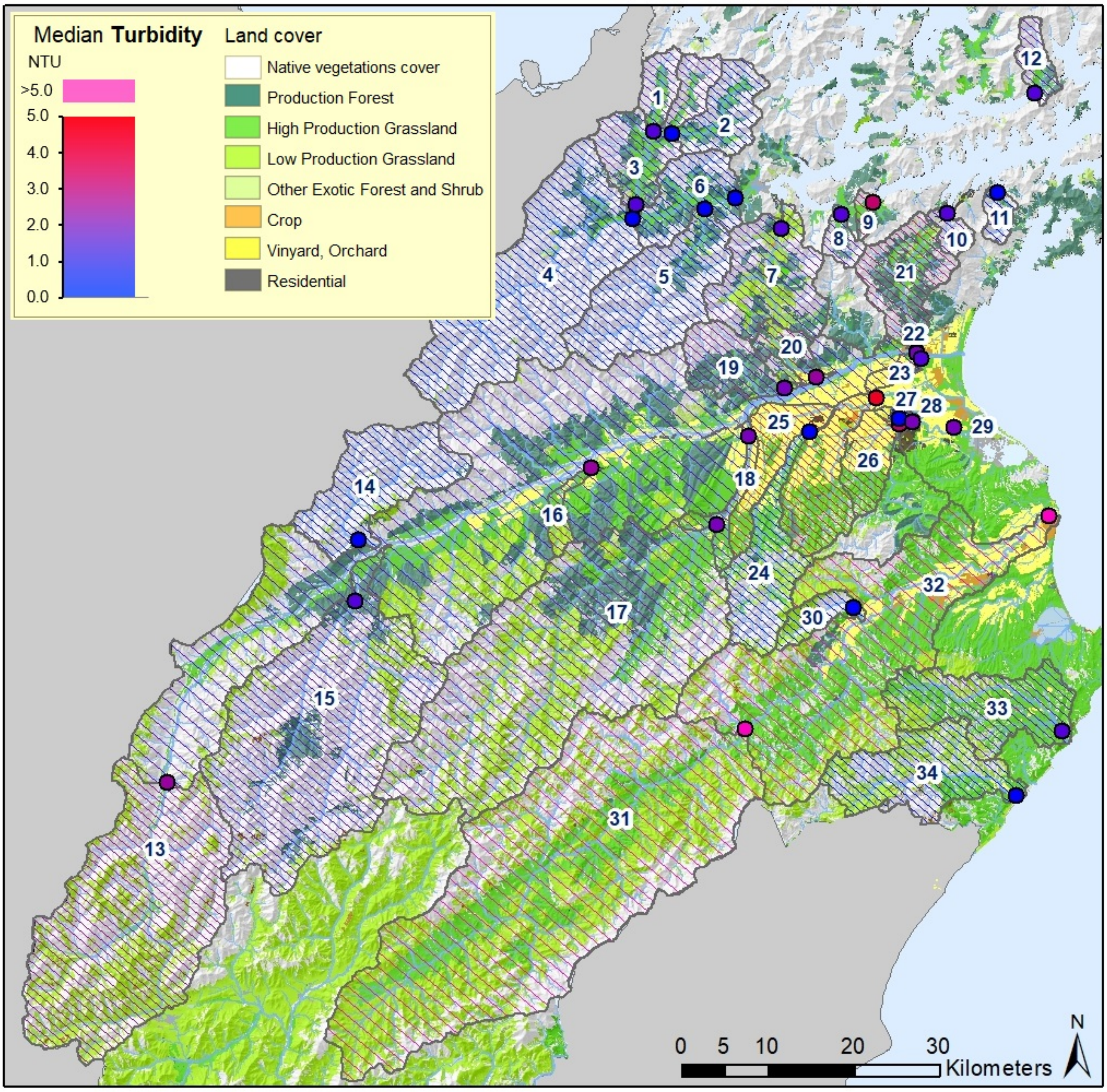

Figure 22: Median Turbidity values at the SoE sites and associated catchment. Wider shading of the catchments indicates that sites represent comparatively large catchments. The numbers correspond to those shown alongside the site names in Figure 23.

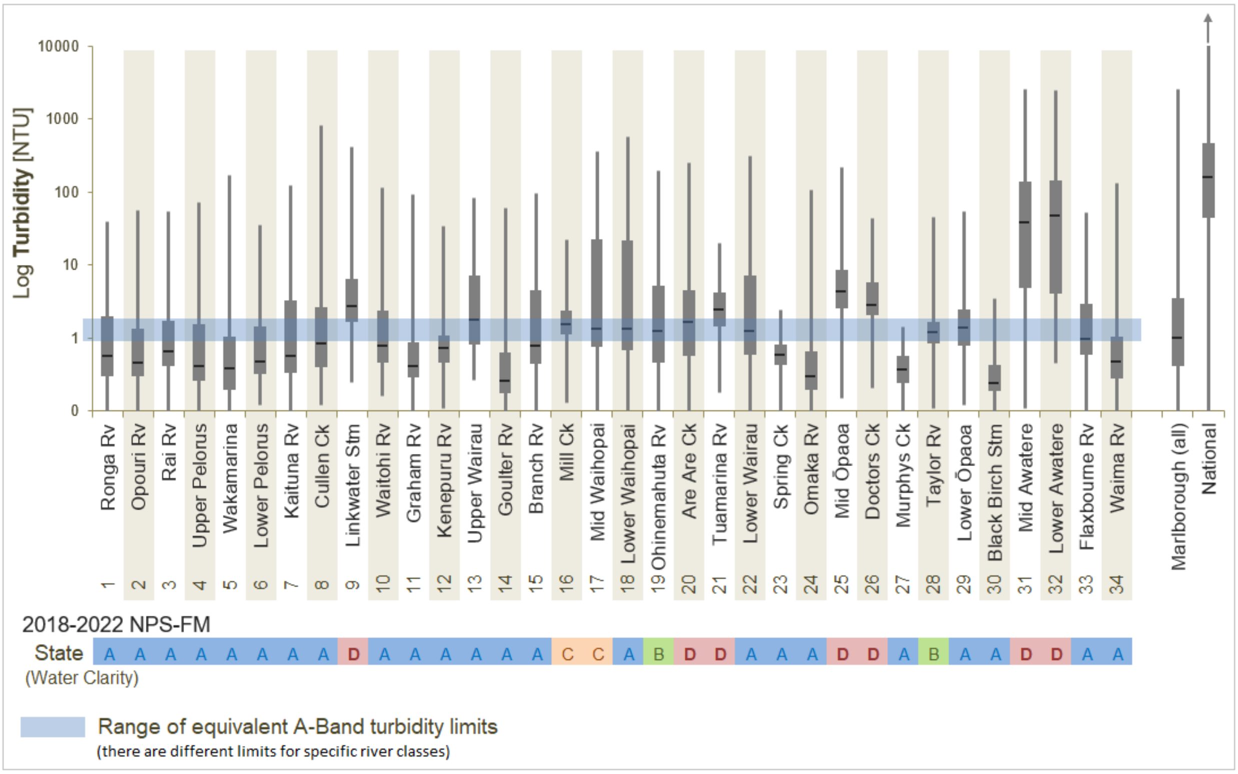

Figure 23: Turbidity values in the monitored waterways. Also shown is the range for the equivalent Water Clarity A-Band limit and NPS-FM states based on these limits.

Figure 23 also shows the NPS-FM states for Water Clarity. Water Clarity serves as another surrogate for sediment concentrations, similar to turbidity. Council has conducted parallel monitoring of both surrogate measures, enabling site-specific conversion of turbidity to Water Clarity.

The NPS-FM sets Water Clarity limits for different river classes based on the Climate and Geology component of the NIWA REC (River Environment Classification) system. Consequently, *Figure 23* shows the range of A-limits for reference. These varying limits mean that sites with similar turbidity levels can have different NPS-FM band states. An example are the two monitoring sites on the Waihopai River, with the upper site falling within the C-Band, while the lower site is in the A-Band.

Among the rivers monitored, the Awatere River stands out with the highest turbidity values and the greatest variability. The sediment in this waterway primarily originates from significant deposits of easily erodible mudstone in the catchment. This implies that a substantial portion of the high sediment load in the river likely results from natural causes. However, human activity, beginning with the early clearance of the natural forest in the catchment, exacerbates mudstone erosion.

The Waihopai River valley also contains a significant proportion of mudstone, coupled with the frequent occurrence of thunderstorms, resulting in substantial slips in the upper catchment and consequently prolonged periods of higher turbidity values.

The rivers with the lowest turbidity levels are the Goulter River and Black Birch Stream, both characterised by very small areas of non-native vegetation within their catchments. In contrast, the Upper Wairau River and Branch River, despite having similarly high proportions of native vegetation cover, exhibit higher turbidity levels. These elevated turbidity levels are likely attributed to geological factors similar to those found in the nearby Waihopai River catchment.

Groundwater-dominated streams, such as Murphys Creek and Spring Creek, typically maintain low turbidity levels. However, Mill Creek stands as an anomaly, with activities in the surface catchment causing turbidity significantly higher than expected from a spring-fed stream.

Comparison with data from other regions reveals that Marlborough's streams and rivers generally carry less sediment than waterways in many other regions (right side of *Figure 23* and *Figure 24*).

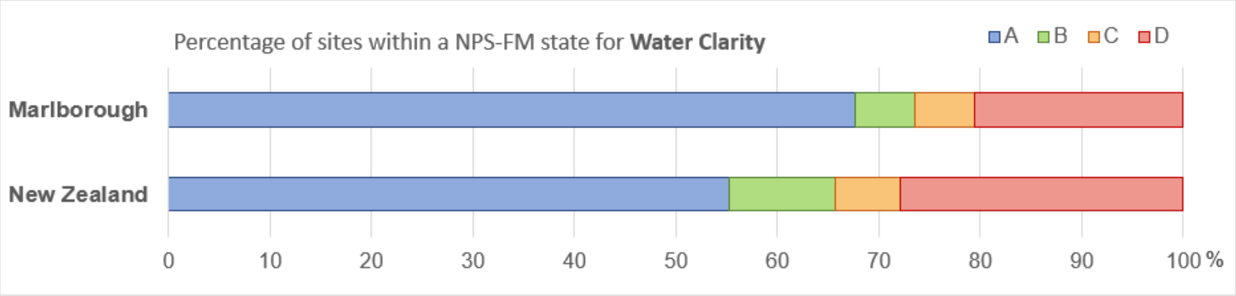

Figure 24: Percentage of sites within the Water Clarity NPS-FM states in Marlborough and nationally (Marlborough excluded).

Trend analysis indicates improvements in turbidity values at several sites, particularly in recent years (*Figure 25*). Significant reductions in turbidity are evident in the Tuamarina River, Linkwater Stream, the Waihopai, and mid Awatere Rivers. Most of these sites also exhibit significant decreasing trends in Total Phosphorus concentrations, highlighting the close relationship between phosphorus and sediment. Somewhat smaller improvements can be observed in the Waitohi and Ōpaoa Rivers, as well as Doctors Creek. Notably, the lower Awatere is the sole site where significant increases in turbidity are observed.

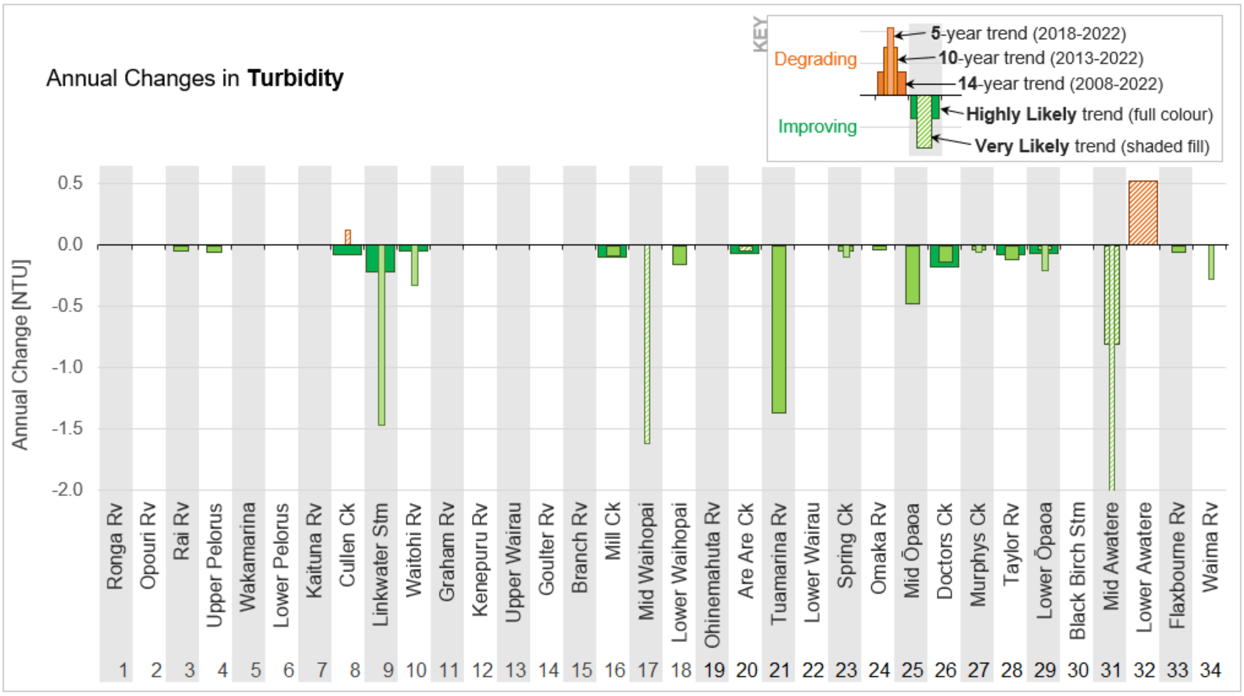

Figure 25: Annual changes in Turbidity over the past 5, 10 and 14 years.

3.4. Heavy Metal concentrations

In 2017, the analysis of State of the Environment (SoE) samples expanded to include dissolved and total concentrations of four heavy metals: cadmium, arsenic, copper, and zinc.

This section primarily centres on the total concentrations of these metals for two reasons. Firstly, at most of the monitored sites, concentrations of dissolved heavy metals are exceptionally low, with detectable levels observed in only a handful of samples. Secondly, total concentrations provide deeper insights into the potential impact of heavy metals on downstream environments and the potential contamination of stream bed sediments.

Cadmium concentrations are almost exclusively below the detection limit. Over the past five years, only a single sample at seven sites registered a measurable cadmium concentration. The monitoring of cadmium will therefore cease at the end of this year.

Detectable concentrations of arsenic are relatively infrequent but have been observed at several sites (*Figure 26*). The Awatere River stands out with the highest number of elevated arsenic concentrations, with 46% of samples exceeding the detection limit of 0.0011 mg/L. The maximum total arsenic concentration recorded in the Awatere River was 0.019 mg/L, while dissolved concentrations remained below detection limits.

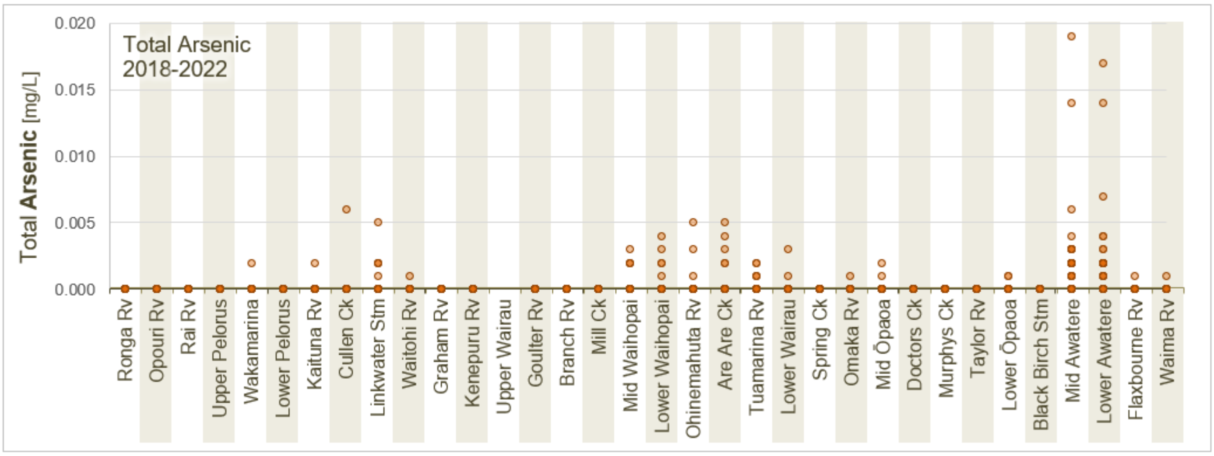

Figure 26: Total Arsenic concentration at the SoE monitoring sites. The circles represent individual measurements.

Other waterways with fewer but still more than three samples containing total arsenic concentrations above the detection limit include Are Are Creek, Tuamarina River, Linkwater Stream, and the Waihopai River.

Measurable concentrations of copper and zinc are comparatively more common and occur at all monitored sites, including rivers with a high proportion of native vegetation cover, such as the Goulter River and Black Birch Stream (refer to *Figure 27* and *Figure 28*). Nevertheless, for the majority of sites, median concentrations are at the detection limit, indicating that 50% or more of the samples have copper and zinc concentrations below detectable levels. Among the sites with more frequently measurable concentrations, the Awatere River records the highest levels. Both copper and zinc exhibit a strong affinity for binding to soil and sediment particles, and the higher concentrations in the Awatere are likely a result of the generally greater suspended sediment content (turbidity) of the water.

Slightly elevated copper concentrations are also observed in the Flaxbourne and Waima Rivers, Linkwater Stream, as well as in waterways originating in the hills southeast of Blenheim, including the Omaka River, mid Ōpaoa, and Doctors Creek.

Apart from minor deposits in the natural geology, sources of copper include pesticides, fungicides, fertilizers, and livestock manure. The occasionally elevated copper concentrations in Marlborough's waterways stem from a combination of these sources.

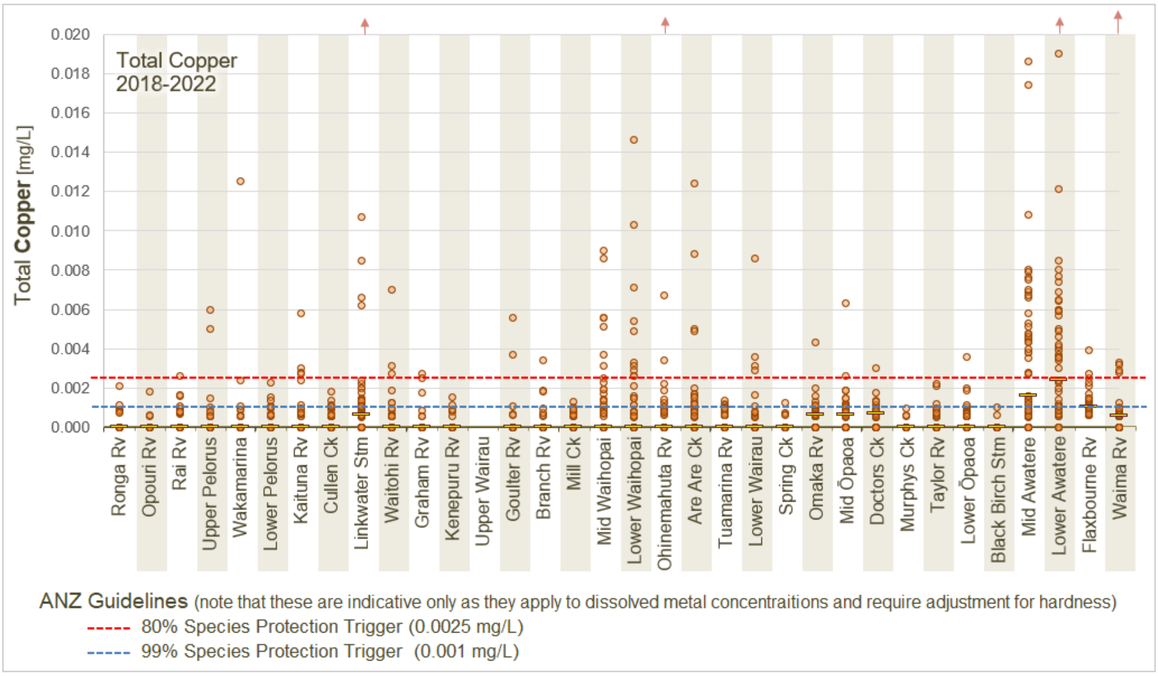

Figure 27: Total Copper concentration at the SoE monitoring sites. The circles represent individual measurements, while the yellow lines indicate median concentrations.

Apart from the generally higher heavy metal concentrations in the Awatere River, elevated zinc concentrations are primarily found in waterways in and around Blenheim, the region's largest urban area. The main sources responsible for these elevated levels are tire wear and vehicle emissions, roofing iron, and potentially sewage. Occasionally higher zinc levels at other sites are predominantly linked to fertilizer and feed supplements.

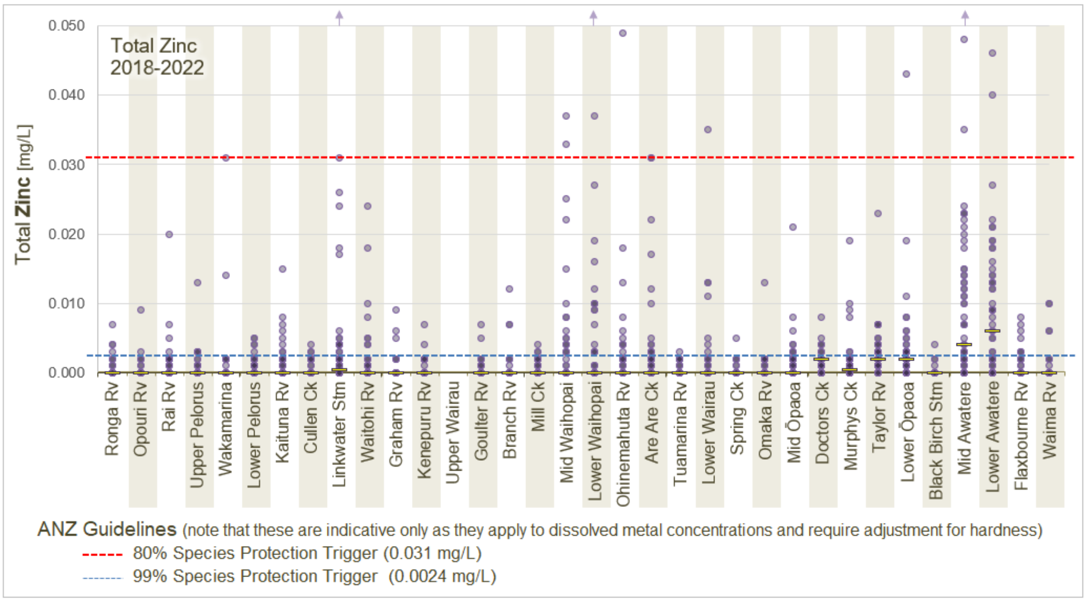

Figure 28: Total Zinc concentration at the SoE monitoring sites. The circles represent individual measurements, while the yellow lines indicate median concentrations.

Due to the substantial number of samples falling below detection limits, trend analysis could only yield meaningful results for sites with median concentrations above detectable levels. Among those sites, most showed no significant changes over time. Exceptions include a very likely increase in total copper concentrations in the Waima River (0.0018 mg/L/a), a highly likely decrease in total zinc concentrations in the Lower Awatere (-0.0008 mg/L/a), and a very likely decrease in zinc levels in the Mid Awatere (-0.0004 mg/L/a).

3.5. E. coli concentrations

E. coli serves as an indicator for the presence of animal droppings or sewage in waterways. In rural areas, primary sources include direct inputs from animals, such as livestock in unfenced stream reaches, as well as wildfowl. Elevated E. coli levels can also result from inadequately functioning private sewage disposal systems for residential buildings. In urban areas, major sources encompass aging or damaged sewage infrastructure, alongside wildfowl such as ducks.

Figure 30, along with the accompanying Map in *Figure 29*, show the E. coli concentrations for the 34 sites of the SoE monitoring programme. Similar to turbidity, the measurement results are presented on a logarithmic scale.

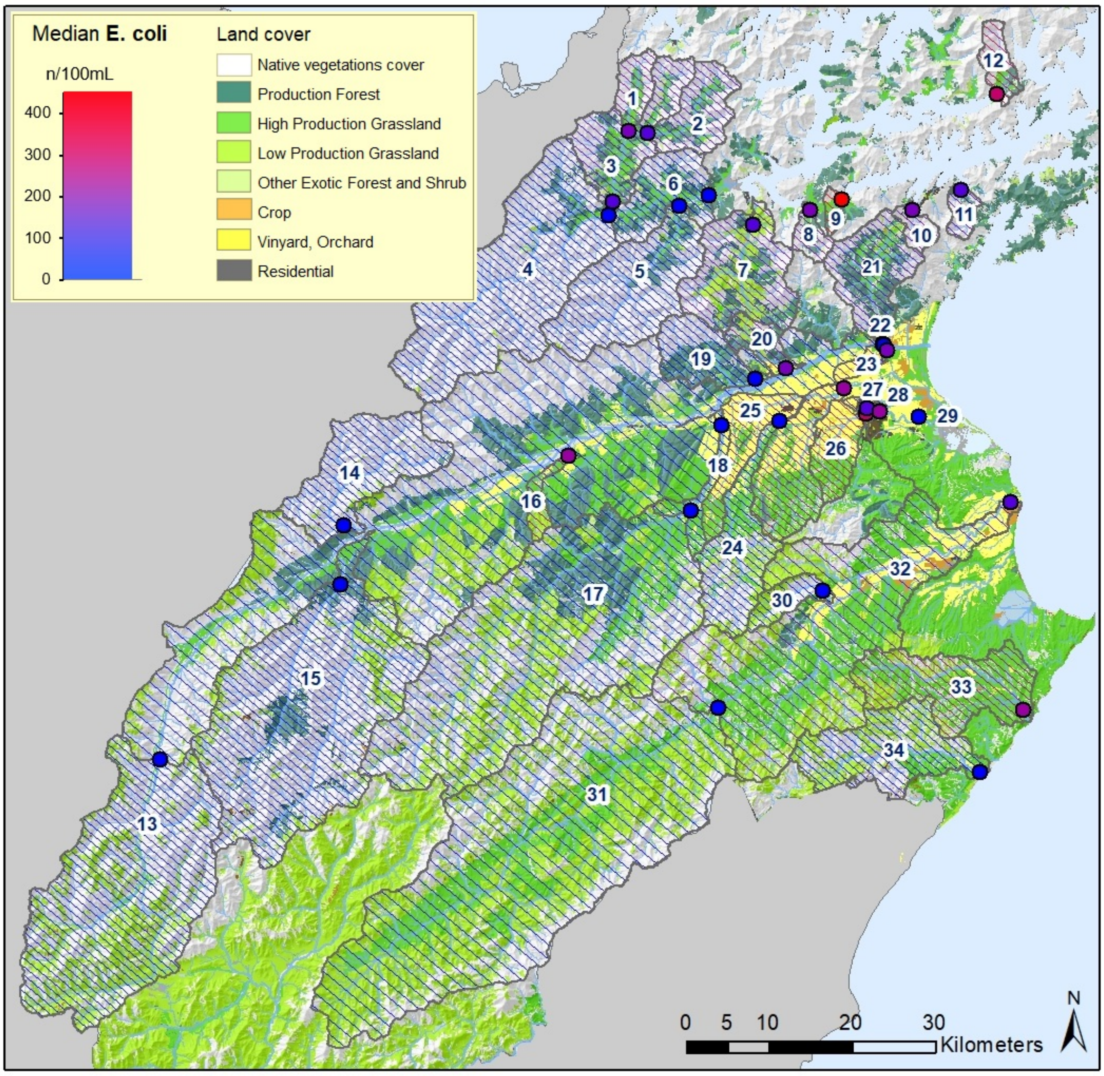

Figure 29: Median E. coli concentrations at the SoE sites and associated catchment. Wider shading of the catchments indicates that sites represent comparatively large catchments. The numbers correspond to those associated with the site names in Figure 30.

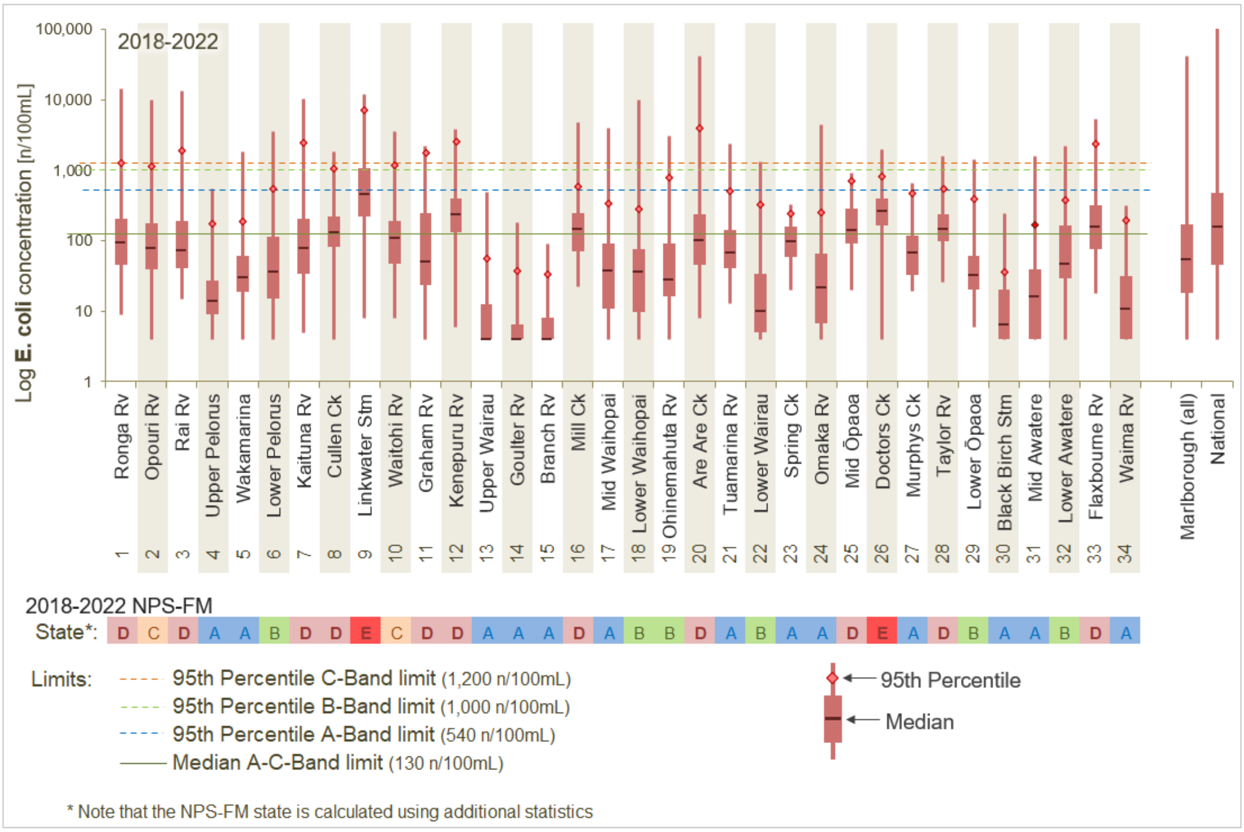

Figure 30: E. coli concentrations in the monitored waterways. Also shown are the Median and 95*th *Percentile NPS-FM limits and states based on these limits and limits of two additional statistics not shown.

E. coli concentrations in natural conditions are typically low, with occasional spikes observed during rainfall runoff events. This phenomenon is evident in the E. coli concentrations in the Goulter, Branch, and Upper Wairau Rivers. Comparatively low E. coli levels are also noted in the Upper Te Hoiere/Pelorus River and the Waima River.

Linkwater Stream and Doctors Creek exhibit the highest E. coli concentrations, leading to their placement in the NPS-FM state within the E-band.

At most sites, the highest E. coli concentrations are generally associated with rainfall. Streams in high rainfall areas in the north of the region experience more surface runoff events, resulting in higher values for NPS-FM E. coli concentrations statistics and consequently lower NPS-FM states. This effect is particularly noticeable for some of the Marlborough Sounds Streams, such as the Graham, which has an NPS-FM state in the D-band despite a large area of native vegetation in the catchment.

Figure 31 shows the relationship between median E. coli concentrations and the percentage of pasture cover within the catchment. Generally, there is an increase in E. coli concentrations with higher pasture cover. However, the patterns become more evident when waterways in high-rainfall areas are separated from those in areas with comparatively little rainfall. Four of the monitored streams show significantly higher E. coli concentrations than can be attributed solely to pasture cover. In the Waitohi River, urban sources from the Picton township are the primary reason for this discrepancy. In the case of the other three, particularly Linkwater Stream, potential causes include poor pastoral management practices or malfunctioning private sewage treatment systems.

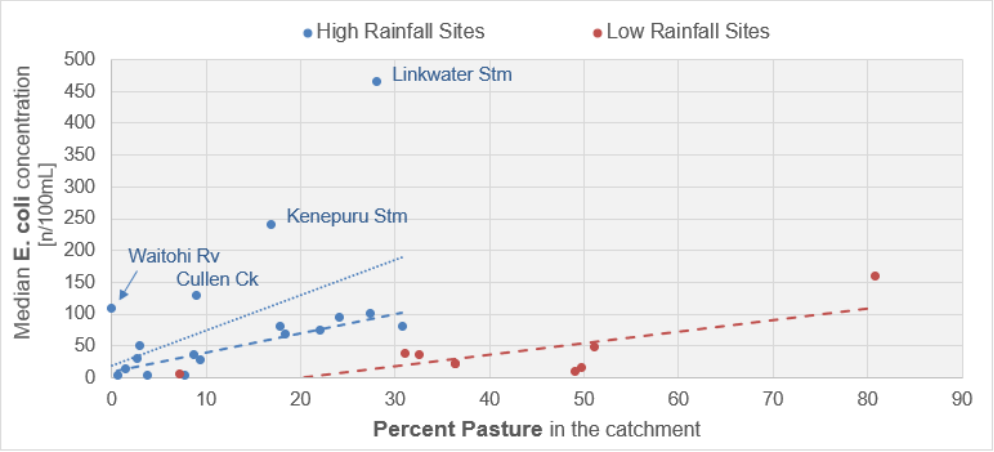

Figure 31: ***Relationship between E. coli concentrations and percentage pasture in the catchment.***

A notable number of sites fall within the D or E-band across the region, indicating that the NPS-FM E. coli standards are relatively stringent when compared to the limits for most other attributes/parameters. However, overall, Marlborough has a significantly larger number of sites within the E. coli A or B-band when compared to the rest of New Zealand (*Figure 32*).

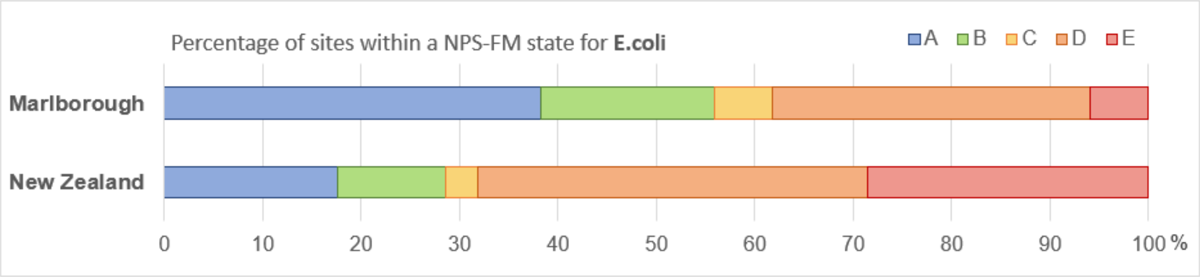

Figure 32: Percentage of sites within the E. coli NPS-FM states in Marlborough and nationally (Marlborough excluded).

Trend analysis reveals significant changes at various sites across the region. These include notable decreases in Are Are Creek, the Kaituna River, and Cullen Creek, but increases in Linkwater Stream.

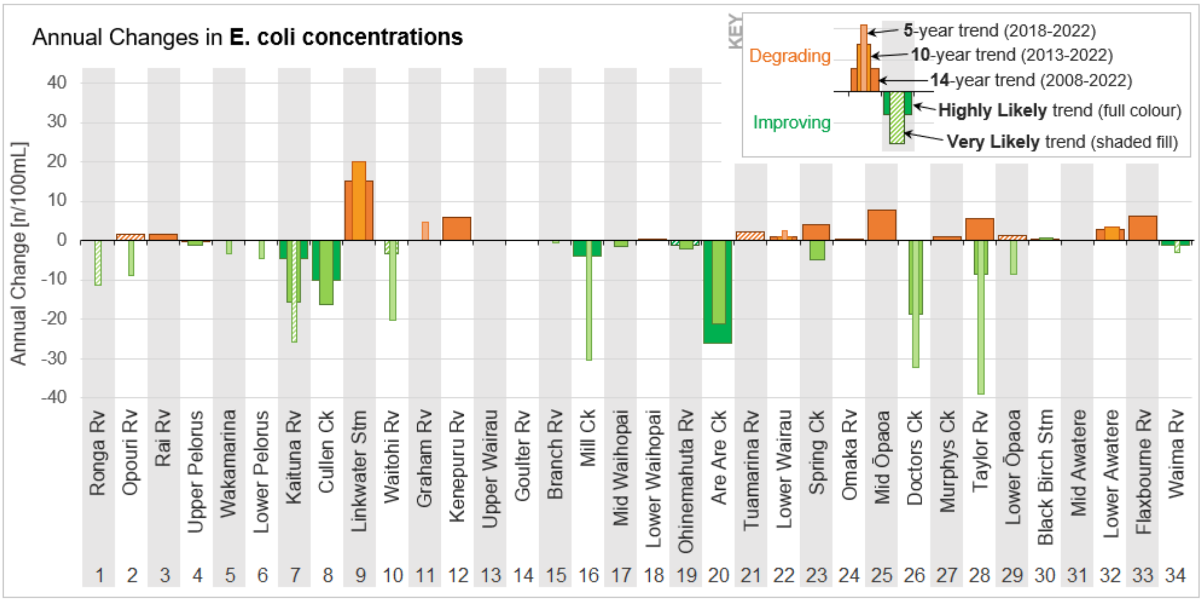

Figure 33: Annual changes in E. coli concentrations over the past 5, 10 and 14 years.

The reduction in E. coli concentrations in Mill Stream, particularly over the last five years, is likely linked to the conversion of pasture into vineyards. In the two urban rivers, the Waitohi and Taylor River, upgrades and repairs to sewage infrastructure have significantly contributed to lower E. coli concentrations. However, the Taylor River has also benefited from substantial improvements in Doctors Creek.

3.6. Water Temperature, Dissolved Oxygen, and pH

These three parameters exhibit a distinct pattern over the course of the day, with higher values typically occurring around midday and lower values at night. Water Temperature and Dissolved Oxygen also exhibit seasonal patterns, with higher Water Temperatures and lower Dissolved Oxygen levels during the warmer months of the year.

Due to these fluctuations, particularly the variability throughout the day, continuous monitoring is the most effective approach. While continuous monitoring will be implemented at selected sites, the high associated costs make it unfeasible for all monitoring locations. Instead, spot measurements are taken during monthly sampling, providing some insight into general values.

3.6.1. Water Temperature

Aquatic organisms, especially many juvenile stages, are highly sensitive to elevated temperatures. Water temperatures above their optimal range can induce stress and, in extreme cases, lead to mortality. An additional factor to consider is that the amount of dissolved oxygen that water can hold decreases with rising water temperatures.

Figure 34 displays water temperature measurements for the 34 Sites of Environmental (SoE) monitoring sites over the last five years. Typically, the lowest temperatures are observed in rivers at higher altitudes, such as the Upper Wairau, Branch, and Goulter Rivers.

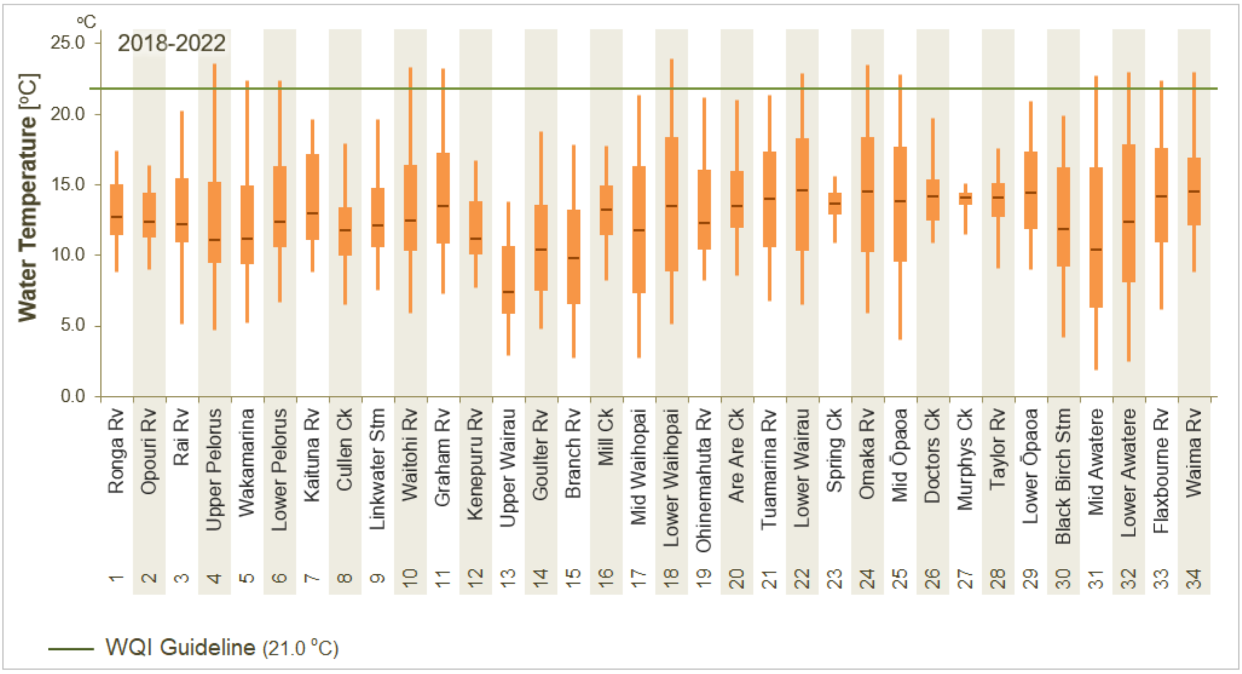

Figure 34: Water Temperature measurements at the SoE monitoring sites. To provide context the guideline for the calculation of the Water Quality Index is shown (see Section 10.2).

Waterways primarily fed by groundwater, such as Murphys Creek and Spring Creek, exhibit a narrow temperature range as groundwater temperatures remain comparatively stable. However, in the case of Mill Creek, despite having a significant groundwater component in its flow, the influence of sun exposure due to a lack of shading riparian vegetation is more pronounced, resulting in greater temperature variability in the stream.

During the warmer months, rainfall can help lower water temperatures. Monitoring sites with the greatest temperature variability are therefore typically situated in the drier parts of the region where the lack of rainfall allows temperatures to rise to higher values. This is particularly notable in larger rivers like the Waihopai and Awatere Rivers. Due to their greater width, riparian vegetation cannot provide adequate shading for these waterways.

Conversely, on smaller streams, the presence of shading riparian vegetation can significantly affect water temperature. An example is Cullen Creek and neighbouring Linkwater Stream. Cullen Creek benefits from a comparatively intact riparian buffer composed of mature trees and shrubs along most of its length, while the lower reaches of Linkwater Stream lack adequate shading. Consequently, Cullen Creek consistently maintains lower and less variable water temperatures.

3.6.2. Dissolved Oxygen

Just like us, aquatic animals and plants require oxygen to survive. Low oxygen levels can lead to stress and ultimately, death among aquatic life. Warmer water can dissolve less oxygen than cooler water, making oxygen stress more prevalent during the summer months when water temperatures rise. Low dissolved oxygen levels can also result from the decomposition of organic materials such as leaf litter and animal droppings.

Figure 35 displays dissolved oxygen concentrations at the monitored river and stream sites. For most sites, dissolved oxygen levels consistently remain well above the guideline of 8 mg/L. However, at some sites, occasional lower dissolved oxygen levels indicate potential oxygen stress for aquatic animals, particularly during the night when there is no oxygen input from aquatic plants.

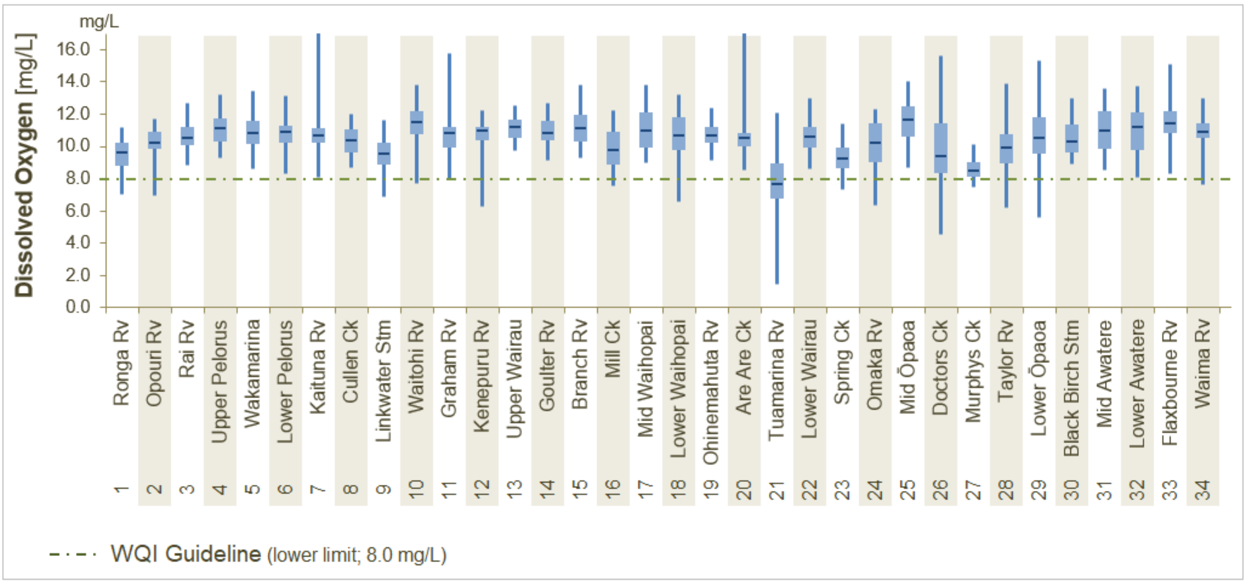

Figure 35: Dissolved Oxygen measurements at the SoE monitoring sites. To provide context the guideline for the calculation of the Water Quality Index is shown (see Section 10.2). Note that unlike for most other parameters this guideline is a lower limit.

The comparatively low dissolved oxygen concentrations in the Tuamarina River can be attributed to the presence of a large natural wetland, the Para Swamp, located upstream of the monitoring site. Wetlands typically contribute a higher amount of organic material, which, as it breaks down, removes oxygen from the water. Furthermore, the slower water flows within wetlands result in reduced water aeration. In the

Tuamarina River, excessive growth of introduced emergent aquatic weeds (macrophytes) in the lower reaches of the river likely exacerbates the reduction in oxygen concentrations. These macrophytes extend above the water surface, releasing oxygen into the air instead of the water. They also create a kind of blanket that limits light penetration into the water, reducing the potential for algae to photosynthesise and release oxygen into the water.

Spring-fed streams, such as Murphys Creek and Spring Creek, naturally exhibit somewhat lower dissolved oxygen concentrations because groundwater typically contains lower oxygen levels.

Doctors Creek displays some of the largest variability in dissolved oxygen levels. This variation is caused by a combination of significant groundwater inflows and excessive growth of aquatic weeds and algae in the lower reaches of the creek. Unlike in the Tuamarina River, a sufficient proportion of the aquatic weeds in Doctors Creek remain submerged under the water surface, releasing oxygen into the water column during the day, resulting in comparatively high oxygen maxima.

Occasional very high dissolved oxygen levels in the Kaituna River and Are Are Creek are also caused by excessive algae growth on the stream bed.

3.6.3. PH levels

pH is a measure of the acidity or alkalinity of water, with values ranging from 0 (strongly acidic) to 14 (strongly alkaline). A pH value of 7.0 is considered neutral. Typically, rivers and streams tend to be slightly alkaline, with pH values around 7.5. This alkalinity is primarily attributed to the natural buffering effect of bicarbonate.

Aquatic organisms have optimal pH ranges that vary among species. In general, eggs and young animals are more sensitive to low pH values. However, the indirect effects of pH often have a greater impact on aquatic ecosystems than the pH level itself. For instance, at high pH values, the toxic form of Ammoniacal Nitrogen becomes more prevalent, and low pH values enhance the toxicity of heavy metals.

The majority of rivers in the region maintain a pH level within the optimal range for aquatic organisms, typically falling between 6.5 and 8.5 (*Figure 36*).

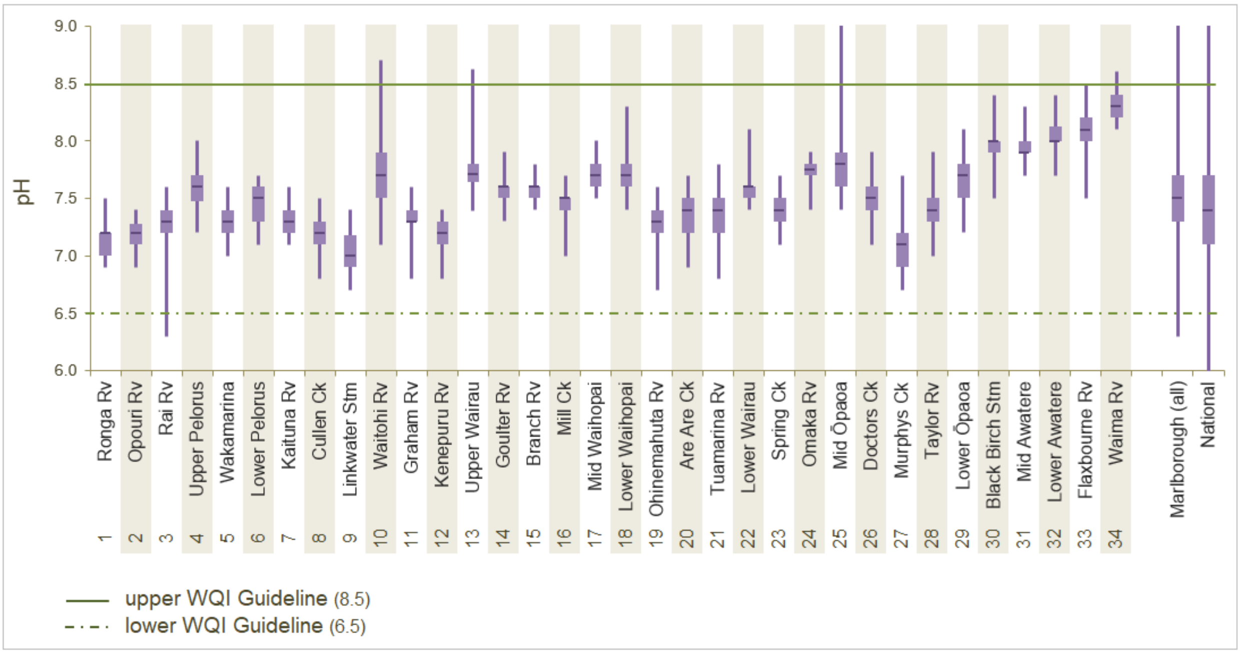

Figure 36: PH measurements at the SoE monitoring sites. To provide context the guidelines for the calculation of the Water Quality Index are shown (see Section 10.2). Note that unlike for most other parameters, the pH has an optimal range with an upper and a lower limit.

The pH of aquatic environments can fluctuate due to various factors. Photosynthetic activity by aquatic plants, for example, can increase pH levels. The highest pH levels are usually observed during dry spells in summer when photosynthesis is at its peak. Occasional high pH levels in the Waitohi and mid Ōpaoa River coincide with dense algae cover, which contributes to the pH fluctuations.

The presence of limestone naturally leads to higher pH values in some rivers and streams, particularly in the southern part of the region. The Waima River, with the largest deposits of limestone within its catchment, consistently records the highest pH levels among all monitored waterways.

3.7. Macroinvertebrates and Periphyton

While the previous sections presented monitoring data for physical and chemical parameters, the following two sections delve into two biological parameters. Of these two, Macroinvertebrates in particular offer insights into the aquatic ecology's response to stressors represented by the physical and chemical parameters.

3.7.1. Macroinvertebrates

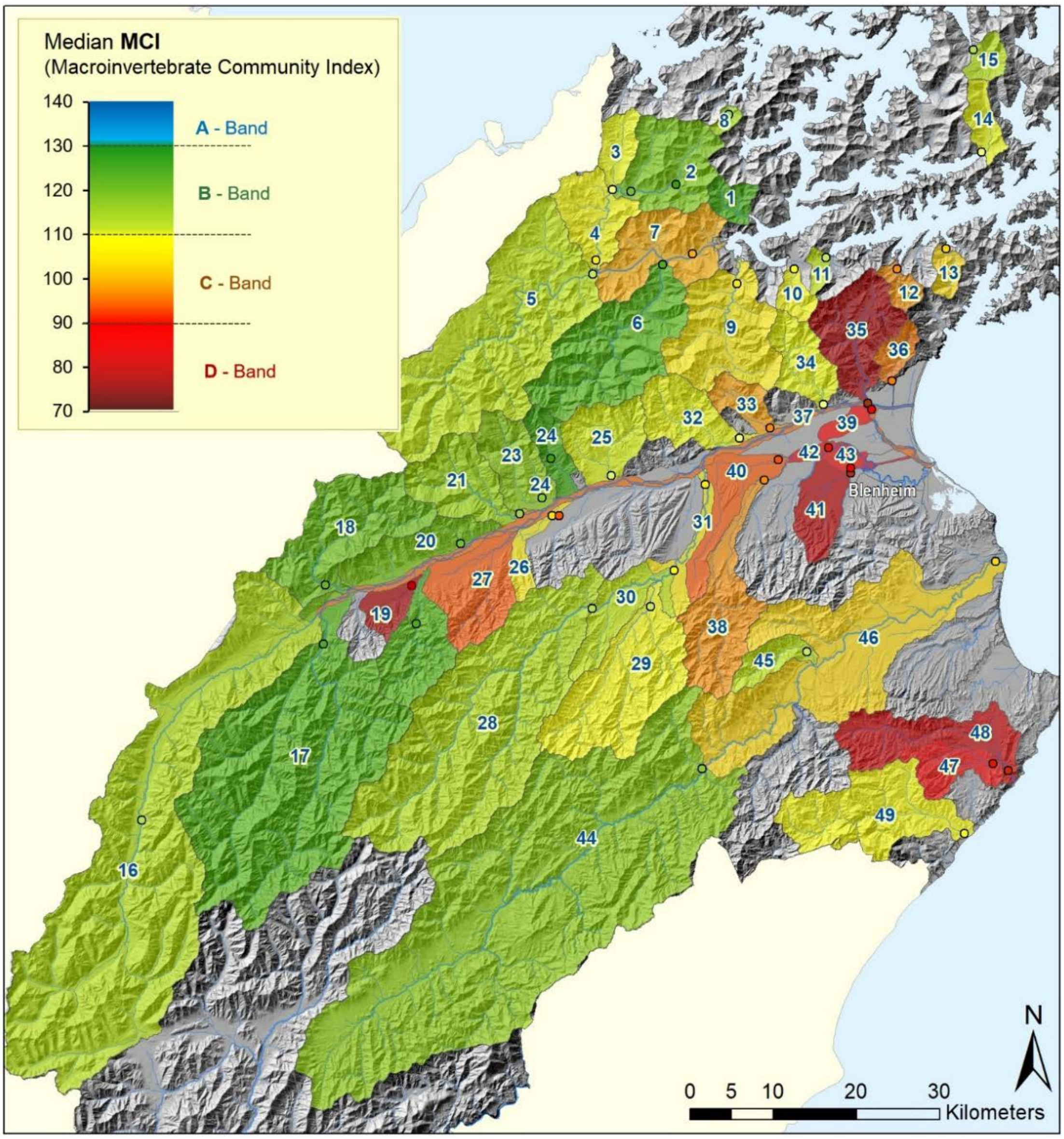

Figure 37: Median MCI scores for the sites monitored on an annual basis. The numbers relate to the sites in Figure 38.

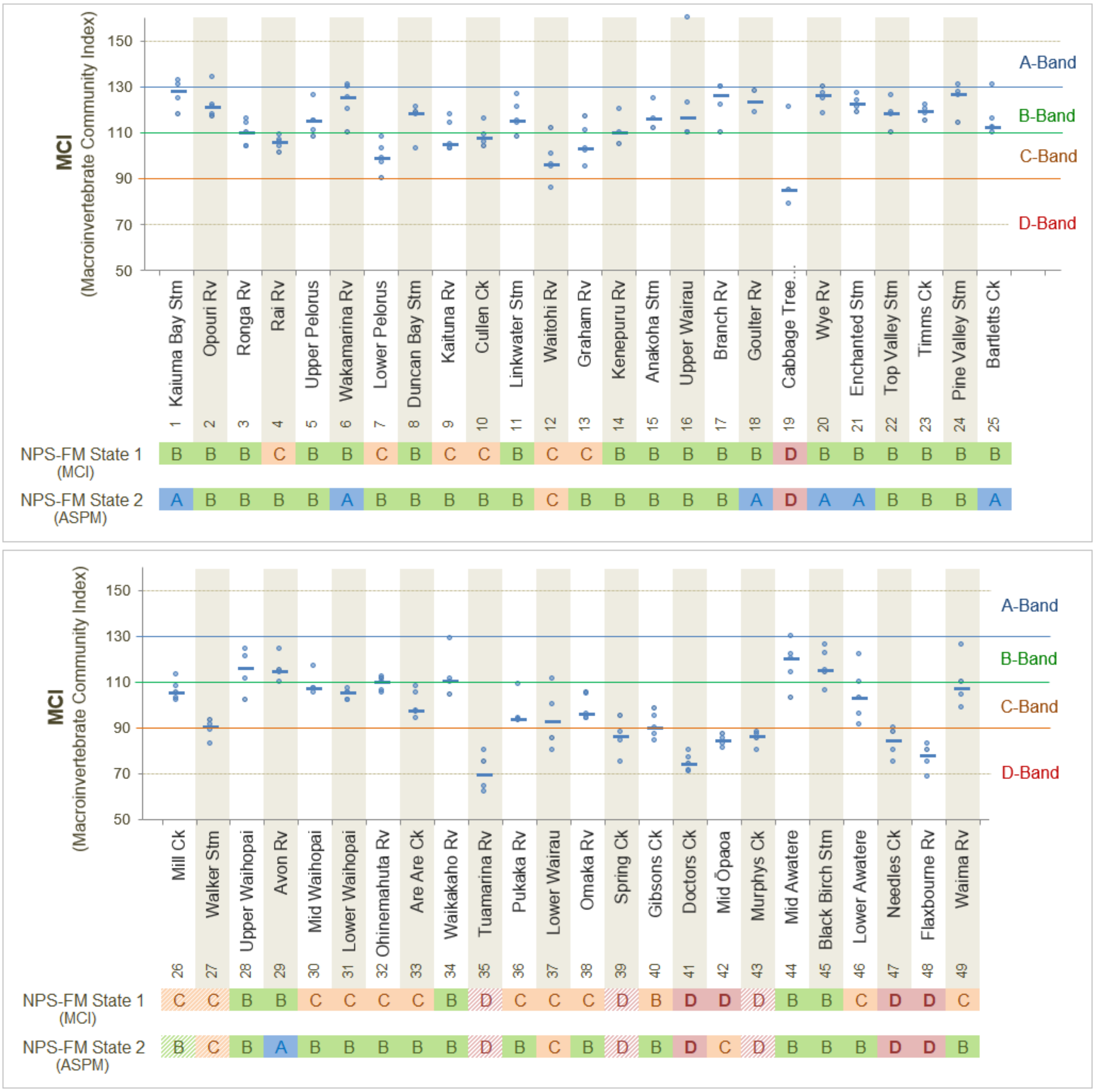

Figure 38: MCI scores over the last five years for the 49 annual monitoring sites. The circles show individual sample scores while the lines show median values. Also shown are the states for both of the NPS-FM attributes (calculated over the same time period).

Macroinvertebrates encompass a wide range of organisms, including insects, worms, snails, and other small aquatic creatures visible to the naked eye. These numerous species exhibit varying sensitivities to changes in their aquatic environment or sub-optimal conditions. Consequently, the composition of species found can serve as an indicator of a waterway's health. Macroinvertebrates offer an integrated perspective on the effects of multiple stressors, such as high nutrient levels and sedimentation. The most commonly used scoring system is the MCI (Macroinvertebrate Community Index). Additionally, the NPS-FM introduces attribute limits for a secondary macroinvertebrate score, the ASPM (Macroinvertebrate Average Score Per Metric), a relatively new measure.

In addition to most of the 34 monthly State of the Environment (SoE) monitoring sites, macroinvertebrates are also sampled in several waterways across the region not covered by the monthly monitoring. Since macroinvertebrates provide an integrated assessment of stream and river health from a single sample, they offer an opportunity to gain a broader understanding of the region's river health at a relatively low cost.

Figure 37 and its companion *Figure 38* illustrate the MCI scores from the most recent five years of monitoring. The graphs in *Figure 38* display both scores from individual samples and the 5-year medians. It is evident that individual MCI scores fall within different NPS-FM bands for most sites, highlighting year-to-year variability. Nonetheless, MCI values tend to stay within a two NPS-FM band range for most sites, offering a reasonable indication of river health.

Noteworthy is the observation that MCI scores tend to be generally higher in rivers and streams located in high rainfall areas in the northern part of the region, primarily shown in the top graph of *Figure 38*. In dryer regions, lower river flows result in higher water temperatures and lower dissolved oxygen levels. Additionally, less frequent flood events lead to greater accumulation of algae on the streambed, reducing habitat quality and increasing daily fluctuations in dissolved oxygen and pH. These factors collectively exert greater stress on the aquatic organisms inhabiting these waterways, resulting in a reduced abundance of sensitive species.

It is important to note that some waterways naturally exhibit lower MCI scores, such as the Tuamarina River and spring-fed streams like Murphys Creek and Spring Creek. However, in other waterways such as Cabbage Tree Gully, Needles Creek, and the Flaxbourne River, low MCI scores are primarily attributed to pastoral land use practices. In the Waitohi River, urban influences are the main contributor to comparatively lower MCI scores.

A noteworthy observation is that MCI scores in the Awatere River demonstrate comparatively good ecological health, despite the generally higher sediment concentrations in the water (see Section 3.3).

Figure 38 also displays the most recent band states for the two NPS-FM attributes, MCI and ASPM. Generally, the ASPM band limits tend to be more lenient than those for MCI, resulting in overall better NPS-FM states for the ASPM attribute. Notably, there is a lack of any sites within the A-band for the MCI attribute, including rivers in catchments that are almost completely covered in native vegetation, such as the Goulter River and Enchanted Stream. This not only applies to the NPS-FM state, which is based on the median score but also to MCI values for individual samples, which rarely fall within the A-band. This suggests that MCI scores within the B- band represent comparatively good river health.

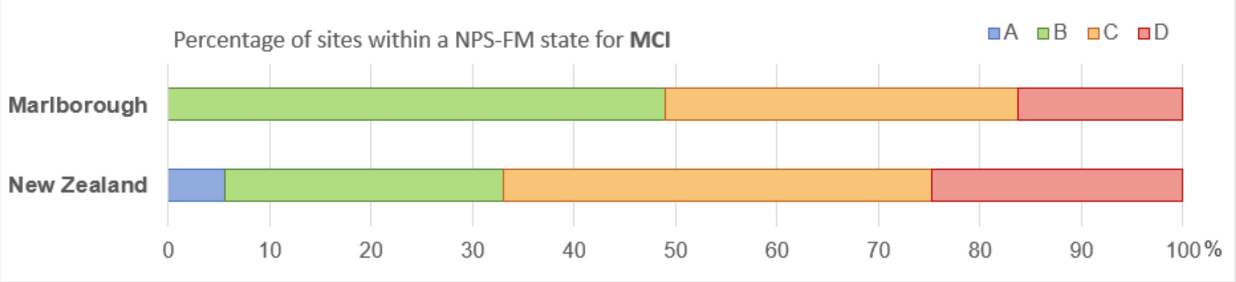

Figure 39: Percentage of sites within the MCI NPS-FM states in Marlborough and nationally (Marlborough excluded).

Figure 39 provides a comparison of MCI states for the main 32 SoE sites within Marlborough[1] with the proportion of NPS-FM states for the rest of New Zealand. It is evident that NPS-FM states within the A-Band are quite rare nationally. Additionally, it is noticeable that despite a comparatively large percentage

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[1] These are those of the 34 monthly monitoring sites at which Macroinvertebrate sampling is possible. The lower Taylor River and the lower Ōpaoa River cannot be sampled due to lack of shallow areas and a large proportion of fine sediment cover.

of waterways falling into the C and D bands within Marlborough, the percentage of sites within these lower NPS-FM bands is lower when compared to the rest of New Zealand.

Trend analysis was carried out for all of the 49 sites monitored. *Figure 40* shows the trend results for the sites for which the analysis indicated significant changes. It is worth mentioning that as macroinvertebrate samples are collected only once per year, the number of data points available for trend analysis is comparatively small. This is the reason that trends were not assessed for the period over the last 5 years. However, even trend results over longer time periods generally need to be interpreted with caution.

Trend analysis reveals changes in MCI scores for several sites, primarily showing reductions. However, it is essential to note that a reduction of 1 MCI score per year is also observed for waterways almost exclusively covered in native vegetation, such as the Goulter River and Enchanted Streams. This suggests that many of the seemingly degrading trends, particularly in the wider Wairau catchment, are likely a result of natural variability. In contrast, trends in other waterways, such as Duncan Bay Stream, and particularly the improving trends in Linkwater Stream and Rai River, are more likely a result of human activity within the catchments.

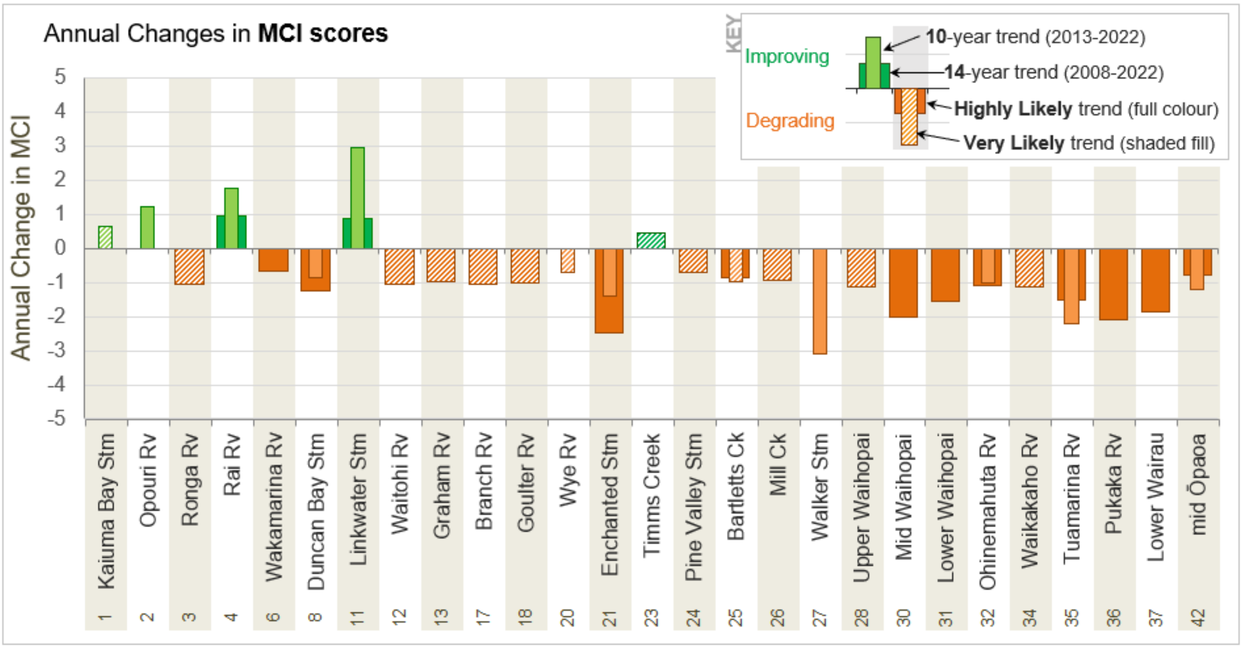

Figure 40: Annual changes in MCI scores over the past 10 and 14 years.

3.7.2. Periphyton

Periphyton monitoring is conducted on a monthly basis and demands considerably more staff time compared to other monthly parameters. Consequently, it is only monitored at a select number of sites across the region. The monitoring method involves scraping algae from stones on the stream bed at multiple locations within the waterway and measuring the Chlorophyll-a concentration of the sample.

Figure 41 presents the Periphyton Chlorophyll-a concentrations at the monitored sites, along with the dissolved nutrient concentrations.

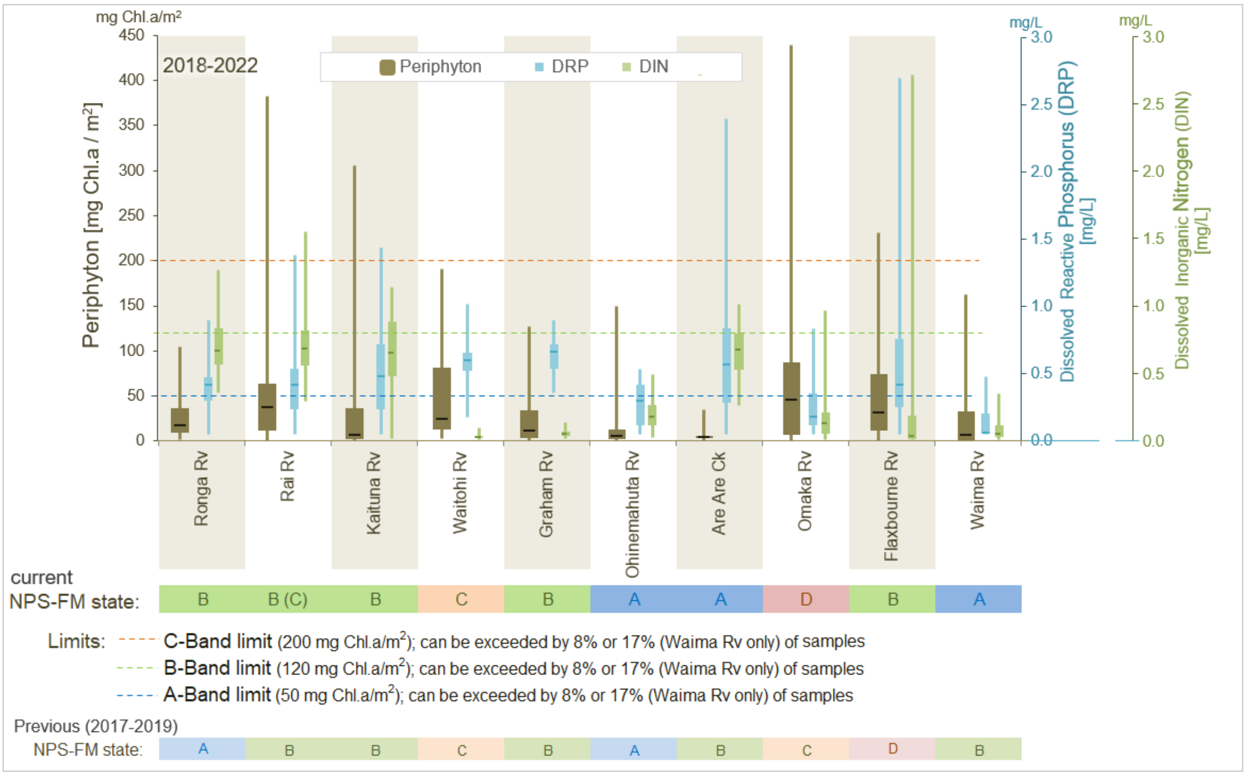

Figure 41: Periphyton Chl.-a, DIN and DRP concentrations as well as Periphyton NPS-FM states.

While the NPS-FM mandates the establishment of dissolved nutrient limits to control excess periphyton growth, the data indicates that there is no clear relationship between periphyton Chlorophyll-a and dissolved nutrient concentrations.

Figure 41 also displays the current NPS-FM states for the monitored sites. To ensure consistency in determining the state for other NPS-FM attributes, the periphyton state was calculated using data collected over a five-year period. Calculation over the minimum period of three years resulted in a different state only for the Ronga River, placing it within the C-band instead of the B-band.

At the bottom of *Figure 41*, the state bands reported in the previous SoE report [23] are shown. These were calculated over a three-year period due to the limited data available at the time. While most of the sites exhibit very little change, differences in the NPS-FM bands are noticeable for waterways in areas receiving comparatively little rainfall, such as the Omaka, Flaxbourne, and Waima Rivers. Flood flows play a crucial role in controlling periphyton growth, as periphyton is removed when stream beds become mobile during higher flows. Therefore, variations in flow conditions, especially the duration of periods with lower flows, are likely to contribute significantly to the differences in NPS-FM state. This complexity makes it challenging to link changes in the periphyton attribute state to human activities within the catchment.

4. Water Quality Index

The Water Quality Index (WQI) serves as a consolidated score reflecting the quality of river water. It is derived from nine chemical and physical parameters measured on a monthly basis. The WQI ranges from 0 to 100 with higher values indicating better water quality.

Appendix 10.2.1 provides a detailed explanation of how the WQI is calculated, the guidelines used, and the interpretation of the water quality categories.

In contrast to the single parameter scores used for the NPS-FM attributes, this index offers a comprehensive overview of the overall water quality at monitoring sites and enables the ranking of waterways. The WQI played a pivotal role in identifying waterways that are degraded or at risk of degradation during the development of the Marlborough Environment Plan (MEP). This identification allowed council to prioritise actions for improvement and formed a strong foundation for seeking external funding for river health enhancement projects. *Figure 42* and left side of the associated graph in *Figure 43* show the most recent WQI values for the monitored waterways. Since the WQI guidelines are based on NPS-FM limits wherever possible, the WQI is closely linked to the NPS-FM attribute states.

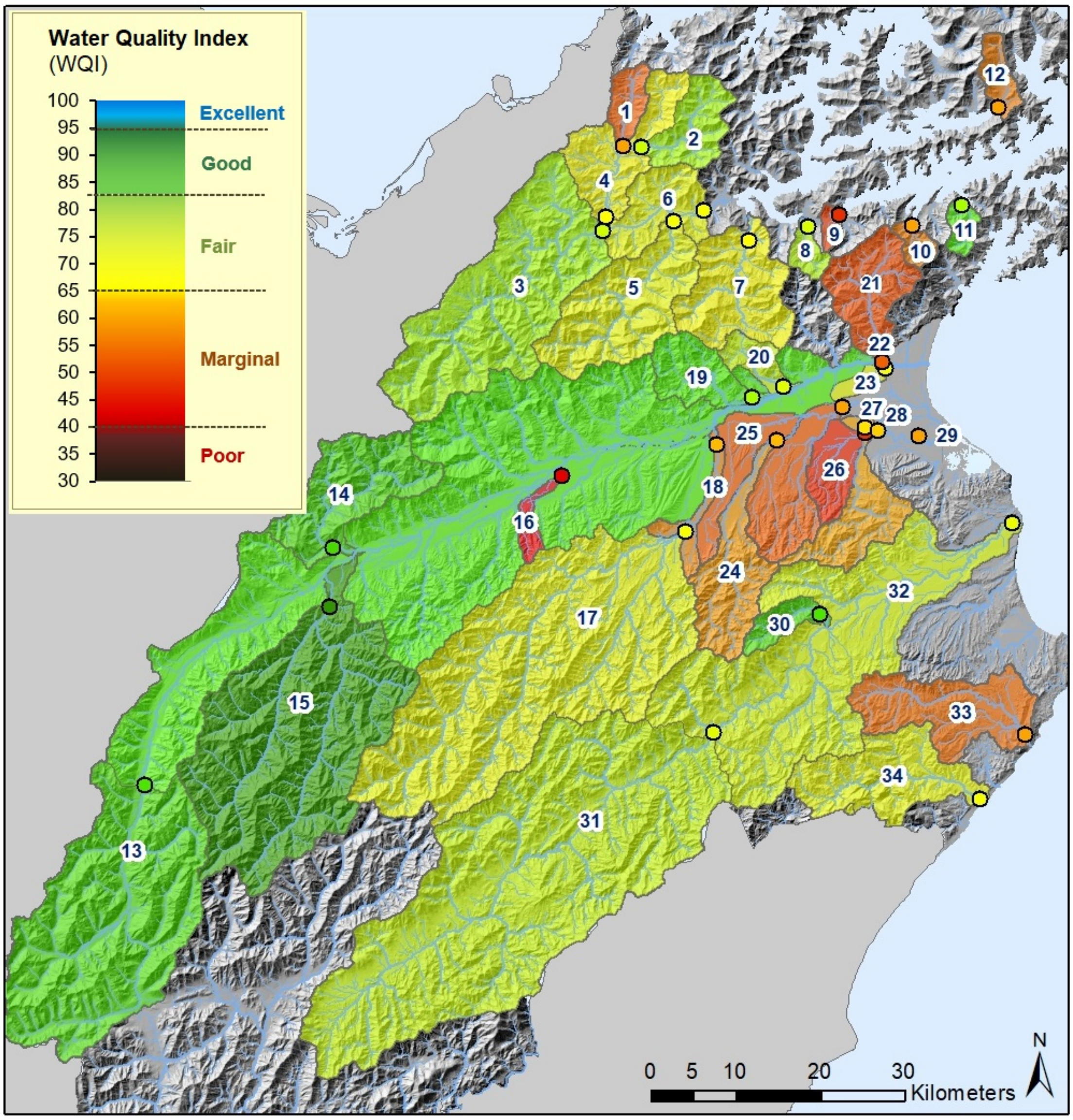

Figure 42: Water Quality Indices for the 34 monthly SoE monitoring sites and their associated catchments. The numbers relate to those on the far left in Figure 43.

Waterways featuring more than one NPS-FM attribute in the D/E-band typically fall within the marginal category of the WQI. Notable examples include Doctors Creek, Linkwater Stream, Tuamarina River, and Flaxbourne River. Waterways with all NPS-FM attributes above the D-band threshold are categorised as having good WQI scores. The top four sites, achieving the highest WQI scores, have all attributes in either the A- or B-band. These sites include the Branch River, Black Birch Stream, and upper Wairau River, all of which boast a significant proportion of native vegetation cover within their catchments.

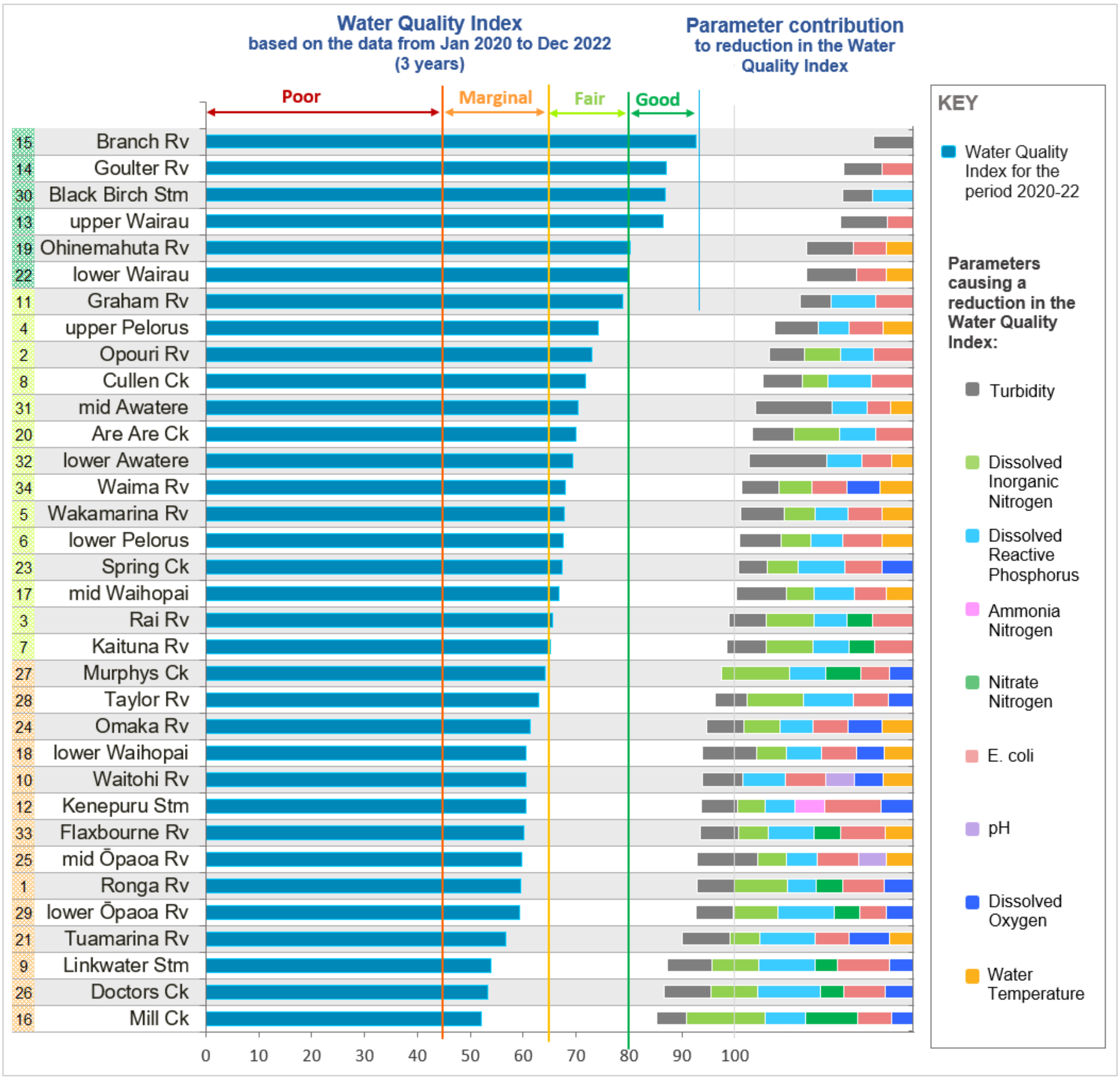

Figure 43: Water Quality Indices for the 34 SoE monitoring sites.

The right side of *Figure 43* shows the individual parameter contributions to the reduction in the WQI. For sites with lower WQI scores, a greater number of parameters contribute to the deterioration of water quality.

The WQI can also be used for a closer examination of the impact of flood flows on general water quality, as demonstrated in *Figure 44*. To achieve this, samples taken during flows exceeding three times the median flow were classified as flood flow data and removed from the dataset.

In most cases, excluding flood flow data leads to higher WQI values. However, the extent of this change varies significantly among sites. For instance, in the Te Hoiere/Pelorus River, the difference is substantial, causing water quality during lower flows to be classified as good. Changes in parameter contributions indicate that higher turbidity and DRP concentrations are predominantly observed during flood flows, suggesting that surface runoff is the primary source of sediment and phosphorus in this river. In the mid Te Hoiere/Pelorus, E. coli concentrations remain consistently low during lower flows, while in the lower Te Hoiere/Pelorus, E. coli levels are occasionally also higher at lower flows, indicating possible direct inputs, for example, from livestock access to tributaries or the main river.

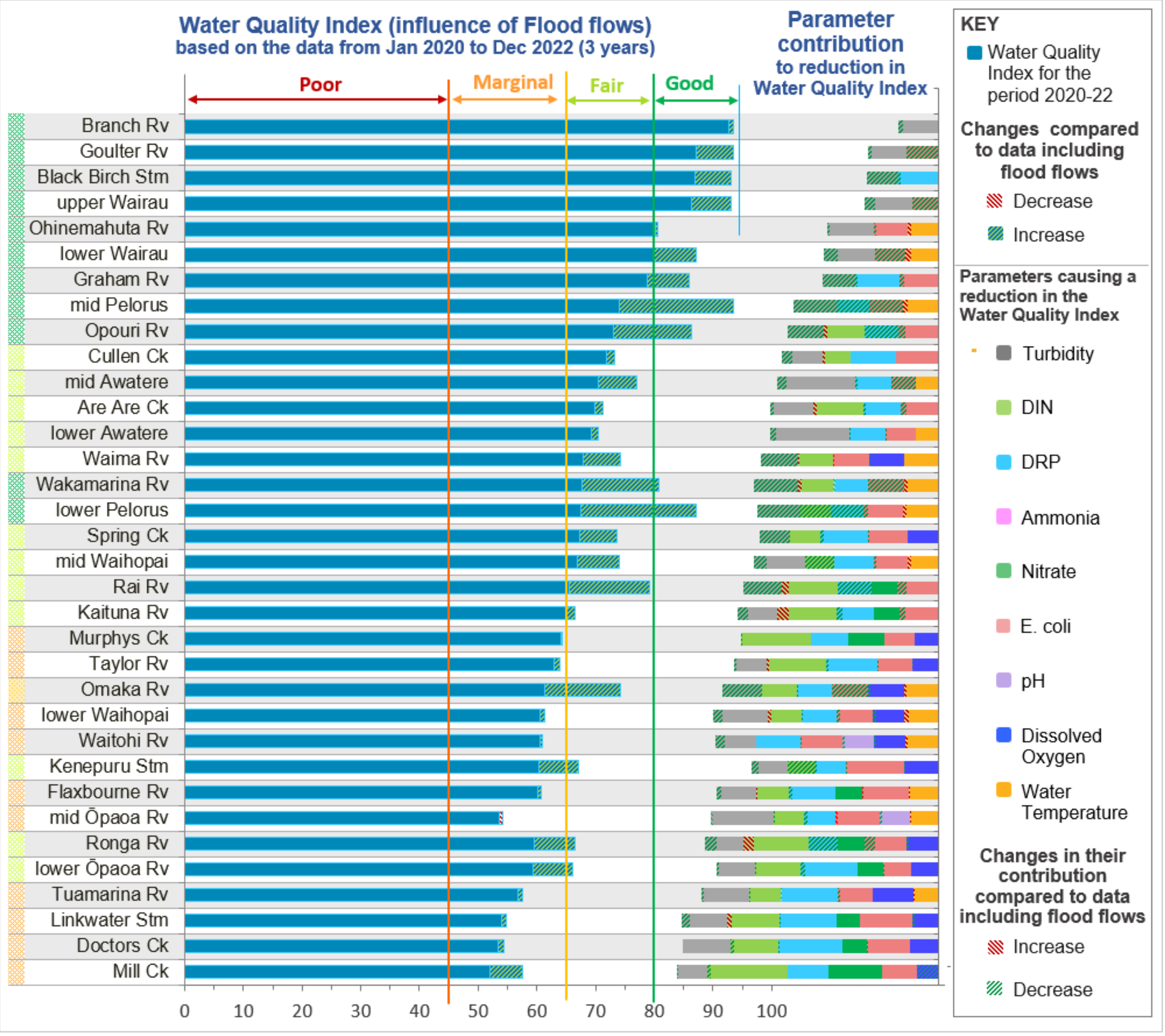

Figure 44: Changes of the Water Quality Index and contributing parameters when data collected during flood flows is removed.

Overall, turbidity and E. coli are the primary parameters that change with increased flow. For several other sites, excluding flood flow data eliminates contributions for either or both parameters. Examples include Black Birch Stream, the Lower Wairau River, the Wakamarina River, and the Omaka River.

However, there are also waterways for which the exclusion of flood flow data has minimal impact on the WQI. These include Linkwater Stream, the Kaituna River, the Taylor River, and Doctors Creek. In these waterways direct inputs of contaminants during lower flows are the main reason for poorer water quality.

5. New Monitoring

Following the release of the 2020 NPS-FM, a network review was conducted in the same year. The review document presented several options to ensure compliance with the monitoring requirements of the NPS-FM and enhance regional monitoring coverage for resource management purposes. Consequently, several new parameters will be monitored, including continuous dissolved oxygen levels and deposited fine sediment. Due to the substantial capital and/or staffing costs associated with this monitoring, these parameters will be implemented at a limited number of sites across the region.

The network review also led to the inclusion of new sites in previously unmonitored rivers catchments, as well as additional monitoring sites on very large rivers such as the Wairau River and Awatere River (refer to *Figure 45*).

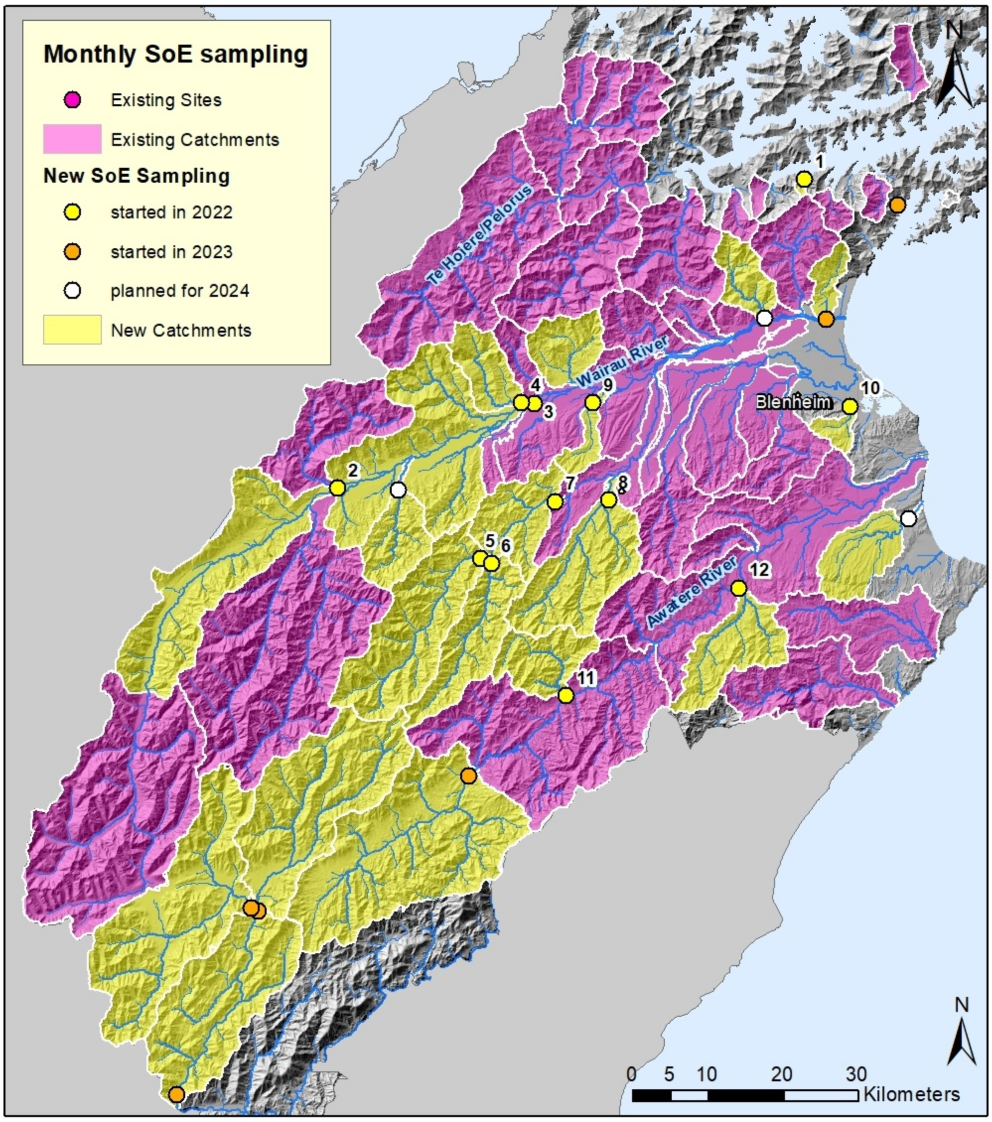

Figure 45: Existing and new monthly monitoring sites and associated catchments. The numbers relate to those in Figure 46.

These sites are being added in a phased approach. Monitoring of the initial set of sites commenced at the beginning of 2022. By the end of 2022, these new sites had been monitored for a year. *Figure 46* shows the Water Quality Indices (WQIs) for data from the year 2022 at the new monitoring sites in comparison to the existing sites during the same period. It is important to note that these results are preliminary since calculation of the WQI requires at least three years of data to yield representative outcomes. Nonetheless, this initial assessment offers valuable insights into the water quality at these new monitoring sites. Most of the new sites exhibit relatively good water quality, but the Medway and Marchburne Rivers indicate somewhat degraded water quality. Notably, the Riverlands Coop Drain demonstrates significantly poorer water quality than all other sites monitored. The three waterways with comparatively low WQIs are likely candidates for inclusion on the list of rivers that are degraded or at risk of degradation.

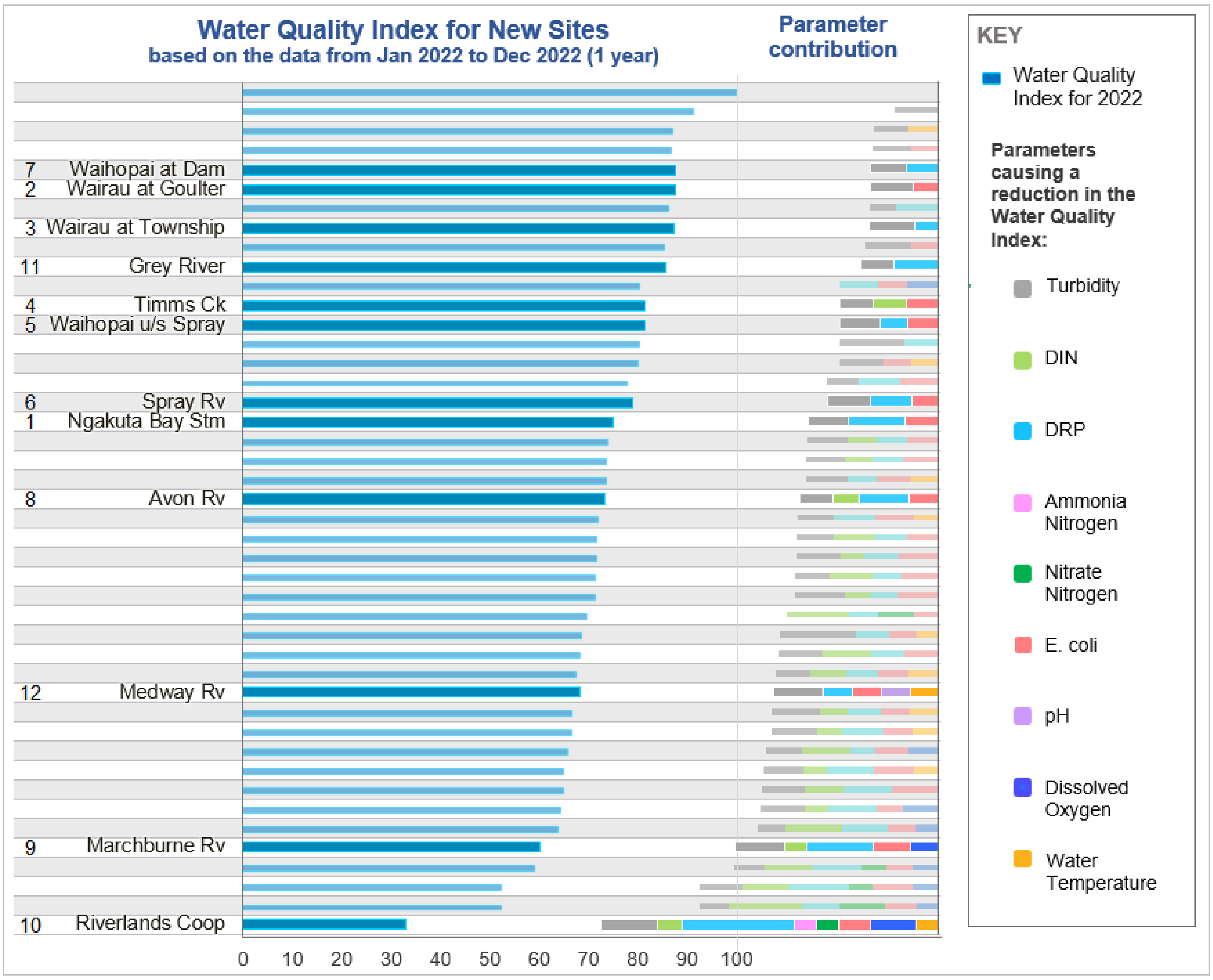

Figure 46: Preliminary Water Quality Indices for new monitoring sites added in 2022 in relation to existing monitoring sites shown in lighter colours.

The network review also led to the introduction of a lake monitoring program, involving monthly monitoring of two lakes, Lake Elterwater and Grovetown Lagoon, and baseline monitoring of three remote lakes. The findings from this new monitoring initiative will be presented in a separate report at the beginning of 2024.

6. Marlborough Environment Plan (MEP)

The Marlborough Environment Plan (MEP) contains several Policies and Objectives that relate to the health of rivers and streams in the region. Also included are anticipated environmental results (AERs), which are targets to be achieved within ten years. One of these AERs relates to river water quality.

Table 2 lists the indicators for the effectiveness of the MEP and associated current progress towards the AER.

Table 2: Anticipated environmental results for water quality, associated targets and current progress towards the targets.

AERs (Anticipated environmental result)	Monitoring effectiveness	Current progress
15.AER.1 Water quality in Marlborough's rivers, lakes and wetlands is suitable to support and sustain swimming, fishing, aquatic ecosystems and customary harvesting	The quality of water in all surface waterbodies routinely monitored is classified as fair, good, or excellent	Although the majority of rivers and streams have water quality in the required classification, 14 waterways are classified as marginal.
	The annual median nitrate concentration in each Freshwater Management Unit is <1 milligram nitrate-nitrogen per litre and the annual 95th percentile concentration is <1.5 milligrams nitrate-nitrogen per litre.	Most rivers and stream meet this target. Only Mill Creek and Murphys Creek have Nitrate concentrations above these limits.
	The annual median ammonia concentration in each Freshwater Management Unit is <0.03 milligrams ammoniacal nitrogen per litre and the annual maximum concentration is <0.05 milligrams ammoniacal nitrogen per litre.	All rivers and stream meet this target.
	The annual median E. coli level in each Freshwater Management Unit is <260 per 100 ml.	When applying this target to all monitored rivers and streams, several waterways do not meet it. For the year 2022, these are Cullen Creek, Doctors Creek, Linkwater Stream, mid Ōpaoa River and Flaxbourne River. Potentially also the Kenepuru River, but there are significant gaps within the data due to issues with site access.
	Water quality which was degraded is enhanced so that the waterbodies can support natural and human use values. Increase in the number of catchment enhancement plans developed and implemented for waterbodies deemed degraded.	There are a number of projects currently in progress with the aim to improve water quality in several degraded rivers and streams (further discussed in the next Section). Catchment enhancement plans will be prepared for the majority of degraded waterways in the coming years.

7. Improving Water Quality

An increase in staff resources for land management in recent years has made it possible to initiate a number of different projects that aim to improve water quality in the region’s rivers and streams. Additionally, with the increased interest in water quality on a national scale, central government funding has been made available to restore the ecological health of waterways. Council has been successful in securing some of this funding, which allows positive action on a greater and more effective scale than would have been possible with ratepayer funding alone.

The first of these projects was the TRIP (Taylor Improvement Project) which was running for several years. This project had the aim improve water quality in the Taylor River and its tributaries, which include Doctors Creek, with improvement actions continuing.

In 2020 the Te Hoiere Project was launched. Council is one of many partners in this initiative to restore the ecological health of this very large catchment.

MEP Policy 15.1.7 requires improvement action to be taken for waterways that are listed in Tables 15.1 and 15.2 as degraded or at risk from degradation (Table 3 and Table 4 in this report). The methodology specified in the MEP (15.M.5) is to establish the causes of degraded water quality and the subsequent development of Catchment Enhancement Plans. The causes of degradation are identified through Catchment Studies, which have been completed for a number of waterways. Catchment Enhancement Plans will be developed through Council’s Catchment Care Programme. Central government funding has also been secured for this programme, which aims to improve water quality in collaboration with the communities in these catchments.

Table 3: Rivers and stream identified in the MEP as degraded and actions to improve their ecological health.

	River	Improvement Actions
Table 15.1 Waterbodies identified as being **degraded**	Are Are Creek	Catchment Study completed; Catchment Care Project
	Doctors Creek	Catchment Study completed; Taylor Improvement Project followed by Catchment Care Project
	Duncan (Linkwater) Stream	Catchment Study completed; Catchment Care Project
	Flaxbourne River	Catchment Study completed; Catchment Care Project
	Mill Creek	Catchment Study planned for the near future; Nitrate sensor recently installed to better understand Nitrate dynamics
	Murphys Creek	Taylor Improvement Project followed by Catchment Care Project
	Omaka River	
	Ōpaoa River	Improvement actions in the Taylor and Doctors Creek will also have positive effect on Lower Ōpaoa
	Ronga River	Te Hoiere Project
	Taylor River	Taylor Improvement Project followed by Catchment Care Project
	Tuamarina River	Catchment Study completed; Catchment Care Project
	Wairau Diversion	Will benefit from Tuamarina River improvements

Table 4: Rivers and stream identified in the MEP as being at risk of degradation and actions to improve their ecological health.

Table 15.1 Waterbodies identified as being **at risk of degradation**	River	Improvement Actions
	Cullens Creek	Catchment Study completed; Te Hoiere Project
	Kaituna River	Te Hoiere Project
	Kenepuru River	Investigation into sources of E. coli
	Lower Pelorus River (downstream of the Rai River)	Te Hoiere Project
	Lower Wairau River from SH1 bridge to the sea	
	Opouri River	Te Hoiere Project
	Rai River	Te Hoiere Project
	Spring Creek	Investigation into sources of E. coli
	Waitohi River	Catchment Study completed

New National Environment Standards for Freshwater and regulations for Stock exclusion released in 2020 will significantly aid the improvement efforts.

8. Acknowledgements

I would like to thank the Environment Monitoring team for reliably sampling water quality every month no matter what the conditions - rainfall, wind, cold winter days or smouldering hot summer days. Without their high-quality work this report would have not been possible.

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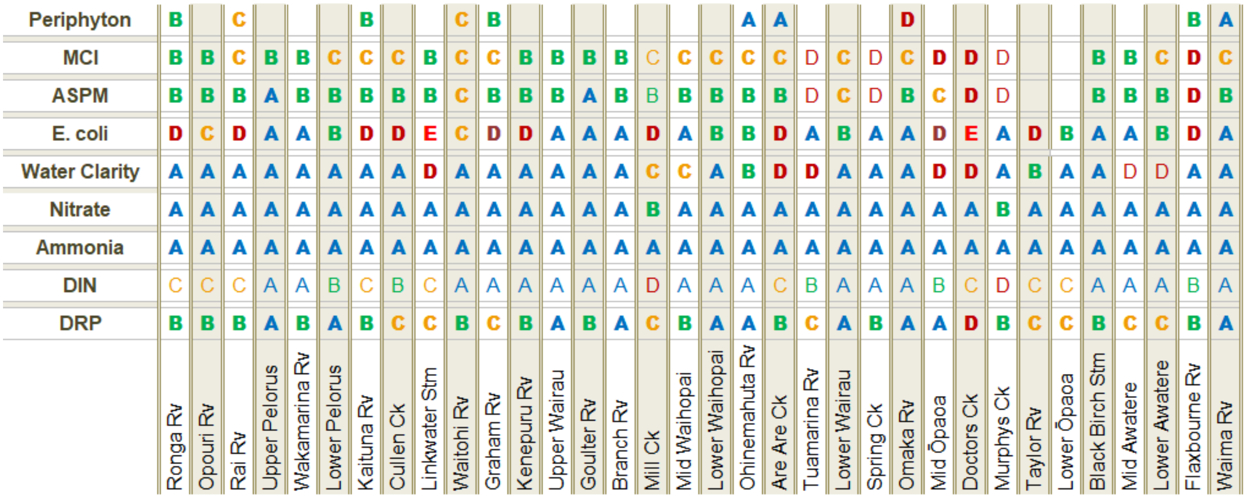
10. Appendices

10.1. Summary of NPS-FM states

The table below shows the attribute states for the State of the Environment monitoring sites based on data collected over the last five years (2018-2022).



	Ronga Rv	Opouri Rv	Rai Rv	Upper Pelorus	Wakamarina Rv	Lower Pelorus	Kaituna Rv	Cullen Ck	Linkwater Stm	Waitohi Rv	Graham Rv	Kenepuru Rv	Upper Wairau	Goulter Rv	Branch Rv	Mill Ck	Mid Waihopai	Lower Waihopai	Ohinemahuta Rv	Are Are Ck	Tuamarina Rv	Lower Wairau	Spring Ck	Omaka Rv	Mid Ōpaoa	Doctors Ck	Murphys Ck	Taylor Rv	Lower Ōpaoa	Black Birch Stm	Mid Awatere	Lower Awatere	Flaxbourne Rv	Waima Rv
Periphyton	B		C				B			C	B								A	A				D									B	A
MCI	B	B	C	B	B	C	C	C	B	C	C	B	B	B	B	C	C	C	C	C	D	C	D	C	D	D	D			B	B	C	D	C
ASPM	B	B	B	A	B	B	B	B	B	C	B	B	B	A	B	B	B	B	B	B	D	C	D	B	C	D	D			B	B	B	D	B
E. coli	D	C	D	A	A	B	D	D	E	C	D	D	A	A	A	D	A	B	B	D	A	B	A	A	D	E	A	D	B	A	A	B	D	A
Water Clarity	A	A	A	A	A	A	A	A	D	A	A	A	A	A	A	C	C	A	B	D	D	A	A	A	D	D	A	B	A	A	D	D	A	A
Nitrate	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A	A	B	A	A	A	A	A	A	A
Ammonia	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
DIN	C	C	C	A	A	B	C	B	C	A	A	A	A	A	A	D	A	A	A	C	B	A	A	A	B	C	D	C	C	A	A	A	B	A
DRP	B	B	B	A	B	A	B	C	C	B	C	B	A	B	A	C	B	A	A	B	C	A	B	A	A	D	B	C	C	B	C	C	B	A

10.2. Water Quality Index calculation

The following section has been taken from the Canadian Water Quality Guidelines for the Protection of Aquatic Life [1].

"The index consists of three factors:

Factor 1: Scope

F1 (Scope) represents the extent of water quality guideline non-compliance over the time period of interest. It has been adopted directly from the British Columbia Index:

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}} \right) \times 100$$

Where variables indicate those water quality variables with objectives which were tested during the time period for the index calculation.

Factor 2: Frequency

F2 (Frequency) represents the percentage of individual tests that do not meet objectives ("failed tests"):

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}} \right) \times 100$$

Factor 3: Amplitude

F3 (Amplitude) represents the amount by which failed test values do not meet their objectives. F3 is calculated in three steps. The formulation of the third factor is drawn from work done under the auspices of the Alberta Agriculture, Food and Rural Development.

(i) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an “excursion” and is expressed as follows. When the test value must not exceed the objective:

$$excursion_i = \left(\frac{FailedTestValue_i}{Objective_j} \right) - 1$$

For the cases in which the test value must not fall below the objective:

$$excursion_i = \left(\frac{Objective_j}{FailedTestValue_i} \right) - 1$$

ii) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or nse, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\#\ of\ tests}$$

iii) F3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (*nse*) to yield a range between 0 and 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01} \right)$$

The CCME WQI is then calculated as:

$$CCMEWQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right)$$

The factor of 1.732 arises because each of the three individual index factors can range as high as 100. This means that the vector length can reach,

$$\sqrt{100^2 + 100^2 + 100^2} = \sqrt{30000} = 173.2$$

as a maximum. Division by 1.732 brings the vector length down to 100 as a maximum.

The most meaningful results are obtained when at least 30 data points are used for the calculation of the Water Quality Index [8, 12]. The Marlborough District Council undertakes monthly sampling of water quality, therefore, to obtain a sufficient number of data points, data from three consecutive years is combined.

During flood flows, turbidity level can be several magnitudes above the guideline value. These events are important to record as they provide an insight into sediment transported into receiving environments downstream, such as Estuaries. However, these data spikes have a disproportionate effect on the Water Quality Index. To reduce their effect, the cube root transformation is applied to turbidity data. This ensures that Water Quality Indices are more representative of overall water quality.

Similar to turbidity, E. coli levels also spike during flood flows. Therefore, the same transformation is applied to E. coli concentration data.

Parameter	Guideline Value	Source
Water Temperature	21.0 °C	Davies-Colley R et al. (2013) [8]; B-band
Dissolved Oxygen	8 mg/L	Davies-Colley R et al. (2013) [8]; B-band; 7-day mean
pH	Lower: 6.5 Upper: 8.5	Davies-Colley R et al. (2013) [8]; B-band
Nitrate Nitrogen	1.0 mg/L	NPS-FM (2020) [26], A-band; Median
Ammonia Nitrogen	0.03 mg/L	NPS-FM (2020) [26], A-band; Median
Dissolved Inorganic Nitrogen	0.50 mg/L	Draft NPS-FM (2019) [25]; B-band; Median
Dissolved Reactive Phosphorus	0.010 mg/L	NPS-FM (2020) [26], A-band; Median
E. coli concentration	130 E.coli/100mL	NPS-FM (2020) [26], A-C-band; Median
Turbidity	1.3 NTU	Draft NPS-FM (2019) [25]; B-band; Median for predominant Class (3)

Table 5: The parameters used for the calculation of the Water Quality Index.

Once calculated, the Water Quality Index produces a number between 0 and 100, with higher indices representing better water quality. Based on the index, water quality of a river or stream can then be categorised into one of five quality classes (*Table 6*, [1]). The classes ‘Excellent’, ‘Good’ and ‘Fair’ represent acceptable water quality, while waterways classed as ‘Marginal’ or ‘Poor’ need to be improved if possible.

Quality Class	Water Quality Index	Description
Excellent	95 -100	Conditions **very close to** natural or pristine level
Good	80-94	Conditions **rarely** depart from natural or desirable level
Fair	65 -79	Conditions **sometimes** depart from natural or desirable level
Marginal	45 - 64	Conditions **often** depart from natural or desirable level
Poor	0 - 44	Conditions **usually** depart from natural or desirable level

Table 6: Quality classes for the Water Quality Index and the associated meaning.

10.2.1. Water Quality Index Results

The table below lists the WQIs for the period 2020-2022. Also shown are the reduction in the WQI for each parameter.

Table 7: the WQIs for the period 2020-2022

Site	WQI	Parameter specific reduction in the WQI								
		Water Temperature	Dissolved Oxygen	pH	E. coli	Nitrate Nitrogen	Ammonia Nitrogen	DRP	DIN	Turbidity
Mill Ck	52.0	0.0	-4.0	0.0	-6.4	-9.7	0.0	-7.6	-14.7	-5.6
Doctors Ck	53.4	0.0	-5.2	0.0	-7.7	-4.6	0.0	-11.7	-8.7	-8.8
Linkwater Stm	53.9	0.0	-4.4	0.0	-9.7	-4.3	0.0	-10.5	-8.8	-8.4
Tuamarina Rv	56.8	-4.4	-7.5	0.0	-6.4	0.0	0.0	-10.3	-5.7	-8.9
lower Ōpaoa Rv	59.4	0.0	-5.0	0.0	-5.1	-4.8	0.0	-10.4	-8.3	-7.0
Ronga Rv	59.5	0.0	-5.4	0.0	-7.7	-5.0	0.0	-5.4	-10.0	-7.0
mid Ōpaoa Rv	59.6	-5.0	0.0	-5.1	-7.8	0.0	0.0	-5.7	-5.5	-11.3
Flaxbourne Rv	60.2	-5.1	0.0	0.0	-8.3	-5.0	0.0	-8.6	-5.7	-7.1
Kenepuru Stm	60.4	0.0	-6.0	0.0	-10.6	0.0	-5.5	-5.6	-5.2	-6.6
Waitohi Rv	60.5	-5.6	-5.3	-5.4	-7.6	0.0	0.0	-8.1	0.0	-7.5
lower Waihopai	60.6	-5.5	-5.2	0.0	-6.6	0.0	0.0	-6.5	-5.5	-10.2
Omaka Rv	61.3	-5.9	-6.3	0.0	-6.6	0.0	0.0	-6.3	-6.6	-7.1
Taylor Rv	62.9	0.0	-4.7	0.0	-6.5	0.0	0.0	-9.4	-10.5	-6.0
Murphys Ck	64.2	0.0	-4.4	0.0	-5.4	-6.6	0.0	-6.7	-12.7	0.0
Kaituna Rv	65.2	0.0	0.0	0.0	-7.2	-4.7	0.0	-6.8	-8.8	-7.3
Rai Rv	65.5	0.0	0.0	0.0	-7.7	-4.6	0.0	-6.2	-9.0	-7.0
mid Waihopai	66.8	-5.0	0.0	0.0	-6.1	0.0	0.0	-7.4	-5.2	-9.5
Spring Ck	67.3	0.0	-5.7	0.0	-7.1	0.0	0.0	-8.8	-5.7	-5.5
lower Pelorus	67.6	-5.9	0.0	0.0	-7.3	0.0	0.0	-5.9	-5.6	-7.8
Wakamarina Rv	67.7	-5.7	0.0	0.0	-6.4	0.0	0.0	-6.1	-5.8	-8.2
Waima Rv	67.9	-6.2	-6.2	0.0	-6.5	0.0	0.0	0.0	-6.2	-6.9
lower Awatere	69.3	-4.1	0.0	0.0	-5.5	0.0	0.0	-6.6	0.0	-14.5
Are Are Ck	69.9	0.0	0.0	0.0	-7.0	0.0	0.0	-6.7	-8.6	-7.8
mid Awatere	70.4	-4.2	0.0	0.0	-4.3	0.0	0.0	-6.6	0.0	-14.4
Cullen Ck	71.9	0.0	0.0	0.0	-7.8	0.0	0.0	-8.2	-4.7	-7.5
Opouri Rv	73.0	0.0	0.0	0.0	-7.4	0.0	0.0	-6.1	-6.8	-6.6
upper Pelorus	74.1	-5.7	0.0	0.0	-6.2	0.0	0.0	-5.7	0.0	-8.2
Graham Rv	78.9	0.0	0.0	0.0	-7.1	0.0	0.0	-8.2	0.0	-5.8
lower Wairau	80.1	-5.0	0.0	0.0	-5.6	0.0	0.0	0.0	0.0	-9.3
Ohinemahuta Rv	80.1	-5.0	0.0	0.0	-6.2	0.0	0.0	0.0	0.0	-8.7
upper Wairau	86.4	0.0	0.0	0.0	-4.8	0.0	0.0	0.0	0.0	-8.8
Black Birch Stm	86.9	0.0	0.0	0.0	0.0	0.0	0.0	-7.6	0.0	-5.5
Goulter Rv	87.1	0.0	0.0	0.0	-5.9	0.0	0.0	0.0	0.0	-7.0
Branch Rv	92.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.4

10.3. Site Information

Table 8: Site information

Short Name	Database (Hilltop) Name	Easting	Northing	NZ Reach	Flow*
Ronga Rv	Ronga River at Upstream Rai River	1649966	5437711	11010920	(✓)
Opouri Rv	Opouri River at Tunakino Valley Road	1652204	5437502	11010920	(✓)
Rai Rv	Rai River at Rai Falls	1648018	5429266	11010920	✓
Upper Pelorus	Pelorus River at Kahikatea Flat	1647585	5427613	11010920	✓
Wakamarina Rv	Wakamarina River at SH6	1656011	5428720	11010920	×
Lower Pelorus	Pelorus River at Fishermans Flat	1659571	5430016	11010920	(✓)
Kaituna Rv	Kaituna River at Higgins Bridge	1664877	5426463	11011383	✓
Cullens Ck	Cullens Creek at Road Bridge	1671802	5428178	11011585	(✓)
Linkwater Stm	Duncan Stream at Outlet	1675552	5429552	11011381	(✓)
Waitohi Rv	Waitohi River at State Highway One	1684133	5428227	11011620	(✓)
Graham Rv	Graham River at Road Bridge	1689949	5430629	11010999	✓
Kenepuru Rv	Kenepuru River at Kenepuru Head	1694287	5442220	11008448	×
Upper Wairau	Wairau River at Dip Flat	1593486	5362089	11023270	✓
Goulter River	Goulter River at Horseshoe Bend	1615505	5390310	11022446.0	✓
Branch Rv	Branch River at Weir Intake	1615310	5383200	11024749	✓
Mill Ck	Mill Creek at Ormonds	1642747	5398630	11019984	✓
Mid Waihopai	Waihopai River at Craiglochart	1657397	5392054	11018880	✓
Lower Waihopai	Waihopai River at SH63 Bridge	1661086	5402329	11018880	(✓)
Ohinemahuta Rv	Onamalutu River at Northbank Road	1665221	5407894	11015812	(✓)
Are Are Ck	Are Are Creek at Kaituna Tuamarina Road	1668891	5409150	11027449	✓
Lower Wairau	Wairau River at Tuamarina	1680623	5412041	11016624	✓
Tuamarina Rv	Tuamarina River at State Highway One	1680588	5412144	11016362	(✓)
Omaka Rv	Omaka River at Hawkesbury Road Bridge	1668150	5402871	11018918	(✓)
Mid Ōpaoa	Opawa River at Hammerichs Road	1675898	5406769	11018918	(✓)
Doctors Ck	Doctors Creek Upstream Taylor	1678538	5403700	11018918	×
Murphys Ck	Murphys Creek at Nelson Street	1678585	5404340	11018918	×
Taylor Rv	Taylor River at Rail Bridge	1680148	5403948	11018918	(✓)
Lower Ōpaoa	Opawa River at Swamp Road	1684887	5403319	11018918	(✓)
Spring Ck	Spring Creek at Wairau River Floodgates	1681052	5411335	11016643	×
Black Birch Stm	Black Birch Stream at Awatere Intake	1673268	5382346	11021883	×
Mid Awatere	Awatere River at Awapiri	1660707	5368307	11021883	✓
Lower Awatere	Awatere River at River Mouth	1695945	5393096	11021883	(✓)
Flaxbourne Rv	Flaxbourne River at Quarry	1697479	5368033	11028279	(✓)
Waima Rv	Waima (Ure) River at SH1 Bridge	1692178	5360509	11030144	(✓)

* ✓ = flow at the site; (✓) = flow is at a nearby site or simulated, × = no flow data available

10.4. Laboratory Analysis

Table 9: Laboratory Analysis

Parameter	Laboratory	Method Description	Detection Limit
Turbidity	Hill Laboratories	Analysis using a Hach 2100 Turbidity meter. APHA 2130 B 21st ed. 2005	0.05 NTU
Nitrate Nitrogen	Hill Laboratories	Calculation: Nitrite/Nitrate-Nitrogen - Nitrite Nitrogen; Nitrite/Nitrate Nitrogen analysed from filtered sample as total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3- I 21st ed. 2005	0.002 mg/L
Total Ammonical Nitrogen	Hill Laboratories	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH_4-N = NH_4-N + NH_3-N). APHA 4500-NH3 F (modified from manual analysis) 21st ed. 2005	0.010 mg/L
	Hill Laboratories	Since 2017: Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH4-N = NH4-N + NH3-N). APHA 4500-NH3 H 23rd ed. 2017	0.005 mg/L
Dissolved Inorganic Nitrogen	Hill Laboratories	Calculation NH_4-N + NO_3-N + NO_2-N	0.010 mg/L
Dissolved Reactive Phosphorus	Hill Laboratories	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st ed. 2005	0.004 mg/L
	Hill Laboratories	Since 2017: Filtered sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 23rd ed. 2017	0.0010 mg/L
pH	Hill Laboratories	pH meter. APHA 4500-H^+ B 21st ed. 2005	0.1
E. coli	Hill Laboratories	Membrane filtration. Count on mFC agar, incubated at 44.5°C for 22 hours, MUG Confirmation. APHA 9222 G, 22nd ed. 2012	1 cfu/100mL
Total Nitrogen	Hill Laboratories	Alkaline persulphate digestion, automated Cd reduction/sulphanilamide colorimetry. APHA 4500-N C & 4500 NO3 -I (modified) 23rd ed. 2017.	0.010 mg/L
Total Phosphorus	Hill Laboratories	Total phosphorus digestion, automated ascorbic acid colorimetry. Flow Injection Analyser. APHA 4500-P H (modified) 23rd ed. 2017	0.002 mg/L
Total Arsenic	Hill Laboratories	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 1-7 2017 / US EPA 200.8.	0.0011 mg/L
Total Cadmium	Hill Laboratories	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 1-7 2017 / US EPA 200.8.	0.000053 mg/L
Total Copper	Hill Laboratories	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 1-7 2017 / US EPA 200.8.	0.00053 mg/L
Total Zinc	Hill Laboratories	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 1-7 2017 / US EPA 200.8.	0.0011 mg/L
Chlorophyll a (Periphyton)	Cawthron	NIWA Periphyton Monitoring Manual (Mod)	